A HYDROLOGIC APPROACH TO ENVIRONMENTAL GOLF AND HAZARD DESIGN WITHIN THE WILDCAT CREEK WATERSHED

by

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A REPORT

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ABSTRACT

The City of Manhattan, Kansas is looking for possible solutions to mitigate flooding along Wildcat Creek within the Wildcat Creek Watershed. Recent flooding has caused substantial property damage. The project presented here brings recreation into the community by designing a golf course in a location along Wildcat Creek that addresses flooding issues, increases infiltration, and improves water quality. The golf industry has a long way to go to become more sustainable. The world is facing many challenges related to water and hydrology. Much of the opposition towards the golf industry is because critics see it as environmentally unfriendly. Golf has the potential to become a catalyst for change in the way we design and develop the landscape around us. The golf industry can become a leader in sustainable design while taking on hydrological concerns within the community.

This project demonstrates the application of a golf course to help mitigate flooding along Wildcat Creek with the use of vulnerability and suitability analysis as a guide to site selection. This method of analysis illustrates the process of identifying and protecting areas vulnerable to degradation by designing a golf course in a suitable location to utilize water hazards to store flood water, provide more floodplain access to effectively increase infiltration capacity, reduce runoff rates, and improve water quality. The report explains the relationship between golf course design and environmental practices as they relate to hydrology on a theoretical site in Manhattan, Kansas.

By integrating golf course design theory and environmentally sound stormwater management practices, water hazards on the golf course can become the fundamental elements used in strategizing the design of the golf course. A conceptual plan was created to maximize the infiltration capacity of the site as well as allow increased floodplain access, and provide a place to store flood water. A golf course can then be properly sited and designed hydrologically around the use of water hazards to help reduce flooding and improve water quality within the watershed.

A Hydrologic Approach to
Environmental Golf and Hazard Design

Within the Wildcat Creek Watershed

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ACKNOWLEDGEMENTS

To my dad for giving me the chance to grow up playing the game of golf.

To my family and friends for all of their love and support.

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Chapter 1

Introduction

The Wildcat Creek Watershed

PROJECT INTRODUCTION

During the 2011-2012 academic year, six graduate students in the department of Landscape Architecture and Regional and Community Planning worked to complete a watershed assessment for the Wildcat Creek Watershed. The group focused on completing the first two phases of Dave Rosgen's (2006) Watershed Assessment of River Stability and Sediment Supply (WARSSS) for the Wildcat Creek Watershed. This assessment was conducted along with, and used to inform individual master's reports that look at possible strategies to reduce flooding within the Wildcat Creek Watershed. This document presents one of those strategies.

This project demonstrates how a golf course can help mitigate flooding along Wildcat Creek with the use of vulnerability and suitability analysis to guide site selection. This method of analysis illustrates the process of identifying and protecting areas vulnerable to degradation by designing a golf course in a suitable location. This project shows how to utilize water hazards to store flood water, and how to effectively increase the infiltration capacity of the site, and improve water quality, This report explains the relationship between golf course design and environmental practices as they relate to hydrology by applying theory from relevant literature to the design of a golf course in the Wildcat Creek Watershed near Manhattan, Kansas.

The game of golf is unique in that there is no other game more dependent on the elements of the landscape to be its playing field. The character that makes a course memorable comes from the natural setting of the golf course. Understanding and addressing the relationship between the golf course and the natural landscape is essential to the design of a golf course (Love, 2008). Golf courses can provide habitat for wildlife, open space, and can be built to be part of a stormwater management system for an entire community (Dodson, 2005 p. 3). The current economy is making it difficult to build new courses and even keep existing courses going. Developers are looking for new ways to make building golf courses financially possible and the golf industry is looking for ways to become more sustainable and efficient in the long term. Because the golf industry is a big business, golf courses can provide a community with recreational opportunities, as well as, the same economic benefits as other types of development. A golf course is an economic engine that can drive the economy and provide the money to not only manage the course but also the natural areas and "green infrastructure" that are part of the golf course budget (Dodson, 2005 p. 3). Hazards are essential to the game of golf in order to create interest, challenge players strategically, and to perform functional uses related to stormwater. Environmentally sensitive areas can provide some of the most distinctive features and scenery on a course when they are incorporated as hazards on a golf course (Love, 2008). The water hazard in particular has become standardized and unexciting over time. Many water hazards look nice aesthetically but are not designed to function ecologically (Richardson & Fine, 2006). Many times when golf courses are built as part of a development, water and drainage are handled in the later stages of the design. This project takes a different approach by addressing hydrologic issues from the beginning of the design process. The placement and design of water hazards on the site drove the design of the golf course. The use of water hazards as the main design feature allowed the golf course to address the flood mitigation needs of the community. This project looks to redefine how golf can be integrated into a community to not only provide recreation but also to help reduce flooding within the Wildcat Creek Watershed.

The golf industry is a big business all over the world. Golf had grown to become a $76 billion industry, with a total impact on the United States economy of $195 billion (http://www.golf2020.com/economicresearch.aspx). Golf has the potential to become a catalyst for change in the way we design and develop the landscape around us. The golf industry can become the leader in sustainable design while taking on environmental concerns within the community.

This project demonstrates how the game of golf can coexist with nature. Golf courses can become an important part of any community's stormwater management program if properly sited and appropriately designed. A golf course can connect natural systems and the beauty of nature into a compatible and sustainable system that works for the benefit of golfers, the environment, and an entire community (Dodson, 2005, p. 2).

DILEMMA

Overall Dilemma

Wildcat Creek in Manhattan, Kansas is located within the Wildcat Creek Watershed shown in Figure 1.1. During recent years the intensity of flooding along Wildcat Creek has grown causing substantial property damage. In 2011 Manhattan, Kansas received almost five inches of rain during a period of only a few hours (Spicer, 2011). Two hundred residents from the City of Manhattan were evacuated from their homes (Anderson, 2011). Much of the flooding is due to changes in the climate, an increase in rainfall intensity, the increasing amount of impervious surface, and changes in land use practices within the watershed. These factors have led to an increase in the velocity of water moving downstream. Degradation of the stream creates a loss of floodplain so water cannot spread, slow, and drop sediment and debris as it naturally would have. The Wildcat Creek Watershed Area Working Group, co-chaired by Riley County and the City of Manhattan, has been established in order to find both short-term and long-term strategies to mitigating future flooding in Wildcat Creek. Images of the 2011 flood are shown in both Figure 1.2 and Figure 1.3.

Wildcat Creek Watershed

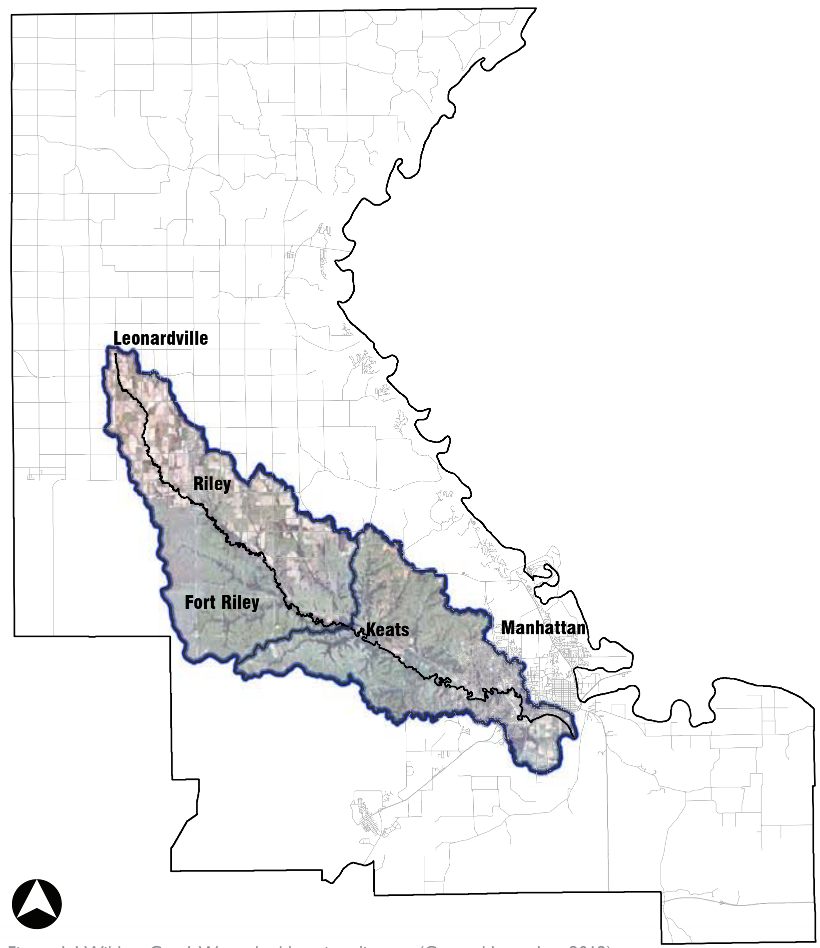


Figure 1.1 Wildcat Creek Watershed location diagram (Created by author, 2012)

2011 Flood

Figure 1.2 Aerial photo of 2011 flooding along Wildcat Creek at the project site (Photo by Rob Ott, City Engineer, 2011)

Figure 1.3 Aerial photo of the 2011 flood along Wildcat Creek near the project site (Photo by Rob Ott, City Engineer, 2011)

Secondary dilemmas to be addressed

Few golf course architects take the time to really understand the ecosystems on a site and how they function within the surrounding landscape (Hurdzan, 2006, p. 410). Developers have begun to depend on extensive use of equipment to modify the land rather than designing golf courses as part of the natural landscape (Dodson, 2005, p.3). The long-term success of a golf course is dependent on understanding the relationship between the final golf course design and the specific site where the golf course is built. A golf course can provide recreation for a community, as well as, function hydrologically in ways other types of development cannot. Golf courses are often built in floodplains and in locations where natural water courses already exist because natural features can make for a better golf experience. When golf holes are in close proximity to natural streams and drainage areas, there is a higher potential for runoff to leach chemicals and pollutants into the stream. Water hazards on golf courses are rarely designed to maximize their potential to perform multiple functions that benefit not only the golf course, but also address hydrologic concerns on the course and downstream.

THESIS

Water hazards on the golf course come in all shapes, sizes and configurations, from waste areas to lakes, and natural water courses. The location where a hazard is placed and how it is used in design are what makes a hazard the most defining component of a golf course (Richardson & Fine, 2006). A golf course can be designed hydrologically within a floodplain around the use of water hazards to reduce flooding along Wildcat Creek, increase infiltration, and improve water quality by creating a challenging course that has a positive impact on playability.

RESEARCH QUESTION

Research Question

How can a golf course be designed hydrologically around the use of water hazards, to reduce flooding from Wildcat Creek and become a significant factor in stormwater management by creating a challenging course with a positive impact on playability?

Supporting Questions

• How do you incorporate multiple stormwater management strategies such as, detention ponds and other stormwater BMP's into the design of the golf course to effectively reduce runoff, improve water quality, and increase infiltration?

• How does the design of a hazard affect the strategy and playability of the golf hole?

• How can stormwater best management practices improve the quality of water leaving the course?

• How can water hazards be designed to store enough water to supply irrigation needs, remove pollutants and excess sediment, while offering golfers a scenic and challenging round of golf?

PROJECT GOALS

• Show how to integrate golf as a recreational amenity into a community to help solve some of the flooding issues within the community.

• Show how water hazards on a golf course can be strategically designed to address functional issues related to quantity and quality, as well as, improve the aesthetic value of the property.

• Use literature as a foundation and guide to support all design decisions.

• Develop a site inventory and analysis that guides site selection and design decisions.

• Design a golf course for maximum playability that conforms to the United States Golf Association's regulations.

• Use hydrology as the driving concept for the golf course routing.

•Use native vegetation to support hydrologic functions and stormwater management.

PHILOSOPHY

My design philosophy is to balance the environmental, economic and social aspects of a project. A thesis statement was generated by combining the topics of golf course design and stormwater management shown in Figure 1.4. The overall design philosophy was combined with the project goals to create a project specific philosophy shown in Figure 1.5 which illustrates how the design of the golf course will interact with the surrounding site.

The diagram is based off of the hydrologic cycle. Hydrology is the study of the movement of water on the earth (Harpstead, 2001, p.75). The hydrologic cycle illustrates water's interaction with the environment. When water evaporates from the ground and forms clouds in the atmosphere, the water falls back to earth in the form of precipitation. Precipitation will enter the soil or run off into streams, marshes, wetlands, or lakes before it evaporates into the atmosphere and the cycle starts again (Harpstead, 2001,p. 76). The water that enters the soil is important to plant growth. Water that reaches the soil surface either infiltrates into the ground or runs off the surface. If the rate that water infiltrates into the soil is less than the rate at which rain falls, water accumulates on the soil surface (Harpstead, 2001, p. 78). Water from the soil is taken up through the plants roots and evaporates through the plant leaves into the atmosphere. Water that evaporates from the soil is called evaporation, and water that evaporates from the plants leaves is called transpiration. When evaporation and transpiration are combined together, it is called evapotranspiration (Harpstead, 2001, p. 80). Runoff water transports soil, which leads to erosion, so it is desirable to keep as much rain where it falls to protect the soil from erosion.

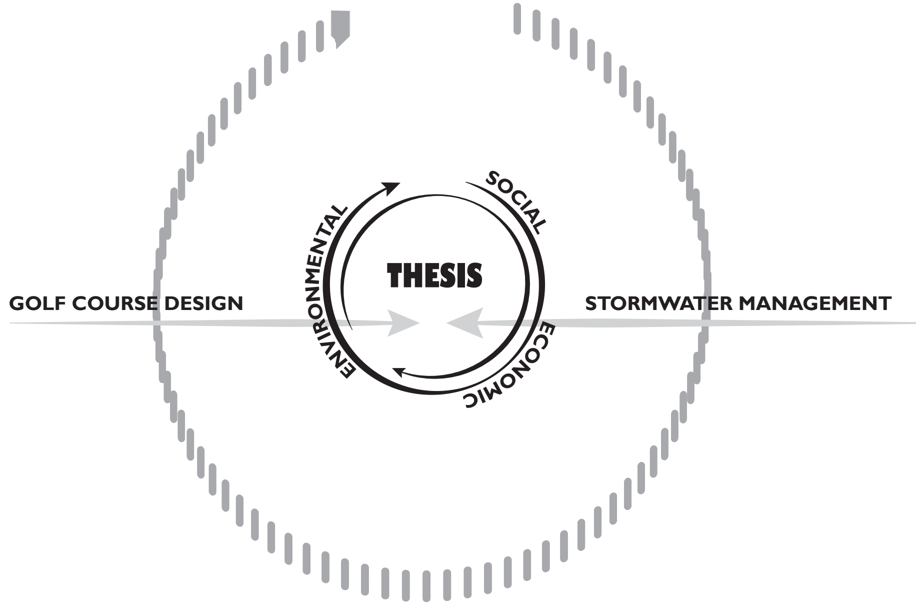


Figure 1.4 Overall philosophy diagram (Created by author, 2012)

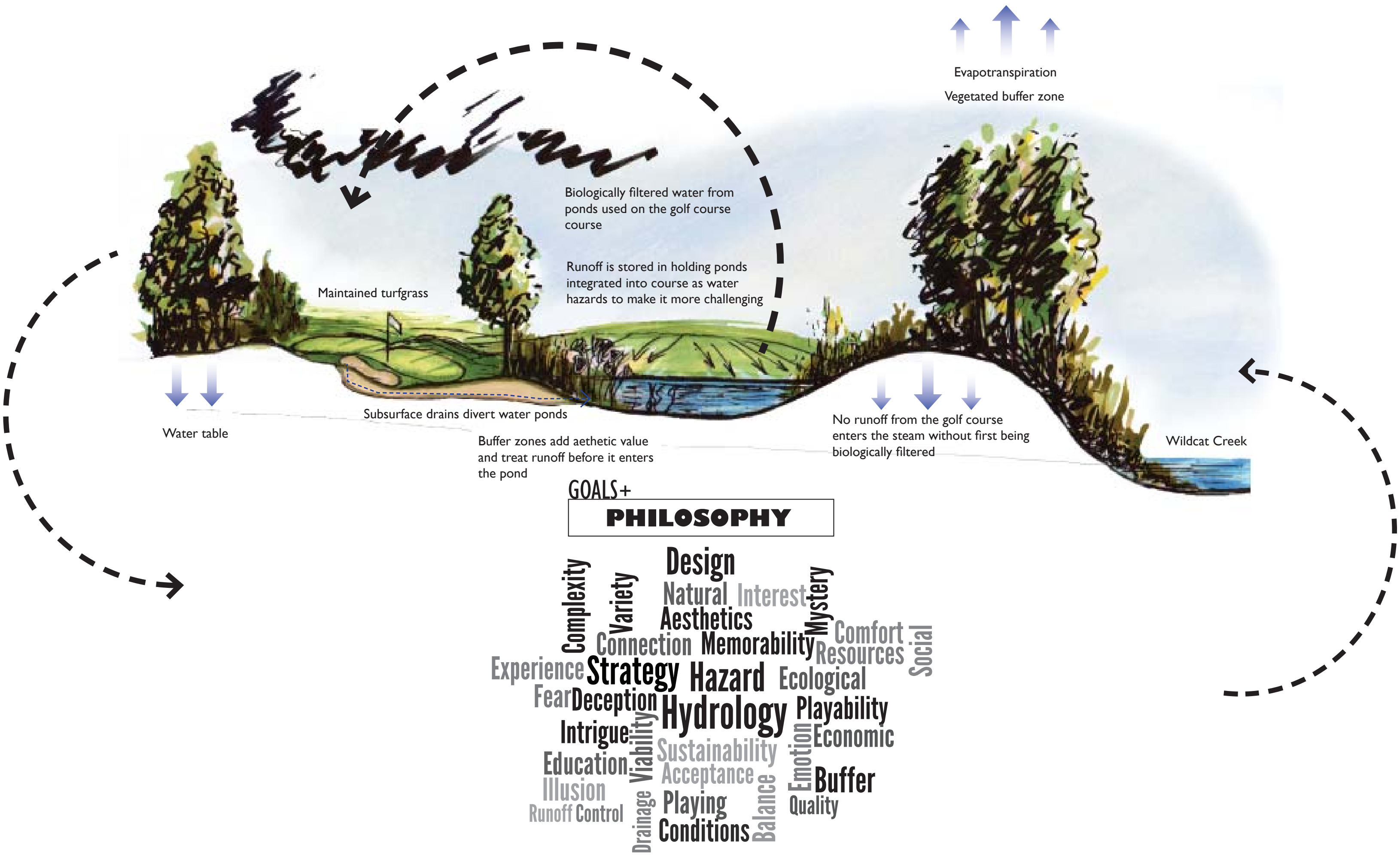


Figure 1.5 Project philosophy diagram (Adapted by author from Muirhead & Rando, 1994)

PROCESS DIAGRAM

To efficiently complete the project, my personal design philosophy was integrated with the path of a golf course specific project as shown in figure 1.6

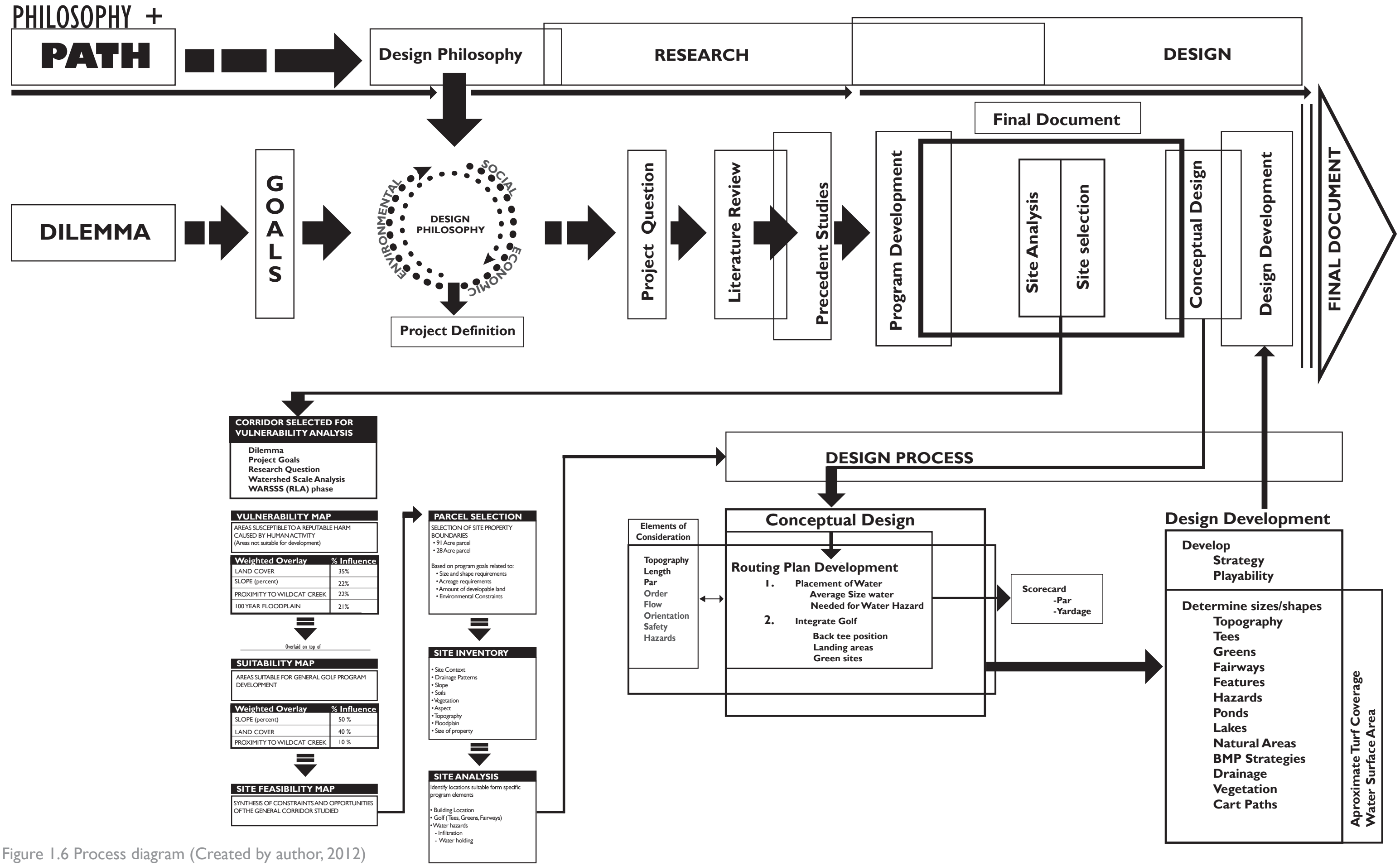


Figure 1.6 Process diagram (Created by author, 2012)

PROCESS TIMELINE

TIME + **TASKS**

Figure 1.7 illustrates the design process as a timeline of activities and tasks. The key dates for deadlines and important tasks to be completed are identified.

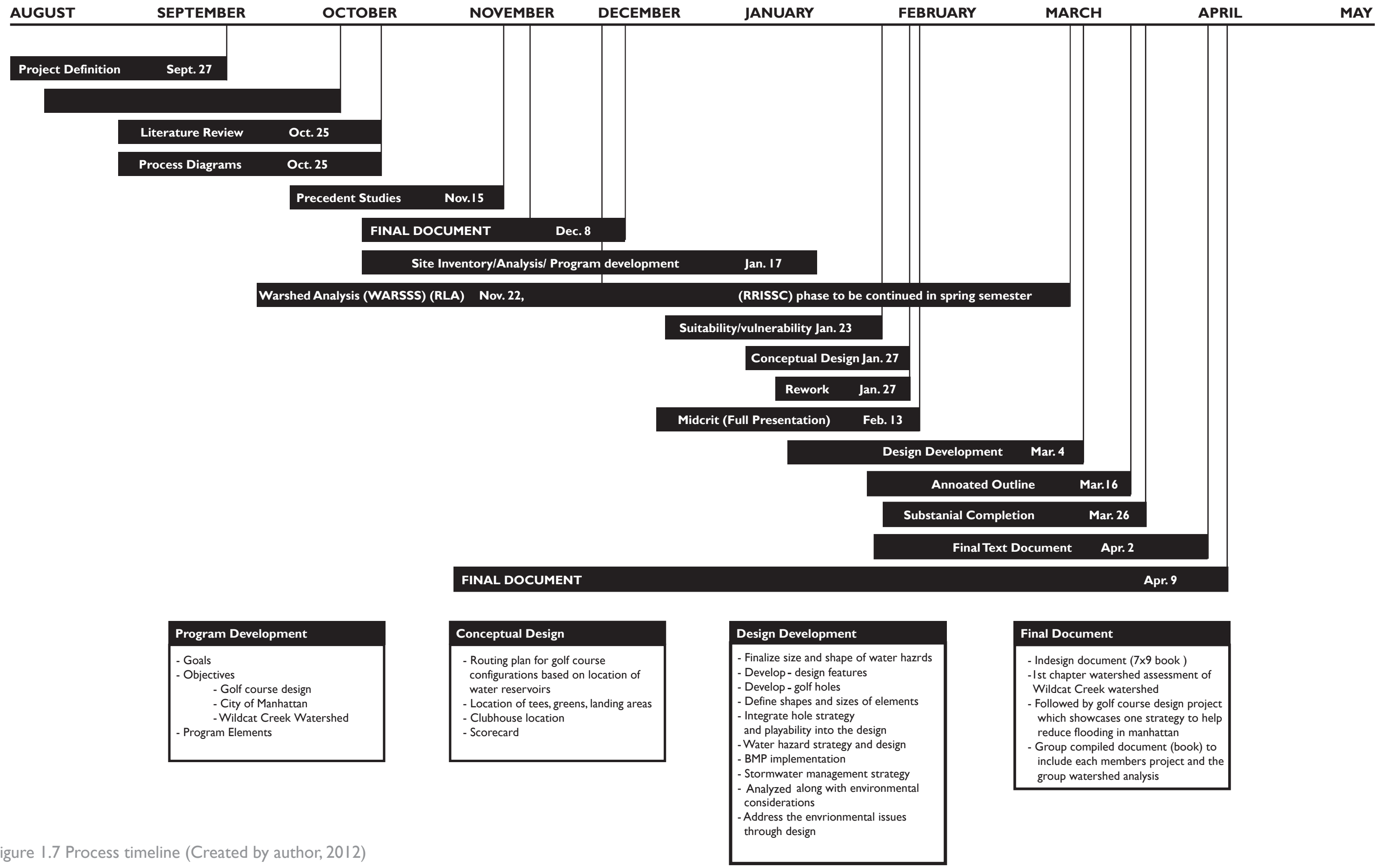


Figure 1.7 Process timeline (Created by author, 2012)

Chapter 2

Background

Literature + Case Studies

Literature

LITERATURE REVIEW

The process of researching and analyzing literature was important to the development of the project. The literature review and annotated bibliography provides a general description of the sources of literature used to guide the genesis of the project, as well as, support the design decisions made throughout the project.

The literature studied can be categorized into two distinctive subject areas; stormwater management and golf course design. Each category is highly specialized. I was interested in the overlap of the two ideas, what techniques are being used today, and what ideas could be investigated further. I have a strong background in the golf industry and have a good understanding of what is important to make the golf side successful. I wanted to learn as much about the environmental side of golf course design as it relates to hydrology as possible in order to bring the two ideas together. Several key literature sources were instrumental in shaping the outcome of the final project

Sustainable Golf Courses: a Guide to Environmental Stewardship provided a good source of information on stormwater management techniques and how they can be applied to a golf course. This book focused on how water quality and quantity must become the main focus of golf course management. This source also acknowledged the relationship of the golf course to the overall watershed. There is a section on Best Management Practices (BMP's) covering a range of different types of practices, such as the use of vegetation, buffers, and swales. The book was a good starting point because it covered a wide range of opportunities that could be further explored.

The book, "Managing Wetlands on golf courses" by Gary Libby, Donald F. Harker, and Kay Harker was similar to the book Sustainable Golf Courses in that both books were sponsored by Audubon International, but this book focused directly on different types of wetlands, wet meadows and techniques for infiltration. There was more information about managing these sources of water on a golf course than actually designing them. This brought to my attention the lack of information available on how to use the information available to implement the techniques all the way through the design process.

"Golf Course Architecture" by Dr. Michael J. Hurdzan was one of the few sources that touched on this idea. This book was one of the few that had a strong link between how to design in an environmentally friendly way of thinking while still acknowledging the importance of good golf course design strategy.

"Golf Course Development and Real Estate" by Desmond Muirhead and Guy L. Rando looked at golf course design from a larger planning scale and using a golf course as open space in a community; This book looked at theoretically applying the hydrologic cycle down to the golf course scale.

After reading the book, "Bunkers, Pits and Other Hazards" by Forrest L. Richardson and Mark K. Fine, the term water hazards became the driving concept for the project. Although the book was not written with the environmental ideas described in the other sources, this book brought to my attention how important and meaningful has been to golf throughout the history of the game. I decided to focus on the water hazard because of the importance to the game, and the ability to address flooding by rethinking how this part of the golf course is designed. The concept of a water hazard connects the two ideas of stormwater management and golf course design in one place. The water hazard is where stormwater management strategies are most likely to be accepted from the golf industry. This is a place on the golf course where there are missed opportunities to implement strategies that not only benefit the environment, but also add to the golf experience, while solving problems that help the community.

Many other sources of literature were used but these were the main sources that shaped the concept of the project presented here in this report. A detailed literature review of individual sources can be found in Appendix-C. There are many sources that contain good ideas and show how different strategies were applied to different parts of a project. But there is not a lot of information on the application of these techniques used throughout the entire design of a project.

LITERATURE MAP

The literature map in Figure 2.1 graphically illustrates how the major topics of each source of literature relate to one another, as well as, the importance to my individual project.

The circles overlap to show the relationships between each of the topics. The size and color of the circles represent the hierarchy of importance to the development of my project. Dotted lines indicate the major topics found within the source of literature. Dotted lines in bold indicate the most important sources used.

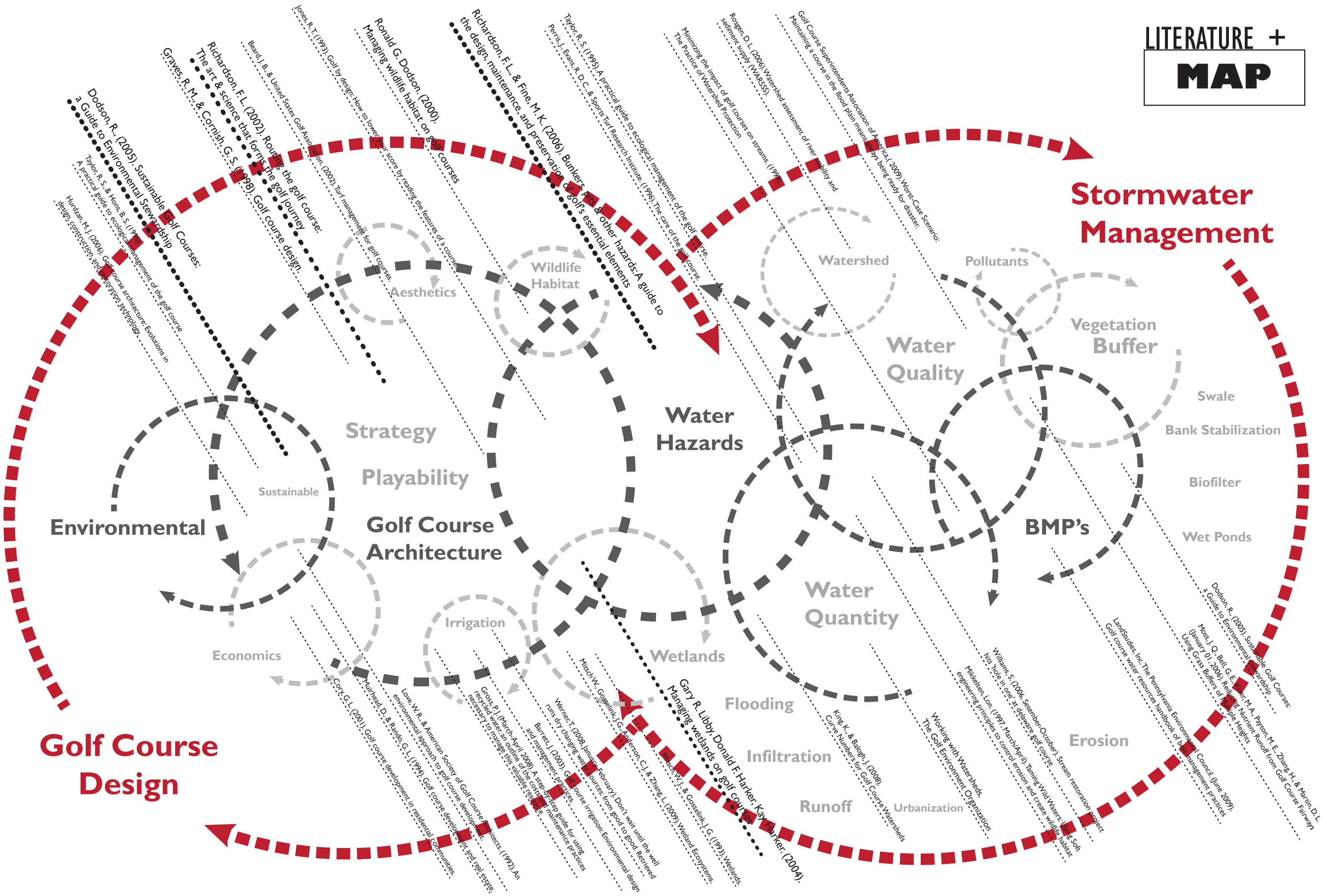


Figure 2.1 Literature map (Created by author, 2012)

BACKGROUND INFORMATION BASED ON LITERATURE

What is a hazard?

What is a hazard in the game of golf? The basic theory of a hazard is to complicate or influence golf shot making so that golfers try to avoid them and, in doing so, create a strategy to play the hole. Golf courses without hazards can be uninteresting while having too many hazards can make the course too difficult. Finding a balance produces the most desirable experience for golfers (Hurdzan, 2006, p. 44).

The concept of a hazard became a defined term over time. Historically the word was used to describe any obstacle that could impede play. Today the rules of golf refer to a defined area marked on the golf course. The term is mostly used to refer to bunkers and water (Richardson & Fine, 2006, p. 12). For the purpose of this report, the term hazard is referring specifically to water hazards of both wet and dry types. A wet water hazard includes lakes, ponds, creeks, wetlands, and any type of reservoir used to hold water. When a ball is hit into these areas, the ball is not recoverable. Dry water hazards are defined under the rules of golf as water hazards yet they are dry most of the time such as infiltration of water into the ground. When a ball is hit into dry hazards; a person can still play his or her shot if the ball is found. All challenging shots in golf are defined by one type of hazard or another (Richardson & Fine, 2006, p. 38). The best hazards create temptation and make the golfer think.

Psychological effects of hazards

A golfer's reaction to a hazard depends on their mindset, the context of the round, a golfer's confidence and their ability to execute the shot. Because of the unpredictably of the golf swing, hazards often introduce the element of fear in the golfer's experience. (Richardson & Fine, 2006, p. 138) The most interesting hazards on a golf course are those that challenge the golfer's competence level. A course that is too easy can lead to boredom. Designs that are too difficult can induce excessive stress (Richardson & Fine, 2006, 136). The goal is to achieve a balance of optimal playing difficulty. If the hazard is too easy or too difficult, then it will not challenge the golfer's playing ability and there will be no emotional response from the golfer (Richardson & Fine, 2006, p.140).

Perception

The actual difficulty of a hazard and the perceived difficulty of the hazard are not the same. Water hazards are perceived to be highly difficult, get the attention of the golfer, stimulate the imagination, and produce an emotional response. A design that is more visually interesting, will be more exciting, and will tend to be perceived as more hazardous even though it may not add more strokes to the scorecard (Richardson & Fine, 2006, p. 145).

Memorability

Unique hazards generate interest and attract golfers and bring marketing potential to the golf course. Hazards are the part of the golf course that golfers will remember the most when they think about the design of a golf course. The best golf courses offer one unique feature that makes it distinctive and memorable. When a golf hole has nothing distinct about it, the hole tends to be forgotten (Richardson & Fine, 2006, 178).

Function, drainage, aesthetics, strategy and playability must be taken into account when designing hazards (Richardson & Fine, 2006, p. 154). Large water hazards must be analyzed for potential benefits, suitability, and efficiency. Preserving natural areas is an excellent way to integrate golf with environmentally sensitive areas. If a hazard can live on its own without someone having to maintain the hazard, then the long term cost associated with maintenance can outweigh a hazard that has to be constantly maintained. Wetlands are an example of a self-sustaining ecosystem (Richardson & Fine, 2006, p. 171). When natural hazards are unavailable, there are both strategic and non-strategic needs to construct artificial hazards. (Richardson, 2006, p. 198). Water serves many useful purposes on the golf course. Ponds and lakes can be used as a safety buffer between golf holes, as well as, a natural buffer that preserves diverse wildlife. Water hazards enhance the aesthetics, provide a source of irrigation, and accommodate for drainage from both on and off site. The soil excavated can provide the fill material to raise fairways, tees, and greens (Hurdzan, 2006, p. 105). Creating a water hazard for good drainage on the course plays just as important of a role as does creating a hazard for aesthetic reasons (Richardson & Fine 2006, p. 200).

Par-3 Design Strategy

The par-3 hole represents a unique condition in golf. A par-3 is a hole that is meant to be played in one tee shot and two putts (Richardson & Fine, 2006, p. 165). This type of hole provides an opportunity to minimize the amount of maintained turfgrass, because of the reduced need for a fairway. Both par-4's and par-5's require a large amount of continuous maintained fairway where as, a par-3 only requires a tee and a green with a small amount of maintained turfgrass to make the hole more playable when golfers miss the green. The area between the tee and the green is available to be planted with native vegetation or defined as a water hazard.

BACKGROUND INFORMATION BASED ON LITERATURE

Design strategies for using hazards

The basic golf shot types and their relationships to a hazard are as follows:

1. **Penal:** A strategy associated with forced carry over an obstacle. This is when the hazard is in the way of a shot and requires the player to carry the ball over the hazard.
2. **Heroic:** This strategy is where the hazard offers incremental degrees of risk and reward, the greater the risk, the better the outcome if golfer can execute the shot correctly.
3. **Detour:** A type of situation where the hazard creates multiple choices for the golfer. These types offer distinct paths around obstacles. You have a choice of whether to bring the hazard into play or not.
4. **Lay-up:** This is where the hazard requires a shorter shot than what the player is normally capable of hitting (Richardson & Fine, 2006, p.39).

Dr. Ed Sadalla, a contributor to the book Routing the Golf Course, says "The way in which water is incorporated into the scene… may increase or decrease its potency." Sadalla cites four factors that add interest and intrigue to water hazards:

1. **Land-water contrast:** The extent to which the distinction between land and water is visible.
2. **Shoreline Complexity**: The variety of shapes that result where land meets water.
3. **Size:** The diversity in the sizes of water area, which tends to add interest.
4. **Internal Contrast:** The height and texture of vegetation within a water feature (Richardson & Fine, 2006, p. 28).

Playability

Playability relates to how fair the game of golf is for players of all ages and skill levels. Playability is what influences the location, size, and shape of features on a golf course. If a golf course is too difficult to play, the experience will not be enjoyable for players of all skill levels. A golf course can be difficult to play from the back tees and still be playable for everyone else. A low handicap player is defined as someone with a higher skill level while a high handicap player is someone with a lower skill level. Golf holes with a penal design force a player to carry the ball over a hazard and are much harder for the average to high handicap golfer. Heroic and strategically designed holes generally have a higher rating of fairness. The fairness of a hole can be altered by the position of the tee box, which is what determines the line of play to the landing area. Increasing the size of the landing areas, hazards, and other design features that define the hole can make the game more playable. Golfers do not mind being fairly challenged and failing, but they do not like holes that demand more out of them than they are capable of. One example of this situation is when a golfer executes a shot to the best of their ability, and still ends up in trouble. Average golfers play for the enjoyment of the game and the recreational value of the sport, so a course should be designed to deliver this experience (Hurdzan, 2006, p. 38).

Case Studies

INTRODUCTION TO CASE STUDY SELECTION

The projects that were chosen for case study analysis in Figure 2.2 were all relevant to a proposal for a golf course that could be built in Manhattan. Not only for recreation but as a way to integrate golf along a stream while at the same time having a positive impact on the Wildcat Creek Watershed in terms of quality and helping to reduce flooding downstream. Raptor Bay and The Old Collier Golf Club were chosen for their environmental aspects of design and specific strategies for holding water and improving water quality. I broke down and simplified the basic process of how to integrate lakes into a golf course for holding water. This was a strategy that I could utilize during the design process. The next four golf courses studied were all located in the Kansas City area. The reason for this decision was because I had access to visit all of them on site as well as GIS data to generate maps from. I have also played each of them from the golfers perspective. I chose to look at these specific courses because of their site characteristics and natural features that define these courses, such as the proximity of the golf hole to the creek running through the golf course. The other important factor to consider was how the golf course fits into the overall watershed. These are some of the premier courses in the country and are also some of the toughest. Hamilton Farms was chosen because it was designed by one of the leading environmental golf design firms. What makes this course different from the other courses is that it is the only United States Golf Association (U.S.G.A.) rated par three golf course in the country. Most Par 3 courses are too short to meet the minimum requirements to be rated by the U.S.G.A. This provides a huge advantage over similar courses because of the marketing value that it could bring to a project like the one presented in this report. This could become a catalyst in connecting the environmental side of the project to the golf industry and help promote awareness that a typical golf course might not receive.

