# Water Harvesting for Pollution Reduction and Revenue Enhancement: Protecting the Triple Bottom Line

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## Abstract

This water harvesting case study at a 4,000 member social club resulted in nitrogen and phosphorus pollution reduction of a major drinking water source, the assurance of a more reliable supply of non-potable water for the golf course and tennis courts irrigation, and the addition of previously non-existent water hazards on the golf course. The final product, a water harvesting system using stormwater, irrigation over wash, HVAC system condensate and swimming pool backwash, supplies non-potable irrigation water with a projected 5-year cost-recovery that protects the triple bottom line, the essence of a sustainable development.

This project arose from too little and too much water on the same property. One was an uncontrolled runoff causing erosion, with its deleterious effects; the second offered a paucity of potable water. In turn, this led to the review, problem-solving and incorporation of a water harvesting system as a water management solution for a 4,000-member social club situated on 45-acres in Raleigh, North Carolina. Critical to maintaining a recreational and social club is an adequate supply of water for the swimming pools, golf courses, kitchen and cooking facilities, and shower and bathing facilities that most clubs have and members expect. This club uses about 4 million gallons of water annually for all purposes, and before this development used potable water exclusively for its watering needs.

## Problems Identified

During mid-2007, the eastern part of the United States was suffering from a severe draught. The impact was such that many locales implemented mandatory water saving and reduction methods. In Raleigh, water restrictions applied especially to the use of water for irrigation purposes and limited water used for that purpose to alternate days of the week. In addition, restrictions were also applicable to the filling of swimming and wading pools.

The Clean Water Act of 1972 and subsequent legislation was another factor impacting the club's water use. This act seeks to restore and maintain the physical, chemical and biological integrity of U.S. waters. Prior to 2007 but still in effect at this time were efforts undertaken through U.S. EPA to reduce the amount of nitrogen and phosphorus run-off from fertilizer applications on landscapes and golf courses. This runoff has been targeted as a major producer of elevated nitrogen and phosphorus levels in the Neuse River as well as other U.S. rivers. In 1998, the North Carolina General Assembly (Division of Water Quality, 2005) designated the Neuse River Basin as nutrient-sensitive waters. The basins are subject to basin-specific Nutrient Sensitive Waters Management Strategies. Rules are specific to riparian buffer protection, agriculture, and nutrient and stormwater management. The nutrient rules cover parks, public rights-of-way, golf courses, cropland, turf grass areas, and lawns and gardens in residential, commercial and industrial areas. Riparian buffers as defined by the U.S. Department of Agriculture's Forestry Service and other sources consist of forest and grass or shrubs designed to intercept surface runoff and subsurface flow and have been shown to be effective in controlling nonpoint source pollution by removing nutrients, especially nitrogen and sediment.

On-site continuous surveys were begun on the club's property in 2006 to determine the amount of nitrogen, phosphorus and total suspended solids migrating into tributaries of the Neuse River. Skipper (2008) surveyed the areas adjacent to and near the club property beginning in 2006. Her results were compiled into a master's thesis for the School of Biological and Agricultural Engineering at N.C. State University. In her thesis, she noted: "A total of four weather stations and eight monitoring stations were installed in the House Creek watershed. Installation of monitoring equipment began in April 2006 at the watershed outlet, and various stations were installed throughout the study, with final installations in February 2008." Sampling was conducted on the club's property for 15 months. Skipper (2008) noted that the scope of her work was a survey of the House Creek watershed. "(The) House Creek watershed is a 217.5 ha (hectare or 2.471 acres), mixed land use watershed located in Raleigh, North Carolina, in the upper Neuse River Basin. The watershed consists of six land use areas: urban (22.8 ha), golf course (19.6 ha), highway (17.3 ha), agricultural/pasture (74.2 ha), residential (29.9 ha) and wooded (53.3 ha). The objectives of this research were to compare runoff volumes, peak flow rates, pollutant concentrations, and loads and exports among land uses, as well as compare upstream sub watersheds to the downstream outlet." Monitoring results from Skipper's survey follow.

**Table 1: Average Pollutant Loads in Stormwater Runoff from Club Property.**

| Pollutant | TKN | $NO_3 + NO_2$ | TN | NH3-N | TP | Ortho-P | TSS |
|---|---|---|---|---|---|---|---|
| Kg/ha (1) | 0.16 | 0.09 | 0.24 | 0.023 | 0.036 | 0.022 | 11.5 |
| Lbs/acre | 0.14 | 0.08 | 0.21 | 0.021 | 0.032 | 0.019 | 10.3 |

**(1) 1 hectare = 2.471 acres**
**TKN = Total kjehldahl nitrogen**
**$NO_3 + NO_2$ = Nitrate-nitrite**
**TN = Total nitrogen**
**NH3 – N = Ammonia-nitrogen**
**TP = Total phosphorous**
**Ortho-P = Orthophosphate**
**TSS = Total suspended solids**

Skipper's survey results also included data on the biotic assemblage, looking specifically for benthic marcroinvertebrates as an indicator of the watershed's relative health. The club's property, which drains through an approximate 12-acre, 65+ year old forest, had the highest values and the healthiest environment of the sites surveyed within the House Creek subwatershed from this perspective.

