WHITEFISH AREA WATER RESOURCES REPORT:
A STATUS OF THE WHITEFISH LAKE WATERSHED AND SURROUNDING AREA

Prepared by:

Whitefish Lake INSTITUTE

Prepared for:
Anderson-Montgomery Consulting Engineers
and
The City of Whitefish

In Fulfillment of:
Department of Natural Resources and Conservation
Watershed Assessment Grant No. RPG-14-0375

26 October 2015

Whitefish Area Water Resources Report: A Status of The Whitefish Lake Watershed and Surrounding Area

Front Matter

Watershed Defined

"..that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community"

– John Wesley Powell
American geologist, ethnologist, explorer and government administrator

Project History & Funding

Long-term watershed level conservation requires a baseline of scientific, cultural, and historical knowledge of an area; an understanding of its physical, biological, and chemical dynamics; and a program to monitor any changes over time from the baseline. With these elements in place, adaptive management plans and education programs can be developed and implemented. Through this DNRC-funded deliverable—the first ever *Whitefish Area Water Resources Report: A Status of the Whitefish Lake Watershed & Surrounding Area*—the Whitefish Lake Institute (WLI) has processed and analyzed the data and information collected since 2007 through its core monitoring program and has assimilated historical data from project partners. The result is a complete water quality status report, a Watershed Restoration Plan, and a scientifically comprehensive foundation for long-term water quality management of the Whitefish Lake Watershed & Surrounding Area.

First established in 1971 as a result of the Executive Reorganization Act of 1971, the Montana Department of Natural Resources and Conservation (DNRC) has the mission of *"Helping to ensure that Montana's land and water resources provide benefits for present and future generations."* As part of their commitment to this mission, DNRC is responsible for promoting the stewardship of Montana's water, soil, forest, and rangeland resources; for regulating forest practices and oil and gas exploration and production (DNRC, 2015). Recognizing the importance of conserving, developing, managing, and protecting Montana's resources, the DNRC awarded a planning grant to the City of Whitefish to identify watershed resource restoration needs, particularly addressing nonpoint source pollution.

Funding for DNRC planning grants was authorized by the 1999 Montana Legislature to facilitate the development of renewable resource projects. These grants fund projects that measurably conserve, develop, manage, or protect Montana's renewable resources. The resulting report of this project is imperative for the ecological health of the project area as it provides baseline knowledge, identifies known and potential resource concerns, and offers recommendations to the conservation management organizations responsible for the health of the watershed. It therefore fits within the scope of projects fundable by this DNRC program.

The City of Whitefish—the project sponsor—contributed funding to this project and engaged Anderson-Montgomery Consulting Engineers, Inc. (AMCE) to manage the contract work. AMCE has successfully supervised several infrastructure projects—from planning through design and construction management—for the City of Whitefish. The Whitefish Lake Institute (WLI) was a sub-contractor to AMCE, providing the project deliverables. Funding for work on the historical sections of the report was contributed by the Whitefish Community Foundation through their annual grant program. The Whitefish County Water District contributed funds for the Graphical Information System (GIS) Maps. The Cadeau Foundation contributed funds from their annual grant program for work on the scientific analysis of the report. Project funding enabled WLI to conduct research; provide data analysis; document cultural, historical, and scientific knowledge; and assemble a Watershed Restoration Plan Task Table.

Through this report, WLI makes management recommendations to the City of Whitefish regarding drinking water and recreation resources; provides actionable measures for state resource managers to protect or restore habitat and resources; communicates historical, cultural, and scientific information to the public to aid in their understanding of the resource; and further contribute to the Environmental Protection Agency's ongoing Total Maximum Daily Load (TMDL) process and Montana's Circular 12A Base Numeric Nutrient Standards development. The report received content contributions from and has been peer reviewed by scientists, educators, resource managers and policy makers. It is being provided to all resource management entities and the general public to increase our collective understanding of the resource and to make more informed resource management decisions.

A report of this breadth and significance requires not only a dedicated effort and funding, but also broad support from the community. WLI collaborated with numerous individuals, organizations, groups, and agencies to complete this project. Collaborators and reviewers are listed in the *Acknowledgements* section.

Citation

Whitefish Lake Institute. 2015. *Whitefish Area Water Resources Report: A Status of the Whitefish Lake Watershed and Surrounding Area*. Prepared for the City of Whitefish and Anderson-Montgomery Consulting Engineers, Inc. as a deliverable for the Montana Department of Natural Resources and Conservation Grant Agreement No. RPG-14-0375.

Data Notification

Data for this report came from numerous sources. WLI will share the data it collected and data sources upon request within a reasonable timeframe.

Data from the Whitefish Lake Institute may be requested in writing via email to mike@whitefishlake.org or mail to Mike Koopal, Whitefish Lake Institute, 550 East 1st St. #103, Whitefish, MT 59937.

Data from the Flathead Lake Biological Station (FLBS) which were provided through reciprocal professional courtesy and incorporated into the narrative and figures in this report are the property of the FLBS. These data cannot be reproduced, manipulated, or used in any format without prior written approval of the FLBS and the Whitefish Lake Institute.

Chapters X-XII contain summary information of known data sources. The primary sources of data include:

Biological
- Montana FWP- Montana Fisheries Information System (MFISH)
- Bollman (2003, 2014, 2015) - Aquatic Invertebrate Surveys
- Bahls (2004)- Periphyton Surveys
- Koopal (2004)- Fisheries Summary Report to DNRC NWLO
- Weaver (2014)- Bull trout information
- The University of Montana Flathead Lake Biological Station- Food Web

Habitat
- Bower (2015): R1/R4 Fisheries Habitat Information
- Koopal (2006): R1/R4 Fisheries Habitat Data Collector's Field Notes
- Weaver (2014): McNeil Core and Substrate Scores

Water Chemistry
- Whitefish Lake Institute: Whitefish Lake and local streams
- The University of Montana Flathead Lake Biological Station: Whitefish Lake
- Montana DNRC: Swift Creek and select tributaries
- Montana DEQ: Local streams

GIS LANDSAT Images

The 7/5/2 band combination is used to represent the LANDSAT image data (RGB channels) in a natural color scheme that enables a basic visualization of landscape features for all readers. This scheme provides a common platform for simple change analysis by visual inspection, such as the impact and recovery (re-vegetation) from timber harvest and fire disturbances.

Content Disclaimer

Content and data for the report were provided by many individuals and organizations, and/or summarized from existing reports and documents. We have made every effort to include and cite this information as accurately as possible. We apologize for any unintentional errors, omissions, or misrepresentations, and will appreciate being notified accordingly at info@whitefishlake.org if any are discovered.

In developing our maps, we employed available GIS to create the most complete depiction of the study area as possible. Our maps are, however, only a representation of the best available data at the time. We are therefore not responsible for errors or omissions in this data.

One goal of this report was to assemble in one document a comprehensive and holistic representation of available information on the study area. The report is meant to be a “living” document in that new or historical data and information may be included in future revisions. Please send suggestions for inclusion to info@whitefishlake.org.

Report User's Guide

KEY

Blue – Map References
Example: Septic Leachate Contamination & Risk Assessment Map (Chapter XXI, Addendum B: GIS Maps

Green – Content References
Example: See Chapter XVI Current and Future Concerns for discussions concerning mercury and PCBs

Burgundy – Data References
Example: Chapter XXII Addendum C Water Chemistry & Temperature Information.

CONTENT ORGANIZATION

Chapters I-IV
Provide background information about the project, WLI, and the natural and cultural history of the project area.

Chapters V-VIII
Provide an introduction to lake ecosystem processes and discusses past studies related to water quality in the project area. In addition, the current methodologies used by WLI to collect water quality are presented, as well as a description of the organization's programs.

Chapter IX
Provides a biological community overview to prepare the reader for the following chapters.

Chapters X-XIII
Provide technical information on the physical, chemical and biological attributes to project area waterbodies.

Chapter XIV
Provides information about the City of Whitefish public infrastructure as related to water quality.

Chapter XV
Provides a discussion and rationale for water quality criteria and standards in assessing the health of local aquatic ecosystems.

Chapter XVI
Provides a discussion on some of the current and future concerns related to water quality in the project area.

Chapter XVII
Provides *Key Resource Findings* and a discussion as determined from information contained in the report.

Chapter XVIII
Provides information about a Watershed Restoration Plan (WRP) and how information in this report is related to that plan.

Acknowledgements

WLI acknowledges the following contributions to this project:

Cover Photo:
gravityshots.com

Data Collection
Chris Ruffatto (2007-2010); WLI Interns: Mary Kohnstamm (2009), Kristi Whisler (2009), Michael Harrison (2010), Leif Castren (2011), Megan Powell (2012), Carl Talsma (2012), Logan Seipel (2013), and Dietrich Perchy (2014).

Equipment
Mike & Marie Shaw for our Ford F150 work vehicle, Bill Leonard (posthumously) for our first research pontoon boat, Harold and Betty Monzingo for our current research pontoon boat, the City of Whitefish and the Montana Department of Environmental Quality for our Hydrolab DS5 sonde and cable, Plum Creek for our Weather Station and Bulk Loading equipment. Jim Berry for voluntarily maintaining our research pontoon boat.

Geographical Information Systems (GIS) Mapping
Peter Petri, Mobile LoGIStics Mapping

Hydrological Analysis Support
Mitch Price, River Design Group

Leadership
WLI Board of Director Members Past and Present. Current members: Andy Feury – President, Hank Ricklefs – Vice President, John Collins – Secretary/Treasurer, Pam Barberis, Greg Gunderson, Susan Fletcher, Ed Lieser, John Muhlfeld, Sharon Morrison, and Jordan White.

WLI Science Advisory Committee Members Past & Present. Current members include: Karin Hilding, Tony Nelson, Eric Sawtelle, Dick Solberg, Brian Sugden, and John Wachsmuth.

WLI Citizens Advisory Committee Past and Present. Current members include: Nicole James, Cindy LaChance, Sue Moll, Linda Sawtelle, Nancy Svennungsen, and Dan Vogel.

Membership
All of the members—past and present—of WLI.

Public
Walt Curtis, Jerry, Aidan & Owen Croskrey, Mae and Case Koopal, and Gigi Gubits for their patience with their family members who make up the WLI staff.

Volunteers
Kristin Ahonen – Flathead Beacon; Annika Gordon – Student: Whitefish High School
Brian Sullivan – Owner: F&H Surveying

WLI Staff

Mike Koopal – Executive Director, Lori Curtis – Science & Education Director, Josh Gubits – Environmental Scientist, Chris Ruffatto – Associate Environmental Scientist, Jen Croskrey – Finance & Administration Manager.

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Dean Sirucek, Retired Soil Scientist, Board Member: Flathead Conservation District, Flathead Basin Commission, Flathead Land Trust

Dick Solberg, Ph.D., Retired Director: Flathead Lake Biological Station

Michael Stickney, Director, Earthquake Studies Office: Montana Bureau of Mines & Geology, Montana Tech of the University of Montana

Brian Sugden, Hydrologist: Plum Creek Timber Company

Mike Suplee, Ph.D., Water Quality Specialist, Standards Division: Montana Department of Environmental Quality

Gary Swanson, P.E., Water/Wastewater Division Manager: Robert Peccia & Associates

Heidi Van Everen, Executive Director: Whitefish Legacy Partners

Marc Vessar, Hydrologist, Northwest Land Office: Montana Department of Natural Resources and Conservation

John Wachsmuth, Conservation Specialist: Montana Fish, Wildlife & Parks

Craig Workman, Public Works Director: City of Whitefish

List of Figures

List of Acronyms

Entities

AMCE	Anderson-Montgomery Consulting Engineers
BN	Burlington Northern
BNSF	Burlington Northern Santa Fe
DEQ	Montana Department of Environmental Quality
DNRC	Montana Department of Natural Resources and Conservation
DPHHS	Department of Public Health and Human Services
EPA	U.S. Environmental Protection Agency
FBC	Flathead Basin Commission
FCD	Flathead Conservation District
FLBS	Flathead Lake Biological Station
FWP	Montana Fish, Wildlife & Parks
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WLI	Whitefish Lake Institute
WQPB	Water Quality Planning Bureau (DEQ)

Units of Measure/Time

°C	degrees centigrade
cfs	cubic feet per second
DBF	Daily Board Feet
FY	Fiscal Year
g	gram, a unit of mass
gpm	gallons per minute
HUC	Hydrologic Unit Code
kg	kilograms, a unit of mass equal to 1,000 grams
MGD	Million Gallons per Day
mg/L	milligrams per liter (parts per million)
µg/L	micrograms per liter (parts per billion)
µS/cm	microsiemens per centimeter, a unit of conductivity
mL	milliliters
MYA	Million Years Ago
NTU	nephelometric turbidity units
s.u.	standard unit

Descriptors

BMP	Best Management Practices
CWA	Clean Water Act
GIS	Geographic Information System
HCP	Habitat Conservation Plan
LDO	Luminescent Dissolved Oxygen
PCB	Polychlorinated Biphenyls
QA	Quality Assurance
QAPP	Quality Assurance Project Plan

RI	Remedial Investigation
SAP	Sampling and Analysis Plan
SMZ	Streamside Management Zone law
SOP	Standard Operating Procedures
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solids
VOC	Volatile Organic Compound
WRP	Watershed Restoration Plan

Table of Contents

I. INTRODUCTION

A comprehensive description and assessment of the Whitefish Lake Watershed and surrounding area has not previously been published. This document therefore has multiple objectives. First it summarizes relevant historical documents and data in an effort to describe what is known about the Watershed and adjacent water resources. Second, it analyzes data collected by resource management agencies and WLI in order to provide a scientific water quality assessment and to propose water quality criteria and benchmarks of a Watershed Restoration Plan (WRP). Lastly, it provides recommendations to address water quality issues through four specific programmatic areas; Restoration & Habitat Protection, Research, Education & Outreach, and Enactment of Governmental Regulations & Policy. These recommendations are found in Chapter XXIII, Addendum D. Watershed Restoration Plan Task Table.

WLI has conducted monitoring and field data collection on Whitefish Lake and its tributaries since 2007, accruing data to report the baseline scientific understanding of the lake and water quality in the Whitefish Lake Watershed. Because water chemistries and conditions change seasonally and annually, specific measurements must be evaluated in respect to one another over time to gain a holistic understanding of a resource. It requires continuous monitoring for many years to comprehend overall lake dynamics. Moving forward from this baseline information, WLI will have the ability to compare natural seasonal and annual lake and tributary dynamics against the established baseline data to identify long term trends. These trends will then inform an interdisciplinary framework of local and watershed level resource management and restoration projects.

Other entities have throughout the years collected scientific and historical data on waterbodies in the Whitefish Lake Watershed. This report summarizes all of the relevant historical data and information that is known, in an effort to understand how natural forces and human activity have influenced water quality trends in the Watershed. It also identifies and describes water quality benchmarks that can be used by resource managers to measure changes over time. Resource managers will then have the task of choosing and implementing options appropriate to their areas of responsibility while employing adaptive management strategies. Additionally, there are a number of resource management activities that overlap one another either geographically or jurisdictionally, adding levels of intricacy to the management process.

Watershed-level management is one of the concepts of *ecosystem management*, a term that although not popularized until the 1990s, has been around since the 1930s. In short, both terms encompass considerations such as biological diversity, ecological integrity, landscape ecology, and sustainability. But most importantly, these terms also include cultural and social issues. By combining all of these aspects into natural resource management, we gain a perspective in our decision making process that links the interconnectedness of ecological processes with human values (Schramm, Jr. & Hubert, 1999).

The community of Whitefish, like most northwestern Montana lake-based communities, has seen growing development pressures over the past decade. These pressures are likely only to increase in the foreseeable future, adding to the demands on local resources and challenges to their managers. David Livingstone of the Northwest Territories Cumulative Effects Assessment and Management Framework Steering Committee brought clarity to the situation noting, “While no one agency has sole responsibility for assessing and managing cumulative effects, it is clear that no agency is without responsibility” (Livingstone, 2004). It is in this spirit that the *Whitefish Lake Water Resources Report: A Status of the Whitefish Lake Watershed and Surrounding Area* was produced, with the hope of increasing partnership activities between community members; nongovernmental organizations; and local, state, and federal resource managers.

A. ABOUT THE WHITEFISH LAKE INSTITUTE

WLI formed in 2005 as a science and education based 501(c) (3) nonprofit corporation to conduct research and provide scientific data on Whitefish Lake and within the Whitefish Lake Watershed. One key objective of the organization was to implement a long-term water quality monitoring program. At its initiation, the goal of the program was to consistently gather physical, chemical, and biological data for the lake and its tributaries over time in an effort to gain a comprehensive understanding of Whitefish Lake Watershed processes. From WLI's start-up in 2005 through 2006, the organization employed only its full-time unpaid Executive Director (ED). During this time, the ED laid the groundwork for the organization, putting in place systems and developing relationships that would prove to last as WLI grew. The organization obtained and retrofitted a research vessel, acquired monitoring equipment including a Hydrolab DS5 data sonde, a turbidimeter, and assembled a weather station and bulk loading precipitation collector.

In 2006, WLI's ED developed the organization's first *Whitefish Lake Water Quality Monitoring Program Master Plan*. The monitoring plan briefly outlined historical information about the resource and illustrated the need for analysis of this information and for a consistent monitoring program. With little certainty of funding and/or partnerships, the plan offered a menu of monitoring options and associated levels of budgets. The ED also began conducting K-12 educational programs and commenced a community stewardship program. From 2007 through 2010, the ED conducted research, engaged in contract work and developed partnerships, and with part-time volunteer help from Whitefish High School instructor Chris Ruffatto, grew WLI's programs to the extent possible with its minimal resources.

In 2011—after seven years of working mostly solo—the ED was able to bring aboard both a Science and Education Director and an Environmental Scientist. With three committed and experienced full-time staff, the organization continued to flourish. In 2012, the *Whitefish Lake Water Quality Monitoring Plan* was updated to the *Whitefish Lake Watershed Water Quality Monitoring Program*. The new program described WLI's scientific goals and objectives as the organization's capacity and funding sources became more sustainable, and the organization broadened its reach to a watershed-wide investigation. The Program is designed to provide a comprehensive understanding of the resource, blending the available physical, chemical, biological and cultural data and information. The monitoring program concentrates on lake dynamics and input sources from tributaries while also investigating watershed processes on a broader scale. WLI's long-term intent and monitoring goals remain in place today, but the organization's methodologies and level of effort have matured.

In 2014, WLI's Board of Directors voted to officially extend the organization's ongoing focus area to include surrounding areas of importance to the Whitefish community, including Cow Creek, Haskill Creek, Upper Whitefish River, and Walker Creek. Today, WLI continues to accomplish its work through three key program areas: Scientific Research, Education & Outreach, and Community Stewardship—all under the leadership of the ED that founded the organization, and with 2 staff members. WLI is not an advocacy organization, but applies its expertise to provide scientific knowledge to citizens and resource managers to inform their decision-making processes. WLI partners with other organizations to creatively fund scientific research and develop programs that benefit the Whitefish Lake Watershed and Surrounding Area water resources.

WLI focuses most of its scientific research work on Whitefish Lake and its tributaries, but also researches other lakes—through the Northwest Montana Lakes Volunteer Monitoring Network (NWMTLVMN). Through special funding and a partnership with Montana Fish, Wildlife & Parks (FWP), WLI coordinates and administers the program, training volunteer citizen scientists in monitoring lakes throughout Flathead, Lake, Lincoln and Missoula Counties.

Efforts through our Education & Outreach program include classroom visits and outdoor education programs for Pre-K through 12 students, in-house college internships, educator in-service training, presentations to civic groups, and Road Scholar programs for seniors. Through our Community Stewardship Program, citizens participate in activities that protect Whitefish Lake and its tributaries, and WLI awards citizens and organizations that make extraordinary stewardship efforts.

In the summer of 2013, after several years of negotiating, fundraising, and project development, WLI opened the *Living Wetlands Interpretive Nature Trail* in the 28.8 acre Averill’s Viking Creek Wetland Preserve which it owns and manages. Collectively, these programs allow WLI to reach over 1,000 citizens of all ages annually. The year 2015 marks the ten-year anniversary of WLI, a notable achievement for a member-based organization in a quickly changing economic, social and political environment.

For the first ten years as an organization, WLI concentrated on addressing human health issues on Whitefish Lake and surrounding waterbodies while building a baseline water quality monitoring program. WLI staff worked through its scientific research, education and outreach, and community stewardship programs to gather information and data, and to educate and engage the community in its efforts. Resulting reports and publications have helped to put the science into context for the community. Educational programs have engaged hundreds of students of all ages in getting to know and understand the water resources in the place they live. These students are, after all, the water quality stewards of tomorrow.

Whitefish Lake
INSTITUTE

Science and Education Today—A Vision for Tomorrow

II. PROJECT AREA

A. WHITEFISH LAKE WATERSHED & SURROUNDING AREA

The project area of this report encompasses the Whitefish Lake Watershed and surrounding hydrologic area of importance to the Whitefish community (See Whitefish Lake Watershed & Surrounding Area map in Chapter XXI: Addendum B). The Whitefish Lake Watershed—like all watersheds—is defined by distinctive natural hydrologic features. Hydrologists use the term *watershed* or *drainage basin* to describe an area of land that captures, stores, and sheds or discharges its surface waters through a single outlet. The water that flows from the land drains to streams, rivers, or other bodies of water from which most watersheds get their names—in this instance the waterbody is Whitefish Lake. Watersheds provide hydrologic functions such as collecting, storing, and releasing water as runoff; and ecological functions such as supplying diverse sites for natural chemical reactions to take place, and providing habitat for plants and animals, including humans.

Watersheds are recognized as the backbones of sustainable human and ecological communities. And for the communities in this combined watershed and surrounding area, Whitefish Lake is also the heart of its economic health and stability. American geologist, ethnologist, explorer, and government administrator John Wesley Powell described a watershed as *"…that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community."* (U.S. EPA, 2015)

The project area includes approximately 160.8 square miles (102,912 acres) and encompasses two defined areas, the Whitefish Lake Watershed and the Upper Whitefish River Watershed. The Whitefish Lake Watershed section is defined in the north by the Swift Creek Headwaters between Herrig Mountain (7,274 ft) and Link Mountain (7,230 ft) and in the south by the outfall of Whitefish Lake to the Whitefish River. The western border includes Stryker Peak (7,338 ft) and Stryker Ridge (6,906 ft) in the north and Lion Mountain (4,000 ft) in the south and encompasses the Beaver Creek Watershed. The eastern border below Link Mountain encompasses Diamond Peak (7,305 ft) in the north, and a portion of the Whitefish Range south past Big Mountain (6,817 ft)—Whitefish's ski area—in the south.

The Upper Whitefish River Watershed ("Surrounding Area") extends the southeastern boundary of the Whitefish Lake Watershed below Big Mountain to include Haskill Basin, Haskill, Walker, and Cow Creeks and the Whitefish River to Highway 40; and includes Lost Coon Lake and Blanchard Lake to the south and west of Highway 93.

The Whitefish Lake Watershed boundary depicted in the maps of this report combine the upper 6th Level Hydrologic Unit Code (HUC) watersheds within the Upper Whitefish River 5th Level HUC watershed and a modified Whitefish Lake 6th level watershed boundary.

WLI field investigations documented that Beaver Lake is hydrologically connected with Beaver Creek and Whitefish Lake. The National Hydrology Dataset lists Beaver Lake hydrologically connected to the Stillwater River in the neighboring 6th level HUC watershed, Stillwater River - Tobie Creek. During high water elevations, Beaver Lake can connect surface flow to Beaver Creek. During low water periods, hyporheic flow from the lake manifests as surface flow in Beaver Creek not far from the lake. It is suspected that the Beaver Lake outlet is comprised of porous glacial till from lateral moraine deposition during glacial activity in the Pleistocene Epoch.

Using private, high resolution LiDAR data with permission from landowner Michael Goguen, Mobile LoGIStics Mapping (MLM) created several runs of hydrological calculations using the Esri ArcGIS Hydrology Tools extension in the Beaver Lake area. These calculations confirmed that Beaver Creek flows from Beaver Lake to Whitefish Lake.

Whitefish Lake

Whitefish Lake (48.4536°N, 114.3796°W) is located at an elevation of 2998.5 feet above sea level at the southern end of the Whitefish Mountain Range. It is 5.7 miles long and 1.4 miles wide with 15.85 miles of shoreline. The lake has an average depth of 109 feet, and is 232 feet at its deepest point (Constellation Services, 2006) The lake has an annual mean lake elevation fluctuation of 3.81 feet (Koopal, 2015).

Although the story is not "official," historians have reported that in the 1850s trappers working in the area noticed Native Americans catching whitefish from the lake and consequently named it Whitefish Lake. The Salish called the lake Epłx̣ʷy̓u which literally means "has whitefish."

Whitefish Lake is classified by the Montana Department of Environmental Quality (DEQ) as an A-1 waterbody meaning it is "suitable for drinking, culinary, and food processing purposes after conventional treatment for removal of naturally present impurities.

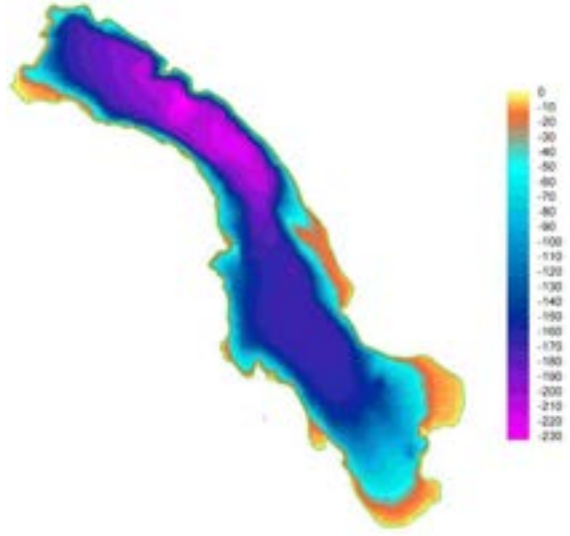


Figure 1. Bathymetric Map of Whitefish Lake. *Courtesy Constellation Services*

Under this classification, water quality must be suitable for bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life; waterfowl and furbearers; and agricultural and industrial water supply" (Montana Department of Environmental Quality, 2012).

According to the US Environmental Protection Agency, the term "303(d)" is *"…short for the list of impaired and threatened waters (stream/river segments, lakes) that the Clean Water Act requires all states to submit for EPA approval every two years on even-numbered years. The states identify all waters where required pollution controls are not sufficient to attain or maintain applicable water quality standards, and establish priorities for development of TMDLs based on the severity of the pollution and the sensitivity of the uses to be made of the waters, among other factors (40C.F.R. §130.7(b)(4)). States then provide a long-term plan for completing TMDLs within 8 to 13 years from first listing."*

Status of TMDL for the Whitefish Lake Watershed
Provided by Jason Gildea from EPA and Kyle Flynn from DEQ

Section 303(d) of the Clean Water Act (CWA) requires states to identify impaired (i.e., polluted) waterbodies and complete total maximum daily loads (TMDLs) for those that are identified. In the Flathead Lake Watershed, Montana Department of Environmental Quality (DEQ) identified multiple waterbodies as impaired because of temperature, sediments, metals, toxics, and nutrients, and TMDLs are needed for each of those waterbodies. The U.S. Environmental Protection Agency (EPA) and DEQ are developing a water quality model to help identify and quantify the sediment and nutrient pollutants in the Watershed, including the Whitefish Lake Watershed. The model is capable of simulating watershed hydrology and pollutant transport, as well as stream hydraulics and instream water quality for those pollutants. Numerous presentations and technical reports that document the model setup to date are available online at: http://montanatmdlflathead.pbworks.com/. A draft model report that describes the work completed to date is also available on the website.

Model development was originally completed by an EPA contractor, however, the model has since been transferred to DEQ and technical staff are currently in the process of performing an internal audit. The review is being conducted to find and correct any errors before the entire model and its results are made available to the public (including to the WLI). There is no timeline for completion of these activities as the level of effort, and associated timeline, will depend on the findings of the audit.

Whitefish Lake has been identified on the 303(d) list as fully supporting aquatic life, however is listed as "Threatened" with PCBs and mercury as the sources of impairment (See Chapter XVI Current and Future Concerns for discussions concerning mercury and PCBs). The sediment listing for Whitefish Lake was removed in 2015. A listing history is discussed in Chapter III Cultural History under Historic Land Use. The lake is a source of drinking water for the City of Whitefish during certain times of the year, generally in late summer. See Chapter XIV Municipal Water Infrastructure, Section A Drinking Water and Diverted Water for more information about the Whitefish Water Treatment Plant.

Whitefish Lake is fed by six perennial tributaries including Swift Creek, Lazy Creek, Hellroaring Creek, Beaver Creek, Smith Creek, and Viking Creek. Swift Creek is the largest tributary to the lake, draining 64% of the total watershed along the Whitefish Range (Petri, 2014). Lazy Creek is a meandering lowland second order stream draining 13.6% of the total watershed. Lazy Creek runs parallel to Swift Creek in the northern valley, also draining into the north end of the lake.

The remaining 22.4% of the Whitefish Lake Watershed is drained by several smaller tributaries. The largest of the small tributaries is Hellroaring Creek which originates on Big Mountain draining about 2.6% of the Watershed. Viking Creek drains 3% of the Watershed through a wetland preserve now owned and managed by WLI. Viking Creek is also influenced by the City of Whitefish water treatment facility overflow and backflush discharge. Smith Creek drains 3.2% and Beaver Creek drains 1.1%, with the remaining 12.5% drainage including overland and ephemeral streams contributions (Petri, 2014).

There are two motorized public access sites on the lake. One is located on the south end of the lake at City Beach and the other is located on the east side of the lake at State Park. There is also a small, little-known, unimproved county access site located near Lazy Bay. City Beach and Les Mason Park serve as the two most popular swimming locations on the lake.

Demographics

Information for this section came from Headwaters Economics (2015) and the U.S. Department of Commerce Census Bureau (2014).

A popular resort community, the City of Whitefish, has a population of approximately 6,650 people. U.S. Census Bureau data show that the population of Whitefish increased 36% since 1980, and 20% since 1990. Recent demographic reports show Whitefish remains one of the fastest growing communities in the state of Montana, with a 28.43% population growth between 2000 and 2013 as compared to 10.7% in the U.S.
The population is generally well-educated, with 46.1% of the population holding Bachelor’s Degrees or higher and only 4% of the population 25 years or older without high school degrees.

The median household income is $44,988 as compared to $53,046 across the U.S. Just over 51% of the population aged 16 to 64 works year round, and 54% works full-time (35 or more hours per week). Just over 20% work 15 to 34 hours weekly. About 19% of the working population works 27 to 49 weeks annually. Citizens tend to stay in or come to Whitefish for retirement as evidenced by 42.4% of households collecting retirement and Social Security income, and 17.3% of the population at 65 or older. Another 29.1% of the population is between 45 and 64. In 35.3% of owner occupied homes, more than 30% of household income is spent on mortgage payments. Seasonal homes make up about 19.8% of housing. Whitefish tends to be perceived as a “wealthy” community. However, it is interesting to note that the per capita income is relatively low compared to many other Montana communities. In fact, the Low-to-Moderate Income (LMI) percentage is relatively high, allowing Whitefish to qualify for public works grants based on financial need.

1. Geographic Scope Related to Columbia River Basin

The Whitefish Lake Watershed is nestled inside the larger Flathead Lake Watershed which encompasses over 6 million acres (9,375 square miles) of land and water. The Flathead Lake Watershed is in turn part of the Columbia River Basin with over 166 million acres (260,000 square miles) (See Columbia River Basin map in Chapter XXI, Addendum B GIS Maps).

Water from the Whitefish Lake Watershed flows through forests, farms and cities eventually reaching the Pacific Ocean at Astoria, Oregon. The outfall of Whitefish Lake is the Whitefish River at the southern end of the lake. Together with the Stillwater River, these two rivers drain the northwest part of the larger Flathead Lake Watershed, joining the upper Flathead River in Kalispell. The North, Middle, and South Forks of the Flathead River join together upstream of Columbia Falls, forming the upper Flathead River system. Together with the Swan River, they drain the eastern portion of the Flathead Lake Watershed and serve as the two central tributaries to Flathead Lake, emptying into the northeast section of the lake.

The waters of the Stillwater, Swan, Whitefish and upper Flathead rivers all unite and join Flathead Lake, the largest natural freshwater lake west of the Mississippi River. At Flathead Lake’s outlet, located at the southwest portion of the lake, the lower Flathead River flows 72 miles to where it joins the Clark Fork River. The Flathead River is the largest tributary of the Clark Fork River and serves as the headwaters of the Columbia River. The 1,270 mile Columbia River flows through four mountain ranges—the Columbia Mountains, Rockies, Selkirk Mountains and the Cascades—and delivers more water to the Pacific Ocean than any other river in North or South America. Water quality in the Whitefish Lake Watershed and Surrounding Area clearly has an influence on many downstream neighbors.

2. Geographic Scope Related to Crown of the Continent Ecosystem

The Whitefish Lake Watershed is also part of the larger Crown of the Continent Ecosystem (See Crown of the Continent Ecosystem map in Chapter XXI, Addendum B GIS Maps)) which covers approximately 18 million acres (28,000 square miles) of the Rocky Mountain region from its northern boundary of the Elk and Highwood Rivers in British Columbia and Alberta to the Blackfoot River Valley in Montana at its southern end. It is one of the most biodiverse ecosystems of its type in North America (Muhlfeld, 2010), encompassing landscapes ranging from mountains to grasslands, forests to barren rocks, and wildlands to busy centers of human activity. It is one of the remaining large wildlife movement corridors and at the same time hosts extensive use of its landscape for human settlement and recreation. The Crown of the Continent faces increasing pressure from resource extraction, residential expansion, and recreational use, which can contribute to increased habitat fragmentation and degradation of water and air quality. Fortunately, there have been positive trends by some resource extraction organizations to protect and permanently conserve large areas of land in the Crown.

B. PROJECT AREA ECONOMICS

The landscape encompassing the Whitefish Lake Watershed and Surrounding Area has a number of assets, some of which tend to be difficult to quantify. The natural environment—clean air, clear water, lush landscapes, and scenic vistas—is the chief asset driving economic demand. This bountiful area pairs youth and retirees, researchers and educators, and resource managers and organizations in a shared pursuit to understand, appreciate, enjoy and preserve this outstanding place.

Public lands and open spaces between the city and neighboring towns attract people and businesses. Similarly, development such as ski areas, golf courses, lodges and a variety of home types all increase the value and appeal of the area. Roads, railways, and airports increase accessibility and connections to metropolitan areas from which come our influx of new residents, businesses and visitors. While this in-migration stimulates the economy, its impact on the watershed may be equally damaging. Because so many combined factors affect the watershed, this is difficult to quantify. Planning for responsible growth is required to balance preservation of the natural environment that attracts people with the growth needed to maintain a vibrant community.

The 2007 Whitefish City-County Growth Policy lists the following goals and activities:

1. **Economic Development Goals:**
    - Maintain a healthy and vibrant base economy that sustains an influx of dollars into the community.
    - Protect the natural resources and unique character and qualities of Whitefish in order to support the continued health of the visitation economy.
    - Seek ways to diversify the local base economy with compatible business and industries such that the character and qualities of Whitefish are protected.
    - Develop and promote Whitefish as a year-round convention and destination resort community providing amenities for the visitor and employment opportunities for area residents.

The City of Whitefish has historically invested in maintaining physical and service infrastructures, improving educational facilities, and fostering new business while maintaining the health of the Watershed. It involves developing appropriate zoning strategies and infrastructures that entice people with fresh ideas and new businesses to the area. It is critical that citizens join local government in continuing to develop growth policies that promote qualitative growth to enable citizen enjoyment while protecting the health of the area’s lands and waterways.

2. Employment Sectors

Using the North American Industry Classification System (NAICS), workers in the Whitefish area between 2009-2013, on average were employed as follows (U.S. Department of Commerce, 2013):

Agriculture, Forestry, Fishing, Hunting, Mining	3.6%
Construction	3.6%
Manufacturing	1.2%
Wholesale Trade	0.2%
Retail Trade	14.6%
Transportation, Warehousing, Utilities	6.4%
Information	4.4%
Finance, Insurance, Real Estate	10.4%
Prof, Scientific, Mgt, Admin, Waste Mgt.	15.5%
Education, Health Care, Social Assistance	16.8%
Arts, Entertainment, Recreation, Accom, Food	16.2%
Other Services	3.7%
Public Administration	3.4%

3. Intrinsic Value

In addition to the value of the landscape for attracting and maintaining residents and visitors, there is an economic value associated with the functionality of the landscape. For instance, our lakes and streams provide relatively clean water for us to drink and to irrigate our lands. What would be the cost to replace that functionality, if it could indeed be replaced?

Economists have developed a number of methods for describing the value of ecosystem functions. There are *direct uses*: the value we get from using part of the environment, such as water, timber, fish, pasture, and substances. There are *indirect uses*—also referred to as *ecosystem services*—such as water storage provided by aquifers, filtration and nutrient cycling provided by wetlands, and soil stabilization provided by plants. Also, there are *optional values* such as agriculture and recreation. Some other values that encompass culture, heritage, and aesthetics fall into other categories depending on cultural and economic viewpoints. Although many people throughout various disciplines have addressed these valuations, the methodologies of determining these values remains complex.

Economists have also worked on understanding and assigning costs associated with environmental effects. For example, there is a definable economic benefit to resource extraction companies working at a headwaters location, but the economic impacts from the resulting ecosystem damage that could result downstream are more difficult to calculate. Several methodologies have been studied and proposed, but resource managers lack a widely accepted set of tools, processes and criteria for decision-making based on such economic value.

In the summer of 2014, the Flathead Lake Biological Station (FLBS) compiled existing economic information for Flathead Lake and reported their results in the article, “Putting a price tag on Flathead Lake” (Flathead Lake Biological Station, 2015). Included in their compilation were the results of a shoreline property valuation calculated by University of Montana economists John Duffield and Chris Neher which concluded that “Flathead Lake boosts shoreline property values by $6 - $8 billion. Nature-based tourism accounts for roughly 20% of the $7.8 billion annual economy of Flathead and Lake Counties, and ecological services (e.g. water supply and purification, flood and drought mitigation) contributes another $20+ billion in benefits to human society.”

Researchers also noted what was not included in the compilation—the difficult to quantify “nonuse” values (the value of existence, species preservation, biodiversity, and cultural heritage) which also correspond to economic declines such as “lower personal incomes, depressed economic conditions and impaired human health.” Also discussed in the article were the costs for repairing ecological degradation, citing Lake Tahoe on the California-Nevada border where $1.4 billion has been spent since the 1960s on water quality restoration and protection projects, $415 million of which was spent since 2010.

Community leaders and resource managers have become increasingly aware of the long-term impacts of human development activities on the health of the watershed. It is increasingly important for these leaders to provide clear and consistent analyses of the costs and benefits, and processes to evaluate their activities. It is equally important for citizens to take responsibility for understanding the long term environmental and economic impacts on the natural resource management decisions they support or oppose. Citizens and their resource managers need to work closely together to sustain and enhance our economic vitality. Simply, it makes financial sense to invest in and protect our natural assets.

III. NATURAL HISTORY

A. CLIMATE

The climate in the area is typical of Northern Rocky Mountain intermountain watersheds west of the Continental Divide. Based on information from a Western Regional Climate Center weather station near Whitefish, average temperatures in the Whitefish Lake area (1948-2005) ranged from 15.5°F in January/February to 80.9°F in July/August (Western Regional Climate Center, 2014). July also had the warmest monthly average maximum for Whitefish (PBS&J, 2006). The project area receives an average 22-26 inches of precipitation annually with summer thunderstorms and winter snows providing a majority of the precipitation. The annual mean snowfall in Whitefish is 74.0 inches. Periodic drought cycles occur in the region at approximately 10-20 year intervals (Western Regional Climate Center, 2014).

Climate and Fire

Climate and weather play key roles in fire in that they contribute to the availability of fuels (trees, shrubs, and greases) and the moisture content of those fuels. Healthy, well watered plant material can hold as much as three times their weight in moisture during their growing season whereas drought stricken or dead plant materials may hold only up to 30% of their weight. Fires are also shaped by seasonal changes such as spring rain and runoff from melting snow pack. Plant material wet from these precipitation events ignite more slowly and burn at lower temperatures. Fires during dry summer months or in areas of prolonged drought tend to burn faster and hotter. Fuel build-up from overcrowded forest stands and natural forest floor litter also contribute to the frequency and intensity of fires. The 100 years of U.S. forest management policy to intervene in the natural cycle of wildland fire is now considered a contributing factor (UCAR, 2012). See Fire History map in Chapter XXI Addendum B GIS Maps for a graphical representation of the history of fire in the study area.

B. GEOLOGY & PHYSICAL GEOGRAPHY

1. Introduction

This section addresses some of the basic knowledge of landform and terrestrial attributes in the study area and the processes by which it has changed over time. Several maps are included to help visually describe the features that have resulted from this geologic activity over deep time. The following maps are found in Chapter XXI Addendum B GIS Maps:

Geologic Formation
Taxonomic Particle Size
Percent Slope
Sediment Hazard
Erosion Potential
Soil – Geomorphic
Existing Vegetation Type

2. Geology & Hydrology

To understand the geology of the Whitefish Lake Watershed, one must look to the deep history of a much larger land mass. During the Late Pleistocene Epoch (126 to 11.7 MYA), the Cordilleran Ice Sheet stretched from the current day southern Yukon Territory and southern Alaska down to the US-Canadian border. Ice advanced along the southern margin of the Cordilleran Ice Sheet down a number of valleys in Montana, Idaho, and northern Washington. The Purcell Lobe blocked the Clark Fork River in the Idaho Panhandle, impounding Glacial Lake Missoula. The Flathead Lobe moved south through many mountainous valleys, terminating in the Flathead Valley south of today's southern shore of Flathead Lake. As the Flathead Lobe retreated, a pro-glacial lake formed at the southern portion of the lobe, a precursor of the modern Flathead Lake. Meltwater from the Flathead Lobe funneled through the Flathead Lake Watershed leaving in its wake a well-preserved record of changing hydrology resulting from deglaciation (Hofmann & Hendrix, 2009) (See sidebar on page 15 of this chapter).

The main lobe of the Cordilleran Ice Sheet entered Montana north of Eureka, crossed the Tobacco Plains to Black Butte where it split in two. Initially, one branch travelled down the Kootenai Valley and the larger branch went up the Tobacco Valley. Its terminal moraines are found south of Flathead Lake at Polson and west of the lake at Big Arm. It was augmented at Columbia Falls by other glaciers that moved down the North Fork and South Fork Flathead River valleys. As the main lobe moved down the Stillwater Valley it was pushed against the western edge of the Whitefish Range. Striations east of the northern end of Whitefish Lake indicate that the ice diagonally overrode the south end of the Whitefish Range. The branches of the Flathead Lobe left behind numerous moraines, including the low recessional moraine that impounds Whitefish Lake and upon which the City of Whitefish was built (Johns, 1970).

Whitefish Lake is therefore the result of Pleistocene Epoch glaciation, with morainal deposits of glacial till at its southern and eastern shores. The till is a heterogeneous mixture composed of unsorted gravels in a silt-clay matrix, suggesting widely varying hydraulic conductivities as well as varied seepage rates. The mix includes lacustrine silt, clay, gravel, and glacial drift. The glacial till of the area was mostly deposited beneath extensive ice sheets, leaving a dense core. Further toward the surface, the till is less dense having been exposed to progressive weathering. Esker deposits of sand, gravel, and cobbles also occur along the shoreline of Whitefish Lake. (Montgomery *et al*, 2006; Jourdonnais *et al*, 1986; USDA Natural Resources Conservation Service, 1960).

One of the hydrologic features of the Whitefish area is seasonally high groundwater, a sign of the proglacial lake that once covered a much larger area where it deposited meters of non-porous lacustrine silt. It is not unusual in the spring to see numerous homes throughout the city with hoses leading from sump pumps to drainage areas.

The Whitefish Lake Watershed and Surrounding Area is located in the southern part of the Rocky Mountain Trench which begins in British Columbia and is bounded by the Whitefish Mountain Range to the north and Swan Range to the east and includes

> the Whitefish and Stryker Faults running northwest to southeast along the east and west sides, respectively, of the lake. The Rocky Mountain Trench was a primary area for repeated southward advances and retreats of the Flathead Lobe of the Cordilleran Ice Sheet and was covered with large glacial lakes as the ice receded. Stagnant melting of glacial materials left behind a kame and kettle topography, glacially sculpted drumlin ridges, coarse fluvial terraces, and morainal deposits (Alt & Hyndman, 1986).
>
> Outcroppings of Precambrian dolomitic limestone occur parallel to and along the lake’s west shore, dipping perpendicularly into the lake at approximately a 30-degree angle. In general, limited groundwater seepage occurs along this west section of shoreline because flows are limited to fractures and joints in confined bedding planes. Hydrolyzed illite and chlorite clays cover these formations, sometimes further restricting groundwater movement. The highest seepage rates are found in the alluvial deposits along the north shore of the lake near Swift Creek where deposits are composed of stratified, well sorted gravels that yield high hydraulic conductivities. Aside from these areas, the glacial soils around the lake are typically non-porous or poorly drained. (Johns *et al*, 1963; Jourdonnais *et al*, 1986).
>
> Two springs were reported on the northeast shore of Whitefish Lake in a glacial moraine with a water table strike of 45°N with a 2°SW dip (Chamberlain, 1976). These springs represent an outcrop of an aquifer or where an aquifer was overlain. Additional springs and seeps were also found along the east shore of the lake downslope from Alpine Village.

Although several types of mineral deposits are found throughout northwestern Montana, there are only two well referenced prospects of ore in the project area. Located at the south end of the Whitefish Mountains on a southwest flowing tributary of Haskill Creek, one prospect was developed by the Micho brothers of Whitefish in the 1940s (Johns, 1970). The other prospect site was located approximately eight miles up Swift Creek on an unnamed tributary. See Chapter IV Cultural History, Section A Historic Land Use, 9 Mining for additional information.

Abbreviated Evolution of Proglacial Whitefish Lake

Sidebar by Cliff Clark, University of Montana, Department of Geosciences

Abstract

The Whitefish Lake Watershed and surrounding area is located in the southern part of the Rocky Mountain Trench, which begins at the Yukon/British Columbia border in the North, and extends south into the Flathead Valley. In the Whitefish Lake area, however, the trench is bounded by the Whitefish Mountain Range to the north and Swan Range to the east, and includes the Whitefish and Stryker Faults running northwest to southeast along the east and west sides, respectively, of the lake.

The Rocky Mountain Trench was a primary area for repeated southward advances and retreats of the Flathead Lobe of the Cordilleran Ice Sheet (~13,000 BP). During the Late Pleistocene, the Cordilleran Ice Sheet covered much of northwestern North America, stretching southward into the Flathead Valley. However, the multiple advances of the Cordilleran Ice Sheet have not been well defined spatially or temporally (Capps 2004). This study attempts to establish a foundation for the Quaternary

history of the Whitefish Lake region, and the maximum extent of Glacial Whitefish Lake during the retreat of the Flathead Lobe of the Cordilleran Ice Sheet.

Introduction

The Flathead Valley was once the geologic setting for one of the major southern lobes of the Cordilleran Ice Sheet during the Pleistocene glaciation termed the Flathead Lobe (L.N. Smith 2004). The progression and retreat of the Flathead Lobe carved the surrounding landscape into its current state we see today. However, much discussion has arisen regarding the geologic setting during this recent glaciation of the Flathead Valley. Chronicling the glacial landscape during the retreat of the Flathead Lobe has been a difficult task to achieve. Due to the scarcity of organic material in the region, the Quaternary history of the Flathead Valley is primarily based on the sedimentology and glacial landform distribution of the area.

Glaciolacustrine sediment, which can be defined as sediments deposited into lakes from glacial meltwater, provide key evidence in the Flathead Valley for the margins of glacial lakes during the retreat of the Cordilleran Ice Sheet. Understanding the chronostratigraphy, and lithology of the Whitefish area based on previous literature and continued research is a necessary step in order to understand the ongoing geologic processes occurring today. In this paper we present evidence for glacial lake boundaries that formed during the retreat of the Flathead Lobe by the use of previous literature, and current stratigraphic and morphometric observations.

Methods

Northwest of Whitefish Lake, in the Stillwater Forest Complex is the location of our study site. The Montana DNRC, Stillwater Unit, granted soil-sampling authorization on this land. In order to ensure a study site that was resistant to erosion, a shallow topographic area was located within the permitted research boundaries. A total of ten dig sites were observed.

At our dig sites, glaciolacustrine sediments were evident. Glacial till was the underlying parent material within each dig site. A bank formation, about 3 meters in height was a boundary for the glaciolacustrine silts and clays. We interpret this bank to be an ancestral shoreline based on stratigraphic evidence. On top of the bank, or shoreline, each excavated hole consisted of primarily glacial till. However, on the flat below the bank was glaciolacustrine sediment overlying glacial till. GPS points were recorded for each dig site, along with altitudes for each point. Since geomorphic responses in the Flathead Valley are fairly limited post-deglaciation we have modeled the altitudes of the ancestral shorelines to represent the glacial lake boundaries that existed ~13,000 BP (Assuming no uplift/minimal erosion).

Analysis/Discussion

1.1 Analysis of Shoreline Evidence

Due to stratigraphic and morphometric observations and evidence, we have concluded that the ancestral shorelines northwest of Whitefish are in fact the ancestral lake boundaries of Whitefish Lake. After modeling the altitude of the lake boundaries, we have further concluded that following the retreat of the Flathead Lobe a large proglacial lake covered much of the valley floor. Our model provides evidence that present-day Flathead Lake and Whitefish Lake were once one large water body after the retreat of the Flathead Lobe. The altitude of the ancestral lake surface was ~934 meters above sea level. Seasonal runoff/glacial melt and discharge may have altered this level ± 3 meters, however, this boundary represents a mean lake level based on our shoreline evidence.

Further ancestral lake evidence is documented to the west of Whitefish, along U. S. Highway 93 in Stillwater valley, where a well-formed recessional moraine dams Whitefish Lake. The lithology of the moraine is primarily rock fragments of the Belt Supergroup series: maroon and green argillite, quartzite, and some limestone (Alden 1953). The moraine is bounded by bedrock along the southwest and northeastern shores of the lake. Overlying the glacial till composed moraine is a layer of glaciolacustrine silt and clay. Based on our model, the lake would have covered this moraine, thus validating the evidence of glaciolacustrine silts and clays in this vicinity.

1.2 Interpretation of Glacial Whitefish/Flathead Lake

As mentioned, glaciolacustrine silts and clays are revealed northwest of Whitefish Lake, and on top of the moraine that borders Whitefish at its southern shore. By modeling our data, a conclusion has been drawn that following the retreat of the Flathead Lobe of the Cordilleran Ice Sheet, a large proglacial lake covered the majority of the valley floor. The discharge of water associated with the retreat of the Flathead Lobe is the primary water source for this water body. Discussion has arisen surrounding Glacial Lake Missoula's influence on this lake. We have concluded that due to the elevation of the Polson Moraine bordering the southern shore of Flathead Lake (~1,000 meters above sea level), Glacial Lake Missoula would have flooded this moraine, and filled the proglacial lake to a level much greater than what is evident. Also, since the ice block damming Glacial Lake Missoula along the Clark Fork River repeatedly failed, we would assume that during the retreat of the Cordilleran Ice Sheet this southern margin of the Purcell Lobe would have been the first to retreat or fail, well before the much larger, denser Flathead Lobe started its retreat. Glacial Lake Missoula most likely bordered the Flathead Lobe during the last glacial maxima, however, we have concluded that it had no influence on our study due to Glacial Lake Missoula having drained prior to the retreat of the Flathead Lobe, therefore establishment of Ancestral Whitefish/Flathead Lake.

Conclusion

Understanding the episodic events that took place during the retreat of the Flathead Lobe of the Cordilleran Ice Sheet is an important aspect to current watershed dynamics within the Whitefish surrounding area. We will continue to better define the boundaries of Glacial Whitefish/Flathead Lake, and furthermore, the geochronology of the Flathead Valley during the late Pleistocene. Stratigraphic evidence, and prior research has helped us better understand the glacial landscape that existed in the Flathead Valley, however, further investigation of this evidence is necessary in order to better define the parameters of these glacial episodic events as it relates to our current understanding of local landform distribution and current watershed dynamics.

See the Glacial Whitefish Lake map in Chapter XXI Addendum B GIS Maps.

3. Seismicity

Information for this section came from the Montana Bureau of Mines and Geology, Earthquake Studies Office.

The project study area lies within the northern end of the Intermountain Seismic Belt (ISB) (Figure 2), an active earthquake zone that extends from northwest Montana to Yellowstone National Park. From Yellowstone, the ISB continues south along the Idaho-Wyoming border, through Utah and into southern Nevada. A west-trending branch of the ISB extends from Yellowstone through southwestern Montana and into central Idaho. This so-called Centennial Tectonic Belt had the two largest historic northern Rocky Mountain earthquakes, the Magnitude (M) 7.3 Hebgen Lake earthquake on August 18, 1959 and the M 6.9 Borah Peak, Idaho earthquake on October 28, 1983. ISB earthquakes tend to occur at shallow depths, typically no deeper than 12 miles below the surface. Except for the very largest earthquakes, ISB earthquakes rarely can be ascribed to mapped faults and apparently result from slip on smaller, discontinuous "blind" faults that do not extend up to the earth's surface.

Montana has a history of large damaging earthquakes. An M 6.6 earthquake centered in the Clarkston Valley near Three Forks in June 1925 heavily damaged brick buildings in Three Forks, Manhattan, Bozeman, and White Sulphur Springs. A decade later, an energetic series of earthquakes centered close to Helena damaged about 60 percent of the buildings and resulted in four deaths. The October 1935 Helena earthquake sequence included an M 6.3 followed two weeks later by an M 6.0 and a total of over 1800 earthquake during the following six months.

Montana's largest historic earthquake occurred August 18, 1959 with an M of 7.3. This powerful earthquake generated surface ruptures along 18 miles (30 km) of two faults north of Hebgen Lake. The surface displacement along the northeast shore of Hebgen Lake was as much as 21 feet of vertical subsidence. This sudden tilting of the lake basin towards the fault generated a huge wave—a seiche—that washed back and forth across the lake, overtopping Hebgen Dam and destroying cabins along the shores. The violent seismic shaking triggered a massive rock slide from the south wall of Madison Canyon, which dammed the Madison River to form Earthquake Lake. The Madison Canyon slide buried part of a campground killing 26 people. Three other people in the surrounding area were killed by rock falls. Over $11 million in damages occurred to highways and bridges.

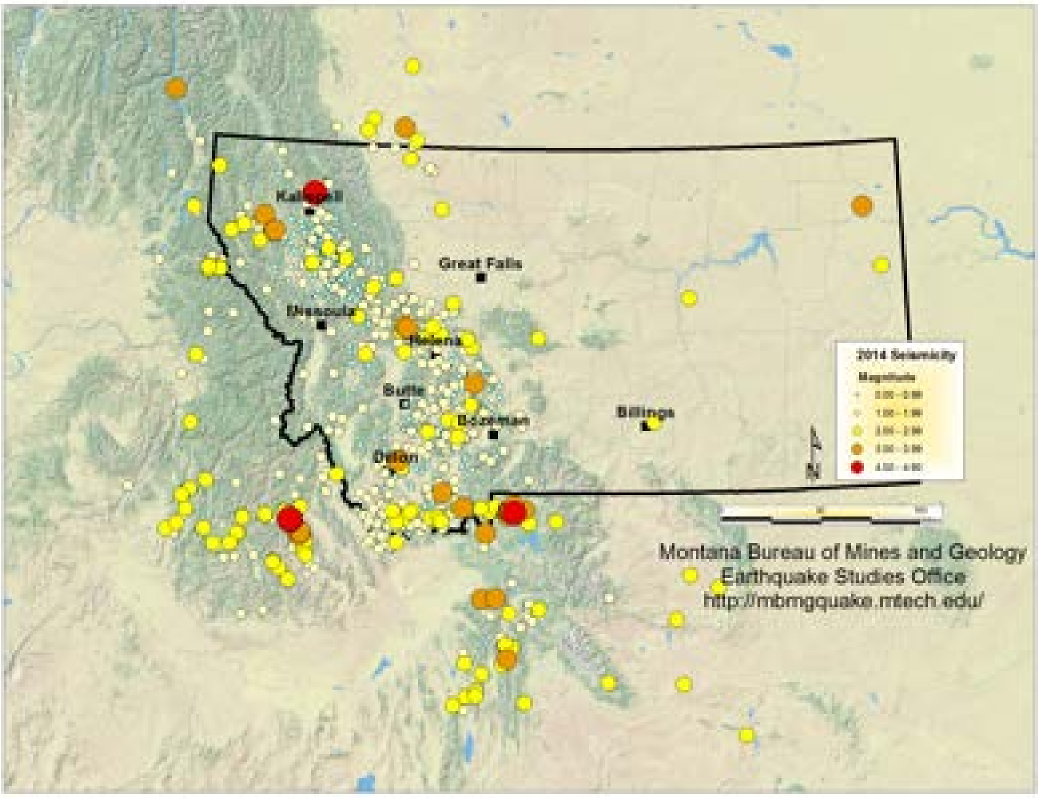


Figure 2. Seismic Activity Montana.
Courtesy Montana Bureau of Mines & Geology Earthquake Studies Office

The 1959 Hebgen Lake earthquake remains the largest earthquake in the northern Rocky Mountains and serves as a graphic example of the devastation a major earthquake can inflict in mountainous terrain—the dire consequences multiply with increasing population and infrastructure in the epicentral area. Newspaper articles, photographs, and personal accounts of the most significant ISB earthquakes document the effects of historic earthquakes (http://www.seis.utah.edu/lqthreat/perseq.shtml).

Although northwestern Montana has endured numerous small to moderate magnitude earthquakes, the historic record does not yet include a major destructive earthquake. A M 5.5 earthquake centered near Lakeside on September 23, 1945 was felt over an area of 36,000 square miles. A M 5.5 earthquake centered near Swan Lake on March 31, 1952 was felt over an area of 30,000 square miles. A M 5.0 earthquake February 4, 1976 was centered near Creston and strongly shook the Big Fork-Kalispell-Whitefish region. During 2014, nine earthquakes with magnitudes ranging from 3.1 to 3.9 occurred in northwestern Montana, including a M 3.9 event centered three miles east of Whitefish on November 15, 2014. Over 360 residents in northwestern Montana and northern Idaho reported feeling the November earthquake. A M 3.6 quake centered near Somers occurred on April 11, 2015. Frequent small to moderate magnitude earthquakes and the existence of several potentially active faults in the region (http://earthquake.usgs.gov/hazards/qfaults/map/) demonstrate the possibility of a larger earthquake. The US Geological Survey's National Seismic Hazard Map quantifies this hazard (http://earthquake.usgs.gov/hazards/products/conterminous/2014/HazardMap2014_lg.jpg).

IV. CULTURAL HISTORY

A. HISTORIC LAND USE

From native inhabitants to early settlers, the people of this lake-centered study area have depended on an abundance of natural resources to sustain and build their communities. The history of the area includes ice and timber harvesting; brick-making; agriculture, mining, and an abundance of recreational pursuits. All of these activities were either seeded or grown by the availability of transportation, particularly the railroad. With community growth come human developments, urbanization, and increasing demands on natural resources. WLI staff members hope that the information contained in this study will help citizens, community leaders, and resource managers develop policies that reflect a balance between the needs of our growing community and protection of our natural resources.

1. Historic Land Clearing

The creation of “Stumptown” literally involved large scale land clearing of trees in a landscape that had many marshy areas. Drainage issues probably were exacerbated by early filling of natural swales and gullies for the building of roads and sidewalks. That process, according to Schaffer and Engelter (2003) started in the 1920s when downtown storm sewers were installed as an overall component of infrastructure improvements including streets, sidewalks and curbs. These actions most certainly decreased water infiltration rates and increased overland flow of water.

One major current day disturbance is readily seen from numerous sites on Whitefish Lake as a large-scale visual landscape scar left by the landowner’s activities. The resulting erosion activity below the property can be seen in Figure 3. Open-cut mining investigator Rod Samdahl of the Department of Environmental Quality reported at the time that the landowner “…cut down all the trees and stripped vegetation and native topsoil from the majority of the 40-to-50 acre site,” and that topsoil was “…used as fill in draws and drainages as deep as 50 feet in places” (Hanners, 2005). In the summer of 2005, WLI was first to report excessive erosion that occurred on the property from a three-day rain event during which over three inches of rain fell. The erosion contributed “inordinate amounts of turbidity and total suspended solids to Hellroaring Creek and ultimately Whitefish Lake” (Koopal, 2005c). WLI worked with the Whitefish Lakeshore Protection Committee to ensure appropriate documentation and water quality sampling. The landowner’s activities resulted in multiple DEQ stormwater violations.

Figure 3. Erosion from Improper Development.
Photo courtesy WLI

Disposal of garbage was an immediate and continuing problem. The *Whitefish Pilot* reported in 1904 that refuse around town was dangerous, and that refuse along the river bank, when eaten by cows, caused germs in the milk supply, which, in turn, could easily cause typhoid (Schaffer and Engelter, 2003). Other anecdotal information suggests that garbage was used to fill in swales in a number of areas around Whitefish Lake. It could be logically assumed by this narrative that the garbage probably contained hazardous materials, such as kerosene that was used both publicly and privately for lamps. Cows grazing in the riparian zone would have exacerbated the effects from prior logging in that area, and would have grazed on riparian bushes and sedges while trampling the river banks and lakeshore, increasing sedimentation as a result.

2. Railroad Transportation

a. <u>Brief History of the Railroad in the Whitefish Area</u>

The company currently known as the BNSF Railway is just the present configuration in the long history of the railroad. In 1878, railroad businessman James J. Hill and his investors purchased the St. Paul and Pacific Railroad, a bankrupt railway with some track in Minnesota. In 1889, Hill changed the name of his railway—which existed mostly on paper—to the Great Northern Railway, and in 1890, he transferred his ownership in all the other rail systems he owned to the Great Northern.

The Great Northern later merged with the Northern Pacific Railway; Chicago, Burlington and Quincy Railroad; and the Spokane, Portland and Seattle Railway to become the Burlington Northern Railroad (BN). BN operated until 1966 when it merged with the Atchison, Topeka and Santa Fe Railway to form the Burlington Northern and Santa Fe Railway (BNSF). In 2009, the BNSF Railway was purchased by Berkshire Hathaway which is controlled by investor, business magnate, and philanthropist, Warren Buffet, who retains the BNSF Railway name.

"That the Great Northern Railway came to Whitefish was a kind of miracle-offspring if vision and grudge; devotion and greed; sweat, hardship, and pure accident" (Schafer and Engelter, 2003). Between 1890 and 1990, over 100,000 people streamed into Montana, which had only become a state in 1889. A very small number of those people made their way to the far northwest corner to the tiny community sprouting up around Whitefish Lake. This was soon to change. Railroad businessman James J. Hill saw enormous opportunity for Montana to become the trade route link between Europe and the Orient. As part of his April 7, 1937 address to the Helena, Montana Chamber of Commerce, Great Northern executive Harold M. Sims, commented, "*…Mr. Hill visioned the railroad he was to build as a gigantic bridge, with Montana as the center pier…"* (Schafer and Engelter, 2003). With Hill's motivation to extend the train system he operated in Montana to the Puget Sound, and with no possibility of a very direct route, his engineer John F. Stevens was sent to examine Marias Pass as a possible route.

Based on Stevens' 1889 report, Hill extended the tracks westward to Marias Pass at about 5213', down the Flathead River through Columbia Falls toward Kalispell. The rail-laying train reached Kalispell on January 1, 1892 bringing with it a mass influx of new residents from Demersville—south of Kalispell—to the new Kalispell town site. The tracks were extended to Jennings, Montana and on to the Cascades in 1892. Difficult grades, severe curves, and a troublesome roadbed forced Hill to find a better route for the part of the track that crossed Haskill Pass. That new route was a 60.5 mile track from Columbia Falls to Whitefish and then on to Rexford. The 8.5 mile track between Columbia Falls and Whitefish was completed in 1903. The remaining track from Whitefish to Rexford—where by 1902, Hill had a spur road leading to the Canadian oil fields—was completed in 1904. The original route from Kalispell to Jennings was abandoned, as were Hill's plans to make first Columbia Falls, and then Kalispell the train's division point.

Whitefish ultimately succeeded Kalispell as the division point for the railroad. There are a number of stories as to why Hill chose Whitefish for the division point, including Hill's concerns over one man's plans for unfair personal profit taking and another's pure business greed. However, it may simply have been the accessibility of water and ice from Whitefish Lake that captured Hill's attention.

Track laying brought to the area work camps, rough hotels, supplies, and much movement of equipment. Most of the equipment was loaded onto wagons from steamboats at Demersville. The wagons were then belayed down steep cliffs to work sites by ropes tied around trees. The largest railroad camp was the central construction site between the head of Whitefish Lake and Lupfer where the main railroad hospital was also situated. Two major railway projects in the Whitefish area included a trestle bridge over Beaver Bay on the southwest lake shore and a tunnel near the head of the lake. Somewhere in 1918-1919, a large, unstable earthen grade replaced the trestle.

A grade from an old railroad spur that was used for moving harvested timber remains visible up the Lazy Creek drainage. There are also numerous areas around the lake where evidence of track-laying sidecasting (the practice of dumping excavated materials) remains, including large angular rocks left behind in many areas of the west lakeshore (Figure 4). Hundreds of men were employed during those railroad building years, surveying, brush clearing, and blasting, leaving clouds of dust in their wake—all work that was unhealthy for the workers and contributed particulates to the lake. The railroad town of Whitefish came about with many challengers. Back in 1891,

Figure 4. Sidecasting at Mackinaw Bay.
Photo Courtesy WLI

Charles Ramsey, who built the second known cabin on the shores of Whitefish Lake, imagined a future filled with tourists. He built a rooming house near his cabin to attract hunters and fishermen, but it eventually also housed railroad workers. It operated as a hotel until 1903, when Jack and Ward Skyles then opened a grocery store with a post office in the old Ramsey building. Mail was addressed to the town of “Ramsey.” Although many people supported the growth of this town at the lake’s edge, others, including Fred B. Grinnell, set their sights on building the town near the rail station where the Great Northern Railway would soon be coming through.

The rough and scrappy town of Whitefish grew to become a City on June 25, 1903. The first passenger train came through Whitefish on Sunday, October 4, 1904, arriving on time to a cheering town and forever changing the community. The first regular meeting of the “Town Council’ was held on July 1, 1905; and the first census of Whitefish was taken in 1905 identifying 950 people.

b. Legacy Pollution

The railroad has historically been an economic blessing to the City of Whitefish, but it has also caused chronic legacy pollution. As noted in the Whitefish Lake Sediment Table (Figure 12 in Section 5 Land Use and Lake Sediment), the clearing of the Great Northern railroad grade at the turn of the 20th century is suspected to have contributed large amounts of fine sediment to Whitefish Lake. The 78-acre fueling and repair facility at the Whitefish West rail yard with its roundhouse and maintenance shops were constructed in 1903 and 1904. Locomotive maintenance continued there until 1958 when those activities were moved to other facilities. Routine fueling and light maintenance of engines at the rail yard continues today.

Spills, leaks, and oily discharge to wastewater lagoons at the rail yard facility have caused soil and shallow groundwater contamination from petroleum products (primarily diesel), polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) volatile organic compounds (VOCs), and heavy metals.

BN installed a lagoon system to contain and treat oily wastewater in the 1960s. In 1973 then BNSF began recovering free petroleum from shallow groundwater through an interception trench just above the Whitefish River. In 1986, EPA consultants inspected the facility and from 1987 through 1989, BNSF conducted investigations to determine the extent of the contamination at the facility. In 1989, during Montana Department of Transportation (MDT) geotechnical studies for a proposed highway overpass, diesel was encountered in the soil. From 1989 to 1992, MDT and its consultants engaged in investigations and design studies to determine the best methodologies for handling contaminated soil and groundwater during the overpass construction process. In 1994, the facility was designated a Montana State Superfund site and in 1998 BNSF was notified that it was liable for cleanup at the facility (Department of Environmental Quality, 2015).

In 1996, a Remedial Investigation (RI) work plan was submitted by BNSF, and in 1998, DEQ issued a Unilateral Administrative Order to BNSF requiring the completion of the RI and feasibility study. Trench repair and improvement work was conducted in 1997. In October 2005, after a few years of drafts and reviews between the parties, DEQ approved work plans to upgrade the interceptor trench and conduct interim remediation of lead-contaminated soil. From 2006 through 2008, BNSF implemented a number of improvements and controls in the rail facility. Since 1991, approximately 15,105 gallons of free product have been recovered from the interceptor trench and 743 gallons from recovery wells. The remaining plume is limited to an area between the turntable and wastewater lagoon.

c. Remediation on the Whitefish River

After a 2007 Environmental Protection Agency (EPA) investigation and sampling of a reported petroleum sheen on the Whitefish River, the EPA ordered BNSF to clean the river along the Whitefish West rail yard. The river cleanup was conducted from 2009 through 2013, removing 26,000 cubic yards of contaminated sediment and backfilling it with river rock. The problem with nutrient or pollutant loading of the Whitefish River is that it is a low gradient river with spring flows largely attenuated by Whitefish Lake. As a result, sediment and pollutants have a tendency to build up over time due to the minimal flushing velocities.

BNSF continues to conduct groundwater monitoring and to recover petroleum contamination from groundwater through the interceptor trench. They are also required by DEQ to produce a Human Health Risk Assessment (HHRA) work plan for the facility. DEQ is reviewing BNSF’s spring of 2015 trichloroethene (TCE) investigation results for the plume located to the west of the roundhouse. An action plan will be developed once this review is complete. DEQ is also evaluating the Whitefish River to see if organisms are being re-established in the post-clean-up sediment (Montana Department of Environmental Quality, 2015).

d. Mackinaw Bay 1989 Trail Derailment

On July 31, 1989, a BNSF freight train derailed from its Hi-Line track approximately four miles northwest of Whitefish. Four diesel-filled tank cars slid down the slope below the track on the west shore of Whitefish Lake at Mackinaw Bay. Three of the four cars leaked between 20,000 and 25,000 gallons of diesel onto the shoreline and into the lake. (Figures 5 and 6) On August 2, 1989, the DEQ sampled residential drinking water supplies obtained from the opposite lakeshore, about one mile east of the derailment site. Although no samples exceeded EPA drinking water standards, several showed very low levels of benzyne, toluene, ethylbenzene, and xylene (BTEX) contamination (Montana Department of Environmental Quality, 2014). The governor of Montana declared a state of emergency in Flathead County as a result of the spill and the lake was temporarily closed to the public. Clean-up efforts at the time included the upland areas and floating petroleum.

Figure 5. 1989 Derailment.
Photo Courtesy Charlie Abell

Figure 6. 1989 Derailment.
Photo Courtesy Charlie Abell

Two weeks after the spill, with much of the surface water contamination contained or removed, contaminated shoreline soils were excavated and landfarmed at BNSFs Whitefish yard. Additional clean-up efforts were conducted in 1991 and 1992 at the appearance of an oily sheen on the lake surface. There was no removal of submerged petroleum from lake sediment at that time.

In 2009—the 20th anniversary of the spill—a report of residual sheen and petroleum hydrocarbons was made by a Whitefish citizen to WLI. WLI conducted an initial investigation and confirmed existence of the contamination, then inserted itself as a catalyst to engage the EPA, DEQ, the City of Whitefish, and BNSF to further study and arrange for additional cleanup from the spill. Testing by WLI confirmed that extractable petroleum hydrocarbon (EPH) contaminant levels in the lake were 16.8 times higher than the maximum contaminant level federal drinking water standards and 8.65 times higher in the surrounding soils.

In May of 2012—twenty-four years after the initial spill—BNSF and its contractors, under the direction of the EPA, began a cleanup effort that included removing approximately 400 cubic yards of contaminated sediment from the bay (Figure 7). A barge-mounted excavator moved soil from the lake to *in situ* rail car bins which were ferried to the Whitefish City Beach boat ramp. Rail car bins were loaded at City Beach to a temporary platform which was erected for staging materials and then trucked to the BNSF Whitefish facility where they were dried prior to being transported to a licensed waste facility in North Dakota. The effort which removed approximately 97% of the contamination was completed on June 25, 2012.

Figure 7. Mackinaw Bay Clean-Up.
Photo Courtesy WLI

e. BN Whitefish Facility State Superfund Site (U.S. Department of Environmental Quality, 2015)

The 78-acre train refueling and repair facility has been in operation since 1903. The facility has three fueling areas including a freight refueling area west of the overpass, and two Amtrak fueling areas east of the overpass. The Amtrak fueling areas are no longer used, however the freight fueling remains active. Fueling, repair, general railroad operations, and wastewater transportation over time resulted in soil and groundwater contamination. Under DEQ oversight, BNSF has been addressing contamination from petroleum products (mostly diesel), PAHs, PCBs, VOCs and heavy metals.

BNSF activities in 2015 include an evaluation of the ecological health of the Whitefish River to find whether BNSF post-cleanup activities enabled sediment dwelling organisms to re-establish themselves; and a Human Health Risk Assessment (HHRA) work plan required by DEQ. This HHRA will result in a feasibility study for treatment options and technologies that will be open to public review and comment. DEQ will evaluate public comment on the proposed plan and result in a final Record of Decision (ROD). BNSF will implement final cleanup per DEQ.

f. Railway Today and in the Future

The Great Northern Railway built the present Alpine style Whitefish train depot in 1928 (Figure 8). In the 1980s, after sixty years of uninterrupted use, BNSF decided to vacate the then badly deteriorated building. The Stumptown Historical Society, which was established to preserve the history of the town of Whitefish and the Flathead Valley, engaged the railroad in a transfer of ownership. Along with that transfer came money that the railroad had intended for a new building, helping fund the depot’s restoration.

Figure 8. Whitefish Train Depot. *Photo courtesy Amtrak*

In 1990 the Stumptown Historical Society completed restoring the depot to its original Glacier National Park chalet-like appearance (Amtrak: Great American Stations, 2014).

Today, the town of Whitefish is considered one of Amtrak’s top ten spots, with service by two daily passenger trains. The Stumptown Museum, located in the historic depot building, houses railroad artifacts and community memorabilia and photographs. Great Northern Locomotive #181, one of only seven of its kind ever built, can be seen at the museum. In 2013, approximately 66,840 of Montana's 148,612 passengers (47%) moved through the Whitefish depot (Amtrak: Fact Sheet, 2014). In addition, an average of 32 BNSF trains traveled through Whitefish daily from June through December of 2013, primarily moving Intermodal, grain, and mixed freight (Matt Jones, personal communication, 2014). Although Amtrak and BNSF continue to work hard to maintain their safety records, there are concerns related to railway transportation. The greatest concerns relate to oil and coal.

3. Ice Harvesting

Following the establishment of the Great Northern division point in Whitefish, the railroad built the first ice house in 1904. There were eventually seven such ice houses, each holding an average of about 10,000 tons of ice. Whitefish native Kevin McCready, the son of a retired railroader, researched and assembled a history of ice harvesting and the railroad's ice houses (Chase, 2009). During his cataloguing and archiving of 120 years of Flathead Valley newspapers for the Museum at Central School, McCready found the first mention of ice harvesting in 1890.

Henry DuPuy and William Penny put up a stock of ice for their own use, after which Penny received a contract to harvest ice for an eating establishment owned by John Clifford who would become the mayor of Demersville. But it was the demand for the transport of fresh fruit that drove the need for refrigerated rail cars and the ice houses in which the ice was stored. According to McCready, the ice houses were designed to vent warm air above where blocks of ice were stacked and covered with sawdust for insulation. The houses were typically stocked with ice in mid-February when ice from Whitefish Lake and other local lakes was at its peak. An annual harvest of 22-30 million pounds was not unusual.

The railroad generally contracted out the ice cutting to local crews, stimulating the economy of Whitefish by providing work for up to 100 men for three to four weeks. Snow was cleared from digging sites on Whitefish Lake using horse-drawn plows and men with shovels. Crews then scored the ice in a grid pattern by driving horses pulling a plow-like implement. A hand powered auger was then used to drill a hole large enough for a human-powered cross-cut style saw that was about five feet long. The crew then floated a 12 x 30 ft raft of ice near the shore where they would chop off blocks about 22 x32 inches and weighing 250-300 pounds each. Poles and gaffs were used to slide the blocks onto the shore where they were loaded by hand or pulled by horse onto railcars, wagons and trucks to be brought to the ice houses. The work—from wrangling the horses on the frozen, icy lakes to moving large, heavy slippery blocks of ice—was extremely dangerous and lives were lost.

In 1923, the Fruit Growers Express and the Great Northern Railway formed the Western Fruit Express to compete with the Pacific Fruit Express and Santa Fe Refrigerator Dispatch. The Fruit Growers Express is now a wholly owned subsidiary of the BNSF Railway. The 1950s brought improvements to the ice harvesting process, including Jeeps with snowplows, gasoline powered saws, and motorized hoists. A February 28, 1951 article in the Daily Inter Lake reported:

"Ice harvesting on Whitefish Lake has become an annual event. Between seven and eight thousand tons have been taken off the lake each year for the past two years…In 1950 the ice measured 14 inches when cut and in 1951 only a foot. What the ice lacked in thickness this year, the temperatures made up for. Cutting was conducted at temperatures of about 20 degrees below zero last year but was about 50 degrees higher this year, or around the freezing point."

Based on McCready's research, the last documented ice harvest of 2,000 tons took place in 1972 (McCready, 2009). Ice harvesting stopped when mechanically refrigerated rail cars came onto the scene obsoleting the need for ice.

WLI past board secretary/treasurer, Charlie Abell worked at the rail yard on the refrigerated rail cars. Charlie worked two summers to make money while he was a college student, working from 8:00 pm to 4:00 am. The platform was designed to be the same height as the rail car opening and had a mechanical chain that moved up and down the approximately 100-yard platform (Figure 9). Using a pointed pole, he pushed the ice blocks onto the cars.

During his senior year of high school, WLI's first board President, Gene Hedman worked loading "cakes" of ice from Whitefish Lake onto a conveyer belt to awaiting trucks that transported the ice to the ice house. According to Gene, "it was the hardest physical work ever done in my life."

Figure 9. Photo of Ice Houses and Rail Cars.
Photo Courtesy of Charlie Abell

4. Timber Harvesting

Content for this section came from personal conversations with Ronald Buentemeier, retired long time employee and General Manager at F.H. Stoltze Land and Lumber Company, who serves as chairman of the Flathead Conservation District board. Mr. Buentemeier made available his extensive timber industry archives, for which we could not do justice in this short section. Additional content was derived from the <u>Flathead National Forest Trails of the Past: Historical Overview of the Flathead</u>

National Forest (2010) and through communications with Brian Sugden, Hydrologist with Plum Creek Timber Company.

The Rocky Mountain States were the last to develop a lumber industry. But, lumber was the first Flathead Valley product exported after the railroad was completed in 1891. The shoreline area around Whitefish Lake was logged in the mid to late 1880s by the Baker Brothers who built a mill at the outlet of the lake. After sawing lumber, it was floated down the lake or hauled by sled across the ice. Every spring, there were great "log drives" (Figure 10) lasting about ten days down the Whitefish River into the Stillwater and Flathead Rivers. "Drives" from Whitefish Lake to the Whitefish River were supplemented by "Splash Dams" which held back the natural flow of water at the lake outlet. Using sluiceways, the water was held back then forced out in one big splash controlled by a combination of lift gates and pry bars.

Figure 10. Whitefish River Log Drive.
Photo Courtesy the McKeen-Gilliland Family & Ron Buentemeier

By 1884, the Anaconda Copper Mining Company (ACM) in Butte, Montana was using 300,000 cords of wood a year provided by mills west of the Continental Divide just for fueling their smelter. ACM was the most productive copper mine in the US at the time and by 1888, they were using 4,000 board feet of timber per day in their mines. Recognizing timber's importance to their operations, ACM bought the Big Blackfoot Milling Company to supply their own needs. In the early 1890s, ACM built its Butte & Montana Company (BMC) mill at the mouth of the Stillwater and Whitefish Rivers east of Kalispell for producing lumber and fuel for the mine's smelters. They also began building a dam at the outlet of Whitefish Lake to raise the water level to move logs down river to what would later become Kalispell. The dam reportedly raised the lake level by eight feet.

BMC purchased forested land near Whitefish Lake, contracting with Taylor & Fogg in 1891 for logs. Taylor & Fogg cut only good timber, skidding it to the lake. By 1892, the federal government brought timber trespass action against BMC and in 1894 sent a special agent to investigate. It was estimated that the company had cut over 6 million board feet from public domain land instead of the land they owned. The case was later dropped when the company filed for bankruptcy. Unable to keep up with increased freight rates, the company was sold at a loss in 1904.

In the background, the 1893 financial crisis that took place during the Harrison administration took a toll on the nation and its burgeoning industries. As the economy rebounded in the Flathead, the demand for lumber steadily increased. The demand became so great that a delegation of Flathead residents headed East to recruit laborers for logging and sawmills. Their efforts resulted in several thousand such workers coming to Montana. An 1898 national survey recorded 24 stationary sawmills, 3 portable sawmills, and 11 shingle mills in the state. Between 1899 and 1908, lumber prices crept up from $1 per thousand board feet to $11 per thousand board feet. Mine and railroad needs dominated the timber industry during this time in Montana.

In 1907, a group of citizens were appointed at a public meeting to bring to the Whitefish City Council the issue of removing the dam at the outlet of Whitefish Lake. After many editorials in the *Whitefish Pilot*, money was set aside to purchase the old dam and remove it. However, at about 2:00 am one June morning, a “deluge of detonations, fireworks, and flying missiles” blew up the dam (Schafer and Engelter, 2003). Legend has it that although no criminals were found at the time, one of the town’s “leading citizens” described in a private document how much fun he had in both blowing up the dam and keeping it a secret.

According to the January 5, 1906 edition of the Whitefish Pilot, there were eight active lumber logging camps in the Whitefish area in the winter of 1906, including the Baker Brothers with 60 men at the mouth of the Whitefish River, the Pluid Brothers who worked with the Bakers, Hutcheson with 35 men (10 cutting logs and 15 cutting telegraph poles), the Michaud Brothers (also miners) east of town, Swisher and Company five miles east of town, Henry Good with 40 men west of Stillwater, State Mill with 55 men, and the Matiskey (Motichka) Brothers with 25 men at Tamarack (Schafer and Engelter, 2003). It was around this time that the Baker Brothers sold their mill to the O’Brien Lumber Company which operated the mill until 1913 and a retail yard until 1928. Hutchison was then constructing a mill near the Hoffman brickyard (See Section 7 of this chapter for more information on brickmaking. O’Brien had in 1901 contracted with the railroad to build a large capacity mill at the head of Flathead Lake. He sold the company to the railroad in 1906 and in 1907 the name was changed (in honor of a Great Northern agent) to Somers Lumber.

Figure 11. Logs Awaiting Sawing at the Old State Mill East of Whitefish River Circa 1900.
Photo Courtesy MMTH Collection & Ron Buentemeier

A 1907 issue of *Montana Beautiful* listed Flathead County sawmills naming three in the Whitefish area. The John O’Brien Lumber Co. with 50 workers and a Daily Board Foot (DBF) capacity of 75,000; Hutchison Lumber Mill with 30 workers and a

35,000 DBF capacity, and a lath mill just east of Whitefish putting out 30,000 DBF of lath. By 1910 there were about 2,000 *logging railroads* in the US allowing for the movement of logs independent of water for river drives or snow for hauling. These logging railroads provided for the delivery of clean logs year round. Lastly, there was the Hutchison Brothers Lumber Company in Whitefish which moved logs on two miles of track from 1909 to 1928. Rail logging plummeted during the Great Depression (1929-1949s) because it was too costly to maintain.

Construction of the Great Northern Railroad in northwestern Montana created a great need for logging along the developing line. Even after completion of the line, 10,000 ties and 1,000 telegraph poles were cut along the line in the Flathead. Timber demand also plummeted with the Great Depression, shuttering mills and changing business structures. Montana sawmills did not recover completely until about 1942. In the mid 1930s, the main uses of forest products were railroad cross ties (western larch, Douglas fir, ponderosa pine); poles (cedar); pilings (Douglas fir and western larch); mine timbers (western larch, Douglas fir, and ponderosa pine); and cordwood, farm timbers, and pulpwood (white fir, Engelmann spruce, and western hemlock). The Christmas tree industry was also a product resulting from the Great Depression.

There are no longer lumber operations in Whitefish, however there are two prominent mills and one specialty mill in nearby Columbia Falls. **F. H. Stoltze Land and Lumber**—the oldest family owned lumber company in Montana—has been at its location for over 70 years. F. H. Stoltze originally established the State Lumber Company in 1891 with operations on the Whitefish River. The last logs were sawn at that mill in 1918, but the company reorganized in that year to extend their operations and make a move to their Half Moon site. In the 1910-1930 timeframe, Stoltze also formed the Empire Lumber Company near the current junction of Truman Creek and Mount Creek. F.H. Stoltze Land Company was formed on August 31, 1912, amending their Articles of incorporation in 1933 to change their name to F. H. Stoltze Land and Lumber Company.

Following the comprehensive guidelines of Stewardship Forestry Principles, the company currently manages approximately 36,000 acres of forests and produces 65-70 million board feet of lumber annually. All company lands are managed in accordance with Montana Forestry Best Management Practices (BMPs) for Water Quality and follow the Montana Streamside Management Zone Law. In addition to adhering to strict industry principles, Stoltze management also directs its staff “to manage the land as if it were your own.” The company also has a long standing open lands policy allowing for legal public access and recreational use of its timberlands. The properties are generally gated to protect water quality, prevent the spread of noxious weeds, and ensure wildlife security, but the lands generally remain available for public use. This policy is a privilege that if abused, can be revoked.

Plum Creek Timber Company, Inc., one of the largest and most geographically diverse private landowners in the U.S., manages approximately 6 million acres in 18 states, with 770,000 acres in Montana after a recent land sale to The Nature Conservancy. They produce lumber, plywood, and medium density fiberboard (MDF), and were the first Montana company to receive Sustainable Forestry Initiative

(SFI) certification. They participate in Montana Forestry BMPs and are implementing a Native Fish Habitat Conservation Plan that was approved by the US Fish & Wildlife Service in 2000 which is designed to protect native bull and cutthroat trout. Streams on Plum Creek property are managed to maintain the four “Cs” for protecting native fish; Cold water, Clean water, Complex habitat, and Connected habitat. Plum Creek also owns a considerable amount of land primarily in the Lazy Creek Watershed and including a small section of Swift Creek.

Tiny, family-owned RBM Lumber mostly salvages wind-blown, diseased, insect-infested, and fire-killed trees, producing beautiful and unusual building and woodworking products. Their down-to-earth practice of imitating nature follows their family goal of responsible forest management. The U.S. Forest Service and Department of Natural Resources & Conservation (DNRC) also manage forested acreage in the Watershed (See Land Ownership map in Chapter XXI Addendum B GIS Maps).The forest products industry played a key role in shaping the Whitefish Lake Watershed, and it continues to contribute to the economy and recreational access of the area.

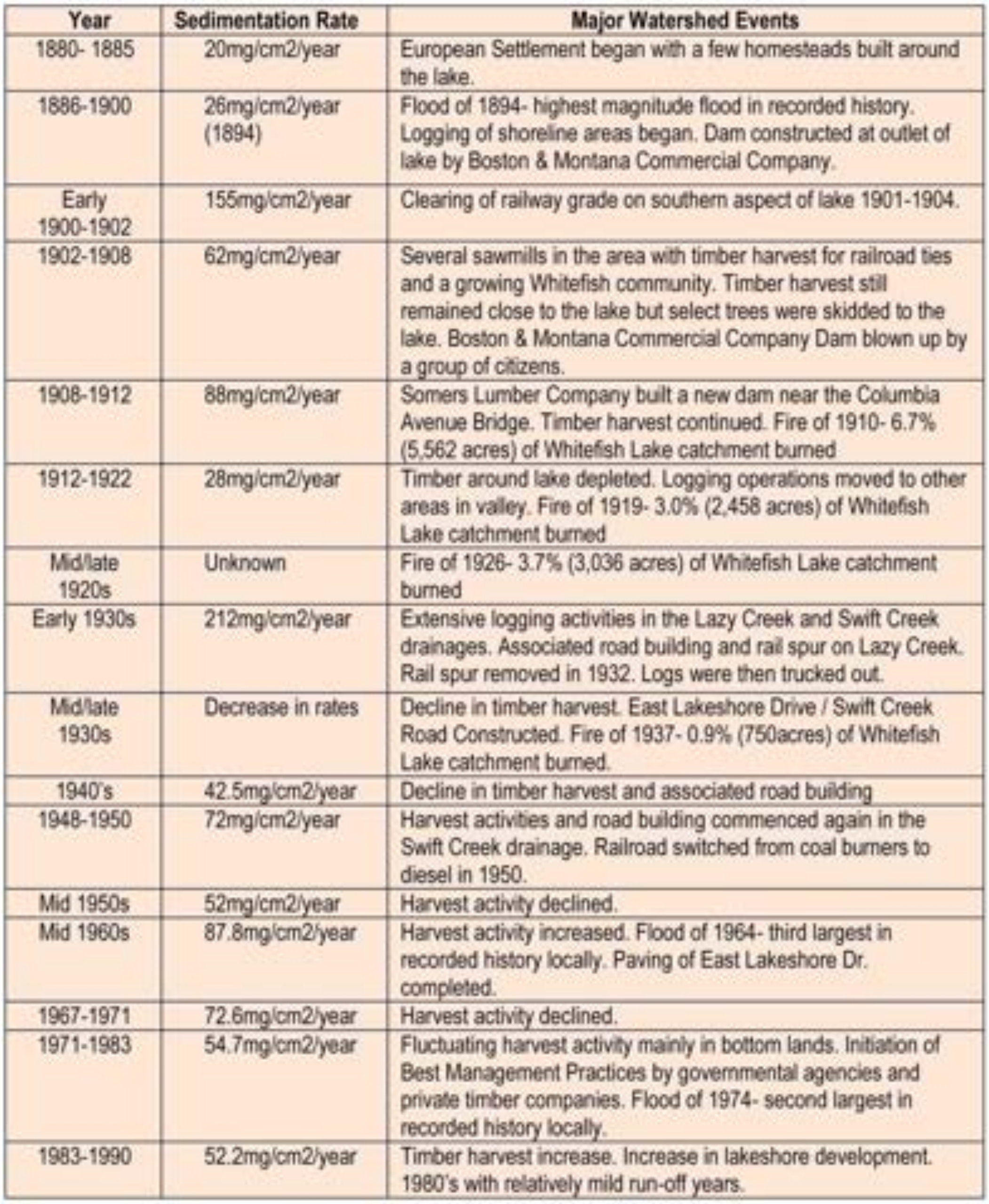
5. Land Use and Lake Sediment

The impacts of urbanization in the project area can be seen in many forms, including the building and widening of roads, shoreline development, increased human access to once wild areas, and the extension of municipal services. One more noticeable and in some areas more measureable result of this urbanization is the increase in sedimentation to waterbodies.

Because natural systems are complex, the dynamics of many factors concurrent to one another can influence sedimentation deposition and cause changes in the food web. For instance, weathering and erosion of land and sediment transportation through waterbodies are natural processes. However, excessive erosion can cause increased suspended sediment that impacts water quality. Suspended sediment can reduce the amount of light that penetrates water. This consequentially can reduce plant and aquatic insect populations which in turn limit food sources for fish and therefore fish populations. Sediment that reaches the bottom of a waterbody can also envelop invertebrate habitat and food sources, impair reproduction of aquatic organisms, and smother eggs and newly hatched fish. In addition to impacts to the ecology of waterbodies, concentrated sediment can result in increased drinking water treatment costs and decreased aesthetics and recreational opportunities.

Figure 12 *Whitefish Lake Sedimentation Rates 1885-1990* is a summary examination of historical Whitefish Lake Watershed events. Spencer (1991) concluded that natural events such as fires and floods—if looked at independently of other factors—appear to have little influence on overall sedimentation rates in the lake. The best example is the flood of 1894, the largest on record, where little additional sediment input was delivered from an undisturbed watershed. However, the report acknowledges that a distinct correlation between natural disturbance events and changes in fine sediment are difficult to make.

By contrast, Spencer (1991) also states that anthropogenic activities such as railroad building and timber harvest do appear to have contributed an unnatural amount of sediment to the lake and that these correlations are more readily apparent. As an example Spencer concludes that the correlation between early 1930's logging activities and increased sedimentation is striking and leaves little doubt concerning a cause and effect relationship between these two events. It is also important to note that the data from the 1991 Spencer report was based on one core sample taken in a deep portion of the lake. Figure 12 shows historical lake sedimentation rates and companion Figure 13 provides a brief narrative of historic land use practices.



Year	Sedimentation Rate	Major Watershed Events
1880- 1885	20mg/cm2/year	European Settlement began with a few homesteads built around the lake.
1886-1900	26mg/cm2/year (1894)	Flood of 1894- highest magnitude flood in recorded history. Logging of shoreline areas began. Dam constructed at outlet of lake by Boston & Montana Commercial Company.
Early 1900-1902	155mg/cm2/year	Clearing of railway grade on southern aspect of lake 1901-1904.
1902-1908	62mg/cm2/year	Several sawmills in the area with timber harvest for railroad ties and a growing Whitefish community. Timber harvest still remained close to the lake but select trees were skidded to the lake. Boston & Montana Commercial Company Dam blown up by a group of citizens.
1908-1912	88mg/cm2/year	Somers Lumber Company built a new dam near the Columbia Avenue Bridge. Timber harvest continued. Fire of 1910- 6.7% (5,562 acres) of Whitefish Lake catchment burned
1912-1922	28mg/cm2/year	Timber around lake depleted. Logging operations moved to other areas in valley. Fire of 1919- 3.0% (2,458 acres) of Whitefish Lake catchment burned
Mid/late 1920s	Unknown	Fire of 1926- 3.7% (3,036 acres) of Whitefish Lake catchment burned
Early 1930s	212mg/cm2/year	Extensive logging activities in the Lazy Creek and Swift Creek drainages. Associated road building and rail spur on Lazy Creek. Rail spur removed in 1932. Logs were then trucked out.
Mid/late 1930s	Decrease in rates	Decline in timber harvest. East Lakeshore Drive / Swift Creek Road Constructed. Fire of 1937- 0.9% (750acres) of Whitefish Lake catchment burned.
1940's	42.5mg/cm2/year	Decline in timber harvest and associated road building
1948-1950	72mg/cm2/year	Harvest activities and road building commenced again in the Swift Creek drainage. Railroad switched from coal burners to diesel in 1950.
Mid 1950s	52mg/cm2/year	Harvest activity declined.
Mid 1960s	87.8mg/cm2/year	Harvest activity increased. Flood of 1964- third largest in recorded history locally. Paving of East Lakeshore Dr. completed.
1967-1971	72.6mg/cm2/year	Harvest activity declined.
1971-1983	54.7mg/cm2/year	Fluctuating harvest activity mainly in bottom lands. Initiation of Best Management Practices by governmental agencies and private timber companies. Flood of 1974- second largest in recorded history locally.
1983-1990	52.2mg/cm2/year	Timber harvest increase. Increase in lakeshore development. 1980's with relatively mild run-off years.

Figure 12. Whitefish Lake Sediment 1880 Through 1990.

Sugden & Woods (2007) investigated unpaved roads as a primary source of sediment in forested watersheds. The study examined sediment production from roads in the Belt Supergroup and glacial till parent materials in western Montana, noting that the factors most responsible for road erosion included time since last grading, roadbed gravel content, road slope, and precipitation. They concluded that as road slope and precipitation increased in these materials, erosion increased, and as gravel content and time since prior grading increased, erosion decreased suggesting that locating roads on coarse sub-soils, minimizing slope, and grading only when necessary can reduce sediment production.

An example of multiple pressures from both natural and anthropogenic sources includes timber harvest with an associated flood event. Timber harvest increases water yield and exacerbates the flashy nature of run-off. This can exert more sheer stress on high mass wasting banks such as those found on Swift Creek (See Chapter X Whitefish Lake Tributaries for additional information on Swift Creek). In addition, fine sediment entrained in stream channels as a result of timber harvest could be washed downstream later during a flood event as pulse loading. Other associated problems like washing out of undersized culverts and the affected road prisms can also influence sedimentation rates.