CASE STUDY SELECTION METHODOLOGY

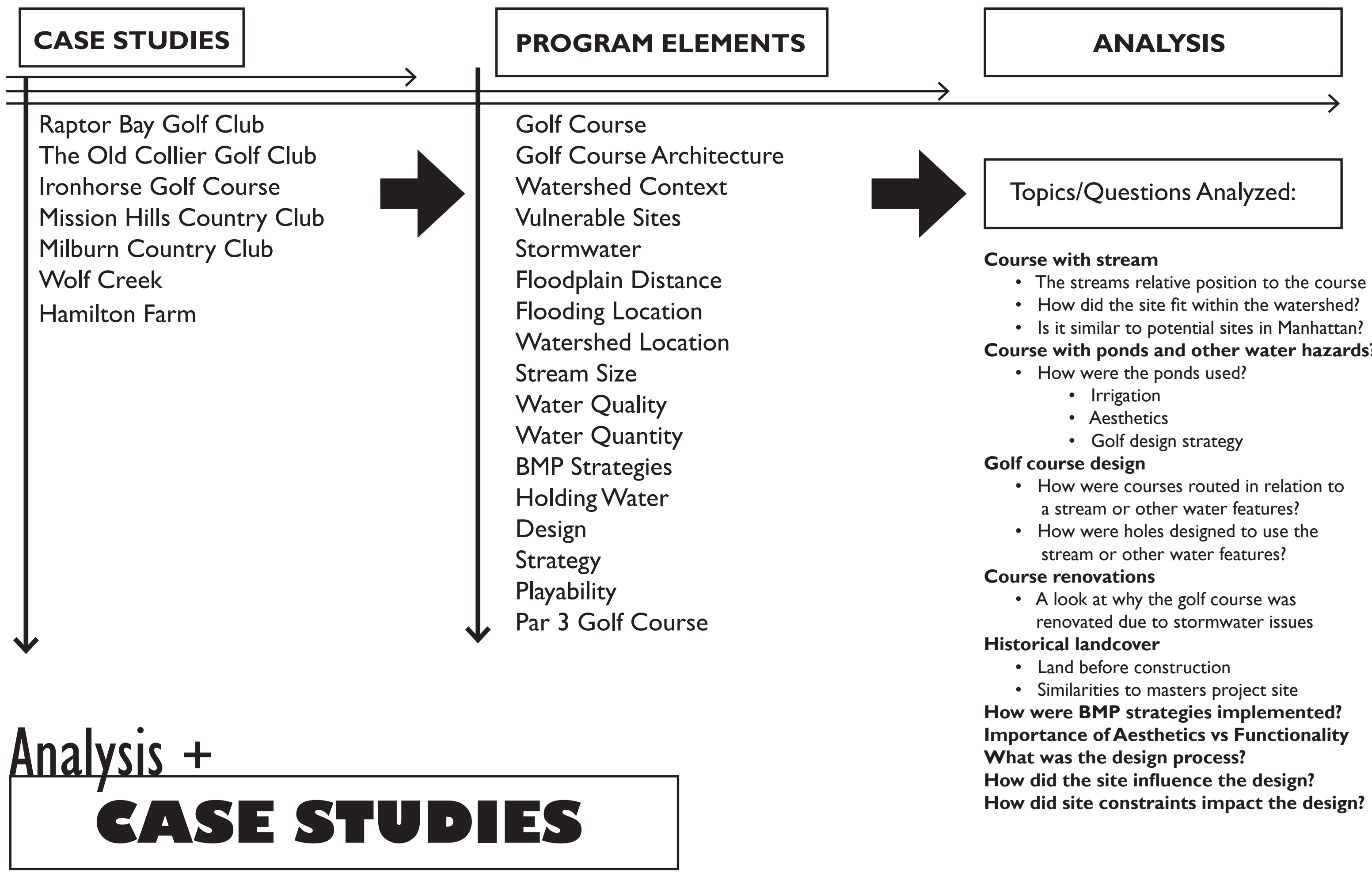


Figure 2.2 Case study selection method (Created by author, 2012)

RAPTOR BAY GOLF CLUB - CASE STUDY

Bonita Springs, Florida
Wetlands designed to treat golf course runoff

KEY FACTS:

Project Issues:
Managing Water sources for golf, wildlife, aesthetics, irrigation, while maintaining overall water quality.

Keywords:
Water Quality
BMP's
Phytozones- A shallow forebay a the edge of the lake.

Holes: 18
Type: Resort Golf Course
Designer: Raymond Floyd
Owner: WCI Communities, Inc.

Awards:
March 2002 became 3rd Audubon International Gold Signature Sanctuary golf course in the world

Site:
The majority of the site consists of vegetated uplands, along with freshwater and brackish water wetlands. A creek runs through the property and drains into the Estero River and then into the Estero Bay.
Total project: 510 Acres
Conservation Easements: 150 Acres (contains, nesting bald eagles, and several gopher tortoises. There is a nature trail and interpretive signs detailing the ecosystem.)
Lakes: 22 Acres
Vegetation:
200 acres of native vegetation and nature preserve are pine flatwoods, xeric oak, and cypress.
Region: Southern Coastal Plain
Watershed: Upper St. Johns

Introduction

Developers often ignore the key natural features of a site when planning a new project. Audubon International has an ecologically based approach when they develop a new project. They will focus on letting the key features become the dominate features of a project. Their approach is to let the existing lay of the land shown in Figure 2.3, control where things go. There are often major constraints to deal with and one of those constraints is protected wildlife species on the property.

The majority of the site consists of vegetative uplands and freshwater wetlands shown in Figure 2.4. One strategy unique to this case study is the idea of a phytozone, which is a planted with native vegetation selected for the ability to take up and filter dissolved nutrients. These phytozones shown if Figure 2.5 are formed by wide earth berms which surround the lake. The pollutants from stormwater runoff settle into the phytozones, which slows and holds stormwater before it flows into the main body of the lakes.

COURSE LAYOUT

Figure 2.3 Aerial photo taken before construction in 1999 (Google Earth, 2010)

Figure 2.4 Aerial photo taken after construction in 2010 (Google Earth, 2010)

PHYTOZONES

Figure 2.5 A lake with a smaller phytozone under construction
(Libby et al., 2004, p.50)

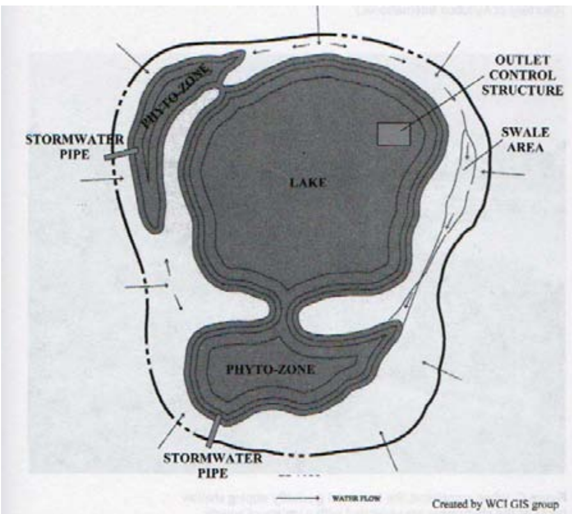


Figure 2.6 Phytozone diagram (Libby et al., 2004, p. 49)

What is a phytozone?

Figure 2.6 illustrates the phytozone concept, which is a shallow forebay a the edge of the lake that integrates the treatment benefits of both a detention basin and a constructed wetland. They are small wetland pockets, constructed to treat runoff from the golf course. They also provide habitat and feeding areas for birds and other wildlife (Libby et al., 2004, p.48).

How phytozones work

- Phytozones protect water quality in lakes both on-site and in water bodies downstream.
- A wide earth berm separates a shallow pool from the main body of the lake. Each phytozone is built so that it receives runoff from stormwater drainage or from swales around the lake.
- The runoff is detained before flowing into the main body of the lake. The phytozone temporarily stores and slows runoff by letting pollutants and solids settle.
- The vegetation planted in the phytozone filters dissolved nutrients.
- Phytozones are sized to treat runoff from smaller frequent storms which has the greatest potential to degrade water quality (Libby et al., 2004, p. 51).

RAPTOR BAY GOLF CLUB - CASE STUDY

Bonita Springs, Florida
Wetlands designed to treat golf course runoff

PHYTOZONES AT RAPTOR BAY

Figure 2.7 Large phytozones (Google Earth, 2010)

Figure 2.9 Golf holes surround all sides of the water (Google Earth, 2010)

Figure 2.8 Use of smaller phytozones (Google Earth, 2010)

Figure 2.10 Golf holes under construction (Google Earth, 2010)

Analysis

Figure 2.7 and Figure 2.8 show several different water hazards on the golf course utilizing the phytozone concept to manage water quality. Drainage from the fairways is controlled by how and where it enters the ponds. Figure 2.9 shows how the holes are designed around each of the hazards for maximum water usage. Often times several holes utilize the same body of water. There may be water on an approach shot to a green on one hole, and then the next hole the water hazard is used to influence your tee shot. In each case the phytozone approach does not affect the playability of a hole, it only affects the aesthetics of the pond visually. Figure 2.10 shows a pond on the golf course under construction. The pond was put in place before the golf holes were built around it. This type of strategy might not be as aesthetically pleasing for a period of time until the vegetation has fully grown in.

Benefits

Phytozones have dramatically increased the variety of bird species at Raptor Bay. Results from the wildlife monitoring program have indicated a substantial increase in the variety of bird species on the property. Twenty-two new species of birds were added to the original list. The berm and gradually sloping shallow banks of the phytozones are vegetated with a variety of aquatic plants shown in Figure 2.11. These plants provide the added benefit of water quality treatment through a combination of trapping solids and taking up dissolved nutrients (Libby et al., 2004, p.

Significance to masters report

The change in elevation on this site ranges from 3 to 12 feet. This is similar to many of the possible sites for a proposed new golf course along the Wildcat Creek. Water slowly accumulates in the lowest points, and over time, significantly influences the character of the site. In the areas that remain wet, vegetation is taller and has greater density which leads to species diversity, and structural diversity providing habitat for many wildlife species. When building Raptor Bay, the designers were challenged with the constraints of having bald eagles on site which are a protected species. This is similar to one of the constraints in the Wildcat Creek Watershed which contains the Topeka Shiner. The Topeka shiner is an endangered minnow that is less than 3 inches long.

Figure 2.11 Phytozone after vegetation grows in (Libby et al., 2004, p. 51)

THE OLD COLLIER GOLF CLUB - CASE STUDY
Naples, Florida
Audubon International Certified Gold Signature Golf Course

KEY FACTS:

Project Issues:
Sustainable economic development and long term environmental quality.

Keywords:
Regional hydrology
Wetlands
Threatened species habitat
Water quality management

Holes: 18
Type: Golf only nature preserve
Designer: Fazio Golf Course Designers
Year Built: 2001

Awards:
1st Audubon International Gold Signature Golf Course

Site:
267 acres total golf course
77 acres of irrigated turf
28 acres of surface water distributed
11 man-made lakes
109 acres of connected native habitat

Region: Upland habitat

Introduction

Old Collier Golf Club shown in Figure 2.12 is the first Audubon International Gold Signature Sanctuary. The design took into account both golfers and wildlife with a new approach to water use, land management, and selection of turf and native plants. The final result provides a great experience for golfers, and at the same time, provides a new model for environmental stewardship.

With a Gold Signature course, members established a partnership with Audubon International prior to selecting the site and design. Audubon International prepared an Environmental Master Plan for all aspects of the property, including detailed, site-specific strategies for natural resource conservation and management, architecture, infrastructure, landscaping, and community outreach. The Old Collier Golf Club showcases the concept of co-habitable "common ground" for sustainable economic development and long-term environmental quality.

Figure 2.12 Golf course layout as it exist in 2011 (Google Earth, 2011)

Turf areas were limited to 77 acres, 35% less than the 90 to 130 acre average for golf courses. By using less turf, irrigation needs were reduced, as well as nutrient run-off, and maintenance costs. Protective berms were created to divert surface runoff away from the mangrove buffer and river. The use of diffusers in lakes and wetlands provide oxygen and prevent killing the fish. Diffusers last longer and use 75% less electricity than fountains. The concrete cart paths were installed only in high use areas and on slopes. The use of pervious concrete blends in with the white sand. Concrete paths lasts longer than asphalt and are 40-70F degrees cooler. (Landscape Architecture Foundation, http://lafoundation.org/research/landscape-performance-series/case-studies/case-study/107/)

Water Quality was the overriding factor in the Old Collier Golf Club. The objective was to maintain or improve the hydrologic standard that was in place prior to property development. The property served as a buffer zone between the river and the 400 acre Naples Park Residential development. The golf course project could not alter the existing hydrology of the area. The property was equipped to retain the total water equivalent of a 25-year storm falling within the property border plus the water draining from Naples Park following a storm (Dodson, 2005, p. 237).

Figure 2.13 shows the property prior to construction. To control and contain the projected water volume from a 25 year storm, eleven lakes (over 28 acres) were constructed as shown in Figure 2.14. Underground pipes connect nine of the eleven lakes so that they may act as a unified storm water management system. Three side by side, 72 inch pipes carry the stormwater from Naples Park through two lakes and then into a wetland zone. The rest of the stormwater is carried through 24 inch pipes. Water quality Best Management Practices(BMP's) include:

- Minimizing chemical applications.
- Implementing operational procedures that isolate turf chemicals from the lakes.
- Irrigation is limited to turfgrass areas only (Dodson, 2005, p. 237).

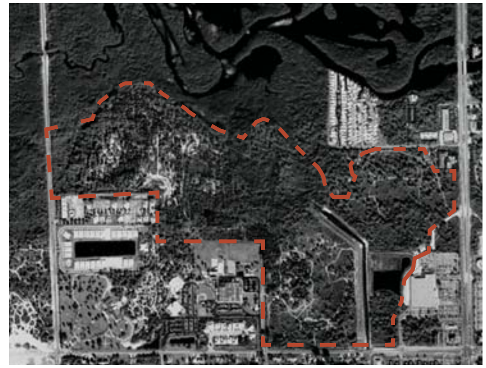


Figure 2.13 Property prior to construction in 1999 (Google Earth, 1999)

Figure 2.14 Golf course layout as it exist in 2011 (Google Earth, 2011)

THE OLD COLLIER GOLF CLUB - CASE STUDY

Naples, Florida

Audubon International Certified Gold Signature Golf Course

Design Process Methodology

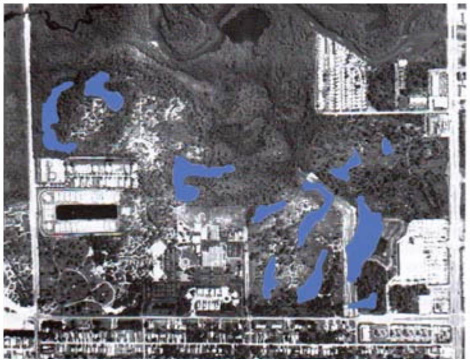


Figure 2.15 Final location of water management lakes (Adapted by author from Dodson, 2005, p.238)

Figure 2.16 Location of Underground pipes for the water management system (Adapted by author from Dodson, 2005, p. 238)

Figure 2.17 Proposed Site plan in January 2000 (Adapted by author from Dodson, 2005, p.239)

Determine lake locations

Connect lakes with pipes

Integrate golf around lakes

Design Process Methodology

Before golf holes were designed, figure 2.15 shows how areas suitable to hold water for irrigation were identified first. Next pipes were installed to connect each of the lakes together. This way the lakes could act as one water management system as seen in figure 2.16. After the stormwater management system was designed, the golf holes were routed around the lakes. The lakes then became water hazards on the course serving multiple functions as seen in Figure 2.17.

Figure 2.18 Habbitat corridors (Google Earth, 2011, adapted by author from http://lafoundation.org/research/landscape-performance-series/case-studies/case-study/107/photos/additional-42/, accessed 2012)

Habitat Corridors

Figure 2.18 shows how the golf course was designed to allow wildlife to travel from one area to the other without the golf course being a barrier. When designed this way animals can move throughout the course from one area of wilderness to another. This increases wildlife on the golf course, as well as, allowing wildlife to thrive in areas surrounding the golf course.

By reducing areas of irrigated turfgrass and using native vegetation in out of play areas, one can create natural corridors and reduce irrigation needs without impacting playability. One example of these areas is the area between tee boxes and the fairway.

Benefits

• Increased number of bird species on the site from 60 to 118. The site has also seen a significant increase in local fauna, including alligators, foxes and the threatened gopher tortoise.

• Retains rainfall from the golf course, as wells as, drainage from a neighborhood to the south for a **25-year storm** event using **eleven water management lakes**.

• Saves $35,000/year in water use compared to a typical golf course by using brackish water from the adjacent Cocohatchee River for irrigation.

Analysis

Several key factors will be taken away from this case study. This project was designed with specific goals. The amount of turfgrass was minimized compared to most golf courses. Hydrology was taken into account from the beginning. The course was designed to hold the volume of water from a 25 year storm plus a park off site. The design process was studied as a way to design golf holes around the hazards rather than trying to fit the hazards in after the routing was completed.

IRONHORSE GOLF CLUB - CASE STUDY
Leawood, Kansas

Key Facts:

Project Issues:
Every effort was made during construction to maintain the natural aspect of the land.

Keywords:
Floodplain
Renovation

Holes: 18
Type: Public golf course
Designer: Hurdzan/Fry Environmental Golf Design
Year Built: 1995

Awards:
1995 Kansas

Course Layout

Figure 2.19 Ironhorse site before construction (Google Earth, 1991)

Figure 2.20 Ironhorse Golf Course Layout
(Generated from GIS NRCS Data by author, 2012)

Figure 2.21 Ironhorse Golf Course Layout (Google Earth, 2011)

Introduction

Ironhorse Golf Club is located in Leawood, Kansas. The course was named Ironhorse after an abandoned railroad right of way that ran through the property (http://clubsg.skygolf.com/courses/course/6421/Ironhorse_Golf_Club.html). One of the unique features of the golf course is the creek that runs through the center of the golf course. The riparian zone around the creek can be seen in Figure 2.19 before construction took place. The course was designed so that the creek comes into play on 17 of the 18 holes. Figure 2.20 shows the extent of the floodplain that covers the golf course. Large sycamore trees, and limestone rocks can be found throughout the course. Figure 2.21 shows the golf course as it is today. The riparian vegetation is not as dense as it was before the course was built, although they left as much woody vegetation as possible. Figure 2.22 shows how the golf course is the outlet for five smaller watersheds.

Watershed Context

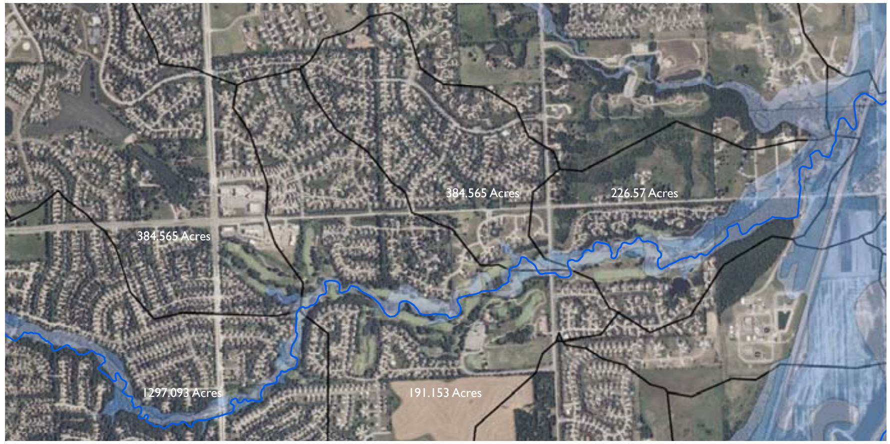


Figure 2.22 Ironhorse Golf Course layout (Generated from GIS NRCS data by author, 2012)

LEGEND

- Streams
- 500 Year
- 100 Year
- Watershed

Design Process

The site on which Ironhorse was built was part of a private/public agreement where a housing developer gave the city land for golf development while the developer kept the surrounding land for housing development. This is a common situation that works very well, because the developer does not have the money to finance the golf course and the city is trying to increase its property for recreation. A golf course is also a profit producing operation. In this case the developer gave the city a series of hilltops and bottomlands next to a creek that regularly floods. The creek normally floods three to four feet above its banks. There were many constraints to deal with on this project. The floodplain had deep soil deposits while the hilltops had thin soils over rock. The golf course site is also bisected by Mission Road, which is the main access road to the course shown in Figure 2.23. The budget only allowed for a single tunnel to be installed under the road so the routing had to work with this single crossing (Hurdzan,2006, p. 224).

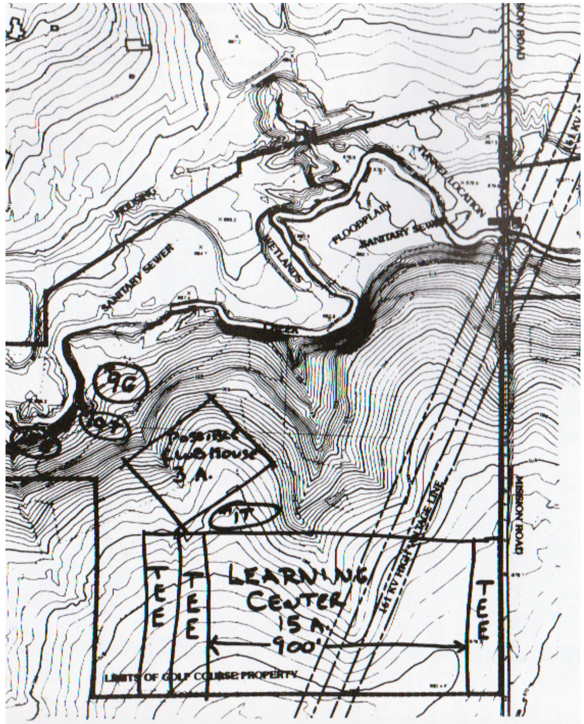


Figure 2.23 Possible clubhouse location, learning center, starting number one and number ten tees, and finishing nine and eighteen green. (Hurdzan, 2006, p. 226)

Design Process

The first thing to do was identify a possible clubhouse location that could be serviced with utilities, easy access, good views, and allow for returning nines. Because most of the land was floodplain, the location was limited to high ground. Three acres were blocked off for the clubhouse, and 15 acres were reserved for the practice facilities. The practice area was given 1200 feet by 500 feet, which allows for tees at both ends and from 45 to 50 stations to hit from, as well as, 900 feet from the front of the tee to the front of the other tee. The starting and finishing points for each nine were made to be within 100 yards of the clubhouse (Hurdzan, 2006, p. 227). The practice area was given 1200 feet by 500 feet which allows for tees at both ends and from 45 to 50 stations to hit from as well as 900 feet from the front of the tee to the front of the other tee. The starting and finishing points for each nine were made to be within 100 yards of the clubhouse (Hurdzan, 2006, p 227). The schematic design phase for the first nine holes is shown in Figure 2.24.

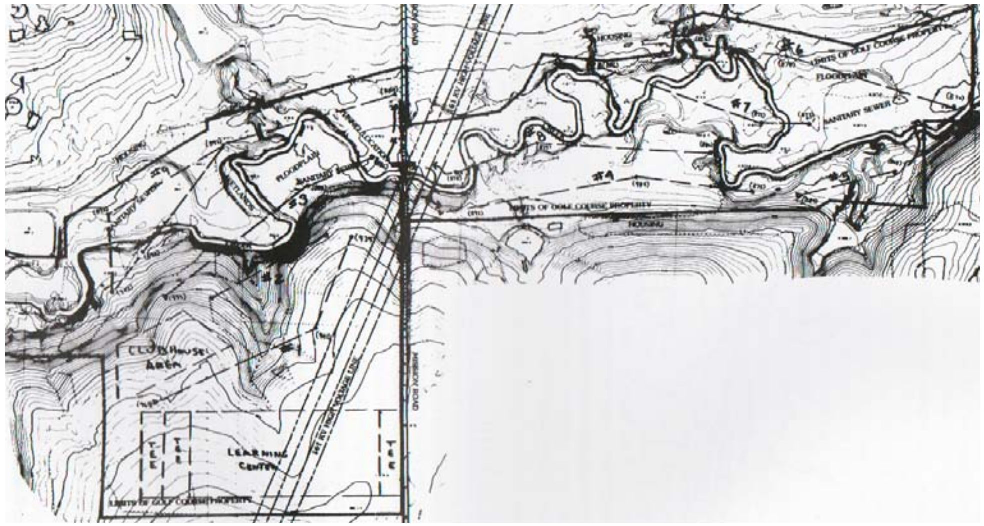


Figure 2.24 Schematic design of the first nine holes at Ironhorse Golf Course. (Hurdzan, 2006, p. 233)

Design Process

Next, holes were laid out starting with the extreme back tee and marking 810 feet for a professional golfer's tee shot landing area. The fairway landing areas were made to be at least 40 yards wide with only about a three percent slope from one side to the other (Hurdzan, 2006, p. 229). Once the routing works, the course is then refined in the design development stage. This stage is shown in Figure 2.25, where shapes, the sizes additional tees, fairways, greens, bunkers, hazards and other water features are defined in the plan. The design development stage is where the architect starts thinking about strategy, drainage, earthwork, and other environmental impacts. The strategy of a hole determines the placement of the hazard (Hurdzan, 2006, p. 234).

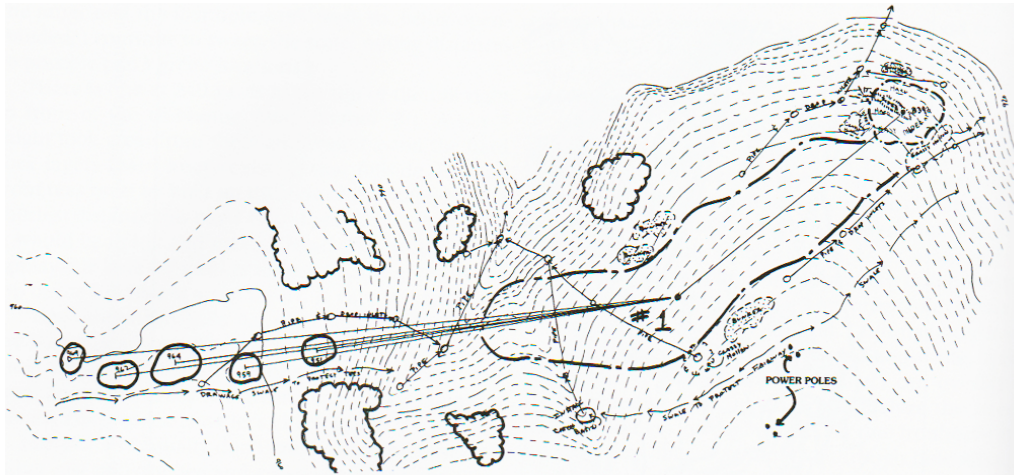


Figure 2.25 During design development the size of the golf features are determined, as well as, strategy and drainage (Hurdzan, 2006, p.234)

Streambank Stabilization

Figure 2.26 Ironhorse Golf Club stream
(Photo courtesy of Ironhorse Golf Club)

Figure 2.27 Ironhorse Golf Club stream
(Photo courtesy of Ironhorse Golf Club)

Figure 2.28 Ironhorse Golf Club stream
(Photo courtesy of Ironhorse Golf Club)

The photos above were taken when the golf course was being renovated due to flooding. Figure 2.26 shows how rip-rap was added to stabilize the bank. The excavator in Figure 2.27 illustrates the height of the cut bank. Figure 2.28 shows the bank just before vegetation was replanted. Golf holes border both sides of the creek in Figure 2.29. Riparian vegetation was left to protect the stream corridor and create a safety buffer between the holes. The large trees on the left side of the hole help to frame the hole and direct the tee shot.

Figure 2.29 Golf holes boarder each side of the creek (Photo by author)

MISSION HILLS COUNTRY CLUB - CASE STUDY
Mission Hills, Kansas

KEY FACTS:

Project Issues:
Built in a floodplain along Brush Creek
Controled by Corp of Engineers

Keywords:
Floodplain
Creek
Renovation

Holes: 18
Type: Private Country Club
Designer: Tom Bendelow
Year Built: 1914

Site: 121 Acres

(http://missionhillscc.member-statements.com/tour/tours)

Introduction

Stretching across 121 acres in Kansas the golf course was built along Brush Creek shown in Figure 2.30. Mission Hills has had a history of flooding problems associated with flash flooding during periods of heavy rains. Modifications to the stream have to be approved by the Army Corp of Engineers. This is a similar situation to Wildcat Creek. The course is located on the banks and hills of Brush Creek. Rock Creek flows into Brush Creek on the southwest corner of the site near the 17th hole. The floodprone areas in Mission Hills are attributed to the increased development in the western area of the watershed. Ever since this time of increased development, Rock Creek and Brush Creek have flooded with greater frequency than previously experienced.

Watershed Context

LEGEND
100 Year Floodplain
500 Year Floodplain
Streams
Watershed Boundaries

Figure 2.30 Mission Hills Golf Course layout diagram
(Generated from GIS NRCS data by author, 2012)

Renovations

In 2006 Mission Hills renovated the entire course to replace the type of grass used on the greens and renovated the bunkers around them. The greens were updated to a new type of grass that could tolerate heat better and would be more resistant to disease. The club took this opportunity to expand the practice range and change the routing of several of the holes.

The second hole was originally a short par three that cut the corner of Brush Creek as shown in Figure 2.31. If a person missed the shot to the right, the ball would land in the creek. In the new design shown in Figure 2.32, the holes were rearranged allow more room to expand the driving range. In many of the old traditional style golf courses a practice facility and driving range were not part of the original designs. This shows that a driving range is a highly desirable amenity to include in the design of new golf courses. A practice facility should always be included in the design from the beginning.

Figure 2.31 Mission Hills prior to renovation 2006 (Google Earth,2006)

Figure 2.32 Mission Hills after renovation 2011 (Google Earth, 2011)

MISSION HILLS COUNTRY CLUB - CASE STUDY
Mission Hills, Kansas

Analysis

This golf course was built along an unstable stream similar to Wildcat Creek and the site for the proposed project in this report. In both situations the flooding causing problems is due to flash floods with higher amounts of rainfall within a short period of time. Figure 2.33 shows how loss of floodplain access and constriction of the stream channel create a higher velocity of water moving downstream, because there is no where for the water to infiltrate into the ground.

Figure 2.34 shows where taller vegetation was left along the stream bank to prevent erosion. Figure 2.35 shows the creek running along the right side of the golf hole to force the golfer to hit the ball straight. If they miss the fairway they will have a difficult time hitting over the creek again to reach the seventeenth green in Figure 2.36. The green is strategically placed on the other side of the creek guarded by a large tree. This hole is one of the toughest in the city because of the position of the creek in relation to the rest of the hole. The hole will play to the same degree of difficulty weather or not the water hazard is wet or dry. This hole is a good example of how natural features were used to create good golf strategy.

Figure 2.33 Brush Creek (Photo by author, 2012)

Figure 2.34 Bridge to hole seventeen green (Photo by author, 2012)

Figure 2.35 View from the seventeenth tee (Photo by author, 2012)

Figure 2.36 View of seventeeth green (Photo by author, 2012)

MILBURN COUNTRY CLUB - CASE STUDY
Overland Park, Kansas

KEY FACTS:

Project Issues:
Redesigning a water hazard to accommodate enough water for irrigation.

Type: Private Country Club
Architect: William Langford
Year Built: 1917
Design: Core Golf Course

Keywords:
Water Feature
Renovation
Irrigation

Holes: 18 Par 72

Yardage:

Championship	7,054	yards
Blue	6,776	yards
White	6,386	yards
Gold	5,892	yards
Red	5,819	yards

Watershed: Turkey Creek Tributary
Main Watershed: 186.533 Acres
Secondary Watershed: 133.939 Acres

Introduction

Situated on an upland site. The golf course property in Figure 2.37 is part of two major watersheds. The majority of the water leaving the course outfalls at the northwest corner of the property near the hole number five green complex. The two major ponds in figure 2.38 contain some of the stormwater draining from the course, but the ponds are also partially recharged by springs.

Course Layout

Figure 2.38 Milburn course layout diagram (Google Earth, 2011)

Watershed Context

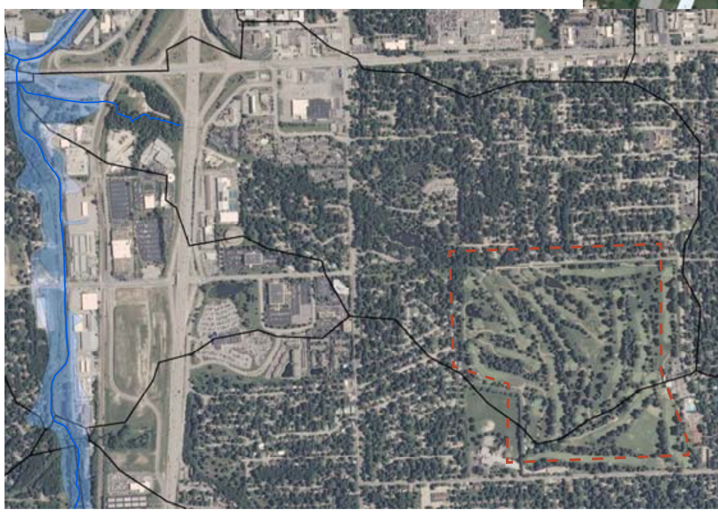


Figure 2.37 Watershed boundary diagram (Generated from GIS NRCS Data by author, 2012)

LEGEND

- 100 Year Floodplain
- 500 Year Floodplain
- Streams
- Watershed Boundaries

Water Hazard Design

Figure 2.39 Existing lake on hole number five (Google Earth, 2012)

Figure 2.40 Proposed redesign of hole number five
(Sechrest Golf Design, Consulting, and Planning, Master Plan for Milburn Country Club 2004)

In 2004, a study was conducted to look at redesigning the pond in Figure 2.39 to increase the storage capacity for irrigation. This was a good example of Strategic golf design of a hazard to accomplish a functional need. The new design shown in Figure 2.40 would not force people to play over the hazard so it would only challenge the better players, rather than hurt the higher handicap player. Not only would this allow them to store more water, but it would also address drainage issues, improve aesthetes, and create a signature hole. Increasing the size of the pond would allow enough water to be stored for use as an alternative source of irrigation water rather than relying on municipal water. This project has not been completed yet, but was part of a master plan by Sechrest Golf Design Consulting and Planning in 2004.

WOLF CREEK - CASE STUDY
Leawood, Kansas

Key Facts:

Holes: 18 Hole Core Golf Course
Par: 72
Yardage: 7,010
Course Rating: 75.7
Course Slope: 144

Type: Private Country Club
Architect: Marvin Ferguson
Year Built: 1971
Year Renovated: 2006 CE Golf Design

Site: 240 Acres

Greens: A4 Bentgrass
Fairways: Meyer Zoysia

Tees: Meyer Zoysia
Roughs: Bluegrass & Fescue Mix
Bunkers: 43
Sand: "Ohio White" sand
Creek: "Wolf Creek"
comes ito play on 11 holes
Lake: 5 acres
comes into play on 2 holes
Native Grasses: 70 acres

Practice Facilities
All Season Practice Facility. 1,000 sq. ft. building with 3 hitting bays from indoor to outdoor with indoor putting green. Located on the driving range. Practice range has zoysia tee boxes on both ends.
Short game practice area:
5 putting & chipping greens and 3 practice bunkers

Course Layout

Figure 2.41 Wolf Creek course layout diagram (Google Earth, 2011)

Introduction

Unlike most modern day golf clubs built by real estate-motivated developers, Wolf Creek was founded by a group of friends that had a love for the game of golf. The property was discovered and the golf course shown in Figure 2.41 was carved out of the woods (https://wolfcreekks.com).

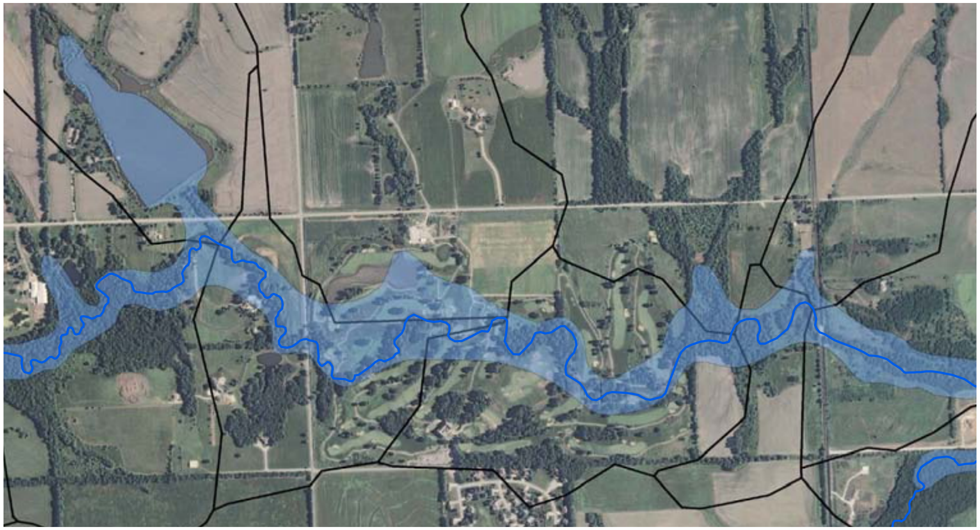


Figure 2.42 Wolf Creek watershed boundary diagram (Generated from GIS NRCS data by author, 2012)

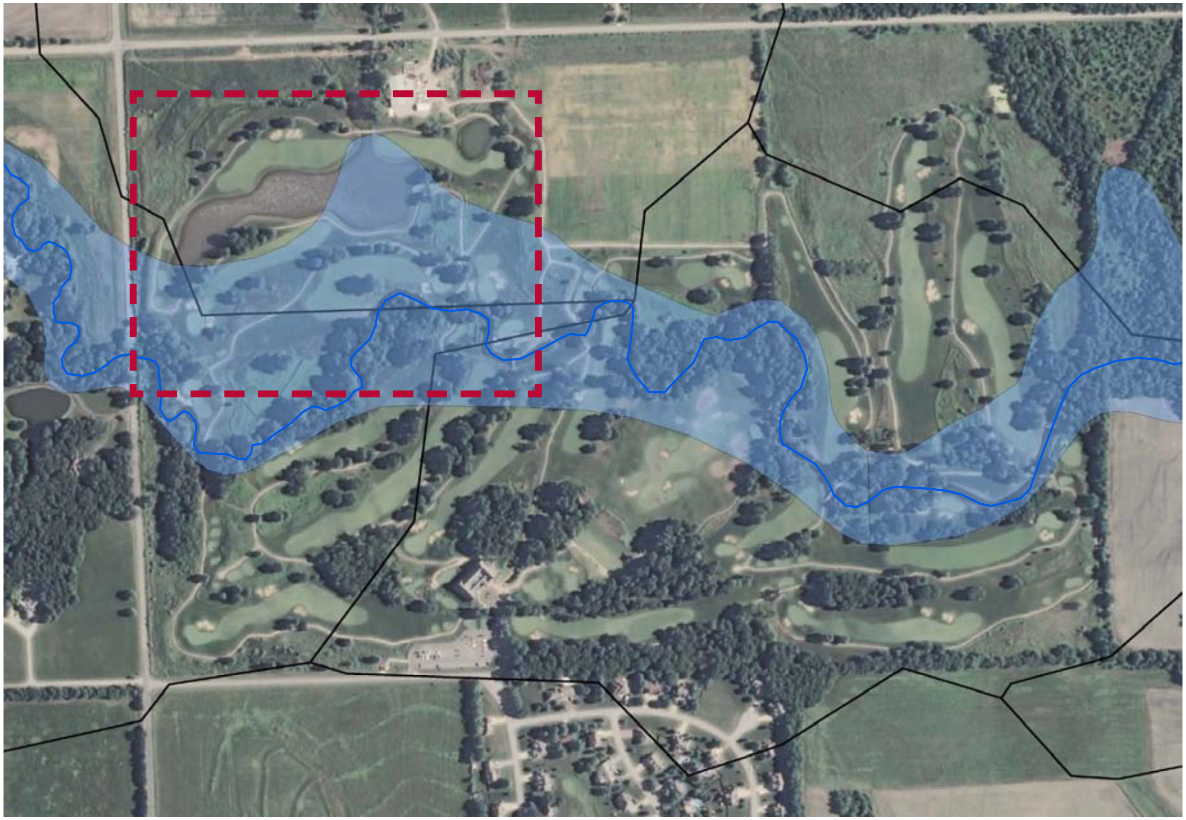
LEGEND

- 100 Year Floodplain
- 500 Year Floodplain
- Streams
- Watershed Boundaries

Renovations

Minor renovations have occurred on the course throughout the years, however much of the course, including most of the greens, have remained unchanged from the original design. The club determined that it was time to renovate the original greens to remove some problems that were present in the top 4” layer of the existing greens mix. This also gave the club the opportunity to change the bentgrass on the greens to A-4, which is a newer, more durable variety of bentgrass. Closing the course for a year to renovate the greens allowed for other golf course renovations to occur simultaneously, without creating additional downtime for the members. Drainage was improved throughout the course to help reduce the maintenance on this low-lying property situated within a floodplain shown in Figure 2.42 (http://www.cegolfdesign.com/cegolf.asp?link=WolfCreek).

WATER HAZARD DESIGN



LEGEND

- 100 Year Floodplain
- Streams
- Watershed Boundaries
- Site Location

Figure 2.43 Existing irrigation pond location map (Generate from NRCS GIS data by author, 2012)

Figure 2.44 Hole before renovation in 2003 (Generated from NRCS GIS data by author, 2012)

Figure 2.45 Hole after renovation in 2012 (Generated from NRCS GIS data by author, 2012)

Analysis

Figure 2.43 shows where the irrigation pond was expanded in relation to the hundred year flood plain. The existing irrigation lake in Figure 2.44 was expanded from two acres to more than five acres in Figure 2.45. A larger pump system was installed to handle the capacity necessary for the new irrigation system that includes more than 1,200 sprinkler heads.

The pond in Figure 2.47 comes further into the area of play now that it has been expanded. Water is now much closer to the edge of the fairway.

HAMILTON FARM GOLF CLUB - CASE STUDY
The Hickory Course
Gladstone, New Jersey

KEY FACTS:

Holes: 18 Hole Par 3 Golf Course

Par: 54

Yardage:
Blue: 3,080
White: 2,599

Course Rating: 57.5

Course Slope: 98

Type: Par 3 private golf course

Architects: Dr. Michael Hurdzan, ASGCA/Dana Fry, ASGCA

Year Built: 2001

PAR-3 GOLF COURSE

Figure 2.46 Course Layout (Google Earth, 2011)

Introduction

One of two courses on the property shown in Figure 2.46, the holes play uphill, downhill, over and beside both ponds, wetlands, trees, ravines and meadows making each hole very distinct and unique. Architects Michael Hurdzan and Dana Fry believe what makes the Hickory Course so much fun to play is the infinite variety of golf shots it demands of the golfers. A full eighteen holes, is the only USGA rated par 3 course in the United States and is designed to challenge every golfer's favorite shot. What sets this short course apart from others is the demands that it puts on the player's short game, which is the kind of challenge that will appeal to better players (http://www.hamiltonfarmgolfclub.com/Default.aspx?p=DynamicModule&pageid=235772&ssid=89025&vnf=1).