In particular, monitoring results had shown that elevated nitrogen and phosphorus levels in a tributary fed by runoff from the club's property were potentially negatively impacting the Neuse River basin. The Neuse River is formed by the confluence of the Flat and Eno Rivers near Raleigh, North Carolina; the longest river in North Carolina and the widest river in the United States—6 miles across at its widest point. The Neuse River flows from the piedmont area of North Carolina to the Pamlico Sound covering approximately 250 miles. The river provides drinking water to 400,000 Raleigh-area residents and its estuary serves as a primary nursery for commercially and recreationally important fish and shellfish. Other cities and towns downstream of Raleigh also rely upon the Neuse for their water supplies. Water sports such as kayaking and sailing as well as other forms of tourism are important economic drivers for the region (Neuse River Keeper Foundation, 2010).

Additional problems with the Neuse River include presence of the bacteria din flagellate Pfieseria piscicida, which blooms with increased nutrient levels. Nitrogen is one of the primary reasons for the increased nutrient levels. Eutrophication (an increase in nutrients such as nitrogen and phosphorus that increase algal growth) of the Neuse River is to such an extent that the pollution has been closely watched by several regulatory agencies with efforts to mitigate it. Sedimentation and algal growth are additional problematic issues with tributaries of the Neuse River.

Specific regulatory requirements impacting this project included the North Carolina Environmental Management Commission's adoption of a set of permanent rules on December 11, 1997, to support implementation of the Neuse River Nutrient Sensitive Waters Management Strategy. One of the permanent rules that the Commission adopted in December 1997 was a riparian buffer protection rule. This rule applies to 50-foot wide riparian buffers directly adjacent to surface waters in the Neuse River Basin, which includes intermittent streams, perennial streams, lakes, ponds, and estuaries, excluding wetlands. By definition, a perennial stream is a well-defined channel that contains water year round during a year of normal rainfall with the aquatic bed located below the water table for most of the year. Groundwater is the primary source of water for a perennial stream, but it also carries stormwater runoff. A perennial stream exhibits the typical biological, hydrological, and physical characteristics commonly associated with the continuous conveyance of water. (Neuse River Basin Nutrient Sensitive Water Management Strategy, 2008).

## Nonpotable Water Needs Quantified

Nonpotable water needs for this club include irrigation of the golf course and tennis courts. Potable water was used for irrigation of the 9-hole golf course and the soft (clay) tennis courts. Watering the approximate 25-acre, Bermuda grass golf course was sporadic and dependent upon the amount of rainfall. When it was necessary to water the golf course, 43 sprinkler heads supplied water at 30 gallons-per-minute at 55 psi, using 2 heads simultaneously for 20 minutes before another 2 were activated. This usage cycle consumed approximately 26,000 gallons of water. A separate water meter for irrigation uses was not added when the club was built in 1960 or thereafter when the water irrigation system was added in the later part of the 1990s. Therefore, the cost of water to the club included both the potable water for irrigation and an equal charge for discharge to the sewage system. Although the water was not being discharged to the sewage system, the charge still applied since a separate meter was not in place to record the actual usage for irrigation purposes. This is a common metering and billing practice for water vendors throughout the United States.

The tennis courts are watered 3 times daily using 27 heads flowing at 6 to 15 gallons per minute for cycles varying from 3 to 20 minutes each. It was not possible to quantify as precisely the amount of water used on the tennis courts as it was for golf, but it was known that the water consumption for both golf and tennis was approximately 1.7 million gallons for the time period of April through September. This was determined from water usage records for the club, which included the kitchen, locker rooms, toilet facilities and two swimming pools and amounted to 3.7 million gallons of water usage annually.

## Solutions Explored

An ad-hoc water conservation committee was formed in the summer of 2008 to address the problems noted above and find solutions focusing especially on Raleigh's water use restrictions. The committee consisted of club members with architectural, engineering, environmental science and plumbing backgrounds and expertise. An initial review investigated drilling a well. But at a cost of $20,000 to $25,000 and with no guarantee of success in getting an adequate supply of water, that solution was tabled in favor of taking advantage of the water available from stormwater runoff. The club receives about 39 inches of rainfall annually.

Other problems that were quickly identified by an ad-hoc committee exploring the problem and identifying solutions included the lack of water hazards on the golf course, erosion of the creek banks in an adjoining nature park also owned by the club, and the use of labor-intensive, 550-gallon cisterns to capture water from roof run-off and manual redistribution of that water on the tennis courts and golf course. The lack of water hazards on the golf course was a key component in successfully marketing this concept to the golfers at the club and the primary piece of the social aspect of the triple bottom line. Thus as the project progressed, a sustainable development was unfolding that would reduce pollution, enhance revenue and provide amenities on the golf course not then available.

The amount of water the property receives from storm events was determined and was the basis of using a pond for collection and irrigation instead of drilling a well. To that end, the first calculations were made to determine the storm water runoff volumes from both pervious and impervious surfaces.

