An Investigation into

Stormwater Management, Pollution, and Monitoring in the Flathead Watershed, Montana: Phase II

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BMP = Best Management Practice

COD = Chemical Oxygen Demand

CIA = Connected Impervious Area

Cu = Total Recoverable Copper

CWP = Center for Watershed Protection

DEQ = Montana Department of Environmental Quality

DO = Dissolved Oxygen

EIA = Effective Impervious Area

EMC = Event Mean Concentration

EPA = U.S. Environmental Protection Agency

FBC = Flathead Basin Commission

FCD = Flathead Conservation District

FRGI = Flathead Rain Garden Initiative

GSI = Green Stormwater Infrastructure

MDT = Montana Department of Transportation

ME Labs = Montana Environmental Laboratory

MS4 = Municipal Separate Storm Sewer System

MTFWP = Montana Fish, Wildlife & Parks

MTNHP = Montana Natural Heritage Program

NAIP = National Agriculture Imagery Program

NCCF = North Carolina Coastal Federation

NMDOT = New Mexico Department of Transportation

Pb = Total Recoverable Lead

RIDOT = Rhode Island Department of Transportation

TIA = Total Impervious Area

TKN = Total Kjeldahl Nitrogen

TN = Total Nitrites and Nitrates

TP = Total Phosphorus

TSS = Total Suspended Solids

USDA = United States Department of Agriculture

UWSGI = University of Wisconsin Sea Grant Institute

WRF = Water Research Foundation

WRWC = Woonasquatucket River Watershed Council

Zn = Total Recoverable Zinc

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PREFACE & ABSTRACT

Preface

The following report is intended for use by the Flathead Basin Commission and the cities, towns, and other relevant entities within the Flathead Basin, Montana, USA, that have contributed data to the project and/or would like to be involved in future stormwater projects in the watershed. The purpose of this report is to provide these entities with (1) a summary of work that has been done by the Flathead Basin Commission and its partners relating to stormwater in 2020 and 2021 and (2) recommendations of future project objectives to protect water quality in the basin through stormwater pollution mitigation. It should be noted that these recommendations are the opinion of the author and, if implemented, are not guaranteed to provide measurable differences in water quality. The following report relies and builds upon work described in "An Investigation into Stormwater Management, Pollution, and Monitoring in the Flathead Watershed, Montana: Phase I," which was written by the author in 2020. Much of the following report was written under the assumption that readers already have knowledge of the project and its Phase I accomplishments. See Henry (2020) for clarification of topics mentioned but not thoroughly described in the following report.

Abstract

Located in northwest Montana, the Flathead Watershed is an ecologically, socially, economically, and culturally vital resource that is anticipated to experience increasing threats to water quality. The purpose of this project is to develop the collective knowledge of stormwater in the basin, one of the many potentially significant causes of water quality degradation. Completed in 2020, Phase I of this project focused on understanding how stormwater is currently being managed within the Flathead Watershed in order to identify locations to prioritize future water quality monitoring efforts. Initiated in 2021, Phase II of this project is focused on further developing the baseline knowledge acquired in Phase I and outlining next steps, which include on-the-ground solutions to improve water quality in the basin. More specifically, the objectives of Phase II were to improve the existing outfall prioritization model to more accurately identify sub-basins within the watershed with high-polluting potential, to advance current monitoring efforts, to support existing and develop new public education and outreach initiatives, and to research and recommend potential future project objectives that would address current and prevent future water quality concerns. Recommendations for future project objectives include: (1) determining programmatic goals for stormwater monitoring and the future uses of the sub-basin prioritization model; (2) increasing the capacity of entities in the basin to effectively manage and maintain their stormwater infrastructure; (3) working with experts to develop best management practice retrofits in sub-basins throughout the watershed; and (4) developing a basin-wide incentive campaign that would encourage the implementation of green stormwater infrastructure in new development and along roadways. By beginning work on these projects now, the Flathead Basin Commission has a unique opportunity to protect water quality prior to extensive degradation.

Introduction

Located in northwest Montana, Flathead Lake and its tributaries are ecologically, socially, economically, and culturally vital resources for residents of the basin. Nestled within the larger Columbia River Watershed, the Flathead Basin has some of the cleanest waters in the country owing to its largely undeveloped status. However, as the population continues to grow and as urbanization and industrialization increase, water quality degradation through stormwater pollution will be an issue on the forefront of decision-makers' and residents' minds in years to come. Within the Flathead Watershed, the quality of the majority of stormwater runoff is unregulated. At the time of this report, the City of Kalispell and the Montana Department of Transportation (MDT) within Kalispell city limits are the only entities within the watershed whose stormwater discharges are regulated by the Montana Department of Environmental Quality (DEQ) under the General Permit for Stormwater Discharges Associated with Small Municipal Separate Storm Sewer Systems (MS4s). Because of this, any work that other cities, towns, or organizations do to monitor or manage their stormwater runoff quality is voluntary. For more information about the natural and anthropogenic settings of the Flathead Watershed and the laws pertaining to stormwater in the basin, see Henry (2020, 7-16).

Purpose

In an effort to increase understanding and awareness of stormwater in the Flathead Watershed, the City of Kalispell and the Flathead Basin Commission (FBC) jointly supported a Big Sky Watershed Corps Member in 2020 to carry out the first phase of this project. The goal of Phase I was to understand how stormwater is currently managed within the Flathead Watershed in order to identify specific locations to prioritize future water quality monitoring efforts. Monitoring results would then be used to confirm pollutant discharge and locations that water quality treatment would have the greatest pollution reduction impact. A more detailed summary of how this goal was accomplished is provided in the following section.

After acquiring the baseline data, the partners supported the same Big Sky Watershed Corps Member in 2021 to continue Phase II of the project. The goal of Phase II has been to utilize the stormwater data collected in Phase I to determine next steps that would reduce stormwater pollutant discharges. More specifically, the objectives of the second phase were: (1) to improve the outfall prioritization model from Phase I to more accurately identify sub-basins in the watershed with high-polluting potential; (2) to advance monitoring efforts through the continued collection of grab samples, experimentation with an automatic stormwater sampler, and conducting dry-weather outfall inspections; (3) to support existing and develop new public education and outreach initiatives; and (4) to research and recommend potential future project objectives to address current and prevent future water quality issues through stormwater pollution mitigation. The following report documents the Phase II accomplishments and outlines recommended future project objectives and the proposed first steps to achieving them.

As previously mentioned, the first phase of this project was completed in 2020 with the goal of acquiring baseline knowledge of stormwater management and quality in the Flathead Watershed. For more detailed descriptions of the Phase I accomplishments mentioned in the following sub-sections, see Henry (2020, 17-57).

Inventory of Stormwater Infrastructure

In order to predict and preempt water quality concerns related to stormwater, it was important to first understand how stormwater is managed by different entities within the Flathead Watershed through the development of a stormwater infrastructure inventory. Existing stormwater infrastructure in the basin's most urbanized areas was included in the digital inventory. Urban areas whose infrastructure is a part of this inventory include Kalispell, Whitefish, Columbia Falls, Evergreen, Lakeside, Bigfork, Polson, and Ronan. Of these urban areas, Evergreen, Lakeside, and Bigfork are considered unincorporated and do not have a centralized, city-owned stormwater system. The inventory was created by requesting access to digitized stormwater data or, in areas that did not have digitized data, organizing citizen science events to help map stormwater systems. Common elements of stormwater infrastructure that are part of the inventory include catch basins, storm lines, storm manholes, outfalls, and urban sub-basin boundaries. Some locations including Kalispell and Whitefish have additional infrastructural elements documented in their city-wide inventories, such as treatment units and infiltration features, but these are not common among all areas. This inventory exists in the form of a digital map and is hosted on the City of Kalispell's servers and on a hard drive owned by FBC.

While compiling the inventory, it was discovered that different urban areas manage their stormwater very differently. For example, both Kalispell and Whitefish had very detailed, digital records of their stormwater infrastructure that they were regularly updating. Polson, on the other hand, possessed only scanned copies of maps developed when their stormwater system was first installed, maps that were not digitized and could not be easily updated. Additionally, the ownership of stormwater infrastructure was not uniform and difficult to determine within and across multiple areas. For example, some stormwater infrastructure in Bigfork is owned by Flathead County, while most infrastructure within the Lakeside Water and Sewer District is privately-owned by many different entities. The question of ownership becomes important when considering what maintenance procedures, if any, are followed for certain types of infrastructure.

Outfall Prioritization Model

Once the inventory had been compiled and the sub-basin boundaries outlined, a simple model for identifying sub-basins with high-polluting potential was created. The model considered three sub-basin characteristics: (1) area, (2) land use type, and (3) the impairment status of the receiving waterbody. Regarding area, small sub-basins (<50 acres) were ranked 0, medium sub-basins (50-100 acres) were ranked 1, and large sub-basins (>100 acres) were ranked 2. Regarding land use, a land use dataset developed by the Montana Natural Heritage Program (MTNHP) in 2013 was used to calculate the percent area comprised of the following general land use groups for each sub-basin: natural, agricultural, residential, and industrial/commercial. Each sub-basin was then assigned to one of the four groups based on the land use type that comprised the largest percent area of the sub-basin. Natural sub-basins were ranked 0, residential and agricultural sub-basins were ranked 1, and industrial/commercial sub-basins were ranked 2. Finally, regarding the impairment status of the receiving waterbody, sub-basins were ranked 0 if they discharge into an unimpaired waterbody or into a closed basin; sub-basins were ranked 1 if they discharge into a waterbody that is impaired with only one pollutant or a waterbody that has not been tested to determine impairment status; and sub-basins were ranked 2 if they discharge into a waterbody that is impaired with more than one pollutant. These individual rankings were then added to generate an overall priority ranking for each sub-basin between 0 and 6.

Of the 177 known sub-basins in the watershed, six sub-basins were ranked as the highest priority (overall ranking of 6). Of these six, four are located in Kalispell, and two are in Whitefish. Six other sub-basins received an overall ranking of 5, of which three are in Kalispell, one in Whitefish, and one in Polson. This version of the outfall prioritization model does not target specific pollutant groups and does not consider multiple land use types within a single sub-basin.

Monitoring

To characterize actual stormwater runoff pollutants, one set of stormwater grab samples was collected at four outfalls in the watershed in the spring of 2020. These outfalls are located in Kalispell (KAL_AC6), Evergreen (EVE_SW1), Columbia Falls (COL_CB1), and Whitefish (WHI_WR5). They were selected because they had previously been sampled by Stanford et al. (1997) and Tappenbeck and Ellis (2011) and, therefore, had water quality datasets that could be expanded upon. For more information about the outfalls themselves, the sampling and analysis procedure that was followed, or the results of that analysis, see Henry (2020, 45-56). In later sections of this report, the results of this sample set are compared to the results of sampling analyses performed by the author in 2021 and those in the literature (Stanford et al., 1997; Tappenbeck & Ellis, 2011).

In addition to stormwater sampling, dry-weather outfall inspections were also performed to detect for illicit discharges, which are discharges into stormwater systems that are not composed entirely of stormwater. In order to be in compliance with its stormwater permit, the City of Kalispell must conduct inspections of its approximately 80 outfalls at least once over the course of each permit cycle. In Phase I, 21 outfalls were inspected, and only two had any measurable flow at the time of inspection. Of those two, neither were believed to be experiencing an illicit discharge based on the runoff's characteristics.

Public Education and Outreach

Finally, the Flathead Rain Garden Initiative (FRGI), a public education and outreach initiative, was launched in 2020. FRGI is jointly supported by the City of Kalispell, FBC, and the Flathead Conservation District (FCD), and its goal is to empower residents of Flathead County to take action against stormwater pollution by building rain gardens on their property. Rain gardens are landscaped depressions filled with native plants that are designed to capture stormwater, filter out any pollutants it contains, and allow it to infiltrate into groundwater. In 2020, the initiative hosted two virtual workshops, engaged 41 residents, and helped build eight rain gardens that collectively manage approximately 100,000 gallons of runoff per year.

Beginning in 2021, Phase II's goals were expanding the knowledge gained in Phase I and using that data to formulate potential future project objectives to improve and protect water quality in the basin from stormwater pollution. These objectives were achieved by (1) improving the Phase I outfall prioritization model; (2) making advancements in stormwater monitoring through continued grab sample collection, automatic sampler experimentation, and dry-weather inspections of outfalls; (3) expanding existing and developing additional public education and outreach initiatives; and (4) researching and planning long-term project objectives.

Revisions to Outfall Prioritization Model

One of the first goals of Phase II was to expand and improve the outfall prioritization model created in Phase I in order to more accurately identify sub-basins with high-polluting potential. In spring 2021, FBC's Technical Committee provided input on suggested model revisions. The Technical Committee is a standing committee of FBC consisting of a core team of experts who provide support and information on specific natural resource projects in the watershed. The Committee recommended two primary revisions: (1) Develop and utilize higher-resolution land use data for the watershed and (2) allow for consideration of multiple land use types within a single sub-basin's ranking.

Land Use Data

The first proposed improvement was to create and utilize higher-resolution land use data from aerial imagery acquired by the National Agriculture Imagery Program (NAIP). The land use data used in the Phase I model was created by the MTNHP using 30-meter resolution satellite imagery and included many land use categories that were irrelevant for a preliminary stormwater analysis. See Henry (2020) for more information about how this land use data was treated and used in the first iteration of the model (67-68). The Technical Committee proposed the integration of land use data using NAIP imagery because of its high, 0.6-meter resolution and because the land use categories could be tailored to include only those that influence stormwater quality and quantity in the watershed.

The land use classes used in analysis were water, agricultural, residential, developed (urban), and undeveloped (natural). Research conducted prior to selecting these categories found that in general, models in the literature most often consider some combination of the following land use types in their analyses: residential, industrial, institutional, commercial, agricultural, roadways, and forested (Kong et al., 2017; Pitt et al., 2004; Pitt et al., 2018; Song et al., 2019; Zgheib et al., 2011). However, because commercial, industrial, institutional, and roadways all appear similarly in aerial imagery, the software was unable to distinguish them from one another, and, therefore, they were lumped into the single category of developed land.

To differentiate these land use categories in the aerial imagery, the Maximum Likelihood Classification tool in ArcGIS Pro was utilized. Training polygons for each land use class were developed, and these polygons were used in the geoprocessing tool to identify and group spectrally similar areas of the landscape. Overall, 1141 training samples were created across the five land use classes: 212 for agriculture, 230 for developed, 558 for residential, 97 for water, and 44 for undeveloped. In general, the samples for water and undeveloped land use classes were larger than those for the other land use types, with residential samples being the smallest and, therefore, the most numerous. See Appendix A for a full description of the methodology used to develop this data. The results of this process are shown in Figure 1.

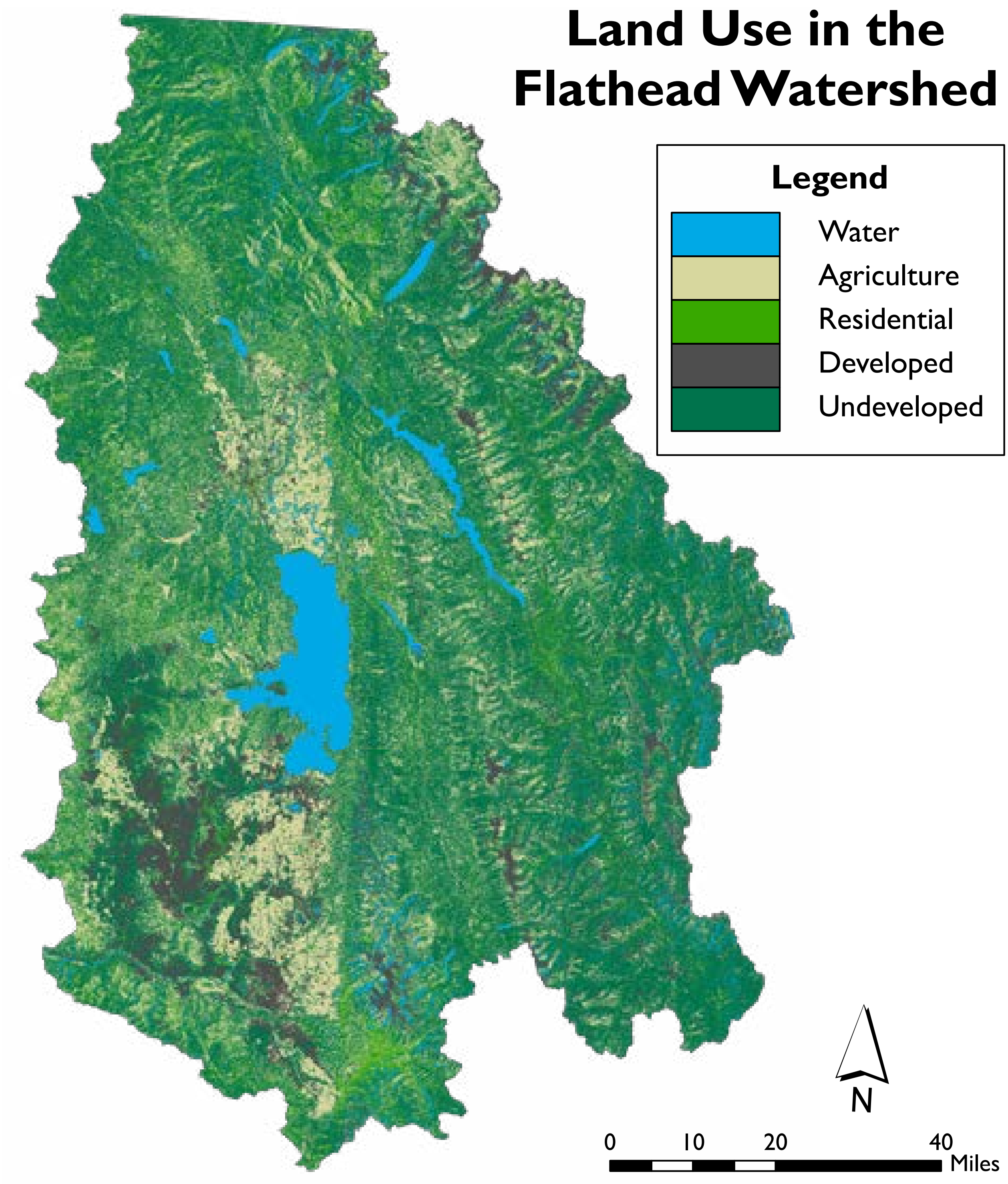


Figure 1. Land use in the Flathead Watershed. Land use data was created using images acquired in 2019 and 2020 by NAIP (USDA, 2020). See Appendix A for data creation methodology. Data only accounts for the portion of the Flathead Watershed in Montana. Projected Coordinate System: NAD 1983 (2011) StatePlane Montana FIPS 2500 (Meters).

Revised Rankings

PROCESS

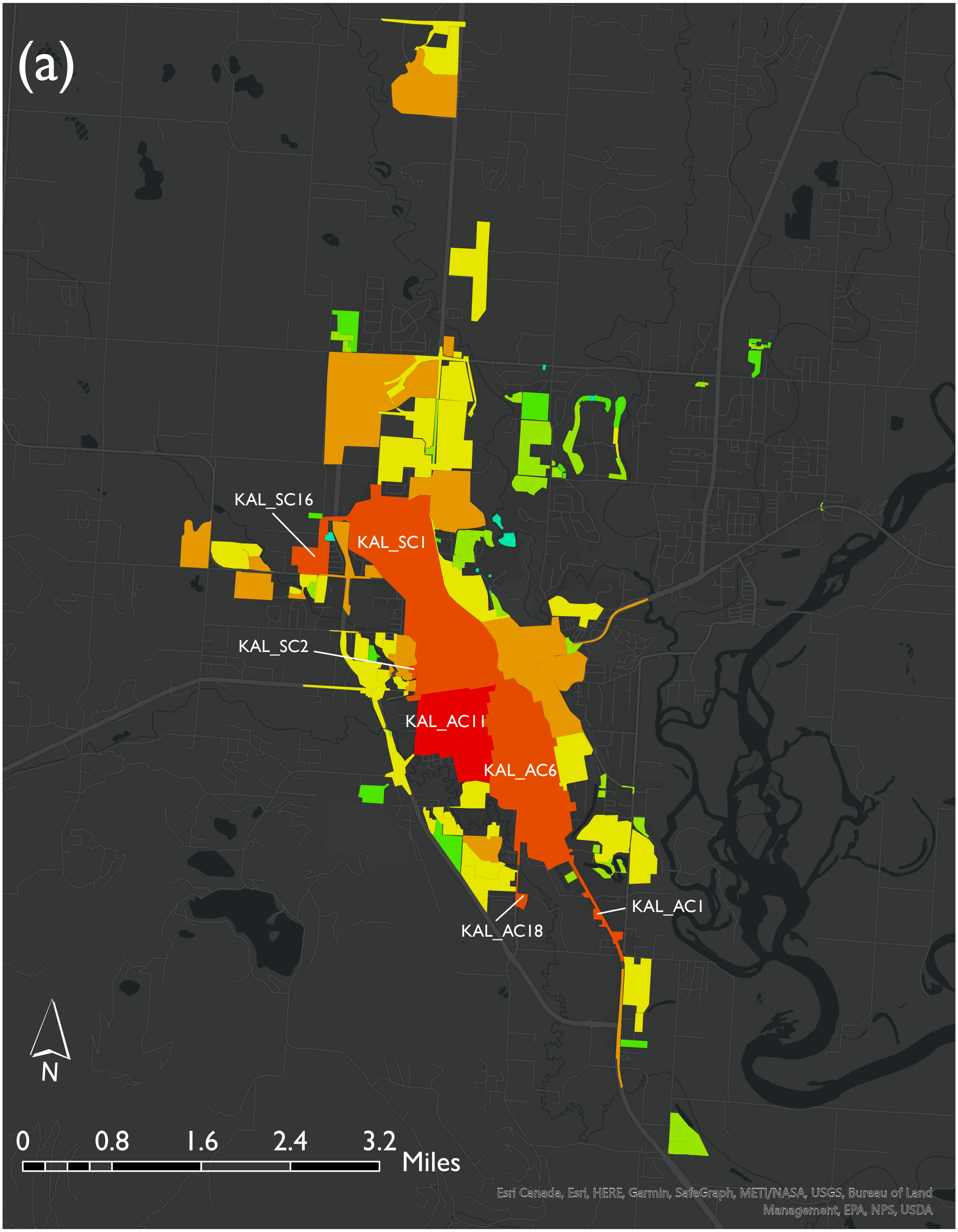
Using this new land use data, a revised system for ranking the sub-basins in the Flathead Watershed was developed. There is consensus in the literature that land use influences both stormwater quantity and quality (Goonetilleke et al., 2005; Ha & Stenstrom, 2003; Maestre & Pitt, 2006; Pitt et al., 2004; Song et al., 2019). However, it is also generally accepted that land use alone cannot predict stormwater quality, as it is affected by other variables on the landscape. One such variable is land use pattern, specifically the degree of connectivity among a single land use type (Lee et al., 2009; Liu et al., 2012; Zgheib et al., 2011; Zhang et al., 2013). Sub-basins with mixed, interspersed land use types have worse stormwater quality, which has been attributed to the complexity of the drainage systems in these scenarios (Lee et al., 2009; Liu et al., 2012).

