Mapping the Boulder City wetlands using a global positioning system (GPS) and a geographic information system (GIS)

Jennifer Lea Bishop
University of Nevada Las Vegas

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Mapping the Boulder City Wetlands Using a Global Positioning System (GPS) and a Geographic Information System (GIS)

by

Jennifer Lea Bishop

A Thesis submitted to the faculty of the University of Nevada, Las Vegas, in partial fulfillment of the requirements for the degree of Bachelor of Science in the Environmental Studies Department.

University of Nevada,
Las Vegas
2000
ABSTRACT

JENNIFER LEA BISHOP. Mapping the Boulder City Wetlands Using a Global Positioning System (GPS) and a Geographic Information System (GIS) (Under the Direction of Krystyna A. Stave and Shawn Gerstenberger)

The Boulder City Wetlands is a constructed wetlands park located in Boulder City, Nevada, approximately 23 miles southeast of Las Vegas, Nevada. Currently, a baseline study of water quality is being conducted in the Boulder City Wetlands. This baseline study of the wetlands is an important step in understanding the development of the Boulder City Wetlands over time. As wastewater is eventually introduced into the existing community tap water running through the wetlands, it is expected that the nitrogen within the water will enhance the growth of vegetation in the surrounding area. Comparing the vegetation growth over time is only possible if a baseline study has been conducted. The intent of this research effort was to conduct a baseline study of the Boulder City Wetlands and develop a system in which environmental scientists can closely monitor the wetlands vegetation. This current and future vegetation monitoring of the Boulder City Wetlands is possible using the technologies of Global Positioning Systems (GPS) and Geographic Information Systems (GIS).
ACKNOWLEDGEMENTS

This thesis has been quite an experience for me, and overall, I have learned a great deal of information as a result of it. However, it is important to note that I could not have completed this research effort without the help of the following people. I would like to take this brief opportunity to thank them for their support.

First, I would like to thank Dr. Krystyna Stave for her guidance during this project. I am very thankful she suggested this topic for my thesis and hope she will encourage other students to pursue follow-on research.

Second, Dr. Shawn Gerstenberger was a wonderful instructor and I learned a tremendous amount of valuable information throughout this past year. I especially appreciate his assistance throughout the thesis process because he was always there for guidance when I needed it.

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Definition of Wetlands</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Types of Wetlands</td>
<td>2</td>
</tr>
<tr>
<td>1.2.1 Coastal Wetlands</td>
<td>3</td>
</tr>
<tr>
<td>1.2.2 Inland Wetlands</td>
<td>3</td>
</tr>
<tr>
<td>1.2.3 Constructed Wetlands</td>
<td>4</td>
</tr>
<tr>
<td>1.3 How Do Wetlands Work?</td>
<td>5</td>
</tr>
<tr>
<td>1.4 Boulder City Wetlands</td>
<td>6</td>
</tr>
<tr>
<td>1.4.1 History of Boulder City Wetlands</td>
<td>6</td>
</tr>
<tr>
<td>1.4.2 Boulder City Wetlands Type</td>
<td>8</td>
</tr>
<tr>
<td>1.5 The Need to Monitor the Boulder City Wetlands</td>
<td>8</td>
</tr>
<tr>
<td>1.6 Global Positioning System (GPS)</td>
<td>9</td>
</tr>
<tr>
<td>1.6.1 Definition and History of GPS</td>
<td>9</td>
</tr>
<tr>
<td>1.6.2 Purpose of GPS</td>
<td>10</td>
</tr>
<tr>
<td>1.6.3 How GPS Works</td>
<td>11</td>
</tr>
<tr>
<td>1.6.3.1 Satellite Ranging</td>
<td>11</td>
</tr>
<tr>
<td>1.6.3.2 Measuring Distance From a Satellite</td>
<td>12</td>
</tr>
<tr>
<td>1.6.3.3 Getting Perfect Timing</td>
<td>13</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figures

Page

1. Map of the Boulder City Wetlands ........................................................................31
I. INTRODUCTION

1.1 Definition of Wetlands

According to many sources, the definition of a wetland is relatively hard to define, most notably, because wetlands have a “considerable range of hydrologic conditions” (Mitsch & Gosselink, 1993, p.21). Much of the difficulty in defining wetlands results from the great variation in their sizes, their locations, and the influence humans have on them. Nonetheless, as legal issues in the environmental field continue to arise, the need for a definition has become great. Consequently, many environmental scientists, environmental managers, and even environmental lawyers have attempted to create one universal definition of a wetland. Perhaps the fact that there are more than 50 definitions used throughout the world to define wetlands lends credit to how difficult or involved the definition of a wetland really is. Despite the many differences, the definition of wetlands usually includes some aspect of the following three components:

1. Wetlands are distinguished by the presence of water, either at the surface or within the root zone.
2. Wetlands often have unique soil conditions that differ from adjacent uplands.
3. Wetlands support vegetation adapted to the wet conditions (hydrophytes) and conversely are characterized by an absence of flooding-intolerant vegetation (Mitsch & Gosselink, 1993, p.22).

From these main components, definitions, such as the following, are derived. Finlayson and Moser (1991, p.8) attempt to simply describe wetlands as “the transitional zone between permanently wet and generally dry environments.” Dennison and Berry take Finlayson’s and Moser’s definition further, and parallel their own definition with the definition used by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency. The definition states, “the term ‘wetlands’ means those areas that are
inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas” (Dennison & Berry, 1993, p. 4-5). Williams adds to the definition dilemma by saying, “Whatever the name given to them, the distinguishing feature about all these types of wetland is the interplay between the land and the water, and consequently they partake of the characteristics of both” (Williams, 1990, p. 9). Lastly, the definition used on the international scale was derived at the Ramsar Convention on Wetlands of International Importance, Especially As Waterfowl Habitat. The definition was designed to provide international protection of wetlands ecosystems on the broadest scale to be used worldwide. “The Ramsar Convention defines wetlands as: areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres [20 feet]” (Dugan, 1993, p.12).