The North Carolina Department of Environment and Natural Resources Stormwater Best Practices Manual, 2007 edition, offers two methodologies to determine the volume of runoff for a given design storm. They are referred to as the Simple Method after Schueler's 1987 publication and the discrete SCS Curve Number Method after NRCS in 1986. The NRCS curve is an empirical formula developed by the U.S. Department of Agriculture's Natural Resources Conservation Service and is a hydrological parameter used to predict runoff or infiltration after rainfall events. SCS refers to the organizations prior name-- Soil Conservation Service. "The Simple Method was developed by measuring the runoff from many watersheds with known impervious areas and curve-fitting a relationship between percent impervious and the fraction of rainfall converted to runoff (the runoff coefficient)." (Stormwater Best Practices Manual, 2007). The Simple method was used to calculate the volume of water generated from storm events and the size of the containment basins for this project. The equations for this method follow. First is the equation to determine the runoff coefficient.

$$R_v = 0.05 + (0.9 \times I_a)$$

Where,

$R_v$ = runoff coefficient (storm runoff inches/storm rainfall inches)

$I_a$ = impervious fraction (impervious portion of drainage area acres/drainage area acres)

The impervious fraction was determined from aerial photographs of the site acquired from the Wake County Geographic Information Services (GIS) maps. The lot size in acres was also determined from property and topographical maps of the site acquired from Wake County GIS maps.

From the data in the Table 2 below, the runoff volume was then calculated using the following equation.

$$\text{Volume} = 3630 \times R_d \times R_v \times \text{Area in acres}$$

Where,

V = volume of runoff to be controlled by the design storm in $ft^3$

$R_d$ = rainfall depth in inches

A = area acres

For the wetland and the land areas draining to the forebay and pond, the following data as shown in Table 2 were used to calculate the runoff from a 1-inch rainfall event.

**Table 2: Stormwater Runoff Drainage to Wetland and Forebay and Pond East Side (1)**

| | Wetland | Forebay and Pond |
|---|---|---|
| Lot size (acres) | 3.87 | 15.58 |
| Total impervious area | 2.26 | 3.09 |
| Percent impervious | 58.4 | 19.8 |

| | | |
|---|---|---|
| $R_v$ | 0.58 | 0.20 |
| Constant | 3630 | 3630 |
| $R_d$ | 1 | 1 |
| Volume ($ft^3$) | 8086 | 12,928 |
| Surface area @ 3' | 2695 | 4309 |
| Area provided ($ft^2$) | 11,777 | 15,188 |

**Footnote to table**
**(1) calculations sized the wetland and ponds solely for storm water runoff**

As this solution was further explored, it became apparent that not only the storm water runoff could be used for irrigation of the golf course and tennis courts but that other water sources could be used as well. There are 2 metal-roofed tennis shelters at the club that each yield about 550 gallons of water for every 1-inch rainfall event. In addition, there is a 27,000 $ft^2$ built-up roof with internal roof drains that could be piped for reuse. Pool backwash for the filter systems produces about 8,000 gallons of water weekly for the months of May through September when the pools are operational. Pool splash-out was viewed as another source to be harvested and while not quantified, it was viewed as being worth the cost of capturing it. While the water harvesting project was being explored, the club was renovated and the HVAC system was completely redone with the addition of 15 self-contained heating and air condition units installed as roof-mounted units. These units were determined to produce about 500,000 gallons of water annually. In addition, over wash from tennis court irrigation was another source, again not quantified but determined to be substantial based on wet spots continually noticed on the areas of the golf course where it drained. Another source was water runoff from a 4-lane highway adjacent to the club property, and which was directed onto the property. Finally, storm water runoff from about 20 acres of the property, some pervious and some impervious, could be captured and reused.

The following table notes the water sources listed above and details the estimated annual water volume from each source using a basis of 39 inches of rainfall per year at this location where applicable and otherwise noting the basis. Some capture efficiencies were measured. For those not measured, the efficiencies are based on data from The Texas Rainwater Harvesting Manual, Rooney Malcolm's Elements of Urban Stormwater Design, and the North Carolina Department of Environment and Natural Resources' Stormwater Best Practices Manual.

**Table 3: Water Harvesting Sources**

| Source | Surface Area (Acres or $Ft^2$) | Capture Efficiency (%) | Estimated Annual Volume (Gals) (1) |
|---|---|---:|---:|
| Ground--Pervious (2) | 14.1 acres | 10 | 149,311 |
| Paved/HardScapes-Impervious | 5.35 acres | 90 | 5,665,348 |
| Highway Point Source Runoff | 1.6 acres | 90 | 254,145 |
| HVAC Condensate | 15 Units | 100 | 500,000 |
| Pool Backwash | Not applicable | 100 | 146,200 |
| Pool Splash Out | Not available | 95 | 500 |
| Roofs-Built up | 27,000 $ft^2$ | 90 | 590,773 |
| Roofs-Metal | 1,200 $ft^2$ | 100 | 29,174 |

| | | | |
|---|---|---|---|
| Tennis Court Overwash | 20,160 $ft^2$ | 10 | 1,633 |
| **Total Water Available** | | | **7,337,084** |