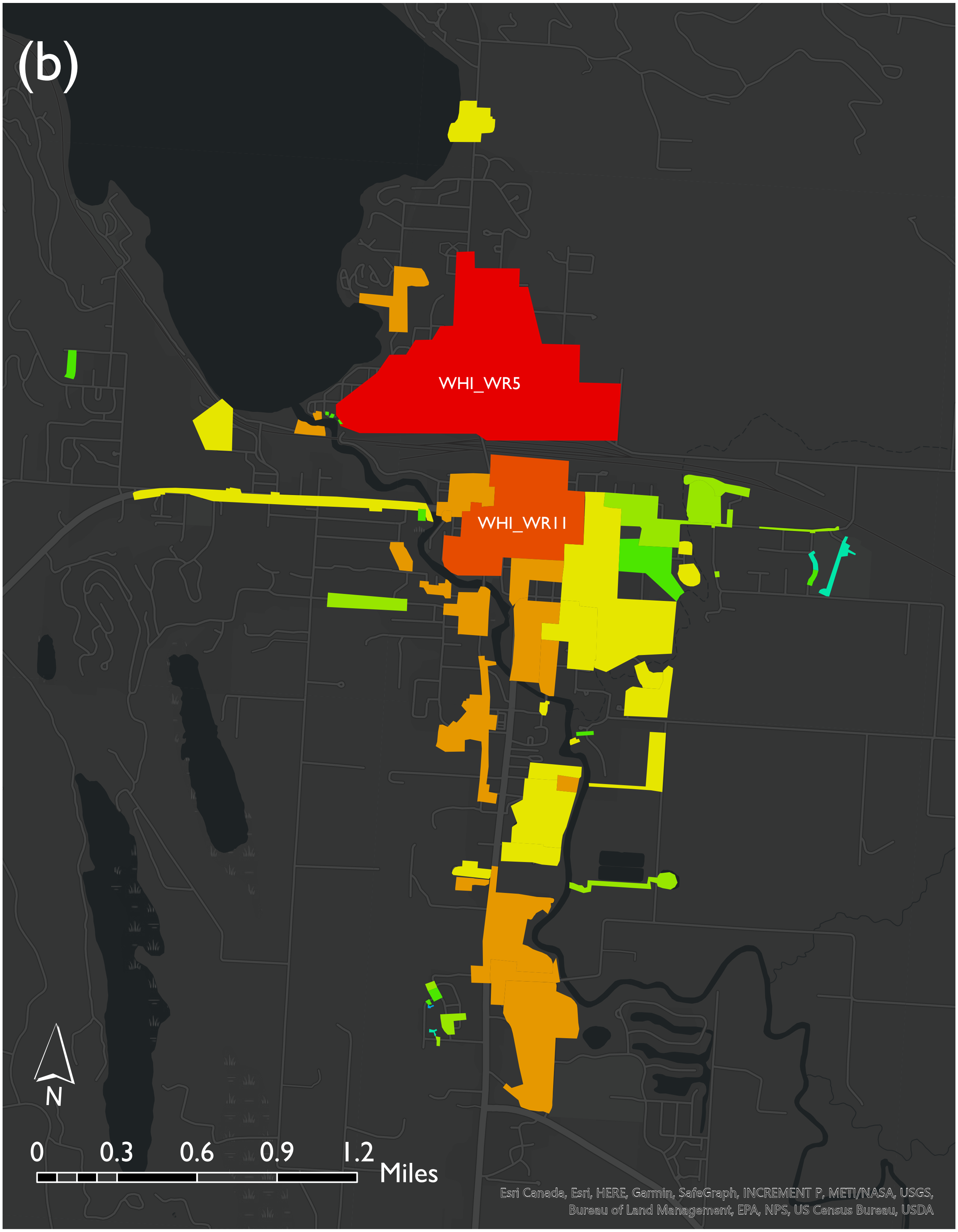
To account for multiple land uses within a single sub-basin, a score for degree of land use mixing was calculated for each sub-basin and considered in the revised outfall prioritization model. This score was calculated based on the difference between the highest and lowest terrestrial land use percentages for each sub-basin. If the difference between the largest and smallest land use classes was 0-15%, the sub-basin was considered higher priority and given a mixed land use score of 2. If the difference was 16-30%, the sub-basin was given a score of 1, and if the difference was 31-100%, the sub-basin was given a score of 0. These percentage groupings were designed to prioritize sub-basins with extremely mixed land use patterns. It should also be noted that the percent of a sub-basin comprised of water was not factored into this calculation.

In addition to the land use mixing score, an area score, an impairment status score, and an urban pollution potential score were also factored into the revised model. The urban pollution potential score takes into account the percent area of developed land uses within a sub-basin. Since urban, developed land influences both stormwater quality and quantity, while residential and agricultural land uses primarily affect only stormwater quality, the urban pollution potential score was given more weight than the other three scores. Sub-basins with 80-100% developed land were ranked 4, 60-79% developed land were ranked 3, 40-59% developed land were ranked 2, 20-39% developed land were ranked 1, and 0-19% developed land were ranked 0. The area scores and impairment status scores were calculated in the same way as they were for the first iteration of the model and are designed to prioritize larger sub-basins that discharge into impaired waterbodies. For more information about how the area and impairment status scores were calculated, see Henry (2020, 38-40). All four scores were then added together to produce an overall ranking.

RESULTS

This process identified nine sub-basins as high-priority. Two sub-basins, KAL_AC11 and WHI_WR5, received the highest overall ranking of 7 (considered first tier priority). The other seven sub-basins—KAL_SC16, KAL_SC1, KAL_AC6, WHI_WR11, KAL_SC2, KAL_AC18, KAL_AC1—received overall rankings of 6 (considered second tier priority) (Figure 2). The Phase II model identified the same six outfalls that ranked first tier priority by the Phase I model. These six outfalls identified by both the Phase I and Phase II models are KAL_SC1, KAL_SC16, KAL_AC11, KAL_AC6, WHI_WR5, and WHI_WR11 (Figure 2) (Henry, 2020, 38-44). However, the Phase II model did not recognize any of the outfalls that the Phase I model ranked in the second tier priority. These outfalls not identified by Phase II include KAL_SWR4, KAL_SWR15, KAL_SC14, KAL_SWR16, WHI_WR30, and POL_FR1 (Henry, 2020, 41-44). Instead, the Phase II model recognized three outfalls as second tier priority that were not identified by the Phase I model. These three outfalls include KAL_SC2, KAL_AC18, and KAL_AC1 (Figure 2). In Phase I, KAL_AC1 and KAL_SC2 received a cumulative ranking of 4, and KAL_AC18 was not included in the Phase I analysis. It was discovered that some outfalls in Kalispell had been excluded in the first phase of analysis due to a user error in data processing. The error was corrected, and the outfalls were included in the Phase II analysis. See Appendix B for the complete list of intermediate scores, Phase I rankings, and Phase II rankings for each of the 212 known sub-basins in the watershed.


(a)
KAL_SC16
KAL_SC1
KAL_SC2
KAL_AC11
KAL_AC6
KAL_AC1
KAL_AC18
N
0 0.8 1.6 2.4 3.2 Miles
Esri Canada, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA


(b)
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WHI_WR11
N
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0.3
0.6
0.9
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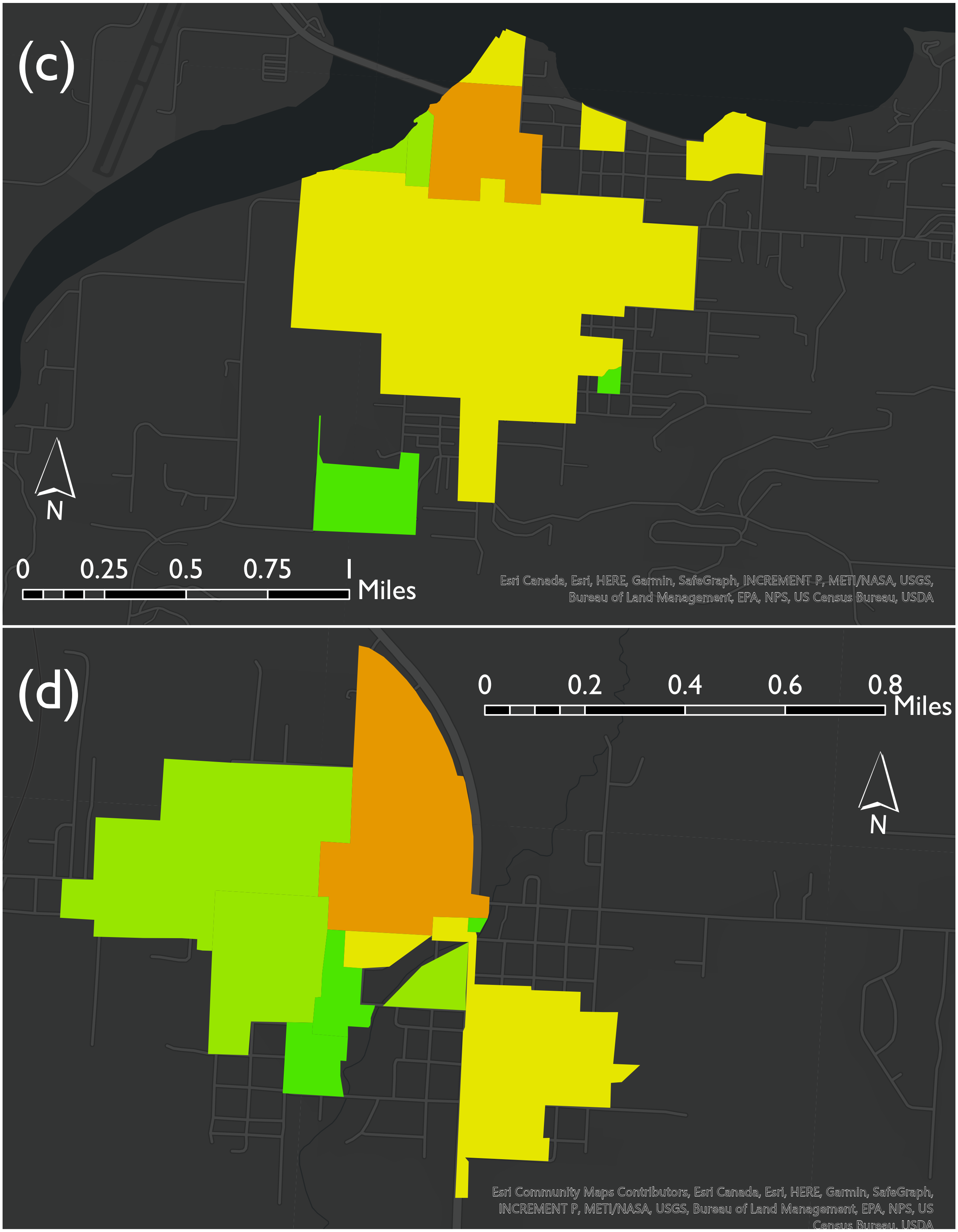
Esri Canada, Esri, HERE, Garmin, SafeGraph, INCREMENT P, METI/NASA, USGS,
Bureau of Land Management, EPA, NPS, US Census Bureau, USDA


(c)
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0.75
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(d)
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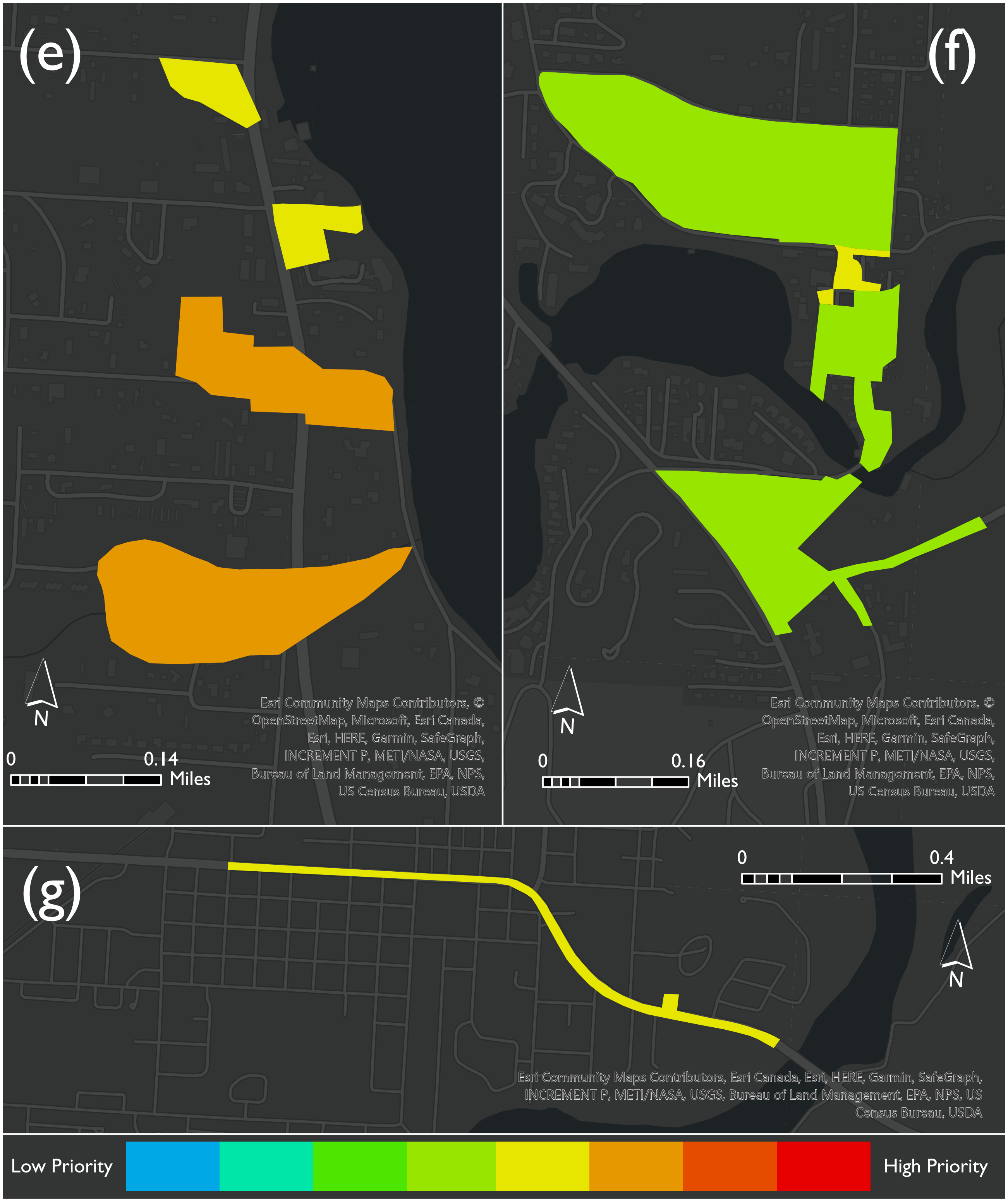


Figure 2. Results of the 2021 outfall prioritization model in (a) Kalispell and Evergreen, (b) Whitefish, (c) Polson, (d) Ronan, (e) Lakeside, (f) Bigfork, and (g) Columbia Falls. High priority sub-basins (cumulative score of 6 or 7) are labeled. Projected Coordinate System: NAD 1983 (2011) StatePlane Montana FIPS 2500 (Meters).

Future Considerations

Although these rankings can be used to give some idea of where high-polluting outfalls in the watershed may be, there are many things that should be considered to improve future versions of this model.

First, there are errors and shortcomings in the newly developed land use data that should be considered. As previously mentioned, all urban areas, including roads and highways, were encompassed in the larger developed land use category because their spectral similarities did not allow the geoprocessing tool to distinguish them. Finding a method to distinguish commercial, industrial, roadways, and highways from one another would likely be beneficial for future stormwater analysis. One potential way to do this would be to use vector data to reclassify pixels in the raster dataset where roadways and highways intersect to add further nuance to the dataset. Additionally, the geoprocessing tool was unable to distinguish barren or snow-covered undeveloped areas from highly developed ones, which is particularly apparent in the southwest portion of the watershed and in areas of Glacier National Park (Figure 1). Because of this, urban land uses are overrepresented in this land use data. Furthermore, it would likely be beneficial to attempt to distinguish high-density from low-density residential areas. Research indicates that detached housing (low-density residential) may more negatively impact stormwater quality than higher-density residential areas (Goonetilleke et al., 2005). While the causes for these trends have not been clearly identified, it is possible that residential landscaping practices may cause the increased pollutant loading and variability seen in low-density residential runoff (Goonetilleke et al., 2005). These trends may influence future land use planning and treatment of residential stormwater and should be further researched. Finally, there are additional land use classes that may be important to consider in future stormwater analyses but were logistically difficult to incorporate into this version of the model, including parkland, golf courses, mining and extraction areas, harvested forestland, and recently burned areas. These areas may have complex impacts on stormwater that the current model fails to consider.

Second, land use pattern should be determined for each sub-basin and considered in future, more complex models. As previously mentioned, research has found land use pattern and the degree of land use mixing and interspersion within a basin to strongly influence stormwater quality. Land use pattern can refer to many characteristics, including the placement and connectivity of impervious surfaces in a watershed. While land use type influences the total impervious area (TIA) and, therefore, affects stormwater quantity, recent research is recognizing that the degree of connectivity of impervious surfaces, or connected impervious area (CIA), often influences stormwater quality more than the TIA because it controls the speed at which stormwater is transported from the landscape into waterbodies. Recent research has been focused on determining methods by which land use pattern and CIA can be calculated, methods which may be considered for use in future model iterations (Ebrahimian et al., 2018; Janke et al., 2011). Even if not factored into priority rankings, land use pattern may be useful in determining most effective locations of stormwater solutions and should be considered in that respect (Kong et al., 2017; Paule-Mercado et al., 2017).

Third and finally, a methodology to account for multiple land use types within a sub-basin according to a “sliding scale,” as proposed by the Technical Committee, was not developed, partially because the land use classes used in the classified land use data are generalized. If more detail is able to be incorporated into the land use dataset, further guidance from the Technical Committee on how best to accomplish this would be beneficial.

Advancements in Monitoring

While the outfall prioritization model can provide an assessment of where pollutants are likely entering waterbodies, stormwater monitoring is necessary to physically characterize runoff across the watershed and to accurately identify solutions to improve stormwater quality. Two forms of monitoring—stormwater sampling and dry-weather outfall inspections—were implemented in Phase II, and their potential uses in future, basin-wide monitoring efforts were examined.

Stormwater Sampling

Stormwater sampling involves the collection of runoff discharging from an outfall during a rain event. There are multiple methods by which these samples can be collected, including manual grab sampling and using an automatic stormwater sampling device.

GRAB SAMPLING

Overview

The technically simpler of the two methods, grab sampling involves personnel manually filling sample bottles with stormwater runoff during a rain event, ideally capturing the first flush. The first flush is the initial runoff from a rain event and often mobilizes the majority of pollutants that have accumulated on the landscape since the preceding precipitation event. Because of this, the first flush often contains higher pollutant concentrations than the rest of the stormwater runoff from the event. To capture the first flush, it is recommended that grab samples be collected within the first hour of rainfall. There are additional conditions for ideal grab sample collection that include a minimum of 0.1 inches of total accumulation at the time of sampling and a dry period of at least two weeks since the preceding rain event. These parameters are meant to ensure that there is an adequate flow volume for sample collection and that pollutants will have had adequate time to reaccumulate on the landscape since they were last washed away. In practice, these conditions are challenging to meet and difficult to predict, especially with many sampling sites across multiple locations.

Procedure

During 2021, grab samples were collected during four storm events at the same four outfalls sampled in 2020. The locations include Kalispell (KAL_AC6), Evergreen (EVE_SW1), Columbia Falls (COL_CB1), and Whitefish (WHI_WR5). The same sampling procedures described in Henry (2020, 49) were followed when possible; however, because of how rarely all three grab sampling parameters are met at all locations during a single storm event, these procedures were relaxed slightly. For example, samples were still collected even if the total precipitation accumulation was less than 0.1 inches at the time of sampling or if the first flush was believed to have already passed. In order to contextualize sampling results, detailed records of weather conditions before, during, and after sample collection were taken (Appendix C). Data from local weather stations was used to determine precipitation accumulations, storm durations, and temperatures at each location, the details of which are shown in Appendix D.

The first of the sampling events (Event 1) occurred in the spring on April 22; the other two (Events 2 and 4) occurred in the late summer on August 8 and August 21, respectively. Event 3 occurred on August 17, but there were only sufficient precipitation volumes for sampling at WHI_WR5. In-field sampling data is shown in Appendix E, and graphs of weather patterns on the day of sampling in each location are shown in Appendix F. The laboratory results from the samples collected in 2021 were compiled and compared to the results from stormwater sample analyses conducted by Henry (2020), Tappenbeck and Ellis (2011), and Stanford et al. (1997) (Table 1 and Figure 3).

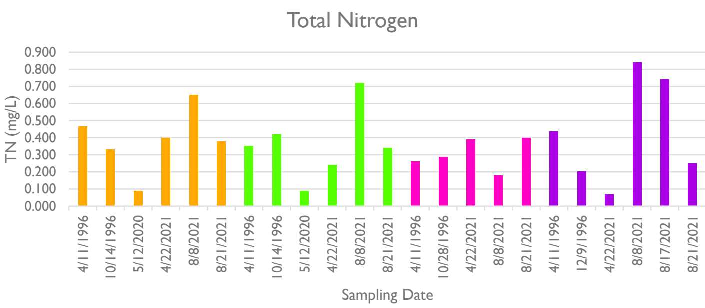
			Sample Parameters										
Outfall Name	**Sampler**	**Sample Date**	**DO (mg/L)**	**pH**	**TSS (mg/L)**	**COD (mg/L)**	**TN (mg/L)**	**TP (mg/L)**	**TKN (mg/L)**	**Cu (mg/L)**	**Pb (mg/L)**	**Zn (mg/L)**	**Oil & Grease (mg/L)**
KAL_AC6	Stanford et al.	4/11/1996	9.0	5.5	369.0		0.465	0.1271		0.007	<0.040*	0.040	
	Stanford et al.	10/14/1996	8.0	7.0	<50*		0.333	0.4394		0.022	<0.040*	0.248	
	Tappenbeck & Ellis	5/16/2011								<0.0040*	0.00024	0.0159	
	Henry	5/12/2020	8.29	8.35	138	177	0.09	0.24	1.57	0.012	0.0060	0.106	1
	Henry	4/22/2021	10.09	8.83	1430	378	0.40	0.88	3.74	0.041	0.0231	0.309	6
	Henry	8/8/2021	6.46	8.05	63	188	0.65	0.30	1.70	0.012	0.0031	0.072	2
	Henry	8/21/2021	7.74	8.36	41	114	0.38	0.18	0.67	0.008	0.0027	0.059	2
Average			8.26	7.68	408	214	0.39	0.36	1.92	0.017	0.0070	0.121	3
EVE_SW1	Stanford et al.	4/11/1996	10.0	5.0	140.0		0.352	0.4968		0.026	0.061	0.322	
	Stanford et al.	10/14/1996	8.0	7.0	100		0.420	0.5226		0.019	<0.040*	0.190	
	Tappenbeck & Ellis	5/16/2011								0.0065	0.00045	0.0118	
	Henry	5/12/2020	8.90	8.50	357	184	0.09	0.32	1.63	0.030	0.0203	0.288	2
	Henry	4/22/2021	10.76	9.07	1970	658	0.24	1.08	2.80	0.086	0.0718	0.775	11
	Henry	8/8/2021	6.88	8.03	298	513	0.72	0.38	4.52	0.044	0.0236	0.270	2
	Henry	8/21/2021	7.97	8.26	97	199	0.34	0.20	1.39	0.021	0.0098	0.164	2
Average			8.75	7.64	494	389	0.36	0.50	2.59	0.033	0.0312	0.289	4
COL_CB1	Stanford et al.	4/11/1996	12.0	7.4	369.0		0.261	0.5776		0.019	0.050	0.203	
	Stanford et al.	10/28/1996	9.5	7.5	317		0.287	0.4895		0.017	0.044	1.260	
	Tappenbeck & Ellis	5/16/2011								0.0064	0.00016	0.0090	
	Henry	5/13/2020	9.51	8.68	287	132	ND*	0.33	1.92	0.015	0.0088	0.152	ND*
	Henry	4/22/2021	10.07	8.39	170	231	0.39	0.29	2.05	0.022	0.0072	0.191	3*
	Henry	8/8/2021	8.33	8.32	142	143	0.18	0.18	0.96	0.009	0.0038	0.110	2
	Henry	8/21/2021	8.36	5.58	57	183	0.40	0.17	1.58	0.017	0.0038	0.124	3
Average			9.63	7.65	224	172	0.30	0.34	1.63	0.015	0.0168	0.293	3
WHI_WR5	Stanford et al.	4/11/1996	10.0	7.0	42.0		0.438	0.2946		0.011	<0.040*	0.435	
	Stanford et al.	12/9/1996	11.0	7.1	2		0.202	0.0673		0.007	<0.040*	0.019	
	Henry	5/13/2020	8.23	8.05	324	128	ND*	0.26	1.54	0.014	0.0125	0.110	ND*
	Henry	4/22/2021	10.48	8.26	169	88	0.07	0.20	0.85	0.008	0.0078	0.053	1*
	Henry	8/8/2021	7.60	8.08	572	401	0.84	0.91	4.33	0.026	0.0145	0.142	3
	Henry	8/17/2021	7.10	8.05	42	197	0.74	0.30	2.46	0.010	0.0023	0.063	2
	Henry	8/21/2021	7.91	7.98	43	108	0.25	0.16	0.54	0.006	0.0030	0.031	1
Average			8.90	7.79	171	184	0.42	0.31	1.94	0.012	0.0080	0.122	2

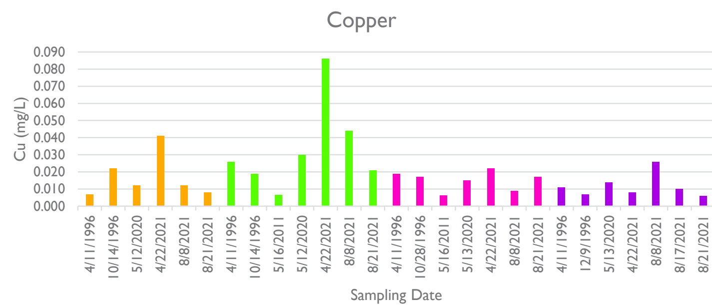
Table 1. Compiled stormwater sampling results from Henry (2021), Henry (2020), Tappenbeck & Ellis (2011), and Stanford et al. (1997). See Tappenbeck & Ellis (2011) and Stanford et al. (1997) for details about their sampling and analysis procedures. * indicates an approximate value and was not included in average calculations.