1.2 Types of Wetlands

Generally speaking, wetlands are either natural or constructed. The natural types of wetlands in the United States can be categorized into two major groups, referred to as coastal wetlands and inland wetlands. Each of these two groups can then be broken down into the seven major types of wetlands. These seven major types of wetlands in the United States are tidal salt marshes, tidal freshwater marshes, mangrove wetlands, northern peatlands, inland marshes, southern deepwater swamps, and riparian wetlands (Mitsch & Gosselink, 1993, p31).
1.2.1 Coastal Wetlands

The coastal wetlands category has the following types: tidal salt marshes, tidal freshwater marshes, and mangrove wetlands. Floods and tides, in general, influence coastal wetlands. Tidal salt marshes are often found along the Eastern Coast of the United States, in the Gulf of Mexico near Louisiana and Texas, on the Alaska coastline, and along some parts of the West Coast. Tidal freshwater marshes are found along the Middle and South Atlantic coasts, but are inland from the tidal salt marshes. The tidal effects influence these wetlands as well. "Tidal freshwater marshes can be described as intermediate in the continuum from coastal salt marshes to freshwater marshes" (Mitsch & Gosselink, 1993, p35). Mangrove wetlands are found primarily in the southern tip of Florida. They are described as being dominated by the *Rhizophora* (red mangrove tree) and the *Avicennia* (black mangrove tree) (Mitsch & Gosselink, 1993, p.34-36).

1.2.2 Inland Wetlands

The inland wetlands category has the remaining four types: inland freshwater marshes, northern peatlands, southern deepwater swamps, and riparian wetlands. As the name describes, inland wetlands can be found in the interior regions of the United States, and are often categorized based on the region of the United States in which they are found. Inland freshwater marshes are often found in isolated basins, on the fringes of lakes, and in sluggish streams and rivers (Mitsch & Gosselink, 1993, p38). The regions of the United States that are home to inland freshwater marshes are the Florida Everglades, the Great Lake coastal marshes, as well as the prairie pothole regions of North and South Dakota. The northern peatlands can be found mainly in Wisconsin, Michigan, Minnesota, the glaciated Northeast, and the Coastal Plain of the Southeast (Mitsch & Gosselink,
The two major types of northern peatlands are known as bogs and fens, and often occur as thick peat deposits in old lake basins. The southern deepwater swamps are found in the Southeastern United States and are woody areas that have standing water in these areas most of the time. The water in these wetlands is mostly rainwater, but they do get flooded annually by adjacent streams and rivers. The last wetland type, riparian wetland, is found in the Southeastern and the arid Southwestern parts of the United States. They are referred to as bottomland hardwood forests and occur along rivers and streams. Occasionally, riparian wetlands are flooded, but most of the time they are dry.

1.2.3 Constructed Wetlands

The wetlands described above occur naturally, but wetlands can be constructed in areas that do not have them. A constructed wetland is a wetland created in a non-wetland site for the sole purpose of wastewater or stormwater treatment (Hammer 1997, p. 9). Constructed wetlands used for wastewater treatment include wet regions dominated by trees and shrubs, and often start with a single plant species dominating the area that provides habitat for animals such as muskrats, blackbirds, and songbirds (Hammer 1997, p. 291). These wetlands are usually considered a low-cost method of cleaning many types of wastewater, and the objective in designing constructed wetlands for wastewater treatment, as defined by Hammer (1997, p.293), include developing a system that is:

1. Capable of providing high-level treatment and discharging relatively clean water;
2. Inexpensive to build;
3. Largely self-maintaining, requiring little or no operation and maintenance time or expense;
4. Manageable by operators with very limited training; and
5. Capable of providing aesthetic/recreational/educational benefits.
1.3 How Do Wetlands Work?

Primarily, wetlands cleanse the surface and groundwater either by filtering the surface water as it percolates through the soils, or by removing the particulate matter and pollutants before the water returns to the surface waters (Dennison & Berry, 1993, p. 8). Wetlands naturally filter out chemical and biological materials and are regarded as sinks for these materials originating from human and natural sources upstream. Sinks are "environmental reservoirs that receive the throughput of society" (McKinney & Schoch, 1998, G-12). Research has also found that wetlands can "cleanse polluted waters, prevent floods, protect shorelines, and recharge groundwater aquifers" (Mitsch & Gosselink, 1993, p.4).

In general, wetlands perform a variety of extremely valuable functions throughout the environment. The following list is only a sampling of some of those very important functions as defined by Dennison & Schmid, (1997 p.2-3):

1. Conveyance and storage of floodwaters. Wetlands can store large amounts of stormwater, reduce flood levels, and may also form natural floodways that convey floodwaters.
2. Prevention of erosion and saltwater intrusion. Coastal wetlands and inland wetlands adjoining large bodies of water reduce the erosional impact of tides and waves.
3. Sediment control. Wetlands reduce the velocity of water, and thereby reduce soil erosion.
4. Wildlife habitat formation. These areas play a major role in supporting a wide variety of plants and animals that rely on the wetlands as their niche. The enormous wetland biomass serves as an excellent habitat for fish and wildlife, including many rare and endangered species.
5. Recreation. Wetlands provide recreation in the form of fishing, hunting, and wildlife observation.
6. Water supply and quality maintenance. Wetlands recharge underground aquifers, serve as a source of surface water supply, and improve water quality by removing excess nutrients and many chemical pollutants.
7. Food production. Wetlands produce large quantities of both plant and animal food.
8. Timber production.
9. Archeological value.
10. Educational and research value.
11. Open space and aesthetic value.

It is important to note that not all wetlands perform all of the above tasks, and this diversity results in the fact that there are several different types of wetlands, as discussed previously. On the other hand, it is also important to note that while there are many types of wetlands, many of these functions do overlap from one type to the next.

1.4 Boulder City Wetlands

1.4.1 History of Boulder City Wetlands

The Boulder City Wetlands is located in Boulder City, Nevada, which is approximately 23 miles southeast of Las Vegas, Nevada. Boulder City was created in the early 1930s as a home for the workers who constructed the Hoover Dam. During this time period, approximately 1500 support facilities, to include homes, dormitories, churches, and schools were built to accommodate the influx of approximately 4,000 Hoover Dam workers. When the dam project was completed in 1935, the U.S. Federal Government appointed Boulder City as the headquarters for many of the government agencies that had continued involvement in the Hoover Dam project. As a result, the U.S. Bureau of Reclamation was the supervising and regulatory agency through which the federal government owned and managed all of the land within Boulder City (Boulder City Nevada webpage, 1999 December 10).