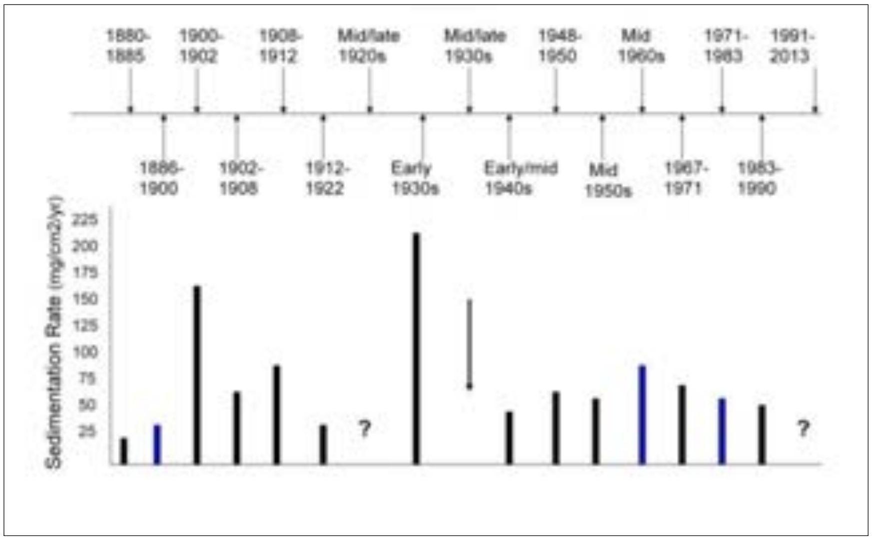


Figure 13. Whitefish Lake Sedimentation 1885-2013.

Whitefish Lake also experiences naturally occurring shoreline erosion from waves and suspension/deposition dynamics. Aside from some specific landowner activities that contribute small sources of sediment, there have been no larger sources of mass shoreline erosion resulting from residential development recorded.

Prior to European settlement, the Whitefish Lake Watershed was undisturbed, subject only to natural fire and flood events. In 1894, the highest magnitude flood event in recorded history occurred in the area but lake sediment rates increased little from background levels. At that time, the well vegetated, intact watershed was able to buffer the effects of the flood. At the turn of the 20th Century, the clearing of the railroad grade and timber harvest around Whitefish Lake caused an increase in sedimentation rates. The highest sedimentation rates were recorded in the early 1930s when the first large scale timber harvest and road building occurred in the Lazy Creek and Swift Creek drainages. It is also unknown what affect aggressive fire suppression in the Whitefish Lake Watershed may have had on sediment delivery to the lake.

It is interesting to note that in 1964 and 1974, the third and second highest magnitude flood events were recorded for the area, but the sedimentation rate was higher than in 1894. By that time the watershed had been disturbed and lost some buffering capacity. Best Management Practice (BMP) implementation in the 1970s could have led, in part, to the reduction in sedimentation rates through 1990. Additional core sampling is needed to bring the period of record to date and to corroborate previous results.

Strong rain events can cause site specific floods that drain sediment and debris into waterways. In 2013, 1.12 inches of rain fell in Whitefish in a 24 hour period (National Weather Service in Baldwin, 2013). This powerful rainstorm led to numerous mudslides sending water toward Whitefish Lake. It also caused the massive breach of a private fishing pond off Big Mountain Road that sent water rushing across East Lakeshore Drive toward Les Mason State Park. The river of water was a few hundred yards wide and carried debris through the Les Mason Park parking area and the surrounding forest. There were numerous smaller mudslides on East Lakeshore Drive that day, and a rock retaining wall on Rest Haven Drive gave way and hit a nearby carport (Baldwin, 2013). The storm also caused some erosion along unmaintained trails on the Toni Matt and Big Ravine slopes of Big Mountain at Whitefish Mountain Resort.

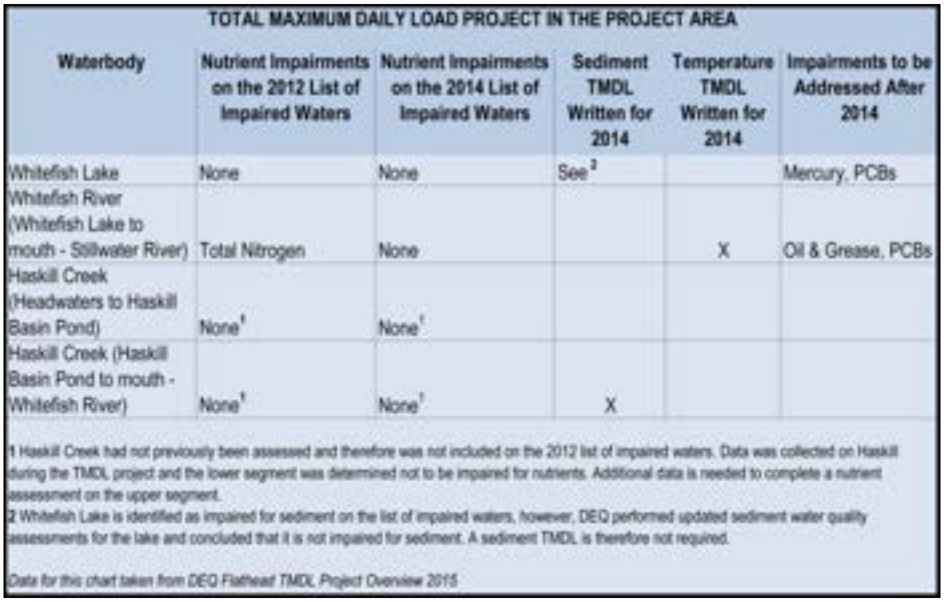
6. 303(d) Listing

Whitefish Lake is on Montana’s 303(d) list of impaired waters. A waterbody is considered to be impaired when there is a violation of one or more water quality standards established to protect any of the applicable beneficial uses. In some cases the violation of a standard will result in the impairment of only a single use; in other situations the violation of one or more standards may result in the impairment of all uses for the applicable classification. According to the 2014 DEQ report (Montana Department of Environmental Quality, 2014), only two waterbodies in the Whitefish Lake Watershed have a 303(d) listing history, Swift Creek (MT76P003_020) and Whitefish Lake (MT76P004_010).

The DEQ relies on a “narrative” standard in instances where there is insufficient information to develop “numeric” standards. These narrative standards describe the desired or allowable condition, or the amount allowable over naturally occurring conditions. Referred to as the “reference condition” this enables the comparison of the naturally occurring condition to actual conditions and identifying whether or not narrative standards are being met (Montana Department of Environmental Quality, 2014).

Pollutants identified on the 303(d) list as causes of impairment to the aquatic life beneficial use of Whitefish Lake include mercury and PCBs. Whitefish Lake was

303(d) listed by the Montana Department of Environmental Quality (DEQ) as *threatened* by sedimentation/siltation in 1996, and remained listed through 2014. EPA policy allows states to remove waterbodies from the list only after they have developed a TMDL (Figure 14) or changes have been made to correct the water quality problems identified. A waterbody can also be removed from the list as a result of a change in water quality standards or designated uses. Designated uses, however must be subject to a thorough analysis to demonstrate that they cannot be attained before they can be deemed unattainable and removed from listing (US Environmental Protection Agency, 2012).



TOTAL MAXIMUM DAILY LOAD PROJECT IN THE PROJECT AREA

Waterbody	Nutrient Impairments on the 2012 List of Impaired Waters	Nutrient Impairments on the 2014 List of Impaired Waters	Sediment TMDL Written for 2014	Temperature TMDL Written for 2014	Impairments to be Addressed After 2014
Whitefish Lake	None	None	See[2]		Mercury, PCBs
Whitefish River (Whitefish Lake to mouth - Stillwater River)	Total Nitrogen	None		X	Oil & Grease, PCBs
Haskill Creek (Headwaters to Haskill Basin Pond)	None[1]	None[1]			
Haskill Creek (Haskill Basin Pond to mouth - Whitefish River)	None[1]	None[1]	X		

1 Haskill Creek had not previously been assessed and therefore was not included on the 2012 list of impaired waters. Data was collected on Haskill during the TMDL project and the lower segment was determined not to be impaired for nutrients. Additional data is needed to complete a nutrient assessment on the upper segment.

2 Whitefish Lake is identified as impaired for sediment on the list of impaired waters, however, DEQ performed updated sediment water quality assessments for the lake and concluded that it is not impaired for sediment. A sediment TMDL is therefore not required.

Data for this chart taken from DEQ Flathead TMDL Project Overview 2015

Figure 14. Project Area Listings.

In the spring of 2014, the Planning, Prevention and Assistance Division of DEQ reassessed the sediment listing for Whitefish Lake (Montana Department of Environmental Quality, 2014). Although DEQ has an assessment methodology for evaluating whether beneficial uses are being attained for streams, they have not yet developed such an assessment for lakes or reservoirs. Therefore, DEQ applied a “weight of evidence” approach to evaluate the sediment listing on Whitefish Lake using the following indicators:

- 303(d) listing history
- Swift Creek Total Suspended Solids (TSS) and comparison to other tributaries
- Whitefish Lake TSS and Secchi depth trend analysis
- Shoreline erosion
- Flathead Lake Watershed model

The results of evaluating the sediment listing using the indicators above follows:

<u>303 (d) Listing History</u>

In Figure 15, the sediment threatened listing for Whitefish Lake appears in 1996, but the lake was listed earlier as threatened by sediment in 1988 and 1992, with breaks in listing in 1990 and 1994. The break in listing explains why the 1996 threatened listing is considered the "cycle first listed" (CFL). According to the Montana Department of Health and Environmental Sciences, the 1988 threatened listing for Whitefish Lake refers to timber harvesting and associated roads from silviculture as the specific source of the threat (Montana Department of Environmental Quality, 2014). The listing was supported by Spencer (1991) who suggested that lake sedimentation rates were much higher in the 20th century as compared to the 1880s, prior to the first sawmill being established in the Watershed.

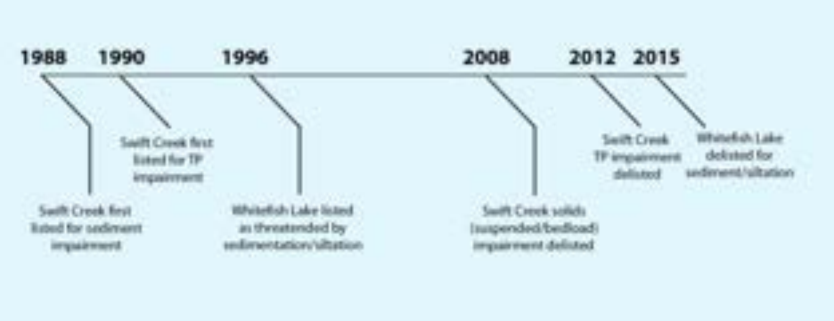


Figure 15. Sediment Listing History.

Further, spikes in sedimentation rates correspond to periods of extensive logging as well as road and rail construction. Spencer also noted that the logging industry's Best Management Practices (BMPs) and improvements in road construction practices in recent decades might explain the drop in sedimentation rates since the mid-1960s. The Streamside Management Zone law—which first went into effect in 1993—has also shown to effectively buffer streams from timber harvest practices. It is important to note that some skepticism has been noted over the fact that the study results are based on only one core sample on Whitefish Lake (Sugden, 2015).

Kirchner et al (2001) suggest that although anthropogenic effects on erosion may significantly disrupt aquatic ecosystems, they may contribute far less to the long-term sediment yield; and that human activities may alter the size and or risk of natural catastrophic events, but because such events are rare, the human impact is difficult to quantify.

The DEQ report clarifies that the threatened listing for Whitefish Lake meant the lake is fully supporting all beneficial uses, but a threat existed that could lead to exceeding the standard in the future. Threatened status reflects either (1) an adverse trend in water quality data; or (2) planned activities that might lead to future sediment impairment (Montana Department of Environmental Quality, 2014).

<u>Swift Creek Total Suspended Solids (TSS) and comparison to other tributaries</u>

Swift Creek was first listed for sediment impairment in 1988, but delisted in 2008. It was also identified as the main contributor of sediment to Whitefish Lake. A number of restoration projects on Swift Creek and its tributaries were performed in an effort to reduce sediment from roads and bridges.

In reviewing sediment loading dynamics on Whitefish Lake, particular attention was paid to Swift Creek given the extent of its overall contributions to Whitefish Lake, draining 65% of the Watershed. Of 15 sample events from 2008-2013 by WLI where 5 key tributaries were all sampled for TSS and discharge on the same date, Swift Creek comprised an average of 82% and median 88% of the total TSS load. All other tributaries combined contributed an average of 18% and median 12% of the TSS load to Whitefish Lake. The DEQ assessment of Swift Creek concluded that "ninety-three percent of the Swift Creek streambanks are stable. Human-caused sediment loads are negligible," suggesting that sediment loading from Swift Creek is predominantly the result of natural sources.

Whitefish Lake TSS and Secchi depth trend analysis

Since TSS at low concentrations can affect light penetration in the water column, DEQ referred to WLI's TSS and Secchi data for their analysis. This data can be found in Chapter XII Whitefish Lake. While seasonable patterns were observed in Secchi data, there were no apparent trends in Secchi depth measurements over time.

Flathead Lake Watershed Model

The EPA-approved Loading Simulation Program (LSPC) in C++ that was used for modeling the Flathead Lake Watershed was also applied to understand loading on Whitefish Lake (Christian, 2014). While natural background constitutes 47% and bank erosion constitutes 40% of the TSS load to the lake, the quantitative and qualitative analyses of land cover and land use in the Whitefish Lake Watershed and lack of anthropogenic sources suggest that bank erosion is mostly natural. This analysis determined that beneficial uses in Whitefish Lake are not currently threatened or impaired by sediment, therefore Whitefish Lake is no longer 303(d) listed (Christian, 2014).

7. Brick Making

Brick making in Whitefish was an idea born of fire. P.J. Hoffman was pulling coals from a campfire when he noticed baked red clay amongst the ashes. This clay is a result of the lacustrine soil left behind from a proglacial lake at the end of the Pleistocene Epoch. The idea came to him that he could make brick in Whitefish, so P.J. and his sons built their brick company. The first brick building in Whitefish was a five-room home at 328 Central Avenue built in 1907. The second was the Pacific Power building on Second Street. These and other buildings, like Loula's (located in the historic Masonic Temple building) (Figure 16), were constructed of Whitefish brick made by P. J. Hoffman and Sons, located northeast of the railroad depot on the north side of the tracks. According to locals, Whitefish brick can be seen today in the walls of The Toggery, a popular clothing, shoe and accessory shop; Montana Coffee Traders; and Loula's restaurant, all in downtown Whitefish.

Brick making proved to be difficult as bricks could not be allowed to freeze during the process. Keeping the fires stoked so as not to lose bricks was a demanding job. At the start of their business, bricks sold for $6 per thousand, which grew to $17 per thousand by 1935. As prices rose, the use of bricks for homes declined as the cost was prohibitive. Son Pete had moved away for work from 1910 to 1912, and returned to find his father's business in debt. In 1923, he moved the business to Kalispell, combining it with the Kalispell brickyard. He continued using Whitefish lacustrine clay for his better brick. His business prospered throughout the thirties, but declined in the forties. He sold the business in 1946, but the new owners were unable to keep the business afloat and by 1948 there was no longer a brick making business in the Flathead.

Figure 16. Photo of Whitefish bricks at Loula's.
Photo Courtesy WLI

8. Agriculture

Historically, agriculture played a significant role in the lower Whitefish Lake Watershed and surrounding area. Oats, wheat and potatoes were the original cash crops in the early 1800s. In the early 1900s, farmers continued growing oats, but added rye, spring and winter wheat, timothy hay, clover, a variety of vegetables and fruits, and dairy cattle (Flathead National Forest, 2010).

Long-time landowner Margaret Murdock (1922 – 2014) recalled in a conversation with WLI staff the cattle drives down current day Wisconsin Avenue. According to Murdock, the small number of vehicle drivers who used the road would stop or pull to the side of the road to allow the cattlemen to drive their herds.

Today's local agricultural production follows some Montana statewide trends such as the increased average age of a farmer from 57.8 to 58.9, the increase in farmers under the age of 35 over the past five years, and the increase in small farms under 50 acres (De Yong, 2014). There was also a statewide 50% increase in the value of agricultural products from 2007 to 2012, reflecting several years of good production, high prices, and increased crop diversification. However, crop prices have fallen since 2012 and De Yong warns that these numbers do not reflect the increased cost of fertilizers, fuels, and rent (2014). In the Whitefish area, younger farmers are increasingly getting involved in the local food movement which includes Farmers Market opportunities and Community Supported Agriculture (CSA) programs. Local restaurants and markets are purchasing more locally gown and raised foods as well.

A number of local farms offer vegetables, fruits, herbs, flowers, seeds and plants, and a few sell chickens and eggs. A substantial amount of land in the surrounding Flathead Watershed remains in agricultural production with hay and grain, cattle and pork producers, goat and horse ranches, and one dairy farm. All of this agriculture plays a fairly small role in the upper watershed, but is a larger contributor in the Whitefish River area. The local Farm Hands organization's mission is "…to reconnect people to the sources of their food and to those who produce it through education, outreach, and market support." Their interactive map at nourishtheflathead.org shows the impressive amount of locally available food, and embodies the growing conversion in the U.S. of large scale to small scale farms.

9. Mining

Mining proved to be mostly an unrealized dream in the Whitefish Area. According to Schafer & Engelter (2003), in 1905, the Lupfer Mining Company had claims eight miles northwest of Whitefish. Despite several months of positive articles in the *Whitefish Pilot* —in particular regarding a ledge of silver-lead— the company disappeared from the headlines within a year. In 1908, a half-page article read, "Rich Ore is Found-Assays from the Micho Prospects-North of Whitefish Show Rich Values-People Have Been Flocking to the Hills to Locate Claims-Mountains Seamed with Rich Veins of Minerals." This excitement too was short-lived. Also in 1908, the *Whitefish Miner* newspaper was launched by publishers H. F. Laeuger and Sam Robertson. Like the mining claims it covered, the paper disappeared shortly after being launched. And in the same year, the Whitefish Mining and Development Company was organized. This company was also gone by the end of 1909.

As noted in the Preceding Natural History Chapter, there was only one well referenced prospect of ore in the project area. The site includes a caved underground mine entrance in grayish-red sericitic argillite interbedded with layers of copper-stained white quartzite and sandstone, and two pits. According to historical accounts, the Micho Brothers had identified seven claims in the area. It is believed that they were exploring iron and copper in the Grinnell formation (Johns, 1970).

10. Recreation

In addition to providing drinking water, Whitefish Lake is a popular recreational lake, offering a sand-enhanced swimming beach, picnic areas, and launch sites for both motorized and non-motorized boating, as well as winter sport activities. City Beach is a popular gathering place with its peak use during summer months.

Boating has a long and storied history on Whitefish Lake. As early as 1904—the year Whitefish became a city—one of the first boat races was held. According to a 2013 *Daily Inter Lake* feature (Hintze), a number of early day watercraft made their way from City Beach to the Point of Pines dance hall on the east side of the lake. In 1906, the Whitefish Pilot reported that "…nearly every family had their own row boat." On July 4th, 1907, the first powerboat race took place on the lake, and in 1908 the Whitefish Launch and Boat Club was organized, paving the way for the formation in the 1930s of the Whitefish Lake Boat Club.

The 1934 Whitefish Lake Regatta was the premier boating event on the lake and "the longest-running powerboat race in the United States before the event was anchored into the history books some six decades later, according to Charlie Abell who was active with the American Powerboat Association for many years" (Hintze, 2013).

Charlie's father, Rusty was active in the Whitefish Lake Boat Club, as was Charlie. His two sons also raced in the Regatta.
Although the increased use of motor boats has added to the enjoyment of the lake, it has also created shoreline erosion issues from wave action, and added polluting gasoline constituents to the lake.

In 2005, WLI conducted a survey of 461 Whitefish school students in grades 4, 8, and 11 to determine their recreational use of Whitefish Lake. The survey, which had a response rate of almost 90%, showed that 88% of these young respondents recreated at the lake—specifically swimming—with 28% swimming more than 20 days the previous year (Koopal, 2006a). Water contact recreation at Whitefish Lake is considered high, influenced by the convenience of City Beach, Whitefish State Park, and Les Mason State Park. For this reason, understanding the extent of pathogens in the lake—human and non-human—in addition to other pollutants is particularly important.

11. Private Sources

There are undoubtedly a number of private citizen actions that have contributed to the degradation of water quality in the area. Prior to the advent of scientific information, people were largely unaware of the impact that they had on aquatic ecosystems or they simply chose to ignore their impacts, as some still do today.

An example includes Joe Bush, who lived at the head end of the lake in the early part of the 1900s. According to Schaffer and Engelter (2003) one autumn his boat sank with several cans of kerosene which caused a miniature oil slick on the surface of Whitefish Lake the following spring after the cans had rusted through. In the last ten years, WLI has received reports from citizens that construction workers have dumped hazardous materials in and around the lake.

Some human activities that impact water quality include conversion of land to residential development, the increased use of fertilizers and pesticides, and the increase of impervious surfaces. As natural landscapes are replaced by housing developments, roads, and parking lots, native vegetation gives way to impervious surfaces and natural infiltration is diminished. More stormwater runoff is carried more quickly to streams resulting in flashier storms and increased flooding.

When combined, past land use activities have had a cumulative impact on water quality in the Whitefish Lake Watershed and secondary effects that linger today. Each action that we as a community undertake to mitigate these past impacts, while reducing current and future pollutant or nutrient loading to our waterways, will help to protect and improve our local aquatic resources for generations to come.

B. WATER QUALITY STEWARDSHIP: HISTORICAL AND CURRENT

This section describes the role, function, and geographic scope of water quality related entities within the Whitefish Lake Watershed and Surrounding Area.

1. **Historical Perspective of Past Water Quality Groups in Whitefish** (Koopal, 2007)

Throughout the history of Whitefish, different groups with various missions have formed to address water quality issues. Some organizations were more successful than others, but the underlying theme is that there have always been citizens actively interested in protecting the aquatic resources around Whitefish. Some of following information came from Stumptown to Ski Town (Schaffer and Engelter, 2003), and A History of Whitefish, (Trippett, 1956):

a. Whitefish Businessmen

In 1907, Whitefish businessmen made efforts to attract the state fish hatchery to Whitefish. The hatchery was later established in Creston.

b. Whitefish Launch and Boat Club

This club was formed in 1908 to increase the recreational boating opportunity on Whitefish Lake.

c. Whitefish Rod and Gun Club

The Whitefish Rod and Gun Club formed in 1910. The group disbanded during WWII, and in 1953, reorganized to protect the local natural resources and to make recommendations on fish and game rules. Along with the Jaycees, this group purchased and developed the State Park Site on Dog Bay, later deeding it to the State. Other activities of this group involved the stocking of fish species and the development of Smith Lake.

d. Whitefish Outdoors Unlimited

This organization was created in 1967 presumably as a successor to previous clubs like the Rod and Gun Club and the Back to Nature Club (little is known about this club). Whitefish Outdoors Unlimited sponsored numerous lectures on conservation.

e. Whitefish Businessmen

In 1973, local businessmen were instrumental in drafting and successfully lobbying the state legislature to pass the Lakeshore Protection Act of 1975. The Lakeshore Protection Act gave the City of Whitefish the authority to create the Lakeshore Protection Committee.

f. Whitefish Basin Project

In 1981, citizens led an effort to maintain the water quality of the lake. The Project led to the formation of the Whitefish County Water and Sewer District in 1982. Voters approved the formation of the district by a margin of four to one.

g. Whitefish Lake Advisory Group

In 1998, a group of Whitefish business leaders invited Governor Racicot to a meeting in Whitefish to discuss the current status of local lakes. Of special interest at the meeting was the discussion of the effect from the *Mysis* shrimp introduction. From that meeting, an ad-hoc group formed called the Whitefish Lake Advisory Group. Unfortunately, after only three meetings, this group dissolved.

h. Swift Creek Coalition

Formed in1999, the Swift Creek Coalition's mission was to maintain a viable, healthy, and sustainable watershed for the benefit of all users. The Swift Creek drainage and its tributaries defined the boundaries. The boundary essentially included the Swift Creek outlet into Whitefish Lake to its headwaters.

The primary goal of the Coalition was to complete a watershed analysis which would provide a consolidated report of the existing condition of the Watershed in terms of vegetation, hydrology, and geomorphology. The Coalition was granted funds under the Clean Water Act, section 319 from the DEQ to evaluate the current conditions of the Swift Creek Watershed. A contractor was employed to gather all available data from landowners, primarily Montana DNRC, Forest Service, and Plum Creek. That report was completed by Watershed Consulting in 2005.

i. Whitefish Water Quality Advisory Committee

Formed in 2007, the Whitefish Water Quality Advisory Committee was committed to protecting and improving the water quality of the City of Whitefish and what was then defined as the Planning Jurisdiction Area, by facilitating an integrated teamwork approach of local water quality interests. Their primary mission was to provide current, accurate water quality information to the community of Whitefish and city government.

The purpose of the Whitefish Water Quality Advisory Committee was not to duplicate the efforts of any existing water quality group, but to utilize the expertise of each through collaboration and sharing of information. Through an integrated approach, comprehensive policy and management recommendations related to water quality in the Whitefish Planning Jurisdiction Area were provided to the City Council, City Staff, and the general public. This committee was disbanded after a report summarizing all of the groups, including an annotated bibliography.

2. Current Whitefish Water Quality Related Groups

a. Whitefish Lakeshore Protection Committee (WLPC)

In the early 1970s, Whitefish Lake home owners and community members became concerned about the amount of work going on at different locations on the lake causing turbulence, sedimentation, and other problems. Development concerns at the time included the Viking Lodge construction, Glenwood Marina, and "island reconstruction" at Lazy Creek. Whitefish City-County Planning Board member Charlie Abell, along with Bruce Tate and attorney Gene Hedman voiced concerns about lakeshore happenings on both Whitefish and Flathead Lakes. They were concerned about losing the shorelines. Senator Bob Brown from Whitefish co-sponsored Senate Bill 175 which passed in 1975 and became Montana Code Annotated 75-7-201. This was enacted at the same time as the Natural Streambed and Land Preservation Act of 1975. The new law's purpose was two-fold: (1) To conserve and protect Montana's natural lakes and their scenic and recreational values; and (2) To provide local governing bodies with adequate statutory power to protect lake areas.

A lakeshore committee was formed in Whitefish after the legislation passed, and was named the Lakeshore Protection Sub-committee of the Whitefish City-County Planning Board. The original members were Charlie Abell (chair), Doug Follett, John Horn, Lyle Phillips, John Rooney, Don Slaybaugh, Gary Stephens, and Bruce Tate. They met, exchanged ideas regarding Whitefish Lake and smaller nearby lakes and drafted the first set of lakeshore regulations. The regulations were adopted by Flathead County and the City of Whitefish and the WLPC began its advisory status with the newly-required permits. With minor modifications, those regulations were later adopted by the County for all Flathead County lakes.

1. **Mission Statement:**

The purpose of the lakeshore regulations were to:

- Protect the fragile, pristine character of Whitefish area lakes and the intertwined adjacent riparian and upland areas;
- Conserve and protect natural lakes because of their high scenic and resource value;
- Conserve and protect the value of lakeshore property;
- Conserve and protect the value of the lakes for the state's residents and visitors who use and enjoy them.

2. **Geographic Scope:**

The regulations initially governed any work which altered Whitefish Lake, Lost Coon Lake and Blanchard Lake, and the land within twenty horizontal feet of the mean annual high water elevation of these lakes.

3. **Goals:**

- To protect and preserve Whitefish Lake for future generations. The goals and objectives of the Whitefish Lake & Lakeshore Protection Committee are best summarized in these points:
    - Regular, ongoing regulation review and updates. *Over 90% of regulation changes and updates* in both the City and County (prior to the City accepting regulation of all of Whitefish Lake) were initiated by the Whitefish Lakeshore Committee;
    - Consistency of interpretation, application and enforcement of regulations. During just the past 14 years, the lakeshore regulatory process has progressed through 4 different planning offices, over

6 different planning directors, and approximately 12-14 different planning staff. *Throughout these transitions, the only assurance of consistency has been the longevity and dedication of WLPC members;*

- Maintain the delicate balance between preserving Whitefish Lake and protecting lakeshore property owner rights. Over half the members of the WLPC were required to be residents or property owners on the lake. Almost half the changes in regulations over the years were to facilitate (improve) the regulation process, and ease or clarify regulations for the benefit of property owners;
- Provide a confidential, easy means for concerned citizens or property owners to report violations. In prior years, almost all violations were first reported to a WLPC member. Committee members were well known around the lake and lakeshore residents felt more comfortable and protective of their neighbor relations by reporting a probable violation in confidence to a WLPC member;
- Ensure accuracy of issued permits. Due to the complexity of the lakeshore regulations, and the turnover of Planning Office staff, it often became the responsibility of the WLPC to prevent errors and omissions in issued permits.

4. Past Accomplishments:

The WLPC oversaw dredging permits in Lazy Bay and at Bay Point without any adverse impacts to Whitefish Lake. The Whitefish Lake Lodge Public Marina was another controversial permit with a successful conclusion. But perhaps the best accomplishment is for someone to simply go out in a boat and motor around the lake and notice the sharp contrasts. On the south end of the lake, where development progressed for decades without lakeshore regulations or the WLPC, there are few trees remaining, and houses, lawns, and other structures extend right down to the high water line. *"What if the entire buildable shoreline was developed like this?"*

5. Current Issues:

One of the biggest issues facing the regulatory process is the transition of property ownership to out-of-state residents, who often do not have the same views and priorities as long-time permanent residents of the area. Some of this transfer is from natural progression as non-residents want a second home in an area like Whitefish, but a secondary contributing factor is the dramatic increase in property taxes that have resulted from soaring property values. Montana families that have owned property on Whitefish Lake for decades or generations are finding it very difficult to afford or justify the increase in taxes over the past decade.

In addition, there is a significant increase in major construction right up to the lakeshore protection zone, as well as a different attitude toward consequences of a lakeshore violation. In a growing number of cases, it seems that the maximum $500 fine is being viewed more as a "permit fee" for doing something (like cutting trees or removing vegetation) that would not be allowed under lakeshore regulations.

In 2012, WLI recognized Jim and Lisa Stack for their passion and contributions to Whitefish Lake through their long service on the Whitefish Lakeshore Protection Committee. Jim served on the committee for 20 years, chairing the committee from 1998-2012. Lisa served as a volunteer administrator for the committee for 16 years. The Stack's institutional knowledge of the lakeshore regulations is unmatched, and guided the standard that was set for lakeshore protection activities. The committee ensured that long-term water quality is at the heart of the decision making process. It was, however, a sometimes difficult and controversial set of regulations to uphold, balancing the lake's health and the needs and desires of a growing community.

In late 2014, as a result of the end of the Whitefish/Flathead County interlocal agreement, and after 39 years of a successful joint city-county lakeshore committee—one that existed long prior to the recently ended inter-local agreement—the continuance of the committee was rejected by the Flathead County Commissioners. Committee participant Koel Abell commented in a Whitefish Pilot opinion piece that "A joint city-county system that had worked, and worked well for nearly four decades was…silenced by the county" (Abell, 2015). It was noted in a city council meeting that during Jim Stack's tenure as chairman, not a single recommendation for permit approval or denial was overridden by either the county commissioners or the City of Whitefish, suggesting a "…high level of trust and respect that both governing bodies had for this impartial committee" (Stack in Baldwin, 2014a).

In 2014, the Flathead Count Commissioners voted 3-0 to include Whitefish Lake and Lost Coon Lake in the county regulations (Hintze, 2015). A number of concerns have resulted from this change, the most important are the lack of "intimate and detailed knowledge" (Abell, 2015) as well as stewardship values that the local committee previously imparted to the decision making process.

In May of 2015, the Whitefish City Council approved the creation of a new seven-member Whitefish Lakeshore Protection Committee to handle permit applications for work on land or on the lake within the mean high water elevation in City limits. Activities such as the installation of docks, landscaping, excavation, and the construction of retaining walls or decks will be handled by the committee. The new committee will be made up of two members who reside within city limits, two who own lakefront property within city limits, two who own lakefront property outside the city limits, and one member of the planning board.

b. <u>Whitefish County Water District</u>

1. <u>Formed</u>

1982 by public vote of a 4-1 margin in favor of creating a district to protect local water quality.

2. <u>Mission Statement:</u>

To maintain and improve water quality in the District and areas affected by the District.

3. <u>Geographic Scope:</u>

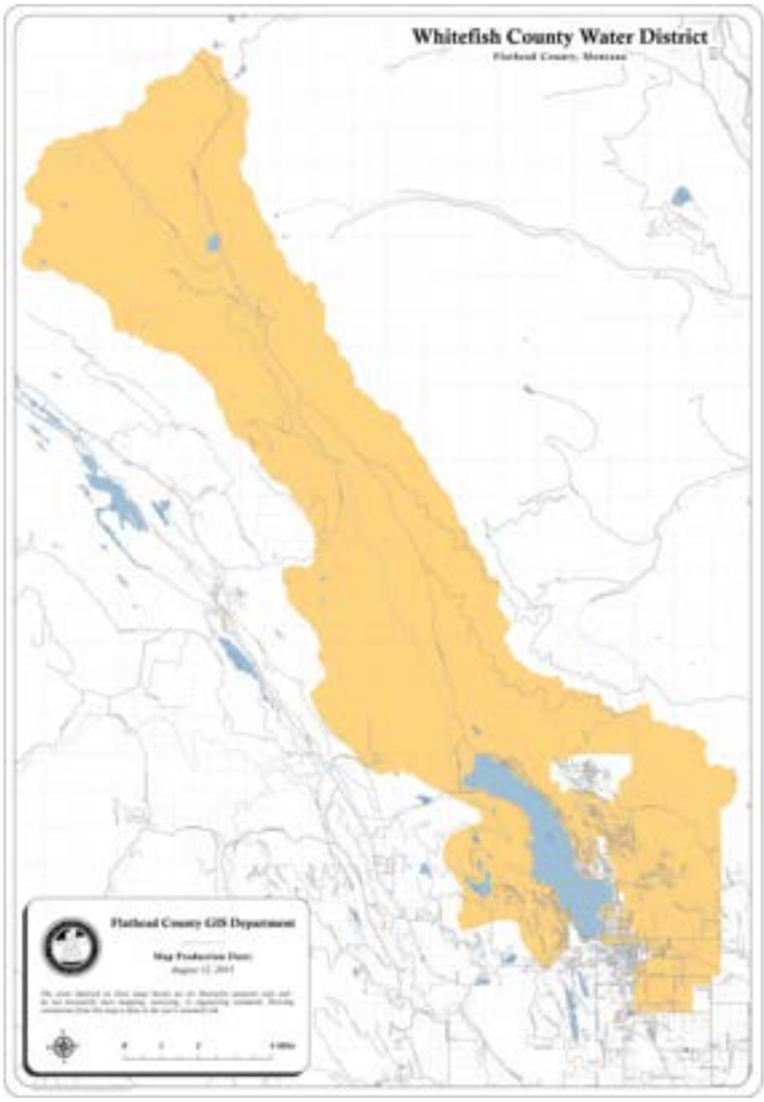


Figure 17. Whitefish County Water District.

4. **Goals:**

Protect and improve water quality.

5. **Accomplishments:**

- The District sponsored grants to support major water quality studies and efforts, and inserted positive influence on water quality projects including:
    - *Natural Resources Inventor*y (1984): A complete description and inventory of the Whitefish Lake Watershed.
    - The baseline *Limnology of Whitefish Lake* (1984): The study provided important baseline information to the board and public regarding the general condition of Whitefish Lake;
    - *Investigation of Septic Contaminated Groundwater Seepage as a Nutrient Source to Whitefish Lake* (1986): The study identified septic leachate pollution in Whitefish Lake, including areas of chronic contamination;
    - City of Whitefish Facilities Plan and City Treatment Plan;
    - Influenced decision making regarding timbers sales and subdivision activities within the District;
    - *Investigation of Septic Leachate to the Shoreline Area of Whitefish Lake* (2011): This study confirmed ongoing septic leachate contamination to Whitefish Lake, developed a risk assessment product, and provided actionable information for resource decision makers and citizens regarding septic systems in the vicinity of Whitefish Lake.
    - In 2015, the District sponsored grants to conduct a Preliminary Engineering Report (PER) in the Lion Mountain area on Whitefish Lake.

c. Haskill Basin Watershed Council (HBWC)

1. **Formed**

2000

2. **Mission Statement:**

The mission of the Haskill Basin Watershed Council is to maintain and enhance the chemical, biological and physical integrity of Haskill Creek by a voluntary and cooperative effort.

3. Geographic Scope:

The Haskill Basin drainage is located north and east of the City of Whitefish and Whitefish Lake, in northwest Montana, Flathead County. Haskill Creek lies within USGS hydrologic unit code 17010210 (Stillwater Watershed). The Haskill Creek Watershed is approximately 10 miles long and has three major tributaries (First, Second and Third Creeks). The Haskill Creek drainage covers approximately 8,281 acres (Private - 4,382 Acres, USFS - 3,379 Acres and State - 520 Acres).

4. Goals:

The agreed upon *goals* for serving the mission statement include:

- Complete a detailed watershed assessment as a basis for setting priorities and measuring progress against objectives over time;
- Maintain, or where needed, restore the chemical, biological and physical integrity of Haskill Creek by stabilizing stream banks, improving stream habitat and riparian vegetation;
- Improve water quality and improve native fish populations;
- Protect the watershed by developing a comprehensive water quality plan based on objective, scientific input from all stakeholders;
- Create a partnership of stakeholders and other interested parties;
- Create an awareness of the Haskill Creek Watershed and the chemical, biological and physical systems within it, through promotion of land treatments which will result in a change in the habits of the Watershed residents that reflect a concern for the Watershed's quality;
- Provide public education, awareness, communication, appreciation, etc., of the Watershed.

5. Past Accomplishments:

The initial Watershed Planning and Assistance grant provided funding to establish the HBWC and develop its mission and goals. The final *Haskill Creek Pollutant Source Assessment and Water Quality Restoration Plan* was completed in 2004 through work accomplished in two EPA/DEQ 319 grants, 202070 and 203069.

The stream segment on the Voermans/Klungness properties was identified as a priority for restoration in the plan. Design for the restoration was completed through another 319 grant. Construction was financed through a grant with Bonneville Power Administration and FWP. Restoration work was completed on approximately 1,100 feet of stream channel in fall of 2005. In spring 2006 a high volume runoff event damaged the restoration work. A new 319 grant in the summer of 2007 enabled repair of the damage. Continued monitoring will help establish a long term data set for trends analysis. The work on the Voermans project reduced bank related sedimentation in Haskill Creek by 86% benefitting not only the landowners, but improved habitat, flood plain functioning, fisheries, and water quality.

A second restoration project was completed on the Reimer property in 2014. This project used funding from DEQ’s 319 program, FWP’s Future Fisheries program, and the Flathead Conservation District to reduce bank-related erosion and sedimentation along a 1,222-ft reach of Haskill Creek. Two bank-stabilization techniques were installed as demonstration projects at five sites: four of the sites used woody debris jams with willow cuttings and the fifth site used a soil lift/willow hedge brush and conifer fascine. High streambanks were excavated to create new floodplain benches, and a vigorous riparian buffer was planted. A local engineering firm, River Design Group, Inc., collaborated with the partners on the project design, construction, and effectiveness monitoring; in addition, they wrote off over $7,000 of construction and installation costs. Students from Whitefish High School’s Project FREEFLOW provided volunteer labor and monitoring for the project. The project was very successful in reducing erosion and sedimentation along the project reach (reduction of approximately 74%), and the established riparian buffer will ensure project longevity.

In addition to implementing restoration projects along Haskill Creek, the Haskill Basin Watershed Council worked with the City of Whitefish to pass a resolution limiting hydropower generation at the water treatment plant to only water necessary for serving city water users. This allows as much water as possible to remain in Haskill Creek and the Basin.

6. Current Issues:

The drainage is impacted in some form by residential and recreational development and agricultural practices. Concerns expressed by stakeholders have included sedimentation by bank erosion, reduced fish populations and lack of fish habitat, water quality, land management impacts, including removal of riparian vegetation, dams, livestock impacts, septic system impacts and dewatering, to name a few. Improved stormwater management and construction practices on Big Mountain are aimed at reducing sedimentation in the headwaters. An ongoing issue is the perched, undersized culvert on the Haskill Basin Road crossing. The group continues working with the City to measure its overflows at the water treatment plant and develop a management plan for the plant that minimizes wasted water.

The HBWC meets on an as needed basis and has numerous active stakeholders, including the Flathead Conservation District (Sponsor), DEQ, Montana Department of Natural Resources and Conservation, US Forest Service, F.H. Stoltze Land & Lumber Company, Natural Resources Conservation Service, FWP, City of Whitefish, Project FREEFLOW, Whitefish Water Department, and numerous residential landowners. There is excellent representation of all stakeholders in the drainage. Additional information on Haskill Basin is available in Chapter XI Upper Whitefish River Drainage, Section C Haskill Creek.

d. Friends of Blanchard Lake

1. Formed

1999

2. Mission Statement:

The Friends of Blanchard Lake's mission is to protect and preserve water quality and natural resources, including wildlife habitat and fisheries, within that geographic area appurtenant to Blanchard Lake, in Flathead County, Montana, its water sources and drainages.

3. Geographic Scope

The geographic area appurtenant to Blanchard Lake.

4. Goals:

To preserve the natural fragile, pristine character of Blanchard Lake through education

5. Past Accomplishments:

- Improved signage at the fishing access site. Signage included a "Respect our Lake" request to slow down, as well as and boating brochures stating regulations;
- Education of property owners through meetings, newsletters, mailings: some topics have included; loons, water quality, protection zone, conservation easements;
- Volunteer monitoring as part of the NWMTLVMN. Assistance to FWP with loon observation;
- Completing process to join Whitefish Area Lake and Lakeshore Protection Regulations.
- Made an unsuccessful petition to FWP to place a horsepower limitation on the Lake in 2000;

6. Current Issues

- Increasing use and development issues;
- Identifying an appropriate mean high water mark;
- Increasing building setbacks and buffer;
- Determining impact of motorized use on water quality.

e. Whitefish School District- Project FREEFLOW

(Flathead River Educational Effort for Focused Learning in Our Watershed)

1. **Formed**

1993

2. **Mission Statement:**

Project FREEFLOW's mission is to provide an opportunity for students to collect scientific data in the area of surface and ground water quality. To offer an avenue for volunteer students to go beyond the science classroom and obtain field science skills on natural resource issues.

3. **Geographic Scope:**

Northern Flathead Valley

4. **Goals:**

Project *FREEFLOW* field research and data gathering is an ongoing, multi-year process. After gathering data students evaluate and write summary descriptions of their work. Finally, students are given the opportunity to publish and present their findings. Their overall goal is to involve students in the many activities related to contemporary natural resource issues in the Flathead Valley.

5. **Past Accomplishments:**

- Numerous years of chemical, physical, and biological data collection on Haskill Creek (three times annually);
- Training teachers in stream ecology and surface water sampling techniques;
- 4 field trips to Iron Horse (during development); 4 field trips to area sewage treatment plants; 3 field trips to City of Whitefish Water Treatment Plant; Numerous field trips to Big Mountain (conservation practices and impacts); and Field trips to the Lost Creek Fan groundwater contamination sites (Geomorphology and Septic Disposal);
- TMDL stormwater runoff sampling (City of Whitefish discharge to Whitefish River);
- Evaluation of Swift Creek mass wasting features and channel stability;
- Montana Water Summit participation;
- Montana Envirothon participation;
- Haskill Creek Watershed Inventory;
- Haskill Creek Stream Reach Inventory;
- Flathead Basin Commission lake monitoring (w/FWP);
- Partnership with Whitefish Lake Institute (Field trips and projects);
- Viking Creek Investigation with WLI as part of the septic leachate study.

- Montana Natural Resource Camp participation;

6. ***Current Issues:***

- Whitefish Area Geology and Groundwater Chemistry;
- Ongoing Haskill Creek Monitoring;
- Lower Haskill Creek Monitoring (for Flathead Conservation District);
- Cow Creek Stream Reach Inventory and Watershed Survey.

3. Whitefish City Government's Role in Water Quality

The City of Whitefish concerns itself with providing a clean and safe environment for its citizens and visitors. The area within Whitefish City limits—including Whitefish Lake—incorporates approximately 7,484 acres. Unlike any other large lake in the State of Montana, Whitefish Lake is located entirely within the boundaries of a municipality, having been annexed to the low water elevation by the City of Whitefish in 2005. The community of Whitefish is located primarily south of the lake on a glacial outwash plain dissected by the Whitefish River and several smaller streams. Glacial features include morainal deposits (lateral, recessional, and terminal), lacustrine sediments, the occasional kettle (pothole), and small pockets of stratified drift.

An interlocal agreement between the City of Whitefish and Flathead County (County of Flathead, 2005) established in 2005, described the Whitefish Planning Jurisdiction—an area outside the City of Whitefish boundaries—within which the City administered (and had done so since 1965) all planning and zoning, subdivision reviews, lakeshore protection regulations, and floodplain regulations through a nine-person Planning Board. The purpose of the interlocal agreement was to centralize management of the area surrounding Whitefish and Whitefish Lake through one governmental agency, streamlining the efforts and developing greater expertise and efficiency than if managed simultaneously by both Flathead County and the City of Whitefish.

In 2014, the interlocal agreement and the Whitefish Planning Jurisdiction, the north fifty percent of which overlaps the Whitefish Lake Watershed, were ended by a Montana Supreme Court decision. Regulatory authority of that area is now administered by Flathead County.

Water quality issues within the Planning Jurisdiction were historically administered by two city departments; the Planning Department and the Public Works Department. The Planning Department provides long-range technical planning, zoning administration and subdivision review to the City of Whitefish and also administers the Lakeshore Protection Programs for Whitefish within City limits. As discussed under *Whitefish Lakeshore Protection Committee,* portions of Whitefish Lake in Flathead County and Lost Coon Lake were both added to the list of lakes under the jurisdiction of Flathead County Lake and Lakeshore Protection Regulations as of April, 2015.

The Public Works Department provides administrative, engineering and field support for a wide range of professional and operational services, including drinking water treatment and distribution, wastewater treatment, and stormwater management systems. See Chapter XIV Municipal Water Infrastructure & Treatment for more information.

4. Agencies Involved in Whitefish Area Water Quality

The following is a brief introduction and description of various other partners involved with water quality in the Whitefish area. Some of the following information was obtained from agency or group websites and through conversations:

a. Flathead Basin Commission (FBC)

In 1983, the Montana Legislature passed a measure to create the Flathead Basin Commission (FBC) to protect the existing high quality of the Flathead Lake aquatic environment; the waters that flow into, out of, or are tributary to the lake, and the natural resources and environment of the Flathead Basin.

In 1999, the FBC initiated the Voluntary Nutrient Reduction Strategy (VNRS) program, a coordinated, basin–wide effort to reduce nonpoint sources of nitrogen and phosphorus pollution at upstream sources from Flathead Lake and on the lake's perimeter. The FBC also coordinates regional efforts related to water quality, including restoration projects and provides educational materials. After two decades of administrative attachment to the Office of the Governor, the Montana Legislature passed SB 138, which permanently attached the FBC to the Montana Department of Natural Resources and Conservation.

The FBC currently focuses its efforts on Aquatic Invasive Species (AIS), transboundary resource efforts with the Great Northern Landscape Conservation Cooperative and the Crown Management Partners, and a cooperative rail safety effort.

The Flathead Basin Commission Volunteer Lakes Monitoring Program (VLMP) was initiated in 1993 by the Flathead Basin Commission as a way to provide local residents a “citizen scientist” opportunity to collect baseline water quality data on lakes in the Flathead Basin. The WLI/FWP Whitefish to Eureka Lake Volunteer Monitoring Program was established in 2007 as a cooperative program between the Whitefish Lake Institute and Montana Fish, Wildlife and Parks. The program was modeled from the VLMP program but was also designed to include an Aquatic Invasive Species monitoring component. Beginning in 2011, FBC partnered with WLI and FWP to combine the two programs. The resulting Northwest Montana Lakes Volunteer Monitoring Network (NWMTLVMN), coordinated and administered by WLI, provides consistent monitoring parameters and reporting techniques to compare trend data across northwestern Montana lakes. Through the program, over 50 citizen scientists donate about 1,000 hours annually to gather water quality data on over 40 lakes in Flathead, Lincoln, Lake, and Missoula counties.

b. Flathead Conservation District (FCD)

Conservation districts grew from public concern for the condition of our natural resources in the 1930s. In 1935, the US Congress declared soil and water conservation to be national policy, with the passage of Public Law 46. At the state level, Montana Conservation District Law (Section 75-7-101 through 75-7-124 MCA) was enacted to allow land users to form soil and water conservation districts. In 1945, the Flathead Conservation District (FCD) was formed. Today, Montana's 58 Conservation Districts (CDs) provide local citizens with an opportunity to shape resource planning in their areas. CDs work locally to fulfill the state's policy to conserve soil, water, and other natural resources of the state.

The Flathead Conservation District (FCD) covers all areas within the county boundaries except within the original (1947) city limits of Kalispell and Columbia Falls. Specifically related to water quality, FCD administers the Natural Streambed and Land Preservation Act (310 permit) and works actively to promote water quality through partnerships, and to provide educational opportunities.

c. Montana Department of Environmental Quality (DEQ)

The Montana Department of Environmental Quality (DEQ) administers various programs related to the standards, monitoring and remediation of water resources, including the following; permitting and compliance, discharge permits, groundwater remediation, public drinking water standards, non-point source pollution, Montana Code standards, subdivisions, stormwater, Total Maximum Daily Load (TMDL), waste water management, water quality monitoring, and wetland conservation. DEQ contracted with WLI from 2008 to 2010 to collect water quality data for its TMDL effort.

DEQ maintains the “EQUIS” database that contains information for local waterbodies. DEQ also has on file a remediation response site report for the 1989 freight train derailment at Mackinaw Bay on Whitefish Lake and for the Burlington Northern Fueling Facility in Whitefish. DEQ provides grants for the purpose of furthering its Non Point Source (NPS) program goals through directly improving impaired waterbodies, monitoring, and education.

d. Montana Department of Fish, Wildlife and Parks

The Montana Department of Fish, Wildlife and Parks (FWP) was established to maintain the long-term viability of Montana's natural, cultural and recreational resources. Related to water quality, FWP manages fish species and fish habitat, including; setting creel limits, conducting habitat and fish population research, redd counts, McNeil Sediment Core, substrate scores, and gill netting and fish tissue analysis for mercury. FWP also offers funding partnerships to improve habitat quality, including the Future Fisheries Improvement Program. FWP is a key program partner with WLI for the NWMTLVMN.

Montana Fish Wildlife and Parks Recreational Trails Program partially funded the development of the Living Wetlands Interpretive Nature Trail in the Averill’s Viking Creek Wetland Preserve which WLI owns and manages. The Preserve protects the wetland through which flows Viking Creek—one of Whitefish Lake's six perennial tributaries. The wetland serves as a water cleansing kidney to Whitefish Lake.

e. Montana Department of Natural Resources and Conservation

The Montana Department of Natural Resources and Conservation (DNRC) was established through the Executive Reorganization Act of 1971. It was restructured in 1995 to place many resource management functions of Montana within one agency. DNRC promotes the stewardship of Montana's water, soil, forest, and rangeland resources. DNRC also regulates forest practices and oil and gas exploration and production, and administers several grant and loan programs.

Related to water quality, DNRC manages and maintains the state-owned dams, reservoirs, and canals. Locally, DNRC manages a substantial portion of the Swift Creek drainage and the area around the Beaver Lakes complex within the Stillwater State Forest. DNRC implements the Montana State Forest Land Management Plan through which state lands are managed to emulate the historical process of natural fires. The Northwest Land Office in Kalispell is also active in monitoring flows and water chemistries in Swift Creek and select tributaries targeting the peak of the hydrograph. DNRC partners with WLI to collect samples and monitor the creek during the remainder of the year.

In early 2015, the DNRC provided nearly $1 million in funding to improve forest and watershed health across the state of Montana. About $80,000 is tagged for the Whitefish Municipal Watershed Fuels Reduction Project. Part of Montana's *Forests in Focus Initiative*, the project funds come from the state's wildfire suppression account. Approximately 1,300 acres of Flathead National Forest land within the Haskill Basin will be treated to prevent a catastrophic wildfire. Another $50,000 will support treatment of the Taylor Hellroaring Resource Management Project which includes about 2,700 acres of land north of Big Mountain. Both areas have sub-alpine stands that are nearing the end of their lifecycle and accumulating fuels, according to Tally Lake Ranger District silviculturist, Michael Reichenberg (Baldwin, 2015). The two projects will be started in 2016 and should take about one year to complete. Another $30,000 will support treatment of 500 additional acres of Flathead National Forest land adjacent to F.H. Stoltze Land and Lumber Co. property for susceptibility to the Douglas fir beetle.

f. United States Army Corps of Engineers

The U.S. Army Corps of Engineers (Corps) carries out a wide array of projects that provide flood protection, hydropower, navigable waters, recreational opportunities and water supply. Related to water quality at a local level, the Corps administers the 404 permit process required for disturbance of wetlands.

g. United States Environmental Protection Agency

The United States Environmental Protection Agency (EPA) carries out both regulatory and voluntary programs to fulfill its mission to protect the nation's waters. EPA enforces federal clean water and safe drinking water laws, provides support for municipal wastewater treatment plants, and takes part in pollution prevention efforts aimed at protecting watersheds and sources of drinking water.

The EPA administers the 303(d) list of national impaired waterbodies. In the state of Montana, DEQ is responsible for maintaining, updating and reporting 303(d) waterbodies to the EPA and developing TMDLs for listed waterbodies.

h. United States Fish and Wildlife Service

The U.S. Fish and Wildlife Service's (USFWS) mission is to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. Related to local water quality issues, the USFWS administers the Threatened and Endangered Species list and offers various funding partnerships, including wetlands protection opportunities.

i. United States Forest Service, Tally Lake Ranger District

The U.S. Forest Service was established in 1905 and manages 193 million acres nationally. Locally, the Flathead National Forest (FNF) is comprised of 2.3 million acres. The Tally Lake Ranger District administers local forest service lands. Very little forest service land is found within the Whitefish Lake Watershed and Surrounding Area (the Big Mountain area comprises the largest Forest Service land in the immediate Whitefish area). In 2013, the FNF announced its plans to begin revising its Flathead National Forest Land and Resource Management Plan (2015). See discussion under Section E Montana DNRC. After holding a number of open house sessions to discuss the plan, a draft proposed action was developed and 60-day public scoping period was set in 2015. A Draft Environmental Impact Statement and 90-day comment period is planned for the first quarter of 2016.

A 2012 planning rule describes requirements associated with restoring and maintaining watersheds and aquatic ecosystems, water resources, and riparian area. It requires the identification of watersheds that are a priority for restoration and maintenance, and that all plans include “components to maintain or restore the structure, function, composition and connectivity of aquatic ecosystems and watersheds in the plan area, taking into account potential stressors including climate change, how they might affect ecosystems and watershed health and resilience” (Flathead National Forest Land and Resource Management Plan, 2015). The Forest Service is required to establish and ensure implementation of Best Management Practices (BMPs) for water quality and the use a Watershed Condition Framework (WCF) to identify priority watersheds, develop watershed action plans, and maintain or restore conditions in those watersheds.

Priority watersheds were also proposed to provide extra protection for primary bull trout streams and the federally listed *threatened* fish. These watersheds overlap with designated “critical habitat” for bull trout. The Whitefish Lake and Upper Whitefish Lake Watersheds are included on this list. The classification system defines watershed conditions based on geomorphic, hydrologic, and biotic integrity relative to potential natural condition. Watersheds are evaluated in the context of natural disturbance regimes, geoclimatic settings, and other watershed factors, and the evaluations encompass both aquatic and terrestrial components as they are inseparably linked to one another.

j. The University of Montana, Flathead Lake Biological Station

The mission of the Flathead Lake Biological Station (FLBS) is to conduct basic and applied research in ecology, with emphasis on freshwater. The FLBS (also known as the Yellow Bay Biological Station) trains graduate students for professional and teaching careers, provides field ecology courses for college students, K-12 teachers, and natural resource professionals, and provides scientific data, interpretation and outreach to help resolve environmental problems and inform public policy locally, regionally, nationally and internationally. FLBS studies conducted on Whitefish Lake have primarily received funding through a sponsoring partnership with the Whitefish County Water District.

In 2006 and 2007 the Whitefish Lake Institute, Senator Dan Weinberg (D), Representative Mike Jopek (D), and The University of Montana worked to increase the existing FLBS appropriation by $25,000 to be used specifically on Whitefish Lake. In 2007, the 60th Montana Legislative Session passed House Bill 2 which included the following language "*Yellow Bay Biological Station is restricted; $100,000 each fiscal year is restricted to laboratory work associated with Flathead basin water quality monitoring, and $25,000 each fiscal year is restricted to limnological investigations on Whitefish Lake in partnership with the Whitefish Lake Institute*." Resulting reports from FLBS's early studies (see Section VI: Historical Studies) provided an important base of information on Whitefish Lake.

C. CURRENT LAND OWNERSHIP

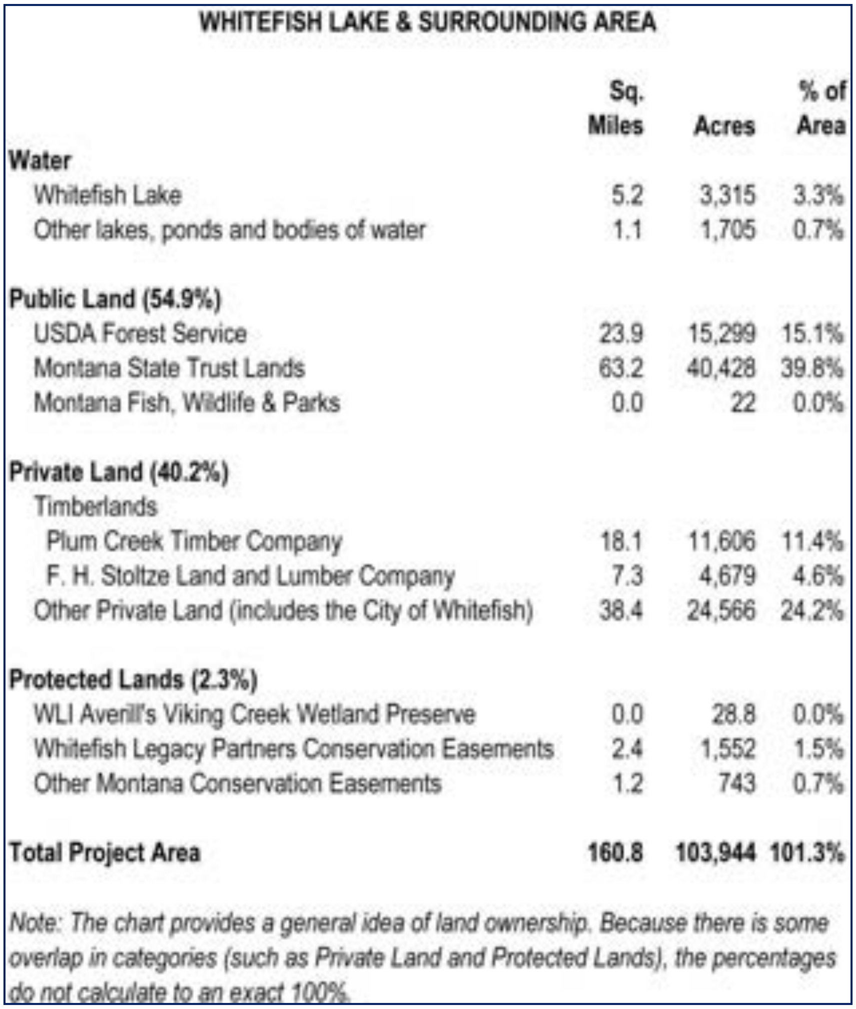
1. Land Ownership

a. Public Lands

Over 54 percent of the project area is public lands including more than 40,000 acres of Montana State School Trust lands. Most of the State Trust Land is in the northern half of the watershed, with some parcels reaching down to the north end of Whitefish Lake. Over 15,000 acres of United States Forest Service (USFS) land lies in the north and along the eastern boundary, particularly to the northeast of Whitefish Lake. The public land includes two state parks—Les Mason on the east shore and Whitefish Lake State Park on the lower west shore that are managed by Montana Fish Wildlife & Parks.

b. Private Lands

Private lands make up just over 24 percent of the project area including about 11,600 acres owned by Plum Creek Timber Company from the center to the western boundary and just over 4,600 acres owned by F.H. Stoltze Land and Lumber Company in the Whitefish River Watershed section of the project area and some parcels north of Whitefish Lake. The remaining 24,500 plus acres is privately owned and includes urban, suburban, and rural lands. The urban land uses are generally residential, commercial, industrial, and destination resorts. The suburban lands are generally residential, and commercial with limited industrial use. The rural areas are rural residential and agricultural.



WHITEFISH LAKE & SURROUNDING AREA

	Sq. Miles	Acres	% of Area
Water			
Whitefish Lake	5.2	3,315	3.3%
Other lakes, ponds and bodies of water	1.1	1,705	0.7%
Public Land (54.9%)			
USDA Forest Service	23.9	15,299	15.1%
Montana State Trust Lands	63.2	40,428	39.8%
Montana Fish, Wildlife & Parks	0.0	22	0.0%
Private Land (40.2%)			
Timberlands			
Plum Creek Timber Company	18.1	11,606	11.4%
F. H. Stoltze Land and Lumber Company	7.3	4,679	4.6%
Other Private Land (includes the City of Whitefish)	38.4	24,566	24.2%
Protected Lands (2.3%)			
WLI Averill's Viking Creek Wetland Preserve	0.0	28.8	0.0%
Whitefish Legacy Partners Conservation Easements	2.4	1,552	1.5%
Other Montana Conservation Easements	1.2	743	0.7%
Total Project Area	**160.8**	**103,944**	**101.3%**

Note: The chart provides a general idea of land ownership. Because there is some overlap in categories (such as Private Land and Protected Lands), the percentages do not calculate to an exact 100%.

Figure 18. Land Ownership Percentages.

c. <u>Protected Lands</u>

Just over 2.3% of the project area is made up of protected lands. This includes over 1,500 acres of City of Whitefish Easements on the southwest boundary, over 700 acres of other conservation easements to the north, east, and south of Whitefish Lake, and the 28+acre WLI owned Averill's Viking Creek Wetland Preserve on the lower east shore of the lake. See <u>Land Ownership</u> map in Chapter XXI Addendum B GIS Maps.

2. Protecting the Land

a. <u>Conservation Easements</u>

A conservation easement is a negotiated agreement between a landowner and a land trust that protects private land in perpetuity while allowing the landowner to continue owning and managing their property. If the land is in production, the owner may continue to produce crops, hay, livestock, timber, and other commodities. Easements vary based on the landowner's intent, but they typically restrict certain activities such as subdivision for residential or commercial activities, surface mining, and toxic waste dumping.

There are a number of reasons to place a property into an easement. The most altruistic reason is the landowner's desire—born of a bond with and passion for the land—to protect the property in its entirety for long after the owners or their families have departed. There are also a variety of financial benefits to easements, including tax relief. Because easements can restrict commercial, industrial and residential subdivision development, the value of the land—in practical terms—is diminished. Since that land was voluntarily diminished for conservation purposes, the landowner can potentially receive tax benefits. In some instances, a landowner who donates land to an easement may be able to deduct from their income tax the value of the easement as a charitable gift (Flathead Land Trust, 2010). Of interest to water quality is that easements also often allow for stream and river channel migration which helps maintain floodplain function.

The key organizations managing conservation easements in and around the Whitefish Lake Watershed and Surrounding Area are Montana Land Reliance, Montana Nature Conservancy, Flathead Land Trust, and the Trust for Public Land. Other lands are protected through the efforts of Whitefish Legacy Partners and WLI. Many of these organizations are involved in other conservation efforts.

1. Montana Land Reliance

On a state-wide scale, the Montana Land Reliance (MLR) partners with landowners to provide permanent protection for private lands that are significant for agricultural production, forest resources, fish and wildlife habitat, and open space. MLR measures its conservation work in miles of streambanks and acres of land and habitat protected. But the legacy of MLR's work is the perpetuation of a lifestyle and economy that rely on responsibly managed private land and open spaces that will continue to nourish the spirit of Montanan's for future generations. MLR's voluntary conservation easements protect 907,425 acres of ecologically, agriculturally, and historically important land and 1,577 miles of stream frontage. Two properties in the study area MLR easements (Montana Land Reliance, 2013).

2. The Flathead Land Trust

The Flathead Land Trust—a 501(c)(3) accredited land conservation organization—was founded in 1985, and received its first 157-acre donated conservation easement in 1988. Celebrating its 30 year anniversary in 2015,it now holds 52 conservation easements and 12 partnership projects protecting over 13,000 acres in the Flathead Watershed. Of these 51 projects, four are completely within the study area boundaries, including a 20-acre and a 58-acre property in the Blanchard Lake wetlands, 52 acres of forestland in the Iron Horse development, and 33 acres northeast of Whitefish. One additional easement encompassing 570 acres of DNRC forestland, on which a portion of the Whitefish Trail is located, straddles the border of the Whitefish Lake Watershed (Flathead Land Trust, 2013).

3. Whitefish Legacy Partners

Whitefish Legacy Partners (WLP) is dedicated to creating conservation, education, and recreation opportunities on lands surrounding Whitefish for future generations. WLP works in partnership with the City of Whitefish to implement goals of the 2004 Whitefish Neighborhood Plan. Critical to the Plan is the management and long-term vision for 13,000 acres of School Trust Lands surrounding Whitefish. The community goals entail “protecting access, water quality, viewsheds, wildlife corridors, and recreational opportunities while generating long-term use of trust lands for Montana’s public schools and universities.” In the first ten years of plan implementation, over 3,000 acres have been permanently protected and over $12 million dollars in gross revenue has been generated for Montana schools and universities.

The Whitefish Trail—WLP’s anchor project—has added 26 miles of scenic trail accessed by seven trailheads throughout Whitefish. The trail segments offer hiking and non-motorized biking on beautiful single-track trails through forested lands alongside streams, passed scenic overlooks, and across gated logging roads. This unique trail system links paved trails in the City of Whitefish and mountain biking trails at Whitefish Mountain Resort to Department of Natural Resources and Conservation (DNRC) State Trust Lands, Flathead National Forest, Montana Fish Wildlife & Parks fishing and boating sites, Flathead Land Trust easement property, and multiple private owner properties.

As part of the Whitefish Legacy Lands Places Worth Protecting Initiative, WLP is working to create permanent conservation area to protect viewsheds, prime wildlife habitat, and the water of Whitefish Lake while providing the public a high quality recreation system with continued forest management by the State with no threat of development. Completed and future trail development is the result of a partnership with the City of Whitefish, the DNRC, Montana State Parks, the USFS, and private conservation-minded individuals. While WLP does not hold any easements, they facilitate easements with other parties. By continuing traditional state forest management on these lands, the project contributes millions of dollars in revenue to Montana schools and universities (Whitefish Legacy Partners, 2013).

4. Montana Nature Conservancy

Since 1978, the Montana Chapter of The Nature Conservancy (TNC) has preserved nearly one million acres in the Crown of the Continent. In partnership with the Trust for Public Land, TNC has purchased more than 310,000 acres of private forest land from Plum Creek Timber Company, reversing a trend of significant land fragmentation. This large scale effort has helped to preserve the natural landscape, and keep open vital connections to seasonal ranges for wildlife throughout Montana. On a watershed scale, the Nature Conservancy has helped local individuals place their land in conservation easements.

Once such property is the 215-acre Battin Nature Conservancy Easement which borders the Whitefish Lake Institute's 28.8 acre wetland on its north and east sides. The easement and the wetland provide a large contiguous area that protects water quality and provides habitat for aquatic, terrestrial and avian wildlife in the heart of Whitefish (Montana Nature Conservancy, 2013).

The *rare* Yellow lady's slipper (*Cypripedium calceolus var. parviflorum)*, and two threatened plant species – northern bastard toadflax (*Geocaulon lividum*) and Spurred gentian (*Halenia deflexa*) – are found on the easement.

In 2015, WLI and the Flathead Conservation District conducted a Yellow lady's slipper survey, finding a small plant community near and overlapping previous distribution identified by Peter Lesica from the University of Montana.

The Le Conte's sparrow has also been observed in wet sedge near the property. With only a few breeding sites west of the Continental Divide for the bird, this site provides important habitat for the birds. WLI and FCD's 2015 survey of the LeConte's sparrow found one individual that momentarily perched on a barbed wire fence separating two former hay meadows

The Battin Nature Conservancy Easement was initially protected through the efforts of Sharlot Battin and her mother, Margaret Murdock. Murdock's mother Bertha Steif Reich originally purchased the property in 1920. In a May 16th, 2014 interview by the Whitefish Pilot's editor Matt Baldwin (2014b), Murdock said, "My mother would say, 'It sure would be nice if we could just leave it this way, because we have moose, we have coyotes, deer and bear on the land, and they have rights, too.'" At age 89, Murdock said the conservation project was the highlight of her life. Battin and Murdock received WLI's Lifetime Achievement Stewardship Award in 2010. In 2013 Murdock was honored by the City of Whitefish.

Whitefish Mayor John Muhlfeld said "Margaret was a leader and pioneer in conserving important lands in Whitefish. Her contributions were significant and will leave a lasting legacy in this community." Born in Whitefish in 1922, Murdock was a second grade teacher for 36 years. She was 91 when she passed away at her home on the property on April 23, 2014. Sharlot is now furthering the family legacy of protecting the land, and contributing her own concepts to how the easement is managed.

5. Trust for Public Land

The Trust for Public Land was founded to create parks and protect land for people to enjoy, and they remain the only large conservation organization focused on this goal. Working from a regional office in Bozeman, Montana, the Trust for Public Land has been at the forefront of preserving the places that Montana communities care about most—that support livelihoods and the outdoor way of life—through their "Parks for People" and "Our Land and Water" initiatives.

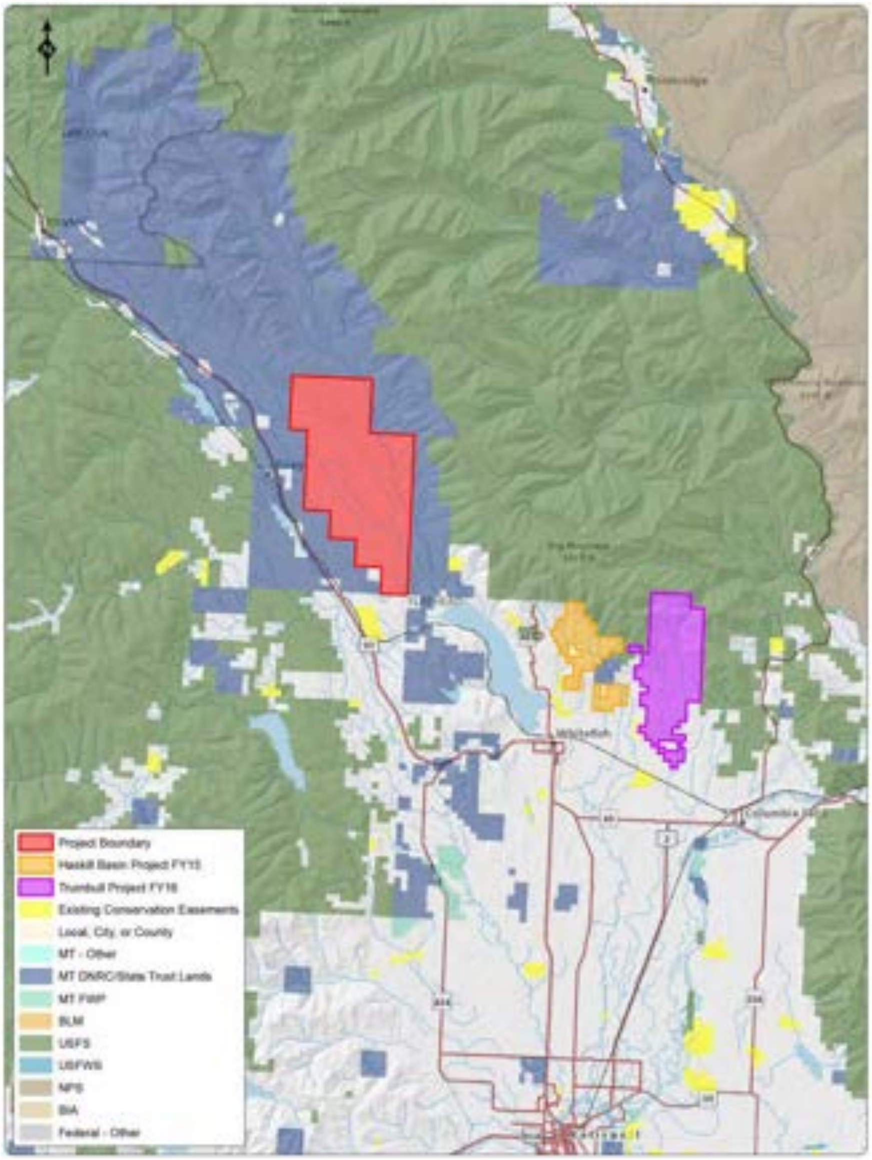


Figure 19. Trust for Public Land Project Map.
Map courtesy Trust for Public Land

Montana's Haskill Basin provides nearly 85 percent of the water supply for the town of Whitefish. The basin's working forest has been harvested by F.H. Stoltze Land & Lumber Company for a hundred years, supporting a timber industry key to the local economy even today. Any development on 3,000 acres of the basin near the Whitefish Mountain Resort and Iron Horse golf community would put the town's water supply and rural character at risk (Figure 19). The Trust for Public Land secured an option to purchase development rights from Stoltze and permanently protect the basin's clean water, recreational access, and wildlife habitat. An easement on the property prohibits all subdivision and development while continuing to allow sustainable timber forest management (The Trust for Public Land – Montana, 2013).

The plan enjoys solid support from Stoltze management who offered to sell the $21 million easement for a discounted price of $17 million, contributing $4 million to the project. The federal Forest Legacy Program covered $7 million. Two million came from the U.S. Fish and Wildlife Service Habitat Conservation Plan Land Acquisition Program, and the $8 million balance came from the community of Whitefish through a 1% resort tax increase which received over 83% of the vote in a local election held April 28, 2015.

In August of 2015, Plum Creek and TPL announced an agreement to work together to conserve 15,334 acres of Plum Creek land above Whitefish Lake (Also Figure 19). The purchased portion of the lands will eventually be transferred to public ownership or to a conservation buyer. The intent of the conservation easement is to be held by FWP and would permit continued sustainable forest management, while prohibiting all future development. The lands are mostly surrounded by Stillwater State Forest land. Through the agreement, TPL will have an option to purchase 1,920 acres and establish a conservation easement on the remaining 13,414 acres.

More than 85% of the water in Whitefish Lake flows down from the north through the Stillwater State Forest, with much of it flowing through Plum Creek property through Lazy Creek and Swift Creek. Subdivisions on this highly developable land have the potential to increase the amount of sediment and septic leachate that reaches the lake. Like the Haskill Basin easement, this land has great appeal with its access close proximity to Whitefish Lake, access to utilities and beautiful terrain. The first step in the project funding process will be to secure $7 million from the federal Forest Legacy Program by the end of 2017. A significant amount of further funding from public and private sources will then be needed to protect the property.

6. Averill’s Viking Creek Wetland Preserve

The 28.82 acre Averill’s Viking Creek Wetland Preserve was gifted to WLI by the Dan Averill family in 2009, as part of the Viking Creek Development proposal. This publicly accessible Preserve is an excellent example of how citizens and developers can work together to protect the health of a watershed, to provide open space in the wildland/urban interface, all while allowing for economic growth in the community.

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Figure 20. Living Wetlands Interpretive Nature Trail.

After several unfavorable development proposals for this land, WLI worked together with the Friends of Wisconsin Avenue Wetlands—a group assembled to protect the wetland—and the Averill family to solidify a development plan that satisfied everyone’s goals. Now owned and managed by WLI, the Preserve offers the *Living Wetlands Interpretive Nature Trail*, a comfortable respite for people who live, work, and play in the area, as well as numerous outdoor education opportunities (Figure 20).

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Like all wetlands, this one is an important link and transition zone between land and water, and it performs several functions vital to our environment and clean water dependent economy. With their characteristic *hydric* soil, shallow water table, and unique plant life, wetlands are considered the most biologically diverse of all ecosystems. The Preserve provides groundwater recharge, water purification, and essential habitat for documented wildlife of the area which includes grizzly bear, black bear, mountain lion, moose, elk, deer, coyote, fisher, turkey, fox, beaver, owls, raptors, numerous birds, amphibians, brook trout, and a host of terrestrial and aquatic insects. WLI's goal in developing an educational trail for the public is to share the history, science, and beauty of the wetland, and to provide a glimpse into the lives of the wildlife with which we share the habitat (Whitefish Lake Institute, 2014).

7. North Fork Watershed Protection Act

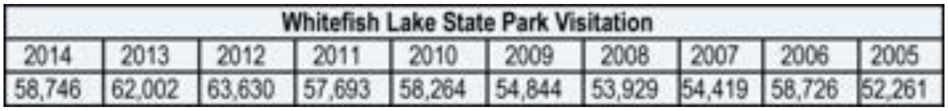
Two pieces of public lands legislation important to the Whitefish Lake Watershed because it includes part of the Whitefish Range, and to northwestern Montana in general passed in December of 2014 after many years of effort by organizations, individuals, and bipartisan political representatives. The *North Fork Watershed Protection Act* bans all future energy leases on 430,000 acres of federal land in the North Fork and Middle Fork of the Flathead River. Part of a larger campaign, this legislation enabled the protection of over 800,000 acres from oil & gas development and mountaintop removal coal mining in the entire Canadian portion of the North Fork of the Flathead River. The *Rocky Mountain Front Heritage Act* was combined with the *North Fork Watershed Protection Act* and placed into amendments to the *National Defense Authorization Act* which passed the Senate on December 12, 2014 in an 89-11 vote. The bill had bipartisan support and was the first wilderness bill in Montana since the 1983 designation of the Lee Metcalf Wilderness (Peterson, 2014 & Brown, 2014).

b. State Parks

Information provided by David Landstrom, Region One Parks Manager, Montana Fish, Wildlife & Parks, (personal communication, 2015).

1. Whitefish Lake State Park

Whitefish Lake State Park is a 10-acre west lakeshore wooded lakeside campground and beach located at Dog Bay at an elevation of 3,012 feet, about two miles from the City of Whitefish. There are 25 varied types of campsites, as well as boating, swimming, fishing and water-skiing. In 1957, land was donated to the state by the Whitefish Junior Chamber of Commerce and the Whitefish Rod and Gun Club. The first development of the park took place in 1966 with initial campsites and latrines. In 1976, the park was redesigned to its current configuration, including the addition of a City sewer easement. A shower house was added in 1994, and the boat ramp was expanded in 2005 and again in 2013. The park is staffed by two paid hosts and one volunteer host.

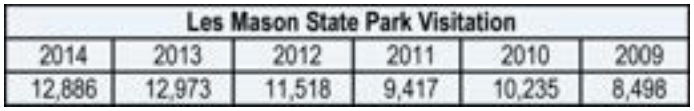


Whitefish Lake State Park Visitation									
2014	2013	2012	2011	2010	2009	2008	2007	2006	2005
58,746	62,002	63,630	57,693	58,264	54,844	53,929	54,419	58,726	52,261

Figure 21. Whitefish State Park Visitation 2005-2014.

2. Les Mason State Park

Les Mason State Park is a day use park located 4.6 miles from the City of Whitefish on the east shore of Whitefish Lake. The park has about 585 feet of sand and gravel lakeshore, making it a popular beach for swimming and picnicking. The Les Mason Recreational Area was created in 1985 when a deed was signed over to the state by Bob and Shirley Jacobsen, Dona and Barb King, and Richard and Elizabeth Snyder. Park amenities were developed between 1985 and 1990. In 1990, the Friends of Les Mason first signed an agreement to operate the park, and renewed that agreement through 2008. In 2009, Montana State Parks took over park operations as a result of a vehicle registration funding source. The park is currently staffed by two volunteer hosts.



Les Mason State Park Visitation					
2014	2013	2012	2011	2010	2009
12,886	12,973	11,518	9,417	10,235	8,498

Figure 22. Les Mason State Park Visitation 2009-1014.

c. County Parks

Flathead County has two small parks on Whitefish Lake. One is an unimproved boat launch with parking off Del Rey Road at the north end of the lake, the other is a walk-in site off Birch Point Drive on the southwest end of Whitefish Lake.

D. COMMUNITY INVOLVEMENT

A Community Forum was held jointly by WLI, the City of Whitefish, and Anderson-Montgomery Consulting Engineers on May 20, 2015 with two main goals. The first goal was to describe and set expectations to the public about this report. The second goal was to gather community input through a Public Comment Period and Social Survey regarding water quality concerns and to collect citizen observations and historical background information. People who have lived in the Whitefish Lake Watershed for some or all of their lives have a unique knowledge of water quality changes over time, and of the activities that may have affected such change.

WLI developed a package for the Community Forum that included a brief description of the project, a preliminary table of contents for the report, a timeframe for the public process, and a survey which could be completed online or in hard copy. City of Whitefish Mayor John Muhlfeld opened the public session, WLI Executive Director Mike Koopal provided a project introduction, and WLI Science & Education Director Lori Curtis discussed the survey and community input process. The meeting was then opened for public input, through which twelve attendees spoke or asked questions. The issues of greatest concern were septic leachate reaching the lake through groundwater from aging systems around and in close proximity to the lake, and the potential for aquatic invasive species infestation. Water quality concerns from the Social Survey are available in Chapter XVI, Section E Current & Future Concerns, B Social.

V. LAKE LIMNOLOGY PRIMER

A. LIMNOLOGY DEFINED

Limnology is freshwater science—the study of inland waters. Water flows to lakes from streams, rivers, groundwater, and precipitation, carrying nutrients, sediments, and pollutants. Additional inputs reach lakes through atmospheric deposition as biological and chemical compounds that are carried through the air. Lakes are defined by processes involving plants, animals, and microorganisms found within the lake, but they are also influenced by other natural processes such as hydrology, weather, and climate; and by human processes such as land use and recreation.

B. LAKE CLASSIFICATION

Limnologists classify lakes and other waterbodies according to a *trophic state*. The trophic state is defined as the total weight of biomass in a given waterbody at the time of measurement. The amount of available nitrogen, phosphorus and other nutrients influence the trophic state. An *oligotrophic* lake has low levels of nutrients and low levels of primary production—the synthesis of organic compounds from carbon dioxide through photosynthesis (using light as an energy source) and chemosynthesis (using the reduction of chemical compounds). A *mesotrophic* lake generally has an intermediate level of productivity, having clear water, sometimes submerged aquatic plants, and a medium level of nutrients. A *eutrophic* lake has high levels of primary productivity resulting from high levels of nutrients, often leading to algal blooms. Lakes with frequent and/or severe algal blooms are considered *hypereutrophic*. There are no hard lines dividing these classifications as they vary based on an individual waterbody’s aquatic productivity.

Several schemes to classify lakes by their eutrophic character have been developed over time. Swedish limnologist Einar Naumann first developed the trophic state concept based on the chemistry of the watershed (Naumann, 1919). His early ideas also contributed to the concepts of nutrient loading, biomass-phosphorus relationships, and the change in a lake’s trophic status with time. August Thienemann simultaneously developed a lake classification scheme, and both were employed until the descriptions failed to match all of the lake types discovered (Thienemann, 1921). Federal requirements of the Clean Water Act now state that all lakes must be classified by their eutrophic character.

A number of indices are now employed to further refine the trophic state of lakes, including but not limited to phosphorus loading and concentration, algal productivity, algal biomass, and hypolimnetic oxygen deficits.

1. Phosphorus Loading

Phosphorus (P) is an essential nutrient for plants and animals and is one of the 20 most abundant elements in the solar system. Under natural conditions, phosphorus is found only in scarce quantities in lakes. Anthropogenic activities have contributed disproportionate loads of phosphorus to freshwater systems, sometimes leading to excessive algal growth. As these large quantities of algae die, they are consumed by bacteria, using up dissolved oxygen, potentially suffocating aquatic life. Increasing phosphorus will tend to move a lake further along the trophic continuum. On one end of the spectrum, low concentrations of phosphorus can limit the growth of aquatic plants, making phosphorus a *limiting nutrient*. At the other end of the spectrum, high levels of phosphorus can cause a lake to become eutrophic.

Although there are currently no models for describing the percentage of phosphorus from nonpoint sources in the state of Montana, the state of Minnesota has determined that typically, about two-thirds of total phosphorus loads to rivers and lakes comes from *nonpoint sources* such as atmospheric deposition, streambank erosion, wastewater treatment systems, urban runoff, and runoff from pasture and croplands (Minnesota Pollution Control Agency, 2007).

Phosphorus in water exists in two forms, dissolved (soluble) and particulate (attached to or part of particulates). *Orthophosphorus* (also known as Soluble Reactive Phosphorus or SRP) is the primary dissolved form of phosphorus and is readily available to algae and aquatic plants. Particulate phosphorus—some of which is contained in plant and animal tissues and other organic matter—can cycle from one form into another. Natural decomposition can convert particulate phosphorus into dissolved phosphorus in water and sediment. Because phosphorus can change forms, it is often measured as *Total Phosphorus,* aiding in understanding its overall ability to provide food for aquatic plants, including algae.

2. Algal Productivity

As noted earlier, *Primary productivity* is the rate at which energy is converted by photosynthetic and chemosynthetic autotrophs (organisms that produce complex organic compounds from simple substances) to organic substances. The total amount of productivity in a waterbody is *gross primary productivity*. *Net productivity* is the organic material remaining after a certain amount of organic material is used to sustain the life of producers. Primary productivity is a well accepted standard for use in trophic state classification.

3. Algal Biomass

Algal biomass is the concentration or weight of algae in a lake at any given point in time. One method for looking at algal biomass is by measuring the plant pigment, chlorophyll *(a)*. This specific form of chlorophyll is used in oxygen photosynthesis, absorbing energy from wavelengths of violet-blue and orange-red light, and reflecting green/yellow light, contributing to the observed green color of most plant life. It is easy to measure, and because it is integral to photosynthesis, chlorophyll *(a)* serves as a link between productivity and production (Carlson, 1992).

Secchi disc depth is also widely used to estimate trophic state. Developed in 1865 for a Vatican-financed Mediterranean oceanographic expedition by Professor P.A. Secchi, the Secchi disc has become a standard piece of equipment for lake scientists. It is a weighted circular disc about eight inches in diameter with four alternating black and white sections painted on the surface. Secchi disc transparency is a function of light reflected from the surface of the disc, which is affected by the absorption characteristics of the water and of dissolved organic matter and particulates in the water (Wetzel & Likens, 1979).

The disc is attached to a measured line that is marked off in meters or feet. The Secchi disc is used to measure how deep a person can see into the water. It is lowered into the lake on the shadowed side of the boat by the measured line until the observer loses sight of it. The disc is then raised until it reappears. Transparency is estimated by the mean of the depths at which the disc disappears from view and when it reappears after being lowered beyond visibility. In extremely clear lakes, disc readings greater than 32 ft (10 m) can be measured.

On the other hand, lakes which are nutrient rich and affected by large amounts of algal growth, suspended sediments, or both often have readings of less than one-half meter. In shallow lakes, it is often impossible to get a Secchi disc reading because the disc hits the bottom before vanishing from sight (USEPA 2007). While transparency itself is not a trophic state indicator, it is influenced by algal density, therefore is applicable as a surrogate indicator of biomass and productivity.

4. Hypolimnetic Oxygen

Dissolved Oxygen presence or absence in the hypolimnion of lakes serves as another major aspect of trophic classification (Carlson & Simpson, 1996). Oxygen depletion can have extensive effects on the chemistry and biota of a lake. Hypolimnetic temperature and dissolved organic compounds contribute to the depletion of oxygen, therefore making hypolimnetic oxygen a defining characteristic of trophic state.

Another form of oxygen depletion occurs in nutrient rich waters, where algae will grow in the warm, sunlit upper layers. Eventually the algae will die and sink into to the dark bottom layer where bacteria and microbes decompose the algae. Because bacteria and microbes need oxygen to live, they can deplete the small amount of oxygen available in the water.

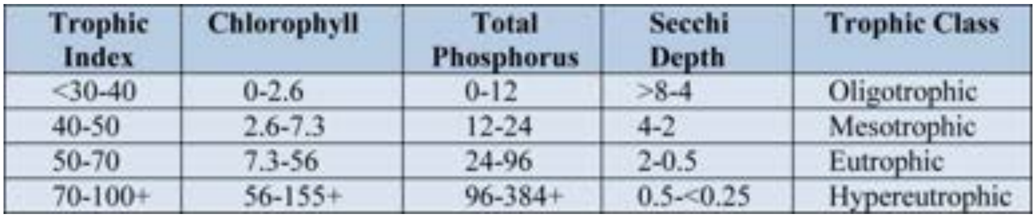
Carlson’s Trophic State Index

One of the more common methods of viewing trophic state—*Carlson’s Trophic State Index (TSI)*—aggregates physical, chemical, and biological measurements. This is one of the most commonly used indices, and is used by the EPA to classify waterbodies. Carlson’s Index uses algal biomass as an objective classifier of a waterbody's trophic status.

Three variables were initially used to calculate Carlson’s Index; chlorophyll *(a)*, total phosphorus, and water clarity (Secchi depth). Later modifications to the TSI added total nitrogen analysis.

The TSI is calculated using this formula:

<u>TSI Calculations</u>:
$TSI(SD) = 60 - 14.41 \ln(SD)$
$TSI(CHL) = 9.81 \ln(CHL) + 30.6$
$TSI(TP) = 14.42 \ln(TP) + 4.15$
$TSI(TN) = 54.45 + 14.43 \ln(TN)$



Trophic Index	Chlorophyll	Total Phosphorus	Secchi Depth	Trophic Class
<30-40	0-2.6	0-12	>8-4	Oligotrophic
40-50	2.6-7.3	12-24	4-2	Mesotrophic
50-70	7.3-56	24-96	2-0.5	Eutrophic
70-100+	56-155+	96-384+	0.5-<0.25	Hypereutrophic

Figure 23. Trophic Class Relationships (Carlson, 1996).

C. PHYSICAL CHARACTERISTICS

There are two main divisions in a lake, the *littoral zone* and the *limnetic zone* (Figure 24). The littoral zone is the shallow part of the lake, typically around the shoreline, where light penetrates through the water to the bottom sediment. The limnetic zone begins at the depth where light can no longer penetrate to the bottom. Rooted plant life grows in the littoral zone where sunlight reaches the bottom, but not in the limnetic zone. Water temperature is also affected in the littoral zone by light penetration as solar energy is absorbed. The distinctions of these two zones shift in lakes seasonally and annually depending on water clarity, sediment infilling, and primary production. The depth at which light is equal to only 1% of the surface light is called the *compensation depth*—the point where respiration is equal to photosynthesis. Above the compensation depth is the *photic (or trophogenic)* zone where plants create more food matter than is consumed, and below it is the *aphotic (or tropholytic)* zone where food consumption by plants is greater than production.

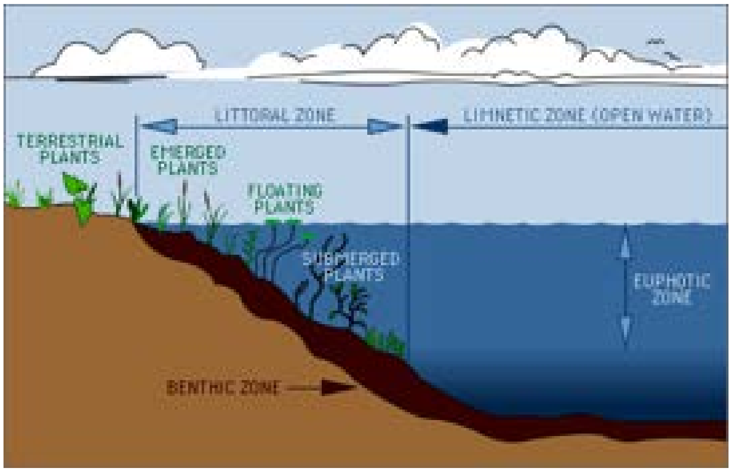


Figure 24. Biological Lake Zones.
Courtesy: Water on the Web

D. SEASONAL DENSITY STRATIFICATION IN TEMPERATE CLIMATES

Typically, deeper lakes in the same latitude as those in the Whitefish Lake Watershed are subject to *stratification*. Stratification in freshwater lakes separates water into three zones, subject to climatic conditions and lake depth. In the summer months, sunlight and warmer weather heat the upper layers of the lake, while deeper waters remain cooler. The greater the depth, the more rapidly the efficiency of heat transfer decreases. The top layer where water is in contact with the atmosphere is the *epilimnion* (Figure 25). Once stratified, the warmer water circulates at a relatively consistent temperature. Below the epilimnion is the *metalimnion*, the transition zone between the surface and deep layers. Within the metalimnion is the *thermocline*--the narrow plane of the water column at which temperature decreases most rapidly with depth.

Below the metalimnion is the *hypolimnion* where cool, mostly nonturbulent water, which is denser than warm water, remains in the bottom layer of the lake. When the epilimnion and hypolimnion do not mix because wind currents or other external energy sources are unable to mix surface energy throughout the water layers, the lake is considered *stratified*. Stratification occurs when surface warming increases the temperature and water density difference to the point where resistance to mixing is greater than the mixing strength of wind turbulence.

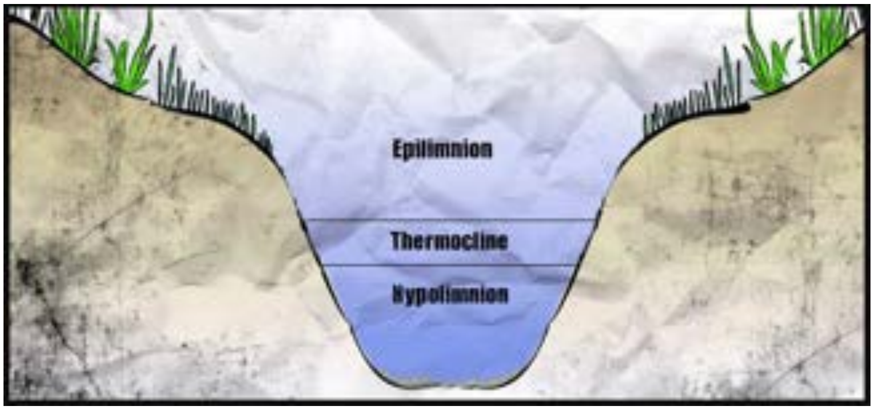


Figure 25. Generalized Lake Stratification Zones.
Courtesy Untamedscience.com

Density plays a key role in modifying the temperature profile of lakes. Water is unusual and differs from most compounds because it is less dense as a solid than as a liquid. Therefore, ice floats, while water just a few degrees above freezing, sinks. Most compounds change from liquid to solid; their molecules become more tightly packed, so the compound is denser as a solid than a liquid. Water at sea level, however, is densest at 39.2°F (4°C) and becomes less dense at both higher and lower temperatures. This density/temperature relationship causes many lakes to stratify or separate into distinct layers.

1. General Seasonal Changes

Spring

The water near the lake's bottom is around 39.2°F just before the ice cover melts in spring. Water above that layer is cooler (near 32°F) just under the ice. As the weather warms, the ice melts and the surface water heats up, therefore decreasing in density. When the temperature/density of the surface water equals the bottom water, very little wind energy can completely mix the lake (*spring turnover*). After the spring turnover, the surface water continues warming as it absorbs heat. As the temperature rises, the water becomes less dense than the water below. Winds may still mix the lake from bottom to top, but eventually the upper layer becomes too warm to mix completely with the denser deeper water. This large density differentiation at higher temperatures prevents the lake water from mixing and creates stratification.

Summer

As summer progresses, the temperature and density differences between the upper and lower layers becomes more distinct and a stronger thermocline is formed. The depth of mixing is limited to the epilimnion and upper metalimnion and depends partly on the exposure to wind, but is most strongly associated with the lake's size and morphology. By the end of the summer, the epilimnion tends to deepen.

Fall

As the weather cools in fall, the epilimnion cools, reducing the temperature and density difference between the epilimnion and the hypolimnion. When surface and bottom water approximate the same temperature and density, fall winds can mix the lake (*fall turnover*). As temperatures consistently drop, the surface water continues to cool allowing freezing to occur.

Winter

A less apparent density stratification occurs under the ice in the winter months. Most of the water column is denser than the super-cooled, lighter water just below the ice. The water column is also isolated from wind and wind-generated convective currents by ice cover, therefore temperature and density layering continues throughout the winter months.

Also in winter in temperate lakes, *inverse stratification* can occur after ice has covered the lake's surface. Just below the ice, the water is at or near 32°F. This water is slightly less dense than water at 39.2°F—despite being colder. The colder, less dense water is trapped above warmer, denser water. There is also the potential for convective currents to form under the ice. Many factors, including amount of snow cover over the ice and ice break-up and shifting, can affect inverse stratification.