WATER HAZARD DESIGN

Figure 2.47 Hole number one (http://www.hamiltonfarmgolfclub.com/default.aspx?p=CourseHole&v)nf=1&ssid=87509&view=l2&crsID=1039&hole=1)

Figure 2.48 Hole number ten (http://www.hamiltonfarmgolfclub.com/default.aspx?p=CourseHole&vnf=1&ssid=87509&view=l2&crsID=1039&hole=1)

Project Relevance

This course was chosen as a case study because it demonstrates the use of a high quality challenging golf experience without the time commitments and space requirements to go with it. Figure 2.47 shows how a vegetative buffer was used around the pond. Being one of the best par-3 examples in the United States, This course provides a precedent for a course length of 3,000 yards. There is a trend moving toward non-traditional courses and taking par 3 golf to the next level. This course shows how one can implement a shorter course that will still challenge beginners, as well as, professionals. Figure 2.48 demonstrates how little fairway grass is needed on a hole. Most of the land between the tee and the green can be devoted to hazards on a par-3 hole. The 3,000 yard length is important because the United States Golf Association does not allow scores entered from courses under 3,000 yards in the handicap rating system. Most short courses were not designed like a championship course, and often many executive courses seem to lack an identity because they do not fall into a specific category like this course.

Chapter 3

Project Programming

Preliminary Program to Guide Site Selection

PROGRAMMING FRAMEWORK

Primary Areas

1. Clubhouse area
2. Practice facilities
3. Golf course configuration and components
4. Maintenance facilities

Clubhouse Area Programming: 4 Acres

Building size
Parking requirements
Access to the course
Cart storage
Cart staging

Practice Facilities: 7 Acres

Practice Greens
Practice putting green at 8000 square feet.
Practice chipping green at 4500 square feet.
Chipping Area
Range
Approximately 10 acres of space for the hitting area
Teaching Area

Other Structures: 1 Acre

Practice facility
Range storage
Maintenance facility
Building
Storage areas
Cart path requirements

Golf course configuration and components:

Number of Holes:	18 holes
Acreage:	
Traditional 18-Hole course	120 -200 Acres
Primary Par 3's	80 Acres
Course Length	
Traditional 18-Hole course	6,000 - 7200 yards Back
	4,500 - 5800 yards Front
18-Hole Par 3 golf course	2,000 - 3,000 Yards Back

Site Requirements:

Drainage: All surface drainage is to be collected from the golf course to prevent runoff into Wildcat Creek. Natural surface drainage is desirable. Natural drainage cost less than artificial drainage from an economic perspective.

Water Requirements:
Quantity needed for Irrigation
Source of Water
Storage needs

Program Analysis

Table 3.1 shows the program as it relates to function, form, economy, and time. This table shows the goals, facts, concepts, needs, and problems associated with each category.

PROGRAM AS IT RELATES TO FUNCTION, FORM, ECONOMY, and TIME

FUNCTION	GOALS	FACTS	CONCEPTS	NEEDS	PROBLEMS
GOLF COURSE	To provide recreation, open space, and reduce downstream flooding. Improve local environmental conditions through ecological design.	Conservation easements have been used to overlay land with golf courses, and use a golf course to protect the surrounding land.	Provide a place to store flood water and use the golf courses a buffer between future development and Wildcat Creek. Mitigate flooding at site scale and the watershed scale.	Size and location of reservoirs to store water.	Balancing the needs of the golf course with the needs of the community and the environment. Flat topography is not desirable for golf and is bad for drainage.
			Increase the infiltration capacity of the site.	Hazards need to have a permeable base to allow for infiltration of water into the ground .	
			Improve the water quality leaving the site.	Vegetation that filters, sediment, chemicals, and other pollutants.	
WATER HAZARDS	To make the course challenging, hold flood water, collect runoff, and provide a source of irrigation.	The soil type and location will influence the cost.	Detention/Retention Ponds, constructed wetlands, wet meadows.	Suitable Location	Lack of a variety of soil types and flat elevation
STORMWATER	Infiltration into the ground	Slopes	Phytozones	Type of Stormwater BMP	Getting data for calculations
	Filtering runoff	Buffer zones	BMP's	Site drainage	
	Reduce sedimentation		Collect and filter stormwater	BMP location	Location that works with strategy of the golf hole
GOLF STRATEGY	Act as buffer	Golf design theory	Golf holes are sited to take advantage of location of hazards	Hazards and golf routing need to be designed at the same time.	Suitable hazard locations have to also be suitable for golf development.
AESTHETICS	Visual appeal	Subjective term	Vegetative buffer zones	Vegetation needs to allow for a fluctuating water level.	Grow in period
PLAYABILITY	Golf course has to play fair for all skill levels.	A golf course plays different depending on the skill level of the player and how far they hit the ball	Designing a course with multiple tee boxes, different approach angles, distances, and landing areas.	Golf design guidelines	Harder to design for. Increasing playability can lead to a loss of natural resources.
INCREASE FLOODPLAIN ACCESS	Allow Wildcat Creek to utilize part of the site when the water level reaches a certain height.	Constriction of the stream channel causes water to move faster downstream	Using an old oxbow to increase floodplain access with the use of constructed wetlands.	Cross sectional area of the stream at 1.5 x the bank full height.	Designing for a fluctuating water level.
Form					
SITE	Aesthetically pleasing	Good aesthetics can increase value.	Water hazards become distinctive features for the golf course	Earthwork	The site is located in a floodplain
ENVIRONMENT	Protect vulnerable areas	Lack of riparian vegetation leads to stream bank destabilization.	Restore riparian edge where vegetation will frame golf holes.	Space and time	Grow in period
QUALITY	Improve water quality	Vegetation can filter sediment	Location influences playability	Location	
QUANTITY	Hold a 25 year storm event	Rainfall Intensity	Based on Strategy	How much runoff is entering the site?	Accurate data
GOLF COURSE	Challenging to players of all skill levels.	Challenging courses bring in more revenue	Form based on strategy and playability		
Economy					
INITIAL COST	Self sustaining	Reduced maintenance costs	Reduce drainage problems	The community could undertake the project as part of a stormwater program.	Initial cost
REVENUE	Reduce damages	Flooding	Minimize flooding downstream	Where is flooding occurring?	High percentage of golf course is within floodplain.
LONG-TERM COSTS	Water hazards become a self sustaining and functioning ecosystem.	Sustainable water hazards are more efficient in the long term.	Vegetative buffer zones provides habitat for different species to thrive in.	Proper design of functioning water hazards	Post construction evaluation
GOLF INDUSTRY	The golf industry can become a catalyst for change and sustainable design.	$76 billion industry	Shorter course, and practice area cater to different demographic, reduce costs.	To prove successful financially. To be accepted by the golf industry, and to be accepted environmentally.	Initial cost
Time					
PAST	Reduce flooding	Historical flood data	More sustainable in the future	Historical flood data for 25 year floodplain	Flooding changes over time
PRESENT	Reduce flooding	Historical stream flow data	Reduces maintenance cost		
FUTURE	Shorter golf course	People have less time to devote to playing the game.	Allows for less time commitment because it takes less time to play a shorter course.	To be marketed properly	The stereotype attached to par 3 golf
	Preservation of open space in area of future development		Location of future development		
	Reduce flooding	Sustainable systems reduce long term costs.	Design water hazards to become functioning ecosystems.	Vegetation types	Grow in period

Table 3.1 Program as it relates to function, form, economy, and time (Created by author, 2012)

Chapter 4

Site Inventory/ Analysis

The Wildcat Creek Watershed

SITE SELECTION AND ANALYSIS

Methodology

A corridor along Wildcat Creek was selected to complete a vulnerability and suitability analysis for the application of a golf course for flood water storage before the exact property boundaries were selected. This corridor was selected based on the regional analysis of the watershed which included the Reconnaissance Level Assessment (RLA)of Rosgen's 2006 Watershed Assessment of River Stability and Sediment Supply. Once the vulnerability and suitability analysis of the corridor was completed, two parcels totaling 114 acres were selected based on the program goals. Suitable locations for individual program elements were studied through suitability analysis. Figure 4.1 describes the process of site selection guided by vulnerability and suitability analysis as well as the site specific inventory and analysis conducted within the site boundaries selected for application.

VULNERABILITY ANALYSIS +
SUITABILITY ANALYSIS

SITE SELECTION METHODOLOGY

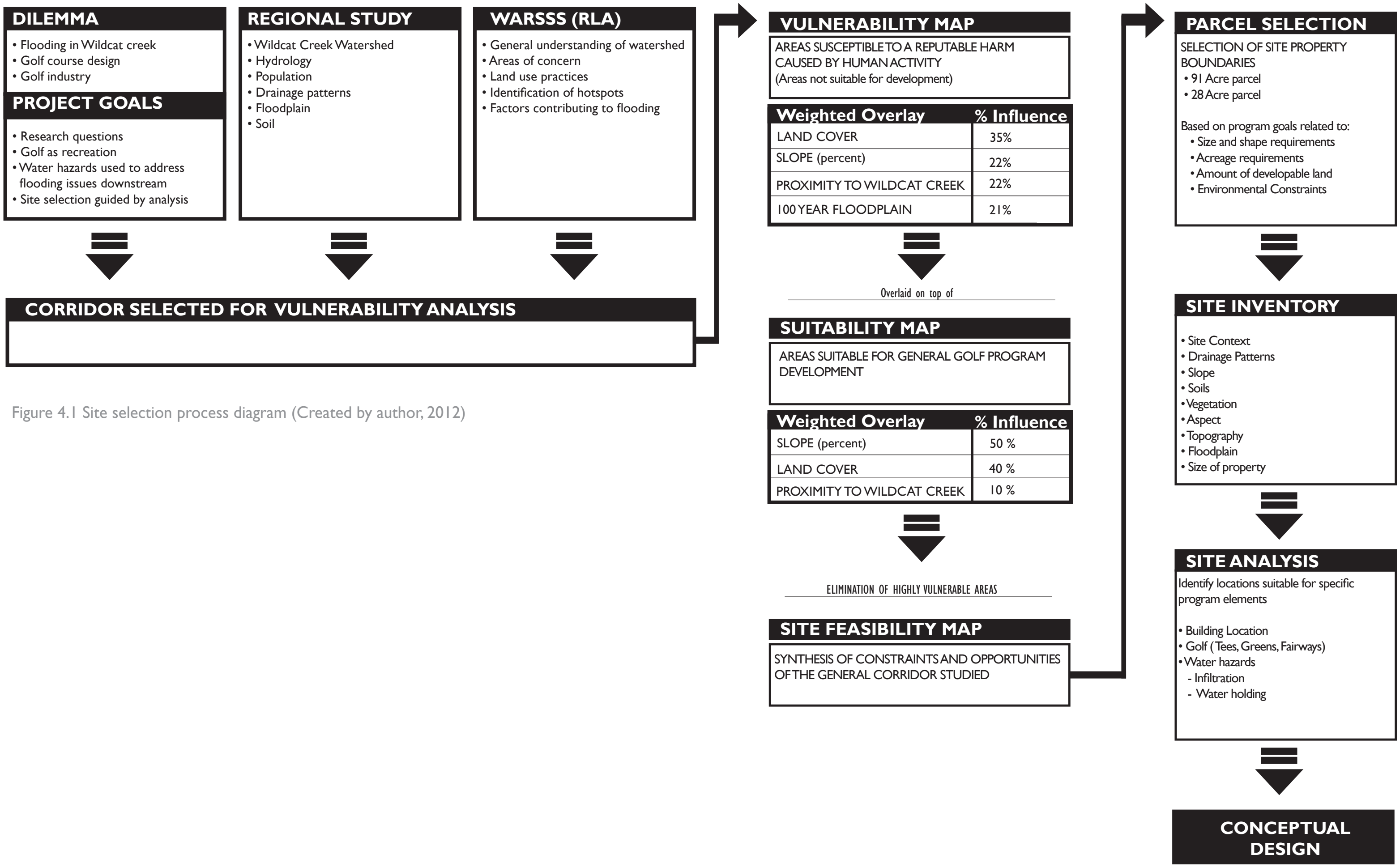


Figure 4.1 Site selection process diagram (Created by author, 2012)

INFLUENCE OF THE WARSSS ASSESSMENT ON SITE SELECTION

The Wildcat Creek Watershed was studied to understand what is happening with existing drainage patterns as well as areas within the watershed that are contributing to excess sediment and factors influencing channel instability at a regional level. This was done as part of a group project using Dr. David L. Rosgen's 2006 Watershed Assessment of River Stability and Sediment Supply (WARSSS). Rosgen's assessment is a three phase tool for assessing river stability and sedimentation at a watershed scale to assess suspended sediment and bedload sediment within rivers and streams. Excess sediment in rivers and streams is caused by high erosion and destabilized stream banks leading to a decline in water quality (U.S. EPA, 2011). This assessment was completed coincident with the individual project. The understanding of what is happening at a watershed scale was used as a framework to guide the individual design project. A watershed analysis done at this level of detail provides a unique opportunity to present a golf course design project and study how the golf course interacts with the overall watershed. The golf course and the drainage patterns within the watershed are inseparably linked together (Dodson, 2005, 44). An understanding of the overall watershed is important when siting a golf course and determining the potential impacts both on-site, and off-site.

WARSSS is characterized by three phases: (i) Reconnaissance Level Assessment (RLA), (ii) Rapid Resource Inventory for Sediment and Stability Consequence (RRISSC), (iii) Prediction Level Assessment (PLA). Each phase moves from a general assessment during the RLA phase to a more specific and detailed assessment by the PLA phase (U.S. EPA, 2011). The RLA phase is a general, quick, qualitative assessment to delineate areas that are more likely to contribute to excess sediment and areas that are unlikely to contribute to excess sediment within the watershed in question (U.S. EPA, 2011). The second phase, RRISSC, builds off of the RLA phase by conducting a more detailed analysis of the problem areas (places that are likely contributing to excess sediment) observed in the RLA phase (U.S. EPA, 2011). The RRISSC further narrows down the key areas from the RLA phase to be brought into the final most thorough phase. The PLA phase allows for an intensive evaluation of key problem areas (delineated by the RLA, key problem areas (delineated by the RLA, then RRISSC phase) within the watershed (U.S. EPA, 2011). The results from this phase can then be used to inform mitigation and management options (U.S. EPA, 2011).

The first phase of The WARSSS assessment looks at the entire watershed and identifies areas and processes that have a high risk of impact on sediment supply and channel stability. To complete the Reconnaissance Level Assessment of WARSSS shown in Figure 4.2, the Wildcat Creek Watershed was divided into 6 sub watersheds based on land use, land cover, stream centerlines, and ridgelines. Next, areas of high risk of impact on sediment supply and channel stability were identified as "hot spots" to look at in further detail later on in the process. After the hot spots were identified; each of the sub watersheds was categorized as a whole and was either eliminated or advanced to the next phase which is the Rapid Resource Inventory for Sediment and Stability Consequence (RRISSC). If a sub- watershed was eliminated, individual hotspots were advanced to the next round.

The WARSSS approach was instrumental in the individual project by helping to delineate problem areas within the Wildcat Creek Watershed and also the locations that are being impacted by the processes of erosion and destabilization. The overall understanding of problems within the watershed helped to select a smaller site within the Wildcat Creek Watershed where an individual project could have a positive impact at the site scale and on the watershed as a whole.

Based on what was learned in the Reconnaissance Level Assessment (RLA), of Rosgen's WARSSS assessment and the goals of the Wildcat Creek Watershed Working Group, a general location was selected. A corridor along Wildcat Creek, just outside the City of Manhattan, was selected as a site for the application of a golf course project. This location was selected because of the high potential to make a large impact on the overall watershed in a relatively short linear distance along the creek as well as its suitability for flood water storage. A golf course in this location would make it possible to help reduce some of the flooding downstream before it enters the city of Manhattan. The location presents an opportunity to preserve some of the land in this area before future development occurs. A golf course would act as a buffer between the stream corridor and the surrounding development. The site would also provide a location to relieve peak flow from Wildcat Creek and provide a location that would allow the site to be designed to increase infiltration capacity of flood waters.

The Presentation of Rosgen's Watershed Assessment For Stream Stability and Sediment Supply (WARSSS) & Partial Design Solutions to Reduce flooding for the Wildcat Creek Watershed can be accessed through the following link: https://krex.k-state.edu/dspace/

Reconnaissance Level Assessment (RLA), of Rosgen's WARSSS Assessment

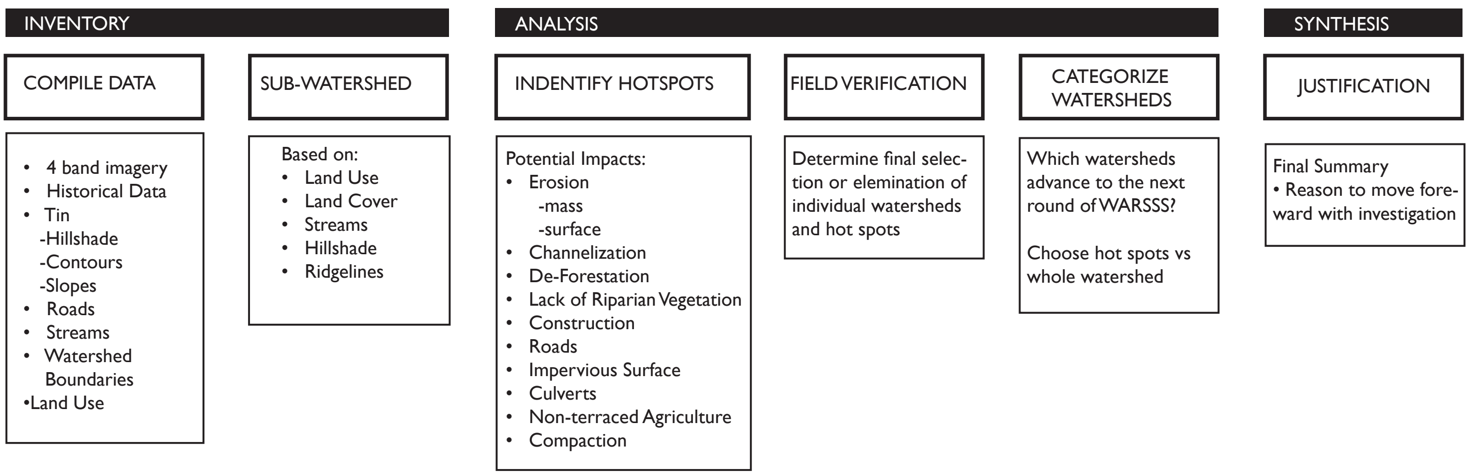


Figure 4.2 Reconnaissance Level Assessment (RLA) process diagram (Adapted by author from Rosgen, 2006)

LOCATION

Located in Riley County, Kansas, just outside the city of Manhattan as shown in Figure 4.3. The site for this project is located in the Wildcat Creek Watershed and borders the North side of Wildcat Creek, upstream from the City of Manhattan. Manhattan is located at the point where the Big Blue River flows into the Kansas River. Before a specific site could be selected for application there had to be a general understanding of the hydrological processes at the watershed scale. The Wildcat Creek Watershed shown in Figure 4.4 encompasses approximately 99 square miles in Riley County, Kansas.

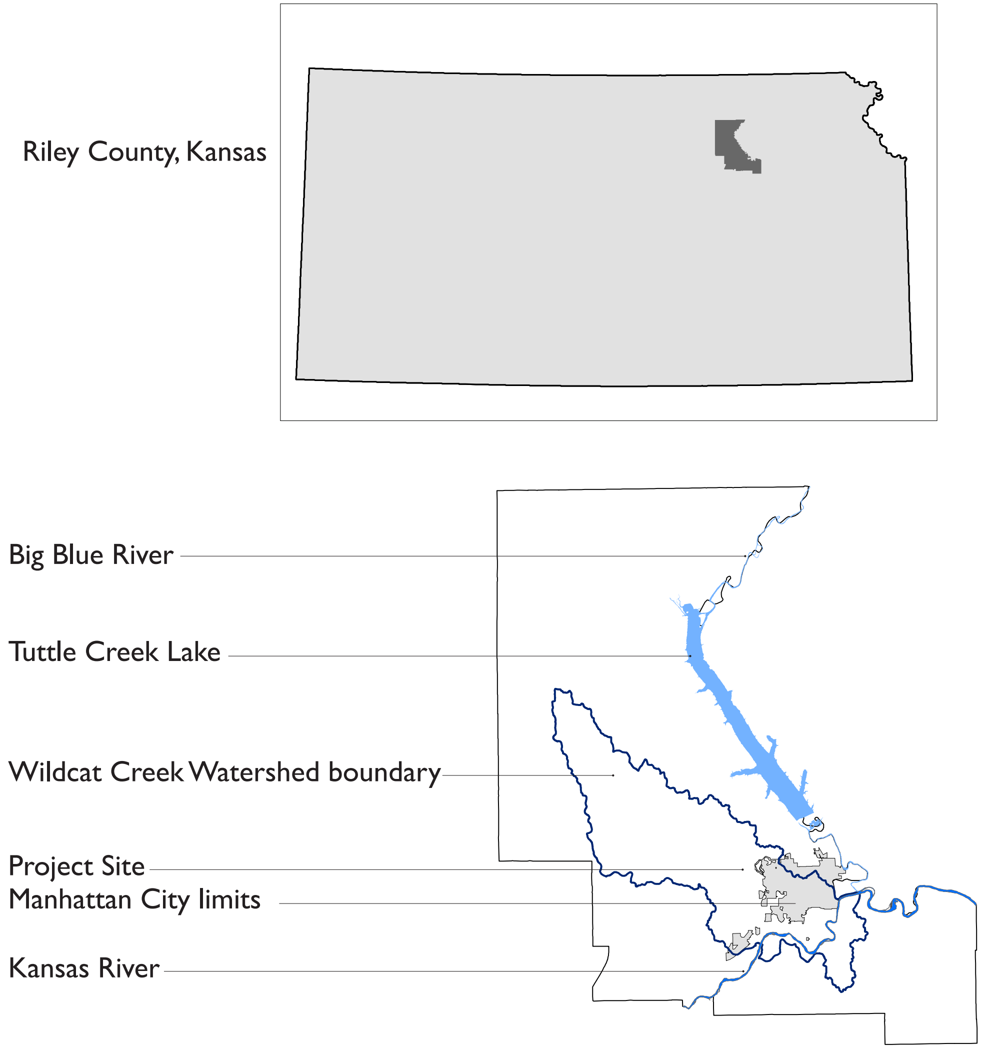


Figure 4.3 Project location within Riley, County (Generated from GIS data by author, 2012)

WILDCAT CREEK WATERSHED CONTEXT

Figure 4.4 Wildcat Creek Watershed (Generated from GIS data by author, 2012)

WATERSHED CONTEXT
Population within the Wildcat Creek Watershed

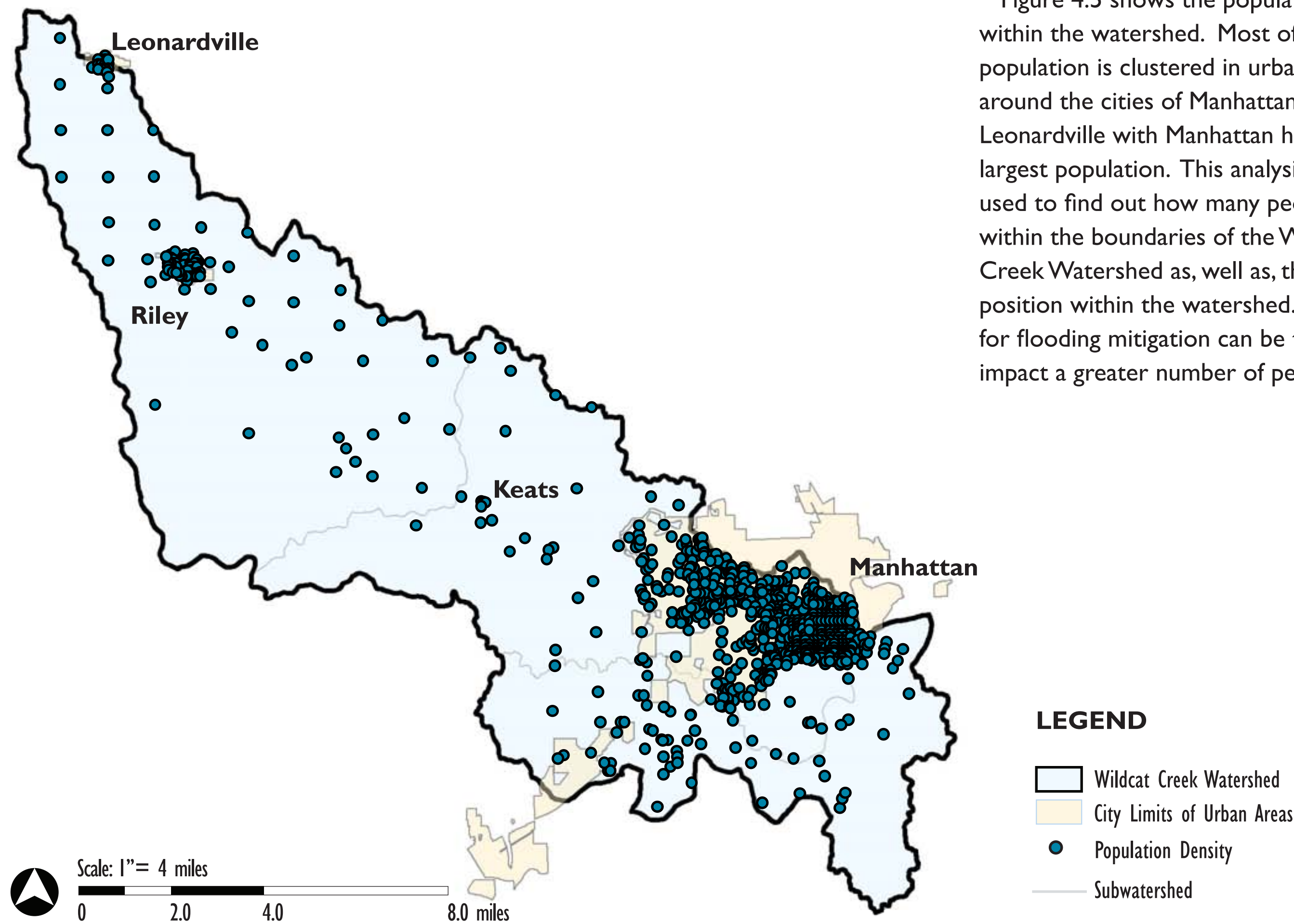


Figure 4.5 Population density (Generated from GIS data by author, 2012)

Figure 4.5 shows the population density within the watershed. Most of the population is clustered in urban areas around the cities of Manhattan, Riley, and Leonardville with Manhattan having the largest population. This analysis can be used to find out how many people live within the boundaries of the Wildcat Creek Watershed as, well as, their relative position within the watershed. A location for flooding mitigation can be targeted to impact a greater number of people.

WATERSHED CONTEXT
Drainage patterns and major water bodies

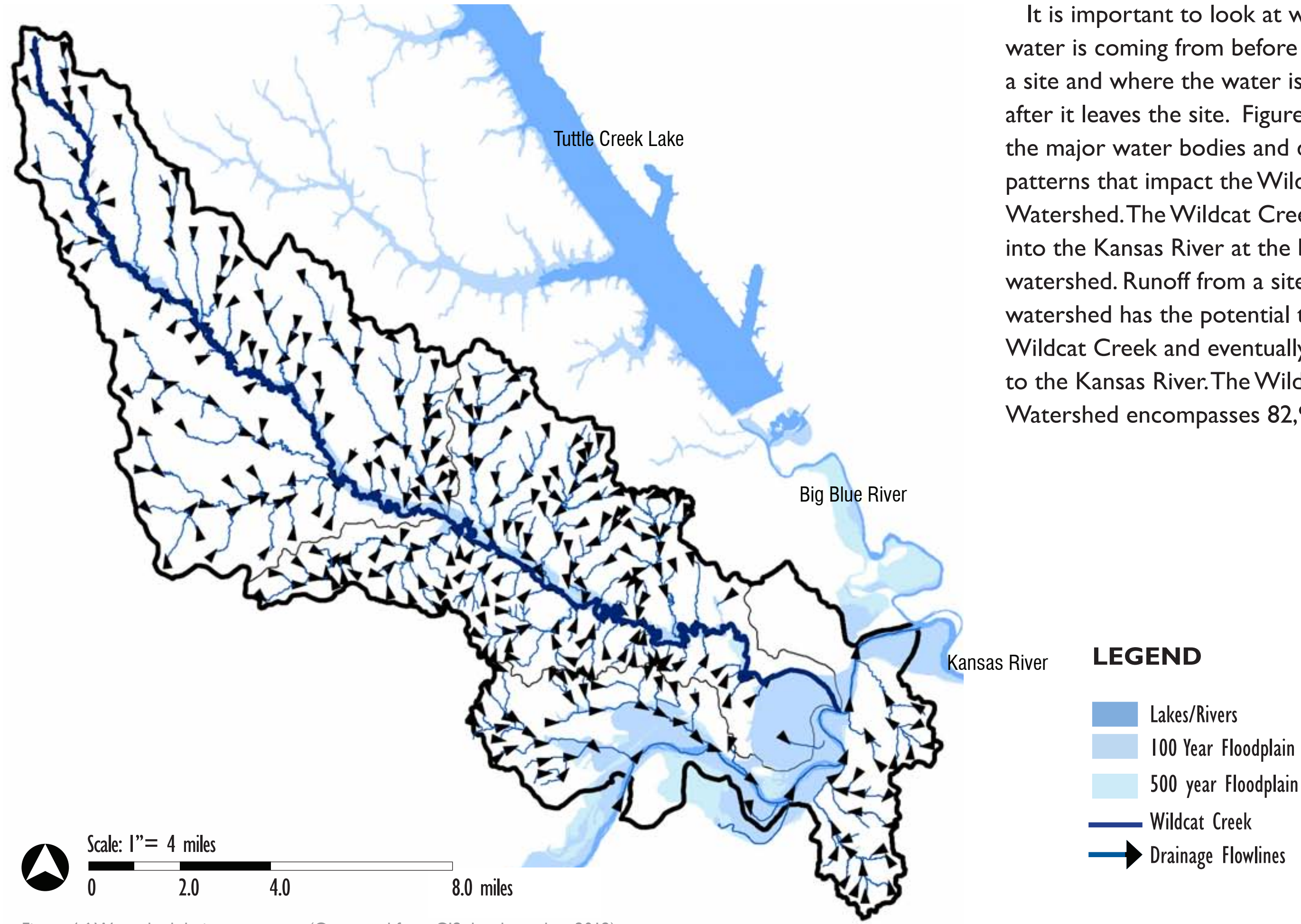


Figure 4.6 Watershed drainage patterns (Generated from GIS data by author, 2012)

It is important to look at where the water is coming from before it enters a site and where the water is going after it leaves the site. Figure 4.6 shows the major water bodies and drainage patterns that impact the Wildcat Creek Watershed. The Wildcat Creek flows into the Kansas River at the base of the watershed. Runoff from a site within the watershed has the potential to flow into Wildcat Creek and eventually make it to the Kansas River. The Wildcat Creek Watershed encompasses 82,900 acres.

WATERSHED CONTEXT
Impervious vs. Pervious Surface

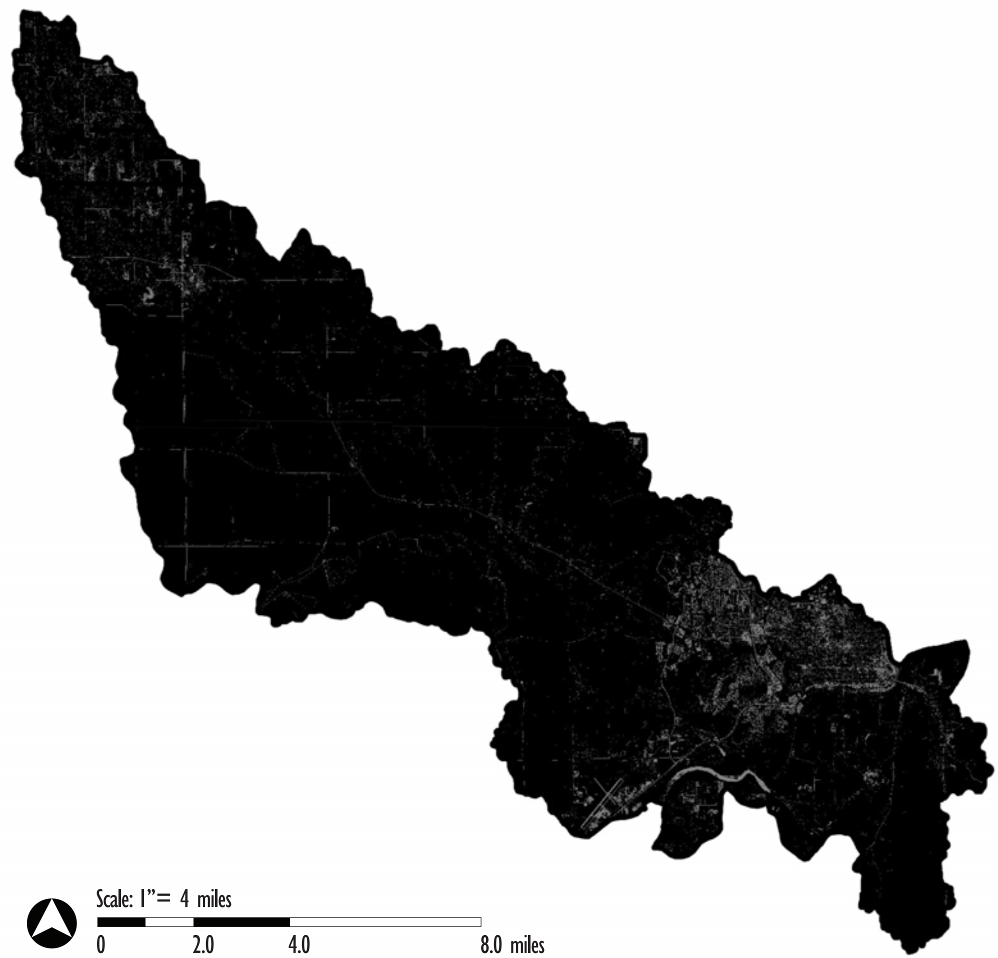


Figure 4.7 Impervious vs. pervious surface (Generated from GIS data by author, 2012)

Impervious surface prevents water from infiltrating into the ground. Large amounts of impervious surface cause an increase in the rate of velocity at which stormwater moves over land and travels downstream. This can cause an increase in peak flow, increased volume, and changes in the rate at which sediment is moved and deposited downstream.

Figure 4.7 shows the highest concentration of impervious surface is found in the lower portion of the watershed within the City of Manhattan. Impervious surface makes up only five percent of the watershed's total area. Ninety-five percent of the watershed is composed of pervious surface.

LEGEND

Surface Type

- Impervious Surface 5%
- Pervious 95%

WATERSHED CONTEXT
Elevation

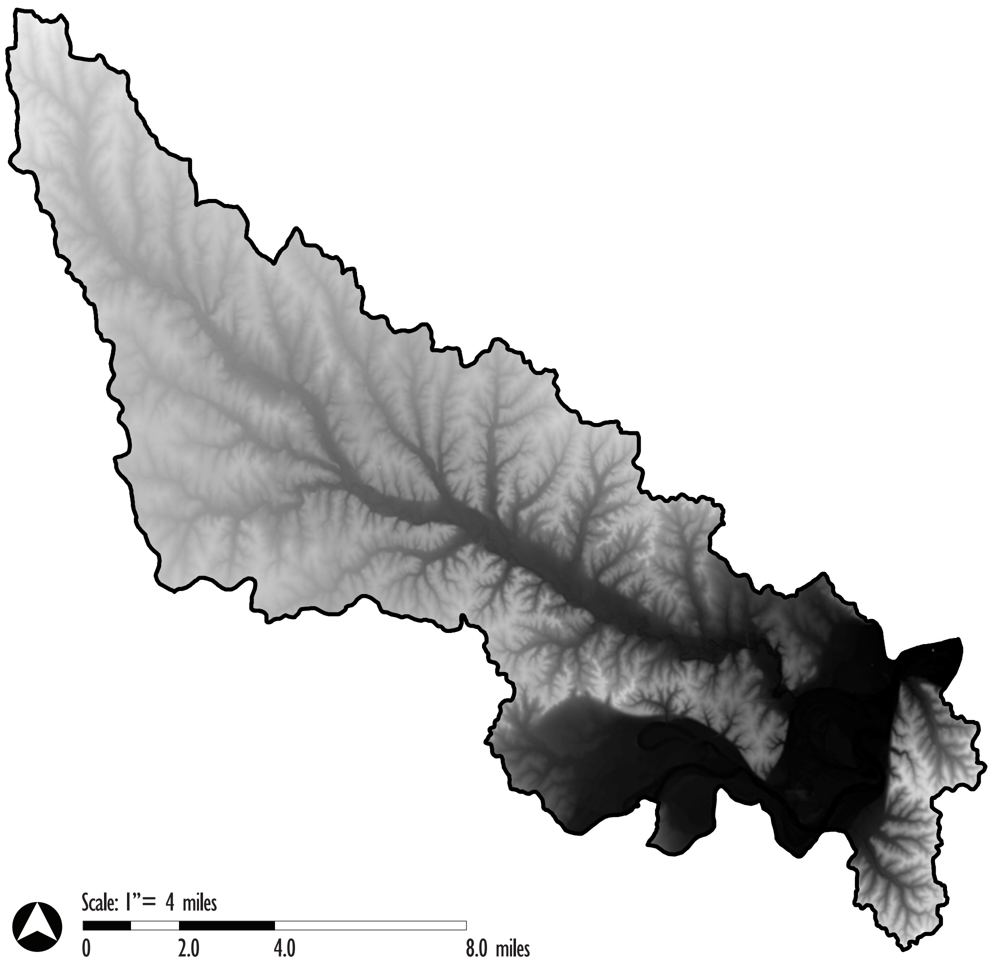


Figure 4.8 Elevation within the Wildcat Creek Watershed (Generated from GIS data by author, 2012)

The lower elevations are shown in black in Figure 4.8 while the ridges and higher elevations are displayed in white. This map can be used to show the extent of the geographical floodplain running through the center of the watershed.

LEGEND
Elevation

High 1453 feet

Low 984 feet

WATERSHED CONTEXT
Soil Drainage Class

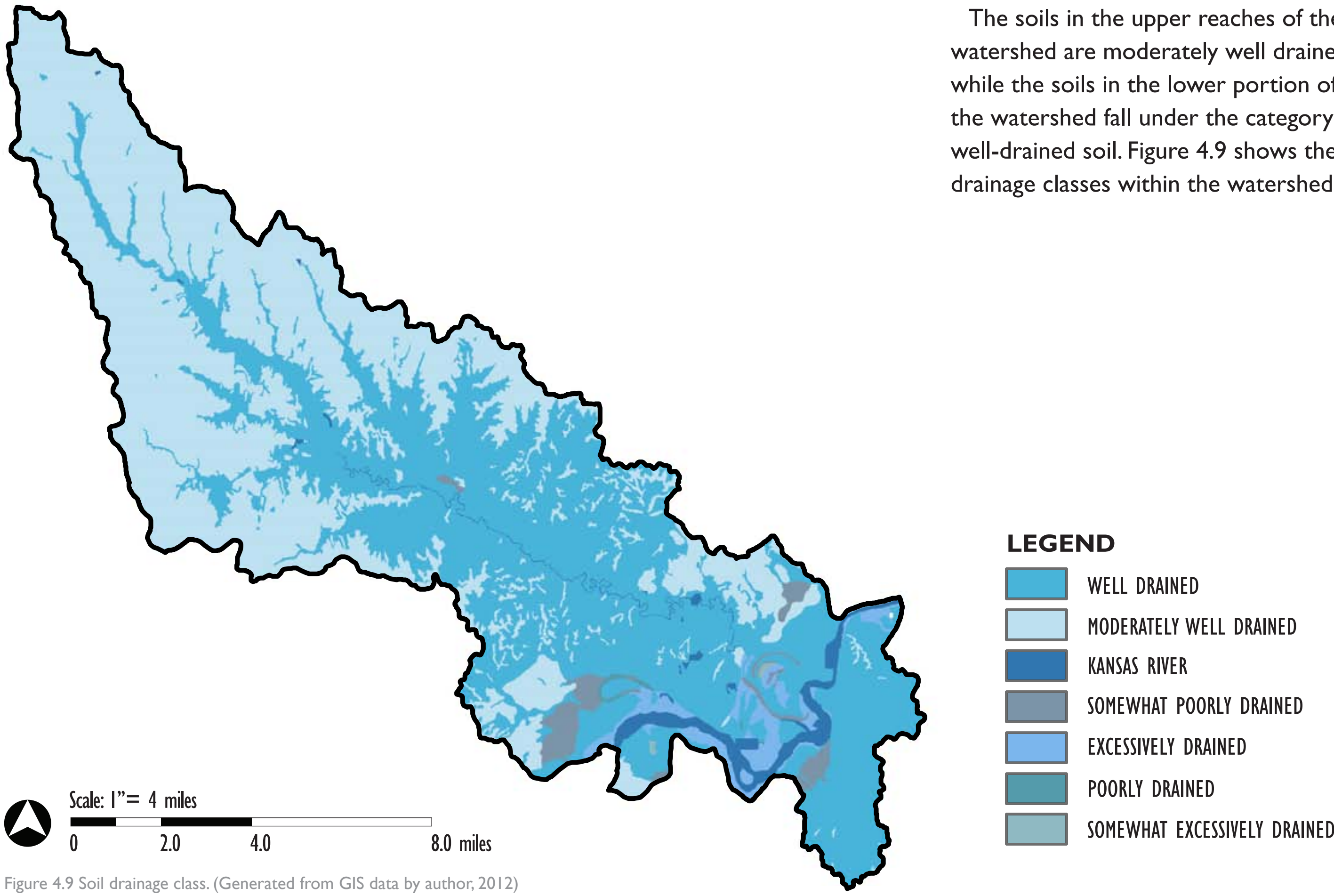


Figure 4.9 Soil drainage class. (Generated from GIS data by author, 2012)

Soil Drainage Class

The soils in the upper reaches of the watershed are moderately well drained while the soils in the lower portion of the watershed fall under the category of well-drained soil. Figure 4.9 shows the soil drainage classes within the watershed.