During the 1940s, Boulder City continued to evolve with much of its development focused on the many government agencies present within the community. Establishing itself as a prosperous community committed to the U.S. Government, while building
itself as a civic-oriented community, helped bring about the 1958 Boulder City Act (P.L. 85-900). This act established an independent municipal government within Boulder City, and the federal government relinquished approximately 33 square miles of land that currently makes up the city limits (Boulder City Nevada webpage, 1999, December 10).

In 1979, Boulder City residents adopted a controlled growth ordinance that limits the number of residential and hotel/motel building permits. As a result, the city has experienced less than three-percent growth each year since the inception of the policy. Currently, the population of Boulder City is approximately 14,730 people. The overall perception of Boulder City is that the community offers a small town atmosphere and an alternative lifestyle to the city of Las Vegas. The citizens of Boulder City also pride themselves on low crime rates, high property values, and excellent recreational complexes.

Once such recreational complex is home to the Boulder City Wetlands, which is located in a 50-acre park on the eastern edge of the city limits. This park is home to baseball and softball fields, a motor cross track, a Veterans Administration Memorial Cemetery, and walking trails surrounding the wetlands area. In February 1995, the Boulder City Council, the U.S. Bureau of Reclamation, and the Nevada Division of Wildlife Services passed a resolution that made provisions for the construction of a wetland area within this 50-acre park. The vision of the Boulder City Wetlands is to irrigate the lawn of Veterans Administration Memorial Cemetery, to provide a habitat for threatened and endangered species of the desert community, and to serve as a recreational facility in terms of providing walking trails within the park (Cartier, 1998, p.1).
The Boulder City Wetlands consists of six ponds and an approximately one mile long stream. The Wetlands Park is supported by the U.S. Department of Interior Bureau of Reclamation, the U.S. Department of Interior National Park Service, the U.S. Department of Agriculture, the Nevada Division of Forestry, the Nevada Division of Wildlife, the Clark County Conservation District, and the residents of Boulder City.

1.4.2 Boulder City Wetlands Type

The Boulder City Wetlands is a constructed wetland. As mentioned earlier, a constructed wetland is a wetland created in a non-wetland site for the sole purpose of wastewater or stormwater treatment (Hammer 1997, p. 9). This particular wetland was built to improve wastewater quality and to mimic a natural desert wetland in which native, but threatened and endangered, plant and animal life could have the opportunity to flourish.

Currently, a baseline study of water quality is being conducted in the Boulder City Wetlands. As a result, the wetlands park contains only community tap water. However, Boulder City will be introducing wastewater into the wetlands in late 2000. At that time, the water flowing into the wetlands will be a mixture of both treated wastewater and potable water that will be used to irrigate the rest of the recreational park and cemetery.

1.5 The Need to Monitor Boulder City Wetlands Vegetation

The baseline study of the wetlands is an important step in understanding the development of the Boulder City Wetlands over time. As the wastewater is introduced into the wetlands, it is expected that the nitrogen within the water will enhance the growth of vegetation in the surrounding area. Comparing the vegetation growth over time is only possible if a baseline study has been conducted. The intent of this research effort
is to conduct a baseline study of the Boulder City Wetlands and develop a system in which environmental scientists can closely monitor the wetlands vegetation. This current and future vegetation monitoring of the Boulder City Wetlands is possible using the technologies of Global Positioning Systems (GPS) and Geographic Information Systems (GIS).

1.6 Global Positioning System (GPS)

1.6.1 Definition and History of GPS

The GPS is a navigation system based on a constellation of twenty-four satellites orbiting the Earth at a very high altitude. The GPS technological undertaking began at the hands of the United States (U.S.) Government to support U.S. Department of Defense (DoD) activities. While the GPS is continually maintained and operated by the DoD, the system is available for use by civilian users. The system was first developed in 1978, with the launching of the first GPS satellite into orbit. Soon after, nine additional satellites were launched into orbit to serve as the proof of the GPS concept. This array of satellites was referred to as Block I. With the GPS concept proven, twenty-three of the twenty-four operational satellites, known as Block II, were launched into orbit between 1989 and 1993. The twenty-fourth satellite completed the navigational constellation when it was recently placed into orbit in 1994 (GPS Primer web site, 1999, December 10). The twenty-four GPS satellites are NAVSTAR satellites manufactured by Rockwell International. The system is designed to orbit the earth every twelve hours at an orbit of approximately 12,600 nautical miles. The satellites have been positioned in space in such an array that signals can be received at any location on Earth from at least five satellites all of the time. The satellite array consists of six orbital planes, each with four satellites,
that are equally spaced at sixty degrees apart and are inclined at 55 degrees relative to the Earth's equator (GPS Primer web site, 1999, December 10). Each satellite weighs approximately 1900 pounds, is 17 feet wide with its solar panels extended, and has a planned lifespan of 7.5 years (Trimble, 1989, p.36).

1.6.2 Purpose of GPS

The government originally invested over twelve billion dollars in the GPS system designed to simplify navigation in the DoD arena as the need for more accurate location measurement increased. The system is capable of providing "all-weather, world-wide, 24-hour position and time information" (Trimble, 1996, p. 1-1). While the GPS navigation system was originally constructed for government use, it actually exists to provide an accurate navigation system for everyone to use if properly equipped with a GPS receiver. The difference between military and civilian use is in the level of service provided by the GPS.

The GPS is capable of providing two levels of service to its users called Precise Positioning System (PPS) and Standard Positioning System (SPS). The PPS is available only to U.S. and U.S. Allied military contingencies and certain U.S. Government agencies. These controlled users have access to cryptographic equipment and keys that allow specially developed receivers to use the data available through the PPS. The PPS uses the exact signals generated from the satellite system and provides its users with a 22-meter horizontal accuracy, a 27.7-meter vertical accuracy, and a 100-nanosecond time accuracy. The SPS, on the other hand, is the system readily available to all civilian GPS users without charge or restriction. The difference between the PPS and the SPS is the level of accuracy. The SPS uses the same satellites as the PPS, but the accuracy of the
signal received through the SPS has been intentionally degraded by the DoD to yield less accurate data. This is called Selective Availability (S/A), and will be discussed later. In general, SPS provides its users with a 100-meter horizontal accuracy, a 156-meter vertical accuracy, and a 340-nanosecond time accuracy (Mobile Aeronautic Education Laboratory web site, 1999, December 10).