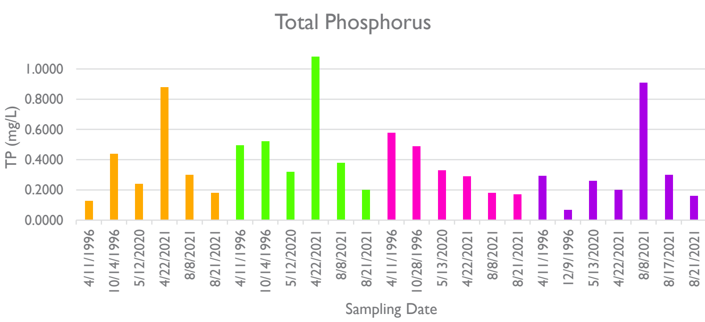
Results

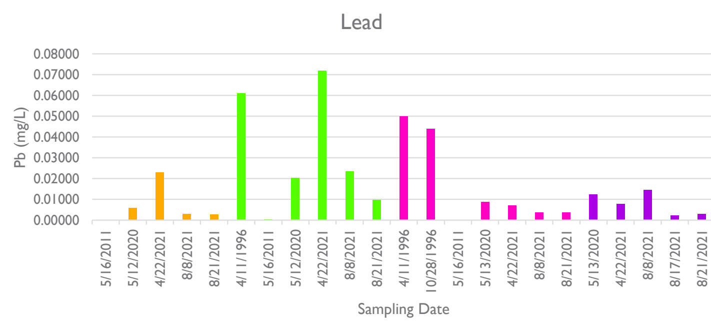
While caution should be taken when comparing stormwater sampling results from multiple events, there are a few trends that emerge from the limited data (Table 1 and Figure 3). The samples collected at KAL_AC6 and EVE_SW1 on 4/22/2021 have higher pollutant concentrations. Particularly, the sample from EVE_SW1 had extremely high TSS, Cu, and oil and grease concentrations and higher-than-average COD, TP, and Zn concentrations. Similarly, the sample from KAL_AC6 has higher-than-average concentrations of TSS, COD, TP, Cu, Zn, and oil and grease. The samples collected on 8/8/2021 are also notable. KAL_AC6, EVE_SW1, and WHIL_WR5 show higher-than-average concentrations of TN. EVE_SW1 and WHI_WR5 also show higher-than-average concentrations of TKN, and WHI_WR5 shows higher-than-average concentrations of TP, as well. The samples collected by Stanford et al. (1997) at COL_CB1 had higher concentrations of Pb than more recent samples, and the fall sample collected in 1996 shows anomalously high Zn concentrations. However, this is not a large enough data set to begin to determine the statistical significance of these apparent trends.

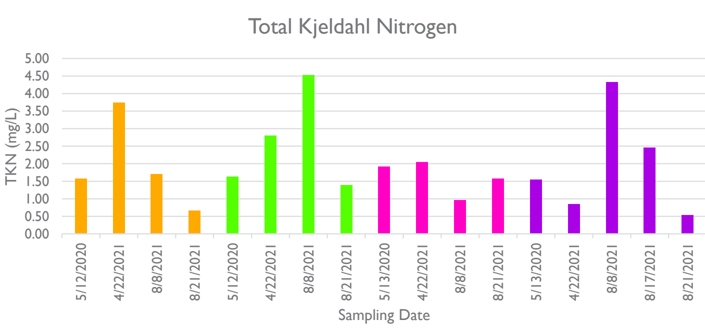
Figure 3. Graphs of compiled stormwater sampling results from Henry (2021), Henry (2020), Tappenbeck & Ellis (2011), and Stanford et al. (1997). See Tappenbeck & Ellis (2011), Stanford et al. (1997), and Henry (2020) for details about the sampling and analysis procedures followed for each sample set.

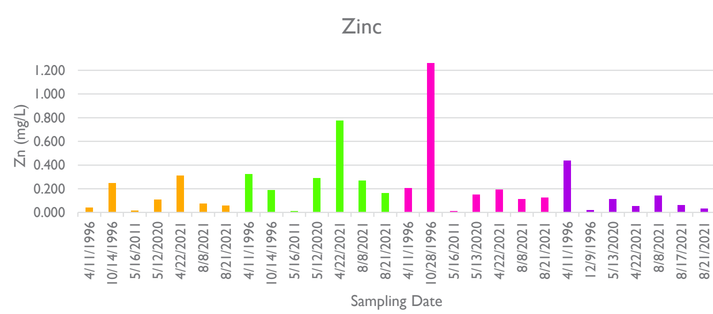


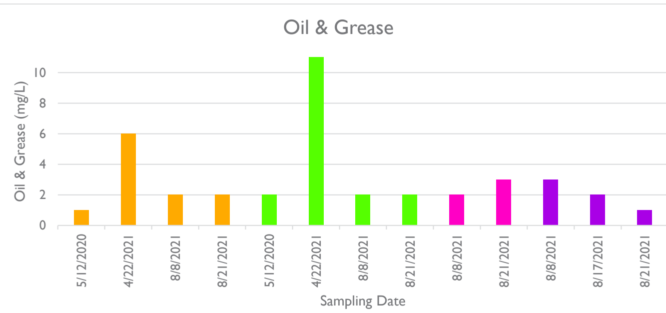












LEGEND

Kalispell | Evergreen | Columbia Falls | Whitefish

Figure 3. Graphs of compiled stormwater sampling results from Henry (2021), Henry (2020), Tappenbeck & Ellis (2011), and Stanford et al. (1997). See Tappenbeck & Ellis (2011), Stanford et al. (1997), and Henry (2020) for details about the sampling and analysis procedures followed for each sample set.

AUTOMATED SAMPLING

Overview

In contrast to manual grab sampling, automatic stormwater sampling requires more upfront work and technical expertise. Automatic samplers are designed to be installed at an outfall prior to a sampling event, and a suction tube from the outfall to the sampler allows the machine's pump to withdraw samples of stormwater throughout the duration of a storm event. In this way, samples collected using an automatic sampler are more representative of the event mean concentrations (EMCs) of pollutants than grab samples, which represent pollutant concentrations at just a moment in time and can be much higher than the event mean if capturing the first flush or much lower if the first flush has already passed. There are multiple ways to program automatic samplers, the two primary ways being flow-weighted sampling and time-based sampling. When programmed for flow-weighted sampling, automatic samplers will be triggered to collect a pre-determined volume of sample after a certain volume of flow has passed from the outfall. To do this, a sensor must be used with the machine to directly measure or indirectly calculate the discharge throughout the storm event. When programmed for time-based sampling, automatic samplers will be triggered to collect a pre-determined volume of sample after a certain increment of time has passed, regardless of the rate of flow from the outfall. In this way, flow-weighted sampling programs allow for the collection of greater sample volumes during periods of higher flow.

Equipment and Procedure

The City of Kalispell owns a Teledyne Isco© 6712 Full-Size Portable Sampler, a 750 Velocity Module, a 913 High-Capacity Power Pack, and an external battery. Together, the external battery and power pack serve to remotely power the automatic sampler, while the velocity module allows for flow-weighted programming. The Teledyne Isco© 750 Velocity Module measures the flow velocity and depth of water at an outfall over the course of the storm event and, when programmed with the outfall's cross-sectional area data, can indirectly calculate the discharge. Together, these instruments allow for the collection of flow-weighted samples and sample initiation to take place once a certain flow is achieved. FBC also purchased a Teledyne Isco© 674 Rain Gauge that is compatible with these instruments. The purpose of the rain gauge is to further inform the initiation of sampling. Through the sampler's extended programming, it's possible to include multiple triggers for sample initiation, such as when there's a certain flow coming from the outfall (as measured by the velocity module) and when certain precipitation accumulations and rates are achieved (as measured by the rain gauge). For example, with these instruments working together, it's possible to start collecting a stormwater sample only when (1) there has been at least 0.15 inches of rainfall in 30 minutes and (2) there is at least one inch of runoff present in the outfall.

Figure 4. Outfall at KAL_AC6. Two pipes converge and discharge into the grassy channel. Picture taken August 8th, 2021.

The automatic sampling equipment was configured for testing at KAL_AC6, an open channel outfall that has a record of stormwater grab sampling (Figure 4). Two pipes discharge into this channel, and the outfall collects runoff from a large portion of downtown Kalispell of primarily commercial land use. To prepare the equipment to collect automatic samples, the cross-sectional area data was collected for the channel. The specific location in the channel to collect samples was chosen based on (1) the distance away from the two pipes and (2) the topography of the channel bottom. At KAL_AC6, the sampling location was chosen because it is far enough away from the two pipes to allow for adequate mixing of stormwater and is an area with a relatively flat channel bottom (Figure 5). At the sampling location, the channel width was determined to be 2.72 meters. Depth was measured at seven points across the channel (every 0.34 meters). Cross-sectional area was then estimated by multiplying the depth measurements at the seven locations by the width between measurements (0.34 meters) to determine approximate areas for each section of stream. Then, the area segments were added together to produce an overall estimate of cross-sectional area. The width-depth measurements taken at KAL_AC6 are shown in Table 2, and a graph of the approximate channel morphology is shown in Figure 6. The midpoint of the wetted area at the time the measurements were collected is labeled in Figure 6 as Mw, and this location is where cross-sectional area measurements were calculated for varying water depths. Because the area-velocity sensor owned by the City of Kalispell measures only water level (depth), these depth-area relationships are necessary in order for the sampler to calculate discharge. The depth-area correlations used to program the automatic sampler for KAL_AC6 are shown in Table 3.

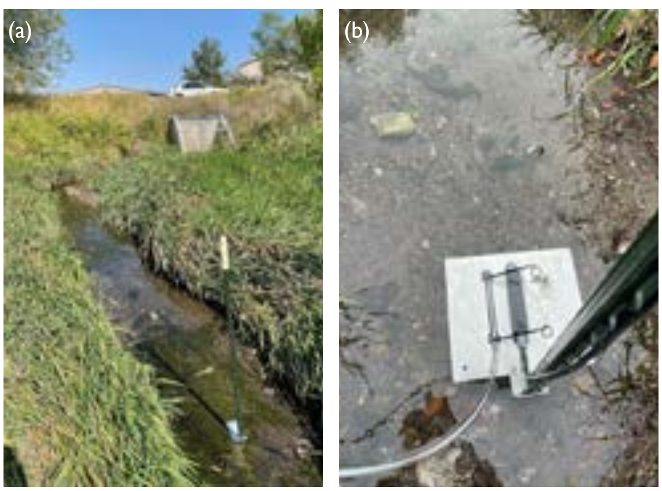


Figure 5. Location along channel at KAL_AC6 to test automatic sampler. (a) T-post and bracket at exact sampling spot. (b) Sensor plate connected to T-post bracket with area-velocity sensor and sampling tube and strainer mounted. Pictures taken August 30, 2021, and September 28, 2021, respectively.

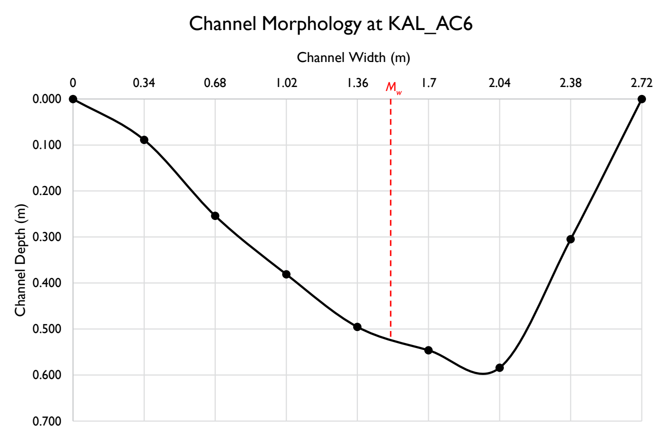


Figure 6. Channel morphology of KAL_AC6 at location of sampling. Created using the width-depth measurements in Table 2. Midpoint of the wetted area (Mw) is 1.54 meters from the left bank and is the spot for which depth-area correlations were calculated.

Width (m)	Depth (m)
0	0
.34	.089
.68	0.254
1.02	0.381
1.36	0.495
1.70	0.546
2.04	0.584
2.38	0.305
2.72	0

Table 2. Width and depth measurements taken at KAL_AC6 at location of sampling. Width measurements indicate the horizontal distance from the left channel bank, and depth marks the distance from the channel bottom to bankfull. These measurements were used to create an approximate outline of channel morphology (Figure 6).

Depth (ft)	Cross-Sectional Area (ft^2)
0.000	0.000
0.430	1.560
0.750	2.950
1.080	5.000
1.250	6.090
1.410	7.190
1.570	8.290
1.740	9.710

Table 3. Depth-area correlations used to program the automatic sampler for KAL_AC6. The depth measurements are for the midpoint of the wetted area (Mw) (Figure 6). Note measurements in feet.

Once the cross-sectional area of the channel was calculated, the other details of the automatic sampling program were chosen. The sampler's extended programming was utilized to collect a combination of time-based (Part A) and flow-weighted samples (Part B). First, the program requires at least 0.15 inches of precipitation over 30 minutes (as measured by the rain gauge attachment) and a water depth of 0.1 feet in the channel (as measured by the area-velocity sensor) in order to initiate sampling. Once these parameters are met, then, Part A, the time-paced program, initiates. To capture the first flush, one 200-mL sample is taken every five minutes for the first hour after initiation. Part B, the flow-weighted program, then takes over and collects one 100-mL sample after every 1,000 gallons of flow pass. Part B runs for the rest of the storm event for a maximum run-time of four hours. All 200- and 100-mL samples are composited into a single 9-liter sample bottle. The measurements collected by the rain gauge and area-velocity sensor are stored by the machine and can be downloaded to a desktop using Flowlink® software after the event. This specific sampling program was chosen based on the suggested stormwater sampling program in the sampler's user manual, and it is likely that experimentation would lead to some alterations in future programing. Unfortunately, the automatic sampler was unable to be tested during a storm event at KAL_AC6 in 2021 due to time constraints.

RESEARCH AND FUTURE CONSIDERATIONS

There are many things to consider when determining what kind of stormwater monitoring program to implement at a given location. Collecting grab samples is generally less expensive and requires minimal technical expertise, but it can be logistically difficult, especially with multiple sampling locations. Grab sampling also requires personnel to be available every time there's a rain event, which is periodically infeasible and can be dangerous depending on the time of day and location. Additionally, it's well-accepted that grab sampling produces a lot of scatter in the data, and pollutant concentrations in grab samples are highly dependent on other variables, including the timing within the event and the season of sample collection (Lee et al., 2007). It usually requires many years of grab sampling data before trends in the pollutant concentrations can be established, and even then, the samplers would need to be collecting accurate discharge measurements every time they sample in order to discern pollutant loading, or EMCs, at an outfall (Lee et al., 2007).

Automatic samplers, on the other hand, produce more consistent data and do not require personnel to go out during a storm event. Rather, staff can set up the sampler prior to an event and pick up the samples afterward. There are even case studies of setups with solar panels to power automatic samplers on-site such that they can be left out and controlled remotely, removing the need to set up the sampler beforehand and only requiring sample pick up after an event (Gillespie et al., 2004). Additionally, when connected to a flow meter, automatic samplers are able to either directly measure or indirectly calculate discharge throughout the course of a storm event and, therefore, more accurately predict EMCs than grab sampling, particularly when a flow-weighted sampling program is used (Harmel et al., 2006 & references therein; Lee et al., 2007; Leecaster et al., 2002). There is also a great deal of flexibility in the type of sampling program enacted using an automatic sampling device. For example, users can collect discrete samples rather than the composite sample described in the program above, allowing for users to assess how pollutant concentrations vary throughout the course of a single storm event.

However, automatic sampling devices have their own set of challenges. First, automatic sampling has a higher upfront cost and long-term equipment maintenance costs that simple grab sampling does not. Additionally, more technical expertise is needed to understand the machine, including how to physically set it up at the chosen outfall and how to determine the best sampling program. Finally, certain pollutant groups cannot be analyzed using automatic samplers, including oil and grease, pH, and DO. These analyses either require preservatives to be added to the sample at the time of collection (as is the case with oil and grease) or require measurements to be taken in the field (as is the case with pH and DO). Therefore, automatic samples are more limited in the types of stormwater quality information they can provide than grab samples.

Weighing these pros and cons of both grab and automatic sampling programs and assessing how they fit into particular monitoring goals will be essential in determining a project's success. Specific recommendations for future monitoring objectives are presented in the "Monitoring and Model Validation" section and consider the benefits and drawbacks mentioned here.

Dry-Weather Outfall Inspections

As previously mentioned, the City of Kalispell is required to conduct dry-weather inspections of its nearly 80 outfalls once every permit cycle (five years) in order to stay in compliance with its stormwater permit. These inspections are intended to detect illicit discharges at stormwater outfalls, which have the potential to be extremely detrimental to water quality.

ACCOMPLISHMENTS

In August of 2021, 29 outfalls in Kalispell were inspected during periods of dry weather. The same outfall inspection process documented in Henry (2020, 57) was followed in 2021. Of these 29 outfalls, three were experiencing dry-weather flow at the time of the inspection. Of these three, only one of these outfalls was listed as potentially experiencing an illicit discharge; the other two were expected to be experiencing flows at the time of inspection because they are mischaracterized as outfalls and are either a culvert channeling a stream or the outflow pipe from a stormwater detention pond. The one outfall of concern is owned by MDT and located off of the U.S. 93 bypass in an area of active, heavy construction, and because of its location, the author was unable to safely identify the source of the flow. However, there were no evident indicators of an illicit discharge (no odor, color, or floatables), so it is unlikely that this flow was posing an urgent threat to local water quality. After reporting the flow to Kalispell's Environmental Coordinator, it was discovered that an unnamed creek nearby is likely the source of the flow seen.

FUTURE CONSIDERATIONS

Because it is the only permitted municipality within the watershed, the City of Kalispell is the only urban area in the Flathead Basin that is known to inspect for dry-weather flows. Because of this, Henry (2020) recommended that these inspections be performed for high-priority outfalls in other cities and towns in the basin in 2021 and that this practice be incorporated into future stormwater programs in these areas (58-59). Although no inspections of outfalls outside Kalispell were conducted in 2021, this continues to be a recommendation to be implemented in the future. However, the appropriate staff members within each area to whom dry-weather flows would be reported should be identified beforehand.

Many urban areas of the watershed do not have staff that are solely dedicated to managing and maintaining stormwater infrastructure, so investigating an illicit discharge would likely not be a high priority for these staff members with multiple other responsibilities. Additionally, because they are unregulated, there is no legal incentive for these cities and towns to care about potential illicit discharges. Therefore, the partners will likely need to create incentives to encourage other urban areas in the basin to adopt this outfall inspection process as part of their regular maintenance program. Recommendations regarding the expansion of the dry-weather outfall inspection process are discussed further in the "Increased Capacity for Management and Maintenance of Stormwater Infrastructure" section.

Public Education and Outreach

To complement and support the technical modeling and monitoring work, public education and outreach programs and events were developed and hosted. These programs and events are intended to raise awareness about nonpoint source pollution issues in the watershed and provide an avenue for residents to take action. Three of the larger programs and events include the Flathead Rain Garden Initiative, an Adopt-a-Drain campaign, and the 2021 Flathead Waters Cleanup.

Flathead Rain Garden Initiative

ACCOMPLISHMENTS

In 2021, FRGI was able to work with five homeowners to build seven rain gardens in Flathead County that collectively manage approximately 90,000 gallons of runoff every year. The team hosted a workshop at the Center for Native Plants in Whitefish in August as part of their summer seminar series, and two of the homeowners who built rain gardens this year did so after learning about the program at this workshop. The other two homeowners learned about the program through word-of-mouth and through a radio advertisement. Check-in visits were conducted for all past participants to (1) see how their gardens progressed over the first year, (2) address any concerns and celebrate any successes, and (3) get feedback about ways in which the program could improve moving forward. Overall, participants expressed very few concerns and offered useful suggestions for program growth and development.

Additional resources were developed to support the program, including a revised homeowner incentive agreement and an accompanying impervious area calculator tool. FRGI utilizes grant and FCD funding to purchase native plants for participating homeowners to put in their rain gardens. In 2020, the incentive program outlined three funding tiers based on the size of the proposed rain garden, giving more money to homeowners that were building larger gardens. It was determined that this method of allocating funding was inadvertently giving more of program funds to homeowners in low-density, typically higher-income neighborhoods. Homeowners in high-density neighborhoods tend to have a fixed amount of available yard space to build gardens, so many were unable to qualify for the highest funding tier despite the fact that some of their gardens would be managing the same amount of runoff annually as some of the larger gardens. Because of this, the 2021 homeowner incentive program was changed to outline funding

tiers based instead on the area of impervious surface that would be contributing drainage to the proposed rain garden. In this way, proposed gardens are granted funding according to the volume of runoff they will capture and infiltrate, the primary metric that determines how effective a garden will be for reducing stormwater pollution. To accompany this revised incentive agreement, an online impervious area calculator tool was developed that allows homeowners to easily measure the area of impervious surface that will be contributing to their garden using satellite imagery. The tool provides an estimated measurement, as it cannot account for the slope of rooftops, but it provides homeowners with a number that they can use to plan and design their rain garden. Additionally, a flyer highlighting key rain garden maintenance practices was developed with assistance from experts at the Center for Native Plants. This flyer was distributed to all 2020 participants to help guide their maintenance efforts.

FUTURE CONSIDERATIONS

FRGI is considering a few options to promote continued program growth. One of these is a referral incentive program that would incentivize past participants to spread the word about the program. Potential incentives for such a program include gift cards to the Center for Native Plants and gardening toolkits with FRGI's logo. Additionally, the program is planning targeted outreach in areas of new development in the county. Areas of new development tend to lack existing landscaping, so targeting these areas would present an ideal opportunity to introduce rain gardens into the original landscaping of homes. Newly developed areas also tend to have construction equipment on-site that could potentially be utilized to excavate rain gardens for interested homeowners. Finally, FRGI is in the process of developing a relationship with a local landscaping company, Forestoration, that could assist homeowners who may require assistance beyond what FRGI can provide. This relationship will

likely prove a viable option for residents who have the resources to hire a landscaper but lack the time or ability to build the garden themselves. The logistics of all these opportunities for growth are currently still in development with the hope that they can be implemented in the coming year.

As FRGI continues to grow and become more recognizable in the community, there are a few opportunities for capacity-building that the program might consider moving forward, as well. For example, FRGI is considering creating a volunteer network that could assist participants with the physical labor required to build rain gardens. A program like this would greatly increase FRGI's capacity to provide residents with technical assistance and would help future participants overcome one of the largest barriers to participation. Currently, a volunteer handbook is being developed and the program logistics worked out in anticipation of a volunteer network being initiated in the next year.

Adopt-a-Drain Campaign

Another education and outreach initiative being developed is the City of Kalispell's Adopt-a-Drain campaign. The Adopt-a-Drain program would recruit Kalispell residents to volunteer to clean debris off storm drains in their neighborhoods both to keep that debris out of local waterbodies and encourage residents to consider nonpoint source pollution and what they leave on the landscape. Program development began at the beginning of 2021 and is still underway.

ACCOMPLISHMENTS

To develop this program, research was done on similar programs across the country and state. Conversations were had with the organizers of the City of Bozeman's program to learn more about how their program operates. Then, elements of these programs were combined to create an ideal program for Kalispell. Because of the city's limited capacity, Kalispell's ideal program is mostly automated, with volunteer registration and drain selection done online through the program's website. Volunteers will need to agree to a liability waiver, read the volunteer guidelines, and watch a training video or attend an in-person training before they are eligible to participate. Toolkits will be available for volunteer teams to pick up at City Hall, which include a broom, dustpan, reflective safety vest, gloves, trash bags, and an informative yard sign in a reusable tote bag with the program's logo. Finally, a brand guide was developed in order to effectively advertise the program. Initially, the city had hoped to launch the program in 2021, but due to unforeseen hurdles with insurance and technical issues with the website, Kalispell was unable to meet this timeline. The city plans to roll out this program as soon as the website is fully functional, and FBC is hoping to use Kalispell's as a pilot for expansion into other urban areas of the watershed.

