Bowman Creek Watershed Management

Monitoring and Maintenance Plan

August 2018

Prepared by
Jacqueline Whalen, *University of Notre Dame*
Gemma Stanton, *University of Notre Dame*

Bowman Creek Educational Ecosystem
bowmancreekproject@gmail.com
www.BCe2.org
LangLab
1302 High Street South Bend, IN 46601

Table of Contents **Page Number**

1. Introduction

1.1 *Purpose of Monitoring and Maintenance Plan*

Located in the Southeast neighborhood of South Bend, Indiana, Bowman Creek functions as an important environmental, economic, and cultural aspect for the City of South Bend. The Bowman Creek watershed has been identified as a vital environmental asset that can help maintain the well-being of both the environment and the residents living within the watershed. Urban green spaces reduce stress within individuals, create more meaningful feelings of attachment to an area within individuals, and increase physical activity (Braubach et al. 2017). Green spaces also improve the environment in which they are located by improving air quality, and reducing noise and extreme heat (Braubach et al. 2017). A long term comprehensive plan is needed to properly maintain and monitor Bowman Creek. Proactive efforts can prevent problems from occurring and mitigate the adverse effects if they do occur.

1.2 *Background*

In the past, Bowman Creek was regarded as an essential component to the Southeast neighborhood during the development of the neighborhood in the early 1900's. George Kessler, a landscape architect hired by the city to design parks and neighborhoods, incorporated Bowman Creek within his urban planning to highlight the creek as an important asset for the neighborhood residents. Community members have memories of fishing, swimming, and finding peace at Bowman Creek. In current times, many community members now view Bowman Creek as a blight within the neighborhood. Parents refuse to let their children even touch the water, many people continue to dump trash in the creek, and homes have been destroyed because of flooding. In 2015, the Southeast Neighborhood Master Plan was created to improve the neighborhood and collected input from neighborhood residents through focus groups. These focus groups ranked the Bowman Creek corridor as the third highest priority of the Southeast neighborhood, but many of the recommendations of the focus groups did not involve the creek corridor (City of South Bend 2015). The community does recognize the creek as an asset, but is unsure on how to benefit from that asset. Developing a monitoring and maintenance plan in order to address the concerns of the community will help to change the perspective about Bowman Creek in the surrounding neighborhood.

Bowman Creek begins at Greentech Dr. where one of its tributary ditches, Auten Ditch, enters the City of South Bend. From Greentech Dr., the creek flows north-east through the Southeast neighborhood of South Bend with many stretches flowing through pipes underground or in culverts beneath the roads (Fig. 1.1) due to urban modification (Deegan 2017). The creek discharges into the St. Joseph River just southeast of E. Lincoln Way and E. Sample St.

Figure 1.1 Map of Bowman Creek obtained from Google Earth Pro identifying where Bowman Creek flows through a culvert to a below ground (green lines) stretch and where the creek is above ground (blue lines). The Southeast neighborhood is identified by the shaded box.

Bowman Creek is considered an impaired waterway and frequent blocking creates floods in the immediate area. When there is a significant amount of rain, the chances of flooding increase and the parts of the creek that are underground do not allow the water to naturally rise along the floodplain, increasing the flow and turbulence of the water. The rerouted parts of the creek that have undergone significant urban modification make it difficult to access those parts of the creek in order to monitor and maintain Bowman Creek.

1.3 *Project Scope*

Currently, Bowman Creek is an impaired waterway located in the Southeast neighborhood of South Bend, Indiana. Many residents in the community and the City of South Bend recognize Bowman Creek as a priority in the neighborhood, but also have concerns about water quality, prevalent litter, flooding, and lack of maintenance along the creek. A long term monitoring and maintenance plan will suggest a strategy to both monitor the areas of concern and maintain the creek in a way that minimizes those concerns and eventually eliminates them. Specifically, the monitoring and maintenance plan will identify plans of action for various issues that may arise around the creek in order to resolve them in a timely, efficient, and effective manner. The plan will include the various chemical, biological, and physical parameters associated with both the monitoring and the maintenance of Bowman Creek. Special areas of concern will be highlighted along with recommendations for specific actions. Final recommendations will be given for action based on feasibility, priority, and available resources.

1.4 *Project Goals*

At a high level, the goals of this plan include improved water quality, improved aesthetic value, and reduction in flooding. While Bowman Creek has been identified as an important neighborhood asset, the data collection and continuous improvement required to care for the creek properly should be better defined. Key stakeholders in this endeavor will be consulted to develop ambitious goals that are measurable and achievable. This plan addresses these goals with proactive strategies that optimize the available resources from the City of South Bend Public Works (PW), Venues, Parks & Arts (VPA), Bowman Creek Educational Ecosystem (BCe2), volunteer groups, and other key stakeholders. Proactive strategies increase the resiliency of the city by enhancing knowledge of our assets and working towards a strong ecosystem that can continuously absorb flooding and reduce contamination with minimal outside support.

2. Monitoring Plan

In order to implement the most successful strategies to revitalize Bowman Creek, a long term plan must be developed to monitor the state of Bowman Creek so that the proper maintenance actions can be carried out when necessary. Data and observations taken through monitoring will be used to identify indicators for maintenance actions such as the removal of invasive plants within an area when increased invasive plant cover has been observed. Through monitoring, accurate data will be collected on the different aspects of the watershed including water quality, biodiversity, community, and hydrology. This data will inform current and future strategies for waterway revitalization in order to identify the most efficient and productive use of time, money, and resources for all the community stakeholders within the watershed area. An overall recommendation that can be utilized during all the monitoring and maintenance actions by either community residents, CoSB officials, or volunteers is taking pictures of the various sites in the watershed as they are doing work or just present in the area. Visual evidence can be used to identify important observational data such as the amount of overgrowth or the presence of litter. *Specific monitoring actions can be found in Appendix A*. Objectives include:

- Increasing strategic monitoring relevant to specific goals
- Collecting accurate and relevant data on water quality, biodiversity, the community, and hydrology
- Using the collected data to develop strategies for current and future revitalization actions
- Increasing communication and transparency on various community stakeholders' responsibilities

2.1 *Water Quality*

The water quality of Bowman Creek has been tested several times over the last three years, but has not been tested as consistently as needed to determine an accurate and clear picture of the overall water quality of the entire Bowman Creek. Volunteer organizations such as Hoosier Riverwatch and the St. Joseph River Basin Commission have been conducting the water quality testing in recent years in Bowman Creek, but the testing has been exploratory in nature. A trained Hoosier Riverwatch stream monitor recommended testing water quality every day for two weeks each season to fully determine the sources that may be contributing to poor water quality. Testing after extreme rain events is also necessary to ascertain how runoff will affect the water quality of Bowman Creek. Currently, trained Hoosier Riverwatch stream monitors collect data on temperature, dissolved oxygen (DO) levels, biological oxygen demand (BOD), pH, ortho phosphate levels, nitrate levels, habitat, macroinvertebrates, stream flow, turbidity, and the pollution tolerance index rating in order to determine the overall water quality index of the waterway. By training a group of dedicated volunteers (local community members, Southeast Organized Area Residents, student associations at local education institutions) through an organization such as Hoosier Riverwatch, the necessary consistent testing could be completed in order to better understand the Bowman Creek watershed and improve the water quality. If funding is needed, the Indiana Department of Environmental Management (IDEM) awards grants to improve water quality. Obtaining a grant through IDEM may be an option in the future.