1.6.3 How GPS Works

In essence, the GPS satellites provide specially coded signals, that when translated in a GPS receiver based at the surface of the Earth, easily and accurately provide position, elevation, velocity, heading, and time. Although the GPS operates on some of the most technologically advanced equipment ever developed, the principles behind the technology can be primarily explained in the six steps outlined below.

1.6.3.1 Satellite Ranging

The basic principle behind the GPS is the availability of using the constructed satellite system, known as reference points, for triangulating exact position on the surface of the earth. This concept is also referred to as satellite ranging. With satellite ranging, the satellites serve as the known reference points essential for pinpointing locations on the earth’s surface.

With utilizing only one specific satellite, the GPS user begins to determine his/her current location. Having the satellite as a reference point and knowing the actual distance from the earth’s surface to the satellite in orbit, allows the GPS to narrow down the user’s position in the universe to a general surface of an imaginary sphere (Trimble, 1996, p. 1-2).
If the user also knows that he/she is a known distance from a second satellite, the GPS narrows the possible positions down to an area where two spheres intersect one another. The logic behind this is the only place in the universe where the user can be “x” distance from satellite A, and “x” distance from satellite B is on the circle where those two spheres intersect (Trimble, 1996, p. 1-2).

If the user introduces a known distance to a third satellite, the GPS limits the possible position locations to two points within the plane of intersection of the three satellite spheres. Mathematically, three intersecting spheres yields only two points in space where the known distance conditions were true (Trimble, 1996, p. 1-3). Trigonometry states that three precise measurements can locate a point in three-dimensional space. Therefore, theoretically, only three measurements are needed to determine location even though the three satellites yield two possible points. This is because one of the two possible points is not a logical answer and the computer system within the GPS receiver aids in determining the inaccurate position. It should be stressed that in everyday use, the GPS user can, indeed, survive with just three satellites after rejecting the position that does not make logical sense (Trimble, 1996, p. 1-4).

However, if the GPS user desires a more technical measurement, a fourth satellite must be introduced. This fourth satellite eliminates the chance for position error and solves for all position unknowns, yielding one possible position location on the surface of the earth (Trimble, 1996, p. 1-5).

1.6.3.2 Measuring Distance From a Satellite

The key behind using GPS is knowing the distance from the GPS receiver on the earth to the satellites in orbit around the earth. Essentially, the GPS determines this
distance by timing how long it takes a radio signal to reach the GPS receiver from a specific satellite in space. We know from science that radio waves travel at the speed of light. If we take the speed of light and multiply that by the time it took for the signal to reach the GPS receiver from the satellite, then we will have the distance between the satellite and receiver. The trickiest part of this concept is knowing when the satellite started sending the radio message to the receiver. This is accomplished by synchronizing the GPS satellites and GPS receivers with the same digital codes at the same time. These codes are also referred to as Pseudo-Random Number (PRN) codes and are complicated sequences so that the code sent by the satellite can be easily compared to the code received by the receiver. The GPS receiver examines the PRN code from the satellite and compares it to the how long ago the receiver generated the same code. The time difference between the two codes is how long the signal took to travel. Multiplying that time by the speed of light yields the actual distance between the satellite and the receiver (Trimble, 1996, p. 1-6, 1-7).

1.6.3.3 Getting Perfect Timing

As stated before, the key to GPS is the ability to accurately measure the distance between the satellite and the receiver. The explanation above describes how this measurement is possible through the precise timing capability of the GPS. But how is this synchronization and resulting generation of the PRN codes possible between the satellite and the receiver? Each of the satellites in orbit is equipped with atomic clocks that are accurate to the nanosecond. Unfortunately, while these atomic clocks are incredibly accurate, they are also remarkably expensive. For the cost reason, the ground receivers are not equipped with such precise timing mechanisms. The way the ground receivers
overcome this imperfection is by using the fourth satellite mentioned earlier to obtain the
precise location. This fourth satellite distance makes up for the imperfect timing offset of
the receiver, removes the timing error between the clock in the receiver and the clock in
the satellite, and determines the receiver's precise location on the surface of the earth
(Trimble, 1989, 24-33).

1.6.3.4 Satellite Positioning

The previous discussion stated that using the GPS requires knowing the distance
between the ground receiver and the satellites in space. The question arises as to how the
positions of the satellites in space are always known. Essentially, the twenty-four
satellites orbiting the earth are so high in space that their orbits, and hence distance to the
surface of the earth, are extremely predictable because the satellite system is not prone to
most atmospheric affects. Despite the certainty of the position of the satellites, the DoD
also has a system in place to monitor the minor orbit variations. The DoD currently has
four monitoring stations, three upload stations, and a master control station (located at
Schriever Air Force Base in Colorado) on earth to monitor the satellites' orbits. These
ground stations measure the altitude, position, and speed of each satellite, and relay the
information back to the satellite. When the satellite broadcasts its next timing
information, each satellite also transmits the minor corrections to each ground receiver

1.6.3.5 Ionospheric and Atmospheric Delays

While the GPS identifies and corrects a number of errors that exist between the
satellite system and the receivers on the surface of the earth, there are still errors that
exist naturally and are difficult to eliminate. These sources of error exist within the

Within the earth’s atmosphere, the ionosphere is the greatest source of error. The ionosphere is an electrically charged region within the earth’s upper atmosphere, located approximately between 30 miles (48 kilometers) and 300 miles (480 kilometers) above the surface of the earth. Within the ionosphere, electrically charged particles (ions) and free electrons facilitate the transmission of radio waves around the earth. The greatest concentrations of these ions and free electrons exist within a 50-mile (80 kilometer) to 250-mile (400-kilometer) range. Especially within this denser portion of the ionosphere, the charged particles affect the speed of the transmission of the GPS radio signals from the satellites to the receivers on the surface of the earth (Lutgens & Tarbuck, 1995, p. 20).