A *dimictic* lake mixes twice annually. Lakes that turnover several times a year are called *polymictic*, and tend to be shallow and/or have a long unimpeded lake surface across which the wind blows (fetch). The rarest type of lake is *meromictic* which means the lake only mixes through part of the water column, and the bottom layers very rarely or never mix with the epilimnion. These are typically very deep lakes that are protected from the wind, or lakes with high salinity; however other unique local conditions can cause meromixis.

VI. HISTORICAL STUDIES

A. PAST STUDIES

Prior studies of Whitefish Lake by other research entities and resource management agencies have been generally limited in duration and/or scope. Before now, these disparate studies had also not been compiled into a master document for review, comparison and evaluation. The data from these past studies, however, contribute to the overall understanding of the lake and the Whitefish Lake Watershed and Surrounding Area. This report compiles and evaluates all previous historical scientific data to begin to quantify the condition of the Watershed and identify work to be done to improve and sustain it. Prior studies include:

1. 1970s

The Montana Department of Natural Resources and Conservation (DNRC) has monitored total phosphorus, nitrate, and nitrite nitrogen concentrations entering Whitefish Lake since 1976. In 1977, the **U.S. EPA** published a report conducted on the trophic status of Whitefish Lake as part of their National Eutrophication Survey. Whitefish Lake was classified as oligotrophic but the EPA warned that any significant increased nutrient loading to Whitefish Lake could result in degradation of water quality, and they urged that “every effort be made to limit phosphorus inputs to the lake” (U.S. Environmental Protection Agency, 1977). Eutrophication in Whitefish Lake should be a slow process given the climate and geology of the area and natural circumstances. However, the lake’s eutrophication process is also linked to cultural (human) impacts. This cultural eutrophication is alarming when considering that the approximately 125 years of European settlement in the Whitefish area only represents roughly 1% of the lake’s approximate 11,000 year history.

2. 1980s

The **Flathead County Sanitarian** conducted dye testing in **1981** and confirmed that septic tank effluent was entering Whitefish Lake from a number of sites along the east lakeshore. In addition, the Sanitarian determined that septic systems were failing in a number of areas other than along the lakeshore (Whitefish County Water and Sewer District, 1984).

The **Flathead Lake Biological Station (FLBS**) began studying Whitefish Lake in **1982**. Their 1982-1983 baseline study indicated that the lake was in a transitional stage of *eutrophication* (Golnar & Stanford, 1984; Golnar, 1986). They reported that most metrics measured at that time (primary productivity, phytoplankton structure and density, total organic carbon, total nitrogen, and light extinction coefficients) were within the typical ranges of an *oligotrophic* waterbody. However, oxygen depletion in the *hypolimnion* (the dense bottom layer of water—below the *metalimnion* (the transition layer between surface and deep water)—in a thermally stratified lake) during late summer, combined with high total phosphorus concentrations $>5 \mu g L^{-1}$ in the *epilimnion* (the top-most layer in a stratified lake) were associated with *mesotrophic* lakes (lakes with intermediate productivity, generally clear with submerged plant life and a medium level of nutrients). The FLBS therefore classified Whitefish Lake as *oligomesotrophic*—meaning it is in a transitory phase toward increased eutrophication.

In September of **1984**, the **U.S. Environmental Protection Agency's Region 8 Water Division** requested laboratory analysis of color infrared aerial photographs of Whitefish, including the developed sections of the Whitefish Lake shoreline. The photos were stereoscopically examined for indications of malfunctioning septic systems. In October of 1984, several suspected failing septic systems were inspected. The ground observations provided an added level of detail that identified and isolated issues other than septic failure—such as Fairyring fungus, natural grass species patterns, and old filled-in drainage channels—so that actual septic system failures were correctly identified. Results of the study showed 85 possible failed septic systems of the 147 investigated, 55 with high confidence (U.S. Environmental Protection Agency, 1985).

The **Whitefish County Water and Sewer** District sponsored a study in **1985** which was funded by the U.S. EPA and conducted by the FLBS to investigate septic contaminated groundwater seepage as a nutrient source to Whitefish Lake (Jourdonnais *et al.*, 1986). That study found evidence of septic contaminated groundwater and surface water along shoreline locations around the lake. The resulting report was used to support a grant application to extend the sewer system along a portion of the east shore of Whitefish Lake—work which was completed in the late 1980s. The report was also instrumental in providing baseline data for later comparison in WLI's septic leachate study. It is interesting to note, however, that not all residences to which the city sewer system was made available are connected.

The **FLBS** returned to Whitefish Lake to take *pelagic* (open surface waters, also known as *limnetic*) limnological measurements in the lake and nutrient concentrations in several of the lake's tributaries in **1986, 1987, and 1993**. Although none of their data were published, some select data were later reported in their Whitefish Lake Water Quality Report (Craft *et al*, 2003).

3. 1990s

The **Flathead Basin Commission Volunteer Lake Monitoring Program** began collecting water clarity data (Secchi depth measurements), water temperature, and dissolved oxygen, and total phosphorus and chlorophyll (*a*) sporadically in summer months in 1993. This program is now part of the **Northwest Montana Lakes Volunteer Monitoring Network** which is discussed in this chapter, Section B Past Whitefish Lake Institute Studies, 4 Northwest Montana Lakes Volunteer Monitoring Network Annual Summary Reports, 2012-2014.

4. 2000s

The 2003 Whitefish Lake Water Quality study by the **FLBS** was the last extensive work conducted on Whitefish Lake before the formation of WLI. This study compared 2002 data to 1983 data, offering a snapshot look at lake changes over the 19 years. That study found that water clarity, hypolimnetic oxygen depletion, and epilimnetic nutrient concentrations had changed little over the timeframe compared—all good news for the lake. However, it also reported increases of 65% in primary productivity (from 69 to 106 g Cm^{-2} yr^{-1}), 61% phytoplankton biomass (from 0.20 to 0.33 cm^3 m^{-3}), and mean maximum chlorophyll *(a)* (from 1.0 to 1.8 mg L^{-1}) all indicating continued *eutrophication* taking place in the lake (Craft et al, 2003).

The report noted that conditions were similar during the two study periods. Runoff over the two years was very similar, with annual discharge at or near the long-term average for both years, and seasonal water flux was similar with the spring *freshet* moving into the lake in early June. However, homogeneity of runoff patterns is complicated in the snapshot approach as noted by the researches in their report.

"To understand how the response variables such as algal growth, water clarity and oxygen consumption are driven by temperature, wind, light, nutrient availability or food web interactions requires many measurements over a long period of time to allow variation in the data to be explained with statistical rigor. Variation caused by the interactions of the driving variables often clutters or masks cause and effect relationships. We only have two points in time where water quality was studied rigorously. Therefore, we have no measure of interannual variation and it may be that there is no significant change in the primary productivity of Whitefish Lake between 1982-1983 and 2001-2002; that is, the rates observed are within the natural variation of the ecosystem."

Given the lack of continuous data, the FLBS researchers were compelled to infer data from their more extensive work on Flathead Lake in order to draw certain conclusions in the Whitefish Lake study. Although it may be reasonable to assume that Flathead Lake dynamics approximate those of Whitefish Lake, they do not account for locally specific geological and hydrological attributes, watershed dynamics or natural and cultural pressures. Only through long-term consistent data collection on Whitefish Lake and in the Whitefish Lake Watershed can definitive conclusions be drawn for Whitefish Lake.

The FLBS study urged continued research on Whitefish Lake and its tributaries, as well as atmospheric deposition in order to increase our understanding of the relationship between natural ecological processes and cultural activities in the Watershed. It also warned of the approaching threshold of change that would be extremely costly, if not impossible to reverse.

B. PAST WHITEFISH LAKE INSTITUTE STUDIES

WLI's initial goals were to develop a baseline scientific understanding of water quality and related public health issues in Whitefish Lake and the Whitefish Lake Watershed. The first several years of WLI's research efforts reflect these goals. This report articulates the results of those efforts and provides a platform from which WLI, as well as other resource organization partners, will prioritize the next phases of research and management activities in the Watershed.

1. Water-Based Recreation Survey on Whitefish Lake, MT (Koopal, 2006)

In 2005, WLI conducted a survey in Whitefish of grades 4, 8 and 11 to determine the extent of childhood recreation on Whitefish Lake. The survey, which had a 90% response rate of all students enrolled in the survey grades, revealed that about 89% of respondents recreated at the lake, with 87% saying they swam for recreation. Of those respondents, 29% said they swam twenty days or more. Given the extent of this contact exposure—which takes place mostly at City Beach— and the results of the concurrent *Gasoline Constituent Loading* study discussed below, the WLI report suggested that the City of Whitefish consider public health safeguards at the City Beach Boat Launch.

2. Gasoline Constituent Loading and Motorized Watercraft Levels, Whitefish Lake, MT (Koopal, 2007)

In **2005** and **2006**, WLI considered the relationship between gasoline constituent loading in the form of benzene, toluene, ethylbenzene and xylene (BTEX) and motorized watercraft densities of Whitefish Lake. BTEX are volatile organic compounds (VOCs) known for their potential to cause numerous human and ecosystem health problems. Results of the study showed that BTEX levels generally increased as motorized watercraft usage increased. The exception to this finding occurred at the City Beach Boat Launch site where concentrations of BTEX were not linearly matched with numbers of motorized watercraft on the lake. The report suggested that a number of secondary inputs were occurring at the City Beach Boat Launch site including irresponsible fuel confinement by boat owners, the draining of boat hull effluent by pulling the transom plugs on the boat ramp, and excessive boat idling in the launch area.

Regardless of the exact source of BTEX contamination to the City Beach area, the report concluded that public health could be compromised as a result of BTEX exposure to recreationists through inhalation, ingestion, and absorption through the skin given the proximity of the City Beach Boat Launch to the City Beach Swimming Area.

WLI explained the results of this study and the recreation survey to Whitefish City Council, urging the consideration of a mitigation device at the boat ramp to protect recreationists. In 2013, the City of Whitefish investigated options and budgeted funds to install a grated trench across the City Beach boat ramp to collect bilge water from transom plug releases, and direct it to a oil/water separator with overflow conveyed to the *vadose* zone (the area that extends from the top of the ground surface to the water table).

Figure 26. City Beach Boat Ramp Trench. *Photo Courtesy WLI*

Clean water is then returned to the lake and contaminated water removed after containment. The installation took place in the spring of 2015 (Figure 27).

3. Whitefish Lake Water Quality Monitoring Program

In **2007**, WLI entered into a contract with DEQ to collect data on Whitefish Lake and its tributaries related to the development of a water quality model for the TMDL Program based on the Flathead Quality Assurance Project Plan (QAPP). That 2007-2009 contract was subject to a Sampling and Analysis Plan (SAP) which was implemented in 2007 and has been followed since that time for data consistency and accuracy. In 2008, the City of Whitefish became a financially contributing project partner for the long-term monitoring of Whitefish Lake, with the remaining project costs covered by WLI membership revenue and grants.

4. Northwest Montana Lakes Volunteer Monitoring Network Annual Summary Reports, 2012-2014 (Gubits)

The Northwest Montana Lakes Volunteer Monitoring Network (NWMTLVMN) grew out of two monitoring programs that were previously underway at WLI. The Flathead Basin Commission (FBC), in cooperation with the FLBS, coordinated the Volunteer Lakes Monitoring Program (VLMP) from 1992-2010. The VLMP trained, equipped and supported local volunteers who collected data and reported on over three dozen lakes in the Flathead Basin.

The EPA and FBC programs were the baseline models for the Whitefish to Eureka Volunteer Lake Monitoring Program (VLMP) which was initiated in 2007 by WLI in partnership with FWP. The Program was established to provide local residents an opportunity to collect baseline data that would help determine the trophic status of lakes and implement early Aquatic Invasive Species (AIS) detection and prevention in Northwest Montana.

In 2010, the Whitefish to Eureka VLMP combined with the FBC VLMP to form the NWMTLVMN. The NWMTLVMN currently has over forty volunteers that monitor a total of fifty locations on forty-one lakes in Flathead, Lake, Lincoln and Missoula counties. The lakes in the program represent diversity in public use, accessibility and morphology. The program relies on volunteer involvement for success and provides training and instruction in accordance with the SAP (WLI, 2011).

The program specifically aims to address the question of whether nutrients are on the rise due to anthropogenic activity around the lakes. To address this question, total phosphorus, total persulfate nitrogen, and chlorophyll (*a*) are collected at the same time each year to develop trend information based on *Carlson's TSI Index*. Among the most important parameters monitored by the volunteers are Secchi disc depth and temperature; however volunteers also serve as reporters for any major or sudden changes that may be observed in or around a lake, and provide early detection monitoring for AIS.

5. Investigation of Septic Leachate to the Shoreline Area of Whitefish Lake, MT (Curtis & Koopal, 2012)

WLI conducted this investigation sponsored by the Whitefish County Water District under the DNRC Renewable Resource Grant & Loan program to determine the spatial and temporal extent of septic leachate to the shoreline area of Whitefish Lake. The study also provides a scientific basis for identifying ecological threats to the lake, economic threats to the community of Whitefish, and potential public health risks resulting from decreased water quality. Synoptic sampling of 20 sites—including one midlake reference site—occurred on 9 sample dates starting in May 2011 and concluding in October 2011. The results of this investigation created actionable information for resource decision makers and Whitefish citizens concerning septic system usage around Whitefish Lake.

Septic “leachate” is the liquid that remains after wastewater drains though septic solids. The liquid contains elevated concentrations of bacteria and organic compounds from waste, detergents, and other household materials. When properly placed, functioning, and maintained, septic systems are designed to collect wastewater to neutralize these contaminants before they enter ground or surface water systems. Decomposition of waste begins in the septic tank and ends in a leachfield after undergoing a series of treatments whereby wastewater is chemically, physically, and biologically processed to remove contaminants. Modern septic systems are considered cost-effective for wastewater treatment, however issues such as improper initial system design, impermeability of soil, improper soil drainage class, improper vertical distance between the absorption field and the water table, improper slope, or improper maintenance may lead to system failure. Even when properly installed and maintained, septic systems have a finite life expectancy.

The study concluded with the development of the Septic Leachate Contamination & Risk Assessment Map (see Chapter XXI, Addendum B: GIS Maps) which identifies confirmed sites of septic leachate contamination as well as areas of low, medium, and high potential for future contamination. In total, WLI identified three confirmed areas of septic leachate contamination, including Site 3: City Beach Bay, Site 5: Viking Creek, and Site 13: Lazy Bay. Two areas of high potential for septic leachate contamination were identified, including Site 12: Lazy Channel and Site 18: Dog Bay State Park Seep. Four areas were identified as having medium potential for septic leachate contamination, including Site 2: City Beach Seep, Site 4: SE Monk’s Bay, Site 11: Brush Bay, and the East Lakeshore from Gaines Point south to north Monk’s Bay, including Site 8: Carver Bay and Site 7: SE Houston Pt. The remaining 10 shoreline sites—with no/low septic densities and/or acceptable test parameter values are considered to have a low potential for contamination by septic leachate.

This report confirmed contamination that was identified in several prior studies and suggested that action be considered. General and site specific recommendations, based largely on examples from other wastewater management programs, were provided to the City of Whitefish as possible actions that can be taken to support the common goal of protecting Whitefish Lake water quality. As a result of this study, the

City formed the ad hoc Whitefish Community Wastewater Committee (WCWC) and engaged WLI for technical advice. The WCWC made management recommendations to the City Council in their report, the *Whitefish Community Wastewater Management Plan* (WCWMP) (Whitefish Community Wastewater Committee, 2013). The WCWMP was officially accepted by a 2015 City Council resolution.

The City Council tabled further action at the end of 2013 awaiting new council members. In late 2014, the WCWMP resurfaced in discussion at City Council. WLI submitted a plan to support the Preliminary Engineering Reports (PER) process, including technical facilitation, planning grant development, RFP process work, and public education. PERs are conducted to analyze the wastewater infrastructure of a predefined area and develop alternatives and cost estimates for potential wastewater management improvements.

In 2015, WLI began supporting the process of conducting PERs in the neighborhoods identified in the WCWMP. The City budgeted significant support for two neighborhood PERs. WLI applied for—on behalf of the Whitefish County Water District—and was awarded two planning grants, and secured additional financial support to conduct one of the PERs. The Lion Mountain neighborhood will be the first project area to have a PER completed by spring of 2016.

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VII. WHITEFISH LAKE INSTITUTE WATER QUALITY MONITORING

A. METHODOLOGIES & PROGRAMS

This section discusses WLI's water sampling methodologies. Other methodologies specific to particular subject matter will appear within those sections.

1. Whitefish Lake, Inlet Tributaries, Whitefish River, Area Streams

WLI monitors two sites on Whitefish Lake including the deep lake site near the main stream inlet area of the lake (Site IP-1) and a site located near the outlet of Whitefish Lake (Site IP-2) in order to describe nutrient cycling. The ongoing monitoring of a mid-lake site by the FLBS compliments this work for a good longitudinal analysis of the lake. Monitoring results from the three sites together provide a good basis for understanding the dynamics of Whitefish Lake. WLI's Site IP-1 is approximately 210 feet (64 meters) deep, and Site IP-2 is approximately 56 feet (17 m) deep. The FLBS site is approximately 160' deep (See Monitoring Sites map in Chapter XXI Addendum B).

The following tributaries are included in the sampling program; Swift Creek (Olney Bridge), Swift Creek (Del Rey Bridge), Lazy Creek, Smith Creek, Hellroaring Creek, and Viking Creek. The Whitefish River—the outflow of Whitefish Lake—is also included in the sampling program. Beaver Creek was added to the sampling regime in 2013. In 2014, WLI added to its sampling regime Cow Creek, Haskill Creek, and Walker Creek. In-situ pressure transducers/temperature loggers were also installed in 2014 on all sampled waterbodies to record temperature and water level information.

At each site, water chemistry suites are collected according to DEQ (2006) as modified by WLI including these chemical analytes; Total Organic Carbon (TOC), Total Persulfate Nitrogen (TPN), Total Phosphorus (TP), Soluble Reactive Phosphorus (SRP), Total Suspended Solids (TSS), and Chlorophyll (*a*). Other chemical analytes have been either added or deleted from the sampling regime based on funding and/or needs.

At each site physical parameters are collected using a Hach DS5 multiprobe sonde including; depth, pH, dissolved oxygen, conductivity, resistivity, salinity, oxidation reduction potential (ORP), photosynthetically active radiation (PAR) – atmospheric and *in-situ*, and total dissolved solids (TDS). A portable Hach 2100P Turbidimeter is used to determine turbidity levels.

WLI conducts stream gauging on all its monitored streams and the Whitefish River. This involves measuring stream stage - the height of the water surface using a staff gauge; collecting periodic discharge measurements - the volume of water in cubic feet per second (cfs) and developing a stage-discharge relationship to maintain a continuous discharge record. In 2014, Hobo U20 Pressure Transducers were installed to continuously measure water level and temperature.

Water Quality Analytes		
ANALYTE	**WHAT IT IS**	**WATER QUALITY SIGNIFICANCE**
WATER CHEMISTRIES		
Total Organic Carbon (TOC)	Material resulting from decaying vegetation, bacterial growth, metabolic changes in living organisms, and chemical compounds or pollutants. The greater the organic content, the more oxygen is consumed.	High organic content increases the growth of microorganisms which contribute to the depletion of oxygen supplies leading to potentially unfavorable conditions for aquatic life.
Total Nitrogen (TN)	Nitrogen is a nutrient that is used by aquatic organisms for growth. Nitrogen occurs naturally in soil, is produced by decaying plant matter and microorganisms, and can enter lakes through the atmosphere. Common anthropogenic sources of nitrogen occur in wastewater, fertilizer manure, agricultural runoff, erosion, and vehicle emissions. WLI analyzes this nutrient as Total Persulfate Nitrogen (TPN).	Excessive nitrogen concentrations—or forms of Nitrogen such as ammonia— in a lake can lead to eutrophication and can be harmful or fatal to fish and invertebrates. It is often the limiting nutrient for primary productivity.
Total Phosphorus (TP)	Phosphorus is a nutrient used by organisms for growth. It occurs naturally depending on the geologic inputs to a lake. Anthropogenic sources of phosphorus include fertilizer, wastewater and detergents. Phosphorus has an affinity to adsorb to soil particles.	Phosphorus is essential to the growth of organisms and can be the nutrient that limits primary production. High levels of phosphorus may cause algae growth. When decomposed by bacteria and microbes, dead and decaying algae can cause oxygen depletion which in turn kills fish and other aquatic organisms in lakes and streams. Lakes that are anoxic at or near the bottom may experience internal loading, where phosphorus is released from benthic sediments through a chemical process.
Nitrite (NO_2) and Nitrate (NO_3)	Nitrogen is one of the most abundant elements and is found as a major component of proteins in the cells of all living things. Nitrogen-containing compounds act as nutrients in aquatic environments. Inorganic nitrogen may exist as nitrate (NO_3) and nitrite (NO_2) or as a gas or ammonia. Organic nitrogen is found in proteins and is recycled by aquatic plants and animals.	Bacteria in water can quickly convert nitrites to nitrates. Nitrate reactions in fresh water can cause oxygen depletion. Aquatic organisms dependent on a consistent oxygen supply can die from oxygen depletion. Oxidized forms of nitrogen are reduced in a dentrification process which allows for the production of N_20, a influential greenhouse gas.
Ammonia (NH3) Amonium (NH4)	About three-fourths of the ammonia produced in the United States is used in fertilizers either as the compound itself or as ammonium salts such as sulfate and nitrate.	NH3 is the principal form of toxic ammonia. Toxic levels are both pH and temperature dependent. Toxicity increases as pH decreases and as temperature decreases. Plants are more tolerant of ammonia than animals, and invertebrates are more tolerant than fish. Hatching and growth rates of fishes may be affected. NH4 –Amonium is the less toxic ionized from of ammonia which occurs when water is acidic and the most inorganic form used in primary productivity.

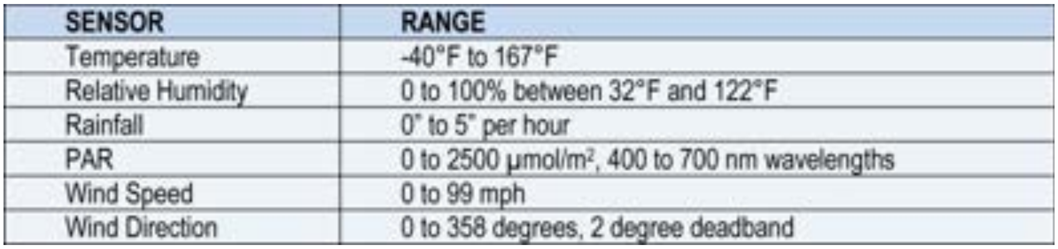
Water Quality Analytes		
ANALYTE	**WHAT IT IS**	**WATER QUALITY SIGNIFICANCE**
Soluble Reactive Phosphorus (SRP)	SRP consists largely of inorganic orthophosphate (PO_4) and is the amount of phosphorus immediately available for algae growth. In phosphorus limited situations, the concentrations are very low or undetectable. As concentrations increase, phosphorus is being supplied at rates faster than its uptake by primary producers.	Measurement of SRP is used as an indicator of the degree of phosphorus limitation of the algae and therefore the health of a waterbody. There is some scientific debate as to the extent SRP represents the orthophosphate form of phosphorus, but it is generally thought that the composition of SRP likely varies with the type of waterbody.
Dissolved Organic Carbon (DOC)	DOC describes dissolved material found in water from organic substances such as decomposed plant matter.	DOC is an indicator of natural and pollutant-caused organic loading in waterbodies.
Total Suspended Solids (TSS)	Suspended particle pollutants that cannot pass through a filter of a specific pore size.TSS measurements provide an actual weight in milligrams per liter (mg/L) of the particulate material present in a water sample.	TSS can lower water quality by absorbing light leading to warmer water temperatures. Increased silt from solids that settle out from the water column can smother aquatic organisms and their eggs.
Chlorophyll (*a*)	Chlorophyll (*a*) is a molecule that is present in all plant cells. The phytoplankton (algae) biomass can be quantified by analyzing the amount of chlorophyll (*a*) in a water sample. Although algae are very important producers in the food web, elevated nutrient concentrations can cause excessive algal growth resulting in a decline in water quality.	Lakes with high concentrations of chlorophyll (*a*) are less transparent, and tend to have higher total nitrogen and total phosphorus loading, and often less oxygen.
HYDROLAB PARAMETERS (Hach DS5 Multiprobe Sonde)		
Temperature	Temperature is important for maintaining aquatic ecosystems, particularly for maintaining available oxygen in water. Temperature is measured in °F or °C.	A rise in water temperature can cause a decrease in dissolved oxygen resulting in an environment that is suboptimal for certain fish species, resulting in fish stress or fish kills and a disruption in the ecosystem.
Depth	All Hydrolab parameters are recorded at depths selected by the user. WLI generally records at every meter from 1-14m, every 2 meters from 14-30m, every 3 meters from 30-45m, and every 5 meters from 45m to the bottom interface.	Recording depths are important for describing the stratification/mixing dynamics and for determining where to take water chemistry samples.

Water Quality Analytes		
ANALYTE	**WHAT IT IS**	**WATER QUALITY SIGNIFICANCE**
pH	pH is a measure of alkalinity of water, and is measured by the concentration of hydrogen ions. The greater the concentration of hydrogen ions, the lower the pH, and vice versa. The acidity of water is measured on a scale of 0 to 14 pH units with 0 being the most acidic and 14 being the most basic. A pH of 7 is typical of tap water, and considered neutral.	pH can affect the solubility of nutrients and metals in water, and the availability of chemicals for aquatic life. Different organisms flourish within different ranges of pH. Low pH can allow toxic compounds to become mobile and "available" for uptake by aquatic plants and animals, producing conditions that are toxic to aquatic life, particularly to sensitive fish species. Changes in acidity can be caused by atmospheric deposition, geological conditions, and certain wastewater discharges. The largest variety of aquatic animals prefers a range of 6.5-8.0.
Luminescent Dissolved Oxygen (LDO)	Measuring the concentration of dissolved oxygen is a general indicator of the diversity of organisms that a waterbody can support, and the overall health of a lake. Oxygen is dissolved into lakes through the atmosphere with wind generated waves and tributary inputs. Water temperature, photosynthesis, respiration, decomposition and lake depth are all determinate variables in the amount of dissolved oxygen that is available in waterbodies. LDO is measured in both mg/L and % saturation.	All organisms have an optimal range of DO, and some require very high levels to flourish. The more dissolved oxygen that is available in the water, the greater diversity of plants and animals can be expected in the water.
Specific Conductivity (SpC)	Conductivity is a measure of the ability to conduct and electric current, and is influenced primarily by the bedrock geology and mineral composition of the sediments through which the water flows. Conductivity values can differ seasonally with temperature, and are most often impacted by the composition of tributaries which reflect the geology of their watershed. Common anthropogenic influences on conductivity are road salt, non point source pollution such as agriculture run-off, wastewater, and industrial effluent. Specific conductivity is measured in mS/cm.	It is used as an indicator of the presence of chlorides, nitrates, sulfates and phosphate anions (negatively charged ions) as well as sodium, magnesium, calcium, iron and aluminum cations (positively charged ions). High conductivity levels may indicate a potential problem from wastewater or other urban pollutants.
Resistivity	Resistivity is the inverse measurement of specific conductivity and is a measurement of how strongly water opposes the flow of electric current. Resistivity is measured in kê-cm.	See Specific Conductivity.
Salinity	Salinity is a measurement of the concentration of salts that are dissolved in a waterbody. Salinity is steadily introduced to lakes from rivers and rainwater, where they concentrate with the evaporative loss of relatively pure water. Salinity is measured in ppt.	In addition to natural variations in salinity, anthropogenic influences such as wastewater and runoff can have a major impact on the salinity of waterbodies and the aquatic plants and animals that live in them.

Water Quality Analytes		
ANALYTE	**WHAT IT IS**	**WATER QUALITY SIGNIFICANCE**
Silica (SiO_2)	Silica is the second most abundant element in the lithosphere, and an essential nutrient for the development of diatoms which build their frustules of silica. Silica is measured in Parts per million (PPM or mL	Silica influences diatoms' equilibrium, size, accumulation of photosynthetic storage, rigidness, and shape. Silica can be a limiting element for diatom growth and survival. Silica depletion allows bluegreen algae to out-complete diatoms and may reflect eutrophication of freshwater lakes.
Oxidation Reduction Potential (ORP)	ORP is a composite measure of the overall balance between oxidizing and reducing processes. It is the seasonal and diurnal changes between photosynthesis and respiration that determines the oxidation-reduction potential of lakes. Oxidation reduction potential is measured in mV.	Oxygen reduction is directly or indirectly responsible for most oxidation of organic matter, nutrient cycling, and energy flow from the lower to higher trophic levels. Anaerobic conditions at the bottom sediment/water interface can produce reducing conditions that will lead to internal nutrient loading.
Photosynthetically Active Radiation (PAR) atmospheric	PAR is the spectral range of solar radiation (400-700 nanometers) that aquatic photosynthetic organisms utilize for the photosynthesis process. Measuring PAR is important because the rate of photosynthesis relates to the amount of light that penetrates a water column.	High levels of PAR can indicate photoinhibition (limiting photosynthesis), which affects submerged aquatic vegetation and certain aquatic species.
Photosynthetically Active Radiation (PAR) *in-situ*	See above. PAR fluctuates as a result of the natural light attenuation of water and the presence of particles, absorptive algal pigments, and dissolved organic material.	PAR is important in identifying the 1% compensation point where photosynthesis is balanced by respiration)
Total Dissolved Solids (TDS)	Total dissolved solids concentration is the sum of positively charged and negatively charged ions in the water, and is measured by the weight of all dissolved solids in the water. TDS can come from both organic and inorganic inputs and there is a close relationship between TDS and SpC. Total dissolved solids are measured in g/l.	TDS—a surrogate of salinity—is typically a function of runoff, geology of the watershed, and size of the waterbody or catchment.
Chlorophyll (*a*) (Fluorescence)	See above. Chlorophyll (*a*) analysis is measured by fluorescence and is reported in µg/L.	See *Chlorophyll (a)* under Water Chemistries and *PAR* under Hydrolab Parameters
TURBIDITY (Hach 2100P Turbidimeter)		
Turbidity	Measures the clarity of water and determines how much light (which is essential for plant growth) gets into the water and how deeply it penetrates.	Excess soil erosion, dissolved solids, excess growth of microorganisms can increase turbidity or increase opaqueness. Turbidity can affect fish reproduction and diminish the ability to feed by certain organisms, and excessive algal growth can result in a decline in water quality.
SECCHI		
Secchi	The Secchi disk was developed by Pietro Angelo Secchi in 1865 to measure water transparency or clarity. Water clarity is affected by natural seasonal variations, soil erosion, runoff and other suspended particles, and by algae.	Secchi readings are an effective tool for measuring turbidity and pollutants, and estimating productivity.

2. WLI Weather Station & Bulk Loading Monitoring

WLI installed a *HOBO Weather Station* and a Aerochem Metrics 301wet/dry bulk precipitation collector in 2007 near Lazy Creek at the north end of Whitefish Lake to study general weather conditions and to document wet and dry atmospheric precipitation. The station is located in an open field on private property to avoid deposition from plant matter. WLI's *HOBO*® *Weather Station* measures and logs temperature, relative humidity, rainfall, photosynthetic active radiation (PAR), wind speed, wind direction, and gust speed data (Figures 27, 28 & 29).



SENSOR	RANGE
Temperature	-40°F to 167°F
Relative Humidity	0 to 100% between 32°F and 122°F
Rainfall	0" to 5" per hour
PAR	0 to 2500 µmol/m², 400 to 700 nm wavelengths
Wind Speed	0 to 99 mph
Wind Direction	0 to 358 degrees, 2 degree deadband

Figure 27. WLI's HOBO® Weather Station Sensors.

a. Bulk Loading

Because surface water begins as either groundwater or atmospheric precipitation, it is important to monitor these systems to understand the variables that control surface water chemistries. Atmospheric deposition is typically sampled within the boundaries of the watershed being studied and in close proximity to the central waterbody being monitored.

Figure 28. WLI Weather Station/Bulk Loading.
Photo courtesy WLI

Figure 29. WLI Weather Station/Science & Education Director, Lori Curtis
Photo courtesy WLI

The *Aerochem Metrics Model 301 Automatic Sensing Wet/Dry Precipitation Collector* is designed to collect rain and snow in one container which is open only during precipitation events. A second container is uncovered between precipitation events to collect dry deposition material. WLI uses this automated system to measure atmospheric fallout data—both wet and dry (bulk) precipitation—to further identify and describe the influence of atmospheric bulk loading to water quality.

b. Statistical Interpretation Overview

The probability value (*p*-value) and the coefficient of determination (r^2) are often used in this report to interpret the significance of trend data in applicable figures. Data were incorporated into NCSS[9] Statistical Software that provided output results describing the relationship between the independent and dependent variables. A Null or Neutral Hypothesis (H_0) or an Alternate Hypothesis (H_a) was determined for the trend in the series based on;

If $p > 0.05$ then H_0 cannot be rejected (a trend is not detected)
If $p < 0.05$ then reject H_0 and accept H_a (a trend is detected)

The r^2 value provides a measure of how well observed outcomes are replicated by the linear regression, as the proportion of total variation of outcomes explained by the regression. An r^2 value near 0 represents a poor relationship of the data points to the regression whereas an r^2 value of 1 represents an exact relationship between the data points to the regression.

A "trend" defines a change between the start and end of a time series where a linear regression shows a statistically significant difference from the null hypothesis. The *p*-value and r^2 value are used as a weight of evidence to determine trend information. The weight is strong when the *p*-value is small and the r^2 value is high as described above. However, the *p*-value and r^2 value are affected by sample size and are more useful when comparing datasets of the same size. Ultimately, the strength of any trend analysis is dependent on the number of data points in the regression.

The widely used nonparametric *Mann-Kendall* two-tailed test was employed to analyze data contained in some of the figures in this report. Nonparametric statistical methods were used because water quality data are generally not normally distributed and because of data variability issues. Data variability issues include seasonal or other cycles, missing values in the period of record, and outlier data. Using the Mann-Kendall test, it is sometimes possible to determine the existence of an increasing or decreasing trend where data variability issues exist.

3. Flathead Lake Biological Station Equipment

Parameters in 1993 were collected using a Hydrolab Surveyor III. From 2000 to January 5, 2012, A Hydrolab 4a was used. A Hydrolab DS5 was used from January 5, 2012 through 2015.

VIII. WHITEFISH LAKE INSTITUTE EDUCATION & OUTREACH

WLI staff believes it is important to educate citizens of all ages about water quality and aquatic ecology. Our citizens are the water quality stewards of today and our students are the water quality stewards of the future. We provide programs for Pre-K through 12 students, college internships, educator in-service training, presentations to civic groups, and Road Scholar programs for seniors. Our Science & Education Director is also an adjunct instructor of Bioregional Theory & Practice and a graduate thesis advisor at Green Mountain College.

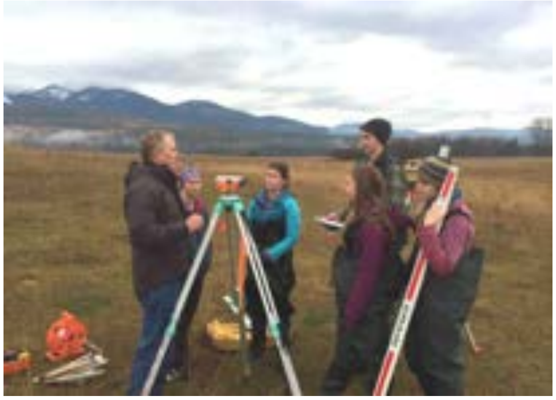


Figure 30. Mike Koopal with High School Students.
Photo Courtesy WLI

Figure 31. Lori Curtis with FREEFLOW Students.
Photo Courtesy WLI

A. PRE-K THROUGH 12

Annual presentations by WLI scientists cover aquatic insects, pond life, fish dissections, and hands-on aquatic invertebrate biological community identification using "keys." Whitefish and Kalispell high schools are introduced to general watershed dynamics, lake ecology, and the effects of introduced species on aquatic environments. WLI partners with Whitefish High School Project FREEFLOW for study field trips and research projects, and also hosts the high school job shadow program.

Figure 32. Mike Koopal Talking Wetland Wildlife with Fifth Graders.
Photo courtesy WLI

Figure 33. Josh Gubits Showing Students Aquatic Insects.
Photo courtesy WLI

B. LIVING WETLANDS INTERPRETIVE NATURE TRAIL

All students now have outdoor education options at the *Living Wetland Interpretive Nature Trail* in the Averill’s Viking Creek Wetland Preserve which WLI owns and manages. This 28.8 acre upland/wetland mosaic is managed for water quality, wildlife value, public awareness, and enjoyment. Bordered on the north and east by the 215-acre Battin Nature Conservancy Easement, the property provides a large contiguous habitat for wildlife in the urban/wildland interface. This project is an excellent example of how disparate entities can work together to protect the health of a watershed and provide open space, while allowing for economic growth in the community.

Figure 34. Main Trailhead.
Photo Courtesy WLI

Figure 35. Swale Bridge.
Photo Courtesy WLI

Figure 36. Lori Curtis & Students Field Journaling.
Photo Courtesy WLI

Figure 37. Jen Croskrey on Wetland Tour.
Photo Courtesy WLI

WLI helped preserve the water cleansing wetland through which runs Viking Creek—one of Whitefish Lake’s tributaries—and developed the trail to provide a quiet respite and educational opportunities for the public. Through our programs, classroom learning opportunities have been extended to the outdoors where students can experience some of the wildlife that make wetlands their home. WLI also developed the *Discovery Guide* full of engaging activities for middle school students introducing them to field journaling and natural discovery through activities in the wetland.

C. TEACHER IN-SERVICE TRAINING

Whitefish School District teachers have an option for in-service training with WLI, where they learn about Whitefish Lake ecology and are familiarized with water quality data collection techniques aboard WLI's research vessel, or learn about wetland attributes at the Averill’s Viking Creek Wetland Preserve.

D. SENIOR EDUCATION

WLI makes available lake ecology programs to seniors through Road Scholar lifelong learning. The programs bring about 700 mostly seniors to Whitefish and Glacier National Park. Road Scholar conducts more than 8,000 programs in all 50 states and over 90 countries.

E. INTERNSHIPS

Internships are available to college students upon instructor recommendation. Student interns have a chance to become field assistants in the scientific process; including data collection, database development, and data interpretation. They learn about stream and lake ecosystems, current watershed issues, and the operations of a small nonprofit corporation. WLI has hosted eight interns from universities in Montana, New York, Utah, Vermont, Washington and Wisconsin, since the program started in 2009.

Figure 38. Interns Kristi Whisler & Mary Kohnstamm.
Photo Courtesy WLI

Figure 39. Intern Lief Castren With Bridge Board Over the Whitefish River.
Photo Courtesy WLI

F. CHRIS RUFFATTO EXCELLENCE IN EDUCATION AWARD

WLI is proud to sponsor the Chris Ruffatto Excellence in Education Award—an avenue for recognizing and honoring educators (traditional and non-traditional) who dedicate their lives to engaging and inspiring the next generation of environmental stewards. WLI named this educational stewardship award in honor of Chris Ruffatto, its first recipient (Figure 40). Chris was recognized for his lifetime dedication to environmental education. Chris mentored thousands of students during his career as a high school educator, always seizing opportunities to involve young people in contemporary environmental issues and challenging their thinking by introducing them to innovative learning techniques. Chris’ extraordinary dedication to establish Project FREEFLOW and involving his students in the Montana Envirothon demonstrated his willingness to extend the classroom and engage the next generation of environmental stewards.

G. COMMUNITY STEWARDSHIP

The Community Stewardship Program provides opportunities for community members to participate in learning about and protecting our natural resources while supporting responsible growth for coming generations. Through the program, WLI recognizes citizens and organizations that make extraordinary stewardship efforts to protect the Whitefish area water resources. Recipients are awarded at WLI's annual fundraiser, the Whitefish Wine Auction for their contributions (Figure 41).

Figure 40. Chris Ruffatto Receives Award. *Photo Courtesy WLI*

Figure 41. Lex Blood Receives 2014 Lifetime Achievement Stewardship Award

The Citizens' Advisory Committee supports WLI's science and education goals and provides a forum for the exchange of information between citizens and WLI. The committee engages in community outreach, provides opportunities for learning about—and engaging in—Whitefish Lake Watershed issues, and comes together each year along with other supporters to plan and volunteer for WLI's fundraiser.

H. CIVIC GROUP PRESENTATIONS

WLI has presented to many local and regional civic groups ranging from the Rotary Club to private homeowners associations on topics ranging from regional issues related to lake ecology to the research underway at WLI. Staff also provides regular updates to city council, project partners and to community support organizations.

IX. BIOLOGICAL COMMUNITY OVERVIEW

A. PRIMARY PRODUCTIVITY

Most inland ecosystems have three fundamental and interconnected trophic levels, primary producers (algae and macrophytes), consumers (animals), and decomposers (small invertebrates, bacteria, and fungi). Biological activity in aquatic ecosystems involves primary and secondary production. Primary productivity describes the rate at which plants and other photosynthetic organisms produce energy-rich organic compounds (biomass) from energy-poor inorganic materials through photosynthesis. Secondary productivity is the transformation through consumption.

Understanding primary productivity in aquatic ecosystems requires the long-term assessment of biophysical processes, climatic differences, and seasonal variation patterns of radiant solar input. Regional nutrient loading and internal water body cycling rates also provide important information for understanding water body changes over time.

The only primary productivity research on Whitefish Lake to date was conducted in 1983 and 2002 by the FLBS (Golnar, 1986 and Craft, Stanford & Jackson, 2003). The 1983 research showed depth profiles of phytoplankton productivity rates from pelagic communities with peaks between 2.5 and 5 meters. Light penetration at these depths averages 26.4% of surface insolation. The lower limit of the euphotic zone (compensation point where photosynthesis is balanced by respiration) often reached to 30 meters in March and April. However, from December to February, photosynthesis was limited to the upper 20 meters of the water column. Researchers suggested this was likely because of reductions in available light due to a lower solar *azimuth* (angle) and mostly cloudy conditions. Some photosynthetic activity occurred below the level of 1% light penetration (the depth of the euphotic zone) which averaged 17.9 meters.

The following results are excerpts from the Craft, Stanford & Jackson (2003) report that was conducted for the Whitefish County Water and Sewer District which compared and quantified results from the two research dates.

Annual primary productivity increased from 69 g C $m^{-2}yr^{-1}$ *in 1983 to 106 mg C* $m^{-2}day^{-1}$*. Although productivity rates were similar from mid fall through mid spring, after the plume from spring runoff hit the lake in late May, productivity in 2002 was twice that in 1983. Mean primary productivity rates increased from 190 to 289 mg C* m^{-2} day^{-1}*.*

In both years, lower primary productivity during the winter gave rise to a peak of approximately 400 g C m^{-2} day^{-1} *in the first week of May, following the lowland runoff as indicated by the April peak in Lazy Creek discharge. Then productivity dropped slightly to about 250 mg C* m^{-2} day^{-1} *in late May just before the peak discharge from high snow melt hit the lake. In 1983, the drop in productivity continue into June before rebounding slightly in July and continuing in the 200-100 mg* $C^{-2}day^{-1}$ *range into August. In 2003, productivity rates not only recovered in early June but continued to climb through June to a second, even higher, peak of 603 mg* C^{-2} *day-1 on June 24th.*

For the remainder of the summer and through September, productivity rates were between 400 and 300 mg C m^{-2} day^{-1}*. These are twice the rates measured in 1983. Mean daily primary productivity rates of 250-300 mg C* $m^{-2}day^{-1}$ *is an acceptable threshold for transition from oligotrophic to mesotrophic condition (Wetzel, 1983). With a mean daily productivity of 289 mg C* m^{-2} day^{-1} *Whitefish Lake now is bordering the mesotrophic classification, which suggests declining water quality.*

A more detailed discussion of primary productivity can be found in Chapter XII. Whitefish Lake.

B. PERIPHYTON

Periphyton is a mixture of algae, cyanobacteria, detritus and heterotrophic microbes that are attached to submerged surfaces in aquatic ecosystems. Periphyton are an important water quality indicator because it has a naturally high number of species, responds quickly to changes, is fairly easy to sample, and is sensitive to changes in its environment. It is particularly sensitive to sedimentation and nutrients as it requires both of these for growth. It also serves as a food source for invertebrates and some fish. Determining periphyton community assemblages is therefore an important component of understanding natural and anthropogenic environmental disturbances to a waterbody.

Montana DEQ (2011) describes periphyton as algae that live attached to or in close proximity to the stream bottom. Periphyton algae may form colonies or filaments that are visible to the naked eye, or they may be one-celled, microscopic plants that are visible only in their accumulated growth. Two basic types of algae are found in Montana streams: diatoms (Division Chrysophyta, Class Bacillariophyceae) and soft-bodied algae. Soft-bodied algae are represented by four major divisions: green algae (Chlorophyta), blue-green algae or cyanobacteria (Cyanophyta), golden-brown algae (Chrysophyta), and red algae (Rhodophyta).

Algae are ubiquitous in Montana surface waters and represented by large numbers of species. As primary producers, algae are more sensitive to certain pollutants such as nutrients and herbicides than other aquatic organisms. Measures of the structure of algal associations, such as species diversity and dominance, can be sensitive and useful indicators of water quality impacts and ecological disturbance (Montana Department of Environmental Quality, 2011).

Periphyton sampling in the project area is limited to one stream survey conducted in 2003 (Bahls, 2004) and one Whitefish Lake survey conducted in 1983 where Golnar (1986) looked at periphyton biomass at littoral sites on Whitefish Lake. Summary results for the 2003 stream survey are found in Figure 42.

Although periphyton have long been used as water quality indicators for lotic (streams and rivers) ecosystems, no metrics have yet been developed for determining pollutant tolerances for periphyton in lentic (freshwater lakes and ponds) ecosystems and interpretation is based on professional experience.

Golnar (1986), concluded that there was an apparent relationship between higher periphyton growth and local shoreline development on Whitefish Lake. While the study found that the higher the shoreline development, the higher the periphyton biomass, the relationship was not conclusive. A number of natural phenomena such as sunlight exposure and higher natural groundwater nutrient levels may have been contributory factors. Further research was recommended to gain a better understanding of this relationship.

Metric	Upper West Fork	Lower West Fork	Upper East Fork	Lower East Fork	Upper Swift Creek	Middle Swift Creek	Lower Swift Creek
Number of Species	33	**20**	12	32	**22**	36	50
Shannon Species Diversity	3.22	**2.08**	0.52	**2.94**	**2.14**	**2.65**	3.99
Pollution Index	2.88	2.97	2.99	2.91	2.88	2.89	2.72
Siltation Index	6.20	1.07	0.25	3.23	0.50	6.58	14.29
Disturbance Index	**29.72**	16.17	4.57	**39.45**	64.01	60.22	**31.65**
Percent Dominant Species	**29.72**	60.28	92.72	**39.45**	64.01	60.22	**31.65**
Percent Abnormal Cells	0	0	0	0	0	0	0

***Bold** indicates minor stress, green indicate moderate stress, red indicate severe stress.*

Figure 42. Whitefish Lake Tributary Periphyton Sampling 2003.

Additional information detailing survey results for periphyton, where it exists, and how it relates to aquatic health can be found under each waterbody chapter of this report. In 2016, WLI plans to sample for periphyton in Whitefish Lake to add to our body of knowledge for this study parameter.

C. MACROINVERTEBRATES

Macroinvertebrates are animals without backbones such as insects, crayfish, snails, and clams. Aquatic invertebrates inhabit seeps, streams, marshes, ponds, lakes, and the hyporheic zone and play a critical role in sustaining healthy aquatic ecosystems, and are a major player in the aquatic food web. They provide food for fish as well as birds, amphibians and reptiles, and they eat bacteria and dead or dying plants. Some live entirely beneath water bodies, others on the surface of the water or on plants along the shoreline. And they move in myriad ways including floating, swimming, gliding, and walking.

Macroinvertebrates are excellent water quality indicators as they are sensitive to environmental changes such as the introduction of pollutants, changes in temperature, increases or decreases in sediment load, and changes in pH levels. For example, stoneflies and mayflies require high levels of dissolved oxygen, so an abundance of these invertebrates is an indication of good water quality. Conversely, aquatic worms and leeches survive in low levels of dissolved oxygen, so their abundance can suggest polluted waters. Macroinvertebrates typically cannot escape poor water quality, and they are generally easy to collect. Figure 43 displays the macroinvertebrate collection sites through the years.

October 21, 2003 Land & Water Consulting Survey Rhithron Analysis	August 27, 2014 DNRC Survey Rhithron Analysis	July 6-9, 2015 WLI Survey Rhithron Analysis
Upper East Fork Swift Creek	Upper East Fork Swift Creek	Middle Swift Creek Mainstem
Lower East Fork Swift Creek	Lower East Fork Swift Creek	Lower Swift Creek Mainstem
Upper West Fork Swift Creek	Upper West Fork Swift Creek	Lower Lazy Creek
Lower West Fork Swift Creek	Lower West Fork Swift Creek	Lower Smith Creek
Upper Swift Creek Mainstem	Middle Swift Creek Mainstem	Lower Hellroaring Creek
Middle Swift Creek Mainstem		Lower Beaver Creek
Lower Swift Creek Mainstem		Lower Viking Creek
		Lower Cow Creek
		Lower Haskill Creek
		Lower Walker Creek
		Whitefish Lake- City Beach
		Whitefish Lake- Monk's Bay
		Whitefish Lake- Brush Bay
		Whitefish Lake- Lazy Bay
		Whitefish Lake- The Island
		Whitefish Lake- State Park

Figure 43. Macroinvertebrate Surveys for the Study Area.

Stanford and Ward (1993) described a wide variety of previously unknown biota, including stoneflies and other large-bodied organisms that exist within alluvial aquifers of the expansive flood plains of the Flathead and other gravel-bed rivers. In groundwater monitoring wells as far as 2-3 kilometers from the main Flathead River channel, they found stoneflies, underscoring the importance of the hyporheic zone where water and materials interchange between the river channel and near-surface groundwater occurs. Organisms living in the groundwater utilize organic matter from the river and floodplain as a food source, thereby filtering, or cleansing the river water as it moves through the porous bedsediments.

Aquatic invertebrates are commonly used as a tool in *bioassessment* since they are known to be important indicators of stream ecosystem health. Bioassessment refers to the process of evaluating the biological condition of a body of water using biological surveys and other direct measurements of the resident biota (US Environmental Protection Agency, 2012). Long lives, complex life cycles and limited mobility mean that there is ample time for the benthic community to respond to cumulative effects of environmental perturbations (Bollman, 2004).

Aquatic invertebrate sample collection for the study area followed the Montana DEQ Standard Operating Procedures of Aquatic Macroinvertebrate Sampling (Bukantis, 1998 and DEQ, 2012b). Aquatic invertebrate survey data in this report found in Figure 44 are summarized by three reports from Bollman (2004, 2014, and 2015) that used a multimetric approach from integrated attributes of the invertebrate community to measure biotic health. The analysis considers probable sources of stress that may be related to biological impairment. However, Bollman (2014) states that linking these patterns and attributes to possible stressors is complex, since streams are potentially subject to multiple sources of disturbance. Sensitive taxa exhibit intolerance to a wide range of stressors that can include, but are not limited to; nutrient enrichment, acidification, thermal stress, sediment deposition, metals contamination, and habitat disruption.

Bollman (2004) utilized two bioassessment indices for stream locations including one developed for western Montana streams based on the Montana Valley and Foothill Prairies (MVFP) ecoregion. The six metrics used by that index are described below to introduce the reader to some of the parameters evaluated in a bioassessment. The second bioassessment index used metrics and criteria from the Montana DEQ method (Bukantis, 1998) which compares metric results to reference streams.

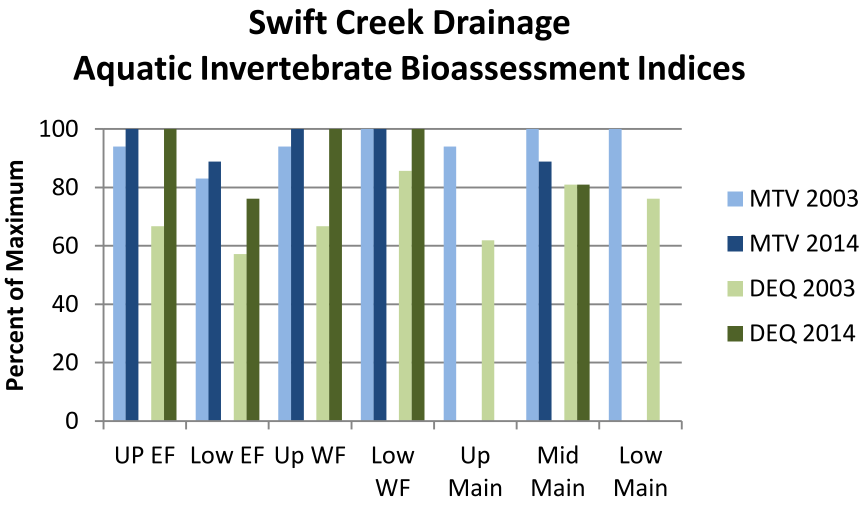


Figure 44. Aquatic Invertebrate Bioassesment Indices - Swift Creek Drainage.

MVFP scores for the 2015 survey sites ranged from 5.56% to 100.00% of maximum possible score. Using the MVFP scoring criteria, four sites were classified as non-impaired. These were Hellroaring, Smith, Swift Delrey and Swift Olney. Two sites, Haskill and Lazy, were slightly impaired. Three sites were classified as moderately impaired: Viking, Walker and Whitefish River. Beaver and Cow were classified as severely impaired.

Additional narrative information detailing survey results for macroinvertebrates, where it exists, and how it relates to aquatic health can be found under each waterbody chapter of this report. There are no developed bioassessment scores for aquatic insects in lakes. As a result, the Whitefish Lake shoreline aquatic invertebrate analysis is presented as narrative based on professional experience, literature, independent research, and other expert sources.

1. Ephemeroptera (mayfly) taxa richness

The number of mayfly taxa declines as water quality diminishes. Impairments to water quality which have been demonstrated to adversely affect the ability of mayflies to flourish include elevated water temperatures, heavy metal contamination, increased turbidity, low or high pH, elevated specific conductance and toxic chemicals. Few mayfly species are able to tolerate certain disturbances to instream habitat, such as excessive sediment deposition.

2. Plecoptera (stonefly) taxa richness

Stoneflies are particularly susceptible to impairments that affect a stream on a reach-level scale, such as a loss of riparian canopy, streambank instability, channelization, and alteration of morphological features such as pool frequency and function, riffle development and sinuosity. Just as all benthic organisms, they are also susceptible to smaller scale habitat loss, such as by sediment deposition, loss of interstitial spaces between substrate particles, or unstable substrate.

3. Trichoptera (caddisfly) taxa richness

Caddisfly taxa richness has been shown to decline when sediment deposition affects habitat. In addition, the presence of certain case-building caddisflies can indicate good retention of woody debris and lack of scouring flow conditions.

4. Number of sensitive taxa

Sensitive taxa are generally the first to disappear as anthropogenic disturbance increases. The list of sensitive taxa used here includes organisms sensitive to a wide range of disturbances, including warmer water temperatures, organic or nutrient pollution, toxic pollution, sediment deposition, substrate instability and others. Unimpaired streams of western Montana typically support at least four sensitive taxa (Bollman, 1998).

5. Percent filter feeders

Filter-feeding organisms are a diverse group; they capture small particles of organic matter, or organically enriched sediment material, from the water column by means of a variety of adaptations, such as silken nets or hairy appendages. In forested montane streams, filterers are expected to occur in insignificant numbers. Their abundance increases when canopy cover is lost and when water temperatures increase and the accompanying growth of filamentous algae occurs. Some filtering organisms, specifically the *Arctopsychid* caddisflies (*Arctopsyche* spp. and *Parapsyche* spp.) build silken nets with large mesh sizes that capture small organisms such as chironomids and early-instar mayflies. Here they are considered predators, and, in this study, their abundance does not contribute to the percent filter feeders metric.

6. Percent tolerant taxa

Tolerant taxa are ubiquitous in stream sites, but when disturbance increases, their abundance increases proportionately. The list of taxa used here includes organisms tolerant of a wide range of disturbances, including warmer water temperatures, organic or nutrient pollution, toxic pollution, sediment deposition, substrate instability and others.

Bollman (2014) also used bioassessment scores for the Montana Department of Environmental Quality (2012) predictive model (Observed/Expected Index). Although the Observed/Expected Index scores indicate impaired conditions in the 2014 survey for all sites, Bollman (2014) found that all streams in the Swift Creek watershed were index outliers and outside the experience of the Observed/Expected model expectations.

Figure 44 shows the bioassessment scores from 2003 and 2014 using the Montana Valley and Foothill Prairies (MTV) ecoregion (Bollman, 1998) and the DEQ method (Bukantis, 1998). The trend for all sites with the exception of mid-Swift Creek are no change or improved scores for each bioassessment method for the study period.

D. FISHERIES

Fisheries information found in this report represents a compilation of existing data from a variety of resources as summarized by Koopal (2004) and updated herein. Quantitative data that are useful for providing comparisons and trend analysis on some Whitefish area waterbodies date back to the late 1970s. In order to meet the habitat recommendations for bull trout and westslope cutthroat trout from the Flathead Basin Forest Practices, Water Quality and Fisheries Cooperative Program (Flathead Basin Commission, 1991), the DNRC contracted with FWP to develop index values of existing habitat quality. Additional fisheries information can be found under each waterbody chapter of this report.

1. Methodology Overview

A general description of the methodologies used by FWP beginning in 1978, in addition to other primary methods employed by management agencies to study the physical and biological parameters of the fisheries resource in the geographic area covered in this report are listed below. Substrate Scores, McNeil Cores, redd counts and some population investigations have been consistently collected since the late 1970's to early 1980's on index streams, and provide valuable trend data. Studies like the R1/R4 fisheries habitat survey and fish passage study are from a single inventory. Other studies specific to a stream or a stream reach are identified under each specific stream heading in the report.

a. Biological

1. Species presence/relative abundance

This technique provides cursory information of the fish species found in a stream or stream reach and the relative abundance of each species and age classes found in that reach. This is referred to as Catch Per Unit Effort (CPUE). This is usually accomplished by a single pass electrofishing effort for any determined length of stream. Snorkeling can also be employed and is represented in some data from the USFS. For lakes, the usual technique is to employ floating and/or sinking gill nets.

2. Population estimates: depletion or mark and recapture

Population estimates provide a quantitative identification of population levels, and are often broken down into age classes within the population. This is subject to a certain confidence limit based on capture rates. These techniques are accomplished through multiple electrofishing passes through a given reach to yield a depletion estimate, or by marking and recapturing individuals of a given reach. Fisheries information in this report is displayed mainly as presence/absence due to lack of long-term population estimate comparisons.

3. Redd counts

Redd counts are a form of estimating adult spawner escapement to a stream or stream reach and provide a relative index for recruitment. Surveys are conducted by walking a stream or stream reach and recording the number of redds (nests found in the substrate). This information is collected annually by FWP for bull trout on index streams.

b. Physical

1. Substrate Scores

A Substrate Score is an ocular assessment of streambed particle size and the relative degree of embeddedness. Embeddedness refers to the degree of armoring, or the tight consolidation of substrate. A higher Substrate Score indicates more favorable fisheries habitat conditions. Low Substrate Scores indicate smaller streambed particles and greater embeddedness, which constitutes poorer quality fish habitat. According to the Flathead Basin Commission Water Quality and Fisheries Cooperative Program report (1991), a stream is considered threatened if the Substrate Score is less than 10 and is considered impaired if the score is less than 9.

2. McNeil cores

McNeil coring is a method used to determine the size range of material in streambed spawning sites. Results are given as a percentage of material less than 6.35mm and indicate the quality of spawning and incubation habitat.

The smaller the percentage of fine material, the better the habitat condition. According to the Flathead Basin Commission Water Quality and Fisheries Cooperative Program report (1991), a stream is considered threatened if the McNeil core is over 35%. Red-flag or "impaired" values are those McNeil cores over 40%.

3. R1/R4 habitat surveys

A modified USFS R1/R4 survey technique measures the instream fisheries habitat. Habitat units are broken down by types; slow (pools) and fast (riffles/runs) and each contain a variety of sub-classes. Lengths, widths and depths are recorded for each habitat unit. Other physical parameters such as large woody debris, undercut banks, unstable banks, and pocket pools are also quantified. Data summarized in this report represents a general summary analysis of those results.

4. Fish passage investigation

Road/stream crossing locations were surveyed to determine the physical characteristics of a culvert(s) and the relation to stream dynamics. Stream channel dimensions were recorded immediately above and below the culvert in addition to a control site located upstream. Results were entered in the FishXing computer database for analysis to determine passage potential for fish species and age classes.

2. Fish Species Overview

The fish of the Whitefish area waterbodies represent a diverse species assemblage of native and introduced species as represented in Figure 45. Further information on the fisheries for each waterbody can be found in the tributary and lake chapters of this report.

a. Sensitive Species

For the purposes of this report, bull trout (*Salvelinus confluentus*) and westslope cutthroat trout (*Oncorhynchus clarki lewisi*) are considered important indicator species whose life requirements have been considered under the *Water Quality Criteria & Standards Section* of this report. Bull trout and westslope cutthroat trout have persisted in the Whitefish Lake Watershed for approximately 10,000 to 12,000 years through droughts, flooding, fires, and human development. They are considered indicator species for environmental disturbance because of their specific spawning and rearing requirement for clean, sediment-free rivers and streams, and for their sensitivity throughout their life histories (Muhlfeld, 2010).

Species	Binomial Name	Approximate Date of Introduction	Status	Habitat
Family Salmonidae				
Bull trout	*Salvelinus confluentus*		Threatened[1] Species of Concern[2]	A,H
Westslope cutthroat trout	*Oncorhynchus clarki lewisi*		Species of Concern[2]	A,E
Arctic Grayling	*Thymallus arcticus*	1928	Extirpated	A,E
Brook Trout	*Salvelinus fontinalis*	1913	Rare	A,EL
Rainbow trout	*Oncorhynchus mykiss*	1914	Rare	L,E
Lake Trout	*Salvelinus namaycush*	1905	Abundant	A,H
Kokanee	*Oncorhynchus nerka*	1916	Extirpated	A,E
Coho Salmon	*Oncorhynchus kisutch*	1941	Extirpated	A,H
Mountain Whitefish	*Prosopium williamsoni*		Common	A,H
Lake Whitefish	*Coregonus clupeaformis*	1890	Abundant	L,H
Pygmy Whitefish	*Prosopium coulteri*		Species of Concern[2]	A,H
Family Cyprinidae				
Fathead Minnow	*Pimephales promelas*		Common	L,EL
Redside Shiner	*Richardsonius balteatus*		Common	L,EL
Northern Pikeminnow	*Ptycholcheilus oregonesis*		Common	L,E
Peamouth	*Mylocheilus caurinus*		Common	L,EL
Longnose Dace	*Rhinichthys cataractae*		Abundant	L,EL
Family Catostomidae				
Longnose Sucker	*Catostomus catostomus*		Abundant	L,?
Largescale Sucker	*Catostomus macrocheilus*		Common	L,EL
Family Esocidae				
Northern Pike	*Esox lucius*	1960s	Rare	L,EL
Family Cottidae				
Rocky Mountain (Mottled) Sculpin	*Cottus bondi*		Common	L,EL
Slimy sculpin	*Cottus cognatus*		Common	L,EL
Shorthead sculpin	*Cottus confusus*		Common	*
Family Centrarchidae				
Pumpkinseed	*Lepomis gibbosus*	1910	Rare	L,EL
Largemouth Bass	*Micropterus salmoides*	1898	Rare	L,EL
Family Percidae				
Yellow Perch	*Perca flavescent*	1910	Common	L,EL

1. Federal listing. 2. Montana listing. Species highlighted in **bold** *are native to area. A=adfluvial; L=lacustrine; E=epilimnetic; H=hypolimnetic; EL=epilimnetic, but mostly littoral (larvae may occur in pelagic zone). Three sculpins have been collected and formally identified in the Flathead Basin upstream of Flathead Lake. Two of them could be in Whitefish Lake, but no formal survey has been completed. *Shorthead sculpin only known to reside in streams and rivers. (From Hanzel, 1969 & Alvord, 1991 as reproduced in Delerey, 1999; and Ellis, 2006, as modified by Koopal, 2015).*

Figure 45. Fish Species Found in Whitefish Area Waterbodies.

Bull trout are federally listed as “threatened” under the Endangered Species Act and westslope cutthroat trout are considered a “Class A Species of Special

Concern” through a joint listing developed by FWP and the Montana Chapter of the American Fisheries Society. Class A species are those that are limited in numbers and/or limited in habitat both in Montana and elsewhere in North America; elimination from Montana would be a significant loss to the gene pool of the species.

The bull trout and westslope cutthroat trout populations of this geographic area support three possible life history patterns that can occupy vast geographic areas. As a result, these two native species require a variety of habitats and are subject to a myriad of anthropogenic affects from land use activities.

Resident- resides and reproduces in natal stream.
Fluvial- out-migrates from natal stream as a juvenile to a larger stream or river to sexually mature and returns to natal stream to spawn.
Adfluvial- out-migrates from natal stream as a juvenile to a lake environment to sexually mature and returns to natal stream to spawn.

Species	Spawning	Egg Incubation	Fry Emergence	Rearing Time (age of fish at outmigration)	Migrational Spawning Movement
Bull trout	Sept.- early October	Sept.-Jan.	April-May	1+ juveniles	July-August
Westslope cutthroat trout	Late April-May	May-June	June-July	Young-of-year and 1+juveniles	March-April

Figure 46. Timing/Life History Characteristics Bull Trout & Westslope Cutthroat Trout.

The Montana Bull Trout Scientific Group (1995) identified important areas to the continued existence of bull trout and classified these into core areas and nodal habitats. Core areas are drainages that historically and currently contain the strongest populations of bull trout and are important for spawning, rearing and adult habitat needs. These habitats are key to the continued existence of bull trout in the Flathead Basin. Swift Creek, West Fork of Swift Creek, and East Fork Swift Creek are considered “Disjunct Core Areas” that are functionally cut off from the greater Flathead Basin bull trout meta-population. Nodal habitats contain vital over-wintering areas, migratory corridors and other habitat critical to the population at some point during the fishes’ life history.

The importance of protecting bull trout core and nodal populations is further validated by genetic research. Kanda and Allendorf (2001) indicated that the large population differentiation within drainages that they detected suggests that little gene flow has occurred among bull trout populations even over short geographic distances and that geographically close populations have been highly isolated reproductively.

Parallel to this, some of the genetic differentiation among populations may have evolved through adaptation to local environments (Fox 1993; Phillipp and

Clauson 1995; in Kanda and Allendorf, 2001). In addition, available data indicate that at times, year classes of bull trout may be produced from a small number of spawners (Kanda, 1998).

Genetic research has also indicated that there is a degree of introgressive hybridization between bull trout and brook trout. Kanda (1998) found that F1 (first generation) fish were not necessarily sterile, as previous research has suggested, but capable of backcrossing with either bull trout or brook trout parental stock. However, the reproductive success of these F2 fish appears to be minimal indicating these two species do not form hybrid swarms.

The goal of bull trout restoration efforts for the migratory population in the Flathead River drainage, according to the Montana Bull Trout Scientific Group (1995) is to maintain or restore self-sustaining populations in the core areas, protect the integrity of the population genetic structure, and enhance the migratory component of the population. Specifically, the goal is to increase bull trout spawners to attain the average redd count level of the 1980's, and to maintain this level for 15 years (3 generations) in the North Fork and Middle Fork Flathead River monitoring areas, provide long term stable or increasing trend in overall populations; and provide for spawning in all core areas.

Liknes (1984) reported that westslope cutthroat trout are known to be present in 27.4% of their historic range in Montana. Liknes and Graham (1988) indicate that the upper Flathead River basin represents the largest stronghold with westslope cutthroat present in 85% of their historic range. Similar to bull trout, Leary *et al.* (1984) indicate that little genetic variation is present within a population but a large amount of variation occurs between populations. However, westslope cutthroat trout hybridize with rainbow trout indefinitely beyond F1 and F2 generations leading to a dilution of pure westslope cutthroat trout genes. Hitt *et al.* (2003) found rainbow trout (*Onchorhynchus mykiss*) introgression spreading rapidly in the Flathead Basin.

1. Life History Habitat Requirements

This discussion is tailored to the habitat requirements of bull trout. Whereas bull trout and westslope cutthroat trout both need rather "pristine" conditions to thrive, bull trout life requirements are more specific, yet generally encompass the physical habitat needs of both species. According to the Montana Bull Trout Restoration Team (2000), bull trout have very strict habitat requirements that are generally referred to as the four C's- clear, cold, complex, and connected. This includes clean, cold water; high levels of shade, undercut banks, and woody debris in streams; and connectivity among and between drainages.

The Montana Bull Trout Scientific Group (1998) stated that the majority of migratory bull trout spawning in Montana occurs in a small percentage of the total stream habitat available. Spawning adults use low gradient areas (<2%)

of gravel/cobble substrate. Proximity to cover for the adult fish (such as pool habitat with overhead protection) before and during spawning is an important habitat component. Adult migratory bull trout enter tributaries when water temperatures drop below 54°F (12.2°C), and spawned from late August through early October after temperatures drop below 48°F (8.9°C) (Fraley and Shepard, 1989). Bull trout also seem to prefer spawning areas of gaining water or ground water up-welling reaches. Actual redd construction often occurs in pool tail-out crests or low gradient riffles.

After redd construction and during egg incubation, the Montana Bull Trout Scientific Group (1998) state that a substantial inverse relationship exists between the percentage of fine sediment in the incubation environment and bull trout survival to emergence. Redds become less suitable for incubating embryos if fine sediments and organic materials are deposited in interstitial spaces of the gravel during the incubation period (Deleray *et al.*,1999). Fine particles impede movement of water through gravel, thereby reducing delivery of dissolved oxygen to, and flushing of metabolic wastes away from incubating embryos. Weaver and Fraley (1991) reported a significant negative correlation between brook trout embryo survival and later fry emergence and sediment fine content (<2.0mm) in tributaries of the Flathead River. The best survival for bull trout embryos is a temperature of approximately 39.2° F (4°C) (Kanda, 1998).

Life history requirements of juvenile bull trout are also very specific. Fraley and Shepard (1989) indicate that juvenile bull trout are very rare in streams with maximum summer water temperature exceeding 59°F (15°C). Juvenile fish utilize pocket pool habitat and the interstitial spaces within the substrate for rearing cover often in close association with large woody debris. Sediment accumulations reduce pool depth and fill in interstitial spaces of the substrate used for cover by juveniles. Woody debris is an essential component not only in forming pools and overhead cover for fish, it also diversifies channel dimensions. The factors that directly affect introduction, stability, or character of stream large woody debris also have a potentially significant influence on native fish populations that utilize streams for spawning, rearing and growth.

Those juvenile bull trout that adopt a fluvial or adfluvial life history pattern generally reside in the stream for one to three years before out-migrating to larger bodies of water to grow to sexual maturity. As a result, the geographic scope utilized by the life history patterns of bull trout can subject this species to diverse anthropogenic influences that often cross jurisdictional and political boundaries.

2. Anthropogenic Influences to Salmonids

Some issues raised by the Montana Bull Trout Restoration Team (1998) in analyzing the relationship between land management activities and habitat requirements of bull trout in the Flathead Basin include; residential and industrial development, mining, livestock grazing, agriculture, irrigation diversions, dams, secondary roads, recreation, transportation systems, fire management and the introduction of non-native species, including Mysis shrimp (*Mysis diluviana*) in local lakes.

Ellis *et al.* (2011) examined the trophic cascade of Flathead Lake from the introduction of species over the last century. Lake trout had remained at low densities for over 80 years but once established, *Mysis* provided a deep water source of food for juvenile lake trout when little had existed previously. Lake trout are piscivores as adults and impacted kokanee (now extirpated) and bull and westslope cutthroat trout are now imperiled.

Weaver (1997) states that a significant decline in redd numbers in the Flathead Basin occurred during the early 1990s due to alteration of the trophic dynamics in Flathead Lake. However, the alteration of the trophic dynamics in Flathead Lake is likely not the only variable in the decline of bull trout populations. Habitat degradation and competition of non-native sympatric trout and char species, along with the introduction of other species, impact competition, hybridization, and predation, limit recovery today.

According to the Montana Bull Trout Scientific Group (1995) past forestry practices (road construction, log skidding, riparian tree harvest, clearcutting, splash dams) were often damaging to watershed conditions and are a major contributing cause of the decline of bull trout. The effects on habitat of these practices include increased sediment in streams, increased peak flows, hydrograph and thermal modifications, loss of instream woody debris and channel stability, and increased access to anglers and poachers. According to Rieman and Clayton (1997) disturbance by fire, harvest activities, and road construction invariably results in greater erosion and sediment production; however, the severity and longevity of increase is highly dependent on site properties and the kind of disturbance.

Road construction causes the most severe disturbance to soils on slopes, far overshadowing fire and logging as a cause of accelerated erosion (Swanson and Dyrness 1975; Beschta 1978; Reid and Dunne 1984 in Rieman and Clayton, 1997). Eaglin and Hubert (1993) found that trout standing stocks had a negative relation with the density of culverts, and that erosion of soil from road surfaces, ditches, and disturbed areas adjacent to roads that subsequently is deposited in stream channels seems to be an important mechanism by which logging has affected stream habitat.

According to Ellis *et al.* (1999), an analysis of the Flathead National Forest water quality monitoring sites in 1997 indicated that as the road miles per acre increased in catchments, total phosphorus and particulate carbon concentrations in monitored streams increased proportionately. The data also indicated that as the percent harvest increased, nitrate plus nitrite nitrogen concentration in these streams increased proportionately.

Other human activities such as residential development have the potential to degrade riparian zones. A healthy riparian area provides stream shade needed to keep stream temperatures cool. If riparian vegetation is destroyed, the effects include increased summer and decreased winter water temperatures resulting from removal of shading and insulating vegetation; reduced large woody debris recruitment caused by removal of source vegetation; reduced pool quality, habitat complexity, channel stability, and bank stability arising from removal of vegetation and bank erosion; and reduced substrate quality by sediment delivery (Montana Bull Trout Scientific Group, 1998).

If large woody debris recruitment is lost in the riparian zone and surrounding upland area, (Hauer, Gangemi and Baxter, 1997) state from their study of large woody debris in the Flathead Basin that the implications for forest managers are twofold: 1) that with harvest comes increased unpredictability in the frequency of size, attachment, and stability of the [instream] large woody debris and 2) riparian zones without harvest may be essential to long term maintenance of natural stream morphology and habitat features.

Anthropogenic influences can also affect migration routes disrupting stream connectivity. Dams, culverts, thermal regimes, dewatering and modified habitat can eliminate or inhibit migrations and straying behavior resulting in small, isolated populations. See Chapter XVI Current & Future Concerns, Section C Biological for information regarding Aquatic Invasive Species concerns related to fisheries.

X. WHITEFISH LAKE TRIBUTARIES

A. INTRODUCTION

In 2015, the EPA issued a letter of approval for DEQ-developed numeric water quality criteria intended to control excessive nutrient (nitrogen and phosphorus) pollution in Montana's streams, rivers, and lakes. Chemical concentrations are displayed against the numeric standard for Whitefish Lake Tributaries (this chapter) and the Whitefish River Drainage (Chapter XI) in Chapter XXII Addendum C Water Chemistry & Temperature Information. During the nutrient standards application period, a minimum dataset of approximately 12-13 samples will be required with a nominal exceedence rate of approximately 20% of all samples evaluated statistically, or as determined by DEQ, before a stream would be considered for 303(d) listing.

In chapters X Whitefish Lake Tributaries and X Upper Whitefish River Drainage, tributaries are generally organized in an upstream to downstream direction. For a small geographic area, there is a high degree of stream diversity based on structural geology, geomorphic attributes, elevation and timing of snowmelt, and land use pressures.

Temperature data for 2014—discussed in the following chapters and found in Chapter XXII Addendum C Water Chemistry & Temperature Information—were recorded by WLI with in-situ pressure transducer/ temperature loggers. Temperature data collected by WLI from 2007-2013 summarized in this chapter were collected using a Hydrolab DS5. An analysis of tributary nutrient loading can be found in the mass balance discussion in the Whitefish Lake Chapter(XII). The mass balance discussion for the Upper Whitefish River can be found in Chapter XI.

Maps showing Stream Channel Type, Fish Passage, and Fish Distribution can be found in Chapter XXI Addendum B Graphical Information System (GIS) Maps.

Three Landsat images provided in this report in Chapter XXI Addendum B Graphical Information System (GIS) Maps represent 1987, 1994, 2004, and 2011 and include:

Upper Project Area: covers the headwaters of the East and West Fork of Swift Creek to just below the confluence with Chicken Creek.

Middle Project Area: covers Chicken Creek to the north end of Whitefish Lake.

Lower Project Area: covers Whitefish Lake, the Surrounding Area and the Upper Whitefish River drainage.

Stream habitats are discussed using the Rosgen Classification system. Developed by David Rosgen in 1994, this system is the most widely applied river classification system in the U.S. (Rosgen, 1994). It identifies streams through four increasingly detailed levels.

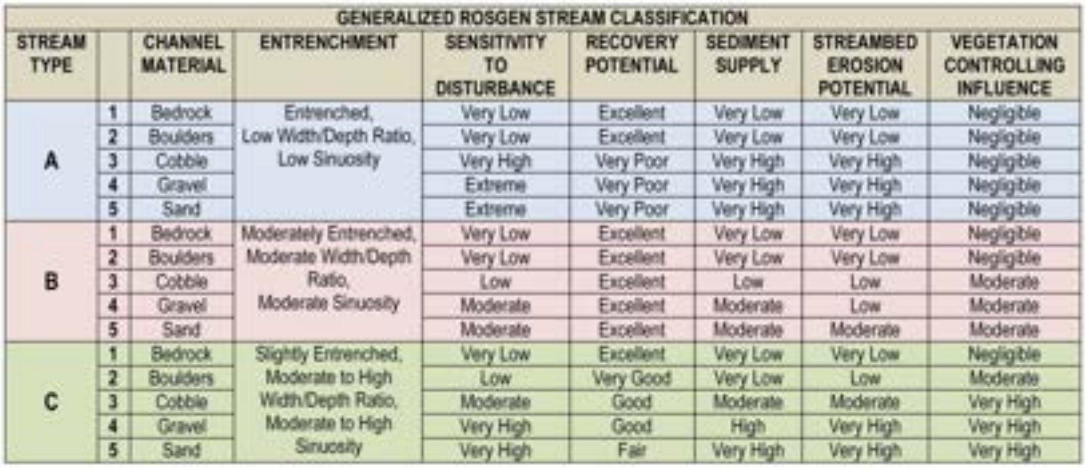
Geomorphic Characterization
Input landforms, lithology, soils, climate, depositional history, basin relief, valley morphology, river profile morphology, and general river pattern data

Morphological Description
Input channel patterns, entrenchment ratio, width to depth ratio, sinuosity, slope, channel material

Stream State/Condition
Riparian vegetation, depositional patterns, meander patterns, confinement features, habitat indices, flow regime, river size category, debris presence/size, channel stability, bank erodability

Verification
Direct measurement of sedimentation transport, erosion rates, aggradation, degradation processes, hydraulic geometry, biological data

Figure 47 displays an abbreviated version of the Rosgen Classification System and its management implications.



GENERALIZED ROSGEN STREAM CLASSIFICATION

STREAM TYPE		CHANNEL MATERIAL	ENTRENCHMENT	SENSITIVITY TO DISTURBANCE	RECOVERY POTENTIAL	SEDIMENT SUPPLY	STREAMBED EROSION POTENTIAL	VEGETATION CONTROLLING INFLUENCE
A	1	Bedrock	Entrenched, Low Width/Depth Ratio, Low Sinuosity	Very Low	Excellent	Very Low	Very Low	Negligible
	2	Boulders		Very Low	Excellent	Very Low	Very Low	Negligible
	3	Cobble		Very High	Very Poor	Very High	Very High	Negligible
	4	Gravel		Extreme	Very Poor	Very High	Very High	Negligible
	5	Sand		Extreme	Very Poor	Very High	Very High	Negligible
B	1	Bedrock	Moderately Entrenched, Moderate Width/Depth Ratio, Moderate Sinuosity	Very Low	Excellent	Very Low	Very Low	Negligible
	2	Boulders		Very Low	Excellent	Very Low	Very Low	Negligible
	3	Cobble		Low	Excellent	Low	Low	Moderate
	4	Gravel		Moderate	Excellent	Moderate	Low	Moderate
	5	Sand		Moderate	Excellent	Moderate	Moderate	Moderate
C	1	Bedrock	Slightly Entrenched, Moderate to High Width/Depth Ratio, Moderate to High Sinuosity	Very Low	Excellent	Very Low	Very Low	Negligible
	2	Boulders		Low	Very Good	Very Low	Low	Moderate
	3	Cobble		Moderate	Good	Moderate	Moderate	Very High
	4	Gravel		Very High	Good	High	Very High	Very High
	5	Sand		Very High	Fair	Very High	Very High	Very High

Figure 47. Abbreviated Rosgen Classifications.

B. EAST FORK SWIFT CREEK

1. Background

The East Fork of Swift Creek is a third order stream originating high in the upper watershed near Red Meadow Pass. The headwater source of this stream is on USFS property with land ownership quickly transitioning to the Stillwater State Forest. The upper reach experiences seasonal dry reaches before it flows into Upper Whitefish Lake, as does the reach below the lake before its confluence with the West Fork of Swift Creek.

Satellite Imagery Summary

The 1987 Landsat image of the East Fork of Swift Creek drainage shows timber harvest units immediately to the northwest of upper Whitefish Lake on the Stillwater State Forest. There is no evidence of timber harvest on USFS property. There are no, or very few and small additional timber harvest units since 1987 with stand replacement occurring. There is no evidence of timber harvest originating in the Whitefish Range bordering the east side of the drainage.

2. Biological

Fisheries

MFISH reports bull trout, westslope cutthroat trout, brook trout, longnose sucker and slimy sculpin in this stream from multiple surveys and professional judgment. In addition, a survey conducted by DNRC on a tributary to the East Fork at River Mile 4.2 found westslope cutthroat trout.

Macroinvertebrates

Upper East Fork Swift Creek

The Bollman (2003) survey found that upper East Fork of Swift Creek supported a benthic assemblage characteristic of unimpaired montane streams and that it is likely not influenced by water quality degradation. In 2003, the number of “clinger” taxa (12) was fewer than anticipated indicating that limitation to the availability of stony substrates due to sediment deposition couldn’t be ruled out. However, in 2013 both “clinger” taxa (19) and caddisfly (7 taxa) were well represented suggesting that stony substrate habitats were not appreciably degraded by sediment deposition.

Semivoltine taxa were not well represented in 2003 where only two taxa were counted with neither abundant. It was suspected that the site experiences periodic dewatering, scouring sediment pulses or other catastrophic events that would abort long life cycles. In 2013, the site supported semivoltine taxa suggesting improved conditions. In addition, the overall taxa richness (32) was high, suggesting diverse and intact instream habitats, riparian function, natural channel morphology and stable streambanks.

Eleven cold stenotherm taxa, accounting for 52% of all organisms, were sampled in 2013. The preferred thermal preference calculated for the assemblage was 50.36°F (10.2°C). No findings suggested metals contamination. Scrappers dominated the functional composition of the sample with ample algal films on stony benthic substrates suggesting an un-shaded channel and low inputs of large organic material or hydrologic conditions not conducive to the retention of such material.

The upper East Fork MTV bioassessment score for 2003 and 2014 ranked *excellent* (94% and 100%) as compared to the percent of maximum from reference streams whereas the DEQ bioassessment score was *poor* in 2003 (66.67%) and *excellent* in 2014 (100%). Both bioassessments showed improvement from 2003 to 2014.

Lower East Fork Swift Creek
Excellent water quality and cold water temperatures are suggested by data at this site in both 2003 and 2013 with six mayfly taxa found each year indicating an unimpaired stream. Stony substrates were not contaminated with deposited sediment as supported by high numbers of "clinger" taxa found both years. Mild nutrient enrichment is indicated by the high tolerance of the two most common taxa (pisidiid snails and the caddisfly *Hydropsyche* sp.). There was evidence through semivoltine taxa that this stream reach had good numbers of long-lived taxa indicating uninterrupted surface flow, and the absence of thermal extremes or scouring sediment pulses. Unlike the upper East Fork Swift site, the five stonefly taxa sampled at the lower East Fork Swift site indicated intact riparian vegetation.

The lower East Fork MTV bioassessment score from 2003 and 2014 ranked *good* (83% and 88.89%) as compared to the percent of maximum from reference streams whereas the DEQ bioassessment score was *poor* in 2003 (57.14%) and *fair* in 2014 (76.19%). Both bioassessments showed improvement from 2003 to 2014.

Periphyton

Upper East Fork Swift Creek
The Bahls (2004) periphyton survey showed moderate stress form the low number of species present (12). The Shannon Species Diversity (0.52) and Percent Dominant (92.72) showed little community diversity indicating severe stress.

Lower East Fork Swift Creek
The Bahls (2004) survey found minor stress in the periphyton community for this stream reach as indicated by the Shannon Species Diversity (2.94), Disturbance Index (39.45) and Percent Dominant (39.45).

3. Habitat

Fisheries Habitat
The East Fork of Swift Creek was broken into three reaches during the R1/R4 survey based on channel type. At the inlet to Upper Whitefish Lake, the East Fork of Swift Creek is a beaver dam influenced multiple channel C4 stream. At that point (Sec. 21BC) the stream becomes a dry channel for approximately 1.6 miles. Beginning in Section 17BD the stream becomes wetted again up to the unnamed tributary originating in Section 6AA with the confluence in Section 9BB. At that confluence, the East Fork of Swift Creek is again dry for 103 feet. This tributary was mistaken for the East Fork of Swift Creek and surveyed over 1,300 feet.

This tributary supplies good flow to the East Fork of Swift Creek and is an A3/A4 channel type. Above this tributary and the dry reach, the East Fork of Swift Creek is a B3/B4 channel type for a short distance. Just over the USFS boundary, the stream transitions into a A3/A4 channel type just before the old road crossing at Section 4BD. Two fish barriers exist in Section 4AA. This area, dominated by a willow floodplain has one barrier approximately 60 feet high and a barrier 16 feet high at a

90 degree angle. From this point, the stream continues at a high gradient ending at 50-60% at the headwaters. The East Fork of Swift Creek maintains relatively stable flows all the way to the headwaters area which consists of a moss covered spring approximately 50 feet across.

Like the West Fork of Swift Creek, the East Fork has large quantities of woody debris that appear to have been in the stream for prolonged periods of time and are stable. Woody debris size is rather uniform and recruitable woody debris is ample. Westslope cutthroat trout were observed in the portion of the stream above the first dry reach and the A type channel. In comparison to the West Fork, the East Fork has more habitat units per length especially in the reach just mentioned. The East Fork underwent past logging in the floodplain area of the first dry reach. Other than that, the East Fork has little anthropogenic influence other than roads. There are some small amounts of natural mass wasting present but with the toes of the slopes relatively stable.

Reach	Generalized Rosgen Stream Channel Type	Total Reach Length (ft)	Avg # LWD/1,000 ft	Total Fast Habitat Unit Area (Sq. ft.)	Total Slow Habitat Unit Area (Sq. ft.)	Fast to Slow Habitat Ratio (Sq. ft.)
1	C	11,800	54	84,769	23,185	1 : 0.27
2	B	9,505	52	101,465	22,786	1 : 0.22
3	A	14,123	58	109,333	17,046	1 : 0.16

Figure 48. Fish Habitat (R1/R4) Summary Data East Fork Swift Creek.

McNeil Core and Substrate Scores

Figure 49 displays the McNeil Core values for East Fork of Swift Creek as sampled by FWP since 1990. McNeil Core values have always fallen below the threatened threshold indicating good site conditions for spawning bull trout.

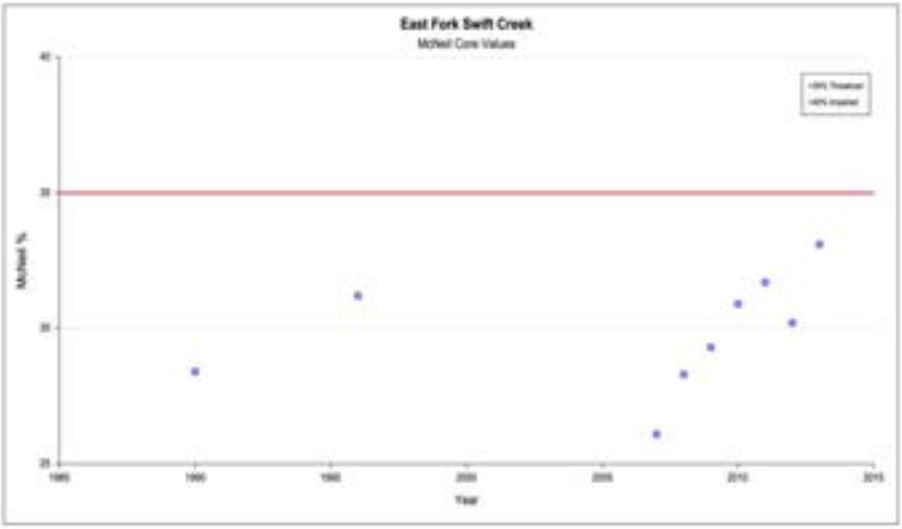


Figure 49. McNeil Core East Fork Swift Creek.

No statistically significant trend information can be drawn from the long-term dataset in this figure due to the high variability in data. However, when the 2007-2013 subset is analyzed independently, a Mann-Kendall test shows a significant trend in the data ($p=0.011$, $r^2 = 0.83$) indicating deteriorating spawning site conditions

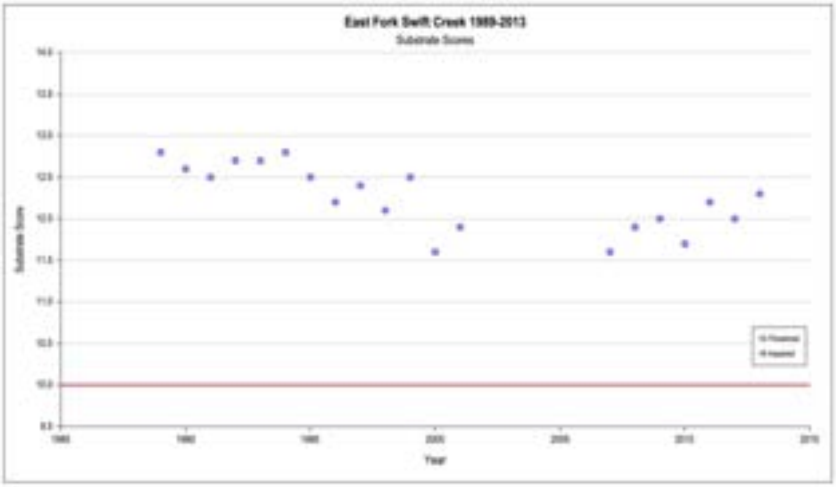


Figure 50. Substrate Score East Fork Swift Creek.

Figure 50 displays the Substrate Scores for East Fork of Swift Creek as sampled by FWP. Substrate scores have always been above the threatened threshold for bull trout spawning and rearing. A Mann-Kendall test shows a significant trend in the data ($p=0.002$, $r^2 =0.49$) indicating a decline in spawning site conditions over time. However, the Mann-Kendall test shows improving site conditions from 2007-2013 ($p=0.048$, $r^2=0.59$).

4. Water Temperature

Figure 51 displays stream temperature data for the East Fork of Swift Creek from 2001-2013. Stream temperatures have been consistently cold with no thermal stress to salmonid species or life stages.

Year	Seasonal Maximum Value (C)	Seasonal Minimum Value (C)	7- Day Averages		
			Maximum (C)	Minimum(C)	Δ T (C)
2001	11.3	2.1	10.8	5.8	5.0
2003	14.7	1.2	13.0	5.7	7.3
2004	11.3	2.0	10.8	6.6	4.2
2006	11.6	1.4	11.2	7.0	4.2
2007	12.1	1.7	11.6	7.1	4.5
2009	11.1	0.0	10.3	5.8	4.5
2010	10.8	2.3	10.1	6.2	3.8
2012	10.6	0.8	9.9	6.2	3.7
2013	10.9	2.7	10.7	6.2	4.5

Figure 51. Stream Temperature Data for East Fork Swift Creek

5. Water Chemistry

East Fork of Swift Creek water chemistry summary figures for Total Phosphorus and Total Suspended Solids can be found in Chapter XXII Addendum C Water Chemistry & Temperature Information. Peak flow usually occurs in late May/early June. Correspondingly, the highest nutrient and sediment loading occurs at that time. All Total Phosphorus concentrations collected from 1980-1997 fall within the State of Montana Wadeable Streams and Rivers Nutrient Criteria. Upper Whitefish Lake most likely serves as a significant sediment and nutrient sink.

C. WEST FORK SWIFT CREEK

1. Background

The West Fork of Swift Creek is a third order stream originating high in the upper watershed near the Stillwater River divide. It is found entirely in the Stillwater State Forest. High elevation lakes exist in the Herrig Creek, Stryker Creek, and Johnson Creek drainages which flow into the West Fork of Swift Creek from the west along Stryker Ridge.

Satellite Imagery Summary

The 1987 Landsat image shows harvest units in the Herrig Creek drainage, Johnson Creek drainage, and upper Stryker Creek drainage with regeneration seen in the 1994 image. The 1994 image shows harvest activity seen on an un-named tributary north of Johnson Creek. Little harvest activity is seen in the 2004 image but by 2011 harvest is seen along the West Fork of Swift from Johnson Creek up past Stryker Creek with additional activity in the un-named tributary drainage.

2. Biological

Fisheries

MFISH reports bull trout, westslope cutthroat trout, brook trout, and slimy sculpin in the West Fork of Swift Creek from multiple FWP surveys and professional judgment. A genetic sample taken in 1984 found the westslope cutthroat population 97.4% pure with 2.5% rainbow trout genetic introgression.

The West Fork of Swift Creek provides vital adfluvial bull trout spawning grounds and rearing habitat for juvenile fish. It is suspected that some of the juvenile bull trout population migrate downstream and enter Swede Creek for rearing.

Bull Trout Redd Counts

Figure 52 displays bull trout redds found in the West Fork of Swift Creek. Survey information since 2005 is encouraging, with a Mann-Kendall test showing a slight statistical trend of increasing numbers of redds ($p=0.050$, $r^2=0.14$). However, total numbers of redds are still at very low densities.

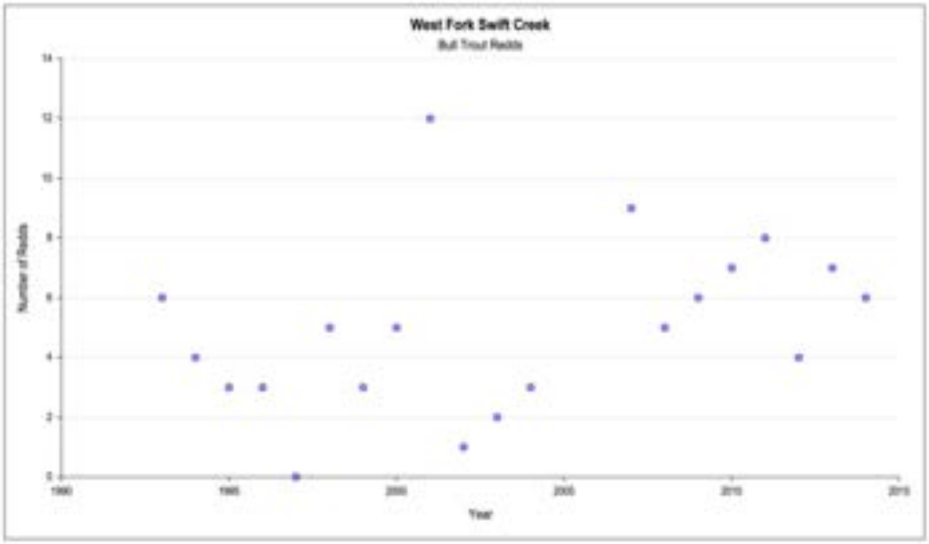


Figure 52. Bull Trout Redds West Fork Swift Creek.

Aquatic Invertebrates

Upper West Fork Swift Creek
Surveys from 2003 and 2013 found a sensitive species assemblage indicating excellent water quality. Groundwater influences were noted by Bollman (2003) via the presence of turbellarian *Polycelis coronata*. Only two semivoltine taxa were reported in 2003 compared to five taxa found in 2013 which indicate improved site conditions related to uninterrupted surface flow, and the absence of thermal extremes or scouring sediment pulses.