In 2013, McCormick Engineering determined that *Escherichia coli* (*E. coli*) levels downstream from the Fox St. tunnel until the creek discharges into St. Joseph River were higher than the legal grab sample limit of 235 colony forming units (CFU) per 100 ml in a single sample. Further *E. coli* testing should be conducted to obtain recent measurements. Once recent data has been analyzed, a testing schedule can be determined if necessary to monitor *E. coli* levels.

A further recommendation from McCormick Engineering, LLC in 2013 included televising the Riley Track Tunnel to inspect for deterioration and contamination from nearby sewer pipes. Along with water quality testing upstream and downstream the Riley Track Tunnel, visual inspections of the interior of the pipes will help catch potential problems before they have irreversible effects on the ecosystem.

An example of a Hoosier Riverwatch sampling is shown in Table 2.1. This data gives an overall picture of the health of the stream and is a valuable resource for observing basic water quality parameters over time, if assessed regularly.

Table 2.1. Water quality data tested at the Supplemental Environmental Project location between S. St. Joseph St. and Carroll St. off of E. Fox St.

Water Quality Parameter	**Observation**
Pollution Tolerance Index	27 PTI
Citizen Qualitative Habitat Evaluation Index	48 CQHEI
Flow	1.35 CFS
Temperature	26.7 degrees Celsius
Temperature Change	0.7 degrees Celsius
Dissolved Oxygen	8 mg/l
Biological Oxygen Demand	3 mg/l
pH	8.4 pH
Ortho Phosphate	0.2 mg/l
Turbidity	60 cm
Water Quality Index	80.65 WQI

Notably, the basic Hoosier Riverwatch assessment does include E. coli testing, but it is difficult to conduct and its accuracy is unknown so other partners will likely need to offer support on that aspect of data collection.

2.2 *Biodiversity*

The biodiversity of Bowman Creek is influenced by many different aspects of both the waterway and the surrounding riparian zone. Biological data such as aquatic community composition and habitat quality can also be used to obtain a holistic assessment of water quality. An annual aquatic community monitoring report published by the cities of Elkhart and South Bend collects data from several sites within Bowman Creek. In the 2017 Elkhart-South Bend Aquatic Community Monitoring report, data shows that Bowman Creek's Index of Biotic Integrity (IBI), a way to determine water quality based on assessing species composition, trophic composition, and fish condition of the local fish communities, has been improving over the most recent years (Deegan 2017). However, the aquatic habitat is of poor quality which can impair fish and macroinvertebrate communities in Bowman Creek (Deegan 2017). Presently, Bowman Creek has a Qualitative Habitat Evaluation Index (QHEI) score of 47 which indicates degraded habitat (Deegan 2017). Even though Bowman Creek was given a low habitat score, there was a

diversity of macroinvertebrates due to the sustained water flow of the creek (Deegan 2017) as seen in Bowman Creek's Invertebrate Community Index (ICI) score. As of right now, the aquatic community monitoring program will continue to monitor several sites within Bowman Creek annually. Hoosier Riverwatch water testing also involves collecting data on macroinvertebrate communities. Macroinvertebrate communities give information on how polluted the waterway is because they differ in how much pollution they can tolerate.

Even though the aquatic communities and habitat of Bowman Creek are being monitored regularly, it is important to also monitor the riparian communities and habitat such as the animals and birds present. This can be accomplished through local citizen science organizations such as the South Bend chapter of the Audubon Society. Through monitoring and collecting data on the quality of habitat and species populations, further strategies can be developed to increase biodiversity within the watershed.

Due to the urbanized nature of Bowman Creek, many stretches of the creek are not always connected within the waterway, especially when there has been less precipitation within the area. If conditions are dry and the water depth has decreased, there is a chance that a culvert that was once level with the creek bed may become a perched culvert rendering it impossible for fish and other aquatic species to travel up- or downstream. Daylighting the creek would improve connectivity of the watershed, biodiversity and vegetation, and could give the creek more capacity for high flows. Past BCe2 interns conducted a feasibility study which goes into greater detail about the benefits and steps necessary to daylight Bowman Creek.

The presence of invasive species remains an extensive problem for many areas in the United States. Bowman Creek is no different with invasive species such as japanese knotwood prevalent in some stretches along the creek. To control the spread of invasive species, volunteers should be trained on the invasive species that have been observed within the Bowman Creek Watershed (Table 2.2) and could use a mobile app such as PictureThis to identify the plants. Visual companion materials such as an identification manual with colored pictures can be developed to aid in finding and removing invasive species. Invasive species require time to fully eradicate. Multiple cuttings and herbicide treatments are necessary. If invasive species are observed before they spread to a large area, early eradication will be more efficient with less associated costs and time needed to complete the removal. Restoration of native plants in place of the invasive plants should be completed to revitalize the ecosystem and increase biodiversity within the area.

When the riparian area along Bowman Creek is not maintained, overgrowth can quickly become detrimental to the waterway. The overgrowth of vegetation within the riparian corridor, especially of a particular species, can negatively impact biodiversity and prevent newly established species from surviving. Overgrowth can reduce the amount of sunlight an area receives and can decrease the amount of nutrients and water available. Increased overgrowth may cause increased dead vegetation within the creek, which, to a certain degree, is beneficial to the creek because it increases dissolved oxygen in the water. However, it also increases chances that an unusually large amount of vegetation may block a stretch of the creek, causing flooding and disconnection within the waterway. Through routine inspections by trained personnel and observational data from volunteer organizations when they are in the area, the amount of overgrowth can be monitored in order to prevent reduced biodiversity and blockages, and promote the health of Bowman Creek.

A catalog of invasive and native plants observed should be open and accessible to the public so that any volunteers who do work near the creek can update the information about invasives and natives. Table 2.3 shows an example of an invasive plant catalog.

Table 2.2. A table outlining the various invasive species observed in Ravina Park with the common and scientific names obtained through the USGS Nonindigenous Aquatic Species Program Database.

