An Ecological Assessment for the Creation of the Kiwanis Environmental Education Preserve (KEEP)

by

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Abstract

The Kiwanis Club of Ann Arbor, a 501(c)(3) non-profit corporation known for its thrift store sale and scholarships for high school students, envisioned a preserve to instill an environmental consciousness in young people in the Ann Arbor area. It is to this effect we conducted a thorough ecological evaluation of the urban forest situated within the 17-acre property belonging to the Kiwanis Club, utilizing field monitoring, geographical information systems, and hydrological modeling. This included an on-site investigation of the KEEP, surveying species of amphibians, mammals, and birds inhabiting the area from early spring through late fall of 2019. A vegetation assessment identified plant species and habitats with an overview of land cover development from 1960 through 2005 using aerial photographs. The water quality of the two on-site ponds, wetlands, and Honey Creek included measures of pH, oxidation-reduction potential, dissolved oxygen, specific conductance, temperature, and metals. Additional analysis characterized benthic macroinvertebrates. Finally, hydrological modeling was conducted to characterize the potential rerouting of stormwater runoff into the two ponds to improve water quality. The findings of this comprehensive environmental assessment of the KEEP natural areas showed: 1) A multitude of habitat types allow for a wide range of wildlife and vegetation diversity, including amphibians, birds, mammals, grasses, shrubs, and trees. 2) Some terrestrial habitats have degraded due to an influx of invasive, non-native species; while others have not and remain high quality. 3) The two ponds and wetlands are severely degraded in terms of physicochemical characteristics due to inadequate water renewal combined with large inputs of natural organic matter, e.g., leaves, algae, and duckweed. This prevents sustainable macroinvertebrate and fish communities. 4) Stormwater runoff from the KEEP building and parking lot are substantial during three seasons of the year and could be routed into the ponds to increase water flushing and renewal, thus improving water quality and allowing for the establishment of benthic and fish communities. Given the above four findings, the proximity of the property to urban and rural populations and schools, and the vision of KEEP leadership, there is tremendous potential for the creation of a unique and valuable educational resource. We recommend three primary site restoration actions: 1) Replant a subset of areas dominated with invasive plants using native species; 2) Route site runoff to one or two of the ponds to improve pond habitat. The pond habitat could also be improved by clearing outflow channels of excessive vegetation that impedes flow and creating a “fish wintering hole” near pond inflows; and 3) Provide improved drainage of the water-saturated forest area created in the past by installing and removing dirt berms. In addition to these restoration activities, future studies should establish a strategy for education kiosk(s) and boardwalks with educational signage. This could include a smartphone software interface with the KEEP database for visitors to learn about the biodiversity and habitats of the KEEP and how they interact in urban-rural areas. Our efforts build a strong foundation for the actualization of the KEEP.

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Chapter 1: Introduction

Environmental education has long been held as important in shaping our attitudes and behaviors towards the environment (Álvarez Suárez & Vega Marcote, 2010; Zsóka et al., 2013). However, we must be aware of how we define and portray nature when providing education (Fletcher, 2017). Often, we only participate in nature and environmental education programs in remote, more pristine areas and the education does not demonstrate the role of human presence commonly found in natural areas in proximity to population centers. This separation can leave people unaware of their responsibility for environmental stewardship. For these reasons, creating a Kiwanis Environmental Education Preserve (hereafter KEEP), a large urban-rural disturbed property, can serve as a much-needed community education center, to influence behaviors and attitudes.

The Kiwanis Foundation with a mission of "improving the world one child and one community at a time" has an international presence with 7,332 clubs worldwide and members present on every continent (*Kids Need Kiwanis*, 2018). The Ann Arbor Chapter of the Kiwanis Foundation (A2KF) opened not long after the first Kiwanis club was founded in Detroit, Michigan in 1915 (Hapgood, 1989). The Kiwanis Club of Ann Arbor Foundation Inc. is a 501(c)3 non-profit dedicated to providing children and families with meaningful opportunities and support. The club is best known for its expansive thrift sales. However, the club provides a greater community impact through the use of store profits to support Meals on Wheels and C. S. Mott Children's Hospital, as well as offering scholarships to college-bound high school graduates and middle schoolers entering summer programs (*Community Impact Report—Kiwanis Club of Ann Arbor Foundation, Inc.*, 2019). The A2KF also supports the Haiti Nursing Foundation, Warm the Children, and UNICEF's Eliminate Maternal Neonatal Tetanus and Iodine Deficiency Disorders campaigns and causes. In 2017, A2KF moved to a 17-acre property and proposed a new project to support environmental education in the community, the KEEP.

The A2KF established a committee to provide insight and guidance in the establishment of the KEEP on the new property. The current property consists of a large building (125,000 sq ft) containing a thrift store, cafeteria/event hall, several office spaces, and extensive warehouse storage. The natural areas adjacent to the building and it's large parking lot contain a wetland, densely vegetated woods, and two ponds (Figure 1). In the past, the property was used for both agriculture and manufacturing of books, so it was a combination of infrastructure, fields, and forests. Since beginning the KEEP project, a landscape architect with Insite Design Studio, Inc. created future plans for the KEEP and collaborated with Eastern Michigan University students to perform a baseline characterization of flora and fauna. They also began forming partnerships with local environmental organizations including the Leslie Science Center. To advance the project further, the committee submitted a master's project request to the University of Michigan's School for Environment and Sustainability (SEAS). This report is the product of that proposal, providing greater depth of site ecological knowledge and recommendations on how to deliver viable environmental stewardship and environmental education practices.

With this background knowledge, our team of three students had three objectives:

1. Characterization of the site: Provide the A2KF with a thorough and in-depth characterization of the site. This characterization is quantitative and qualitative in nature and consists of five major groups: land cover classification and change, vegetation inventory, wildlife inventory, water quality, and stormwater modeling.
2. Management recommendations: The site characterization provides land management recommendations to increase the educational value and ecological function of the site.

3. Educational materials: The characterization database serves as a foundation of educational materials in the form of an Environmental Systems Research Institute (ESRI) story map for future KEEP projects.

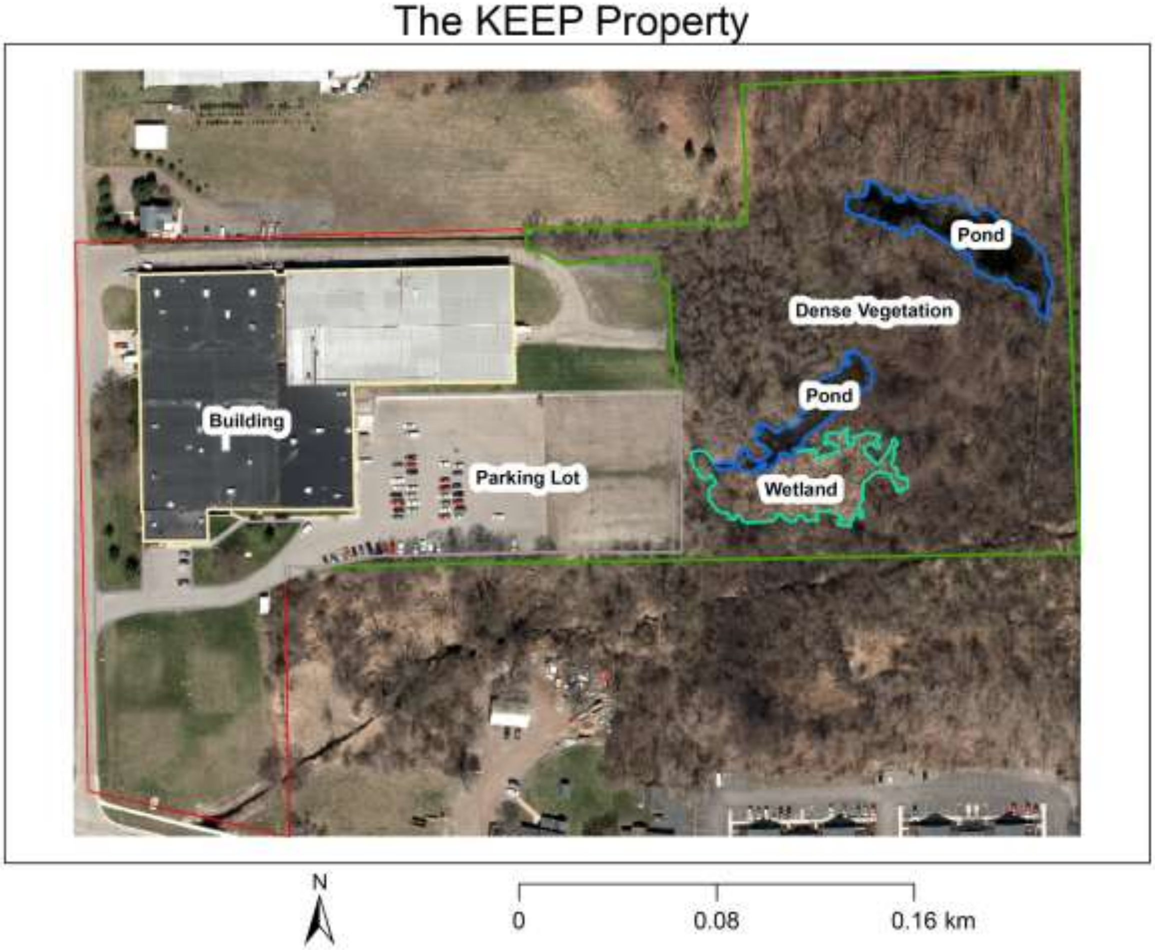

Figure 1. Map of the KEEP property displaying the building, parking lot, wetland, densely vegetated woods, and two ponds (polygons were manually classified from SEMCOG 2015). The components of the KEEP are displayed on an aerial image (SEMCOG 2015) and bordered by the property boundary (Washtenaw County GIS Program 2019). The map is projected in State Plane Michigan South (m) and uses the North American Datum of 1983.

Chapter 2: Land Cover History of the KEEP

2.1 Background

The KEEP property has been owned by A2KF for a short period of time, making a long history of changing livelihoods prior to their ownership. This variety of livelihoods and location in a populated commercial landscape lends the KEEP to being highly modified by humans. Because of this, we determined it was important to understand land cover and land cover change on the property. A change in land cover may lead to the simplification of ecosystems, including lower species diversity (Schulte et al., 2007). Invasive plants thrive on these disturbances because they reduce competition with natives for space, light, water, soil nutrients, and other resources. (Corbin & D'Antonio, 2004). Agriculture, depending on its intensity, has also been shown to leave a lasting legacy with impacts on ecosystems, such as species richness and communities, through soil properties (Dupouey et al., 2002). Due to these impacts, this land cover information on the KEEP can be helpful in shaping restoration plans and ecological research and teaching (K. Bergen et al., 2018; K. M. Bergen & Dronova, 2007; Schulte et al., 2007).

In the case of historical land cover classification with no ground truth data, manual classification with the aid of a simplified classification scheme, minimum mapping unit, and ancillary data is effective at understanding land cover and its change (K. Bergen et al., 2018). We used these methods on the five aerial photos of the KEEP property to aid in the completion of our first objective of characterization of the KEEP. With these methods and the results they produce, we will better understand how the current land cover of the KEEP came to be and produce maps that can be used as educational tools in the future use of the KEEP.

2.2 Methods

With this analysis, we worked to answer the questions: 1) What is the current land cover of the KEEP?, and 2) How has the land cover of the KEEP changed throughout history? We completed a manual land cover classification as well as a land cover change analysis from the 1800s to present to achieve this goal (Figure 2). We began this analysis by finding the digitized 1800 land cover classification by the State of Michigan (2019; Figure 3f; Appendix B Figure B1). We then began looking for aerial photographs temporally spaced by 10 years apart, going as far back as possible. This search led to a collection of 5 aerial photos (see Figure 3) spanning the time period of 1960 to 2015 provided by SEMCOG (2005, 2015; Figure 3a and b) and by Washtenaw County GIS Program (1960, 1984, 1990; Figure 3c, d, and e). These aerial photos were then used in a land cover classification and land cover change analysis.

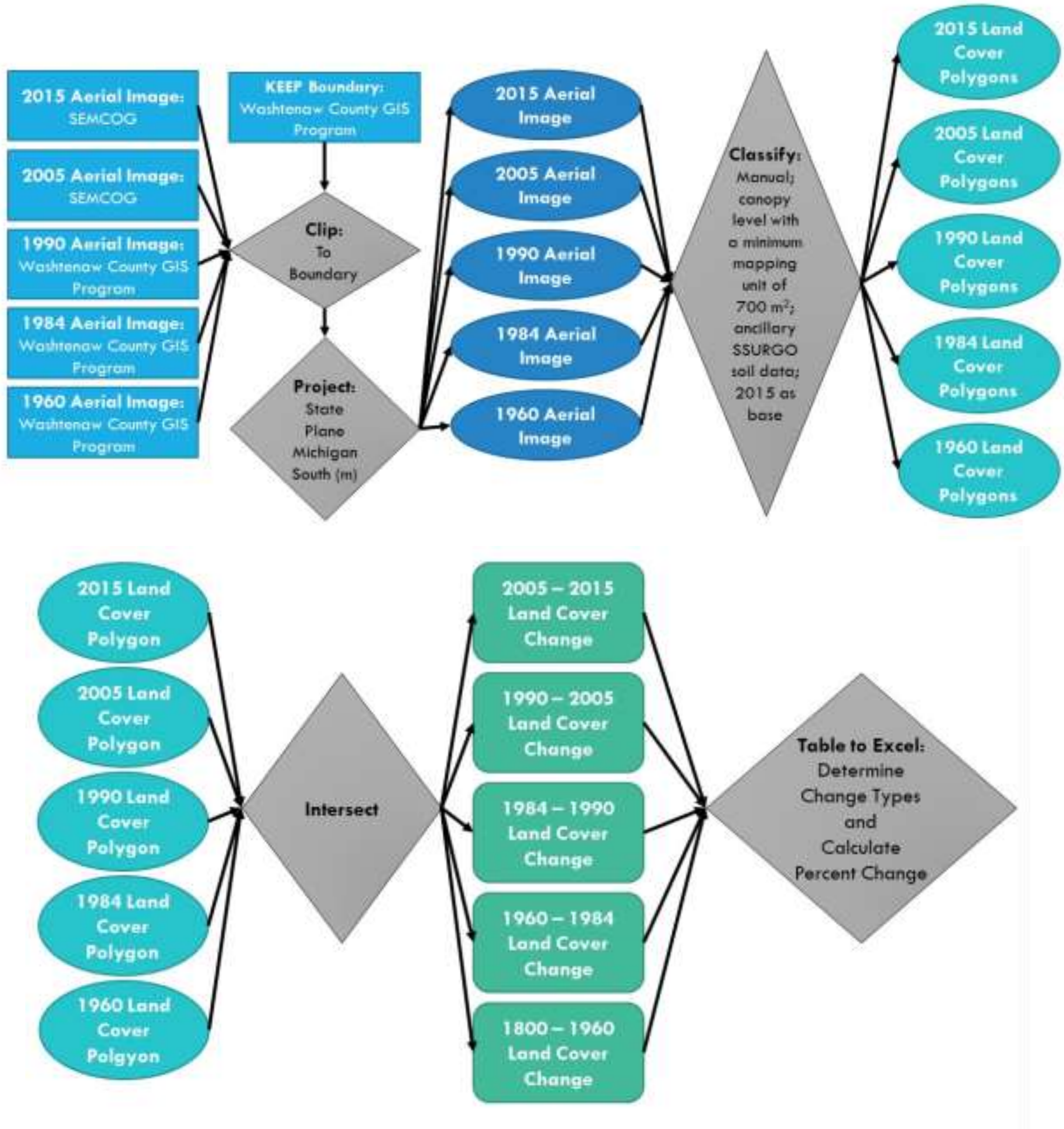

Figure 2. Flow diagram of methods for land cover classification and change analysis. Methods were completed using ArcMap and Excel.

We began our land cover classification by projecting all aerial images to State Plane Michigan South (m) and using the North American Datum of 1983 (Figure 3). These projected images were then clipped to a polygon feature of the KEEP property created from an image of Washtenaw County GIS Program's tax properties (2019) georeferenced using ground control points methods to the 2015 SEMCOG aerial image. Once all images were clipped and projected, we began the manual classification of each image. A polygon feature class was created for each aerial image to contain polygons of different land covers

(Table 2) adapted from Anderson et al. (1976). To aid in manual classification, we used a minimum mapping unit of 700 m^2 to capture the diversity of the KEEP, while not mapping individual trees, as well as used ancillary data. The ancillary data used included SSURGO Web Soil Survey data (2019) and current vegetation data collected by our team. The methods for the vegetation data collection are outlined in Chapter 3 of this report. We classified aerial photos working back through time starting with 2015 as the most information was known about 2015 land cover with the previously mentioned vegetation survey. The products of these land cover classifications were polygon feature classes for each of these years (Fig. 4, larger maps of each year in Appendix B Figures B2- B6).

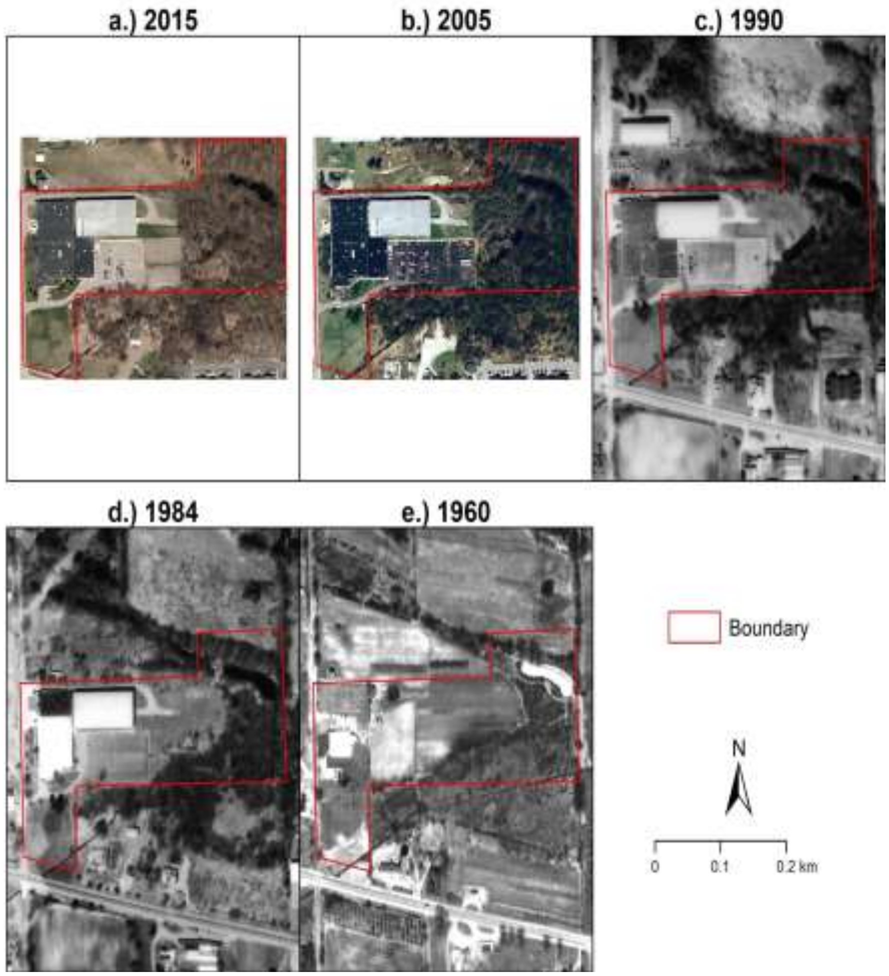

Figure 3. Aerial photographs of the KEEP in a.) 2015, b.) 2005, c.) 1990, d.) 1984, and e.) 1960 (SEMCOG, 2005, 2015; Washtenaw County GIS Program, 1960, 1984, 1990). The photographs are displayed within the KEEP property boundary (Washtenaw County GIS Program, 2019). All photographs are projected in State Plane Michigan South (m) and use the North American Datum of 1983.