The earth’s troposphere also affects the transmission of GPS signals from satellites to receivers. The troposphere is “the lowermost layer of the atmosphere marked by considerable turbulence and, in general, a decrease in temperature with increasing height” (Lutgens & Tarbuck, 1995, p. 455). In addition, this layer is meteorologically significant because all of the earth’s weather phenomena occur here. The weather events in the troposphere, specifically existing water vapors and dust particles, can have adverse affects on the propagation of signal transmission. Both the troposphere and the ionosphere errors have a negative impact on the positional accuracy of the GPS. While both of these errors are almost impossible to eliminate, the errors can be mitigated using mathematical techniques and scientific modeling (Trimble, 1989, p. 38-47).
1.6.3.6 Differential Correction

Differential correction (DGPS) is “the process of correcting GPS positions at an unknown location (rover) with data collected simultaneously at a known location (base station)” (Trimble, 1996 p. Glossary-6). DGPS attempts to eliminate the error deliberately introduced by the DoD which was previously identified as Selective Availability. S/A is the “artificial degradation of the satellite signal by the DoD” (Trimble, 1996, p. Glossary-23). As mentioned previously, the DoD degrades the accuracy of the GPS signal from the satellite to a commercial receiver to deny unauthorized users precise location information. This degradation results in large position, velocity, and time errors that are standard across all commercial receivers. DGPS helps to correct these errors and increase the accuracy of the collected GPS data, but requires two receivers. One receiver, often referred to as a rover, is the receiver being utilized by the user involved in the field data collection effort. The second receiver, referred to as a base station, is a GPS receiver that has been placed at a known location on the surface (or some known distance above the surface) of the earth. This base station acts as a reference point for the satellite system and determines the errors that exist within the transmitted data from the satellite system. When the error correction data from the base station is applied to the data collected in the field, the errors in the data collected by the rover are virtually removed. The application of the base station data is possible in one of two methods: real-time differential correction or postprocessed differential correction. Real-time differential correction occurs in the field as the data is being collected. This is possible because “the base station calculates and broadcasts (through radio signals) the error for each satellite as it receives the data. This correction is received by the rover,
which applies the correction to the position it is calculating" (Trimble, 1996, p. 1-16). Postprocessed differential correction does not occur in the field. Instead, the rover collects the data and stores it to a file in the receiver while the base station simultaneously collects its data and stores it to a file in a computer. The data from the two files are downloaded and run through data correction software which creates a “differentially corrected rover file” (Trimble, 1996, p. 1-16).

1.6.4 Goal of GPS

The goal of GPS is to provide an opportunity for people on Earth to know where they are and where they are going. The GPS is the most scientifically advanced, geographically precise, and economically affordable means to superior navigation in existence today.

1.7 Geographic Information Systems (GIS)

1.7.1 Definition of GIS

A GIS is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. The three basic components of GIS are data capture and storage, data manipulation and analysis, and display and hard copy output.

1.7.2 Purpose of GIS

The purpose of a GIS is to provide the user with the ability to analyze geographic data and the information linked to that data in stored databases. With GIS’ ability to easily capture, store, manipulate, analyze, and display geographic data, it represents the most dynamic mapping system available today.
1.7.3 Goal of GIS

The goal of GIS is to graphically represent spatial relationships and provide spatial measurement analysis capabilities such as distance (measuring the length from one point to another point), perimeter (getting the actual distance around certain features), and area (finding the spatial extent of certain features). A GIS will visually display geographic data to help a user see relationships that are not always apparent in other forms of data representation. In the end, GIS lets a user work with tables, charts, and maps, simultaneously, to represent geographic data.

1.7.4 How GIS works?

GIS integrates data that has been collected at different times, at different scales, using different methods of data capture (Trimble, 1996, p. 2-2). As mentioned previously, the basic components to a GIS are data capture and storage, data manipulation and analysis, and display and hard copy output. Capturing data in a GIS includes digitizing existing map products, scanning images from aircraft and satellites, entering tabular data, entering text data, creating data in the form of points, lines, and polygons, and utilizing a GPS. The GIS then stores these data formats by combining them and integrating them into a large and dynamic database. From this database, the GIS allows these different types of information to be separated and represented in different layers (also to be referred to as themes or coverages). A GIS manages these themes according to the information contained within them because each is made up of features that have a set of common attributes. Each of these themes is capable of being accessed, edited, and/or manipulated independently. The GIS then allows the data to be analyzed by accessing the different themes either alone or in combination with other themes, and using many of the
querying and other analysis tools available through specific software programs. When the
data has been fully prepared and analyzed, the GIS then permits the user to combine data
themes as necessary. When the user has defined the desired combination of themes, the
GIS provides the user with graphical editing tools to assign symbology or create text to
help display the information either on the computer screen or in a hard copy map format.

II. MATERIALS

2.1 Global Positioning System

For this research effort, a Trimble Navigation Limited GeoExplorer II GPS
receiver and its related Pathfinder Office software were utilized. In addition, the Las
Vegas Valley Water District’s base station served as the source for the necessary data to
perform (DGPS).

2.1.1 GPS Receivers

There are many commercial vendors in the GPS receiver industry, and each
vendor often has a variety of GPS receivers within their own product line. The GPS
receivers available on the commercial market vary in their size, shape, weight,
complexity, accuracy, the number of positions each stores, the number of channels each
uses to track satellites, and cost. While these differences do exist from one receiver to the
next, each receiver basically accomplishes the same goal. The receiver inputs the signals
from the GPS satellites in its range, determines the position of the receiver based on those
GPS satellite signals, and displays the information on the receiver as latitude and
longitude coordinates, elevation, velocity, heading, and time.