Location: Ravina Park	
Common Name	Scientific Name
European lake sedge	*Carex acutiformis Ehrh.*
broadleaf dock	*Rumex obtusifolius L.*
bittersweet nightshade	*Solanum dulcamara L.*
crack willow	*Salix fragilis L.*
ladysthumb	*Persicaria maculosa S.F. Gray*
true forget-me-not	*Myosotis scorpioides L.*
water mint	*Mentha aquatica L.*
spearmint	*Mentha spicata L.*
barnyard grass	*Echinochloa crus-galli (L.) Beauv*
poison hemlock	*Conium maculatum L.*
redtop	*Agrostis gigantea Roth*
narrow-leaved cattail	*Typha angustifolia L.*
watercress	*Nasturtium officinale R. Brown*
yellow fieldcress	*Rorippa sylvestris (L.) Bess.*

This catalog of native and invasive species would also benefit maintenance organizations such as City of South Bend VPA, so that they have an easily accessible resource to identify and

protect native species. Table 2.3 shows an example of a catalog that includes color pictures that would assist volunteers and maintenance crews to identify native versus invasive species.

Table 2.3. A invasive plant catalog with pictures gives readers an easy way to distinguish undesired plants.

Common Name	Scientific Name	Picture
European lake sedge	*Carex acutiformis Ehrh.*	
broadleaf dock	*Rumex obtusifolius L.*	

2.2 *Community*

In order to revitalize the creek holistically, the neighborhood must be invested in creek upkeep. Currently, parts of the creek are viewed more as a place to dump trash instead of a natural green space, which has adverse effects on the creek's aesthetic value as well as water quality and biodiversity. To alleviate these adverse effects, local organizations and volunteer groups should be deployed to monitor the levels of litter and encourage neighbors to refrain from dumping in the creek. If needed, a drone may be deployed for monitoring garbage levels along less-accessible areas of the creek, though this option is more labor-intensive and may not work if there is a glare on the water.

Area residents have also expressed concern regarding visibility around the creek since some areas are overtaken by invasive species and overgrowth. Lack of visibility limits the perceived safety of the creek, even in areas that should be considered safe, such as Ravina Park. In order to combat this perception, cultivation of low-grow native plants should be pursued as well as monitoring of invasive species growth and any general overgrowth. This is best monitored through volunteer groups and 311 calls that report complaints about visibility or safety near the creek.

During extreme rain events, residents and businesses located within the floodplain of Bowman Creek may be subject to rapid flooding and the associated damages that flooding may

cause. Flooding may also occur when debris blocks the waterway or a bar screen at one of the many culvert and tunnel entrances that the creek flows through. To decrease flooding of residential and commercial buildings, routine inspections of the various culverts and tunnels is necessary to monitor whether a blockage has formed or is forming. By catching and clearing a developing blockage, flooding and damages will be reduced within the floodplain.

2.4 *Hydrology/Geology*

In some areas, Bowman Creek has been observed to be a losing stream, meaning its cross-sectional area decreases over its distance. This may be due to leakage into the aquifer or nearby pipes. Additionally, control structures upstream in Auten Ditch at Greentech Pond and AM General create barriers that limit creek flow. On the other hand, the control structures drastically increase flow when water reaches a certain level. This drastic increase of flow causes erosion and can lead to incision in the long term and flooding in the short term. Bank erosion can be monitored by periodically measuring the cross sectional area of the creek to determine whether there has been an increase of area due to bank erosion.

Compounded with the upstream control structures, the confinement of the creek to underground pipes and culverts limits its ability to absorb rain events beyond the design capacity of these culverts. Pipes and culverts do not provide the energy dissipation due to friction that can be provided by a plant-populated floodplain. Moreover, there are bar screens at many pipe entrances designed to catch trash and large debris, but the clogging of these bar screens causes flooding during heavy rain events.

The monitoring actions associated with the flow include aggregating and analyzing data from existing EmNet flow sensors near Riley High School and expanding these sensors to other areas of the creek. Bowman Creek Educational Ecosystem has the capacity to design and expand these sensors, but the deployment of this technology should be accompanied by increased awareness of the data it produces. Both higher-than-average flow, which may lead to flooding or erosion, and lower-than-average flow, which may be detrimental to the ecosystem. Information about the flooding over the length of the creek can also show where the creek may be losing water and whether this issue should be fixed which can be done through tracking the cross sectional area of the creek or by using the LIDAR surveying method.

In addition to new technology, 311 calls should be monitored and mapped along Bowman Creek to identify any areas where flooding or blockages are reported. Other low-tech options include periodic visual inspections of the bar screens for blockages that may be done in tandem with other regular maintenance such as street sweeping. Aggregating all of this data will assist Bowman Creek stakeholders in making informed maintenance decisions based on real evidence.

The U.S. Fish and Wildlife Service partnered with several other organizations to develop a stream crossing data collection procedure. This data sheet, shown in Figure 2.4, can be used on Bowman Creek crossings to determine the passability and ecosystem-friendliness of culverts.

Stream Crossing Data Sheet

Site ID: _____

General Information

Stream Name: _____ **Road Name:** _____

Name of Observer(s): _____ **Date:** _____

GPS Waypoint: _____ **GPS Lat/Long:** _____

County: _____ **Township:** _____ **Range:** _____ **Sec:** _____

Adjacent Landowner Information: _____ **Additional Comments:** _____

Crossing Information

Crossing Type: Culvert(s) no.: _____ Bridge Ford Dam Other: _____

Structure Shape: Round Square/Rectangle Open Bottom Square/Rectangle Pipe Arch Open Bottom Arch Ellipse

Inlet Type: Projecting Mitered Headwall Apron Wingwall 10-30° or 30-70° Trash Rack Other

Outlet Type: At Stream Grade Cascade over Riprap Freefall into Pool Freefall onto Riprap Outlet Apron Other

Structure Material: Metal Concrete Plastic Wood

Substrate in Structure: None Sand Gravel Rock Mixture

General Condition: New Good Fair Poor

Plugged: _____ % Inlet Outlet In Pipe

Crushed: _____ % Inlet Outlet In Pipe

Rusted Through? Yes No **Structure Interior:** Smooth Corrugated

Multiple Culverts/Spans

Number the culverts/spans left to right, facing downstream.
Include #s in site sketch on back page

Culvert/ Span #	Width (ft)	Length (ft)	Height (ft)	Material

Structure Length (ft):[1] _____ **Structure Width (ft):**[1] _____ **Structure Height (ft):**[1] _____

Structure Water Depth (ft):[1] **inlet** _____ **outlet** _____ **Perch Height (ft):**[1] _____ or NA