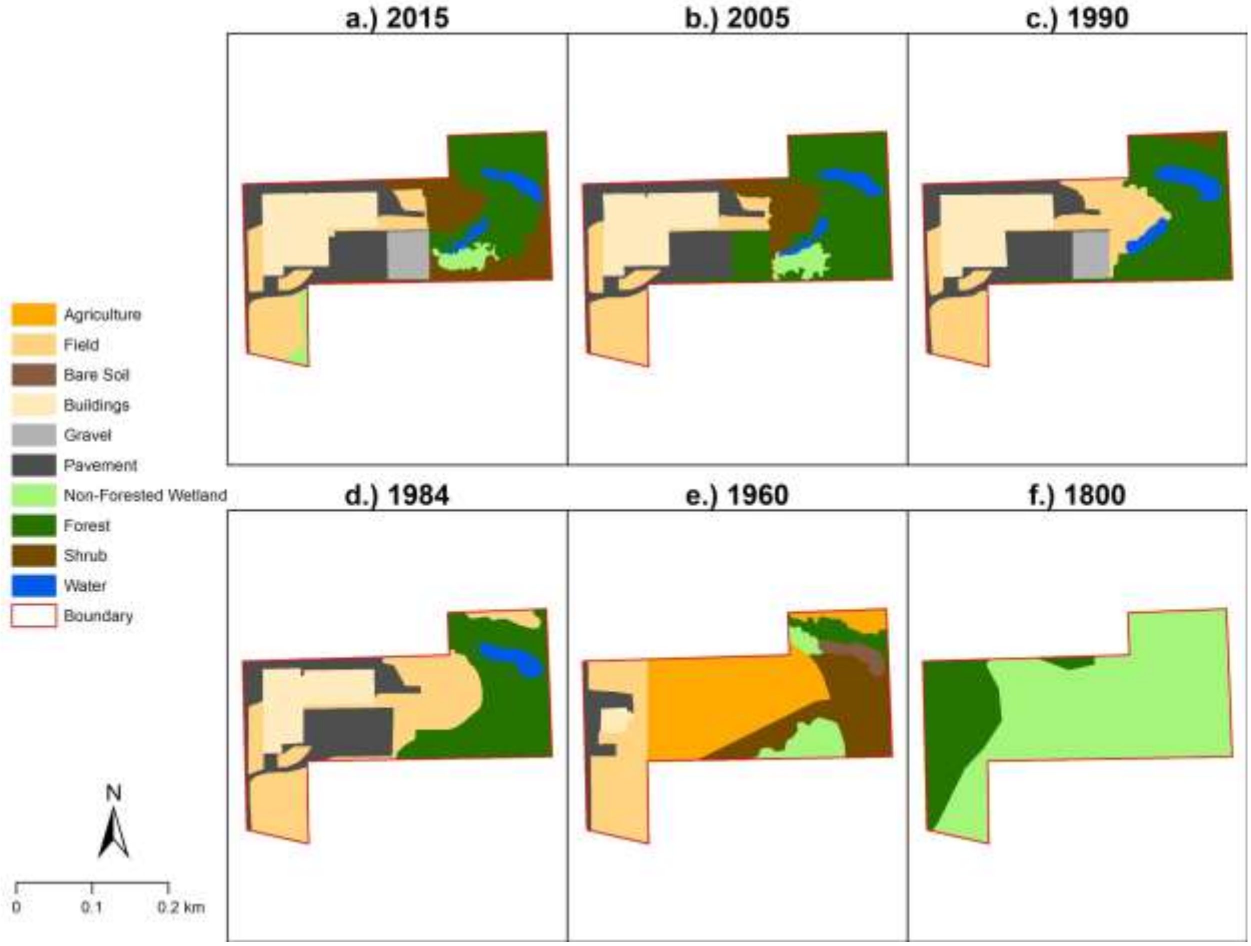

Figure 4. Land cover throughout the KEEP in a.) 2015, b.) 2005, c.) 1990, d.) 1984, e.) 1960, and f.) 1800 (SEMCOG, 2005, 2015; State of Michigan, 2019; Washtenaw County GIS Program, 1960, 1984, 1990). The land covers are displayed within the KEEP property boundary (Washtenaw County GIS Program, 2019). All maps are projected in State Plane Michigan South (m) and use the North American Datum of 1983.

Table 1. Land cover classifications and their definitions used to classify land cover on the KEEP from five years of

aerial images spanning the time period of 1960 to 2015.

Code	Classification	Definition
1	Shrub	Vegetation cover dominated by shrubs (woody low growth)
2	Non-forested wetland	Vegetation cover dominated by herbaceous species and soils poorly drained or very poorly drained
3	Forest	Vegetation cover dominated by trees (woody vertical growth)
4	Bare Soil	Absence of all vegetation with soil exposed
51	Buildings	A human-created structure for industrial, commercial or private use
52	Pavement	Impervious surface used for roads and parking lots
53	Gravel	Ground covered in gravel used for parking lots
54	Field	Clear-cut grass areas influenced by humans
55	Agriculture	Human modified land used for crop growth
6	Water	Areas of exposed water including natural and man-made ponds

We then began a land cover change analysis by using the ArcGIS Intersect tool on the polygon feature classes for each change period. This resulted in an output polygon feature class for each change period. We then used the Table to Excel tool to export this change data and categorized the different change types (Table 2). We calculated the percent change in each time period by dividing the area of the change type by the total area of the KEEP property (Figure 2). The result was a percent change in land cover change type for each time period (Appendix B Tables B1 – B4).

Table 2. A list of change types and their definitions used in the land cover change analysis of the KEEP property.

These change types do not reflect all possible changes, only land cover changes that occurred and are encompassed in the cumulative sum to 99% area in any time period of change.

Change Type	**Definition**
No Change	Land cover remained the same
Clear Cut	Non-forested Wetland, Shrub, or Forest to field
Clear Cut and Infrastructure Addition	Non-forested wetland, shrub, or forest land cover to building, pavement or gravel land cover
Infrastructure Addition	Field land cover to building, pavement or gravel
Infrastructure Loss	Pavement or gravel land cover to shrub, forest, or field land cover
Paved	Gravel land cover to pavement land cover
Obstructing Drainage	Any cover to water or non-forested wetland land cover
Creating Drainage	Water land cover to any land cover
Abandoned Agriculture	Agriculture land cover to field land cover
Wetland Succession	Non-forested wetland land cover to shrub or forest land cover
Forest Succession	Shrubland cover to forest land cover
Succession from Agriculture	Agriculture land cover to non-forested wetland, shrub, or forest land cover
Succession from Disturbance	Field land cover to shrub or forest
Forest to Shrub	Forest land cover to shrubland cover (possible error)
Errors	Building land cover to any land cover

The major sources of error in our land cover classification and change analyses were the lack of an accuracy assessment and the limits to the use of aerial photography in land cover classification. We were unable to perform an accurate assessment of our land cover classifications as ground truth data is not available in historical years for the KEEP property to compare the classified land covers to. With two different sources for our aerial photographs, the temporal resolution of the photographs varied with some photographs in leaf-on and some in leaf off periods. The spatial resolution of the aerial photographs may also vary between the different sources, leading to differences in classifications between years. This may cause variation in land cover classifications between years. It is also difficult to distinguish between forest and shrub covers with only aerial photography due to only having a visual of the canopy. Even with these sources of errors and limitations, we believe this classification and analysis provides a good basis for understanding the environmental history of the KEEP and how it shaped the environment we see on the property today.

2.3 Results and Discussion

2.3.1 Land use as of 1800

The land use in the 1800s consisted of two different land cover types: an Oak-Hickory forest and a wet prairie (Fig 4f and Appendix B Figure B1). These two land covers suggest a spatial difference in water drainage across the KEEP property with the west side of the property consisting of well-drained soils and the east side of the property consisting of poorly drained soils. Although these two land covers are not present on the property today, this drainage pattern still continues to influence the land covers on the property.

2.3.2 Land use as of 1960

The primary land use in 1960 was agriculture (Figure 4e and Appendix B Figure B2). At this time in history, there were no ponds on the property. However, we see the beginnings of the north pond on the property with bare soil displayed where the pond is being dredged to be filled with water in the future. This 1960 land cover is a drastic change from the recorded 1800 land cover with fields, agriculture, and infrastructure replacing the wet prairie, as well as agriculture, shrubs, non-forested wetlands, and bare soil replacing the majority of the Oak-Hickory Forest.

2.3.3 Land use as of 1984

The changes consisting of the greatest percent of the KEEP from 1960 to 1984 were infrastructure additions (30.53%), abandoned agriculture (17.07%), and forest succession (15.56%). This time period also had a large amount of land cover change with only 18.96% of the KEEP property remaining the same land cover. We see this reflected in the 1984 land cover (Figure 2.23d and Appendix B Figure B3) with much of the agriculture we saw in 1960 now fields and the shrubs and wetlands we saw in 1960 now forest. The main building of the KEEP property was also extended sometime in this time period and the dredged bare soil has since filled with water to form the North Pond we see in 1984.

2.3.4 Land use as of 1990

From 1984 to 1990, there was little land-use change (88.05% no change). Of the small changes, the largest were infrastructure addition (5.35%), succession from disturbance (3.33%), obstructing drainage (1.51%), and clear cut and infrastructure addition (1.37%). The fields from abandoned agriculture continued their succession with the beginnings of forest and shrubland covers. There was also a gravel parking lot added (Figure 4c and Appendix B Figure B4). This addition likely led to the creation of the South Pond on the property due to the unintended consequences of changing drainage patterns.

2.3.5 Land use as of 2005

Over the next time period, there is minimal change (82.76% no change), with succession from disturbance (8.63%), obstructing drainage (3.22%), and infrastructure addition (1.41%). The field closest to the building continues succession from agriculture in 1960 to the field in 1984 and now to the shrub in 2005. Another major change is the addition of a new wetland area south of the southern pond as drainage patterns continue to change (Figure 4b and Appendix B Figure B5).

2.3.6 Land use as of 2015

The time period leading to the most recent land cover continues similar to the two previous time periods. Again, 82.43% of the KEEP did not change. There is additional drainage obstruction (2.89%) likely as water continues to be rerouted by humans whether unintentional or intentional. Forest succession (1.35%) of shrubland cover to forest land cover occurs. One difference from the previous two time periods is the influence of the forest to shrub (8.91%) change. A new shrub area arises, previously forest, which is dominated by Common Buckthorn (*Rhamnus cathartica;* Figure 4a and Appendix B Figure B6). Perhaps this resulted from forest clear-cutting followed by the growth of invasives in the ten-year span. However, this change may simply be resulting from errors generated using aerial photographs to classify land cover. Aerial photos only provide a view of the canopy, so at times it is difficult to distinguish shrubs and forests. This error is less likely in the most recent year (2015) as we have vegetation data (2019) to help guide our classification.

2.4 Conclusion

The land cover history of the KEEP has been strongly influenced by human disturbance. The historical use for agriculture in 1960 has continued to guide succession through the following 60 years. This legacy of agriculture is supported by previous studies and could be due to impacts on soil properties from agriculture (Dupouey et al., 2002). There were also extensive infrastructure additions that disrupted drainage patterns. These high disturbance activities are common in urban-rural boundary areas and demonstrate their major influence on current day vegetation and its invasive dominance. These invasive species dominant today likely thrived in the absence of resource competition from natives in the agriculture and abandoned cleared areas of the KEEP (Corbin & D’Antonio, 2004). This current day vegetation is discussed in the following chapter.

Chapter 3: Vegetation Survey and Findings

3.1 Background

As discussed in Chapter 2, the site has a long history of human use and modification, imparting varying degrees of disturbance which are likely the primary driver of novel plant communities and distinct habitat types. For example, much of the stormwater runoff received by the property remains stagnant within a large central portion of the KEEP with poorly drained soils. This area is characterized as wet woods, west of the South Pond and south of the North Pond. Another legacy of the KEEP's historical land use is the presence of a concentrated stand of low-quality vegetation directly east of Kiwanis's loading dock. Formerly agricultural land, it became dominated by Common Buckthorn when left fallow. Buckthorn has since expanded throughout the KEEP, particularly along Honey Creek and the parking lot drainage ditch. Invasive species are defined as those that were introduced to new areas outside of their native range and have since caused harm to the established plant community by virtue of competitive life-history traits and the absence of their native predators and pathogens in their new settings. The KEEP contains many species that the Michigan Department of Natural Resources has classified as invasive, as well as several nonnatives that impart low quality without being considered invasive (https://www.michigan.gov/invasives).

Within this section, we describe the heterogeneity of plant life in the KEEP and provide a semi-quantitative picture of biodiversity and structural complexity found across the vegetated landscape. This biodiversity refers to the variety and distribution of different plant species across the landscape, and structural complexity is the characterization of differences in age, size, density, and height. A diverse and structurally complex forest provides the greatest variety of ecosystem services and wildlife resources. The vegetation types are directly tied to the wildlife diversity that inhabits the KEEP. Therefore, we believe a greater degree of vegetative diversity promotes a more engaging setting for visitors and more opportunities for environmental education.

3.2 Methods

On September 14th, 2019, a quantitative vegetation survey was conducted to characterize groundcover, overstory, and understory of the KEEP. Using the boundaries of cover type from aerial photography analysis (See Chapter 2), we isolated seven distinct areas or stands of the KEEP. For large stands (stands 1, 3, 5, and 6), the overstory was sampled in a circular 314 m^2 plot, where DBH and species of all trees over 9 cm in diameter were quantified. Within these larger plots, understory in two smaller circular 50.27 m^2 subplots was sampled recording DBH and species of all trees between 3 and 9 cm in diameter. At the center of the plot, a 1-by-1-meter frame was established to estimate the percent cover of the ground, specifying bare ground, leaf litter, and plant cover, identifying species of cover and their respective percent composition. For small stands (stand 2, 4, and 7), the same methodology was used, with overstory plots being 100 m^2 in area, and understory plots being 16 m^2 in area (Figure 5).

The analysis of our vegetation survey focuses on four key metrics: 1) Shannon diversity index score, 2) density of individuals per square meter of the forest, 3) total basal area per square meter of the forest, and 4) above-ground biomass per square meter of forest. The first is an index used frequently by ecologists as a measure of diversity, considering both species richness and evenness, providing a score on a scale of 0 to 1, with 1 being most diverse. The second metric is individuals surveyed divided by area surveyed and will lend us insight into how densely vegetated each stand of the KEEP is. The third metric takes density and incorporates the diameter and subsequent basal area of each surveyed tree. When compared with individual density, this metric can inform general patterns of age and canopy structure: for example, a densely vegetated stand with a low basal area per square meter would indicate a stand dominated by small, young trees. High basal area values indicate older trees present in the stand, which we would expect to be less dense in distribution. If a stand were to have a high basal area per square meter and a high density of individuals, we could assume a strong understory population complimenting the older less dense trees. The fourth metric was calculated using DBH-dependent allometric equations specific to tree species (Table 3). Above-ground biomass per square meter of forest can be used as an estimation of productivity or age of a stand, with more biomass either indicating the presence of large, old trees, or many trees of a particularly dense species. When discussing each stand in turn, we will also interpret metrics 2-4 using the species composition that make up each figure in each stand. This allows us to interpret which species may be responsible for different patterns of density, growth, and age that we derive from analysis (Table 4).

Table 3. Allometric equations used to calculate aboveground biomass of surveyed tree species. Some species had no readily available equation, in which case a replacement equation was assigned and the replacement justified by literature.

Tree Species	**Allometric Equation**	**Species of Equation (yellow if replaced)**	**Source of Equation**	**Source of rationale for replacement**
Acer negundo	$=0.1789 * dbh^{2.334}$	*Acer negundo*	(Ter-Mikaelian & Korzukhin, 1997)	
Acer rubrum	$=0.1789 * dbh^{2.334}$	*Acer rubrum*	(Ter-Mikaelian & Korzukhin, 1997)	
Acer saccharinum	$=0.1676 * dbh^{2.3646}$	*Acer saccharinum*	(Ter-Mikaelian & Korzukhin, 1997)	
Acer saccharum	$=0.1676 * dbh^{2.364}$	*Acer saccharinum*	(Ter-Mikaelian & Korzukhin, 1997)	(Barnes & Wagner Jr., 2004)
Lonicera mackii	$=(29.615 * dbh^{3.243})/1000$	*Sambucus spp.*	(Perala & Alban, 1993)	(Ricardi et al., 2007)
Populus deltoides	$=0.0527 * dbh^{2.5084}$	*Populus deltoides*	(Ter-Mikaelian & Korzukhin, 1997)	
Prunus serotina	$=0.0716 * dbh^{2.6174}$	*Prunus serotina*	(Ter-Mikaelian & Korzukhin, 1997)	
Quercus alba	$=0.2022 * dbh^{2.1666}$	*Quercus alba*	(Ter-Mikaelian & Korzukhin, 1997)	
Quercus bicolor	$=0.1335 * dbh^{2.422}$	*Quercus bicolor*	(Ter-Mikaelian & Korzukhin, 1997)	
Quercus imbricaria	$=0.2482 * dbh^{2.19}$	*Quercus coccinea*	(Ter-Mikaelian & Korzukhin, 1997)	(Barnes & Wagner Jr., 2004)
Rhamnus cathartica	$=(38.1111* dbh^{2.9})/1000$	*Rhamnus spp.*	(Perala & Alban, 1993)	
Salix alba	$=0.0616 * dbh^{2.5094}$	*Salix spp.*	(Ter-Mikaelian & Korzukhin, 1997)	
Ulmus americana	$=0.825 * dbh^{2.468}$	*Ulmus americana*	(Ter-Mikaelian &	

			Korzukhin, 1997)	
Ulmus pumila	=0.0048879 * $dbh^{1.613}$	*Ulmus pumila*	(McHale et al., 2009)	

Additionally, we included a fifth descriptor derived from the vegetation survey that should be viewed more as a visualization tool than a metric. As per ground cover survey methodology, we estimated percent presence of different cover types on the forest floor of each stand, such as bare ground, leaf litter, woody debris, herbaceous plants, and moss or fungi. We present this information as a square tree map representing an idealized square meter of forest floor, and how much of it is occupied by these different cover types. This visual also incorporates basal area, wherein the basal area per square meter metric of each stand is converted into a percentage of the idealized square meter of the forest floor.

Finally, we include an additional metric for each stand and a summary of the whole KEEP that incorporates both species formally identified in our vegetation survey *and* species informally identified throughout our many visits to the KEEP. The latter are mostly herbaceous species while the former are woody. We compiled all species observed and conducted a floristic quality assessment (FQA), per the methodology of the assessment's developers (Freyman et al., 2016). Keep in mind that many of these observations were taken without standardized methodology across the KEEP, meaning resulting floristic quality index (FQI) scores may be skewed towards more frequently visited spaces, or towards easier-to-identify/unique species. Adjusted FQI scores incorporate rarity, invasive presence, and regional abundance, with scores of 1 through 19 indicating low-quality vegetation, and scores of 20-35 indicating high-quality vegetation (Table 4).

Table 4. Description of metrics used in vegetation analysis.

Metric	Description	Interpretation	Units
Adjusted Floristic Quality Index of Entire Plant Community	A measure of the quality of a plant community, based on the presence of natives vs. invasives, and based on rarity and regional abundance	1-19 indicates a low-quality plant community. 20-40 indicates a high-quality plant community.	Unitless; scale from 1 to 40
Shannon Diversity Index of Forest	A measure of diversity and evenness across the surveyed trees.	0 indicates low diversity and evenness. 1 represents high diversity with perfect evenness between species	Unitless; scale from 0 to 1
Forest Density	A measure of surveyed trees divided by area surveyed.	Higher values indicate a more closely packed forest community, likely associated with younger/smaller trees. Lower values indicate a more spread out forest community, likely associated with older/larger trees.	Individuals/m^2
Forest Basal Area by Forest Area	A measure of the area of surveyed tree trunks at their base, divided by area surveyed.	Higher values indicate the presence of large/old trees or many trees. Lower values	cm^2/m^2

		indicate the presence of either a few trees or young/small trees.	
Aboveground Forest Biomass by Forest Area	An estimation of the mass held in observed trees aboveground, divided by area surveyed.	Higher values indicate more mass being held by the tree community, likely in large or dense trees. Lower values indicate less mass being held by the tree community, likely in small/young or light trees.	kg/m^2

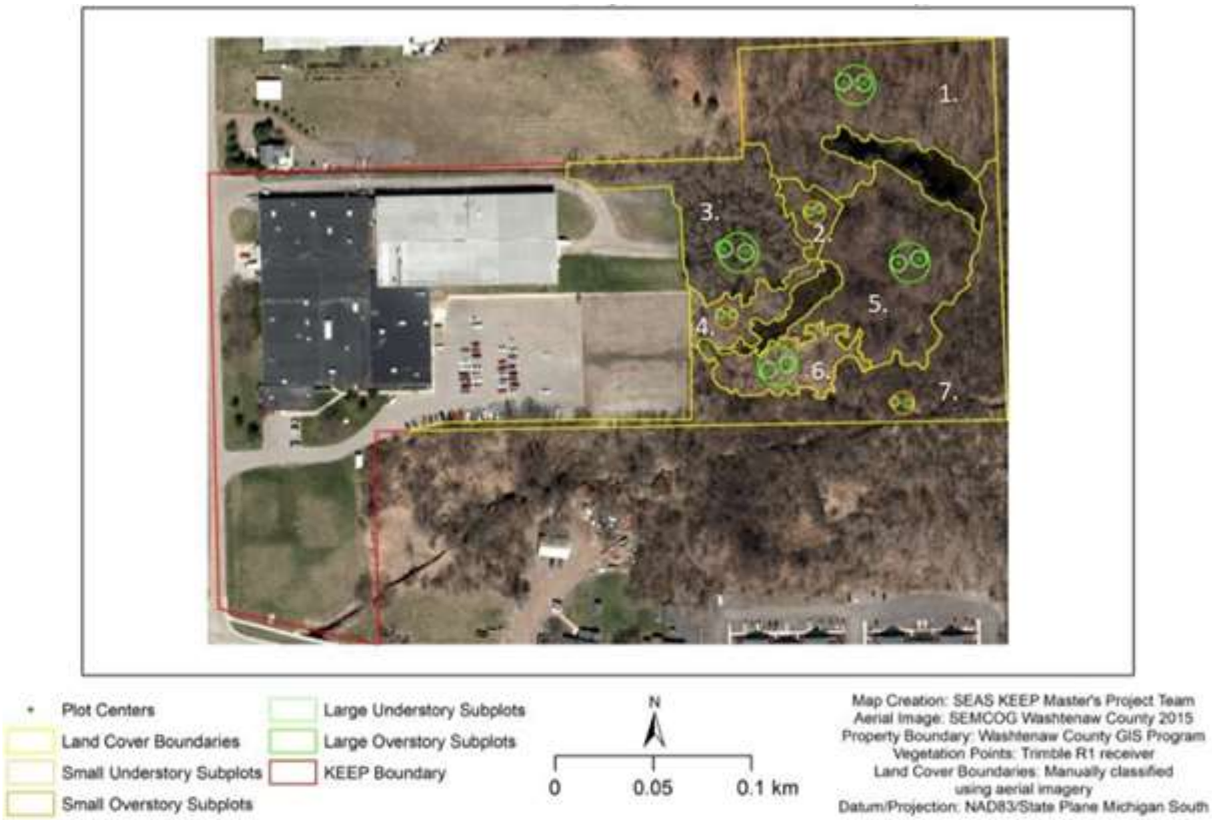

Figure 5. Aerial map of the Kiwanis Thrift Store and the KEEP, Stands are outlined in yellow and numbered in grey, overstory vegetation survey plots outlined in green and orange, and understory plots outlined in lime green and brown. The map is projected in State Plane Michigan South (m) and uses the North American Datum of 1983.