**Footnotes to table**
**(1) Estimated volume includes evaporative losses occurring during runoff**
**(2) Volume estimated based on rainfall events of duration and volume exceeding ground percolation expectations where pervious surfaces included**

## Water Sources Prohibited from Use

Sources of water not used included water from the locker room showers and lavatories, water from the kitchen sinks and dish washing machine and toilet facility discharges. Some of these, i.e. toilet discharges and dishwashing effluents are generally referred to as black water while the water from the bathing facilities and specifically the lavatories and showers, as well as the kitchen sinks (without the food waste) are considered graywater. In North Carolina as well as in many parts of the United States, untreated graywater is sewage. The 2006 edition of the North Carolina Plumbing Code defines graywater as “waste discharged from lavatories, bathtubs, showers, clothes washers and laundry sinks.” North Carolina’s mandate through the Department of Environment and Natural Resources’ Non-Point Source Pollution Program of the Division of Environmental Health cautions that this type of household wastewater may contain disease-producing organisms and should not be used to water plants such as trees, vegetable gardens or flowers. By law then, this wastewater must be disposed of through a permitted treatment system, either a publically-owned treatment plant or a permitted septic tank system. The statutory authority is codified in the North Carolina code and can be found online at http://www.deh.enr.state.nc.us/osww_new/new1/images/Rules/1900RulesAugust2007.pdf.

The North Carolina Department of Environment and Natural Resources’ position that untreated wastewater is unhealthy is based on the potential contact with humans since it might contain disease-producing pathogens either from human discharges such as fecal matter or from on the body (e.g. staph), both of which are infectious. Second, their position holds that untreated wastewater attracts animals and pests, which can spread diseases.

The North Carolina rules and regulations do allow graywater to be recycled for home use. The 2006 N.C. Plumbing Code allows treated household graywater to be used for specific purposes if treated as is specified in the code and standards. It can be used for flushing toilets that are located in the same building as the graywater recycling systems. These recycling systems can also be used for irrigation purposes when approved by the authority having jurisdiction. Graywater used in a graywater recycling system must be filtered and disinfected before it can be recycled for flushing of toilets or irrigation.

Additional data on graywater usage as well as prohibitions for its use can be found from reports available from the American Water Works Association, the Water Reuse Association and the Water Environmental Federation. One white paper sponsored by the American Water Works Association (Sheikh, 2010) noted that about 7% of U.S households were using graywater in 2006 and estimates that 10% may be using it by 2030. Where prohibitions do exist, the arguments against using graywater note elevated levels of sodium, boron, nitrogen, phosphorus, fecal coliform, chlorine residuals, bleach compounds and malodorous smells. In the white paper of the American Water Works Association et al., the author overviews 5 states which have regulations that govern the use of graywater. North Carolina is one of the states reviewed.

## Business Model

The development of a business model was deemed critical to allow further work on the project. This included not only showing a cost-benefit analysis that established that the project could pay for itself in a time frame that would be acceptable to the club board of directors but the ability to impact the triple bottom line—balancing social, environmental and economic consequences. This current tenet of business management is the core of sustainable development.

At the time that the project was being developed for presentation to the board of directors, water usage data was available through the latter part of 2008. For this paper, the actual data was updated through 2010. Data for years 2011 through 2014 are forecast based on usage from prior years.

**Table 4: Actual and Projected Water Consumption and Costs 2003--2014**

| Year | 100's $Ft^3$ | Gals | Cost | Cost/Gallon | % Annual Cost/Gallon Increase |
|---|---|---|---|---|---|
| 2003 | 2786 | 2,084,207 | $12,517 | $0.0060 | ---- |
| 2004 | 4157 | 3,109,852 | 18,986 | 0.0061 | 1.6 |
| 2005 | 4759 | 3,560,208 | 25,574 | 0.0071 | 14.1 |
| 2006 | 4654 | 3,481,657 | 27,278 | 0.0078 | 9.0 |
| 2007 | 5228 | 3,911,067 | 33,383 | 0.0085 | 8.2 |
| 2008 | 3938 | 2,945,700 | 29,457 | 0.01 | 15.0 |
| 2009 | 3615 | 2,704,020 | 28,195 | 0.010 | 0 |
| 2010(1) | 5830 | 4,360,840 | 57,048 | 0.013 | 23.1 |
| 2011(2) | 5849 | 4,375,000(3) | 61,250 | 0.014 | 7.1 |
| 2012 | 5849 | 4,375,000 | 70,000 | 0.016 | 12.5 |
| 2013 | 5849 | 4,375,000 | 74,375 | 0.017 | 5.9 |
| 2014 | 5849 | 4,375,000 | 81,812 | 0.0187 | 9.1 |

**Footnotes to table**
**(1) A second pool with a water volume of 145,000 gallons was added in 2010**
**(2) Years 2011—2014 are based on linear regression projections and historic valuations based on actual consumption and costs for years 2003--2010**
**(3) Stabilized water consumption for years 2011-2014 based on maintaining the club membership cap of 900 members**

Knowing the historic water usage volume and costs allowed the designers and planners to project and quantify future costs. It also then was possible to quantify the cost savings if sources other than potable water could be used.