The shredder community was underrepresented in 2003 suggested that riparian inputs of large organic matter may be limited, or hydrologic conditions at the site may prevent the retention of such material. However, 2013 data showed high overall taxa richness (33) suggesting intact and diverse habitat conditions with high predator taxa indicating that small invertebrate taxa in the drift are a major energy source in this reach. In addition, scrappers strongly dominated the assemblage, suggesting limited riparian shading and ample algal films.

The upper West Fork of Swift Creek MTV bioassessment score from 2003 and 2014 ranked *excellent* (94% and 100%) as compared to the percent of maximum from reference streams whereas the DEQ bioassessment score was *poor* in 2003 (66.67%) and *excellent* in 2014 (100%). Both bioassessments showed improvement from 2003 to 2014.

Lower West Fork Swift Creek
High mayfly taxa (8) were found in both 2003 and 2013 indicating excellent water quality at this site. The turbellarian *Polycelis coronate* was common, suggesting groundwater influence on surface flow. Surveys found that sediment deposition and

pollution seem unlikely at this site. Overall diversity (37 taxa) was high in 2013 indicating excellent instream habitat conditions. A lack of semivoltine taxa (one in 2003 and two in 2013) suggest that recent scour events, dewatering, or thermal stress may have been influential.

The lower West Fork of Swift Creek MTV bioassessment score from 2003 and 2014 ranked *excellent* (100% and 100%) as compared to the percent of maximum from reference streams whereas the DEQ bioassessment score was *good* in 2003 (85.71%) and *excellent* in 2014 (100%).

Periphyton

Upper West Fork Swift Creek

The 2004 survey showed minor stress in the periphyton community as indicated by the Disturbance Index (29.72) and Percent Dominant (29.72).

Lower West Fork Swift Creek

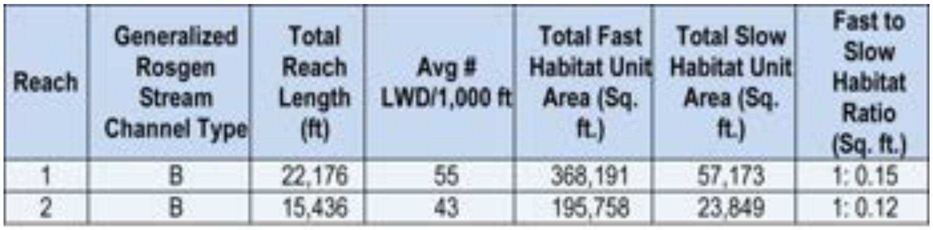
The 2004 survey showed minor stress in the periphyton community for this stream reach from the Number of Species (20) and Shannon Species Diversity (2.08) and moderate stress in the Percent Dominant (60.28).

3. Habitat

Fisheries Habitat

Generally, the West Fork of Swift Creek maintains a consistent 2-4% gradient. In addition, the stream maintains the same level of confinement except for a few short reaches in the upper drainage where the floodplain expands. Instream and recruitable large woody debris is abundant and uniform in size. Much of the large woody debris had been instream for a prolonged length of time and were basically “built in” and very stable. Instream cobble and boulders are influential in forming habitat (pocket pools) secondary to the woody debris. Very few areas of bank erosion were found and were natural. The riparian area is dense with good root mass to stabilize the banks.

The stream has relatively long sections of low gradient riffles separated by quality pools mainly formed by woody debris. Many of the low gradient riffles occur where the stream is channelized and the pools seem to develop in areas of minor sinuosity where large woody debris aggregates accumulate (Figure 53).



Reach	Generalized Rosgen Stream Channel Type	Total Reach Length (ft)	Avg # LWD/1,000 ft	Total Fast Habitat Unit Area (Sq. ft.)	Total Slow Habitat Unit Area (Sq. ft.)	Fast to Slow Habitat Ratio (Sq. ft.)
1	B	22,176	55	368,191	57,173	1: 0.15
2	B	15,436	43	195,758	23,849	1: 0.12

Figure 53. Fish Habitat (R1/R4) Summary Data West Fork Swift Creek.

At the confluence of the East Fork, the West Fork appears to be a losing water reach and gains more flow upstream. At the headwaters, the stream again looses flow rapidly and habitat units are less obvious to delineate. The channel becomes dry downstream of the bridge to Herrig Lake. The first order tributary in Section 12 (right side) however, does have flow. The largest fish observed was eight inches. No fry were observed in the shoreline areas.

McNeil Core and Substrate Scores

Figure 54 shows McNeil Core values for the West Fork of Swift Creek as sampled by FWP since 1990. McNeil Core values have always fallen below the threatened threshold indicating good site conditions for spawning bull trout. Trend information shows a statistically significant decline in value, (Mann-Kendall p=0.001, r^2=0.55) an indication of better site conditions for the sampled period.

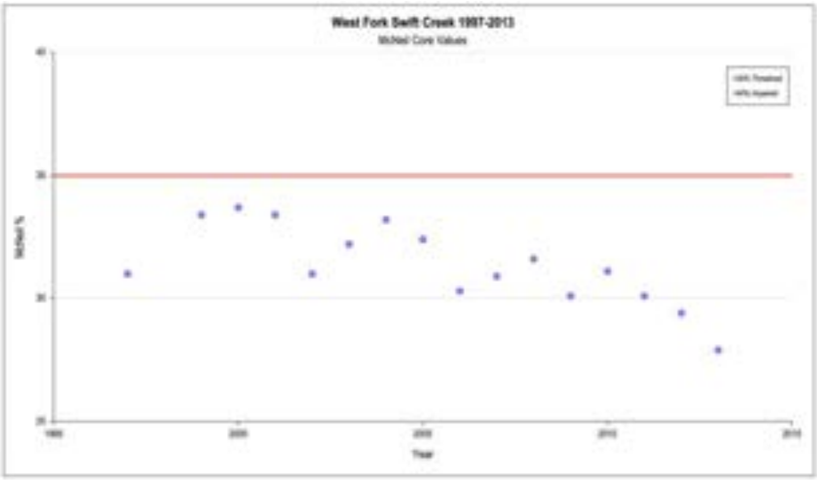


Figure 54. McNeil Core West Fork of Swift Creek.

Figure 55. shows the West Fork of Swift Creek Substrate Score as sampled by FWP since 1994. Substrate scores have always been above the threatened threshold for bull trout spawning and rearing. There is no significant statistical trend in this data.

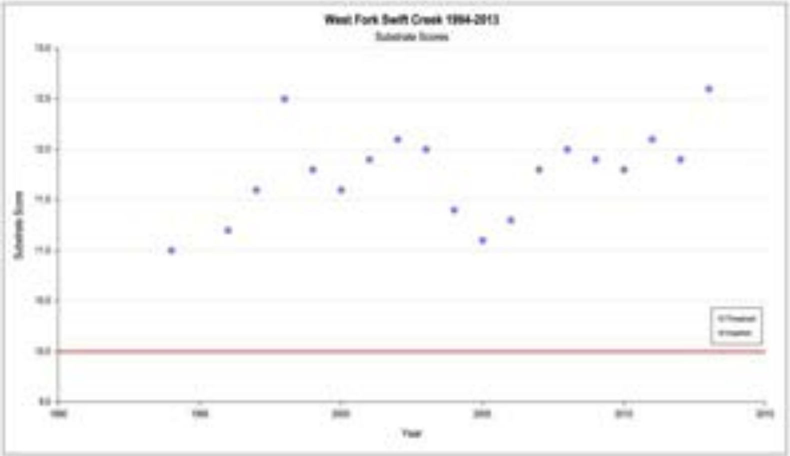


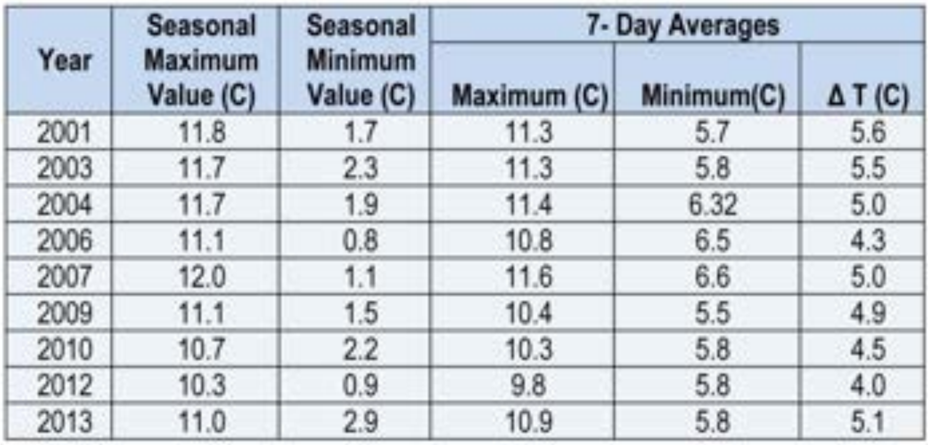
Figure 55. Substrate Scores West Fork of Swift Creek.

4. Water Temperature

Figure 56 displays stream temperature data for the West Fork of Swift Creek from 2001-2013. Stream temperatures have been consistently cold without any thermal stress to salmonid species or life stages.

5. Water Chemistries

West Fork of Swift Creek water chemistry summary figures for Total Phosphorus and Total Suspended Solids can be found in Chapter XXII. Addendum C Water Chemistries & Temperature Information.



Year	Seasonal Maximum Value (C)	Seasonal Minimum Value (C)	7- Day Averages		
			Maximum (C)	Minimum(C)	Δ T (C)
2001	11.8	1.7	11.3	5.7	5.6
2003	11.7	2.3	11.3	5.8	5.5
2004	11.7	1.9	11.4	6.32	5.0
2006	11.1	0.8	10.8	6.5	4.3
2007	12.0	1.1	11.6	6.6	5.0
2009	11.1	1.5	10.4	5.5	4.9
2010	10.7	2.2	10.3	5.8	4.5
2012	10.3	0.9	9.8	5.8	4.0
2013	11.0	2.9	10.9	5.8	5.1

Figure 56. Stream Temperature West Fork Swift Creek.

Peak stream flow occurs in late May/early June. Correspondingly, the highest nutrient and sediment loading occurs at that time. All Total Phosphorus concentrations collected for the study period with the exception of one sample in 1993 fall within the State of Montana Wadeable Streams and Rivers Nutrient Criteria.

D. HERRIG CREEK

1. Background

Herrig Creek is a second order stream found entirely on the Stillwater State Forest that enters the West Fork of Swift Creek from the west between Herrig Mountain and Stryker Peak.

Satellite Imagery Summary
As mentioned in the West Fork of Swift Creek Landsat imagery summary, the 1987 image shows harvest units in the Herrig Creek drainage with regeneration seen in the 1994 image. No harvest activity is apparent since the 1987 image.

2. Biological

The only information known to exist for Herrig Creek is from a fisheries habitat survey. A fish survey should be conducted on Herrig Creek above the fish barriers based on westslope cutthroat trout genetic purity levels found in Johnson and Stryker

Creeks. However, drift down from fish stocked in Herrig Lake have probably lead to genetic introgression. No aquatic insect information exists for this stream. See Chapter XIII Other Project Lakes Section C Herrig Lake for additional information.

3. Habitat

Fisheries Habitat

Herrig Creek- Reach 1

Reach 1 of Herrig Creek is very steep and is predominately an A2a channel type. The reach starts out as a low gradient riffle, gravel/cobble dominated channel. Herrig Creek rapidly picks up gradient and becomes a high gradient riffle cobble/boulder dominated channel. There are many cascades formed by bedrock that are fish barriers. Fish were seen at Habitat Unit 48 – below the major fish barriers. The channel shape on this reach was primarily triangular. There was woody debris seen in many habitat units, however most of the large wood debris recorded did not span the channel but was lying on a steep side bank.

Herrig Creek- Reach 2

This reach of Herrig Creek has a significantly lower gradient than Reach 1. The reach extends from where the gradient flattens to the source at Herrig Lake. Many fish were seen throughout this reach. This reach had extensive large woody debris and a few big log jams with 15-30 pieces. This reach is dominated by low gradient riffles, and a few high gradient riffles separated by woody debris formed pools. The average slope was 3.5-4%. At Habitat Unit 207, the gradient shifts for a short period of steeper, high gradient riffle, cascade dominant habitat types. The channel then flattens out to the source at Herrig Lake.

Reach	Generalized Rosgen Stream Channel Type	Total Reach Length (ft)	Avg # LWD/ 1,000 ft	Total Fast Habitat Unit Area (Sq. ft.)	Total Slow Habitat Unit Area (Sq. ft.)	Fast to Slow Habitat Ratio (Sq. ft.)
1	A	3,260	158	32,894	7,519	1 : 0.23
2	B	9,578	145	72,317	23,012	1 : 0.32

Figure 57. Fish Habitat (R1/R4) Summary Data Herrig Creek.

4. *Water Chemistry*

No water chemistry information exists for this stream.

5. Water Temperature

No water temperature information exists for this stream.

E. STRYKER CREEK

1. Background

Stryker Creek is a second order stream found entirely on the Stillwater State Forest that originates at the base of Stryker Peak and flows east to the West Fork of Swift Creek. This stream is not labeled on most maps.

Satellite Imagery Summary
As mentioned in the West Fork of Swift Creek Landsat imagery summary, the 1987 photo shows harvest units in upper Stryker Creek with regeneration seen in the 1994 image. No other harvest activity was seen in this drainage other than along the lowest reach of Stryker Creek adjacent to the West Fork of Swift Creek that occurred sometime between 2005 and 2011.

2. Biological

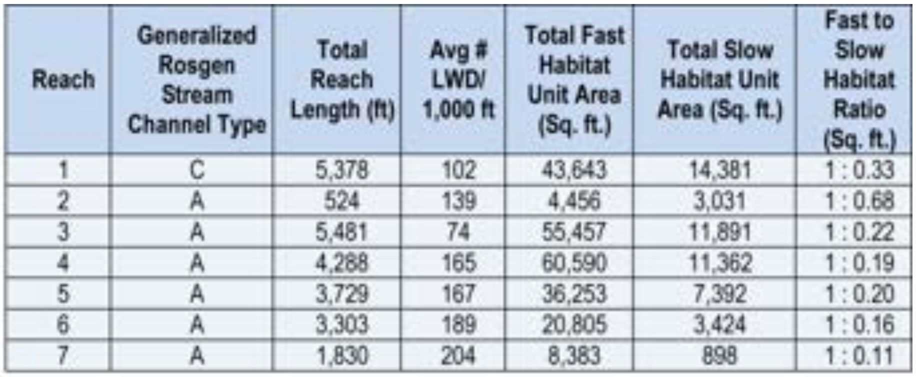
MFISH reports brook trout, rainbow trout, and westslope cutthroat trout in Stryker Creek. based on a DNRC 2008 survey, genetic analysis found that Stryker Creek very likely contains a non-hybridized (pure) westslope cutthroat trout population. No aquatic insect data exists for this stream.

3. Habitat

Fisheries Habitat
Fish habitat notes were completed for the first three of seven reaches completed for Stryker Creek.

Stryker Creek- Reach 1
The downstream end of Stryker Creek was dry at the time of the survey. There is a small pool 318 feet upstream of the mouth with water flowing into it. The flow measured at the first available spot (Habitat Unit #5) was 0.09cfs. This reach is primarily a C3 channel type. The reach is dominated by a mix of low and high gradient riffles and boulder formed pools. The channel is generally wide (bankfull much wider than wetted width) and was composed primarily of small cobble. Large woody debris was moderate in abundance in this reach, however, there were a few large log jams. The log jams occasionally caused the stream to spread out into the flat wide floodplain. The stream is braided in this reach through an alder/conifer forest with significant subsurface flow. The many braids then reconnect to form a single flowing channel. Fish were seen in the upstream end of this reach. This was a gaining reach with more water at the upstream than the downstream end.

Stryker Creek- Reach 2
This reach is a short, steep section of Stryker Creek. It is an A2 channel type. The reach is dominated by cascades and high gradient riffles separated by boulder and bedrock formed scour pools. Large woody debris was seen in approximately half of the habitat units.



Reach	Generalized Rosgen Stream Channel Type	Total Reach Length (ft)	Avg # LWD/ 1,000 ft	Total Fast Habitat Unit Area (Sq. ft.)	Total Slow Habitat Unit Area (Sq. ft.)	Fast to Slow Habitat Ratio (Sq. ft.)
1	C	5,378	102	43,643	14,381	1 : 0.33
2	A	524	139	4,456	3,031	1 : 0.68
3	A	5,481	74	55,457	11,891	1 : 0.22
4	A	4,288	165	60,590	11,362	1 : 0.19
5	A	3,729	167	36,253	7,392	1 : 0.20
6	A	3,303	189	20,805	3,424	1 : 0.16
7	A	1,830	204	8,383	898	1 : 0.11

Figure 58. Fish Habitat (R1/R4) Summary Data for Stryker Creek.

Stryker Creek- Reach 3
This reach is a B3/B4 channel type. Flow of 3.06cfs was measured at Habitat Unit #21. The reach is dominated by high and low gradient riffles and boulder formed scour pools. Fish were seen at many sites throughout this reach. Similar to downstream reaches, there were a few areas where the stream spread out into many braids on the floodplain.

4. Water Chemistry

No water chemistry information exists for this stream.

5. Water Temperature

No water temperature information exists for this stream.

F. JOHNSON CREEK

1. Background

Johnson Creek is a second order stream found entirely on the Stillwater State Forest that originates from two small lakes west of Antice Point. The stream flows east to the West Fork of Swift Creek. This stream is not labeled on most maps.

<u>Satellite Imagery Summary</u>
The 1987 Landsat image shows harvest units in the Johnson Creek drainage with regeneration seen in the 1994 image. Little additional harvest activity is seen in the 2004 image but by 2011 harvest is seen in the lower reach along the West Fork of Swift along with a harvest unit in the upper watershed.

2. Biological

MFISH reports westslope cutthroat trout in Johnson Creek based on multiple surveys. A genetic analysis from 1992 with a sample of 52 fish found 98.9% westslope cutthroat trout genes with 1.1% Yellowstone cutthroat trout introgression. A 1998 genetic sample found 100% westslope cutthroat genes but the sample size was limited to only three fish.

3. Habitat

Fisheries Habitat
No habitat information is known to exist for this stream other than the reach near the confluence with the West Fork of Swift Creek can be dry at base flows.

4. Water Chemistry

No water chemistry information exists for this stream.

G. SWIFT CREEK (MAINSTEM)

1. Background

Included in this sub-chapter are data from the mainstem of Swift Creek and upper mainstem tributaries including; Antice Creek, Chicken Creek, and Swede Creek. Those three tributaries are first to enter Swift Creek after the West Fork and East Fork of Swift Creek confluence and have more available resource information. Information on the other smaller tributaries to Swift Creek draining from the Whitefish Range is included in the *Small Swift Creek Tributaries* sub-chapter.

In geological terms, Swift Creek is still very young and undergoing post-glaciation adjustment. The stream channel is actively eroding glacial till and reworking the post-glacial sediment deposits. Swift Creek is a fourth order stream draining 63% of the Whitefish Lake Watershed and the stream begins at the confluence of the West Fork and East Forks of Swift Creek.

Figure 59. Swift Creek High Flow at Delrey Bridge 2011.

Swift Creek flows primarily through the Stillwater State Forest with approximately six miles through Plum Creek land. Beyond the West Fork of Swift Creek and Antice Creek, all of the other tributary inputs originate from the Whitefish Range on the eastern side. Most of those tributaries (*See Smaller Swift Creek Tributaries*) are steep first or second order streams.

Similar to Lazy Creek, Swift Creek was extensively logged in the 1930s, including road development that involved multiple stream crossings. Considerable discussion has centered on the many large mass wasting banks along Swift Creek and whether or not anthropogenic factors have exacerbated erosional forces and sediment loading to Swift Creek and Whitefish Lake. The eroding bank issue is discussed as an additional sub-chapter for this stream found after the *Habitat Section*.

Satellite Imagery Summary

Because of the large geographic scope of the mainstem of Swift Creek drainage, comments in this summary pertain only to activity along the stream channel itself. See sub-chapters for Chicken Creek, Antice Creek, Swede Creek and Smaller Swift Creek Tributaries for additional information.

The 1987 satellite image shows harvest activity near Swift Creek just below the Antice Creek confluence. This harvest area shows some additional harvest units located further away from Swift Creek on the Stillwater State Forest. Some harvest on Plum Creek land had started by this time. In addition, some harvest units are seen in the unnamed tributaries located directly to the east of Plum Creek on the Stillwater State Forest in the Whitefish Range.

The 1994 image shows additional harvest on Plum Creek land and on the Stillwater State Forest immediately downstream of Plum Creek land around the confluence of Werner and Taylor Creeks. The 2004 photo shows timber harvest extending downstream from the Taylor Creek confluence to the Anchor Creek confluence.

2. Biological

Fisheries

Swift Creek has a high fisheries value affording habitat and connectivity to bull trout and westslope cutthroat trout. Adfluvial bull trout migrate from Whitefish Lake to the upper reach of Swift Creek and the West Fork of Swift Creek to spawn. Swift Creek and its tributaries, especially Swede Creek, offer rearing habitat for juvenile bull trout. Johnson Creek and Stryker Creek contain relatively pure westslope cutthroat trout populations with little genetic introgression.

MFISH reports multiple fish surveys on Swift Creek from 1989 to 2006. Many species are found in the stream including; bull trout, westslope cutthroat trout, rainbow trout, brook trout, mountain whitefish, and slimy sculpin.

Bull Trout Redd Counts

Figure 60 displays bull trout redds found in Swift Creek from FWP surveys. The Mann-Kendall test shows an increasing trend in bull trout redds ($p=0.014$, $r^2=0.32$).

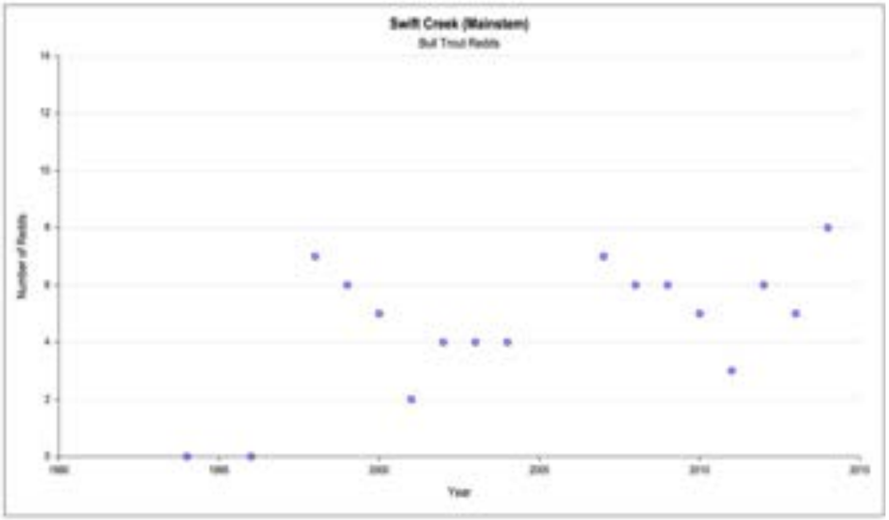


Figure 60. Bull Trout Redd Count Swift Creek Mainstem.

Figures 61 and 62 display the combined redd count total for the Swift Creek drainage (main Swift Creek and the West Fork of Swift Creek). As combined, the dataset shows a statistical increasing trend in total number of redds for the study period (p=0.012, r^2=0.36) based on the Mann-Kendall test. However, total redds surveyed remain at very low densities, suggesting a precariously low adfluvial population.

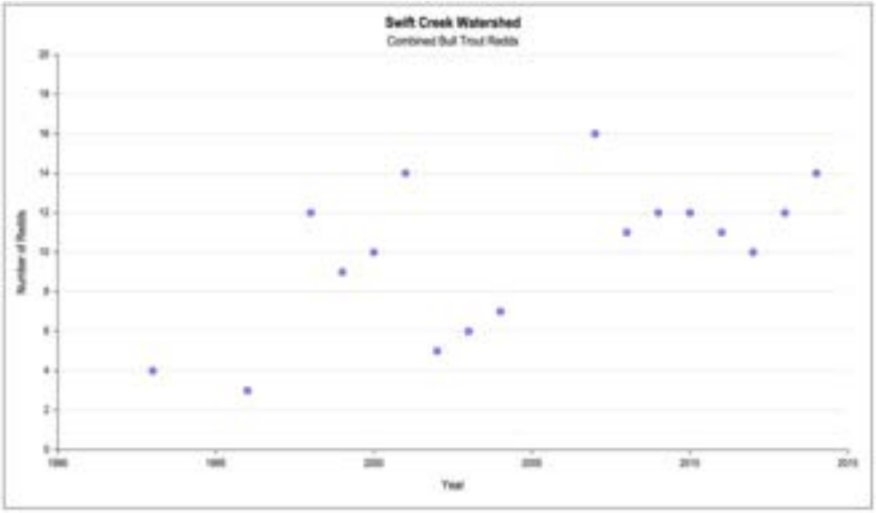


Figure 61. Bull Trout Redds Swift Creek Mainstem and West Fork.

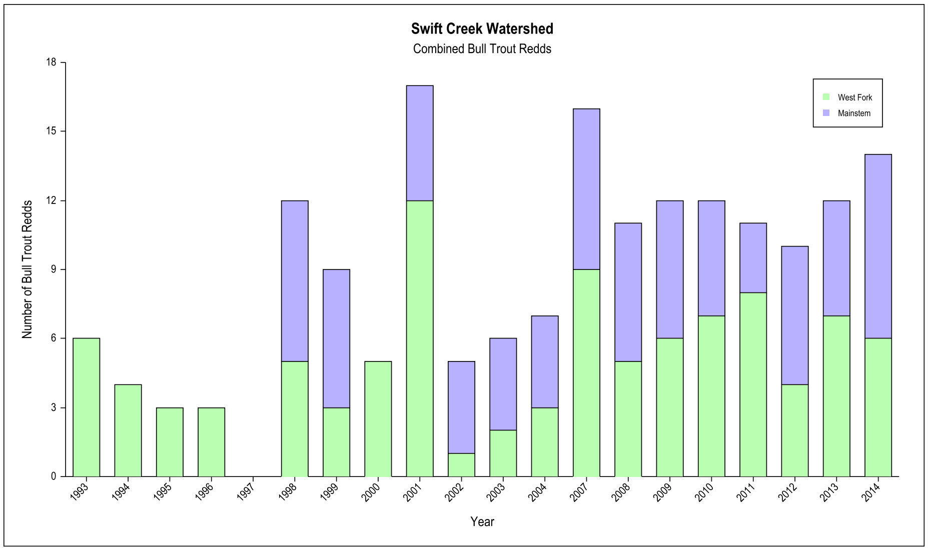


Figure 62. Bull Trout Redds Swift Creek Mainstem and West Fork.

<u>Macroinvertebrates</u>

Upper Swift Creek

The upper Swift Creek site was sampled in 2003 but not 2013. Evidence suggests that water quality was good at this site. The 11 “clinger” taxa in the sample were fewer than expected and mild effects from sediment deposition cannot be ruled out. Overall taxa richness (25) was slightly lower than expected but the rich predator fauna (9) indicate that instream habitats were varied. Eight stonefly taxa showed that morphological elements like streambanks and riparian areas were undisturbed.

The upper Swift Creek MTV bioassessment score in 2003 ranked *excellent* (94%) as compared to the percent of maximum from reference streams whereas the DEQ bioassessment score in 2003 was *poor* in 2003 (61.9%).

In 2015, ten mayfly taxa were found in this sample. *Drunella coloradensis*, an ephemerellid, was the most abundant mayfly (156 specimens, 29.5% of the assemblage) followed by *D. doddsii* (31 specimens, 5.9% of the assemblage) a pollution sensitive, cold stenotherm. The low biotic index value (2.01), the high number of sensitive taxa (12), and no tolerant taxa in this sample suggest an intolerant assemblage. Of the functional feeding groups, collectors composed 36.3% of the assemblage. All of these results suggest excellent water quality at this site. The low MTI (2.06) suggests no metals contamination.

Of all the sites sampled, this sample had the second largest number of cold stenotherm taxa (10) that composed almost 10% of the assemblage. As expected given the relative abundance of cold stenotherms, the temperature preference of the assemblage was only 11.5 °C, the second lowest of all the sites. There were 12 caddisfly taxa in this sample, the highest among all the sites. The high FSBI (6.21, the highest among all the sites) and 29 “clinger” taxa (tied for the highest number among all the sites) combined with the high number of caddisfly taxa suggest that the deposition of fine sediment did not limit colonization in this reach. The assemblage appears to be sediment-intolerant.

An intact, complex in-stream habitat is suggested by the high taxa richness (50) at this site. A diverse group of stonefly taxa (7), including both shredders and predators, were collected from this site, thus there seems to be little impact to riparian zones, channel morphology and stream banks. Four semi-voltine taxa were collected, suggesting stable instream conditions where flood-induced scour, inputs of toxins, and widely varying temperatures seem unlikely. As with Swift Delrey, scrapers (50.9%) and gatherers (35.5%) dominated the functional feeding groups and shredders were of low relative abundance (1.7%).

Middle Swift Creek

The middle Swift Creek site was sampled in 2003 and 2013. This site supported a diverse and sensitive functional assemblage and high mayfly taxa richness suggests excellent water quality. High overall taxa richness supports this reach having diverse instream habitats. In addition, the 2013 survey found turbellarian *Polycelis coronata*, suggesting inputs of groundwater. The 2013 survey also noted the possibility of monotonous instream habitat conditions. There was a small proportion of shredders indicating limited riparian inputs of large organic material or hydrological conditions that do not favor the retention of such material.

The mid Swift Creek MTV bioassessment score from 2003 ranked *excellent* (100%) and *good* (88.89%) in 2014 as compared to the percent of maximum from reference streams whereas the DEQ bioassessment score was *good* in for both years (80.95% and 80.95%).

Lower Swift Creek

The lower Swift Creek site was sampled in 2003 but not 2013. Six mayfly taxa collected at this site indicate excellent water quality. The seven caddisfly taxa and 13 “clinger” taxa suggested that substrate habitats were essentially uncontaminated by sediment deposition. The lower Swift Creek MTV bioassessment score in 2003 ranked *excellent* (100%) as compared to the percent of maximum from reference streams whereas the DEQ bioassessment score was *fair* in 2003 (76.19%).

In 2015, a very diverse mayfly fauna of 13 taxa were collected from this site. The heptigeniid mayfly *Epeorus longimanus* (211 individuals, 39.1% of the assemblage) dominated the mayflies. Also, the mayfly assemblage included several specimens of 3 sensitive and cold stenotherm species (*Drunella doddsii*, *Epeorus deceptivus* and *E. grandis*). A relatively intolerant assemblage is suggested by a low biotic index value of 2.18, a very low percentage of tolerant taxa (0.2%), and the presence of 6 sensitive taxa. Collectors composed only 34.1% of the assemblage. These results suggest excellent water quality at this site. There was no evidence of metals contamination. Five cold stenotherm taxa were collected accounting for approximately 8% of the assemblage. The temperature preference of the assemblage was 12.5 °C. Caddisflies were well represented by 7 taxa and “clingers” were represented by 22 taxa. These findings suggest that the deposition of fine sediment did not limit colonization in this reach. The assemblage appears to be moderately sediment-intolerant given the above information and an FSBI of 5.95.

Taxa richness (46) was high at this site suggesting a complex in-stream habitat this is intact. Only 3 stonefly taxa were recorded from this site all of which were predators. However, 1 specimen of the cold stenotherm, sensitive species *Doroneuria sp.* was collected. Thus, slight impacts to riparian zones, channel morphology and stream banks cannot be ruled out. Six semi-voltine taxa were collected, suggesting stable in-stream conditions. Scour, toxic inputs, and thermal extremes seem unlikely. Gatherers (32.8%) and scrapers (58.7%) dominated the functional feeding groups suggesting the importance of fine particulate organic matter and autochthonous production to the energy flow of the system. As indicated by the lack of shredding stonefly taxa, shredders were of low relative abundance (1.7%).

Periphyton

Upper Swift Creek
Bahls (2004) indicate that periphyton data showed minor stress as indicated by the Number of Species (22) and Shannon Species Diversity (2.14) and moderate stress as displayed by the Disturbance Index (64.01) and Percent Dominant (64.01).

Middle Swift Creek
Bahls (2004) found minor stress in the periphyton community for this stream reach from the Shannon Species Diversity (2.65) and moderate stress in the Disturbance Index (60.22) and Percent Dominant (60.22).

Lower Swift Creek
Bahls (2004) found minor stress in the periphyton community for this stream reach from the Disturbance Index (31.65) and Percent Dominant (31.65).

3. Habitat

Fisheries Habitat
Swift Creek is characterized by long habitat unit types (mainly low gradient riffles) with instream habitat comprised of larger cobble to small boulder forming pocket pools, or large woody debris. Large woody debris is generally found at the margins of the stream channel and has a limited role in habitat formation/cover at base flows. However, in areas of increased sinuosity, large woody debris aggregates form. Many of these aggregates had over 20-30 pieces. Mass wasting banks are prevalent in this stream. In areas of mass wasting where the toe of the slope has been stabilized in some capacity, there is vegetated growth.

Reach	Generalized Rosgen Stream Channel Type	Total Reach Length (ft)	Avg # LWD/ 1,000 ft	Total Fast Habitat Unit Area (Sq. ft.)	Total Slow Habitat Unit Area (Sq. ft.)	Fast to Slow Habitat Ratio (Sq. ft.)
1	C	20,790	58	449,212	82,723	1 : 0.18
2	C	53,647	51	1,766,193	77,341	1 : 0.04
3	C	18,499	104	489,835	59,597	1 : 0.12

Figure 63. Fish Habitat (R1/R4) Summary Data for Swift Creek.

<u>McNeil Core and Substrate Scores</u>

Figure 64 displays the McNeil Core values for Swift Creek as sampled by FWP since 2000.

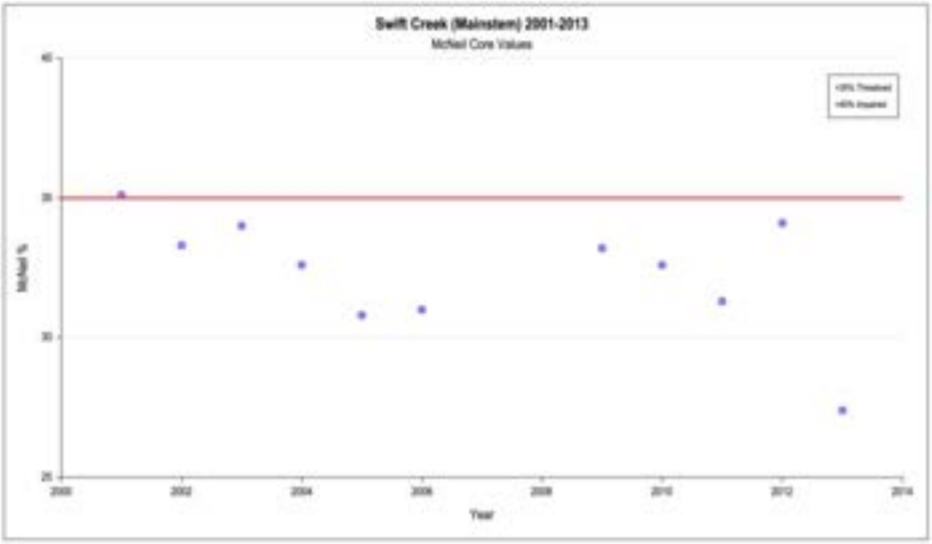


Figure 64. McNeil Core Swift Creek Mainstem.

In 2001, the McNeil Core value was at the threatened level but since then values have fallen below the threatened threshold indicating good site conditions for spawning bull trout. The interannual variability in the data does not yield statistically significant trend information.

Figure 65. displays the Substrate Score Swift Creek as sampled by FWP since 2002. Substrate scores have always been above the threatened threshold for bull trout spawning and rearing and the data does shows a statistically positive trend using the Mann-Kendall test (p=.004, r2=.60).

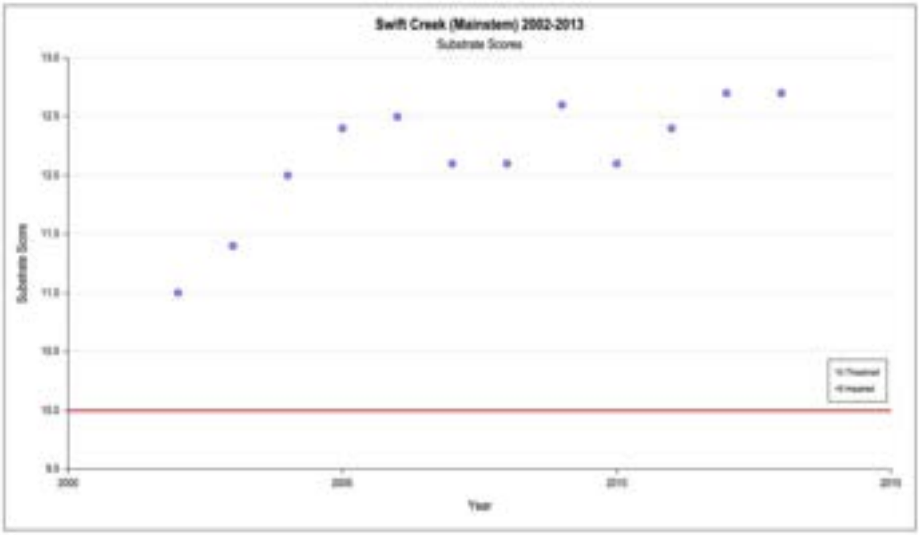
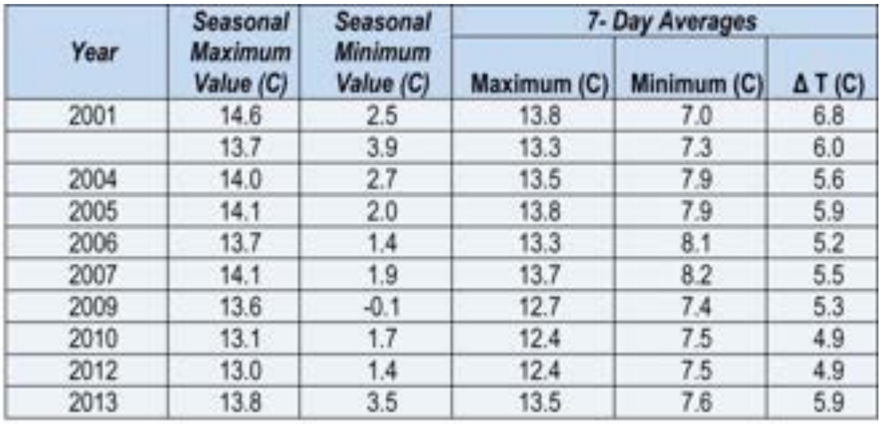


Figure 65. Substrate Scores Swift Creek Mainstem.

4. Water Temperature

Figure 66 displays stream temperature for Swift Creek from 2001-2013. Stream temperatures have been consistently cold without any thermal stress to salmonid species or life stages.



Year	Seasonal Maximum Value (C)	Seasonal Minimum Value (C)	7- Day Averages		
			Maximum (C)	Minimum (C)	Δ T (C)
2001	14.6	2.5	13.8	7.0	6.8
	13.7	3.9	13.3	7.3	6.0
2004	14.0	2.7	13.5	7.9	5.6
2005	14.1	2.0	13.8	7.9	5.9
2006	13.7	1.4	13.3	8.1	5.2
2007	14.1	1.9	13.7	8.2	5.5
2009	13.6	-0.1	12.7	7.4	5.3
2010	13.1	1.7	12.4	7.5	4.9
2012	13.0	1.4	12.4	7.5	4.9
2013	13.8	3.5	13.5	7.6	5.9

Figure 66. Summary Stream Temperature Data Upper Swift Creek.

2014 continuous temperature data for Swift Creek can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information and shows the peak temperature at 72°F on August 2nd. Water temperature data from 2007-2013 were within the range for salmonid species and life stages.

Mass Wasting Banks

Montana DNRC performed two inventories of the mass wasting glacio-fluvial banks along lower Swift Creek (Shultz 1984 and Uncle Buds 2001). These eroding banks are found from the Olney (11.5RM) Bridge downstream to approximately two miles above the Swift Creek confluence with Whitefish Lake.

Shultz (1984) documented 51 eroding banks according to the study methodology and Uncle Bud (2001) surveyed 63 eroding banks, 47 of the same sites as the previous study. Shultz (1984) stated that approximately 87% of the total annual sediment load for Swift Creek originated from the lower 10 miles of the stream and speculated that the eroding banks were the contributory mechanism, some with a very high delivery potential. Shultz (1984) measured sediment yields for six years below the study reach and for four years above the study reach and calculated that from the measured portion of the banks 100 to 125 tons of sediment per surface acre per year was contributed to Swift Creek. That study mapped the combined surface area of the 51 banks at 30 acres.

In 2004, the Swift Creek Coalition contracted with Land & Water Consulting, Inc as part of the Preliminary TMDL Planning Project to provide an analysis of the eroding banks to provide insight into erosion mechanisms for these banks and a judgment of the percent of the total erosion volume from these banks that is human-caused.

The erosion of streambanks (including terraces) is generally related to two processes: fluvial entrainment and the weakening and weathering of bank materials which enhances the potential for mass wasting (Thorne, 1982). Shultz (1984) also documented rainstorms with photos of rill and gully erosion from the banks.

Land & Water Consulting, Inc. (2005) state that in the process of fluvial entrainment, erosion is primarily related to near-bank flow velocities, and the type, density, and root structure of vegetation. Weakening and weathering processes reduce the strength of bank materials and thereby promote mass failure largely based on soil moisture condition and the condition of vegetation on top of the bank.

Another failure mechanism identified by Land & Water Consulting, Inc. (2005) with potential along Swift Creek is sapping (or piping) which is commonly observed where there are alternating strata of more and less cohesive sediments within a bank. The less cohesive strata are coarser and therefore have higher hydraulic conductivities. Where these strata underlay less conductive strata, sapping may occur. The coarser sediment is weakened and weathered away while the cohesive layer remains intact and forms an overhanging block that eventually fails.
Land & Water Consulting, Inc. (2005) identified issues surrounding the potential failure mechanisms, including;

- Modifications to bank-top vegetation
- Mid-slope erosion
- Toe failure

The researchers concluded that the first two mechanisms are interrelated and therefore could be considered as one mechanism. The reasoning was that the removal of vegetation (i.e. timber harvest or fire) from the terraces will result in increasing soil moisture because there will be less snow interception and less evaportranspiration. Some of this increased soil moisture will move as shallow and mid-depth subsurface flow and will reach the surface again at the face of the eroding bank which will bring about the sapping at mid-slope. Toe failure by fluvial entrainment is certainly occurring on the banks where Swift Creek flows come in contact, especially during the peak of the hydrograph.

Land & Water Consulting, Inc. (2005) concluded that the previous two inventories of the eroding banks (Shultz 1984 and Uncle Buds 2001) had insufficient data to fully evaluate a trend in condition but there were lines of evidence of general trends involving surface area and slope of eroding banks. Of the 47 sites that Uncle Buds (2001) re-surveyed from Shultz (1984) and whereas some error should be contributed to differences in measurement methodologies, 34 of the 47 sites (72%) had a larger area in 1984 than in 2001.

Land & Water Consulting, Inc. (2005) found no statistically significant relationship between bank slope and either percent canopy cover or “logged area” in the contributing area and concluded that increased sapping that results from logging and brings about mid-slope bank erosion does not appear to be a prominent process along Swift Creek.

Land & Water Consulting, Inc. (2005) conducted a shear stress analysis of bank material related to fluvial entrainment, or toe scour, and determined the channel forming flow at 817cfs. The question raised by the report is what was the pre-timber management runoff value? In other words, has timber harvest increased infiltration rates causing greater water yield (peak flows) and sheer stress?

Using DNRC water yield information, Land & Water Consulting, Inc. (2005) concluded that the pre-timber management flow was 735cfs or 6.9% sheer stress less than that of the 817cfs found currently and attributable to human actions. However, the analysis was for a fully-forested condition whereas historical stand structure in the Swift Creek drainage was most likely influenced by wildfire. This would mean the historical, pre-settlement water yield was higher than what was calculated in the study. Given these substantial sources of potential error, the study ultimately concluded that it is impossible to state with any certainty what proportion of the sediment from the eroding banks along Swift Creek is anthropogenic but was estimated by the author based on professional judgment to be less than 5%.

5. Water Chemistry

Swift Creek water chemistry summary figures for Total Phosphorus, Total Nitrogen, Total Organic Carbon, and Total Suspended Solids can be found in Chapter XXII Addendum C Water Chemistries and Temperature Information. Swift Creek is a typical mountain stream with peak flows in late May/early June. Based on volume, Swift Creek contributes the highest sediment and nutrient load to Whitefish Lake. Total Suspended Solids and phosphorus were elevated in the 1990s indicating watershed disturbance. An increase in timber harvest in the 1990s was identified through Landsat imagery, and above average flow events occurred in 1996 and 1997. Management of the Swift Creek drainage is paramount in protecting Whitefish Lake since much of the phosphorus budget of the lake is set by this fluvial source. Whitefish Lake is phosphorus limited usually starting at the end of June. Any elevated phosphorus input from Swift Creek could drive primary production to the detriment of lake health.

H. ANTICE CREEK

1. Background

Antice Creek is a second order stream found entirely on the Stillwater State Forest that flows southeasterly to Swift Creek.

Satellite Imagery Summary
The 1987 Landsat image shows a significant level of harvest activity in the Antice drainage. Since that time, very little additional harvest activity is shown on the aerial maps.

2. Biological

MFISH reports brook trout, westslope cutthroat trout and sculpin in Antice Creek based on a 1993 FWP survey.

3. Habitat

Fisheries Habitat
Antice Creek was broken into 4 reaches during the R1/R4 survey. Reach 1 of Antice Creek averages about 4% gradient. It is a C4b channel type. The downstream end of this reach is at the mouth of Antice Creek and it extends up to where the slope changes noticeably. The reach is characterized by a mix of high and low gradient riffles interspersed with pools. Most of the pools are formed by large woody debris, which is abundant in this reach. There were six side channels recorded in this reach. Many fry (25 mm to 45 mm) and one adult fish (6-7 inches) were observed. There was one mass wasting bank observed.

Reach 2 of Antice Creek averages about 1-2% gradient. It is a C4 channel type with some areas that could be labeled E4 due to highly sinuous sections. This reach is characterized by low gradient riffles, runs and many large beaver complexes. There were four beaver complexes that were close to or longer than 1,000 feet. These large beaver complexes contain multiple channels, islands and much large woody debris. Large woody debris was seen in almost all habitat units and many large aggregates contained 10 or more pieces. There were fry observed throughout this reach, as well as multiple adult fish (4-7 inches). This reach also contains a large blown out beaver dam with a new channel cutting through the silt of the old pond bottom.

Reach 3 of Antice Creek has an average gradient of about 3% and is a C4b channel type. This reach was split as the channel picks up gradient slightly and the dominance of beaver ponds ends. The channel becomes much smaller as many tributaries split from the main flow.

The reach is characterized by runs and low gradient riffles separated by woody debris formed pools. Woody debris was seen in almost every habitat unit in this reach. However, towards the upstream end of this reach Antice is out of thick forest and into a grass/willow dominated system. The channel becomes very narrow (three feet) and flows underground at multiple locations. Fry were observed in small pools throughout this reach. No fry were seen above the culvert at habitat unit 125 (there was a nine inch drop from culvert).

Reach 4 of Antice Creek was originally marked as a tributary of Reach 3; however, it shows up as the main channel on maps. It begins as it splits off to the northwest. The average slope on this reach is 1.5-3% and it is a C5b channel type.

The reach is characterized by low gradient riffles and woody debris formed pools. Woody debris was observed in virtually all of the habitat types and often obscured the channel. The reach is relatively short as the channel split into multiple threads and went underground at Habitat Unit 34, creating a low flow fish barrier. Fry were observed in one pool on this reach of Antice Creek.

Reach	Generalized Rosgen Stream Channel Type	Total Reach Length (ft)	Avg # LWD/ 1,000 ft	Total Fast Habitat Unit Area (Sq. ft.)	Total Slow Habitat Unit Area (Sq. ft.)	Fast to Slow Habitat Ratio (Sq. ft.)
1	C	3,497	127	45,825	11,140	1 : 0.24
2	C	13,757	143	75,892	244,887	1 : 3.22
3	C	6,891	118	19,056	19,450	1 : 1.02
4	C	1,022	147	2,498	283	1 : 0.11

Figure 67. Fish Habitat (R1/R4) Summary Data for Antice Creek

4. Water Chemistry

No water chemistry information exists for this stream.

5. Water Temperature

No temperature data exists for this stream.

I. SWEDE CREEK

1. Background

Swede Creek is a first order stream that flows into Swift Creek from the east just downstream of the East Fork of Swift Creek and West Fork of Swift Creek confluence. The headwaters of this stream is found on USFS land and quickly transitions to the Stillwater State Forest.

Satellite Imagery Summary
Swede Creek does not show any discernible timber harvest activity although there may have been a very small harvest unit near the Swift Creek confluence.

2. Biological

MFISH reports bull trout in Swede Creek from a DNRC 2008 survey. Bower (2015) indicates that brook trout are now found in the upper reaches of this stream. As noted in the Swift Creek sub-chapter, Swede Creek may serve as important rearing habitat for juvenile bull trout.

3. Habitat

Fisheries Habitat
No field notes exist from the R1/R4 fisheries habitat survey but summary data is found in Figure 68.

Reach	Generalized Rosgen Stream Channel Type	Total Reach Length (ft)	Avg # LWD/ 1,000 ft	Total Fast Habitat Unit Area (Sq. ft.)	Total Slow Habitat Unit Area (Sq. ft.)	Fast to Slow Habitat Ratio (Sq. ft.)
1	A	762	148	4,754	1,709	1 : 0.36
2	A	1,757	190	12,788	5,558	1 : 0.43
3	A	1,028	125	9,849	693	1 : 0.07

Figure 68. Fish Habitat (R1/R4) Summary Data for Swede Creek.

4. Water Temperature

Figure 69 displays stream temperature from two sites on Swede Creek from 2001-2013. Stream temperatures have been consistently cold without any thermal stress to salmonid species or life stages and are likely a low thermal barrier to westslope cutthroat trout embryo survival. Swede Creek maintains the most consistent stream temperature with the least amount of variance of any stream in the project area due to spring activity.

Year	Seasonal Maximum Value (C)	Seasonal Minimum Value (C)	7- Day Averages		
			Maximum (C)	Minimum (C)	Δ T (C)
2012-Upper	6.0	3.7	5.8	4.9	1.0
2012-Lower	6.6	3.4	6.4	5.1	1.3
2013-Upper	6.1	4.0	6.0	5.0	1.0
2013-Lower	6.8	3.7	6.7	5.3	1.4
2014-Upper	6.0	3.9	5.9	4.9	1.0
2014-Lower	7.0	3.9	6.8	5.1	1.7

Figure 69. Summary Stream Temperature Data for Swede Creek.

5. Water Chemistry

No water chemistry information exists for this stream.

J. CHICKEN CREEK

1. Background

Chicken Creek is a second order stream found entirely on the Stillwater State Forest that flows from the Whitefish Range west to Swift Creek approximately three miles downstream of the East Fork of Swift Creek and West Fork of Swift Creek confluence.

Satellite Imagery Summary
Chicken Creek does show some timber harvest activity in its lowermost reach in 1987 with no activity since that time.

2. Biological

MFISH reports brook trout and westslope cutthroat trout in Chicken Creek based on a 1992 FWP survey.

3. Habitat

Fisheries Habitat
Chicken Creek was broken into two reaches during the R1/R4 survey. Reach 1 begins at the mouth of Chicken Creek and extends upstream to where a consistent gradient shift occurs. The average slope on this reach is 2-4% and it is a C4b channel type. The lower 16 habitat units could have been separated out into a different reach as they have a lesser gradient and are dominated by a series of beaver dams. The remainder of this reach is characterized by low gradient riffles, runs, and a few high gradient riffles separated by woody debris formed pools. Large woody debris was seen in almost every habitat unit, some with very large aggregates. Large woody debris also influenced the presence of side channels in a few locations. Fry were observed in beaver ponds at the downstream end and at one habitat unit upstream. Adult fish were also observed at two locations in this reach.

Reach 2 of Chicken Creek has an average slope of 5%. It is a B4a/B3a channel type (channel material changes from gravel to cobble dominated moving upstream). The reach is characterized by high gradient riffles and cascades separated by woody debris and boulder formed pools. The channel is very confined in some areas and more open in others. There are many pocket pools formed behind large boulders and most of the habitat units had some large woody debris. There were several tributary confluences in this reach. At Habitat Unit 59 the channel is braided and water flows out 15 feet wide over cobbles before narrowing to a single channel again downstream. No fish or fry were observed, however, rainy weather limited visibility. There were two potential fish barriers before a definite fish barrier at Habitat Unit 158.

Reach	Generalized Rosgen Stream Channel Type	Total Reach Length (ft)	Avg # LWD/ 1,000 ft	Total Fast Habitat Unit Area (Sq. ft.)	Total Slow Habitat Unit Area (Sq. ft.)	Fast to Slow Habitat Ratio (Sq. ft.)
1	C	4,871	143	19,323	45,662	1 : 2.36
2	B	5,815	155	31,827	2,952	1 : 0.09

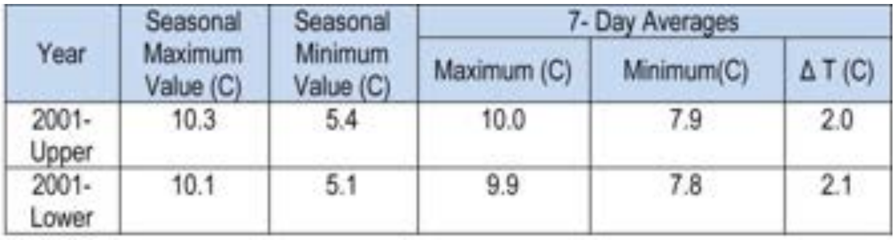
Figure 70. Fish Habitat (R1/R4) Summary Data East Fork Chicken Creek.

4. Water Temperature

Water temperature data for Chicken Creek for two sites in 2001 can be found in Figure 71. It appears that spring activity influences temperature from the upper site to the lower site, where lower temperatures are displayed.

5. Water Chemistry

Chicken Creek water chemistry summary figures for Total Phosphorus and Total Suspended Solids can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. Peak stream flow occurs in late May/early June. Correspondingly, the highest nutrient and sediment loading occurs at that time. Total Suspended Solids values (range) were the highest in the 1990s. Most Total Phosphorus concentrations collected for the study period with the exception of one sample in 1994 and one sample in 2002 fell within the State of Montana Wadeable Streams and Rivers Nutrient Criteria.



Year	Seasonal Maximum Value (C)	Seasonal Minimum Value (C)	7- Day Averages		
			Maximum (C)	Minimum(C)	Δ T (C)
2001-Upper	10.3	5.4	10.0	7.9	2.0
2001-Lower	10.1	5.1	9.9	7.8	2.1

Figure 71. Summary Stream Temperature Data Chicken Creek.

K. SMALL SWIFT CREEK (MAINSTEM) TRIBUTARIES

1. Background

The following small tributaries to the mainstem of Swift Creek drain from the east along the Whitefish Range. Many of these streams have USFS ownership in the headwaters before transitioning to the Stillwater State Forest. These small tributaries are either first or second order streams generally characterized by steep gradients with limited fisheries value until they reach the forest floor/floodprone area of the main Swift Creek channel. Little information exists for these streams other than a few fish surveys and fish passage surveys at culvert sites. These streams provide limited fisheries recruitment to the main Swift Creek system but probably deliver cold and clean water to the system.

No habitat or water chemistry data exists for these streams. Aerial photo and limited biological information is found below. The streams are organized in an upstream to downstream order.

2. Un-Named Tributary to Swift Creek, Rm 11.6

Westslope cutthroat trout are found in this stream based on a 2011 DNRC survey.

3. Gill Creek

Gill Creek does not show any apparent timber harvest activity through 1994. By 2004, a significant amount of the watershed had been harvested with no additional harvest activity seen in the 2011 map. MFISH reports brook trout and westslope cutthroat trout in this stream based on professional judgment.

4. Werner Creek

Werner Creek does not show any apparent timber harvest activity through 1994. By 2004, a significant amount of the lower watershed had been harvested and the 2004 map shows the extent of the 2001 Werner Fire. No further disturbance is shown on the 2011 map. MFISH reports brook trout and westslope cutthroat trout in this stream based on professional judgment.

5. Taylor Creek

Taylor Creek does not show any apparent timber harvest activity through 1994. By 2004, a significant amount of the lower watershed had been harvested and the 2004 map shows the extent of the 2001 Werner Fire. The 2011 map shows additional timber harvest activity at mid-elevations.
MFISH reports brook trout and westslope cutthroat trout in this stream based on a 1992 FWP survey.

6. Hemlock Creek

The 1987 aerial photo shows a mid-elevation timber harvest unit on Hemlock Creek. No additional activity was observed in the 1994 photo. The 2004 photo shows timber harvest of the lower watershed. MFISH reports westslope cutthroat trout in this stream based on professional judgment.

7. Trail Creek

The 1987 aerial photo shows a mid-elevation timber harvest unit on Hemlock Creek. No additional activity was observed in the 1994 photo. The 2004 photo shows timber harvest of the lower drainage. MFISH reports brook trout and westslope cutthroat trout in this stream based on professional judgment.

8. Anchor Creek

No timber harvest activity is seen until the 2004 photo which shows timber harvest in the lower drainage. MFISH reports brook trout based on professional judgment and westslope cutthroat trout in this stream based on a 2008 DNRC survey.

9. Bear Creek

No timber harvest activity is seen until the 2004 photo which shows a timber harvest in the lower drainage. Brook trout and westslope cutthroat trout inhabit this stream based on a survey by DNRC in 2008.

10. King Creek

No timber harvest activity is seen until the 2004 photo which shows a timber harvest in the lower and mid-elevations of this drainage. MFISH reports brook trout and westslope cutthroat trout in this stream but a 2008 DNRC survey found no fish.

L. LAZY CREEK

1. Background

Lazy Creek is a second order lowland stream that drains 13% of the Whitefish Lake Watershed. The stream enters the northwest corner of Whitefish Lake at Lazy Bay. Lazy Creek has three forks (West, Middle, and East) that originate on Plum Creek land. The stream is aptly named, characterized by relatively slow moving water without much gradient especially in the lowest reach where there is a large wetland complex approximately one mile from Whitefish Lake. For one-half mile before entering Whitefish Lake, the stream flows through private ownership.

Figure 72. Lazy Creek Wetlands.

The Lazy Creek drainage was first extensively logged in the 1930s, including construction of a railroad spur to export timber. The area regenerated following the 1930s harvest and then was re-harvested between 1980 and 2005.

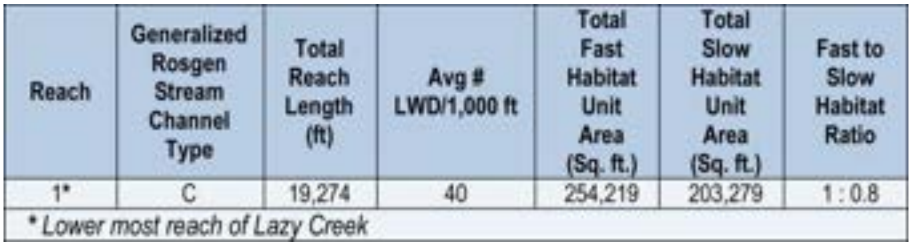
Satellite Imagery Summary

The 1987 Landsat image of the Lazy Creek drainage shows nearly all of the drainage with extensive canopy cover and little sign of recent timber harvest except in the northernmost six sections owned by Plum Creek where harvest units are evident. By 1994, approximately 50% of the timber in the drainage was harvested, and by 2005, nearly all of the timber was harvested on Plum Creek land except for the Streamside Management Zone (SMZ). The 2011 aerial photo shows regeneration of the area with shrubs and young trees.

2. Biological

Fisheries

Deleray (2004) reports brook trout in this stream from presence / absence surveys conducted in the early 1990's. MFISH reports brook trout in both the East Fork and West Fork of Lazy Creek as extrapolated from multiple surveys and observations.



Reach	Generalized Rosgen Stream Channel Type	Total Reach Length (ft)	Avg # LWD/1,000 ft	Total Fast Habitat Unit Area (Sq. ft.)	Total Slow Habitat Unit Area (Sq. ft.)	Fast to Slow Habitat Ratio
1*	C	19,274	40	254,219	203,279	1 : 0.8
* Lower most reach of Lazy Creek						

Figure 73. R1/R4 Fisheries Habitat Summary Data Lazy Creek.

Macroinvertebrates

In 2015, the mayfly assemblage included 7 taxa dominated by individuals in the genus *Drunella* (24 individuals, 4.5% of the assemblage). Only 1 pollutions sensitive taxon was found; however, tolerant organisms composed only 8.7% of the sample. The biotic index value (4.47) was moderately elevated above expectations and the gatherers and filterers were 46% of the functional composition of the assemblage, indicating a moderately tolerant assemblage at this site. These results suggest that water quality was slightly impaired here and that the water quality impairment may be related to nutrient enrichment. There was no evidence of metals contamination. Only 2 cold stenotherm taxa were collected at this site accounting for approximately 3.4% of the invertebrates collected in the sample. The temperature preference of the assemblage was 15.3 °C. Caddisflies were represented by 6 taxa and "clingers" were represented by 18 taxa. These findings suggest that the deposition of fine sediment did not limit colonization in this reach. The FSBI (3.84) indicated a moderately sediment-tolerant assemblage.

Taxa richness (49) was high at this site suggesting that in-stream habitats were diverse and intact. Only 2 stonefly taxa were found in this sample. *Malenka sp*. was the most abundant (13 individuals, 2.5% of the assemblage) with only 1 *Kogotus* (0.2 % of the assemblage) found. Thus slight impacts to riparian zones, channel morphology and/or stream banks cannot be ruled out. Four long lived taxa were collected, suggesting stable instream conditions. Scour, toxic inputs, and thermal extremes seem unlikely. All functional feeding groups were well represented. The dominance of gatherers (31.1%) and filterers (14.9%) suggests the importance of fine particulate organic matter to the energy flow of the system. Interestingly, shredders were 31.8% of the assemblage suggesting that litter fall was extremely important in this system.

3. Habitat

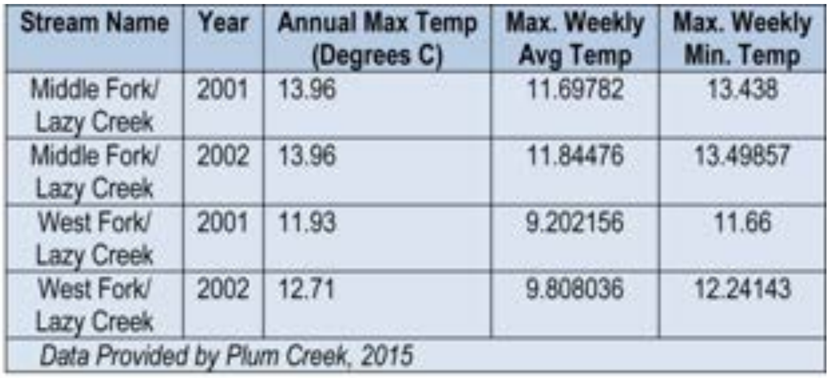
Fisheries Habitat

The instream habitat surveyed in lower Lazy Creek is characterized by a comparatively high proportion of slow habitat types (pools) when compared to other local streams resulting from the low gradient of this stream. The woody debris available to provide fish habitat in the lower reach is limited in supply and comprised mainly of smaller diameter pieces that did not qualify under the survey protocol. From the confluence with Whitefish Lake, Lazy Creek is a C4 channel type with a 0.5% gradient. Willows and alders grow within the active wetted width in many places. From the private/state boundary in Section 6, the woody debris in the stream channel is mainly influenced by decadent alder input.

The stream is still around 0.5% gradient in this area. Upon entering Plum Creek property, the stream is part of a large beaver dam/wetland complex. At the newer concrete bridge, the stream becomes a more typical mountain stream with a gradient from 1-2%. In this reach, a large number of brook trout were observed with active redd construction at the time of the survey (October 5-8, 2006). Above the old bridge crossing in Sec. 31, the stream enters into a long riffle followed by a lower gradient, run habitat type until the end of the survey at the approximate Plum Creek boundary.

4. Water Temperature

2014 continuous temperature data for Lazy Creek can be found in Chapter XXII Addendum C Water Chemistry & Temperature Information. Water temperature peaked on July 7th at 66°F (18.88°C). Water temperature data collected via a Hydrolab from 2007-2013 were within the range for salmonid species and life stages. Additional temperature information from 2001 and 2002 was provided by Plum Creek Timber Company in Figure 74.



Stream Name	Year	Annual Max Temp (Degrees C)	Max. Weekly Avg Temp	Max. Weekly Min. Temp
Middle Fork/ Lazy Creek	2001	13.96	11.69782	13.438
Middle Fork/ Lazy Creek	2002	13.96	11.84476	13.49857
West Fork/ Lazy Creek	2001	11.93	9.202156	11.66
West Fork/ Lazy Creek	2002	12.71	9.808036	12.24143

Data Provided by Plum Creek, 2015

Figure 74. Lazy Creek Stream Temperatures 2001 & 2002.

5. Water Chemistry

Lazy Creek water chemistry summary figures for Total Phosphorus, Total Nitrogen, Total Organic Carbon, and Total Suspended Solids can be found in Chapter XXII Addendum C Water Chemistry & Temperature Information.

Because Lazy Creek is a lower elevation stream, peak flow usually occurs in early April. Correspondingly, the highest nutrient and sediment loading occurs at that time. WLI found that Total Suspended Solids and Total Phosphorus levels were elevated in the 1990s corresponding with timber harvest in the drainage. Currently Total Phosphorus and Total Nitrogen levels meet the Montana Wadeable Streams and Rivers Nutrient Criteria.

Lazy Creek does contribute a relatively high total organic carbon to Whitefish Lake. Total Organic Carbon includes humic substances. Humic substances are the end product of decaying plant matter. According to Cole (1994) humic substances are polymeric mixtures derived mostly from plant matter including lignins, cellulose, proteins and fats. Humic substances are recalcitrant to biological degradation and tend to have low turnover rates in aquatic systems (Wetzel, 2001).

The high organic carbon concentrations in Lazy Creek are due to the slow meandering nature of this stream but mainly influenced by the wetland complex found lower in the drainage. Organic carbon can influence hypolimnetic oxygen consumption in lakes. However, Craft et. al (2003) indicate that dissolved forms of carbon from wetlands are generally not very labile and not good for bacteria in the lake. The study concluded that any hypolimnetic oxygen depletion in Whitefish Lake is a result of allochthonous loading of nutrients stimulating in-lake production of algae, not carbon loading from the Lazy Creek wetlands.

There is a possibility that the organic carbon loading could have a localized affect to dissolved oxygen levels in the immediate Lazy Bay area, however, this has not been documented. According to Wetzel (2001), lakes highly stained with humic organic compounds are frequently under-saturated even in the epilimnetic strata and whereas many mechanisms can be involved, at least some of the oxygen uptake results from purely chemical oxidations and from photochemical oxidations induced by ultraviolet light.

M. BRUSH CREEK

1. Background

Brush Creek is a low elevation first order stream originating on the Stillwater State Forest before flowing through private ownership near Whitefish Lake at Brush Bay.

Satellite Imagery Summary
No evidence of landscape disturbance in seen in the Landsat image for this stream.

No biological, habitat, or water chemistry information exists for this stream.

N. SMITH CREEK

1. Background

Smith Creek is a second order stream that originates in the Whitefish Range on USFS property before flowing through Plum Creek and private land before it enters Smith Lake. Below Smith Lake, the stream flows through the Stillwater State Forest until right before it enters Whitefish Lake, where there is a small reach of private ownership.

Satellite Imagery Summary
Smith Creek shows some disturbance activity in the upper watershed in 1984 without any further disturbance seen in the 1994 image. By 2004, timber harvest units appear at mid-elevation and were expanded as observed in the 2011 image.

2. Biological

Fisheries
Although no fish surveys have been conducted on this stream, MFISH reports brook trout and westslope cutthroat trout based on professional judgment. A survey by Koopal at WLI in 2014 found westslope cutthroat from Smith Lake moving into the Smith Creek inlet reach during the spawning season, providing evidence that some natural recruitment from stocked fish takes place in the system. No habitat data exists for this stream other than stream temperatures from 2014, found in Chapter XXII Addendum C Water Chemistry and Temperature Information.

Historic “stocking” activities were conducted by the Whitefish Rod and Gun Club in the early 1940s. According to a 1942 Whitefish Pilot article, member sportsmen constructed a boom and brush breakwater to push approximately 20,000 small fish from a Smith Lake rearing pond to Whitefish Lake. Above Smith Creek, logs were rolled into the lake and chained to a boom. Small brush was piled behind the boom to create a habitat for the small fish to hide from larger fish and anglers (Schafer and Engelter, 2003).

Macroinvertebrates

In 2015, a fairly diverse mayfly fauna of 8 taxa were sampled at this site. These taxa were dominated by *Baetis tricaudatus* (27 individuals, 6.1% of the assemblage); however, they did include several specimens of *Drunella spinifera* (10 individuals, 2.3% of the assemblage), a pollution sensitive and cold stenotherm species. A biotic index value of 3.67, a percentage of tolerant taxa of 4.5%, and the presence of 5 sensitive taxa in the sample suggests a relatively intolerant assemblage. These results suggest good water quality at this site. However, collectors composed 67.3% of the assemblage indicating that fine particulate matter was also prevalent at the site. There was no evidence of metals contamination. Four cold stenotherm taxa were collected accounting for approximately 6.3% of the invertebrates collected in the sample. The temperature preference of the assemblage was 12.9 °C. Caddisflies were well represented by 8 taxa and “clingers” were represented by 22 taxa. These findings suggest that the deposition of fine sediment did not limit colonization in this reach. The FSBI (4.16) suggests a moderately sediment-intolerant assemblage.

Taxa richness (46) was high at this site suggesting a complex in-stream habitat this is intact. At least 5 stonefly taxa, including both predators and shredders, were recorded from this site, thus riparian zones, channel morphology and stream banks were probably in good condition. Six semi-voltine taxa were collected, suggesting stable in-stream conditions. Thus, it seems unlikely that catastrophes such as scour-inducing floods, occasional release of toxins, or wide temperature variations occur. All functional feeding groups were well represented with the dominant groups being the gatherers (43.2%) and filterers (24.1%) suggesting the importance of fine particulate organic matter to the energy flow of the system. In addition, shredders were abundant (11.0%) suggesting ample inputs of streamside vegetation.

3. Water Chemistry

WLI started collecting water chemistry information on Smith Creek in 2008. Smith Creek water chemistry summary figures for Total Phosphorus, Total Nitrogen, Total Organic Carbon, and Total Suspended Solids can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. Lower Smith Creek flows are largely buffered by Smith Lake. As a result, chemistry concentrations are fairly consistent throughout the year. There are a few relatively high Total Suspended Solids concentrations but are suspected to correlate with rain events. Smith Creek results for Total Phosphorus and Total Nitrogen, with the exception of one sample, fall within the proposed Montana Wadeable Streams and Rivers Nutrient Criteria.

4. Water Temperature

2014 continuous temperature data for Smith Creek can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information, and shows the peak temperature at 72°F on August 2nd. Water temperature data from 2007-2013 were within the range for salmonid species and life stages.

O. HELLROARING CREEK

1. Background

Hellroaring Creek is a third order stream that drains 2.5% of Whitefish Lake watershed. The stream originates on USFS land in the Whitefish Range and within the skiable *Hellroaring Basin* boundaries of Whitefish Mountain Resort. In the lower one mile reach it flows through private ownership before entering Whitefish Lake at Hellroaring Point.

Figure 75. Hellroaring Creek Near the Confluence with Whitefish Lake.

Satellite Imagery Summary
Hellroaring Creek shows some timber harvest activity in the upper watershed in 1984 without any further disturbance seen in the 1994 image. By 2004, private residential development is seen expanding west of the ski resort and a clearing of private land just east of East Lakeshore Drive. The clearing of land on private property led to high turbidity documented in 2006 during storm events. As a result, the landowner received a stormwater violation fine and was subject to remedial action by the DEQ.

2. Habitat

Fisheries
No biological or habitat information exists for this stream. Hellroaring Creek maintains cold temperatures with relatively little fluctuation. This stream should be surveyed for fish distribution with a corresponding genetic analysis.

Macroinvertebrates
In 2015, twelve mayfly taxa, the highest among all the sites, were found in this sample. The mayflies were dominated by the heptageniids *Rhithrogena sp.* (89 specimens, 21.3% of the assemblage), *Epeorus grandis* (16 specimens, 3.8% of the assemblage; a cold stenotherm and pollution sensitive species) and *Cinygmula sp.* (14 speciments, 3.4% of the assemblage). The extremely low biotic index value (1.03), the high number of sensitive taxa (19), and no tolerant taxa in this sample suggest an extremely intolerant assemblage. Of the functional feeding groups, collectors composed only 12.7% of the assemblage. All of these results suggest excellent water quality at this site. The low MTI (1.55) suggests no metals contamination. The largest number of cold stenotherm taxa (15), composing almost 37% of the assemblage, were found at this site. As expected given the relative abundance of cold stenotherms, the temperature preference of the assemblage was only 10.8°C, the

lowest of all the sites. There were 8 caddisfly taxa and 29 “clinger” taxa (tied for the highest number among all the sites). Consequently, the deposition of fine sediment appears to not limit colonization in this reach. Given an FSBI of 5.41, the assemblage appears to be moderately sediment-intolerant.

An intact, complex in-stream habitat is suggested by the high taxa richness (53) at this site. In this sample there was an extremely diverse group of stonefly taxa (11) with both shredder and predator functional feeding groups and some cold stenotherm and pollution sensitive taxa collected. Thus impacts to riparian zones, channel morphology and stream banks seem unlikely. Five long-lived taxa were collected, suggesting stable instream conditions where flood-induced scour, inputs of toxins, and widely varying temperatures seem unlikely. All functional feeding groups were well represented in this sample with scrapers (47.1%) and shredders (24.4%) dominating.

3. Water Chemistry

WLI started collecting water chemistry information on Hellroaring Creek in 2008. Hellroaring Creek water chemistry summary figures for Total Phosphorus, Total Nitrogen, Total Organic Carbon, and Total Suspended Solids can be found Chapter XXII Addendum C Water Chemistry and Temperature Information. Peak flow usually occurs in early in late May/early June. Correspondingly, the highest nutrient and sediment loading occurs at that time. Hellroaring Creek Results for Total Phosphorus and Total Nitrogen fall within the proposed Montana Wadeable Streams and Rivers Nutrient Criteria.

4. Water Temperature

2014 continuous temperature data for Hellroaring Creek can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. Water temperature peaked on August 2nd, 5th, and 13th at 54F. Water temperature data from 2007-2013 show this stream is consistently cold and within the range for salmonid species and life stages.

P. EAGLE CREEK

1. Background

Eagle Creek is a small ephermeral stream located between Smith Creek and Hellroaring Creek.

Figure 76. Eagle Creek Near East Lakeshore Drive.

Satellite Imagery Summary
No landscape disturbance is seen in the Eagle Creek drainage other than limited residential development.

2. Biological

No biological, habitat, or water chemistry information exists for this stream.

Q. BEAVER CREEK

1. Background

Beaver Creek is a second order stream that originates from Beaver Lake either through surface or hyporheic flow depending on Beaver Lake elevation levels. The stream flows east through private ownership from Beaver Lake to a small impoundment to the west of the BNSF railroad grade. Originally, a railroad trestle spanned Beaver Bay with the stream flowing underneath but the trestle was later replaced with an earthen impoundment. The stream exits the impoundment via a culvert and is conveyed through the railroad grade to a very short stream reach before it enters Whitefish Lake at Beaver Bay.

Satellite Imagery Summary
Beaver Creek does not show any disturbance activity until 2004 when it appears there were small timber harvest units to the south of Beaver Lake and private residential development primarily to the north of Beaver Creek. Private residential development slightly expanded in the 2011 image. Beaver Creek enters the lake at Beaver Bay on the west shore below the train tracks and a small human-made holding pond as seen in Figure 77.

Figure 77. Beaver Bay With Beaver Creek & Holding Pond.
Photo Courtesy gravityshots.com.

2. Biological

No biological or habitat information exists for this stream other than stream temperature from 2014, found in Chapter XXII Addendum C Water Chemistry and Temperature Information.

Macroinvertebrates
In 2015, low mayfly taxa richness (1, *Baetis tricaudatus*) and an elevated biotic index (5.25) suggest that water quality was impaired in this reach. There were no sensitive taxa collected and relatively tolerant organisms (35.1%), including the caddisfly *Cheumatopsyche sp.* (27.9%), were abundant at this site. The functional composition of the assemblage was strongly dominated by gatherers and filterers (84.5%): a pattern that is sometimes interpreted as evidence of water quality impairment. The taxonomic composition of the assemblage suggests nutrient enrichment in this reach. Although the MTI was high (4.49), it was not higher than the biotic index (5.25) thus, little evidence for metals contamination was found. Only 1 caddisfly taxon and 6 “clinger” taxa were present in this sample: both fewer than expected. The FSBI was 2.59 indicating that the taxa were fine sediment tolerant. These findings suggest that sediment deposition may have limited colonization of the stony substrate habitats.

Taxa richness (30) was moderate at this site, but the second lowest of all the sites examined in this study, thus impacts to in-stream habitats cannot be ruled out. The sample contained only 1 stonefly taxon, the nemourid, *Malenka* sp. Low stonefly diversity may indicate disturbed reach-scale habitat features. Only two long-lived taxa were present, thus periodic thermal extremes, dewatering, or toxic pollutants cannot be ruled out in this reach. The domination of the assemblage by filterers (61.1%) and gatherers (23.5%) may indicate water quality impairment and that fine organic particulates were an important energy source in this reach.

3. Water Chemistry

WLI started collecting water chemistry information on Beaver Creek in 2013. Beaver Creek water chemistry summary figures for Total Phosphorus, Total Nitrogen, Total Organic Carbon, and Total Suspended Solids can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. Because of the buffering effect of the BNSF impoundment, stream volume does not widely fluctuate at the sample site. Total Suspended Solids concentrations are low as a result and Total Phosphorus concentrations are below Montana Wadeable Streams and Rivers Nutrient Criteria. Conversely, Total Organic Carbon levels are slightly elevated form increased water contact time with the landscape in Beaver Lake and the BNSF impoundment.

All Total Nitrogen concentrations do not meet the Montana Wadeable Streams and Rivers Nutrient Criteria. The reasons for the high Total Nitrogen concentrations in Beaver Creek need to be further investigated, starting with a longitudinal synoptic sampling of the stream and determining the dynamics of the BNSF impoundment. Total Nitrogen loading from Beaver Creek can affect primary production in this area of Whitefish Lake where nitrogen limitation or co-limitation with phosphorus is often observed (see Whitefish Lake Mid-Lake 1987-2014 Molar TN:TP Ratio in Figure 111).

4. Water Temperature

2014 Continuous temperature data for Beaver Creek can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. Water temperature peaked on July 76th and August 2nd at 76F. There is a warming effect from the BNSF impoundment on the west side of the railroad tracks. Temperatures reached were stressful to salmonids but no fish have been observed in this short reach of the stream. This stream should have a westslope cutthroat trout genetic survey to determine if a pure strain exists.

R. VIKING CREEK

1. Background

Viking Creek is the unofficial name of this second order stream that flows into Whitefish Lake at Monk’s Bay. The North Fork of Viking Creek flows from the City of Whitefish Water Treatment Plant with source water originating from Haskill Basin. The Middle and South Fork of Viking Creek originate in the Battin Nature Conservancy Easement before entering WLI’s Averill’s Viking Creek Wetland Preserve. From Wisconsin Avenue, the stream is conveyed to Whitefish Lake via a long (approximately 550 feet) culvert.

Viking Creek is significantly influenced by groundwater and the City of Whitefish Water Treatment Plant which discharges overflow water from the reservoir to the stream. In addition, to maintain disinfecting cartridge equipment, the Whitefish Water Treatment Plant discharges water at varied times from a holding pond according to its NPDES permit. Additional information on the Whitefish Water Treatment Plant can be found in Chapter XIV Municipal Water Infrastructure & Treatment.

Satellite Imagery Summary

By 1984, the Viking Creek drainage had disturbance activity mainly related to residential development with slow expansion shown in 1994. By 2004 a private timber harvest unit is seen on the north end of the property that WLI is now restoring. Gradual residential expansion continued as observed in the 2011 image.

2. Biological

Fisheries

In 2015, a project coordinated by WLI and in partnership with FWP and Project FREEFLOW found brook trout in the lower reach of this stream on WLI property and on the Battin property.

Macroinvertebrates

In 2015, only 5 mayfly taxa were collected at this site and their abundance was low (only 17 individuals, < 4% of the total individuals in the sample). None of the mayfly taxa were sensitive taxa. Tolerant organisms composed 7.4% of the assemblage in line with the moderately high biotic index value (5.08). Interestingly, the only sensitive taxon found in the sample was the chironomid, *Heterotrissocladius sp.*, which was very abundant (42 specimens and slightly < 10% of the overall invertebrate abundance at the site). The assemblage was dominated by the filterer and gatherer functional feeding groups (71.2%). The dominance of the filterer and gatherer functional feeding groups and the elevated biotic index suggest that water quality is impaired at this site and the impairment could result from nutrient enrichment. There was no evidence of metals contamination. Only one cold stenotherm taxon was found in the sample. The temperature preference of the assemblage was 15.1 °C. Fine sediment probably limits colonization of invertebrates at this site because only 2 caddisfly taxa and 9 “clinger” taxa were found. The low FSBI (1.96) also supports this contention.

Taxa richness was high (46) indicating that in-stream habitats were probably diverse and intact. The only 2 stonefly taxa collected from this site were two nemourids (*Malenka* sp. and *Zapada cinctipes*) suggesting that intact riparian zones did contribute appreciable amounts of leafy and woody material to the stream. However, the low stonefly diversity suggests that there may be some impact to channel morphology and stream banks. In-stream conditions were probably stable as 6 semi-voltine taxa were collected, making it unlikely that periodic disruptions like flood-related scour, toxic inputs, and thermal variation occurred. The dominance of gatherers (47.7%) and filterers (23.5%) suggests that fine particulate organic matter was an important component of the energy flow of the system. In addition, shredders were abundant (14.3%) again suggesting ample inputs of streamside vegetation.

3. Habitat

No habitat surveys exist for this stream. In the lower reach, Viking Creek is a low gradient stream and the channel has cut through pro-glacial lacustrine sediment. Limited, but available pockets of spawning gravel exist.

4. Water Chemistry

WLI started collecting water chemistry information on Viking Creek in 2007. Viking Creek water chemistry summary figures for Total Phosphorus, Total Nitrogen, Total Organic Carbon, and Total Suspended Solids can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. It is estimated that this lowland stream would probably contain peak flow in late April or early May but the hydrograph is influenced by the Whitefish Water Treatment Plant where spillage from the reservoir coincides with the peak flow from Haskill Creek. Water chemistries correspond to the varied flow input from the water treatment plant.

The stream's chemical constituents also seem to be influenced by the water treatment plant's NPDES permit where backflush water used to clean cartridge media is stored in a concrete reservoir to meet turbidity standards before it is discharged into Viking Creek. The conveyance of this discharge involves approximately 150 gallons per minute over the course of four hours, but this can increase with backwash demand (when more lake water is being used). As a result, Viking Creek can see rapid fluctuation in stream level over a short time period resulting in increased Total Suspended Solids and nutrients. Total Nitrogen and Total Phosphorus values exceeded the Montana Wadeable Streams and Rivers Nutrient Criteria on two occasions.

5. Water Temperature

2014 continuous temperature data for Viking Creek can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. Water temperature peaked on July 13th at 63°F. Water temperature data from 2007-2013 were within the range for salmonid species and life stages.

XI. UPPER WHITEFISH RIVER DRAINAGE

A. INTRODUCTION

In the geographic scope of this study, there are three tributaries inputs (Cow, Haskill, and Walker Creeks) to the Upper Whitefish River. There is also effluent from the Whitefish Water Treatment Plant and from various stormwater conveyances (see Chapter XIV Section B Stormwater for additional information). Figure 78 displays the contributory tributary loads to the Upper Whitefish River. Although small, Cow Creek transports a high phosphorus and nitrogen load to Whitefish Lake and is clearly degraded from past and present land use practices including channelization and livestock use. Walker Creek also shows high nutrient values and flows through agricultural and residential areas. Past stream restoration efforts on Haskill Creek, which flows through agricultural lands in the lower reach, have reduced sediment input and phosphorus loading.

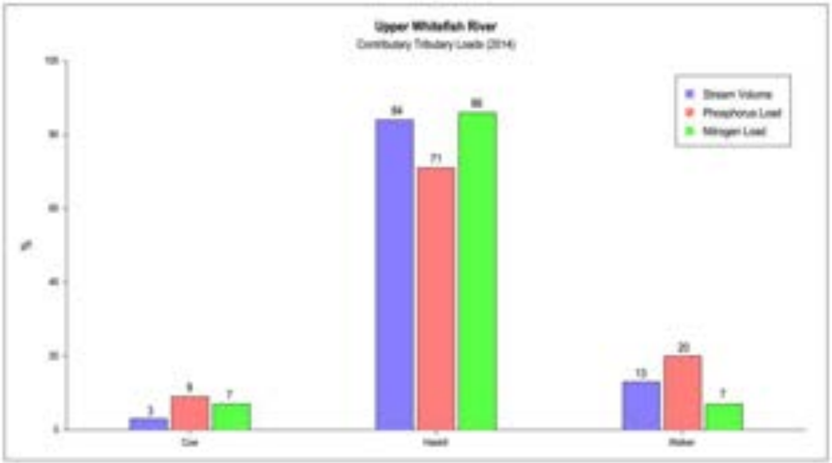


Figure 78. Tributary Loads, Upper Whitefish River, 2014.

B. UPPER WHITEFISH RIVER

1. Background

The uppermost reach of the Whitefish River flows from the Whitefish Lake outlet for approximately 2.5 miles through Whitefish City limits. After city limits, it transitions through a private property mix of residential and agricultural use until the Highway 40 Bridge. Beyond the Highway 40 Bridge is outside the scope of this study.

Whitefish Lake buffers the discharge conveyed to the Whitefish River during the peak of the hydrograph and during storm events. Relyea (2005) reports that this buffering effect yields less erosional and depositional activity resulting in less floodplain development along the main channel. In other words, the water in the channel tends to stay in the channel with little lateral exchange. In addition, the buffering effect of Whitefish Lake and the low valley gradient make this river susceptible to impacts from increased sediment loading from its inability to transport material.

Satellite Imagery Summary

By 1987, the Landsat image shows that the upper Whitefish River had extensive urban and agriculture use, with an expansion of urban area and a decrease of agricultural area by 2011.

2. Biological

Fisheries

MFISH reports brook trout, bull trout, rainbow trout, westslope cutthroat trout, largescale sucker, longnose sucker, mountain whitefish, northern pike, northern pikeminnow, peamouth chub, redside shiner, and slimy sculpin in the Whitefish River based on professional judgment. A genetic sample targeting westslope cutthroat trout in 2001 showed 98.20% rainbow trout and 1.8% westslope cutthroat trout from a sample of 15 fish.

Macroinvertebrates

In 2015, only 4 mayfly taxa, dominated by the baetid *Acerpenna pygmaea* (40 specimens, 8.1% of the assemblage) were found at this site. The biotic index value (7.02) was elevated above expectations and the highest of any site in this study. Tolerant organisms composed 40.2% of the assemblage and only 1 sensitive taxon, the chironomid, *Heterotrissocladius sp.*, represented by 1 specimen, was collected. Collectors were 81.3% of the functional feeding composition of the assemblage. The dominance of the filterer and gatherer functional feeding groups and the elevated biotic index suggest that water quality is impaired at this site and the impairment may result from nutrient enrichment. The high relative abundance of hemoglobin-bearing organisms (11.2%), including several hemoglobin-bearing midges (e.g., *Microtendipes sp.* (2.8%), *Ablabesmyia sp.* (2.4%)), suggests that hypoxic substrates may be present at this site.

There was no evidence of metals contamination. No cold stenotherm taxa were collected at this site. The temperature preference of the assemblage was 18.3 °C, the highest among all the sites. There were 3 caddisfly taxa and only 3 "clinger" taxa found in the sample, suggesting that fine sediment limits colonization in this reach. The FSBI (3.57) indicated an assemblage with moderate tolerance to fine sediment deposition.

The data indicated that in-stream habitats were intact and probably diverse because taxa richness was moderately high (37). No stonefly taxa were found in this sample indicating impacts to channel morphology and stream banks. Only 1 long-lived taxon was collected, indicating that scour, toxic inputs, and thermal extremes could not be ruled out as impacts in this reach. The functional feeding groups were dominated by gatherers (62.9%) and filterers (18.7%) suggesting the importance of fine particulate organic matter to the energy flow of the system.

3. Habitat

No habitat information exists for this stream. However, the river is low gradient with high amounts of fine sediment.

4. Water Chemistry

From the lake outlet to the end of the project area, the Whitefish River is subject to inputs from groundwater, tributaries, stormwater and the City of Whitefish Sewage Treatment Plant point discharge. This sampling site is near the outlet of Whitefish Lake to account for lake export. WLI started collecting water chemistry information on Whitefish River in 2009. Whitefish River water chemistry summary figures for Total Phosphorus, Total Nitrogen, Total Organic Carbon, and Total Suspended Solids can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. Results for Total Phosphorus and Total Nitrogen fall within the Montana Wadeable Streams and Rivers Nutrient Criteria.

Downstream of the WLI sampling location on the Whitefish River, Relyea (2005) reported that the Whitefish Wastewater Treatment Plant during the 2003/4 water year discharged between 0.5 to 4% of the total discharge of the river. The report noted the disproportionately high degree of influence this effluent has on the river can be explained by the oligotrophic nature of the river source. The WWTP is a secondary treatment plant with a tertiary treatment process to remove phosphorus through the use of a flocculating clarifier. Some practical improvements are possible to upgrade the existing system to a tertiary treatment capable of removing both phosphorus and nitrogen. Land application of a portion of the plant’s effluent flow may also be viable. In 2007, WLI presented information to the Whitefish City Council from independent testing related to the release of petroleum products into the Whitefish River via a series of seeps along the shoreline near Town Pump. In that presentation, the chemical analysis of benzene leaking into the Whitefish River was shown to be 39 times the Maximum Contaminant Level for drinking water.

That presentation prompted an August 13th, 2007 letter from the City Council to DEQ urging prompt attention to this issue. DEQ’s response was that they have known about this problem since January 2003. The DEQ letter states that “although there have been delays in investigating the cause of the seep and designing corrective measures, this work is progressing at an acceptable rate.” Full remediation is still pending for this site.

5. Water Temperature

2014 continuous temperature data for the upper Whitefish River can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. Water temperature peaked on August 6-7th at 75°F. Water temperature data from 2009-2013 often show temperatures in the 70s°F which can stress salmonid species and life stages. The Upper Whitefish River temperature is affected by the release of warm epilimnetic water from Whitefish Lake.

C. COW CREEK

1. Background

Figure 79. Cow Creek Near High Point on 2nd Estates.

Cow Creek is a second order tributary to the Whitefish River approximately four miles downstream of Whitefish Lake and found entirely on private land comprised of a mix of agricultural and residential use.

There are also multiple stormwater discharges into this stream. Relyea (2005) reported that for the 2003/4 water year, the stream contributed 1% of the Whitefish River volume.

Satellite Imagery Summary
By 1987, the Landsat image shows that Cow Creek, just like the upper Whitefish River, had extensive urban and agriculture use, with an expansion of urban area and a decrease of agricultural area by 2011.

2. Biological

Fisheries
MFISH reports brook trout and rainbow trout in this stream based on professional judgment. In 2015, a project coordinated by WLI involving FWP and Project FREEFLOW found only longnose suckers and fathead chubs in the reach of the stream just south of the railroad tracks.

Macroinvertebrates
In 2015, the mayfly taxa richness was very low (1, *Baetis brunneicolor*) and the biotic index was very high (6.97) at this site. No sensitive taxa were collected and tolerant organisms (87.1%) dominated the assemblage at this site. The functional composition of the assemblage was strongly dominated by gatherers and filterers (78.1%). All of these factors suggest that water quality was impaired at this site perhaps through nutrient enrichment. Although the MTI was high (4.19), it was not higher than the biotic index (6.97) thus, little evidence for metals contamination was found. No cold stenotherm taxa were encountered in the sample. The temperature preference of the assemblage was 16.4°C. Only 1 caddisfly taxon and 5 “clinger” taxa were present in this sample: both fewer than expected. The FSBI was 2.43 indicating that the taxa were fine sediment tolerant. These findings suggest that sediment deposition may have limited colonization of the stony substrate habitats.

Although taxa richness (28) was moderate, it was the lowest among all the sites in this study, thus impacts to in-stream habitats cannot be ruled out. The sample contained only 1 stonefly taxon, the nemourid, *Malenka* sp., at very low abundance (2, 0.4% of the assemblage). Low stonefly diversity may indicate disturbed reach-scale habitat features. Four long-lived taxa were collected, suggesting stable instream conditions where flood-induced scour, dewatering, and thermal extremes seem unlikely. The domination of the assemblage by filterers (6.2%) and gatherers (72.0%) probably indicate that fine organic particulates were an important energy source in this reach. Shredders were relatively abundant (16.8%) suggesting ample inputs of streamside vegetation.

3. Habitat

No habitat information exists for this stream. It is a low gradient stream with high amounts of fine sediment.

4. Water Chemistry

WLI started collecting water chemistry information on Cow Creek in 2014. Cow Creek water chemistry summary figures for Total Phosphorus, Total Nitrogen, Total Organic Carbon, and Total Suspended Solids can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. All results for Total Phosphorus and Total Nitrogen exceed the Montana Wadeable Streams and Rivers Nutrient Criteria. There is high density livestock use of the stream and riparian area.

5. Water Temperature

2014 continuous temperature data for Cow Creek can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. Water temperature peaked on August 13th at 77F which can stress salmonid species and life stages.

D. HASKILL CREEK

1. Background

The Haskill Basin covers approximately 8,200 acres (12.8 mi^2) in the southwestern flank of the Whitefish Mountain Range of which 28% is owned by F. H. Stoltze Land & Lumber, 26% is owned by private landowners, 41% is U.S. Forest Service owned, and just under 6% is State of Montana/BNSF/and other owners. Five headwaters tributaries originate two miles northeast of the City of Whitefish in the Whitefish Mountains converging to form Haskill Creek. The three main tributaries are First Creek, Second Creek, and Third Creek with two minor tributaries being Fourth and Fifth Creeks. The headwaters of First, Second, Third, and Fourth Creeks begin on USFS land including a portion of the Whitefish Mountain Ski Resort. The stream flows through a section of state school trust land at the confluence of Fourth Creek.

Haskill Creek is a third order stream that flows approximately 11 miles to its confluence with the Whitefish River. Elevation in the basin ranges from 6,900 feet on Big Mountain in the Whitefish Mountain Resort to 3,000 feet at the confluence with the Whitefish River. (Flathead Conservation District, 2015 and River Design Group, Inc, 2007). Relyea (2005) reported that for the 2003/4 water year, the stream contributed up to 20% of the volume to the Whitefish River during its peak flow in mid-April. The majority of ownership at mid-elevation is F.H. Stoltz. In the valley bottom, land is comprised of agricultural and residential use before its confluence with the Whitefish River.

Figure 80. Haskill Creek Culverts on Monagan Road.

As noted in Section XIV Municipal Water Infrastructure & Treatment, Section A. Drinking Water & Consumptive Water Use, Second and Third Creeks are currently the primary source of municipal water for the City of Whitefish. Land use in the upper and middle portions of the basin is dominated by recreational use (Winter Sports Incorporated) and timberlands (F. H. Stoltze Land & Lumber Co.). Evergreen, deciduous, mixed forest cover types dominate about 44% of the basin, with commercial and urban developments associated with Big Mountain and Glacier Village comprising about 22% of the area and largely confined to the First and Second Creek drainages (River Design Group, 2007).