3.3 Results and Discussion

3.3.1 Overall KEEP Patterns

During our vegetation survey, we observed 144 living trees from 14 species, with Common Buckthorn being the most frequently occurring species, followed by Siberian Elm (*Ulmus pumila*) and Box Elder (*Acer negundo*). 67 were categorized as understory, and 77 as overstory. When examining the distribution of DBH classes, we see a typical negative exponential relationship characteristic of a multi-age forest (Figure 6). The overall density of trees across the KEEP is 0.18 individuals per square meter, which will be used as a benchmark against which densities of individual stands will be compared. The basal area per square meter of the KEEP area is about 45.6 cm^2 per square meter, and aboveground biomass is about 116.1 kg per square meter of the KEEP area (Table 5, Figure 7). The KEEP scores 0.725 on the Shannon Diversity Index and 28.9 on the adjusted Floristic Quality Index, the latter of which is based on formal and informal observations of 40 plant species (Table 5).

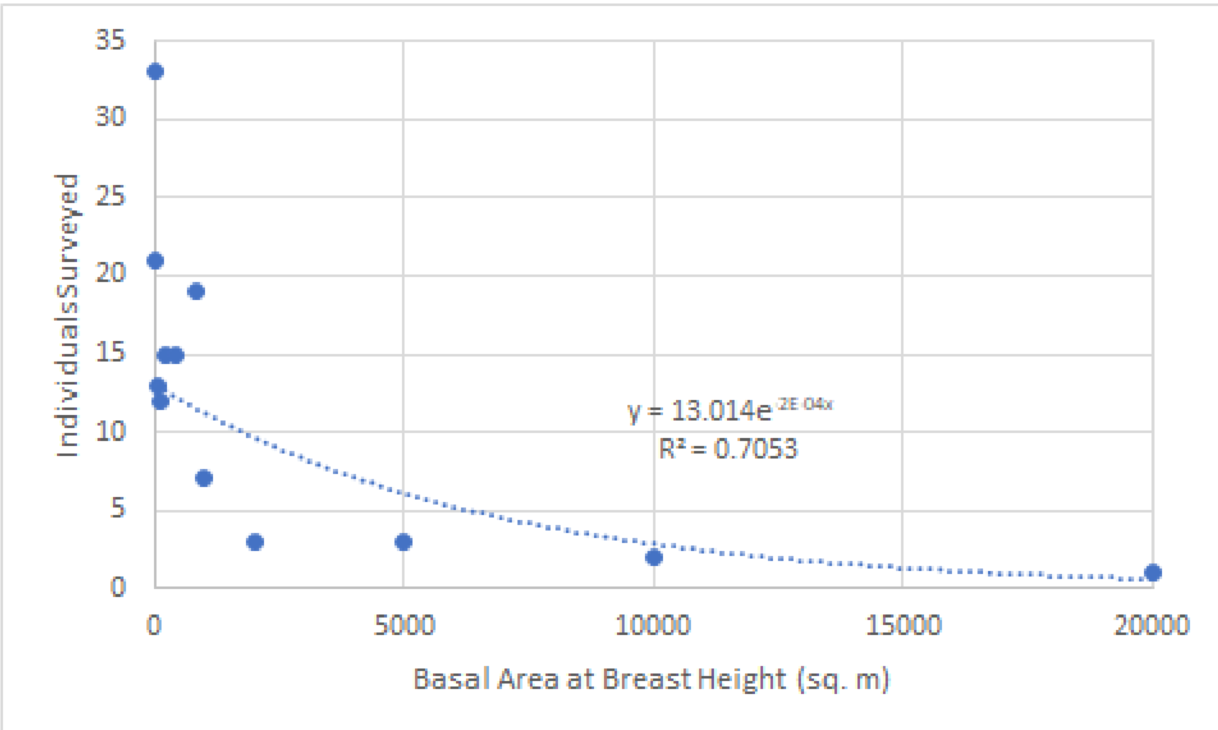

Figure 6. Distribution of DBH classes in surveyed trees.

Table 5. Compiled diversity and forest structure indices across all seven KEEP stands.

Stand #	Community type	Total Species	Adjusted Floristic Quality Index (FQI)	Shannon Diversity Index (SDI)	Density (Individ./ sq. m)	Basal area by forest area (sq. cm/sq. m)	Aboveground Biomass by forest area (kg/sq. m)

1	Oak Forest	11	28.9	0.840	0.13	18.734	10.735
2	Upland Shrub Willow Overstory	7	15.1	0.545	0.29	112.661	82.406
3	Upland Shrub Elm Overstory	5	22.4	0.505	0.31	33.369	47.804
4	Cottonwood Forest	6	2.9	0.727	0.18	307.064	234.071
5	Wet Forest	12	33.8	0.699	0.19	34.315	23.251
6	Non-forested Wetlands	11	23.1	0.733	0.03	3.411	2.007
7	Riparian Shrub	10	39.8	0.000	0.29	7.369	2.839
Total	KEEP totals	40	28.9	0.725	0.18	45.576	116.064

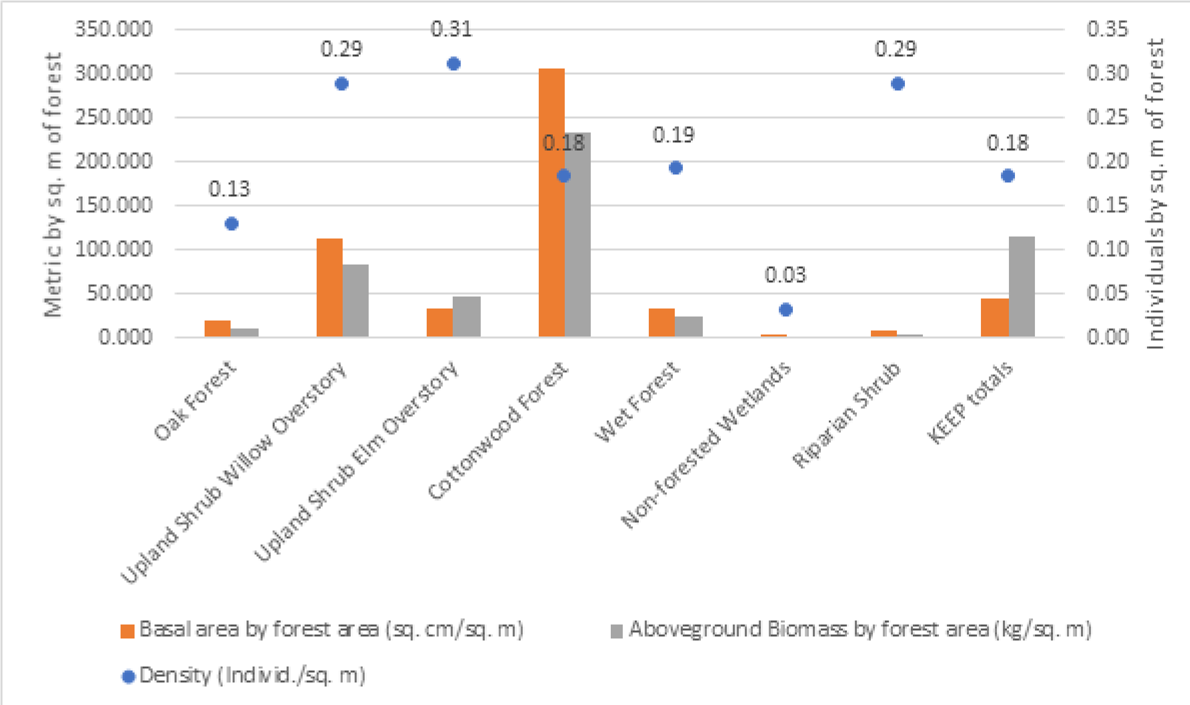

Figure 7. Individual density, basal area by forest area, and aboveground biomass by forest area of surveyed trees across all seven KEEP stands.

3.3.2 Oak Forest

Out of 26 trees surveyed, Black Cherry (*Prunus serotina*) and White Oak (*Quercus alba*) were the most common species in the Oak Woods, both predominantly appearing in the overstory (Figure 8a). There are an estimated 0.13 individuals, 18.7 cm^2 of basal area, and 10.7 kg of aboveground biomass per square meter of Oak Forest (Table 5, Figure 7). The understory is only slightly denser than the overstory, and the species composition of both is fairly similar (Figure 8a). The majority of basal area and biomass is contained in Black Cherry trees (Figure 8b-c).

Based on observations in the field, it is not surprising that the Oak Forest is less densely forested compared to other parts of the KEEP, but it is surprising that its aboveground biomass and basal area is so comparatively low (Figure 7). We might expect the oaks to be champions of sequestering carbon, but those surveyed here were in a DBH range that ultimately did not translate into massive amounts of biomass stored. Not captured by the survey were one or two massive oaks (Figure 8e-f) that, if they had been surveyed, may have tipped the biomass totals away from this trend. When taking these larger individuals into consideration, it seems the White Oak is successful in recruiting, which is promising for the future of this stand.

The Oak Woods survey yielded a Shannon Diversity Index of 0.84, the highest out of all the stands (Table 5). When taking into account herbaceous members observed formally and informally, the Oak Woods scores a 28.9 on the adjusted Floristic Quality Index, which is surprisingly the same score as the KEEP overall. Most of the forest floor is bare ground and woody debris, with some leaf litter and woody shrubs and vines present (Figure 8d).

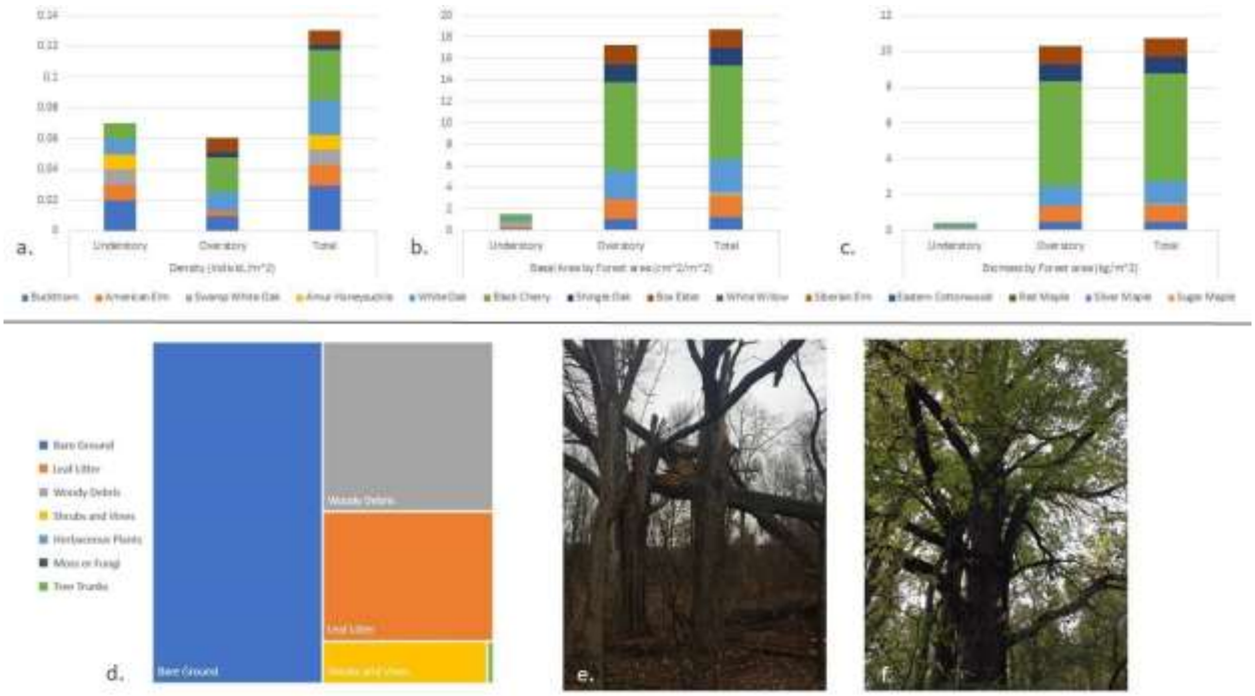

Figure 8. Oak Forest summary. (a) The number of individuals observed by species and presence in understory and overstory. (b) The density of observed individuals per square meter by species and presence in understory and overstory. (c) Square centimeter of Basal area to a square meter of Forest Area ratio by species and presence in understory and overstory. (d) Percent cover of one square meter of the sampled forest floor. (e) Fallen limbs and snags found in White Oak overstory of Oak Forest. (f) White Oak in Oak Forest leafing out.

3.3.3 Upland Shrub Willow Overstory

This stand is distinct in its slight elevational dip and its White Willow overstory. Within, we surveyed 12 trees, most of which were Common Buckthorn, followed by White Willow (*Salix alba*) and Box Elder (Figure 9a). There are an estimated 0.29 individuals, 112.7 cm^2 of basal area, and 82.4 kg of aboveground biomass per square meter of Upland Shrub Willow Overstory (Table 5, Figure 7). This is one of the densest stands that hold a significant amount of biomass, the former being attributable to the pervasive presence of Buckthorn in the understory, and the latter to the presence of larger individuals (Figure 9a-c). However, our vegetation survey did not capture any willow in the understory, indicating the Buckthorn may be preventing recruitment by the overstory. This disruptive presence is also reflected in the relatively low Shannon and FQI scores, 15.1 and .55 respectively (Table 5).

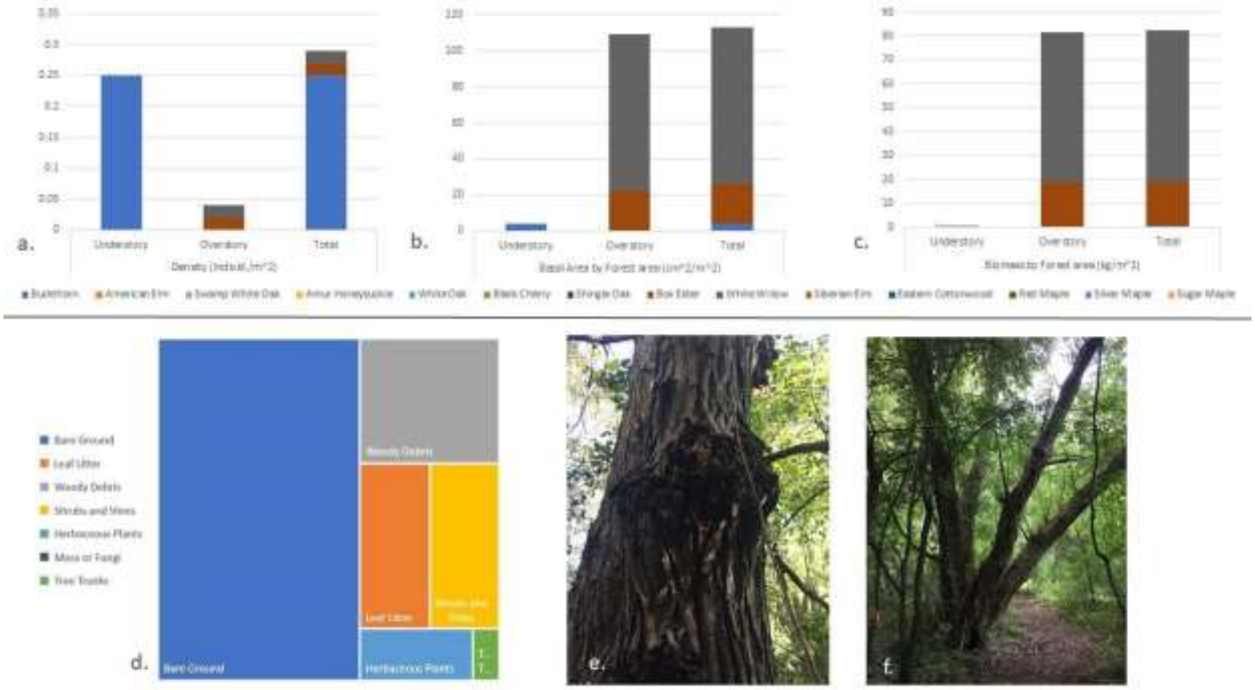

Figure 9. Upland Shrub Willow Overstory summary. (a) Number of individuals observed by species and presence in understory and overstory. (b) Density of observed individuals per square meter by species and presence in understory and overstory. (c) Square centimeter of Basal area to square meter of Forest Area ratio by species and presence in understory and overstory. (d) Percent cover of one square meter of sampled forest floor. (e) White Willow with canker. (f) White willow on KEEP path in spring.

3.3.4 Upland Shrub Elm Overstory

This stand owes its vegetation composition to being tilled and left fallow. It is characterized by a thick understory of Buckthorn and an overstory of Siberian Elm (*Ulmus pumila*), the densest stand in the KEEP (Figure 7, Figure 10). There are an estimated 0.31 individuals, 33.4 cm^2 of basal area, and 47.8 kg of aboveground biomass per square meter of Upland Shrub Elm Overstory (Table 5, Figure 7). The understory is far denser than overstory, (Figure 3.35a) but makes up only a fraction of total biomass (Figure 10c). These factors combine to produce an inhospitable environment for high plant diversity. It should be noted that while our field survey did not capture any herbaceous or woody groundcover, we did observe Garlic Mustard (*Alliaria petiolate*) and Dame's Rocket (*Hesperis matronalis*) in its edges, as well as a single patch of False Solomon's Seal (*Maianthemum racemosum*) further in. It is likely due to this last species that the Upland Shrub Elm Overstory stand scores 22.4 on the adjusted Floristic Quality Index, which is higher than its Willow Overstory neighbor (Table 5). The tree community scores a .505 on the Shannon Diversity Index, likely due to the relative even distribution of the two species present. (Table 5).