FUTURE CONSIDERATIONS

Regarding possible expansion of the program across the Flathead Basin, there are many items for FBC to consider. First, because Kalispell is the only permitted municipality in the basin, other urban areas in the Flathead Watershed don't have a regulatory incentive to implement a program like this. It is unlikely that a city would be willing to use its limited resources and staff time to implement a new program that would divert from its existing responsibilities, especially when the only visible incentives for an unpermitted entity (i.e., improved water quality and increased public awareness) are difficult to measure. Additionally, many of these areas do not have access to the online tools that Kalispell has used to create its program website. Therefore, programs in these areas likely wouldn't be as automated as Kalispell's and would require more staff involvement to run, which further disincentivizes program expansion. That said, FBC might consider purchasing a license to access the online tools that Kalispell used to develop its program and host a website for a basin-wide program that any urban area in the watershed could utilize. In this scenario, cities and unincorporated towns could both participate, as the need for an incorporated city government to run the program would be eliminated. If FBC were to pursue this route, there are many logistics that would need to be sorted, including how to quickly and easily report maintenance concerns to the relevant entities, but it is a viable option to expand the program into unregulated areas of the basin.

Flathead Waters Cleanup

In addition to these ongoing education and outreach programs, the inaugural 2021 Flathead Waters Cleanup event was held. FBC co-hosted this event with FCD, and volunteers were able to sign-up to pick up trash along or within any waterbody in the basin. Site selection and volunteer registration were entirely virtual through the event webpage, and on Saturday, August 14, volunteers went to their selected waterbody to pick up trash anytime throughout the morning and afternoon. Later in the afternoon, volunteers were encouraged to bring their trash to Sacred Waters Brewery, the venue for the event's afterparty. The trash that volunteer teams brought to the afterparty was weighed, and these teams were entered to win prizes. Volunteer teams were also encouraged to fill out an online post-cleaning survey where they could document important metrics—including the number of hours worked and miles of riverbank/lakeshore they helped to clean—and submit pictures to a photo contest. Prizes were donated by local outfitters, recreation rental companies, and other event sponsors, and they were awarded to volunteer teams who collected the most trash by weight and by volume, who found the most unique/weirdest item, and who submitted the best and funniest photos, along with other random prize drawings for which all volunteer teams were eligible. In total, during the 2021 Flathead Waters Cleanup, 201 volunteers removed over 2,600 pounds of trash from local waterbodies and helped to improve approximately 114 miles of riverbank and lakeshore. The public response to the event was overwhelmingly positive, and it is hoped that this was the first of what will become an annual event for the Flathead Basin.






In addition to revising the outfall prioritization model, continuing and researching stormwater monitoring techniques, and furthering public education and outreach initiatives, one of the primary goals of Phase II was to develop recommendations for potential future project objectives that would build upon the data collected and use it to implement on-the-ground solutions to improve and protect water quality. Four possible project objectives are discussed in the following sections: (1) Hold internal discussions to determine the purpose and goals of the monitoring program and future of the outfall prioritization model within the context of FBC's overall mission; (2) work with cities, towns, and MDT to help increase their capacity for effective management and maintenance of stormwater infrastructure; (3) partner with experts and decision-makers in the watershed to develop and implement retrofit recommendations in high-priority sub-basins; and (4) create a campaign to incentivize green stormwater infrastructure in new development and along roadways.

Monitoring and Model Validation

First, FBC should consider further discussion to identify exactly what the commission hopes to accomplish with its monitoring and modeling efforts. There are many things to consider regarding the future of the stormwater monitoring program and the future uses of the outfall prioritization model, and there are many possible directions FBC could take. A few such considerations and potential directions are discussed below.

One avenue FBC might consider is to validate the existing outfall prioritization model by continuing and expanding its stormwater monitoring program. Model validation would create a scientific-basis on which the high-priority sub-basins are identified and would allow FBC to better understand the sub-basin characteristics that influence stormwater quality locally. The following are proposed steps FBC could follow to accomplish this objective:

1 FBC could consider revising the high-resolution land use data so that it more accurately distinguishes between land use types and includes all land use classes relevant to stormwater quantity and quality in the watershed. Within the 2021 timeline, a land use dataset of the highest quality possible was infeasible, and because of this, the land use data used in the current prioritization model has significant errors. These shortcomings and some proposed methods by which to revise them are discussed in the preceding "Revisions to Outfall Prioritization Model" section.

2 FBC could then consider using the land use data to identify sub-basins in the watershed that are highly uniform on which to focus monitoring efforts. These uniform sub-basins would be comprised of only one land use class and ideally would be similarly-sized. A monitoring program for these uniform sub-basins could then be established in order to understand the local impacts of land use type on stormwater quality. This monitoring could be accomplished through a grab or automatic sampling program, but an automatic sampling program is recommended so that more accurate measures of pollutant loading could be determined. See the "Advancements in Monitoring" section for a detailed discussion about the pros and cons of each sampling technique.

3 Revisions to the existing outfall prioritization ranking model could then be made from the findings of the stormwater quality data collected through the land use-specific monitoring process. Currently, urban land use classes are assumed to be the most detrimental to stormwater quality based on findings in the literature, but this assumption has not been validated by local data. Understanding what pollutants are associated with which land use classes and their relative pollutant loading could be useful in determining how different land use classes are treated by the model. Similarly, more research could be done into the influence of land use pattern and the interspersion of multiple land use types on stormwater quality. Spatial configurations of different land use types within a sub-basin determine effective impervious area (EIA), which has been shown to influence stormwater quality. Determining EIA for each sub-basin and factoring that into the prioritization rankings may improve the model's ability to accurately predict outfalls with high-polluting potential. Ebrahimian et al. (2018) and Janke et al. (2011) outline methods by which EIA can be calculated for a drainage area.

4 FBC could consider developing a more rigorous, long-term monitoring program at outfalls with a mix of priority rankings. To do this, FBC could first conduct a “quick scan” of some high-, medium-, and low-priority sub-basins identified by the revised model by collecting one set of grab samples at all outfalls being considered for long-term monitoring. Maharjan et al. (2016) recommend this practice for narrowing down the suite of sampling locations on which to focus. FBC could then purchase and set up automatic sampling devices at the chosen locations. Flow-weighted sampling programs using these samplers would allow FBC to more accurately characterize the EMCs and loading of different pollutants at each outfall. Additionally, FBC might consider utilizing sensors to assist in basin-wide continuous monitoring. StormSensor© is an example of a platform that would support continuous monitoring of flow level at outfalls. More research would need to be done into the benefits of continuous monitoring and available platforms and technologies if this were considered a viable option for FBC.

While the above steps would result in scientifically-based identification of high-priority sub-basins in the Flathead Watershed, FBC will need to consider if putting the time and resources into this validation process is a high enough priority and necessary to furthering their overall mission. There are several drawbacks to such an approach, including the length of sampling record that would be needed and the time, staff capacity, and money required to collect high-quality stormwater samples at outfalls across the basin. The literature indicates that many years of stormwater sampling data at an outfall is necessary to start to determine trends in stormwater quality, and even then, it is difficult to compare stormwater quality data between outfalls because of spatial and temporal differences in precipitation rates and volumes, especially if this data comes from grab sampling (Lee et al., 2007). The research does not specify an exact number of years, but based on conversations with experts in the field, it is likely that ten or more years of sampling data would be needed to begin to establish statistical trends.

Furthermore, the staff time, personnel, and monetary resources required to conduct even a simple grab sampling program at many diverse outfalls across the basin would likely pose challenges for FBC. In a grab sampling scenario, multiple staff members would be needed to collect samples at multiple, dispersed locations. The above steps propose purchasing automatic sampling devices to use at outfalls in order to acquire stormwater quality data with the greatest accuracy possible, and in this scenario, cost would need to be considered. These devices cost thousands of dollars apiece, excluding the cost of the necessary accessories, the personnel time needed to set them up, and the long-term maintenance costs. This investment would be significant for FBC and would still likely require a decade of data, depending on the number of samples collected each year, before statistical trends could be established, and model validation could occur. FBC will need to determine if this timeline is feasible given the rate of growth and the urgent need to address stormwater concerns in the basin. It should also be noted that members of FBC have previously stated that the primary purpose of validating the model would be to accurately identify high-priority areas in which to implement retrofits, which is discussed further in subsequent sections. While retrofits would ideally be implemented in the highest-polluting sub-basins, it is also highly plausible that many future retrofits will be implemented opportunistically, targeting the “low-hanging fruit” and constructing them in sub-basins where possible, regardless of their priority ranking. Retrofits can be expensive and time-consuming to implement, so it may not be possible or amenable to implement them in the highest-priority sub-basins. Additionally, cities and towns in the basin will likely have their own priorities when it comes to stormwater retrofits that would not be captured by the model. To go through the work needed to validate a model and then not be able to implement retrofits in the highest-priority areas identified would not be cost-effective and ultimately not most beneficial to water quality.

5 Finally, FBC could make revisions to the sub-basin characteristics considered by the model based on the long-term sampling data such that the highest-polluting sub-basins as determined by the sampling data are identified by the model as the highest-priority.

Because of these considerations, it is recommended that FBC clarify priorities and subsequently determine the future of the monitoring and modeling efforts. It is recommended that FBC considers the following questions. First, what does FBC hope to learn from this stormwater sampling data? Is the primary purpose of this data to validate the model, or is there another objective for continuing a sampling program? The answer to this question will determine whether to continue and/or expand a sampling program, what type of sampling program to implement, and on which outfalls to focus monitoring efforts. It is likely that the stormwater from all large, urban sub-basins in the Flathead Watershed contains some kind of pollution, so how critical is it for FBC's mission to characterize the specific pollutants present at each outfall? Second, how important is it for FBC to validate the results of the sub-basin prioritization model with sampling data? Is the ultimate goal to have this model go through a peer-review process, as is the goal for FBC's septic risk model, or is it just meant to be used to inform FBC's efforts within the basin? How will validating the model further FBC's larger mission to protect water quality, and is it essential to achieving this mission? These questions are essential to ensuring that any time, energy, and resources spent validating the sub-basin prioritization model are entirely necessary and helping to further FBC's goals and overall mission. Once FBC is able to confidently answer these questions, next steps can be formulated regarding the future of its monitoring and modeling efforts.

Increased Capacity for Management and Maintenance of Stormwater Infrastructure

Through observations made in the field in 2020, a large disparity in the capacities among and between different entities to keep track of and maintain their stormwater infrastructure was identified. Because of this, the second proposed project objective is to work with cities, towns, and MDT to increase their capacity for effective management and maintenance of their stormwater infrastructure and minimize these disparities. The methods that FBC might consider using to accomplish this vary between the different entities within the watershed.

INCORPORATED CITIES

The incorporated cities within the Flathead Watershed include Kalispell, Whitefish, Columbia Falls, Polson, and Ronan. These cities have a local government body, and most of these cities also have a centralized, traditional stormwater system that is owned by the city. Henry (2020) describes the stormwater infrastructure present in each city and the state of this infrastructure for those cities whose stormwater systems were investigated in the field (17-37). In terms of management, there is great diversity among the cities' abilities to digitally map and update their stormwater assets, practices necessary for effective infrastructure management. For example, both Kalispell and Whitefish have access to online mapping tools that allow for them to easily and efficiently keep their stormwater infrastructure up-to-date. The City of Polson, however, does not have access to these tools and, therefore, did not possess a digital record of its stormwater assets at the time of the Phase I report (Henry, 2020, 24-26). Similarly, in terms of maintenance of infrastructure, the City of Kalispell has a procedure for regularly vacuuming out its catch basins and a method for easily communicating maintenance needs with crews. On the other hand, Polson's infrastructure appeared as though it had not been maintained in quite a while at the time of the citizen science data collection event in August 2020, and the oversight of the city's centralized stormwater system had been passed between departments multiple times within the year (Henry, 2020, 24). In this way, some cities in the basin possess a greater capacity to effectively manage and maintain their infrastructure than others.

To remedy these disparities, it is recommended that FBC conduct meetings with each city individually to identify the specific barriers they face when it comes to managing and maintaining their infrastructure. A few examples of potential barriers include lack of staff capacity, a lack of financial resources, a lack of incentive, and a lack of equipment or technical know-how. The exact methods by which FBC is able to increase a city's capacity will be determined by the specific barriers identified. For example, if a city identifies a lack of know-how as their primary barrier to effective maintenance, FBC might consider hosting a workshop for city employees to learn about the importance of maintaining stormwater infrastructure and how to develop a proactive maintenance procedure.

MONTANA DEPARTMENT OF TRANSPORTATION

MDT is an important entity in the Flathead Basin, as it owns the majority of stormwater infrastructure along highways and major roadways. Additionally, aside from the City of Kalispell, MDT within Kalispell city limits is the only other permitted entity in the watershed. Despite this, some of MDT's infrastructure across the basin appeared to be poorly or irregularly maintained during field observations in 2020, even within Kalispell city limits. During conversations with experts in the basin, the possibility that local MDT offices and crews may not even own a vacuum truck, the tool necessary to effectively maintain catch basins, was mentioned. Although this has not been confirmed by MDT, a lack of access to equipment such as this would pose a huge barrier to effective infrastructure maintenance. Furthermore, when local MDT representatives were asked to share their infrastructure data during the creation of the inventory in Phase I, they shared scanned copies of hand-drawn as-builts, and there was no indication that local MDT offices have digital records of their stormwater assets or that these records had been updated since the infrastructure was installed (Henry, 2020, 17-57). In this way, an approach similar to that recommended for incorporated cities is recommended for MDT. To identify barriers local MDT crews face to effective infrastructure management and maintenance, it is recommended that FBC conduct meetings with local MDT representatives to discuss their current management and maintenance procedures, any improvements that could be made, and how FBC might be of assistance.

UNINCORPORATED TOWNS

The unincorporated towns in the Flathead Watershed include Bigfork, Lakeside, and Evergreen. These areas have a water and sewer district but do not have a city government or a city-owned, centralized stormwater system. Lakeside and Evergreen contain a mix of privately-, county-, and MDT-owned infrastructure, while Bigfork has a relatively newly installed stormwater system that's owned by Flathead County (Henry, 2020, 27-33). Because of its unique central system that is owned by a government entity, it is recommended that Bigfork be treated in the same way as the incorporated cities of the basin, following the recommendations outlined in the preceding sections. Lakeside and Evergreen, however, are unique and will likely require a different approach. Because infrastructure in these locations that is not owned by MDT or Flathead County is owned by private entities, there is no central body to oversee management and maintenance of the infrastructure. Instead, updating records and performing maintenance on catch basins and other damaged infrastructure would be the responsibility of the numerous private businesses and residents. In this way, FBC's best course of action would likely be to educate infrastructure owners and incentivize effective maintenance. To do this, FBC might consider sending a survey to residents and businesses in Lakeside and Evergreen to determine if they own stormwater infrastructure and if they have established management and maintenance procedures. Depending on the results of this survey, FBC might then consider hosting a workshop for infrastructure owners to educate about the importance of proper maintenance and how to develop a proactive maintenance plan. FBC will likely need to offer an incentive to encourage survey participation and on-going maintenance, so it may be useful to conduct a focus group of infrastructure owners to identify the barriers they experience when it comes to maintenance and what incentives would be most effective for overcoming them.

ADDITIONAL CONSIDERATIONS

FBC should consider the larger question of how the basin-wide infrastructure inventory will be accessed by all relevant entities and kept up-to-date into the future. It is also likely that individual cities may note a lack of access to digital mapping tools as a barrier to effective stormwater management. A solution to both these concerns lies in providing broad access to digital mapping resources and a centrally-hosted, digital stormwater infrastructure inventory that all entities in the basin can access and edit. Currently, the inventory is being stored on a hard drive owned by FBC and on a publicly available Experience Builder created through the City of Kalispell's Esri© license that is only editable by the creator. Ideally, one digital version of the data would exist that is unable to be edited on the public-facing side but able to be updated on the back end by entities who have been granted access, namely FBC and city, county, and tribal governments.

There are a few options FBC might consider when it comes to digital mapping resources. First, FBC might consider purchasing an Esri© license and hosting the inventory of infrastructure data through an online product, such as a simple Web Map, a Hub, an Experience Builder, or a Web App. It would likely be possible to link the infrastructure records of areas that already regularly perform updates such that FBC's hosted inventory would be automatically updated when changes are made to a city's individually-hosted data (assuming these individual records are Esri© compatible). It may also be possible to link a public Survey123 form to a such an Esri© product so that residents and businesses who own private infrastructure can alert FBC of changes made to their assets. Because this survey would be available to the public, the changes made to the inventory through the survey submissions should not be automated and should be reviewed by FBC staff before changes to the inventory are made. Second, there are other platforms designed for MS4 permit compliance that might be useful for FBC for this purpose. One of these platforms is 2NDNATURE© Software. This digital platform allows users to host their infrastructure data and can also provide sub-basin rankings similar to those produced from the outfall prioritization model. The platform can also develop a prioritized list of BMP maintenance practices that would most benefit water quality (Tanner, 2021). The software has a version that is specifically designed for rural communities at a lower cost than the traditional version and would likely be sufficient for FBC's purpose. FBC should consider further investigating the applications of this software as they pertain to the needs of the Flathead Watershed. Third and finally, there are a few open-access mapping tools, such as QGIS®, that might also be used for this purpose. QGIS® is an open-source tool and, therefore, does not require a license to use. However, it is unclear whether this tool can support the creation of products that can be accessed online by multiple entities, which would be essential for FBC's purposes. More research would need to be done on this and similar tools in order to better understand their potential applicability. It is recommended that FBC discusses how involved the commission would like to be when it comes to hosting stormwater infrastructure data, weigh these options for ensuring long-term relevance of the data, and develop next steps accordingly.

Development of Retrofit Recommendations for High-Priority Sub-Basins

The third proposed future objective of this project is to develop and implement best management practice (BMP) retrofits for high-priority sub-basins in the Flathead Watershed. By definition, retrofitting involves constructing stormwater treatment facilities in areas of existing development with inadequate or no treatment facilities (Stein, 2021). Therefore, this project objective would be purely retroactive, implementing BMPs in order to minimize already existing threats to water quality.

Best Management Practices

BMPs are defined as effective or practicable means of preventing or reducing the amount of pollution generated by nonpoint sources (Stein, 2021). BMPs are typically separated into two categories based on their primary function, either runoff reduction or runoff treatment (HDR, 2017). For those BMPs that remove pollutants from stormwater runoff, there are a number of different pollutant removal processes utilized, including biological uptake, chemical transformation, filtration, infiltration, sedimentation, and sorption (HDR, 2017; Stein, 2021). Because of different primary functions and pollutant removal mechanisms, all BMPs are not applicable at every location within a watershed, and BMPs need to be carefully selected for each outfall. In the simplest scenario, the type of BMP that would be useful for water quality improvement within a given sub-basin is determined by (1) the specific types of pollutants being discharged at that outfall and (2) the primary function and pollutant removal mechanisms that a BMP utilizes. For example, a BMP that utilizes only the sedimentation pollutant removal mechanism would not be useful for removing dissolved pollutants such as road salts and nutrients. There are many other factors that also play a role in BMP selection at a location, including political and public support, land availability, construction cost, groundwater level, soil type, and maintenance costs (Stein, 2021). Common examples of BMPs and their respective pollutant removal mechanisms are shown in Table 4. See HDR (2017) for more information about types of BMPs and an in-depth discussion about the BMP selection process for stormwater systems in Montana.

BMP Case Studies

Two programs were encountered that focus specifically on developing stormwater retrofits. The first is a program developed by the City of Lancaster, PA. Lancaster is a small city, covering 7.4 square miles with approximately 60,000 residents. The city has a combined sewer system, and one of the goals of their retrofitting program is to implement runoff reducing BMPs to minimize combined sewer overflows. Launched in 2011, the program so far has completed approximately 70 projects—including rain gardens, vegetated curb extensions, green rooves, and permeable pavements—and has another approximately 160 projects currently in design (Hocker & Austin, 2021). The program builds retrofits on both private and public property, such as city parks, the right-of-way, and other city properties, and sites for retrofits are prioritized according to a sewershed priority score, an inclusivity score, the condition of the pavement, and site slope (Hocker & Austin, 2021). Maintenance of retrofits on city-owned

Common BMPs	Pollutant Removal Mechanisms					
	Biological Uptake	Chemical Treatment	Filtration	Infiltration	Sedimentation	Sorption
Bioretention	X	X	X			X
Dispersion	X			X		X
Biofiltration Swale	X	X	X		X	
Wet Detention Basin	X				X	
Permeable Surfaces			X	X		
Hydrodynamic Separators					X	
Filtration Devices			X			
Infiltration Basin				X		
Detention Basin					X	

Table 4. Pollutant removal mechanisms of common BMPs. Created from information contained in HDR (2017) and Stein (2021).

land is conducted by city staff, and it is unclear how Lancaster ensures projects on private property receive proper maintenance. The city also conducts baseline monitoring for new projects and on-going monitoring of existing projects, along with monthly inspections to ensure BMP functionality (Hocker & Austin, 2021). Because the City of Lancaster is similarly-sized to Kalispell, more research into Lancaster's retrofitting program may be helpful in guiding future program design in the Flathead Basin.

The second program is the Philadelphia Water Department's Green City Clean Waters program. Similar to Lancaster, the City of Philadelphia is also a combined sewer system, and the water department initiated their retrofit program with the goal of preventing or eliminating combined sewer overflows. The Green City, Clean Waters program implements retrofits on both public and private property, including greening streets, neighborhoods, parks, recreation spaces, city facilities, schools, parking lots, and vacant lands (Chiorean, 2021). The majority of projects completed since the program's inception 10 years ago are on private property (Chiorean, 2021). The program relies heavily on estimates of BMP effectiveness and triple bottom line calculations to foster public buy-in and to ensure external funding for these retrofits (Chiorean, 2021). It is unknown how the responsibility of BMP maintenance is determined for projects on either public or private property.

Additional Considerations

There are numerous things to consider should a plan for retrofitting be explored by FBC. First and foremost is funding. The upfront cost of retrofitting can be very expensive, including the cost of planners, designers, engineers, contractors, materials, and land, if necessary. Because of this, FBC will have to consider how much of these upfront costs the commission is willing and able to assume. In areas of the watershed that are unpermitted and have no regulatory incentive for water quality control measures, it is possible that the only method FBC would have of incentivizing retrofitting would be to cover the entire cost of construction. In this case, FBC would need to investigate grant opportunities and other potential avenues for covering these financial burdens.

Second, the issue of long-term BMP maintenance should be considered. All BMPs require some degree of long-term maintenance, whether that's dredging an infiltration basin or vacuuming out a hydrodynamic separator. FBC would need to determine how much involvement it is willing and able to have in the maintenance process. If FBC were to decide that it wanted as little involvement in the maintenance process as possible, a maintenance agreement would need to be drafted up with the responsible entity on who will be covering the cost of and assuming responsibility for maintenance. This document would need to be carefully reviewed by a legal team to ensure FBC's investments are protected.

Third, FBC would need to consider the issue of measuring BMP effectiveness. It has been made clear through conversations with organizers of similar BMP-incentive programs that measuring the effectiveness of BMPs and communicating those metrics is important for garnering public support. People will be most willing to support the implementation of these BMPs, especially on their own private property, when the effectiveness of such BMPs can be proven. However, collecting these measurements can be difficult and would require staff capacity or contracting out research. More research into the benefits and costs of BMP monitoring and methods of measuring BMP effectiveness would likely need to be conducted.

Fourth and finally, FBC would likely need to conduct more monitoring before these BMP selections could be made. As previously mentioned, the type of pollutants present in the stormwater at a given outfall is an important criterion for selecting BMPs that would be appropriate. Because of this, a baseline of stormwater quality data at the outfalls selected for retrofitting is likely necessary and would need to be collected prior to BMP selection and implementation, a process that would likely be lengthy and costly. FBC would need to better understand the pros and cons of developing this baseline data before proceeding with the retrofitting process.

Creation of a Green Infrastructure Incentive Program

The fourth and final proposed future project objective is a basin-wide incentive campaign to promote green stormwater infrastructure (GSI) in new development and along roadways in the basin. In contrast to the proposed BMP retrofitting program, this project would be proactive, seeking to incorporate GSI into stormwater system designs before they are constructed. It's no secret that the Flathead Basin is experiencing tremendous growth. Over just the past decade, the population of Flathead County has increased by approximately 15% according to the 2020 U.S. Census. A GSI incentive campaign such as the one proposed here would be designed to preemptively address threats to water quality that tend to follow growth and development by promoting more sustainable stormwater management.

Green Infrastructure

GSI includes a suite of BMPs that seek to mimic the natural hydrology of an area by promoting infiltration of stormwater runoff. Generally considered to be more sustainable than traditional stormwater management techniques, GSI includes a subset of BMPs that manage stormwater primarily through runoff reduction. Traditional, or grey, stormwater management systems seek to catch stormwater runoff, convey it through a series of pipes, and discharge it at an outfall. GSI, on the other hand, seeks to capture stormwater runoff and store it so that it can either be infiltrated into groundwater or evapotranspired by vegetation, thereby reducing discharge volumes at outfalls. Examples of GSI include bioretention, infiltration basins and trenches, rain gardens, green roofs, permeable pavements, constructed wetlands, and stormwater tree pits. There are numerous resources available online to learn more about the different types of GSI and their benefits.