WATERSHED CONTEXT
Hydrologic Soil Groups

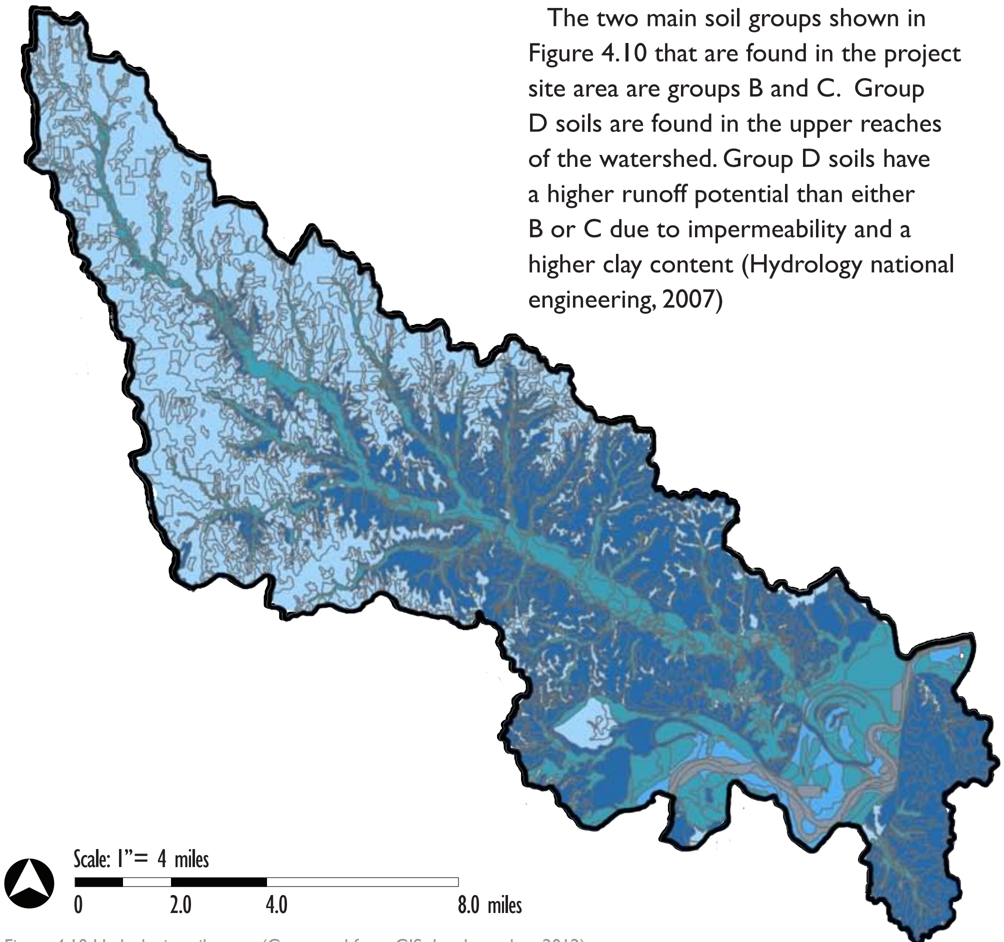


Figure 4.10 Hydrologic soil group (Generated from GIS data by author, 2012)

Hydrologic Soil Groups

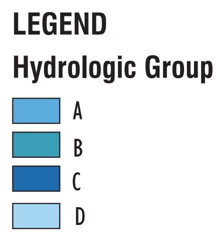
The two main soil groups shown in Figure 4.10 that are found in the project site area are groups B and C. Group D soils are found in the upper reaches of the watershed. Group D soils have a higher runoff potential than either B or C due to impermeability and a higher clay content (Hydrology national engineering, 2007)

Group B Soils

Soils in group B have moderately low runoff potential when saturated. Water is transmitted through the soil easily. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand. Group B soils have loamy sand or sandy loam textures and 24 inches or greater to the depth of the water table. These soils are found mostly in the floodplain above the alluvial aquifer (Hydrology national engineering, 2007).

Group C Soils

Soils in this group have moderately high runoff potential when saturated. These soils are less permeable than group B. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand (Hydrology national engineering, 2007).



VULNERABILITY ANALYSIS

For the purpose of this project; vulnerability is referred to as susceptibility to damage caused by a human activity or a irreparable harm. Disturbance in vulnerable areas can cause instability of natural systems and can lead to an increase in degradation. A vulnerability analysis was conducted to identify areas unsuitable for development. Table 4.1 shows the series of individual maps found in Appendix-A, and the ratings for each of the individual variables used in the weighted overlay analysis in Figure 4.11. Each of the variables was given a rating from one to nine.

A rating of one was given to the most vulnerable variables while a nine was given to the least vulnerable variables. The least suitable areas are displayed in red and the most suitable areas for development are displayed in green. Each of the individual maps was given a weighted percentage of influence.

The most suitable location for hazards designed for infiltration into the ground are located on the southern half of the site within the floodplain boundary. The land in this area is almost completely flat and the soils are the most permeable.

Land cover was given a higher weighted percentage because it was important to protect the riparian vegetation found along Wildcat Creek. In the location studied, the riparian edge was the highest priority to protect from development. Each layer was overlaid onto one another and a map was generated to reflect the ratings. The red areas are the most vulnerable while the green areas are the least vulnerable. Areas in red were identified as being too vulnerable to develop in. Design strategies were then utilized to protect and restore these areas.

VULNERABILITY MAP
AREAS SUSCEPTIBLE TO A REPUTABLE HARM BY HUMAN ACTIVITY (Areas not suitable for development)

LAYER	Influence
LAND COVER (VEGETATION TYPES)	35%
	VALUE
Trees/Woody Vegetation	1
Crops/Agricultural Fields	9
Grassland	3
Impervious Surface	8
Water	1

LAYER	Influence
FLOODPLAIN (100 year)	21%
	VALUE
Within Floodplain	1
Outside of Floodplain	0

LAYER	Influence
SLOPE (PERCENT)	22%
	VALUE
0 - 3	8
3 - 6	5
6 - 10	5
10 - 15	4
15 - 21	3
21 - 28	2
38 - 52	2
52 +	1

LAYER	Influence
PROXIMITY to WILDCAT CREEK (150' Buffer)	22%
	VALUE
Inside of buffer zone	1
Outside of buffer zone	0

Evaluation Scale 1 to 9
1 = Most Vulnerable
9 = Least Vulnerable

Table 4.1 Vulnerability analysis Process Diagram. (Created by Author, 2012)

VULNERABILTY MAP

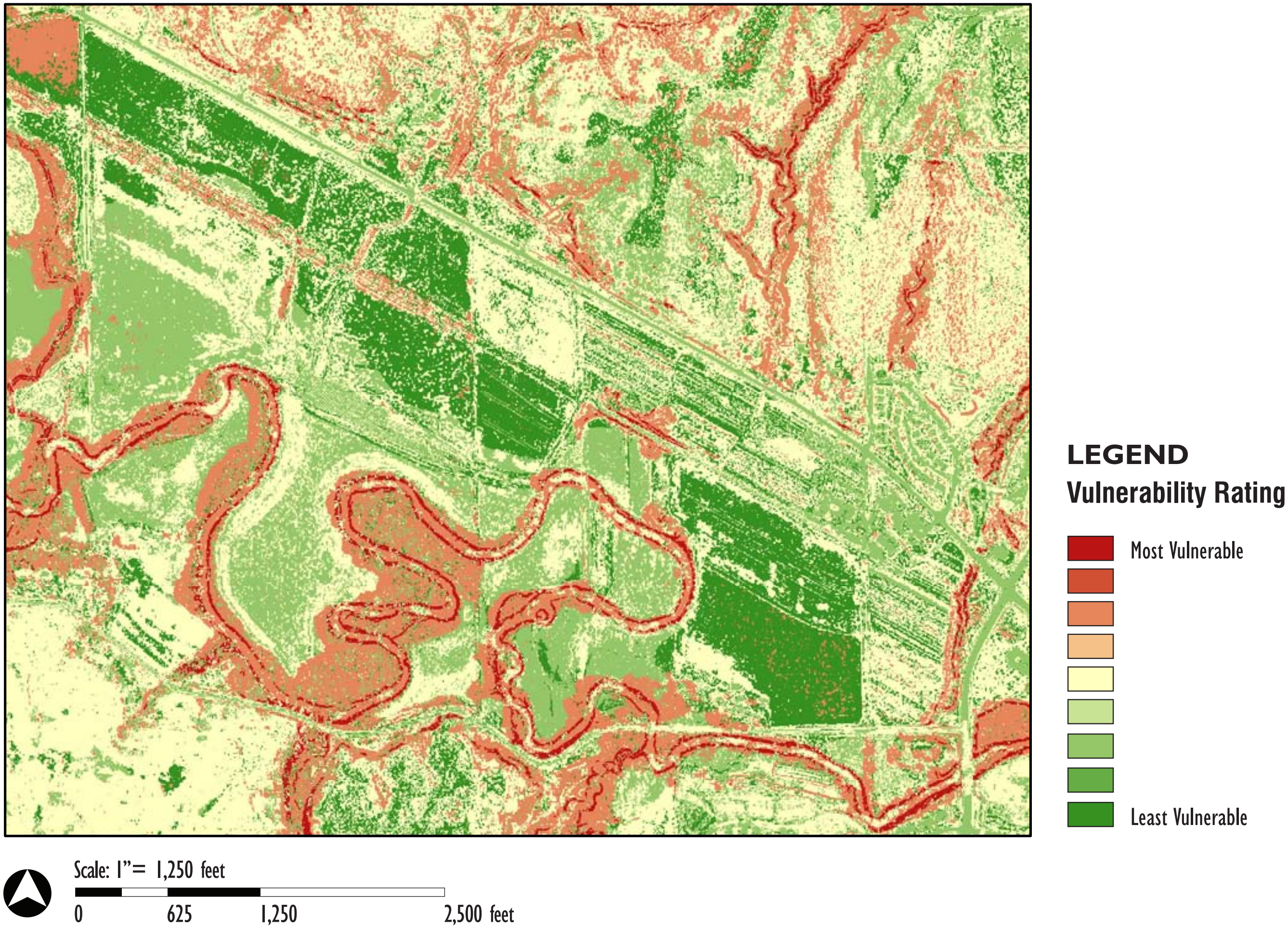


Figure 4.11 Vulnerability analysis map. (Generated from GIS data by Author, 2012)

SUITABILTY ANALYSIS

This project refers to suitability as the ability to support a proposed design element from a program. Three factors were used to determine suitable locations for general golf development. Land cover, slope, and the proximity to Wildcat Creek. These variables were determined to have the biggest impact on the location of the routing of the golf holes. Soils were studied in terms of ability to support turfgrass but because the whole site is in a floodplain, the soil types and landforms are very similar with no distinctive features to make one area more suitable than another area. There were no key advantages of one soil type over the other soil type, therefore soil types were eliminated from this model. Proximity to natural features such as streams and creeks are more desirable for designing golf holes.

Table 4.2 shows the series of individual maps found in Appendix-A, and the ratings for each of the individual variables used in the weighted overlay analysis. Each of the variables was given a rating from one to nine.

SUITABILITY MAP
GOLF COURSE LOCATION

LAYER	Influence
LAND COVER (VEGETATION TYPES)	40%
	VALUE
Trees/Woody Vegetation	1
Crops/Agricultural Fields	8
Grassland	9
Impervious Surface	1
Water	1

LAYER	Influence
SLOPE (PERCENT)	50%
	VALUE
0 - 3	8
3 - 6	9
6 - 10	7
10 - 15	7
15 - 21	5
21 - 28	5
38 - 52	3
52 +	1

LAYER	Influence
PROXIMITY to STREAMS (300' Buffer)	10%
	VALUE
Inside of buffer zone	9
Outside of buffer zone	0

Evaluation Scale 1 to 9
1 = Least Suitable
9 = Most Suitable

Table 4.2 Golf suitability process diagram (Created by author, 2012)

A rating of one was given to the least suitable variables while a nine was given to the most suitable variables. The weighted overlay analysis map in Figure 4.12 consists of four different individual layers that were identified as having the most influence on the site; land cover, floodplain boundaries, slope, and proximity to Wildcat Creek.

GOLF SUITABILTY

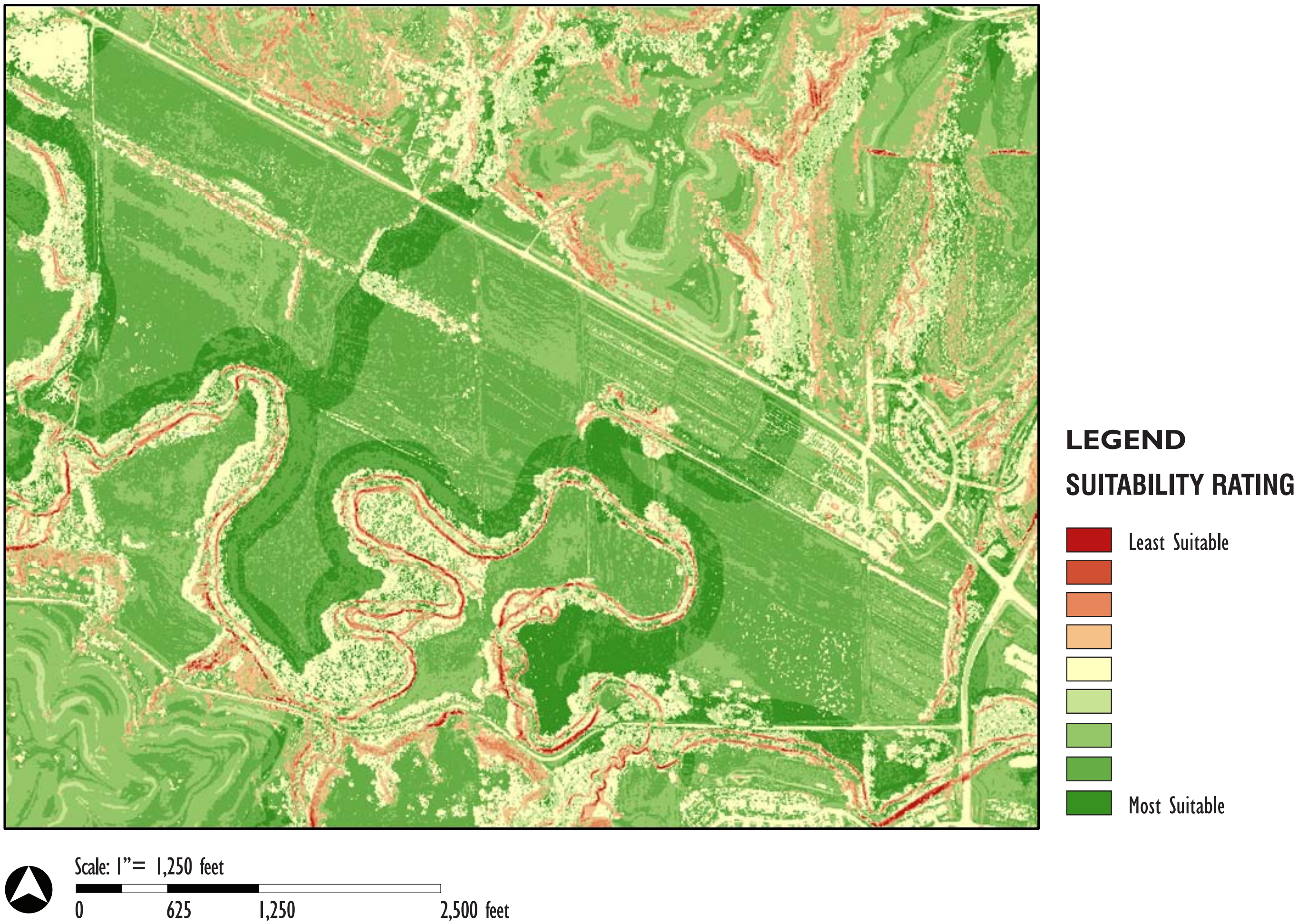


Figure 4.12 Golf suitability analysis map. (Generated from GIS data by author, 2012)

SITE SELECTION

Selecting the specific parcel boundaries

The areas determined to be the most vulnerable were identified and outlined in red in Figure 4.13. The vulnerable areas were then eliminated from the total land available to develop in. Two parcels of land totaling 114 acres were selected to become the property boundaries. A 91 acre parcel and a 28 acre parcel were selected after comparing the Vulnerability analysis with the general golf suitability map in Figure 4.14. When the site constraints were factored in, only 91 acres were suitable for development. Figure 4.15 shows the parcel boundaries selected. This site was selected for its ability to support the design program and project goals. Parcel size, shape, property access, stream crossings, landform, the location of Wildcat Creek, and the amount of riparian vegetation present were all taken into account in addition to the vulnerability model. Identifying the constraints on a site will help to inform the design process so that strategies to protect and restore vulnerable areas can be implemented into the design.

Vulnerabilty Analysis Map

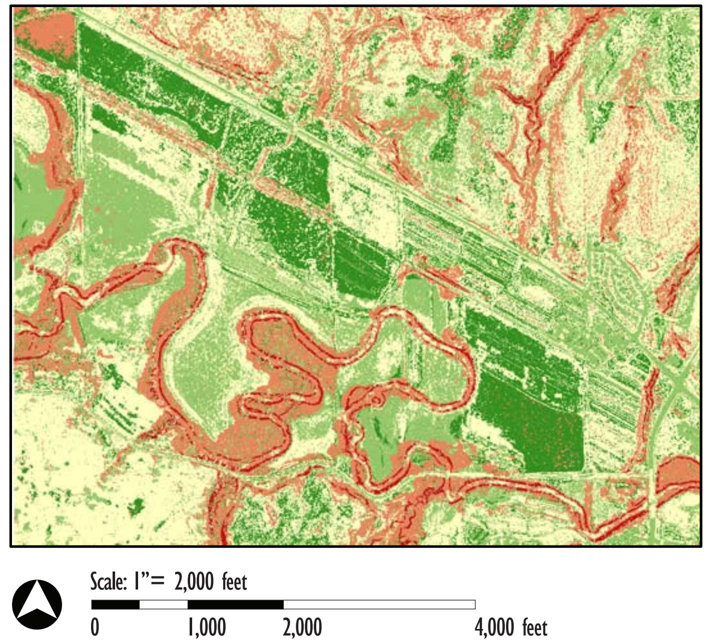
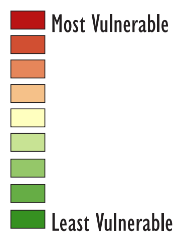
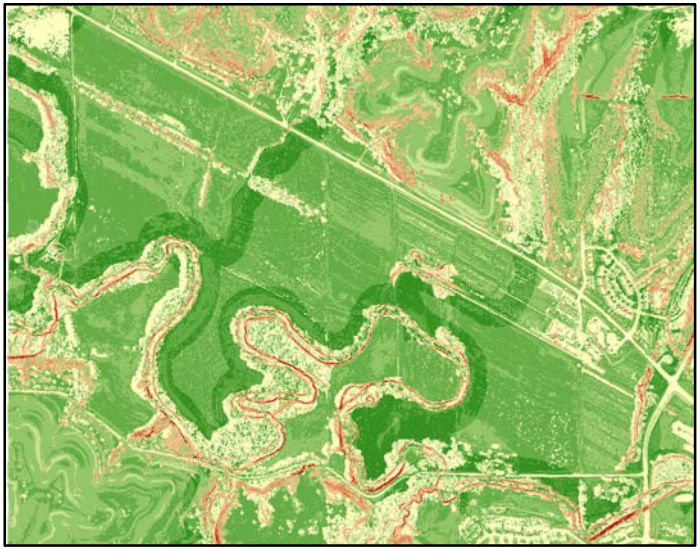


Figure 4.13 Vulnerability map (Generated from GIS data by author, 2012)

LEGEND
Vulnerability



Golf Suitability Map



Scale: 1"= 2,000 feet

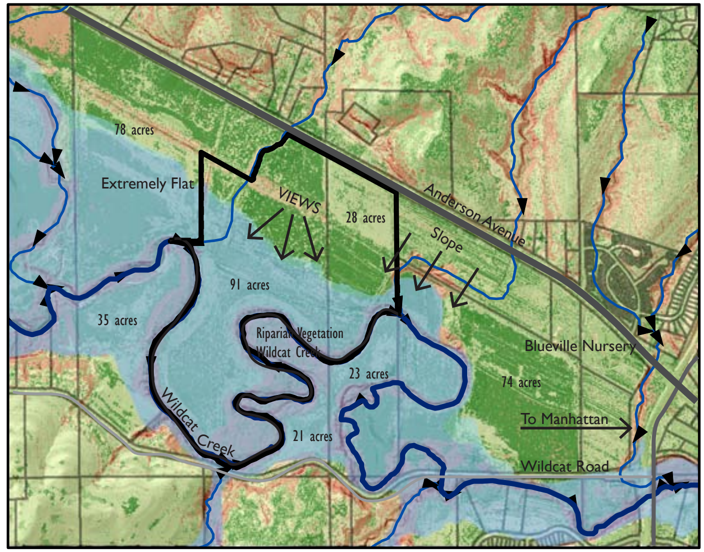
0 1,000 2,000 4,000 feet

Figure 4.14 General golf suitability map (Generated from GIS data by author, 2012)

LEGEND
Suitability

- Least Suitable
- Most Suitable

Site Constraints and Opportunities



Scale: 1"= 2,000 feet

0 1,000 2,000 4,000 feet

Figure 4.15 Site constraints map (Generated from GIS data by author, 2012)

LEGEND
Suitability

- NOT SUITABLE FOR ANY DEVELOPMENT (Vulnerable Areas to Protect)
- SUITABLE FOR DEVELOPEMNT

- Selected Parcels
- Existing Parcels
- 100 Year Floodplain
- 500 year Floodplain
- Wildcat Creek
- Drainage flowlines
- Vulnerable Area (No developement allowed)

SITE CONTEXT
Corridor studied for site feasibility

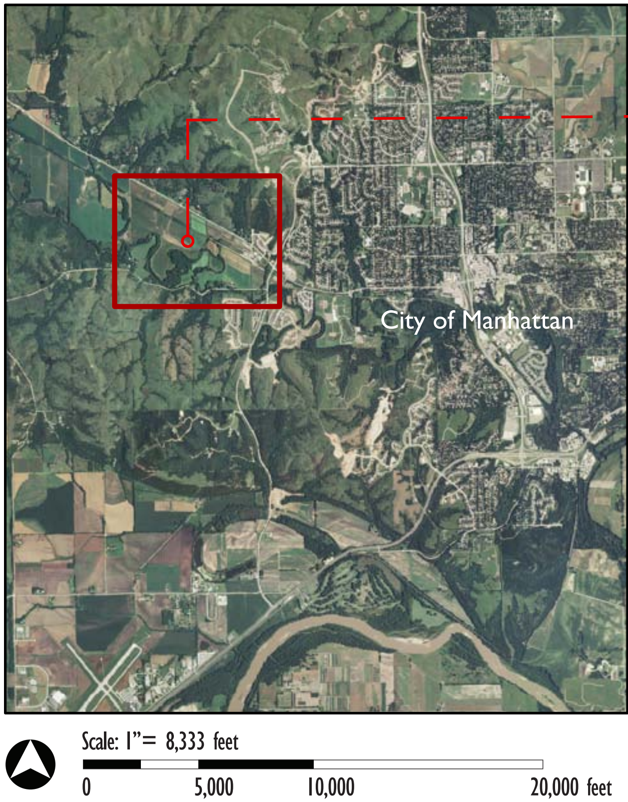


Figure 4.16 Project location (Generated from GIS data by author, 2012)

Figure 4.16 shows the corridor located northwest of the City of Manhattan.

Site Boundaries

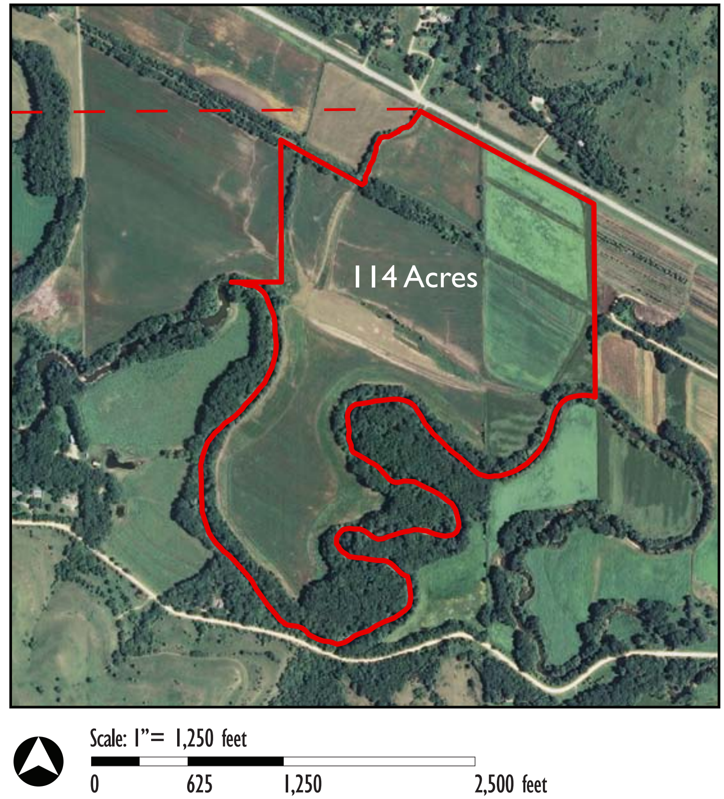


Figure 4.17 Project location with site boundary (Generated from GIS data by author, 2012)

The site boundaries selected for the project are outlined in red and can be seen in Figure 4.17

SITE PHOTOS

Figure 1.18 shows the woody vegetation that can be found on site. Although the site is surrounded by trees along the riparian edge, there is very little vegetation in the center of the site.

Figure 4.18 Looking to the south from Anderson Avenue (Photo by author, 2012)

Existing wildlife can be seen in Figure 4.19 and Figure 4.20 which shows the presence of White Tail Deer. Wild turkeys can be seen in Figure 1.3. Figure 4.21 and Figure 4.22 show images of the existing site looking to the south from Anderson Avenue with distant views of the Flint Hills in the background.

Figure 4.19 Presence of White Tail Deer on site (Photo by author, 2012)

Figure 4.20 Presence of wild turkeys on site (Photo by author, 2012)

Figure 4. 21 Existing site in 2012 looking southwest from Anderson Avenue (Photo by author, 2012)

EXISTING SITE PHOTO

Figure 4.22 Existing site in 2012 looking South from Anderson Avenue (Photo by author, 2012)

EXISTING SITE PHOTO

SITE INVENTORY

The site inventory stage of the process involved collecting information and data about the site and its surroundings. Figure 4.23 shows a diagram of the information collected for the site specific inventory during this stage. This data was then used to conduct a site suitability analysis for four specific program elements in order to find the most suitable location on the site. The first major program element was the clubhouse area. The next program element studied was a location for flood water storage. Locations for flood water storage were studied in terms of infiltration into the ground and ability to hold water on site. The last major element studied was a suitable location for golf holes.

The 114 acre site is bordered by Anderson Avenue to the north and is located above the alluvial aquifer in the floodplain. The land is very flat with views of distant hills on to the north and south. This land has been used as terraced agricultural fields. Woody vegetation is found mostly along the riparian edge of Wildcat Creek. Taller grasses and vegetation can be found just outside of the riparian zone out to about 150 feet from the centerline of the creek. The slopes on the site range from 0 to 10 percent, with the steeper slopes found only on the banks of Wildcat Creek and in places where the land has been terraced. A large amount of the land is flat and is in the range of 0 to 1 percent. The northern half of the site slopes to the south-southwest in the direction of Wildcat Creek. This part of the site has the steepest slopes.

The soil complexes found on the site are all prime agricultural soil. The properties of the different soil types are very similar because they are all in a floodplain. Tully Silty Clay Loam soil complex is classified as eroded and is located near the upper part of the foot slopes. The only hydric soils on site are along the southern part of the site,protected by dense woody vegetation, where the water drains before it enters Wildcat Creek.

Wildcat Creek is the biggest natural feature that impacts the property. The southern property line follows the center line of Wildcat Creek. Because of the tight meander bends in this part of the creek, the property has the potential to impact a large amount of the creek but in a relatively short distance. Two drainage ditches flow across the site from the north before they discharge directly into Wildcat Creek. The drainage way on the west side of the site contains runoff from a 90 acre watershed north of the site. An undeveloped site like the one selected has many similar properties and often lacks distinctive variables to give one element a big advantage over the other.

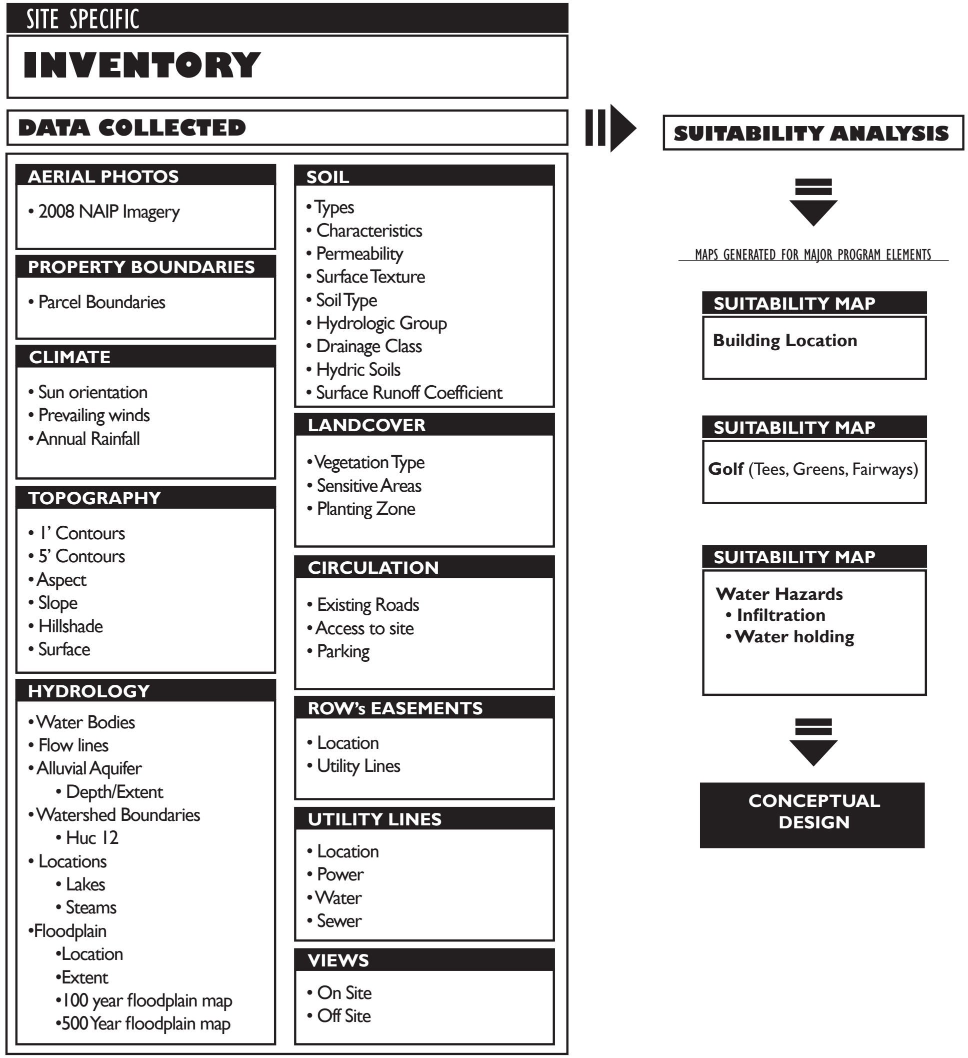


Figure 4.23 Site specific Inventory diagram (Created by author, 2012)

CLUBHOUSE SUITABILITY ANALYSIS

Table 4.3 shows the series of individual maps which are found in Appendix-A, and the ratings for each of the factors used in the weighted overlay analysis. The weighed overlay analysis map shown in Figure 4.24 consists of six different individual layers; floodplain, slope, vegetation, soil, and the proximity to roads. Each of the individual variables were rated from one to nine. A rating of one was given to the least suitable variables while a nine was given to the most suitable variables. The individual maps were then given a weighted percentage of the total.

The least suitable areas are displayed in red and the most suitable areas for development are displayed in green. Each of the individual maps was given a percentage of influence.

The most suitable building location for the clubhouse is located on the northern half of the site outside of the floodplain boundary near Anderson Avenue.

SUITABILITY MAP

BUILDING LOCATION
CLUBHOUSE

LAYER	Influence
FLOODPLAIN (100 year)	20%
	VALUE
Within Floodplain	0
Outside of Floodplain	9

Evaluation Scale 1 to 9
1 = Least Suitable
9 = Most Suitable

LAYER	Influence
SLOPE (PERCENT)	16%
	VALUE
0 - 1	3
1 - 2	8
2 - 3	9
3 - 5	7
5 - 7	3
7 - 10	2
10 +	2

LAYER	Influence
VEGETATION (LAND COVER TYPES)	16%
	VALUE
Trees/Woody Vegetation	1
Crops/Agricultural Fields	1
Grassland	5
Impervious Surface	8
Water	9

LAYER	Influence
SOIL (AMOUNT OF CLAY)	16%
	VALUE
0	1
0-27	3
27-28.9	7
28.9-31.29	4
31.29-40.59	8
31.29-41.40	9

LAYER	Influence
PROXIMITY to ROAD (1000' Buffer)	16%
	VALUE
Inside of buffer zone	7
Outside of buffer zone	0

LAYER	Influence
PROXIMITY to ROAD (500' Buffer)	16%
	VALUE
Inside of buffer zone	8
Outside of buffer zone	0

Table 4.3 Clubhouse suitability analysis diagram (Created by author, 2012)

CLUBHOUSE SUITABILITY MAP
Weighted Overlay Analysis

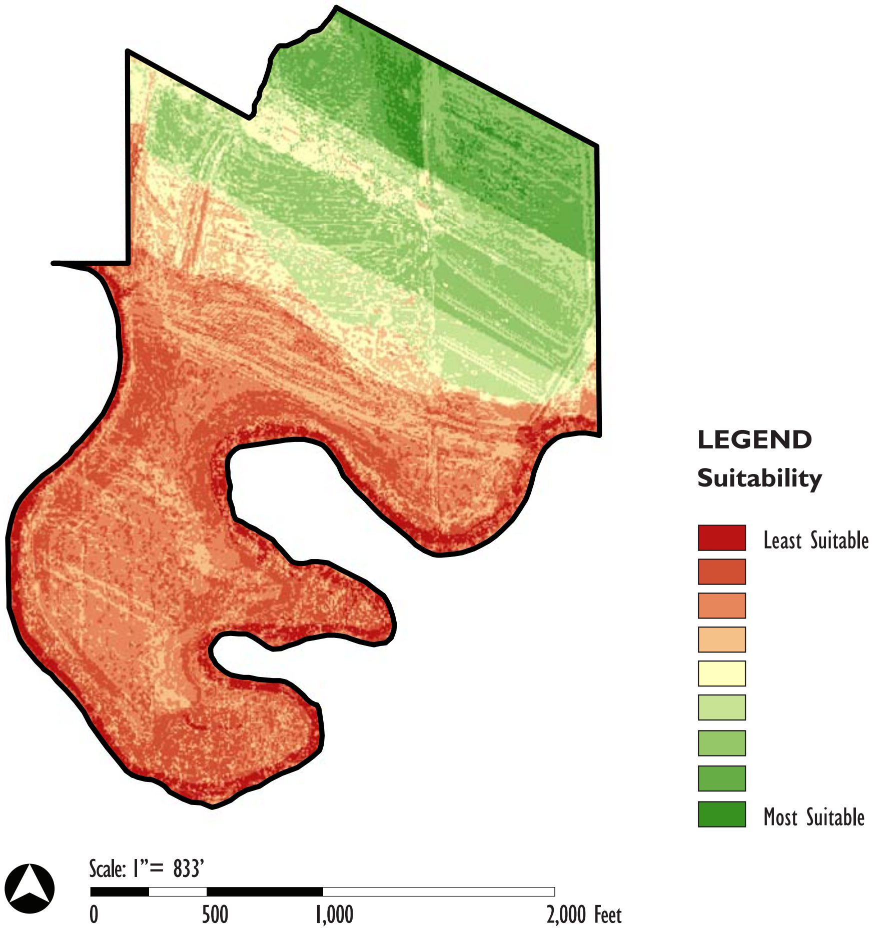


Figure 4.24 Clubhouse suitability map (Generated from GIS data by author, 2012)

WATER HAZARDS SUITABILITY ANALYSIS
Suitable locations for infiltration

Table 4.4 shows the series of individual maps found in Appendix-A, and the ratings for each of the individual variables used in the weighted overlay analysis. Each of the variables was given a rating from one to nine. A rating of one was given to the least suitable variables while a nine was given to the most suitable variables. The weighed overlay analysis map shown in Figure 4.25, consists of five different individual layers; soils, floodplain, slope, permeability, and land cover.

The least suitable areas are displayed in red and the most suitable areas for development are displayed in green. Each of the individual maps was given a percentage of influence.

The most suitable location for hazards designed for infiltration into the ground are located on the southern half of the site within the floodplain boundary. The land in this area is almost completely flat and the soils are the most permeable.

SUITABILITY MAP
WATER HAZARDS WATER INFILTRATION

LAYER	Influence
SOIL (AMOUNT OF CLAY)	20%
	VALUE
0	8
0-27	7
27-28.9	8
28.9-31.29	4
31.29-40.59	3
31.29-41.40	1

LAYER	Influence
FLOODPLAIN (100 year)	20%
	VALUE
Within Floodplain	8
Outside of Floodplain	0

LAYER	Influence
SLOPE (PERCENT)	20%
	VALUE
0 - 1	8
1 - 2	7
2 - 3	6
3 - 5	5
5 - 7	4
7 - 10	3
10 +	2

LAYER	Influence
PERMEABILITY (SOIL KSAT inches per hour)	20%
	VALUE
Stream Channel	1
3.5	2
8.4	4
8.6	7
9.0	9

LAYER	Influence
LAND COVER (VEGETATION TYPES)	20%
	VALUE
Trees/Woody Vegetation	1
Crops/Agricultural Fields	9
Grassland	8
Impervious Surface	1
Water	9

Evaluation Scale 1 to 9
1 = Least Suitable
9 = Most Suitable

Table 4.4 Suitability model (Created by author, 2012)

WATER HAZARDS SUITABILITY MAP
Suitable locations for infiltration

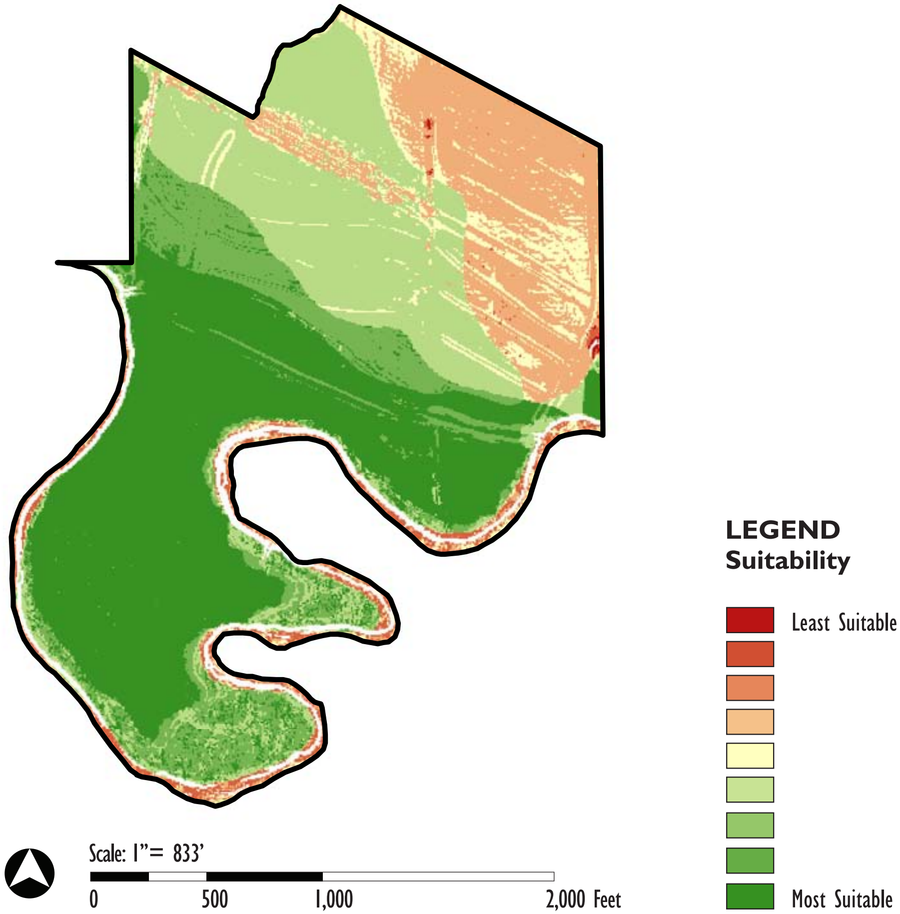


Figure 4.25 Suitability of water hazards for the purpose of infiltration (Generated from GIS by author, 2012)

WATER HAZARDS SUITABILITY ANALYSIS
Suitable locations for water retention

Table 4.5 shows the series of individual maps found in Appendix-A, and the ratings for each of the individual variables used in the weighted overlay analysis. Each of the variables was given a rating from one to nine. A rating of one was given to the least suitable variables while a nine was given to the most suitable variables. The weighed overlay analysis map shown in Figure 4.26 consists of five different individual layers; soils, floodplain, slope, permeability, and

The least suitable areas are displayed in red and the most suitable areas for development are displayed in green. Each of the individual maps was given a percentage of influence.

The highest clay content was found in the Tully Silty Clay Loam along Anderson Avenue. This soil was the least permeable on the site but is found on steeper slopes. Ivan and Kennebec Silt Loams were the second highest in terms of the percentage of clay. Ivan and Kennebec Silt Loam was the most suitable because of the water holding capacity and proximity to the creek. Being the only partially hydric soil on the site, make Ivan and Kennebec Silt Loams the most subject to flooding.