Based on population growth projections for the City of Raleigh and historic water consumption cost increases for the years FY 2003 through FY 2008, the authors conservatively projected future water consumption cost increases of 10% per year. As noted in the footnote to Table 4, this value was also validated by a linear regression analysis.

The reduced water cost for irrigation was then compared against the cost of building the system needed to harvest the water from the sources identified previously. The preliminary construction budget that follows was used as the cost of the project.

**Table 5: Preliminary Construction Budget**

| **Item** | **Units** | **Qty** | **Unit Price** | **Total** |
|---|---|---|---|---|
| Clearing | Acres | 1.5 | $12,000 | $18,000 |
| Erosion Control | Ls(1) | 1 | 8,000 | 8,000 |
| Grading | Cy(2) | 6000 | 8 | 48,000 |
| Outlet Structures | Ls | 1 | | 25,000 |
| Pump and Wetwell | Ls | 1 | 25,000 | 25,000 |
| Landscape | Ls | 1 | 18,000 | 18,000 |
| Wetland Plants | Ls | 1 | 25,000 | 25,000 |
| Design | | | | 18,000 |
| Testing | | | | 9,000 |
| Inspection | | | | 7,500 |
| Contingency | | | | 27,000 |
| **Total Estimated** | | | | **$229,500** |

**Footnotes to table**
**(1) Ls—lump sum**
**(2) Cy—cubic yards**

The reduction of the nitrogen migrating offsite from fertilizer applications to the golf course was viewed as a one-time revenue stream in addition to the cost savings anticipated from eliminating or reducing the purchase of potable water for irrigation of the golf course and tennis courts. Previously, the North Carolina General Assembly had set goals for nitrogen reduction in specified river basins and watersheds in the state. They also specified that before developers could receive final approval for site plans from local governments that the anticipated nutrient loading for nitrogen, and where applicable phosphorus, be determined for a 30-year period. If it was then determined that the nutrient loading exceeded either a rule or law, the developer has the option of either off-setting it on site, choosing a third-party mitigation provider such as the North Carolina Ecosystem Enhancement Program, or using a compensatory mitigation bank to purchase or buy down the excess loading requirements. At the time that the business model was being developed, it was anticipated that the nitrogen credit could be sold and that it would be worth $70,000 for this club's property. (As of 1.1.2011, nitrogen credits for the Neuse River are valued at $20.59 per pound.)

The choice of the management strategy was also influenced by the amount of nitrogen credit following completion of the project. Table 6 gives the allowable values available.

**Table 6: Nutrient Removal Efficiencies for Best Management Practices Used Under Neuse River Stormwater Rules**

| Best Management Practice | Total Nitrogen | Total Phosphorus |
|---|---|---|
| Wet Pond | 25 | 40 |
| Stormwater Wetland | 40 | 40 |
| Sand Filter | 35 | 45 |
| Bio Retention | 35 | 45 |
| Grass Swale | 20 | 20 |
| Vegetated Filter Strip w/Level Spreader (1) | 20 | 35 |
| 50’ Restored Riparian Buffer w/Level Spreader | 30 | 30 |
| Dry detention | 10 | 10 |

**Footnotes to table**
**(1)Without internal water storage**

After the preliminary budget was developed, it was possible to determine the economic feasibility of the project. By using the cost of water from Table 4 and assuming that over 1M gallons per year could be obtained from water harvesting for irrigation use on the golf course and tennis courts, then a cost reduction or positive revenue stream could be determined. In addition, as noted above, the nitrogen offset credit was assumed to be $70,000 and was treated as an income stream. These values then were compared against the cost of building the pond and wetlands using the algorithm below.

The payback period and the return on investment are the two primary means of determining if a capital project is financially feasible. For this project, the payback method was used. The following equation was used to determine the payback period.

$$\text{Payback period (in years)} = \frac{\text{Total capital costs - Nitrogen offset credit}}{\text{Annual net operating cost savings}}$$

As noted previously, the total capital costs were projected to be $229,500 prior to receiving the nitrogen offset credit; the nitrogen offset credit is presumed to be $70,000. The total capital cost projected was then $161,000. However, actual construction costs of $172,658 less the nitrogen offset credit of $70,000 yields a total construction cost of $102,658.

The annual operating savings are projected to be the cost of the water not purchased and used for irrigating the golf course and tennis courts, minus annual maintenance costs. Not included in the payback period analysis but worthy of future consideration is the potential for a reduction in the amount and thus cost of fertilizers used. Specifically, since the water entering the pond from runoff of the golf course will be nutrient-enriched, it should reduce the amount of fertilizer purchased since the nitrogen and phosphorus is being re-applied. If this does reduce the fertilizer requirements as expected, then the payback period will be shortened. Water costs are escalating each year so the equation was run with the values for each year entered until the annual net operating savings exceeded the total capital cost minus the nitrogen offset credit. This then showed that the project was projected to produce a net positive cash flow by 2015.

Of interest is the comparison of the projected costs versus the actual construction costs. From the footnote to the table, note that some of the costs initially projected were not incurred since some services and materials were donated by club members.