Areas of Implementation

In March of 2021, the North Carolina Coastal Federation (NCCF) released an action plan that they and a large group of partners developed to identify opportunities for the use of GSI (or what they refer to as nature-based stormwater solutions) in new development, through retrofits, along roadways, and on working lands. They developed expert work groups around these four areas of implementation, and each work group identified impediments and subsequent solutions to GSI implementation in their specific sector (NCFF, 2021). NCCF then used the input from these work groups to develop a list of critical first steps to remedying these impediments and encouraging nature-based stormwater solutions in their watersheds. Many of the proposed project ideas and methods presented in the following sections are based on the recommendations NCCF and its partners identified in their research. Specifically, FBC is encouraged to consider incentivizing GSI in new development and along roadways, two of the four areas identified by NCCF.

NEW DEVELOPMENT

The first proposed area of implementation for a GSI incentive campaign is within new development. The first proposed goal of this incentive campaign is to conduct an audit of existing county and municipal codes and ordinances to identify possible structural barriers to GSI implementation. For example, some landscaping codes may only allow the planting of turf grass, and outdated parking ratios may lead to an unnecessarily large, paved area around a new building (Noordyk, 2021). Revisiting these municipal and county building codes and ordinances to identify barriers such as these would likely be the first project goal of a GSI campaign. Even if no outright barriers exist in the codes, conducting an audit may still be a worthwhile endeavor in order to revise the language to encourage GSI over grey stormwater management techniques. The City of Kalispell conducted an audit of their municipal codes and ordinances in 2020 using a Code and Ordinance Worksheet developed by the Center for Watershed Protection (CWP). The purpose of this tool is to help local development regulators identify revisions that allow or require site developers to minimize impervious cover, conserve natural areas, and use runoff reduction practices to manage stormwater (CWP, 2017). This tool was chosen by Kalispell primarily because the spreadsheet automatically calculates scores for highly urban, urban, suburban, and rural forms of development. Other tools exist for conducting these code and ordinance reviews, including a workbook developed by the University of Wisconsin Sea Grant Institute (UWSGI) and its partners and a scorecard created by the U.S. Environmental Protection Agency (EPA) (UWSGI, 2018; EPA, 2009). More research into these benefits and drawbacks of these different tools would need to be conducted, and FBC would need to determine how involved to be in the review process, either directly or through a contractor.

Once regulatory barriers to GSI implementation in each municipality's and county's codes and ordinances are identified and addressed as needed, projects encouraging and assisting developers with implementing GSI can then be initiated. The first of these proposed project goals is to develop an economic impact analysis that compares the costs of GSI to traditional, grey stormwater management practices. Examples of things that an economic impact analysis could weigh include the upfront costs of construction, the long-term costs of maintenance, the value of jobs created, and the effect of each practice on property values (NCCF, 2021). A tool created by the Water Research Foundation (WRF) and its partners exists for quantifying the triple bottom line benefits of GSI and could be useful in developing an economic impact analysis. These triple bottom line assessments consider the economic, social, and environmental implications of GSI as compared to traditional stormwater management systems, metrics which are typically difficult to measure (Clements, 2021). Specifically, this tool calculates the benefits of GSI in the following categories: avoided infrastructure costs, avoided replacement costs, energy savings, water supply, air quality, property values, heat stress, recreation, green job creation, water quality, carbon, and ecosystem (WRF, 2021). Allowing developers and decision-makers to understand how GSI compares to traditional stormwater management systems will be key to gaining their support and interest in sustainable stormwater designs. An economic impact analysis of this kind could also be useful for educating the public about sustainable stormwater management and ensuring public support of GSI projects (Clements, 2021).

Other project goals within new development could focus on easing the burden on designers and developers by increasing their capacity to implement GSI through education and resource development. FBC might consider creating generalized maps of cities in the basin outlining areas where different GSI practices would be best or worst suited. For example, there are areas in Evergreen where groundwater is very high, and certain infiltration-based BMPs would not be best suited. These maps could then be used by designers to guide their GSI selection process and could be useful both for the proposed GSI incentive campaign and the retrofitting program. Additionally, FBC might consider hosting workshops to educate developers and decision-makers about the benefits and drawbacks of GSI. The previously discussed economic impact analysis and triple bottom line assessments could be useful in guiding the conversations and points addressed in such workshops. These are just a few of the many potential directions a campaign of this kind could take, and they are meant to initiate conversations within FBC for further idea generation.

ROADWAYS

The second proposed area of implementation is along roadways, primarily highways and other major roads. Therefore, to successfully develop project goals in this category, FBC would need to work closely with MDT to identify barriers and incentivize GSI implementation in MDT designs. Similar to new development, the first logical project goal would be to conduct a technical review of existing MDT building and design codes and practices to identify and address any structural barriers to GSI implementation. In 2020, the New Mexico Department of Transportation (NMDOT) conducted such a technical review of their National Pollutant Discharge Elimination System Manual (Griego, 2021). NMDOT expanded the use of GSI in the manual's BMP index and consulted with NMDOT staff and the public throughout the process. In the end, they created a BMP matrix with application, cost, function, and maintenance to help guide BMP selection (Griego, 2021; NMDOT, 2020). More research into NMDOT's review process and lessons learned could be useful in guiding a similar review and revision process with MDT.

Capacity-building project goals similar to those proposed in the area of new development are also recommended for FBC's work with MDT. FBC might consider developing criteria for prioritizing segments of highways for GSI retrofits and hosting technical workshops for transportation planners and designers about the benefits and drawbacks of GSI. One of the largest obstacles FBC may need to overcome in encouraging MDT to implement effective GSI, either in retrofits or new projects, is a concern about staff capacity and know-how for long-term maintenance. NMDOT experienced push-back from staff who were concerned about the additional time and energy required to maintain a vegetated infiltration basin, for example, as opposed to a grassy field that can simply be mowed (Griego, 2021). NMDOT indicated changing the staff mindset surrounding maintenance as one of their areas of future work, and it will likely need to be something FBC considers if such a campaign were to be pursued.

GSI Case Studies

There are many GSI incentive campaigns across the country that are similar to the proposed programs described above. One of the arguably most well-recognized of these is in the Clean Water Partnership in Maryland. This program is a partnership between Prince Georges County and Corvias and focuses on implementing BMPs on private property. The program pairs GSI-expert contractors and engineering firms with less experienced ones as a way to educate local companies about GSI (Jones, 2021). The county enters into a 30-year maintenance agreement with the private entity to ensure the longevity of their investment, and the partners have developed a strong relationship with the local public schools and implement BMPs on school properties that can double as educational tools for students (Jones, 2021).

There are other programs that focus on GSI implementation on public school properties, including a partnership between Stormwater Solutions Engineering and Reflo, a nonprofit (Koch & Hegarty, 2021). These partners work with local landscape architects to install BMPs on Milwaukee School District properties that also serve as outdoor learning spaces. Crews of students and teachers called “green teams” are responsible for maintaining projects through this program (Koch & Hegarty, 2021).

Many cities across the country have implemented programs for incentivizing GSI, including White House, Tennessee, New York City, and Seattle (Jackson, 2021; Enoch, 2021; Tackett, 2021). While New York City and Seattle have programs that are very different in size and scope to any program FBC might develop, it may be worthwhile to further explore the City of White House’s program. A small, Phase II MS4 like Kalispell, White House has developed a robust BMP implementation program funded entirely by a stormwater utility fee that has seen much success over the past few years (Jackson, 2021).

Perhaps the program most similar to one that might be created by FBC is a program developed by the Woonasquatucket River Watershed Council (WRWC), a nonprofit with a mission similar to FBC’s, and the Rhode Island Department of Transportation (RIDOT). These partners utilize an interesting funding system whereby the nonprofit applies for a grant or loan from the Rhode Island Infrastructure Bank, which RIDOT backs and matches (Lehrer et al., 2021). The partners employ crews of young people to construct the BMPs, and RIDOT pays the nonprofit to conduct long-term maintenance on these BMPs (Lehrer et al., 2021). While FBC is not a nonprofit, the similarity of WRWC’s mission to FBC’s and FBC’s potential desire to partner with the state’s Department of Transportation makes this partnership and funding mechanism potentially plausible for any future program developed.

Additional Considerations

There are a number of additional considerations FBC would have to weigh if a GSI incentive campaign was pursued as a future project objective. First, FBC would need to consider public perception of GSI and sustainable stormwater management techniques across the basin. Public support and buy-in would be incredibly important for the success of an incentive campaign of this nature. Understanding current attitudes and how this campaign and associated education and outreach efforts might alter these attitudes would be an important first step for FBC. Furthermore, FBC might also consider equitability implications of targeted GSI implementation and how equity might factor into its GSI priorities in the watershed. As previously mentioned, there are many social benefits associated with GSI implementation, benefits that some areas of the watershed may benefit more from than other areas. While FBC's primary motivation for launching a campaign of this kind would be to protect water quality, FBC should also consider the many benefits that could be reaped from such a program and use these benefits to alleviate inequities in whatever ways possible. FBC might consider holding conversations about equity and the role it should play in the future prioritization of its GSI projects. Finally, as with the proposed BMP retrofitting program, the issues of funding sources and maintenance responsibilities would need to be considered with a GSI incentive campaign, as well. More research would need to be conducted into the funding mechanisms and maintenance procedures utilized by the above case studies. Unique funding mechanisms encountered so far in the research include an environmental impact bond that is used by Buffalo, New York, and a stormwater credit trading market that is used by Cook County, Illinois (McFoy, 2021; Jenkins & Wilson, 2021). It is unclear whether either of these options could be used by FBC, but further research into these mechanisms is recommended.

All four of these project objectives have been proposed because of each of their potential to assist FBC in furthering its mission of protecting and improving water quality in the Flathead Basin. However, because the success of one proposal has the potential to be strongly dictated by that of another, FBC will need to develop a clear, well-researched plan for project development, complete with its organizational principles, priorities, and a list of first steps. Some recommended first steps are detailed here, but it will be the job of FBC to determine if these priorities are in line with the commission's water quality goals and if these first steps are realistic given its capacity and resources.

First Steps

The following is a list of recommended first steps for FBC to take in 2022 that would guide and promote the development of the proposed projects.

+ FBC staff should hold an internal conversation with commission members, members of the Technical Committee, and trusted partners to:
  - Clarify FBC's goals for stormwater monitoring and modeling as it relates to the process of model validation and the model's future uses. FBC will need to determine if going through the process of validating the model is worthwhile given the time and resources it may require.
  - Determine how involved FBC is willing and able to be in hosting the basin-wide digital stormwater infrastructure data and if resources to support that are available. By serving as host, FBC would create a centralized hub of stormwater data for the entire watershed that all relevant entities could access and update. However, doing so would require that FBC have the tools (e.g., an Esri© license) and the staff capacity to manage the digital inventory.
  - Discuss the proposed project objectives, focusing on their potential to further the commission's water quality goals and their feasibility given FBC's capacity and resources. FBC will need to determine if these projects accurately reflect their organizational priorities and are worthwhile and plausible to pursue.

+ Based on the results of the aforementioned conversation, FBC should develop a future plan for its monitoring and modeling efforts. If validating the model is a high priority for the commission, FBC might consider following the steps outlined in the "Monitoring and Model Validation" section. If not, FBC should then determine what its monitoring and modeling goals are and develop a monitoring plan accordingly.

+ Regarding increasing capacity for stormwater management and maintenance, FBC should meet individually with municipal governments, county governments, water and sewer districts, and MDT representatives to:
  - Relay findings from Phase I and Phase II of this project as it relates to their particular location.
  - Discuss their stormwater management and maintenance techniques and identify barriers that prevent them from managing and/or maintaining their infrastructure as well as they would like. This discussion will only be relevant to owners of stormwater infrastructure and may not be applicable to meetings with water and sewer districts.

ROADMAP FOR FUTURE PROJECT OBJECTIVES

- Regarding both BMP retrofitting and GSI incentivization, FBC should continue research into other programs across the country. Many municipal, county, state, and nonprofit programs support both retrofits in areas of existing infrastructure and BMP implementation in new development, so while these are presented as different project goals above, they may fall into the same overarching program. Understanding more about partnerships, methods, and funding mechanisms utilized in other areas could help inform FBC's ideal program structure.

- FBC should create a BMP/GSI Committee (similar to its Onsite Wastewater Treatment Committee) that would help inform future project goals and strategies relating to retrofitting and GSI implementation in new development. This committee should be composed of experts from across the state who are familiar with BMPs, specifically GSI, including but not limited to engineers, contractors, landscape architects, and government representatives (municipal, county, tribal, state, and federal). A committee of this sort would be instrumental in fostering the partnerships and guiding a future BMP/GSI campaign.

- FBC should continue to support public education and outreach initiatives, including the Flathead Rain Garden Initiative and a 2022 Flathead Waters Cleanup event. FBC should also continue to support Kalispell's launching of its Adopt-a-Drain campaign and assess the level of support it may provide to other municipalities across the basin who may be interested in adopting a similar program. Because all other cities in the basin are unpermitted and, therefore, have no regulatory incentive to host a program of this sort, FBC may need to consider creative options for encouraging program expansion to other cities.

While this list of steps is not exhaustive, it is intended to guide FBC's efforts throughout 2022 and set the commission up for success in the project areas. It should be noted that the projects proposed in this report are large and may take many years, possibly even decades, to fully develop and implement. FBC and its partners in the basin have a unique opportunity to stop extensive water quality degradation before it starts, and the steps FBC takes in the next few years will be vital in defining the future of these projects and the impacts they will have on defending the water resources of the Flathead Basin.

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REFERENCES

Center for Watershed Protection, 2017. COW Scoring Spreadsheet. https://owl.cwp.org/mdocs-posts/cow-scoring-spreadsheet/

Chiorean, S., 2021. Green City, Clean Waters: GSI and Triple Bottom Line Benefits in Philadelphia. Part of a larger presentation titled Quantifying and Monetizing the Triple Bottom Line Benefits of Green Stormwater Infrastructure. Lecture, The Water Research Foundation, online. September 23, 2021. https://www.waterrf.org/resource/quantifying-and-monetizing-triple-bottom-line-benefits-green-stormwater-infrastructure

Clements, J., 2021. Framework and Tool for Quantifying the Triple Bottom Line Benefits of Green Stormwater Infrastructure. Part of a larger presentation titled Quantifying and Monetizing the Triple Bottom Line Benefits of Green Stormwater Infrastructure. Lecture, The Water Research Foundation, online. September 23, 2021. https://www.waterrf.org/resource/quantifying-and-monetizing-triple-bottom-line-benefits-green-stormwater-infrastructure

Ebrahimian, A., Gulliver, J.S., and Wilson, B.N., 2018. Estimating effective impervious area in urban watersheds using land cover, soil character and asymptotic curve number. Hydrological Sciences Journal 63, 513-526. https://doi.org/10.1080/02626667.2018.1440562

Enoch, M., 2021. NYC Green Infrastructure. Part of a larger presentation titled Quantifying and Monetizing the Triple Bottom Line Benefits of Green Stormwater Infrastructure. Lecture, The Water Research Foundation, online. September 23, 2021. https://www.waterrf.org/resource/quantifying-and-monetizing-triple-bottom-line-benefits-green-stormwater-infrastructure

Environmental Protection Agency, 2009. Water Quality Scorecard: Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scales. https://www.epa.gov/sites/default/files/2014-04/documents/water-quality-scorecard.pdf

Gillespie, J., Riddle, J.H., Behrens, B., 2004. Tips to Improve Wet-Weather Monitoring. APWA Reporter.

Goonetilleke, A., Thomas, E., Ginn, S., Gilbert, D., 2005. Understanding the Role of Land Use in Urban Stormwater Quality Management. Journal of Environmental Management 74, 31-42. https://doi.org/10.1016/j.jenvman.2004.08.006

Griego, A., 2021. Successful Transformation of NMDOT's NPDES Guidance Manual to Promote Arid Region Green Infrastructure and Low Impact Development. Lecture, StormCon, Milwaukee, WI. September 15, 2021.

Ha, H., Stenstrom, M.K., 2003. Identification of Land Use with Water Quality Data in Stormwater Using a Neural Network. Water Research 37, 4222-4230. https://www.oieau.org/eaudoc/system/files/documents/38/190762/190762_doc.pdf

Harmel, R.D., King, K.W., Haggard, B.E., Wren, D.G., Sheridan, J.M., 2006. Practical Guidance for Discharge and Water Quality Data Collection on Small Watersheds. American Society of Agricultural and Biological Engineers 49, 937-948. https://elibrary.asabe.org/abstract.asp?aid=21745

HDR, 2017. Montana Post-Construction Storm Water BMP Design Guidance Manual. Prepared for Montana's MS4 Municipalities.

REFERENCES

Henry, E.A., 2020. An Investigation into Stormwater Management, Pollution, and Monitoring in the Flathead Watershed, Montana: Phase I. Prepared for Flathead Basin Commission.
https://flatheadbasincommission.org/assets/docs/DNRC-Stormwater-Web.pdf

Hocker, R.A., Austin, K., 2021. Stormwater Retrofitting. Lecture, Center for Watershed Protection, online. July 28, 2021.
https://www.cwp.org/webcasts-2021/

Jackson, A., 2021. Infrastructure and Urban Planning for an Effective Stormwater Management Program and Permit Compliance. Lecture, StormCon, Milwaukee, WI. September 15, 2021.

Janke, B., Gulliver, J.S., Wilson, B.N., 2011. Development of Techniques to Quantify Effective Impervious Cover. University of Minnesota, St. Anthony Falls Laboratory, Project Report No. 555.
https://conservancy.umn.edu/handle/11299/181835

Jenkins, J., Wilson, R., 2021. StormStore – A Pilot Stormwater Credit Trading Market in Cook County, IL. Lecture, StormCon, Milwaukee, WI. September 15, 2021.

Jones, E., 2021. Clean Water Partnership. Part of a larger presentation titled Stormwater BMP Maintenance Programs: From Pilot to Practice. Lecture, Stormwater Journal, online. April 21, 2021.
https://event.webcasts.com/starthere.jsp?ei=1451798&tp_key=e9923734e8

Koch, K., Hegarty, J, 2021. 2019-2020 Green Infrastructure Upgrades at Various Milwaukee Public Schools. Lecture, StormCon, Milwaukee, WI. September 14, 2021.

Kong, F., Ban, Y., James, P., Dronova, I., 2017. Modeling Stormwater Management at the City District Level in Response to Changes in Land Use and Low Impact Development. Environmental Modelling and Software 95, 132-142.
http://dx.doi.org/10.1016/j.envsoft.2017.06.021

Lee, H., Swamikannu, X., Radulescu, D., Kim, S., 2007. Design of Stormwater Monitoring Programs. Water Research 41, 4186-4196.
https://doi.org/10.1016/j.watres.2007.05.016

Lee, S.W., Hwang, S.J., Lee, S.B., Hwand, H.S., Sung, H.C., 2009. Landscape ecological approach to the relationship of land use patterns in watersheds to water quality characteristics. Landscape Urban Plan 92, 80-89.
https://daneshyari.com/article/preview/1050271.pdf

Leecaster, M.K., Schiff, K., Tiefenthaler, L.L., 2002. Assessment of Efficient Sampling Designs for Urban Stormwater Monitoring. Water Research 36, 1556-1564.
https://pubmed.ncbi.nlm.nih.gov/11996344/

Lehrer, A., Richardson, A.D., O'Rourke, S., 2021. Let's Make a Deal: Copy RI's Unique Green Infrastructure Partnership Funding Model. Lecture, StormCon, Milwaukee, WI. September 14, 2021.

Liu, A., Goonetilleke, A., Egodawatta, P., 2012. Inadequacy of land use and impervious area fraction for determining urban stormwater quality. Water Resources Management 26, 2259-2265.
https://link.springer.com/article/10.1007%2Fs11269-012-0014-4

REFERENCES

Maestre, A., Pitt, R.E., 2006. Identification of Significant Factors Affecting Stormwater Quality using the National Stormwater Quality Database. Journal of Water Management Modeling R225-13, 287-325. https://www.chijournal.org/R225-13

Maharjan, B., Pachel, K., Loigu, E., 2016. Towards Effective Monitoring of Urban Stormwater for Better Design and Management. Estonian Journal of Earth Sciences 65, 176-199. https://doi.org/10.3176/earth.2016.12

McFoy, O., 2021. Scaling-up Green Stormwater Infrastructure on Private Properties Through an Environmental Impact Bond in Buffalo, NY. Lecture, StormCon, Milwaukee, WI. September 14, 2021.

Montana Fish, Wildlife & Parks, 2018. Flathead Basin in Montana. GIS data. https://www.arcgis.com/home/webmap/viewer.html?url=https://services3.arcgis.com/Cdxz8r11hT0MGzg1/ArcGIS/rest/services/Flathead_Basin_in_Montana/FeatureServer/0&source=sd

Montana Natural Heritage Program, 2013. Montana Landcover Framework 2013. GIS data. https://mslservices.mt.gov/Geographic_Information/Data/DataList/datalist_Details.aspx?did={B24A26F3-0BAD-42FC-858A-426FD5DF1063}

New Mexico Department of Transportation, 2020. National Pollutant Discharge Elimination System Manual: Stormwater Management Guidelines for Construction, MS4, and Industrial Activities.

Noordyk, J., 2021. Tackling Barriers to Green Infrastructure One Code at a Time. Lecture, StormCon, Milwaukee, WI. September 15, 2021.

North Carolina Coastal Federation, 2021. Action Plan for Nature-Based Stormwater Strategies: Promoting Natural Designs that Reduce Flooding and Improve Water Quality in North Carolina. https://www.nccoast.org/wp-content/uploads/2021/03/NBSS-Action-Plan.pdf

Paule-Mercado, M.A., Lee, B.Y., Memon, S.A., Umer, S.R., Salim, I., Lee, C.H., 2017. Influence of land development on stormwater runoff from a mixed land use and land cover catchment. Science of the Total Environment 599, 2142-2155. https://doi.org/10.1016/j.scitotenv.2017.05.081

Pitt, R.E., Maestre, A., Morquecho, R., Williamson, D., 2004. Collection and Examination of a Municipal Separate Storm Sewer System Database. Journal of Water Management Modeling R220-13. https://www.chijournal.org/Content/Files/R220-13.pdf

Pitt, R., Maestre, A., Clary, J., 2018. The National Stormwater Quality Database (NSQD), Version 4.02. https://www.nccoast.org/wp-content/uploads/2021/03/NBSS-Action-Plan.pdf

Song, H., Qin, T., Wang, J., Wong, T.H.F., 2019. Characteristics of Stormwater Quality in Singapore Catchments in 9 Different Types of Land Use. Water 11. https://doi.org/10.3390/w11051089

Stanford, J.A., Ellis, B.K., Craft, J.A., Poole, G.C., 1997. Water Quality Data and Analyses to Aid in the Development of Revised Water Quality Targets for Flathead Lake, Montana (FLBS Report 142-97). Prepared for Flathead Basin Commission.

Stein, S., 2021. BMP Selection to Improve Your Watershed. Lecture, StormCon, Milwaukee, WI. September 13, 2021.

Tackett, T., 2021. Investing in Green for Scale and Impact: Seattle's Grow Green Stormwater Infrastructure Program. Part of a larger presentation titled Quantifying and Monetizing the Triple Bottom Line Benefits of Green Stormwater Infrastructure. Lecture, The Water Research Foundation, online. September 23, 2021. https://www.waterrf.org/resource/quantifying-and-monetizing-triple-bottom-line-benefits-green-stormwater-infrastructure

Tanner, M., 2021. Digital Transformation is Revolutionizing Stormwater Programs: How to be Ready for the Changes Ahead. Lecture, StormCon, Milwaukee, WI. September 15, 2021.

Tappenbeck, T.H., Ellis, B.K., 2011. Assessment of Groundwater Pollutants and Contaminants in the Shallow Aquifer of the Flathead Valley, Kalispell, Montana: Phase I (FLBS Report #207-11). Prepared for Flathead Basin Commission.