SUITABILITY MAP
WATER HAZARDS HOLDING WATER

LAYER	Influence
SOIL (AMOUNT OF CLAY)	20%
	VALUE
0	1
0-27	3
27-28.9	4
28.9-31.29	8
31.29-40.59	7
31.29-41.40	8

LAYER	Influence
FLOODPLAIN (100 year)	20%
	VALUE
Within Floodplain	8
Outside of Floodplain	3

LAYER	Influence
SLOPE (PERCENT)	20%
	VALUE
0 - 1	8
1 - 2	7
2 - 3	6
3 - 5	5
5 - 7	4
7 - 10	3
10 +	2

LAYER	Influence
PERMEABILITY (SOIL KSAT inches per hour)	20%
	VALUE
Stream Channel	1
3.5	8
8.4	7
8.6	4
9.0	3

LAYER	Influence
LAND COVER (VEGETATION TYPES)	20%
	VALUE
Trees/Woody Vegetation	1
Crops/Agricultural Fields	9
Grassland	8
Impervious Surface	1
Water	9

Evaluation Scale 1 to 9
1 = Least Suitable
9 = Most Suitable

Table 4.5 Suitability model (Created by author, 2012)

WATER HAZARDS SUITABILITY MAP
Suitable locations for holding water

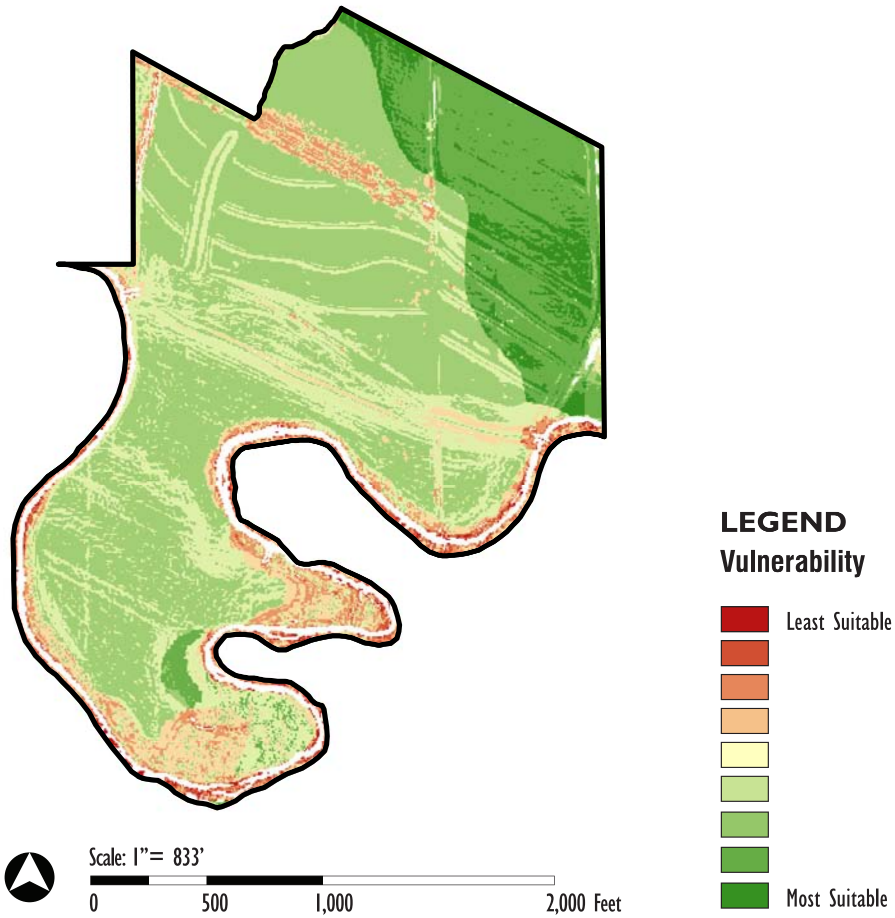


Figure 4.26 Water hazard suitability for holding water (Generated from GIS by author, 2012)

GOLF COURSE SUITABILTY ANALYSIS
General Golf Development

Table 4.6 shows the series of individual maps found in Appendix-A, and the ratings for each of the individual variables used in the weighted overlay analysis. Each of the variables was given a rating from one to nine. A rating of one was given to the least suitable variables while a nine was given to the most suitable variables. The weighed overlay analysis map shown in Figure 4.27 consists of three different individual layers; soils, floodplain, slope, permeability, and land cover.

The least suitable areas are displayed in red and the most suitable areas for development are displayed in green. Each of the individual maps was given a percentage of influence. The biggest constraint for golf development was the slope and drainage. Desirable slopes are found on the northern half of the site, while the southern half is very flat. The slopes on the southern half of the site are less than 1 percent which is not suitable for proper drainage. This part of the site will have to use water hazards to control runoff and drainage to keep water out of in play areas and contained within stormwater management areas defined as water hazards.

SUITABILITY MAP
GOLF COURSE MAINTAINED TURFGRASS (In play Areas)

LAYER	Influence
LAND COVER (VEGETATION TYPES)	50%
	VALUE
Trees/Woody Vegetation	1
Crops/Agricultural Fields	8
Grassland	9
Impervious Surface	1
Water	1

LAYER	Influence
SLOPE (PERCENT)	35%
	VALUE
0 - 1	5
1 - 2	7
2 - 3	8
3 - 5	9
5 - 7	9
7 - 10	6
10 +	3

LAYER	Influence
PROXIMITY to STREAMS (300' Buffer)	15%
	VALUE
Inside of buffer zone	8
Outside of buffer zone	0

Evaluation Scale 1 to 9
1 = Least Suitable
9 = Most Suitable

Table 4.6 Golf course suitability analysis diagram (Created by author, 2012)

GOLF COURSE SUITABILTY MAP

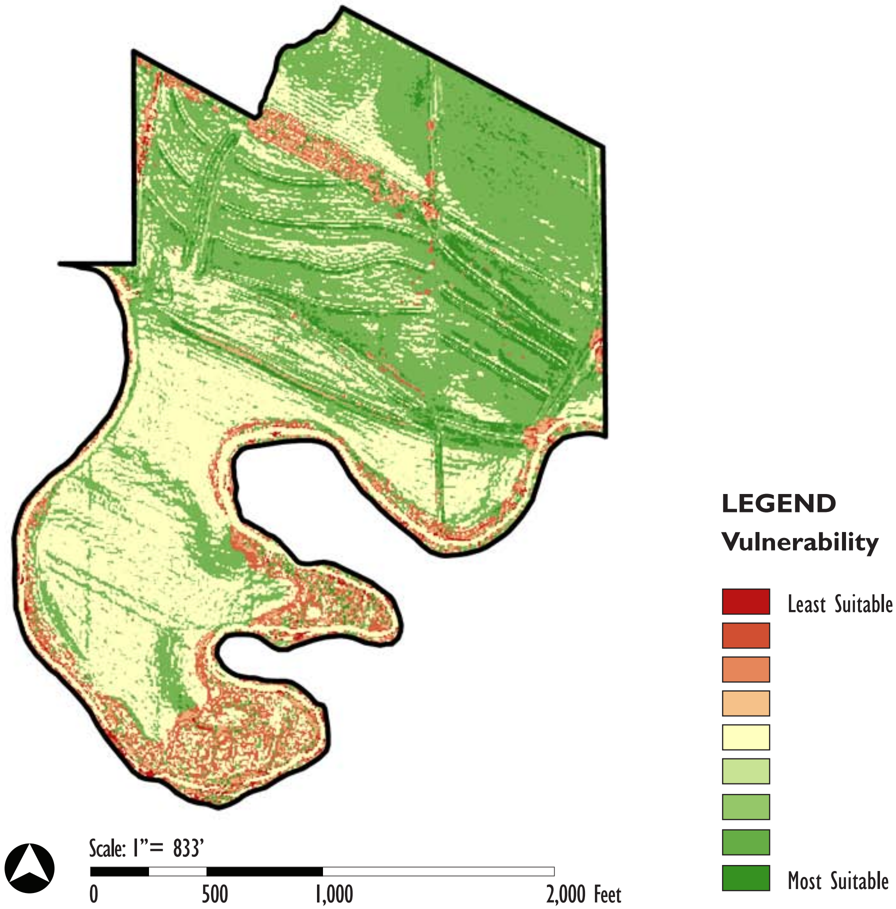


Figure 4.27 Golf course suitability (Generated from GIS by author, 2012)

Chapter 5

Design

Application of golf course design to mitigate flooding

Conceptual Design

Strategic Framework + Design Concepts

CONCEPTUAL DESIGN

Conceptual Design Introduction

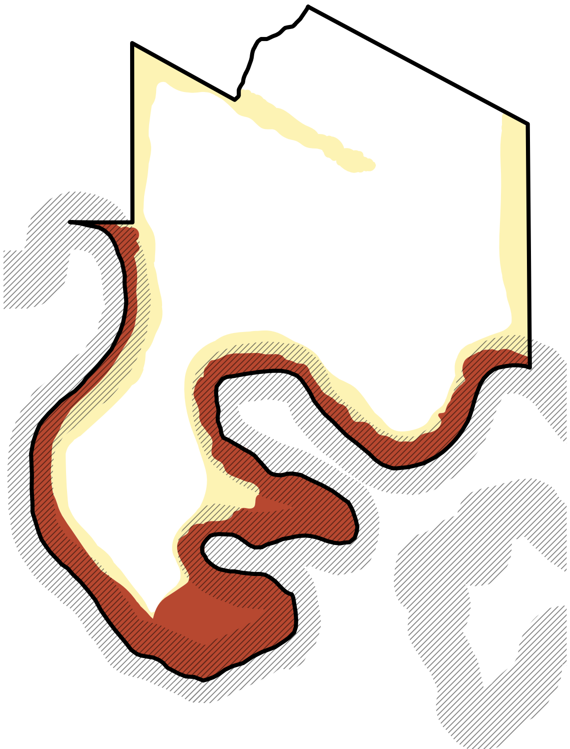
After the completion of a detailed site analysis, two design concepts were developed in response to the existing site conditions and the goals of the project. The concepts were differentiated by the way stormwater was controlled on site and the impact of the site on Wildcat Creek. Each concept was analyzed for its ability to support the golf program and how well the concept worked with natural systems.

Strategic Framework

A framework to guide design was based on the site analysis. Development was kept a minimum of 150 feet away from the center line of Wildcat Creek as shown in Figure 5.1. Highly vulnerable areas susceptible to irreparable harm were determined unsuitable to be developed in. Minimal development was allowed in moderately vulnerable areas. Placement of golf holes near Wildcat Creek allows the use of the riparian edge to frame the hole. This strategy utilizes the woody vegetation surrounding the creek as a hazard and visually brings Wildcat Creek into play of the golf hole without having a negative impact on the stream. Greens should be placed a maximum distance of 125 feet from the riparian edge so that the trees will still come into play on the golf hole. Locating greens near the riparian zone provides an incentive to spend money to improve the riparian edge in places that are beneficial to golf strategy. Bioswales were used around tees and greens to treat and prevent stormwater from discharging directly into Wildcat Creek. The concept section in figure 5.2 shows the existing site conditions. Figure 5.3 shows the proposed condition where minimal golf development was used to improve overall conditions.

CONCEPTUAL DESIGN

Strategic Framework Diagram



LEGEND
Strategic Framework

- Highly Vulnerable (Non Developable)
- Moderately Vulnerable
- 150' Buffer Zone

Figure 5.1 Design framework diagram (Created by author, 2012)

Concept Sections

Figure 5.2 Typical concept section of existing site condition (Created by author, 2012)

Figure 5.3 Typical concept section of proposed site (Created by author, 2012)

CONCEPT 1
Summary

Golf Strategy

Entry to the site is from the north, off of Anderson Avenue. The clubhouse facility, parking lot, driving range, and maintenance facility were located outside of the 100-year floodplain. A 3,020 yard golf course was designed around 17 acres of water hazards. The course flows in a clockwise direction to direct errant shots hit to the right, on the property. A detailed hole by hole analysis is shown in Table 5.1.

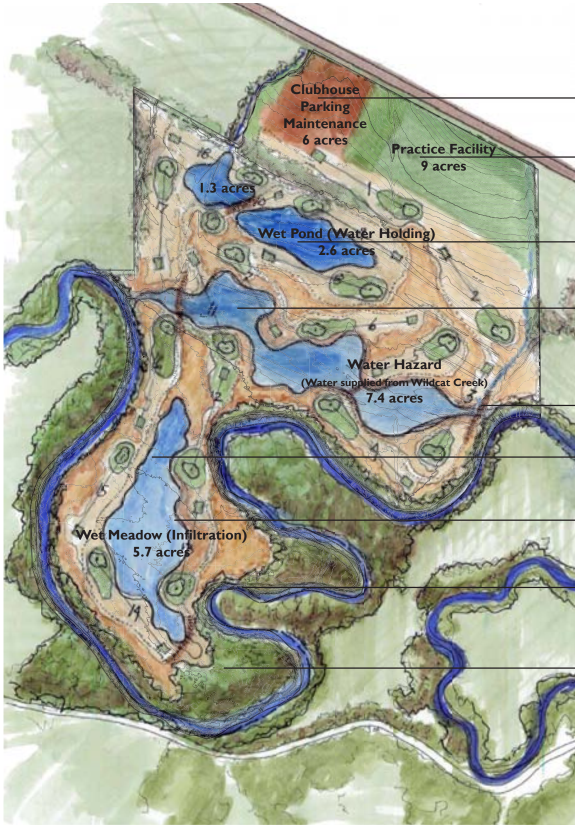
Hydrologic Strategy

Concept one shown in Figure 5.4 attempts to maintain the natural drainage on site by placing hazards in low areas unsuitable for golf development. Water is collected into a holding pond to treat and store water for irrigation in a location that collects runoff from both on-site, and off-site. The holding pond collects water from a stream that currently flows across the site and discharges directly into Wildcat Creek. When the water level in Wildcat Creek reaches a specific elevation, the water is diverted into a degraded oxbow that flows across the middle of the site. This concept allows Wildcat Creek controlled access to the floodplain. Wet meadow grasses placed in a location where drainage is directed, acts as a hazard to direct runoff from the golf course to the center of the site.

Flow		Design Features							
Hole	Par 3 Initial Routing Yardage 3,020 yards	Hole Direction (Degrees)	Change in Direction	Water hazard comes into play on hole (left or right side)	Forced carry over water hazard	Wildcat Creek comes into play (left or right side)	Average Distance Between Holes (feet)	Stream Crossing	Change in elevation from tee to green (feet)
1	200	115					240		+ 3
2	170	140	X				180		- 10
3	170	210	X	R	X	L	180	X	- 5
4	190	315	X	R		L	270		+ 2
5	140	120	X				180	X	+ 6
6	170	265	X	L			180		- 4
7	160	340	X		X		120		+10
8	200	110	X	L			180		- 2
9	170	115		L			150		+ 4
10	120	250		L and R	X		180	X	- 5
11	160	155	X	L and R	X		90	X	- 3
12	180	200	X	R		L	150		+ 2
13	150	195		R		L	300		- 1
14	200	330	X	R		L	150		+ 1
15	150	140	X	R		L	150		0
16	170	160				L	300		- 3
17	160	10		R			150	X	+ 9
18	150	120	X	R				X	+ 2
	75 100 125 150 175 200 225								

Table 5.1 Golf hole analysis for concept 1(Created by author, 2012)

CONCEPT 1
Plan



The clubhouse, parking lot, and maintenance building was placed outside of the 100-year floodplain within close proximity to Anderson Avenue to minimize the amount of impervious surface close to Wildcat Creek.

The range and the practice facility were placed near the clubhouse so that golfers would be hitting balls to southeast and not have to look into the sun during the evening hours.

Stormwater management ponds act as a biologic filter to collect and treat water in order to reduce sediment and chemicals from surface runoff, maintain water quality, provide habitat for wildlife, and act as an aesthetically pleasing hazard that comes into play on the golf course. Water is collected from a small stream that enters the property.

When the water level in Wildcat Creek reaches a specific elevation, it is diverted into an old oxbow that runs across the middle of the site. Here water is then treated through a series of ponds in this naturally low area.

Boardwalks serve as bridges for circulation over the wetland areas.

Surface runoff is diverted into a series of strategically located water hazards so that no runoff water is allowed to enter Wildcat Creek without first being biologically filtered

Wet meadow plants act as a buffer between golf holes. Water drains to the center of the property. This hazard also acts as a buffer between golf development and Wildcat Creek.

By increasing the use of native prairie and wet meadow grasses on the site water is taken up by plant roots and the soil water returns to the atmosphere by evaporation from the soil surface by transpiration through the plant leaves.

Places where there was a high amount of woody vegetation along the riparian edge were left undisturbed.

Figure 5.4 Concept plan 1 (Created by author, 2012)

CONCEPT 1
Stormwater Strategies

The individual site factors in Table 5.2 were used to calculate the runoff were used to calculate the stormwater runoff for the wet pond and the wet meadow hazard in Figure 5.5. Using the Rational Method, the calculations for the wet pond are shown in Table 5.3 and the calculations for the wet meadow are shown in Table 5.4.

Factors	
Slope (%)	8.0
Length (feet)	3758
Area (Acres)	90
Coefficient	.49
Tc	53.6

Table 5.2 Wet pond runoff site factors (Created by author, 2012)

CONCENTRATION TIME

$$tc = .619\,(1.1\text{-}C)\,L^{.5}\;S^{-.33}$$

$$53.56 = .619\,(1.1\text{-}.49)\,3758^{.5}\;.08^{-.33}$$

L = Length of the catchment along the main stream from the basin outlet to the most distant ridge. (feet)

S = Average slope of the catchment (percent)

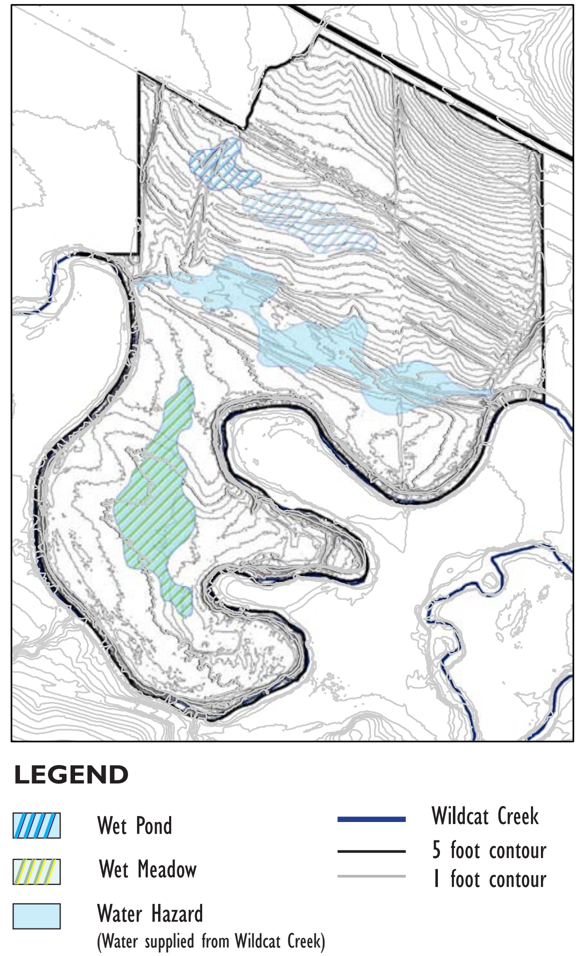


Figure 5.5 Stormwater management strategy locations (Created by author, 2012)

CONCEPT 1
Runoff Calculations

WET POND

A x C x I = Q

Storm	Duration (Hours)	(A) Area of basin (acres)	(C) Runoff Coefficient	Rainfall Intensity	(I) Adjusted Rainfall Intensity	(Q) Discharge (acre inches per hour)	Acre Feet
2 year storm	1	90	.49	1.6	1.8	79.38	6.58
10 year storm	1	90	.49	2.4	2.8	123.48	10.29
25 year storm	1	90	.49	2.9	3.2	141.12	11.76

Table 5.3 Wet pond runoff calculations (Created by author, 2012)

WET MEADOW

A x C x I = Q

Storm	Duration (Hours)	(A) Area of basin (acres)	(C) Runoff Coefficient	(I) Rainfall Intensity	(Q) Discharge (acre inches per hour)	Acre Feet
2 year storm	1	44	.40	1.6	24.64	2.05
10 year storm	1	44	.40	2.4	36.96	3.08
25 year storm	1	44	.40	2.9	44.66	3.72

Table 5.4 Wet meadow runoff calculations (Created by author, 2012)

CONCEPT 2
Summary

Golf Strategy

Entry to the site, the clubhouse facility, parking lot, driving range, and maintenance facility were located outside of the 100-year floodplain similar to concept One. A 2,990 yard golf course was designed around 18.4 acres of water hazards. The course flows in a clockwise direction to direct errant shots hit to the right, on the property. A detailed hole by hole analysis is shown in Table 5.5.

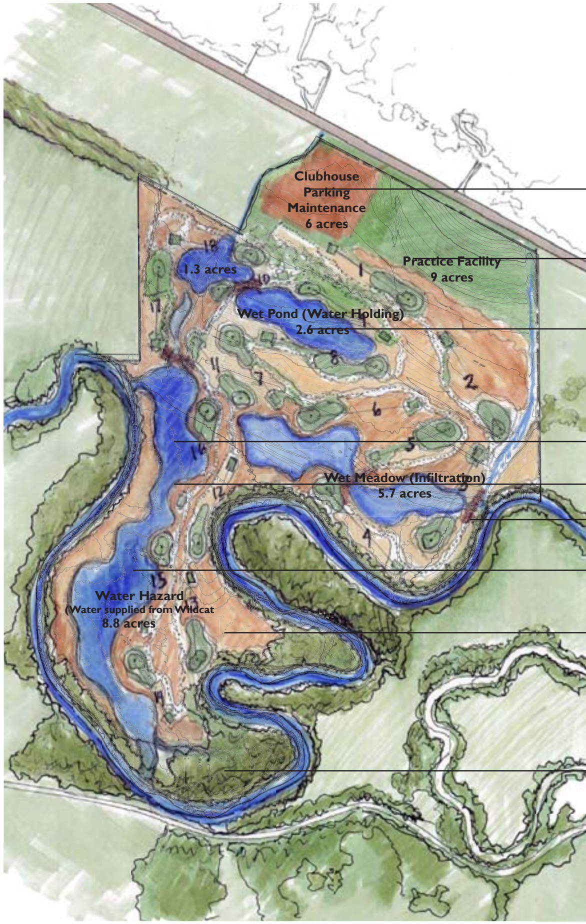
Hydrologic Strategy

Concept Two shown in Figure 5.6 collects water into a holding pond to treat and store water for irrigation. The holding pond collects water from a stream that currently flows across the site and discharges directly into Wildcat Creek. When the water level in Wildcat Creek reaches a specific elevation, the water is diverted into a constructed wetland hazard that flows along the east side of Wildcat Creek. This strategy allows Wildcat Creek controlled access to the floodplain. The location allows the longest overland flow through the hazard before re-entering Wildcat Creek. Wet meadow grasses, planted in the degraded oxbow, create a hazard that acts as an infiltration basin before discharging into Wildcat Creek. This hazard collects runoff on site, and provides an outlet for overflow from the wet pond.

Flow		Design Features							
Hole	Par 3 Initial Routing Yardage 3,020 yards	Hole Direction (Degrees)	Change in Direction	Water hazard comes into play on hole (left or right side)	Forced carry over water hazard	Wildcat Creek comes into play (left or right side)	Average Distance Between Holes (feet)	Stream Crossing Required	Change in elevation from tee to green (feet)
1	180	120					130		- 1
2	180	150	X				150		- 10
3	170	210	X	R	X	L	180	X	- 5
4	200	320	X	R		L	270		+ 2
5	180	70	X				180	X	+ 7
6	170	265	X	L			150		- 5
7	150	320	X		X		120		+7
8	200	115	X	L			120		0
9	180	310	X	L			120		+ 5
10	130	260		L and R	X		270	X	- 4
11	150	140	X				300		- 4
12	170	200	X			L	150		+ 2
13	150	170					300		- 3
14	200	220	X	L	X		150		+ 1
15	150	15		L	X		110		+ 1
16	170	20		L			450		- 2
17	160	0		R			150	X	+ 4
18	150	100	X	R	X			X	+ 4
	75 100 125 150 175 200 225								

Table 5.5 Golf hole analysis for concept 2 (created by author, 2012)

CONCEPT 2
Plan



The clubhouse, parking, and maintenance building were placed outside of the 100 year floodplain within close proximity to Anderson Avenue to minimize the amount of impervious surface close to Wildcat Creek.

The range and the practice facility were placed near the clubhouse and so that golfers would be hitting balls to the southeast and not have to look into the sun during the evening hours.

Stormwater management ponds act as a biologic filter to collect and treat water in order to reduce sediment and chemicals from surface runoff, Maintain water quality, provide habitat for wildlife, and act as an aesthetically pleasing hazard that comes into play on the golf course.

When the water level in Wildcat Creek reaches a specific elevation, the water is diverted from the creek into a large pond that acts as a water hazard for the golf course. The hazard runs from north to south along the high side of the property in the southern half of the site. Golf holes are routed along the east side of the hazard.

Vegetated buffer strips are used near sensitive areas

Boardwalks serve as bridges for circulation over the wetlands ponds, and other wet meadows areas.

Constructed wet meadow areas act as a buffer between golf holes. Water drains to the center of the property. This hazard also acts as a buffer between golf development and Wildcat Creek.

By increasing the use of native prairie and wet meadow grasses on the site, water is taken up by plant roots and the soil water returns to the atmosphere by evaporation from the soil surface by transpiration through the plant leaves.

Places where there was a high amount of woody vegetation along the riparian edge were left undisturbed.

Figure 5.6 Concept plan 2 (created by author, 2012)

CONCEPT 2
Stormwater Strategies

The individual site factors in Table 5.6 were used to calculate the stormwater runoff for the wet pond and the wet meadow hazard in Figure 5.7. Using the Rational Method, the calculations for the wet pond are shown in Table 5.7 and the calculations for the wet meadow hazard are shown in Table 5.8.

Factors	
Slope (%)	8.0
Length (feet)	3758
Area (Acres)	90
Coefficient	.49
Tc	53.6

Table 5.6 Wet pond runoff site factors
(Created by author, 2012)

CONCENTRATION TIME

$$tc = .619\,(1.1 - C)\,L^{.5}\,S^{-.33}$$

$$53.56 = .619\,(1.1 - .49)\,3758^{.5}\,.08^{-.33}$$

L = Length of the catchment along the main stream from the basin outlet to the most distant ridge. (feet)

S = Average slope of the catchment. (percent)

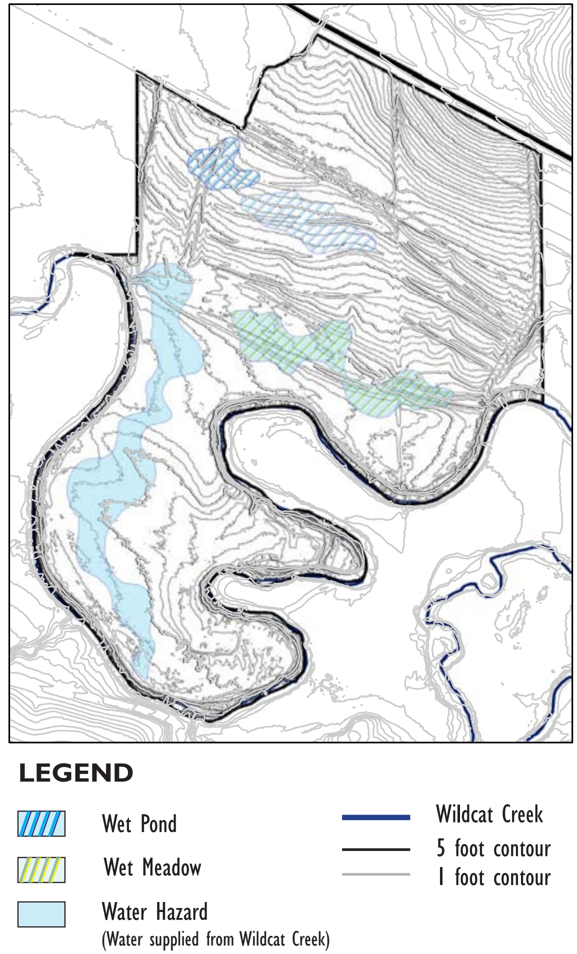


Figure 5.7 Stormwater management strategy locations
(Created by author, 2012)

RUNOFF CALCULATIONS

WET POND

A x C x I = Q

Storm	Duration (Hours)	(A) Area of basin (acres)	(C) Runoff Coefficient	Rainfall Intensity	(I) Adjusted Rainfall Intensity	(Q) Discharge (acre inches per hour)	Acre Feet
2 year storm	1	90	.49	1.6	1.8	79.38	6.58
10 year storm	1	90	.49	2.4	2.8	123.48	10.29
25 year storm	1	90	.49	2.9	3.2	141.12	11.76

Table 5.7 Wet pond runoff calculations (Created by author, 2012)

WET MEADOW

A x C x I = Q

Storm	Duration (Hours)	(A) Area of basin (acres)	(C) Runoff Coefficient	(I) Rainfall Intensity	(Q) Discharge (acre inches per hour)	Acre Feet
2 year storm	1	20	.35	1.6	11.20	.93
10 year storm	1	20	.35	2.4	16.80	1.40
25 year storm	1	20	.35	2.9	20.30	1.69

Table 5.8 Wet meadow runoff calculations (Created by author, 2012)

EVALUATION SUMMARY
Concept 1

Advantages

• The advantage of this concept is that it utilizes a natural oxbow that flows across the property in a low area on the site. In the event of a storm this area historically has flooded in the past. This location works well with the golf routing, allowing the holes to be designed around the pond. This area is not suitable for golf because of the high possibility of flooding. Water will be supplied to this area by runoff from on-site as well as from Wildcat Creek with the use of a headgate so that when water reaches an elevation of 1.5 times higher than bankfull the hazard will give Wildcat Creek controlled access to more floodplain.

• The location of the larger hazard in Concept 1 allows for a longer golf course.

• The location of the wet meadow on the southern half of the site allows for a golf routing that can have holes on both sides of the hazard and collect drainage runoff in the center of the site.

• The golf course routing flows better because of the separation between holes, and use of hazards as a safety buffer between holes.

• Concept 1 requires more bridges and boardwalks to cross the hazards.

• The wet meadow hazard can collect more water than in concept 2.

Disadvantages

• The disadvantage is that a large amount of water will cross the site in the event of flooding and may reduce access to the southern half in the event of a large flood.

• Several bridges/boardwalks would be required.

• The wet meadow hazard cannot collect enough runoff to maintain standing water.

• Golf development is more spread out.

EVALUATION SUMMARY
Concept 2

Advantages

• The maximum amount of area designed to be used as water hazards is 18.4 acres, which is more than Concept 1 can hold.

• Wildcat Creek supplies water to a large water hazard on the southern half of the site when the creek reaches the bank full stage. This hazard acts as a buffer between Wildcat Creek and the development on the property.

• Concept 2 does not require as many stream, or hazard crossings. This concept also provides access to all of the property by land rather than the use of bridges.

• Golf development is more compact and clustered together.

• Allows more room to re-establish the riparian edge along the east side of Wildcat Creek.

• By increasing the use of native prairie and wet meadow grasses on the site, water is taken up by plant roots and the soil water returns to the atmosphere by evaporation from the soil surface or transpiration from plant leaves.

Disadvantages

• The disadvantage is that a large amount of water will cross the site in the event of flooding and may reduce access to the southern half in the event of a large flood.

• The location of the hazard in the southern part of the site impacts the golf routing in negative way, by requiring holes to be closer together and not allowing for adequate safety buffers.

•The location of the southern hazard would require more cut and fill earthwork to create the large water feature.

• Routing water from Wildcat Creek into a hazard in this location would require more reinforcement where water enters the site to prevent water from flooding across the site.

FINAL EVALUATION SUMMARY

Concepts to bring into final design

The following are the key ideas from both concept one and concept two that were determined to be brought forth into the development of the master plan.

• Increase flood water storage capacity for Wildcat Creek and provide more floodplain access.

• Place hazards in locations that work with the natural drainage patterns to minimize earthwork.

• Utilize the natural oxbow that flows across the property to integrate wetlands as part of a stormwater management strategy. In the event of a storm this area historically has flooded in the past. This location works well with the golf routing, allowing the holes to be designed around the hazard while keeping maintained areas out of the low landform.

• Allow adequate separation between holes and use of hazards as a safety buffer.

• The location of the wet meadow on the southern half of the site works with the natural drainage and allows for a golf routing that can have holes on both sides of the hazard.

• By increasing the use of native prairie and wet meadow grasses on the site, water is taken up by plant roots and the soil water returns to the atmosphere by evaporation from the soil surface through the plant leaves.

• Use of native plants to support soil development.

• Re-establish the riparian edge along Wildcat Creek in locations that improve the golf routing.

• Golf course is routed so that out of bounds is on the left of most holes since most golfers slice the ball to the right.

Strategies

Stormwater Management

BMP STRATEGIES

Water Quality & Water Quantity

1. **INLET CONTROL**
   - **Native Grasses**
   - **Riparian Vegetation**
   - **Vegetative Buffer Zones**
   - **Bioswales**

2. **OUTLET CONTROL**
   - **Water Hazards**
     - **Wet Meadow**
     - **Pocket Wetlands**
     - **Wet Pond**
     - **Forebay**
     - **Floodplain Access**

Strategies

One of the goals of this project is to treat stormwater before it enters a natural watercourse. Drainage from the golf course should not discharge directly into Wildcat Creek without undergoing adequate filtration. The Best Management Practices for stormwater management used in this project can be separated into two categories: Inlet control practices, and outlet control practices. The inlet control practices protect water quality and reduce the impacts of storm water on receiving bodies of water. These practices are strategies such as bioswales and vegetative buffer zones (Dodson, 2005, p. 69). Best Management Practices for pollutant removal are more effective when a combination of at least two systems is used together (Dodson, 2005, p. 76). Vegetation was used to reduce the velocity of stormwater runoff. Vegetation also filters sediment, chemicals, and prevents erosion of the bank.

Vegetated Buffer Zone

The Audubon Cooperative Sanctuary program and many Best Management Practice guidelines recommend using a vegetative buffer around all water bodies. On sites where fertilizers and pesticides are routinely used, these buffers are an important way of protecting water quality and providing wildlife habitat (Libby et al., p.18). A vegetative buffer zone, with a minimum width of 15 feet, was implemented around all water hazards with the use of plants to stabilize slopes, filter pollutants, trap excess sediment from runoff, reduce erosion, and slow down water before entering the hazard. The buffer zone consists primarily of native grasses, herbaceous plants, and shrub. The height of the plant material used was dependent on how the type of vegetation used affects the playability of the golf hole.

Bioswales

Bioswales contain dense vegetation and grasses. They are effective strategies for improving water quality. The bioswales are infiltration basins about nine inches deep with engineered soils planted with dense vegetation to promote infiltration and treat stormwater (Dodson, 2005, p.75). These grassed swales carry stormwater runoff to either the treatment pond or the wet meadows shown in Figure 5.8. Bioswales are used to control drainage from the parking lot, and treat the water before the water enters the irrigation pond. Bioswales on the golf course capture runoff near cart paths and direct it into one of the larger wet meadow hazards. This strategy prevents runoff from discharging directly into Wildcat Creek. The water has to pass through the water hazards first which acts a biological filtering systems. According to studies done by the United States Environmental Protection Agency, A vegetative filter can remove 70 percent of sediment, and more than 50 percent of nutrients (Dodson, 2005).

Water Hazards

The outlet control practices used are the water hazards. These strategies are in the form of a water treatment pond used to collect and store water for irrigation. The wet pond was constructed to contain the volume of water from a 25-year storm, in addition to the maintained water level, with the use of an extended detention basin. Overflow is directed through bioswales to a wetland area before it flows into Wildcat Creek.

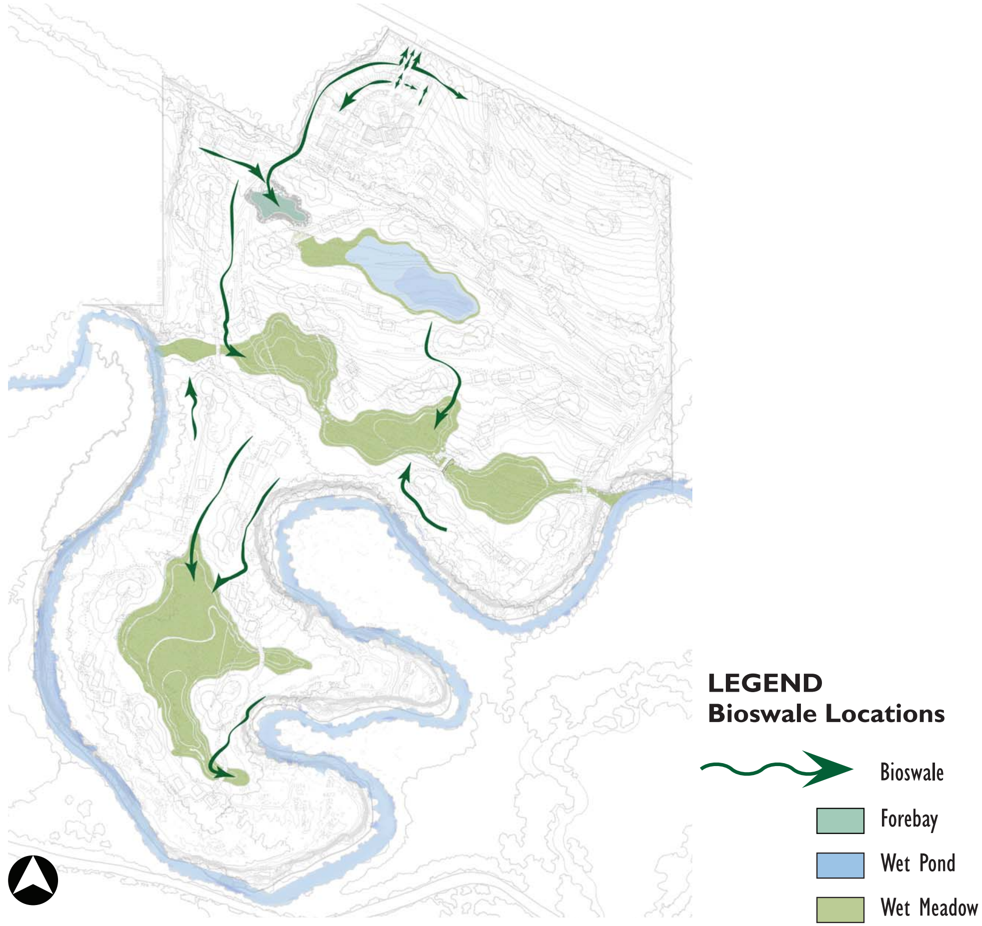


Figure 5.8 Bioswale location diagram (Created by author, 2012)

Vegetation

Vegetation Class

A traditional 18-hole golf course, with a total of 190 acres, typically has 2 to 4 acres of putting green area, 2 to 4 acres of tee boxes, and 30 to 40 acres of fairway area (Beard, 2002, p. 30). Table 5.9 shows the acreage of each of the different vegetation classes found in the 18-hole par 3 golf course designed in this project. Figure 5.9 illustrates the location of each of the vegetation classes. The amount of irrigated turfgrass (Tees, Fairways, and Rough) found on this golf course is slightly higher than required because the course has been designed for maximum playability, and a driving range was included in order to attract a broader market. The 18-hole par 3 course contains 2.47 acres of putting green area, 1.85 acres of tee box area, and 2.52 acres of fairway. A golf course that is maintained with high quality vegetation covering the land has many benefits to the community other than to the golf course itself (Beard, 2002, p. 30). These benefits can be more beneficial than comparative typical urban development or even agricultural production (Beard, 2002, p. 30). The perennial vegetation

2002, p. 30). The perennial vegetation used in this project helps to control soil erosion due to wind and water, and support soil development. The vegetation works to prevent downstream flooding by soaking up stormwater runoff through the extensive fibrous root systems of the plants and holding it on site before releasing it back into the atmosphere through evapotranspiration. Vegetation and turfgrass offer one of the best systems for trapping pollutants before they enter surface water in streams (Beard, 2002, p. 30). Eighty-two percent of the site in this project has been allocated to out of play areas that support these systems to create a diverse ecosystem that contributes in a positive way to the Wildcat Creek Watershed.

Vegetation Class	Area (Acres)
Water Hazards	16.44
Rough	14.18
Fairway	2.52
Tee Boxes	1.85
Putting Greens	2.47
Native Grasses	54.30
Existing Woody Vegetation	24.00
Proposed Woody Vegetation	6.00
Building/Parking	2.50

Table 5.9 Vegetation class diagram (Created by author, 2012)

LEGEND

Irrigated Turfgrass

- Rough
- Fairway
- Tee
- Putting Greens

Non-Irrigated Vegetation

- Native Grasses (Medium to Dry)
- Wet Meadow Plants
- Existing Woody Vegetation
- Proposed Woody Vegetation

Figure 5.9 Vegetation class diagram (Created by author, 2012)

STORMWATER MANAGEMENT STRATEGIES
Vetetation

Irrigation Requirements

Determining the watering needs of a golf course was calculated based on climate data and the amount and type of turfgrass being irrigated as shown in Table 5.10. The location of the irrigated turfgrass is shown in Figure 5.10.

A reservoir was built to collect runoff from the proposed site and the drainage from a 90 acre watershed off-site in order to supply the golf course with a source of irrigation water. The reservoir was sized to also contain the runoff from a 100-year storm event on top of the maintained water level. The storage reservoir was located at the highest elevation so that gravity can help maintain pressure and flow to reduce pumping costs. By centrally locating the source of irrigation it can be distributed across the course as quickly as possible (Muirhead & Rando,1994, p. 92).

1. Fairways and Rough

16.7 acres of fairway and rough

x 1 inch water/week

16.7 acre-inches/week

or 1.30 acre-feet/week

2. Greens and Tees

4.90 acres of greens and tees

x 1.5 inches water/week

7.35 acre- inches/week

or .60 acre-feet/week

3. Golf Course Totals

Fairways/Rough 1.30 acre-feet/week

Greens/Tees .60 acre-feet/week

Total 51.570 acre-feet/week

(Hurdzan, 2006, p. 212)

LEGEND
Irrigated Turfgrass

Fairway/Rough

Tee Area/Geens

Figure 5.10 Vegetation class diagram (Created by author, 2012)

Vegetation Type	Acreage	% of Site	Water Requirements inches/week	Acre-Inches water/week	Acre-Feet water/week	Gallons acre-inch	Gallons water/week
Fairways/Rough	16.70	15%	1.00	16.70	1.30	27,0000	35,100
Greens/Trees	4.90	.04%	1.50	7.35	0.60	27,0000	16,470
Total				24.05	1.91		51,570

Table 5.10 Vegetation class diagram (Created by author, 2012)

STORMWATER MANAGEMENT STRATEGIES
Water Hazards

Wet Meadow

Wet meadows are a type of marsh that are found in shallow lake basins, low-lying farmland, poorly drained fields, and the land between shallow marshes and upland areas. Wet meadows are a type of wetland that resembles grasslands, because the wet meadows are typically drier than other marshes except during periods of seasonal high water. Wet meadows are without standing water for most of the year, but the high water table allows the soil to remain saturated (Wet meadows, 2012). Wet meadows develop on soils that are high enough to prevent standing water from remaining throughout the growing season but stay wet within an inch of the surface (Libby et al., 2004, p.113). A variety of grasses that prefer wet areas such as, sedges, rushes, and wetland wildflowers thrive in the highly fertile soil of wet meadows. The primary water supply to wet meadow areas is precipitation (Wet meadows, 2012). Wet meadow conditions often exist along a stream such as Wildcat Creek. The type of vegetation found in these areas can tolerate submerged or Open water in marshes and wet meadows is typically dominated by floating plants. The biggest factor that influences vegetation in a wet meadow is the changing water depth, which is the deciding factor that determines which plants grow where (Libby et al., 2004, p.113). The plant species found in wet meadows do not just randomly mix together. Each species has a preferred habitat. Different species will occur in different zones at different elevations. Rushes, and sedges will typically be the dominant species of plants that occupy the flooded edge of the hazards while native prairie grasses will occupy the higher elevations and moderate to dry areas on the site. Each species of plants will naturally migrate to the conditions they prefer. These changes will vary from year to year as changes in climate occur (Mitsch & Gosselink,1993, p. 344). At low water levels vegetation in marshes can become very dense. Periodic drying and flooding is generally beneficial, but dramatic changes in water-levels should be minimized. The water level for inland marshes fluctuates as changes in rainfall occur. Structures that control water levels can be beneficial to a site that has modified stream flow. Even small areas of wet meadows and marshes will attract a diversity of wildlife.