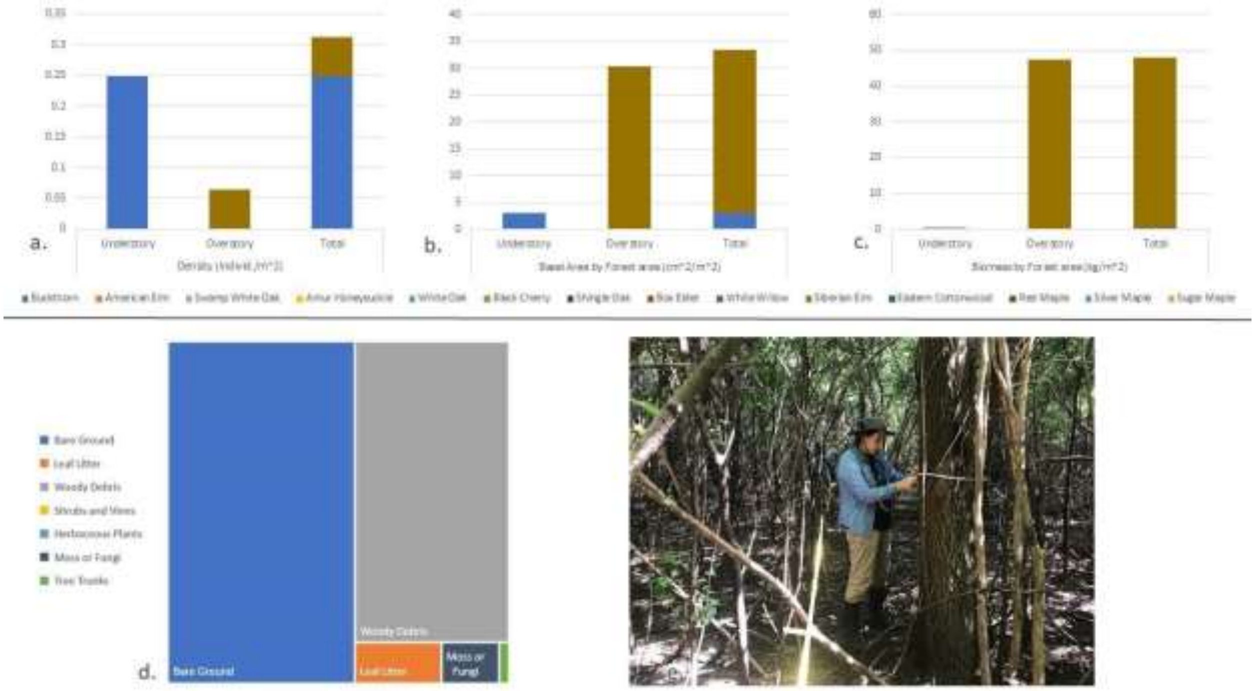

Figure 10. Upland Shrub Elm Overstory summary. (a) Number of individuals observed by species and presence in understory and overstory. (b) Density of observed individuals per square meter by species and presence in understory and overstory. (c) Square centimeter of Basal area to square meter of Forest Area ratio by species and presence in understory and overstory. (d) Percent cover of one square meter of sampled forest floor. (e) Katherine Ferran in foreground and Joy Yakie in background conducting vegetation survey in the Upland Shrub Elm Overstory stand.

3.3.5 Cottonwood Forest

We distinguished the area that borders the northwest edge of the South Pond and connects to the parking lot as its own stand characterized by large cottonwoods. We surveyed 12 trees, most were Eastern Cottonwood (*Populus deltoides*), followed by Box Elder and Buckthorn (Figure 11). Several things are notable: it holds the most above-ground biomass of any stand, (Table 5, Figure 7) has a relatively high Shannon Index value, yet has the lowest adjusted FQI score of any stand (Table 5). There are an estimated 0.18 individuals, 307.1 cm^2 of basal area, and 234.1 kg of above-ground biomass per square meter of Cottonwood Forest (Table 5, Figure 7). The forest floor is dominated by leaf litter and woody debris, which may be a factor in the absence of many herbaceous species (Figure 11d).

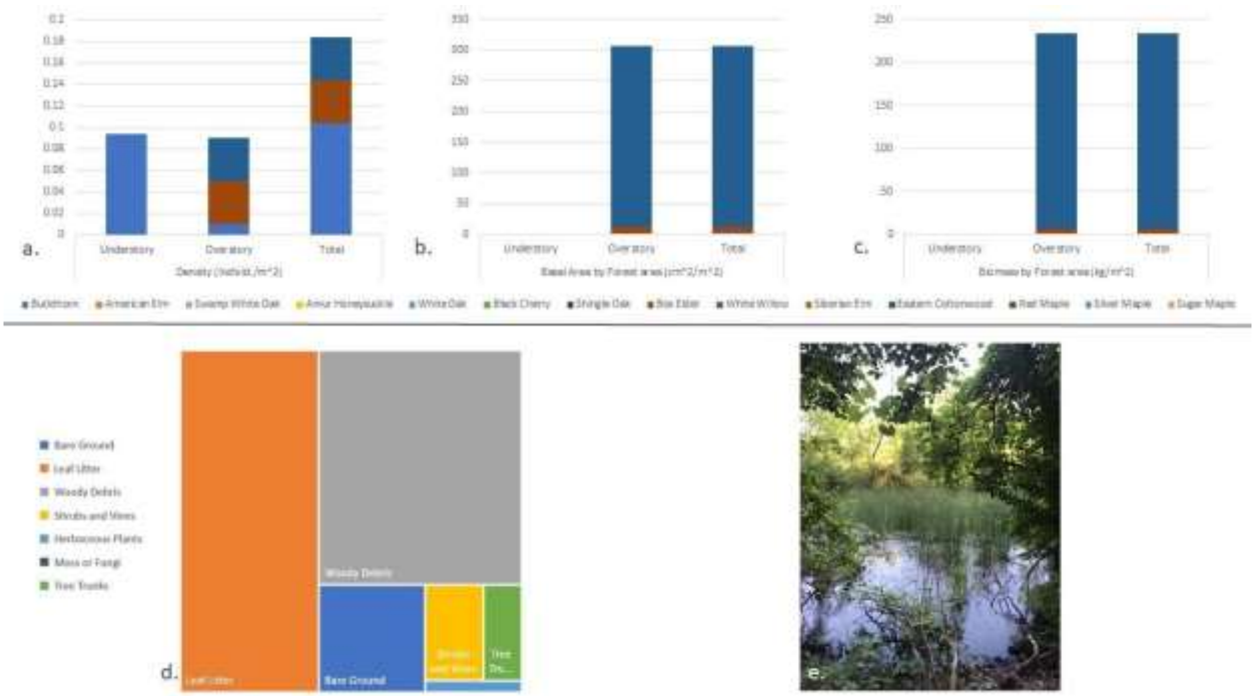

Figure 11. Cottonwood Forest summary. (a) Number of individuals observed by species and presence in understory and overstory. (b) Density of observed individuals per square meter by species and presence in understory and overstory. (c) Square centimeter of Basal area to square meter of Forest Area ratio by species and presence in understory and overstory. (d) Percent cover of one square meter of sampled forest floor. (e) Viewpoint of the South Pond from within the Cottonwood Forest.

3.2.6 Wet Forest

This large expanse of the KEEP becomes saturated during rainy seasons, which, when accompanied by the poor drainage of the sandy loam soil has since shaped the biotic community. We surveyed 31 trees, 15 of them being Buckthorns in the understory, the rest being an assemblage of Silver Maple (*Acer saccharinum*) and Red Maple (*Acer rubrum*), with one Swamp White Oak (*Quercus bicolor*) and one Sugar Maple (*Acer saccharum*) (Figure 12). Groundcover survey found a large percentage of moss, herbaceous plants, and shrubs and vines like Virginia creeper (*Parthenocissus quinquefolia*) and Riverbank Grape (*Vitus riparia*) (Figure 12d). Not captured by our survey were several Silky Dogwoods (*Cornus amomum*) and many herbaceous plants like Canada clearweed (*Pilea pumila*), sensitive fern (*Onoclea sensibilis*) and Bittersweet Nightshade (*Solanum dulcamara*).

There are an estimated 0.19 individuals, 34.3 cm^2 of basal area, and 23.3 kg of aboveground biomass per square meter of Wet Forest (Table 5, Figure 7). Buckthorn dominates the understory, with several unique species contributing to the total basal area and biomass of the stand (Figure 12a-c). The presence of maples, elms, and oaks lend themselves to a relatively high Shannon Diversity Index score of 0.7, and the wealth of unique herbaceous community members thriving in the mud scores this stand a 33.8 on the adjusted FQI, the second-highest of all the stands (Table 5). The groundcover diversity can owe itself to the constant availability of water and the relatively low density of the overstory, allowing for plenty of light and moisture.

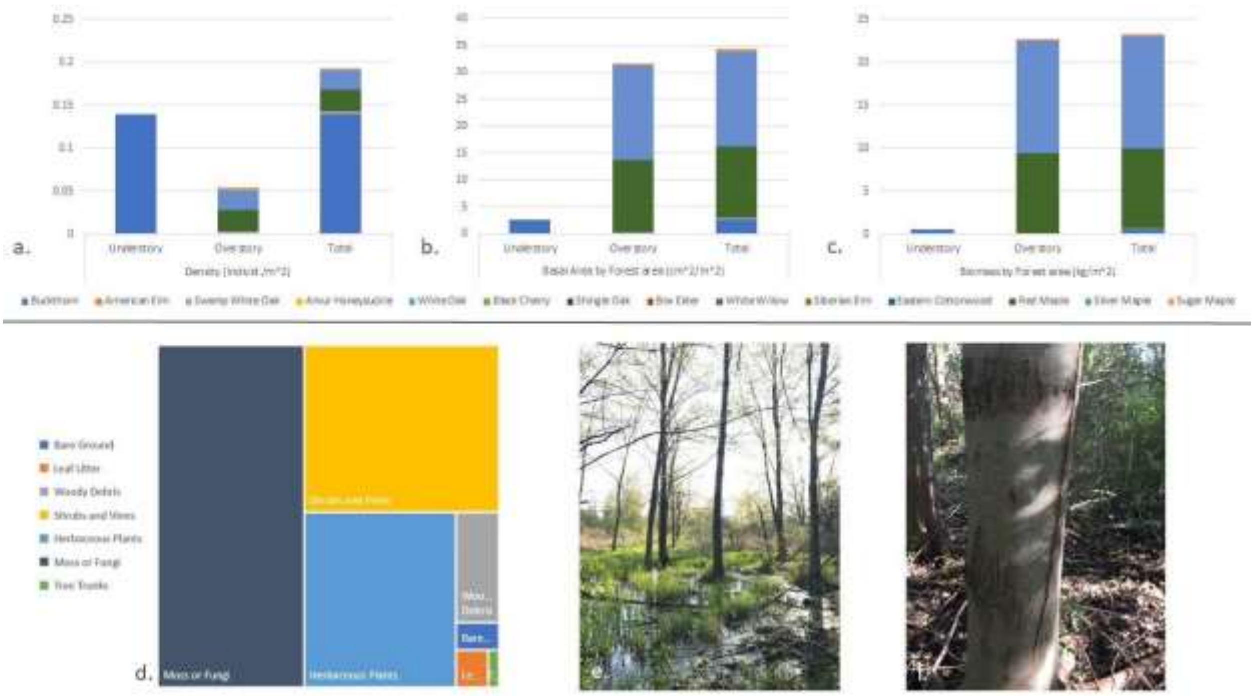

Figure 12. Wet Forest summary. (a) The number of individuals observed by species and presence in understory and overstory. (b) The density of observed individuals per square meter by species and presence in understory and overstory. (c) Square centimeter of Basal area to square meter of Forest Area ratio by species and presence in understory and overstory. (d) Percent cover of one square meter of the sampled forest floor. (e) Wet woods and Maples, leading to the wetlands. (f) Close-up of Red Maple bark in the Wet Forest.

3.3.7 Non-forested Wetland

This stand owes its vegetative composition to the formation of the South Pond to its north. The South Pond formed from parking lot runoff and does not have a defined southern border, meaning the runoff it receives seeps readily into this open wetland, which eventually drains into Honey Creek to the south. The Non-forested Wetland is characterized by a very low density of trees and a dominant presence of herbaceous plants and grasses (Figure 7, Figure 13). Groundcover is predominantly Reed Canary Grass (*Phalaris arundinacea*), with noted survey capture of species like Jewelweed (*Impatiens capensis*), Multiflora Rose (*Rosa multiflora*), and Bittersweet Nightshade. Not captured by the survey was Swamp Milkweed (*Asclepias incarnata*), Purple Loosestrife (*Lythrum salicaria*), Sandbar Willow (*Salix exigua),* and members of the *Asteraceae* family. The few trees present were Buckthorn, Box Elder, and Swamp White Oak. (Figure 13).

There are an estimated 0.03 individuals, 3.4 cm^2 of basal area, and 2 kg of aboveground biomass per square meter of Non-forested Wetland (Table 5, Figure 7). This is the least dense stand and the densest in terms of groundcover. While diverse in composition, the vegetation of the Non-forested Wetland scores a value of 23.1 on the adjusted Floristic Quality Index, which is lower than one might expect given the rare and unique members found within. This is likely due to the presence of notoriously noxious invasives like Purple Loosestrife and Reed Canary Grass. Insect diversity in this site was high, with sightings of Monarch Butterfly caterpillars and a ground nest of bees (Figure 13f). This area has the potential to house native and charismatic wildflower species that are likely stifled by invasive grasses.

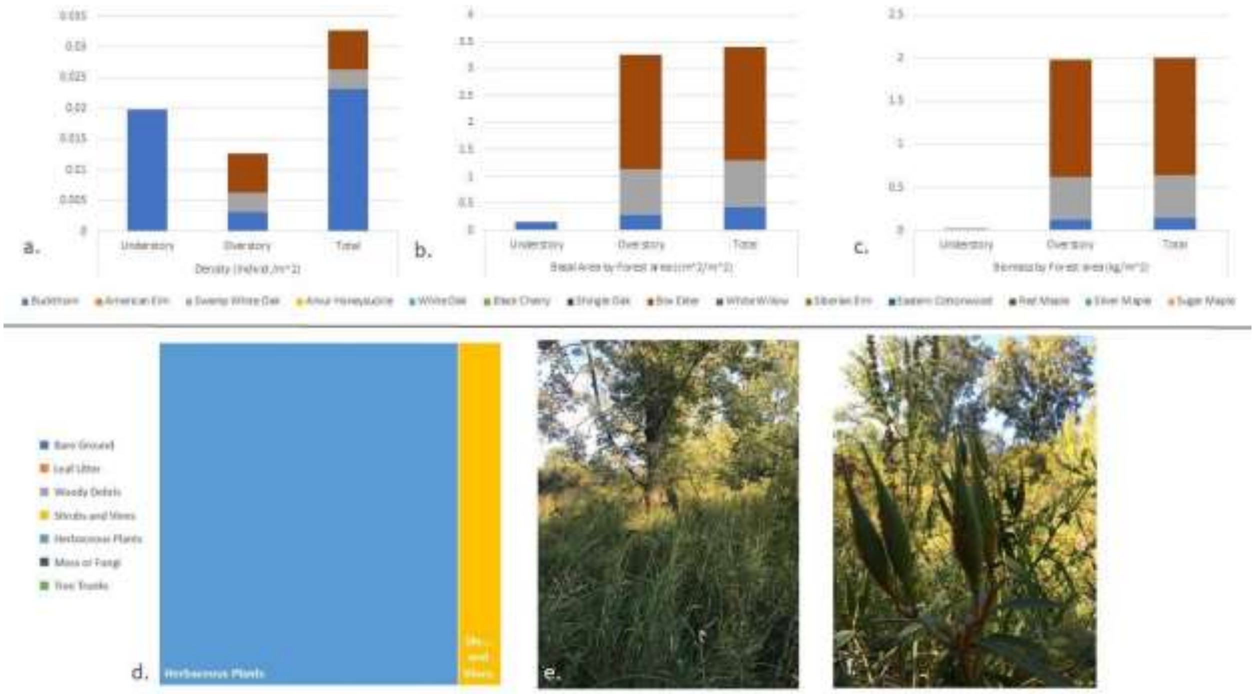

Figure 13. Non-forested Wetlands summary. (a) Number of individuals observed by species and presence in understory and overstory. (b) Density of observed individuals per square meter by species and presence in understory and overstory. (c) Square centimeter of Basal area to square meter of Forest Area ratio by species and presence in understory and overstory. (d) Percent cover of one square meter of sampled forest floor. (e) Joy Yakie and Sarah Brannon measuring the diameter of a Box Elder in the wetlands. (f) Orange aphids covering swamp milkweed seed pods in the wetlands.

3.3.8 Riparian Shrub

We characterized this stand as the forest bordering Honey Creek and the drainage ditch. Here, the overstory is practically nonexistent, and the vast majority of trees are Buckthorn (Figure 14). Not captured by the survey are Box Elder and a unique species of willow. There are an estimated 0.3 individuals, 7.4 cm^2 of basal area, and 2.8 kg of aboveground biomass per square meter of Riparian Shrub (Table 5, Figure 7). This tree community scores a zero on the Shannon Diversity Index, given only one tree species was surveyed. Like the Wet Forest, this stand has a vivacious herbaceous community not represented in the vegetation survey, which manifests in our results with a value of 39.8 on the adjusted Floristic Quality Index, the highest of any stand (Table 5). Herbaceous species observed in this area include Marsh Marigold (*Caltha palustris*), Skunk Cabbage (*Sympocarpus foetidus*), and Jack-in-the-Pulpit (*Arisaema triphyllum*). This stand represents a large portion of the KEEP that is low in tree diversity and is difficult to access and navigate but contains some exemplary and unique herbaceous members.

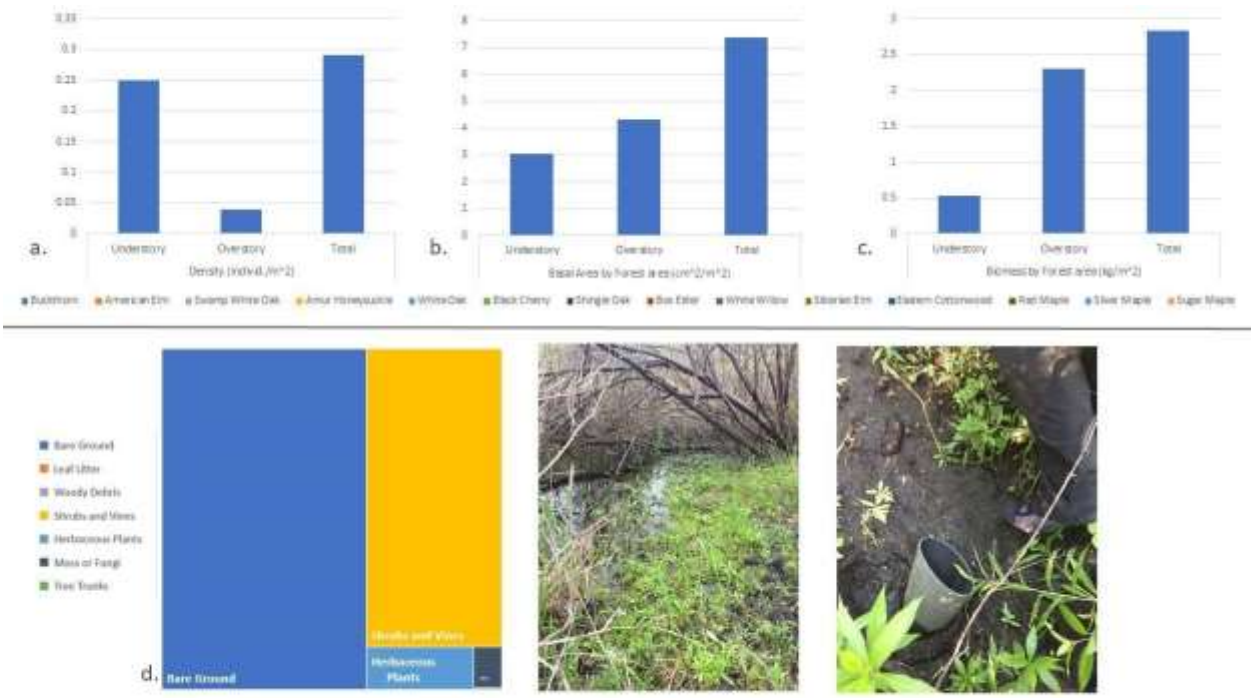

Figure 14. Riparian shrub summary. (a) Number of individuals observed by species and presence in understory and overstory. (b) Density of observed individuals per square meter by species and presence in understory and overstory. (c) Square centimeter of Basal area to square meter of Forest Area ratio by species and presence in understory and overstory. (d) Percent cover of one square meter of sampled forest floor. (e) The junction of the drainage ditch with Honey Creek at the southeast corner of the KEEP. (f) Sarah Brannon's boot getting stuck in the mud along Honey Creek.

3.3 Conclusion

Several conclusions can be drawn from this large database: 1) Vegetation stands dominated by Buckthorn are at risk of declining in quality as overstory members die out and are not replaced due to understory exclusion; 2) Some stands with a high non-native presence or a weak tree community are contributing more diversity than stands more native and healthy in composition; and 3) Despite a legacy of disturbance, plant communities show clear signs of productivity and ecological complexity. This property is characteristic of novel community assemblages borne from disturbance and succession, making it the perfect backdrop for visitation experiences that emphasize ecological lessons in resiliency and sustainability in urban green space.

Chapter 2 elaborated on the progression of disturbance and succession, and here coupled with our profile of the current plant community, we can better understand how these plant communities came to be. For example, that the property was dominated by wetlands prior to land use could imply the presence of native seed banks that facilitated the rather rapid development of the Non-forested Wetland and the Wet Forest, two areas that saw little direct disturbance compared the Upland stands, but have changed due to hydrologic modifications. Additionally, it seems that the Oak Forest is remnant Oak-Hickory forest, a classic native Michigan community that could be restored. We develop further on these conclusions in Chapter 8, where we recommend management practices specific that could build upon the current vegetative community's diversity and health.