Embedded Depth of Structure (ft):[1] **inlet** _____ **outlet** _____

Structure Water Velocity (ft/sec):[1] **inlet** _____ **outlet** _____

Structure Water Velocity Measured: At Surface or _____ **ft Below Surface** **Measured With:** Meter or Float Test

Stream Information

Stream Flow: None < ½ Bankfull < Bankfull = Bankfull > Bankfull

Scour Pool (if present) **Length:** ____ **Width:** ____ **Depth:** ____ **Upstream Pond (if present)** **Length:** ____ **Width:** ____

Riffle Information

(measured in a riffle outside of zone of influence of crossing)

Water Depth (ft): _____ **Bankfull Width (ft):** _____ **Wetted Width (ft):** _____ **Water Velocity (ft/sec):** _____

Dominant Substrate: Cobble Gravel Sand Organics Clay Bedrock Silt **Measured With:** Meter or Float Test

Road Information

Type: Federal State County Town Tribal Private Other:

Road Surface: Paved Gravel Sand Native Surface **Condition:** Good Fair Poor

Road Width at Culvert (ft): _____ **Location of Low Point:** At Stream Other **Runoff Path:** Roadway Ditch

Embankment: **Upstream** **Fill Depth (ft):** _____ **Slope:** Vertical 1:1.5 1:2 >1:2

Downstream **Fill Depth (ft):** _____ **Slope:** Vertical 1:1.5 1:2 >1:2

Left Approach: **Length (ft):** _____ **Slope:** 0% 1-5% 6-10% >10% **Ditch Vegetation:** None Partial Heavy

Right Approach: **Length (ft):** _____ **Slope:** 0% 1-5% 6-10% >10% **Ditch Vegetation:** None Partial Heavy

[1] - Fill out for primary culvert (culvert #1). If multiple culverts are used, number each and use embedded table. Form Date: February 28, 2011

Erosion Information

Use a new row for each distinct gully/erosion location. Note prominent streambank erosion within 50 feet of crossing.

Location of Erosion Ditch, approach, or streambank Left or right facing downstream	**Erosion Dimensions (ft)**			**Eroded Material Reaching Stream?**		**Material Eroded** Sand, Silt, Clay, Gravel, Loam, Sandy Loam or Gravelly Loam.
	Length	**Width**	**Depth**			
				Yes	**No**	
				Yes	**No**	
				Yes	**No**	
				Yes	**No**	
				Yes	**No**	

If there is erosion occurring, can corrective actions, such as road drainage measures, be installed to address the problem? **Y** **N**

Extent of Erosion: Minor Moderate Severe Stabilized

Erosion Notes:

Photos – enter photo number in blank corresponding to location

❑ Site ID _____ ❑ Upstream Conditions _____ ❑ Downstream Conditions _____

❑ Inlet _____ ❑ Outlet _____ ❑ Road Approach – Left _____ ❑ Road Approach – Right _____

Summary Information

Would you consider this a priority site? Fish Passage Erosion Why?

Would you recommend a future visit to this site? Yes No **Why?**

Were any non-native invasive species observed at the site? Yes No **If yes, what species were observed?**

Site Sketch

Draw an overhead sketch of crossing. Be sure to mark North on the map and to indicate the direction of flow. Include major features documented on form, such as erosion sites, multiple culverts, scour pool, impounded water, etc.

Figure 2.4. The Great Lakes Stream Crossing Data Sheet outlines relevant data for determining appropriateness of stream crossings.

3. Maintenance Plan

Using the data collected from monitoring Bowman Creek, routine maintenance procedures will need to be developed in order to properly care for the watershed so that the state of Bowman Creek does not deteriorate over time. Past maintenance actions include removing woody debris blockages, relining tunnels and pipes that the creek flows through, removing litter, replacing bar screens, and trimming problemental tree limbs. By performing data informed maintenance actions, serious problems occurring in the watershed may be greatly reduced or altogether avoided. Taking proactive measures now may prevent problems in the future while saving time and resources. *Specific maintenance actions can be found in Appendix B.*

3.1 *Water Quality*

The water quality of Bowman Creek is affected by a large range of other factors, making it difficult to target specific maintenance actions that will have the greatest positive effect on water quality. Performing maintenance actions that pertain to other parameters such as biodiversity, community, and hydrology will promote better water quality in the watershed as a whole. For example, maintenance actions performed to improve the community such as cleaning up litter in the creek will also improve the water quality by removing sources of contamination. Direct maintenance actions such as using ultraviolet radiation to treat the water would not be cost- or time-effective. Native plant restoration along the creek would also provide natural filtration methods to improve the water quality while increasing natural habitat. Indirect water quality maintenance actions over time will improve the quality of the water gradually while also accomplishing an action that directly improves on a target different from that of water quality.

3.2 *Biodiversity*

In order to maintain biodiversity and eventually improve it, removing overgrowth and invasive species are key for the revitalization of Bowman Creek. Similar to water quality, the biodiversity in the Bowman Creek watershed is affected by many of the maintenance actions that are performed, even if they do not seem to directly have an effect on the aquatic and riparian biodiversity. Maintaining the natural riffles of Bowman Creek creates a more favorable habitat for aquatic species and increases the amount of dissolved oxygen in the water that is available for use. By removing invasive plants and overgrowth within the riparian corridor and planting native plants, a more natural habitat will be established with no one single species dominating the available nutrients and space to grow. Re-establishing native plants within the area after invasive and overgrowth removal has been completed will allow for an increase in the number of species natural to the area while also providing a natural filtration system for the Bowman Creek waterway to improve water quality.

3.3 *Community*

Maintenance actions along Bowman Creek within the community are necessary in order to sustain the perception that Bowman Creek does not negatively affect the living experiences of

those community residents. Community members wish to live in a clean, safe area that they can call home. To preserve that feeling of safety and cleanliness, actions must be taken periodically such as picking up litter, removing overgrowth that prevents visibility, and maintaining structures that reduce flooding to create that feeling of well-being whether residents are just visiting Bowman Creek or actually living within the riparian corridor. Educational opportunities along the creek will also promote a positive perception of the creek and communicate the importance of having green spaces in the neighborhood. However, community residents' perceptions of Bowman Creek will not change immediately. Consistent and continued maintenance and outreach are needed to make a meaningful difference in perception.

3.4 *Hydrology/Geology*

Maintenance actions to improve the hydrology of Bowman Creek consists of actions that maintain the current hydrology of Bowman Creek and actions that would improve upon the creek's condition. The urbanized condition of Bowman Creek requires maintenance of the various pipes, tunnels, and culverts that the creek flows through. However, actions such as daylighting Bowman Creek should be considered in order to decrease the amount of yearly maintenance necessary in the watershed. After examining the various urbanized structures used in Bowman Creek, daylighting and the removal of control structures should be assessed and implemented in order to create a more natural flow, habitat, fish connectivity, and floodplain.