During dry years, buried seeds in mudflats germinate to grow a cover of annuals and perennials. When rainfall returns to normal, the mudflats are inundated and the annuals disappear, leaving only the perennial emergent species (Mitsch & Gosselink,1993, p. 345).

The wet meadow plants used in the project can be found in Appendix-C.

STORMWATER MANAGEMENT STRATEGIES
Water Hazards

Systems to address in the design of water hazards

1. **Volume:** If a specific volume is required for storage purposes the pond has to hold enough water to sustain the course. It also has to be large enough to be able to hold the quantity of water entering the basin. The fluctuation of the surface water level can increase shoreline erosion and lead to poor aesthetics if the reservoir is not filled unless it has been designed to allow for fluctuating water levels (Richardson & Fine, 2006, p. 201).

2. **Shoreline:** The edges of water features have to be stabilized in order to prevent erosion. Vegetated buffer strips will be established around each of the hazards to filter runoff entering the basin (Richardson & Fine, 2006, p. 201).

3. **Slopes:** A pond design will have a gradual shelf that extends out for 10 or more feet before the slope drops off. The slope of the pond edge should accommodate for different levels of vegetation (Richardson & Fine, 2006, p. 201).

4. **Water Quality:** The overall water quality must be taken into account. The water feature needs to become a living ecosystem full of plants, animals, and microorganisms. The use of aquatic plants along the shoreline will help maintain a stable ecosystem (Richardson & Fine, 2006, p. 201).

STORMWATER MANAGEMENT STRATEGIES
Water Hazards

Earthwork Estimation

Table 5.11 shows the total earthwork calculations. A rough grading plan using a three foot contour interval was completed in Figure 5.11 to show the location where the site would be disturbed and the average depth of the disturbance.

Factors	Volume (Cubic Yards)
Cut Factor	1.0
Fill Factor	1.0
Cut Volume	147,009.82
Fill Volume	12,003.75
Net Volume	135,006.07

Table 5.11 Earthwork Calculations (Created by author, 2012)

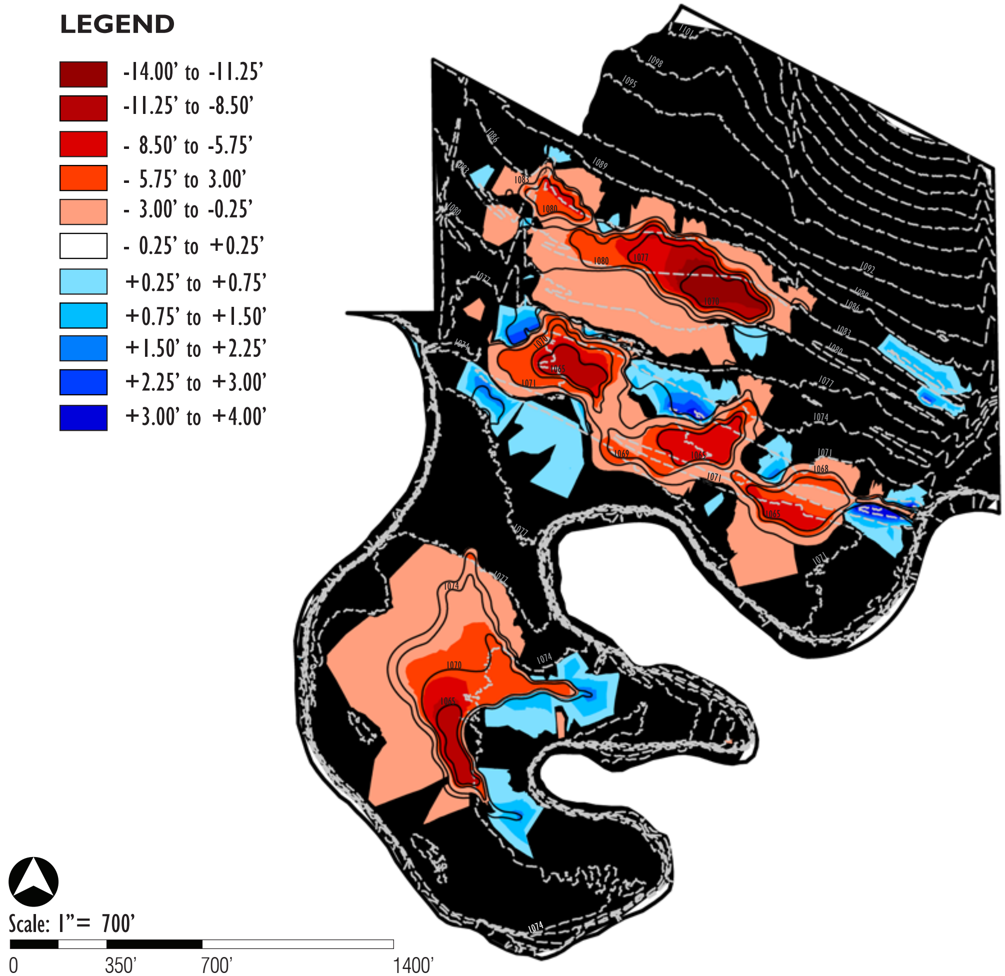


Figure 5.11 General grading plan (Created by author, 2012)

STORMWATER MANAGEMENT STRATEGIES
Water Hazards

The individual site factors in Table 5.12 were used to calculate the total stormwater runoff for each of the hazard areas in Figure 5.12. Using the Rational Method, the calculations for the wet pond are shown in Table 5.13 and the calculations for the wet meadow hazard are shown in Table 5.14. The total acre-feet of area required was then used to further refine the size of the water treatment ponds in order to hold the desired storm event for the project. This project was able to contain the runoff from a 100-year storm event for a one hour duration.

Factors	
Slope (%)	8.0
Length (feet)	3758
Area (Acres)	90
Coefficient	.49
Tc	53.6

Table 5.12 Wet pond runoff site factors
(Created by author, 2012)

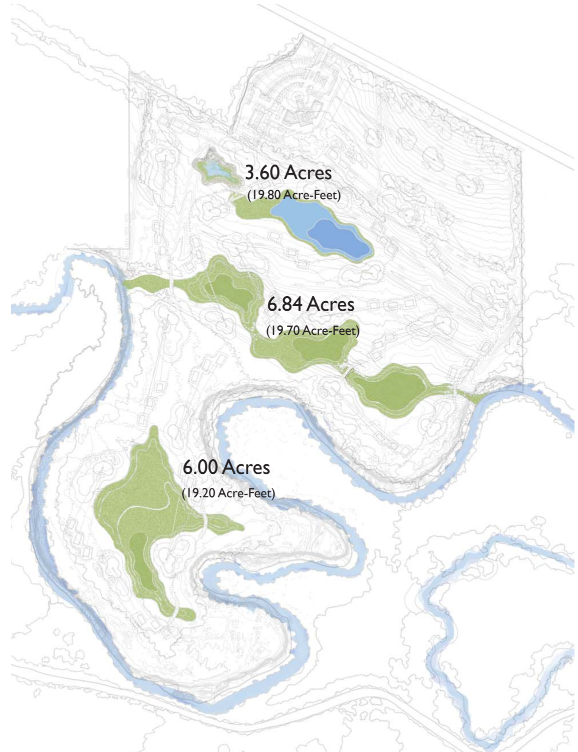


Figure 5.12 Stormwater management strategy locations
(Created by author, 2012)

LEGEND
Water Hazards

- Wet Pond
- Wet Pond (deeper storage zone)
- Wet Meadow
- Pocket Wetlands (Vernal Pools)

CONCENTRATION TIME

$$tc = .619\,(1.1-C)\,L^{.5}\,S^{-.33}$$

$$53.56 = .619\,(1.1-.49)\,3758^{.5}\,.08^{-.33}$$

L = Length of the catchment along the main stream from the basin outlet to the most distant ridge. (feet)

S = Average slope of the catchment (percent)

STORMWATER MANAGEMENT STRATEGIES
Runoff Calculations

WET POND

A x C x I = Q

Storm	Duration (Hours)	(A) Area of basin (acres)	(C) Runoff Coefficient	Rainfall Intensity	(I) Adjusted Rainfall Intensity	(Q) Discharge (acre inches per hour)	Acre Feet
2 year storm	1	90	.49	1.60	1.80	79.38	6.58
10 year storm	1	90	.49	2.40	2.80	123.48	10.29
25 year storm	1	90	.49	2.90	3.20	141.12	11.76
100 year storm	1	90	.49	3.70	4.10	163.17	13.59

Table 5.13 Wet pond runoff calculations (Created by author, 2012)

WET MEADOW

A x C x I = Q

Storm	Duration (Hours)	(A) Area of basin (acres)	(C) Runoff Coefficient	(I) Rainfall Intensity	(Q) Discharge (acre inches per hour)	Acre Feet
2 year storm	1	44	.40	1.60	24.64	2.05
10 year storm	1	44	.40	2.40	36.96	3.08
25 year storm	1	44	.40	2.90	44.66	3.72
100 year storm	1	44	.40	3.70	65.12	5.40

Table 5.14 Wet meadow runoff calculations (Created by author, 2012)

Design Application

Master Plan

MASTER PLAN

A master plan for the application of a golf course to mitigate downstream flooding along Wildcat Creek is shown in Figure 5.13. Water quality is addressed through water treatment ponds that act as a biologic filter to reduce sediment and chemicals from surface runoff. These stormwater management areas were designed to act as an aesthetically pleasing water hazard on the golf course. Wet meadow grasses were used as a hazard designed to help increase the infiltration capacity of the site. The golf holes were placed in strategic locations to bring the water hazards into play as much as possible. These water hazards were designed to collect the runoff from a 100-year storm event for a one hour duration.

When the water level in Wildcat Creek reaches a specific elevation, the water is diverted into an old oxbow that flows across the middle of the site. This concept allows Wildcat Creek controlled access to the floodplain.

Cart paths that go across parts of the hazards or low areas are constructed in the form of a boardwalk to minimize the impact on the area and allow water to move under them naturally. The boardwalks help avoid removing vegetation and disturbing the site (Libby et al., 2004, p. 151). The wood used for boardwalks should be treated with a copper based wood preservative. Other types of preservatives can harm plants, fish and wildlife (Libby et al., 2004, p. 105). The use of boardwalks crossing the hazards brings the golfer into the experience. This interaction with the hazard makes the area more accessible and keeps people from feeling excluded from environmentally sensitive areas using vegetative buffer zones around hazards.

Figure 5.13 Conceptual master plan (Created by author, 2012)

GOLF COURSE COMPONENTS

Golf Course Layout

The 114 acre site contains a 18-hole par-3 golf course, driving range and practice facility. The course is 3,008 yards from the back tee, and 2,101 yards from the front tee. Table 5.15 shows the yardage for each individual hole. Water hazards, placed in strategic locations, come into play on 14 of the 18 holes as shown in Figure 5.14. The course contains a variety of natural features that include trees, prairie grasses, wet meadows, ponds, and creeks.

HOLE	1	2	3	4	5	6	7	8	9	Out
CHAMPIONSHIP	195	177	182	172	140	175	152	198	178	1569
BLUE	140	150	145	153	123	133	125	150	156	1275
PAR	3	3	3	3	3	3	3	3	3	27
RED	117	130	110	123	100	96	116	130	135	1057

10	11	12	13	14	15	16	17	18	IN	TOTAL
133	158	169	160	152	140	195	169	163	1439	3008
110	130	146	140	130	135	160	150	140	1241	2516
3	3	3	3	3	3	3	3	3	27	54
93	115	120	125	110	116	130	125	110	1044	2101

Table 5.15 Golf course scorecard with hole length in yardage (Created by author, 2012)

Figure 5.14 Golf course layout (Created by author, 2012)

GOLF COURSE COMPONENTS

Golf Facility

A fully functioning golf facility with adequate space and size was included in the program. The clubhouse facility is shown in Figure 5.15. The organization and flow of this area in relation to the golf course is an important element of a successful business operation. The square footage needed for each element including storage for the required number of carts was taken into account.

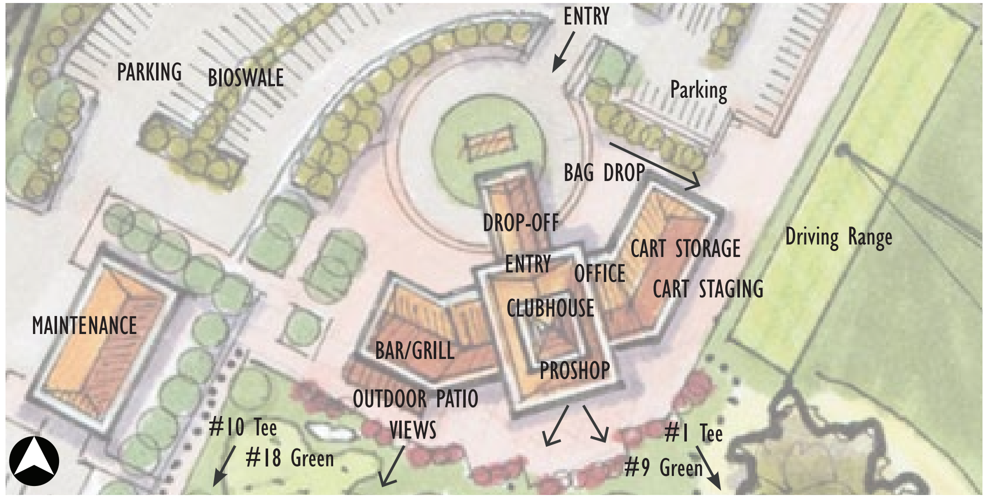


Figure 5.15 Golf facility program diagram (Created by author, 2012)

Clubhouse Area:	**4 Acres**
Building size	
Parking requirements	150 stalls
Cart storage area	40 carts
Cart staging area	

Practice Facilities:	**10 Acres**
Driving Range	
Practice Greens	8000 square feet.
Practice Chipping Green	4500 square feet.

Other Structures: 1 Acre

Range storage
Maintenance facility
- Building
- Storage areas

Cart paths
Boardwalks/Bridges over low areas

GOLF HOLE BY HOLE ANALYSIS

Golf Strategy

Each golf hole was evaluated from a strategic standpoint in Table 5.16 The holes were designed to make each shot interesting and challenging for the golfer. This analysis not only looks at the ideas from a golf point of view, but it also looks at how each golf shot is influenced by the location of the hazard.

GOLF COURSE

Flow		Design Features		
Hole	Par 3 Initial Routing Yardage	Hole Direction (Degrees)	Change in Direction	Water hazard comes into play on hole (left or right side)
1	195	115		
2	177	140	X	
3	182	210	X	R & L
4	172	315	X	R
5	140	120	X	
6	175	265	X	L
7	152	340	X	L
8	198	110	X	L
9	178	115	X	L
10	133	250	X	L and R
11	158	155	X	L and R
12	169	200		R
13	160	195		R
14	152	330	X	R
15	140	140	X	R
16	195	160		
17	169	10		R
18	163	120	X	R
	75 100 125 150 175 200 225			

Table 5.16 Golf hole by hole analysis diagram (Created by author, 2012)

Forced carry over water hazard	Bail Out Area Provided	Wildcat Creek comes into play (left or right side)	Average Distance Between Holes (feet)	Stream Crossing/BoardWalk Required	Tee Elevation (feet)	Green Elevation (feet)	Change in elevation from tee to green (feet)
			150		1093	1090	+ 4
			150		1089	1084	- 10
	X	L	130	X	1077	1070	- 5
	X	L	250	X	1071	1072	+ 2
			160		1073	1076	+ 6
	X		200		1076	1073	- 5
	X		200		1075	1080	+11
	X		120		1082	1079	- 3
	X		150	X	1083	1087	+ 5
50yds (front) / 85yds(back)	X		150	X	1088	1081	- 5
65yds (front) / 83yds(back)	X		150	X	1079	1075	- 3
	X	L	150		1076	1077	+ 3
40yds (front) / 100yds(back)	X	L	300	X	1075	1074	- 2
	X	L	100	X	1075	1076	+ 2
	X	L	300		1076	1077	1
	X	L	300	X	1076	1077	- 4
			140		1076	1085	+ 9
	X		N/A	X	1087	1089	+ 2

EXTENDED STORAGE POND
Irrigation pond for water treatment

Golf Functions

The pond in figure 5.16 acts as an aesthetically pleasing hazard that comes into play on the golf course. Golf holes were routed on each side of the pond. Visually water is very intimidating for the golfer. A tee shot from the back tee has to fly over the corner of the hazard leaving little room for error. A tee shot from the foreward tee box is not required to fly over the hazard and has more room for error if a less skilled player hits a bad shot.

Hydrologic Functions

Lakes and ponds are inland basins that contain standing water (Libby et al., 2004, p.9). The pond acts as a biologic filter to collect and treat water. A 6-foot minimum vegetative buffer was kept between the irrigation pond and the maintained rough. A forebay shown in Figure 5.17 placed in the inlet helps improve water quality and trap sediment before it enters the pond. This pond collects the runoff from the golf course as well as water off site. The pond is sized to hold the required irrigation to water the golf course. plus the equivalent of a 100-year storm event

Figure 5.16 Extended storage pond surrounded by native prarie grasses (Created by author, 2012)

on top of the maintained water level. Wet meadow grasses are planted in this area to allow for infiltration during a storm event. The area for holding water would have a lined bottom to hold water on site. Figure 5.18 shows the deep reserve located in the lower portion of the pond that could hold the 2 acre-feet of water required to irrigate the course in a period of drought.

Figure 5.17 Extended storage pond diagram (Created by author, 2012)

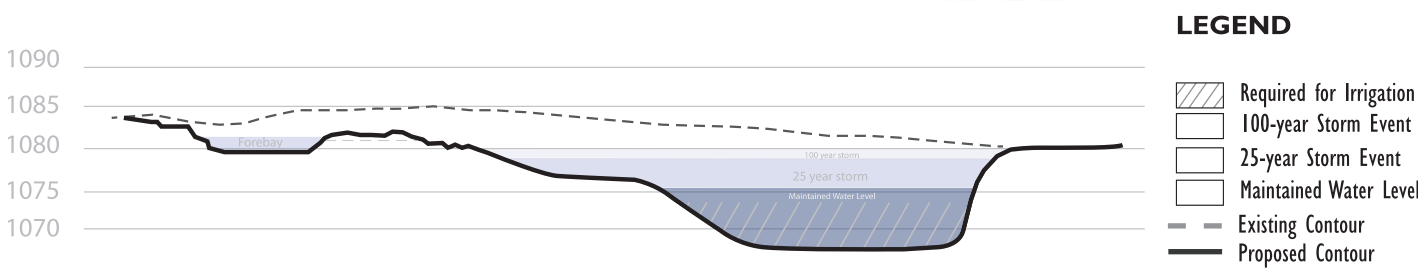


Figure 5.18 Section AA extended storage pond (Created by author, 2012)

WET MEADOW HAZARD
To increase floodplain access for Wildcat Creek

Golf Functions

This low area on the site was designed as a hazard to come in and out of play of on several golf holes by surrounding part of the green.

Hydrologic Functions

The hazard in Figure 5.19 was designed to increase the floodplain access of Wildcat Creek in the event of high flowing water. Figure 5.20 shows the hazard during the event of a flood. Oxbow wetlands are very important to adjacent stream systems and should be protected and restored (Libby et al., 2004, p. 79). Native vegetation is used to filter sediment and pollutants from runoff that enters the hazard. The hazard is made up of wet meadow grasses, with sedges concentrated in deeper pocket wetland pools. The pocket wetlands shown in Figure 5.21 that would contain water for a longer period of time. Using wet meadow grasses allows for a fluctuating water level. This hazard would receive water from Wildcat Creek when the water level reached just above 1.5 times the bank full height shown in Figure 5.22. This would flood roughly one time per year.

Figure 5.19 Water hazard shown with Wildcat Creek at low flow (Created by author, 2012)

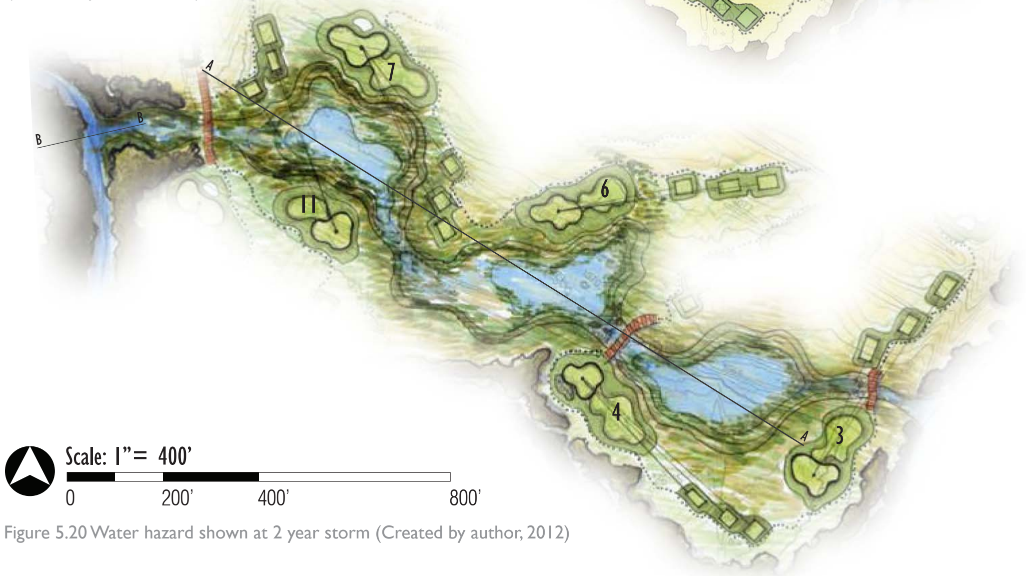


Figure 5.20 Water hazard shown at 2 year storm (Created by author, 2012)

The inlet from Wildcat Creek would be controlled with the use of a headgate. For most of the year the water hazard would be dry and look like Figure 5.23. During a 2-year storm event the water hazard would fill with water and look like Figure 5.24.

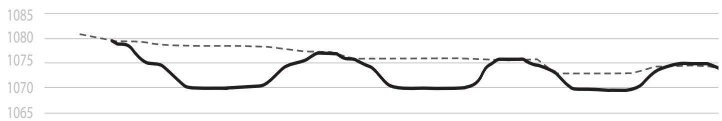


Figure 5.21 Section AA showing depth of pocket wetlands (Created by author, 2012)

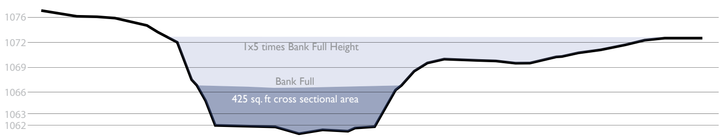


Figure 5.22 Section BB of Wildcat Creek (Created by author, 2012)

LEGEND

Existing Contour

Proposed Contour

Figure 5.23 Wet meadow hazard perspective shown at low flow (Created by author, 2012)

Figure 5.24 Wet meadow hazard perspective shown at 2-year storm event (Created by author, 2012)

WET MEADOW HAZARD

To increase the infiltration capacity of the site

Golf Functions

A cart path was routed along the outside of the holes in Figure 2.25 to bring the hazard into play on the inside of the holes. This way the cart path does not interfere with play. Figure 2.26 shows the deepest area of the hazard is concentrated around the greens so that if water levels are high enough, these areas will fill up first. Visible water increases the perceived difficulty of the hole. The hazard comes into play for back tee boxes more than the front tee. This way a less skilled player is not forced to hit as accurate of a shot.

Hydrologic Functions

This hazard was designed to help increase the infiltration capacity of the site. The hazard was designed to work around the natural landform. Soil was excavated to allow the hazard to hold the equivalent of a 100-year, 1 hour storm event. The site naturally drains through the wet meadow plants between the golf holes shown in Figure 5.27. From here water flows into the hydric soils on the southeast corner of the site before the water enters Wildcat Creek as shown in Figure 5.28.

Figure 5.25 Wet meadow hazard diagram (Created by author, 2012)

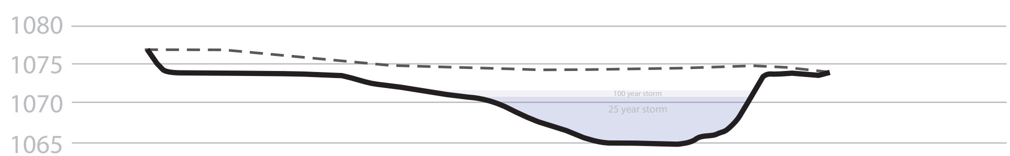


Figure 5.26 Section AA wet meadow (Created by author, 2012)

Figure 5.27 Wet meadow hazard directing drainage between the tees and green (Created by author, 2012)

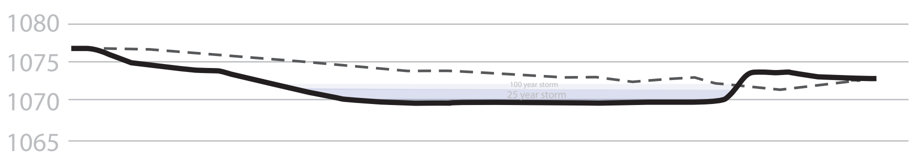


Figure 5.28 Section BB wet meadow (Created by author, 2012)

Chapter 6

Conclusions

CONCLUSIONS

This project concludes that a golf course can be designed to provide flood water storage, increase the infiltration capacity, and provide Wildcat Creek with more floodplain access in the event of a flood. The water hazard is the element that brings function and design together.

Designing water hazards in locations that work with the natural systems of a site, creates a self-sustaining ecosystem that can be used to treat and filter stormwater. By increasing the use of native prairie and wet meadow grasses on the site, more water can be taken up by plant roots and returned to the atmosphere through evapotranspiration. Using native grasses as a design feature provided 50 acres of land to support soil development. Re-establishing the riparian edge along Wildcat Creek in specific locations not only improves the design of the golf holes but also reduces runoff rates and improves stream bank stability.

A Par-3 hole is more advantageous to the use of design elements that benefit both golf and the environment. The use of 18-hole par-3 golf course dramatically reduces the amount of maintained turfgrass required compared to a traditional 18-hole course. Par-3's have the advantage of using the space between the tee and green for native vegetation and the creation of hazards, whereas, a par-4 or par-5 requires a large amount of highly maintained turfgrass for the second and third shot. The shorter course minimizes costs associated with maintenance, and the facilities required. Using par-3 holes, reduces the amount of fertilizer, pesticides, and water required.

Designing for maximum playability requires more fairway turf around the green, but these areas provide a less skilled player with a place to miss the green and still being able to keep their ball in play. The advantage of a course that is appealing to all skill levels is that it caters to a wider marketable audience. The skill level required to play the course could be adjusted for specific environmental and marketing goals of the project through the elimination of multiple tee boxes and the amount of turf around the green.

Water serves many different purposes on the golf course. Water hazards can be used to create strategy, provide a safety buffer, enhance aesthetics, promote diverse wildlife, or supply a source of irrigation. If the course is designed to meet specific goals, the hazards can be used to mitigate flooding downstream and improve water quality. Modern earth moving equipment, synthetic liners, and the ability to supply water to the hazards, make it easy to construct hazards on almost any site (Hurdzan, 2006, p. 105). From a golf standpoint it is important to consider the design of the hazards and how it affects the game of golf. From an environmental standpoint the location and design has to work with existing hydrology, natural systems, and the climate to create a thriving ecosystem that ensures long-term success. When building a new golf course, an in-depth site analysis and program that responds to the existing site conditions can benefit the entire community as well as the golf course itself. When a golf course is designed to eliminate negative impacts on the surroundings, the benefits a golf course can bring to a community are greater than the harms that impact the surrounding site.

This project demonstrates how the game of golf can work with natural systems to not only improve the golf experience and provide a strong framework for long term economic success, but also golf courses can become an important part of any community's stormwater management program if properly sited and designed. Golf development can provide a place for recreation while also taking on environmental concerns within the community. A golf course can connect natural systems into a sustainable system that works for the benefit of golfers, the environment, and the community. The design solution in this project was driven in response to site specific conditions. The process, methods, and strategies used are universally applicable to golf development on other sites.

A golf course can be designed hydrologically within a floodplain around the use of water hazards, to reduce flooding along Wildcat Creek. Water hazards on the golf course can be designed to increase infiltration, and improve water quality while also creating a course that challenges the best players, as well as, beginners.

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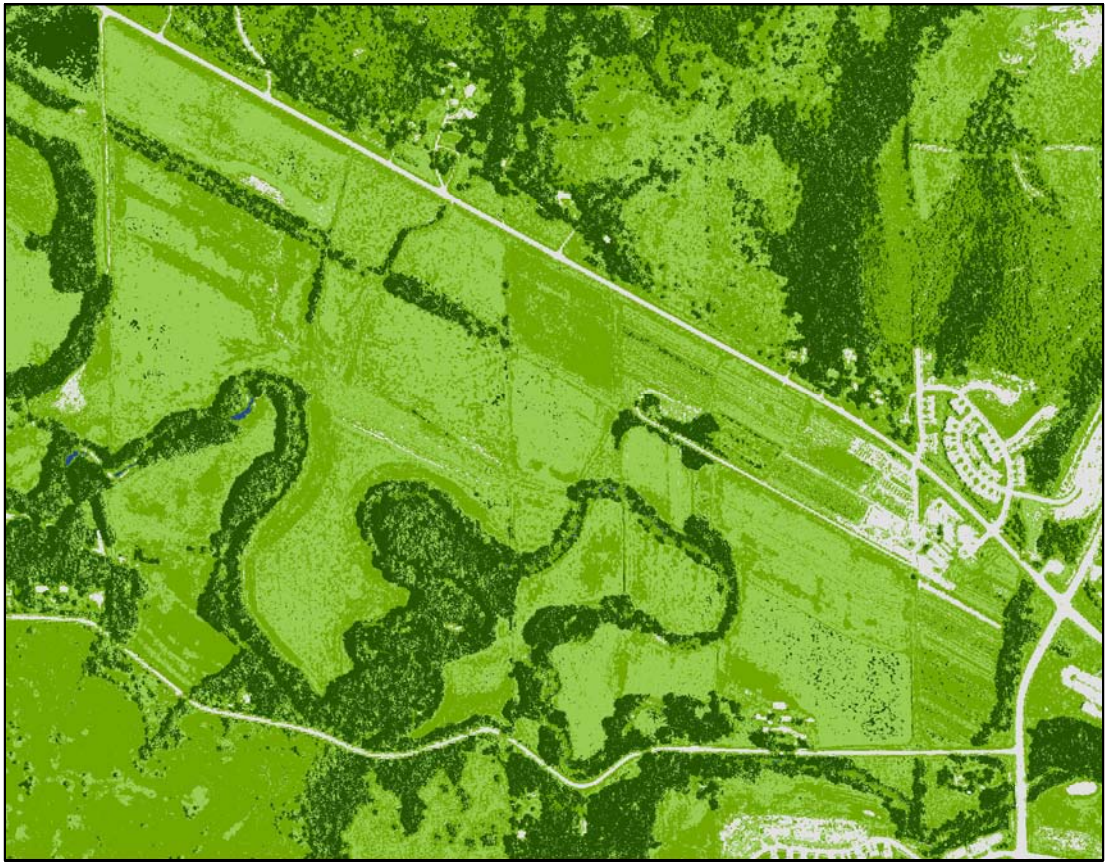
Appendix - A

Maps

VULNERABILITY ANALYSIS
Land Cover



Scale: 1"= 1,250 feet

0 625 1,250 2,500 feet

Figure A.1 Land cover image classification (Generated from GIS data by author, 2012)

Land cover shown in Figure A.1 was given the highest weighted value due to the importance of maintaining woody vegetation along the riparian edge of Wildcat Creek. Grasslands were more important to protect than tillage agriculture because of their ability to reduce sediment and slow runoff to increase infiltration of water into the ground. Agricultural land was determined to be the least vulnerable to damage caused by development.

LEGEND

Influence 35 %

Land Cover	**Value (1to 9)**
Trees	1
Cropland	8
Grassland	3
Impervious Surface	9
Water	1

VULNERABILITY ANALYSIS
100 Year Floodplain

The area within the 100 year floodplain was determined to be more vulnerable than the land outside of the limits. During the recent flash floods water has reached the limits of the 100 year floodplain shown in Figure A.2.

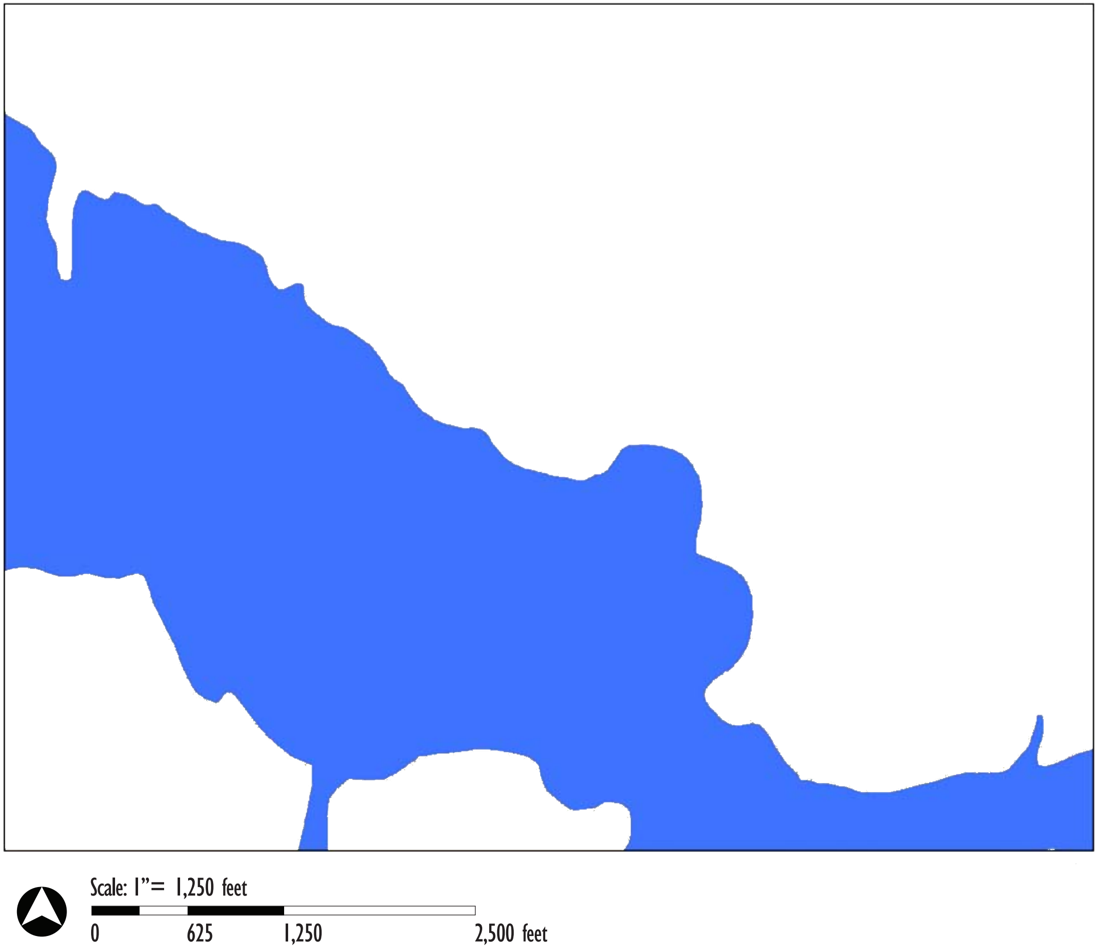


Figure A.2 100 year floodplain (Generated from GIS data by author, 2012)

LEGEND

Influence **21 %**

Floodplain	Value (1 to 9)
Outside floodplain	0
FEMA 100 Year Floodplain	1

VULNERABILITY ANALYSIS
Slope Percentage

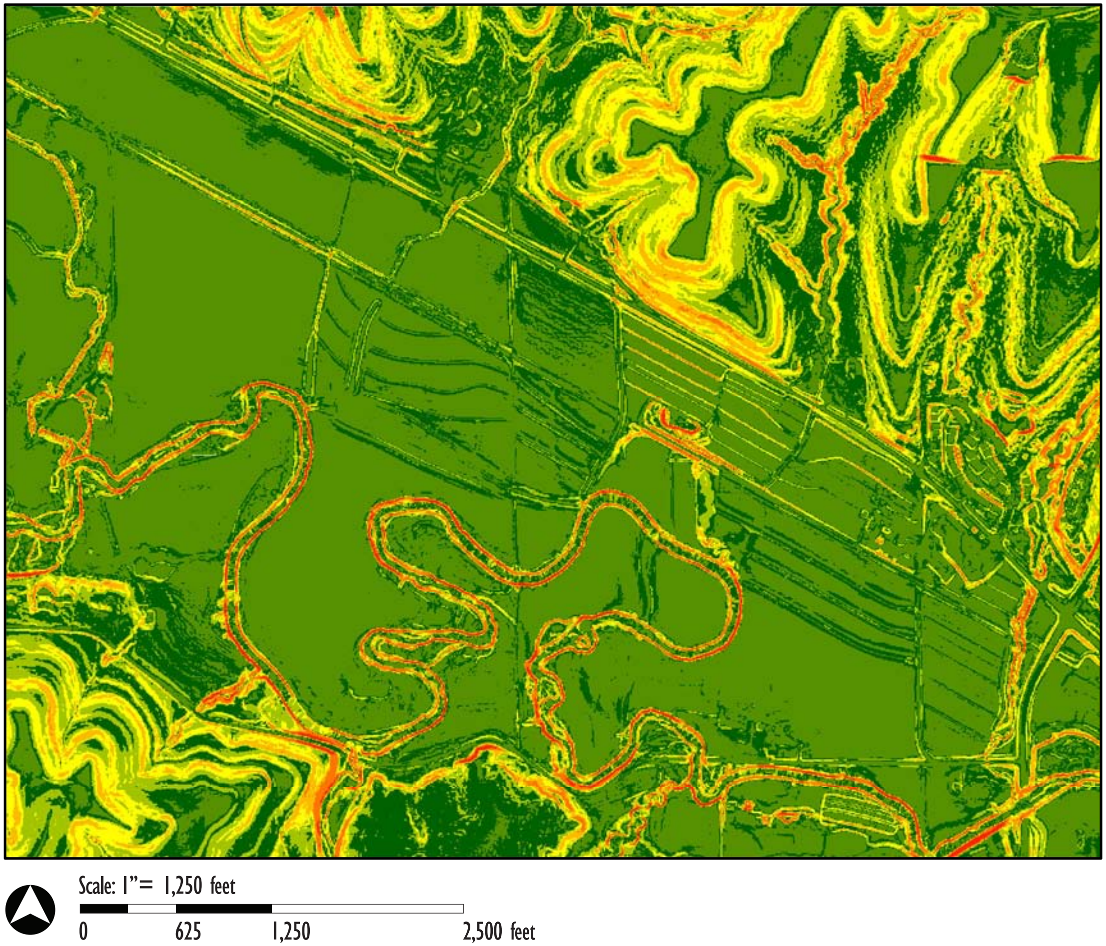


Figure A.3 shows the slope percentages on site. This study is looking at the application of flooding mitigation techniques within a floodplain region along Wildcat Creek. The majority of the land in this region has a slope range from 0-3 percent. The higher slope percentages that range from 10- 30 percent are found only along the bank Wildcat Creek. These areas were considered highly vulnerable.

LEGEND

Influence 22 %

Slope percentage	Value (1 to 9)
0-3%	8
3-6%	5
6-10%	5
10-15%	4
15-21%	3
21-28%	2
28%+	2

Figure A.3 Slope percentage. (Generated from GIS data by author, 2012)

VULNERABILITY ANALYSIS
150 Foot Buffer Zone

For this project a 150 foot buffer from the centerline of Wildcat Creek was established. This zone shown in Figure A.4 was determined to be highly vulnerable to any disturbance.