Chapter 4: Wildlife Survey and Findings

4.1 Background

The situation of the preserve at an urban-rural interface provides an ecosystem supporting the presence of diverse species. With an annual high temperature of approximately 15 C and a low of 4.4 C, with the highest temperatures occurring July to August, the forested area provides a habitat heterogeneity encouraging biodiversity of amphibians, birds, and mammals. Within the land, we classified seven habitats throughout the property to contextualize species distribution and use of space in the urban-rural forest. The seven classified habitats were: oak forest, riparian shrub, wet forest, non-forested wetland, cottonwood forest, upland shrub elm overstory, and upland shrub willow overstory. All of these classified habitats were surveyed for wildlife except the last, upland shrub will overstory, due to its small size.

Figure 15. A map displaying the seven habitats within the KEEP. The map was created by the UM SEAS KEEP Master's Project Team. The vegetation covers were manually classified from aerial imagery and vegetation data collected by the team (SEMCOG 2015). The map also displays an aerial background image and property boundary (SEMCOG 2015; Washtenaw County GIS Program 2019). The map is projected in State Plane Michigan South (m) and uses the North American Datum of 1983.

4.2 Methods

Our approach towards inventorying the frogs, birds, and mammals present in the KEEP was done mostly through on-site field visits, as well as audio and on-site camera recordings. Here, we present an overview of frogs, birds, and mammals found in the preserve from late spring to the fall of 2019. Our findings also indicate locations with the highest frequency of wildlife activity.

Frog observations were carried out from April through June. The observations were done mostly in the evenings after 6:30 pm. Audio recordings of the frog calls on each visit were done in mostly three observation sites: a trail along the south side of the north pond, the east side of the south pond, and the intersection of honey creek and the county drain. We also made recordings at the south of the non-forested wetland and at the edge of the parking lot area that meets the preserve. Frog identifications were based on recordings of frog calls in comparison to recordings from Michigan's Department of Natural Resources (DNR). Bird surveys were done through field visits and photo capture from cameras placed throughout the KEEP. To confirm the species identity, the Cornell Lab of Ornithology, a noted conservation non-profit on ornithology, was consulted.

Other wildlife recordings were done via six trail cameras placed at strategic points across the classified habitats. The cameras were moved every two weeks for a two months period beginning mid-May to early August, thereby covering most habitats in the property. The placement of cameras was based on a combination of randomized points generated in ArcGIS and *in situ* observation of wildlife signs, like tracks, scat, and sightings. GPS coordinates of these selected points were recorded using the Survey123 ArcGIS app and smartphone receiver to ensure full coverage in the camera placement around the property. The resulting survey points covered six of the seven established habitats throughout the property.

Table 6. GPS location of camera placement across the different habitats.

<table>
<tr><th rowspan="2">Habitats</th><th colspan="4">Coordinates</th></tr>
<tr><th>1st Placement</th><th>2nd Placement</th><th>3rd Placement</th><th>4th Placement</th></tr>
<tr><td>Upland Shrub Elm Overstory</td><td>-83.855249, 42.293483</td><td>-83.854771, 42.29344</td><td>-83.855029, 42.292992</td><td>-83.854569, 42.293163</td></tr>
<tr><td rowspan="2">Oak Forest</td><td rowspan="2">-83.854688, 42.293587</td><td rowspan="2">-83.853613, 42.293566</td><td rowspan="2">X</td><td>-83.85412, 42.293711</td></tr>
<tr><td>-83.854543, 42.293704</td></tr>
<tr><td rowspan="3">Riparian Shrub</td><td>-83.853348, 42.293395</td><td>-83.854893, 42.29236</td><td rowspan="3">-83.853632, 42.292482</td><td rowspan="3">X</td></tr>
<tr><td>-83.853615, 42.292679</td><td>-83.854331, 42.29239</td></tr>
<tr><td>-83.854176, 42.292458</td><td>-83.853994, 42.292391</td></tr>
<tr><td rowspan="3">Wet Forest</td><td rowspan="3">-83.854188, 42.292763</td><td rowspan="3">X</td><td>-83.853581, 42.293231</td><td rowspan="3">-83.854288, 42.293216</td></tr>
<tr><td>-83.853838, 42.292987</td></tr>
<tr><td>-83.853917, 42.293402</td></tr>
<tr><td>Cottonwood Forest</td><td>X</td><td>-83.854883, 42.29276</td><td>X</td><td>X</td></tr>
<tr><td rowspan="2">Non-forested Wetland</td><td rowspan="2">X</td><td rowspan="2">X</td><td>-83.857321, 42.291652</td><td>-83.854423, 42.292638</td></tr>
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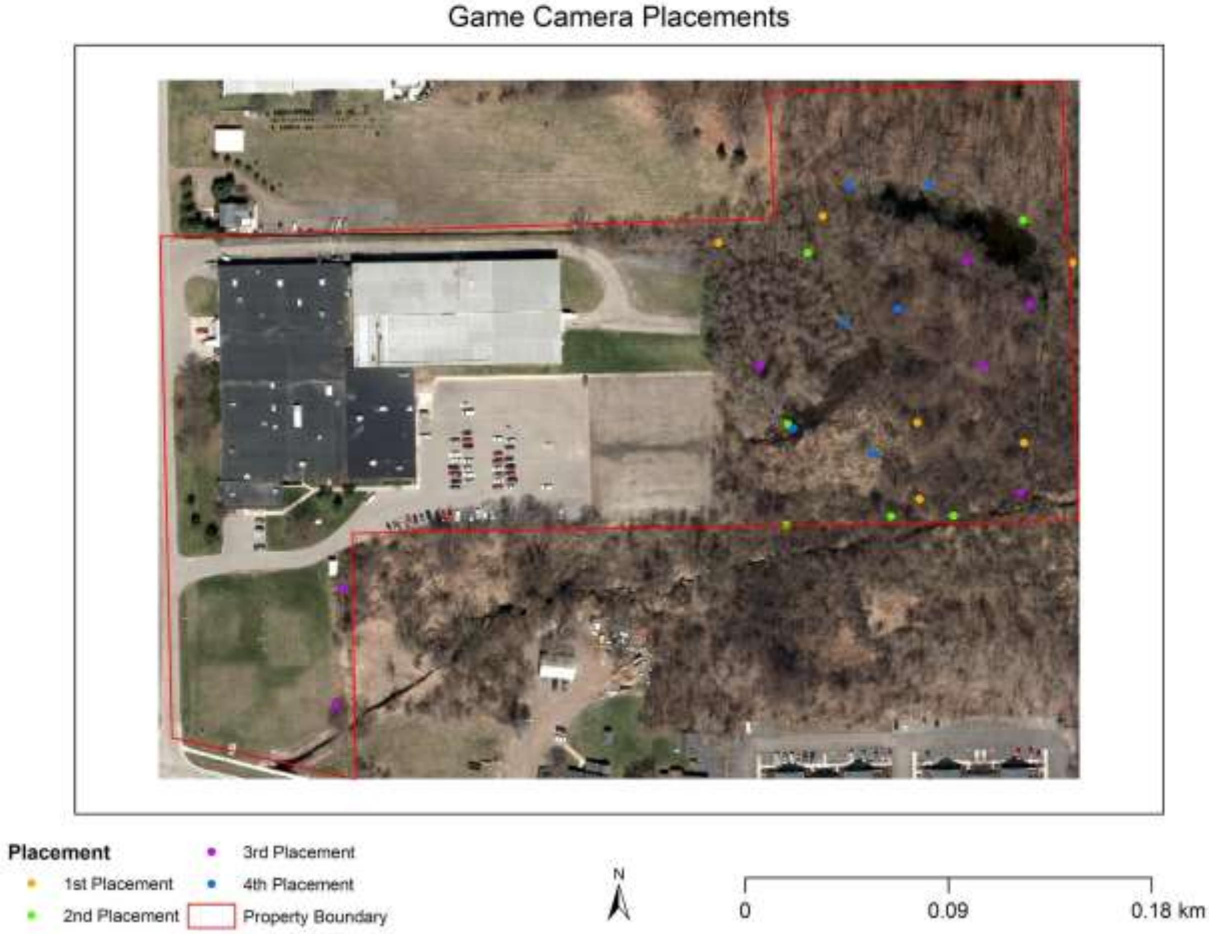

Figure 16. A map showing camera placements on the preserve. The map was created by the UM SEAS KEEP Master's Project Team. Game camera placement points were collected using Survey123 and are displayed with the KEEP property boundary and a background aerial image (Washtenaw County GIS Program 2019; SEMCOG 2015). The map is projected in State Plane Michigan South (m) and uses the North American Datum of 1983.

4.3 Results and Discussion

The preserve is inhabited by a wide range of wildlife species. Diverse species of frogs, birds, and mammals found used the preserve as a passage route to nearby boundaries or as an annual home.

4.3.1 Mammals

Wildlife populations found in the preserve come from different families. While many were observed in the day during on-site visits, a high number of observations were captured on camera during the night and early mornings.

Table 7. Mammals found in the preserve from on-site visits and camera captures.

Species Found	Scientific Name	Species Found	Scientific Name
Coyote	*Canis latrans*	Skunk	*Mephitis mephitis*
White-tailed deer	*Odocoileus virginiana*	Eastern fox squirrel	*Sciurus carolinensis*
Eastern chipmunk	*Tamias striatus*	Woodchuck	*Marmota manax*
Rabbit	*Oryctolagus cuniculus*	Black Squirrel	*Sciurus meridionalis*
Virginia opossum	*Didelphis virginiana*	Red squirrel	*Sciurus vulgaris*
Raccoon	*Procyon lotor*	Eastern Grey squirrel	*Sciurus carolinensis*
Wood mouse	*Apodemus sylvaticus*		

Figure 17. Wildlife captured around the KEEP habitats from 05/20/2019 - 08/01/2019

In addition to on-site visits, recorded GPS coordinates also gave precise locations of where the wildlife images were taken. These images show that Upland Shrub Elm Overstory and Oak Forest have the highest wildlife activity based on the frequency of captured wildlife photos. The frequency of wildlife activity and their specific location is detailed in Table 8.

Table 8. Wildlife activity and precise location in the different habitats.

Habitat	Frequency of Wildlife Sightings	Coordinates with the highest activity (total number of individuals; camera name)	Coordinates with wildlife biodiversity (number of different species; camera name)
Upland Shrub Elm Overstory	219	-83.854771, 42.29344 (71; B4) -83.854569, 42.293163 (69; D4)	-83.854771, 42.29344 (20; B4)
Oak Forest	198	-83.85412, 42.293711 (82; D5) -83.854543, 42.293704 (116; D6)	-83.854543, 42.293704 (20; D6)
Riparian Shrub	126	-83.853348, 42.293395 (33; A3) -83.853632, 42.292482 (47; C1)	-83.853632, 42.292482 (18; C1)
Wet Forest	60	-83.853917, 42.293402 (36; C6)	-83.853917, 42.293402 (9; C6)
Cottonwood Forest	23	-83.854883, 42.29276 (25; B3)	-83.854883, 42.29276(4; B3)
Non-forested Wetland	21	-83.857321, 42.291652 (8; C3A) -83.854853, 42.292743 (7; D2)	-83.854853, 42.292743 (3; D2)

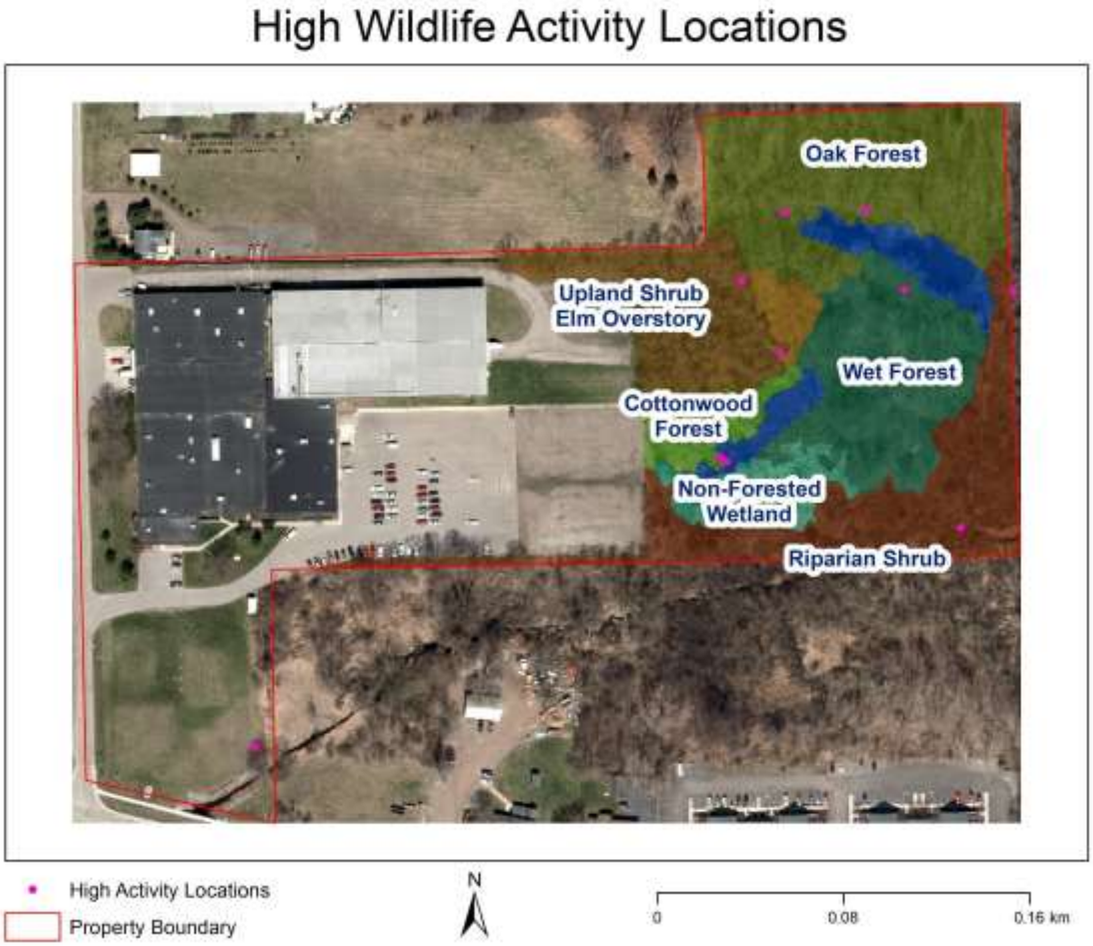

Figure 18. A map showing the locations of game camera placements with high wildlife activity on the preserve. The map was created by the UM SEAS KEEP Master's Project Team. Game camera placement points were collected using Survey123 and are displayed with the KEEP property boundary and a background aerial image (Washtenaw County GIS Program 2019; SEMCOG 2015). The vegetation covers were manually classified from aerial imagery and vegetation data collected by the team (SEMCOG 2015). All points are subject to a possible location error of up to 10m due to tree cover and poor phone receiver accuracy. One point we believe to have been affected by this error is displayed north of the non-forested wetland. This point was collected in the non-forested wetland along the pond. The map is projected in State Plane Michigan (m) and uses the North American Datum of 1983.

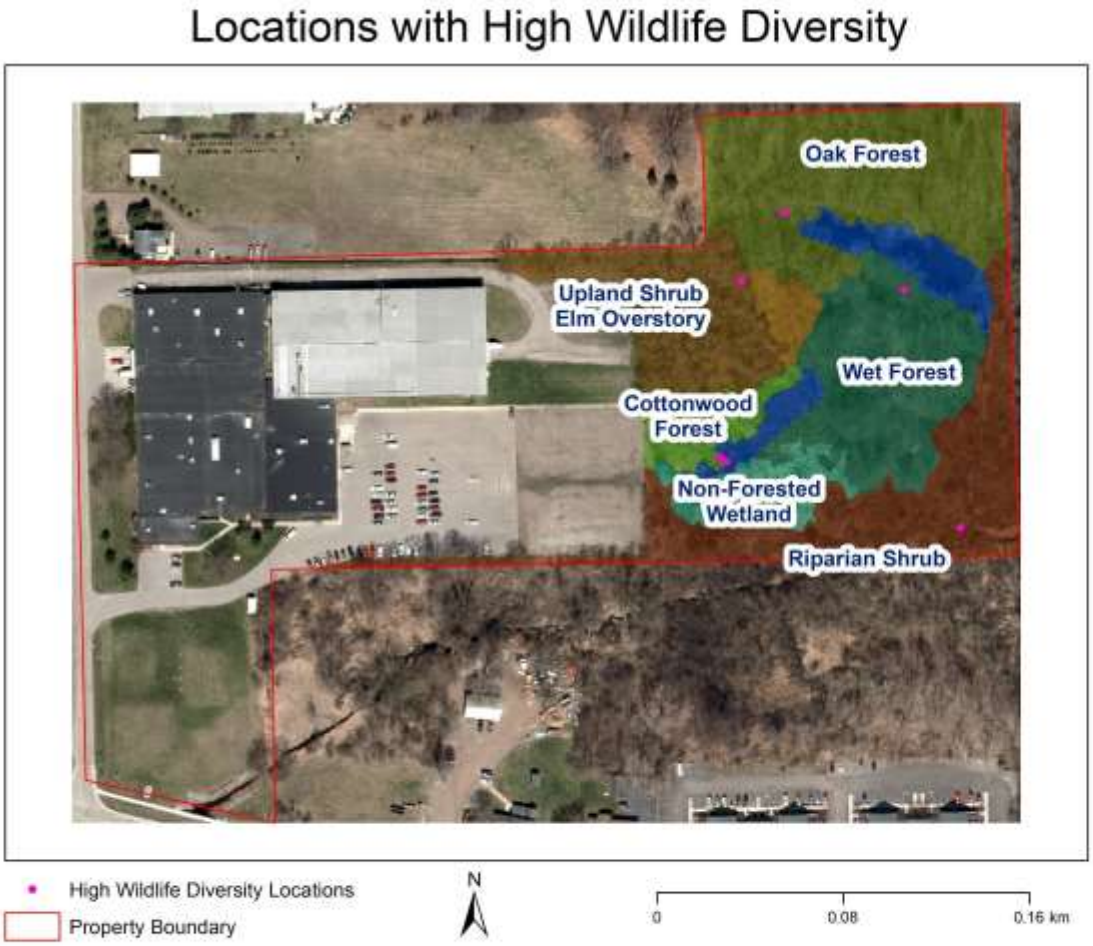

Figure 19. A map showing the locations of game camera placements with high wildlife diversity on the preserve. The map was created by the UM SEAS KEEP Master's Project Team. Game camera placement points were collected using Survey123 and are displayed with the KEEP property boundary and a background aerial image (Washtenaw County GIS Program 2019; SEMCOG 2015). The vegetation covers were manually classified from aerial imagery and vegetation data collected by the team (SEMCOG 2015). All points are subject to a possible location error of up to 10m due to tree cover and poor phone receiver accuracy. One point we believe to have been affected by this error is displayed north of the non-forested wetland. This point was collected in the non-forested wetland along the pond. The map is projected in State Plane Michigan (m) and uses the North American Datum of 1983.

4.3.2 Birds

Diverse species of birds were found distributed across the property, which is expected given the range of habitats. Either perched or foraging on the ground, over 20 species were found on the preserve. Most of the birds observed were located in the Upland Shrub Overstory: specific location: -83.854771, 42.29344.

Table 9: Species of birds present in the preserve.

Species Found	**Scientific Name**	**Species Found**	**Scientific Name**
Northern Flicker	*Colaptes auratus*	Hairy Woodpecker	*Dryobates villosus*
European Starling	*Sturnus vulgaris*	Green Heron	*Butorides virescens*
Downy Woodpecker	*Dryobates pubescens*	Wood Thrush	*Hylocichla mustelina*
American Robin	*Turdus migratorius*	Brown-headed Cowbird	*Molothrus ater*
Gray Catbird	*Dumetella carolinensis*	Blue Jay	*Cyanocitta cristata*
Northern Cardinal	*Cardinalis cardinalis*	Wild Turkey	*Meleagris gallapavo*
Wilson's Snipe	*Gallinago delicata*	American Dipper	*Cinclus mexicanus*
Song Sparrow	*Melospiza melodia*	Field Sparrow	*Spizella pusilla*
Red-winged Blackbird	*Agelaius phoeniceus*	Rose-Breasted Grosbeak	*Pheucticus ludovicianus*
Common Grackle	*Quiscalus quiscula*	House Finch	*Haemorhous mexicanus*
		Mallard	*Anas platyrhynchos*

Figure 20: Birds captured around the KEEP habitats from 05/20/2019 - 08/01/2019

4.3.3 Amphibians

From our frog recordings carried out from April 17 through the end of July, we confirmed the presence of three species of frogs: the spring peeper, western chorus frog, and green frog.