Silviculture in the upper watershed led to the start of the resort area. Timber and salvage harvesting then occurred as a result of ski run development, including slashing, trampling, and piling and burning trees (River Design Group, 2007). In the late 1950s and 1960s, timber was harvested on the north slope in response to a spruce bark beetle epidemic (U.S. Department of Agriculture Soil Conservation Service, 1995), and regeneration and salvage harvests were applied. Previously harvested areas are now dominated by spruce, subalpine fir, huckleberries and alder. Timber harvest activities are now confined to residential developments in the First Creek headwaters area, and silviculture continues in the middle portion of the Watershed. The lower valley sees mixed crop, pasture and other agriculture with residential developments. In recent years, sediment from point and non-point sources has increased throughout Haskill Basin due to anthropogenic modifications such as land cover disturbance, stream straightening, floodplain encroachment, and residential and commercial development (Kurth, 2015).

Streamflow in the Basin is highly variable, both seasonally and annually, and municipal water demands often exceed natural streamflow during summer months resulting in stream dewatering.

Satellite Imagery Summary

By 1987, the upper Haskill Basin (First Creek) showed the build out of the ski resort and the lower reach had been converted to agricultural use by that time. The 1994 image shows a timber harvest unit at the base of Third and Fourth Creeks and expansion of the base area at the ski resort. In 2004, continued resort expansion occurred with private development. In addition, a timber harvest unit is seen between the Second and Third Creek drainages which showed expansion in the 2011 photo.

2. Biological

Fisheries

MFISH reports brook trout and westslope cutthroat trout in this stream based on multiple surveys. Historically, Haskill Creek likely supported westslope cutthroat and bull trout populations, and a genetic sample collected in 2001 from a sample of 25 fish found a 100% pure strain westslope cutthroat trout population inhabiting the middle portion of the Creek. The 2001 fish survey suggested that non-native brook trout are currently widely distributed and well established in the Haskill Creek System. A genetic sample of 30 fish in 2007 found 99.1 % westslope cutthroat trout and rainbow trout introgression of 0.9%

Macroinvertebrates

In 2015, the mayfly assemblage was fairly diverse: 9 mayfly taxa (including at least 5 taxa of Baetidae) were found in the sample and no one taxon dominated the mayfly assemblage. Only 2 sensitive taxa were found and both were Chironomidae (*Cricotopus (Nostococladius) nostocicola* and *Heterotrissocladius sp.*). The biotic index value (4.68) was moderately elevated above expectations, tolerant organisms were abundant (40%), and the collectors and filterers were 38% of the functional composition of the assemblage, indicating a moderately tolerant assemblage at this site.

These results suggest that water quality was mildly impaired here and that the water quality impairment may be related to nutrient enrichment. Although the high value of the MTI (4.56) could suggest metals contamination, the presence of heptageniid mayflies combined with a MTI value that was not higher than the biotic index value (4.68) provides no evidence for metals contamination. Only 1 cold stenotherm taxon was collected at this site accounting for only approximately 1% of the invertebrates collected in the sample. The temperature preference of the assemblage was 16.1 °C. Caddisflies were represented by 8 taxa and “clingers” were represented by 19 taxa.

These findings suggest that the deposition of fine sediment did not limit colonization in this reach. The FSBI (3.22) indicated a moderately sediment-tolerant assemblage.

Taxa richness (64) was very high at this site, the highest among the samples, suggesting that in-stream habitats were diverse and intact. At least 4 stonefly taxa, including both predators and shredders, were recorded from this site, thus riparian zones, channel morphology and stream banks were probably in good condition. Eight semi-voltine taxa were collected, suggesting stable instream conditions. Scour, toxic inputs, and thermal extremes seem unlikely. All functional feeding groups were well represented. The relative abundance of gatherers (23.9%) and filterers (13.8%) suggests the importance of fine particulate organic matter to the energy flow of the system. Interestingly, scrapers were 42.5% of the assemblage suggesting that autochthonous production was as important to the system as the particulate organic matter.

3. Habitat

Habitat No habitat inventories have been conducted for this stream. MFISH notes that past channel straightening and riparian clearing have impaired stream conditions and increased sediment supply to the stream.

4. Water Chemistry

WLI started collecting water chemistry information on Haskill Creek in 2014. Haskill Creek water chemistry summary figures for Total Phosphorus, Total Nitrogen, Total Organic Carbon, and Total Suspended Solids can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. All results for Total Phosphorus and Total Nitrogen fall within the Montana Wadeable Streams and Rivers Nutrient Criteria.

5. Water Temperature

2014 temperature information can be found in Appendix X. Maximum temperature peaked on August 2nd, 3rd, 5th, and 13th at 66°F, within the range for salmonid species and life stages.

E. WALKER CREEK

1. Background

Walker Creek is a first order lowland tributary to the Whitefish River approximately 5 miles from the Whitefish Lake outlet found entirely on private land. Relyea (2005) reported that for the 2003/4 water year, the stream contributed 3% of the Whitefish River volume.

Figure 81. Walker Creek Near High Flow, 2014.

Satellite Imagery Summary

The 1987 Landsat image shows a small timber harvest unit in the upper part of the drainage with more harvest units shown at mid-elevation. The lower reach of Walker Creek had been converted to agriculture and residential development by that time. In 1994 the harvests units in the upper and mid drainage were slightly expanded. No discernible harvest units are seen in the 2004 and 2011 images with regeneration occurring and residential development slightly increasing.

2. Biological

Fisheries

In 2015, a project coordinated by WLI involving FWP and Project FREEFLOW found brook trout in the lower reach of this stream.

Macroinvertebrates

Six mayfly taxa were found in the 2015 sample; however, none of the taxa were very abundant and none of them were cold stenotherm or pollution sensitive taxa. The biotic index value (5.27) was elevated above expectations and tolerant organisms composed 23.5% of the assemblage. Only 1 sensitive taxon was found, the chironomid *Heterotrissocladius sp.*, and collectors were 57.9% of the functional feeding composition of the assemblage. These results suggest a moderately tolerant assemblage indicative of water quality impairment. Hemoglobin-bearing organisms, including several hemoglobin-bearing midges (e.g., *Microtendipes sp.* (5.5%), *Ablabesmyia sp.* (2.5%)), were 14.2% of the assemblage suggesting that hypoxic substrates may be present at this site.

The elevated biotic index combined with the suggestion of hypoxic substrates suggests that the water quality impairment may be related to nutrient enrichment. The MTI (3.52) suggest no metals contamination. No cold stenotherm taxa were collected at this site. The temperature preference of the assemblage was 16.4 °C. There were 4 caddisfly taxa and 15 “clinger” taxa in the sample. These findings are inconclusive about whether or not the deposition of fine sediment limits colonization in this reach. However, the FSBI (2.91) indicated that the assemblage maybe dominated by taxa tolerant to fine sediment.

The data indicated that in-stream habitats were intact and probably diverse because taxa richness was high (49). Three stonefly taxa were found at this site including two nemourids (*Malenka* sp. and *Zapada cinctipes*) and one specimen of perlodid. These results suggest that riparian zones contribute appreciable amounts of leafy and woody material to the stream; however, the low number of stonefly taxa indicates that impacts to channel morphology and stream banks could not be ruled out. Six long-lived taxa were collected, suggesting stable in-stream conditions. Scour, toxic inputs, and thermal extremes seem unlikely. All functional feeding groups were well represented with the dominant groups being the gatherers (20.5%) and filterers (37.4%) suggesting the importance of fine particulate organic matter to the energy flow of the system. In addition, shredders were abundant (9%), again suggesting ample inputs of streamside vegetation.

3. Habitat

No habitat information exists for this stream. The stream is low gradient with high amounts of fine sediment.

4. Water Chemistry

WLI started collecting water chemistry information on Walker Creek in 2014. Walker Creek water chemistry summary figures for Total Phosphorus, Total Nitrogen, Total Organic Carbon, and Total Suspended Solids can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. All results for Total Phosphorus and Total Nitrogen fall within the Montana Wadeable Streams and Rivers Nutrient Criteria except for one Total Nitrogen sample.

5. Water Temperature

2014 continuous temperature data for Walker Creek can be found in Chapter XXII Addendum C Water Chemistry and Temperature Information. Water temperature peaked on July 17th at 75F which can stress salmonid species and life stages.

XII. WHITEFISH LAKE

A. INTRODUCTION

This chapter describes the physical, chemical and biological conditions of Whitefish Lake (Figure 82). Background information for the lake can be found in Chapter II Project Area.

B. PHYSICAL PROPERTIES

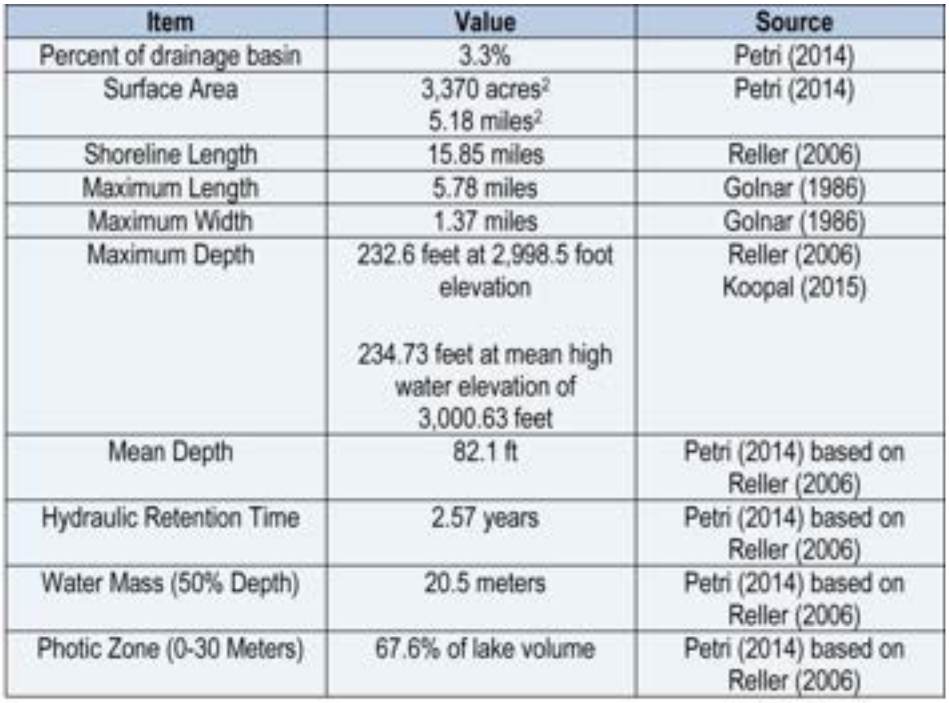
The geology of the Whitefish Watershed is largely composed of the Piegan group belt series (42%) and alluvium (43%), with smaller formations of Grinnel Argillite (8%) and Ravalli group (2%) belt series (Ellis & Craft, 2008). For a full discussion on the geology and glaciations of the area, refer to Chapter III Natural History.

1. Morphometrics

The size and shape of a lake basin affect nearly all physical, chemical, and biological parameters of lakes including the extent of material loading from the surrounding drainage basin (Wetzel, 2001). The morphology of a lake is an important factor in controlling the trophic status, physicochemistry, primary production, and distribution of aquatic life. Morphological factors include, but are not limited to; lake origin, size, depth, elevation, aspect, geology, hydrology, length of shoreline, and extent of the littoral zone.

Figure 82. Whitefish Lake.
Photo courtesy gravityshots.com

Various researchers (EPA 1975, Golnar 1986, Reller 2006, Petri 2014, and Koopal 2015) have supplied information on the morphometric attributes of Whitefish Lake. Figure 83 provides the best available morphometric information utilizing advances in technology over time. As an example, EPA (1977) and Golnar (1986) describe maximum depth that is less than that found by Reller (2006) who conducted an exhaustive study using 43,581 soundings. The Reller (2006) survey was conducted at a surface elevation of 2,998.5 ft. and associated statistics of mean depth, and the depth to volume curve are based on that survey.



Item	Value	Source
Percent of drainage basin	3.3%	Petri (2014)
Surface Area	3,370 acres^2 5.18 miles^2	Petri (2014)
Shoreline Length	15.85 miles	Reller (2006)
Maximum Length	5.78 miles	Golnar (1986)
Maximum Width	1.37 miles	Golnar (1986)
Maximum Depth	232.6 feet at 2,998.5 foot elevation 234.73 feet at mean high water elevation of 3,000.63 feet	Reller (2006) Koopal (2015)
Mean Depth	82.1 ft	Petri (2014) based on Reller (2006)
Hydraulic Retention Time	2.57 years	Petri (2014) based on Reller (2006)
Water Mass (50% Depth)	20.5 meters	Petri (2014) based on Reller (2006)
Photic Zone (0-30 Meters)	67.6% of lake volume	Petri (2014) based on Reller (2006)

Figure 83. Whitefish Lake Morphometric Attributes.

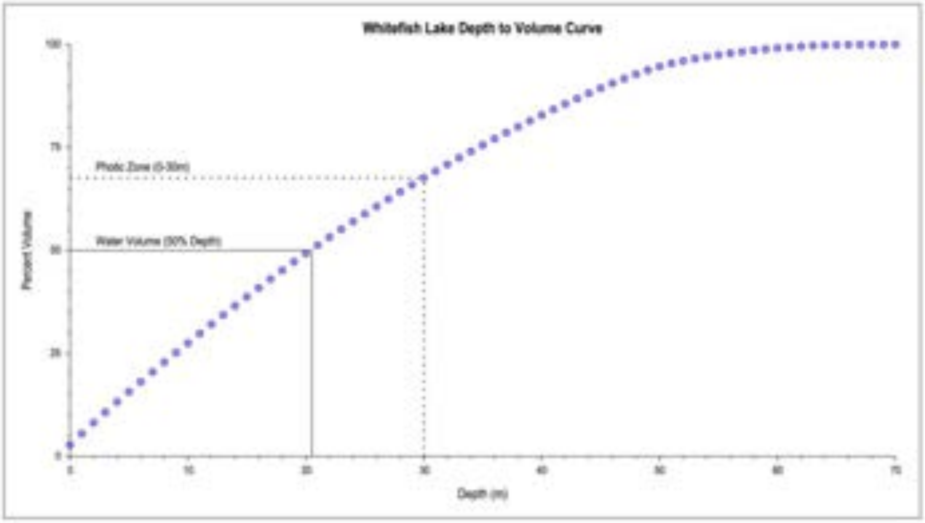


Figure 84. Whitefish Lake Depth to Curve Volume.

Figure 84 displays Whitefish Lake depth to volume curve with the percentage of the lake in the photic zone (0-30M). When calculating the surface acreage of the lake, Petri (2014) used the National Hydrography Dataset which lists an elevation of 2,998.91 feet. In determining the maximum depth, both survey elevation from the

Reller (2006) survey and the actual mean high water elevation of 3,000.63 calculated by Koopal (2015) for the past 58 years ending in 2014 were used.

2. Water Balance

Whitefish Lake tributary input volume data collected by the DNRC on Swift Creek since the 1970s has been used in previous research (EPA 1975, Golnar 1986, and Craft *et al.* 2003) for water balance and mass balance equations. Golnar (1986) estimated that Swift Creek contributes approximately 66% of the lake volume, Lazy Creek 13%, precipitation 4%, and the remaining from smaller tributaries. Groundwater is not suspected of being a significant contributor to Whitefish Lake.

In 2014, WLI installed pressure transducers to continually monitor stream level at all monitoring sites. The pressure transducer information as calibrated to staff discharge relationships will allow for a more detailed annual water budget determination as a component of future mass balance calculations for the lake. The 2014 volume estimate shows Swift Creek contributing 80.1% of the volume, Lazy Creek 7.0%, Hellroaring Creek 2.9%, Smith Creek 1.5%, Viking Creek 0.9%, Beaver Creek 0.5%, and precipitation 7.1%.

For approximately half of the streams in the project area with high elevation headwaters (i.e. Swift, Smith, Hellroaring, Haskill Creeks) the peak of the hydrograph occurs mid-May to early June. For the remainder of the streams in the project area that originate at lower elevations (i.e. Lazy, Viking, Walker, Cow Creeks) the peak of the hydrograph occurs in mid to late April.

The Whitefish Lake outflow was measured by the US Geological Survey (USGS) at Site 12366000 on the Whitefish River at the Tetrault Road Crossing near Whitefish from 1928 to 2006 at which time the station was retired. A new station (Site 12366080) for the Whitefish River in Kalispell was established in 2007 approximately nine river miles downstream from the previous site. Annual peak flows for the two sites are found in Figure 85. Golnar (1986) estimated that the Whitefish River outflow was 81% of total inputs with approximately 5% lost to evaporation. The remainder of the lake outputs may have represented groundwater losses or error in individual estimates.

Whitefish Lake has a medium flushing rate which impacts nutrient dynamics. The lake renewal (hydraulic retention) time calculated for Whitefish Lake in 1975 was 2.54 years (EPA, 1977). When that value is converted using the more accurate volume calculations based on Reller (2006), a value of 2.74 years is obtained. Likewise, the Golnar (1986) value of 2.73 years was converted to 3.04 years. In total, data from 1982-2014 (N=11) were analyzed for hydraulic retention time based on morphometric values derived from Reller (2006) using the Vollenweider (1975) Phosphorus Loading Model (see Trophic Status sub-section of this chapter). The mean hydraulic retention time calculated for Whitefish Lake is 2.57 years. This equates to approximately 38.9% of the lake flushed for an average year. The rate of flushing affects nutrient dynamics; for instance, a rapid flushing rate is advantageous in a lake that has undergone nutrient enrichment.

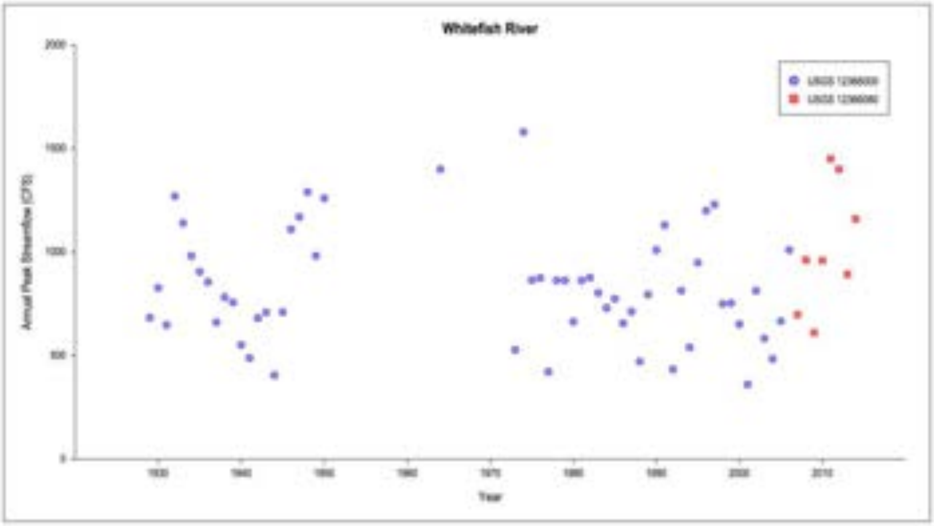


Figure 85. Annual Peak Flow for USGS Sites 12366000 and 12366080.

The Golnar (1986) and Craft *et al.* (2003) studies were conducted when the Whitefish River discharge levels were near the long-term average of 6.3 X 10^{10} $m^3 yr^{-1}$ for 1973 to 2002. In addition, the seasonal pattern of water flux through Whitefish Lake was very similar; in both years the spring turbidity plume of freshet flows moved into the lake in early June (Craft *et al.*, 2003). The consistency in the water balance for those two years provides a good foundation for comparisons in the Nutrient Mass Balance and Primary Productivity sub-sections of this report.

Groundwater

Because a potentially significant input of nutrients to lakes—particularly those with shoreline developments—can occur through groundwater, a 1985 study was conducted by the Flathead Biological Station to determine groundwater inputs to Whitefish Lake (Jourdonnais *et al.*, 1986). The study was designed to better understand the potential for septic contamination reaching the lake through groundwater.

That study found the water balance of Whitefish Lake to be dominated by stream flow and concluded that only 0.5% of the total water volume input to the lake was attributable to groundwater flow, and total soluble phosphorus loading through groundwater accounted for about 0.3% of total loading from all sources. The groundwater flux contributions to the overall water budget of the lake were also considered very low when compared to values reported on other lakes which ranged from 14.3% (Belanger et al, 1985) to 30% (Brock et al, 1982). However, the study also concluded that despite the low percentage of groundwater inputs of nutrients to the lake overall, the inputs were localized to specific shoreline areas highlighting chronic contamination from shoreline development.

Golnar (1986) found higher accumulation of benthic biofilms (periphyton) in recently developed areas of the shoreline of Whitefish Lake compared to forested shorelines apparently related to nutrient loading from groundwater seeping onto the shoreline. Craft *et al.* (2003) state that groundwater may be more of a contributor than in the past owing to the increase in land use conversion from forested to urban or exurban since 1986. It's clear that shoreline development affects water quality in the littoral zone where bio-available nutrients are probably quickly assimilated by macrophytes and the algal community.

WLI staff have responded to numerous concerns of near shore algal bloom in recent years. Anecdotal accounts support a trend where observations from many long-time shoreline residents recall clear rocks along the shoreline having changed to a green/dusky appearance from periphyton growth over time. It will be important to conduct further studies in the littoral zone to better understand groundwater flux and nutrient contributions to the lake and inform shoreline development decisions.

3. Ice Cover

Ice information on Whitefish Lake has been documented by various citizens through the years but the quality of the data for ice-on and ice-off dates are questionable based on the definition used by multiple observers. For example, it is not clear if ice-off was defined as the whole lake being cleared of ice or just a certain area(s). Anecdotal accounts describe the high degree of variability in how the ice finally goes off the lake, either as an overnight event or one that takes days.

The recorded information shows that ice-on dates can be highly variable, ranging from early December to early March, and specific climatic conditions consisting of very cold and windless days are needed for ice to form. Ice formation starts in the bays and extends out to pelagic areas in a general direction from City Beach to the head end of the lake where fluvial currents from tributaries are an influence.
Actual ice cover information for whether or not the lake completely froze is a more simplistic observation yielding more reliable information. From 1914 to 1962, Whitefish Lake did not freeze in the winters of 1933-1934, 1940-1941, 1952-1953, and 1960-1961. This equates to non-freeze conditions for 8% of the 48 year recorded period. No records exist for 1962 to 1995. From 1996 to 2015, there are 15 years with data and Whitefish Lake did not completely freeze (in many years the bays froze) the winters of 1998-1999, 1999-2000, 2011-2012 and 2012-2013. This equates to non-freeze conditions for 27% of the most recent recorded period, perhaps reflecting warmer climatic conditions (*see a further discussion of ice cover in the Concerns Chapter*).

4. Physical Parameters

Physical water quality parameters were collected via a Hydrolab DS5 sonde at incremental depths from the surface to the bottom of the lake. Other values, such as light extinction, can be calculated from the data. Turbidity was measured via a Hach Portable 2100 Turbidimeter. An analysis of key Whitefish Lake physical properties over time show relatively consistent baseline dynamics. However, there is some slight intra-annual variance driven by meteorological conditions. An inter-annual longitudinal gradient can also be seen in the lake based on fluvial inputs and fluxes in physical, chemical, and biological interactions.

<u>Thermal Stratification and Mixing</u>
Whitefish Lake is dimictic meaning it typically stratifies and mixes twice a year. This is a common pattern for lakes of this size at this latitude. See Figure 86 for a representative look at the stratification and mixing pattern at three sites representing a longitudinal profile of Whitefish Lake.

Around the beginning of May, the surface layer of Whitefish Lake starts to warm and a weak stratification develops by early June with the thermocline located at approximately 5 meters (See Figures 87 and 88 for seasonal thermocline depths). By mid-August the lake reaches its maximum temperature of around 70F (thermocline at around 10 meters). Data show a very slight warming of the hypolimnion during the stratification period.

By early September, the epilimnion has begun to cool but the lake is strongly stratified (thermocline at approximately 11 meters). A lowering of the thermocline continues through the fall season. By mid October the epilimnetic temperature is in the mid 50F but the lake is still strongly stratified (thermocline ranges from 11-17m).

In November, the maximum depth of

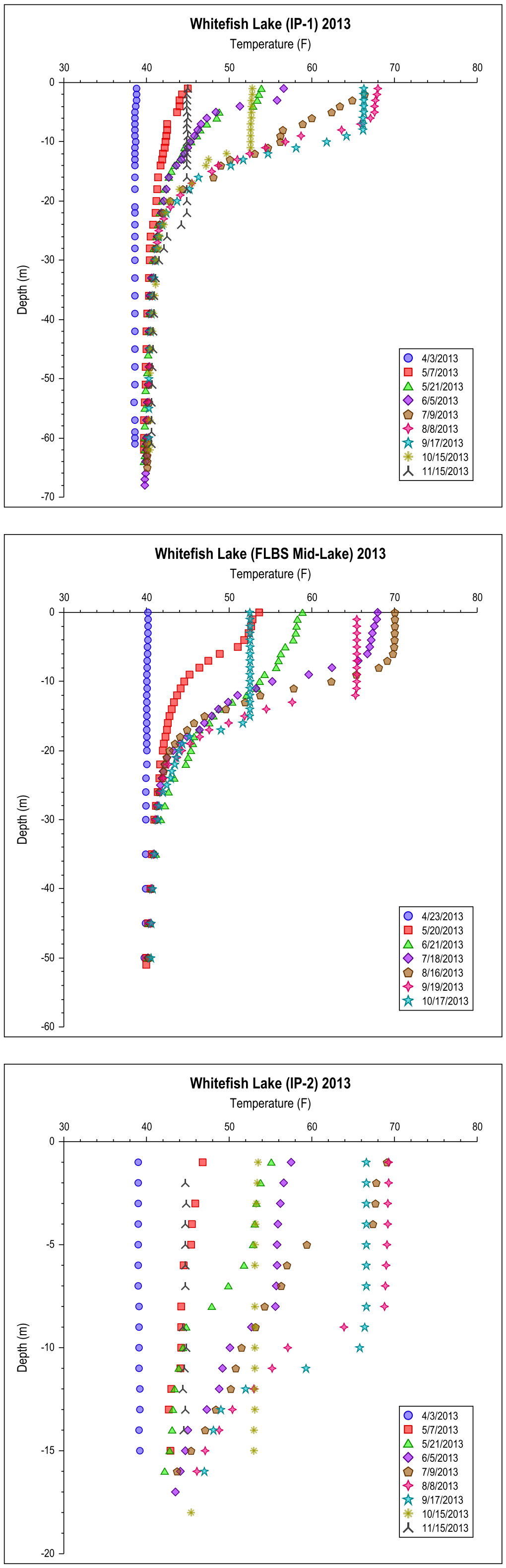


Figure 86. Typical Stratification & Mixing Pattern for 3 Sites on Whitefish Lake 2013.

the thermocline is approximately 24 meters but with cooling temperatures, the epilimnion is nearing the point of maximum density. By early December, the lake becomes isothermal and subject to fall overturn. If the lake freezes in the winter, as is the predominate scenario, it becomes inversely stratified with super-cooled temperatures found just under the ice.

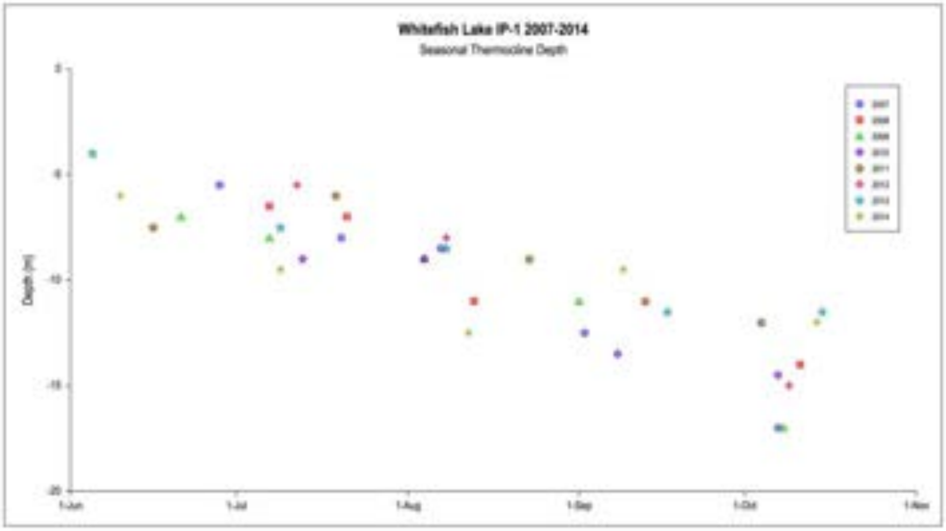


Figure 87. Whitefish Lake Seasonal Thermocline Depth IP-1 (2007-2014).

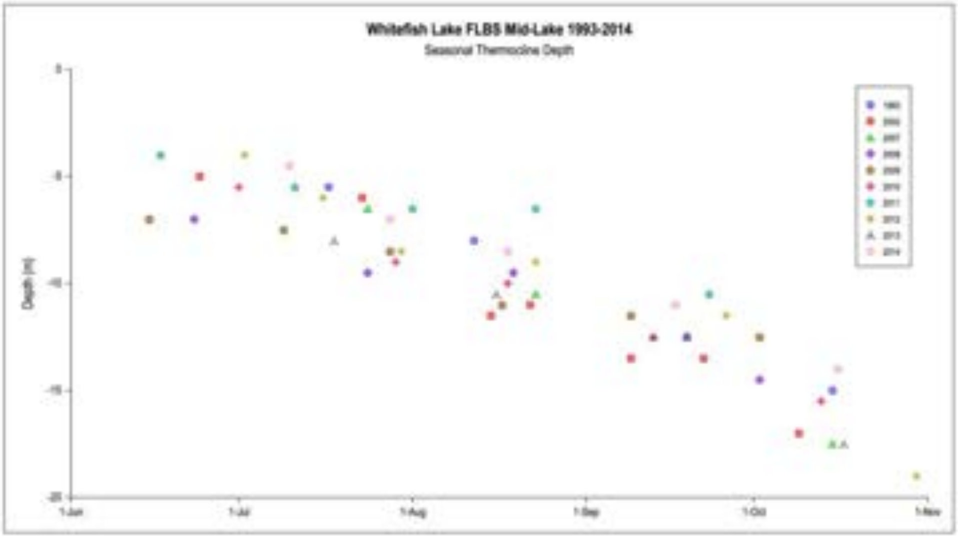


Figure 88. Whitefish Lake Seasonal Thermocline Depth Mid-Lake (1993-2014).

In years where sampling occurred under the ice (2010 and 2014), it appears that convective currents extend to a depth of around 30 meters. Golnar (1986) reported a well-mixed (isothermal) epilimnion during the winter of 1982-1983, due to the absence of ice cover over most of the lake surface. Intra-annual temperature and stratification variance in Whitefish Lake over the sampled period is slight other than in 2011 when a slower warming of the epilimnion and reduced maximum temperature were recorded due to the high water year.

A longitudinal analysis of the temperature data shows that the FLBS mid-lake site follows a similar temperature regime to IP-1 but with a slightly earlier onset of stratification. In addition, the epilimnion is deeper throughout the stratified season at the mid-lake site as compared to IP-1. At the shallower IP-2 site, only weak stratification exists from July through September with isothermal (mixed) conditions by late October, 1.5 months before mixing occurs at IP-1.

Dissolved Oxygen

Dissolved oxygen is vital to the aquatic food web. Low dissolved oxygen levels limit the temporal and spatial habitat for aquatic invertebrates, salmonids or other aquatic life and can add to cumulative environmental stress for certain species and/or life stages.

In most lakes the phytoplankton community contributes the bulk of oxygen supply because tremendous amounts of chlorophyll are present in epilimnetic and metalimnetic algal populations. In shallow waters the limnetic phototrophs may be overshadowed by littoral species—the macrophytes, the attached algae, and benthic algal mats being the chief producers (Cole, 1994). Oxygen can also be delivered to the lake from streams, mixed into the lake from wave action, or by direct exchange with the atmosphere via a pressure differentiation. Whereas oxygen is supplied to the lake during photosynthetic processes during the day, respiration continues at night where there is usually a decline in dissolved oxygen levels.

It has been well documented that increased nutrient loading to lakes can result in declining oxygen with depth, increased algal blooms and increased primary production (Wetzel, 2001); and the measurement of dissolved oxygen near the lake bottom may be a particularly good signal for monitoring early signs of eutrophication of a lake (Ellis, 2006).

Figure 89 displays dissolved oxygen concentrations at all Whitefish Lake sites during at typical year (2013). The lake shows evenly mixed dissolved oxygen concentrations through April with supersaturated conditions developing in the epilimnion through most of the stratified season. The super saturation dissolved oxygen bump observed in the data is a result of the preferred position of the phytoplankton community where oxygen produced is at the maximum just above the depth of these primary producers `.

Hypolimnetic Oxygen Deficit

Because of the flux of chemical, biological and physical components to the lake system, dissolved oxygen levels can often be varied at depth. Depletion of dissolved oxygen in the deep layers (hypolimnion) will occur in deep lakes like Whitefish Lake in association with the summer thermal stratification that prevents water mixing throughout the water column (Craft *et al.* 2003). However, oligotrophic lakes like historic Whitefish Lake generally do not exhibit dissolved oxygen saturation levels below 90%. Increased nutrients can drive higher primary productivity levels where, with depth, dissolved oxygen decreases resulting from the microbial respiration process of decomposing organic matter in the hypolimnion.

Depletion of oxygen from the deep water layers, if severe, could change the redox gradient at the water sediment interface, resulting in the release of large amounts of soluble reactive phosphorus (SRP) and ammonia into the water column of the lake (see Oxidation Reduction Potential in this chapter). The dissolved oxygen threshold for this scenario was determined to be 0.4 mg/L^{-1} by Stumm and Morgan (1996) and a 1.0mg/L value is often set as a threshold warning for lakes given variations and fluxes.

Butler *et al.* (1995) describe that lakes accumulate high concentrations of SRP at the water-sediment interface as a function of anoxic bacterial metabolism in the sediments, coupled with the upward migration of water upon compaction. If oxygen concentrations are high, the SRP is held in the sediments at the interface by the positive (oxidizing) redox gradient. However, anoxic conditions at the lake bottom would be expected to result in a sudden release of SRP from the sediments into the water column. This would result in a drastic change in the trophic state of Whitefish Lake, with the potential to accelerate eutrophication in downstream Flathead Lake.

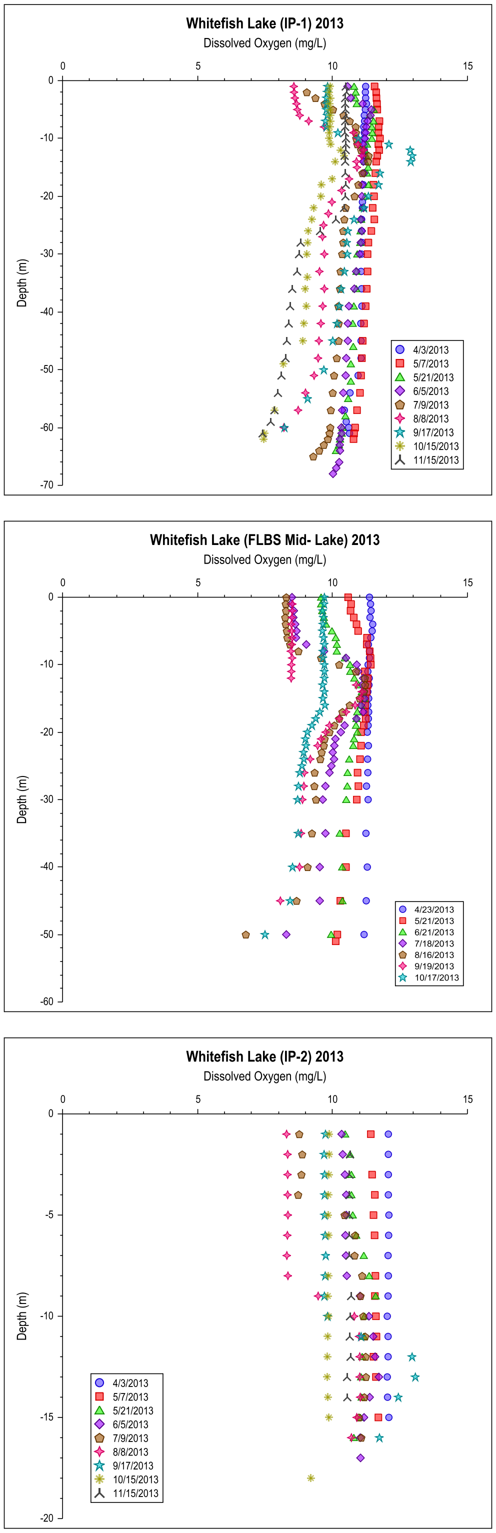


Figure 89. Typical DO for Three Whitefish Lake Sites, 2013.

The EPA (1977) found no depression of dissolved oxygen even during the stratified season at depths as great as 51.8 meters (the presumed reach of their monitoring equipment). A uniform dissolved oxygen concentration would indicate classic oligotrophic conditions. Questions remain on the validity of that data based on analytical methods at that time, and the researchers may not have corrected for temperature effects on oxygen solubility.

According to Craft *et al.* (2003) late summer/early fall oxygen profiles in Whitefish Lake measured in 1982-1983, 1993, and 2001-2002 all have similar patterns. Oxygen saturation in the epilimnion is near 100%, declining to about 70% in the metalimnion and upper hypolimnion, further declining to 50-60% saturation near the bottom (approximately 6-7mg/L^{-1}). The benthic dissolved oxygen patterns between 2002 and 2013 remained stable, but 2014 shows a decrease in dissolved oxygen at the benthic interface for both sites as depicted in Figure 90.

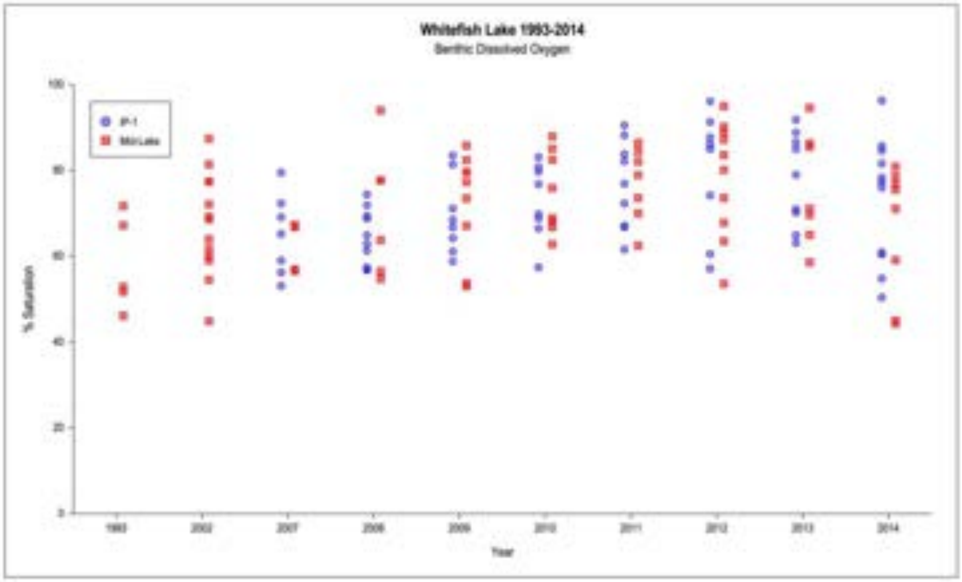


Figure 90. Whitefish Lake Benthic Dissolved Oxygen (1993-2014).

<u>Volumetric Hypolimnetic Oxygen Demand (VHOD)</u>

Volumetric Hypolimnetic Oxygen Demand (VHOD) represents the rate at which oxygen is consumed in the hypolimnion during the stratified period. Once the lake stratifies, the hypolimnion is cut off from atmospheric oxygen inputs from the strong temperature and density gradient between the epilimnion and the hypolimnion. Essentially the dissolved oxygen budget for the hypolimnion is established at the onset of stratification and is consumed at a typically linear rate during summer and early fall until the lake mixes. VHOD can be used as a surrogate or additional tool while analyzing primary productivity rates and phosphorus loading, but should be viewed in context of all fluxes occurring in the lake.

VHOD was calculated for both site IP-1 where fluvial inputs are greatest and at the mid-lake site where the strongest stratification pattern is displayed. General parameters used to determine data inclusion for any particular year include: 1) start date of June 15 for stratification, 2) end date October 15 due to dissolved oxygen intrusion into upper hypolimnion, and 3) a minimum of a 40 day window to measure from the start date and end date. Incremental layers from the hypolimnion were analyzed ranging from 17-50 meters. The rate of oxygen depletion varies throughout the water column in the hypolimnion, especially near the water and sediment interface (Cornett & Rigler, 1987; Nurnberg, 1995) which Whitefish Lake displayed. The totaled value for the hypolimnion is displayed in Figure 91 and 92. A Mann-Kendall test for IP-1 shows an increased rate of consumption trend over time ($P=0.014$, $r^2=0.60$). At the mid-lake site, there was no trend over time based on the high value in 1993, but when 2007-2014 is looked at independently, the Mann-Kendall test shows an increased rate of consumption trend ($P=0.014$, $r^2=0.68$).

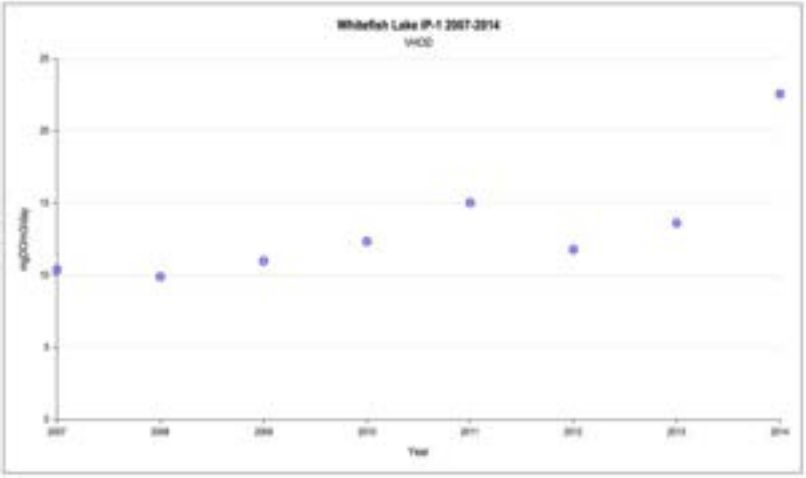


Figure 91. VHOD at IP-1.

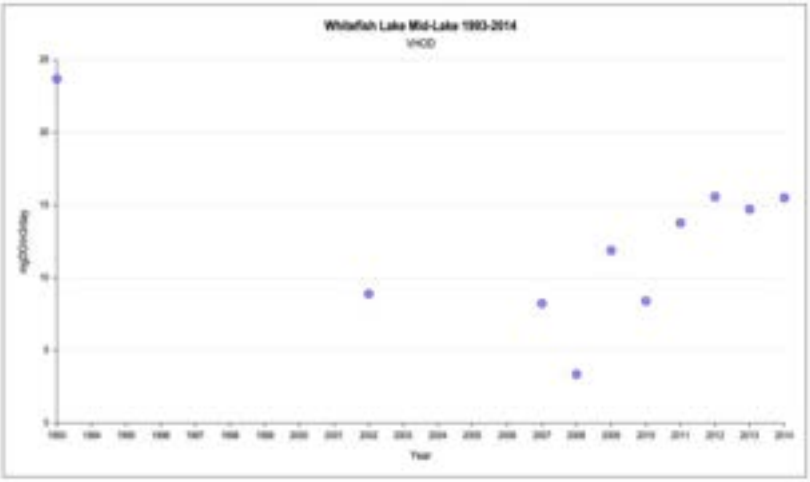


Figure 92. VHOD at Mid-Lake.

Water Transparency and Light Extinction

Water transparency is commonly and inexpensively measured using a Secchi disc. Whereas Secchi disc readings can be influenced by many factors leading to imprecise measurements, when the results are looked at collectively, the influence of sediment and/or algal production in a lake can be determined. Light extinction determines the photic zone where light penetrates down to 1% of the incident surface light - the point where oxygen production and respiration are equal. Light extinction is determined by the relationship of atmospheric and *in-situ* photosynthetic active radiation (PAR) - the specific light wavelength used by chlorophyll.

Secchi Disc

Secchi disc transparency is a function of the reflection of light from its surface, and is therefore influenced by the adsorption characteristics both of the water and of its dissolved and particulate matter. In general, Secchi disc transparency depth correlates with the depth of approximately 10 percent of surface light (Wetzel, 1975).

Figure 93 displays seasonal Whitefish Lake Secchi disc information from 2007-2014. Secchi depth in Whitefish Lake exhibits a seasonal pattern with the seasonal minimum occurring during spring runoff/spring turnover (May 1-June 30) and the seasonal maximum occurring in late summer (August 15-September 15) which is considered to be least influenced by sediment and primary productivity, yielding the best long-term trend information.

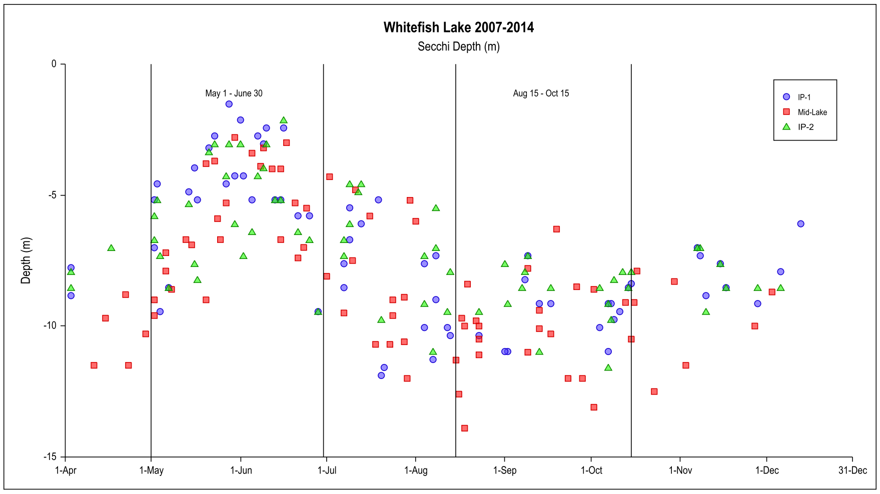


Figure 93. Seasonal Secchi Disc Depth 2007-2014.

Figure 94 displays the annual Secchi Disc results. In general, the mean Secchi depth shows a slight reduction is water clarity from 2001 to 2008 with a further increase in 2011 and 2012. However, inter-annual meteorological conditions and point in time sampling make trend analysis difficult.

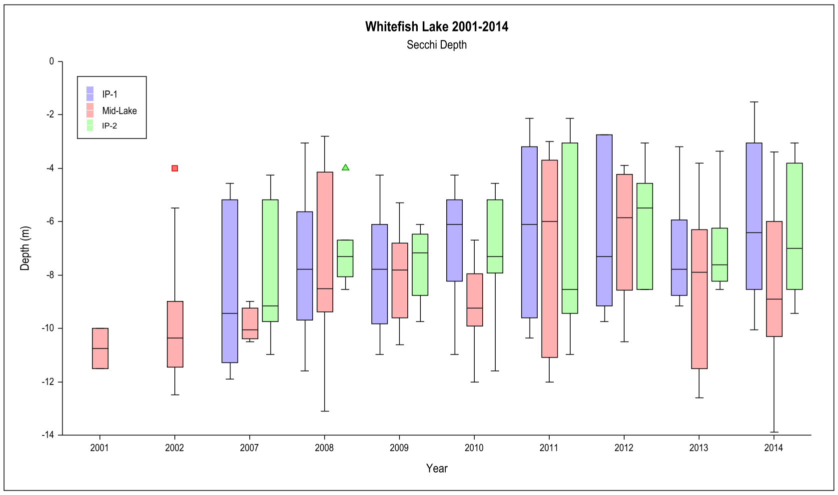


Figure 94. Annual Secchi Disc Depth 2007-2014.

Photosynthetic Active Radiation (PAR)

Photosynthetic Active Radiation (PAR) for Whitefish Lake is influenced by spring runoff that causes reduced near-surface light penetration. As the stratified season develops, light penetration is generally deeper at the surface.

Throughout the year, a consistent light extinction pattern is seen where approximately a 10% light availability at 10 meters is reduced to near 1% at the depth of the in-situ monitoring cable (14 meters) (Figure 95).

The maximum extent of the 1% compensation point for primary productivity generally deepens later in the stratified period but this is also the time when nutrients are often in limited supply in the epilimnion.

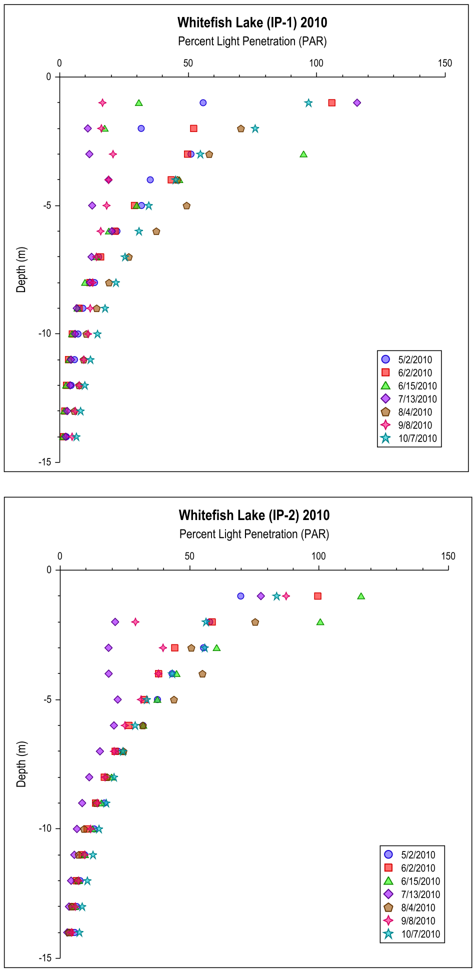


Figure 95. Typical Seasonal PAR Two Sites 2010.

Other Physical Properties

Other physical properties of Whitefish Lake collected by WLI and other researchers (EPA 1977, Golnar 1986, Craft *et al.*,2003) include pH, conductivity, Total Dissolved Solids, turbidity, oxidation reduction potential, and chlorophyll(*a*) fluorescence.

pH

pH is a measure of the molar concentration of hydrogen ions in water and is commonly referred to as acidity or basicity of the water. Ellwood *et al.* (2009) refer to lower pH values and oversaturation of carbon dioxide due to organic matter degradation. Microbes use oxygen to breakdown long chained carbon molecules to simpler end products. Dissolved carbon dioxide forms carbonic acid, decreasing pH levels.

Whitefish Lake is considered basic or alkaline extending from the epilimnion into the upper hypolimnion, however, at depth the lake trends towards a neutral concentration. pH follows a similar pattern of lake stratification (Figure 96). The lower pH at depth is at least partially a function of an increase in carbon dioxide from the total amount of organic material decaying in the hypolimnion, including that faction of precipitating dead algae.

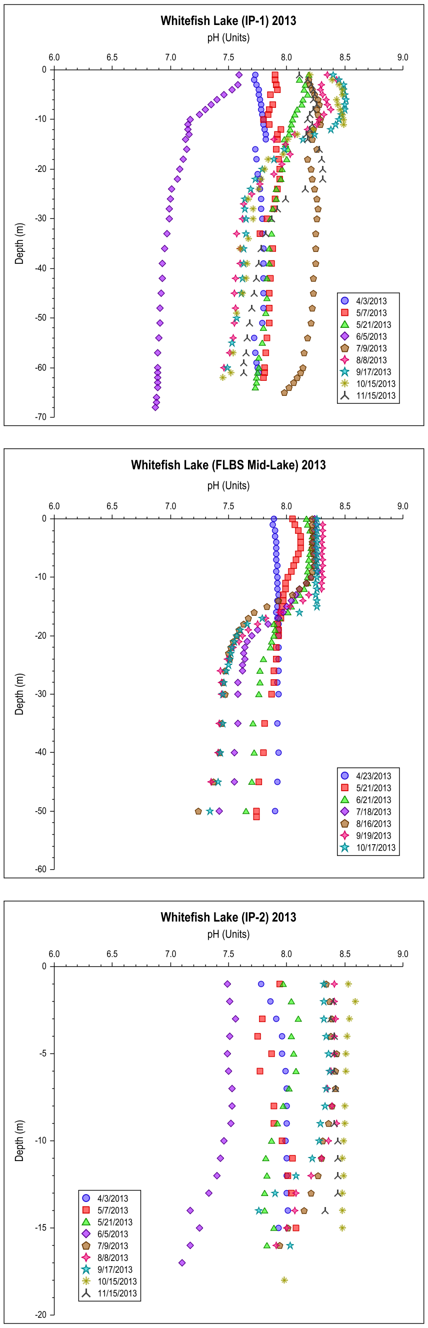


Figure 96. Typical Seasonal pH Pattern Three Sites 2013.

Conductivity

Conductivity is the ability of water to pass an electrical current and is influenced by the presence of inorganic dissolved solids (i.e. salts). Conductivity in Whitefish Lake is fairly static around 150-170µs/cm, with slight intra-annual changes observed. Conductivity falls to lower levels in the epilimnion and metalimnion during the stratified season reflecting the influence of primary production (Figure 97).

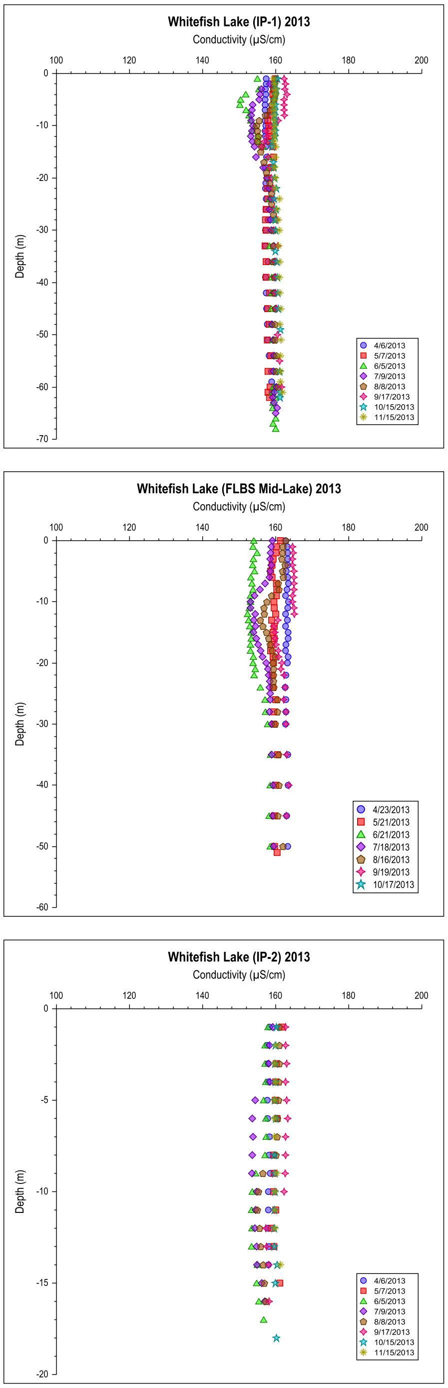


Figure 97. Typical Seasonal Conductivity Pattern Three Sites 2013.

Total Dissolved Solids (TDS)

There is a close relationship between Total Dissolved Solids (TDS) and conductivity but they are not the same thing. Whereas conductivity measures the ability of water to conduct electricity, TDS is the combined total of solids dissolved in water and is expressed as mass per unit volume of water. TDS is Whitefish Lake consistently ranges from 0.10 to 0.11g/L (Figure 98).

Turbidity

Turbidity makes water cloudy or opaque and indicates the amount of solids suspended in the water, including soil particles and organic matter (e.g., algae). Turbidity measures the amount of light scattered from a sample (more suspended particles cause greater scattering).

Turbidity values at IP-1 are influenced by fluvial currents and the sediment loads they carry. At this site, turbidity ranged from 0.2 to 7.1NTU from 2007-2014. Values are largely influenced on sample timing versus the spring freshet.

Data do indicate that the highest turbidity values at IP-1 are often in the 10 meter range suggesting that fluvial currents exist in the lake at this site where water from Swift Creek is plunging down into the Whitefish Lake water column to a depth of equal density. At IP-2, the turbidity data is more uniform with generally lower values yet the spring freshet still influences values at this location. Figure 99 displays turbidity values from 2011 which was a high water year.

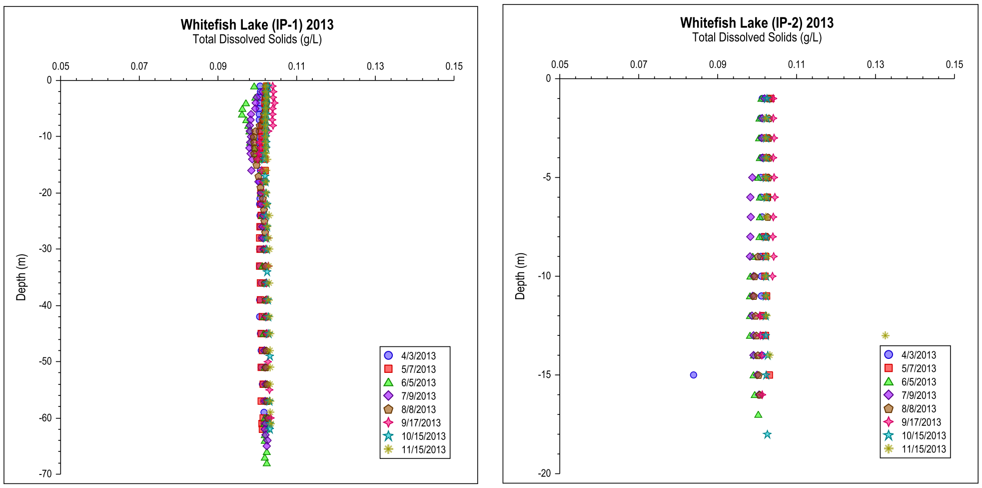


Figure 98. Typical Seasonal TDS Pattern Two Sites 2013.

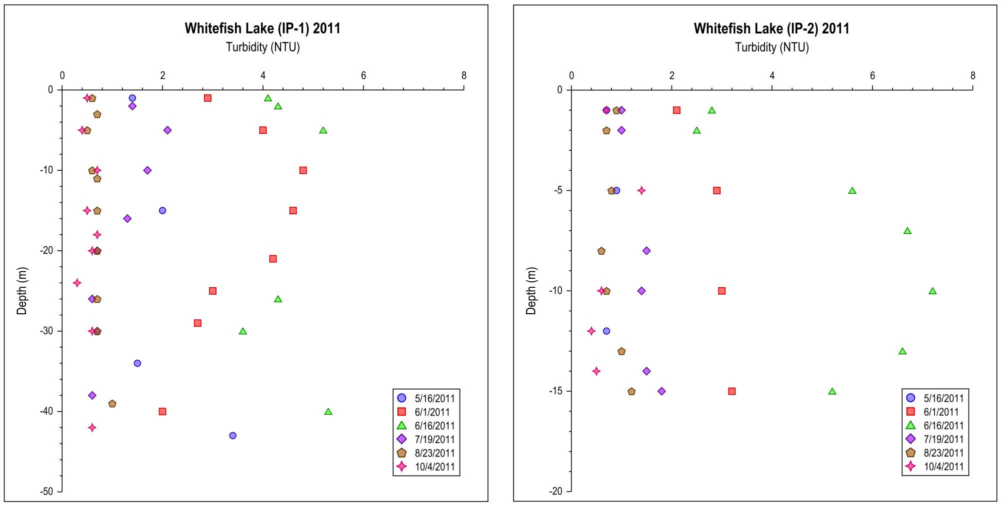


Figure 99. Seasonal Turbidity Patterns Two Sites 2011.

Oxidation Reduction Potential

The Oxidation Reduction Potential (ORP), or redox, is the ability of water to accept electrons. Of particular concern are low ORP values (E_h<200mV) when combined with low dissolved oxygen levels of less than 1mg/L at the benthic interface which increases the risk that phosphorus stored in the lake sediments can be released, leading to accelerated eutrophication.

ORP in Whitefish Lake generally ranges from 250-500 mV, which preclude the release of stored phosphorus. However, the high water year in

2011 appears to have influenced ORP in 2012 and to a lesser extent 2013 where a wider range of values were reported with four samples below 200mV at Site IP-1 (Figure 100).

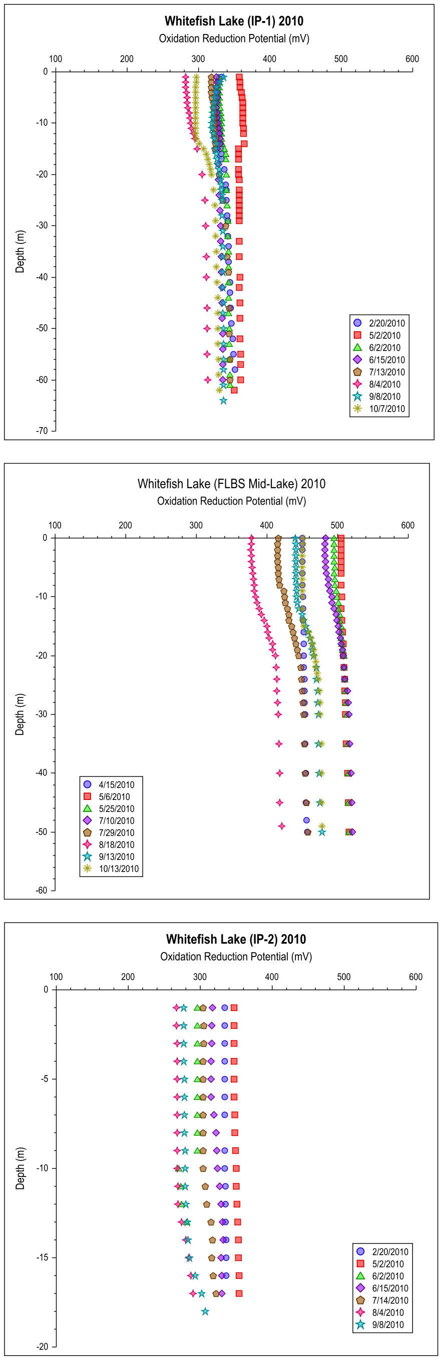


Figure 100. Typical Seasonal ORP Pattern Three Sites 2013.

Chlorophyll (a) Fluorescence

Light energy absorbed by chlorophyll molecules can be used in photosynthesis, dissipated as heat, or re-emitted as light - *fluorescence*.

Field fluorescence which provides an estimate of the distribution of primary producers, with the depth of maximum fluorescence is generally associated with the depth of maximum primary production (Butler *et al.*, 1995). The maximum chlorophyll (*a*) laboratory sample is collected from the depth of maximum fluorescence.

Figure 101 shows the seasonal distribution of phytoplankton as represented by chlorophyll (*a*). A “bump” is often observed near the thermocline in late spring/early summer as warming water temperatures and fluvial nutrient loading increases phytoplankton growth potential.

B. CHEMICAL PROPERTIES

1. Chemical Concentrations

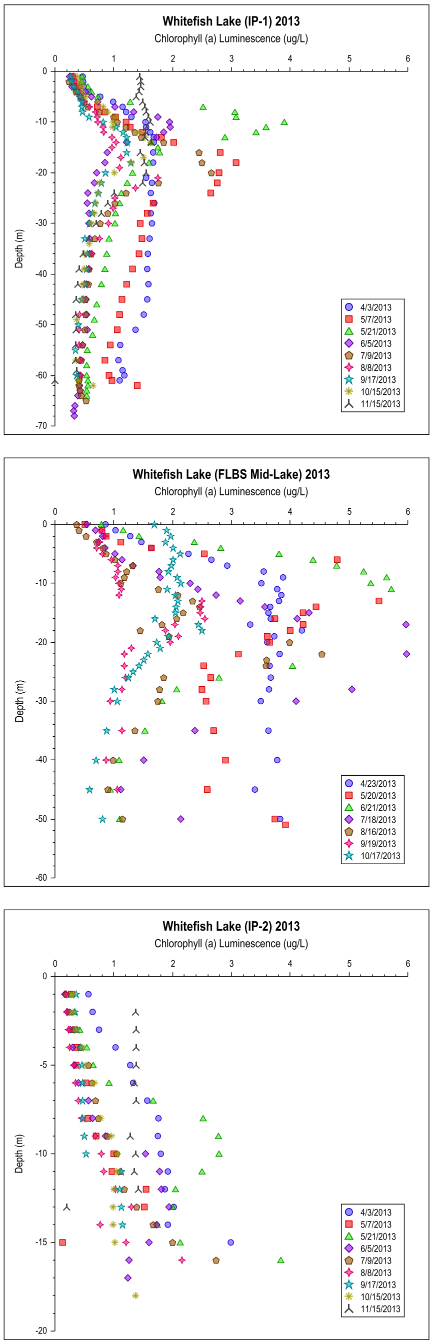


Figure 101. Typical Seasonal Chlorophyll (*a*) Fluorescence Pattern Three Sites 2013.

WLI and FLBS routinely collect chemical parameters at discrete depths at three sites on Whitefish Lake, including but not limited to; Total Phosphorus, Soluble Reactive Phosphorus, Total Nitrogen, Organic Carbon, and Total Suspended Solids. Chemical parameters are then analyzed by a qualified laboratory that follows Quality Assurance/Quality Control measures. For comparative reasons, data from an approximate 5 meter and 45 meter depth range in the lake have been used in most of the following data presentations.

Nutrients can be delivered to Whitefish Lake via tributary conveyance, atmospheric deposition, groundwater interaction, or internal loading as previously discussed, or by organisms. For instance, it is well documented that in forested ecosystems, pollen grains can affect the nitrogen budget of adjacent aquatic ecosystems. Large pollen grain accumulations are seen on Whitefish Lake every year especially along windward shorelines. Another example are the large numbers of sea gulls that often overnight on the lake, and excrete nutrients, after foraging at the Flathead County Landfill and other locales during the day.

Analysis of the seasonal concentration of Total Phosphorus and Total Nitrogen at Site IP-1 yielded homogenous concentrations at depth and highly variable annual concentrations as influenced by fluvial inputs. Nutrient concentrations at the FLBS Mid-Lake Site reflect more stable water column conditions and provide a better long-term trend comparison as displayed in Figures 102, 103, and 104. See Nutrient Mass Balance, Limiting Nutrients, and Primary Productivity for nutrient implications.

Figure 102 displays Total Phosphorus concentrations in Whitefish Lake. The data suggest that total phosphorus has declined in recent years after higher levels in 2011 and 2012. It is suspected that larger flushing flows such as 2011 scour previously armored sediments from tributary channels and deliver pulse loads to Whitefish Lake, and may even influence the nutrient loading the subsequent year. Koopal (2014b) described the same relationship of higher nutrient concentrations the year after a high flow event (2011) in nearby Swan Lake, however the determination of nutrient transfer rates is inherently complex. Soluble Reactive Phosphorus (SRP) is displayed in Figure 103. This inorganic form of phosphorus is easily assimilated by algae and other microbiota, and as a result is rarely found in high concentrations in the water column.

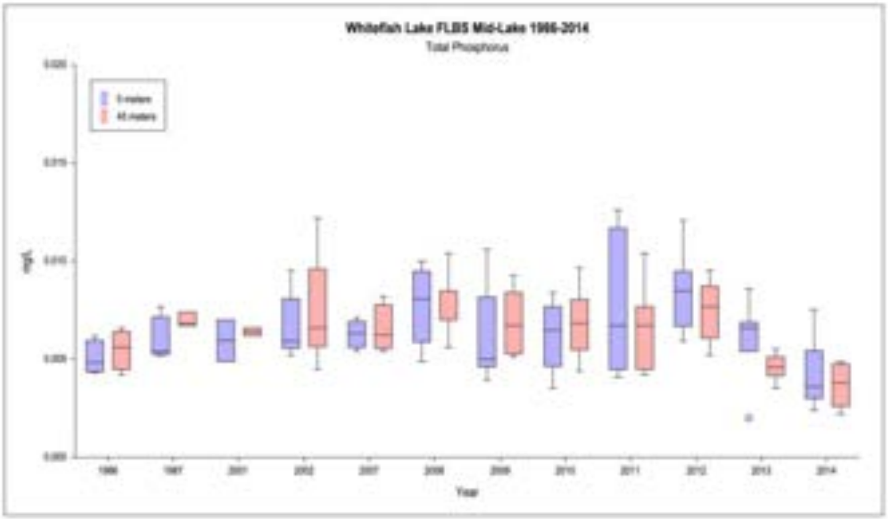


Figure 102. Annual TP Concentrations FLBS Mid-Lake 1986-2014.

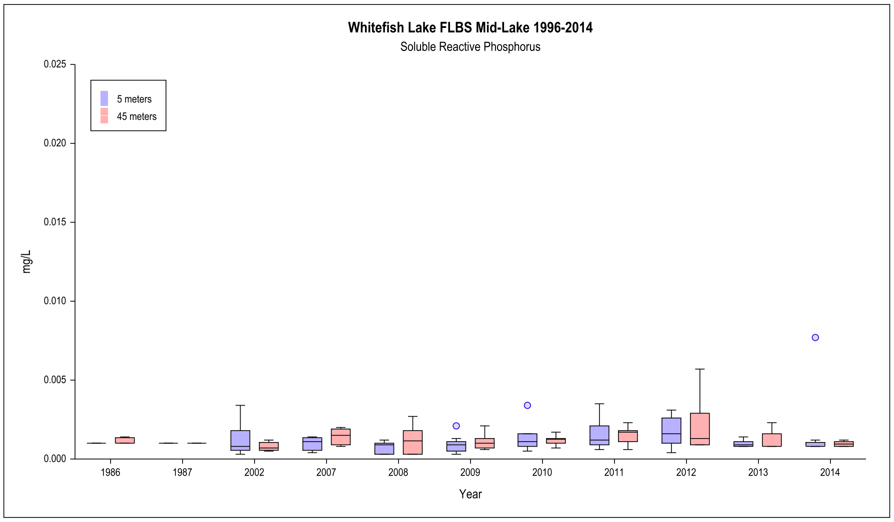


Figure 103. Annual SRP Concentrations FLBS Mid-Lake 1996-2014.

Figure 104 displays Total Nitrogen concentrations in Whitefish Lake. Globally, nitrogen production for agriculture, from the consumption of fossil fuels, and from other human activities has reached all-time highs within the last decade (Gu *et al.*, 2013) (see discussion of atmospheric deposition under Nutrient Mass Balance). Total nitrogen in Whitefish Lake has been stable since 2001 with a pulse shown in 2011 during the high flow year. Laboratory values for the inorganic forms of nitrogen; ammonia (NH_3), nitrite (NO_2) and nitrate (NO_3) were predominately below the laboratory detection limit precluding a valid interpretation of the data.

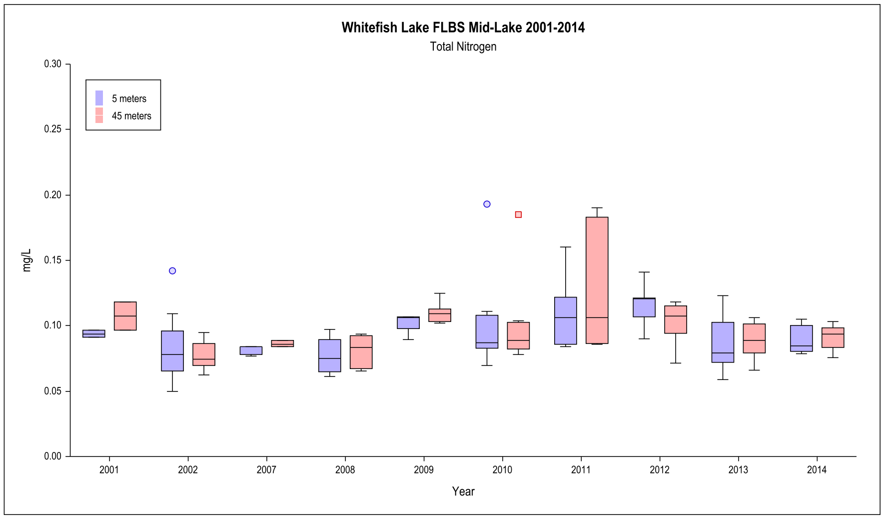


Figure 104. Annual TN Concentrations FLBS Mid-Lake 1996-2014.

Figure 105 displays Total Organic Carbon concentrations in Whitefish Lake. Recent values are similar to the 1980s after slightly higher concentrations in 1993 (5M and 45M) and 2001 (5M).

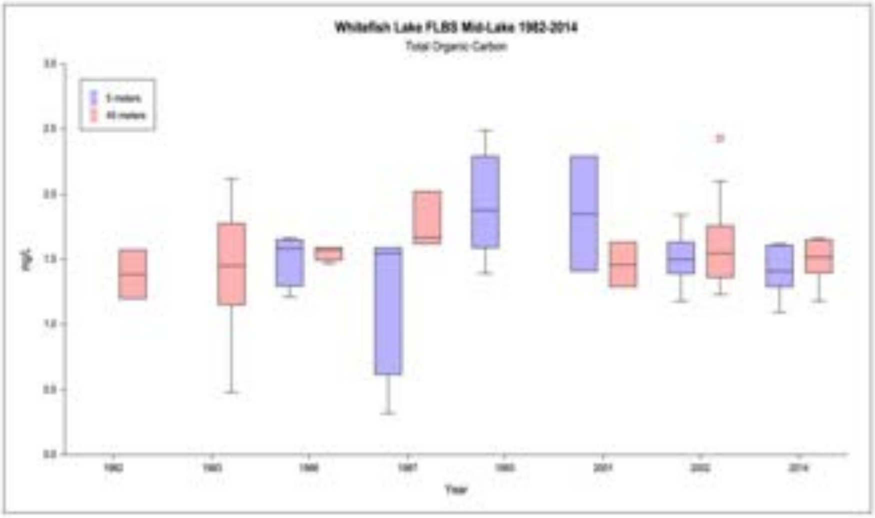


Figure 105. Annual TOC Concentrations FLBS Mid-Lake 1982-2014.

Other chemical parameters have received limited sampling throughout the years. Sulfate at the mid-lake site ranged from 1.5mg/L to 2.3mg/L in 1982, 1986 and 1994. Reactive Silica at the mid-lake site ranged from 6.1mg/L to 9.0MG/L in 1986, 1993, and 2014; and at Site IP-1 values ranged from 6.7 to 7.5 mg/L in 2014.

The data do not show the hypolimnion as a significant nutrient pool for any chemical parameters as near equal concentrations of nutrients are displayed at both the 5 and 45 meter depths.

2. Nutrient Controllability

There is no “point” source discharge into Whitefish Lake. Shoreline stormwater inputs are limited to natural conveyances and a few outfalls from very small sub-basins. In 1977 the EPA estimated lakeshore septic tanks to have contributed 0.9% of the phosphorus load and 1.3% of the nitrogen load but noted an actual shoreline survey would have to be completed to determine the significance of those sources (U.S. Environmental Protection Agency, 1997). Jourdonnais *et al*. (1986) investigated groundwater seepage as a nutrient source to Whitefish Lake and concluded the overall effect to nutrient loading to the lake was negligible (<1%) but that localized groundwater inputs can significantly affect the littoral zone in some areas.

Since there is no point source loading to Whitefish Lake and stormwater and groundwater is limited, tributary loading and atmospheric deposition are the driving force behind the Whitefish Lake nutrient budget.

3. Nutrient Mass Balance

The transport and fate of nutrients is important to understand as they relate to primary production and the overall health of Whitefish Lake. Most of the nutrient loading to the lake is conveyed by tributaries during the spring freshet. What happens to these nutrients based on lake fluxes is important to understand.

Initially, the buoyancy of tributary in-flow relative to a receiving lake is important in determining the transport and fate of constituent loads. Less dense or positively buoyant inputs are straightforward as they tend to enter across the surface waters as an overflow, and are effectively integrated in the upper waters through wind-driven mixing (Martin and McCutcheon, 1999). In contrast, negatively buoyant inflows tend to plunge, often to metalimnetic depths during the stratified season. This plunging effect has been observed at Site IP-1 near the main tributaries to the lake.

Ellis and Stanford (1988) found that for Flathead Lake, not all of the sediment - phosphorus discharged by tributaries is mobilized by the microbial community in the water column of the lentic system receiving the riverine flow. Stanford and Ellis (2002) found most of the sediment-bound phosphorus that discharged into the Flathead Lake during spring snowmelt is biologically unavailable. Ellis (2006) found that increased concentrations of nitrate and ammonium from riverine sources were consistent with urbanization and forest disturbance.

Pearl (1997) found that atmospheric deposition of nitrogen actually exceeds riverine inputs to surface waters. Ellis *et al.* (2015) documented in Flathead Lake significantly increasing trends in atmospheric loading of ammonium (NH_4) and nitrate/nitrite ($NO_{2/3}$) and decreasing trends in phosphorus (P) from 1985-2004. Atmospheric loading of $NO_{2/3}$ and NH_4 increased by 48% and 198% and total P decreased by 39%.

Aerosols in the airshed are substantially increased during periods of air stagnation caused by temperature inversions. Entrainment of dust from agricultural fields and rural roads and smoke from forest fires and household and industrial combustion occurs. In addition NH_4 and TN loads were frequently elevated when controlled slash and agricultural burns or forest fires occurred. During inversions, total hectares burned were significantly correlated with atmospheric TN loading ($p<0.05$). Whereas P atmospheric loading declined during the study period, the atmosphere was clearly a source of P for Flathead Lake and TP and SRP loading and fine soil and smoke buildup during periods of poor air circulation likely are the primary sources of P (Stanford and Ellis, 2002).

Ultimately, atmospheric deposition contributed annual on average 10% of the N load and 7% of the P load for Flathead Lake (Ellis, 2006). TN in atmospheric deposition in Whitefish Lake was similar to Flathead Lake but TP was 2X that of Flathead. Craft *et al.* (2003) reported that atmospheric nutrient loading not only contributes a substantial portion of total nutrient load, but it is also a very important contributor of nutrients in the summer and fall months as nutrient availability in the epilimnion is depleted by algae production.

Elser *et al.* (2009) report that increased atmospheric deposition of inorganic nitrogen has probably caused a shift from natural N limitation to P limitation in many unproductive lakes. For Flathead Lake, Ellis *et al.* (2015) found that NH_4 was the primary form of nitrogen from the atmosphere and NO_3 was the primary form of nitrogen in tributary inputs.

In calculating stream loading for Whitefish Lake, the EPA (1977) study relied on a modified USGS computer program where nutrient loads from un-sampled tributaries were estimated using the means of nutrient loads collected and applying the means to the drainage area of the smaller streams. The Golnar (1986) and Craft *et al.* (2003) studies relied on calculations for smaller streams based on the measured output of Swift Creek and Hellroaring Creek drainages per unit area, and nutrient concentrations were assumed to match Hellroaring Creek data. The Golnar (1986) and Craft *et al.* (2003) field investigations used the same methodology, had similar water balance years, and provide a comparative analysis.

Volume loading and mass balance equations in previous studies on Whitefish Lake have relied on limited point (cfs) measurements on Swift Creek and to a lesser extent on Lazy Creek. Hellroaring Creek served as a proxy for the remaining small tributaries where discharge and nutrient concentrations were estimated from a per unit area comparison to Swift Creek.

WLI began further refinements in calculating nutrient mass balance in 2014. Rather than extrapolating loading information based on proxy, the specific nutrient loading for each stream will be determined. As an example, data for Beaver Creek shows high nitrogen concentrations and Viking Creek shows high nitrogen and phosphorus concentrations beyond what would be expected for these smaller streams.

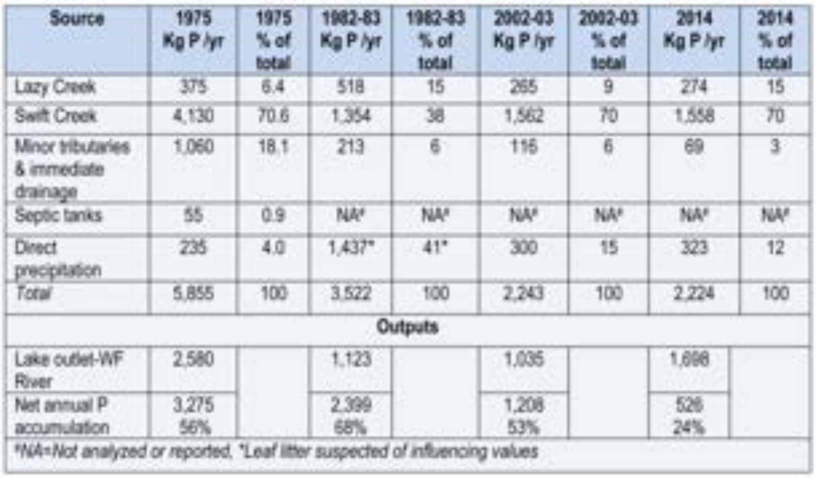
The EPA (1977) noted the phosphorus export of “unimpacted” Swift Creek was relatively high at 21 kg/km^2/yr compared to the mean export rate (8 kg/km^2/yr) of 37 Montana tributaries sampled in the survey. The researchers noted that McDonald Creek also had a rather high export rate of 26 kg/km^2/yr, and the entire drainage of that stream is in Glacier National Park. See discussion on the Swift Creek Mass Wasting Banks under the stream chapter.

Research by Golnar & Stanford (1984) and Craft, Stanford & Jackson (2003) concluded that atmospheric loading contributes a significant portion of total phosphorus and nitrogen to Whitefish Lake, and that they are also important contributors of nutrients in summer and fall when nutrient availability in the epilimnion is depleted by algae production. According to their collective research, total phosphorus from bulk precipitation accounted for 31% of total phosphorus load to Whitefish Lake from October 1, 1982 to October 1, 1983.

Atmospheric nitrogen loading accounted for 20% of the total input. From November 1, 2001 to October 21, 2002, atmospheric phosphorus accounted for 15% and nitrogen 15%. It was noted that rainfall was much greater in 1983 than in 2002 leading to the greater phosphorus loading in 1983 over 2002. Unfortunately, the researchers suggested that contamination issues from nearby vegetation in 1983 may have rendered the comparison between years less reliable.

It was also discussed that a decrease in phosphorus loading was an expected outcome as a result of the reduced use of sand and gravel in exchange for de-icing compounds on roads. One of the reasons for making the change to de-icers was to decrease air-born particulates and associated phosphorus loading to waterbodies. Local studies have also found that dust contributes significant phosphorus; and smoke and ash from wildfires contribute significant phosphorus and nitrogen to the water surface (Hauer & Spencer, 1998).

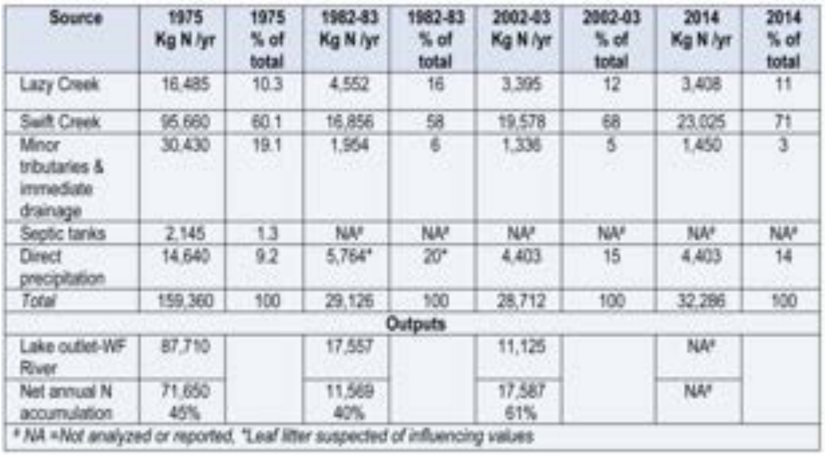
Figure 106 displays phosphorus loading and Figure 107 displays nitrogen loading information for Whitefish Lake as calculated from the EPA (1977), Golnar (1986), Craft *et al.* (2003), and WLI in 2014. The loading information from the first three studies were looked at in concert for an overall generalized estimate of source nutrient loading in Figure 108 and the 2014 loading information is found in Figure 109 but does not account for septic input.



Source	1975 Kg P /yr	1975 % of total	1982-83 Kg P /yr	1982-83 % of total	2002-03 Kg P /yr	2002-03 % of total	2014 Kg P /yr	2014 % of total
Lazy Creek	375	6.4	518	15	265	9	274	15
Swift Creek	4,130	70.6	1,354	38	1,562	70	1,558	70
Minor tributaries & immediate drainage	1,060	18.1	213	6	116	6	69	3
Septic tanks	55	0.9	NA*	NA*	NA*	NA*	NA*	NA*
Direct precipitation	235	4.0	1,437*	41*	300	15	323	12
Total	5,855	100	3,522	100	2,243	100	2,224	100
Outputs								
Lake outlet-WF River	2,580		1,123		1,035		1,698	
Net annual P accumulation	3,275 56%		2,399 68%		1,208 53%		526 24%	

**NA=Not analyzed or reported, *Leaf litter suspected of influencing values*

Figure 106. Phosphorus Loading Whitefish Lake.



Source	1975 Kg N /yr	1975 % of total	1982-83 Kg N /yr	1982-83 % of total	2002-03 Kg N /yr	2002-03 % of total	2014 Kg N /yr	2014 % of total
Lazy Creek	16,485	10.3	4,552	16	3,395	12	3,408	11
Swift Creek	95,660	60.1	16,856	58	19,578	68	23,025	71
Minor tributaries & immediate drainage	30,430	19.1	1,954	6	1,336	5	1,450	3
Septic tanks	2,145	1.3	NA*	NA*	NA*	NA*	NA*	NA*
Direct precipitation	14,640	9.2	5,764*	20*	4,403	15	4,403	14
Total	159,360	100	29,126	100	28,712	100	32,286	100
Outputs								
Lake outlet-WF River	87,710		17,557		11,125		NA*	
Net annual N accumulation	71,650 45%		11,569 40%		17,587 61%		NA*	

** NA =Not analyzed or reported, *Leaf litter suspected of influencing values*

Figure 107. Nitrogen Loading, Whitefish Lake.

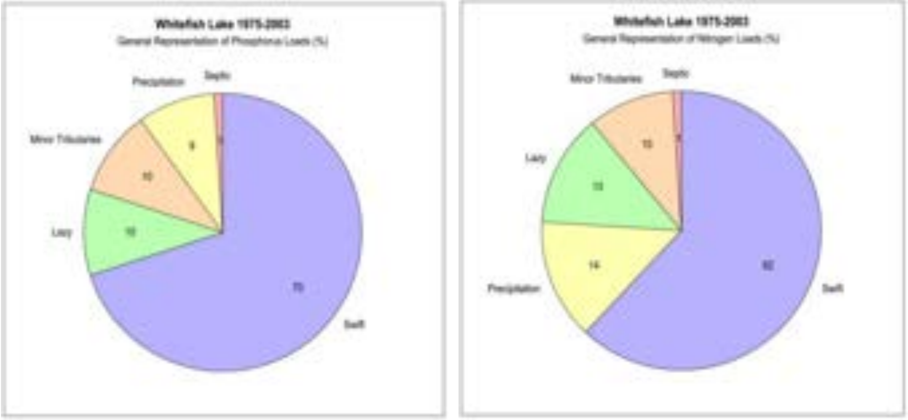


Figure 108. Phosphorus and Nitrogen Loads 1975-2003, Whitefish Lake.

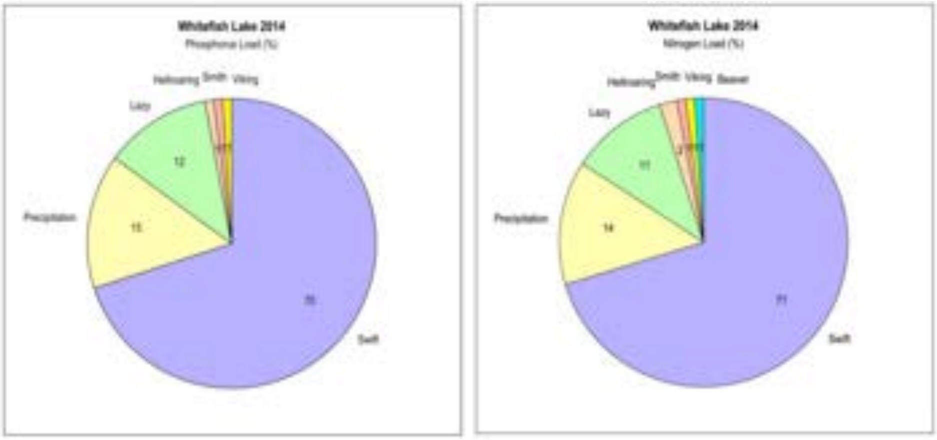


Figure 109. Phosphorus and Nitrogen Loads 2014, Whitefish Lake.

Whitefish Lake nutrient sink percentages range from 24% to 68% for phosphorus and 40% to 61% for nitrogen. Ellis (2006) reported that 42% of the annual total nitrogen and 73% of the total phosphorus input into Flathead Lake is retained, tied up by a steep chemical gradient in the bottom sediments.

<u>Limiting Nutrients</u>

Nutrient dynamics and, in particular, nutrient limitation is widely recognized as critical to understanding nutrient-poor ecosystems and the onset of eutrophication (Wetzel, 2001). The limiting nutrient concept or “Law of the Minimum” developed by Liebig well over a century ago states that the yield of any organism will be determined by the abundance of the substance that, in relation to the needs of the organism, is least abundant in the environment. In multispecies algal communities, growth rates among different species are likely to be limited by different resources, including differing nutrients (Wetzel, 2001).

In the classical analysis of Japanese lakes, Sakamoto (1966) reported strong N limitation if TN:TP <10:1 by mass (22:1 by moles), strong P limitation if TN:TP >17:1 by mass (38:1 by moles), and either nitrogen or phosphorus limitation at intermediate ratios. These boundaries were later confirmed by Forsberg and Ryding (1980) using algal bioassays and were supported empirically by Smith (1982).

Figures 110, 111, and 112 display the molar TN:TP ratio for the three long-term monitoring sites on Whitefish Lake. The three sites include; IP-1 sampled by WLI located off Hellroaring Point near the majority of stream inputs, FLBS Mid-Lake, and IP-2 sampled by WLI near City Beach.

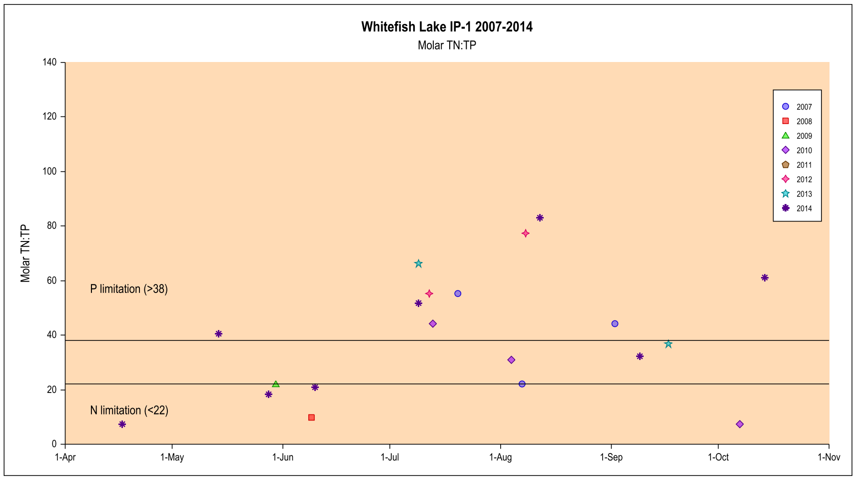


Figure 110. Molar TP:TN IP-1, 2007-2014.

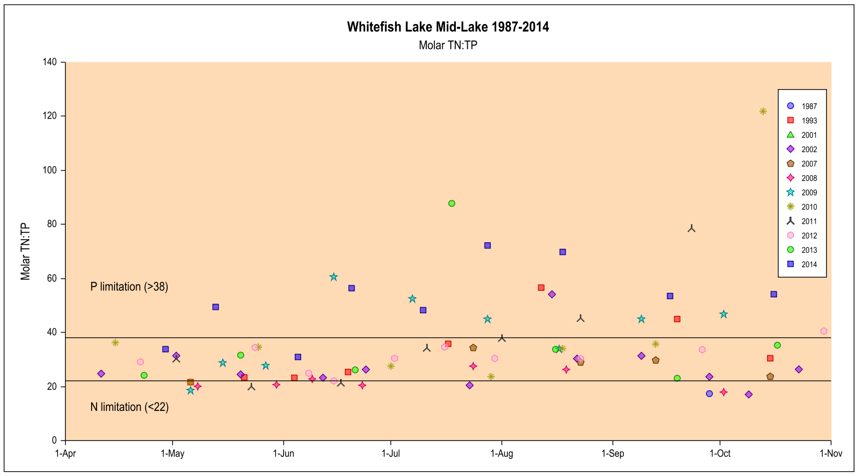


Figure 111. Molar TN:TP Mid-Lake, 1987-2014.

The molar TN:TP for all Whitefish Lake sites shows spatial and temporal variance. The EPA (1977) study indicated nitrogen limitation in June and phosphorus limitation in July and September in Whitefish Lake. The molar TN:TP for Site IP-1 indicates that this part of the lake is influenced by fluvial entrainment of nutrients during peak flows. This site shows a phosphorus limitation starting after the spring freshet (early July) although more data is needed for the waning hydrograph period. It appears that the FLBS Mid-Lake site displays a phosphorus limitation sooner than IP-1 (mid-June) and is predominately co-limited during the growing season. The earlier phosphorus limitation at mid-lake is probably due to the precipitation of fluvial sediment with adsorbed phosphorus, and utilization by primary productivity.

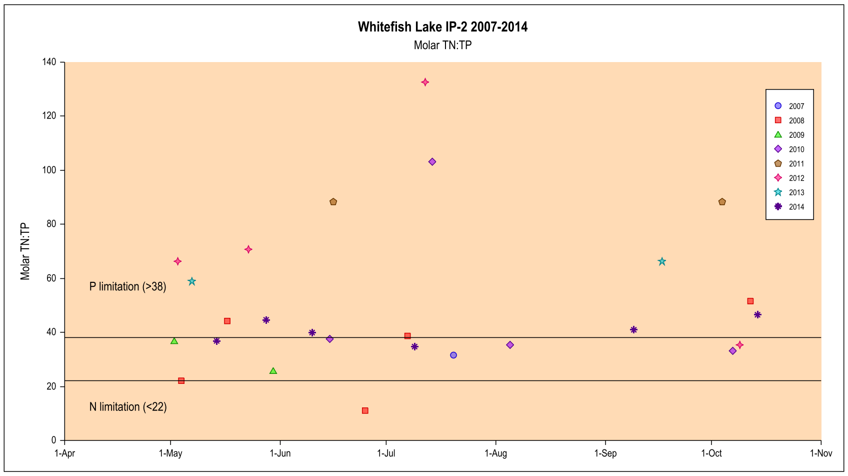


Figure 112. Molar TN:TP IP-2, 2007-2014.

It's clear that the lack of fluvial inputs at IP-2, coupled by fluvial sediment deposition and primary productivity uptake of nutrients in the lake before this site create a predominately phosphorus limitation for the entire growing season. During mid- to late stratification when both inorganic forms are below detection limit, atmospheric inputs, high in inorganic N, may have the potential to increase production.

The most compelling long-term trends for nutrients in Flathead Lake according to Ellis (2006) were the increasing $NO_{2/3}$ concentration and load from many tributary inputs and atmospheric deposition. Given that primary production appears to be limited by both N and P, the increase in loading of N is of particular concern.

If phosphorus pulses occur, it can be taken up in excess of requirements and stored inside algal cells in a process called luxury consumption. This stored P can allow algae to grow even if P concentrations are low in the water column. If controlling such P pulses is impossible (e.g. pulses associated with high runoff events in spring), control of N could become necessary (Dodds and Welch, 2000).

Management activities can influence the spatial and temporal extent of limiting nutrients. In well forested drainages, nutrients are retained by recycling between soil and vegetation compartments. Any disturbance in a forested drainage via cultural development (i.e. timber harvest, road building, residential) or natural (fire or flood) can alter nutrient cycling pathways. As a result, a disturbed watershed losses capacity to retain nutrients and exports them to downstream waters.

Advancements in forestry practices—Best Management Practices (BMPs), the Flathead County Phosphate Ban in 1985 and the partial sewering of East Lakeshore Drive prompted by the Jourdonnais *et al.* (1986) study have undoubtedly reduced phosphorus loading in the project area. However, near Site IP-2, the highest development density around the lake coupled with natural lake dynamics and nutrient availability gives this area of the lake the highest potential to react to any phosphorus input which could lead to water quality degradation.