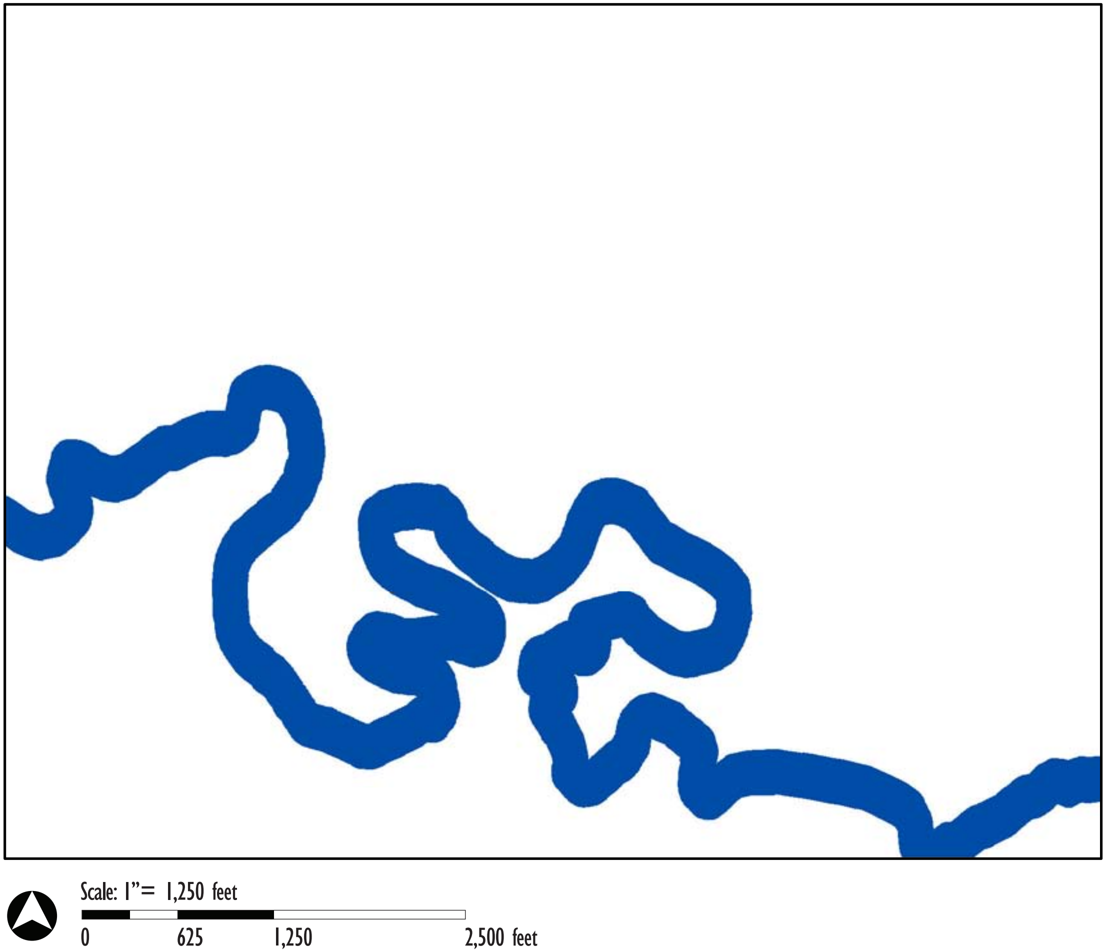


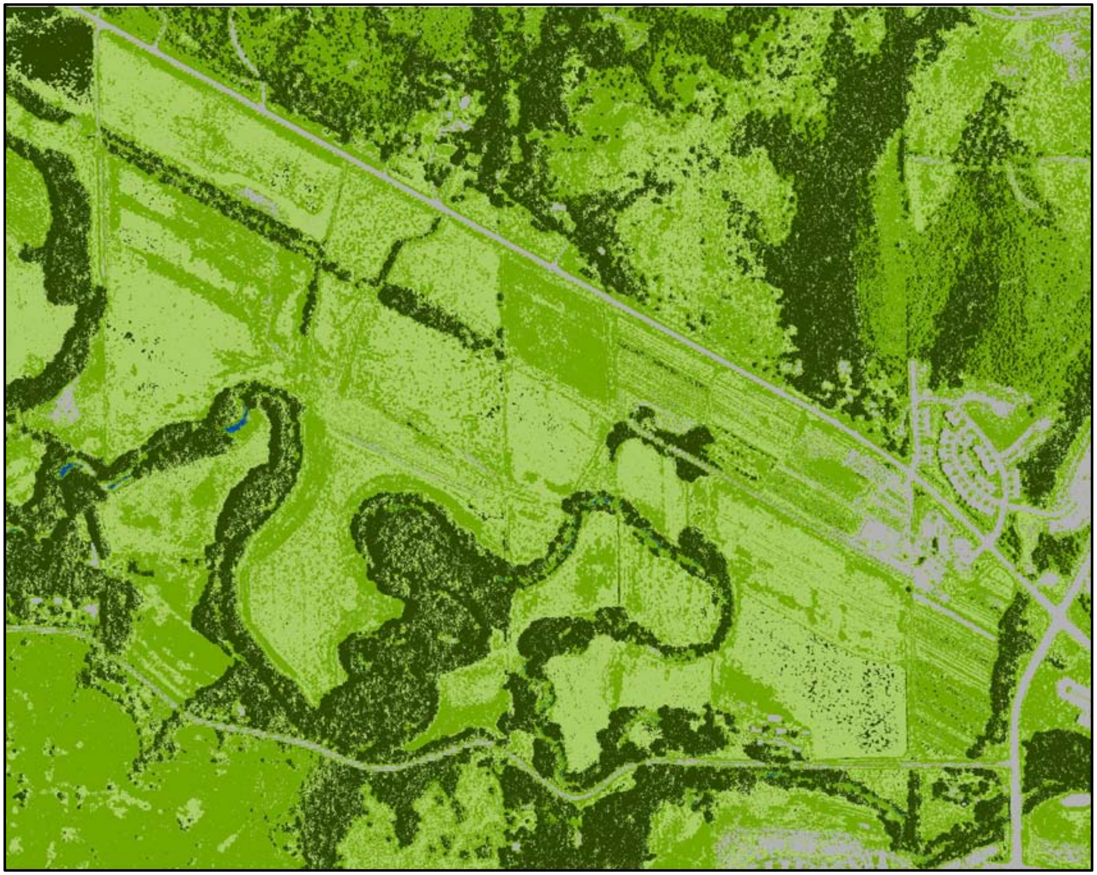
Figure A.4 150 foot buffer zone around Wildcat Creek (Generated from GIS data by author, 2012)

LEGEND

Influence **22 %**

150' Buffer	**Value (1 to 9)**
Outside Buffer	0
Within 150 foot Buffer	1

GOLF SUITABILITY ANLAYSIS
Vegetation



Trees and woody vegetation in Figure A.5 are desirable features necessary for a golf course. It is important to keep this areas intact. Grassland and agricultural fields and cropland are the areas least susceptible to damage by any golf course development.

LEGEND

Influence **40 %**

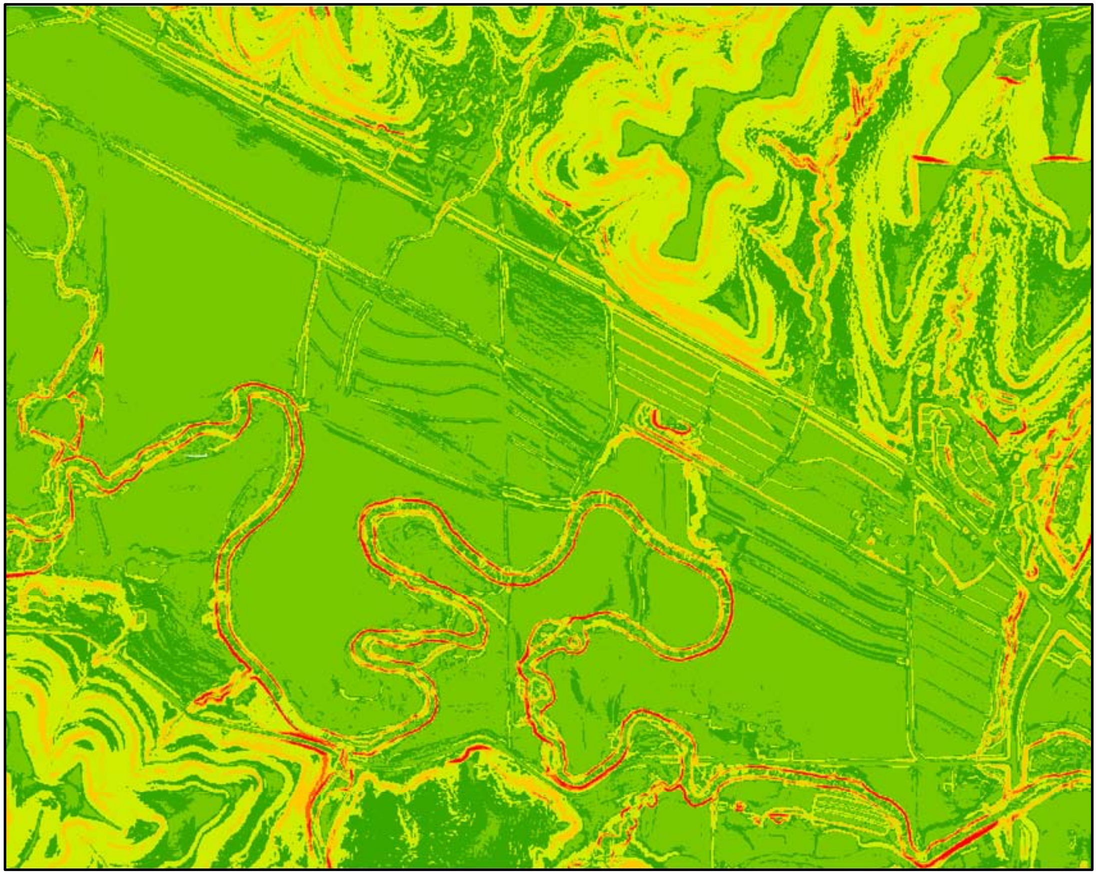
Land Cover	Value (1 to 9)
Trees	1
Cropland	9
Grassland	8
Impervious Surface	1
Water	1

Scale: 1"= 1,250 feet

0 625 1,250 2,500 feet

Figure A.5 Land cover image classification (Generated from GIS by author, 2012)

GOLF SUITABILITY ANALYSIS
Slope



Proper drainage requires slopes greater than two percent. Because the majority of the site falls under the range of 0-3 percent, as shown in Figure A.6, some earthwork will be required.

LEGEND

Influence 50 %

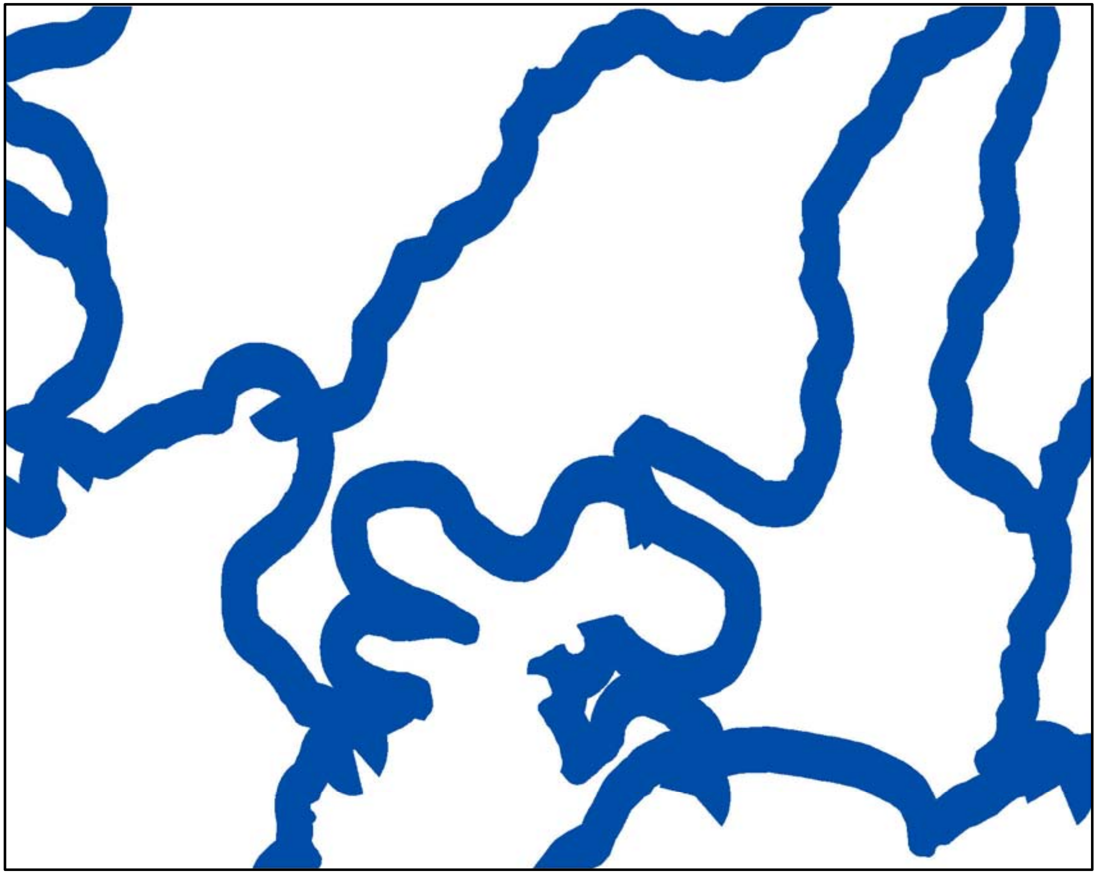
Slope percentage	Value (1 to 9)
0-3%	8
3-6%	9
6-10%	7
10-15%	7
15-21%	5
21-28%	5
28%+	3

Scale: 1"= 1,250 feet

0 625 1,250 2,500 feet

Figure A.6 Slope percentage (Generated from GIS by author, 2012)

GOLF SUITABILITY ANALYSIS
Proximity to Stream Corridors



Creeks and drainage ways are highly desirable features to become design features that are part of a golf hole. Figure A.7 shows where a 300 foot buffer was established around all drainage ways, because this is the maximum distance that a golf hole would be able to utilize these drainage ways and natural watercourses as part of the hole. These drainage ways can become water hazards that can improve the golfers experience by adding to the aesthetics, strategy, difficulty of the hole when incorporated into the hole when brought into play.

LEGEND

Influence 10%

300' Buffer	**Value (1 to 9)**
utside Buffer	0
/ithin 300 foot Buffer	9

Scale: 1"= 1,250 feet

0 625 1,250 2,500 feet

Figure A.7 The 300' buffer around drainage flowlines (Generated from GIS by author, 2012)

CLUBHOUSE SUITABILITY ANALYSIS
Vegetation

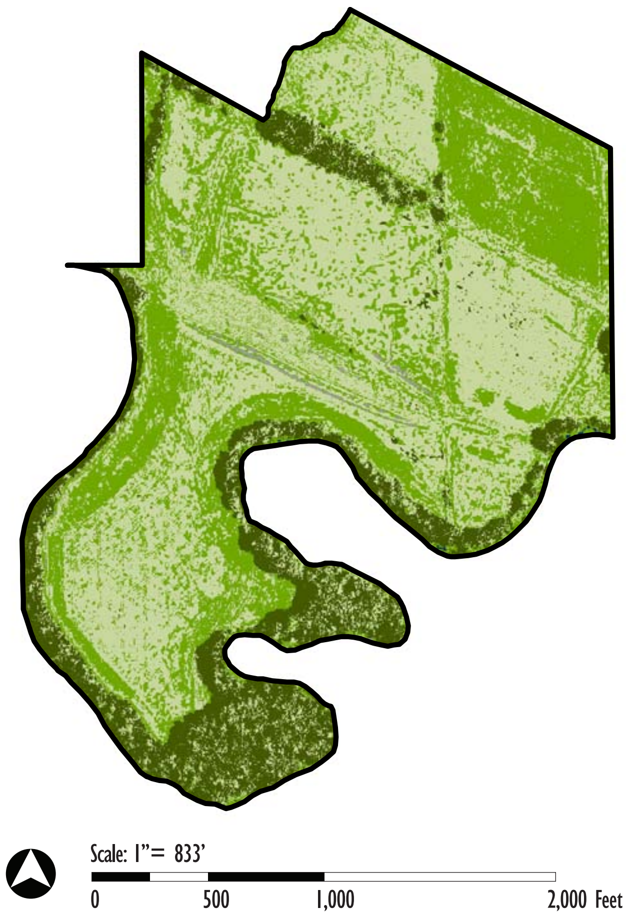


Figure A.8 Vegetation Layer (Generated from GIS data by author, 2012)

Figure A.8 shows the vegetation on site. Because of the lack of woody vegetation present, and the importance of preserving as much woody vegetation as possible, vegetation classed as trees was rated highly vulnerable.

LEGEND

Influence 20 %

Land Cover	Value (1 to 9)
Trees	1
Cropland	9
Grassland	5
Impervious Surface	8
Water	1

CLUBHOUSE SUITABILITY ANALYSIS
Slope

Figure A.9 Slope percentage (Generated from GIS data by author, 2012)

In Figure A.9, slopes greater than seven percent were generally located along the banks of drainage ways. Slopes in this range were given a value that reflected as highly vulnerable.

LEGEND
% Influence 16 %

Slope percentage	Value (1 to 9)
0-1%	3
1-2%	8
2-3%	9
3-5%	7
5-7%	3
7-10%	2
10%+	2

CLUBHOUSE SUITABILITY ANALYSIS
100-Year Floodplain Boundary

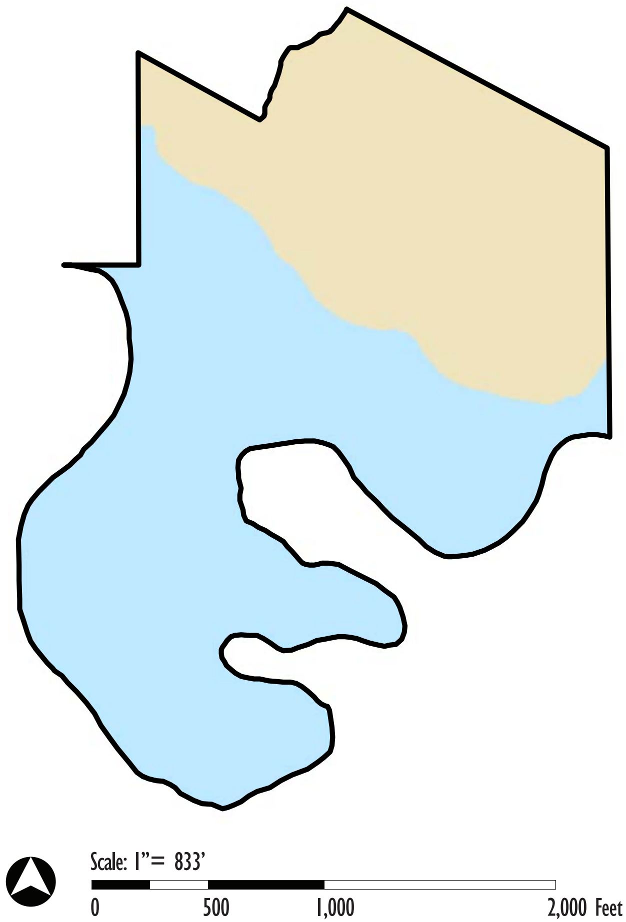


Figure A.10 100 Year floodplain (Generated from GIS data by author, 2012)

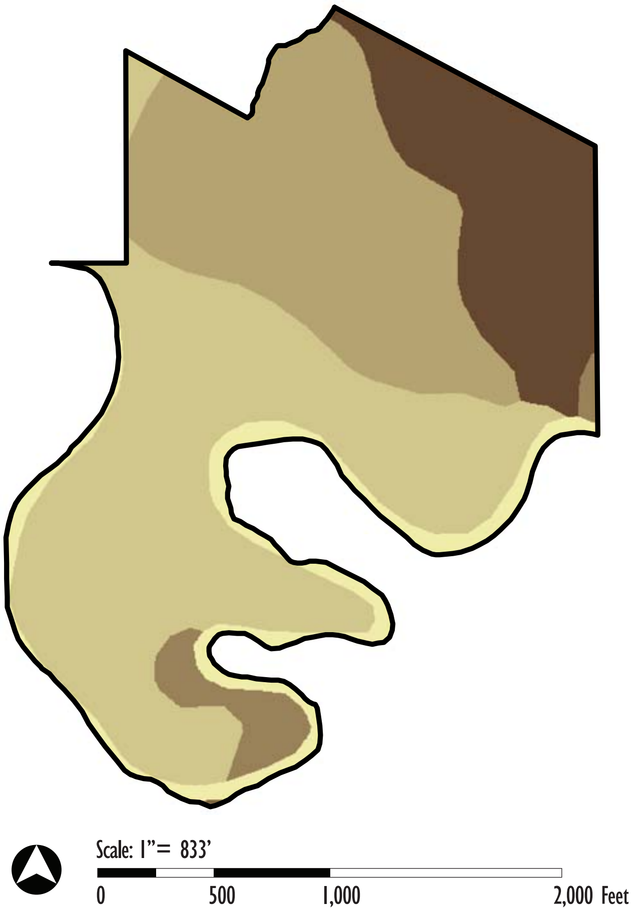
When constructing a building to become the clubhouse using slab on grade construction, it is important that the building is located outside of the 100 year floodplain boundary. All areas within the 100-year floodplain boundary shown in blue in Figure A.10, were not considered for the location of the clubhouse. The location of the floodplain was given a higher percentage of influence over other factors to determine building suitability.

LEGEND
% Influence 16 %

Floodplain	Value (1 to 9)
100 Year Floodplain	0
Outside floodplain	9

CLUBHOUSE SUITABILITY ANALYSIS
Soil (Percent of Clay)

Soil properties are important to take into consideration when defining suitable locations for a building. Figure A.11 shows the percent of clay found on each part of the site. The soil along the road has the highest clay content as well as the highest potential for runoff. The soil in this area is also in the worst condition as far as erosion.



LEGEND
% Influence 16%

Amount of Clay	Value
41.4	8
31.3	8
28.9	4
27	3
Stream Channel	1

Figure A.11 Percent of clay found in the soil (Generated from GIS data by author, 2012)

CLUBHOUSE SUITABILITY ANALYSIS
Site Access (Proximity to Anderson Avenue)

Access to the site is important for visibility. Anderson Avenue is the only road that provides access to the site in Figure A. 12 and is located along the north edge of the property boundary.

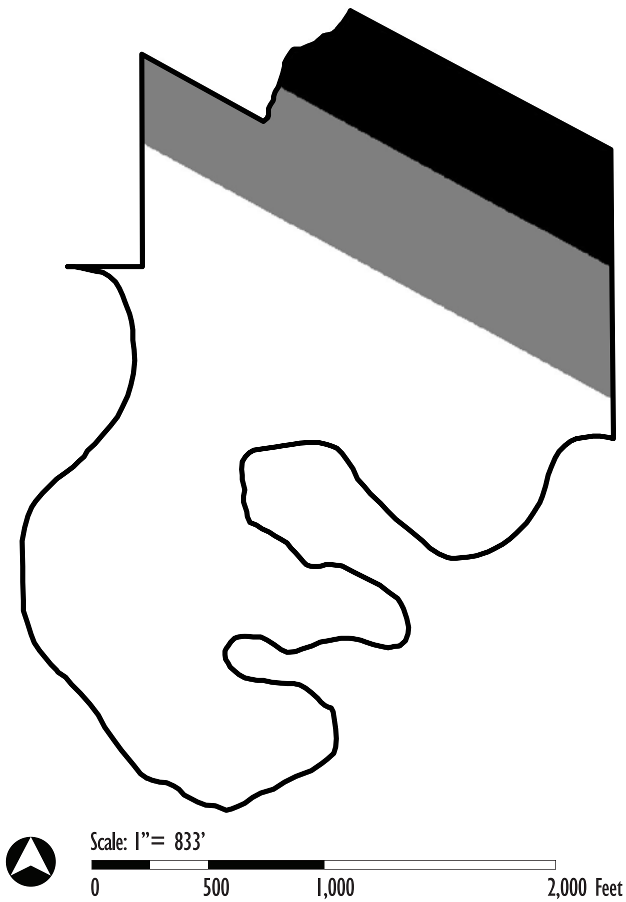


Figure A.12 Distance to Anderson Avenue (Generated from GIS by author, 2012)

LEGEND

% Influence 16 %

Floodplain	Value (1 to 9)
500'	8
1000'	7
Outside boundary	0

WATER HAZARD SUITABILITY (Infiltration)
Soil (Percent of Clay)

In Figure A.13, the soils on site were looked at in terms of the percentage of clay present. Soils with a high clay content are less permeable. Water does not infiltrate into the ground as well as other soils.

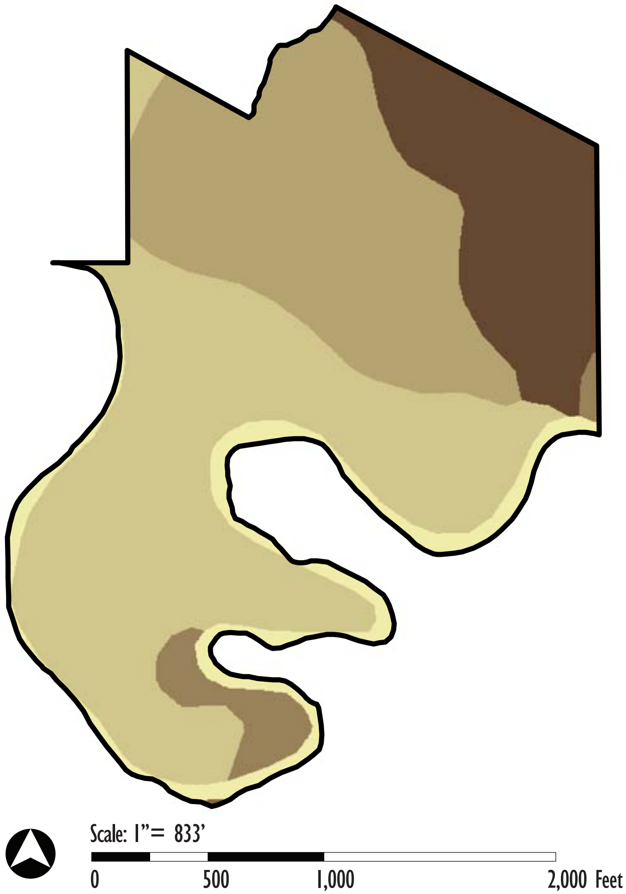


Figure A.13 Percent of clay (Generated from GIS data by author, 2012)

LEGEND
% Influence 20%

Amount of Clay	Value
41.4	1
31.3	3
28.9	4
27	8
Stream Channel	8

WATER HAZARD SUITABILITY (Infiltration)
Permeability (Hydraulic Conductivity)

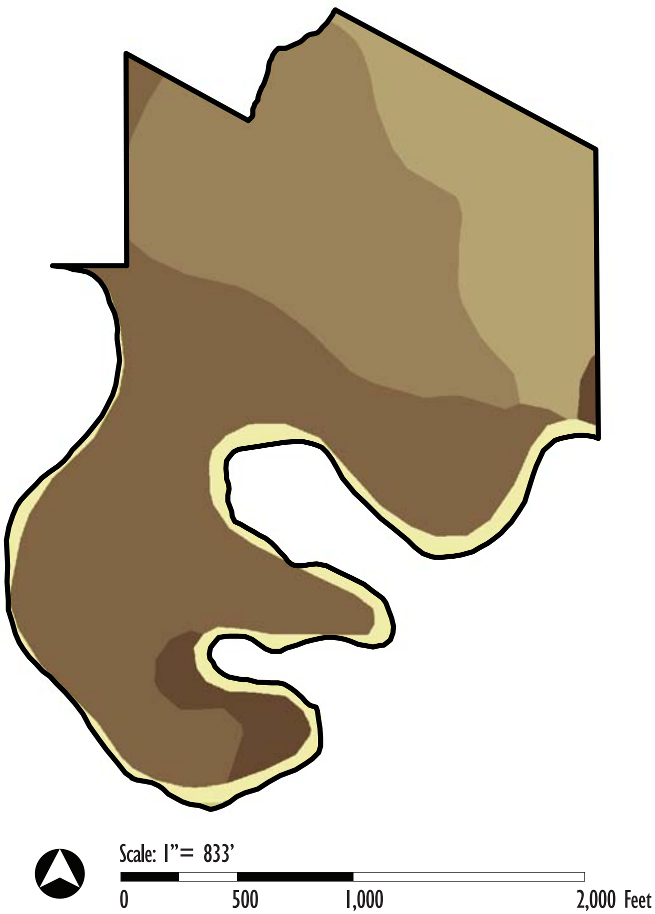


Figure A.14 Soil permeability (Generated from GIS data by author, 2012)

Soil permeability in Figure A.14 was studied in terms of hydraulic conductivity which describes water movement through the soil in inches per hour. Soil types that allow water to move through the soil at faster rates are more permeable. Soil types that allow water to move through the soil at a slower rate are considered less permeable. Infiltration of water into the ground requires soils that are more permeable.

LEGEND
% Influence 20%

Ksat (Inches per hour)	Value
9	9
8.5	7
8.4	4
3.5	2
Stream Channel	1

WATER HAZARD SUITABILITY (Infiltration)
100-Year Floodplain

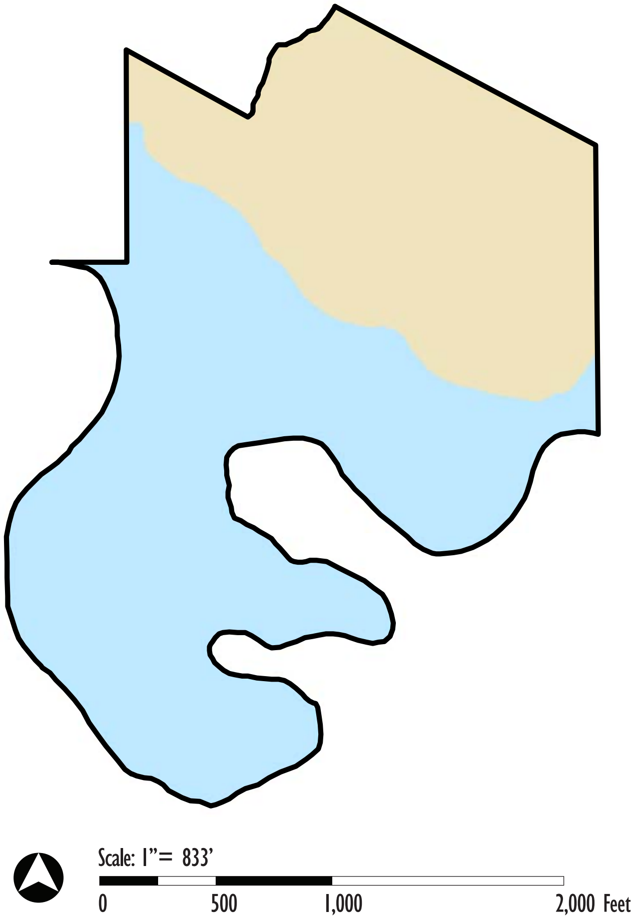


Figure A.15 100 year floodplain (Generated from GIS data by author, 2012)

Land that falls within the 100-year floodplain boundary is more likely to flood than land outside of this boundary. Flood prone areas in Figure A.15 are more desirable locations to hold water for infiltration into the ground and are more likely to fill with water.

LEGEND

% Influence 20 %

Floodplain	Value
100 Year Floodplain	0
Outside floodplain	1

WATER HAZARD SUITABILITY (Infiltration)
Slope Percentage

Figure A.16 Slope percentage (Generated from GIS data by author, 2012)

Flat locations in Figure A.16 are more desirable for holding water than land with a higher slope percentage.

LEGEND
% Influence 20 %

Slope percentage	Value
0-1%	8
1-2%	7
2-3%	6
3-5%	5
5-7%	4
7-10%	3
10%+	2

WATER HAZARD SUITABILITY (Retention)
Soil (Percent of Clay)

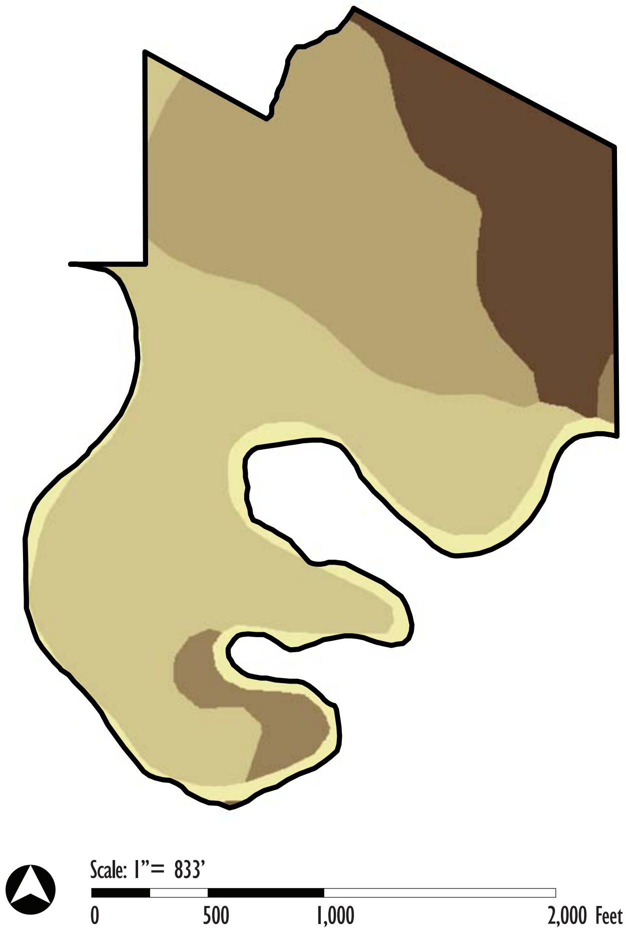


Figure A.17 Percent of Clay found in soils (Generated from GIS data by author, 2012)

The percentage of clay in the soil will determine how permeable the soil is. Soils with a higher percentage of clay are not as permeable and do not allow water to move through the soil as fast. Clay soils are good to use on the bottom of the pond to prevent water from infiltrating into the ground. If clay soils are not available, the pond has to be sealed. Figure A. 17 shows the percent of clay in each soil type found on site.

LEGEND
% Influence 20%

Percent of Clay	Value
41.4	8
31.3	8
28.9	4
27	3
Stream Channel	1

WATER HAZARD SUITABILITY (Retention)
Permeability (Hydraulic Conductivity)

Soil permeability is represented in Figure A. 18. Soils with low permeability are more desirable for retention ponds. It is more cost effective to put retention ponds in a location that is conducive to holding water.

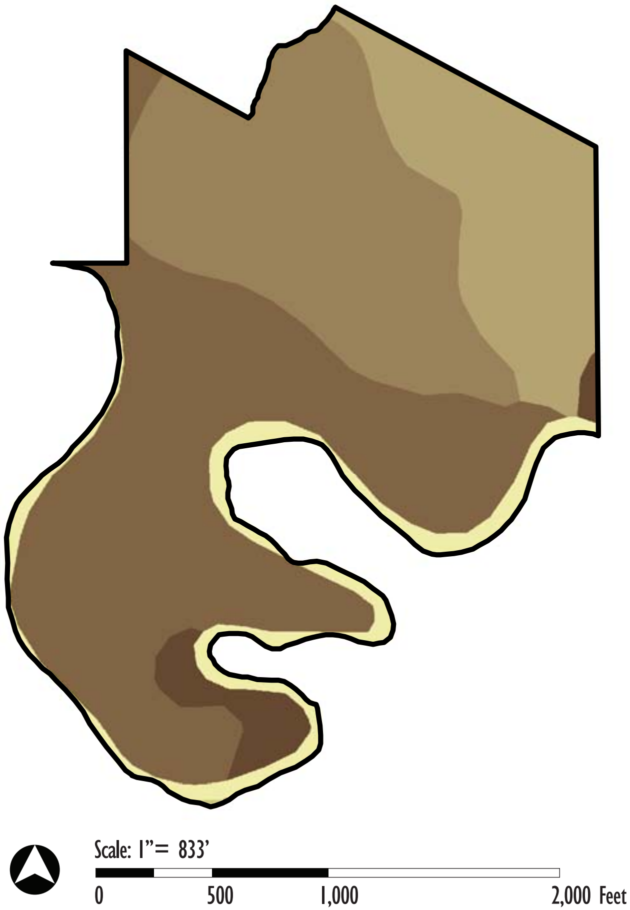


Figure A.18 Soil permeability (Generated from GIS data by author, 2012)

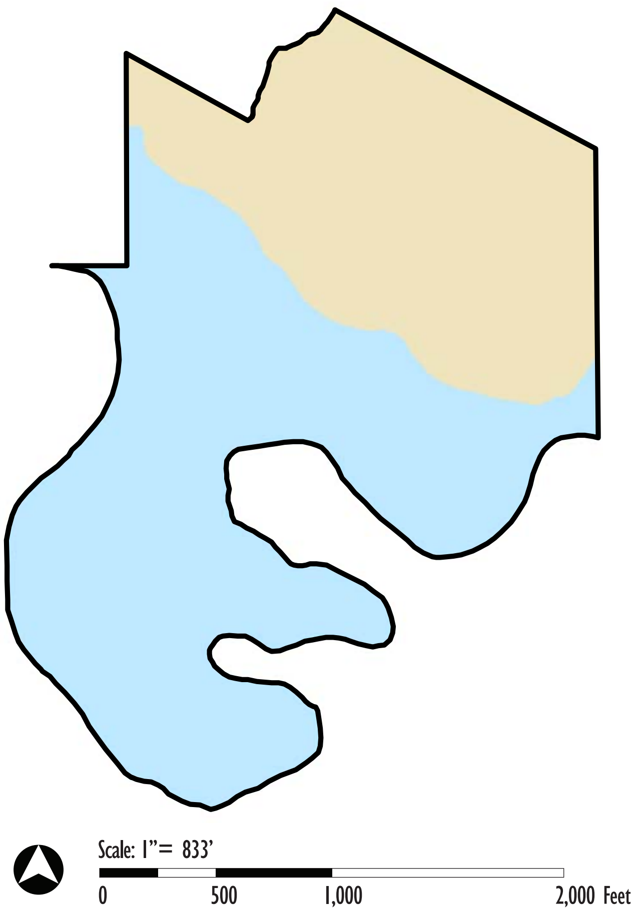
LEGEND

% Influence 20%

Ksat (Inches per hour)	Value
9	2
8.5	4
8.4	7
3.5	8
Stream Channel	1

WATER HAZARD SUITABILITY (Retention)
100- Year Floodplain

Land that falls within the 100-year floodplain boundary is represented in the color blue in Figure A.19. Land within the 100-year floodplain boundary was given a higher rating because this area is more prone to capture flood water.



LEGEND

% Influence 20 %

Floodplain	Value
100 Year Floodplain	8
Outside floodplain	0

Figure A.19 100 year floodplain (Generated from GIS data by author, 2012)

WATER HAZARD SUITABILITY (Retention)
Slope Percentage

Figure A.20 Slope percentage (Generated from GIS data by author, 2012)

Water accumulates in naturally low areas surrounded by slopes. This type of landform would naturally hold water. Higher slope percentages were given a lower rating because more earthwork would be required to construct a retention pond. The slope percentages are shown in Figure A.20.

LEGEND
% Influence 20 %

Slope percentage	Value
0-1%	8
1-2%	7
2-3%	6
3-5%	5
5-7%	4
7-10%	3
10%+	2

GOLF COURSE SUITABILTY
Landcover

Landcover is dividend into four classifications shown in Figure A.21.

LEGEND

% Influence **50 %**

Land Cover	Value (1 to 9)
Trees	1
Cropland	9
Grassland	8
Impervious Surface	1
Water	1

Figure A.21 Landcover (Generated from GIS data by author, 2012)

GOLF COURSE SUITABILTY
Slope Percentage

Figure A.22 Project Location (Generated from GIS data by author, 2012)

Two percent slopes are required for drainage. Slopes between two and seven percent were given the highest ratings for the location of the golf holes om Figure A. 22.

LEGEND

% Influence 35 %

Slope percentage	Value (1 to 9)
0-1%	5
1-2%	7
2-3%	8
3-5%	9
5-7%	9
7-10%	6
10%+	3

GOLF COURSE SUITABILTY
Proximity to Natural Features

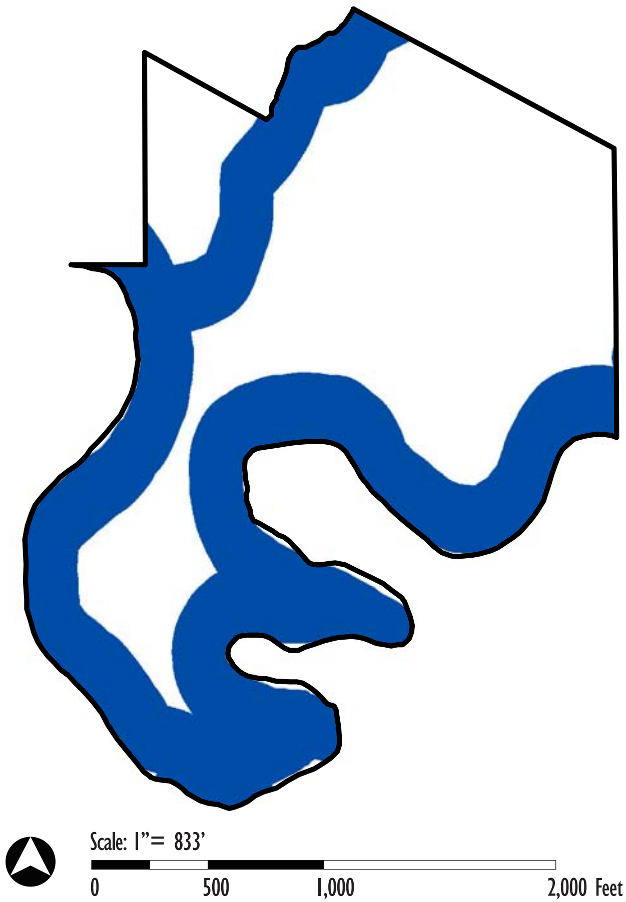


Figure A.23 Proximity to natural features (Generated from GIS data by author, 2012)

A 300 foot buffer zone was established around the major drainage ways on site in Figure A. 23. This is the maximum distance that a golf hole can use a natural feature as a design element for the hole. Natural drainage ways make the golf experience more desirable.