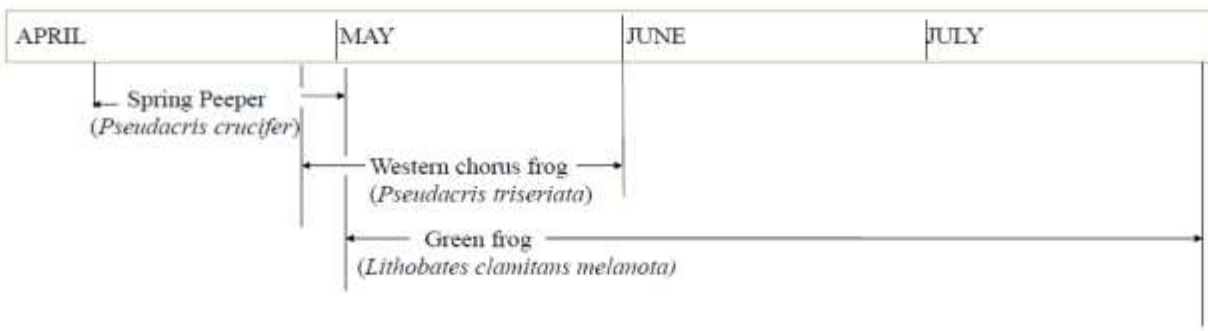

Figure 21: Frogs found in the KEEP and the duration of their presence based on calls

4.4 Conclusion

Birds, wildlife, and amphibian presence in the KEEP show a wildlife-supporting ecosystem that characterizes the preserve in the midst of an urban environment. This is due to the climate condition and the neighboring environment around the preserve.

That being said, most species observed could be described as common and metropolitan. This is not of much consequence when it comes to ecological functioning, but the site's appeal to visitors may be bettered by the confirmed presence of less common species, or iconic Michigan species like Kirtland warblers, Eastern Box Turtles, and Massasauga rattlesnakes. Providing habitat for a greater diversity of wildlife can be achieved through targeted management practices, which we will elaborate upon in Chapter 8.

Additionally, there are some conservation implications for the results of our wildlife survey. Some observed species may serve as good ecological citizens: the possum's tick-dependent diet helps control the spread of Lyme disease (Keesing et al., 2010), squirrels and chipmunks increase the likelihood of oak acorn survival (Raghavendra et al., 2007), and amphibians can help control mosquito populations (Barnett, 1977). However, some are associated with negative ecological consequences, like the overpopulation of white-tail deer causing overbrowsing (Goetsch et al., 2011), or declines in songbird populations due to the nest parasitism of the Brown-headed Cowbird (Farrell et al, 2011). And finally, there is less visitation by species dependent on water features like those found on the property than there could be. Although we found wildlife such as ducks and woodchucks, these sightings were fleeting and rare. The apparent unattractive nature of the two ponds is likely due to the absence of aquatic food sources for these animals as a result of poor water quality. The following two chapters focus on these water features in greater detail.

Chapter 5: Water Quality Analysis

5.1 Background

The heterogeneity of the KEEP site is evident not only in the diverse habitat, vegetation, and wildlife present but also in water bodies in and around the property. Two ponds (North Pond and South Pond), a wetland, and a drainage channel that empties into the Honey Creek all are unique aquatic ecosystems of the preserve. The hydrology of the water bodies is elaborated in Chapter 6 (Stormwater Modelling). Water quality typically refers to the physicochemical characteristics, such as dissolved oxygen, pH, hardness, temperature – and has a major role in determining which aquatic biota will thrive there, ranging from warm to cold water species, and pollution-tolerant to pollution-sensitive species.

In addition to physicochemical characteristics, there are other major determinants of aquatic biodiversity. One such determinant of species presence is water flow, such as fast flow in a stream, slow flow in a large river, or no flow in a pond or wetland. Some species require flowing water that is highly aerated, such as mayflies, stoneflies, and trout. Others prefer quiescent waters, such as midges, oligochaetes, and carp. A third major determinant of aquatic biodiversity includes other habitat characteristics, such as sediments and substrates, aquatic vegetation, refuges and habitat cover for predator protection, vegetative riparian (bank) zones, leaf litter inputs, shading vs. sunlight, water turbidity, and pool and riffle zones versus. channelized waterways. Finally, a fourth commonly used determinant of water quality is benthic macroinvertebrate diversity. The types of species found in a waterway are often indicative of whether there are high-quality waters, e.g., stoneflies, or poor water quality, e.g., midges and oligochaetes.

5.2 Methods (Field and Lab)

This section covers field and lab testing of the water bodies on the preserve. The field testing included surface water specific conductance (SPC), dissolved oxygen (DO), oxidation-reduction potential (ORP), pH, temperature, and metals in the North and South Pond, Honey Creek, and in the county drain. In addition, qualitative observations of water flow and habitat were conducted.

The physicochemical parameters of SPC, DO, ORP, pH, and temperature were measured using a calibrated YSI multi-probe instrument. Metals analyses were conducted at UM in Dr. Burton's laboratory using an Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) analysis. Blanks, controls, and duplicates were measured, following standard quality assurance/quality control guidelines, to ensure the data quality of the metals analyses. Water samples were preserved with acid upon collection and refrigerated until analyses. Sediment samples were extracted using the water elutriate procedure which extracts water-soluble fractions from the sediment particles (Burton & Pitt, 2002).

Grab water samples were sampled to measure base flow conditions and high flow waters were also sampled to assess water quality that is dominated by diffuse runoff, and is often contaminated in urban-rural areas. High flow samples were captured in Honey Creek by mounting stormwater sampling bottles to the stream depth gauge mounted to a tree adjacent to the stream. These bottles captured water once the stream depth rose approximately one foot during a runoff event. The bottles were retrieved after the storm event and water samples preserved with acid.

Benthic macroinvertebrates were collected by collecting sediments from Honey Creek and the two ponds. Sediment samples containing the benthic invertebrates were preserved with alcohol until they were enumerated. Organisms were enumerated using standard taxonomic keys to the family level.

5.3 Results and Discussion

Water and benthic samples were collected on the following dates: June 15th, July 16th, August 1st, and October 10th, 2019. Water quality results are presented in Table 10, and metal concentrations (low and high flows) in Tables 11-14. Benthic macroinvertebrates are shown in Table 15.

The findings were not unexpected for waterways in urban-rural landscapes. The term “Urban Syndrome” has been used for decades to describe stream water quality in urban land uses as being uniformly degraded. Urban runoff is typically contaminated with high levels of some metals, such as copper and zinc (from brake pads and galvanized metals) (Burton & Pitt, 2002). Polycyclic aromatic hydrocarbons (PAHs) are also common synthetic organic chemicals that leach from asphalt, driveway sealants, oil and greases from vehicles, and combustion of gasoline and diesel. These are quite toxic to high-quality aquatic life, particularly in the presence of sunlight. Nutrients and pesticides are also common from land runoff, as are high levels of turbidity from soil erosion. A high percentage of impervious areas (rooftops, roadways, parking lots) prevent runoff from seeping into the ground and are rapidly transported at higher than normal volumes into neighboring streams. This not only introduces the contaminants noted above but results in flashy flows that have high power and erode stream banks and wash away fish and benthic habitat (Burton & Pitt, 2002). So, it is common to find pollution tolerant aquatic organisms in urban-rural waterways with low biodiversity.

The DO in the ponds and county drain was very low during the daytime hours. During daylight, photosynthesis occurs and aquatic algae and plants produce oxygen, thus, this is the period of the day when DO should be at its highest level. It is likely that DO in these systems drops to zero each night, thus preventing any benthic invertebrates or fish, even pollution tolerant species, from living. This is the case in the KEEP, but, in addition, the low water quality for the ponds is being driven by a lack of runoff. The lack of flow in the ponds and water renewal, combined with a huge input of natural organic matter from leaf litter and decaying aquatic macrophytes (duckweed and algae), ensures that DO levels will be low to nonexistent, thus preventing desirable aquatic life from occurring. In addition, Honey Creek primarily flows through urban-rural disturbed areas and therefore receives a high loading of contaminants from runoff. Though it is flowing and not choked by organic matter, it is of poor quality.

Table 10. Results from on-site water sampling on 06/15/2019 during low flow conditions.

Parameters	Sampling Site			
	North Pond	South Pond	Honey Creek	County Drain
Temperature (0C)	16.6	16.6	16.2	15.2
Dissolved oxygen	2.23	2.9	4.5	1.6
pH	7.55	7.43	7.54	7.55
Specific conductance (microsenes)	700	754	618	812
Oxidative retention potential	-225	754	31.9	- 80.2

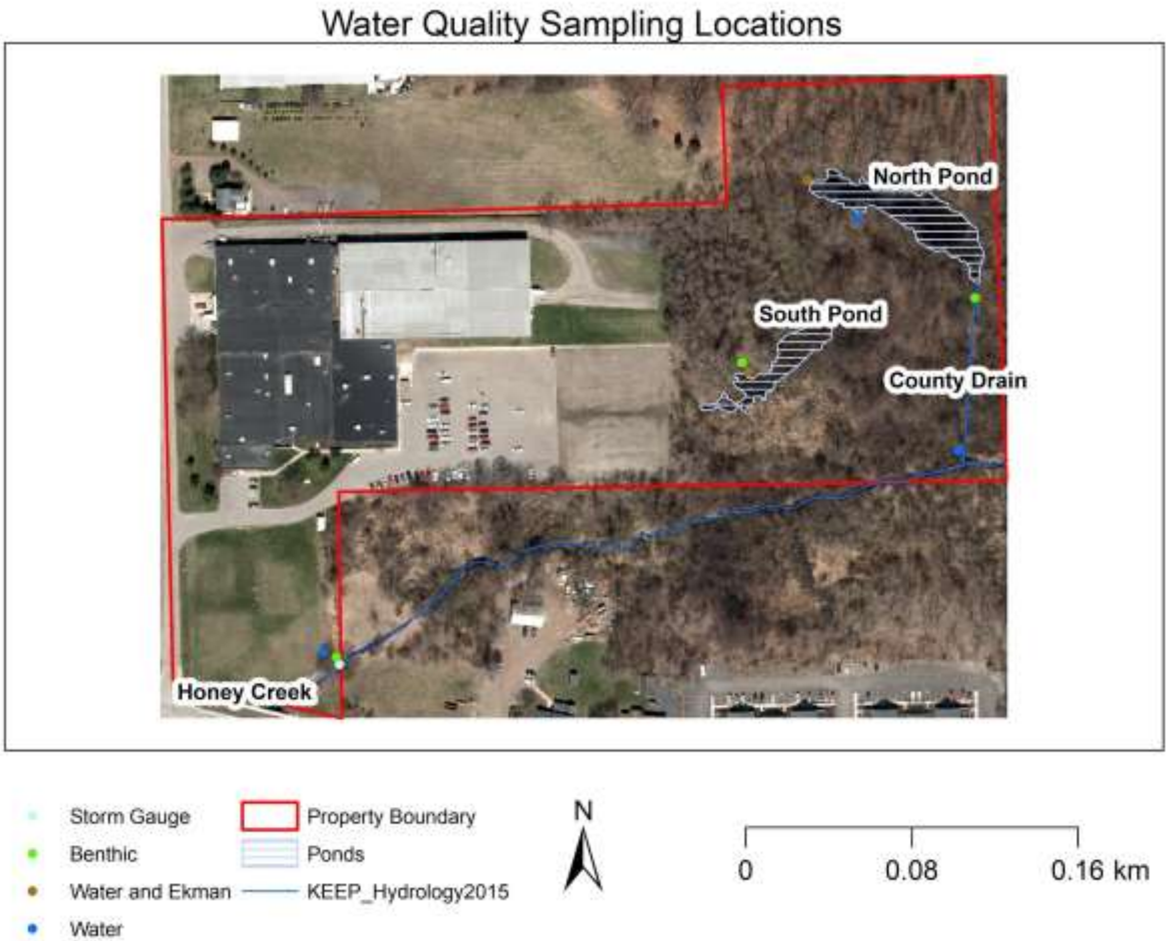

Figure 22. Map contextualizing field water quality testing results. The map was created by the UM SEAS KEEP Master's Project Team. Water sample points were collected using Survey123 and are with an aerial image and property boundary (SEMCOG 2015; Washtenaw County GIS Program 2019). The map is projected in State Plane Michigan South (m) using the North American Datum 1983.

Metals in water and sediment were analyzed from one grab sample of North and South Ponds and Honey Creek. Water samples were also collected at low flow and some higher flows from the county drain, the parking lot, and Honey Creek. The metals measured included chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni) and zinc (Zn). Of these metals, Cu and Zn are commonly associated with urban runoff. Zn contamination exceeded acute toxicity thresholds, meaning aquatic organisms would die with short exposures. Copper levels are above chronic toxicity levels at either low and high flows for the water bodies tested except for the county drain. These results confirm the parking lot and Honey Creek are contaminated primarily for vehicle-related Cu and Zn. This suggests PAHs should also be elevated. The South Pond receives some parking lot runoff and has slightly elevated Cu levels. The North Pond contained similar Cu levels in some samples, despite receiving no parking lot runoff, hence, indicating that infiltration or other water routes that drain into the North Pond may also contain vehicle-related contaminants. During one high-flow event, the County drainage ditch did see acutely toxic Zn levels while North Creek did not, implying other sources of runoff accumulating in this ditch (Tables 11 and 13, Figure 22).

Table 11. North Pond Water analysis: Water and muck metal analysis. Results include filtered and particulate average. Metal concentrations in Mg/L. Yellow cells indicate values surpassing chronic toxicity levels. Red cells indicate values surpassing acute toxicity levels.

Sample Date	Sample Description	Water Level Description	Analysis Description	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Zn**
6/15/2019	Water Sample Location 1	Low Flow	Filtered	0.0115	0.0085	0.484	0.1375	0.005	0.023
6/15/2019	Water Sample Location 1	Low Flow	Particulate	0.011	0.008	0.4895	0.134	0.006	0.02
6/15/2019	Water Sample Location 2	Low Flow	Filtered	0.011	0.0095	0.8105	0.1515	0.0055	0.0985
6/15/2019	Water Sample Location 2	Low Flow	Particulate	0.0115	0.009	0.805	0.148	0.006	0.0985
6/15/2019	Muck Sample	Low Flow	Filtered	0.0115	0.009	0.2475	0.6965	0.0045	0.0335
6/15/2019	Muck Sample	Low Flow	Particulate	0.011	0.009	0.2255	0.014	0.0045	0.0075
7/16/2019	Water Sample Location 1	High Flow	Filtered	0.0115	0.008	0.5115	0.3315	0.006	0.044
7/16/2019	Water Sample Location 1	High Flow	Particulate	0.011	0.0085	0.4355	0.3345	0.006	0.0495

Table 12. South Pond Water analysis:Water and muck metal analysis. Results include filtered and particulate average. Yellow cells indicate values surpassing chronic toxicity levels. Red cells indicate values surpassing acute toxicity levels

Sample Date	Sample Description	Water Level Description	Analysis Description	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Zn**
6/15/2019	Muck Sample	Low Flow	Filtered	0.011	0.008	0.2265	0.0425	0.0055	0.0445
6/15/2019	Muck Sample	Low Flow	Particulate	0.011	0.008	0.222	0.014	0.0055	0.0195
7/16/2019	Water Sample Location 1	High Flow	Filtered	0.011	0.0075	1.933	0.1115	0.007	0.1035
7/16/2019	Water Sample Location 1	High Flow	Particulate	0.011	0.007	1.917	0.1095	0.008	0.075
7/16/2019	Water Sample Location 2 (Parking Lot Runoff)	High Flow	Filtered	0.011	0.009	0.226	0.015	0.009	0.113
7/16/2019	Water Sample Location 2 (Parking Lot Runoff)	High Flow	Particulate	0.011	0.009	0.231	0.015	0.0085	0.1125

Table 13. County Drain samples analysis: Water and muck metal analysis. Results include filtered and particulate average. Yellow cells indicate values surpassing chronic toxicity levels. Red cells indicate values surpassing acute toxicity levels.

Sample Date	Sample Description	Water Level Description	Analysis Description	Cr	Cu	Fe	Mn	Ni	Zn
6/15/2019	Water Sample	Low Flow	Filtered	0.011	0.008	1.9255	0.1785	0.005	0.0665
6/15/2019	Water Sample	Low Flow	Particulate	0.011	0.008	1.958	0.1755	0.005	0.0705
7/16/2019	Water Sample	High Flow	Filtered	0.011	0.0075	1.9385	0.2265	0.006	0.1415
7/16/2019	Water Sample	High Flow	Particulate	0.011	0.0075	1.971	0.2245	0.006	0.0665

Table 14. Honey Creek Water analysis: Water for Honey Creek Pond. Results include filtered and particulate average. Yellow cells indicate values surpassing chronic toxicity levels. Red cells indicate values surpassing acute toxicity levels.

Sample Date	Sample Description	Water Level Description	Analysis Description	Cr	Cu	Fe	Mn	Ni	Zn
6/15/2019	Water Sample	Low Flow	Filtered	0.011	0.0085	0.8135	0.0875	0.006	0.026
6/15/2019	Water Sample	Low Flow	Particulate	0.011	0.0085	0.8475	0.0875	0.007	0.1505
7/16/2019	Water Sample	High Flow	Filtered	0.0125	0.0095	0.23	0.018	0.007	0.451
7/16/2019	Water Sample	High Flow	Particulate	0.012	0.011	0.25	0.022	0.007	0.1965
7/16/2019	Stream Gauge Sample	High Flow	Filtered	0.011	0.011	0.226	0.021	0.007	0.07
7/16/2019	Stream Gauge Sample	High Flow	Particulate	0.011	0.011	0.239	0.022	0.0075	0.0755
8/1/2019	Stream Gauge Sample	High Flow	Filtered	0.0115	0.0095	0.2485	0.0225	0.0075	0.152
8/1/2019	Stream Gauge Sample	High Flow	Particulate	0.012	0.01	0.3025	0.024	0.008	0.1585

5.3.1 Lab Analysis: Macroinvertebrate

Benthic mLab analysis of macroinvertebrates showed only pollution-tolerant species, as expected. This indicates that most of the species that exist in North Pond, South Pond, and Honey Creek are pollutant tolerant. Gastropods, a highly tolerant class of species, were obvious in North Pond, followed by South Pond. Snails are capable of surviving in low to no oxygen environments since they move to the surface. Their presence suggests poor water quality and contamination in both ponds. (See the site history in Chapter 1). Crayfish and leeches observed in Honey Creek are also pollution-tolerant and can survive at low DO conditions.

Table 15. Macroinvertebrates from on-site sampling.

Macroinvertebrates found	Site sampled and species abundance

Common name	Species Order	North Pond (no. of individuals)	South Pond (no. of individuals)	Honey Creek (no. of individuals)
Crayfish	Gastropoda	0	0	1
Leech	Annelida	0	0	3
Gilled snail	Gastropoda	4	0	1
Orb snail	Gastropoda	5	1	0
Pill	Gastropoda	2	0	1
Pouch snail	Gastropoda	6	2	2

Habitat was generally of poor quality in each of the aquatic systems, with South Pond and Honey Creek having fair quality. North Pond is choked with decaying organic matter (leaves and aquatic vegetation), so the sediments are not conducive to aquatic life. Though there is a good riparian zone, there is too little water renewal to provide adequate DO levels and flush the organic matter from the system. The County Drainage Ditch that flows from the North Pond also is choked but primarily with aquatic plants and again has inadequate flow. The South Pond is not covered by a tree canopy as the North Pond and Ditch are, so there is less decaying organic debris. However, the aquatic macrophytes that decay promote nightly anoxia, and poor quality sediments given the lack of flow through the system. The emergent macrophytes provide some habitat for insects and birds, but the lack of benthos and fish deters birds that feed on aquatic organisms, such as herons. The habitat of Honey Creek is degraded due to it being channelized which results in flashy flows and lack of protection for organisms. The sediments are primarily sand and of low heterogeneity.

5.4 Conclusion

The aquatic habitat, low or flashy flows, and water physicochemistry all are indicative of low-quality ecosystems, some of which are receiving contaminated runoff. The poor benthic macroinvertebrate communities substantiate the poor quality, as does the subsequent lack of aquatic bird visitation and residency. One could argue these symptoms are the result of the man-made nature of the water features, as our historical land cover analysis and research (see Chapter 2) show that the North Pond was excavated for agricultural purposes, and that South Pond was unintentionally formed after the installation of buildings and parking lots on the property. In this way, there was never a “native” aquatic community, nor was there ever a naturally-occurring source of higher-quality inflow. We conclude that the water features of the property are in great need of management, which we explore in greater detail in chapters 6 and 8.