If daylighting the creek is not feasible, more maintenance will be required in the form of replacing and repairing the pipes, tunnels, and culverts to decrease the number of future problems that may arise from the deterioration of urbanized stretches of the creek. The urbanized nature of Bowman Creek requires bar screens at the various entrances and exits of the creek when it flows underground. In order to be effective, the bar screens require regular maintenance in the form of clearing out debris and fixing or replacing broken bar screens as preventative measures to decrease the amount of creek blockages and flooding within the area. Maintenance actions should be taken now for the upkeep of Bowman Creek, but future options to reduce the maintenance required should be assessed.

4. Key Locations

Several key locations along Bowman Creek have been identified because they are accessible to both community residents and the City of South Bend or they are locations of ongoing and future revitalization strategies (Fig. 4.1).

Figure 4.1. Map obtained from Google Earth Pro showing key locations.

4.1 *Control Structure at Greentech Pond* (Location A in Fig. 4.1)

Auten Ditch is one of the three tributary ditches that combine to become Bowman Creek. Auten Ditch flows into a retention pond located on Greentech Dr. right at the beginning of Bowman Creek and is under ownership by Republic Waste Services. A small control structure or weir is located within the retention pond. Currently, the weir at Greentech Pond allows only a small flow from the retention pond unless the top of the weir is reached, in which case the flow is increased drastically (Fig. 4.2).

Figures 4.2.a(left) and 4.2.b (right). A higher water level in the retention pond results in drastically higher flow rates downstream due to the weir.

The weir prevents connectivity within the Bowman Creek watershed for aquatic species such as fish and creates unnatural flow patterns depending on the amount of water available. Extreme rain events cause a large increase in the amount of water allowed through by the control structure which can cause incising and erosion within the waterway. The presence of an outflow

culvert downstream of the weir's entrance presents the danger of undercutting of the creek bed due to erosion. Undercutting not only decreases the velocity of the creek and creates a stagnant area but also compromises the integrity of the culvert itself over time. The dangers of weir failure and undercutting at this point include sediment loads washing downstream and burdening ecosystems and compromising the integrity of the road over the culvert.

A feasibility study has been conducted on the removal and replacement of the control structure at Green Tech Pond. Currently, the retention pond is not accessible so it will be necessary to form amicable relationships with the property owner in order to obtain the correct permissions needed to remove or modify the control structure. It is recommended that future BCe2 interns begin collecting the necessary data for permits and making connections with the property owners with the support of the CoSB in future years to make a final assessment on whether the control structure should be removed and/or replaced. Depending on the data collected, strategies can be determined that will benefit the ecosystem and hydrology of Bowman Creek the most.

4.2 *Discount Muffler and Tire* (Location B in Figure 4.1)

Located at Fox St. and Michigan St., Bowman Creek becomes above ground and runs along the Discount Muffler and Tire shop before flowing underneath Fox St. as shown in Figure 4.3.

Figure 4.3 Upstream and downstream views of Bowman Creek near Discount Muffler and Tire

The creek channel is surrounded by concrete banks in order to prevent erosion. The tunnel entrance at Fox St. contains a bar screen and the tunnel entrance has been recently redone to prevent flooding. In February, Bowman Creek flooded at this location and damaged a nearby house and sidewalk. This location is accessible and has had a history of flooding, indicating that there is a great need to frequently monitor and maintain the state of the Fox St. tunnel entrance.

4.3 *SEP Site* (Location C in FIgure 4.1)

The CoSB in partnership with BCe2 has recently undertaken a Supplemental Environmental Project (SEP) involving the beautification and revitalization of a stretch of Bowman Creek that runs through the Southeast neighborhood. The SEP site is located between S. St. Joseph St. and Carroll St. off of E. Fox St. and has a project budget of $30,000.

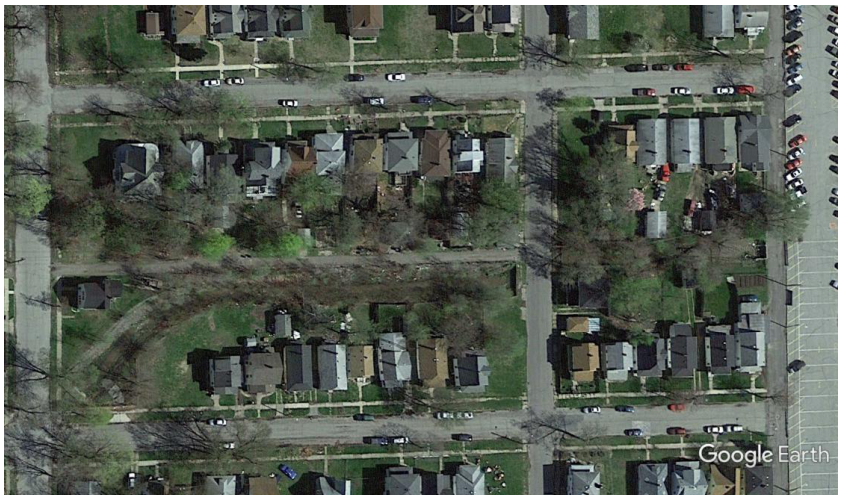

Figure 4.4. Aerial photo of SEP site

The Supplemental Environmental Project came to fruition in lieu of environmental fines for sewer overflow. Overall goals include improving the aesthetic of the area so that neighborhood residents can enjoy the green space and revitalizing the section of the creek. The scope of the project includes replacing the current chain link fence along the creek with a split timber guard rail, planting native plants, and restoring a rain garden. Water quality testing was done at this location to provide a baseline for data collected in the future to be compared to in order to analyze whether any of the revitalization strategies within the area are contributing to better water quality. There is prevalent litter presence within the area and an annual creek clean up occurs during the Back the Bend, an annual service event within the South Bend community. Water quality and the presence of litter should be monitored through the use of volunteer organizations such as Hoosier Riverwatch in order to determine whether the improvements within the SEP site have made a difference. Recommended maintenance actions include:

- Annual weeding of the on site rain garden with support from BCe2
- Annual litter clean up with support from Back the Bend in the spring
- Sprout cutting and treatment of invasive species such as Japanese knotwood and overgrowth in four months with support from VPA and the CoSB's arborist

4.4 *James Whitcomb Riley High School* (Location D in Figure 4.1)

The local educational institution within the Southeast neighborhood is James Whitcomb Riley High School (Riley HS), a magnet school with an engineering program. Bowman Creek flows up to Riley HS before flowing into an underground tunnel at Fellows St. The creek then travels beneath Riley HS before flowing back over ground at Studebaker Golf Course. The study conducted by McCormick Engineering in 2013 observed abnormally high *E. coli* levels downstream of the Riley HS track tunnel. However, when tested again, these levels were not abnormal. It is recommended that BCe2 interns should work with Riley HS to test upstream and downstream of the Riley HS track tunnel to determine the source of contamination. By testing at various times such as when students are in school and out of school, it would be possible to eliminate or confirm that Riley HS facilities are contaminating the creek. Continuous televising of the tunnel should also be done in conjunction with the water testing to identify whether any unknown sources are contributing to contamination. Daylighting has been considered for a long

term revitalization strategy at Riley HS. A feasibility study conducted by BCe2 interns in 2017 weighs the costs and benefits of daylighting at Riley HS recommending daylighting.