Trimble has been a leader in the GPS data acquisition field since the mid-1980s.
Their GeoExplorer II was chosen because it is a pocket-sized, lightweight, six-channel
data collection effort for two reasons. First, the Las Vegas Valley Water District data collection point is located in the Las Vegas Valley, which is relatively close to the Boulder City Wetlands. This is important because the closer the base station is to the field data collection point, the more accurate the DGPS data will be for application to the field data points. Second, the data files are “stored in 1 hour increments and stored on a 24 hour basis each day of the year” (Las Vegas Valley Water District web site, 2000, January 26). This is important because the DGPS data must have been collected in the same time frame as the field data. Many base stations only collect data at certain times of the day, thus limiting field data collection times. The Las Vegas Valley Water District base station collects data continuously throughout the year and posts its data by 3:00 A.M. the next day. This unlimited range of base station data permits field data collection efforts to occur at anytime in the day, any day of the year. Furthermore, it allows the timely differential correction of the field collected GPS data when leaving the field to process the data.

2.1.3 Pathfinder Office Version 2.0

The Pathfinder Office is a windows based application designed to simplify the data processing efforts. Using the Pathfinder Office software package, data dictionaries can be created to ensure data collection and processing techniques are documented, differential corrections to the data can occur, and resulting data can be entered into a GIS (Dana, 1999). As mentioned previously, base station data can be applied to data collected in the field by either real-time differential correction or postprocessed differential correction. For this research effort, postprocessed differential correction was accomplished using the Trimble Navigation Pathfinder Office, Version 2.0. This software
provides all the necessary tools to download the base station data and the rover data and ultimately correct and view the collected GPS data. In addition, this software package provides suitable formats in which the collected data can be exported to a GIS.

2.2 Geographic Information Systems

2.2.1 ArcView GIS Version 3.1

For the research effort, Environmental Systems Research Institute’s (ESRI) ArcView GIS Version 3.1 was utilized. ESRI was founded in 1969 “as a research organization to develop new methods for managing geographic information” (Environmental Systems Research Institute, 1995, p. v). Through its development over the last thirty years, the company has become the world’s leader in GIS software, offering numerous software packages capable of solving virtually all questions involving geographic information. ArcView GIS is but one of ESRI’s product lines and is the leading desktop mapping and GIS software package currently available. It provides the user with a user-friendly, Windows based environment, and allows the user to “visualize, explore, query, and analyze data geographically” (Environmental Systems Research Institute, Brochure, p. 1). Through the graphical display of geographic data, hidden patterns, relationships, and trends become readily apparent when using a software package such as ArcView GIS. ArcView GIS was chosen because of its easy to use interface, its capability to integrate GPS data and tabular data, and its suite of editing and display tools to present professional quality map products.
III. METHODS

The methods followed for this research effort included the following major steps: data capture by the GPS, data storage by the GPS, data input from the base station, and data storage in the GIS.

3.1 Data Capture by the GPS

Data capture was accomplished by using the GPS to collect data on the following major features of the wetlands: stream, trail, ponds, fence, primary road, secondary roads, weirs, pond intakes, and Typha domingensis (Southern Cattail) vegetation in the stream and the ponds. Collecting this GPS data provided the necessary latitude and longitude points for each of the respective features. The following discussion outlines the steps taken to accomplish the data capture for each feature.

3.1.1 Stream

The stream was the most challenging feature to collect data for because it was filled with running water and an abundance of vegetation that made traversing the feature difficult at times. To accomplish data capture for this feature, I marked a start/stop point on the ground, held the GPS at shoulder height parallel to the ground, and walked from the start/stop point along the perimeter of the stream until I returned to the start/stop point. The perimeter of the stream is fairly well marked because the stream is lined with cement. By walking along the edge of the cement, the data capture represented the true capacity of the stream rather than the daily fluctuation of water flow.

3.1.2 Trail

To accomplish the data capture for the trail, I marked a start/stop point on the ground, held the GPS at shoulder height parallel to the ground, and walked from the start
point along the centerline of the trail. I completed a figure eight shape, and ended at the start/stop point.

### 3.1.3 Ponds

To accomplish data capture for the ponds, I marked a start/stop point on the ground, held the GPS at shoulder height parallel to the ground, and walked from the start/stop point along the perimeter of each pond until I returned to the start/stop point. The perimeter of each pond was very difficult to distinguish. Clear definition of the perimeter did not exist, so for this study, the perimeter is defined as the line where the water level stopped. While collecting the perimeter data, I walked along the edge of the water, not in it.

### 3.1.4 Fence

To accomplish the data capture for the fence, I marked a start/stop point on the ground, held the GPS at shoulder height parallel to the ground, and walked from the start/stop point along the inside edge of the fence. I was certain to ensure my left leg was as close to the fence as possible. In addition, I was careful to capture the true shape of the fence by specifically stopping at each major point (e.g. corner) to ensure a data point was logged for that major portion of the feature. I ended data collection for this feature when I reached the start/stop point.

### 3.1.5 Primary Road

To accomplish data capture for the only primary (paved) road, I marked a start/stop point on the ground, held the GPS at shoulder height parallel to the ground, and walked from the start/stop point along the perimeter of the pavement until I returned to
the start/stop point. The perimeter of the pavement is defined as the line that exists when
the pavement either abuts the concrete shoulder or the existing dirt.

3.1.6 Secondary Roads

To accomplish the data capture for the secondary (unpaved) roads, I marked
multiple start/stop points on the ground, held the GPS at shoulder height parallel to the
ground, and walked from the start/stop point along the centerline of the perceived road.
The road is only defined as that line which marks the edges of the disturbed land from the
undisturbed land as created by vehicular traffic. To stay as much in the center as possible,
I followed behind a car as it drove the along the secondary road. The driver of the car was
able to keep the car along the perceived center of the width of the road, and I was able to
keep the GPS in the center of the width of the car’s tire tracks. This made data collection
more efficient and accurate because it was much easier to stay in the center of an
approximately five-foot wide set of tire tracks than twenty feet of unpaved roads.

3.1.7 Weirs

To accomplish data capture for the weirs, I held the GPS at shoulder height
parallel to the ground, and stood in the center of each weir. Each weir was a cement
block. The weir at the north end of the stream was 66” x 36”. All other weirs were 77” x
74”.