**Table 7: Actual Construction Costs**

| | |
|---|---:|
| Engineering and Design | $11,835 |
| General Contractor | 143,649 |
| Landscape Contractor* | 1,005 |
| Irrigation Contractor | 14,537 |
| Permits and Fees | 1,632 |
| **Total** | **$172,658** |

**Club members donated time, plant materials and financial resources for plants, trees and shrubs valued in excess of $8,000.*

Construction was completed in November 2010 and a certificate of completion was issued by the City of Raleigh, North Carolina's Stormwater Utility Division on 1.1.2011. A description of the physical features of the completed system follows.

## Wetland and Ponds Physical Features

Maintaining a 50 feet wide buffer from all sides of the Neuse River buffer was one constraint on the pond location and is a is one regulatory-specified method of reducing the amount of runoff into a water resource. Riparian buffers are vegetated areas next to water resources that reduce pollutant movement into surface waters, provide bank stabilization, as well as provide aquatic and wildlife habitats. They are typically 25 to 50 feet on each side of perennial streams; North Carolina prohibits construction or related activities within 50 feet of the Neuse River buffer.

Water harvested first flows to the wetland unless it has been channeled directly to the forebay or the pond. The wetland has 4 basins and is oriented in a general water flow direction of west to east on the higher elevations of the property. The 4 basins, shallow land and shallow water areas cover 11,777 $ft^2$ and include a forebay with1178 $ft^2$, 2 shallow pools, and a deep pool with 1175 $ft^2$. The shallow water area is 4713 $ft^2$ and the shallow land area is 4711 $ft^2$. The shallow water depth is 6 inches and the deep pool depth is 3 feet. Surrounding the 4 interior basins is a shelf for wetland plants which is at 464 feet elevation and is 6.25 feet wide. Embankments on interior sides of the wetland are sloped from 3H:1V to 4H:1V. Discharge from the wetland is through an 18-inch HDPE (high density polypropylene) piping to a grassed swale, which drains to the forebay of the main pond. The wetland receives water from the tennis court overwash during the three daily soft court irrigation cycles, and storm water runoff from all elevations on the south side of the wetland greater than 466 feet. Water draining into the wetland from the tennis courts enters from a 6-inch drain and is discharged into a scour hole with a class B rip rap (generally rock, concrete or similar materials used on shorelines or streambeds to armor the area and protect against scour or water erosion) apron serving as a deceleration pad. The berm's elevation surrounding the wetland is 464 feet. The forebay pool depth is 459 feet, the 2 shallow pools have elevations of 460 feet and the deep pool elevation is 459 feet. A CMU (concrete masonry unit) box weir (here an open top concrete box which allows water to flow over the top and used to control the height of the water in the basins as the first means of controlling flooding) outlet structure is located in the deep pool which is the fourth basin and has a 4-inch drain with a 4-inch gate valve to allow drainage of the wetland for future maintenance needs. The outlet box is equipped with a flattop CMU that covers a 6-inch weir opening with expanded steel grating serving as a trash screen. This unit provides flood control for the wetland and is designed to release water at 462.81 feet; the permanent pool elevation being 462 feet. The berm that the box weir outlet drains through has an elevation of 464 feet and was built with a 3' x 3' x 1' anti-seep collar to reduce the hydraulic conductivity of the water against the berm and the 18- inch HDPE discharge pipe that flows through the berm.

Water discharged from the wetland empties into a scour (creation of a hole when sediment such as sand and rocks is washed away from the bottom of a water system) hole with class B rip rap then flows across a grassed swale draining to the forebay of the pond. The 3320 $ft^3$ (24,835 gallons) forebay receives water from the wetland located south of the forebay and at an elevation of 440 feet maximum. Water also enters the forebay from the backwash of the three swimming pools, splash out from the three pools, the main building roof drains that serve the 27,000 $ft^2$ roof, the two tennis court pavilion roofs that have metal roof surface areas of 2400 $ft^2$ in aggregate, HVAC condensate discharge from the 15 units on the roof of the main building and storm water runoff from both pervious and imperious portions of the property with elevations greater than 440 feet. The depth of the forebay is from 435.5 feet to 440 feet giving a maximum water depth of 4.5 feet. There is a bermed area between the forebay and the main pond. This serves as an access area for golf course use and is the area where the underground utilities lines for the potable water for the buildings and structures on the lower portions of the property are located. It is also where the conduits for the electrical lines and irrigation control lines are buried. Water drains from the forebay to the main pond through a 24-inch HDPE pipe.