Chapter 6: Stormwater Modeling

6.1 Background

One challenge to KEEP management is the unique hydrology of the site. The property sits in a network of wet woods and modified residential and commercial space, and thus has seen modifications to the direction, flow, and drainage of stormwater, with only intermittent stream flows following rain events or snowmelt (Chapter 5). As described in Chapter 3, the site hydrology has greatly affected its plant communities, habitats, aquatic life, and wildlife that depend on waterways. There are 4 hydrologic modifications that have occurred from past human disturbance that primarily impact the KEEP: 1) the creation of the North Pond receiving minimal runoff, 2) parking lot drainage into the South Pond, 3) the constructed drainage channel connecting the ponds to Honey Creek, and 4) the earthen berms established along the North Pond and parking lot.

The North Pond was excavated around 1960 (see Chapter 2.3) as a detention pond for agricultural purposes. To prevent the pond from overflowing, the north edge of the pond was fortified with a berm, and a drainage ditch dug to allow the pond to drain into Honey Creek. This ditch runs north to south on the eastern edge of the property and is fortified on its western edge with a berm. While no longer having water pumped directly into it, the North Pond receives a minimal amount of runoff through a point on its western edge. The South Pond did not begin to develop until around 1990 (see Chapter 2.5), presumably due to the construction of the large parking lot to its west. The South Pond began collecting stormwater off the parking lot and draining into the non-forested wetland to its south. Two drainage ditches were constructed on the southernmost edge of the non-forested wetland to allow water to drain into Honey Creek. The pond continues to receive runoff from the Kiwanis Thrift Sale parking lot, despite the construction of a berm in front of its accumulation point. As previously stated, (see Chapter 3.1), a great deal of parking lot runoff flows and infiltrates into the wet forest and keeps the soil saturated for much of the year.

Our first objective is to estimate how much stormwater the entire system, specifically the two ponds, receives in an average year. It is our belief that the water quality of both ponds could be improved with further modifications to the site's hydrology, but in order to make recommendations, we must first better understand the volume of surface water currently present in the system. The scope of our project originally included *in situ* assessment of runoff into North Pond, but the low and shallow flows did not allow for physical quantification. As an alternative, we conducted a spatial analysis of the site's watersheds using ArcGIS and modeled seasonal runoff using RStudio. Our second objective after establishing this baseline of inflow into the two ponds is to model the outcome of installing two rainfall collection systems on the Kiwanis property that would collect and redirect rainfall received by the property and redirect collected water into the two ponds. Hereafter, we refer to these two steps of our analysis as "*status quo* inflow" and "recommended modified inflow."

6.2 Methods

6.2.1 *Status Quo* Inflow

A watershed is an approximate area from which a stream or pond is likely to receive surface water runoff. One can apply rainfall in inches, and multiply it by the area of the watershed to estimate the water in cubic inches received by a watershed during a storm event. But not every drop of water received by the watershed directly translates into runoff received by the ponds: much of it moves into different compartments, such as soil absorption, plant uptake, drainage into groundwaters, or into ponds, wetlands, and streams. To take into account this abstraction of stormwater while estimating total runoff received, we followed the runoff Curve Number methodology developed by the USDA Natural Resources Conservation Service (*Urban Hydrology for Small Watersheds*, 1986). This method requires a watershed to be divided into areas, or sub-basins, based on soil type and cover type. One must assign a Curve Number (CN) to each of these sub-basins based on its cover and soil type that represents the proportion of rainfall likely to be lost to runoff. Therefore, to conduct our analysis, we first needed to estimate the watershed area of the two ponds, and the soil and cover types of these watersheds.

Using the Spatial Analyst toolbox within ArcGIS, we were able to estimate the watersheds of both the North Pond and South Pond, derived from a one-meter elevation model of the property, downloaded from a 2003 USGS dataset. The Hydrology toolbox within ArcGIS converts elevational differences into the theoretical flow direction and accumulation of stormwater, creating a theoretical stream network. The "watershed" function allows one to create an estimate of the area that drains into a specified point within this theoretical stream network.

With the area of each watershed estimated, we used satellite imagery available within ArcGIS to digitize the cover types within the watersheds. The NRCS documentation provides CNs for urban and wooded cover types, giving us some classification terms to work with. (Appendix C) Digitization of cover type was estimated manually, and as such is subject to bias. Next, we imported the soil types of the watersheds from the NRCS web soil survey portal, which provided us with the areas of each soil type and their hydrologic soil group rating, which is needed to select an appropriate CN. The merging of these variables resulted in a table of entries describing each sub-basin that had a unique CN number. The CN entries were then converted into the variable *S*, using the following formula: $S = (\frac{1000}{CN}) - 10$. This table was uploaded into R studio, along with rain gauge data for the year 2015, as inches received in 15-minute intervals from the City of Ann Arbor Jackson Road rain gauge. This rain gauge reports on rainfall every 15 minutes for the entirety of the year 2015, and is approximately 4 miles east of the Kiwanis Thrift store and was selected as the most suitable source of historical rainfall data (Figure 23).

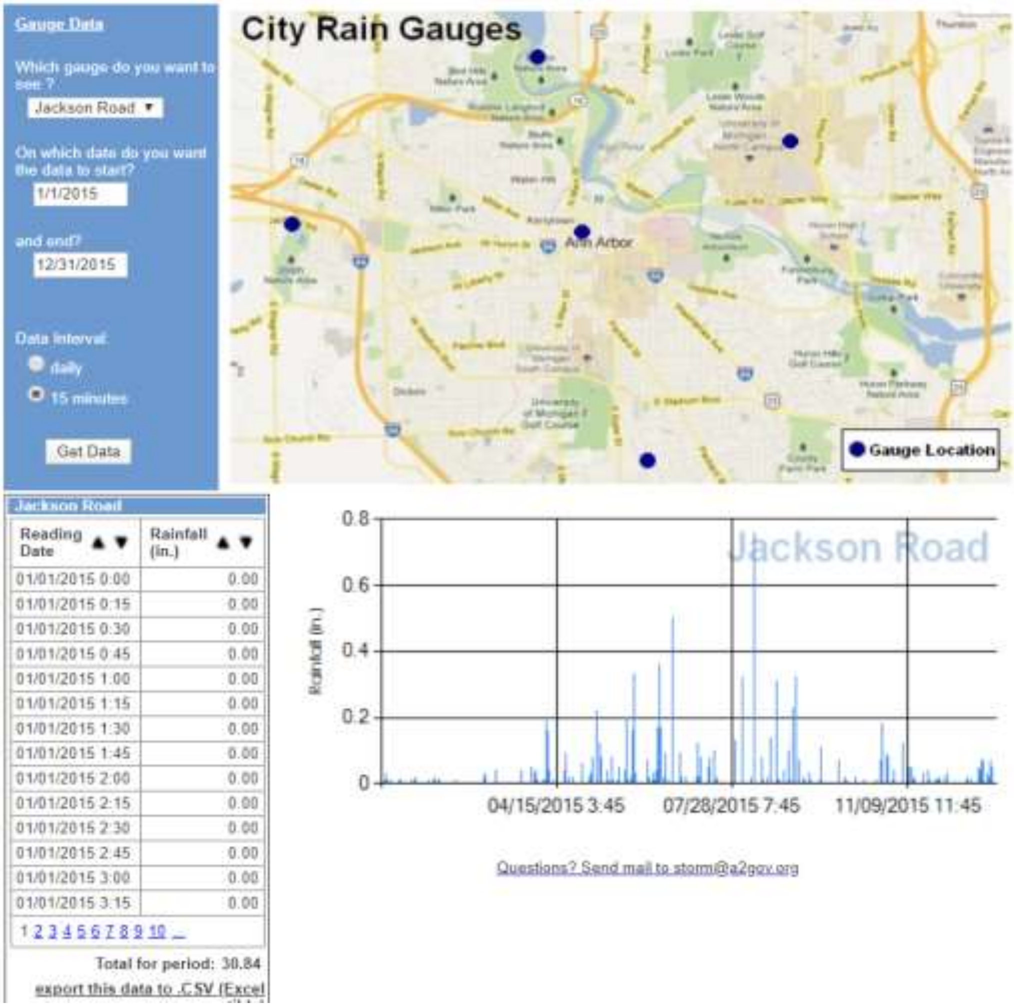

Figure 23. Screen capture of Ann Arbor rain gauge data portal, depicting the 2015 dataset.

Within RStudio, we first calculated the runoff from each of the sub-basins with unique CNs at every time-step, using the following formula: $R_t = \sum_{n=i} \frac{(P_t - .2S_i)^2}{(P_t + .8S_i)} \times A_i \times 0.00439$, where *i* is the sub-basin being analyzed, *R* is runoff for in gallons for timestep *t*, *P* is rainfall in inches for timestep *t*, *i* is the sub-basin, *A* is the area of the sub-basin, and *S* is the value calculated above using the CN of the sub-basin. *R* over time for both basins was recorded for every 15-minute interval.

6.2.2. Recommended Modified Inflow

We here elaborate on our recommendation of the installation of two stormwater collection systems, one aboveground to collect rainfall off of the Kiwanis warehouse roof, and one underground to collect flooding from off the gravel parking lot. Currently, rainfall that collects on the roof of the Kiwanis warehouse is rerouted under the parking lot and directly into Honey Creek, but clients indicate that about 75% of the roof's area could be used to collect stormwater to be directed into an on-site rain barrel. This barrel could then be outfitted with a pump and a hose connecting the reservoir to the North Pond. Our hope is that by increasing water flow directly into the North Pond, we would see improvements in water and sediment quality therein (Figure 24).

The underground storage system would be installed underneath the natural drainage point that receives all water off the parking lot. Water stored therein could then be redirected via a hose to the North

Pond. Once full, this reservoir could also pump directly into the South Pond, thus speeding up the drainage of storm surges into the South Pond and eventually through the non-forested wetland and into Honey Creek (Figure 24). The main objective of this second collection system would simply be to reduce flooding of the parking lot.

To illustrate how these two collection systems would operate in tandem, we have used the same 2015 rainfall data explored in Chapter 6 to model how rainfall could be collected and redirected into either pond. Within this model, we create a theoretical tank and pump that is in constant operation, able to shift between two pump speeds depending on the volume of inflow. Every 15 minutes, the model inputs rainfall in inches from the Jackson Road Gauge dataset, multiplies it by the area of the roof, and modifies the theoretical volume of water in the tank by adding this inflow value and subtracting the volume being pumped out into the North Pond. If the tank is full, the model will record the overflow, which we assume is lost to the South Pond watershed (Figure 25). We then employ a second model run that once again evaluates the runoff received by the South Pond that accumulates in the parking lot, now adding the volume of water that overflowed from the rooftop collection apparatus. We create a second theoretical tank and record inflow, outflow, and overflow at every 15-minute interval. Overflow we specify as being diverted directly into the South Pond, and outflow being diverted into the North Pond. Thus, we can give an estimation of the modified volume of water that both ponds would receive should the two collection systems be installed. For more detailed documentation of these models, see Appendix C.

Figure 24. Diagram of proposed rerouting of stormwater off the Kiwanis Club warehouse and parking lot into the North and South Ponds. Aerial image from Google Earth. Pop-up images from RainHarvest.com. Not to scale.

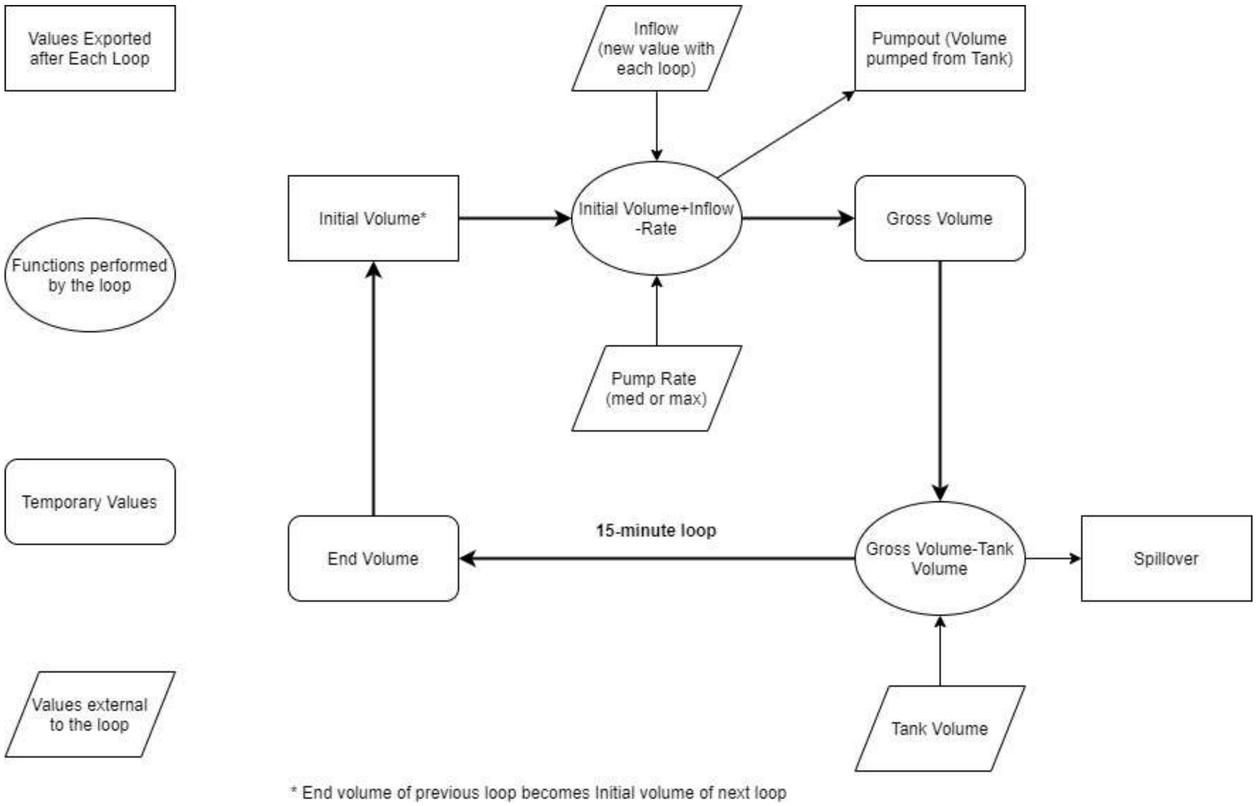

Figure 25. A flow chart depicting the calculations, inputs, and outputs made within one loop of a theoretical stormwater collection system model used in RStudio (See Appendix C). The loop begins with "initial volume" and is continued via the bolded arrows.*

6.3 Results and Discussion

6.3.1. *Status Quo* Inflow

Spatial analysis in ArcGIS indicates that runoff from about 72.2 square kilometers may currently drain into the North Pond, and about 17.8 square kilometers into the South Pond. Within the North Pond watershed, two kinds of soil are present: Gilford Sandy Loam (Gf) and Spinks-Oshtemo Loamy Sands (SrB). SrB soils were the only soils present in the South Pond Watershed. There were 18 sub-basins in the South Pond Watershed, and 14 in the North Pond Watershed. Cover types in both included woods, woods-grass combination, gravel, pavement, lawn, and gravel (Figure 26).

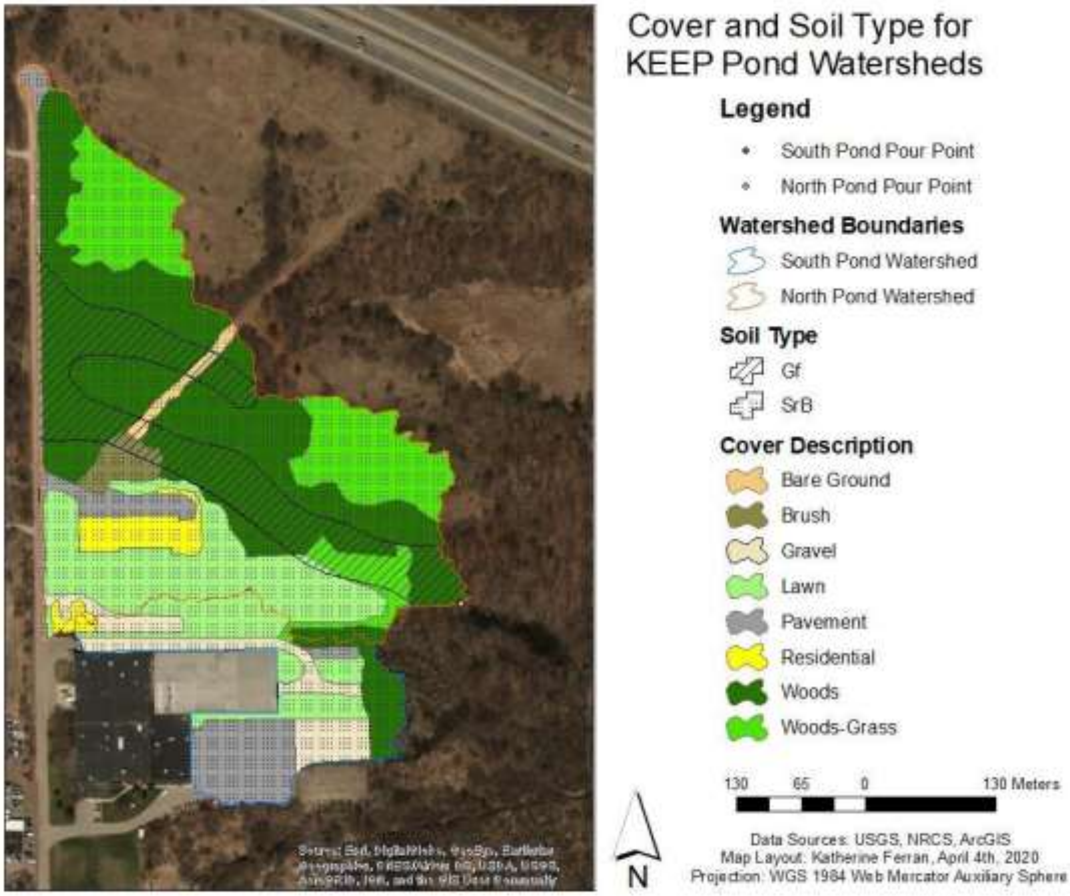

Figure 26. Cover and soil type for KEEP Pond watersheds and sub-basins.

Through this analysis, we estimate the North Pond may have received up to 5.13 million gallons, and the South Pond up to 1.78 million gallons of runoff in the year of 2015 (Figure 27). Compared to field observations of water moving into the North Pond, this strikes us as a vast overestimation for annual patterns. Based on observations of low flow into the North Pond entry point after high-volume storm events, it seems as if a great deal more runoff is being lost to abstraction than our watershed analysis may indicate.

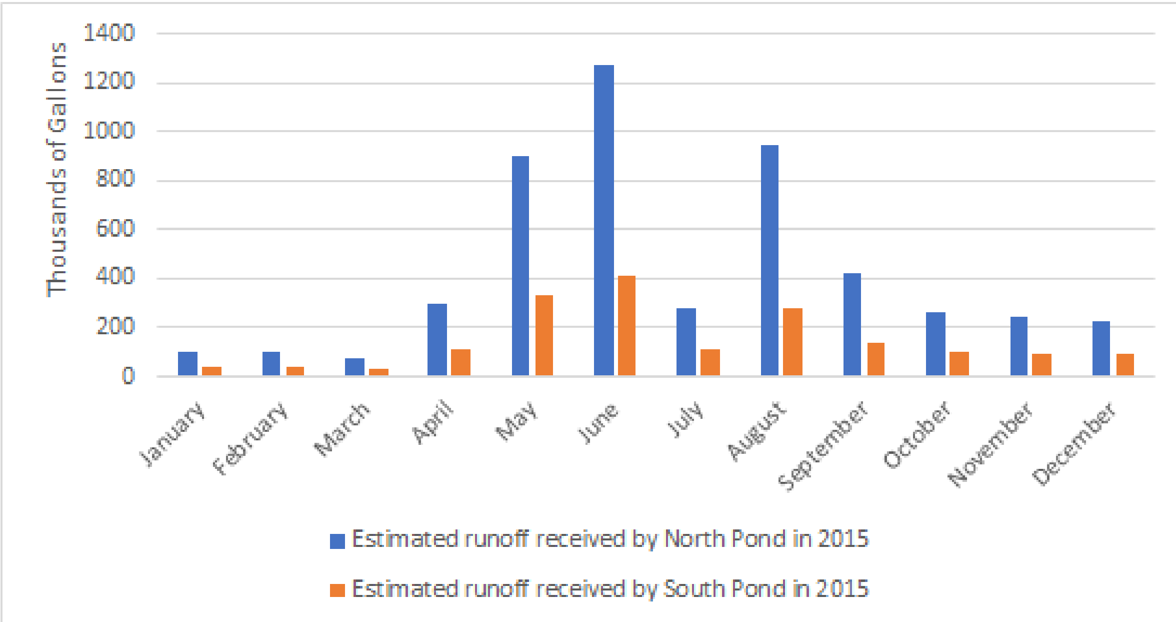

Figure 27. Estimated runoff received by the North and South Ponds in 2015.