C. FOOD WEB

1. Primary Productivity

Chlorophyll are pigments by which the energy of sunlight is captured for photosynthesis. Chlorophyll (*a*) is the molecule which makes photosynthesis possible by passing its energized electrons on to molecules that manufacture sugars. Ultimately, photosynthesis uses the energy in sunlight to fix carbon dioxide (CO_2) into organic material. Primary producers (algae) use some of their newly formed carbon products immediately for energy and maintenance. The remaining photosynthetic products are available for plant growth or consumption by the heterotrophic community and constitute *net primary production* (NPP). Algal biomass is the amount of algae in a water body at a given time.

The seasonal pattern of phytoplankton biomass in temperate oligotrophic lakes is frequently described by a pronounced spring bloom followed by a summer depression, a subsequent fall bloom, and low levels in winter. Golnar (1986) generally described the process in Whitefish Lake where after a low growth period in winter, the spring biomass peak correlates with increased light and temperature. An abrupt decline follows, possibly due to nutrient depletion or increased grazing with low summer biomass. In the late summer or fall, there is resurgence prior to fall overturn where biomass is reduced with the upwelling of cold water.

However, Stockner and Shortread (1975) state that generalizations ignore the floristic difference between lakes; for example, the occurrence of autumn biomass peaks has been shown to vary even within different sub-basins of a lake. In a study of 56 north-temperate lakes, Marshall and Peters (1989) found that in oligotrophic lakes, chlorophyll (*a*) concentrations were generally low for the first four months of the year and concentrations increased during April and May, and then fluctuated about the mean for the rest of the year. The researchers found that the synchronous summer depressions and fall blooms in oligotrophic lakes are not evident overall.

Golnar (1986) and Craft *et al.* (2003) have provided a description of the phytoplankton community structure and dynamics in Whitefish Lake for two similar water discharge and seasonal water flux years. In both years lower primary productivity, as measured via light-dark bottle ^{14}C isotope analysis, during the winter months gave rise to a peak of approximately 400 C $m^{-2}yr^{-1}$ in the first week of May following spring turnover and the lowland runoff as indicated by the April peak in Lazy Creek discharge (Craft *et al.*, 2003).

Productivity then dropped slightly in late May about 250 C $m^{-2}yr^{-1}$ just before the peak discharge from high flows hit the lake. Golnar (1986) described that the sudden productivity crash occurred despite increases in day length, surface irradiance, and water temperatures, and seemed to be closely related with sediment import during runoff. The timing and extent of primary production is quite varied and not necessarily depicted very well by point in time sampling. Golnar (1986) noted a seasonal maxima in early May but within two weeks, levels had dropped considerably.

In 1983, the drop in productivity continued into June before rebounding slightly in July and leveling off (100-200 C $m^{-2}yr^{-1}$) through August. In 2002, productivity rates not only recovered in early June but continued to climb through June to a second, even higher, peak of 603 C $m^{-2}yr^{-1}$. For the remainder of the summer through September, the researchers found productive rates from 300 to 400 $Cm^{-2}yr^{-1}$, twice the rates measured in 1983. In 1983, there was a much smaller peak in production in mid-September whereas in 2002 showed continued declining values with a very minor peak in early October.

Craft *et al.* (2003) found that annual primary productivity in Whitefish Lake increased from 69g $Cm^{-2}yr^{-1}$ in water year 1983 to 106g $Cm^{-2}yr^{-1}$ in water year 2002 and that mean daily primary productivity rates increased from 190 to 289g $Cm^{-2}yr^{-1}$ respectively. Although productivity rates were similar from mid fall through mid spring, after the plume from spring runoff hit the lake in late May, productivity in 2002 was twice that in 1983.

Figure 113 displays net primary productivity on a calendar year basis with the mean value displayed. NPP was significantly lower in 1982 and 1983 and roughly doubled in 2002. It is highly likely that the introduction and establishment of *Mysis* shrimp created a step increase in primary production after 1983 and before 2002, where a new dynamic equilibrium was reached. The same step increase in primary production as a result of *Mysis* introduction was documented by Ellis (2006) in Flathead Lake. From 2002 to 2013 values are stable and no trend is apparent except for an increase centered on the higher tributary flows of 2011.

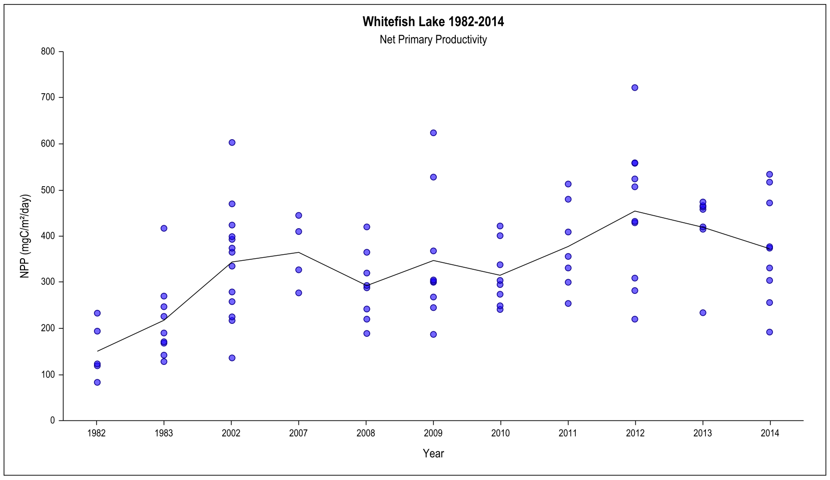


Figure 113. Net Primary Productivity Whitefish Lake 1983-2013.

The phytoplankton community in Whitefish Lake was much more dynamic in 1982-1983 (more specific dominant groups) than in 2002-2003 where co-dominance was found throughout the year (Craft *et al.*, 2003). Phytoplankton mean annual total biomass increased from 0.20cm^{3}m^{-3} in water year 1983 to 0.33cm^{3}m^{-3} in water year 2002 but still below the 1cm^{3}m^{-3} threshold that indicates a switch from oligotrophic to mesotrophic conditions. An increasing trend in algal biomass suggests that water quality had declined in 2002 as researchers had robust time series data showing a clear transition over time.

Biomass of primary producers can also be expressed by the content of chlorophyll (*a*) in the lake water and data for Whitefish Lake shows the values for the 2003 study stayed about the same 0.8 to 1.0 mg/L^{-1} for the period of record, but that the maximum concentrations have risen rather dramatically from about 1.0 to 1.8 mg/L^{-1}. A correlation exists between chlorophyll (*a*) concentrations and NPP in Whitefish Lake as displayed in Figures 115 and 115.

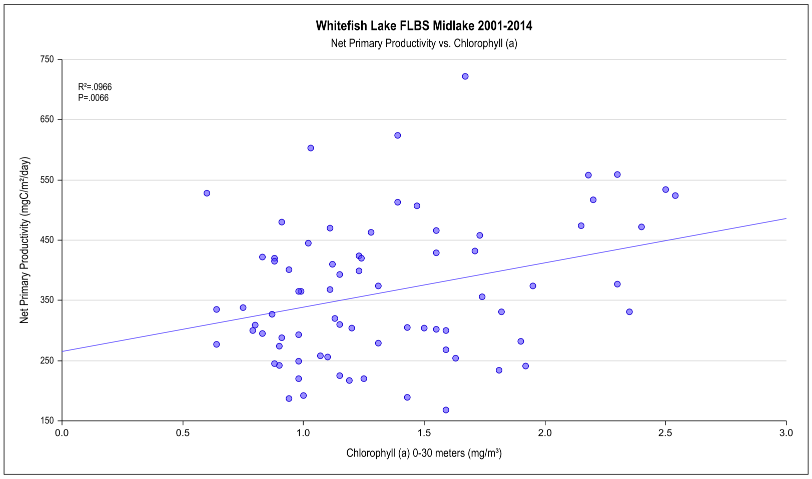


Figure 114. Net PP vs. Chl (*a*) 0-30 M Integrated Mid-Lake 2001-2014.

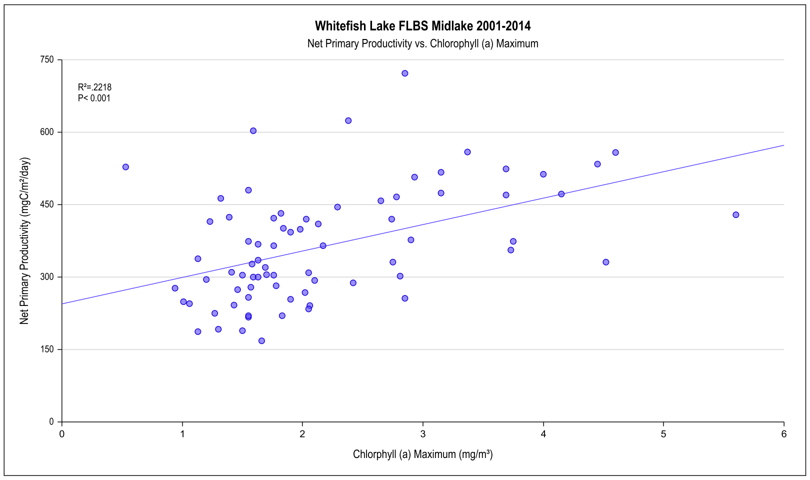


Figure 115. Net PP vs. Chlorophyll (*a*) Maximum Mid-Lake 2001-2014.

The maximum chlorophyll (*a*) value provides a stronger statistical correlation to NPP than does the 0-30 meter value, however, there is still high variability in the data. A clear statistical relationship between nutrients and chlorophyll (*a*) could not be drawn for Whitefish Lake probably due to internal fluxes, the rapid assimilation of inorganic nutrients, and shading effect.

2. Periphyton

As previously discussed, Golnar (1986) found higher levels of periphyton associated with developed shoreline areas of Whitefish Lake, however there was a lack of a clear seasonal pattern due to the time required by algal colonization of substrate. In addition, Whitefish Lake fluctuating levels probably influence periphyton colonization (*see Lake Elevation in this chapter*). Whereas periphyton have been used as a metric in streams, no metrics for lakes have been developed.

3. Macrophytes

It is well known that the shoreline areas of lakes tend to be more productive than the open water zone. Increased production can result from shoreline nutrient inputs in addition to the unique physical attributes of the littoral zone. For example, the slope of the littoral zone and the type of substrate found there has a great influence on the biomass and distribution of the aquatic macrophyte community. In Whitefish Lake, Lazy Bay, Beaver Bay, Carver Bay and Monk's Bay have a gently sloped littoral zone that allows the deposition of fine materials and formation of gyttja which is nutrient rich and favors the establishment of aquatic macrophytes.

According to Jackson and Moquin (2011) macrophytes compete with phytoplankton for nutrients when abundant by storing nutrients in their tissue and by producing a group of chemicals called allelophathic compounds that reduce growth rates of phytoplankton. Macrophytes can also provide refuge to large-bodied zooplankton such as Daphnia that are the most effective algal grazers. Macrophytes also provide fish habitat for different species or life stages. Unfortunately, in Whitefish Lake, this means spawning and hiding cover that favors introduced species like northern pike.

In 2013, WLI conducted a 395 point macrophyte and substrate survey along the Whitefish Lake shoreline (see Dominant Macrophyte Distribution and Dominant Substrate Distribution maps in Chapter XXI Addendum B GIS Maps). The survey consisted of determining the composition and relative abundance of plant species at each location, along with characterizing the lake substrate to determine areas suitable for plant colonization. No exotic invasive species were found.

Additional surveys have been conducted by WLI for early detection monitoring of Eurasian watermilfoil (EWM) at many locations including Beaver Bay, Lazy Bay, State Park, the outfall of Viking Creek and City Beach. In 2012, a concerned Whitefish resident believed there may have been EWM in the Lazy Bay channel, further investigation proved that it was northern milfoil. No EWM was discovered during the surveys, however, additional surveying is recommended based on suitable areas for colonization, recreational pressure, and proximity to Beaver Lake which does have EWM.

4. Aquatic Invertebrates

Zooplankton

Little information on the Whitefish Lake zooplankton community exists. In 1979, 1984 and 1985, Anderson (1987) found cyclopoids copepods as the most abundant organism every month sampled during the three years followed by cladocerans and calanoids. The low numbers of calanoid copepods were mostly comprised of the genus *Epischura* with infrequent occurrence of *Diaptomus*. Cladocerans were comprised of the species *Bosmia longirostris, Daphnia thorata*, *Daphnia longiremus*, and rare occurrence of *Leptodora*.

Ellis *et al*. (2011) found on Flathead Lake that after *Mysis* introduction (*see Mysis shrimp discussion*) that cladocerans were reduced by 78% overall, and *Bosmina longirostris*, which dominated cladoceran abundance before Mysis, declined by 92%. Conversely, *Daphnia thorata* now dominate cladoceran numbers, increasing in the epilimnion every summer, apparently adapted to warmer temperatures that allow it to avoid predation by the cold-adapted *Mysis*.

5. Macroinvertebrates

The following information on Whitefish Lake littoral macroinvertebrates was provided by Bollman (2015) based on data collected by WLI on July, 9th 2015.

Sixty-eight unique invertebrate taxa in 20 taxonomic groups (phylum, class, or order) were identified in six samples. The analyses of taxonomic composition of Whitefish Lake samples suggests that the sites can be roughly sorted into 2 general taxonomy-based categories: sites dominated by non-insects, including Sites 1 (City Beach), 2 (Monk’s Bay), 5 (Brush Bay) and 6 (Lazy Bay) and sites dominated by mayflies, including Sites 3 (Mackinaw Point) and 4 (just south of Les Mason Park). The sites dominated by non-insects support more stress-tolerant assemblages, while the sites dominated by mayflies support more stress-sensitive assemblages.

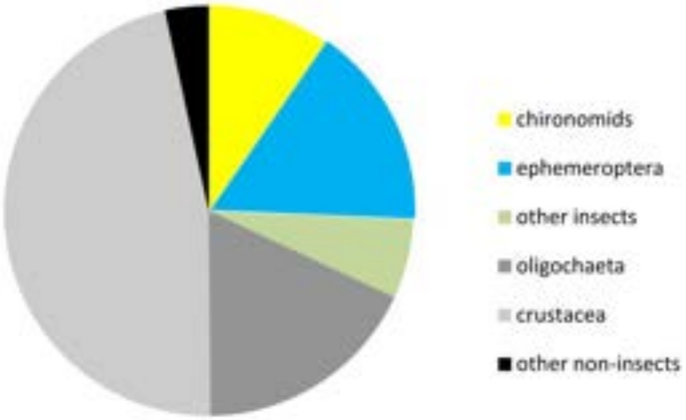


Figure 116. Littoral Invertebrates: Taxonomic Composition, All Samples Combined.

The functional analyses of Whitefish Lake samples suggests that sites can be roughly sorted into two general function-based categories: sites dominated by gatherers (omnivores and detritivores), including Sites 1, 2, 3, and 5, and sites dominated by other functional groups. Site 4 is apparently dominated by scrapers, and Site 6 by shredders. Site 5 might be considered functionally transitional, because, while the greatest proportion (53.9%) of invertebrates collected there were gatherers, significant numbers (38.1%) were shredders. These findings emphasize the uniqueness of Site 4 among the studied sites: it supported the most stress-sensitive assemblage, and was dominated by scrapers, which were less common if not absent, at all other sites.

Site 1 (City Beach) had the lowest taxa richness (13 taxa) among the six lake sites sampled in this study, and the lowest organism density: only 57 individuals were present in the sample.

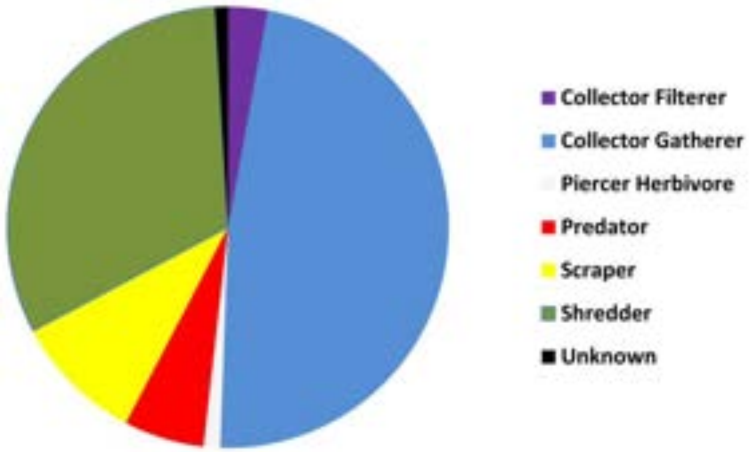


Figure 117. Littoral Invertebrates: Functional Composition, All Samples Combined.

The depauperate fauna represented in the sample gives few clues about the characteristics of the substrate or water quality. The low diversity and abundance suggests disturbance, which may have been natural, such as that due to wave action, or monotonous habitats. Oligochaetes (Lumbriculidae and Naididae) were the most abundant taxa. The naidid worms suggest sandy substrates with accumulations of silt and/or organic material. They are often associated with macrophytes or filamentous algae: the mayfly *Tricorythodes* sp. also suggests the presence of macrophytes. Four hemoglobin-bearing chironomid taxa, representing 8.8% of the sampled fauna, suggests areas of hypoxic substrate. The functional composition of the invertebrate assemblage at this site was strongly dominated by gatherers: in this case, oligochaetes were the primary representatives of the functional group. This pattern suggests a heavy dependence on detritus as an energy source for invertebrates at this site.

At Site 2 (Monk's Bay) invertebrates were moderately abundant. Twenty-four taxa were represented, about the average number for Whitefish Lake sites in this study. Oligochaetes and other non-insect taxa dominated the taxonomic composition of the sample. Lumbriculid worms were the most abundant organisms, suggesting fine sediment substrates. Isopods (*Caecidotea* sp.) were common: warm water temperatures and some organic nutrient enrichment are suggested. Well-oxygenated substrates are suggested by the low abundance (1.7% of the assemblage) of hemoglobin-bearing chironomids.

Gatherers, including the lumbriculid oligochaetes and the amphipod *Hyalella* sp., dominated the functional composition of the assemblage, suggesting that the primary energy source may have been detritus. Scrapers were notably absent, suggesting a lack of stony substrates or intense shading.

At Site 3 (Mackinaw Point) invertebrates were somewhat sparse. Twenty-five taxa were counted: diversity was about average for studied sites. Site 03 was apparently one of only 2 sites (sites 03 and 04) that supported *Paraleptophlebia* sp. This mayfly was the most abundant taxon at site 03, accounting for 24.0% of sampled organisms. Several rheophilic taxa, including *Paraleptophlebia* sp., *Ecdyonurus* sp., *Cheumatopsyche* sp., and several others, suggest that the fauna was influenced by flowing water at this site. The site supported the largest relative abundance of hemoglobin-bearing midges (13.0%) among the sites in this study: areas of poorly oxygenated sediments are suggested. Gatherers dominated the functional composition of the assemblage. Ten percent of sampled animals were filter-feeders: these included the midges *Microtendipes* sp. and *Tanytarsus* sp., as well as the blackfly *Simulium* sp. The significant contribution of these organisms to the functional mix supports the hypothesis that lotic conditions were present here.

At Site 4 (just south of Les Mason Park) invertebrates were moderately abundant and taxa richness (22) was slightly less than average for sites in this study. The dominant taxon at this site was the mayfly *Ecdyonurus* sp., a mayfly associated with flowing water. It accounted for 53.6% of invertebrates in the sample. Other rheophilic taxa present here included the mayflies *Paraleptophlebia* sp. and *Maccaffertium* sp., and the caddisfly *Apatania* sp. along with several chironomid taxa. Generally, these faunal components suggest clean stony substrates, with minimal fine sediment deposition. The assemblage was the most sensitive among Whitefish Lake assemblages studied here, suggesting good water quality. Sediments were probably well-oxygenated, since hemoglobin-bearing taxa were not common. Uniquely among studied sites, this location supported a functional composition dominated by scrapers, especially the heptageniid mayflies *Ecdyonurus* sp. and *Maccaffertium* sp. This suggests well-established algal films and cobble/boulder substrates.

At Site 5 (Brush Bay) invertebrates were abundant and taxa richness was higher here than at any other studied site: the site supported at least 34 taxa. The fauna was distinctly lentic, and characteristic of a montane lake with organic silt and sand substrates as well as ample leaf litter. The dominant taxa were the amphipods *Gammarus* sp. and *Hyalella* sp., suggesting a detritus-based food web. Substrates appear to have been well-oxygenated, since the sample contained few hemoglobin-bearers. The elmid *Dubiraphia* sp. was common here, suggesting the presence of macrophytes. Both Sites 05 and 06 supported abundant shredders: in both cases, the amphipod *Gammarus* sp. was the most abundant member of this group. This suggests that leaf litter, woody debris, and/or senescent macrophytes were an important local energy source. Gatherers, especially the amphipod *Hyalella* sp. and the oligochaete *Bothrioneurum vejdovskyanum*, both detritivores, were the dominant functional group.

Similar to Site 5, Site 6 (Lazy Bay) supported abundant invertebrates and a rich (30 taxa) fauna. The dominant taxa were the amphipods *Gammarus* sp. and *Hyalella* sp., together accounting for 58.6% of the sampled assemblage. Silty substrate with ample leaf litter is suggested. Ten percent of the organisms in the sample were hemoglobin-bearing midges, including *Dicrotendipes* sp. and *Microtendipes* sp. Areas of hypoxic substrates seem likely. Notably, ceratopogonid gnats were common in the sample: this suggests the proximity of grazing cattle or other blood sources, which are required by the adult stages of these pests. The functional composition of the sampled assemblage included abundant shredders (especially *Gammarus* sp.) and gatherers (especially *Hyalella* sp. and *Dicrotendipes* sp.). Silty organic substrates and leaf litter, woody debris and/or senescent macrophyte material were likely important local energy sources.

Mysis Shrimp

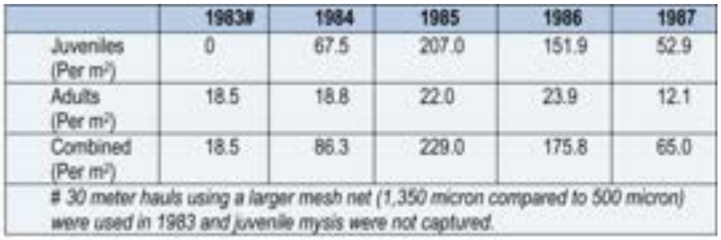
Spencer *et al.* (1991) described the most deterministic event in the legacy of Flathead Lake and indeed the Flathead Basin as the introduction and establishment of *Mysis* shrimp (*Mysis diluviana*) (Figure 118), a native of the North American Great Lakes that lie on the Canadian Shield. Beattie and Clancey (1991) reported that the *Mysis* introductions were expected to provide a food source for benthic-feeding fishes such as lake trout, and for pelagic planktivores such as kokanee salmon. Ellis et. al (2011) report that the expected increased forage for kokanee salmon from the *Mysis* shrimp transplant was based on erroneous interpretations of the results of such introductions elsewhere.

In 1968, *Mysis* shrimp were transplanted by Montana Fish, Wildlife & Parks from Waterton Lake, Alberta to several large northwestern lakes in FWP- Region 1 (Domrose, 1982). Whitefish Lake and McGregor Lakes received the first plant in June and were also part of the second plant that year in September. During 1968, 1975 and 1976, Rumsey (1988) reported that mysids were transplanted to 12 lakes in northwest Montana, including; Ashley, Bull, Crystal, Dickey, Holland, Little Bitterroot, McGregor, Middle Thompson, Spar, Swan, Tally, and Whitefish Lakes.

Figure 118. *Mysis* Shrimp.
Photo Courtesy NOAA Great Lakes Environmental Research Laboratory

Six of the original 12 lakes were found to contain *Mysis* following initial introductions; Ashley, Little Bitterroot, McGregor, Swan, and Whitefish. *Mysis* then drifted downstream from Swan, Whitefish and/or Ashley Lake(s) to populate Flathead Lake where they were first collected in 1981 (Rumsey, 1988). *Mysis* populations were well established in Whitefish Lake by 1976. In August of that year, an estimated 2,400 individuals were collected from four 5-minute and one 10-minute meter net hauls, and densities at the time were believed to be the greatest in McGregor and Whitefish Lakes (Domrose, 1982).

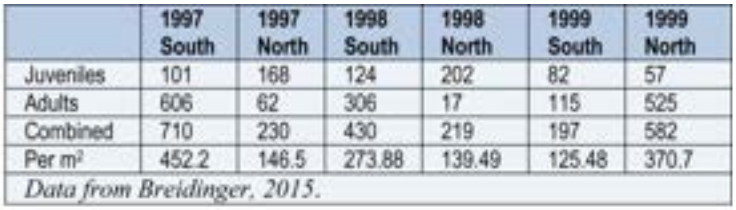
Unfortunately, *Mysis* survey data for Whitefish Lake employed different methodologies and limited data exists. (Figures 119 and 120).



	1983#	1984	1985	1986	1987
Juveniles (Per m²)	0	67.5	207.0	151.9	52.9
Adults (Per m²)	18.5	18.8	22.0	23.9	12.1
Combined (Per m²)	18.5	86.3	229.0	175.8	65.0

 # 30 meter hauls using a larger mesh net (1,350 micron compared to 500 micron) were used in 1983 and juvenile mysis were not captured.

Figure 119. Average June *Mysis* Densities.



	1997 South	1997 North	1998 South	1998 North	1999 South	1999 North
Juveniles	101	168	124	202	82	57
Adults	606	62	306	17	115	525
Combined	710	230	430	219	197	582
Per m²	452.2	146.5	273.88	139.49	125.48	370.7

Data from Breidinger, 2015.

Figure 120. Average June *Mysis* Densities, 1997-1999.

Additionally, *Mysis* populations seem to demonstrate much temporal and spatial variation in their horizontal and vertical distribution, which makes accurate and precise estimates of their numbers difficult to obtain (Lasenby, 1991).

By June of 1979, *Mysis* shrimp, of which the average size was over 10mm and two percent of the sampled averaged 20mm in length, were abundant at all depths sampled. Immature *Mysis* were 4 to 6mm in length (Anderson and Domrose, 1982). Based on the survey data and time from introduction, it is estimated that the Whitefish Lake *Mysis* population peaked and reached carrying capacity sometime from 1973-1976. This is corroborated by fisheries data where Anderson (1987) found that lake whitefish and lake trout populations increased between sample periods (1979-1984). There would have been a delayed effect from peak *Mysis* and the increased number of lake whitefish and lake trout from the enhanced forage base. In addition, in 1976, the kokanee salmon population declined dramatically in Whitefish Lake. There would have been a more immediate effect on this species based on direct competition with *Mysis* for zooplankton (see section kokanee salmon discussion in Fisheries).

Mysis were found to reach their carrying capacity within 10 years in Flathead Lake (Beattie and Clancey, 1991) and in many other large, oligotrophic lakes (Northcote *et al*., 1973). Ellis et. al (2011) report that the *Mysis* Explosion Period in Flathead Lake was from 1985-1988 where zooplankton abundance and biomass declined by half. Within two years of *Mysis* peak abundance, the population retreated to less than half of the peak level, and now fluctuates but averages about one third peak density.

Ellis et. al (2011) found on Flathead Lake that the kokanee sport fishery collapsed the year after peak *mysis* abundance, and the large-bodied zooplankton (cladoceran and copepod) forage base in Flathead Lake markedly declined along with a shift for the rest of the zooplankton and phytoplankton community. *Mysis* reside near the lake bottom during the day and vertically migrate in the water column to near surface waters at night to forage, preferring the larger bodied and slower zooplankton species. These same zooplankton species were also the preferred prey of kokanee salmon, a daytime ocular feeder. The competition for forage between kokanee and *Mysis* is one contributory factor to the extirpation of kokanee in Flathead Lake and Whitefish Lake.

The trophic cascade set in motion by *Mysis* affects at least three trophic levels (phytoplankton, zooplankton and fish) of the lake's food web with implications to nutrient cycling. Ellis (2006) found a step increase in primary production in Flathead Lake during the *Mysis* upheaval but no trend in the period before or after *Mysis*. However, the larger zooplankton have decreased, creating a lower trophic food web similar to lakes where lake trout and mysids are native. Herbivorous zooplankton have increased post-*Mysis* and are a significant predictor of declining chlorophyll (*a*).

Mysis introductions to lakes may set up complex interactions with several processes that advance eutrophication (Northcote, 1991). Mysids may cause eutrophication by selectively feeding on cladoceran zooplankton of a certain size (Kinsten and Olsen, 1981); by benthic feeding which may stir up sediments and stimulate release of phosphorus (Kasuga and Otsuki, 1984); by migrating nightly to the metalimnion or near-surface waters stimulating phytoplankton productivity through their excretions (Madeira *et al.*, 1982; Seale and Boraas 1982); or by feeding on diatoms and diatom fragmentation adding significant amounts of dissolved organic carbon which is then available to bacterial and algal consumption (Sierszen and Brooks, 1982).

6. Fisheries

For a complete list of the fish found in the project area see Figure 45 in Chapter IX Biological Community Overview, Section D Fisheries. From the end of the Pleistocene Epoch roughly 12,500 years ago, Whitefish Lake's food web developed slowly as native fish colonized the lake. The historic fish species assemblage consisted of bull trout as the top predator and westslope cutthroat trout as a pelagic surface feeder, along with various forage species and benthic dwellers. Many of these fish adopted an adfluvial life history, utilizing the Swift Creek Watershed for spawning and rearing. It was a time when fish niches were well defined and there was a stable food web subject only to natural events.

Starting roughly 100 years ago, representing approximated 1% of the lake's history, various fish species have been introduced to the lake, either stocked based on management objectives or illegally planted by private citizens. In total, these introductions have had major repercussions to the food web and the plight of native species. During the last 100 years, the food web has been in a constant flux as introduced fish species compete for niches with some species flourishing while others are now extirpated.

According Anderson (1987) kokanee salmon were introduced to Whitefish Lake in 1945 and because of successful spawning along the shoreline of Brush Bay supplemented with annual stocking, became a major fish species through the mid 1970s. According to Anderson and Domrose (1982) Whitefish Lake spawn taking operations were initiated in 1967. Kokanee eggs were collected to compliment various sources for stocking Montana waters, including Whitefish Lake. Kokanee spawners in Whitefish Lake between the years of 1967 through 1975 averaged between 12 and 14 inches in length.

In 1976, the kokanee fishery in Whitefish Lake declined dramatically apparently in response to competition with *Mysis* and the state spawning crew reported the average length of spawners declined to 11 inches (Anderson, 1987). As a result, spawn taking operations were discontinued. By 1980, Anderson and Domrose (1982) indicate that historic kokanee spawning came to an end. That year they observed no active redds or spawners and gill nets fished over the spawning area down to 60 feet were unsuccessful in capturing any kokanee. Between 1970 and 1992, 4,786,773 kokanee were stocked into Whitefish Lake with a final plant of larger (7 inch) fish in 1992. Kokanee stocking was abandoned due to poor returns and kokanee are now extirpated from Whitefish Lake.

Lake trout were stocked seven different years in Whitefish Lake from 1941-1952 but remained at low densities until *Mysis* became established. Gill net surveys in 1979 (see Figures 121 and 122) found lake trout the lake trout composition in sinking gill nets to be around 7%. *It is important to note that fish survey information for figures 121 and 122 is from limited sets and contains various sample sizes. When available, data were combined to better represent the population structure during time periods. Figures should be interpreted as general trends in the fishery. The spatial and temporal extent of the net sets and/or intra-annual conditions may have favored the capture of certain species over others.

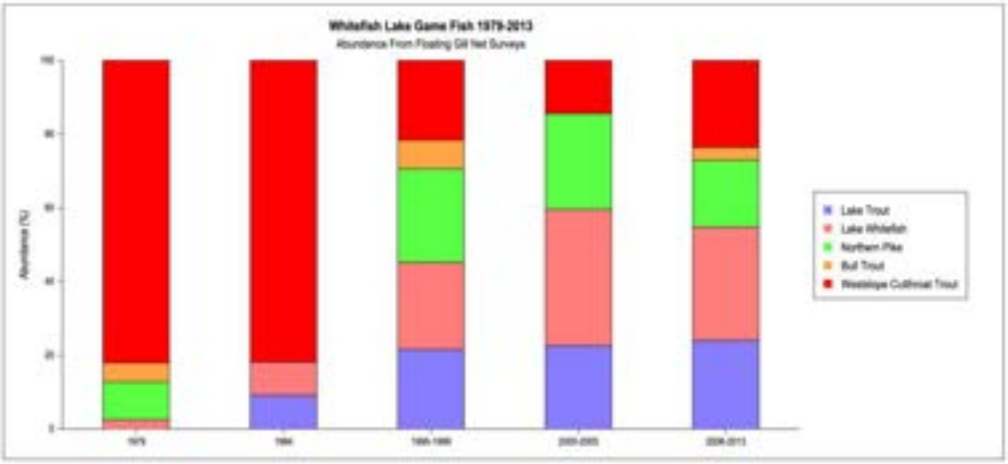


Figure 121. Game Fish from Floating Gill Net Surveys, 1979-2013.

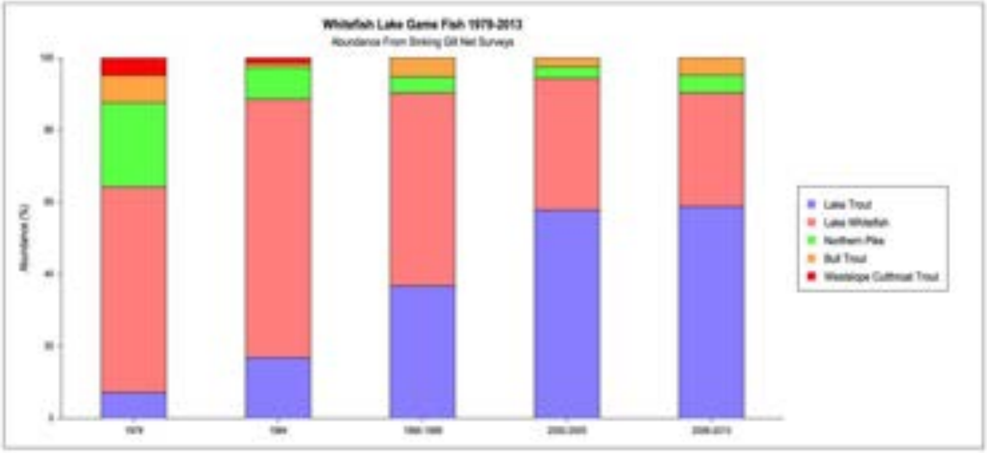


Figure 122. Game Fish from Sinking Gill Net Surveys, 1979-2013.

In 1984, after peak *Mysis*, the lake trout population expanded significantly (17%) in addition to being found in the floating gill net survey. According to Ellis et. al (2011) *Mysis* became a new forage base for benthic dwelling juvenile lake trout which had been introduced to Flathead Lake 80 years prior but existed in lower densities. The increase in lake trout populations have also resulted in a reduction of native westslope cutthroat and bull trout populations. The same trophic cascade appears to have occurred in Whitefish Lake which has a parallel historic and current fish species assemblage.

Figure 123. Gordy Duvall With Lake Trout, 1950s.
Photo Courtesy Stumptown Historical Society.

Lake trout populations continued to expand in the 1990s and 2000s competing or preying upon almost every other species found in Whitefish Lake. Lake trout could have exploited native peamouth chub and native pygmy whitefish populations upon colonization in Whitefish Lake leading to very large individuals as evidence by anecdotal accounts and photos (Figure 123). Current anecdotal accounts indicate that although there are higher densities, the average size has been reduced, indicating competition within the species. Lake trout reproduce along the shoreline of the lake in the fall and is long-lived, giving it a competitive advantage over the other top end predator bull trout which are obligate stream spawners and have a shorter life span.

Lake whitefish were introduced to Whitefish Lake in 1910 (Anderson, 1987). This species was well established pre-*Mysis* but at lower densities when the juvenile stage became an immediate benefactor of *Mysis* introduction. The lake whitefish population increased in the 1984 gill net survey and has slowly declined throughout the years, most likely the result of increased competition and predation by lake trout, after other forage fish densities decreased.

Northern pike were illegally planted or immigrated to Whitefish Lake sometime in the early 1970s (Anderson and Domrose, 1982). It's quite possible that northern pike initially foraged on peamouth chub, a native sympatric prey species. Anderson (1987) found that there was a sharp decline in peamouth chubs from 1979 to 1984 and northern pike catch and growth rates had slowed since 1979. It's likely that peamouth chub were also preyed on by the lake trout population that started to take off during that time period. Northern pike now exist in smaller numbers and are limited in habitat containing aquatic vegetation that they use for lie and wait predation and reproduction.

There have been many other fish introductions to Whitefish Lake including Arctic Grayling which were unsuccessfully stocked in 1928 and 1952 (extirpated). Coho salmon were unsuccessfully stocked in 1941(extirpated). Brook trout were stocked in 1925, 1947, and 1951. Rainbow trout were stocked four years from 1924-1991. An undisclosed cutthroat strain (probably Yellowstone) was stocked 18 years from 1925-1969. Westslope cutthroat trout have been stocked 33 years from 1975-2008. See Smith Lake under Other Project Lakes for a description of the history of this lake as a rearing pond with the release and flushing of westslope cutthroat down Smith Creek to Whitefish Lake.

Native bull trout and westslope cutthroat trout have clearly been affected by the introductions of other species in Whitefish Lake. Both sinking and floating gill net surveys through the years have documented the decline of these species which is problematic for fisheries managers given that bull trout are a listed threatened species under the Endangered Species Act.

Ellis *et al.* (2011) indicated that in Flathead Lake, extirpation of some of the native fishes (bull trout and westslope cutthroat trout) in the near future seems possible and recovery of these populations will be difficult given strong food web control by the expansive lake trout population.

Figure 124. Bull Trout.
Photo courtesy U.S. Fish & Wildlife Service.

As native species, bull trout (Figure 124) and westslope cutthroat trout populations are strong indicators of overall lake ecosystem health – such as water quality and water temperatures. Lake trout, the new dominate species in the lake, has evolved to different environmental conditions and is likely more tolerant to environmental disturbance. Recent gill net surveys (2011) do show bull trout and westslope cutthroat trout in the catch and bull trout spawning habitat conditions and number of spawners in the Swift Creek drainage is encouraging (see Swift Creek and West Fork of Swift Creek sub-sections). However, the number of bull trout spawners as evidenced by redd counts is perilously low and this small, nodal population is worthy of enhanced protection measures. Nodal habitat is defined by waters that provide migratory corridors, overwintering areas, or other critical life history requirements (Montana Bull Trout Scientific Committee (1996).

Figure 125 displays statewide mail creel survey information for Whitefish Lake. Angler days closely mirror the popular kokanee salmon fishery and its crash around 1976. Based on the wide array of species introductions and the effect to the food web, Whitefish Lake has in general transitioned away from a predominately top water fishery to a deep water fishery.

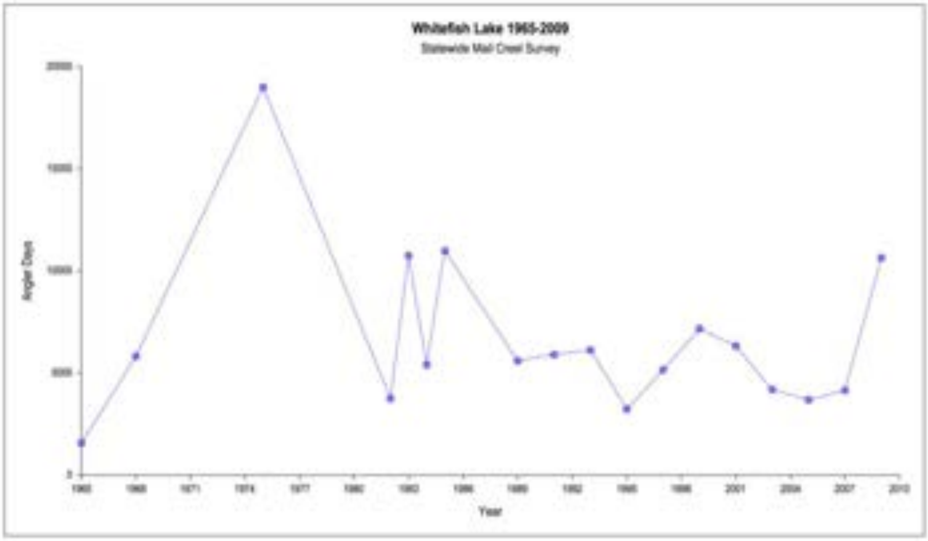
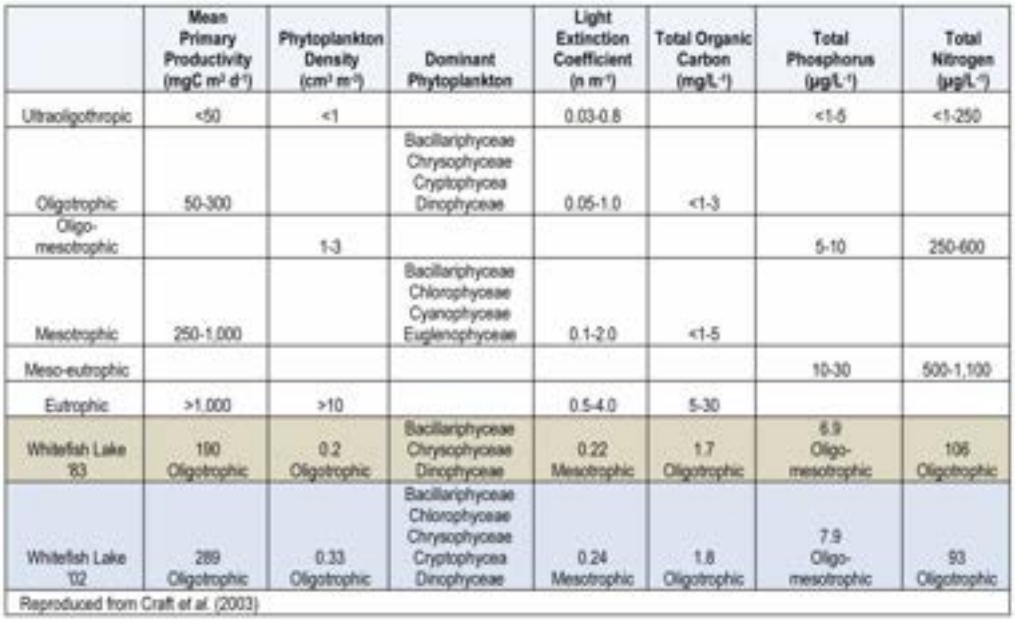


Figure 125. Montana State Mail Creek Survey.

D. TROPHIC STATUS

The EPA (1977) classified Whitefish Lake as oligotrophic and ranked it first in overall trophic quality when compared to the 15 Montana lakes and reservoirs sampled during the National Eutrophication Survey. Phytoplankton density continues to remain in the ultra-oligotrophic category. However, Golnar (1986) and Craft *et al.* (2003) determined eutrophication was occurring in the lake from key variables including; primary productivity, light extinction coefficient, and total phosphorus (Figure 126) leading them to re-classify the lake as oligo-mesotrophic. Total phosphorus continued to be in the oligo-mesotrophic category post 2003 with lower levels observed recently in 2013-2014.

Wetzel (1983) determined that mean primary productivity rates of 250 to 300g Cm^{-2}yr^{-1} is an accepted threshold for transition from oligotrophic to mesotrophic conditions. In 2002, with a mean daily productivity of 289g Cm^{-2}yr^{-1}, Whitefish Lake was bordering the mesotrophic classification which suggested a decline in water quality.



	Mean Primary Productivity (mgC m^{2} d^{-1})	Phytoplankton Density (cm^{3} m^{-3})	Dominant Phytoplankton	Light Extinction Coefficient (n m^{-1})	Total Organic Carbon (mg/L^{-1})	Total Phosphorus (µg/L^{-1})	Total Nitrogen (µg/L^{-1})
Ultraoligothropic	<50	<1		0.03-0.8		<1-5	<1-250
Oligotrophic	50-300		Bacillariphyceae Chrysophyceae Cryptophycea Dinophyceae	0.05-1.0	<1-3		
Oligo-mesotrophic		1-3				5-10	250-600
Mesotrophic	250-1,000		Bacillariphyceae Chlorophyceae Cyanophyceae Euglenophyceae	0.1-2.0	<1-5		
Meso-eutrophic						10-30	500-1,100
Eutrophic	>1,000	>10		0.5-4.0	5-30		
Whitefish Lake '83	190 Oligotrophic	0.2 Oligotrophic	Bacillariphyceae Chrysophyceae Dinophyceae	0.22 Mesotrophic	1.7 Oligotrophic	6.9 Oligo-mesotrophic	106 Oligotrophic
Whitefish Lake '02	289 Oligotrophic	0.33 Oligotrophic	Bacillariphyceae Chlorophyceae Chrysophyceae Cryptophycea Dinophyceae	0.24 Mesotrophic	1.8 Oligotrophic	7.9 Oligo-mesotrophic	93 Oligotrophic

Reproduced from Craft et al. (2003)

Figure 126. Key Trophic Variables and Whitefish Lake Status.

In addition, Craft *et al.* (2003) found an increase in Chlorophyta (green algae) in the phytoplankton community, indicative of a shift from oligotrophic to mesotrophic conditions in Whitefish Lake. Craft *et al.* (2003) also found that the biomass stayed about the same 0.8 to 1.0 mg/L^{-1} for the period of record, but that the maximum concentrations have risen rather dramatically from about 1.0 to 1.8 mg/L^{-1}.

Considerable effort has been extended by various agencies and researchers to develop methods that can be used to determine the relationship between nutrients and trophic status and the extent to which a watershed can be altered before the aquatic ecosystems it contains begin to exhibit impaired water quality. Phosphorus concentration has been used extensively in developing trophic state indices mostly because it is widely considered a limiting factor for algal growth in lakes.

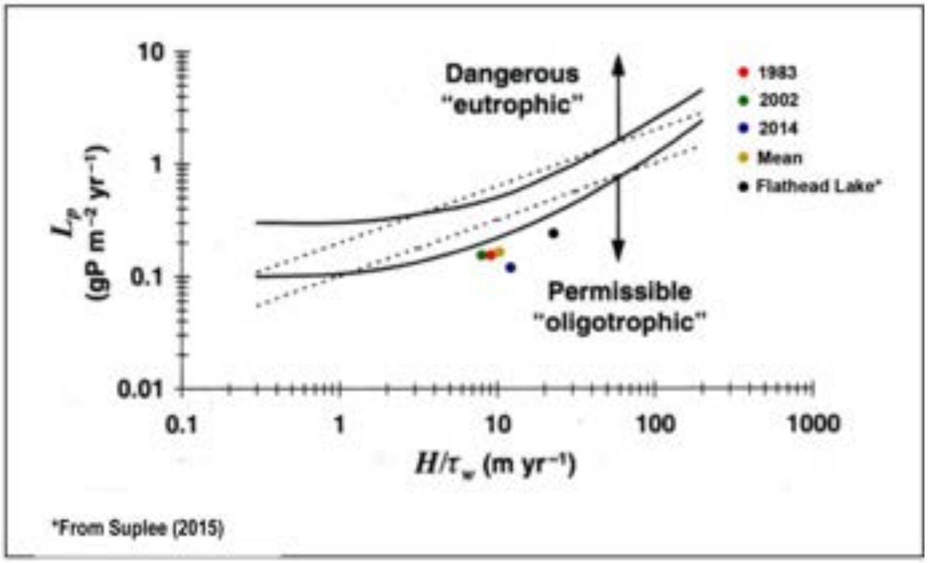
1. Vollenweider Calculation

Several scientists have over time provided different approaches to quantifying the relationship between nutrients and trophic status. The most widely accepted tool to determine a threshold of change related to nutrient input to lake ecosystems is based on the work of Vollenweider (1975) or Vollenweider and Kerekes (1980). The model is based on the total phosphorus load versus primary productivity response. In phosphorus limited lakes, there is a strong relationship between phosphorus and plant biomass. This relationship allows phosphorus to be used to estimate production (Vollenweider, 1976).

The EPA (1977) calculated the phosphorus loading at 0.43 g/m^2/yr and compared that value to those proposed by Vollenweider and Dillon (1974). The EPA concluded that any significant increase in the phosphorus loading would result in a noticeable degradation of water quality and every effort should be made to limit phosphorus inputs to the lake.

Research by (Golnar & Stanford, 1984), found Whitefish Lake falls near a critical threshold of phosphorus loading. Their research concluded that based on the application to the Vollenweider & Kerekes model, "…the lake is in danger of serious eutrophication problems (e.g. excessive algal blooms), if total phosphorus inputs increase in the future.

The Vollenweider (1975) as adapted by Chapra (1997) loading plot for Whitefish Lake is displayed in Figure 127 for 1983, 2002, 2014, and as a mean value. In calculating the surface overflow rate (qs) (meters/yr), the flushing rate volume for 1983 and 2002 was derived from a staff discharge relationship from the lake outlet as developed by the researchers. In 2014, the flushing rate was taken from the U20 discharge information on the Whitefish River at the Columbia Avenue Bridge. The Columbia Avenue Bridge value was then compared to the downstream USGS site by adding the Upper Whitefish River tributary inputs (Cow, Walker, Haskill, Whitefish Wastewater Treatment Plant). There was an 11% discrepancy between the two sites most likely from the contribution of groundwater downstream of Walker Creek.



*From Suplee (2015)

Figure 127. Vollenweider's (1975) Loading Plot as Applied by Koopal (2015)

In calculating the areal Total Phosphorus load (g/m2/yr), an inorganic phosphorus coefficient (3.55-30.7%, Mean=12.9%) was applied to the annual Total Phosphorus Load/ P Load (Metric tons/yr) to match the observed combined 5M and 45M mean Total Phosphorus value at the Mid-Lake site. Ellis & Stanford (1988) found inorganic phosphorus comprised 73-97% of fluvial sediments for the Flathead River-Lake ecosystem. For 1983, the atmospheric phosphorus loading was adjusted to better represent the values found in 2002 and 2014 as the 1983 values were over-reported due to leaf litter deposition in the collection bucket.

As predicted by the EPA (1977) and Golnar & Stanford (1984) Whitefish Lake teeters at the edge of a trophic state transition. A similar situation exists for Flathead Lake as determined by Suplee (2015). Caution should be exercised in attempting to draw trend information from the figure. The loading plot is influenced by the dynamic relationship between flushing rate and phosphorus loading and both can display significant inter-annual variability based on meteorological conditions and land use pressures.

The most compelling long-term trends for nutrients in Flathead Lake according to Ellis (2006) were the increasing nitrate/nitrite concentration and load from many tributary inputs and atmospheric deposition. Given that primary production appears to be limited by both nitrogen and phosphorus, the increase in loading of nitrogen is of particular concern. This same co-limitation scenario exists for Whitefish Lake. Smith (1982) stresses that nitrogen can significantly modify a lake’s biological response to phosphorus and the chlorophyll yield is dependent on both the phosphorus concentration and the TN:TP ratio. This is largely based on the nutrient physiology of different algal communities. As water quality candidate criteria are evaluated for Whitefish Lake, models like Smith (1982) which gives comparable weight to both nitrogen and phosphorus will need to be investigated.

E. LAKE ELEVATION

Purpose

An elevation analysis of Whitefish Lake has multiple implications. First, the mean high water elevation determination from this analysis can be compared to the existing mean high water elevation used in the current lakeshore protection regulations to determine if an adjustment is needed. Second, the mean low water elevation is needed to answer regulatory questions for the City of Whitefish which annexed the bottom of the lake in 2005, Flathead County which now administers the lakeshore protection regulations, Montana DNRC which regulates the state owned lakebed, and private landowners whose property extends to the mean low water elevation. In addition, this lake elevation analysis could assist the joint 310/404 permitting process administered by the Flathead Conservation District and U.S. Army Corps of Engineers.

Increasing water draws on Whitefish Lake is also an issue for the City of Whitefish and its residents. Water users include the City of Whitefish for drinking water, lakeshore residences, and golf courses (see Chapter XIV Municipal Water Infrastructure, Section

A Drinking Water & Consumptive Water Use).

Study Background

In partnership with Brian Sullivan of F&H Surveying of Whitefish, WLI completed an elevation analysis of Whitefish Lake along with associated statistics for Whitefish Lake spanning 58 years (1957-2014) (Koopal, 2015).

Historical surveying data was on file with Brian Sullivan of F&H Surveying. The data came from several original sources that used numerous modems and gauges. All of the data were compiled to eliminate variations caused by the use of two modems (NGVD29 and NAVD88) and various sites and gauges. The most recent data since 2002 were compiled using the NAVD88 modem at City Beach. Surveys prior to 2002 utilized the NGVD29 modem which corresponds to a 3.78 foot difference in elevation which was converted to the NAVD88 modem.

Much of the earliest data were compiled by John D. Horn who installed a gauge near the southeast shore of Whitefish Lake but also utilized survey sites at City Beach and the mouth of the Whitefish River. Annual survey data are varied in the amount of the calendar year that was covered. Many years had good survey data for the high water elevation time period but did not have any data for the low water elevation time period, and vice versa.

Mean High Water Elevation Analysis Methods

In the 58 year time period from 1957, 39 years have survey data. Of the 39 years with survey data, 34 years were used to calculate the mean high water elevation using Primary and Secondary Data. The high water analysis included data from years that showed a ramp up to the maximum elevation and a ramp down (Primary Data N=21), or data that was collected having missed May but began in June (Secondary Data N=13). It is reasonable to assume that the true mean high water elevation is slightly higher than the results of this analysis based on the fact that the survey may not have been conducted on the actual day of high water (Primary Data), or high water could have occurred prior to June 1 (Secondary Data) as occurred six times with the Primary Data.

Mean Low Water Elevation Analysis Methods

Of the 39 years with survey data, 23 years were used to calculate the mean low water elevation. The low water analysis included fall data from years that showed a ramp down to the minimum elevation and a ramp up (Primary Data N=8), or data that was collected after August 31 (Secondary Data N=15). It is reasonable to assume that the true mean low water elevation is slightly lower than the results of this analysis based on the fact that the survey may not have been conducted on the actual day of low water (Primary Data), or low water could have occurred after the end of the fall survey season (Secondary Data).

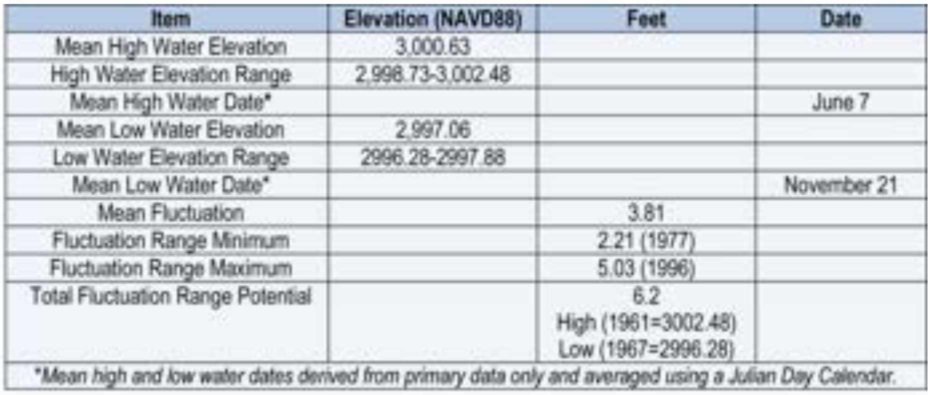
There is very little survey data from January through March, but for three years in the late 1980s (1987-1989), elevations recorded in March at the mouth of the Whitefish River during ice conditions were slightly lower than the historic fall low. The March data points were not included in the overall data analysis for consistency, and unknowns remain about the ice conditions at the time and how that may have influenced the survey.

Mean Fluctuation Analysis Methods

Of the 39 years with survey data, 21 years were used to calculate the mean fluctuation for the lake. Adequate survey data (Primary and/or Secondary Data) from both high and low elevation periods for the same year needed to be included in the fluctuation analysis.

Results

The mean maximum high water level for Whitefish Lake over the study period is 3,000.63 (NAVD88) as compared to 3,000.79 (NAVD88) used in the current lakeshore protection regulations- a lowering of 0.16 feet. The average mean minimum water elevation is 2,997.06 (NAVD88). It was noted that if the late 1980s values were folded into the analysis, the mean minimum water elevation would be 2,996.95 (NAVD88) for the study period. Key summary statistics from this study are found in Figure 128.



Item	Elevation (NAVD88)	Feet	Date
Mean High Water Elevation	3,000.63		
High Water Elevation Range	2,998.73-3,002.48		
Mean High Water Date*			June 7
Mean Low Water Elevation	2,997.06		
Low Water Elevation Range	2996.28-2997.88		
Mean Low Water Date*			November 21
Mean Fluctuation		3.81	
Fluctuation Range Minimum		2.21 (1977)	
Fluctuation Range Maximum		5.03 (1996)	
Total Fluctuation Range Potential		6.2 High (1961=3002.48) Low (1967=2996.28)	

**Mean high and low water dates derived from primary data only and averaged using a Julian Day Calendar.*

Figure 128. Whitefish Lake Elevation Summary Table.

Recommendations

In 2015, WLI recommended that when Flathead County updates the Flathead Lakeshore Protection Regulations that the *new mean high water elevation for Whitefish Lake be established at 3,000.63 (NAVD88)*. An alternative would be to keep 3,000.79 (NAVD88) as the official mean high water elevation based on data limitation factors mentioned in this memo and to provide continuity with the public. It was also recommended that the City of Whitefish, Flathead County, and Montana DNRC *establish 2,997.06 (NAVD88) as the mean low water elevation*.

Result

DNRC requested that the jurisdictional low water boundary follow State of Montana (A.R.M. 36.25.1101) which utilizes the 10th percentile on navigable waterways for state land leasing. Koopal (2015) modified the low water analysis using the 10th percentile method for the same period of record and calculated 2,996.44 feet as the low water elevation for jurisdictional purposes.

On April 28th, the Flathead County Commissioners adopted revisions to county-wide Flathead County Lake and Lakeshore Protection Regulations (Flathead County 2015) to add Whitefish, Blanchard, and Lost Coon Lakes to the list of lakes under the jurisdiction of those regulations. All lakes in rural Flathead County "having a water surface area of at least 20 acres for at least six months in a year of average precipitation" are now regulated by one set of regulations. Flathead County Lake and Lakeshore Protection Regulations;

Effective September 15, 2005, the City of Whitefish annexed "that body of water known as "Whitefish Lake," extending only to the low water mark of Whitefish Lake" (Resolution #05-25). Therefore, Flathead County jurisdiction of rural properties on Whitefish Lake extends up from the low water mark. The low water mark of Whitefish Lake is 2,996.44' (NAVD88), which is the 10th percentile low water elevation calculated from a 2015 Whitefish Lake Institute analysis of the best available low water elevation data. The mean annual high-water elevation for Whitefish Lake has been established at 3,000.63' (NAVD88).

On June 1, 2015 the City of Whitefish passed Ordinance No. 15-09 that amended Whitefish City Code Title 2, Title 12, Title 13 and Title 14 pertaining to the Lake and Lakeshore Regulations to remove references to the extraterritorial planning jurisdiction, the Whitefish City-County planning board, and Blanchard Lake, and define city limits. Under Code Title 12 (Sub-division Regulations) the City maintained the mean high water elevation at 3,000.79' and established the low water elevation of 2,996.44' for all properties annexed into the city limits and Whitefish Lake. The mean high water elevation is subject to re-evaluation after five consecutive years of data which will occur in 2015. On June 1, 2015 the City of Whitefish also passed Ordinance No. 15-10 creating the Whitefish Lake and Lakeshore Protection Committee for the lake area administered by the city.

XIII. OTHER PROJECT AREA LAKES

A. INTRODUCTION

Some of the lakes covered in this section are also discussed in the Northwest Montana Lakes Volunteer Monitoring Network (NWMTLVMN) Summary Report (Gubits, 2015). These lakes are sampled once per year (July-August) for water chemistries and twice per year (July-August, October) for physical parameters. Water chemistry charts for these lakes can be found in comparison to other similar sized lakes of the NWMTLVMN in Chapter XXII, Addendum C - Water Chemistry and Temperature Information, Other Project Area Lakes.

B. UPPER WHITEFISH LAKE

1. General Description

Upper Whitefish Lake is located in Flathead County 25 miles north of Whitefish at an elevation of 4,549 feet. Surrounding land ownership is 100% State Trust Lands. This oligotrophic lake has a surface area of 80 acres and a maximum depth of 24 feet. There is one motorized public access located on the northeast end of the lake.

2. Physical & Chemical Properties

Historic temperature and oxygen profiles show that Upper Whitefish Lake becomes weakly stratified during summer sampling dates. Hydrolab profiles show that the lake was mixed during fall sampling dates.

Upper Whitefish Lake is nutrient poor as evidenced by low phosphorus and nitrogen. The 2011 calcium concentration was reported at 19mg/L classifying it as a low risk for zebra mussel colonization.

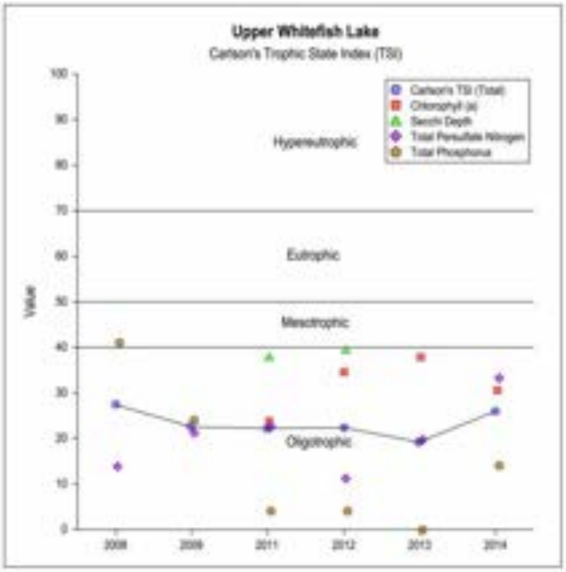


Figure 129. Carlson's TSI, Upper Whitefish Lake.

3. Biological Community

<u>Fisheries</u>
MFISH reports bull trout, westslope cutthroat trout, and longnose sucker in the lake. Upper Whitefish Lake is stocked with westslope cutthroat trout. Historical fish stocking records are found in Figure 130.

Species	Years Stocked
Rainbow Trout	1941
Lake Trout	1952
Arctic Grayling	1954-1961(N*=6)
Cutthroat Trout	1934-1969 (N=13)
Westslope Cutthroat Trout	1973-2009 (N=35)
**N=Number of years stocked within time period.*	

Figure 130. Fish Stocking Records for Upper Whitefish Lake

C. HERRIG LAKE

1. General Description

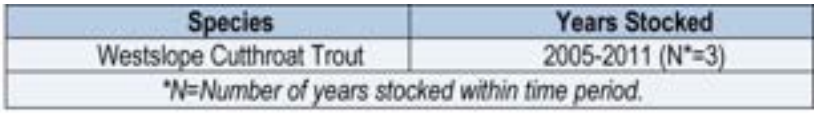
Herrig Lake occupies a cirque basin in the headwaters of the West Fork of Swift Creek. The source of water for Herrig Creek, this shallow lake is approximately 830 feet long and 500 feet wide.

2. Physical & Chemical Properties

No physical or chemical property information is available for this lake.

3. Biological Community

<u>Fisheries</u>
MFISH reports westslope cutthroat trout, and golden trout in Herrig Lake. Historical fish stocking records are found in Figure 131.



Species	Years Stocked
Westslope Cutthroat Trout	2005-2011 (N*=3)
**N=Number of years stocked within time period.*	

Figure 131. Fish Stocking Records for Herrig Lake.

D. SMITH LAKE

1. General Description

Smith Lake is located within the Stillwater State Forest approximately six miles north of Whitefish on Smith Creek. Prior to the construction of a dam in the late 1930s by either the Civilian Conservation Corps or the Whitefish Rod and Gun Club, the lake was natural and most likely spring-fed with a surface area of about 5 acres. The dam expanded the lake to 18.5 acres, after which the lake was used for rearing fish for stocking until the late 1960s (Montana Department of Natural Resources & Conservation, 2010). In 2000, DNRC Dam Safety classified the dam as a “high hazard” due to its location above a county road. The lake level was lowered by about 3 feet to meet safety standards, trees growing on the dam were removed, and debris was cleared from the spillway and upstream of the structure. There is no boat access to this lake.

The lower lake level adversely affected the recreational fishery, and brook trout then dominated the lake. A new dam was completed in 2012 which allowed the lake to return to full pool. In the fall of 2012 and spring of 2013, DNRC, FWP, and volunteers from the Flathead Valley chapter of Trout Unlimited released westslope cutthroat trout into the lake.

2. Physical & Chemical Properties

No physical or chemical property information is available for this lake.

3. Biological Community

Fisheries

According to Delerey (personal communication, 2014) Smith Lake is currently stocked with westslope cutthroat trout and a sterile triploid rainbow trout. Historical fish stocking records are found in Figure 132.

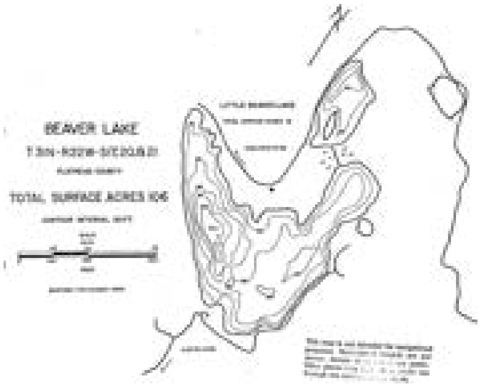
Species	Years Stocked
Westslope Cutthroat Trout	2013
Rainbow Trout	2013-2014 (N=2)
Cutthroat Trout	1939-1960 (N=16)
Golden Trout	1961
**N=Number of years stocked within time period.*	

Figure 132. Fish Stocking Records for Smith Lake.

E. BEAVER LAKE

1. General Description

Beaver lake is located in Flathead County northwest of Whitefish on the northern edge of Lion Mountain at an elevation of 3,258 feet. The lake has a catchment area of 2,043 acres composed of the Piegan group belt series (46%) and alluvium (38%) (Ellis & Craft, 2008). This oligotrophic lake has a surface area of 144 acres and a maximum depth of 96 feet. Beaver Lake has one motorized public access site on the south side of the lake.



2. Physical & Chemical Properties

Historic temperature and oxygen profiles show that Beaver Lake is stratified in summer, and has been within the avoidance threshold range for salmonids at depths of up to seven meters during July and August. Historic oxygen profiles show that Beaver Lake has been between avoidance and anoxic thresholds for salmonids at depths greater than 10 meters. Anoxia has been observed at depths greater than 15 meters. When anoxic conditions occur at the benthic interface an oxidation reduction potential exists and nutrients stored in the sediment can be liberated back into the water column given the right conditions. Depth profiles suggest that the ideal depth for salmonid habitation during summer months is between 6-12 meters.

Beaver Lake consistently ranks highest among medium sized lakes in the NWMTLVMN program for phosphorus, nitrogen and chlorophyll (*a*) levels.

The Carlson's TSI (Figure 133) suggests this lake is experiencing eutrophication. Beaver Lake's 2010/2011 average calcium concentration was 40mg/L classifying it as a high risk for zebra mussel colonization.

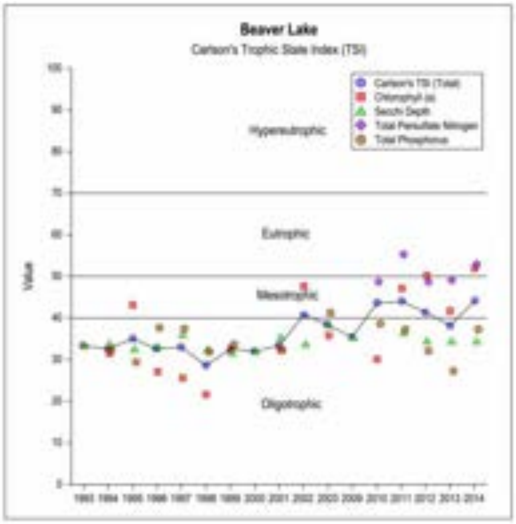
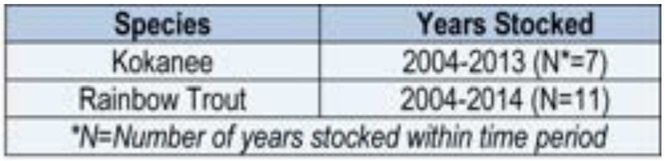


Figure 133. Carlson's TSI, Beaver Lake.

3. Biological Community

Fisheries

MFISH reports brook trout, rainbow trout, kokanee salmon and fathead minnow in Beaver Lake. Historical fish stocking records are found in Figure 134.



Species	Years Stocked
Kokanee	2004-2013 (N*=7)
Rainbow Trout	2004-2014 (N=11)
**N=Number of years stocked within time period*	

Figure 134. Fish Stocking Records for Beaver Lake.

Macrophytes

In mid-October of 2011, Eurasian watermilfoil *(Myriophyllum spicatum)* was discovered in Beaver Lake. The relatively small patch was found near the boat ramp by DNRC during a training retreat. See Chapter XVI Current and Future Concerns, Section C: Biological, Aquatic Invasive Species for information on the multi-agency workgroup that was established to address the infestation, and for a current update.

F. LITTLE BEAVER LAKE

1. General Description

Little Beaver Lake is located in Flathead County, 4.5 miles from Whitefish, and is hydrologically connected to Beaver Lake at high water.

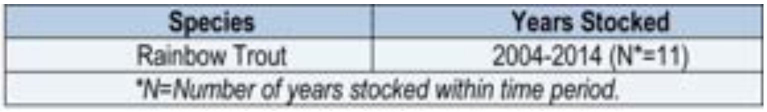
2. Physical & Chemical Properties

No physical or chemical property information is available for this lake.

3. Biological Community

Fisheries

MFISH reports westslope cutthroat trout, rainbow trout, redside shiner, and fathead minnow in Little Beaver Lake. Historical fish stocking records are found in Figure 135.



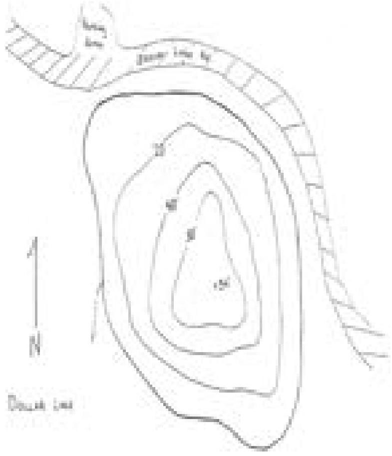
Species	Years Stocked
Rainbow Trout	2004-2014 (N*=11)
*N=Number of years stocked within time period.	

Figure 135. Fish Stocking Records for Little Beaver Lake

G. DOLLAR LAKE

1. General Description

Dollar Lake is located in Flathead County west of Whitefish Lake at an elevation of 3,398 feet. Dollar Lake is oligo-mesotrophic with a surface area of 8.4 acres and a maximum depth of 48 feet. Surrounding land ownership is 100% State Trust Lands. There is one primitive non-motorized public access site on Dollar Lake.



2. Physical & Chemical Properties

Historic temperature and oxygen profiles show that Dollar Lake is stratified during summer sampling dates. Historic temperature profiles indicate that the lake has been within the avoidance threshold range for salmonids at depths to 5 meters during July and August. Historic summer oxygen profiles indicate that Dollar Lake has been anoxic when stratified at depths greater than eight meters. Depth profiles suggest that the ideal depth for salmonid habitation during summer months is between 5-8 meters. Fall Hydrolab profiles show that the lake becomes evenly mixed or very weakly stratified.

Dollar Lake ranks high among lakes of similar size for phosphorus, nitrogen, and chlorophyll (*a*). Dollar Lake's 2011 calcium concentration was reported at 38mg/L classifying it as a high risk for zebra mussel colonization.

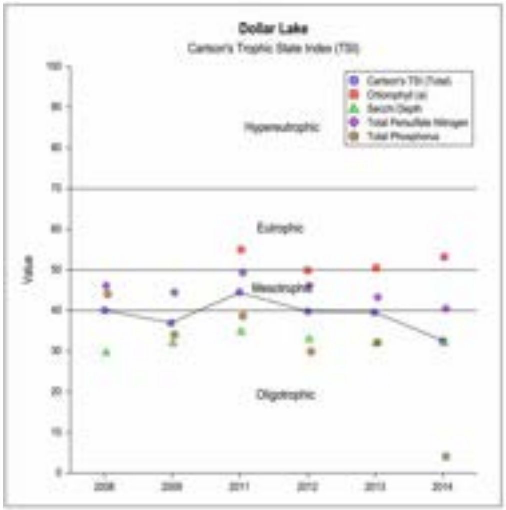


Figure 136. Carlson's TSI, Dollar Lake.

3. Biological Community

Fisheries

MFISH reports westslope cutthroat trout and rainbow trout in Dollar Lake. Historical fish stocking records are found in Figure 136. In October 2007, the lake was chemically treated with liquid rotenone to eliminate fathead minnows and redside shiners. It is a closed basin lake depending entirely on stocking for maintaining a trout population.

Species	Years Stocked
Rainbow Trout	2004-2014 (N=10)
Westslope Cutthroat Trout	2004-2009 (N=5)
**N=Number of years stocked within time period.*	

Figure 137. Stocking Records for Dollar Lake.

Macrophytes

A visual survey for EWM was conducted in 2011, 2012 and 2013 at the public access for Dollar Lake because it is located 4.5 miles from Beaver Lake in which EWM was discovered in 2012. No EWM was found, however, additional monitoring was recommended at that time based on its proximity to Beaver Lake and the high amount of fishing pressure (boat traffic) it receives. A macrophyte survey was conducted on the lake on September 4, 2014. A total of 46 sites were surveyed for aquatic plants, shoreline plants and substrate. Plants that were commonly observed but were not dominant include flatstem pondweed, and Richardson's pondweed.

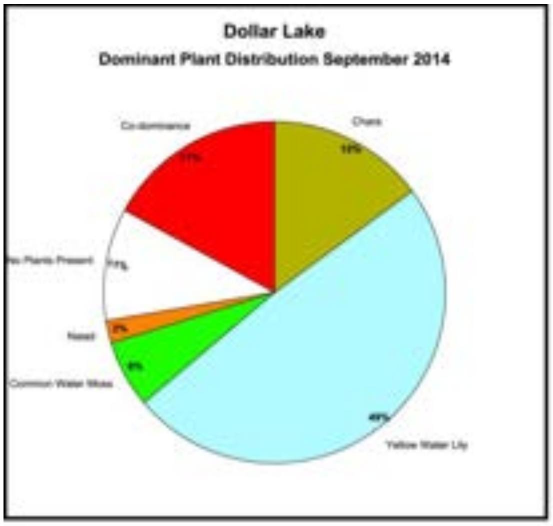


Figure 138. Dominant Plant Distribution, Dollar Lake.

Shoreline plants in order of dominance included: Bulrush, Cattail, Carex, Horsetail. The discovery of northern milfoil in Dollar Lake and its close proximity to Beaver Lake (where Eurasian watermilfoil was found in 2012) makes it a high risk for EWM infestation.

Naiad is an aquatic plant that grows rooted in the substrate however fragments that have detached from the plant can survive freely. The seeds from this plant provide an important food source for shorebirds and waterfowl. Although naiad was the least dominant plant in Dollar Lake, it was observed growing in extremely dense patches along the south end of the lake.

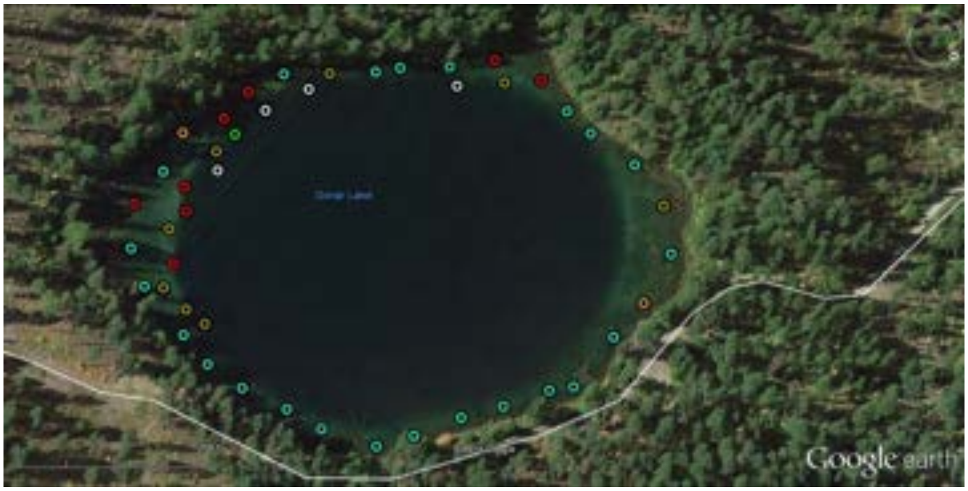
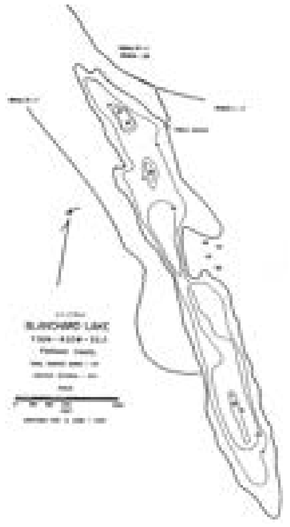


Figure 139. Dominant Plant Distribution Map, Dollar Lake.

Yellow water lily is identified by its heart shaped leaves which are mostly emergent, and provide shelter and shade for fish and invertebrates. Its yellow flowers can be seen throughout the summer, and it usually grows in water 1-3m deep. American pondweed is a long-leaved pondweed that's leaves can sometimes still be seen during winter months. Substrate composition for all sites was predominately gyttja, followed by gravel, boulder and cobble.

H. BLANCHARD LAKE

1. General Description



Blanchard Lake is located in Flathead County three miles west of Whitefish at an elevation of 3,178 feet. It has a catchment area of 2,649 acres. The geologic formations in the watershed are dominated by glacial till (54%) with the remaining area in the Piegan group belt series (Ellis & Craft, 2008). A meso-oligotrophic lake, Blanchard has a surface area of 143 acres and a maximum depth of 30 feet. There is one motorized public access on the far north end of the lake.

2. Physical & Chemical Properties

Historic temperature and oxygen profiles show that Blanchard Lake is either stratified or weakly stratified during summer sampling dates. There is a good chance that this lake is polymictic based on meteorological conditions. Historic temperature profiles show that Blanchard Lake has been within the avoidance threshold range for salmonids to a depth of up to six meters during August. Historic oxygen profiles show that Blanchard Lake has been between avoidance thresholds and anoxic conditions for salmonids at depths greater than six meters. Hydrolab profiles show that the lake was mixed during fall sampling dates.

Blanchard Lake consistently ranks high for nitrogen in comparison to similar sized lakes in the area and lower for phosphorus. Blanchard ranks low for chlorophyll (*a*) concentrations probably as a result of increased competition from macrophytes for available nutrients. Blanchard Lake's 2011 calcium concentration was reported at 34mg/L classifying it as a high risk for zebra mussel colonization.

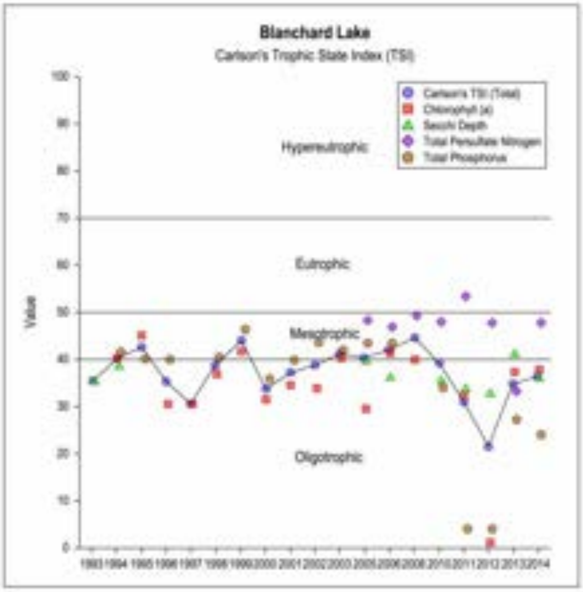
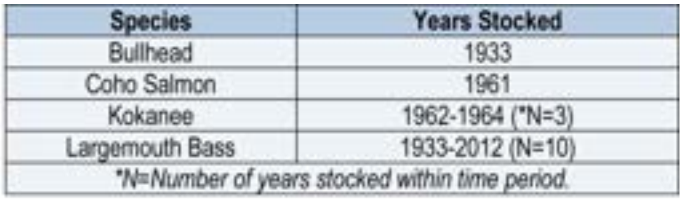


Figure 140. Carlson's TSI, Blanchard Lake.

1. Biological Community

Fisheries

Blanchard Lake is considered a warm water fishery. MFISH reports large-mouth bass, northern pike, pumpkinseed and yellow perch in Blanchard Lake.



Species	Years Stocked
Bullhead	1933
Coho Salmon	1961
Kokanee	1962-1964 (*N=3)
Largemouth Bass	1933-2012 (N=10)
*N=Number of years stocked within time period.	

Figure 141. Fish Stocking Records for Blanchard Lake.

Macrophytes

A macrophyte survey was conducted on Blanchard Lake on September 3, 2014. A total of 222 sites were surveyed for plants/algae. Dense macrophyte beds exist in Blanchard Lake and several plant species were found during the survey.

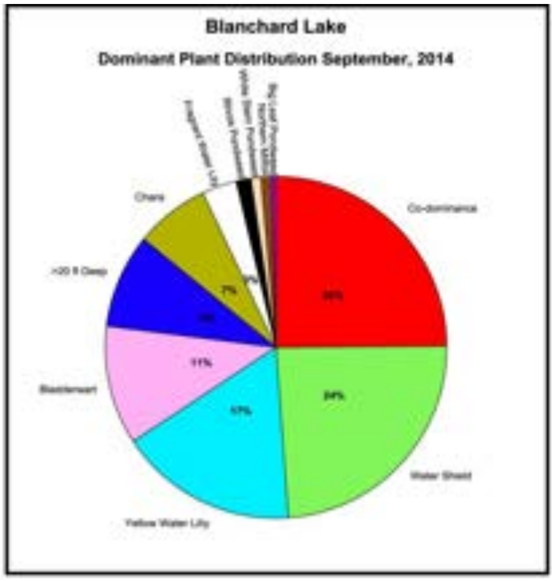


Figure 142. Dominant Plant Distribution, Blanchard Lake.

Although native northern milfoil was not a dominate plant, it exists throughout much of the lake. The pink teardrop icons on the map represent fragrant water lily, an invasive plant that has been intentionally planted in Blanchard and other nearby lakes as an ornamental.

Fragrant water lily has symmetrical white or pink blooms and heart-shaped glossy green floating leaves with a purple underside. The leafstalk is submerged grows out of large rhizomes which serve as a common food source for muskrats. The flowers range from 3-15 inches wide with several broad, curved petals that narrow toward the center. They are found in still, relatively shallow water (5-7 ft.) in water bodies such as lakes and ponds with silty beds. Native to the eastern portion of North America, its commercial popularity has caused its extensive dispersal throughout North America. The plant is now considered a secondary invader that can achieve extraordinary population growth and destabilize ecosystems.

Illinois pondweed is a submerged plant that is native to Montana. Illinois pondweed has both submerged and floating leaves up to eight inches in length. Green flowers extend three inches from the water's surface and are organized in whorls. Illinois pondweed is often confused with Richardson's pondweed (native), and non-native curly leaf pondweed.

Figure 143. Dominant Plant Distribution Map, Blanchard Lake.

An EWM survey was conducted near the public access site after the discovery in Beaver Lake. No EWM was found, however, northern milfoil was found throughout the lake. In 2012, what is believed to have been whorled milfoil was found.

I. LOST COON LAKE

1. Description

Lost Coon Lake is located in Flathead County near the Whitefish Lake Golf Course in Whitefish at an elevation of 3,149 feet. Surrounding land ownership is 100% private. It is a closed basin lake that is fed by groundwater, with connectivity to Blanchard Lake during years with an extremely high water yield. An oligo-mesotrophic lake, Lost Coon has a surface area of 62 acres and a maximum depth of 14 feet. There is no public access to the lake.

2. Physical & Chemical Properties

Historic temperature and oxygen profiles show that Lost Coon Lake is evenly mixed or weakly stratified during summer sampling dates. The lake is probably polymictic based on meteorological conditions. Historic temperature profiles show that Lost Coon Lake has been within the avoidance threshold range for salmonids to a depths of three meters during July and August, and historic oxygen profiles show that the lake has been between avoidance and anoxic concentration thresholds for salmonids at depths greater than two meters. Depth profiles suggest that the ideal depth for salmonid habitation during summer months is between 2-3 meters. Fall Hydrolab profiles show that the lake was evenly mixed during all sampling dates.

Lost Coon ranked relatively high for phosphorus, nitrogen, and chlorophyll (*a*) as compared to other lakes of similar size.

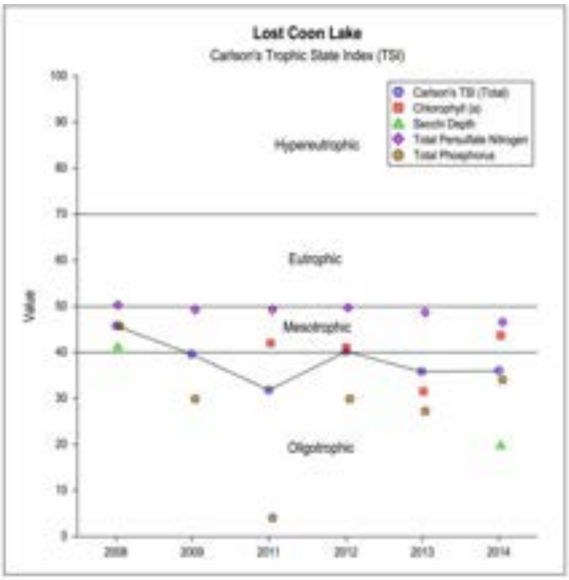


Figure 144. Carlson's TSI, Lost Coon Lake.

3. Biological Community

Fisheries

The lake is considered a warm water fishery. MFISH reports black bullhead, northern pike, pumpkinseed and yellow perch in Lost Coon Lake. No fish stocking has taken place in this lake.

Macrophytes

A Macrophyte survey was conducted on Lost Coon on September 8, 2014. A total of 108 sites were surveyed for aquatic plants, shoreline plants and substrate. Plants that were commonly observed but were not dominant include eel grass.

Shoreline plants in order of dominance included: Cattail, Carex, and Equisetum. Lost Coon Lake has very dense macrophyte beds. Several springs exist, in which macrophyte composition changed primarily to mare's tail and northern milfoil.

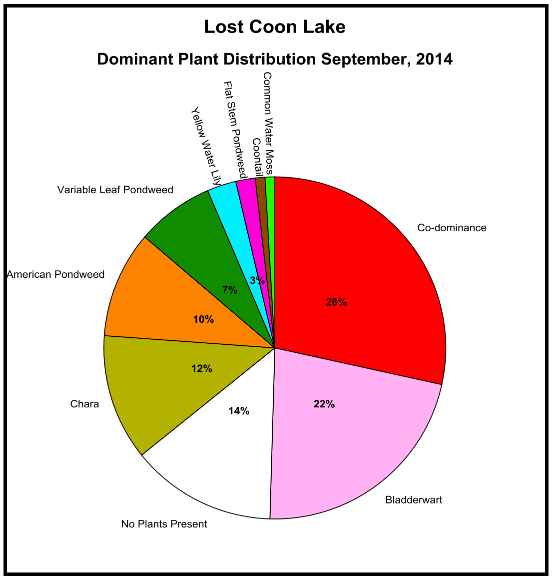


Figure 145. Dominant Plant Distribution, Lost Coon Lake.

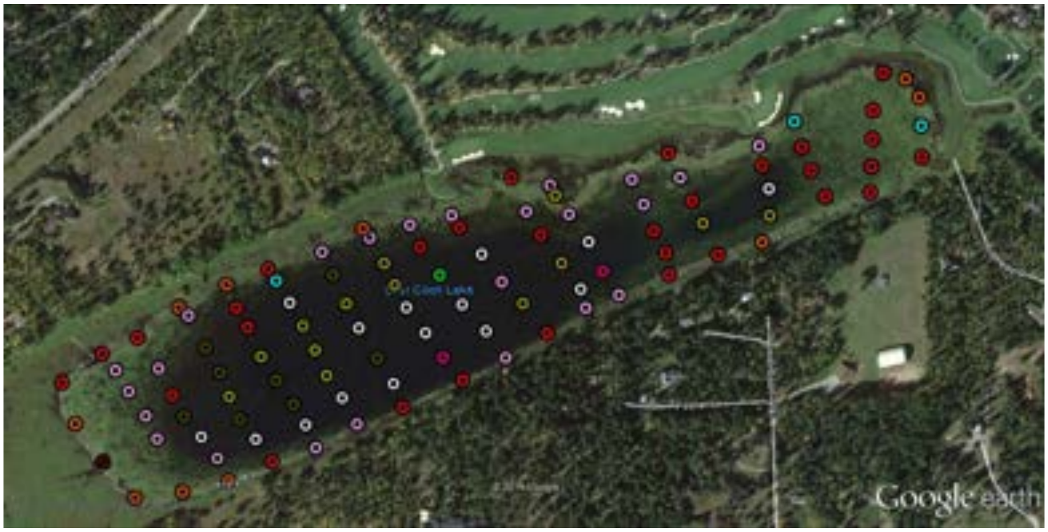


Figure 146. Dominant Plant Distribution Map, Lost Coon Lake.

American pondweed and yellow water lily's floating leaves blanket the lake's surface during summer/early fall. Common bladderwort is a native aquatic plant that has floating stems that can grow 2-3 meters long. The stems of these branches have transparent bladders that capture tiny invertebrates.

Coontail is an aquatic rootless perennial forb that is native to the United States and Montana. It is generally a dark or olive green color and forms dense colonies. Like EWM, Coontail reproduces through stem fragmentation. Coontail is often mistaken for Eurasian watermilfoil because of its ability to form dense colonies and the whorled leaves which resemble that of EWM. Coontail gets its name from the crowding of leaves at the end of branches which resemble a raccoon’s tail. Additionally, coontail prefers similar conditions as EWM, although it does not require sediment as it is a rootless macrophyte and derives its nutrients, like algae, from the water column and not sediment. It is very tolerant of high water temperature and drought conditions. Coontail leaves are much coarser than EWM leaves and are toothed. Coontail makes excellent food for birds. Substrate composition for all sites was predominately gyttja.

XIV. MUNICIPAL WATER INFRASTRUCTURE & TREATMENT

A. DRINKING WATER & DIVERTED WATER USE

This section was completed with the support of the Montana Department of Natural Resources & Conservation.

The Public Works Department administers public drinking water services known as the Public Water Supply (PWS). The Montana Source Water Protection Program (Montana Department of Environmental Quality, 1999) and the federal Safe Drinking Water Act (SDWA) require that municipalities conduct an assessment and report to assist them in identifying potential contaminant sources near City of Whitefish wells and to provide a plan to protect drinking water resources in the City of Whitefish. The Source Water Delineation and Assessment Report (Acton, 2002) serves this requirement. Because the City of Whitefish water supply comes from surface water, it is classified by the Montana Source Water Protection Program as highly sensitive to contamination.

Within the limits of the City of Whitefish, residential drinking water comes from the municipal PWS. Residents outside of City limits use private water wells or surface water. The Whitefish PWS is classified by the SDWA as a “community system” because the system serves at least 25 year-round residents through at least 15 connections. In fact, in 2014 the system served approximately 6,500 residents through over 3,500 connections. Source water is obtained through a surface water intake located approximately 1,200 feet off Mountain Harbor in the southeastern part of Whitefish Lake at a depth of approximately 50 to 60 feet, and three intakes are located on perennial streams within the Haskill Basin north of the City of Whitefish. One of those intakes is on Haskill Creek, the other two are on unnamed creeks designated as Second and Third Creeks—tributaries to Haskill Creek.

Second and Third Creeks are currently the primary source of municipal water for the City of Whitefish with approximately 90% of the total volume used annually coming from the Haskill Basin. Over the past ten years, that number has been as high as 97% and as low as 80% annually. In the summer months—June through August—the usage tends to be around 75% (Acton, 2015). Historically, the City used First Creek which was abandoned in 1975 due to *Escherichia coli* (*E. coli*) contamination and sediment from development and channel alterations.

According to the City, there remain concerns for using First Creek due to potential pollutants during spring runoff from horse barns on Big Mountain. Additional information on Haskill Creek is available in Chapter XI Upper Whitefish River Drainage, Section C. Haskill Creek. Water pumped from Whitefish Lake has to be pumped 0.8 miles to the treatment plant adding significant cost to supplying the water (Water Rights Solutions, 2009)

Water Rights

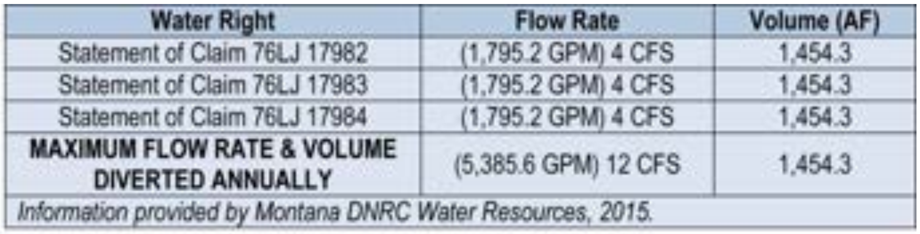
Montana’s 1972 Constitution declared all surface water and ground water to be the property of the state; recognized and confirmed all prior use, and required all subsequent appropriations of water to be made according to legislative direction. In

1973, the Montana legislature passed the Montana Water Use Act requiring recording of water rights existing prior to July 1, 1973 with the DNRC, and launched the ongoing statewide adjudication of water right claims (Water Right Solutions, Inc. 2009).

The total quantity of water legally allowed to enter the City of Whitefish's Water Treatment Plant annually is based on six municipal rights (three on Whitefish Lake and three on Haskill Creek, totaling 3,182 AF. The City can either get all its water from the lake and/or split the demand between the lake and Haskill Creek.

Haskill Creek Water Rights for Municipal Use

The three water rights listed in Figure 147 allow the City to divert water from Haskill Creek. This water is used for potable water for the City service area. Combined flow between the three rights is 5,385.6 gpm (12 cfs) up to 1,454.3 AF.



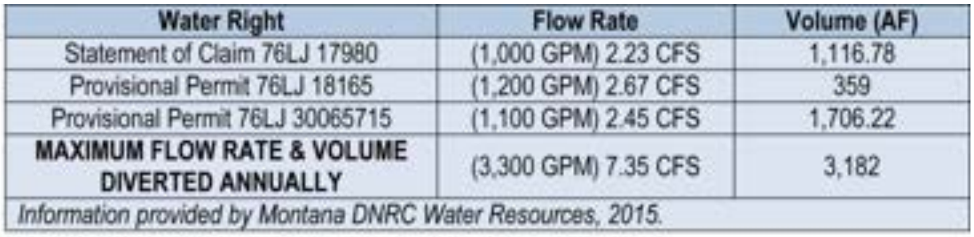
Water Right	Flow Rate	Volume (AF)
Statement of Claim 76LJ 17982	(1,795.2 GPM) 4 CFS	1,454.3
Statement of Claim 76LJ 17983	(1,795.2 GPM) 4 CFS	1,454.3
Statement of Claim 76LJ 17984	(1,795.2 GPM) 4 CFS	1,454.3
MAXIMUM FLOW RATE & VOLUME DIVERTED ANNUALLY	(5,385.6 GPM) 12 CFS	1,454.3

Information provided by Montana DNRC Water Resources, 2015.

Figure 147. City Water Rights, Haskill Creek.

Whitefish Lake Water Rights for Municipal Use

Municipal use of Whitefish Lake water consists of three water rights listed in Figure 148. They share the same point of diversion in Monk's Bay (NW1/4NE1/4SW1/4 of Section 24, Township 31N, Range 22W). While there are currently three variable capacity pumps, at full build out, the City would like to add a fourth pump. Water is used for potable water for the City service area. Combined flow between the three rights is 3,300 gpm (7.35 cfs) up to 3,182 AF.



Water Right	Flow Rate	Volume (AF)
Statement of Claim 76LJ 17980	(1,000 GPM) 2.23 CFS	1,116.78
Provisional Permit 76LJ 18165	(1,200 GPM) 2.67 CFS	359
Provisional Permit 76LJ 30065715	(1,100 GPM) 2.45 CFS	1,706.22
MAXIMUM FLOW RATE & VOLUME DIVERTED ANNUALLY	(3,300 GPM) 7.35 CFS	3,182

Information provided by Montana DNRC Water Resources, 2015.