Water then flows from the forebay to the pond. The pond has a capacity of 19,383 $ft^3$ (145,000 gallons) and in addition to receiving water from the forebay, receives water from the discharge of the 4-lane highway on its east side and from storm water runoff from elevations >435 feet on the south and west sides of the pond. A rip rap lined plunge pool with class b stone was employed to serve as a deceleration pad and absorb some of the water flow's energy for the runoff water entering from the 4-lane highway east of the club's property. The plunge pool is 10 feet wide by 12 feet long and is 12 inches deep. The sides of the pool are sloped 2H:1V. The volume of the pool is approximately 120 $ft^3$ (about 900 gallons), the approximations acknowledging the uneven surface areas created by the rip rap. This pool serves as a level spreader to allow the water to be discharged into the pond in a sheet flow. Water flow from the pond is through a 36-inch RCP (reinforced concrete pipe) leading first to a rip rap lined scour box. The water flow's energy from the pond is reduced before it enters into the existing drainage of the Neuse River basin by a concrete level spreader located beyond the scour box. The pond has a box weir outlet structure for flood control with a 6-inch bottom drain to allow the pond to be emptied for future maintenance. The drain is at an elevation of 426 feet while the elevation of the dam is 435 feet; the maximum depth of the water before overflowing the top of the dam therefore being 9 feet. However, the overflow for the weir is 433 feet which would direct the water into the outlet box before reaching the top of the dam. A rip rap lined emergency spillway on the west side of the pond has an elevation of 433.5 feet. Greater than capacity water flow volumes are first exhausted through the box weir, then the emergency spillway before it reaches the top of the dam. The pond has a 9' x 9' x 1' anti-seep collar for protection of the dam against the hydraulic conductivity of the water. There is a shelf for wetland plants on three sides of the pond at 433 feet elevation which is 7' above the floor of the pond. The shelf is 10 feet wide with a 5 degree slope toward the pond. Embankments on all interior sides of the forebay are sloped 3H:1V.

Water flow to the 6065 $ft^3$ (45,369 gallons) capacity pond on the west side of the property is fed entirely from storm water runoff with construction similar to the pond on the east side. It has a CMU box weir outlet structure with a 6- inch bottom drain at 437 feet elevation. Water entering the weir is discharged through an 18-inch RCP to a 6' x 4.5' x 18" deep scour hole lined with class B rip rap. The bottom of the pond has an elevation of 435 feet with the overflow to the weir at 440 feet, limiting the water depth to 5 feet. The box weir has diamond-shaped grating at the opening for trash and debris control. The top of the dam is 442 feet and the emergency spillway elevation is 441 feet. The normal pool elevation is 440 feet. Embankments on all interior and exterior sides of the pond are sloped 3H:1V.

The electrical service to supply the pump provided a challenge. Initially it was determined that a 7.5 horse power pump would be needed to supply an adequate water pressure and flow for the irrigation patterns needed for the golf course, and to get water to the tennis courts, the most distant part of the system to be served. The resulting head pressure to overcome was determined to be 280 feet. The pump size needed to supply the water and flow rates was then determined to be 7.5 horsepower. The maintenance building with an electrical service closest to the wet well for the pump is about 400 feet from the source of the electrical service to the panel designated to serve the pump. Existing electrical loading in the maintenance building was determined to be low enough that the existing circuit from that source would support the new 7.5hp pump load wise and the panel would not be overloaded. The concern however became the voltage drop from the source to the load with the pump running. This was a calculated to be about a 42 volts drop from the source 400 feet away to the maintenance shop with the pond pump running. With a source voltage of 240V at the disconnect switch located near the pool, the voltage at the maintenance shop wood conceivably drop to about 198V when the pump is running. Motors rated 230V and designed to properly operate at +/- 10% of 230V would be operating at 198V which is 86% of 230V, and below the recommended thresholds.

The solution then was to find a submersible pump that could operate at 200 volts. One was located which was designed to run at 60Hz, 200V, 25.1A at 3450 RPM and yield 7.5 horsepower on a 3-phase circuit. The last issue to overcome was the need to supply a 3-phase circuit. The panel in the maintenance shed was wired as single phase as were all other circuits on the club's property. This last hurdle was cleared by using a variable speed drive that converts the single phase to 3-pahse voltage. A NEMA 3R, with HOA switch, surge arrestor, 3% line reactor, and pressure transducer were supplied with the system.

## Landscaping

Guidance and specifications for the species of trees, shrubs, and grasses for the wetland and pond areas was available from the NC Department of Environment and Natural Resources. These plantings must be ones that can tolerate being in water as well as out of water for substantial periods of time.

For this project, 24 River Birch trees, and 2240 plants, shrubs, and grasses were specified. Plants used or to be added include Blue Flag Iris, Pickerelweed, Duck Potato, Soft Stem Bulrush, Primrose Willow, Lizard's Tail, American Lotus, Yellow Pond-Lily and Woolgrass. Minimum sizes at plantings include 8 feet for the trees and $4in^3$ for the potted plants. Recommendations followed or to be followed include planting herbaceous plants at 2 feet on center and shrubs at 5 feet on center. These plantings will cover 4713 $ft^2$ of shallow water area and 4711 $ft^2$ of shallow land areas.

## Maintenance

Three distinct maintenance needs with ponds and wetlands are time and event driven. These maintenance issues include plant and vegetation installation with their usually one-time special-needs care as the plantings mature or adapt and begin to thrive in a new environment. Second are those maintenance items associated with specific storm events. The third group of maintenance needs is the routine and preventive maintenance tasks.