United States Department of Agriculture, 2020. Montana 2019 NAIP Orthophotos. GIS Data. https://ftpgeoinfo.msl.mt.gov/Data/Spatial/MSDI/Imagery/2019_NAIP/

University of Wisconsin Sea Grant Institute, 2018. Tackling Barriers to Green Infrastructure: An Audit of Local Codes and Ordinances. https://www.seagrant.wisc.edu/wp-content/uploads/2018/09/GIAT.pdf

Water Research Foundation, 2021. Framework and Tool for Quantifying the Triple Bottom Line Benefits of Green Stormwater Infrastructure. https://www.waterrf.org/resource/framework-and-tool-quantifying-triple-bottom-line-benefits-green-stormwater-infrastructure?ula=true

Weather Underground, 2021a. Weather History for KMTCOLUM1. https://www.wunderground.com/dashboard/pws/KMTCOLUM1

Weather Underground, 2021b. Weather History for KMTKALIS52. https://www.wunderground.com/dashboard/pws/KMTKALIS52

Weather Underground, 2021c. Weather History for KMTKALIS96. https://www.wunderground.com/dashboard/pws/KMTKALIS96

Weather Underground, 2021d. Weather History for KMTWHITE29. https://www.wunderground.com/dashboard/pws/KMTWHITE29

Zgheib, S., Moilleron, R., Chebbo, G., 2011. Influence of the Land Use Pattern on the Concentrations and Fluxes of Priority Pollutants in Urban Stormwater. Water Science and Technology 64, 1450-1458. https://doi.org/10.2166/wst.2011.770

Zhang, G., Guhathakurta, S., Dai, G., Wu, L., Yan, L., 2013. The Control of Land-Use Patterns for Stormwater Management at Multiple Spatial Scales. Environmental Management 51, 555-570. https://link.springer.com/article/10.1007%2Fs00267-012-0004-6

APPENDIX A: METHODOLOGY FOR DEVELOPING FLATHEAD BASIN LAND USE RASTER DATASET

The land use data used in the analyses in this report was created by the following methodology. Aerial imagery acquired by the National Agriculture Imagery Program (NAIP) in 2019 and 2020 was downloaded for Flathead, Lake, Lincoln, Lewis and Clark, Missoula, Powell, and Sanders counties (USDA, 2020). Each of the county mosaics was projected to the NAD 1983 (2011) StatePlane Montana FIPS 2500 (Meters) coordinate system. A mosaic dataset was created, each of the individual county mosaics was added to it, and the image was exported. The resulting raster dataset was clipped to the extent of the Flathead Watershed using data published by Montana Fish, Wildlife, and Parks (MTFWP, 2018). The resulting raster dataset contained high-resolution, true color imagery of the entire Flathead Watershed.

Training samples were then created using ArcGIS's image classification tools for the following land use classes: water, agriculture, residential, developed (urban), and undeveloped (natural). Table 5 shows the number of training samples and the percentage of classified pixels for each land use class.

Pixel Value	Land Use Class	# Training Samples	% Classified Pixels
1	Water	97	61.24
2	Agriculture	212	6.63
3	Residential	558	1.41
4	Developed (Urban)	230	1.16
5	Undeveloped	44	29.57

Table 5. Classification data for each land use type.

A signature file was created using these training samples and used in the Maximum Likelihood Classification geoprocessing tool to classify the entire image of the Flathead Watershed. In the final raster dataset, cell values of 1 represent water, 2 represent agricultural, 3 represent residential, 4 represent developed, and 5 represent undeveloped land use classes. The final raster dataset and all intermediate products are stored on an external hard drive owned by the Flathead Basin Commission.

Once the land use dataset had been created, a model was then developed and used to extract the land use data for each individual sub-basin in the watershed. Figure 7 is a graphic representation of this model. The land use tables for each sub-basin were merged and exported to a Microsoft Excel spreadsheet through which the data was able to be analyzed.

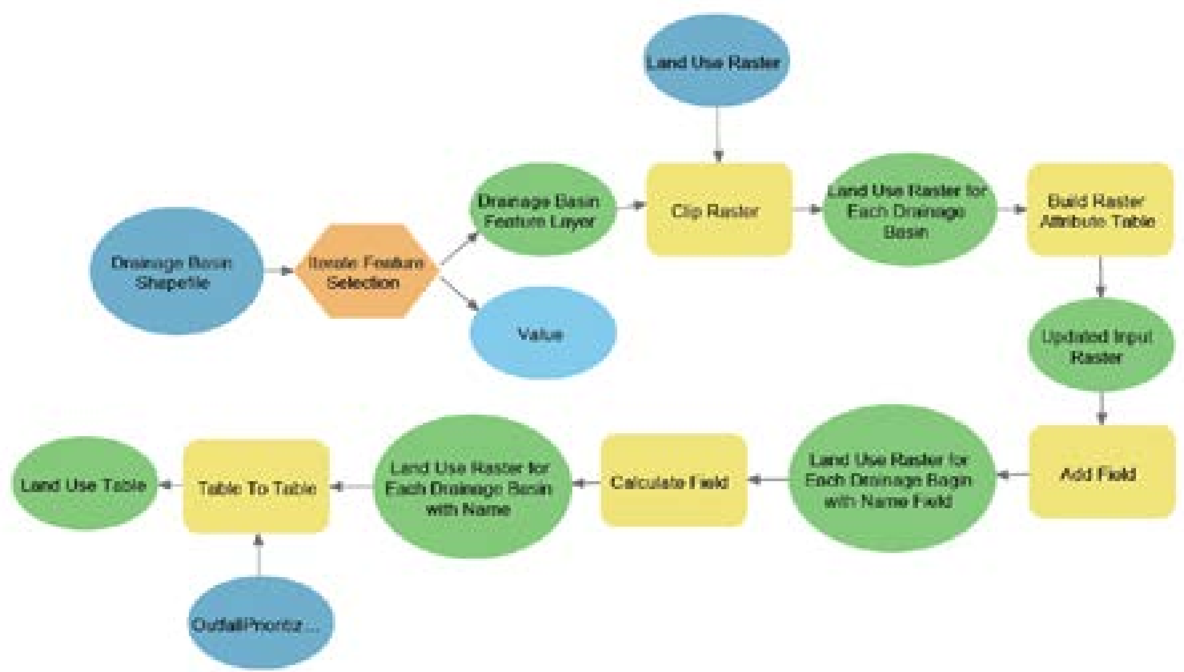

Figure 7. Graphic representation of model used to extract data for each sub-basin within the Flathead Watershed.

APPENDIX B: 2021 OUTFALL PRIORITIZATION RANKING CHART

Name	Total Area (acres)	Area Score	Receiving Waterbody	Impairment Status	Pollutants of Impairment	Impairment Score	Water (%)	Agriculture (%)	Residential (%)	Developed (%)	Undeveloped (%)	Urbanized Score	Max Land Use Diff (%)	Mixed Land Use Score	Phase I Ranking	Phase II Ranking
KAL_AC11	292	2	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	2	23	23	41	11	2	30	1	6	7
WHI_WR5	260	2	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	6	28	16	31	18	1	14	2	6	7
KAL_AC1	28	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	0	7	4	83	6	4	80	0	4	6
KAL_AC18	9	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	0	7	4	83	6	4	79	0	N/A	6
KAL_AC6	547	2	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	2	22	18	47	11	2	35	0	6	6
KAL_SC1	701	2	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	3	22	14	47	14	2	33	0	6	6
KAL_SC16	119	2	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	2	25	13	45	15	2	33	0	6	6
KAL_SC2	4	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	2	3	12	81	2	4	79	0	4	6
WHI_WR11	103	2	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	6	16	17	51	10	2	41	0	6	6
EVE_SW1	10	0	Stillwater River	IMP 1	Sediment	1	0	0	1	99	0	4	99	0	3	5
KAL_AC19	18	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	0	7	2	79	12	3	77	0	N/A	5
KAL_AC4	38	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	2	27	19	41	13	2	28	1	3	5
KAL_CB6	155	2	Closed Basin	CB	N/A	0	4	24	15	40	17	2	26	1	4	5
KAL_SC10	5	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	2	8	12	69	10	3	61	0	4	5
KAL_SC14	51	1	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	3	22	15	53	8	2	45	0	5	5
KAL_SC18	3	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	2	3	15	78	3	3	75	0	4	5
KAL_SC20	5	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	7	9	18	61	5	3	56	0	3	5
KAL_SC21	2	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	4	9	12	68	6	3	62	0	4	5
KAL_SC22	63	1	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	1	26	6	57	10	2	51	0	N/A	5
KAL_SC24	50	1	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	3	11	11	57	18	2	46	0	N/A	5
KAL_SC25	12	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	1	17	10	64	8	3	56	0	N/A	5
KAL_SC4	4	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	2	12	16	64	6	3	59	0	4	5
KAL_SC6	35	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	1	5	10	77	6	3	72	0	4	5
KAL_SWR15	404	2	Stillwater River	IMP 1	Sediment	1	0	28	3	47	22	2	44	0	5	5

APPENDIX B: 2021 OUTFALL PRIORITIZATION RANKING CHART

Name	Total Area (acres)	Area Score	Receiving Waterbody	Impairment Status	Pollutants of Impairment	Impairment Score	Water (%)	Agriculture (%)	Residential (%)	Developed (%)	Undeveloped (%)	Urbanized Score	Max Land Use Diff (%)	Mixed Land Use Score	Phase I Ranking	Phase II Ranking
KAL_SWR16	152	2	Stillwater River	IMP 1	Sediment	1	2	29	6	45	18	2	39	0	5	5
KAL_SWR4	266	2	Stillwater River	IMP 1	Sediment	1	2	22	21	44	10	2	34	0	5	5
KAL_SWR5	63	1	Stillwater River	IMP 1	Sediment	1	5	27	19	27	22	1	8	2	4	5
LAK_FL3	8	0	Flathead Lake	IMP >1	TN, TP, Mercury, and PCBs	2	8	10	9	68	5	3	62	0	4	5
LAK_FL4	14	0	Flathead Lake	IMP >1	TN, TP, Mercury, and PCBs	2	6	25	21	25	23	1	4	2	4	5
POL_FR4	67	1	Flathead River	NT	N/A	1	0	18	6	64	13	3	58	0	4	5
RON_SC1	77	1	Spring Creek	NT	N/A	1	0	25	5	60	10	3	55	0	3	5
WHI_WL2	16	0	Whitefish Lake	IMP >1	Mercury and PCBs	2	8	26	22	24	20	1	6	2	3	5
WHI_WR1	1	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	10	15	18	28	30	1	15	2	3	5
WHI_WR12	3	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	11	18	18	33	21	1	15	2	4	5
WHI_WR13	14	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	7	24	24	26	18	1	9	2	4	5
WHI_WR14	24	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	7	22	17	40	14	2	25	1	4	5
WHI_WR15	14	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	10	18	20	31	21	1	12	2	4	5
WHI_WR16	27	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	6	9	11	65	8	3	57	0	4	5
WHI_WR18	8	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	7	25	20	28	20	1	8	2	4	5
WHI_WR23	3	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	9	20	18	31	22	1	13	2	4	5
WHI_WR28	40	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	3	20	7	64	6	3	58	0	4	5
WHI_WR29	12	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	4	13	11	62	9	3	53	0	4	5
WHI_WR30	58	1	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	4	29	12	38	18	1	26	1	5	5
WHI_WR31	4	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	4	26	23	25	21	1	5	2	4	5
WHI_WR33	3	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	13	9	10	66	3	3	63	0	4	5
WHI_WR6	3	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	14	21	20	21	24	1	5	2	3	5
WHI_WR8	15	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	7	9	14	62	7	3	55	0	4	5
WHI_WR9	1	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	4	9	16	67	4	3	63	0	4	5

APPENDIX B: 2021 OUTFALL PRIORITIZATION RANKING CHART

Name	Total Area (acres)	Area Score	Receiving Waterbody	Impairment Status	Pollutants of Impairment	Impairment Score	Water (%)	Agriculture (%)	Residential (%)	Developed (%)	Undeveloped (%)	Urbanized Score	Max Land Use Diff (%)	Mixed Land Use Score	Phase I Ranking	Phase II Ranking
BIG_BH2	1	0	Bigfork Harbor	NT	N/A	1	2	6	12	61	18	3	54	0	3	4
COL_CB1	13	0	Closed Basin	CB	N/A	0	1	3	2	92	3	4	90	0	2	4
EVE_CB7	0	0	Closed Basin	CB	N/A	0	0	0	0	83	17	4	83	0	2	4
KAL_AC10	3	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	2	29	17	42	10	2	31	0	4	4
KAL_AC15	35	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	0	24	5	35	35	1	30	1	4	4
KAL_AC16	3	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	1	28	17	48	5	2	43	0	4	4
KAL_AC17	4	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	1	24	18	51	5	2	46	0	4	4
KAL_AC2	49	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	1	25	23	42	9	2	32	0	4	4
KAL_AC20	8	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	3	25	15	45	12	2	33	0	N/A	4
KAL_AC3	37	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	2	25	21	41	11	2	31	0	4	4
KAL_AC5	8	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	1	30	16	43	10	2	33	0	3	4
KAL_AC7	36	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	2	30	21	32	15	1	17	1	3	4
KAL_AC8	3	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	2	25	18	45	9	2	36	0	3	4
KAL_AC9	18	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	2	23	19	44	12	2	32	0	4	4
KAL_CB1	213	2	Closed Basin	CB	N/A	0	1	33	9	46	11	2	38	0	4	4
KAL_CB11	3	0	Closed Basin	CB	N/A	0	1	5	6	83	5	4	79	0	N/A	4
KAL_CB12	55	1	Closed Basin	CB	N/A	0	1	5	10	74	10	3	70	0	N/A	4
KAL_CB18	45	0	Closed Basin	CB	N/A	0	0	3	4	80	14	4	77	0	N/A	4
KAL_CB19	102	2	Closed Basin	CB	N/A	0	0	34	2	42	22	2	40	0	N/A	4
KAL_CB7	66	1	Closed Basin	CB	N/A	0	0	11	4	69	16	3	66	0	1	4
KAL_CB8	56	1	Closed Basin	CB	N/A	0	2	6	7	79	6	3	72	0	3	4
KAL_DBS3	77	1	Dry Bridge Slough	NT	N/A	1	1	33	25	28	13	1	21	1	4	4
KAL_LSC1	53	1	Little Spring Creek	NT	N/A	1	1	13	5	57	25	2	52	0	4	4
KAL_LSC2	25	0	Little Spring Creek	NT	N/A	1	0	6	8	67	19	3	61	0	3	4

APPENDIX B: 2021 OUTFALL PRIORITIZATION RANKING CHART

Name	Total Area (acres)	Area Score	Receiving Waterbody	Impairment Status	Pollutants of Impairment	Impairment Score	Water (%)	Agriculture (%)	Residential (%)	Developed (%)	Undeveloped (%)	Urbanized Score	Max Land Use Diff (%)	Mixed Land Use Score	Phase I Ranking	Phase II Ranking
KAL_MS5	82	1	Muscrat Slough	NT	N/A	1	1	40	20	26	13	1	27	1	3	4
KAL_SC11	9	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	2	34	14	37	14	1	23	1	4	4
KAL_SC12	4	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	2	16	10	57	15	2	46	0	4	4
KAL_SC13	7	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	3	37	15	35	10	1	27	1	4	4
KAL_SC15	44	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	2	24	12	48	14	2	36	0	4	4
KAL_SC17	11	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	3	38	9	42	7	2	34	0	4	4
KAL_SC19	10	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	5	24	16	45	10	2	35	0	3	4
KAL_SC23	18	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	2	36	15	37	10	1	26	1	N/A	4
KAL_SC26	1	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	7	12	24	51	6	2	45	0	N/A	4
KAL_SC3	3	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	7	13	13	59	8	2	51	0	3	4
KAL_SC5	3	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	1	15	9	54	21	2	44	0	3	4
KAL_SC7	6	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	5	21	15	53	6	2	47	0	3	4
KAL_SC8	7	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	3	30	11	34	23	1	22	1	4	4
KAL_SWR1	60	1	Stillwater River	IMP 1	Sediment	1	1	30	11	45	14	2	34	0	3	4
KAL_SWR17	59	1	Stillwater River	IMP 1	Sediment	1	1	20	5	49	26	2	44	0	4	4
KAL_SWR19	27	0	Stillwater River	IMP 1	Sediment	1	1	20	1	62	17	3	61	0	3	4
KAL_SWR22	43	0	Stillwater River	IMP 1	Sediment	1	0	13	2	64	21	3	62	0	3	4
KAL_SWR7	96	1	Stillwater River	IMP 1	Sediment	1	4	34	13	39	11	1	28	1	4	4
KAL_UT3	8	0	Unnamed Tributary	NT	N/A	0	2	2	4	90	3	4	88	0	N/A	4
KAL_WR2	6	0	Whitefish River	IMP 1	Sediment	1	0	17	15	64	5	3	60	0	2	4
LAK_FL1	2	0	Flathead Lake	IMP >1	TN, TP, Mercury, and PCBs	2	12	8	24	53	3	2	50	0	4	4
LAK_FL2	2	0	Flathead Lake	IMP >1	TN, TP, Mercury, and PCBs	2	7	7	18	58	11	2	51	0	4	4
POL_FL1	14	0	Flathead Lake	IMP >1	TN, TP, Mercury, and PCBs	2	1	26	6	47	21	2	40	0	4	4
POL_FL2	10	0	Flathead Lake	IMP >1	TN, TP, Mercury, and PCBs	2	0	25	7	46	22	2	38	0	4	4

APPENDIX B: 2021 OUTFALL PRIORITIZATION RANKING CHART

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POL_FL3	25	0	Flathead Lake	IMP >1	TN, TP, Mercury, and PCBs	2	1	28	6	49	15	2	43	0	3	4
POL_FR1	441	2	Flathead River	NT	N/A	1	0	35	4	37	23	1	33	0	5	4
RON_SC3	61	1	Spring Creek	NT	N/A	1	0	31	4	47	18	2	43	0	4	4
RON_SC5	6	0	Spring Creek	NT	N/A	1	0	9	4	79	9	3	75	0	3	4
WHI_CC10	86	1	Cow Creek	NT	N/A	1	5	24	17	39	14	1	25	1	4	4
WHI_CC13	23	0	Cow Creek	NT	N/A	1	6	25	21	28	20	1	8	2	3	4
WHI_CC4	2	0	Cow Creek	NT	N/A	1	5	31	20	27	17	1	14	2	2	4
WHI_CC5	4	0	Cow Creek	NT	N/A	1	11	25	16	27	21	1	11	2	2	4
WHI_CC8	13	0	Cow Creek	NT	N/A	1	7	28	15	30	20	1	14	2	2	4
WHI_CC9	4	0	Cow Creek	NT	N/A	1	11	28	14	21	26	1	14	2	3	4
WHI_WL1	13	0	Whitefish Lake	IMP >1	Mercury and PCBs	2	13	18	17	42	11	2	31	0	3	4
WHI_WL3	14	0	Whitefish Lake	IMP >1	Mercury and PCBs	2	9	27	20	16	28	0	12	2	4	4
WHI_WR10	25	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	4	17	12	53	14	2	41	0	4	4
WHI_WR17	1	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	4	23	10	48	16	2	39	0	4	4
WHI_WR20	0	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	5	35	19	25	15	1	19	1	3	4
WHI_WR21	6	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	5	23	14	37	21	1	24	1	3	4
WHI_WR22	11	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	2	22	4	56	16	2	52	0	4	4
WHI_WR24	30	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	10	15	13	47	15	2	34	0	4	4
WHI_WR25	10	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	4	13	12	59	12	2	48	0	2	4
WHI_WR32	4	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	11	8	11	55	14	2	47	0	4	4
BIG_BH1	30	0	Bigfork Harbor	NT	N/A	1	3	29	7	45	16	2	37	0	3	3
BIG_SR1	7	0	Swan River	NT	N/A	1	10	13	11	45	21	2	35	0	3	3
BIG_SR2	14	0	Swan River	NT	N/A	1	6	19	10	34	32	1	24	1	3	3
EVE_CB1	1	0	Closed Basin	CB	N/A	0	4	12	16	62	6	3	56	0	2	3

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EVE_CB11	3	0	Closed Basin	CB	N/A	0	6	8	12	68	6	3	62	0	2	3
EVE_CB3	1	0	Closed Basin	CB	N/A	0	7	8	12	66	7	3	59	0	1	3
EVE_CB6	1	0	Closed Basin	CB	N/A	0	2	15	14	63	5	3	58	0	1	3
EVE_CB8	0	0	Closed Basin	CB	N/A	0	0	5	0	69	26	3	69	0	2	3
EVE_CB9	0	0	Closed Basin	CB	N/A	0	0	3	4	77	16	3	74	0	2	3
KAL_AC13	40	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	0	28	2	28	42	1	41	0	4	3
KAL_AC14	1	0	Ashley Creek	IMP >1	TN, TP, Sed, DO, and Temp	2	1	14	6	30	49	1	43	0	2	3
KAL_CB14	5	0	Closed Basin	CB	N/A	0	1	13	5	72	10	3	67	0	N/A	3
KAL_CB15	1	0	Closed Basin	CB	N/A	0	2	21	7	61	8	3	54	0	N/A	3
KAL_CB16	32	0	Closed Basin	CB	N/A	0	2	10	10	70	8	3	61	0	N/A	3
KAL_CB20	69	1	Closed Basin	CB	N/A	0	3	33	17	32	16	1	17	1	N/A	3
KAL_CB24	11	0	Closed Basin	CB	N/A	0	2	10	10	70	8	3	62	0	N/A	3
KAL_CB29	29	0	Closed Basin	CB	N/A	0	5	25	16	41	14	2	27	1	N/A	3
KAL_CB31	4	0	Closed Basin	CB	N/A	0	6	5	12	75	2	3	73	0	N/A	3
KAL_CB32	3	0	Closed Basin	CB	N/A	0	1	6	11	79	3	3	75	0	N/A	3
KAL_CB34	5	0	Closed Basin	CB	N/A	0	1	5	19	73	2	3	70	0	N/A	3
KAL_CB35	4	0	Closed Basin	CB	N/A	0	4	13	14	60	9	3	51	0	N/A	3
KAL_CB36	8	0	Closed Basin	CB	N/A	0	0	15	3	67	15	3	64	0	N/A	3
KAL_CB5	15	0	Closed Basin	CB	N/A	0	2	16	5	63	13	3	58	0	2	3
KAL_DBS1	3	0	Dry Bridge Slough	NT	N/A	1	0	36	25	24	14	1	22	1	3	3
KAL_DBS2	4	0	Dry Bridge Slough	NT	N/A	1	1	35	23	28	13	1	23	1	3	3
KAL_MS1	3	0	Muscrat Slough	NT	N/A	1	1	34	21	34	11	1	23	1	2	3
KAL_MS2	7	0	Muscrat Slough	NT	N/A	1	0	33	16	43	8	2	35	0	3	3
KAL_MS3	2	0	Muscrat Slough	NT	N/A	1	0	28	23	39	10	1	29	1	3	3

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KAL_MS4	2	0	Muscrat Slough	NT	N/A	1	1	16	20	53	9	2	44	0	3	3
KAL_MS6	1	0	Muscrat Slough	NT	N/A	1	1	11	21	59	8	2	51	0	2	3
KAL_SC9	6	0	Spring Creek	IMP >1	TN, TP, Sed, and DO	2	1	40	8	34	16	1	32	0	4	3
KAL_SWR10	26	0	Stillwater River	IMP 1	Sediment	1	2	37	18	25	18	1	19	1	2	3
KAL_SWR11	6	0	Stillwater River	IMP 1	Sediment	1	8	24	19	37	13	1	24	1	3	3
KAL_SWR14	6	0	Stillwater River	IMP 1	Sediment	1	1	23	19	45	11	2	34	0	3	3
KAL_SWR2	9	0	Stillwater River	IMP 1	Sediment	1	3	34	14	39	10	1	29	1	3	3
KAL_SWR3	1	0	Stillwater River	IMP 1	Sediment	1	6	13	16	49	15	2	36	0	3	3
KAL_SWR6	8	0	Stillwater River	IMP 1	Sediment	1	1	12	14	52	22	2	40	0	3	3
KAL_SWR8	8	0	Stillwater River	IMP 1	Sediment	1	6	28	21	31	15	1	17	1	3	3
KAL_WR1	9	0	Whitefish River	IMP 1	Sediment	1	0	28	16	45	11	2	34	0	3	3
POL_FR2	7	0	Flathead River	NT	N/A	1	0	29	6	32	33	1	27	1	3	3
POL_FR3	10	0	Flathead River	NT	N/A	1	0	35	7	30	28	1	29	1	3	3
RON_RCB1	89	1	Ronan Canal B	NT	N/A	1	0	49	3	35	13	1	47	0	4	3
RON_RCB2	40	0	Ronan Canal B	NT	N/A	1	0	27	4	54	15	2	50	0	3	3
RON_SC2	1	0	Spring Creek	NT	N/A	1	0	30	1	57	12	2	56	0	3	3
RON_SC4	8	0	Spring Creek	NT	N/A	1	0	40	3	41	16	2	37	0	3	3
WHI_CB12	1	0	Closed Basin	CB	N/A	0	6	21	13	42	18	2	29	1	2	3
WHI_CB15	3	0	Closed Basin	CB	N/A	0	12	17	12	42	17	2	30	1	2	3
WHI_CB3	2	0	Closed Basin	CB	N/A	0	1	9	9	72	9	3	63	0	2	3
WHI_CB5	9	0	Closed Basin	CB	N/A	0	7	27	15	24	27	1	11	2	2	3
WHI_CB8	0	0	Closed Basin	CB	N/A	0	3	12	7	68	11	3	60	0	2	3
WHI_CC1	5	0	Cow Creek	NT	N/A	1	3	27	13	34	23	1	21	1	1	3
WHI_CC2	11	0	Cow Creek	NT	N/A	1	5	36	11	36	12	1	25	1	2	3