Figure 148. City Water Rights, Whitefish Lake.

According to Greg Acton, Utility Operations Supervisor, of the three pumps currently in operation, a single pump operates at over 1,200 gpm, and two pumps operating simultaneously pump approximately 1,150 gpm each (2,350 gpm total). Although the system is designed to operate three pumps at 1,080 gpm each (3,240 gpm total), the City has not yet run all three pumps at one time. The system operates one or two pumps as needed with the third used as a backup. The total design capacity of the Whitefish

Lake pumping facility is 6.0 million gallons per day (mgd) from four pumps. The pumping rate to supply 6 mgd is 4,167 gpm total or 1042 gpm per pump (Water Right Solutions, Inc. 2009)

The City of Whitefish PWS infrastructure includes a water utility physical plant and an eight million gallon ground reservoir at the water treatment plant, two steel tanks on Grouse Mountain, a lake pumping station, four pressure boosting stations, a water treatment facility, and 44 miles of distribution piping. Water is collected in a surface water holding reservoir north of the City. Following treatment, the water is placed into one of a number of holding tanks for distribution. Switching between Whitefish Lake and Haskill Basin water supplies is non-trivial, as it takes a couple of days for operators to find the right blend and treatment balance.

The City uses a Contact Absorption Clarifier (CAC) Water Treatment Plant with a two-stage filtration process including an “upflow” clarifier to remove approximately 75% of turbidity through coagulation, and a carbon and sand filter to “polish” the water before being disinfected with chlorine (Applied Water Consulting, 2013). The City also needs to flush and backwash the water treatment system. Backwash from cleaning the cartridge units is conveyed to a settling pond (concrete raceway) where the water sits to achieve turbidity levels and other water chemistry values in accordance with the City’s National Pollutant Discharge Elimination System (NPDES) permit.

The water is then spilled out into Viking Creek (See Chapter X Whitefish Lake Tributaries, Section O Viking Creek) at approximately 150 gpm over the course of four hours, although this can increase with backwash demand when more lake water is being used (personal conversation with Greg Acton, 2015). In the Haskill Basin Reservoir Management Plan prepared for the City (Applied Water Consulting, 2013), the amount of excess water from the reservoir spilled into Viking Creek averaged 415 gallons per minute over the nine-month period that was studied.

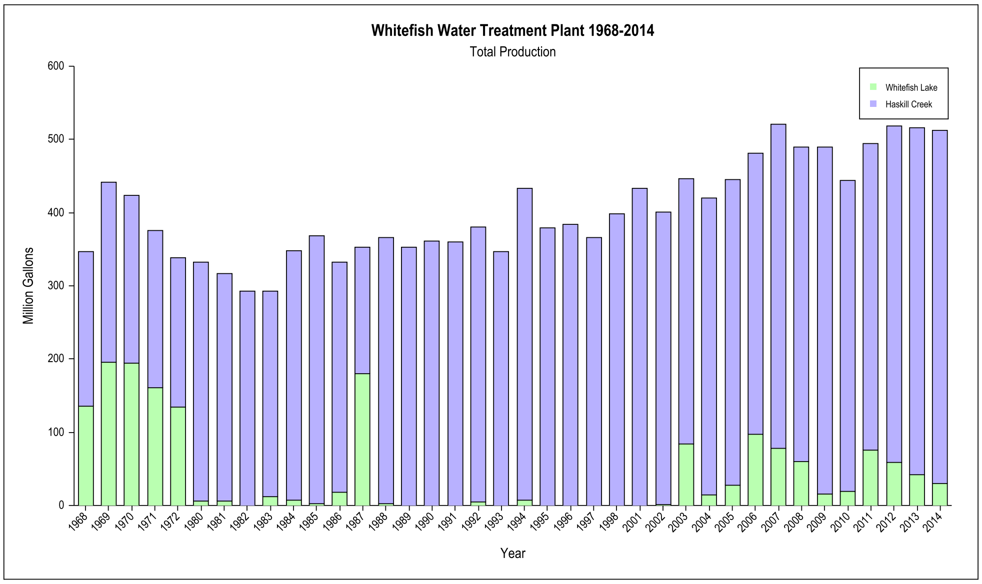
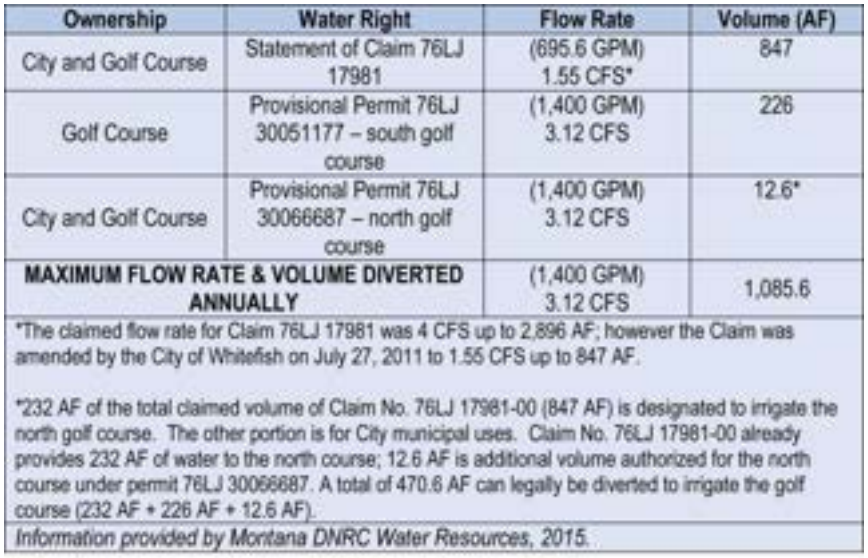


Figure 149. Whitefish Water Treatment Plant 1968-2014 – Total Production.

Whitefish Lake Water Rights for Whitefish Lake Golf Club

The City of Whitefish and/or the Whitefish Golf Club have three water rights in Section 26, Township 31 north, Range 22 west on Whitefish Lake. The total quantity of water legally diverted from the pumping station is 3.12 cfs up to 1,085.6 AF. See Figure 150 for breakdown of each right.



Ownership	Water Right	Flow Rate	Volume (AF)
City and Golf Course	Statement of Claim 76LJ 17981	(695.6 GPM) 1.55 CFS*	847
Golf Course	Provisional Permit 76LJ 30051177 – south golf course	(1,400 GPM) 3.12 CFS	226
City and Golf Course	Provisional Permit 76LJ 30066687 – north golf course	(1,400 GPM) 3.12 CFS	12.6*
MAXIMUM FLOW RATE & VOLUME DIVERTED ANNUALLY		(1,400 GPM) 3.12 CFS	1,085.6

*The claimed flow rate for Claim 76LJ 17981 was 4 CFS up to 2,896 AF; however the Claim was amended by the City of Whitefish on July 27, 2011 to 1.55 CFS up to 847 AF.

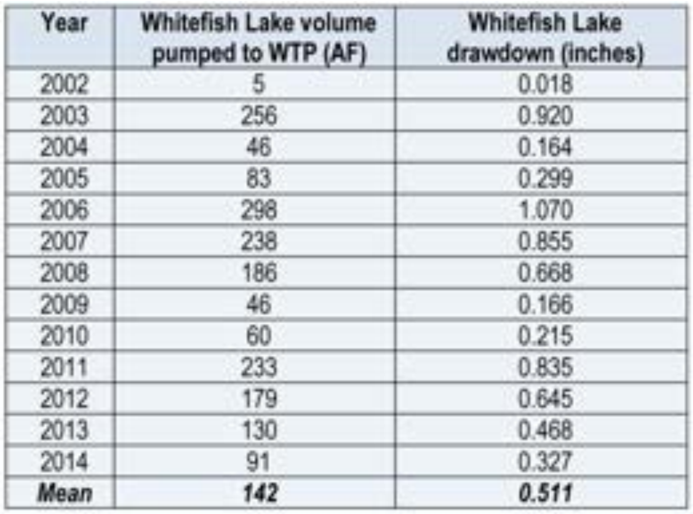
*232 AF of the total claimed volume of Claim No. 76LJ 17981-00 (847 AF) is designated to irrigate the north golf course. The other portion is for City municipal uses. Claim No. 76LJ 17981-00 already provides 232 AF of water to the north course; 12.6 AF is additional volume authorized for the north course under permit 76LJ 30066687. A total of 470.6 AF can legally be diverted to irrigate the golf course (232 AF + 226 AF + 12.6 AF).

Information provided by Montana DNRC Water Resources, 2015.

Figure 150. City & Golf Course Combined Water Rights.

In 2015, the City of Whitefish received updated water rights allowances that will allow its municipal water system to serve approximately double its current population. A search of water rights specific to Whitefish Lake through the DNRC database found 228 unique water rights on Whitefish Lake totaling 8,510.92 acre feet. The three largest water right holders of Whitefish Lake are the City of Whitefish, Whitefish Lake Golf Club, and Mountain Harbor Condominiums which comprise 88% of the total potential volume use. Iron Horse Golf Club has one water right for 2.3% of the total acre feet allocated. The highest City of Whitefish diversion use was 2007 when the city used 1600 acre feet for the year which according to City Manager Chuck Stearns was likely a dry year. The new water rights allow the city to use 3,182 acre feet per year.

Actual Whitefish Lake diversion use varies but is far lower than the maximum potential. The City of Whitefish Water Treatment Plant (WTP) pumps water from the lake to blend with the Haskill Basin source at different times of the year (see Chapter XII Whitefish Lake, Section D for Whitefish WTP information). Figure 151 shows the amount of Whitefish Lake water pumped to the WTP since 2002 and how much lake elevation is drawn down as a result independent of evaporative rates and lake surface area as levels decrease. In 2014, the Whitefish Lake Golf Course reported the use of 111.9 AF (Terry Nelson pers. communication.) which equates to 0.4 inches draw down in Whitefish Lake.



Year	Whitefish Lake volume pumped to WTP (AF)	Whitefish Lake drawdown (inches)
2002	5	0.018
2003	256	0.920
2004	46	0.164
2005	83	0.299
2006	298	1.070
2007	238	0.855
2008	186	0.668
2009	46	0.166
2010	60	0.215
2011	233	0.835
2012	179	0.645
2013	130	0.468
2014	91	0.327
Mean	***142***	***0.511***

Figure 151. Whitefish Lake Water Volume & Drawdown.

Under a hypothetical scenario, if the 2014 diverted volume used by the City of Whitefish is combined with the Whitefish Lake Golf Course, and if a conservative use estimate of 50% is applied to all remaining water rights allocations, Whitefish Lake would have been drawn down 2.57 inches as a result of diverted water use in 2014. If all water rights were used to their maximum potential at a beginning lake surface elevation of 2,998.5 feet, there would be a drawdown of 30.57 inches without adjusting for lake surface acreage as drawdown occurs.

Potential contaminant sources for public water supplies include:

- Large quantity hazardous waste generators
- Landfills
- Hazardous waste contaminated sites
- Underground storage tanks
- Major roads and rail transportation routs
- Cultivated cropland
- Animal feeding operations
- Wastewater lagoons or spray irrigation
- Septic systems
- Sewered residential areas
- Storm sewer outflows
- Floor drains, sumps, and dry wells
- Abandoned or active mines

Significant contaminants posing potential threats to the Whitefish PWS include nitrate, pathogens, herbicides, pesticides, Volatile Organic Compounds (VOCs), petroleum hydrocarbons, and total dissolved solids. The City of Whitefish routinely monitors for more than 80 constituents in drinking water according to federal and state laws. The City also has in place a set of management recommendations for preventing significant contaminants from entering drinking water resources and for addressing specific sources of contaminants should they pose a threat to the system. The 2014 Annual Drinking Water Quality Report for the City of Whitefish Water Utility concluded that the City drinking water is safe and meets federal and state requirements (City of Whitefish, 2014).

A concern beyond the potential contamination sources for the City's water supply is the increased sediment rate that could result from a catastrophic crown fire in the Haskill Basin. According to Benda and Dunne (1997), sediment delivery to streams can be highly episodic as a result of major wildfires and storms. Fires are well recognized as catalysts for sediment transport and represent a large portion of total long-term erosion (Swanson, 1981; Meyers & Pierce, 2003). Reneau *et. al* (2007) showed that the major impacts from ash and other fine sediment occurred in the first year after the fire. In their study, over 90% of the ash was delivered to the water body in the first year, and other fine sediments declined rapidly after the first year, although fine sediment loads remained significantly above pre-fire averages for the five years of the study. A catastrophic fire in the Haskill Basin could take the water resource off-line for as little as a year to much longer depending on the enormity of the fire and other complicating factors.

Also in 2015, a comprehensive easement in Haskill Basin was secured through the Trust for Public Land in an agreement that included the purchase of discounted development rights from Stoltze Land & Lumber Company, funding from the federal Forest Legacy Program and the USFWS Habitat Conservation Plan Land Acquisition Program, and a resort tax increase in the City of Whitefish.

As early as 1978, the City drilled a number of wells—with many drilled to bedrock—in search of a tertiary drinking water source. The City requires a 600 gpm capacity to service the community. When pumped all day, most drilled wells ran dry. In the mid-to-late 1990s, the City drilled a number of wells closer to Whitefish Lake, but hardness, iron, and manganese levels were poor. One well drilled on Armory Road was good, but yielded only 12 gpm. That well is now used by the dog park.

There are a number of actions the City may consider moving forward to address the Water Treatment Plant infrastructure and to plan for growth. Efficiencies could be maximized with more sophisticated inflow/outflow management; water tank storage could be considered; the intake pipe could be extended to a greater depth in the lake to reach water that has a lower pH and less Total Organic Carbons (TOCs) which would decrease treatment costs; and investigations can continue to find a tertiary source. WLI and the Haskill Basin Watershed Council continue to share ideas and concerns with the City regarding its ineffiviencies at the WTP and resulting effects on Viking Creek and Haskill Creek.

Of the many questions received by WLI throughout the year, boaters in particular are curious about the pipes in the lake just off City Beach. Although neither are currently used as intakes, the pipe that extends furthest into the lake was a City of Whitefish drinking water intake, and the other was for the Great Northern (now Burlington Northern Santa Fe). The hovercraft garage used to house a pump station for the City. Today, there is a stormwater catch basin below the building where stormwater is conveyed to the lake via the City's old water intake pipe. According to sources within the City, the amount of conveyance is thought to be minimal.

B. STORMWATER

Urban development increases the potential for stormwater impacts to water quality. As stormwater flows over roadways, sidewalks, driveways, parking lots, and other impervious surfaces, it can pick up soil, debris, chemicals, and other pollutants or pathogens and convey them to receiving waterbodies. Stormwater runoff can also affect flooding and flood intensity, groundwater infiltration rates, and stream stability.

According to Oasis Environmental (2008), the contribution of stormwater effluent to water quality degradation on Flathead Basin waterbodies remains largely unknown due to a lack of empirical studies. Limited stormwater data information exists for the Whitefish area starting with the Flathead Drainage 208 Project (Montgomery, 1977). This study estimated concentrations of nutrients and suspended solids based on land use type at six sites in Whitefish. The sites were;

- Baker Street Bridge
- Edgewood Drive/Cow Creek
- Detention Basin/Cow Creek
- 2nd St. West Bridge
- Highway 93 DQ
- North of the Burlington Northern Railroad

During the Phase I TMDL development for Flathead Lake, Stanford *et. al* (1997) collected grab samples at the same Flathead Drainage 208 Project sites. Storm water was sampled during a single storm event in the spring of 1996 and again during the dry season at outfalls where discharge was present. Loading rates were calculated but it is unknown what type of storm event qualified for sampling and at what point in the storm event the samples were taken. Overall, Stanford *et. al* (1997) concluded that significant nutrient loading was found in the agricultural and residential portions of the Watershed compared to the undeveloped forested areas and that the urban and agricultural land types contribute a disproportionate amount of nutrient loading relative to their acreage in the Watershed.

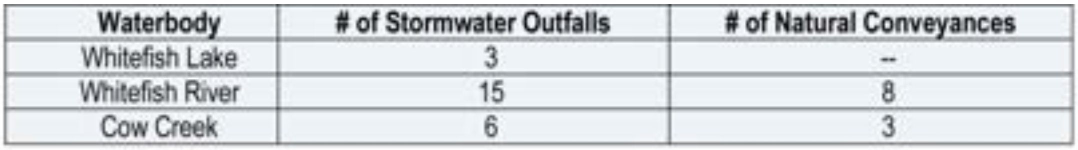
Koopal (2014a) used the Washington State Department of Ecology methodology (2002) to define a Qualifying Storm Event and analyzed nutrient and pollutant loading based on the "first flush" principle for a stormwater sampling project that compared pre- and post-stormwater infrastructure improvements in Bigfork, Montana. "First flush" sampling collects water samples during the first hour of the storm event and is based on the principal that 90% of the TSS that has been stored on impervious surfaces is flushed during that period. To be considered a Qualifying Storm Event, the storm must meet three conditions:

1. Be preceded by at least 24 hours of no greater than trace precipitation,

2. Have an intensity of at least 0.1 inches of rainfall (depth) of rain in a 24 hour period,
3. Must be collected during the first hour of discharge from a stormwater outfall, not when rainfall begins.

The study found that volume reduction strategies and engineered solutions significantly reduced nutrient and contaminant loading to Bigfork Bay and Flathead Lake (Koopal, 2014a).

The existing stormwater system of the City of Whitefish services approximately 150 sub-basins (See Stormwater map Chapter XXI, Addendum B GIS Maps). There is a complex system of detention ponds, swales, roadside ditches, pipes, manholes, catch basins, and treatment systems that convey and treat storm runoff to Whitefish Lake, the Whitefish River, and Cow Creek (Figure 152). The City of Whitefish stormwater infrastructure contains 14 ponds (six maintained by the City), 500 catch basins, 300 manholes, 60,000 feet of pipe and 17 City-maintained treatment systems (HDR Engineering, 2006; Hilding, 2015). Seven of the 17 city maintained treatment systems were installed since 2006, including two at Geddes Ave., one at Baker Ave., three at Highway 93, and one at the downtown parking lot.



Waterbody	# of Stormwater Outfalls	# of Natural Conveyances
Whitefish Lake	3	--
Whitefish River	15	8
Cow Creek	6	3

Figure 152. City of Whitefish Stormwater Waterbody Conveyances.

The City of Whitefish reviews all stormwater plans in city limits. The Montana DEQ Subdivision Program reviews stormwater management plans for sub-divisions outside of city limits that are less than 20 acres. According to HDR Engineering (2006), the majority of new development that has occurred since the previous stormwater planning effort does not connect to existing infrastructure within the stormwater system and is comprised primarily of detention ponds and infiltration systems (Robert Peccia & Associates, 1997).

Many stormwater sub-basins of the Whitefish area are challenging to manage based on underlying geology, soil types, and topography. The pro-glacial lake at the end of the Pleistocene Epoch left in its path lacustrine (clay) soils which limit water infiltration creating low depth to groundwater and dissected outwash terraces that create more stormwater sub-basins when development is overlaid.

The Whitefish Stormwater System Utility Plan (HDR Engineering, 2006) discussed protection of critical areas, including critical conveyances which precipitated a discussion and the passage of the Whitefish Critical Areas Ordinance in 2008, which later became the Whitefish Water Quality Protection Plan.

In order to better address stormwater in areas with difficult drainage challenges that are experiencing increased development pressure, the City of Whitefish designated lands of five drainage study areas where improvements were needed including; State Park Road, Karrow Avenue, Monegan/Voerman, the Armory, and Northeast Whitefish (HDR Engineering, 2006). Stormwater conveyance is a first step in addressing stormwater issues in the Whitefish Watershed and surrounding area.

A conceptual stormwater sampling plan (Koopal, 2013) was prepared for the City of Whitefish that provided an efficiency and cost comparison of the “first flush” sampling technique versus “event mean concentration” sampling. The collection of grab samples during the first hour of the storm event (first flush) is a standard that has been used by various states and municipalities. However, there have been studies that have employed “time weighted” or “flow weighted” samples to collect an integrated sample throughout the entire storm event via automatic event mean concentration samplers. Event mean concentration samplers provide a more detailed analysis of the storm event, but are more costly to implement.

In 2014, WLI was contracted to conduct stormwater sampling as part of the City of Whitefish’s pilot Nutrient Trading study. WLI based the study on their Stormwater Sample and Analysis Plan, which follows the Montana DEQ Flathead Quality Assurance Plan. Results of the sampling were provided to Robert Peccia & Associates (RPA) for final analysis. Four stormwater sites based on their proximity to the WWTP’s discharge point in the Whitefish River, and ten surface water river sites above and below the WWTP discharge were sampled on two “Qualifying Event” dates. The sites were:

<u>Stormwater</u>
North of the Burlington Northern Railroad
Riverside Park Pond
Hamilton/Baker
Spruce Court

<u>Surface Water</u>
Mouth of Cow Creek
Swift Creek at Delrey
Swift Creek at Olney
Haskill Creek Near Mouth
Viking Creek Near Mouth
Walker Creek Near Mouth
Whitefish River at Columbia Bridge
Whitefish River at JP Road
Whitefish River at Highway 40
Whitefish River at Lake Outlet

WLI provided water samples to Energy Laboratories in Helena, Montana for analysis of total phosphorous (TP), soluble reactive phosphorus (SRP), total persulfate nitrogen (TPN), ammonia, nitrate, nitrite, total organic carbon (TOC), and total suspended solids (TSS). Additionally, WLI deployed a Hydrolab DS5 to collect parameters including temperature, dissolved oxygen (DO), pH, conductivity, salinity, total dissolved solids (TDS), oxidation reduction potential (ORP), and relative chlorophyll *(a)*. Flow calculations were also performed and provided as a value in cubic feet per second (CFS). A summary of the sampling results from RPA is presented in Figure 153:

When evaluating the results it is important to note that the current instream standards for the Whitefish River which is located in the Northern Rockies Ecoregion (as defined in Circular DEQ12-A) are 0.275 mg/l TN and 0.025 mg/l TP. These standards are in effect from July 1st to September 30th of each year and will be used as an initial gauge for the significance of the results.

<u>Stormwater Samples</u>

Two nutrient samples were taken at each of the four stormwater sampling sites. All of the stormwater samples exceeded the instream standard for TN and four out of the eight total samples exceeded 1 mg/l of TN. Only two of the TP samples (taken at the WR River Outfall location) exceeded the instream standard. Stormwater loadings were a very rough estimate and were based on an assumed 20 minute long discharge at each location. It should be noted that the stormwater flow rate can vary significantly over time as can the nutrient concentration which typically decreases over time after the "first flush." The duration of the discharge will vary significantly with each storm or melt event.

TN loadings ranged from 0.0001 to 0.0873 lbs for 20 minutes of flow. TP loadings ranged from 0.0001 to 0.0076 lbs for 20 minutes of flow. The actual nutrient load from stormwater runoff will vary depending upon the duration of the runoff, time duration between storms, etc. The nutrient concentrations are significantly higher than those found in the Whitefish River and nearby streams. However, the overall nutrient load in the discharge appears to be very low at first glance. Additional work will need to be performed to estimate total volume of runoff generated over the course of a year at these sites to get a better handle on a yearly load estimate.

Of the 18 samples taken in the Whitefish River, three samples exceeded the in stream standard for TN. However each of these high values occurred in November of 2013 outside of the July-September window. The 18 samples that were taken in the Whitefish River in 2014 verify that the concentrations of TN and TP are below the in stream standards during the time window they are in effect.

Sample Location	Sample Type	Range of Total Nitrogen Sample Results (mg/l)	Range of Total Phosphorus Sample Results (mg/l)	Range of TN Loading (lbs/day) or lbs/20 Minutes for Stormwater Samples	Range of TP Loading (lbs/day) or lbs/20 Minutes for Stormwater Samples	# of Samples
Whitefish River Outfall	Stormwater	0.35 -1.28	0.26 – 0.37	0.0001-0.0005	.0001-.0001	2
Riverside Pond	Stormwater	0.71-0.86	0.062-0.270	0.0013-0.0873	0.0004-0.0076	2
Hamilton/Baker Outfall	Stormwater	0.89-1.12	0.119-0.213	0.0011-0.0033	0.0001-0.0002	2
Spruce Court Outfall	Stormwater	1.08-1.25	0.092-0.236	0.0008-0.0013	0.0001-0.0002	2
Mouth of Cow Creek	Surface Water	0.306-1.3	0.013-0.052	0.15-19.48	0.02-0.32	8
Swift Creek at Delrey	Surface Water	0.045-0.290	0.002-.064	5.98-182.25	0.31-2.51	8*
Swift Creek at Olney	Surface Water	0.058-0.083	ND-0.007	22.70-25.56	0-1.95	4**
Haskill Creek Near Mouth	Surface Water	0.069-0.027	0.004-0.011	1.36-49.6	0.11-3.91	8
Viking Creek Near Mouth	Surface Water	0-0.320	0.008-0.019	0.21-0.76	0.03-0.07	8*
Walker Creek Near Mouth	Surface Water	0.237-0.37	0.011-0.034	0.54-26.07	0.03-0.77	8
Whitefish River at Columbia Bridge	Surface Water	0.105-0.61	0.005-0.012	134.4-409.2	2.6-20.7	3
Whitefish River at JP Road	Surface Water	0.16-0.9	0.006-0.022	198.3-623.5	4.8-623.5	3
Whitefish River at Highway 40	Surface Water	0.141-1.07	0.008-0.022	203.5-549.5	4.8-49.5	3
Whitefish River at Lake Outlet	Surface Water	0.076-0.64	0.004-0.012	26.9-449.6	1.1-46.9	9

Figure 153. Summary of Sampling Results from RPA.

The results for Walker Creek, Viking Creek, Haskill Creek, Swift Creek and Cow Creek and the stormwater samples are discussed in more detail below:

> <u>Cow Creek</u> There were eight samples taken in 2014 between April 16 and October 16. All of the TN samples exceeded the 0.275 mg/l instream standard for TN and six of the TP samples exceeded the instream standard (three of which were in the July-September window). Flows ranged from a high of 1248 gpm in April to a low of 40.4 gpm in September. TN loads ranged from a high of 19.48 lbs/day in April to a low of 0.15 lbs/day in September. TP loads ranged from a high of 0.32 lbs/day in May to a low of 0.02 lbs/day in September. Generally nutrient loadings increased as flows decreased in late summer and fall.

Walker Creek There were eight samples taken in 2014 between April 16 and October 16. All of the total nitrogen samples exceeded the 0.275 mg/l instream standard for TN. One phosphorus sample taken on June 10th (0.316 mg/l) exceeds the instream standard for TP but is outside of the July-September window when the standards are in effect. The highest nutrient loads for Walker Creek occurred in April when the stream flow was 5866 gpm. The TN loading was 26.07 lbs/day and TP 0.77 lbs/day. After April the loading results dropped significantly each month to a low of 0.54 lbs/day of TN and 0.03 lbs/day of TP in the month of September. Flows in the creek ranged from 188 gpm in September 2014 to 5866 gpm in April 2014. Generally as the flows in the creek decreased from highs in the spring to lows in the fall so did the TN and TP loads.

Viking Creek There were eight samples taken in 2014 between April 16 and October 16. Only the sample taken in April (0.320 mg/l) exceeded the instream standard for TN which is outside of the July-September window. None of the phosphorus samples exceeded the instream standard. Five flow measurements were taken in the creek ranging from 727.1 gpm in September 130.2 gpm in August. No flow measurements were taken in April or May. TN loads based on flow measurements taken in June, July, August, September and October were all less than 1 lb/day. TP loads were all less than 0.1 lb/day.

Haskill Creek There were eight samples taken in 2014 between April 16 and October 16. None of the samples exceeded the instream standards for either TN or TP. TN loads were highest in the spring with a 49.6 lb/day load occurring in May which decreased to 1.1 lb/day in September. TP loads were highest at the end of May at 3.91 lbs/day decreasing to 0.11 lbs/day in September. Flows ranged from 35,352 gpm in May to 1162 gpm in October. Generally as flows decreased in late summer and fall so did the nutrient loads.

Swift Creek at Olney Four samples were taken in 2014 for TN, one each in the months of July August, September and October. Three TP samples were taken in 2014 one each in the months of July August and September. None of the samples exceeded the nutrient instream standards. TN loads were 67.4 lbs/day (at a flow of 30,236 gpm) in August and 50.9 lbs/day (at a flow of 22,830 gpm) in September. TP loads were approximately 0 lbs/day in August and 1.95 lbs/day in September.

Swift Creek at Delrey Eight TN samples and seven TP samples were taken in 2014 from April to October. Only the April TN sample (0.290 mg/l) exceeded the instream standard, but was outside the July-September window. The May 27, 2014 sample for TP (0.064 mg/l) exceeded the instream standard, but was outside the July-September window. Instream flows ranged from a high of 113,743 gpm in July to a low of 11,094 gpm in October. TN loads ranged from 182 lbs/day in April to a low of 5.98 lbs/day in October. TP loads ranged from 9.43 lbs/day in July to a low of 0.31 lbs/day in October. Generally as flows decreased so did the nutrient loads.

The following initial conclusions can be made from the sampling effort that was undertaken in 2014:

- Cow Creek and Walker Creek routinely exceed the Northern Rockies Ecoregion (NRE) in stream standard of 0.275 mg/l for TN (as defined in Circular DEQ12-A).
- Cow Creek routinely exceeded the NRE in stream standard of 0.025 mg/ for TP.
- Based on the 2014 sample results; Haskill Creek, Swift Creek and Viking Creek do not appear to have nutrient concentrations that exceed the NRE instream nutrient standards.
- While the concentration of nutrients in the stormwater samples is high compared to the stream samples, the overall load into the Whitefish River appears to be low due to the duration and magnitude of the flow. Further analysis will be needed to confirm this assumption.
- Nutrient loads from the sampled tributaries to the Whitefish River are highest in spring and early summer due to higher flows generated by runoff and generally decrease in late summer and fall due to lower flow rates. The highest loads occur outside the July-September window when the instream nutrient standards for the Whitefish River are in effect.
- Based on sampling results only, it appears that Cow Creek and Walker Creek have the most potential for future nutrient trading.
- There is more potential to obtain credits for nitrogen because in general phosphorus loads and concentrations are low, possibly due to soil adsorption.

WLI is currently developing a *Conceptual Riverside Stormwater Pond Management Plan*. This plan will provide for more effective stormwater treatment at the Riverside Stormwater Pond (RSP), to improve water quality conveyed to the Whitefish River from the RSP, and to improve aesthetics for the public. It includes information gathering and monitoring to assist the City of Whitefish in stormwater management decisions. A partnership was assembled to conduct this work that includes City of Whitefish City Engineer, Karin Hilding; adjacent property owner, Scott Elden; Whitefish High School Chemistry and Physics teacher, Todd Spangler; Whitefish High School student, Barret Gray, and WLI Executive Director, Mike Koopal. The project will also serve as a Whitefish High School student independent study.

Deliverables will include collection of physical parameters, muck layer depth evaluation, a yellow flag iris survey, a cost estimate for floating island treatment, aeration research, and creation of a GIS map. All project partners are providing in-kind services.

WLI recommends a comprehensive stormwater treatment plan that could lead to nutrient load reduction credits, and the examination of water quality levels at the outfalls. The end result would be to prioritize any treatment improvements based on the level of pollutant and nutrient loads to local waterbodies. Stormwater improvements could lead to nutrient load reduction credits under a Nutrient Trading Program.

C. WASTEWATER

1. City of Whitefish Wastewater System

Sewage was likely dealt with as a matter of inconvenience in Whitefish in the early days. The early technologies of outhouses and chamber pots were followed by cesspools built with little guidance by trained professionals. As a result, in 1919, Schaffer and Engelter (2003) state that after a real “hassle” a sewer system was put into the lakeside community of Whitefish Lake. It also appears that some sewer work was completed “in-town.”

Schaffer and Engelter (2003) state that in 1928, twenty-two outdoor toilets were condemned on property inside the sewer district. One by one, others were eliminated as “public nuisances.” In 1933 a Federal Public Works Program began which included the installation of sanitary sewers.

However, Schaffer and Engelter (2003) also indicated that by 1955 it was obvious that an overall program of sewer improvement was essential. Heavy rains had flooded streets and basements, indicating storm sewer weaknesses. The State Board of Health was exerting pressure, calling attention to the pouring of raw sewage into Whitefish River, and giving the City five years to solve its sewage problem.

Even with the advent of modern sewer lines that now partially extend on each side of the lake, problems still exist. Montana DEQ (2014) reported 16 occasions from January 2004 through June 2006, during which sewage from the city collection system overflowed from manholes due to blockages in sewer lines, or overflowed from lift stations due to equipment failures. Sewage from some of the overflows reached Whitefish Lake or the Whitefish River. Contributory factors to some of the violations were the combination of heavy rain periods with an infrastructure incapable of handling the increase of volume from infiltration, and illegal sump pump connections. In 2005, an estimated 5,000 gallons of sewage may have leaked into Whitefish Lake over a two week period from a lakeshore manhole cover. The cause of the problem was faulty electrical equipment at a pump station.

Under a Consent Order signed by Montana DEQ and the City of Whitefish, the City agreed to increase the number of employees assigned to operate and maintain the sewage collection system and to upgrade portions of the sewage collection system. A $41,200 penalty was assessed. The penalty was mitigated by a combination of a $16,236 cash payment by the City and a distribution of $31,735 to WLI specifically for the purchase and maintenance of water quality monitoring equipment.

The modern City of Whitefish sewer system includes about 46 miles of conventional gravity sewer mains, 18 lift stations, 13 duplex grinder pump stations which each serve 1020 residences, and two septic tank pump systems on the east shore of Whitefish Lake. The WWTP is located on 40 acres south of town alongside the Whitefish River and has a capacity of 1.8 mgpd. The system collects wastewater, delivers it to the main sewage liftstation then to an aerated lagoon treatment system which has a flocculating clarifier for the removal of phosphorus, finally discharging the water to the Whitefish River as regulated by state permit.

Liftstation installation dates range from 1960 to 2003, with the main liftstation having undergone a rehabilitation effort in 2003. The lagoons at the Whitefish Water Treatment Plant were built in 1979. An alum based phosphorus removal process was added and improvements to the main lift station were made in 1986. The lagoons were upgraded in 2002 with sludge removal in treatment cell #1 and installation of a new aeration system including blowers and diffusers. In 2009, an automated 6mm perforated screen was installed to replace the 2” bar screen that required manual cleaning. A second flocculating clarifier with new chemical feed equipment was brought online. In 2012, the State mandated disinfection before effluent enters the Whitefish River (Cassidy *et al*, 2008). The City has continued to contract with engineers to identify wastewater system weaknesses and make improvements to the system including the 2011 project to rehabilitate 11,400 linear feet of sewer mains.

The bulk of the sewer system includes conventional gravity sewers, augmented by lift stations where required by terrain. Lift stations located in close proximity to the lake include Mountain Park, Boat House, Birch Point, City Beach, Viking, Monk’s Bay, and Houston Point. Big Mountain contracts with the City and uses a closed interceptor to discharge its sewage effluent into the Whitefish system. According to an engineering report prepared for the City of Whitefish (Anderson-Montgomery, 2005), the City’s gravity sewers have performed satisfactorily with the exceptions of typical root intrusions, cracked pipe sections, and occasional joint separations in older vitrified clay pipe sections. Manholes have been upgraded or replaced as needed due to structural deterioration. Hydraulic performance of the existing gravity system is good and the capacity of the treatment plant is sufficient to serve current customers and growth through the year 2020 (City of Whitefish, 2012b). In rural areas not covered by the sewer system, septic tank/drainfield systems are the primary form of sewage disposal.

Future wastewater discharge permits for the WWTP will likely have significantly reduced loading limits for nutrients (nitrogen and phosphorus) due to the adoption of instream standards for nutrients in the state’s surface waters. One option for meeting these reduced limits is through a process called *nutrient trading* as authorized by the Montana Department of Environmental Quality (DEQ) and outlined in its *Circular DEQ-13 Montana’s Policy for Nutrient Trading.* Nutrient trading can be used to:

- Comply with an approved total maximum daily load (TMDL) for nutrients
- Offset a new or increased discharge of nutrients

- Comply With water quality based effluent limits for nutrients
- Offset a new or increased discharge of nutrients into high quality waters

Anderson-Montgomery Consulting Engineers (AMCE) was contracted by the City of Whitefish to conduct research into the possibilities of participating in a nutrient trading program during the same timeframe as WLI's research for this report. AMCE subcontractors WLI and Robert Peccia & Associates (RPA) shared information during the process to avoid any duplication of efforts and to share resources where possible. A preliminary assessment was provided by RPA for this report, however a full nutrient trading report will be made available from AMCE. RPA's assessment follows:

DEQs Circular 13 defines nutrient trading as "…a market-based approach to achieving water quality standards in which a point source purchases pollutant reduction credits from another point source or a nonpoint source in the applicable trading region that are then used to meet the source's pollutant discharge obligations. To be creditable to the source purchaser, the credits must reflect an actual, pollutant load differential below the credit seller's baseline. Under certain circumstances, a point source buyer may have to purchase more than one pound of pollutant reduction to equal a pound of discharged at its outfall.

In other words if a point source discharger such as the WWTP can find a means to reduce the nutrient loading into its receiving stream (Whitefish River) by means other than increasing its treatment efficiency, it can receive credits in pounds per day of nutrients that would reduce its actual daily nutrient loading in order to meet permit limits. For example if the WWTP found a source of nutrient discharge into the Whitefish River such as runoff of animal waste from a feedlot or pasture, a nutrient laden stormwater discharge, or fertilizer runoff, it could pay to mitigate the nutrient discharge from the source and receive a credit for the reduction in pounds per day. In order to receive the credit, the amount of reduction must be quantified by a methodology acceptable to DEQ. Various quantification methodologies have been developed by states that currently have nutrient trading policies in place.

In order for the WWTP to receive trading credits, nutrient sources that have a potential for trading must discharge into the river either above the treatment plant's discharge or in close proximity if the source discharges downstream of the plant's discharge. The definition of "close proximity" for sources downstream of the WWTP discharge will have to be verified with DEQ. It also bears mentioning that initial conversations with DEQ indicated that nutrient sources that discharged into or above Whitefish Lake would likely have reduced nutrient trading potential due to the attenuation of the nutrients in the Lake. This point seems to be open for debate if significant sources are discovered above or around the lake. For example the numerous septic systems around the lake could be a potential source for nutrient trading.

In order to make an initial determination as to whether or not there are potential nutrient trading sources entering the Whitefish River near the WWTP discharge, an *initial sampling plan was developed to screen for the presence of nutrients in stormwater discharge points and at or near the mouth of nearby tributary streams that flow into the Whitefish River. If significant concentrations of nutrients were detected, additional sampling further upstream and/or a visual survey of the watershed or stormwater drainage basin will be undertaken in the future in order to locate the source of the nutrients. The sampling and results are found in the Stormwater section above (Robert Peccia & Associates, 2015).*

The City of Whitefish was issued a new MPDES wastewater discharge permit in August, 2015 with new effluent standards for total nitrogen, total phosphorus, and ammonia removal

2. Septic Systems

The effective lifespan of septic systems varies according to a number of factors, including system type, overall soil suitability, installation, maintenance, and usage. Prior to advancements in septic system technology starting in 1990, septic systems generally lasted 15 to 20 years. Given optimal conditions, the average lifespan of post 1990 systems is approximately 30 years, after which time systems may fail and nutrients may leach into groundwater (Flathead County Health Department, 2012). In 1998, the Flathead County Health Department estimated that more than 50% of the individual septic systems in Flathead County were over 20 years old (Flathead Lakers, 2002).

Multiple studies (Craft et al, 2003, Whitefish County Water and Sewer District, 1984, Jourdonnais et al, 1986, U.S. Environmental Protection Agency, 1977, U.S. Environmental Protection Agency, 1984; Curtis & Koopal, 2012) confirm the problem of septic leachate from aging or failing onsite septic systems entering the lake through groundwater.

In 2011, WLI conducted the *Investigation of Septic Leachate to the Shoreline of Whitefish Lake, MT (Curtis & Koopal, 2012)* for the Whitefish County Water District under the DNRC Renewable Resource Grant & Loan program to determine the spatial and temporal extent of septic leachate to the shoreline area of Whitefish Lake. The study provided a scientific basis for identifying ecological threats to the lake, economic threats to the community of Whitefish, and potential public health risks resulting from decreased water quality. Synoptic sampling of 20 sites—including one midlake reference site—occurred on 9 sample dates starting in May 2011 and concluding in October 2011. The results of the investigation were intended to serve as actionable information for resource decision makers and Whitefish citizens concerning septic system usage around Whitefish Lake.

Septic “leachate” is the liquid that remains after wastewater drains though septic solids. The liquid contains elevated concentrations of bacteria and organic compounds from waste, detergents, and other household materials. When properly placed, functioning, and maintained, septic systems are designed to collect wastewater to neutralize these contaminants before they enter ground or surface water systems. Decomposition of waste begins in the septic tank and ends in a leachfield after undergoing a series of treatments whereby wastewater is chemically, physically, and biologically processed to remove contaminants.

Modern septic systems are considered cost-effective for wastewater treatment, however issues such as improper initial system design, impermeability of soil, improper soil drainage class, improper vertical distance between the absorption field and the water table, improper slope, or improper maintenance may lead to system failure. Even when properly installed and maintained, septic systems are inherently limited in treatment capacity, restricted to primary removal of solids and limited reduction is organic compounds present in wastewater. They also have a finite life expectancy.

Previous studies on Whitefish Lake have indicated septic system failures, and confirmed the presence of OBAs from household cleaning products commonly found in septic leachate. The 2011 investigation was designed to build on the techniques and results of prior studies, but employ newer data collection techniques along with bacterial source tracking methodologies. Because septic leachates are known to contain elevated concentrations of both organic and inorganic compounds, the study employed a toolbox of techniques, including; fluorometry, dissolved organic carbon (DOC), fluorometry/DOC ratio (F/DOC), *E. coli* enumeration, human DNA biomarkers, conductivity, total dissolved solids (TDS), and GIS methodologies and tools. In addition to data collection and analysis, a historical record for the study area was established.

In addition to basic cleaning components, 97% of laundry detergents in the U.S. contain Optical Brightening Agents (OBAs). OBAs are added to laundry soaps, detergents, and other cleaning agents because they adsorb to fabrics and materials during the washing and cleaning processes making clothes appear brighter. Laundry wastewater is the largest contributor of OBAs to wastewater systems. The presence of OBAs in wastewater with laundry effluent as a component is therefore considered an excellent indicator of septic or sewage system failure. Because the specific light spectrum emitted from OBAs found in cleaning products is easily measurable, it is one of the key data parameters used in tracking ineffective sewage treatment from septic systems.

The 2011 study concluded with the development of the Septic Leachate Contamination & Risk Assessment Map (Chapter XXI, Addendum B: GIS Maps) which identified confirmed sites of septic leachate contamination as well as areas of low, medium, and high potential for future contamination. Of the three confirmed areas (City Beach Bay, Viking Creek, and Lazy Bay), it was concluded that the City Beach Bay contamination was most probably caused by human excrement from swimmers at City Beach being dispersed via natural or boat-wash currents to the sample site. There are no septic systems in the area and no breaks in sewer lines were discovered. No sewer infrastructure issues were found at Viking Creek, underwent additional investigation. Lazy Bay remains an area of concern due to aging septic systems in the Lion Mountain development above the lake.

Six areas were identified as having medium to high potential for septic leachate contamination including Lazy Channel, Dog Bay State Park Seep, City Beach Seep, SE Monk’s Bay, Brush Bay, and the East Lakeshore from Gaines Point south to north Monk’s Bay – including Carver Bay and SE Houston Pt. These sites have also shown contamination in prior studies, and represent locations where action should be considered.

The City of Whitefish convened an ad-hoc committee of the City Council to review the 2012 report and make recommendations. Based on the conclusions of the committee and their Whitefish Community Wastewater Management Plan, the City of Whitefish accepted the plan through a council resolution and committed financial support for the first Preliminary Engineering Report (PER) to address septic contamination in the Lion Mountain Area above Dog Bay State Park Seep. Planning Grant funding to conduct the PERs was also received from the Treasure State Endowment Fund (TSEP) and the DNRC. While it may take many years and many partners to address all of the areas of contamination, this is a first step toward a safer, healthier lake.

XV. WATER QUALITY CRITERIA

A. CRITERIA & STANDARDS BACKGROUND

Water quality standards are the scientific foundation for maintaining fish and wildlife, recreational uses, and sources of drinking water. *Water quality standards* consist of a designated use(s) for a waterbody, water quality criteria to protect the designated uses, and an anti-degradation policy.

Montana waterbodies are classified according to the present and future beneficial uses that they should be capable of supporting (75-5-301 MCA). Whitefish Lake is classified as an A-1 waterbody. Beneficial uses for A-1 waterbodies include suitability for drinking, culinary, and food processing purposes after conventional treatment for removal of naturally present impurities. Water quality must be suitable for bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply.

DEQ (2006) states that reasonable land, soil, and water conservation are not always accomplished by using best management practices (BMPs). BMP’s are land management practices that provide a degree of protection for water quality, but they may not be sufficient to achieve compliance with water quality standards and protect beneficial uses. Therefore, reasonable land, soil, and water conservation practices generally include BMPs, but additional measures may be required to achieve compliance with water quality standards and restore beneficial uses.

Water quality criteria consist of numeric and narrative criteria to identify levels of individual pollutants, or water quality characteristics, or descriptions of conditions of a waterbody that, if met, will generally protect the designated use(s). Having clear numeric criteria is important for establishing watershed planning, protection and restoration, and for innovations such as market-based incentives and trading.

This report consists of the requisite baseline information to inform the criteria development process. As a logical extension of this report, WLI will forward the Whitefish Lake numeric water quality criteria recommendations for TP, TN, chlorophyll (*a*), and Secchi disc to DEQ to review and consider for inclusion in Circular DEQ-12A. Numeric Standards found in Chapter XV. Water Quality Criteria, Section D. Proposed Water Quality Criteria are for Flathead Lake Standards and are being used as a starting point for comparison to values to be developed for Whitefish Lake.

B. HISTORICAL BASELINE REFERENCE CONDITIONS

Unfortunately, no water quality data exists for Whitefish Lake which would accurately describe true historic lake conditions. Beginning in the 1890s, the lake began to experience fluxes to its biological, chemical, and physical properties due to land use pressures and the introduction of non-native species.

Little water quality data exists for Whitefish Lake prior to the 1980s except for the United States Environmental Protection Agency National Eutrophication Survey conducted in 1975 (EPA, 1977). This is an important report as it describes lake conditions prior to major food web transition as a result of *Mysis* shrimp. Of the many species introductions to Whitefish Lake, *Mysis* represent the most dramatic in terms of their effect to the food web and nutrient cycling.

In 1982-1983, the University of Montana Flathead Lake Biological Station (FLBS) began collecting water quality information at a mid-lake site on Whitefish Lake (Golnar, 1986). Golnar's 1986 work was then compared to results found by Craft *et al.*, (2003).

WLI formed in 2005 and began collection water quality information in 2007 on Whitefish Lake from the deep lake site near Hellroaring Creek and from an outlet site near City Beach. In addition, WLI has been consistently collecting data on all tributary inputs, as well as recording atmospheric deposition. WLI data and post 2002 FLBS data have been used to describe current conditions.

1. Food Web Flux Summary

It is estimated that the peak *Mysis* period occurred from 1973-1976. A step increase in primary productivity during the *mysis* upheaval was reported in Flathead Lake (Ellis, 2006), but no trend before or after was observed. Since around 1980, the *Mysis* population is suspected to have reached a dynamic equilibrium at lower densities.

In addition to the mysid introduction, numerous fish species have either been legally or illegally introduced to Whitefish Lake with varying success. Most notably were lake Whitefish (1915), lake trout (1941), Kokanee salmon (1945), and northern pike (early 1970s).

The native fish assemblage of Whitefish Lake consists of bull trout, westslope cutthroat trout, mountain whitefish, pygmy whitefish, longnose sucker, largescale sucker, northern pikeminnow, peamouth chub, redside shiner, and three species of sculpin (Deleray 1999). The effects to the native fish species assemblage from the *Mysis* introduction and non-native fish species introductions can be found in Chapter IX Biological Community Overview, Section D. Fisheries. In effect, a trophic cascade is suspected to have occurred in Whitefish Lake based on information known from Flathead Lake by Ellis (2011) as a result of species introductions with implications to the food web and nutrient cycling.

2. Physical Landscape Flux Summary

The Whitefish Lake Watershed has been subject to both natural and anthropogenic land disturbance activities (see Chapter IV Cultural History, Section A. Historic Land Use). The dominant natural land disturbance activities include floods and fire. The most significant flooding occurred in 1894 followed by 1974 and 1964 respectively. Major fires (greater than 1% of the Watershed area) include 1910, 1919, 1926, 1937, and 2001.

The dominant land uses of the Whitefish Lake Watershed include timber harvest and shoreline development. From 1886-1900, much of the timber along the shoreline of Whitefish Lake was harvested and yarded in the lake. From 1900-1904 the railroad line was constructed along the west shore of Whitefish Lake. Large-scale timber harvest and associated road building in Lazy Creek and Swift Creek began in the 1930s and continues today. Timber harvest Best Management Practices (BMPs) were implemented in the 1970s and 1980s.

Shoreline development along Whitefish Lake dates back to the late 1880s with sporadic cabins along the lake. The townsite of Ramsey appeared in the early 1900s near the Whitefish River outlet. Development around the lake remained restricted until the Civilian Conservation Corps (CCC) constructed a road along the east side of the lake and up the Swift Creek drainage. Yet, development remained slow until the 1970s and 1980s when shoreline development substantially increased. In the mid 1980s as concerns over shoreline development grew, a group of Whitefish residents were instrumental in passing legislation at the state level which gave local authorities the option of developing local lakeshore regulations.

C. HISTORICAL BASELINE REFERENCE CONDITIONS DETERMINATION

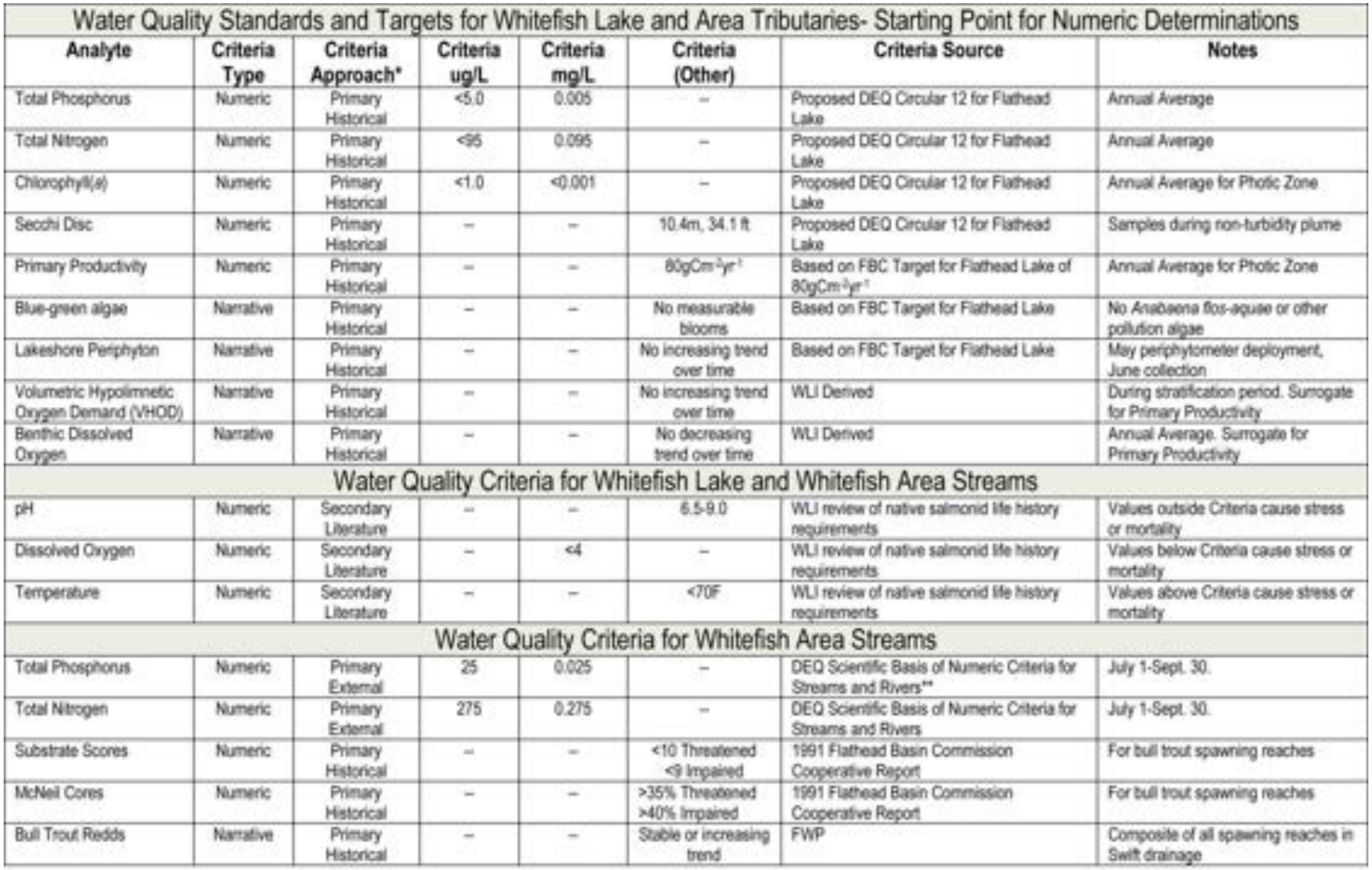
No true historical water quality baseline condition can be determined prior to species introductions and major land use activities. The National Eutrophication Survey in 1975 (EPA, 1977) was conducted during the estimated peak *mysis* period. Whitefish Lake. In addition, some cultural eutrophication had occurred in the lake from land use activities prior to 1975. Relevant data from that project will be analyzed independently for consideration in criteria development. A caveat to the EPA work is that it represents only three sample visits for one year providing minimal intra-annual and no inter-annual information for that time period.

The FLBS water chemistry data from 1982-1983, is an important dataset to best approximate post-*Mysis* and post-fish introduction baseline conditions. The FLBS 2002-2003 dataset provides an important comparison to the 1982-1983 study. As such, an equitable comparison of the lake's current condition to 1983 can be made. In addition, many regulatory activities from 1975-2000 (lakeshore regulations, phosphate ban, BMPs, SMZs, and HCPs) have influences nutrient loads.

D. PROPOSED WATER QUALITY STANDARDS AND TARGETS STRATEGY

The Whitefish Lake and Area Tributaries Water Quality Criteria introduced herein will be developed primarily from Golnar (1986) post-*Mysis* and post-fish introduction era.

The Golnar (1986) dataset will then be compared to the Craft et al. (2003) dataset and current information. Water quality criteria are simply water quality standards which have yet to be adopted into law. Setting water quality standards is about establishing the desired condition for the waterbody (within its natural capabilities) (Suplee, 2005).



Water Quality Standards and Targets for Whitefish Lake and Area Tributaries- Starting Point for Numeric Determinations							
Analyte	**Criteria Type**	**Criteria Approach***	**Criteria ug/L**	**Criteria mg/L**	**Criteria (Other)**	**Criteria Source**	**Notes**
Total Phosphorus	Numeric	Primary Historical	<5.0	0.005	–	Proposed DEQ Circular 12 for Flathead Lake	Annual Average
Total Nitrogen	Numeric	Primary Historical	<95	0.095	–	Proposed DEQ Circular 12 for Flathead Lake	Annual Average
Chlorophyll(a)	Numeric	Primary Historical	<1.0	<0.001	–	Proposed DEQ Circular 12 for Flathead Lake	Annual Average for Photic Zone
Secchi Disc	Numeric	Primary Historical	–	–	10.4m, 34.1 ft	Proposed DEQ Circular 12 for Flathead Lake	Samples during non-turbidity plume
Primary Productivity	Numeric	Primary Historical	–	–	$80gCm^{-2}yr^{-1}$	Based on FBC Target for Flathead Lake of $80gCm^{-2}yr^{-1}$	Annual Average for Photic Zone
Blue-green algae	Narrative	Primary Historical	–	–	No measurable blooms	Based on FBC Target for Flathead Lake	No *Anabaena flos-aquae* or other pollution algae
Lakeshore Periphyton	Narrative	Primary Historical	–	–	No increasing trend over time	Based on FBC Target for Flathead Lake	May periphytometer deployment, June collection
Volumetric Hypolimnetic Oxygen Demand (VHOD)	Narrative	Primary Historical	–	–	No increasing trend over time	WLI Derived	During stratification period. Surrogate for Primary Productivity
Benthic Dissolved Oxygen	Narrative	Primary Historical	–	–	No decreasing trend over time	WLI Derived	Annual Average. Surrogate for Primary Productivity
Water Quality Criteria for Whitefish Lake and Whitefish Area Streams							
pH	Numeric	Secondary Literature	–	–	6.5-9.0	WLI review of native salmonid life history requirements	Values outside Criteria cause stress or mortality
Dissolved Oxygen	Numeric	Secondary Literature	–	<4	–	WLI review of native salmonid life history requirements	Values below Criteria cause stress or mortality
Temperature	Numeric	Secondary Literature	–	–	<70F	WLI review of native salmonid life history requirements	Values above Criteria cause stress or mortality
Water Quality Criteria for Whitefish Area Streams							
Total Phosphorus	Numeric	Primary External	25	0.025	–	DEQ Scientific Basis of Numeric Criteria for Streams and Rivers**	July 1-Sept. 30.
Total Nitrogen	Numeric	Primary External	275	0.275	–	DEQ Scientific Basis of Numeric Criteria for Streams and Rivers	July 1-Sept. 30.
Substrate Scores	Numeric	Primary Historical	–	–	<10 Threatened <9 Impaired	1991 Flathead Basin Commission Cooperative Report	For bull trout spawning reaches
McNeil Cores	Numeric	Primary Historical	–	–	>35% Threatened >40% Impaired	1991 Flathead Basin Commission Cooperative Report	For bull trout spawning reaches
Bull Trout Redds	Narrative	Primary Historical	–	–	Stable or increasing trend	FWP	Composite of all spawning reaches in Swift drainage

Figure 154. Water Quality Standards and Targets for Project Area.

XVI. CURRENT AND FUTURE CONCERNS

A. INTRODUCTION

This section covers a few general water quality concerns for the project area. The Watershed Restoration Plan table contains a comprehensive list of water quality issues, concerns, and goals identified by WLI, project partners, and the public.

B. SOCIAL

1. Community Forum

On May 20th, the Whitefish Lake Institute, City of Whitefish, and Anderson-Montgomery Consulting Engineers jointly held a Community Forum to introduce this project—the *Whitefish Area Water Resources Report: A Status of the Whitefish Lake Watershed and Surrounding Area*—to the public and to obtain comments from citizens. Attendees received a Project Description, Project Outline, and a Community Survey. Approximately 50 people attended. Mayor John Muhlfeld provided introductory comments.

Whitefish Lake Institute (WLI) executive director, Mike Koopal provided context for the report, and WLI Science and Education Director, Lori Curtis, discussed the survey and public comment process. Eleven community members provided comments or asked questions. Long-time resident Dick Solberg spoke enthusiastically about the importance of people being a voice for the lake and for considering the health of the lake and its importance to the economy when making community decisions. Dan Weinberg, one of the initial board members for WLI and an ex-state senator, spoke very passionately about the need to act on the issue of septic pollution on Whitefish Lake. He questioned why individuals seem to think they have the right to pollute the lake and expressed his heartfelt frustration with the apparent lack of action to date to address the septic pollution issue. Another long-time resident with a deep relationship with Whitefish Lake—Charlie Abell—addressed his concerns about Aquatic Invasive Species, bladder/wake boats, and the introduction of non-native species.

2. Public Survey

A public survey was made available from Monday, May 11th through Wednesday, May 27thin hard copy and online. There were a total of 47 respondents to the survey. Of those who responded, 21% were under18, 11% were 18-29, 13% 30-44, 17% 45-59, and 38% were 60 or over. Household incomes ranged from 25% under $49,999, 13% between $50,000 and $64,999, 17% $75,000 and $99,999, 22% $100,000 to $124,999, 7% earned $150,000 to $174,999, and 18% hade household incomes over $200,000. Respondents were 61% democrats, 32% independents, and 2% republicans. Ninety-four percent are homeowners while 6% are renters. About 60% are people who do not live on the lake or have a view of the lake, while 40% live on or have a view of the lake. Of that 40%, 6% live outside the City of Whitefish.

The respondents were evenly split between anglers and non-anglers, while 87% use human-powered watercraft or sailboats, 26% use motor boats or personal motorized watercraft, and 2% do not recreate by watercraft. Swimmers in Whitefish Lake make up 90% of respondents. Seventy-eight percent of respondents feel there is too much boat traffic on the lake and 87% feel the boat ramp at City Beach is often overcrowded.

Almost 48% of respondents felt that drinking water was the most important reason to protect water quality while 30% identified fish and wildlife. When asked to rank “physical” concerns, aging septic systems is the greatest public concern at 49%, followed by the removal of native vegetation and planting of nonnative vegetation at 21%. Aging sewer infrastructure ranked third and sediment from landscape disturbance fourth. The greatest “chemical” concerns are railroad related pollution at 46%, nutrients such as nitrogen and phosphorus at just over 24%,volatile organic compounds (VOCs) at just over 22% followed by pharmaceuticals and personal care products and mercury. Over 79% of respondents felt that water quality is important to the economy of Whitefish. 100% of respondents felt it is important for the City to have local management of Aquatic Invasive Species issues.

WLI thought it would be interesting to see how many people knew which 6 perennial streams feed Whitefish Lake. About half of the respondents got about half of them right. They are Beaver Creek, Hellroaring Creek, Lazy Creek, Smith Creek, Swift Creek, and Viking Creek. Almost 87% of respondents expressed interest in learning more about stormwater and wastewater systems in the program area, and 100% of respondents expressed some or much interest in seeing the results of the report. Similarly, over 95% of respondents expressed a willingness to contribute to the cost of protecting and improving water quality in the Whitefish area.

Of the individually provided comments and concerns, the greatest number were related to septic leachate and AIS, while boat usage, lakeside development, chemicals pollutants including fertilizer and pesticide use, and shoreline erosion and sediment issues were the next most mentioned concerns. Railroad pollutants, general overuse, and global climate change were also discussed.

C. BIOLOGICAL

1. Aquatic Invasive Species

One of the greatest economic and environmental concerns in the Whitefish Lake Watershed and Surrounding Area, throughout the state of Montana, and the entire US is the introduction of Aquatic Invasive Species (AIS). AIS are responsible for 48% of the species listed under the Endangered Species Act and they have cost the US economy billions of dollars (Montana Noxious Weed Summit Advisory Council, 2011). Over 70 species of AIS have been reported in the state of Montana alone. AIS have the potential to impair water supply lines, power generation facilities, and irrigation infrastructures. With a lack of natural predators and the ability to survive in a wide range of environmental conditions, AIS tend to be highly competitive.

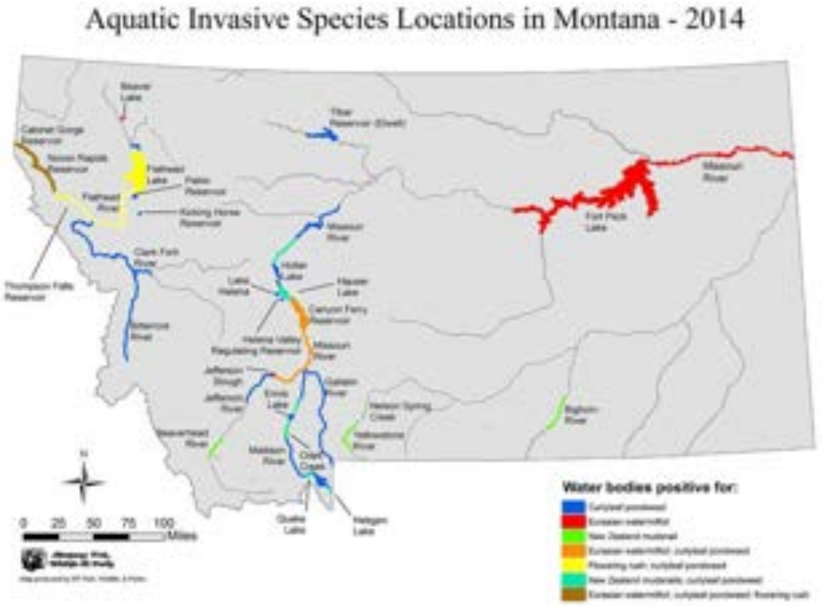


Figure 155. Aquatic Invasive Species in Montana.

The concern for AIS was brought home to Whitefish on May 8, 2015, when a newly created AIS checkpoint in Browning stopped a boat from Minnesota headed for Whitefish Lake that was fouled with zebra mussels. The checkpoint is the result of a unique partnership formed in early 2015 between the Blackfeet Nation and the Flathead Basin Commission. The Blackfeet previously adopted an ordinance to protect its resources from AIS, requiring all boaters to obtain a certificate of inspection prior to launching on tribal waters (Hungry Horse News, 2015).

With environmental adaptability and efficient use of resources, AIS have the ability to severely impact native fisheries and aquatic plant communities, and affect the quality of drinking water and recreational resources. Invasive mussels have the capacity to increase human and wildlife exposure to pollutants such as Polychlorinated biphenyls (PCBs) and Polycyclic acromatic hydrocarbons (PAHs) because these toxins accumulate in the tissue of mussels and are passed up through the food chain (NOAA Fisheries Service, 2013).

a. Environmental and Economic Impacts

According to the Flathead Basin Commission Aquatic Invasive Species Briefing Sheet (Flathead Basin Commission, 2012), some of the most notable environmental impacts that have occurred as a result of AIS are:

- Declines in salmonids: Infested rivers have seen salmonid growth rates decline by 60% and overall conditions by 38%.

- Dead zones in lakes: Lake Erie experienced a "dead zone" of oxygen depleted water as a result of a significant zebra mussel infestation.

- Avian botulism: Over 2,500 shorebirds were killed on a 35-mile stretch of shoreline of Lake Michigan in 2007.

- Food web disruption: Mussels on Lake Erie filter the entire water column 20 times daily consuming 26% of the primary production.

Economic impacts associated with mussel infestations to date are also extensive (Flathead Basin Commission, 2012). Most economic impact assessments are based on costs incurred by dam and power operations, water treatment plants, and associated local economies. Estimates in the US suggest that hydropower industries are incurring $1 billion dollars annually in post mussel infestation maintenance, followed by staggering regional economic losses such as $100s of millions annually in the Columbia River Basin, $94.5 million annually in Idaho, and $22.4 million annually in the Lake Tahoe region. Other losses include:

- $11 million annually to Orange and Lachloosa Lake in Florida due to infestation of aquatic weeds

- In the Great Lakes, a 10-20% decrease in property values, 11-35% decrease in recreational fishing, a 13-33% decrease in commercial fish landings, and a $30,000 to $118,000 per facility cost to raw water users

- A $445 million predicted loss in British Columbia if their $350,000 aquatic plant control program was terminated, citing $85 million in lost tourism revenue (1700 jobs), and $360 million in real estate value.

The Flathead Basin Commission also predicted an economic impact in Montana as follows:

- 10-30% decrease in tourism
- 10-20% increase in utility rates
- 10-20% decrease in property values and taxes
- 10-20% increase in water infrastructure operations and maintenance
- Millions of dollars in capital costs for new infrastructure.

Recreational boating and fishing contribute $671 million dollars to the Montana economy. A 10% decrease would represent a $67 million dollar loss to the economy. The benefit:cost ratio for prevention of mussel introductions range from 25:1 to 70:1.

b. AIS Programs

At the state level, FWP partners with the Montana Department of Agriculture (MDA), Montana Department of Natural Resources & Conservation (DNRC) and the Montana Department of Transportation (MDT) to implement the Aquatic Invasive Species Management Plan with a goal to "…minimize harmful impacts of AIS through the prevention and management of AIS into, within and from Montana" (Schmidt & McLane, 2014). This early detection and monitoring plan has been in place since 2004. FWP reported in 2014 that 187 waterbodies, 456 unique sites and 616 total sites were inspected in Montana with no new populations of AIS found in those inspected waterbodies (Schmidt & McLane, 2014).

Watercraft inspection stations are part of this statewide plan, with locations selected "…based on angler pressure, boater movement, estimated risk of AIS introduction, logistics, and input from other agencies and stakeholder groups" (Boos et al, 2014) (Figure 157).

Watercraft Inspection Station Summary from 2012 - 2014
(Includes MT Dept of Agriculture data)

	Days Operated			Inspection Numbers			Failed Boats		
Inspection Station	2012	2013	2014	2012	2013	2014	2012	2013	2014
Billings Roving	13	28	45	77	707	741	2	59	7
Bozeman Roving	34	50	53	704	1655	951	2	5	3
Clearwater Junction	118	104	80	9941	9608	7051	27	112	99
Coram	-	-	122	-	-	3460	-	-	19
Culbertson	28	79	46	55	205	104	2	6	1
Dena Mora	101	74	98	1889	1332	1878	30	58	7
Dillon	87	93	95	819	919	767	1	7	13
Eureka	110	98	84	1782	1325	1119	6	35	19
Fort Peck Roadway	3	86	83	122 (Marina)	417	1444	2	7	8
Fort Peck Roving	84 (MDA), 8 (FWP)	43	16	2069 (MDA), 54 (FWP)	402	113	22 (MDA), 0 (FWP)	3	1
Hardin	88	91	94	1297	2129	2247	8	75	58
Helena Roving	100 (MDA), 87 (FWP)	80	59	2132 (MDA), 2172 (FWP)	2383	1639	33 (MDA), 14 (FWP)	59	13
Missoula Roving	50	40	65	495	691	1340	3	98	11
Noxon	102	63	60	2081	732	747	35	10	8
Plains	102	-	-	3504	-	-	25	-	-
Ronan	140	89	100	5045	4745	4854	29	22	17
Swan Roving	59	52	27	499	590	487	1	6	3
Sweetgrass	-	-	11	-	-	20	-	-	0
Thompson Falls	-	72	102	-	1354	2080	-	203	106
Troy	102	124	103	4212	3001	2370	32	32	57
Shelby/Conrad	-	45	-	-	344	-	-	0	-
Wibaux	67	94	102	313	502	627	5	5	1
	2012	2013	2014	2012	2013	2014	2012	2013	2014

Figure 156. Montana Watercraft Inspection Stations
Courtesy Montana Fish, Wildlife & Parks

In the Flathead Basin, AIS management is described under the Flathead Basin Aquatic Invasive Species Strategic Prevention Plan which is implemented by the Flathead Basin AIS Work Group (2011). The group's stated mission is "…to work locally to prevent the introduction of aquatic invasive species into the Flathead Basin, and to help contain, control and, where possible, eradicate the aquatic invasive species present in the Flathead Basin" (Flathead Basin AIS Work Group, 2011).

The following organizations and agencies originally partnered to form the Group:

- Confederated Salish & Kootenai Tribe
- Flathead Basin Commission
- Flathead Conservation District
- Flathead County
- Flathead Lake Biological Station
- Flathead Lakers
- Flathead National Forest
- Glacier National Park
- Lake County
- Missoula County
- Montana Department of Agriculture
- Montana Department of Fish, Wildlife & Parks
- Sanders County
- U.S. Geological Survey
- Whitefish Lake Institute

At the local level, in 2013 the City of Whitefish began supporting the City of Whitefish Aquatic Invasive Species Conceptual Management Plan recommended by WLI (2013). The plan budget included support for a boat inspection station, monitoring and control of EWM on Beaver Lake, early AIS plant detection on Whitefish Lake and other surrounding waterbodies, environmental DNA analysis of water samples, and support of a City Beach boat launch inspection station. The City has provided ongoing support for a local AIS program since 2013. The 2015 management plan submitted by WLI includes ongoing monitoring and control of EWM at Beaver Lake, early AIS detection, eDNA analysis of water samples, a City Beach boat launch inspection effort, a commercial use permit program, and Level II AIS training. Given current AIS funding and resource constraints across the state, the City is compelled to protect its resources through these local efforts.

WLI provides oversight and training to City of Whitefish employees for the City Beach watercraft inspection station. Employees are trained to perform inspection protocols, record data, and identify high risk watercraft. A total of 1,016 boats were inspected between the months of May and September. In 2014, there were a total of 55 inspection days making for an average of 18 boats inspected per day. Boats were most frequently inspected between 12:00pm and 6:00pm except on Saturdays where they were inspected from 9:00am to 6:00 pm.

The majority of watercraft inspected were boats (Figure 157). Personal watercraft (PWC) including kayaks, paddle boards, and inflatables are often launched on the beach rather than the boat ramp and therefore were not inspected. Inspectors were trained to inspect all boats using the public launch access and if there were no boats launching they were instructed to inspect PWC launching at or near the beach.

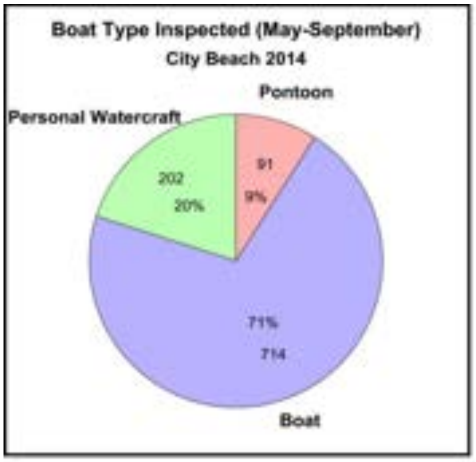


Figure 158. City Beach Boat Inspections by Type of Watercraft.

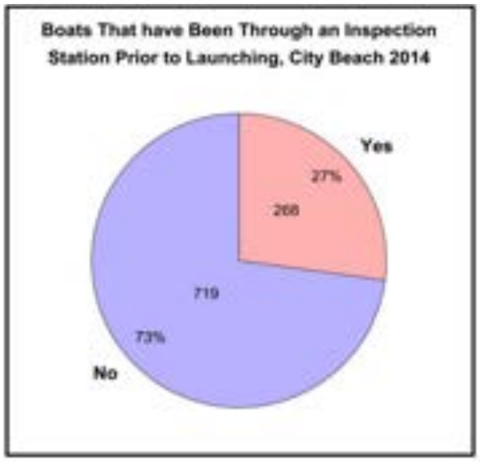


Figure 157. City Beach Boat Inspections by Prior Inspection Station.

Nearly three quarters of the watercraft that were inspected reported that they had not been through an inspection station prior to launching in Whitefish Lake (Figure 158). It is suspected that many previously non-inspected boats are transferring from local waterbodies. The majority of the boats that had been inspected reported having been through either a border inspection station or the inspection station at Corum. Three quarters of all boats reported having last launched in Whitefish Lake (Figure 159). It is important to identify boats that are considered “high risk.” Nine percent of all boats reported having last launched in Flathead Lake which has known AIS infestations of both curly leaf pondweed and flowering rush.

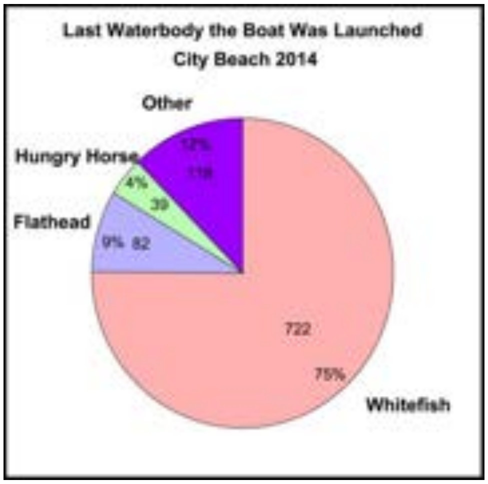


Figure 159. City Beach Boat Inspection by Prior Launch.

Watercraft that have out of state license plates are also considered to be “high risk” because zebra and quagga mussels can live up to 30 days attached to a boat or trailer, depending on temperature and humidity. Standing water inside a watercraft can also be a vector for fish pathogens. Whitefish Lake allows boats with ballast tanks to launch, and many boats drained water into the lake prior to launching. A handful of boats pulled transom plugs draining standing water directly onto the boat ramp from the last waterbody they visited.

Data indicates that the busiest days at City Beach occur during July with the first week of the month being extremely busy with recreationalists gearing up for the Independence Day holiday. The busiest day of the year was on Saturday July 21st, when 56 watercraft were inspected.

AIS is particularly complex to address because it involves a number of conveyance modes. AIS may travel naturally from one waterbody to another via tributary streams. People have unfortunately proven to be excellent, if accidental, conveyors as well. At the smallest scale, a fisherman can transport AIS from lake to lake by not decontaminating their waders and boots. On a larger scale, recreational boats can transport AIS from state to state if they are not properly decontaminated. On a grand scale, AIS have been moved from country to country in the ballast water of ships. At any scale, managing the conveyance of AIS is a vast and costly challenge. Not managing it, however, can lead to much greater costs and much more complex challenges.

c. Aquatic Invasive Species in the Project Area

Of particular concern in the Whitefish Lake Watershed are those AIS which have been found in the Watershed and a few that have been identified in close proximity.

Eurasian watermilfoil (*Myriophyllum spicatum)*

The greatest current concern is for Eurasian watermilfoil. This aquatic invasive plant was previously introduced from Europe and Asia and is found all over the U.S. Eurasian watermilfoil (EWM) was introduced to the eastern U.S. between the 1800s and the 1940s (Couch & Nelson, 1985 and Reed, 1977). The first specimen was collected from Lake Meridian near Seattle in 1965, and was found in Lake Washington in the 1970s. It was established during this same period in British Columbia, traveling downstream to Lake Osoyoos and the Okanogan River in central Washington. EWM is now found in the Columbia, Okanogan, Snake, and Pend Oreille Rivers and nearby lakes. Its distribution in western Washington closely follows the Interstate 5 corridor, suggesting its spread from lake to lake by recreational boats. (Washington State Department of Ecology, 2010).

The plant spreads primarily by natural fragmentation which occurs after flowering at the end of its growing season, and by mechanical fragmentation such as cutting through by outboard motor blades. Fragments survive long-distance transportation by water currents and can be transported from one waterbody to another attached to boat trailers or motors. Each fragment has the potential to establish an individual plant. EWM also produced large quantities of seeds, however they are considered of little or no importance in dispersal of the plant. The plants die back to root crowns during winter month. (Smith and Barko, 1990).

Figure 160. Eurasian Watermilfoil.
Photo courtesy WLI

Figure 161. Eurasian Watermilfoil on boat motor.
Photo courtesy U.S. Fish & Wildlife Service

EWM is highly invasive, colonizing streams, small rivers, ponds, lakes, and reservoirs. The plant is rooted and submerged, with primary stems forming a dense canopy on water surfaces. This dense canopy interferes with recreational activities such as fishing, boating, and swimming, and clogs water intake pipes and power generation facilities. In addition to providing good habitat for mosquito breeding, the dense canopies can prevent wind from mixing the oxygenated surface waters with the deeper water layers robbing the water of life supporting oxygen. These canopies can also shade out and out-compete desirable native plant species (Smith and Barko, 1990).

In October 2011, EWM was discovered by the DNRC near the boat ramp on Beaver Lake. As a tributary to Whitefish Lake, an infestation in Beaver Lake poses a great threat to the lake, which outflows to the Whitefish River eventually reaching Flathead Lake and the Columbia River Basin.

Figure 162. AIS Response Team on Beaver Lake.
Photo Courtesy WLI

An AIS response team—of which WLI was a member—responded to the discovery for further investigation. Bottom barriers were placed over the identified patch and a control/eradication plan was developed by a multiple agency group in which the City of Whitefish and WLI participated.

In the summer of 2012, snorkel surveys and subsequent diver dredging were conducted twice. Three pounds of EWM were removed by Ace Diving during the first effort, and twenty pounds were removed by Hanson Environmental during the second dredge event. No additional EWM occurrences were identified in the second snorkel survey.

The City of Whitefish funded an AIS program as recommended by WLI in 2013 and 2014. One component of the program was to survey and dredge any EWM plants found in Beaver Lake. Two combined snorkel survey and dredge events were completed in the summer of 2013, one at the beginning of July, and the other in mid-August. The entire littoral zone of Beaver Lake was visually surveyed by a snorkeler. Aside from one afternoon during which wake boats created shoreline turbidity, visibility was excellent during both inspections. Although no new areas of infestation were found, some re-growth was seen in the three patches that were dredged in 2012. In July of 2013, five pounds of EWM were removed and another one pound in August through diver dredging.
In 2014 and 2015, single snorkel and re-dredges were conducted with approximately one pound of EWM removed both years. With shoreline EWM appearing to be suppressed in Beaver Lake and only limited plants remaining, an annual snorkel and dredge is planned for 2016 and into the future. (Hanson Environmental, 2015)

Due to the close proximity of Beaver Lake to Whitefish Lake, WLI deploys a turbidity curtain (Figure 163) to prevent fragments from moving downstream toward the lake. The curtain—provided by the Flathead Lakers—is installed at the outlet of Beaver Lake where Beaver Creek begins to flow. The curtain is deployed by WLI staff in the spring and removed in the fall on an annual basis. WLI also partnered with the Flathead Basin Commission to conduct a 100-point AIS presence/absence survey on Whitefish Lake. No EWM or other invasive plant species were found. EWM efforts will continue in the future.

Figure 163. Turbidity Curtain on Beaver Lake. *Photo courtesy WLI*

Zebra mussel (*Dreissena polymorpha)*

Figure 164. Zebra Mussels on Propeller.
Photo courtesy U.S. Fish & Wildlife Service

Another major AIS concern in the project area is for the tiny (<50mm) zebra mussel. a freshwater mollusk which has been steadily invading U.S. rivers and lakes since 1988 (Benson et al, 2014). Originating from Poland and the former Soviet Union, the mussel was first found in Lake St. Clair—a small waterbody connecting Lake Huron to Lake Eerie. Biologists suppose the mussels were transported in a ship's ballast water from a freshwater European port and later discharged to the Canadian side of the lake (Hoodle, M, n.d.). The female zebra mussel produces between 30,000 and 1 million eggs annually, with 2 percent reaching adulthood (Benson *et al*, 2014). Young mussels are free swimming, but older mussels attach themselves to hard surfaces such as boats, navigational buoys, pipes, pilings, docks, and hard-surfaced creatures like other mollusks, and turtles via their byssus, an external multi-threaded organ. Adult zebra mussels filter up to a quart of water daily, which when multiplied by millions of mussels equates to filtering potentially all of a waterbody in a day. Given that these mussels share food sources with other species, they have the ability to deplete these sources causing a decline in native fish and birds. They also interfere with the feeding and growth of other mollusks and crustaceans by colonizing their shells and bodies (Benson *et al*, 2015).

Quagga mussel (*Dreissena rostriformus*)

The Quagga mussel is also a small (<40mm) freshwater mollusk which has been invading U.S. waters since 1989. First sighted in the Great Lakes near Port Colborne, Lake Eerie, it was not recognized as a distinct species until 1991 (Mills et al, 1996). Indigenous to the Dneiper River drainage of Ukraine and Ponto-Caspian Sea, it was initially identified in 1890 and named in 1897. It is named after the "quagga", an extinct African relative of the zebra (May and Marsden, 1992). By 2007, quagga populations were found in Lake Mead, Lake Havasu, and Lake Mohave.

Figure 165. Quagga Mussels on Rock.
Photo courtesy U.S. Fish & Wildlife Service

By the end of that year and early 2008, infestations were discovered in 15 southern California reservoirs, and veligers (juvenile mussels) were found in six

Colorado reservoirs. Like zebra mussels, quaggas appear to have been spread via ballast water discharge from transoceanic ships.

Mature females can produce up to one million eggs per year with 1-2% reaching adulthood. Similar to zebra mussels, the young quaggas are free swimming, and adult mussels attach themselves to hard surfaces and hard-surfaced creatures uses their byssus. Prodigious water filterers, quaggas remove food sources from the water, greatly impacting the food web. Water filtration by both quaggas and zebras increase water transparency upsetting species dominance and altering ecosystems. As their waste decomposes, oxygen is depleted and pH is decreased resulting in toxic byproducts. They also accumulate toxins in their tissues at levels 300,000 times greater than concentrations usually found in the environment, and pass these up through the food chain (Snyder *et al.*, 1997).

In 2013 & 2014, WLI collected water samples on a number of lakes including Whitefish Lake. The University of Montana Conservation Genetics Laboratory processed and analyzed Environmental DNA samples and found no presence of either zebra or quagga mussels. In addition, microscopy samples sent to FWP found no presence.

Curly leaf pondweed (*Potamogeton crispus*)

Curly leaf pondweed is a hardy, very adaptive submerged invasive aquatic plant that can tolerate extreme conditions including low light and very cold water. It is a perennial plant found in lakes, ponds, and slow moving streams. Native to Eurasia, Africa, and Australia, it was accidentally introduced to United States waters in the mid-1880s by hobbyists who used it as an aquarium plant. Unlike many native aquatic plants, it actively grows throughout the winter. In late spring and early summer, its flower spikes rise above the water surface, then drops fruit and stem pieces (turions) to the bottom of its host waterbody. New plant structures grow rapidly from the turions, creating dense mats of plant matter below the water surface, and shading and suffocating other vegetation. The leaves are reddish-green, oblong, and about 3 inches long, with distinct wavy edges that are finely toothed. (Montana Weed Control Association, 2015). Infestations have been discovered in several isolated patches in Flathead Lake and the Flathead River.

Figure 166. Curly Leaf Pondweed. *Photo Courtesy mtweed.org.*

In 2013 and 2014, Lake County and the Lake County Conservation District—with funding from the Department of Natural Resources and Conservation and HB 223 conservation district grants worked together to address a growing curly leaf pondweed infestation on Flathead Lake. The plants were spreading on at least seven bays and channels on the northern half of the lake, and throughout about 12 miles of the Flathead River upstream from the lake. Diver dredging work to remove the plants required permission from property owners. The Flathead Basin AIS Work Group, Flathead Basin Commission, Flathead Lakers and Lake County collaborated on the project.

Flowering Rush (*Botomus umbellatus*)

Figure 167. Flowering Rush.
Photo courtesy KGW.com

Native to Eurasia, Flowering rush was introduced to the U.S. as an ornamental plant because of its beautiful flowers. It is found in riparian areas, wetlands, lakes, streams, marshes and ditches where it is wet and receives full sun. The perennial plant primarily reproduces through creeping rhizomatous roots and bulblets produced on the rhizomes. It flowers from June through August. The weed infests about eight million acres in Montana (Montana State University, 2010). Flathead Lake has gone from one infestation in 1964 to uncountable numbers over the past 50+ years. It has also spread to the Clark Fork River and downstream to Lake Pend Oreille in Idaho. Researchers from the University of Montana, the Salish Kootenai College, and the Confederated Salish & Kootenai Tribes have joined in a joint management project on Flathead Lake that includes mapping, modeling, hand removal, herbicide applications, and an outreach and education campaign.

Yellow flag iris (*Iris pseudacorus*)

Figure 168. Yellow Flag Iris.
Photo Courtesy Invasive Species Council, British Columbia.

Yellow flag iris is a perennial wetland plant native to Europe, with occurrences in North Africa and the Mediterranean region. It was introduced into the U.S. as an ornamental plant for use in aquariums and ponds, and has been used in water treatment plants and for mining reclamation due to its ability to remove heavy metals from water through its roots. It has a large, beautiful yellow flower similar to other iris species, and is pollinated by insects. The plant continues spreading across the U.S.

infesting stream banks, ponds, wetlands, and marshes. Roots are generally four to eight inches but can extend up to 12 inches, and it reproduces through both root fragmentation and seeds. Seeds are produced between July and October with each plant producing about six pods each. It out-competes native vegetation and negatively impacts wildlife habitat, particularly for ducks, geese, reptiles and small mammals. Its thick growth can obstruct natural water movement and clog irrigation systems (Jacobs et al, 2011). Yellow flag iris has been found at Blanchard Lake and in the Riverside Stormwater Pond.

Fragrant Water Lily (*Nymphaea ordata*)

The fragrant water lily is an aquatic plant with large, radially symmetrical white or pink blooms and heart-shaped glossy green floating leaves with a purple underside. The leafstalk is submerged grows out of large rhizomes which serve as a common food source for muskrats .The flowers range from 3-15 inches wide with several broad, curved petals that narrow toward the center. The center has one pistil that is densely packed with bright yellow stamens.

They are found in still, relatively shallow water (5-7 ft.) in waterbodies such as lakes and ponds with silty beds. It is the most common white water lily. Native to the eastern portion of North America, its commercial popularity has caused its extensive dispersal throughout North America. The plant is now considered a secondary invader that can achieve extraordinary population growth and destabilize ecosystems. A 10x10 patch of nearly 200 pounds of fragrant water lily which had been introduced by a Beaver Lake lease-holder was removed by hand from Beaver Lake in 2013. The plant is also growing extensively in Blanchard Lake (Hanson Environmental, 2013). Additionally plants have been found in the Whitefish River and the Riverside Pond in Riverside Park.

Figure 169. Fragrant Water Lily. *Photo Courtesy ecy.wa.gov*

AIS threats in the Flathead Basin include the fish, amphibians, invertebrates, plants, parasites, and pathogens, and mammals listed in Figure 170.

Species	Priortity Class	Legal Status
FISH		
Asian carp species (bighead, grass, silver, and black)	1	Prohibited
Black bullhead	4	Unclassified
Eurasian ruffe	1	Prohibited
Lake trout	4	Unclassified
Northern snakehead	1	Prohibited
Brook trout	4	Unclassified
Rainbow trout	4	Unclassified
Brown trout	4	Unclassified
Largemouth Bass	4	Unclassified
Walleye	4	Unclassified
Northern pike	4	Unclassified
Pumpkinseed	4	Unclassified
Lake Whitefish	4	Unclassified
Round goby	1	Prohibited
Tench	1	Unclassified
Walking catfish	1	Prohibited
Yellow perch	4	Unclassified
White perch	1	Prohibited
Zander	1	Prohibited
AMPHIBIANS		
African clawed frogs		Prohibited
North American bullfrog		Prohibited
MOLLUSKS		
New Zealand mud snail	1	Prohibited
Quagga mussel	1	Prohibited
Zebra mussel	1	Prohibited
CRUSTACEANS		
Rusty crayfish		Prohibited
PLANTS		
Eurasian watermilfoil	4	
Curley leaf pondweed	4	
Flowering rush	4	
Yellow flag iris	4	
PARASITES AND PATHOGENS		
VHS virus	1	
Whirling disease	2	
MAMMALS		
Nutria	1	Prohibited

Species in ***bold italics*** are found in the study area. **1**:These species are not known to be present within the Flathead Basin, but have a high potential to invade. Limited or no known management strategies for these species exist. Appropriate action for this class includes prevention of introductions and eradication of pioneering populations. **2**: These species are present and established within the Flathead Basin and have the potential to spread further. Limited or no known management strategies for these species exist. These species can be managed through actions that involve mitigation of impact, control of population size, and prevention of dispersal to other waterbodies. **3**: These species are not known to be established in the Flathead Basin and have a high potential for invasion. Appropriate management techniques are available and include prevention of introduction and eradication of pioneering populations. **4**: These species are present and have the potential to spread within the Basin, but management strategies exist for these species and include mitigation of impact, control of population size, and prevention of dispersal to other waterbodies. Classification in Exotic Wildlife Administrative Rules ARM 12.6.2220. From the Statewide ANS Management Plan., as adapted by WLI 2015.

Figure 170. Aquatic Invasive Species in Montana.

2. Introduced Species

There have been numerous non-native species introductions to Montana waters over the years. Some of these introductions were done intentionally by resource managers in an attempt to boost fisheries, and others were done illegally by individuals for a variety of personal reasons (See Chapter XII Whitefish Lake for information on *mysis* shrimp). Today, we recognize that introduced species have the potential to dramatically and irreversibly alter freshwater ecosystems. Introduced species may out-compete native species for food and habitat, carry and spread diseases and parasites to native species, and hybridize (interbreed) with native species, all actions which can alter or destroy fisheries. For these reasons, it is now illegal to intentionally move species from one waterbody to another.

There are several examples of planned species introductions that have disturbed or altered freshwater ecosystems over the past 100 years, including rainbow trout and brook trout, but none has caused a more dramatic shift in the food web than the introduction of *Mysis* shrimp. See the Whitefish Lake and Fisheries chapters for more information.

3. Harmful Algal Blooms

Harmful algal blooms (HABs) are overgrowths of algae in water. Of particular concern are HABs consisting of blue-green algae (cyanobacteria) that have the potential to create microcystin toxins. Microcystin toxins have been known to kill waterfowl, pets and livestock that consume the water and pose a health risk and irritant to swimmers. The toxins produced during blooms are possible carcinogens to humans and current research is studying the link between certain cyanobacterial toxins and neurological disease. Additionally, cyanotoxins can put drinking water utilities at risk or impart a taste or odor unpleasant to the consumer.

HABs also decrease recreational use and aesthetic value of a waterbody from the vast mats of algae and the smell associated with their decomposition. HABs negatively impact the food web by decreasing the amount of nutrients available to phytoplankton preferred by zooplankton. As a result, there are decreased food sources for secondary and tertiary consumers. In addition, the decomposition of the large algal mats leads to decreased dissolved oxygen levels near the benthos.

Related to other phytoplankton, cyanobacteria have a competitive advantage when lake mixing in the epilimnion is weak (i.e. calm and warm days) with ample sunlight. Abundant nutrients are often needed for these blooms to occur, however, some species of cyanobacteria can fix nitrogen from the atmosphere giving them a competitive advantage if nitrogen is limited in supply. Conversely, an increase in nitrogen from atmospheric inputs (see Whitefish Lake Chapter) can create a phosphorus limitation which could preclude the cyanobacteria advantage. In fact, blooms of noxious blue-green algae Anabaena flos-aquae have disappeared in recent years on Flathead Lake as atmospheric nitrogen loading has increased (Ellis *et al.* 2015).

D. PHYSICAL

1. Land and Recreational Use Effects on the Lake

a. Shoreline Development

The nearshore or littoral zone is where the greatest and most visible impacts of human development to the lake are apparent. Like wetlands, natural shorelines act as buffers between lake water and the land surrounding it. Shoreline vegetation filters nutrients and pollutants, reduces erosion, and provides wildlife habitat. Nearshore development can remove much of the natural vegetation, reducing the cleansing and buffering capacity of the shoreline and decreasing habitat. The clearing of land to develop residences and neighborhoods also increases the amount of impervious surfaces which in turn increases surface runoff from precipitation to the lake. Fertilizers used to maintain non-native vegetation such as lawns and gardens also increase the load of nutrients reaching the lake. Lastly, depending on available building sites, many new homes around Whitefish Lake do not have access to the City of Whitefish sewer system, triggering the need for new septic system installations.

Shoreline development that protects water quality therefore requires regulations such as development setbacks and impervious surface limits, as well as thoughtful planning such as minimal disturbance, the use of native vegetation, and the limited application of fertilizers, soil amendments, and pesticides. Where septic systems are required, care should be taken to identify the best type of system for the landtype, slope, proximity to the lake, and size of the household. Once installed, septic systems must be maintained, including regular pumping and inspections.

As noted in Chapter XIV Municipal Water Infrastructure & Treatment, Section C. Wastewater, there are a number of aging septic systems on Whitefish Lake. Septic system issues have been identified, whereas contaminants known as septic leachate are known to be polluting the lake (U.S Environmental Protection Agency, 1977; Flathead County 1981; U.S. Environmental Protection Agency, 1984; Jourdonnais *et al.*, 1986; Craft *et al*, 2003; and Curtis & Koopal, 2012. An effort is underway to begin addressing the septic leachate issue.

b. Boating

Potential hydrodynamic boating impacts to lakes include wake-induced shoreline erosion, and turbulent prop wash and boating activities can potentially impact sediment as deep as 4.6 m (Beachler and Hill, 2003). Boat activity on lakes raise suspended sediment levels and prevents it from settling out, potentially moving the sediment to new locations based on prevailing winds and currents. Re-suspended sediment can increase internal phosphorus loading that drives primary productivity.

The size of boat wakes depends on a boat's size, speed, passenger or cargo load, hull shape, and water depth Some boats are designed to leave a larger wake for certain water sports such as wake boarding and water skiing. In addition to shoreline erosion, the wave activity created by these boats poses safety concerns for other watercraft users (Canadian Coast Guard, 2005). State agencies across the country are expressing concerns and in some cases implementing rules and fines for boat caused erosion.

No Wake Zones

All watercraft operating on public lakes and reservoirs greater than 35 surface acres within the project area are limited to no-wake speed from the shoreline to 200 feet from the shoreline. The exceptions include; personal watercraft which must maintain a minimum operating speed to remain upright and maneuver in the water may travel at that minimum operating speed following the most direct route through the no-wake zone to and from shore; and motorized watercraft towing a skier from or to a dock or the shore, except that watercraft must travel the most direct route through the no-wake zone.