3.1.8 Pond Intakes

To accomplish data capture for each pond intake, I held the GPS at shoulder
height parallel to the ground, and held the GPS over the intake.
3.1.9 *Typha Domingensis* Vegetation in the Stream

To accomplish data capture for the *Typha domingensis* vegetation in the stream, I marked a start/stop point on the ground, held the GPS at shoulder height parallel to the ground, and walked from the start/stop point along the perimeter of each distinct group of cattails. The perimeter of the *Typha domingensis* is defined as the line in which vegetation no longer grows.

3.1.10 *Typha Domingensis* Vegetation in the Ponds

To accomplish data capture for the *Typha Domingensis* vegetation in each pond, I marked a start/stop point on the ground and held the GPS at shoulder height parallel to the ground. With the aid of chest waders, I walked from the start/stop point along the perimeter of the *Typha Domingensis*. This process entailed walking along the edge of the pond as well as in the pond. The perimeter of the *Typha Domingensis* is defined as the line in which vegetation no longer grows.

3.2 Data Storage in the GPS

The next step involved storing the collected data within the GPS. The data for each of the features can be collected and stored as three basic shapes--points, lines, or polygons--within the GPS. Points represent features that have definite locations, but do not have a large enough area to necessitate using a polygon shape (e.g. weirs and pond intakes). Lines represent features that have a definite length to them, but are too narrow to use a polygon shape (e.g. trail, fence, and secondary roads). Polygons represent features that are too large to necessitate using a point or line (e.g. stream, ponds, primary road, and cattail vegetation). As the data was collected in the field by the GPS, the latitude and longitude of each data point was initially stored in the GPS. The collected
data can be stored and can remain in the GPS as long as there is sufficient memory within the system. Each file stored in the GPS is referred to as a rover file.

3.3 Data Input From the Base Station

Upon returning from the field, I downloaded the rover files into Pathfinder Office, saved the data, and awaited the posting of the day’s base station files on the Las Vegas Valley Water District’s web site. Again, the Las Vegas Valley Water District posts its base station data at 3:00 A.M. each day. When the data was available, I selected the appropriate base station data that matched the time of my data collection. The time is significant because the correction to be performed cannot occur unless the field data collection times match the base station data collection times. As soon as I identified the necessary base station files, I downloaded the base station data and saved it in Pathfinder Office. Using Pathfinder Office, I performed differential correction and created new, corrected files. Lastly, using Pathfinder Office, I exported these corrected files as an ArcView GIS shapefile data format.

3.4 Data Storage in the GIS

As with the GPS, data storage also occurs when the collected data is exported from the GPS and imported into the GIS. Storing the data in a GIS is a more versatile storage platform because a GIS offers the opportunity to graphically view and later manipulate the data. The GPS does not provide such interface with the data. Within the GIS, the data is stored as shapefiles and themes (to be explained in the Results section).
IV. RESULTS

The results of this research project were created using the following steps: data display, data analysis, data manipulation, and data query.

4.1 Data Display

Data display occurred in two different capacities during this research effort. The first data display occurred using the Pathfinder Office software package. This software package permitted the user to graphically view the collected data as soon as the collected GPS data from the field was downloaded into the Pathfinder Office application. The results of this step were quite alarming because when the data is originally collected in the field and differential correction has not yet been applied, the resulting data display does not appear to be representative of the feature that the data was just collected from. As a result, the collected points, lines, and areas appear to be misplaced or out of sequence. But once the differential correction data from the base station was applied to the field data, the Pathfinder Office software was used to see how much the base station data helped to improve the overall quality and accuracy of the collected field data.

The second display of collected GPS data occurred using the ArcView GIS software package. Displaying the data in the GIS made the relationships among the data features apparent. From this visual display of spatial data (point, line, and area representation of geographic features), I was able to view each data layer with respect to all the other data layers. This graphical representation assisted me in viewing the data results and conducting the proper analysis of the data. In the end, the GIS helped me make the necessary map products that best depicted the wetlands data.
4.2 Data Analysis

During data analysis, I observed the different data layers in the GIS to visually analyze the existing relationships among the different data features. This step helped to ensure the data collection was complete, and served as a basis upon which the quality of the collected data was assessed. From this assessment, determinations were made concerning which shapefiles needed to be corrected through data manipulation.

4.3 Data Manipulation

Typically during the data manipulation step, I would have edited the necessary shapefiles to make each theme appear more representative of the shape of each geographical feature being mapped. However, based on the previous data analysis step, I decided that data manipulation of the shapefiles was not necessary for the successful and accurate completion of this research effort.

4.4 Data Query

The last step, data query, involves the ability to ask questions of the GIS to determine spatial relationships among the data that may not be readily apparent. The ability to perform data queries is a unique feature of the GIS that makes it such a dynamic and flexible tool. Having completed all of the previous steps in the research process, I determined that data query was not necessary for the successful and accurate completion of this research effort.
V. FINAL PRODUCTS

5.1 Shapefiles

ArcView GIS links the collected data features to their specific attribute data using themes. A theme is made up of a set of geographic features of the same type with a set of common attributes. These ArcView themes can be created from a variety of geographic data sources such as images, computer-aided design drawings, spatial data, and even tabular data. For this thesis, spatial data was used. The spatial data was in the form of ArcView shapefiles. A shapefile is ArcView’s format for storing the collected data features and its associated attributes. Converting the spatial data that resided in the GPS data files created the shapefiles used in this thesis. The shapefile was the preferred data format because a shapefile displayed the geographic information more rapidly than other data formats.

This research effort consisted of nine distinct shapefiles which translated into nine ArcView themes. Within the ArcView GIS, these separate themes represent the stream, trail, ponds, fence, primary road, secondary roads, weirs, pond intakes, and *Typha domingensis* vegetation in the stream and the ponds at the Boulder City Wetlands.

5.2 Map

The final map product clearly represents the data collected at the Boulder City Wetlands. To create this final map, individual shapefiles were combined to create the necessary display of data. Attached Figure 1 depicts the combined graphical display of each of the previously mentioned data layers. This data represents the raw data collected using the GPS and was not manipulated in any way.
VI. DISCUSSION

The goal of this research effort was to demonstrate that a GPS and a GIS could be used to establish the baseline vegetation data in the Boulder City Wetlands. Furthermore, the overall intention of this research effort was to actually conduct that baseline vegetation study of the Boulder City Wetlands to help develop a system in which environmental scientists could closely monitor the wetlands vegetation in the future. While satisfying both the overall intention and goal of the thesis were the objectives of this research effort, the following discussion addresses how the goal of the thesis was successfully accomplished, how the overall intention was not completely accomplished, and suggestions for future research efforts.