4.5 *Ravina Park* (Location E in Figure 4.1)

Ravina Park is located at Indiana Ave. at Lebanon St. Bowman Creek runs through the park and residents are able to walk down stairs that lead to the creek bank. Remnants of a concrete bridge shown in Figure 4.5 that was destroyed by a tree during a heavy storm block the channel and limit its capacity due to two remaining culverts.

Figure 4.5. The old concrete bridge contains two culverts, but these are not always enough to handle the flow.

During heavy flow, the creek sometimes flows around this concrete structure and washes out the surrounding banks. Future plans for this broken bridge include removing the concrete and repairing sidewalks around the block to provide Americans with Disabilities Act-compliant access to the area. The CoSB is also completing a project at Ravina Park in 2018 to stabilize the creek banks.

Community residents have highlighted positive and negative aspects of Bowman Creek at Ravina Park. There is a large amount of overgrowth around the creek at Ravina Park which has created feelings of unease among residents due to lack of visibility and perceived hazard. However, several people have also expressed how peaceful they feel next to the creek where they can sit and enjoy the natural beauty of the space or even fish. These concerns can easily be resolved by removing some of the overgrowth that is present along the creek at Ravina Park which would create more visibility to increase perceptions of safety among residents while still allowing residents to enjoy being at Bowman Creek. The easy accessibility makes this location a prime spot for water quality testing, wildlife observations, and volunteer work.

5. Recommendations

5.1 *Citizen Science Monitoring for E. coli*

Citizen science methods for monitoring are preferred since they are low-cost and community-engaged. However, for particular tests like *E. coli* that are not covered in a Hoosier

Riverwatch assessment there is a concern regarding citizen science accuracy. For initial testing of *E. coli* in Bowman Creek, it is recommended that existing St. Joseph River testing in the Public Works division be extended to Bowman Creek. If this is not feasible in the long term, citizen science testing for *E. coli* can be simultaneously implemented and compared to the Public Works results. If the citizen science methods are shown to be accurate over time, they can replace Public Works testing altogether. Similar approaches may be taken to any other parameters of concern.

5.2 *Access*

Even after significant research, the access laws surrounding Bowman Creek are not clear. Although some aboverground sites are physically accessible, they may not be legally accessible, which could cause tensions in the neighborhood. In order to prevent such tensions, monitoring and maintenance stakeholders should pursue conservation easements along the creek where they do not exist. The legal technicalities surrounding creek access can also be clarified through further discussions with Indiana Department of Environmental Management and the Indiana Department of Natural Resources or city officials. If concerns arise regarding legal access to points on the creek, efforts may be focused on publicly accessible sites listed above.

5.3 *Control Structure and Daylighting*

Bowman Creek Educational Ecosystem and other stakeholders are interested in projects beyond routine maintenance that should be explored in the future as part of managing the creek. For example, removing the control structure at Green Tech Pond would benefit the whole ecosystem and would help reach water quality and biodiversity targets. Similarly, daylighting the creek at Riley HS and other locations where it is underground would provide natural purification, community aesthetic improvement, and more drainage capacity. Bowman Creek Educational Ecosystem has conducted feasibility studies on both of these projects that can be pursued in the future.

5.4 Education and Outreach

In order to continue having open dialogue about Bowman Creek between community residents, the CoSB, and volunteer organizations, it is necessary to incorporate education and outreach within watershed improvement. Currently, the Advanced Placement Environmental Science class at Riley HS does test the water quality of Bowman Creek at the Riley HS tunnel entrance and incorporates it into their curriculum. If this curriculum could be modified and expanded to lower grades and younger students, a greater number of students testing water quality would provide support for monitoring the water quality while also educating the students about Bowman Creek. In conjunction with water quality testing at Bowman Creek, it is recommended that instructors also teach on the invasive and native plants that are present within the Bowman Creek watershed. Both of these topics will empower students, particularly those who live in the Southeast neighborhood, to take care of the watershed. Observational data can be collected on what invasive and native species are present at the locations where students are testing water quality. This data may be used further to help monitor within the Bowman Creek

watershed. Educational materials have been developed that would be helpful such as invasive and native plant catalogs.

For students testing water quality, it also would be beneficial to partner with a trained Hoosier Riverwatch stream monitor in order to learn about what macroinvertebrates are and what they mean for the health of a creek. The students could conduct macroinvertebrate sampling to analyze for themselves on what the macroinvertebrates present indicate about the state of Bowman Creek. Along with learning about macroinvertebrates, it is important to also talk about the other aquatic species present such as the local fish communities. A potential resource to explore is the Elkhart-South Bend Aquatic Community Monitoring program and the professionals that publish the report each year may be interested in speaking to local students about the results that have been found in regards to Bowman Creek.

Another opportunity for increasing educational outreach in the Bowman Creek watershed is partnering with BCe2 interns to host outreach events at local organizations such as Southeast Organized Area Residents (SOAR) and the local chapter of Boys and Girls Clubs of America. Outreach events could include information presented here in the monitoring and maintenance plan. By reaching out to local educational institutions and hosting outreach events, community residents can become educated on the actual state of the creek and may even be able to provide support for collecting monitoring data or performing maintenance actions.

6. Conclusion

Bowman Creek represents an environmental and cultural asset for the residents of the Southeast neighborhood and the City of South Bend, which makes it imperative that Bowman Creek is properly taken care of. In order to manage the Bowman Creek watershed, monitoring through the collection of quantitative and qualitative data must be aggregated and then analyzed to understand the problems Bowman Creek faces. The monitoring of Bowman Creek can be used to identify indicators for the necessary maintenance actions to be carried out that will best support a healthy creek with an end goal of the improvement of Bowman Creek. To do this, neighborhood residents, volunteer organizations, citizen science, local educational institutions, and the City of South Bend should come together to revitalize the waterway and the surrounding riparian area so that generations of South Bend citizens can continue to enjoy Bowman Creek.