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WHI_CC3	23	0	Cow Creek	NT	N/A	1	7	24	18	34	18	1	16	1	3	3
WHI_CC6	0	0	Cow Creek	NT	N/A	1	0	43	12	32	13	1	30	1	3	3
WHI_WR26	7	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	9	31	9	16	35	0	26	1	4	3
EVE_CB2	12	0	Closed Basin	CB	N/A	0	5	23	18	43	11	2	33	0	1	2
EVE_CB4	1	0	Closed Basin	CB	N/A	0	6	13	20	54	8	2	47	0	2	2
EVE_CB5	2	0	Closed Basin	CB	N/A	0	4	15	15	59	7	2	52	0	2	2
KAL_CB10	2	0	Closed Basin	CB	N/A	0	0	29	10	54	7	2	47	0	2	2
KAL_CB13	37	0	Closed Basin	CB	N/A	0	2	29	17	39	13	1	26	1	N/A	2
KAL_CB17	32	0	Closed Basin	CB	N/A	0	2	33	10	45	11	2	35	0	N/A	2
KAL_CB2	12	0	Closed Basin	CB	N/A	0	0	25	14	53	8	2	45	0	2	2
KAL_CB21	2	0	Closed Basin	CB	N/A	0	0	26	3	41	30	2	38	0	N/A	2
KAL_CB22	1	0	Closed Basin	CB	N/A	0	1	17	20	54	8	2	46	0	N/A	2
KAL_CB23	7	0	Closed Basin	CB	N/A	0	3	12	14	58	13	2	45	0	N/A	2
KAL_CB26	4	0	Closed Basin	CB	N/A	0	2	33	6	44	16	2	38	0	N/A	2
KAL_CB28	3	0	Closed Basin	CB	N/A	0	1	18	17	53	10	2	43	0	N/A	2
KAL_CB30	1	0	Closed Basin	CB	N/A	0	0	44	2	49	6	2	48	0	N/A	2
KAL_CB33	34	0	Closed Basin	CB	N/A	0	1	21	23	45	10	2	35	0	N/A	2
KAL_CB9	4	0	Closed Basin	CB	N/A	0	0	20	4	42	34	2	39	0	2	2
KAL_UT1	22	0	Unnamed Tributary	NT	N/A	0	4	34	12	41	9	2	32	0	4	2
KAL_UT2	10	0	Unnamed Tributary	NT	N/A	0	2	20	7	55	17	2	48	0	3	2
POL_PCB1	43	0	Polson Canal B	NT	N/A	1	0	26	5	36	32	1	31	0	2	2
POL_PCB2	3	0	Polson Canal B	NT	N/A	1	0	44	6	26	24	1	39	0	3	2
RON_SC6	10	0	Spring Creek	NT	N/A	1	0	40	7	33	20	1	34	0	3	2
RON_SC7	10	0	Spring Creek	NT	N/A	1	0	45	5	30	19	1	40	0	2	2

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WHI_CB11	0	0	Closed Basin	CB	N/A	0	0	21	2	56	20	2	54	0	2	2
WHI_CB14	1	0	Closed Basin	CB	N/A	0	4	20	12	50	14	2	38	0	2	2
WHI_CB2	1	0	Closed Basin	CB	N/A	0	26	16	19	17	23	0	7	2	2	2
WHI_CB6	2	0	Closed Basin	CB	N/A	0	22	12	22	31	13	1	19	1	1	2
WHI_CB7	1	0	Closed Basin	CB	N/A	0	15	13	20	31	22	1	18	1	1	2
WHI_CC7	18	0	Cow Creek	NT	N/A	1	2	50	11	25	12	1	39	0	3	2
WHI_WR19	1	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	6	41	20	0	33	0	40	0	4	2
WHI_WR2	0	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	9	55	14	8	14	0	47	0	3	2
WHI_WR3	0	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	0	63	14	13	10	0	53	0	3	2
WHI_WR4	0	0	Whitefish River	IMP >1	Oil & Grease, PCBs, and Temp	2	6	9	31	14	40	0	32	0	2	2
EVE_CB12	1	0	Closed Basin	CB	N/A	0	1	41	6	27	26	1	35	0	2	1
KAL_CB25	4	0	Closed Basin	CB	N/A	0	1	43	8	39	10	1	35	0	N/A	1
KAL_CB27	1	0	Closed Basin	CB	N/A	0	0	41	14	36	9	1	32	0	N/A	1
KAL_SWR20	4	0	Stillwater River	IMP 1	Sediment	1	1	64	10	4	21	0	60	0	1	1
KAL_SWR21	9	0	Stillwater River	IMP 1	Sediment	1	1	59	13	5	23	0	54	0	1	1
KAL_SWR9	1	0	Stillwater River	IMP 1	Sediment	1	10	9	62	12	7	0	55	0	3	1
WHI_CB1	3	0	Closed Basin	CB	N/A	0	0	48	4	35	13	1	44	0	2	1
WHI_CB4	1	0	Closed Basin	CB	N/A	0	20	13	18	19	30	0	16	1	2	1
WHI_CB9	0	0	Closed Basin	CB	N/A	0	25	28	12	7	28	0	21	1	2	1
WHI_CB10	0	0	Closed Basin	CB	N/A	0	0	57	3	3	37	0	55	0	2	0

Abbreviations: IMP >1 = Impaired with more than one pollutant, IMP 1 = Impaired with one pollutant, NT = Not tested for impairments, CB = Closed basin

APPENDIX C: 2021 WEATHER TRACKER

April 2021														
		Kalispell			Evergreen			Columbia Falls			Whitefish			
Date	Description	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	Sampling Event & Notes
4/1	Mostly Sunny	68.0	27.7	0.00	72.5	23.2	0.00	64.8	26.8	0.00	68.5	25.7	0.00	-
4/2	Mostly Sunny	66.7	35.4	0.00	69.8	28.8	0.00	66.0	33.1	0.00	67.5	30.0	0.00	-
4/3	Mostly Sunny	62.8	33.8	0.00	67.6	28.9	0.00	65.7	31.1	0.00	66.4	28.9	0.00	-
4/4	Cloudy	61.0	39.4	0.00	62.8	37.4	0.00	56.7	39.0	0.00	58.5	35.2	0.00	-
4/5	Cloudy	54.9	36.3	0.02	60.4	32.9	0.04	59.9	35.2	0.00	60.3	31.6	0.06	-
4/6	Mostly Sunny	57.0	29.7	0.00	62.2	25.0	0.00	60.4	27.5	0.00	61.2	26.1	0.00	-
4/7	Mostly Sunny	65.5	29.5	0.00	66.2	24.6	0.00	64.8	27.7	0.00	66.0	25.2	0.00	-
4/8	Cloudy	48.2	33.4	0.01	50.0	30.2	0.04	48.4	30.7	0.00	46.9	28.2	0.05	-
4/9	Mostly Sunny	57.2	28.4	0.00	57.2	26.1	0.02	53.8	28.2	0.00	58.1	25.2	0.01	-
4/10	Cloudy	45.3	33.1	0.00	47.1	33.6	0.00	46.0	33.6	0.00	46.6	28.8	0.02	-
4/11	Cloudy	45.9	26.2	0.00	48.7	25.9	0.00	49.6	28.2	0.00	44.6	23.2	0.00	-
4/12	Mostly Sunny	46.4	24.8	0.00	49.5	23.2	0.00	52.2	28.6	0.00	49.5	22.1	0.00	-
4/13	Mostly Sunny	46.0	26.4	0.00	49.1	22.1	0.00	49.5	28.9	0.00	46.8	23.0	0.00	-
4/14	Mostly Sunny	54.1	27.3	0.00	60.3	22.8	0.00	56.1	28.6	0.00	57.2	24.1	0.00	-
4/15	Mostly Sunny	60.6	30.7	0.00	63.7	28.4	0.00	62.4	33.1	0.00	63.3	27.5	0.00	-
4/16	Mostly Sunny	64.6	31.3	0.00	67.5	27.7	0.00	65.8	30.4	0.00	69.3	27.5	0.00	-
4/17	Mostly Sunny	66.9	31.6	0.00	68.9	27.5	0.00	69.4	32.2	0.00	73.2	26.8	0.01	-
4/18	Snow	59.9	32.2	0.01	61.0	29.7	0.01	61.2	31.3	0.02	63.5	29.8	0.01	-
4/19	Mostly Sunny	47.8	25.2	0.05	-	-	-	48.0	26.1	0.02	-	-	-	-
4/20	Mostly Sunny	55.2	28.6	0.00	56.3	25.0	0.00	55.2	27.1	0.00	59.0	25.2	0.00	-
4/21	Mostly Sunny	58.3	27.3	0.00	61.5	23.2	0.00	61.2	23.7	0.00	64.8	25.0	0.00	-
4/22	Cloudy	45.9	30.0	0.38	45.7	31.3	0.33	44.8	30.2	0.07	44.6	32.7	0.01	Event 1
4/23	Cloudy	46.4	32.5	0.00	49.8	33.3	0.00	45.7	31.3	0.00	49.3	32.7	0.00	-
4/24	Cloudy	54.5	36.7	0.16	55.2	36.3	0.21	52.3	36.1	0.17	52.5	35.4	0.10	Not enough time elapsed
4/25	Cloudy	52.9	37.0	0.44	56.8	39.7	0.43	51.4	34.3	0.38	49.5	36.1	0.28	Not enough time elapsed
4/26	Cloudy	54.9	35.1	0.04	55.0	35.2	0.01	54.1	33.6	0.01	55.0	33.3	0.28	-
4/27	Mostly Sunny	64.0	32.0	0.00	63.9	28.9	0.00	62.6	27.3	0.00	66.9	28.0	0.00	-
4/28	Cloudy	74.5	49.8	0.00	74.5	47.3	0.00	73.4	45.1	0.00	75.4	45.7	0.00	-
4/29	Cloudy	-	-	-	-	-	-	-	-	-	-	-	-	No station data available
4/30	Mostly Sunny	72.1	54.3	0.00	71.4	52.3	0.00	-	-	-	72.1	47.5	0.00	-

APPENDIX C: 2021 WEATHER TRACKER

May 2021														
		Kalispell			Evergreen			Columbia Falls			Whitefish			
Date	Description	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	Sampling Event & Notes
5/1	Mostly Sunny	68.4	46.4	0.00	70.9	41.5	0.00	68.5	42.6	0.00	72.0	39.9	0.00	-
5/2	Cloudy	61.5	41.7	0.00	62.8	38.1	0.00	60.1	37.4	0.12	64.0	37.8	0.01	-
5/3	Cloudy	58.5	34.3	0.00	60.6	32.2	0.01	60.4	32.5	0.00	61.5	31.6	0.01	-
5/4	Cloudy	63.5	39.7	0.00	-	-	-	63.0	37.8	0.00	63.9	38.1	0.00	-
5/5	Mostly Sunny	-	-	-	-	-	-	-	-	-	-	-	-	No station data available
5/6	Mostly Sunny	80.2	41.5	0.00	-	-	-	79.3	42.3	0.00	81.9	36.3	0.01	-
5/7	Cloudy	67.5	42.4	0.01	62.4	42.6	0.01	65.7	41.0	0.02	56.5	39.0	0.01	-
5/8	Cloudy	46.2	39.0	0.00	44.4	40.5	0.17	41.7	36.3	0.26	43.2	36.7	0.27	-
5/9	Cloudy	50.7	36.7	0.01	52.7	38.1	0.01	52.0	34.9	0.00	53.2	36.5	0.01	-
5/10	Mostly Sunny	-	-	-	-	-	-	-	-	-	-	-	-	No station data available
5/11	Cloudy	61.0	35.1	0.00	61.3	32.9	0.00	59.9	30.2	0.00	61.3	31.3	0.00	-
5/12	Mostly Sunny	65.3	34.3	0.00	68.0	35.2	0.00	66.2	34.2	0.00	67.5	30.9	0.00	-
5/13	Cloudy	69.8	47.7	0.03	73.0	48.6	0.02	70.5	43.5	0.03	71.6	43.7	0.03	-
5/14	Mostly Sunny	72.9	42.8	0.00	75.0	42.3	0.00	74.1	45.3	0.00	75.0	39.9	0.06	-
5/15	Mostly Sunny	76.8	42.1	0.00	79.3	41.2	0.00	76.8	41.9	0.00	82.4	37.9	0.00	-
5/16	Mostly Sunny	79.2	44.6	0.00	79.7	41.4	0.00	79.3	41.2	0.00	81.9	38.7	0.00	-
5/17	Mostly Sunny	61.9	52.5	0.00	-	-	-	61.0	47.1	0.00	59.0	45.9	0.00	-
5/18	Cloudy	55.4	34.3	0.00	-	-	-	55.6	28.2	0.00	55.4	30.6	0.00	-
5/19	Cloudy	-	-	-	57.9	31.1	0.00	-	-	-	-	-	-	-
5/20	Cloudy	50.2	39.6	0.05	51.8	39.9	0.04	49.8	38.3	0.00	55.2	39.4	0.00	-
5/21	Cloudy	46.6	39.0	0.00	47.8	38.8	0.00	45.1	37.6	0.00	48.4	39.0	0.00	-
5/22	Mostly Sunny	65.5	39.0	0.00	68.5	38.7	0.00	65.1	37.0	0.00	69.8	38.7	0.00	-
5/23	Scattered Showers	54.3	41.2	0.69	52.9	43.9	0.84	51.8	40.8	0.91	50.2	41.5	0.70	Prioritizing auto data
5/24	Scattered Showers	54.5	42.4	0.64	53.2	44.6	0.50	47.1	40.3	1.76	49.1	41.5	0.80	-
5/25	Cloudy	64.4	46.4	0.26	66.0	50.0	0.27	64.2	46.0	0.37	66.4	45.7	0.15	-
5/26	Cloudy	64.0	48.0	0.20	68.7	46.0	0.14	63.7	44.8	0.20	64.0	45.3	0.06	-
5/27	Foggy	74.7	41.4	0.02	73.2	42.3	0.00	73.2	37.4	0.00	73.2	40.5	0.00	-
5/28	Cloudy	60.3	46.9	0.00	61.5	42.6	0.00	55.4	37.9	0.00	60.4	39.6	0.00	-
5/29	Mostly Sunny	66.4	37.6	0.00	68.5	36.9	0.00	67.6	31.1	0.00	71.6	34.3	0.00	-
5/30	Mostly Sunny	73.8	40.6	0.00	75.9	39.4	0.00	74.8	37.6	0.00	79.0	36.1	0.00	-
5/31	Mostly Sunny	79.5	46.6	0.00	79.7	42.1	0.00	80.6	39.6	0.00	84.0	39.6	0.00	-

June 2021															
		Kalispell			Evergreen			Columbia Falls			Whitefish			
Date	Description	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	Sampling Event & Notes
6/1	Mostly Sunny	82.6	52.5	0.00	83.1	48.2	0.00	84.0	47.1	0.00	86.7	45.9	0.00	-
6/2	Mostly Sunny	86.9	54.3	0.00	87.1	52.2	0.00	88.0	50.2	0.00	91.0	48.6	0.00	-
6/3	Mostly Sunny	93.6	57.7	0.00	91.4	53.1	0.00	91.4	52.3	0.00	90.5	50.0	0.00	-
6/4	Mostly Sunny	84.6	61.9	0.00	84.4	60.4	0.00	83.8	55.0	0.00	88.2	54.7	0.00	-
6/5	Mostly Sunny	69.3	53.2	0.00	70.7	48.0	0.00	68.4	50.5	0.00	72.1	47.3	0.00	-
6/6	Cloudy	62.1	49.6	0.00	63.7	45.1	0.00	62.8	47.7	0.00	63.7	43.3	0.00	-
6/7	Cloudy	65.1	43.0	0.00	65.3	40.5	0.00	59.7	38.7	0.00	63.0	41.9	0.01	-
6/8	Mostly Sunny	72.5	47.3	0.00	73.6	47.7	0.00	66.7	47.5	0.00	71.8	46.4	0.01	-
6/9	Scattered Showers	61.7	45.1	0.43	64.0	49.6	0.47	60.3	48.0	0.47	64.2	44.4	0.39	-
6/10	Scattered Showers	54.7	46.4	1.03	56.3	49.8	1.13	51.4	44.4	0.83	53.6	44.1	0.63	Budget concerns
6/11	Foggy	66.0	37.9	0.00	67.1	41.0	0.01	66.0	34.3	0.01	65.1	37.9	0.00	-
6/12	Cloudy	68.4	48.7	0.32	72.0	49.8	0.25	68.7	46.8	0.34	77.9	48.9	0.17	-
6/13	Mostly Sunny	87.8	46.8	0.00	88.3	47.8	0.00	91.8	45.7	0.00	89.2	41.9	0.00	-
6/14	Mostly Sunny	91.0	58.3	0.00	90.7	56.3	0.00	92.7	58.6	0.00	95.4	52.7	0.00	-
6/15	Cloudy	78.8	56.5	0.07	79.5	54.1	0.09	76.3	53.8	0.04	79.7	55.8	0.01	-
6/16	Mostly Sunny	72.7	51.6	0.00	75.6	50.0	0.00	71.6	47.3	0.00	74.3	49.1	0.01	-
6/17	Mostly Sunny	79.0	46.2	0.00	79.7	42.4	0.00	77.2	37.6	0.00	80.6	40.3	0.06	-
6/18	Mostly Sunny	82.6	49.6	0.00	-	-	-	84.2	43.5	0.00	86.0	44.4	0.00	-
6/19	Mostly Sunny	79.2	52.7	0.00	-	-	-	83.3	45.3	0.00	81.3	46.4	0.00	-
6/20	Cloudy	75.9	52.9	0.36	70.0	60.6	0.00	75.7	50.4	0.22	76.3	51.1	0.28	-
6/21	Mostly Sunny	78.8	49.1	0.00	-	-	-	80.6	47.3	0.00	83.5	45.5	0.00	-
6/22	Mostly Sunny	90.9	53.6	0.00	89.4	52.3	0.00	88.7	47.3	0.00	91.9	48.2	0.00	-
6/23	Mostly Sunny	83.7	59.2	0.07	82.8	57.9	0.06	79.7	52.2	0.00	82.2	53.1	0.00	-
6/24	Cloudy	79.0	56.3	0.29	81.9	53.4	0.30	80.4	51.3	0.02	83.1	54.0	0.07	-
6/25	Mostly Sunny	84.6	55.2	0.00	87.3	58.5	0.00	85.1	53.2	0.00	89.6	51.8	0.00	-
6/26	Mostly Sunny	91.0	61.2	0.00	92.1	60.4	0.00	91.6	59.2	0.00	94.5	56.1	0.00	-
6/27	Mostly Sunny	94.8	61.0	0.00	93.4	60.1	0.00	95.0	58.8	0.00	97.7	55.2	0.00	-
6/28	Mostly Sunny	97.3	62.8	0.00	97.7	61.0	0.00	97.0	61.7	0.00	99.9	57.9	0.00	-
6/29	Mostly Sunny	102.0	66.4	0.00	102.7	64.0	0.00	103.3	64.8	0.00	103.1	60.8	0.00	-
6/30	Mostly Sunny	102.0	62.8	0.00	102.0	59.0	0.00	102.6	68.4	0.00	103.8	58.5	0.00	-

APPENDIX C: 2021 WEATHER TRACKER

July 2021														
		Kalispell			Evergreen			Columbia Falls			Whitefish			
Date	Description	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	Sampling Event & Notes
7/1	Mostly Sunny	95.4	64.8	0.07	95.7	62.1	0.06	97.9	66.4	0.00	99.9	58.8	0.50	-
7/2	Mostly Sunny	93.2	61.2	0.10	91.9	63.5	0.12	92.8	58.1	0.06	93.0	59.4	0.03	-
7/3	Mostly Sunny	91.0	57.4	0.00	91.9	53.4	0.00	92.1	49.3	0.00	94.3	52.3	0.00	-
7/4	Mostly Sunny	92.3	56.8	0.00	92.5	52.7	0.00	93.7	52.2	0.00	95.4	51.6	0.00	-
7/5	Mostly Sunny	90.5	61.3	0.00	93.2	61.2	0.00	91.6	66.4	0.00	94.6	61.2	0.00	-
7/6	Mostly Sunny	90.0	60.3	0.00	90.9	61.0	0.00	91.2	63.3	0.00	92.3	58.8	0.00	-
7/7	Mostly Sunny	88.2	59.2	0.03	90.1	57.2	0.04	88.2	60.4	0.00	91.8	54.7	0.02	-
7/8	Mostly Sunny	86.5	57.9	0.00	88.3	55.6	0.00	87.8	55.4	0.00	92.5	56.7	0.00	-
7/9	Mostly Sunny	88.9	61.5	0.00	91.2	58.6	0.00	89.8	58.6	0.00	93.7	57.9	0.00	-
7/10	Mostly Sunny	93.0	55.8	0.00	92.1	52.3	0.00	92.8	55.8	0.00	94.8	50.4	0.00	-
7/11	Mostly Sunny	92.8	56.3	0.00	92.8	51.6	0.00	93.2	51.1	0.00	95.5	51.1	0.00	-
7/12	Mostly Sunny	92.7	56.3	0.00	95.2	52.9	0.00	94.3	54.3	0.00	96.6	50.9	0.00	-
7/13	Mostly Sunny	91.2	60.1	0.00	92.5	56.7	0.00	91.2	69.3	0.00	93.4	55.9	0.00	-
7/14	Mostly Sunny	91.6	58.3	0.00	93.2	54.7	0.00	94.1	59.2	0.00	95.0	54.7	0.00	-
7/15	Foggy	93.2	59.0	0.00	93.4	54.1	0.00	93.7	52.9	0.00	94.3	53.1	0.00	-
7/16	Foggy	86.2	57.9	0.00	88.2	52.2	0.00	89.4	48.6	0.00	89.4	52.5	0.00	-
7/17	Foggy	87.1	57.9	0.00	89.1	52.9	0.00	89.6	49.5	0.00	91.6	52.2	0.00	-
7/18	Foggy	93.0	58.5	0.00	96.1	54.3	0.00	94.1	55.8	0.00	95.4	54.0	0.00	-
7/19	Foggy	85.8	59.7	0.00	87.1	55.4	0.00	87.8	59.7	0.00	87.4	54.9	0.00	-
7/20	Foggy	88.2	65.5	0.00	88.7	61.9	0.00	85.1	60.6	0.00	84.4	59.7	0.17	-
7/21	Foggy	85.1	56.8	0.00	88.0	55.9	0.00	84.0	51.4	0.00	86.2	53.2	0.00	-
7/22	Mostly Sunny	84.0	55.0	0.00	85.8	50.0	0.00	84.9	46.0	0.00	90.3	48.6	0.00	-
7/23	Foggy	84.6	50.7	0.00	85.3	44.1	0.00	85.5	42.4	0.00	89.1	43.9	0.00	-
7/24	Foggy	86.9	53.2	0.00	89.2	47.1	0.00	88.2	46.0	0.00	90.5	47.1	0.00	-
7/25	Foggy	90.7	55.0	0.00	93.4	49.6	0.00	93.0	50.7	0.00	95.5	48.4	0.00	-
7/26	Foggy	91.0	57.7	0.00	92.8	51.4	0.00	94.1	52.3	0.00	93.2	51.1	0.00	-
7/27	Mostly Sunny	94.3	60.8	0.00	96.6	52.9	0.00	94.3	52.7	0.00	99.3	52.7	0.01	-
7/28	Mostly Sunny	87.1	63.3	0.02	90.3	64.8	0.01	88.7	64.9	0.00	92.3	64.2	0.00	-
7/29	Foggy	96.4	63.9	0.00	96.4	59.7	0.00	95.5	59.2	0.00	98.4	59.0	0.00	-
7/30	Foggy	96.8	61.7	0.00	99.5	56.7	0.00	98.2	60.8	0.00	99.1	55.4	0.00	-
7/31	Foggy	100.8	66.9	0.00	103.6	60.4	0.00	99.1	71.1	0.00	100.6	61.5	0.00	-