As noted, the no wake zone buffer is important for safety but also for shoreline protection. Large waves produced by watercraft can further erode shoreline areas and deliver sediment to the lake. No wake speeds also reduce impacts from the re-suspension of sediment from prop wash as previously discussed.

Lake Specific Research

Several studies have been conducted to understand boat wake erosion on rivers (Bauer *et al.*, 1992; Cameron & Bauer, 2014; Laderoute, 2013; Mississippi Department of Natural Resources, 2015), however few studies are available regarding boat wake erosion on lakes. In particular, Cameron & Bauer's (2014) extensive research on the Lower Shushap River in North Okanagan revealed strong implications of boating waves damaging riparian zones, making a valuable contribution to resource management strategies.

Long-time Whitefish Lake residents have noticed and reported changes in the shoreline and declines in lake appearance with increased boating activity. It would be beneficial to develop a research project to compare the seasonal shoreline changes for Whitefish Lake and lakes of similar trophic status located in comparable environments that do and do not allow motorized watercraft. Such a comparison may provide scientific evidence to resources managers who regulate boating activities on the lake.

2. Temperature Change

According to the NASA Earth Observatory (http://earthobservatory.nasa.gov) the world is getting warmer. Whether the cause is human activity or natural variability—and the preponderance of evidence says it is humans—thermometer readings all around the world have risen steadily since the beginning of the Industrial Revolution

An ongoing temperature analysis conducted by scientists at NASA's Goddard Institute for Space Studies concluded the average global temperature on Earth has increased by about 0.8° Celsius (1.4° Fahrenheit) since 1880. Two-thirds of the warming has occurred since 1975, at a rate of roughly 0.15-0.20°C per decade.

a. Lake Temperature Regimes

Mean annual air temperature is a variable that can affect a number of lake dynamics. Jankowski *et al.* (2006) suggest that climate change can result in changes in heat balance, temperature profiles, and vertical mixing in lakes, which in turn will affect vertical fluxes of nutrients and dissolved oxygen, and hence the productivity and composition of the lake plankton. Mean annual air temperature is also a variable that affects the number of ice-free days in North American Lakes (Shuter *et al.*, 1983) and could influence the timing of spring blooms and winter minima (Marshall and Peters, 1989).

Whitefish Lake, a lake that typically stratifies in both summer and winter could transition to a new dominate seasonal pattern of a longer and more intense summer thermal stratification season and a cool season consisting of reduced mixing potential throughout the rest of the year. Warmer surface temperatures will increase the depth of the thermocline and the duration of the stratified period which will effectively reduce the amount of available habitat for cold water species. In addition, *mysis* shrimp are known to avoid surface waters above 58°, and during a prolonged stratification period this could once again alter the phytoplankton and zooplankton community assemblages in the epilimnion – a change that was originally precipitated by *mysis* shrimp. A new seasonal pattern could also exacerbate VHOD where a longer period of stratification and a reduction in the frequency and intensity of deep water mixing could result in uninterrupted deep-water oxygen depletion. An intermediate phase may include delayed ice formation and cover duration due to time needed in fall for the large body of water to cool.

Any temperature increase is key to creating conditions in which algae thrive, and when coupled with increased nitrogen and phosphorus loading could create accelerated eutrophication with the potential to counteract long-term measures to ameliorate the effects of anthropogenic eutrophication. Warmer lake surface temperature will lead to a deepening of the epilimnion, reducing available habitat for cold water species in the hypolimnion. Ultimately, there will be an increase in cumulative environmental stressors and disease potential to native species and more favorable conditions for non-native species.

Loss of Ice

Ice typical forms under very cold and windless conditions where wind induced wave action does not lap over and break newly formed primary ice expanding out from the shoreline. It takes until late November or early December for the surface of Whitefish Lake to cool and reach the temperature of maximum depth. At that time, fall overturn can be initiated, where wind energy can vertically mix and evenly distribute dissolved oxygen and nutrients in the lake.

In Whitefish Lake, the typical historical scenario of ice cover during the winter limits algal production. This is primarily due to the snow on top of the ice which prevents sunlight penetration needed for photosynthesis.

As discussed in Chapter XIII Whitefish Lake, there has been a trend towards more ice free conditions in the past 100 years. Should an ice free scenario become the norm for Whitefish Lake, the system could respond with a general increase in algal production, including a shift in community assemblage, with cascading changes to the entire food web. Based on other unique local lake inputs and the complexity of the food web, it’s hard to predict how this will affect specific species and other trophic interactions.

b. <u>Stream Temperature Regimes</u>

Williams *et al.* (2015) suggest that climate change can alter the timing of peak flows- earlier peak flows could result in lower summer flows, altering flow regimes, creating more frequent and intense disturbances, and increasing stream temperature. Changing stream dynamics and affect bull trout and westslope cutthroat trout life history requirements (see fisheries chapter).

3. Railway Transportation

a. <u>Oil and Gas Transportation</u>

In the U.S., the volume of oil transported by rail increased 4,111 percent between 2008 (with 9,500 rail cars) and 2013 (with 380,000 railcars) (Miller, 2014). With an increase in the quantity and volatility of materials transported by rail through Whitefish, citizens, resource managers, first responders, and BNSF are all concerned. Oil transport tankers are a common sight in the Whitefish train yard, with about one trainload of up to 100 cars of crude oil per day passing through downtown Whitefish and along the shores of Whitefish Lake.

Concerns are heightened by the increased production of crude oil from the Bakken area of eastern Montana and western North Dakota and the resulting 40-fold increase in lengthy oil-carrying trains heading from oil fields to refineries. This oil ignites at a lower temperature rendering it more volatile (Peterson & Baldwin, 2014). According to the Association of American Railroads, six out of every ten barrels of Bakken oil is moved to refineries via rail (Miller, 2014). Accidents in 2013 in Alabama, North Dakota, and Quebec involving Bakken crude have left Whitefish residents uneasy.

One of the areas of greatest concern is the roadless north end of Whitefish Lake where, if a spill and/or fire occurred, there would be no immediate access for response crews or firefighters. Flathead County firefighters and first responders trained with BNSF crews in mock rail disasters involving Bakken crude. The rail company provides training to over 3,000 emergency responders annually. The Flathead County Office of Emergency Services noted in 2014 that training with BNSF has built strong relationships across all emergency responders. However, a large incident involving Bakken crude—according to Columbia Falls Fire Chief Rick Hagen— would be disastrous, in spite of the best preparation (Peterson & Baldwin, 2014)

b. Coal Transportation

Trains carrying coal also pose a number of concerns, including noise and vibration, rail track degradation, and health and water quality concerns from coal dust. Coal dust is lost throughout the loading, transportation, and unloading processes. Companies such as BNSF impose strict tenets based on their 2011 Coal Loading Rule in an effort to reduce coal dust (BNSF: Railway Statement, 2014). Studies in the Powder River Basin (PRB) by the company have shown that "coal dust poses a serious threat to the stability of the track structure and the operational integrity of (our) lines in, and close to, the mines in the PRB" (BNSF: Railway Statement, 2014).

Coal dust also poses well-known risks to human health. The mining and transporting of coal results in some coal fracturing into particles smaller than 500 microns which become airborne dust. Particles smaller than 10 microns can be inhaled into the respiratory system as evidenced by the progressive, incurable, and sometimes fatal Coal Worker's Pneumoconiosis (CWP) or Black Lung Disease (Hathaway et al, 1991). Coal dust can also exacerbate asthma and (Chronic Obstructive Pulmonary Disease) COPD, and cause chronic bronchitis (Marine et al, 1988).

With China building one new coal-fired power plant a week, the need for US coal seems endless. It would require unprecedented regional coal movement by rail to feed the proposed Gateway Pacific Terminal. Located in the state of Washington, this multi-commodity handling facility would link Asia's insatiable demand with Montana and Wyoming's supply. The rail corridor would extend from Montana and Wyoming mines through Sandpoint, Idaho to Spokane, Washington; down through the Columbia River Gorge, up the Puget Sound coast passing Longview, Tacoma, Seattle, Edmonds, Everett, Mt. Vernon, Bellingham, and Ferndale (CoalTrainFacts.org, 2015).

In Whitefish, the railroad crosses the Whitefish River and closely parallels Whitefish Lake for approximately six miles. WLI is concerned with direct, indirect and cumulative effects to aquatic ecosystems associated with the deposition on diesel particulate matter and coal dust constituents. In 2012, WLI requested that the US Army Corps of Engineers Northwestern Division consider a comprehensive Programmatic Environmental Impact Statement (PEIS) pursuant to the National Environmental Policy Act to consider impacts from increased coal train traffic. WLI requested that the post consumer effect of coal burning from the Asian market also be examined due to trade wind deposition of mercury and its bio-magnification potential in the food web.

c. Vibration

Trains are also a source of ground-borne vibrations which cause rattling of windows, rumbling sounds, shaking of items in cabinets and on shelves, and the perceptible movement of building floors. Train wheels rolling on their rails create vibration which is transmitted through the track support system which in turn excites the ground creating waves of vibration that move through various soil and rock structures to the foundations of nearby structures (Acoustical Society of America, 1983).

Some Whitefish lakeside homeowners have expressed concerns about whether such vibration is strong enough to harm septic systems or water lines. Finding an answer may be complicated, as there are a number of factors that influence ground-borne vibrations. These include the suspension and condition of each vehicle as well as its speed; the condition of the rail system; the soil conditions and depth to bedrock in the area; and the condition of the receiving structure. A complex engineering study would be required to better understand the effects of railroad propagated vibration on homes, their water delivery and treatment systems, and public infrastructure.

E. CHEMICAL

1. Nutrient loading

Nutrient loading describes the widely accepted concept that the quantity and type of nutrients (such as nitrogen, phosphorus and sulfur) entering a lake directly affects its trophic state. Lake ecosystem responses to those nutrients is also dependent on its physical and geochemical attributes, vegetation, and atmospheric components (Likens & Bormann, 1979). Human activity has increased the levels of nutrients reaching our waterbodies. The two main categories of nutrients are *point source*, such as municipal and industrial waste, and *non-point source* such as agricultural, domestic, and industrial run-off, stormwater, and septic system leaching. The origination of point source nutrients can generally be easily identified and monitored while non-point source pollutants tend to be spread broadly and difficult if impossible to pin-point or monitor.

Phosphorus is a necessary nutrient for plant growth, but it can promote excessive plant growth that favors algae, eventually affecting water quality. Phosphorus is therefore considered a limiting factor for eutrophication in aquatic ecosystems. Since the 1970s phasing out of phosphate-containing detergents, the main sources of phosphates and nitrates tend to come from improperly managed agricultural, domestic, and industrial run-off, and septic and sewer systems. Most of these sources are considered non-point source, although some may be attributed to point sources such as a sewer pipe.

Anthropogenic activity has increased phosphorus cycling on earth by four times, mostly due to the production and application of fertilizers. Between 1950 and 1995, approximately 600,000,000 tons of phosphorus was added to the earth's surface, mainly on croplands (Carpenter et al, 1998). The United Nations Educational, Scientific, and Cultural Organization (UNESCO) reported that there has been a ten-fold increase in nitrogen to some rivers draining industrialized regions of the world (Environmental Literacy Council, 2014).

According to Carpenter et al (1998), nutrient flows to aquatic ecosystems are directly related to excess fertilization and the creation of surplus nitrogen and phosphorus. Because some phosphates adhere to soil, they are transported downstream to water bodies through erosion, and released slowly into the water; and are also volatilized to the atmosphere re-depositing on other land masses and waterbodies. Atmospheric deposition to waterbodies can also travel from great distances.

As described in Chapter V Lake Limnology Primer, Section A Limnology Defined, eutrophication has a number of negative effects in aquatic ecosystems, including increased algae and aquatic weed growth which leads to a decline in water quality for fisheries, recreation, and agriculture. Nitrate pollution also poses threats to drinking water quality for humans and wildlife. High nitrate concentrations in drinking water have been linked in studies to Methemoglobinemia and "blue baby" syndrome (Avery, 1999), hypertension (Malberg *et al*, 1978), central nervous system birth defects (Dorsch *et al*, 1984), certain cancers (Hill *et al*, 1972) non-Hodgkin's lymphoma (Ward *et al*, 1996 & Weisenberger, 1991), and diabetes (Parslow *et al*, 1997). Additional research is needed to further understand these linkages, but concern for nitrate related health risks from sewage outfall remains high. Some high nitrate readings have been recorded in the west Flathead Valley.

Excess sulfur is produced primarily by fossil fuel and metal processing emissions and results in particulate that falls to the earth as acid precipitation. This precipitation can contribute to changing the pH of lakes and streams, creating an environment too acidic for aquatic life. Nitrogen, phosphorus and sulfur loading to waterbodies can significantly decrease water quality as well as plant and animal species diversity.

Under section 303(d) of the Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters. These are waters that are too polluted or otherwise degraded to meet the water quality standards set by states, territories, or authorized tribes. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop *Total Maximum Daily Loads* (TMDLs) for these waters. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards. The "Flathead - Stillwater Planning Area Nutrient, Sediment, and Temperature TMDLs and Water Quality Improvement Plan" was approved by the U.S. EPA in December of 2014. Through this process, Whitefish Lake was delisted for sediment.

Ongoing efforts to quantify and understand nutrient loading continue today. Important factors in reducing or buffering nutrient loading include laws to regulate the quantity of pollutants being added to the environment, increased implementation of sustainable farming and ranching methods, and maintenance and restoration of water cleansing wetlands.

2. Mercury

Mercury (Hg) is a naturally occurring element in the earth's crust that is present in our air, soil, and water. It is found as an elemental metallic, and in inorganic and organic forms. Volcanic eruptions and emissions from the ocean are key natural sources of mercury. Anthropogenic sources include fuels, raw materials, and waste from industrial processes. Because mercury is re-emitted into the environment from land and water, some of the mercury circulating throughout the environment today was released years ago. Exposure to mercury can harm human organs and affect the nervous system. (U.S. Environmental Protection Agency, 2005).

Coal-burning power plants account for 50 percent of all anthropogenic sources of mercury emissions to the air in the United States. Because mercury is present in coal, it is released into the air when coal is burned. The EPA estimates that about one quarter of U.S. coal-burning power plant emissions are deposited within the U.S. with the remainder entering the global cycle; and less than half of all mercury deposition within the U.S. comes from U.S. sources (U.S. Environmental Protection Agency, 2005).

Another common form of human exposure to mercury is consumption of fish or shellfish. Airborne mercury eventually settles directly into waterways or on the land where it can be washed into water. Once it enters a waterbody, microorganisms change it into highly toxic methyl mercury, which then bioaccumulates in fish and shellfish that eat the microorganisms and remains toxic to humans and wildlife that eat the polluted fish.

The Montana Department of Public Health and Human Services (DPHHS) has issued advisories for the consumption of fish from Montana waters based on exposure to mercury; methyl mercury; polychlorinated biphenyls (PCBs); arsenic; cadmium; selenium; and other metals, pesticides and organic compounds. Based on these advisories, Montana Fish, Wildlife & Parks Montana Sport Fish Consumption Guidelines (FWP, 2014) describes both the benefits and dangers of consumption of fish from Montana waters and identifies how safe particular fish are to include in human diets. While fish consumption may contribute good proteins low in saturated fats our diets, it can also expose us to more methyl mercury (causes damage to the nervous system), PCBs (developmental and immune system damage), and other pollutants than the human body can tolerate.

Whitefish Lake guidelines include recommended amounts of lake trout, lake Whitefish, and northern pike for various population segments such as ‘men & women where women are not of childbearing age’ and ‘women (of childbearing age) and children’ (DPHHS, FWP). It is important to know and understand both the benefits and the risks of fish consumption.

Makarowski (2014) analyzed PCB and mercury concentrations in sediment and fish tissue for Whitefish Lake, and in sediment and macroinvertebrates for the Whitefish River for the purpose of characterizing water quality conditions, indentifying “hot spots” and updating Montana’s sport fish consumption guidelines. Compared to 2000, the 2014 fish tissue dataset is more comprehensive (i.e., more species and length categories sampled) and mercury concentrations are generally lower with less stringent fish consumption advisories.

3. Pharmaceuticals and Personal Care Products

Pharmaceuticals and Personal Care Products (PPCPs) is a category of naturally occurring and synthetic compounds found in prescription and over-the-counter drugs for humans and domesticated animals, nutritional supplements, medical diagnostic agents, cosmetics, fragrances, sunscreen, and insect repellent, and other products.

PPCPs enter terrestrial and aquatic environments through a number of direct and indirect means. On a larger scale, they travel through industrial effluent, animal feedlots, wastewater effluent, septic leachate, landfill leachate, and sewer overflows. They get into these environments by natural processes such as humans excreting medications that have not been metabolized into wastewater or septic systems; washing sunscreen and insect repellent into waterways while swimming; and by releasing antibiotic soaps, cosmetics, skin aging solutions, and perfumes into water collections systems when washing or bathing; and by farm animals excreting hormones and antibiotics onto terrestrial environments where they are washed into surface waters and groundwater during precipitation events. Other methods of introduction include improper disposal of PPCPs, such as flushing expired or unused pharmaceuticals down the toilet or pouring them down a sink drain, and through the improper discharge of commercial wastes (Daughton, 2001).

PPCPs have and continue to be detected in U.S. groundwater, streams, rivers, lakes and reservoirs. As an example, over 80% of 139 streams sampled in 30 states by the United States Geological Survey in 2002 showed traces of common medications such as acetaminophen, hormones, blood pressure medicines, codeine, and antibiotics (Kolpin et al, 2002). Although the compounds are typically found in very low concentrations considering potential human health impacts, they have been linked to impacts on aquatic ecosystems, with such results as adverse effects on invertebrates; and changes in fish sex ratios, changes in fish nesting behavior, and the development of female characteristics in male fish (New Hampshire Department of Environmental Services, 2010).

The full scope of the presence of PPCPs and the toxicological significance to humans or terrestrial and aquatic ecosystems is far from understood, and there are a number of differing perspectives on the potential threats to humans and non-humans. However, certain compounds are gaining attention. Antimicrobials pose a number of health hazards, including but not limited to selective pressure for resistance (unabated growth), tolerance (temporary stoppage of growth with continued viability), resistance, which can be permanent, and the potential to alter microbial species diversity (leading to altered successional consequences) (Daughton, 2001). Today, conventional drinking water and wastewater treatment processes may reduce some PPCPs, but they do not remove them from water.

Among the many recommendations made by the EPA National Exposure Research Laboratory (Daughton, 2001) proper disposal of unused PPCPs is one of the easiest first steps in addressing this issue. In February of 2007, the White House Office of National Drug Control Policy issued the first consumer guidelines for the environmentally safe and legal disposal of prescription drugs. This program enables and encourages pharmacies, police departments, and other facilities to collect unused pharmaceuticals. Locally, the Whitefish Police Department, in partnership with the Northwest Drug Task Force and Citizens for a Better Flathead developed the *Waste Not* program through which pharmaceutical products can be disposed of safely at the Whitefish Police Department (Whitefish Police Department, 2015). Additional recommendations include directing further research dollars to studying the effects of PPCPs in the environment; developing “greener” products by minimizing dosages, maximizing biodegradability, controlling stereochemistry; developing guidelines for minimizing dosages; individualizing dosages by body weight and other factors; and public education on individual behaviors and activities regarding drug use and disposal (Daughton, 2001).

4. Polychlorinated Biphenyls (PCBs)

Whitefish Lake and the Whitefish River are on the 303(d) list as impaired for Polychlorinated Biphenyls (PCBs). PCBs are part of a category of human-made chemicals known as chlorinated hydrocarbons. They were manufactured in the US from 1929 through 1979 when they were banned. PCBs were used in numerous commercial and industrial applications including electrical, hydraulics, paint, plastics, rubber, pigments & dyes, and heat transfer. They were popular due to their electrical insulating properties, chemical stability, non-flammability, and high boiling point, but had a variety of toxic consequences when they entered the environment during the manufacturing processes. Although no longer in production, pre-1979 products may contain PCBs (U.S. Environmental Protection Agency, 2013).

PCBS continue to be released into the environment from a variety of sources including leaks from PCB-containing electrical transformers, improper disposal of PCB-containing consumer products into municipal facilities not designed to handle hazardous waste, and from poorly maintained hazardous waste sites. PCBs do not readily break down; therefore they continue cycling between air, soil and water. They can be carried long distances and are found worldwide in areas far from any prior PCB manufacturing sites. They can accumulate in the leaves of food crops and plants, and like mercury, are bioaccumulated in fish that eat PCB-laden microorganisms.

According to the U.S. EPA (2013), PCBs have been demonstrated to cause adverse effects on human and/or animal immune systems, reproductive systems, nervous systems, endocrine systems, and cause cancer. Because Whitefish Lake is listed as “Threatened” with PCBs, it is important to follow recommendations for the consumption of fish from the lake and to continue monitoring the lake for pollutants.

Makarowski (2014) analyzed PCB concentrations in sediment and fish tissue for Whitefish Lake, and in sediment and macroinvertebrates for the Whitefish River for the purpose of characterizing water quality conditions, indentifying “hot spots” and updating Montana’s sport fish consumption guidelines. The study found PCBs in sediment and fish tissue from Whitefish Lake are below detection and give no indication of PCB contamination. The study also found no detectible PCBs in samples collected from tributaries to Whitefish Lake. Therefore, PCBs are not longer indicated as a contaminant in the 2014 consumption advisories for Whitefish Lake.

PCB’s samples collected from the Whitefish River were below detection; however, PCBs have been detected during remedial activities of a State Superfund Site near the BNSF Fueling Facility on the river. PCBs are pending a post-remediation review on the Whitefish River. According to Brumm (2015) the Whitefish River PCB impairment resolution options include; a de-listing only if monitoring shows the river currently meeting water quality standards, develop a TMDL, or other pollution control requirements such as Category 4b listing which expects to attain all water quality standards within a reasonable period of time (i.e. the source of the pollutant is known and remedial activities have mitigated the problem).

5. Benzyne, toluene, ethylbenzene and xylene (BTEX)

Benzyne, toluene, ethylbenzene and xylene (BTEX) are volatile organic compounds (VOCs) known for their potential to cause numerous human and ecosystem health problems. VOCs change easily from liquid to gas (vapor), therefore they travel airborne into soils and waterbodies. While short-term exposure can cause central nervous system issues such as dizziness, exhaustion, and loss of coordination, as well as respiratory issues, long-term exposure can affect the kidneys, liver, and blood systems and lead to leukemia and various cancers.

Benzyne is found in petroleum products such as gasoline, as well as many common household products such as paints, dyes, resins, furniture polish, detergents, insecticides, and cosmetics. It is also found in cigarette smoke, adding to the dangers of smoking and exposure to second hand smoke. Toluene is found in petroleum products, paint solvents, gums, oils, and resins. Ethylbenzene is mostly used as an additive to gasoline and aviation fuel, but may be present in some paints, inks, and pesticides. Xylene is found in gasoline and is used as a solvent in the printing industry (Agency for Toxic Substances and Disease Registry, 2015).

BTEX exposure can occur by ingestion (drinking contaminated water), inhalation (breathing contaminated air), or absorption of polluted air or water through the skin. Because BTEX has been associated with watercraft use on Whitefish Lake (Koopal, 2007), it remains a concern as the lake receives increasing pressure by motorized watercraft. A mitigation device at the City Beach boat ramp will capture and remove contaminants from transom plug water, but there remains the possibility of contamination from fuel spillover and emissions from watercraft operating on the lake.

6. Perchlorates

One of Whitefish's popular events is Independence Day—Fourth of July Fireworks on Whitefish Lake. Unfortunately, along with the celebration of our independence that has become ubiquitous with freedom, standard fireworks often bring carcinogens and hormone-disrupting substances to our waterways. Fireworks cause pollution in a multitude of ways from manufacturing and transportation to air, water, and noise pollution. One of the greatest concerns related to water quality is the use in fireworks of *perchlorates*, a highly water soluble propellant that can affect the functioning of the metabolism-regulating thyroid gland. The Center for Disease Control warns that perchlorate exposure can result in thyroid damage and hinder brain development in infants. EPA studies have shown that perchlorates are found in waterbodies and water supply wells near fireworks displays and that perchlorate levels rise up to 1,000 times from pre-fireworks measurements and can take months to dissipate. (Wilkin, 2007)

The good news is that there are safer alternatives to perchlorate for fireworks. The Walt Disney Company—although not usually known for pioneering environmental causes—in 2004 pioneered a new technology for using compressed air instead of perchlorate-containing gunpowder to launch fireworks, eliminating the need for gunpowder. The company made its patent details available to the pyrotechnics industry in the hopes of having a beneficial impact on the industry at large. The safer fireworks are at face value almost two times the cost of conventional fireworks. However, pollution cleanup and affects on human health dramatically increase the cost of standard fireworks, making the alternatives far more attractive (Halford, 2008).

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XVII. KEY RESOURCE FINDINGS AND DISCUSSION

A. INTRODUCTION

Few ecological studies are long-term enough to show trends; although where available, they have increased our understanding of natural dynamics and proven beneficial across multiple disciplines. Whereas data for the aquatic resources contained in this report may seem to provide a long-term analysis, most of the data actually represents a short-term view. Of the longer term data that does exist, most is limited in sample frequency, and the methodologies employed to collect and analyze the data have periodically changed. Careful consideration must be given to acceptance of false hypotheses due to complexities associated with inter-annual and intra-annual variation from the limited dataset.

Due to the constant flux in physical, chemical and biological components of aquatic ecosystems, there is often difficulty in determining cause and effect relationships. This flux is compounded by source loading types. The Whitefish Wastewater Treatment Plant effluent represents the only point source in the geographic scope of this study while all other sources are non-point. Since non-point sources are often diffuse in their impact, a direct cause and effect relationship is hard to develop.

As a result of limited datasets and non-point source loading types, the analysis of only one or a few independent variables is often ineffective to evaluate the overall health of a lake or stream. As a result, a multivariate analysis is often employed to determine a weight of evidence (WOE) to best describe the health and trends of a resource based on the available information.

WOE is used to characterize a process or method in which all scientific evidence relevant to the status of a causal hypothesis is taken into account. To be effective, the WOE needs to provide a transparent mechanism to address inconsistencies between different pieces of evidence and to articulate uncertainties that reflect the varied types and quality of available information. Ultimately a WOE approach can make risk assessment and risk management recommendations more consistent and effective. It is under this WOE approach that the following *Key Summary Findings* have been developed.

B. WHITEFISH LAKE TIMELINE (KEY PERIODS)

Historic Whitefish Lake conditions were undoubtedly pristine with a stable food web subject only to natural events (fires and floods). Since European settlement, baseline lake conditions have been punctuated by anthropogenic activities, including; construction of the railroad, timber harvest and associated road construction, shoreline development, and other land use pressures.

Starting roughly 100 years ago, representing approximately 1% of the lake’s history, various fish species were introduced to the lake, either stocked based on management objectives or illegally planted by private citizens. In total, these introductions have caused major repercussions to the food web and contributed to the plight of native species. During the last 100 years, the food web has been in constant flux as introduced fish species compete for niches leaving some species flourishing and others extirpated or at high risk for extirpation.

Even with land use pressures and the introduction of non-native species, the lake shows evidence of developing quasi-stable states after each disruption, showing evidence that the water quality of the lake can rebound. In the lake's favor are its flushing rate, low nutrient geology, a forested upper watershed, and a relatively low human population in the watershed. However, each time an anthropogenic activity contributes to the cumulative stress to the lake, it could lose its ability to buffer future impacts. Whitefish Lake shows evidence of nearing a tipping point, or a trophic state transition where the outcome is negative to the lake and the local community. Listed below are distinct time periods that provide a closer look at events that have shaped the lake's history.

Pre-European Period (Pre 1880)

The *Pre-European Period* for Whitefish Lake represents pristine water quality and a watershed with a high capacity to buffer natural events like flood and fire. During this time period, there was a well defined native fish species community assemblage without niche competition. The highest magnitude flood event in recorded history for the Whitefish area occurred in 1894 but there was little increased sedimentation in the lake suggesting an intact watershed.

Stumptown Period (1880 - 1940)

The *Stumptown Period* represents the initial development of the area and of early Whitefish (Stumptown). The initial development includes the construction of the railroad along the west shore of the lake (1901-1904), the initial harvest and associated road building with stream crossings in the Lazy Creek and Swift Creek drainages, and timber harvest of the shoreline area. Real estate development began around the lake, leading to public infrastructure extension. Multiple non-native fish species introductions took place over this period, most notably lake whitefish in 1915. The most severe fire disturbances to the area occurred in 1910, 1919 and 1926. It is important to note that fire activity post 1926 is rare suggesting aggressive fire suppression management. The sedimentation rate to Whitefish Lake in the 1930s was the highest on record.

Ski Town Period (1941 - 1967)

Development expanded around Whitefish Lake and in Whitefish during the *Ski Town Period*. The community started the slow transition from a railroad and timber economy to a tourism economy as the Big Mountain Ski Resort (now Whitefish Mountain Resort) was established in 1947 and grew. Two notable fish introductions occurred during the time period including lake trout (1941) and kokanee salmon (1945). Lake trout, an adult piscivore, began niche competition with native bull trout but remained at relatively low densities. Kokanee salmon began niche competition with native peamouth chub and westslope cutthroat trout, and became the most popular sport fishery in the history of Whitefish Lake. The third highest magnitude flood event in recorded history for the Whitefish area occurred in 1964.

Mysis Explosion Period (1968 - 1980)

The *Mysis Explosion Period* represents the timing for the most deleterious non-native species introduction to Whitefish Lake. Spencer et al., (1991) described the most deterministic event in the legacy of Flathead Lake and indeed the Flathead Basin as the introduction and establishment of *Mysis* shrimp (*Mysis diluviana*). Introduced to Whitefish Lake in 1968 with peak numbers estimated to have occurred from 1973-1976, *Mysis* shrimp have profoundly impacted the lake's food web and nutrient cycling. Lake whitefish and lake trout— introduced deep water species—benefited from the increased forage base that *Mysis* provided. Northern Pike were introduced to Whitefish Lake in the early 1970s with peak levels thought to have occurred around 1980.

During this time period, the lake was thrust into its most chaotic food web transition. There was also a "*Mysis* bump" observed in primary production between 1983 and 2002 resulting in the way nutrients are cycled in the lake, possible leading to co-limitation of nutrients (phosphorus and nitrogen). The second highest magnitude flood event in recorded history for the Whitefish area occurred in 1974. This period represents the first regulatory action designed to protect the lake with the passage of the Whitefish Lakeshore Protection Act of 1975. Also in 1975, the first cursory limnological study of Whitefish Lake took place by the EPA (1977).

Forestry Period (1981-2000)

A number of regulatory actions during the *Forestry Period* heightened protection and cultural awareness of water quality issues. The Flathead County Phosphate ban occurred in 1983. The Forestry Best Management Practices (BMP) Notification Law became part of the Protection of Forest Resources law in 1989. The Montana Streamside Management Law took effect in 1991. In 1996, DNRC began implementation of a Biodiversity Strategy to emulate natural fire disturbance regimes in the Stillwater State Forest through management actions.

However, there was a high amount of timber harvest activity in the watershed (either as first cut or second cut), second only to the 1930s. Even with SMZ and BMP protection tools in place, delay on the ground could have occurred. DEQ (2006) concluded that reasonable land, soil, and water conservation are not always accomplished by using BMPs. BMP's are land management practices that provide a degree of protection for water quality, but they may not be sufficient to achieve compliance with water quality standards and protect beneficial uses. Therefore, reasonable land, soil, and water conservation practices generally include BMPs, but additional measures may be required to achieve compliance with water quality standards and restore beneficial uses.

Key streams (Lazy Creek and Swift Creek) displayed higher chemical and sediment concentrations conveyed to Whitefish Lake, and bull trout spawning site conditions showed more fine sediment. During this time period there was also increased shoreline development and an ever increasing pressure by recreational users on the lake. During the *Forestry Period*, it is clear that niche competition among fish species as a result of *Mysis* shrimp had transitioned to favor lake whitefish and lake trout at the expense of native bull trout and westslope cutthroat trout. The first comprehensive study of Whitefish Lake occurred in 1982-1983 by Golnar (1986). In 1996 and 1997 there were above average stream flows with streambed scouring capacity.

Protection Period (2001 - Current)

Beginning in the *Protection Period*, forest harvest activities slowed and chemical concentration levels in streams decreased. Except for 2011 and 2012, there has not been a high flushing flow event to scour stream channels and deliver pulse loads to Whitefish Lake. Lake trout have become the dominant fish species in the lake (60% of sinking gill net catch). Native bull trout and westslope cutthroat trout populations appear to have stabilized and even slightly increased from gill net and bull trout redd information. However, overall population densities remain very low (see Indicator Species).

Perhaps the most noteworthy activity of this time period is the expansion of research, management, and regulatory measures to protect water quality. In 2000, Plum Creek's Habitat Conservation Plan (HCP) was completed. Habitat Conservation Plans are long-term plans authorized under the federal Endangered Species Act (ESA) for private landowners to conduct activities that have the potential to impact threatened or endangered species, such as bull trout, in exchange for mitigation and conservation measures. DNRC followed with a HCP in 2011. The HCPs effectively build upon SMZs and BMPs with additional layers of protection such as increased buffer zones and specific road building requirements.

In 2004, The Whitefish Area Trust Lands Neighborhood Plan was approved for the 13,000-plus acres of State Trust Land surrounding the City of Whitefish and defined future land uses for Trust Lands that support clean water, quality wildlife habitat, viewshed protection, and high quality public recreation access.

Craft et al., (2003) provided a follow up examination and comparison of water quality to Golnar's (1986) work and showed evidence of cultural eutrophication. Founded in 2005, the Whitefish Lake Institute began baseline monitoring of the lake and tributaries in 2007 while finding additional annual funding for the Flathead Lake Biological Station to continue their research on the lake. In addition, WLI completed reports equally focused on ecosystem health and public health, looking at gasoline constituent loading Koopal (2006) and an investigation of septic leachate to the lake, Curtis & Koopal (2012).

The City of Whitefish passed the Critical Areas Ordinance (2008) which was later abbreviated to become the Whitefish Water Quality Protection Ordinance (2012). In 2014, based on a Montana Supreme Court ruling the City of Whitefish lost to Flathead County control of the extra-jurisdictional area. The implications to lakeshore protection regulations and zoning are yet to be determined. In 2015, the voters of Whitefish approved a 1% Resort Tax increase to fund a conservation easement facilitated by the Trust for Public Land for Haskill Basin, and a large conservation easement proposal was introduced for Plum Creek land in the Lazy and Swift Creek drainages.

C. INDICATOR SPECIES

Native bull trout and westslope cutthroat trout are important barometers to aquatic health because of their long evolutionary history in the area, and their survival and adaptation through natural disturbance regimes. Due to declining bull trout numbers and range, the Montana Bull Trout Scientific Group (1995) identified goals to maintain or restore self-sustaining populations in core areas, protect the integrity of the population's genetic structure, and enhance the migratory component of the population. Specifically, the group called for long-term stable or increasing trend in overall populations; and provide for spawning in all core areas.

The Whitefish Lake bull trout population is considered to be nodal and disjunct from the greater Flathead bull trout meta-population. Most likely, the Whitefish River serves as a connectivity barrier as a result of higher temperatures and undesirable habitat conditions found there.

Native bull trout and westslope cutthroat trout populations in Whitefish Lake and tributary streams have declined through the years as a result of non-native species introductions as discussed in the Chapter XII Whitefish Lake: Fisheries. Bull trout spawning site conditions as determined by most McNeil Cores and Substrate Scores show an encouraging trend in recent years. Redd count data, a surrogate for actual population surveys, also shows an encouraging recent trend.

However, it is very important to note that the Whitefish Lake bull trout population as represented in Swift Creek, and the West Fork of Swift Creek redd count data show a perilously low population level for this disjunct population. Bull trout are at a high level risk for extirpation in the watershed. Ellis et al., (2011) indicated that in Flathead Lake, extirpation of some of the native fishes (bull trout and westslope cutthroat trout) in the near future seems possible and recovery of these populations will be difficult given strong food web control by the expansive lake trout population.

Land use practices utilizing traditional tools like SMZs, BMPs, to protect native species may not provide the requisite layer of protection given the high level of risk to these species. The advent of the Plum Creek and DNRC HCPs will provide more protection for sensitive species and hopefully stabilize runoff patterns and decrease soil erosion and nutrient leakage from the watershed.

D. STREAMS AND RIVERS OF THE PROJECT AREA

The following summary consists of key points for select streams in the project area. Additional information for these streams and others in the project area can be found in Chapter X Whitefish Lake Tributaries and XI Whitefish River Drainange.

East Fork of Swift Creek

The East Fork of Swift Creek McNeil Cores and Substrate Scores show lower value bull trout spawning site conditions in the 1990s with site improvement seen in the 2000s. The East Fork serves as a migratory barrier above and below Upper Whitefish Lake due to dry channel segments during base flows. Upper Whitefish Lake likely serves as a nutrient sink for the stream.

West Fork of Swift Creek

The West Fork of Swift Creek had slightly elevated TSS values in the 1990s. Since the 1990s, McNeil Cores, Substate Scores, bull trout redds, and macroinvertebrate data suggest that stream conditions are improving. This stream and its tributaries (Herrig, Johnson, and Stryker Creeks) have the highest fisheries resource value for adfluvial bull trout and resident westslope cutthroat trout.

Swift Creek

Swift Creek is the pulse of Whitefish Lake. In geological terms, this stream is very young and still undergoing post-glaciation adjustment with numerous natural mass wasting banks. This stream contributes most of the water volume and nutrient budget to Whitefish Lake. Swift Creek shows elevated nutrient and TSS concentrations in the 1990s. During the 1990s, Landsat imagery shows a higher density and overall acreage contained in timber harvest on both Plum Creek and State Trust Land located primarily downstream of the unnamed tributary just upstream of Gill Creek.

It is not exactly known if the increase in timber harvest activity and/or perhaps an increased erosion rate from the Swift Creek mass wasting banks led to the higher chemical concentrations. Other variables can be ruled out such as nutrient loading from fires since no significant activity was recorded for the area in the 1990s. In addition, whereas there were higher than average peak stream flows in 1996 and 1997 that certainly scoured the channel, the peak flows observed in 2011 and 2012 were higher with lower Total Suspended Solids and Total Phosphorus concentrations. It’s interesting to note that the third highest peak flow for the decade occurred in 1991 but delivered many of the higher Total Suspended Solids and Total Phosphorus concentration values for the decade. It’s likely that accumulated stream channel material was scoured from the lower gradient reaches of the stream that year.

If the theory that the mass wasting banks in the lower 10 miles of the stream led to the increased nutrient loads in the 1990s is more closely examined, it seems unlikely. The only plausible theory that the mass wasting banks contributed an inordinate amount of sediment to the stream channel in the 1990s would have been from high rainfall that could have infiltrated the slopes and caused piping through the less cohesive bank strata layers leading to failure of upslope material. The Western Regional Climate Center shows that 1993 had the highest mean summer rainfall from 1948-2006. However, chemical concentrations that year and following years do not support this theory.

Of the mass wasting sites in 1984 that were re-surveyed in 2001, 34 of the 47 banks (72%) had a larger surface area in 1984 than 2001. This suggests healing over time, at least along the borders of these slopes, but increased mass wasting from the central zones of the banks during the time period still cannot be ruled out. There is, however, no mass wasting in Lazy Creek where extensive timber harvest occurred during the decade and the same increased nutrients concentrations were documented.

Various other studies have shown a parallel of forest activity and increased nutrient loads.
According to Ellis et al. (1999), an analysis of the Flathead National Forest water quality monitoring sites in 1997 indicated that as the road miles per acre increased in the catchments, total phosphorus and particulate carbon concentrations in the monitored streams increased proportionately. The data also indicated that as the percent harvest increased, nitrate plus nitrite nitrogen concentration in these streams increased proportionately. Rieman and Clayton (1997) state that disturbance by fire, harvest activities, and road construction invariably results in greater erosion and sediment production; however, the severity and longevity of increase is highly dependent on site properties and the type of disturbance.

Since 2000, McNeil Cores, Substrate Scores and bull trout redds show stream conditions are improving. The fisheries habitat survey indicated that the toes of many of the mass wasting slopes were becoming vegetated and could provide increased streambank stabilization for typical bankfull flows.

Very close scrutiny needs to be applied to any land management activities near any waterbody upstream of the Chicken Creek confluence on Swift Creek and how it may impact bull trout habitat. Whereas the mass wasting banks are a natural phenomenon, management activities need to avoid increasing water yield as this can increase stream volume and sheer stress at, and just above bankfull elevations, leading to sediment and nutrient loading to Whitefish Lake. Conversely, management should consider habitat augmentation projects that provide increased resting cover for spawning fish, young of the year, and juvenile fish. The habitat surveys for Swift Creek and the West Fork of Swift Creek documented long, homogenous habitat units without much in-stream large woody debris habitat.

Lazy Creek
Lazy Creek drains 13% of the Whitefish Lake Watershed. Timber harvest first occurred in the 1930s serviced by a railroad spur. Landsat imagery shows that nearly all of the timber in the drainage on Plum Creek land received a second harvest in the 1990s and possibly into the early 2000s. As a result, there was an increase in TSS and nutrient concentrations. Lazy Creek also contributes a high amount of Total Organic Carbon to Whitefish Lake based on the slow meandering nature of this stream and the wetlands found in the lower reach.

However, it appears that the organic carbon is not labile. The organic carbon concentrations may have a localized effect to Lazy Bay dissolved oxygen concentrations but the loading does not appear to significantly affect the Whitefish Lake pelagic zone.

Hellroaring Creek
In 2006, private land clearing resulted in erosion and sediment loading to Whitefish Lake during heavy rain events. The sediment delivery to the lake caused a deltaic shelf at the mouth of the stream which has been colonized by macrophytes. Overall, this stream is characterized by cold temperatures, low nutrient levels, and a steep gradient which could provide native fisheries a competitive advantage. A fisheries survey is needed for this stream to determine if a genetically pure strain westslope cutthroat trout population exists especially as fish migration barriers are suspected to prevent the movement of non-native species.

Beaver Creek
Beaver Creek originates from Beaver Lake either as surface or hyporheic flow and is conveyed to a small reservoir next to the BNSF railroad grade. From the reservoir the stream is conveyed via a culvert to a small free flowing stream reach right before the confluence with Whitefish Lake. WLI began collecting water quality information on this stream in 2013 in the short stream segment near the lake. Total Nitrogen concentrations are above the Montana Wadeable Streams and Rivers Nutrient Criteria. Additional data points are needed to provide the requisite dataset to determine if this stream warrants 303(d) listing. Macroinvertebrate data show this stream as severely impaired. The high nitrogen concentrations need to be investigated. No noticeable stream channel alteration has been observed between Beaver Lake and the reservoir. It could be that the Beaver Lake and reservoir nitrogen outputs are the cause. Longitudinal synoptic sampling is recommended to provide additional information. Beaver Creek is also relatively high in Total Organic Carbon loading, most likely the result of wetland influence near the impoundment.

Viking Creek
The lower reach of Viking Creek flows through the Battin Nature Conservancy Easement and the Averill's Viking Creek Wetland Preserve owned and managed by WLI. The stream flow is artificially augmented from Whitefish Water Treatment Plant overflow. The stream is also affected by water discharged from a holding pond to meet NPDES permit standards for water used to backflush disinfecting cartridge equipment. As a result, the normal hydrograph for this stream which would show peak runoff in mid to late April is delayed until late May/early June. In addition, the treated backflush water is conveyed to Viking Creek as a pulse leading to high TSS and phosphorus concentrations displayed out of the peak hydrograph window. The macroinvertebrate community data shows this stream as moderately impaired. A comprehensive Whitefish Water Treatment Plant Management Plan is needed to improve water use efficiencies at the plant and to provide maximum ecological

benefit to Viking Creek and Haskill Creek. (See the discussion on Haskill Creek below).

Upper Whitefish River

The portion of the upper Whitefish River examined by this report extends from the Whitefish Lake outlet to the Highway 40 Bridge. The Whitefish River is 303(d) listed for temperature, and the upper reach displays summertime temperatures stressful to salmonids. The hydraulic grade control at the outlet of Whitefish Lake buffers water delivery and the low gradient makes for a slow moving, reduced energy river with limited lateral movement. Additionally, the baseline nutrient concentrations in the Whitefish River are set by export from Whitefish Lake. WLI's monitoring site on the Whitefish River is near the outlet of the lake. Downstream of the site, stormwater conveyances and the Whitefish Wastewater Treatment Plant effluent add to nutrient and pollutant loading. A comprehensive stormwater management plan is needed and the City of Whitefish is currently working on upgrade plans at the wastewater treatment plant. The macroinvertebrate analysis classified this stream as moderately impaired.

Cow Creek

Cow Creek is in definite need of restoration to improve water quality. WLI began collecting water quality information on this stream in 2014. All Total Phosphorus and Total Nitrogen values exceed the Montana Wadeable Streams and Rivers Nutrient Criteria. Cow Creek has experienced channel modification and continues to receive livestock grazing in specific reaches. In addition, there are multiple stormwater outlets to the stream. The macroinvertebrate analysis classified this stream as severely impaired.

Haskill Creek

Second Creek and Third Creek, upper watershed tributaries to Haskill Creek are currently the primary source of municipal water for the City of Whitefish. Municipal water demands often exceed natural stream flow during summer months resulting in stream dewatering. Haskill Creek supports a near 100% pure strain westslope cutthroat trout population. Recently, restoration projects on the lower reach of this stream have reduced sediment and nutrient loading to the upper Whitefish River. A comprehensive Whitefish Water Treatment Plant Management Plan is needed to improve water use efficiencies at the plant and to provide maximum ecological benefit to Viking Creek and Haskill Creek. (See the discussion on Viking Creek above).

Walker Creek

Walker Creek Total Phosphorus and Total Nitrogen values hover at the Montana Wadeable Streams and Rivers Concentration threshold. Livestock grazing near the Dillon Road Crossing could contribute to the problem and off-stream watering with fencing could benefit the stream. The macroinvertebrate analysis classified this stream as moderately impaired.

E. WHITEFISH LAKE

Whitefish Lake is a geographic cornerstone to the Whitefish community offering lifestyle amenities, municipal drinking water, and economic benefits. Whitefish Lake is an A-1 listed waterbody, meaning it receives the highest level of protection currently afforded a state waterbody. A-1 beneficial uses include the most sensitive water applications (i.e. drinking water after conventional treatment, swimming/recreation, and growth and propagation of salmonid fishes and associated aquatic life). In 1975, the EPA (1977) ranked Whitefish Lake first in overall trophic quality when compared to 15 Montana lakes and reservoirs sampled during the National Eutrophication Survey.

Previous studies (EPA, 1975; Golnar, 1983; Craft et al., 2003) have demonstrated Whitefish Lake's baseline water quality condition and response, and that its trophic state is changing based on cultural eutrophication. Special investigations (Jourdonnais et al., 1986; Koopal, 2006; Curtis & Koopal, 2012) highlight septic leachate pollution in Whitefish Lake, and that a large proportion of current septic systems have reached their lifespan, and that gasoline constituent loading can affect public health at specific locations.

Whitefish Lake occupies 3.3% of its drainage basin. The lake is medium sized lake with a medium flushing rate (mean hydraulic retention time=2.57 years). There is a large percentage of the lake found within the photic zone (67.6%). The lake displays rather uniform annual patterns for physical parameters like temperature, pH, oxidation reduction potential and conductivity but date show that high flow events like 2011 and 2012 can create a punctuated disturbance in these parameters before they approximate pre-disturbance values.

Whitefish Lake is dominated by snowmelt runoff from the Swift Creek drainage. In 2014, Swift Creek conveyed 80% of the water volume to the lake followed by Lazy Creek and direct precipitation at 7%, Hellroaring Creek 2.9%, Smith Creek 1.5%, Viking Creek 0.9% and Beaver Creek 0.5%. Groundwater is not considered a significant volume contributor but may play an influential role in nutrient loading at select shoreline locations.

Swift Creek contributes approximately 70% of both the Total Phosphorus load and Total Nitrogen load to Whitefish Lake. Lazy Creek and direct precipitation adds 10-15% each and the remainder comes from smaller tributaries. The lake serves as a significant sink for nutrients effectively tied up in the benthic sediments due to a strong chemical gradient. The significance of septic pollution to the lake's nutrient load remains unclear as primary producers in the littoral zone most likely rapidly assimilate the nutrients. Anecdotal accounts articulate that the lake's shoreline rocks have transitioned from clean and crisp in appearance to a dusky green/grey, indication that sediment and nutrient loading are supporting periphyton growth.

In general, the long-term pelagic monitoring sites on Whitefish Lake show co-limitation of nutrients (phosphorus and nitrogen) but phosphorus limitation is common after the spring freshet. The three sample locations show spatial and temporal variance along a longitudinal gradient. At Site IP-1 near the headwaters area of Swift and Lazy Creek, the data indicates fluvial entrainment of sediment and phosphorus with phosphorus limitation starting around early July. At the Mid-lake site, it appears that fluvial entrained sediment and phosphorus has either precipitated to the lake bottom or has been utilized by primary producers as this site shows a phosphorus limitation earlier in June. At Site IP-2, near the lake outlet, it's clear that between nutrient sink and uptake by primary producers, this area of the lake is phosphorus limited most of the year.

Based on the limiting nutrient information, the part of the lake with the highest potential to react to an increase in phosphorus loading from anthropogenic sources is the southeast portion of the lake. This is the shoreline area with the highest development. Any additional phosphorus input from anthropogenic activities such as septic leachate, fertilizer runoff, and shoreline erosion will artificially drive primary production to the detriment of the lake's health. Another phosphorus loading concern for the lake is from land use management or large local forest fires, especially in fall where additional phosphorus inputs would drive primary productivity which is typically low at that time of year.

Data show evidence that Whitefish Lake has undergone nutrient enrichment—undesirable for an historic oligotrophic lake like Whitefish Lake—since the early 1980s. The primary producer community indicates a decline in water quality from 1983 to 2003 when viewed from multiple parameters. Net primary productivity was significantly lower in 1982 and 1983 and roughly doubled in 2002. It is highly likely that the effect from the introduction and establishment of *Mysis* shrimp created a step increase in primary production where a new dynamic equilibrium was reached. From 2002 to 2014 no trend is apparent in primary productivity.

The phytoplankton community in Whitefish Lake was much more dynamic in 1982-1983 (more specific dominant groups) than in 2002-2003 where co-dominance was found throughout the year (Craft et al. 2003). Phytoplankton mean annual total biomass increased from $0.20cm^3m^{-3}$ in water year 1983 to $0.33cm^3m^{-3}$ in water year 2002 but was still below the $1cm^3m^{-3}$ threshold that indicates a switch from oligotrophic to mesotrophic conditions. An increasing trend in algal biomass suggests that water quality had declined in 2002 as researchers had a robust time series dataset showing a clear transition over time. Biomass of primary producers can also be expressed by the content of chlorophyll (*a*) in the lake water. Data for Whitefish Lake shows the values for the 2003 study stayed about the same 0.8 to 1.0 mg/L^{-1} for the period of record, but that the maximum concentrations had risen rather dramatically from about 1.0 to 1.8 mg/L^{-1}.

The role of the lake's internal nutrient budget and cycling is not clearly understood. It could be that inorganic phosphorus entrained in fluvial input is in excess of primary producer requirements of that year and therefore sinks. It could then be redistributed in the water column during spring or fall turnover where inorganic factions would be available for primary production. Primary productivity may be more influenced by the nutrient budget set by the lake after spring circulation and lowland runoff rather than peak runoff that delivers a high allochthonous load of sediment and nutrients, but turbid conditions could limit light penetration and chlorophyll (*a*) production.

As a surrogate measurement of primary production, benthic dissolved oxygen shows lower than expected concentrations for a classic oligotrophic lake where typical 90-100% oxygen saturation values are shown throughout the water column. In addition, the rate of oxygen consumption as displayed by volumetric hypolimnetic oxygen demand has increased in recent years. Collectively these two indicators also suggest that Whitefish Lake is undergoing nutrient enrichment leading to higher primary productivity.

It has long been recognized that excessive phosphorus loading is directly linked to cultural eutrophication (Vollenweider, 1982). The EPA (1977) calculated the phosphorus loading of Whitefish Lake at 0.43 $g/m^2/yr$ and compared that value to those proposed by Vollenweider and Dillon (1974). The EPA concluded that any significant increase in the phosphorus loading would result in a noticeable degradation of water quality and every effort should be made to limit phosphorus inputs to the lake.

Research by Golnar (1986) found Whitefish Lake falls near a critical threshold of phosphorus loading. Their research concluded that based on the application to the Vollenweider & Kerekes model, "…the lake is in danger of serious eutrophication problems (e.g. excessive algal blooms), if total phosphorus inputs increase in the future.

When the Vollenweider (1975) loading plot as adapted by Chapra (2013) is populated with loading data from 1983, 2002 and 2014, it shows the lake teetering at a critical threshold of trophic transition from oligotrophic to mesotrophic conditions corroborating aforementioned warnings. Other indicators from the primary producer community and dissolved oxygen levels echo this conclusion. A transition to mesotrophy can occur with a modest increase in phosphorus. Typical mesotrophic conditions caused by nutrient enrichment would among others; increase algal production, decrease water clarity, decrease dissolved oxygen levels impacting aquatic species, potentially alter the food web yet again, and create conditions that may be more favorable for aquatic invasive species.

The fact that a number of research parameters indicate that Whitefish Lake is at a tipping point in trophic transition provides merit for continued progression in management strategies, research and community involvement. As previously mentioned, Whitefish Lake has the ability to rebound after punctuated events but a new and higher internal nutrient budget is set. Cumulative impacts may reduce the lake's ability to recover as effectively in the future. Out of our control are variables like meterological conditions and atmospheric nutrient loading. However, there are things in our control to mitigate anthropogenic sources and they are outlined in Chapter XVIII Watershed Protection Plan.

F. OTHER PROJECT AREA LAKES

Blanchard Lake

Blanchard Lake is hydrologically closed and subject to groundwater levels. Nutrient concentrations rank relatively high for similar sized lakes in northwest Montana and assimilation is controlled by the macrophyte community. Invasive fragrant water lily, an ornamental has been illegally planted in the lake and is found at multiple locations.

The highest recreational use for this lake is as a warm-water fishery. Consideration should be given to a motorized horse power restriction operation or a no-wake speed. Montana law states that watercraft operating on public lakes and reservoirs greater than 35 surface acres within the western fishing district are limited to no-wake speed from the shoreline to 200 feet from the shoreline. All watercraft operating on public lakes and reservoirs in the western fishing district that are 35 acres or fewer of surface water are limited to a no-wake speed. Blanchard Lake is 143 acres but the morphology of the lake is long and narrow, effectively limiting the area in which larger horsepower watercraft can operate. Shoreline erosion caused by waves can contribute more nutrients to the lake.

Beaver Lake

Beaver Lake shows a trend toward eutrophication and ranks high in nutrients compared to other northwest Montana lakes of similar size. Nearby Dollar Lake also shows high nutrient levels which could be based on unique geology to the area. In 2011, Eurasian watermilfoil was discovered in Beaver Lake near the boat ramp. Upon discovery of the infestation, multiple partners convened a working group to address the issue. Bottom barriers were installed over large patches of the infestation and suction dredging was employed for small patches and individual plants. Since the original control/eradication effort, WLI has submitted an annual AIS Management Plan to the City of Whitefish including a line item for continued suction dredging efforts. Since 2011, there has been a substantial reduction in the amount of EWM found and current efforts dredge isolated single plants. Based on the early intervention of this invasion, eradication goals are still reasonable to pursue. The Beaver Lake effort will continue as a line item in the City of Whitefish AIS Management Plan into the future to mitigate this threat. Based on the close proximity of Beaver Lake to Whitefish Lake and the multiple potential vectors to spread this plant, current management efforts are valid and warranted.

G. THE FUTURE

Smart water quality planning must account for a changing world. Locally, the City of Whitefish should consider the Whitefish Lake Watershed as part of its infrastructure and provide the requisite level of support for its protection. At the state level, if a new beneficial use category of “Unique Scenic Value” is incorporated into rule (ARMs) than there is justified reason to include Whitefish Lake based on the scenic, recreational, and economic benefit to all Montanans. Whitefish Lake’s developed standards could be associated with this new beneficial use to provide more protective benchmarks to maintain the lake’s earlier/existing conditions and to steer it away from the trophic state tipping point.

All project partners should work more closely to develop a comprehensive inter-disciplinary plan for the resource beyond jurisdictional roles or geographic scopes. In particular, a closer look is needed to provide protective measures for the Whitefish Lake adfluvial bull trout population. Plans need to be developed now to forecast scenarios and mitigation measures for potential issues that carry major implications, such as AIS introductions and climate change.

Ultimately, cumulative anthropogenic non-point sources, as examined in this report have led to water quality issues. Biologically, the introduction of many non-native species to the lake and local tributaries has jeopardized native species like bull trout and westslope cutthroat trout. Conversely, many management activities have, or have the potential to mitigate water quality risks. There are many water quality improvement task items identified in this report that can and should be implemented by the community and project partners to improve water quality, protect native species, and leave a lasting legacy.

XVIII. WATERSHED RESTORATION PLAN

A. WATERSHED RESTORATION PLAN INTRODUCTION

The objective of a Watershed Restoration Plan (WRP) is to meet water quality goals for a waterbody related to non-point source (NPS) producing activities. The Montana Department of Environmental Quality (DEQ) and the U.S. Environmental Protection Agency (EPA) are required to develop Total Maximum Daily Loads (TMDLs) and water quality restoration plans for water quality improvement on waterbodies in which one or more pollutants impair legally designated beneficial uses. In addition, a WRP can address numeric and/or narrative water quality criteria and locally derived benchmarks, all with a common theme of protecting and restoring the watershed for public health, recreational pursuits, and fish and wildlife protection. Please see Chapter II Project Area, Section A. Whitefish Lake Watershed & Surrounding Area for information on TMDL development for the Whitefish Lake Watershed.

The US Environmental Protection Agency (EPA) provides an integrated framework to achieve the water quality goals of a Watershed Restoration Plan through the nine key elements listed below which have been addressed as thoroughly as possible by this report.

Nine Elements of a Watershed-based Restoration Plan (WRP)
1. An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan), as discussed in item (2) immediately below. Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed (e.g., X numbers of dairy cattle feedlots needing upgrading, including a rough estimate of the number of cattle per facility; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded stream bank needing remediation).

2. An estimate of the load reductions expected for the management measures described under paragraph (3) below (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time). Estimates should be provided at the same level as in item (1) above (e.g., the total load reduction expected for dairy cattle feedlots; row crops; or eroded stream banks).

3. A description of the NPS management measures that will need to be implemented to achieve the load reductions estimated under paragraph (2) above (as well as to achieve other watershed goals identified in this watershed-based plan), and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.

4. An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan. As sources of funding, States should consider the use of their Section 319 programs, State Revolving Funds, USDA's Environmental Quality Incentives Program and

Conservation Reserve Program, and other relevant federal, state, local and private funds that may be available to assist in implementing this plan.

5. An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the NPS management measures that will be implemented.

6. A schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious.

7. A description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented.

8. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether this watershed-based plan needs to be revised or, if a NPS TMDL has been established, whether the NPS TMDL needs to be revised.

9. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (8) immediately above.

B. WATERSHED RESTORATION PLAN TASK TABLE INTRODUCTION

The information contained in this report and the Watershed Restoration Plan (WRP) Task Table (Chapter XXIII. Addendum D) contained herein addresses the water quality objectives of federal and state agencies and the intent of the WRP process, while also assisting the local community and stakeholders in understanding water quality trends and the health of its aquatic ecosystems. The table addresses a much wider range of watershed-level water quality issues and activities than the standard “9 Elements.” In short, this table is intended to be useful for management agencies and the local community to achieve all of its water quality goals.

The WRP Task Table includes 64 items broken down into major categories including:

- City of Whitefish – Policy & Government
- Education & Outreach
- Research
- Restoration & Habitat Protection
- Miscellaneous

Each of the 64 water quality improvement task items were ranked relative to one another by the WLI Science Advisory Committee and then priority ranked as Tier I, II, & III. Whereas this priority ranking provided information for WLI and project partners to pursue projects, it does not preclude the completion of lower ranked projects if funding availability or other variables make them timely to complete.

To be useful to this wide constituency, WLI's WRP Task Table will be utilized along with adaptive management strategies to estimate project costs and to identify funding sources, activities, and timelines for meeting local water quality benchmarks while integrating TMDL pollution reductions and targets wherever possible. However, there is uncertainty in predicting future political, social and environmental conditions and how water quality could be affected. This WRP is designed to be used over a five-year period (2016-2020) at which time a review will be required.

With the publication of this report, WLI has defined and documented the resource issues in the study area that need attention in order to protect and improve local water resources for the future. The resulting WRP Task Table will serve as a central record of projects that require the collective attention of local, state and federal resource managers, as well as citizens. We hope this work will also serve to further the cultural understanding of "place" in the Whitefish area.

Professor Emeritus Robert L. Thayer, Jr. wrote: *"Life-place culture, I think, is not a concept to be grasped hard by a tightly clenched fist; rather, it must be held lightly and balanced in the palm of an open hand. It also requires the joining of many hands—the active engagement of student hands raised in question, of clasped hands around shovels, of cradled hands around new seedlings, of hands shaking in agreement, of hands patting people on the back, of hands raised in celebration."*

XIX. LITERATURE CITED

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XX. ADDENDUM A - GLOSSARY

Abiotic – Not alive; non-biological; for example, temperature and mixing are abiotic factors that influence the O2 content of lake water whereas photosynthesis and respiration are biotic factors that affect O2 solubility.

Absorption - Physical adhesion of molecules of dissolved substances to the surfaces of solids or liquids with which they are in contact.

Adsorption - Physical adhesion of molecules from a gas, liquid, or dissolved solid to the whole volume of a material.

Acid – A solution that is a proton (H^+) donor and has a pH less than 7 on a scale of 0-14. The lower the pH the greater the acidity of the solution.

Acidic – The condition of water or soil in which substances lowers the pH below 7.0.

Acidification – A process by which the acidity of the water is raised (pH is lowered).

Aerobic – Requiring oxygen to live or occurring in the presence of oxygen.

Airshed – The atmosphere adjacent to a drainage basin.

Algae – Simple single-celled (phytoplankton), colonial, or multi-celled, mostly aquatic plants, containing chlorophyll and lacking roots, stems and leaves. Algae is either suspended in water (phytoplankton) or attached to rocks and other substrates (periphyton). Algae are an essential part of the lake ecosystems and provide the food base for most lake organisms, including fish. (Refer to Phytoplankton and Periphyton).

Algal Bloom – A heavy growth of algae in and on a body of water. This usually is a result of high nitrates and phosphate concentrations entering water bodies.

Allochthonous – Materials formed outside and transported into the system in question; externally derived.

Alluvial Fan – A fan-shaped accumulation of alluvium deposited at the mouth of a ravine or at the juncture of a tributary stream with the main stream.

Alkalinity – The acid-neutralizing capacity of water. It is primarily a function of the carbonate, bicarbonate, and hydroxide content in water. The lower the alkalinity, the less capacity the water has to absorb acids without becoming more acidic.

Ambient - Background or away from point sources of contamination.

Ammonia (NH_3) – A nitrogen-containing substance which may indicate recently decomposed plant or animal material.

Amonium (NH_4) The less toxic ionized form of ammonia which occurs when water is acidic. It is the most inorganic form used in primary productivity

Anaerobic – The absence of oxygen. In limnology it is used synonymously with "*anoxic.*"

Anions – Negatively charged ions.

Anoxia – Conditions of being without dissolved oxygen (O_2).

Anoxic – Completely lacking in oxygen.

Anthropogenic - A factor related to human activity or involvement.

Aquifer – A geologic stratum containing groundwater that can be withdrawn and used for human purposes.

Attenuation – The decline of any kind of flux through a medium.

Autochthonous – Materials formed within the systems; internally derived.

Autotroph – Literally "self-nourishing"; an organism capable of synthesizing its own organic compounds from inorganic energy and nutrient sources (e.g. photosynthetic plants).

Baseflow – The portion of streamflow derived from groundwater (i.e. dry-weather flow).

Basin - A drainage area or watershed in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Bedrock – The solid rock beneath the soil or loose sediments.

Benthic - Relating to the lake's bottom structure or community.

Benthic Zone – Lake bottom sediment.

Beneficial Uses - A Water Quality Standards term that determines how a resource is valued. Beneficial uses can be grouped into three broad categories; recreation, aquatic life and water supply.

Best Management Practices (BMPs) – An engineered structure or management activity that eliminates or reduces adverse environmental effects of pollutants.

Bioavailability – The capability for ready absorption and assimilation (of a nutrient) by growing plants.

Bicarbonate – The anion HCO_3^- A contributor to Total Dissolved Solids. High concentrations sometimes occur in waters which are low in calcium and magnesium and especially where processes releasing carbon dioxide such as sulfate reduction are occurring.

Bioaccumulation – The increase in concentration of a chemical in organisms that reside in environments contaminated with low concentrations of various organic compounds. Also used to describe the progressive increase in the amount of a chemical in an organism resulting from rates of absorption of a substance in excess of its metabolism and excretion. Certain chemicals, such as pcb's, mercury, and some pesticides, can be concentrated from very low levels in the water to toxic levels in animals through this process.

Bioavailable – Able to be assimilated (absorbed) by organisms.

Biotic – Referring to a live organism or assemblage of organisms.

Blue-green Algae (see Cyanobacteria)

Buffer (1) – A designated area adjacent to and a part of a slope or landslide hazard area which protects slope stability, attenuation of surface water flows, and landslide hazards reasonably necessary to minimize risk; or A designated area adjacent to or a steep slope or wetland that is an integral part of the aquatic ecosystem; or waterbody.

Buffer (2) – A substance which tends to keep pH levels fairly constant when acids or bases are added. (See Alkalinity).

Buffering Capacity – Ability of a solution to resist changes in pH when acids or bases are added; the buffering capacity of natural waters is mostly due to dissolved carbonate rocks in the basin; equivalent to acid neutralizing capacity.

Bulk Precipitation – Atmospheric deposition in both wet and dry forms.

Carbon Assimilation/Fixation – The photosynthetic incorporation of inorganic carbon into cell material (organic carbon).

Carnivores – Organisms that consume other organisms.

Catchment – An area of land where surface water from rain, melting snow or ice converge in a single point, usually the low elevation exit of a basin where the waters join another water such as a river, lake, reservoir, or wetland.

Cations – Negative ions.

Channel – A long, narrow excavation or surface feature that conveys surface water and is open to the air.

Char – Char (genus *Salvelinus*) are distinguished from trout and salmon by the absence of teeth in the roof of the mouth, presence of light colored spots on a dark background, absence of spots on the dorsal fin, small scales, and differences in the structure of their skeleton. (Trout and salmon have dark spots on a lighter background).

Chlorophyll – Green pigment in plants that transforms light energy into chemical energy in photosynthesis. A measurement of chlorophyll *(a)* (one type of chlorophyll) is commonly used as a measure of the algae content of water.

Circulation (Lake) – The mixing of lake water by advective (horizontal – i.e. wind energy, inflowing streams) or convective (vertical) currents induced by cooling and evaporation).

Clarity – Transparency; routinely estimated by the depth at which you can no longer see a Secchi disc.

Clean Water Act – A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation’s waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Compensation Point – The depth of water where photosynthesis and respiration balance each other; the lower limit of the euphotic zone.

Conductivity – A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water. It can be used as a general indicator of the quality of the water and can also suggest presence of unidentified material in the water.

Consumers – Organisms that must eat other organisms for their energy metabolism; organisms that cannot produce new organic matter by photosynthesis or chemosynthesis.

Convection Currents – Air or water movement caused by changes in density or thermal (temperature) gradients.

Conveyance System – Drainage facilities and features that collect, contain, and provide for the flow of surface and storm water from the highest points on the land down to receiving water. Conveyance systems are made up of natural elements and of constructed facilities.

Cultural Eutrophication - The accelerated or premature aging of a lake from nutrient input as a result of anthropogenic (human) influences.

Cyanobacteria (Community referred to as Blue-green algae) – Bacteria that photosynthesizes (use sunlight to produce food). While cyanobacteria occur naturally in all lakes and ponds, elevated nutrient levels may cause cyanobacteria to "bloom" or grow out of control and cover the lake surface. The concern associated with cyanobacteria is that some species produce toxins that may affect domestic animals or humans through skin contact or ingestion. These toxins may cause a variety of symptoms, including nausea, vomiting, diarrhea, fever, skin rashes, eye and nose irritations general malaise, and even death.

Decomposition – The breakdown of organic matter by bacteria and fungi.

Denitrification – Anaerobic bacterial process metabolism in which nitrate is used instead of oxygen during the oxidation of organic carbon compounds to yield energy (respiration). The process oxidizes organic carbon and (chemically) reduces nitrate to the gaseous end products N_2 (nitrogen gas) or N_2O (nitrous oxide). This is the major process used in wastewater treatment plants to ultimately convert *combined* nitrogen to a non-polluting state.

Density Stratification – Creation of layers in a waterbody due to density differences; controlled by temperatures, dissolved solids concentration and particle concentration.

Detritus – Dead or decaying organic matter; technically called organic detritus to distinguish it from the mineral detritus classified by geologists.

Diatom – Group of algae characterized by glass (silica) cell wall, beautifully ornamented; often the brown stuff attached to rock surfaces.

Diel – A 24 hour period of time.

Diffusion – The movement of a substance from an area of high concentration to an area of low concentration. Turbulent diffusion, or mixing, results from atmospheric motions (wind) diffusing water, vapor, heat, and other chemical components by exchanging parcels called eddies between regions in space in apparent random fashion. Molecular diffusion, which operates in stagnant zones, such as at the bottom sediment-water boundary in a deep lake, occurs much, much more slowly and so is important only on a very small scale such as right at the bottom.

Dimictic – A lake that mixes freely twice a year, typically in spring and fall, is thermally stratified in the summer, and has a stable temperature in the winter.

Discharge – Runoff, excluding offsite flows, flow, built conveyance systems, or infiltration facilities.

Dissolved Oxygen – The amount of oxygen in the water. Dissolved oxygen may be produced by algae and aquatic plants or mixed into the water from the air. It is used by fish, aquatic insects, and other aquatic animals.

Dissolved Oxygen Profile – A graph of the amount of dissolved oxygen per unit depth; where the depth is on the z (vertical) axis and dissolved oxygen is on the x (horizontal) axis. Limnologists plot graphs this way but be sure to note that the depth (z) axis is really for the independent variable and the horizontal (x) axis is really for the dependent variable.

Dry Deposition – Fine particulate matter and aerosols settling from the atmosphere onto lake and land surfaces during periods with no precipitation.

E. coli – A common bacteria that is specific to the intestines of warm blooded animals. It is often used as an indicator of the possible presence of other, more harmful (pathogenic) bacteria.

Ecology – The study of the interactions between organisms and their environments.

Ecoregion – An environmental area characterized by specific land uses, soil types, surface form, and potential natural vegetation.

Ecosystem –All of the organisms in a defined space in association with their interrelated physical and chemical environment.

Effluent – Liquids discharged from sewage treatment plants, septic systems, or industrial sources to surface water or groundwater.

Epilimnion – The upper, well-circulated, warm layer of a thermally stratified lake. This water is turbulently mixed throughout at least some portion of the day by wind, and because of its exposure, can freely exchange dissolved gases (such as O_2 and CO_2) with the atmosphere. (Refer to Hypolimnion and Metalimnion).

Erosion – The gradual wearing away of land surface materials, especially rocks, sediments, and soils, by the action of water, wind, or a glacier. Usually erosion also involves the transport or eroded material from one place to another.

Euphotic Zone – The illuminated zone of a lake including the littoral (near shoreline) and limnetic (open water) regions.

Eutrophic - A nutrient rich and highly productive lake, generally characterized by high levels of biological production, often shallow with limited oxygen in the bottom layer of the lake. (Refer to Mesotrophic and Oligotropic).

Eutrophication - The aging process of lakes as they acquire sediment and nutrients over time. (Refer to Cultural Eutrophication).

Erosion – The detachment and transport of soil or rock fragments by water, wind, ice, etc.

Evaporation – The process of converting liquid to vapor.

Exceeded – Did not meet.

Exotic Species – A plant or animal species introduced to an area from another country or state that is not native to the area.

Export Rate – Amount of a particular nutrient or contaminant annually transported from its source to a lake or stream; usually related to land uses and expressed per unit area per year.

Fetch – Distance the wind blows over water without appreciable change in direction; relates to intensity of turbulent mixing.

Fecal coliform – That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 Celsius. Fecal coliform are "indicator" organisms that suggest the possible presence or disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100mL).

Fecal Coliform Bacteria – Bacteria from the intestines of warm-blooded animals. Most of the bacteria are not themselves harmful, but they are measured or counted as an indicator of the possible presence of harmful bacteria.

Flagellate – A microscopic organism possessing one or more whip-like filaments enabling it to move about.

Flourometry - An analytic method for detecting and measuring fluorescence in compounds that uses ultraviolet light stimulating the compounds, causing them to emit visible light.

Flow Rate – The rate at which water moves by a given point; in rivers and streams it is usually described in cubic meters per second (m^3/sec) or cubic feet per second (cfs).

Flushing Rate – The retention time (turnover rate or flushing rate), the average length of time water resides in a lake, ranging from several days in small impoundments to many years in large seepage lakes. Retention time is important in determining the impact of nutrient inputs. Long retention times result in recycling and greater vulnerability to eutrophication.

Food Web – Food chains hooked together into a complex interconnected web.

Geographic Information System (GIS) – A computer system, which allows for input and manipulation of geographic data to allow researchers to manipulate, analyze and display the information in a map format.

Grab Sample – A discrete sample from a single point in the water column.

Grazers – Herbivores; zooplankton in the open water zone.

Green Algae – Are a large, informal grouping of algae including chlorophyte and charophytes which grow when light, pH temperature and nutrient levels are conducive to growth. Generally high levels of nutrients, particularly phosphorus, controls the growth of green algae in freshwater ecosystems.

Groundwater – Water stored beneath the surface of the earth. The water in the ground is supplied by the seepage of rainwater, snowmelt, and other surface water into the soil. Some groundwater may be found far beneath the earth surface, while other groundwater may be only a few inches from the surface. Groundwater discharges into lowland streams to maintain their baseflow.

Hardness – A measure of the dissolved solids in a water sample usually comprised of calcium and magnesium.

Hardwater – Lakes that have a high buffering capacity and are not generally sensitive to acid deposition. These lakes have dissolved salt concentrations greater than 120 mg/L.

Headwater – The source and upper reaches of a stream.

Herbivores – Plant eaters.

Heterogeneous - Not uniform; patchy.

Heterotroph – An organisms dependent on organic materials originally produced by autotrophs as a source of energy and nutrients.

Hydrograph – A graph of the rate of runoff (i.e. stream discharge) plotted against time for a point on a stream channel.

Hydrology – The science dealing with the properties, distribution and circulation of water. The term usually refers to the flow of water on or below the land surface before reaching a stream or man-made structure.

Hypolimnetic Oxygen Depletion – A condition where the dissolved oxygen in the bottom layer (hypolimnion) of a water body is gradually consumed through respiration and decomposition faster than it can be replaced over the course of the summer. A similar phenomenon may occur in the winter under ice cover. The rate at which O_2 is depleted is a measure of the productivity of the system.

Hypolimnion – The deep, cold, relatively undisturbed bottom waters of a thermally stratified lake. It is isolated from wind mixing and typically too dark for much plant photosynthesis to occur. (Refer to Epilimnion and Metalimnion).

Impervious Surface – A hard surface area which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development; and/or a hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots and roads.

Inorganic – Substances of mineral, not carbon original.

In-situ Incubation – A temporary growth condition established for isolated samples of natural microbial communities where they are returned to their original location (depth) to closely simulate natural growth rates over a prescribed period of time.

Insolation – The sum of incoming (diffuse and direct) solar radiation; total solar radiation.

Internal Loading – The release of phosphorus from the lake bottom sediments into the bottom layer of the water; enhanced by oxygen levels on the bottom of the lake which decline to less than 0.5mg/L.

Inverse Stratification – A condition common to temperate lakes in the winter in which slightly warmer water sits beneath colder but less dense water (the density of water is greatest at 4 degrees Celsius).

Invertebrates – Animals without internal skeletons. Some require magnification to be seen well, while others such as worms, insects, and crayfish are relatively large. In general, more varied invertebrate communities indicate healthier water bodies.

Ion – An electrically charged particle dissolved in an aqueous solution, usually water.

Isothermal – Constant temperature.

Lake Profile – A graph of a lake variable per depth; where the depth is on the z-axis and the variable is on the x-axis. Depth is the independent variable and the x-axis is the dependent variable.

Landscape – All the natural geographical features, such as fields, hills, forests, and water that distinguish one part of the earth’s surface from another part. These characteristics are a result not only of natural forces but of human use of the land as well.

Leach(ing) – The process by which soluble materials in the soil, such as salts, nutrients, pesticide chemicals or containments, are washed into a lower layer of soil or are dissolved and carried away by water.

Lentic – Referring to standing waters such as ponds and lakes.

Limnetic Zone – Open water zone.

Limiting Nutrient – The nutrient that is in lowest supply relative to the demand. The limiting nutrient will be exhausted first by algae, which require many nutrients and light to grow. Inputs of the limiting nutrient will result in increased algal production, but as soon as the limiting nutrient is exhausted, growth stops. Phytoplankton growth in lake waters are generally phosphorus limited, but may be co-limited by phosphorus and nitrogen.

Limnology – The study of the biology, chemistry, and physics of freshwater lakes and ponds.

Littoral (Zone) – The shoreline zone of a lake where sunlight penetrates to the bottom and is sufficient to support rooted plant growth.

Load allocation - Part of a TMDL/water quality restoration plan that is assigned to report sources of pollution, and is intended to meet identified targets.

Loading Rate – The rate at which materials (typically suspended sediment, nutrients [N and P], or contaminants) are transported into a water body.

Lotic – Refers to running waters such as streams and rivers.

Low-Impact Development – A type of site development and design in which runoff water is allowed to infiltrate into the soil rather than flowing directly into a lake or stream. Low-impact development allows the lake or stream to function in a more natural way, with less human impact.

Macronutrients – A chemical element necessary in large amounts for the growth of plants.

Macrophytes – Higher aquatic plants; in the sense of "higher" evolutionarily than algae and having roots and differentiated tissues; may be emergent (cattails, bulrushes, reeds, wild rice), submergent (water milfoil, bladderwort) or floating (duckweed, lily pads).

Mean Depth – The average depth of a water body; determined by dividing lake volume by the surface area (also called z mean).

Mercury – A naturally occurring metal that may be found in rocks, soils, sediments, and the atmosphere. Human activities, such as coal burning and industrial uses, have increased the amount of mercury emitted to the environment. Mercury may enter lakes by atmospheric deposition. The mercury then enters the food chain and bioaccumulates in aquatic animals.

Meromictic – Describing a lake that doesn't mix completely. Only partially circulating, with the lower, denser layers never mixing with the upper layers.

Mesotrophic – A condition of lakes that is characterized by moderate concentrations of nutrients, algae, water transparency. A mesotrophic lake is not as rich in nutrients as eutrophic lake, but richer in nutrients than an oligotrophic lake.

Metabolism – The chemical and physical processes continually going on in living organisms and cells, by which the energy is provided for cellular processes and activities, and new material is assimilated to repair waste.

Metalimnion – The middle or transitional zone between the well-mixed epilimnion and the colder hypolimnion layers in a stratified lake. This layer is also referred to as the thermocline.

Micronutrient – Trace nutrients required by microorganisms or zooplankton such as molybdenum and cobalt. Nitrogen and phosphorus are considered to be macronutrients.

Mineralization – The breakdown of organic matter to inorganic substances (including nutrients) by bacteria, fungi.

Mixolimnion – The upper layer of water that can mix completely at least once a year in a meromictic lake.

Monimolimnion – Bottom layer of stagnant water in a meromictic lake that never is completely mixed.

Morphometry – Relating to the shape of a lake basin; includes parameters needed to describe the shape of the lake such as volume, surface area, mean depth, maximum depth, maximum length and width, shoreline length, shoreline development (length of the perimeter, or shoreline divided by the calculated diameter of a circle of equivalent area [how convoluted the shoreline is]), depth versus volume and surface area curves.

Net Productivity – Gross community productivity minus community respiration.

Neuston – (1) The collection of minute or microscopic organisms that inhabit the surface layer of a body of water. (2) Organisms resting or swimming on the surface of still bodies of water.

Nitrate, nitrite (NO_3, NO_2) – Two types of nitrogen compounds. These nutrients are forms of nitrogen that algae may use for growth.

Nitrification – Bacterial metabolism in which ammonium ion (NH_4^+) is oxidized to nitrite (NO_2^-) and then to nitrate (NO_3^-) in order to yield chemical energy that is used to *fix* carbon dioxide into organic carbon. The process is a type of chemosynthesis which is comparable to photosynthesis except that chemical energy rather than light energy is used. These bacteria are aerobic and so require dissolved oxygen in order to survive.

Nitrogen – One of the elements essential as a nutrient for growth of organisms.

Nitrogen Fixation – The conversion of elemental nitrogen in the atmosphere (N_2) to a form (e.g., ammonia) that can be used as a nitrogen source by organisms. Biological nitrogen fixation is carried out by a variety of organisms; however, those responsible for most of the fixation in lakes are certain species of blue-green algae.

Non-point Source Pollution – Pollution that originates from diffuse areas and unidentifiable sources, such as agriculture, the atmosphere, or ground water. (Refer to Point-Source Pollution).

Nonstructural BMP – A preventative action to protect receiving water quality that does not require construction. Nonstructural BMPs rely predominantly on behavioral changes in order to be effective. Major categories of non-structural BMPs include education, recycling, maintenance practices and source controls.

NPDES – National Pollutant Discharge Elimination System. The part of the Clean Water Act which requires point source discharges to obtain permits. In Montana, these permits are referred to as MPDES and are administered by the Montana Department of Environmental Quality.

Nuisance Blooms – Referring to obnoxious and excessive growths of algae caused by excessive nutrient loading; often due to scum forming cyanobacteria (blue-green algae) that can regulate their buoyancy to float high in the water column to obtain sunlight.

Nutrients – Elements or compounds essential for growth of organisms.

Nutrient Loading – Discharging of nutrients from the watershed (basin) into a receiving water body (lake, stream, wetland); expressed usually as mass per unit area per unit time (kg/ha/yr or lbs/acre/year).

Oligotrophic - A relatively nutrient poor lake, characterized by low biological production. Typically clear and deep with bottom waters high in dissolved oxygen. (Refer to Eutrophic and Mesotrophic).

Omnivorous – Capable of eating plants, fungi and animals.

Organic – Substances which contain carbon atoms and carbon-carbon bonds.

Outflow – Water flowing out of a lake.

Outliers – Data points that lie outside of the normal range of data. Ideally, outliers must be determined by a statistical test before they can be removed from a data set.

Overturn – Vertical mixing of water layers caused by seasonal changes in temperature (i.e. in spring – after surface ice disappears, and fall –as stratification breaks down); (also see Circulation).

Oxygen – An odorless, colorless gas; combines to form water; essential for aerobic respiration.

Paleolimnology – The study of the history of lakes via the analysis of organisms and chemistry of lake bottom sediments.

PAR – Abbreviation for photosynthetically active radiation: that portion of the solar spectrum (400-700 nm wavelength), used in photosynthesis.

Parameter – A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

Pelagic - The open water area of a lake.

Periphyton – A general term for microfloral growth on benthic substrates.

pH – A measure of the concentration of hydrogen ions. Used to describe the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while high pH (7-14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral.

Phosphorus – Key nutrient influencing plant growth in lakes. Soluble reactive phosphorus (PO_4^{-3}), also known as orthophosphorus, is the amount of phosphorus in solution that is most readily available to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form.

Photic zone - That area of the lake's water column where light penetrates.

Photosynthesis – The process by which green plants convert carbon dioxide (CO_2) dissolved in water to sugars and oxygen using sunlight for energy. Photosynthesis is essential in producing a lake's food base, and is an important source of oxygen for many lakes.

Phytoplankton – Microscopic floating plants, mainly algae, that live suspended in bodies of water and that drift about because they cannot move by themselves or because they are too small or too weak to swim effectively against a current. (Refer to Algae).

Planktivores – Animals that eat plankton; usually refers to fish that feed on zooplankton but can also refer to fish that graze on algae; includes invertebrate predators.

Planktonic – Referring to the "freely floating" organisms of the open water (including algae, bacteria, zooplankton); a misnomer in that most algae do not float.

Plankton Net – A fine mesh net used to collect microscopic plants and animals.

Pleistocene Epoch – The earlier portion of the Quaternary period dating from 1.7-2 million years before present to approximately 10,000 years ago.

Point Discharge – The release of collected and/or concentrated surface and storm water runoff from a pipe, culvert, or channel.

Point Source Pollution – Pollution into a water body from a specific and identifiable source, such as municipal or industrial outfalls.

Polymictic – A term used to describe shallow lakes that mix more than twice a year. These lakes may mix on a daily basis or every few days.

Ppb – Part-per billion; equivalent to a microgram per liter (ug/L).

Ppm – Part-per-million; equivalent to a milligram per liter (mg/L).

Primary Consumers – First level of consumers according to the ecological pyramid concept; organisms that eat herbivores grazers.

Primary Productivity – The productivity of the photosynthesizers at the base of the food chain in ecosystems. This refers to the yield of new biomass growth during a specified time period. The entire year's accumulation is termed annual production.
Productivity – The time rate of production of biomass for a given group of organisms; essentially the net growth rate of organisms.

Profile – A vertical, depth-by-depth characterization of a water column, usually at the deepest part of a lake.

Profundal zone - The surface bottom areas beyond the littoral zone where light does not penetrate.

Reach – A specific portion or segment of a stream or river with uniform characteristics.

Relative Depth – A measure of how deep a lake is relative to its surface area.

Respiration – The metabolic process by which organic carbon molecules are oxidized to carbon dioxide and water with a net release of energy. Aerobic respiration requires, and therefore consumes, molecular oxygen (carried out by algae, zooplankton, benthic invertebrates, fish, many bacteria, people). Certain bacteria can use nitrate in place of oxygen (denitrifiers) or sulfate (sulfate reducers), but only under anaerobic (anoxic) conditions – typically present only in the sediments or in the hypolimnion after prolonged oxygen depletion has occurred.

Retention Coefficient (R) – The proportion of nutrient inputs that remain in the lake; the difference between annual inputs and outputs, divided by the annual input.

Riparian – Pertaining to the banks of rivers and streams, and also wetlands, lakes, or tidewater.

Riprap – Large rocks placed along the bank of a waterway to prevent erosion.

Runoff – Water originating from rainfall and other precipitation that ultimately flows into drainage facilities, rivers, streams, springs, seeps, ponds, lakes, and wetlands as well as shallow groundwater.

Salmonid – Any fish that belong to the family Salmonidae. Includes salmon, trout, char, whitefish, and grayling.

Secchi depth – Measure of transparency of water obtained by lowering a Secchi disc into water until it is no longer visible.

Secchi disk - A black and white device, similar in size and shape of a dinner plate, lowered into the water to measuring the depth of light penetration.

Sedimentation – The removal, transport, and deposition of detached soil particles by flowing water or wind. Accumulated organic and inorganic matter on the lake bottom. Sediment includes decaying algae and weeds, precipitated calcium carbonate (marl), and soil and organic matter eroded from the lake’s watershed.

Seep - An area where groundwater emerges to surface flow.

Shoreline – The zone where lake and land meet. Shorelands are defined as the lands 1,000 ft from the ordinary high water levels.

Sink– A part of the physical environment, or a physical system that absorbs some form of matter or energy.

Sinusoidal – A wave the amplitude of which varies in proportion to the sine of time.

Spatial – A scale that refers to the size of a water body or land mass in relation to its larger catchment area or basin, and its longitudinal and latitudinal zonation and geographic position.

Solute – A substance which can be dissolved into another substance.

Solution – A homogenous mixture of two substances.

Sonde – Device for testing physical or chemical conditions.

Spring Turnover – Period of complete or nearly complete vertical mixing in the spring after ice-out and prior to thermal stratification.

Staff Gauge – A vertical gauge placed in a stream or river to relate discharge measurements to water stage levels.

Stage Height – Water surface elevation.

Standard – A legally established allowable limit for a substance or characteristics in the water, based on criteria. Enforcement actions by the appropriate agencies can be taken against parties who cause violations.

Stratification – An effect where a substance or material is broken into distinct horizontal layers due to different characteristics such as density or temperature.

Stratification of Lakes – A layering effect produced by the warming of the surface waters in many lakes during summer. Upper-waters are progressively warmed by the sun and the deeper waters remain cold. Because of the difference in density (warmer water is lighter), the two layers remain separate from each other: upper waters “float” on deeper waters and wind induced mixing occurs only in the upper waters. Oxygen in the bottom waters may become depleted. In autumn as the upper waters cool, the whole lake mixes again and remains mixed throughout the winter, or until it freezes over.

Stratified – Separated into distinct layers.

Stream Discharge – The volume of water passing through a stream cross section during a given period of time.

Stream Order – The position a section of stream occupies in relation to the rest of the drainage system: headwater streams are designated first order, each successive order results where two branches of equal order meet.

Structural BMP – Constructed facilities or measures to help protect receiving water quality. Examples include storage, vegetation, infiltration, and filtration.

Substrate – Attachment surface or bottom materials in which organisms can attach or live-within; such as rock, sand or muck substrate, or woody debris and living macrophytes.

Supersaturation – When a substance is more highly concentrated (more saturated) in another substance than is normally possible under normal temperature and pressure.

Surface Tension – A phenomenon caused by a strong attraction towards the interior of the liquid action on liquid molecules in or near the surface in such a way to reduce the surface area.

Suspended Sediment (SS or Total SS[TSS]) – Very small particles which remain distributed throughout the water column due to turbulent mixing exceeding gravitational sinking; also see turbidity.

Synoptic survey – Data collected simultaneously or over a short period of time.

TDS – Total dissolved salts or solids in a volume of water; usually in mg/l; estimated by EC (electrical conductivity).

Temperate – Refers to lakes located in a climate where the summers are warm and the winters moderately cold. The Northern Temperate Zone is between the Tropic of Cancer and the Arctic Circle.

Temperature – A measure of whether a substance is hot or cold.

Temperature Profile – A graph of the temperature per depth; where the depth is on the z-axis and temperature is on the x-axis.

Temporal – Characterize over time (e.g., temporal trends).

Telemetry – Automatic recording and transmission of data.

Tertiary Consumers – Larger consumers in the fourth tropic level like adult northern pike, ospreys and humans that eat fish.

Thalweg – The deepest and fastest moving portion of a stream.

Thermistors – Data loggers - their resistance is dependent on temperature.

Thermal Stratification – A process by which a deep lake becomes layered by temperature in the summer months. The layers will separate because colder water sinks to the bottom, leaving warmer water at the surface. Because these layers form chemical and biological barriers, limnologists sample at each layer of the lake. During the winter months, when ice forms on the lake, Inverse Thermal Stratification occurs under the ice, in which colder, less dense water overlies warmer, denser water near the maximum density of four degrees Celsius.

Thermocline – The depth at which the temperature gradient is steepest during the summer; usually this gradient must be at least 1 degree C per meter of depth. The thermocline is referred to as the metalimnion.

Topography – Configuration of physical surface of land; includes relief imprints and locations of all man-made and natural features.

Total Dissolved Solids (TDS) – The amount of dissolved substances, such as salts or minerals, in water remaining after evaporating the water and weighing the residue.

Total Maximum Daily Load (TMDL) – A Total Maximum Daily Load is a plan to attain and maintain water quality standards by addressing the load allocation of specific pollutants in waters that are currently not meeting them. A TMDL is equal to the sum of all of the following: (1) individual waste load allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the waste load determination. A reserve for future growth is also generally provided.

Total suspended solids – Portion of solids retained by a filter.

Transparency – A measure of water clarity often determined by the depth at which a Secchi disk can be seen below the surface of the water. Transparency may be reduced by the presence of algae and suspended materials such as silt and pollen.

Tributary – A stream that flows to a larger stream or other body of water.

Trophic Classification – Biologically ranking the quality of lakes using a system that incorporates several parameters, including phytoplankton, chlorophyll *a* concentrations, and nutrient concentrations.

Trophic State – Trophic state refers to the biological production, both plant and animal life, that occurs in a lake. Eutrophication is the process by which lakes are enriched with nutrients, increasing the production of rooted aquatic plants and algae. The extent to which this process has occurred is reflected in a lake's trophic classification or state: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile).

Trophic Status – Rating of the condition of a lake on the scale of oligotrophic-mesotrophic-eutrophic.

Trophic Web – Conceptual model of the interconnections of species of organisms according to their different feeding groups.

Turbidity - A measure of reflected light from sediments or other matter suspended in the water.

Turnover – Fall cooling and spring warming of surface water act to make density uniform throughout the water column. This allows wind and wave action to mix the entire lake. Mixing allows bottom waters to contact the atmosphere, raising the water's oxygen content. However, warming may occur too rapidly in the spring for mixing to be effective, especially in small sheltered kettle lakes.

Water Column – A conceptual column of water from lake surface to bottom sediments.

Water Density – The ratio of water's mass to its volume; water is the most dense at four degrees Celsius.

Water Residence Time – The number of years required to completely replace the water volume of a lake by incoming water, assuming complete mixing.

Watershed – All land and water areas that drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Watershed Area : Lake surface area ratio – A_w:a_0 ; a measure relating to how much land area is there relative to lake area in a given watershed.

Weathering – The mechanical and chemical breakdown and dissolution of rocks.

Wet Deposition – Precipitation of all kinds.

Wetland – An area inundated or saturated by ground or surface water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

Winterkill – A sudden and dramatic mass fish death caused by insufficient oxygen in a frozen lake.

Zooplankton – Small, free swimming or floating animals in water, many microscopic.

XXI. ADDENDUM B - GEOGRAPHIC INFORMATION SYSTEM (GIS) MAPS

From Chapter II – Project Area, Section A. Whitefish Lake Watershed & Surrounding Area
Whitefish Lake Watershed and Surrounding Area
Columbia River Basin
Crown of the Continent Ecosystem

From Chapter III – Natural History, Section A. Climate
Fire History

From Chapter III – Natural History, Section B. Geology & Physical Geography
Geologic Formation
Taxonomic Particle Size
Percent Slope
Sediment Hazard
Erosion Potential
Soil – Geomorphic
Existing Vegetation Type
Glacial Whitefish Lake

From Chapter IV – Cultural History, Section C. Current Land Ownership
Land Ownership

From Chapter VI – Historical Studies, Section B. Past Whitefish Lake Institute Studies
Septic Leachate Contamination & Risk Assessment

From Chapter VII – Whitefish Lake Institute Water Quality Monitoring, Section A. Methodologies & Programs
Monitoring Sites

From Chapter X – Whitefish Lake Tributaries, Section A. Introduction
Stream Channel Type
Fish Passage
Fish Distribution
Upper Project Area Satellite Imagery
Middle Project Area Satellite Imagery
Lower Project Area Satellite Imagery

From Chapter XII – Whitefish Lake
Dominant Macrophyte Distribution
Dominant Substrate

From Chapter XIV – Municipal Water Infrastructure & Treatment, Section B. Stormwater
Stormwater

XXII. ADDENDUM C - WATER CHEMISTRY & TEMPERATURE INFORMATION

WHITEFISH LAKE TRIBUTARIES

UPPER WHITEFISH RIVER DRAINAGE

OTHER PROJECT AREA LAKES

XXIII. ADDENDUM D - WATERSHED RESTORATION PLAN TASK TABLE

See separate document "Addendum XXIII Watershed Restoration Task Table.pdf

NATURE'S WONDER

In 2015, WLI discovered perfectly formed larch needle balls along a small shoreline reach of Whitefish Lake in about two feet of water. Although balls comprised of organic matter (in this case larch needles) are uncommon, they have been reported worldwide and are often called surf balls or beach balls. Gift shops are known to sell these oddities as whale burps, whale barf balls, whale fur balls and moose balls.

Unique conditions are needed to form these balls. It is suspected that they are formed from surf action along the shoreline where as waves approach; they drag on the lake bottom, causing the wave crest to curl and crash onto the beach. The curling action may roll materials into a ball. However, the balls found in 2015 were within five feet on one another, suggesting other specific local conditions. Visit us at the office to see these unique creations from Mother Nature, or stop by the Stumptown Historical Society for two examples from Lindbergh Lake.

Figure 171. Pine Needle Balls from Whitefish Lake.
Photo Courtesy WLI