Works Cited

Braubach, Matthias, et al. “Effects of Urban Green Space on Environmental Health, Equity and Resilience.” *Theory and Practice of Urban Sustainability Transitions Nature-Based Solutions to Climate Change Adaptation in Urban Areas*, 2 Sept. 2017, pp. 187–205., doi:10.1007/978-3-319-56091-5_11.

Deegan, Daragh. *Aquatic Community Monitoring on the St. Joseph River and Several Tributaries, Elkhart, & St. Joseph Counties: 2017 Annual Report*. City of Elkhart,

2017, *Aquatic Community Monitoring on the St. Joseph River and Several Tributaries, Elkhart, & St. Joseph Counties: 2017 Annual Report*.
City of South Bend. *Southeast Neighborhood Master Plan.* City of South Bend, 2015.
David L. McCormick, PE, D. WRE. *Bowman Creek Supplemental Environmental Project.* McCormick Engineering, LLC. 2013.

Appendix A: Organizations

Organizations

311/Code Enforcement: CoSB department in charge of upholding city codes. Issues violations such as unlawful and uncontrolled trash dumping. 311 is the call center for citizens to report violations and could be used as a resource to gather monitoring data such as reports of litter, overgrowth, and flooding. Code Enforcement can be reached at 574-233-0311 or https://southbendin.gov/department/code-enforcement/ .

Audubon Society: Local South Bend Chapter of the Audubon Society. May be contacted to host informal bird counting events within the Bowman Creek Watershed. A key contact is Victor Riemenschneider who responds to inquiries on the website and can be reached through the "Contact Us" form on their website, http://www.sbeaudubon.org/ .

Back the Bend: The University of Notre Dame partnering with the South Bend community to host an annual day of service in April. Every year, one of the service projects includes a Bowman Creek cleanup of trash and brush at Ravina Park and the Supplemental Environmental Project site. More information can be found at http://backthebend.nd.edu/ .

Bowman Creek Educational Ecosystem (BCe2): A summer internship program that pilots community-engaged, sustainable projects to address real world challenges in the Southeast neighborhood of South Bend, IN. This plan has been developed by BCe2 interns who could provide support for many of these monitoring and maintenance actions, future revitalization strategies, and ongoing work at the Supplemental Environmental Project. More information can be bound at https://www.bce2.org/ .

Cardno: A native plant nursery in Indiana that provided the native plants that were planted at the Supplemental Environmental Project site and could be used in future native plant restoration actions. More information can be found at https://www.cardnonativeplantnursery.com/home .

City of South Bend (CoSB): The municipal government of South Bend, Indiana and responsible for the Supplemental Environmental Project. More information can be found at https://southbendin.gov/ .

Ecological Advocacy Committee: A committee formed to serve in advising the Park Board on how to enhance and maintain the ecological health of the environment surrounding and within the City of South Bend. An important resource for any revitalization or restoration strategies. More information can be found at http://sbvpa.org/activities/nature/ecological-advocacy-committee/ .

Hoosier Riverwatch: Citizen science initiative in Indiana dedicated to monitoring water quality, watershed education, and water clean-up activities. Important resource for water quality testing of Bowman Creek. More information can be found at http://www.hoosierriverwatch.com/ .

Indiana Department of Environmental Management (IDEM): The Indiana environmental protection agency responsible for overseeing and implementing federal and state regulations in regards to the environment. An important resource for any environmental work done within Bowman Creek. More information can be at https://www.in.gov/idem/ .

Indiana Master Naturalists: A program that provides many hands-on opportunities to learn about Indiana natural resources while also doing volunteer service. Local naturalists may be a resource in obtaining watershed information and may be a good partner for invasive plant removal. More information can be found at https://www.in.gov/dnr/parklake/6321.htm .

James Whitcomb Riley High School (Riley HS): Local Southeast neighborhood high school that has a section of Bowman Creek running underneath the track field. It will be important to establish amicable relationships with the high school in order to conduct water quality testing at the Riley HS track tunnel. More information can be found at http://riley.sb.school/ .

Midwest Invasive Plant Network: Organization with the goal of reducing invasive plant species within the midwest. Important resource for invasive plant removal including information on invasive prevention, risk assessment, and early detection. More information can be found at https://www.mipn.org/ .

Public Works (PW): City department that encompases engineering, streets, and sewers. More information can be found at https://southbendin.gov/department/public-works/ .

Southeast Organized Area Residents (SOAR): The neighborhood association for the Southeast neighborhood. An important resource for doing volunteer activities within the Southeast neighborhood and holding educational and outreach opportunities. SOAR can be reached at soarforward.wordpress@gmail.com or https://soarforward.wordpress.com/ .

St. Joseph River Valley Fly Fishers: A local club dedicated to fly fishing, the conservation and restoration of rivers and lakes, and public education programs. A potential partner and resource for volunteer and educational opportunities. More information can be found at http://sjrvff.com/ .

Venues Parks and Arts (VPA): City department overseeing South Bend's parks, trails, golf courses, and recreational areas. Responsible for grounds maintenance and an important partner and resource for carrying out this monitoring and maintenance plan. Key contact is John Martinez. More information can be found at https://southbendin.gov/department/venues-parks-and-arts/ .

Appendix B: Monitoring Actions

Water Quality Monitoring

Activity type					
Data collection of temperature, dissolved oxygen (DO) levels, biological oxygen demand, pH, ortho phosphate levels, nitrate levels, habitat, macroinvertebrates, stream flow, turbidity, and the pollution tolerance index rating.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources Needed*	*Recommendations*
IDEM Water Quality Standards	Every Season	Hoosier Riverwatch, BCe2	Medium	Hoosier Riverwatch test kit, Ecological Advocacy Committee	Testing everyday for two weeks and after major rain events.

Activity type					
Measuring *E. coli* levels.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources Needed*	*Recommendations*
Below legal grab sample limits of 235 CFU/100 ml	Weekly and after major rain events	Riley HS, BCe2, PW Water/Wastewater	Medium	Coliscan *E. coli* testing kit, professional testing lab, Ecological Advocacy Committee	Citizen scientist testing of water samples, test also at lab to determine accuracy. If deemed accurate, test exclusively through citizen scientists.
Activity type					
Televising the Riley Track Tunnel.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Reducing *E. coli* levels downstream of the Riley Track Tunnel.	Continuous video monitoring	Riley HS, PW (Streets and Sewers, Engineering), BCe2	High	Robotic camera	In conjunction with televising, *E. coli* testing should be done multiple times a day, upstream and downstream of the tunnel, when a high student population is present and not present.