6.1 The Goal

The goal of showing that a GPS and a GIS could be used to map the vegetation at the Boulder City Wetlands was a success. By the end of the research effort, I had successfully collected data for the stream, ponds, trail, primary road, secondary roads, fence, weirs, pond intakes, and *Typha domingensis* vegetation located in the Boulder City Wetlands. With such successful data capture for these features, it can be concluded that the GPS is a useful tool in mapping the Boulder City Wetlands.

While data was successfully captured for the major features at the Boulder City Wetlands, the data collection effort was sometimes a challenging task. Some of the challenges faced while collecting the data were as follows: sometimes poor satellite ranging, resulting in time-consuming delays; high water levels in the stream making it difficult to map the perimeter of some vegetation types in the stream; limited access to the Bureau of Reclamation for usage of some equipment to permit wading in the stream.
and ponds; and problems with the base station, resulting in having to recollect a day's worth of data. However, as mentioned previously, despite these challenges the GPS did capture feature data that was essential to the baseline study.

In addition, after viewing the results of the GPS data collection efforts using the GIS, it was quite clear that, indeed, the GIS is also a useful tool in mapping the Boulder City Wetlands. The GIS provided the necessary capability to take the geographic coordinates of the data collected from the GPS, and graphically display those points as recognizable features within the GIS. With such a display, a user of the GIS can clearly discern the locations of the stream, ponds, trail, primary road, secondary roads, fence, weirs, pond intakes, and *Typha domingensis* vegetation, and understand the geographical relationships that exist among them. As a result, it is determined that the GIS is not only a useful tool, but a necessary tool to successfully display and manipulate the collected GPS data.

6.2 The Intent

As previously stated, the overall intention of this research effort was to conduct the baseline vegetation study of the Boulder City Wetlands to help develop a system in which environmental scientists could closely monitor the wetlands vegetation in the future. Unfortunately, this intention was not completely accomplished because all of the existing vegetation types at the Boulder City Wetlands were not successfully captured during the data collection efforts. In fact, the only vegetation type that was mapped was the *Typha domingensis*. The decision to map only the *Typha domingensis* vegetation was based on the following determination. During the analysis of the collected data, it was apparent that the GPS being used was not of sufficient resolution to deliver the necessary
geographical accuracy for this project. By this it is meant that this Trimble GPS could not yield data that would accurately reflect real world coordinates for each data point on a map. This situation occurred because the Trimble GPS being used for this research effort only had a 2-5 meter accuracy after differential correction from a base station. That means for each data point collected, the actual geographic location of the data point in the GIS could realistically be off approximately 6-15 feet. This margin of error, while often acceptable when mapping large areas or areas that do not require a great deal of accuracy, is not acceptable when trying to conduct a baseline study of vegetation where accurate representation of each point is critical in monitoring future growth. This concept was evident when collecting and mapping point data for the weirs in each pond. Each weir is approximately 6.4 feet by 6.1 feet. This size is significant because the margin of error contained within this Trimble GPS is potentially greater than the total space occupied by this feature. In fact, after collecting the data and observing the data in the GIS, the point features depicting each weir location was not accurately representative of its real world location. When applying these lessons to mapping vegetation that is oftentimes less than one square foot, it was apparent that such an effort would not be productive and not yield accurate results. As a result, the only vegetation that was mapped with some success was the Typha Domíngensis. The data collection and mapping was possible for this vegetation because the Typha Domíngensis grows in relatively large groupings that extend, most times, beyond the potential error of the GPS. Since only the Typha Domíngensis vegetation was able to yield usable data, it is interpreted that the overall intent of this thesis was not accomplished. However, despite the fact that all of the vegetation at the Boulder City Wetlands was not successfully mapped, this effort did yield feature data
(fence, ponds, primary and secondary roads, and trail) that could be useful and applicable to future research efforts.

6.3 Future Research Efforts

The Boulder City Wetlands baseline vegetation data project is not complete. As a result, it would be beneficial for another student to apply the lessons learned from this research effort to a new data collection effort that would complete the project. The following suggestions are offered as more efficient and effective means to collect the necessary data.

First, the GPS and the GIS option for collecting vegetation data is an extremely viable option. However, if this method is chosen in the future, the student must have access to a GPS receiver that is capable of attaining sub-meter accuracy after differential correction. Only a GPS with this type of resolution will yield data results that can be mapped with confidence.

Second, there was an opportunity to purchase an aerial photograph from Bechtel Nevada’s Remote Sensing Laboratory during this research effort. However, the Environmental Studies Department could not, during the time of this research, fund the approximately $2,000 endeavor. For future effort, this low altitude (approximately 12,000 feet) aerial photograph offers an alternative method for mapping the wetlands. A future researcher could actually digitize the major features and vegetation data at the wetlands directly from the photograph. Such an effort would, most likely, not require use of a GPS and would yield fairly accurate data.

Third, another viable and highly accurate approach in mapping the vegetation, although much more expensive than the previous two methods, is to investigate other
remote sensing and digital-image processing opportunities. Remote sensing is defined as “the technique of obtaining information about objects through the analysis of data collected by special instruments that are not in physical contact with the objects of investigation” (Avery & Berlin, 1992, p. 1). Digital-image processing is explained as “a sophisticated grid approach, where the cell size is very small, similar to those cells on a television screen. Maps are created directly from photo-imagery such as that from satellite or aerial photographs” (Steiner, 1991, p. 150). Further research should be done to see if these three suggestions would be affordable to the University.

VII. SUMMARY

Overall, this thesis was a very worthwhile and productive research effort. A tremendous amount of field experience was gained during this study, and from that, this researcher has benefited. It would be encouraging to see another student apply the data and research presented here and complete the Boulder City Wetlands baseline vegetation study in the future.


Wolf, T.J. (1999). Establishing a Multifunctional GPS Base Station for Survey and Resource Grade Applications. Las Vegas Valley Water District, Las Vegas, NV.