LEGEND

% Influence 15%

300' Buffer	Value (1 to 9)
Outside Buffer	0
Within 300 foot Buffer	9

SITE INVENTORY

Soil Types

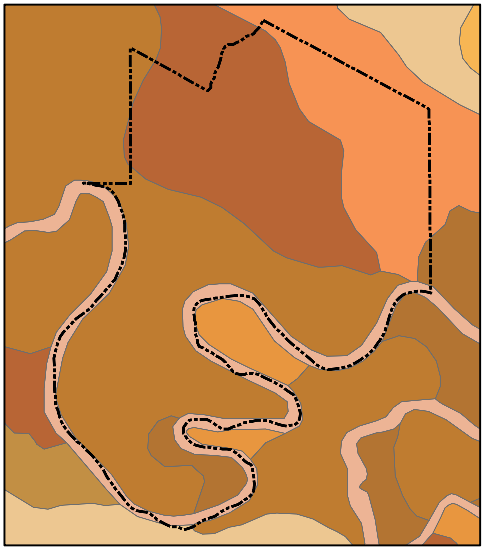


Figure A.24 Soil types found on site
(Generated from GIS data by author, 2012)

SOIL	
Reading Silt Loam, (Rarely Flooded)	
PROPERTY	VALUE
% SLOPE	1
LANDFORM	Terraces
DRAINAGE CLASS	Well Drained
PERMEABILITY	Moderately-Low
% SAND	7
% SILT	66
% CLAY	27
FREQUENCY OF FLOODING	Rare
FREQUENCY OF PONDING	None
DEPTH TO RESTRICTIVE	More than 80 inches
DEPTH TO WATER TABLE	201
ORGANIC MATTER	2.06
AVAILABLE WATER CAPACITY	High (About 11.2 inches)
HYDROLOGIC GROUP	B
Kfactor ROCK	.32
Kfactor WHOLE SOIL	.32
TOPSOIL RUNOFF COEFFICIENT	Fair
SOIL STABILITY	Fair

Table A.1 Reading Silt Loam, (Rarely Flooded)
(Generated from GIS data by author, 2012)

SOIL	
Reading Silt Loam, (1-3 percent slopes)	
PROPERTY	VALUE
% SLOPE	2
LANDFORM	Terraces
DRAINAGE CLASS	Well Drained
PERMEABILITY	Moderately-Low
% SAND	7.1
% SILT	64
% CLAY	28.9
FREQUENCY OF FLOODING	Rare
FREQUENCY OF PONDING	None
DEPTH TO RESTRICTIVE	More than 80 inches
DEPTH TO WATER TABLE	201
ORGANIC MATTER	2.06
AVAILABLE WATER CAPACITY	High (About 11.1 inches)
HYDROLOGIC GROUP	B
Kfactor ROCK	.32
Kfactor WHOLE SOIL	.28
TOPSOIL RUNOFF COEFFICIENT	Fair
SOIL STABILITY	Fair

Table A.2 Reading Silt Loam (1-3 percent slopes)
(Generated from GIS data by author, 2012)

LEGEND
Slope percentage

- Tully Silty Clay Loam (3-7% slopes, eroded)
- Reading Silt Loam (1-3% slopes, rarely flooded)
- Reading Silt Loam (Rarely flooded)
- Ivan and Kennebec Silt Loams (0-1% slopes Occasionally flooded)

Reading Silt Loam

This soil forms in alluvial sediments on the foot slopes of the valleys of most creeks. Reading Silt loam is a well drained soil with moderately slow permeability, and they rarely are flooded. This soil takes up water very well and releases it readily for plant use. The surface runoff is medium with good fertility. Management is needed to control erosion from water. The principle crops that grow in this soil are wheat, grain sorghum, corn, and alfalfa. This soil is well suited to native and tame perennial grasses, to trees for windbreaks and for woodland production, and to the development of wildlife habitat (http://websoilsurvey.nrcs.usda.gov/, 2011). The individual properties of Reading Silt Loam are shown in Table A.1 and Table A.2.

Soil Types

SOIL	
Tully Silty Clay Loam, (3-7 percent slopes)	
PROPERTY	VALUE
% SLOPE	6
LANDFORM	Hillslopes
DRAINAGE CLASS	Well Drained
PERMEABILITY	Low Permeability
% SAND	7.6
% SILT	51
% CLAY	41.4
FREQUENCY OF FLOODING	None
FREQUENCY OF PONDING	None
DEPTH TO RESTRICTIVE	More than 80 inches
DEPTH TO WATER TABLE	201
ORGANIC MATTER	1.59
AVAILABLE WATER CAPACITY	Moderate (About 7.9)
HYDROLOGIC GROUP	C
Kfactor ROCK	.32
Kfactor WHOLE SOIL	.28
TOPSOIL RUNOFF COEFFICIENT	Poor
SOIL STABILITY	Poor

Table A.3 Tully Silty Clay Loam
(Generated from GIS data by author, 2012)

SOIL	
Ivan and Kennebec Silt Loams, Occassionaly Flooded	
PROPERTY	
% SLOPE	1
LANDFORM	Floodplains
DRAINAGE CLASS	Well Drained
PERMEABILITY	Moderate Permeability
% SAND	8.9
% SILT	65.8
% CLAY	31.3
FREQUENCY OF FLOODING	Occasional
FREQUENCY OF PONDING	None
DEPTH TO RESTRICTIVE	More than 80 inches
DEPTH TO WATER TABLE	36-60 inces
ORGANIC MATTER	3.76
AVAILABLE WATER CAPACITY	Very High (About 12.6 inches)
HYDROLOGIC GROUP	B
Kfactor ROCK	.32
Kfactor WHOLE SOIL	.32
TOPSOIL RUNOFF COEFFICIENT	Fair
SOIL STABILITY	Poor

Table A.4 Ivan and Kennebec Silt Loam
(Generated from GIS data by author, 2012)

Tully Silty Clay Loam

(3-7 % slopes, eroded)

Tully Silty Clay Loam is located near the upper part of the foot slopes. The soil has a high available water capacity and takes up water well. The main concern for this soil type is control of erosion. It is important to keep the surface layer in good condition so the soil can take up water readily and be worked easily. This soil is suited to all crops grown in Riley County and native and tame perennial grasses, to trees for windbreaks, and to the development of wildlife habitat (http://websoilsurvey.nrcs.usda.gov, 2011). The individual properties of Tully Silty Clay Loam are shown in Table A.3.

Ivan and Kennebec Silt Loam, Occasionally Flooded

Ivan and Kennebec Silt Loam is found on 0-1 percent slopes. These soils are on the floodplains of most creeks and are generally found in nearly flat slopes. The soils absorb water well and release it readily for plant use. This type of soil is well suited to tame and native perennial grasses, to trees for windbreaks and for woodland production and the development of wildlife habitat (http:/websoilsurvey.nrcs.usda.gov, 2011). Table A.4 shows the individual properties of this soil complex.

SITE INVENTORY
Floodplain and Hillshade Analysis

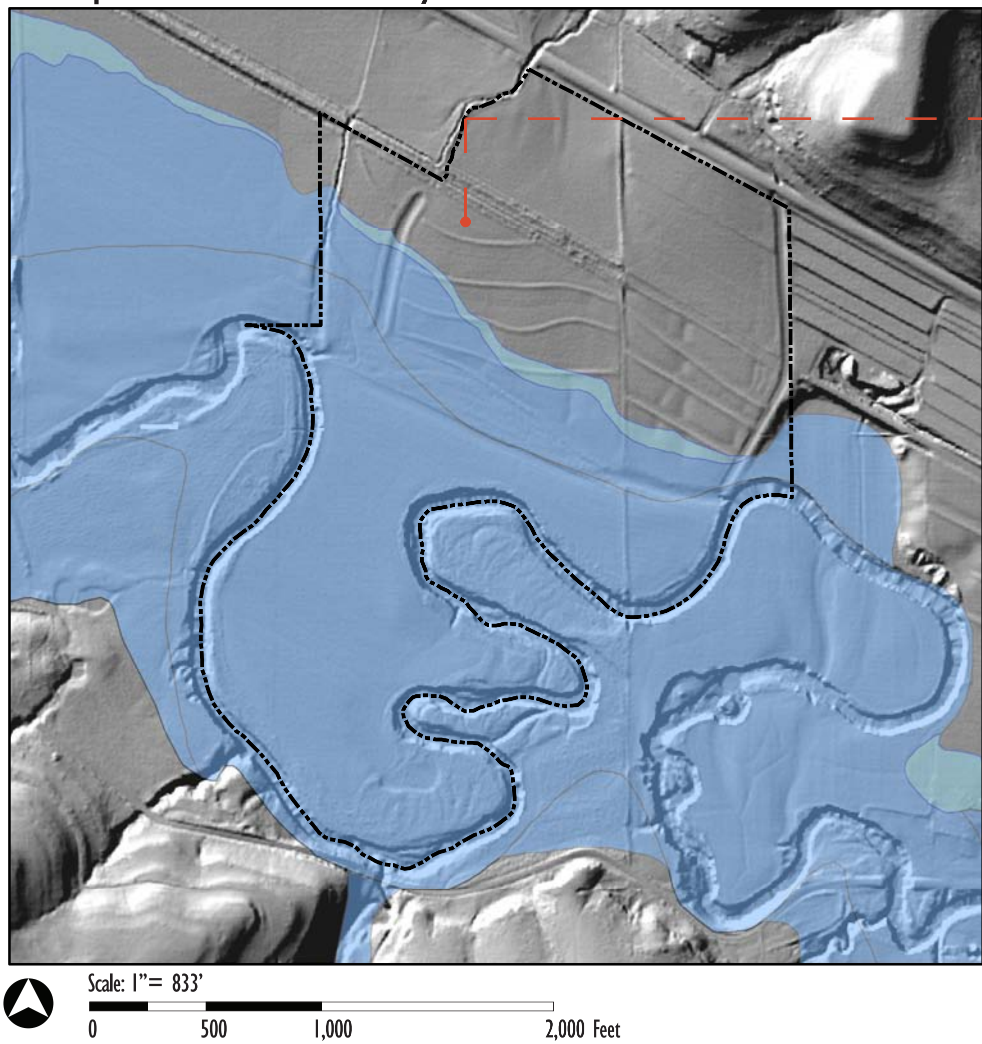


Figure A.25 Hillshade analysis with floodplain overlay (Generated from GIS data by author, 2012)

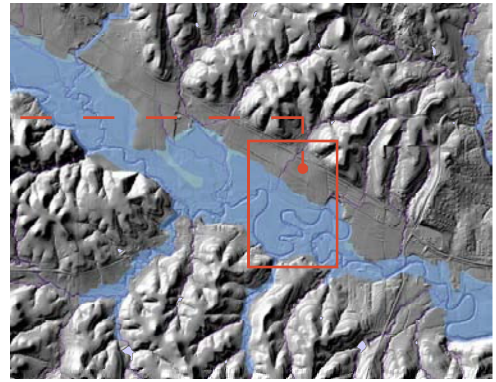


Figure A.26 Project Location
(Generated from GIS data by author, 2012)

The site sits above the alluvial aquifer in the floodplain. The land is very flat with distant hills on both sides of Wildcat Creek as seen in Figure A.25 Figure A.26 shows how the land within the property boundary lines slopes down to the edge of the floodway. This land has been used as terraced agricultural fields.

LEGEND

- 100 Year Floodplain
- 500 year Floodplain
- Floodway Boundary

SITE INVENTORY
Land Cover Types

Figure A.27 Landcover image classification (Generated from GIS data by author, 2012)

Land cover has been classified into seven different types based on aerial photos in Figure A.27 by the use of image classification in GIS. Woody vegetation is found mostly along the riparian edge of Wildcat Creek. Taller native grasses can be found just outside of the riparian zone out to about 150 feet from the centerline of the creek. This zone provides a backdrop for golf and can be carefully integrated into the design of the golf holes.

LEGEND
Slope percentage

- Trees
- Cropland
- Grassland
- Roads
- Buildings
- Water
- Parking Lots
- Property Boundary
- Wildcat Creek

SITE INVENTORY
Slope percentage

The slopes on the site range from 0 to 10 percent with the steeper slopes found only on the banks of Wildcat Creek and in some of the places where the land has been terraced. A large amount of the land is flat and is in the range of 0 to 1 percent. The slope percentage is shown in Figure A. 28.

LEGEND
Slope percentage

- 0-1%
- 1-2%
- 2-3%
- 3-5%
- 5-7%
- 7-10%
- 10%+

Figure A.28 Slope percentage (Generated from GIS data by author, 2012)

SITE INVENTORY
Aspect

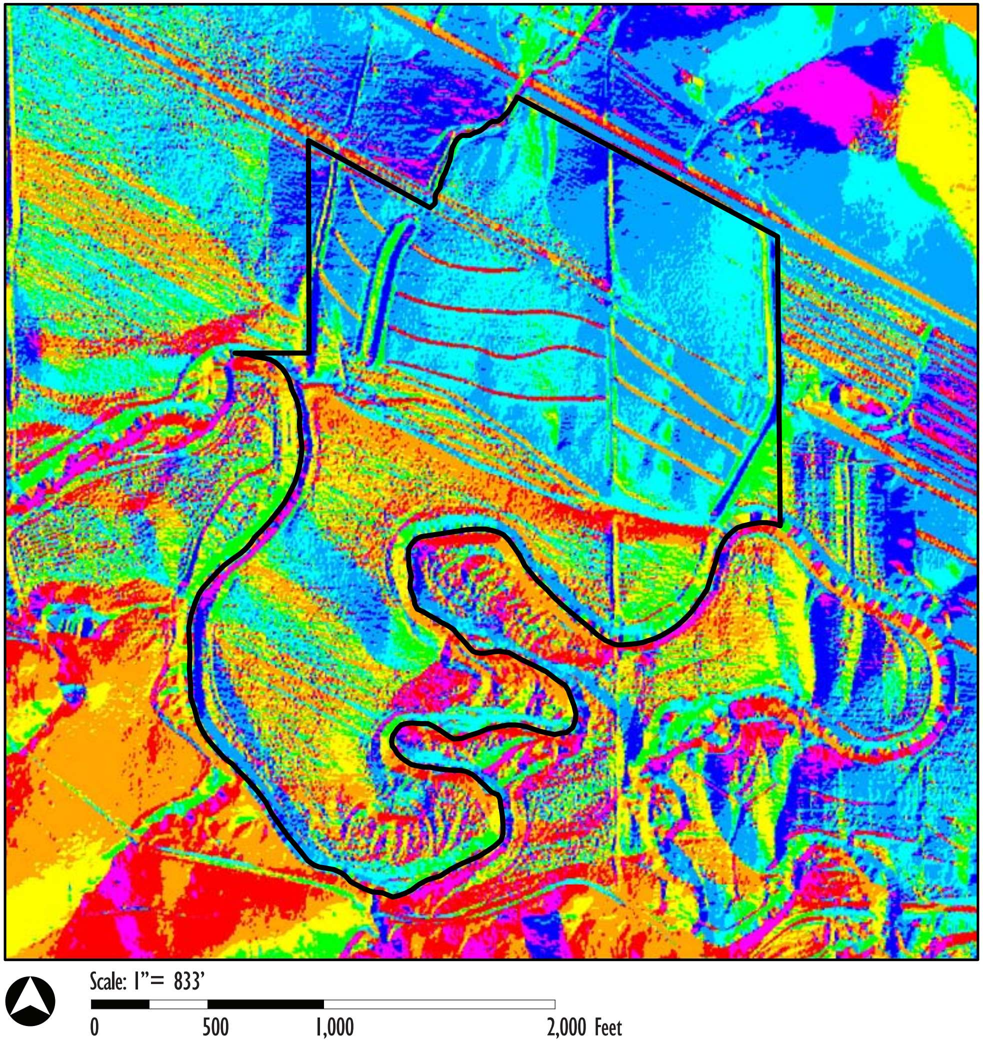


Figure A.29 Aspect (Generated from GIS data by author, 2012)

Figure A.29 shows how the northern half of the site slopes to the south-southwest in the direction of Wildcat Creek. This part of the site has the steepest slopes.

LEGEND
SUITABILITY RATING

- Parcel Boundary
- Flat
- North
- Northeast
- East
- Southeast
- South
- Southwest
- West
- Northwest
- North

Appendix B
Tables

VEGETATION
Plant Pallette

Program Element - *Wet Meadow*

COMMON NAME	BOTANICAL NAME	WATER NEEDS	EXPOSURE	COLOR	FLOWERING TIME	LOCATION USED
Canada Wild Rye	Elymus canadensis	moist to med	sun	green	late summer	Wetland/Swales
Virginia Wild Rye	Elymus virginicus	wet to moist	sun	green	late summer	Wetland/Swales/
Fox Sedge	Carex vulpinoidea	wet to moist	sun	green	late spring	Wetland
Owl Fruit Sedge	Carex stipata	wet to moist	shade	green	late spring	Wetland
New England Aster	Aster novae angliae	moist to med	sun	violet	fall	Wetland/Swales/
Blue Vervain	Verbbena hastata	wet to moist	sun	blue,violet	late summer	Wetland
Cardinal Flower	Lobelia cardinalis	wet to moist	sun	red	late summer	Wetland
Green Bulrush	Scirpus atrovirens	wet to moist	sun	green	late sping	Wetland
Inland Rush	Juncus interior	wet to moist	sun	green	late spring	Wetland
Prairie Cordgrass	Spartina pectinata	wet to moist	sun	green	late summer	Wetland
Sawtooth Sunflower	Helenium autumnale	wet to moist	sun	yellow	late summer	Wetland/Swales
Swamp Milkweed	Asclepias incarnata	wet to med	sun	pink	lat summer	Wetland/Swales/
Switchgrass	Panicum virgatum	moist to drained	sun	greed	late sumer	Swales/Treatment
Tall Bellflower	Campanula americanum	moist to med	shade	blue	late summer	Wetland/Swales/
Aromatic Aster	Aster oblongifolius	med to dry	sun	violet, lavender	fall	Swales/Treatment
Switchgrass	Panicum virgatum	moist to drained	sun	greed	late sumer	Swales/Treatment
Big Bluestem	Andropogon geradii	med to drained	sun	green	late summer	Swales/Treatment
Indian Grass	Sorghastrum nutans	moist to drained	sun	yellow	summer	Swales/Treatment
Little Bluestem	Schizachyrium scoparium	drained to dry	sun	blue-green	late summer	Top of Berms
Prarie Dropseed	Sporobolus heterolepis	drained to dry	sun	tan	late summer	Top of Berms
Side-oats grama	Bouteloua curtipendula	wet to moist	sun	yellow	late summer	Top of Berms
Swamp Dogwood	Cornus amomum	drained to dry	sun	white	late spring	Top of Berms
Western Wheat Grass	Pascopyrum smithii	med to drained	sun	green	late summer	Swales/Treatment

Table B.1 Wet meadow plants (Adapted by author from http://www.kansasnativeplants.com/, 2012)

VEGETATION
Plant Pallette

Program Element - *Pocket Wetlands*

COMMON NAME	BOTANICAL NAME	WATER NEEDS	EXPOSURE	COLOR	FLOWERING TIME	LOCATION USED
Inland Rush	Juncus interior	wet to moist	sun	green	late spring	Wetland
Green Bulrush	Scirpus atrovirens	wet to moist	sun	green	late sping	Wetland
Fox Sedge	Carex vulpinoidea	wet to moist	sun	green	late spring	Wetland
Owl Fruit Sedge	Carex stipata	wet to moist	shade	green	late spring	Wetland
Swamp Milkweed	Asclepias incarnata	wet to med	sun	pink	lat summer	Wetland/Swales
Cardinal Flower	Lobelia cardinalis	moist to med	sun	red	late summer	Wetland

Table B.2 Wet meadow plants used in the wettest areas (http://www.kansasnativeplants.com/, 2012)

Program Element - *Prairie Grasses*

COMMON NAME	BOTANICAL NAME	WATER NEEDS	EXPOSURE	COLOR	FLOWERING TIME	LOCATION USED
Little Bluestem	Schizachyrium scoparium	drained to dry	sun	blue-green	late summer	Top of Berms
Side-Oats Grama	Bouteloua curtipendula	wet to moist	sun	yellow	late summer	Top of Berms
Prarie Dropseed	Sporobolus heterolepis	drained to dry	sun	tan	late summer	Top of Berms
Indian Grass (Taller)	Sorghastrum nutans	moist to drained	sun	yellow	summer	Swales/Treatment
Switchgrass (Taller)	Panicum virgatum	moist to drained	sun	greed	late sumer	Swales/Treatment
Big Bluestem (Taller)	Andropogon geradii	med to drained	sun	green	late summer	Swales/Treatment

Table B.3 Native Prairie Grasses (http://www.kansasnativeplants.com/, 2012)

Appendix - C
Literature Review

LITERATURE REVIEW

Dodson, Ronald. G. (2000). Managing wildlife habitat on golf courses. Chelsea, Michigan: Ann Arbor Press.

Keywords:

Wildlife Habitat, Golf Courses, Development, Management, Wildlife

Review:

This book provides a basic foundation for managing wildlife habitat on golf courses. It focuses on the relationship between wildlife habitat and the game of golf. It looks at fundamental concepts and how they are applied on a golf course, because golf courses present unique challenges and opportunities. Sometimes the requirements of the game of golf and the requirements for nature are not the perfect match. The book provides a practical framework for environmentally sensitive land management practices. There has to be a balance between the natural environment and the traditions of the game, if one wants to support the effort of moving in a sustainable direction. Vegetation selection is critical, it impacts wildlife management but also the economic maintenance of the completed course and environmental issues related to pesticide use and water conservation (Dodson 9). When you select plants only for aesthetic reasons, they then become poor economic reasons and eventually cost more in the long run (Dodson 9). This idea goes along with incorporating the economics into my concept that sustainability is good for economics in the long run.

Dodson, R., (2005). Sustainable Golf Courses: a Guide to Environmental Stewardship. Hoboken, NJ: Wiley & Sons.

Keywords:

BMP's, structural contols, watershed, vegetative filter, swales, buffers, detention basin, pollutant removal, wet ponds, biofilters,

Review:

The water quality and conservation section of this book talks about water being the most significant issue facing the future of golf. Water use efficiency, new types of turfgrass, and improved cultural practices are all ways the industry is working to address this issue. Water quality and quantity must become the main focus of golf course management. This books talks about what makes up a watershed and its relationship to the golf course. There is a section on Best Management Practices (BMP's). It lists different types as well as vegetative practices such as filtration technique, buffers, and swales. The other group of BMP's is classified into structural BMP's such as detention basins, ponds, and biofilters. It provides a couple of examples of how some of these techniques were applied to specific golf courses. There is also a chart on storm water pollutant removal efficiencies utilizing urban BMP designs.

This is a good source of information on stormwater management techniques and how they can be applied to a golf course.

LITERATURE REVIEW

Gary R. Libby, Donald F. Harker, Kay Harker. (2004). Managing wetlands on golf courses. Hoboken, NJ: John Wiley & Sons.

Keywords:

wetlands, wetland management, golf courses

Review:

This book shows you how to manage seven different types of wetlands found on golf courses. Golf courses are diverse landscapes that offer and opportunity to showcase natural plant communities and wildlife habitats. Wetlands are one of the most valuable of these habitats. This book covers a lot of information on how to manage wetlands with effective techniques to improve water quality, and wildlife habitat found on a golf course. It covers several case studies where golf courses are managing wetlands successfully. "When integrated into the golf course design, the wetland system can hold stormwater runoff, filter nutrients and pollutants, trap sediments, and attract wildlife, while offering golfers a naturally scenic round of golf"(Libby 149). Another important connection for me to make with my project can be found in the following statement: "In the design phase of development, wetland features and functions should be considered along with routing plans" (Libby 149).

I plan to use this book as a basis for the theory of connecting water hazards on golf courses to a healthy wetland ecosystem because it was written specifically for managing wetlands on golf courses.

Golf Course Superintendents Association of America,(2009).

Worst-Case Scenario: Maintaining a course in the flood plain means always being ready for disaster. Retrieved from http://www2.gcsaa.org/GCM/2009 /march/feature6.asp

Keywords:

Intensive Urban Drainage Systems, Sustainable Drainage, Watershed, Urbanization, surface run-off, sub-surface run-off, sediment, percolate, diffusely, aquatic ecosystems.

Review

By protected and enhancing aquatic ecosystems with the integration of sustainable drainage techniques, golf courses can play a positive role in the function of a watershed. Technology and engineering are very important as far as treating and providing water to a consumer, but this also has to be connected to as many natural hydrological systems as possible. Urbanization has created a drainage system that causes runoff to pass over concrete surfaces picking up sediment, detergents and chemicals that will require an energy intensive treatment to break down chemical and hydrocarbons. Golf courses can provide a sustainable drainage technique. The principle of sustainable drainage is critical to whether a golf course contributes in a healthy way to a watershed.

This is a short article showing one of the critical factors in the use of a golf course as a positive role in the function of a watershed.

LITERATURE REVIEW

Gross, P. J. (March-April 2008). A step-by-step guide for using recycled water. an outline of the costs and maintenance practices necessary to manage this valuable resource. Green Section Record.

Keywords:

Water Quality, Water Treatment, Leaching, Aeration, Drainage, Water features

Review:

This article talks about how the supply of water is decreasing and the costs keep going up. Recycled water is a necessary and viable alternative for irrigation of golf courses and other large turf areas. This article gives a step-by-step approach to using recycled water and the estimate of costs based on the experiences of 13 golf courses in the southwest United States. It covers testing, water treatment, Leaching, Aeration, drainage, Fertility and how all this impacts the quality, playing condition of turf and the irrigation system used to water it.

The last section looks at how lakes and reservoirs can be used for storage of recycled water. But also looks at the problems that are often encountered such as the algae and aquatic weeds that result from the increased nutrient content and detract from the general appearance of the water feature.

King, K., & Balogh, J. (2008). Curve Numbers for Golf Course Watersheds. Transactions of the ASABE , 51(3), 987-996.

http://www.ars.usda.gov/SP2UserFiles/person/3013/King32.pdf

Keywords:

Design, Hydrology, Modeling, Runoff, Turfgrass, Urban, Infiltration, Curve Numbers

Review:

This article looks at stormwater runoff and how it's a critical component in understanding the hydrology of a site. The curve number method (CN) is a method used to determine the excess rainfall. Measured hydrologic data from golf course watersheds is limited. In this experiment two courses in two different climates were studied for five years. Morris Williams Municipal Golf Course located in Texas, and Northland Country Club, located in Minnesota. Slope, drainage density, and connectivity had the most impact on establishing a CN. This study determined that understanding local climate and site characteristics that influence the hydrology were the most important when it comes to determining a curve number.

This study backs up the importance of having local measured data and determining curve numbers for golf course watersheds in particular should not be based on traditional sources that only look at hydrologic soil classifications and land use or vegetative cover types.

LITERATURE REVIEW

LandStudies, Inc, The Pennsylvania Environmental Council. (June 2009). Golf course water resources handbook of best management practices. Retrieved from http://wren.palwv.org/library/documents/Golf_BMP_Handbook_3.pdf

Keywords:

BMP's, Golf Courses, Water Reuse, Buffers, Stormwater,

Review:

This handbook provides an overview of 18 different Best Management Practices to improve and protect water resources. It contains links to many other resources that can be consulted in association with golf and the environment. It states the importance of mapping out and inventory of everything on the site so you can see the bigger picture of everything involved. It also talks about the importance of monitoring so you can measure the success of the strategies used. The rest of the handbook goes through each of the different BMP's that can be used. Each page contains benefit, why it is important, how to go about implementing them and examples with links to other resources specifically for each of the different Best Management Practices (BMP's).

This is a good source for common BMP's used on a golf course, their benefits and things to take into consideration with each one as well as golf specific examples of how they were used.

Mikkelsen, Lon. (1997, March/April). Taming Wild Waters: Using Soft engineering principles to control erosion and create wildlife habitat. USGA Green Section Record, Retrieved from http://turf.lib.msu.edu/gsr/1990s/1997/970310.pdf

Keywords:

Buffer Zone, Peak Flow, Bank Erosion, Soft Engineering Principles

Review:

Streams can play multiple roles on a golf course landscape. Streams play a major role in the layout and design, but also have the ability to contain and release surface and sub-surface runoff water from the course. The relationship between the two when ignored, can lead to a single objective design. The article says the starting point for designing a successful stream or restoring a degraded one is to examine the watershed. Golf Courses need to be re-evaluated by architects when the current hydrology or stream flow is no longer supported by the stream channel. It also looks at the idea of soft engineering principles. Selecting construction materials based on the water velocity and flow characteristics, and the establishment of native riparian vegetation to provide a resistant erosion barrier. It also talks about how these must be adjusted to avoid conflict with golf course management considerations.

This article looks at urbanization on a watershed specifically looking at reevaluating golf courses. Storing stormwater in floodplains can be included in the design of parks and golf courses.

LITERATURE REVIEW

Minimizing the impact of golf courses on streams. (1994). The Practice of Watershed Protection, 1(2), 73-75. Retrieved from http://www.hillsborough.wateratlas.usf.edu/upload/documents/294_Golf Courses- Minimizing the Impact of.pdf

Keywords:

Water Quality, Water Quantity, Pollutants, Stormwater, Stream Crossings, Buffer, Infiltration,

Review:

"If golf courses are not designed properly, they have the potential to disrupt and degrade the wetlands, floodplains, riparian zones, and forests that contribute to stream quality." A second concern is the large amount of chemicals that are used on golf courses that have the potential to pollute water sources. "It is important to integrate the layout of the course with the natural features of the site." The article has a small diagram illustrating several bullet points that are important to these concerns. It also has a simple concept diagram showing how water is treated on a golf course to remove pollutants from a green. It states the point that golf courses are not always appropriate to size stormwater practices systems for water quality based on conventional sizing rules, because they are based on impervious surfaces and golf courses are mostly made up of pervious surface.

This article was based off guidelines for new courses built in Baltimore County, Maryland.

Moss, J. Q., Bell, G. E., Kizer, M. A., Payton, M. E., Zhang, H., & Martin, D. L. (January 01, 2006). Reducing Nutrient Runoff from Golf Course Fairways Using Grass Buffers of Multiple Heights. Crop Science Madison, 72-80. DOI: 10.2135/cropsci2005.0110

Keywords:

Runoff, Buffer, Golf Courses, Turfgrass,

Review:

This article focuses on golf course runoff, but covers a unique point that could be applied to other places. It looks at the fact that golf course fairways often border water features, and that fact there is a lot of fertilizer nutrients being used in these areas, the potential for surface runoff into nearby water is significant. This study was completed to see if bermudagrass buffers that were mowed at different heights, increasing from low to high, could reduce nutrient runoff better than a buffer mowed at a single height. It found that during both irrigation and natural rainfall, the graduated buffer delayed the time from the beginning of precipitation to the beginning of runoff. It also found that it reduced runoff volume and reduced the amount of nutrients lost to water runoff. It concluded that the establishment of graduated buffers along golf course fairways and other turf areas could make a significant difference in the amount of N and P entering the surface water.

LITERATURE REVIEW

Richardson, F. L. (2002). Routing the golf course: The art & science that forms the golf journey. New York: J. Wiley & Sons

Keywords:

Golf Course Design, Routing, Design Process, Golf Strategy,

Source:

This book looks at the processes involved in routing the golf course. It would be a good resource to consult when looking at how to re-design wildcat creek from the golf course design perspective. It talks about how things such as climate affect the routing plan. There is a section on Water on Page 54. The author states that "Water is a feature of land that must be carefully considered in terms of a range of causes and effects." Even a single Element like water plays many roles on the golf course and each of these has to be looked at. Another important idea related to the Wildcat Creek project is that it may not be possible to create a championship course in the land available. On page 102 the author talks about executive courses which are shorter than regulation length so that also take less time to play. They are made up of mostly of par three holes and can be a wide range of different lengths which might be needed in this project. It also addresses their lack of performance based solely on their ability to be accepted. The book goes through all the types and characteristics of golf courses and design guidelines to follow.

Taylor, R. S., & Hons, B. S. (1995). A practical guide to ecological management of the golf course. Alne: The British and International Golf Greenkeepers Association.

Keywords:

Golf Courses, Water Features, Water Quality, Water Quantity Ecology, Habitat, Vegetation, Fertilizers, Pesticides, Design

Review:

There is a section in this book called water features and it looks at their development and management. Golf courses with their own natural water resources, whether it is a stream, or pond, are valuable assets if they are properly developed and managed. They can enhance the golfer's environment, as well as the conservation of the area. It looks at the problems encountered with water features, such as loss of water quality, habitat, and inefficient usage of water resources for irrigation purposes. A pond or lake can transform a boring hole into an attractive strategic hazard. You have to look at water quantity so that proper water levels can be maintained. This book refers to streams as ditches and how they would be better managed. The next section looks at other environmental concerns; specifically looking at the use of pesticides and fertilizers.

This book would be useful for looking at the main ideas associated with water features and topics to research more in depth.

LITERATURE REVIEW

Werner, T. (2008, January-February). Don't wait until the well runs dry changing water sources: from good to good. Retrieved from http://turf.lib.msu.edu/2000s/2008/080110.pdf

Keywords:

Water Quality, Water Treatment, Leaching, Aeration, Drainage, Water features

Review:

This article talks about how the groundwater supply is decreasing and the costs keep going up. Recycled water is a necessary and viable alternative for irrigation of golf courses and other large turf areas. This article gives a step-by-step approach to using recycled water and the estimate of costs based on the experiences of 13 golf courses in the southwest United States. It covers testing, water treatment, leaching, aeration, drainage, Fertility and how all this impacts the quality, playing condition of turf and the irrigation system used to water it.

The last section looks at how lakes and reservoirs can be used for storage of recycled water. But also looks at the problems that are often encountered such as the algae and aquatic weeds that result from the increased nutrient content and detract from the general appearance of the water feature.

Williams, S. (2006, Setember-October). Stream restoration project hits 'hole in one' at delaware golf course. Green Section Record, 14-19.

Keywords:

Stream Channel, Stabilization, Habitat, Endangered Species, Development, Corridor, Runoff, Degradation, Impervious Surface,

Review:

This article shows how a Delaware golf course stream that was flooding as a result of increased development and increased volumes of water entering the stream during storm events. The lack of stream banks in place resulted in the undercutting of banks and the loss of fairway and tees. Some of the causes were traced back to the rapid increase in impervious surfaces. This causes the volume of surface water runoff associated with each storm event to increase, which leads to more water entering waterways at a faster rate. This resulted in excessive erosion, destruction of habitat, and water quality degradation. Stream banks are being undercut and large volumes of sediment are being released into waterways. The first step was to identify the most degraded stream segments. This stream was home to the endangered bog turtle. The goals included: stabilization of the stream banks to reduce erosion, creation of habitat by putting in a sequence of riffles and pools in the channel and planting the banks with trees, and improving water quality. They installed three acres of wetlands next to the stream channel. During the final phase they planted native trees and shrubs along the stream.

LITERATURE REVIEW

Mitsch W., Gosselink, J.G., Anderson, C.J. & Zhang, L. (2009). Wetland Ecosystems. New Jersey: John Wiley & Sons, Inc.

Keywords:

Systems, Wetlands, Ecosystem, Algae, Biomass, Climate, Flooding, Nutrient, Costal Wetlands, Marshes, Freshwater wetlands, Hydrology, Vegetation, Invasive Plants

Review:

Wetland ecosystems should be looked at as a whole system. The idea of everything working as a system is a good point to take away from this resource. This book is relatively up to date and references many other new sources for further information. I think it covers the broad idea of wetland ecology as a subject rather than getting to involved in the technical data side. "Ecosystems are defined as the whole system including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment of the biome- the habitat factors in the widest sense" The author goes on to state that ecosystems have been considered by many to be the most fundamental unit of study in ecology" (Mitsch, 2009, p. 1). It also looks at vegetation and the invasive species of plants in wetlands.

Overall it is a good book with diagrams to help understand a wetland ecosystem as a whole system rather than getting into too much detail.

Working with Watersheds, The Golf Environment Organization,

Retrieved October 3, 2011, from http://www.golfenvironment.org/about/answers/water/

Keywords:

Intensive Urban Drainage Systems, Sustainable Drainage, Watershed, Urbanization, surface run-off, sub-surface run-off, sediment, percolate, diffusely, aquatic ecosystems.

Review:

By protected and enhancing aquatic ecosystems with the integration of sustainable drainage techniques, golf courses can play a positive role in the function of a watershed. Technology and engineering are very important as far as treating and providing water to a consumer, but this also has to be connected to as many natural hydrological systems as possible. Urbanization has created a drainage system that causes runoff to pass over concrete surfaces picking up sediment, detergents and chemicals that will require an energy intensive treatment to break down chemical and hydrocarbons. Golf Courses can provide a sustainable drainage technique. The principle of sustainable drainage is critical to whether a golf course contributes in a healthy way to a watershed.

This is a short article showing one of the critical factors in the use of a golf course as a positive role in the function of a watershed.

Appendix - D

Glossary

GLOSSARY

100 year Floodplain- Land that has a 1 to 100 probability of flooding each year.

Aggradation- "A raising of local base level due to sediment depositional processes over time" (Rosgen, 2006)

Bankflow depth (mean)- the distance between the creek surface and bankfull stage (Rosgen, 2006)

Bankflow width- Width of the stream at bankfull stage (Rosgen, 2006)

Base flow- "Stream flow coming from groundwater seepage into stream." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Basin – "A physiographic region bounded by a drainage divide; consists of a drainage system comprised of streams and often natural or man-made lakes." Another name for a watershed. (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Best Management Practice- Slowing and controlling stormwater runoff through systems that improve the quality of water in urban and rural environments. Typically used with areas that do not have high levels of infiltration and do collect stormwater runoff.

Biological Characteristics – "A characteristic of water defined by the levels of bacteria, viruses, and microscopic animals present." (Bell, Eccles, Garber, Kerby & Swaffar, 2004) Characteristics that are used to determine water quality.

Channel- An area intended for a concentrated flow of water that is designed and built to handle stream flow/water movement. Some areas may be ephemeral, but during rain events, water fills the otherwise dry creek bed.

Conservation – "Conservation is the wise use of natural resources (nutrients, minerals, water, plants, animals, etc.) Planned action or non-action to preserve or protect living and non-living resources." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Degradation - "A lowering of local base level over time due to channel incision processes" (Rosgen, 2006)

GLOSSARY

Discharge – "The outflow of water, originating from either a pipe or stream, into a larger body of water." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Ecosystem- "A group of plants or animals together with that part of the physical environment with which they interact." (Bell, Eccles, Garber, Kerby & Swaffar, 2004) Food, shelter, and water systems of an area working together to support each other.

Filtration – "A treatment technology used to remove inorganic compounds from water." (Bell, Eccles, Garber, Kerby & Swaffar, 2004) Gravel or vegetative sources can be used to clean water as it passes through.

Flood Plain – A lowland area that has a high flooding risk. The official boundary is set by FEMA, causing higher insurance rates of developed land within this area.

Flow – "The rate of water discharged from a source expressed in volume with respect to time." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Ground Storage – "A below ground tank for storing water" also known as stormwater cisterns. (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Groundwater – "Water that flows or seeps downward and saturates soil or rock forming pockets of stored water." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Hydrologic Cycle- "Complete cycle through which water moves from the oceans, through the atmosphere, to the land and back to the oceans." (Bell, Eccles, Garber, Kerby & Swaffar, 2004) The cycle or evaporation, clouds forming, rain or snow falling, and runoff back into the water source.

GLOSSARY

Hydrology- "A study of water and its properties, circulation, principles and distribution." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Impermeable- "Geologic formations that resist water percolating through them." (Bell, Eccles, Garber, Kerby & Swaffar, 2004) Buildings, pavement (impermeable), infrastructure, and rock are some examples of impermeable surfaces that don't collect water and create higher levels of runoff.

Intermittent Stream- "A stream or reach of a stream that flows only at certain times of the year." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Infiltration- Water seeping into the ground and creating moist soil, feeding plants through the root system, and preventing water from leaving the site. This is encouraged through the use of permeable materials, sandy soils, and vegetation.

Leaching- "The separation of constituents from the soil by the movement of water through the ground. The soluble components are carried down by the moving water where they may enter ground water aquifers." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Mouth of Stream- "The point of discharge of a stream into another stream, lake or sea." (Bell, Eccles, Garber, Kerby & Swaffar, 2004) The point to were a tributary enters Wildcat Creek or were Wildcat Creek enters the Kansas River.

Municipal Water System- "A water system that serves at least 25 people, or has more than 15 service connections used by residents more than six months per year, governmental entity such as a city, county, town, village, sanitary district, state, or federal institution owned." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Natural Flow- "Rate that water moves past a specific point on a natural stream. The flow comes from a drainage area in which there has been no stream diversion caused by storage, import, export, return flow, or change in consumptive use; caused by land use modifications." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

GLOSSARY

Percolation- "The downward movement of water through the soil." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Permeable- "A characteristic of underground formations which have pores or openings that permit liquids to pass through." (Bell, Eccles, Garber, Kerby & Swaffar, 2004). Areas or materials with high levels of infiltration.

Perennial Stream- "A lasting or active stream that runs water throughout the year." (Bell, Eccles, Garber, Kerby & Swaffar, 2004). Wildcat creek is an perennial stream.carried down by the moving water where they may enter ground water aquifers. Persistent Pollutant- "A pollutant which degrades very slowly and remains in the environment for years." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Pollution of Water- "When the level of concentration is high enough to impair water quality to a degree that it has an adverse effect upon any beneficial use of the water." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Rip Rap- "Crushed and broken stone of varying sizes placed to cover soil. Used for landscaping and erosion control." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Riparian- Area that is adjacent to the creek and helps increase infiltration, commonly wooded. The riparian area often is a protector of the creek and a boundary between development or agricultural land and the creek.

Runoff- Stormwater that leaves the original point source and continues onto another property or location. Finding ways to reduce runoff will reduce flooding. Part of flooding is a result of too much runoff from other locations descending into a new location.

Sedimentation- "The deposition of silt, soil, clay or sand particles in locations where slow-moving water loses its ability to hold heavier particles in suspension." (Bell, Eccles, Garber, Kerby & Swaffar, 2004) The changes in erosion processes will become critical in the RLA portion of the WARSSS analysis.

GLOSSARY

Static Water Level- “The water level in a well when the pump is not running.” (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Storm Water- “Rain water that is not treated and flows into a storm drain or storm ditch then into streams rivers and lakes.” (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Stormwater Management- “The collection, conveyance, storage, treatment and disposal of stormwater runoff to prevent accelerated channel erosion, increased flood damage, and degradation of water quality.” (Montgomery County Planning Department, 2009.)

Stream Bank Stabilization- “Attempts to retard the banks from eroding by use of vegetation, weirs, riprap, etc.” (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Surface Erosion- “The wearing away of the surface by water, wind, ice, or other erosional processes” (Rosgen, 2006) Sustainability- A blend of social, economic, and environmental features in the landscape that allow the site to survive and hopefully thrive into the future. (Triple Bottom Line)

Sustainable Development- “Development that meets the needs of the present without sacrificing the ability to meet future needs.” (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Upland- Area within watershed that does not exist in the floodplain.

Vulnerability Assessments- “An assessment performed for all community and non-transient, non-community public water systems every three years. It consists of an inventory of potential contamination sources in a delineated area; includes: well construction and pesticide susceptibility and industrial chemical use evaluations; and vulnerability to volatile organic compounds (ethylene dibromide, asbestos and coal tar).” (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

GLOSSARY

Water Pressure- "The force of the water available in a water supply system." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Water source- "The origin of water in a water supply system, usually a well, reservoir, or river." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Water Table- "The upper portion of the part of the ground that is completely saturated with water. The water level in a well when the pump is not running." (Bell, Eccles, Garber, Kerby & Swaffar, 2004)

Watershed- Land that directs water into a concentrated water drainage way.

Watershed Planning- Process focusing on the means to "…resolve and prevent water quality problems that result from both point source and nonpoint source problems." Watershed planning process includes: Build partnerships, characterize watershed to identify problems, set goals and identify solutions, design an implementation program, implement the watershed plan and measure progress and make adjustments. (United States Environmental Protection Agency, 2008)

Wetland- An ecosystem that consists of physiochemical environment (e.g., soil, chemistry, and water quality), hydrology (e.g., water level flow, frequency, and water quantity), and biota (e.g., vegetation, animals, and microbes). 3 major types of wetlands exist: Coastal wetlands, Freshwater swamps and marshes, and Peatlands (Mitsch et al, 2009, p. 2).