Biodiversity Monitoring

Activity type					
Elkhart-South Bend Aquatic Community Monitoring program collecting data of local aquatic species communities.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Higher IBI and QHEI	Annually	Elkhart	High	Electrofishing equipment	Increasing the number of monitoring sites within Bowman Creek Watershed.
Activity type					
Collecting data on macroinvertebrate species composition.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Higher ICI	Annually	Elkhart	High	Biological	Determining the

				monitoring equip.	pollution tolerance index rating in conjunction with the ICI rating.
Activity type					
Observational data on the presence of species other than fish and macroinvertebrates.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Increase in the number and diversity of native species present in the area.	Annually	Audubon Society	Low	Indiana Master Naturalists, Ecological Advocacy Committee	Reaching out to Audubon Society or similar associations to hold annual species counts.
Activity type					
Collecting data on the number and type of invasive species present within the watershed.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Identifying and determining the cover of invasive species	Biannually	Back the Bend, Midwest Invasive Plant Network	Medium	Invasive plant catalog, Midwest Invasive Plant Network	Partnering with local organizations to train volunteers to identify invasive species.
Activity type					
Observing and analyzing whether overgrowth in the area is creating problems.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Decrease in the amount of woody debris blockages and increase in plant biodiversity.	Seasonally	Back the Bend, Hoosier Riverwatch, volunteer organizations	Medium	Invasive and native plant catalog	During community and volunteer events within the area, visual observations about the amount of overgrowth should be collected.

Community Monitoring

Activity type					
Collection of observational and visual data on the amount of litter present.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Reducing the amount of litter present within the riparian area and the waterway and the number of 311 calls pertaining to litter	Bi-monthly	Riley HS, Notre Dame, GreeND, Back the Bend, community residents	High	Code Enforcement for supplies and pickup	Partnering with local organizations and surveying community residents to determine whether litter is present within the creek.
Activity type					

Monitoring 311 calls from community residents within the neighborhood that pertain to overgrowth and safety.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Increasing the perception of safety within the watershed.	Continuous	311, SB Police, BCe2	High	311 records	Analyzing the type of 311 calls received in the area and surveying residents on their perceptions of safety.
Activity type					
Monitoring CoSB calls from community residents within the neighborhood that pertain to flooding.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Decreasing flooding and associated damage to community residents	Continuous	Public Works, 311, Engineering	High	311 records, Engineering records of drainage issues	Placing flow sensors along various stretches of Bowman Creek where flooding would negatively impact the community residents.
Activity type					
Collecting data on neighborhood residents and local educational institutions about watershed knowledge.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Increase in local watershed knowledge of the community	Annually	Riley HS, Notre Dame/IUSB/Ivy Tech, BCe2	High	Surveys, Ecological Advocacy Committee	Surveying neighborhood residents and students about the Bowman Creek watershed.

Hydrology Monitoring

Activity type					
Collecting depth and flow data through sensors.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Decreasing dry stretches and flooded stretches	Continuous	Riley High School, BCe2, City of South Bend, Public Works, EmNet	High	Arduino technology	Expanding the sensors already placed at Riley HS.
Activity type					
Examining the state of stream crossings, control structures, and bar screens.					

Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Increasing fish passage and hydraulic flow, reducing flooding	Annually	Elkhart, Public Works	Medium	Great Lakes Stream Crossing Data sheet, Jerry Sweetin	Using a uniformed procedure to collect data and facilitate aggregation of data on the state of stream crossings and control structures (ex. Great Lakes stream crossing data sheet)
Activity type					
Visually inspecting banks for erosion and/or taking measurements to compare over time the channel dimensions.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Identifying where in the waterway erosion is occurring	Biannually	Elkhart, Hoosier Riverwatch	Medium	Erosion identification training	Hoosier Riverwatch collects measurements of the cross sectional area when water quality testing which can be used to determine if erosion has occurred.

Appendix C: Maintenance Actions

Water Quality Maintenance

Activity type					
Re-adjusting or replacing natural riffles within Bowman Creek if they move out of place or deteriorate.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Maintaining dissolved oxygen levels with improvement over time	Annually	St. Joseph River Valley Fly Fishers, Public Works, VPA	Medium	Aquatic biologist, IDEM	Creating a plan for the future on the best placement of riffles within the watershed.

Activity type					
Placing native plants within the riparian corridor where there are few or none.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Increasing natural water quality improvements	Annually	PW, VPA, Cardno, Hoosier Riverwatch, BCe2	Medium	Cardno, Indiana Master Naturalists	Restoring natural banks to Bowman Creek and removing concrete.
Activity type					
Repairing and relining pipes and tunnels that could contribute as sources of contamination.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Reducing sources of contamination	Annually	Public Works (Engineering, Sewers and Streets)	Medium	Streets and Sewers, Engineering supplies and expertise	Planning and implementing projects to repair and line pipes and tunnels along Bowman Creek.

Biodiversity Maintenance

Activity type					
Removal of invasive species within the waterway and the riparian corridor.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Decrease in invasive species cover within the watershed	Annually	VPA, Hoosier Riverwatch, BCe2	Medium	Invasive and natural species catalog	Mapping coverage areas within the watershed of specific invasive species.
Activity type					
Removal of overgrowth in areas where it has become a nuisance.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Decrease in the amount of overgrowth	Biannually	VPA, Public Works, volunteers, BCe2	Medium	Yard work equipment, herbicides	Aggregating 311 calls to create a map of where residents have complained of overgrowth.

Community Maintenance

Activity type					
Removal of litter within the waterway and the riparian corridor.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Reducing the amount of litter present within the riparian area and the waterway and the number of 311 calls	Biannually	Back the Bend, Notre Dame/IUSB/Ivy Tech student organizations,	Medium	Code Enforcement for supplies and pickup	Partnering with local organizations and community members to remove litter within the creek and riparian

pertaining to litter		GreeND, SOAR, Riley High School			corridor.

Hydrology Maintenance

Activity type					
Repairing and replacing if necessary the pipes, tunnels, and culverts that the creek flows through.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Preventing future problems that may arise if the structures are not maintained	Annually	PW, VPA, Streets	High	Streets and Sewers, Engineering supplies and expertise	Daylighting the underground stretches of Bowman Creek to reduce the amount of maintenance needed.
Activity type					
Repairing and replacing bar screens at underground stretches of the creek's entrances and exits.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Preventing future blockages and flooding	Annually	PW, VPA	High	Streets and Sewers, Engineering supplies and expertise	Daylighting the underground stretches of Bowman Creek to reduce the number of bar screens needed and the amount of maintenance needed.
Activity type					
Stabilizing banks along the creek to prevent erosion.					
Target	*Frequency*	*Potential Partners*	*Priority*	*Resources*	*Recommendations*
Reducing the amount of bank erosion	Annually	Public Works, VPA, Cardno	Medium	INDR LARE grants, technical expertise from Cardno	Using the installation of native plants to stabilize the banks and exploring other stabilization options that promote vegetation growth.