6.3.2. Recommended Modified Inflow

As mentioned above, for the year 2015, the North Pond may have received up to 5.13 million gallons of stormwater runoff in the year 2015, and the South Pond up to 1.78 million gallons. We estimate if the two stormwater collection systems stored 5100 gallons each, the North Pond would have received an additional 1.4 million gallons of water, which would reduce inflow into South Pond by about 850,000 gallons (Figures 28 and 29). This specific scenario assumes an always-running pump, but actual systems of this type allow for manual control of pump rates, meaning clients could control the outflow directly, and experiment with what pump schedule would reduce overflow the most or create more consistent inflow into the two pond year round.

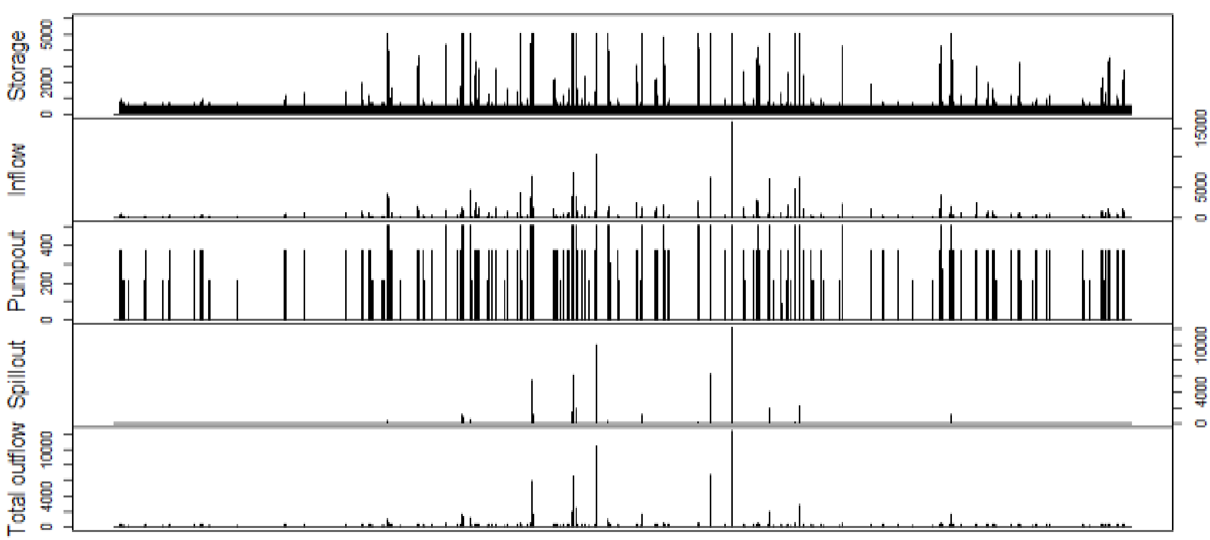

*Figure 28. Modelled inflow, outflow, overflow, and storage of the theoretical **rooftop** stormwater catchment system using a 5100 gallon tank. Y-axis is time in 15-minute intervals for the year of 2015. X-axes are in gallons.*

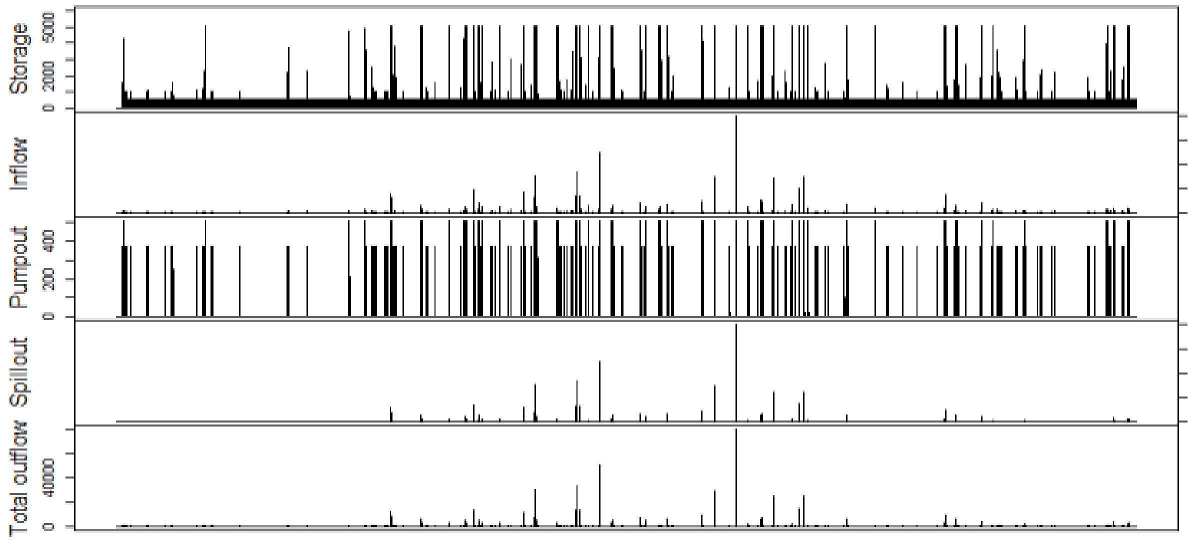

Figure 29. Modeled inflow, outflow, overflow, and storage of the theoretical ***parking lot*** *stormwater catchment system using a 5100-gallon tank. Y-axis is time in 15-minute intervals for the year of 2015. X-axes are in gallons.*

6.4 Conclusions

We here argue that the installation of two rainfall collection systems would benefit the KEEP by increasing inflow into the North Pond by an estimated 1.4 million gallons a year. According to our analysis, this would be in addition to a baseline inflow of 5.13 million gallons a year, which may be an overestimation, given our observations of actual inflow into the North Pond. We encourage our clients to use the model we have provided to experiment with scenarios using different tank sizes or pump rates.

Limitations of our modeling include the assumption of instantaneous runoff occurring at every timestep, in that all precipitation after a certain amount is lost to different environmental compartments, flows immediately towards the collection points. This does not take into consideration the delayed release of water from snowmelt, or the time it takes for runoff to travel from within the watershed into the collection point.

Chapter 7: Educational Resources

7.1 Background

In completion of our third objective, we created an interactive story map of our findings to be used as a foundational education tool in the future use of the KEEP. The story map can be found at https://storymaps.arcgis.com/stories/66d8989460494dc2bccb3ed39747c47c. ESRI has multiple story map web applications that use multimedia including maps to draw importance to the where, or location, of a story. These story maps are therefore important in environmental education endeavors like the founding of the KEEP. Story maps have been shown to be effective at teaching both on their own and with PowerPoint presentations with positive and motivated student responses (Cope et al., 2018; Marta & Osso, 2015). They can be used to convey summaries, change over time, and narratives, all useful for education at the KEEP (Marta & Osso, 2015).

These story maps, if made effectively, promote problem and value-based education, an education of activism (Marta & Osso, 2015). There are five principles for creating an effective story map: 1) Connecting with the audience, 2) Luring people into your story, 3) Choosing a template that is best for your audience, 4) Creating maps that are easy to read, and 5) Striving for simplicity (Wilber, 2018). We kept these principles in mind in the following methods and results of the KEEP story map.

7.2 Methods

The story map was created using ESRI Story Map web application basic template for simplicity. We created the map with a K-12 grade level student, the future users of the KEEP audience in mind. We followed a simplified version of this report for the structure of the story map as it provided a strong narrative basis. All map images in the story map were created in ArcMap using shapefiles acquired from various sources or created by our team from manual classification and GPS recorded points (SEMCOG, 2015; Washtenaw County GIS Program, 2019). Specific sources of each image can be found in the credits section of the story map. For specific methods completed by our team for shapefile creation and data collection, view method sections of Chapters 2 and 3 of this report. We created three interactive maps using ESRI Story Map Shortlist ("Wildlife" and "Also Keep Your Eye Out For…") and Story Map Tour ("Try Your Hand at Tree Identification") Web Apps. These maps were first created in ArcMap where layers and symbology were added, and then uploaded onto ArcGIS Online and created into the above web apps. All images displayed in the interactive maps were collected on the KEEP property using game cameras or phone cameras. Points for the interactive maps were collected using phones and the Survey123 app. All map images and interactive maps were supplemented with titles and text to provide the narrative of the KEEP described in the results below.

7.3 Results and Discussion

The story map begins with a short background of the Kiwanis club and the KEEP, including a display of the habitats defined by our team. We then display and describe the past land covers and the changes that occur to create the land cover and vegetation we see today. This leads directly to the plant quality throughout the KEEP and future management recommendations of invasives. We then end the story map with three interactive maps displaying the wildlife, observations made at the KEEP, and tree identification. These maps can be used on the property and will display a location point of the story map user allowing the user to move throughout the property and find each point in the map. We used basic language and provided sufficient definitions for any expert terminology used to make the story map usable for the intended audience. These components came together to form the complete KEEP story map at the URL above.

7.4 Conclusions

We believe the information provided and interactive maps will be a foundational introduction and understanding of the property in the future use of the KEEP. We followed the five principles for creating an effective story map (Wilber, 2018). We connected with our K-12 audience through avoidance and explanation of expertise terminology, interactive components, and a connection to their community. We lured people in with enticing images and grasping questions. We chose a simple template for easy phone use by the intended audience, and we created easy-to-follow maps and a simplified storyline. With adherence to these effective story map guidelines, we created a fundamental education tool for the KEEP.

Chapter 8: Recommendations for the KEEP

This comprehensive study has provided a large foundational database on which future directions of the KEEP can be based. Below we provide a series of recommendations related to each aspect of our study, which can be considered as options to pursue in the future.

Stormwater Collection and Redirection

Rainfall collection systems should be installed (Chp 6) to route water into the two ponds, thereby improving their physicochemical and ecological quality. We also recommend the removal of all berms on the property, which will allow the wet woods to drain more readily into the drainage ditch, reduce forest flooding, possibly allow for historic native vegetation patterns, and reduce mosquito breeding. Improving the drainage may require some shallow swales to be installed. Creating a winter fish refuge (a deep ~ 4-6 ft hole) at the headwaters of each pond would improve chances for a sustainable fish population to establish. If clients wished for other means by which to improve the Pond's water quality, the direct application of solar-powered aerators should be considered. The drainage canals from each pond should be cleared of excessive macrophyte growth and organic debris to facilitate drainage.

Future Hydrological Evaluation and Monitoring

The model we have built to assess the KEEP hydrology and to illustrate the possible outcomes of modifications is entirely based on spatial analysis, rainfall data collected nearly a mile away from the KEEP, and many simplified assumptions (see Chapter 6). To improve the quality of its predictions, we recommend the collection and incorporation of observable inflow and outflow from both ponds, perhaps during or after high-volume storm events. This data could then be combined with our analysis to create a linear regression between assumed inflow from our watershed analysis and actual inflow observed over time.

Additionally, should the clients move forward with these modifications, we recommend monitoring of water and sediment quality within the North Pond to assess restoration effectiveness. This should include DO and conductivity at a minimum and be done by either Kiwanis volunteers or with the help of the Huron River Watershed Council and their water quality monitoring program.

Vegetation Diversity

To better serve the Kiwanis Club's goals of providing the backdrop for environmental education opportunities, we suggest several actions leading towards improved management of woody and herbaceous diversity in the KEEP. There are many reasons to manage for diversity: a diverse forest is more resilient towards stressors (Dymond et al. 2014) and has a greater capacity to provide ecosystem services like carbon sequestration, air quality improvement, and water filtration (Beier et al., 2015). Forest diversity is inextricably linked with forest structure and composition, driven by successional processes that favor trees with different life-history traits over time (Barnes et al. 1988). Mature or well-managed forests tend to be multi-aged with a negative exponential distribution of diameter classes (Pond & Froese, 2015), which promotes understory and groundcover diversity while additionally providing a wealth and variety of habitat and resources for wildlife (Munro et al. 2009).

Overall, the KEEP currently provides a variety of habitats and resources that can be built upon by our management recommendations. While the conclusion of our vegetation survey and observational assessment painted an optimistic picture for the current state of plant community diversity and structure in the KEEP (Chapter 3.3), there is room for biodiversity improvement, as we believe greater floristic diversity will create a more engaging setting for visitors and will provide more opportunities for environmental education.

The first challenge we wish to address is the management of Common Buckthorn. This invasive shrub is well-studied for its ability to reduce forest diversity by suppressing canopy tree recruitment, altering soil conditions to favor its own growth over competitors, and facilitating invasive earthworms that come with their own negative effects on Midwest forest ecosystems (Heneghan et al., 2006). Buckthorn is resolutely established in many stands of the KEEP, and because of its omnipresence both within the site and in neighboring areas, it is unrealistic to advocate for its complete eradication. Therefore, we elaborate on an adaptive management plan that emphasizes experimental control methods that emphasize the re-establishment of desirable plant species over the eradication of Buckthorn. We recommend a number of different management actions be taken seasonally, described below:

- Spring
  - Removal: Removal in spring is not often encouraged, as Buckthorn is a competent re-sprouter and at its most vivacious during the growing season. However, we hypothesize that the repeated removal of resprouts during the growing season may be enough to stress the Buckthorn. One of the reasons Buckthorn is so successful is its nitrogen-rich litter aids in the germination of new Buckthorns. If older Buckthorns are cut and re-sprout multiple times in the spring, it is possible that this over-exclusion could increase uptake of nitrogen and starve Buckthorn seedlings. Additionally, springtime removal will allow more light to reach the understory to facilitate the germination of desirable trees and the recruitment of canopy trees.
    - Hand-pull or Weed Wrench: For Buckthorn under 5 cm in diameter, we suggest use of a Weed Wrench, other weeding tools, or hand-pulling to remove both aboveground and belowground biomass. This is more disruptive in nature, which can be useful for reseeding purposes. This process is more labor-intensive and need not be used for every target Buckthorn within the specified size range.
    - Cut-and-burn: For Buckthorn greater than 5 cm in diameter, we recommend mechanical removal of above-ground biomass (via brush-cutting or chainsaw) and chemical treatment of the stump. Clients have stipulated they do not intend to ever use herbicides for invasive control. Where traditional Buckthorn control dictates the application of 50% glyphosate to a cut stump, we recommend burning the stumps as an alternative (Nagel et al., 2008).
  - Reseeding: Springtime is the best time to reseed for many species, including oaks (Grossnickle & Ivetić, 2017). We recommend collecting seeds on-site, but clients may wish to investigate purchasing options for native Michigan tree seeds to get started.
    - Broadcast seeding: In areas where Buckthorn was removed using the cut-and-burn strategy, we recommend hand-distributing a 50:50 mix of seed and mixture media, like vermiculite, sawdust, or potting soil. Try to scatter approximately one-half cup of this seed mixture per square meter of the forest floor.
    - Spot seeding: We suggest intentional burial of seeds into disturbed spots where Buckthorn was hand-pulled/weed-wrenched. This re-seeding should be done in tandem with hand-pulling and weed-wrenching, and seeds being put in place of the removed Buckthorns as soon as possible.
  - Additional modifications
    - Consider our hydrological recommendations and limit flooding of the Wet Forest and Riparian Shrub by regulating flow in and out of the two recommended stormwater catchment systems.
- Summer
  - Removal: Continue to mechanically remove Buckthorn resprouts frequently, via chainsaw, brush-cutting, and handsaws. Do not bother with hand-pulling and

weed-wrenching: summertime temperatures make this method much more difficult, and the disturbance left behind can be favorable for the late establishment of invasive species. New tree and shrub growth should be protected from deer grazing with temporary predator guards.

- Fall
    - Removal
        - Continue to mechanically remove Buckthorn resprouts frequently, via chainsawing, brush-cutting, and hand sawing. Try to do the bulk of the removal *before* Buckthorns start fruiting.
    - Reseeding
        - Some hardwood species are better suited for seeding in the Fall. We recommend again using a broadcast seeding method on areas with recent Buckthorn removal.
    - Additional modifications
        - Collect seeds of overstory tree species and desirable herbaceous species. For proper seed collection procedure, visit the US Forest Service's website on the subject: https://www.fs.fed.us/wildflowers/Native_Plant_Materials/developing/collecting.shtml. Explore seed exchange programs with entities like Project Grow and Matthaei Botanical Gardens in the Ann Arbor area.
        - As previously stated, Buckthorn leaf litter is a key element to its success: it is high in nitrogen and decomposes easily, altering soil nitrogen levels to favor more Buckthorn recruitment. For this reason, we suggest complete removal of Buckthorn litter from targeted areas in the KEEP, via raking and removing the leaves. This practice would be labor-intensive and particularly difficult to carry out in the wetter plots of the KEEP, so we recommend only experimenting with the raking and removal of Buckthorn litter in the dryer stands, like Upland Shrub Willow and Elm understory stands, and the Cottonwood Forest.
- Winter
    - Removal: Focus on removing as much Buckthorn mass as possible during this time, temperature allowing, using the cut-and-burn methodology.

Secondly, we briefly address another woody invasive. Our hope is removing the drainage ditch berm will allow the wet woods to drain more readily, which may change its vegetation community and structure. We suggest girdling Norway Maples before the berm's removal, ideally before they seed again, to prevent them from becoming more prolific in the wet woods.

Thirdly, within the Non-forested Wetland, experiment with purple loosestrife biocontrol by purchasing and releasing *Galerucella calmariensis* and continuing to monitor the beetle population and purple loosestrife herbivory every spring to determine if more beetles need to be purchased to bolster the population. With regards to the reed canary grass, cover portions of grass with opaque black plastic tarps during growing seasons. This method will not eliminate the invasive grasses but has been shown to greatly reduce their density (Apfelbaum & Sams, 1987). The whole field need not be covered, but if reed canary grass is successfully reduced, we recommend seeding these areas with native wet prairie species like Black-Eyed Susan (*Rudbeckia hirta*), goldenrods (*Solidago* spp.), Virginia mountain mint (*Pycnanthemum virginianum*), and purple meadow rue (*Thalictrum dasycarpum*). Allowing them a foothold will increase diversity and provide competition against the invasives. Alternatively, or complementarity, placing live willow stakes spaced 0.6 and 0.91 meters in wetlands have been seen to decrease Reed Canary grass coverage by 68% (Kim et al., 2006). We suggest sandbar willow stakes since the species is already present here.

Wildlife Diversity

We documented areas with high wildlife activity as well as habitats supporting a high diversity of wildlife. We provided GPS coordinates of all wildlife hotspots. We, therefore, recommend a focus on these locations for any ecological enhancements. On-site cameras showed areas in different microhabitats frequented by wildlife. The installation of deer fences in a select portion of the Oak Forest will encourage wildflower growth. The trails should be maintained as wildlife pathways. The KEEP provides a home to various bird species. To further increase abundance and biodiversity, the installation of a range of bird box houses should be considered in areas of optimal habitat. This could include boxes for owls, wood ducks, wrens and chickadees, and kestrels along the field lines. Purple martin “condominiums" on the parking lot perimeter would aid in mosquito control and provide wonderful viewing of their acrobatics and hearing their “churtles.” Bird boxes catch the interest of those visiting the KEEP. Bird diversity could be enhanced around the North Pond by the removal of high limbs and a few canopy trees. Finally, a nice amphibian population of frogs exists in the KEEP. These likely need no focus, as the improved pond water quality will indirectly improve their community.

Education Resource Enhancement

Enormous potential exists for using the KEEP to educate students and the public in the greater Ann Arbor area about how nature and humans interact. We suggest the tools and implemented recommendations of this project be utilized in this future education program. One component of our project was the creation of an ESRI Story Map about the KEEP (Chapter 7). We recommend this be used on student smartphones in future educational activities on the KEEP. Such activities could include: 1) Teaching scientific methods and the importance of observations through the hands-on activity of recording observations of signs of wildlife (tracks, scats, or sightings) using the interactive maps as guides for locations and identifications; Developing follow-up research questions and methods; 2) Teaching tree identification and their habitat requirements with the interactive map as a guide, and 3) Learning about human impacts on and management of the environment through a discussion of past land use and a walkthrough of current habitats. There will be an opportunity for educating on invasive management, stormwater management, and water quality through signage and educational talks. These will be developed further in the second UM SEAS KEEP Master’s Project’s work.

Conclusions

With the implementation of these educational resource recommendations and stormwater, vegetation, and wildlife management recommendations, the KEEP will increase both its educational value and ecological function. The A2KF will be responsible for decisions regarding the implementation of these recommendations. However, through our project, we have provided sufficient information for making these management decisions and proceeding with the development of the KEEP.

Chapter 9: References

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Chapter 10: Appendices

Appendix A: Master File Index

Appendix B: Land Cover

Appendix C: KEEP Stormwater Modeling Technical Document