APPENDIX C: 2021 WEATHER TRACKER

August 2021														
		Kalispell			Evergreen			Columbia Falls			Whitefish			
Date	Description	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	Sampling Event & Notes
8/1	Foggy	96.3	67.8	0.67	99.5	63.9	0.87	97.5	66.0	0.26	99.5	65.8	0.13	Out of town
8/2	Foggy	80.2	66.4	0.01	81.9	71.1	0.00	75.9	63.9	0.52	80.2	65.1	0.00	-
8/3	Foggy	88.3	63.0	0.00	90.1	63.9	0.00	87.6	58.6	0.00	89.2	61.5	0.00	-
8/4	Foggy	90.7	58.5	0.00	93.9	55.6	0.00	91.2	56.5	0.00	92.3	55.4	0.00	-
8/5	Foggy	85.8	59.7	0.00	87.3	58.3	0.00	87.8	57.2	0.00	86.2	58.5	0.00	-
8/6	Foggy	84.4	60.3	0.00	85.1	58.3	0.00	84.9	57.4	0.00	86.7	58.3	0.00	-
8/7	Foggy	83.3	63.0	0.00	85.1	59.9	0.00	81.7	63.7	0.00	85.1	58.3	0.00	-
8/8	Cloudy	70.3	50.7	0.55	72.0	52.0	0.48	72.9	50.9	0.61	70.0	51.1	0.35	Event 2
8/9	Cloudy	72.0	50.4	0.04	76.5	52.2	0.00	69.4	49.5	0.04	74.1	49.8	0.04	-
8/10	Mostly Sunny	84.4	52.2	0.00	84.4	53.4	0.00	82.0	48.9	0.00	84.0	50.7	0.00	-
8/11	Mostly Sunny	94.6	59.5	0.00	93.6	55.8	0.00	93.0	53.4	0.00	95.2	53.4	0.00	-
8/12	Mostly Sunny	88.5	63.9	0.00	90.9	61.2	0.00	87.1	65.1	0.00	91.4	59.0	0.00	-
8/13	Foggy	91.9	58.1	0.00	93.2	54.7	0.00	91.0	58.6	0.00	94.6	53.1	0.00	-
8/14	Foggy	88.0	58.1	0.00	88.9	54.9	0.00	88.9	54.9	0.00	-	52.7	0.00	-
8/15	Foggy	96.6	57.4	0.00	97.5	55.6	0.00	96.3	52.9	0.00	98.1	54.5	0.00	-
8/16	Foggy	90.1	62.6	0.00	90.1	54.9	0.00	88.7	55.6	0.00	88.0	54.7	0.00	-
8/17	Scattered Showers	70.3	49.8	0.04	63.9	50.7	0.02	64.4	47.3	0.15	64.0	48.9	0.27	Event 3 - Only Whitefish
8/18	Cloudy	67.1	48.7	0.06	70.2	50.7	0.05	69.6	46.6	0.02	68.5	47.8	0.03	-
8/19	Foggy	72.1	45.5	0.07	76.5	46.2	0.05	72.7	41.5	0.02	78.6	44.2	0.01	-
8/20	Cloudy	74.1	51.8	0.20	77.0	54.7	0.21	71.8	52.2	0.10	74.8	50.9	0.21	Rained at night
8/21	Cloudy	63.5	53.2	0.13	66.6	53.2	0.05	61.7	51.1	0.10	65.1	50.9	0.15	Event 4
8/22	Cloudy	73.2	52.9	0.00	75.2	53.4	0.00	71.4	51.6	0.01	73.8	52.5	0.04	-
8/23	Mostly Sunny	70.3	47.3	0.00	71.8	45.9	0.00	68.0	41.5	0.00	68.4	44.4	0.02	-
8/24	Mostly Sunny	72.1	41.0	0.00	76.3	38.5	0.00	72.5	34.9	0.00	76.1	37.0	0.00	-
8/25	Mostly Sunny	76.6	44.4	0.00	79.5	41.9	0.00	74.7	45.0	0.00	77.9	44.4	0.00	-
8/26	Mostly Sunny	75.7	48.6	0.00	80.4	46.9	0.00	75.9	43.7	0.00	75.9	44.4	0.00	-
8/27	Rain	67.1	51.4	0.94	69.3	52.9	0.54	62.2	49.6	0.55	64.0	50.0	0.40	Accumulation not predicted
8/28	Rain	71.4	47.8	0.00	74.8	52.0	0.00	71.8	44.8	0.01	75.6	46.2	0.01	-
8/29	Foggy	77.4	46.6	0.00	80.4	47.5	0.00	77.0	43.0	0.00	81.9	42.8	0.00	-
8/30	Mostly Sunny	81.5	49.1	0.00	85.1	46.6	0.00	81.9	47.1	0.00	84.0	44.6	0.00	-
8/31	Mostly Sunny	70.3	48.6	0.00	73.0	43.5	0.00	69.1	40.5	0.00	73	42.8	0.00	-

APPENDIX C: 2021 WEATHER TRACKER

September 2021														
		Kalispell			Evergreen			Columbia Falls			Whitefish			
Date	Description	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	Sampling Event & Notes
9/1	Mostly Sunny	71.2	41.1	0.00	72.1	38.1	0.00	68.4	36.7	0.00	71.8	41.4	0.00	-
9/2	Mostly Sunny	73.4	42.3	0.00	77.0	39.6	0.00	71.8	40.5	0.00	77.7	42.6	0.00	-
9/3	Mostly Sunny	73.2	43.5	0.00	77.5	41.2	0.00	74.1	40.6	0.00	79.0	40.5	0.00	-
9/4	Mostly Sunny	77.7	46.6	0.00	80.4	42.6	0.00	77.2	42.4	0.00	82.0	41.5	0.00	-
9/5	Mostly Sunny	85.5	47.3	0.00	86.2	43.3	0.00	84.4	40.5	0.00	86.4	41.9	0.00	-
9/6	Mostly Sunny	81.3	57.7	0.00	82.6	52.0	0.00	79.2	51.4	0.00	81.3	53.2	0.00	-
9/7	Mostly Sunny	83.7	49.3	0.00	86.9	43.5	0.00	82.8	42.6	0.00	85.6	43.5	0.00	-
9/8	Mostly Sunny	80.2	50.0	0.00	83.3	44.8	0.00	80.6	50.5	0.00	82.9	44.6	0.00	-
9/9	Foggy	82.9	49.8	0.00	86.0	45.1	0.00	83.5	43.3	0.00	88.7	46.0	0.00	-
9/10	Foggy	75.4	57.0	0.21	77.2	52.0	0.22	74.8	50.2	0.22	73.8	53.1	0.13	Rained at night
9/11	Cloudy	63.5	51.6	0.33	66.0	51.8	0.37	59.0	54.0	0.34	58.8	52.9	0.20	Rained at night
9/12	Foggy	67.3	43.5	0.00	68.9	46.4	0.00	65.1	42.4	0.00	67.1	44.2	0.00	-
9/13	Foggy	69.4	49.6	0.04	74.8	49.8	0.04	68.2	45.1	0.05	70.7	47.7	0.07	-
9/14	Mostly Sunny	71.4	43.5	0.00	74.8	44.6	0.00	71.2	40.8	0.00	75.6	39.9	0.00	-
9/15	Cloudy	72.3	54.3	0.00	74.3	54.7	0.00	70.7	52.2	0.02	70.0	51.6	0.01	-
9/16	Mostly Sunny	64.6	42.1	0.00	66.7	39.0	0.00	62.2	34.2	0.00	68.9	37.2	0.00	-
9/17	Cloudy	71.1	33.4	0.00	73.0	32.0	0.00	68.7	31.1	0.00	68.5	30.9	0.00	-
9/18	Cloudy	67.1	48.0	0.02	66.9	43.9	0.04	64.8	43.9	0.01	63.1	48.6	0.00	-
9/19	Cloudy	56.1	46.4	0.31	61.2	48.6	0.30	55.4	44.4	0.38	58.8	44.6	0.21	In Milwaukee for StormCon
9/20	Cloudy	58.8	42.8	0.03	60.1	42.4	0.01	57.4	42.6	0.01	60.6	40.3	0.04	-
9/21	Foggy	65.3	36.1	0.00	68.4	35.6	0.00	65.3	33.3	0.00	71.8	34.3	0.00	-
9/22	Mostly Sunny	73.2	38.7	0.00	76.5	37.8	0.00	71.1	36.7	0.00	72.7	34.9	0.00	-
9/23	Mostly Sunny	71.1	47.3	0.00	73.0	43.0	0.00	69.1	39.7	0.00	77.4	40.8	0.00	-
9/24	Mostly Sunny	70.7	42.8	0.00	75.6	40.8	0.00	69.6	36.7	0.00	79.2	37.9	0.00	-
9/25	Mostly Sunny	76.3	45.7	0.00	79.5	44.6	0.00	76.5	44.2	0.00	83.1	42.8	0.00	-
9/26	Mostly Sunny	79.7	45.5	0.00	83.7	43.5	0.00	77.0	40.3	0.00	80.1	41.2	0.00	-
9/27	Cloudy	73.4	42.4	0.00	74.7	40.1	0.00	69.6	38.8	0.00	69.6	38.5	0.00	-
9/28	Cloudy	58.6	45.1	0.02	56.8	43.5	0.02	55.4	45.3	0.08	54.5	42.3	0.05	-
9/29	Cloudy	59.5	41.4	0.02	62.1	38.7	0.02	57.9	37.2	0.00	63.7	39.9	0.00	-
9/30	Mostly Sunny	66.7	34.3	0.00	70.3	33.4	0.01	65.8	29.8	0.00	70.7	31.6	0.01	-

APPENDIX C: 2021 WEATHER TRACKER

October 2021														
		Kalispell			Evergreen			Columbia Falls			Whitefish			
Date	Description	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	High (°F)	Low (°F)	Pre (in)	Sampling Event & Notes
10/1	Mostly Sunny	67.6	45.3	0.00	73.0	40.6	0.00	65.1	38.5	0.00	77.7	41.4	0.00	-
10/2	Mostly Sunny	67.6	36.1	0.00	70.3	32.7	0.00	66.2	30.7	0.00	71.8	32.0	0.00	-
10/3	Mostly Sunny	74.3	42.1	0.00	76.1	39.0	0.00	72.3	37.8	0.00	74.3	41.5	0.00	-
10/4	Mostly Sunny	76.8	38.8	0.00	81.0	33.8	0.00	73.0	35.1	0.00	80.4	33.6	0.00	-
10/5	Mostly Sunny	80.4	45.0	0.00	80.1	40.6	0.00	77.4	40.5	0.00	81.7	40.5	0.00	-
10/6	Mostly Sunny	62.4	43.7	0.00	65.1	42.3	0.00	63.9	33.6	0.00	64.9	36.0	0.00	-
10/7	Mostly Sunny	56.7	30.7	0.00	61.0	29.1	0.00	55.8	25.9	0.00	63.0	28.4	0.00	-
10/8	Cloudy	54.0	28.0	0.00	55.0	25.3	0.00	54.9	25.3	0.00	56.3	30.6	0.00	-
10/9	Mostly Sunny	59.5	31.5	0.00	63.1	28.6	0.00	57.9	26.1	0.00	63.1	27.0	0.00	-
10/10	Cloudy	55.8	36.9	0.02	58.6	35.2	0.01	55.4	27.9	0.00	57.4	31.6	0.00	-
10/11	Mostly Sunny	51.4	28.6	0.00	54.7	25.2	0.00	50.0	24.3	0.00	52.3	26.1	0.00	-
10/12	Mostly Sunny	50.9	23.2	0.00	56.8	21.0	0.00	48.4	24.8	0.00	55.9	21.9	0.02	-
10/13	Cloudy	42.4	23.4	0.00	44.2	17.4	0.00	40.6	17.6	0.01	42.4	18.9	0.00	-
10/14	Cloudy	47.7	32.0	0.00	51.1	30.9	0.00	44.6	32.5	0.00	45.7	30.9	0.00	-
10/15	Cloudy	52.9	39.2	0.00	54.3	37.9	0.00	49.3	37.6	0.00	47.8	36.7	0.00	-
10/16	Mostly Sunny	68.5	34.9	0.00	71.1	32.4	0.00	65.8	32.5	0.00	71.1	33.3	0.00	-
10/17	Mostly Sunny	68.7	33.4	0.00	73.6	29.3	0.00	69.1	30.6	0.00	70.7	28.6	0.00	-
10/18	Mostly Sunny	71.8	36.3	0.00	72.7	31.5	0.00	66.7	34.3	0.00	66.4	29.7	0.00	-
10/19	Mostly Sunny	64.8	35.8	0.00	68.2	34.3	0.00	62.1	42.1	0.00	67.8	34.2	0.00	-
10/20	Cloudy	60.4	35.1	0.00	62.8	31.3	0.00	58.3	33.4	0.00	60.6	30.7	0.00	-
10/21	Foggy	59.7	34.9	0.00	65.1	34.5	0.00	57.0	30.7	0.00	61.0	32.7	0.00	-
10/22	Rain	53.6	36.3	0.19	55.0	33.8	0.25	54.0	36.0	0.60	54.9	32.5	0.39	Rain overnight
10/23	Cloudy	54.3	43.2	0.39	56.5	42.8	0.35	52.0	40.8	0.58	51.4	40.6	0.34	Rain overnight
10/24	Cloudy	52.2	37.9	0.04	55.0	37.0	0.09	52.3	36.9	0.16	53.2	38.7	0.11	-
10/25	Cloudy	51.3	39.0	0.06	52.0	35.4	0.07	46.9	35.6	0.33	49.8	35.1	0.16	-
10/26	Cloudy	53.8	37.6	0.00	55.0	35.1	0.00	49.5	36.5	0.00	51.8	37.4	0.00	-
10/27	Cloudy	52.9	41.4	0.01	55.9	37.0	0.01	48.7	40.5	0.02	50.5	33.1	0.02	-
10/28	Cloudy	50.4	37.4	0.03	54.1	35.2	0.04	54.9	37.6	0.11	47.3	30.7	0.07	-
10/29	Cloudy	58.6	43.0	0.44	58.3	42.1	0.46	56.7	39.2	0.75	50.4	36.9	0.67	Vacation
10/30	Mostly Sunny	45.1	29.7	0.00	47.3	27.9	0.00	43.3	30.6	0.00	45.0	25.7	0.03	-
10/31	Mostly Sunny	44.6	22.5	0.00	47.3	23.7	0.00	42.3	27.0	0.00	40.5	22.1	0.00	-

APPENDIX D: LOCAL WEATHER STATION DATA

	Kalispell	Evergreen	Columbia Falls	Whitefish
Weather Station ID	KMTKALIS96	KMTKALIS52	KMTCOLUM1	KMTWHITE29
Station Name	Downtown Kalispell	River Place	Tamarack Lane	Murray Ave
Lat/Long	48.195°N, 114.311°W	48.22°N, 114.285°W	48.385°N, 114.189°W	48.412°N, 114.354°W
Elevation (ft)	3071	3071	3133	3054
Hardware	Ambient Weather WS-2902	Ambient Weather WS-1200-IP (Wireless)	La Crosse	AcuRite Pro Weather Center
Software	AMBWeatherV3.0.3	Weather logger V3.0.7	AMBWeatherV4.2.6	myAcuRite
Retrieved from	https://www.wunderground.com/dashboard/pws/KMTKALIS96	https://www.wunderground.com/dashboard/pws/KMTKALIS52	https://www.wunderground.com/dashboard/pws/KMTCOLUM1	https://www.wunderground.com/dashboard/pws/KMTWHITE29

Weather station data used to monitor stormwater sampling conditions in Kalispell, Evergreen, Columbia Falls, and Whitefish. Data from these weather stations were used to create the 2021 Weather Tracker (Appendix C), to retrieve weather graphs for each location (Appendix F), and to determine precipitation accumulations and storm durations at time of sampling (Appendix E). All weather station data obtained from Weather Underground (2021a, 2021b, 2021c, 2021d).

APPENDIX E: IN-FIELD STORMWATER SAMPLING DATA

The following tables present the in-field measurements collected during each stormwater sampling event. Precipitation accumulation and storm duration data obtained from local weather stations (Appendix D and Appendix F). Sample spot refers to end of pipe (1), inside of catch basin (2), in stream (3), or in manhole (4). Precipitation refers to no rain (1), light rain (2), rain (3), heavy rain/storm (4), or snow (5). Weather refers to 0-5% (1), 5-25% (2), 25-75% (3), 75-99% (4), or 100% humidity/cloud cover (5).

EVENT 1

Date: 4/22/2021				**Sampler Name:** Emilie Henry									
			Kalispell		**Evergreen**			**Columbia Falls**			**Whitefish**		
Total Accumulated Precipitation at Time of Sampling (in):			0.22		0.26			0.07			0.01		
Storm Duration from Beginning to Time of Sampling (hrs):			1.37		1.50			2.43			1.62		
					DO Meter				**pH Meter**				
Site Name	**Location**	**Type**	**Sample Spot**	**Time**	**DO (mg/L)**	**Sample Temp (°C)**	**Pressure (hPa)**	**% of Air Sat**	**pH**	**Sample Temp (°C)**	**Air Temp (°F)**	**Precip**	**Weather**
Kalispell - City Shop (KAL_AC6)	Near City Shops off of 1st Ave. W (48.18342°N, 114.3125°W)	Com	1	11:46 AM	10.09	8.1	907	95.5	8.83	8.4	38	4-5	5
Evergreen - HWY 2 (EVE_SW1)	Under bridge over Stillwater River on HWY 2 (48.21083°N, 114.2872°W)	Com/Res	1	12:14 PM	10.76	6.6	910	97.8	9.07	7.9	38	4-5	5
Columbia Falls - HWY 2 (COL_CB1)	Off of HWY 2 near C. Falls Marine Services (48.36773°N, 114.1751°W)	Ind/Res	1	12:55 PM	10.07	6.8	908	92.3	8.39	6.7	38	1	4
Whitefish - City Beach (WHI_WR5)	Near City Beach just north of railroad (48.41472°N, 114.3508°W)	Com	1	1:26 PM	10.48	6.3	908	94.7	8.26	7.2	39	1	4
Date Equipment Last Calibrated: 4/22/2021		Delivered to ME Labs: 4/22/2021 at 2:30 PM						Delivered by: Emilie Henry					

EVENT 2

Date: 8/8/2021				**Sampler Name:** Emilie Henry									
			Kalispell		**Evergreen**			**Columbia Falls**			**Whitefish**		
Total Accumulated Precipitation at Time of Sampling (in):			0.09		0.12			0.26			0.13		
Storm Duration from Beginning to Time of Sampling (hrs):			3.25		3.75			3			1		
Kalispell - City Shop (KAL_AC6)	Near City Shops off of 1st Ave W (48.18342°N, 114.3125°W)	Com	1	-	-	-	-	-	-	-	-	-	-
Evergreen - Hwy 2 (EVE_SW1)	Under bridge over Stillwater River on Hwy 2 (48.21083°N, 114.2872°W)	Com/Res	1	-	-	-	-	-	-	-	-	-	-
Columbia Falls - Hwy 2 (COL_CB1)	Off of HWY 2 near C. Falls Marine Services (48.36773°N, 114.1751°W)	Ind/Res	1	-	-	-	-	-	-	-	-	-	-
Whitefish - City Beach (WHI_WR5)	Near City Beach just north of railroad (48.41472°N, 114.3508°W)	Com	1	12:12 PM	7.10	18.8	902	85.7	8.05	18.5	54	3	5
Date Equipment Last Calibrated: 8/16/2021		Delivered to ME Labs: 8/18/2021 at 9:10 AM						Delivered by: Emilie Henry					

APPENDIX E: IN-FIELD STORMWATER SAMPLING DATA

EVENT 3

Date: 8/17/2021					**Sampler Name:** Emilie Henry								
			Kalispell		**Evergreen**			**Columbia Falls**			**Whitefish**		
Total Accumulated Precipitation at Time of Sampling (in):			-		-			-			0.13		
Storm Duration from Beginning to Time of Sampling (hrs):			-		-			-			1		
					DO Meter				**pH Meter**				
Site Name	**Location**	**Type**	**Sample Spot**	**Time**	**DO (mg/L)**	**Sample Temp (°C)**	**Pressure (hPa)**	**% of Air Sat**	**pH**	**Sample Temp (°C)**	**Air Temp (°F)**	**Precip**	**Weather**
Kalispell - City Shop (KAL_AC6)	Near City Shops off of 1st Ave W (48.18342°N, 114.3125°W)	Com	1	-	-	-	-	-	-	-	-	-	-
Evergreen - Hwy 2 (EVE_SW1)	Under bridge over Stillwater River on Hwy 2 (48.21083°N, 114.2872°W)	Com/Res	1	-	-	-	-	-	-	-	-	-	-
Columbia Falls - Hwy 2 (COL_CB1)	Off of HWY 2 near C. Falls Marine Services (48.36773°N, 114.1751°W)	Ind/Res	1	-	-	-	-	-	-	-	-	-	-
Whitefish - City Beach (WHI_WR5)	Near City Beach just north of railroad (48.41472°N, 114.3508°W)	Com	1	12:12 PM	7.10	18.8	902	85.7	8.05	18.5	54	3	5
Date Equipment Last Calibrated: 8/16/2021		Delivered to ME Labs: 8/18/2021 at 9:10 AM						Delivered by: Emilie Henry					

EVENT 4

Date: 8/21/2021					**Sampler Name:** Emilie Henry								
			Kalispell		**Evergreen**			**Columbia Falls**			**Whitefish**		
Total Accumulated Precipitation at Time of Sampling (in):			0.1		0.05			0.09			0.14		
Storm Duration from Beginning to Time of Sampling (hrs):			1.5		1.75			1.5			3		
					DO Meter				**pH Meter**				
Site Name	**Location**	**Type**	**Sample Spot**	**Time**	**DO (mg/L)**	**Sample Temp (°C)**	**Pressure (hPa)**	**% of Air Sat**	**pH**	**Sample Temp (°C)**	**Air Temp (°F)**	**Precip**	**Weather**
Kalispell - City Shop (KAL_AC6)	Near City Shops off of 1st Ave W (48.18342°N, 114.3125°W)	Com	1	10:08 AM	7.74	17.2	905	90.2	8.36	16.5	53	3	5
Evergreen - Hwy 2 (EVE_SW1)	Under bridge over Stillwater River on Hwy 2 (48.21083°N, 114.2872°W)	Com/Res	1	10:31 AM	7.97	17.2	906	92.8	8.26	16.2	53	3	5
Columbia Falls - Hwy 2 (COL_CB1)	Off of HWY 2 near C. Falls Marine Services (48.36773°N, 114.1751°W)	Ind/Res	1	11:08 AM	8.36	16.9	902	97.1	5.58	16.4	55	2	5
Whitefish - City Beach (WHI_WR5)	Near City Beach just north of railroad (48.41472°N, 114.3508°W)	Com	1	11:50 AM	7.91	16.2	902	90.6	7.98	15.2	55	2	5
Date Equipment Last Calibrated: 8/16/2021		Delivered to ME Labs: 8/23/2021 at 9:10 AM						Delivered by: Emilie Henry					
Note: Samples kept in refrigerator between time of collection and delivery to ME Labs.													

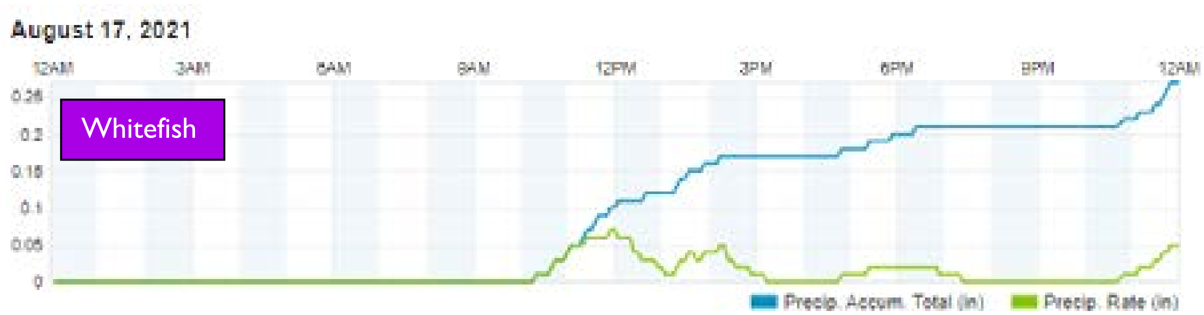
APPENDIX F: WEATHER GRAPHS FOR SAMPLING EVENTS

The following graphs show the precipitation rates and total accumulated precipitation over the course of the sampling events for 2021 in Kalispell, Evergreen, Columbia Falls, and Whitefish. Graphs were produced using local weather station data (Appendix D) and obtained from Weather Underground (2021a, 2021b, 2021c, 2021d).

EVENT 1

EVENT 2

EVENT 3



EVENT 4

August 21, 2021