The wet detention basin, pretreatment areas including forebays and the vegetated filters where provided, and the wetland require attention specific to the installation of the plants, grasses and trees and include the following recommendations:

- Immediately after the wet detention basin is established, the plants on the vegetated shelf and perimeter of the basin should be watered twice weekly if needed, until the plants become established (commonly six weeks).
- No portion of the wet detention pond should be fertilized after the first initial fertilization that is required to establish the plants on the vegetated shelf.
- Stable groundcover should be maintained in the drainage area to reduce the sediment load to the wet detention basin.
- Immediately following construction of the stormwater wetland, bi-weekly inspections should be conducted and wetland plants watered bi-weekly until vegetation becomes established (commonly six weeks).
- No portion of the stormwater wetland should be fertilized after the first initial fertilization that is required to establish the wetland plants.
- Stable groundcover should be maintained in the drainage area to reduce the sediment load to the wetland.

After construction is completed, there will be on-going routine and preventive maintenance needs for the ponds, forebay and wetlands associated with a water harvesting system. The following list offers a summary of the key items that should be routinely addressed:

- Presence of trash and debris
- Bare soil and erosive gullies
- Vegetation too short or too long
- Inlet device pipes or swales clogged
- Outlet device piping clogged
- Sediment accumulation greater than design depth
- Presence of weeds or other invasive plants or grasses
- Dead, diseased or dying plants
- Excessive algal growth
- Shrubs or trees growing on embankments
- Beaver or muskrat activity
- Substantially flooded shallow land after storm events
- Displaced rip rap from energy of storm event
- Sediment accumulation at level spreader
- Screens or filters clogged
- Pump not operating properly
- Mosquitos present

The inspection frequency necessary to identify and schedule maintenance for the items in the above list is based on the occurrence of significant falling weather events as well as a pre-determined time interval. In general, after the wet detention pond is established, it should be inspected once a month and within 24 hours after every storm event greater than 1.0 inches (or 1.5 inches if in a coastal area). Records of operation and maintenance should be kept in a known location and must be available upon request.

Roofing systems often employed to capture falling weather, should also be checked routinely. To ensure proper operation as designed, a licensed Professional Engineer, Landscape Architect, or other qualified professional should inspect the system annually. Internal roof drains and gutter systems should be inspected after every significant falling weather event to ensure that they continue to operate as designed.

The embankments and dam are critical features that must be properly maintained to assure the integrity of the entire system. The bands and embankments should be inspected once a year by a dam safety expert.

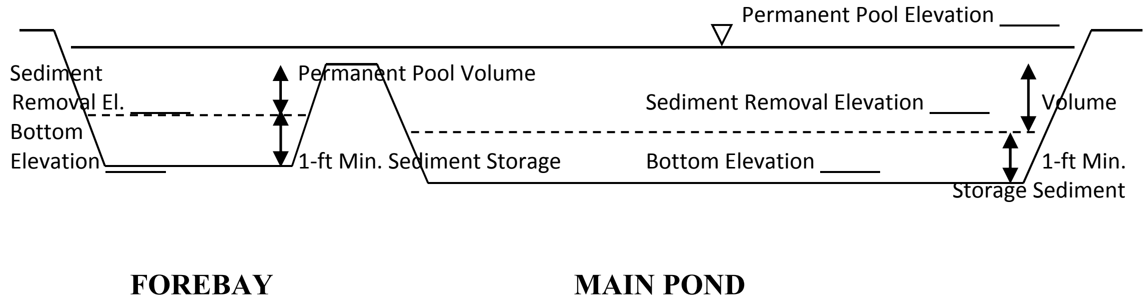
The measuring device used to determine the sediment elevation shall be such that it will give an accurate depth reading and not readily penetrate into accumulated sediments.

Sedimentation control and removal is based on the permanent pool depth of the pond. The N.C. Department of Natural and Environmental Resources (Stormwater Best Practices Manual, 2007) offers and recommends that the following design parameters be used, as shown in the diagram that follows, to establish maintenance criteria for sediment removal. As noted, "When the permanent pool depth reads _x_ feet in the main pond, the sediment shall be removed.

When the permanent pool depth reads _x_ feet in the forebay, the sediment shall be removed."

**BASIN DIAGRAM**

*(fill in the blanks)*




Perceived and sometimes real problems associated with pond and wetland maintenance include insect, and particularly mosquito infestations. Critical to eliminating or at least minimizing this potential is a design that exposes the water to direct sunlight. By removing the overhead foliage and thus providing direct sunlight to the water surface, an environment not conducive to a mosquito habitat is created. In this project, mature vegetation was removed from both the ponds and wetland sites. Although some trees do remain near the water bodies, photographs of the completed design show open areas on at least 2 of the 4 directional quadrants.

Approximately 35 soft and hardwood trees with calipers as great as 24 inches were removed in the pond and wetland area however, an environment conducive to a robust and active wildlife population still exists. This project, on an approximate 45-acre tract, near the heart of downtown Raleigh, a metropolitan city of >400,000 citizens, is bounded by limited access 4-lane highways on 3 sides and the N.C. State School of Veterinary Medicine with its open pastures for animal grazing and large multi-story teaching and treatment facilities on the 4$^{th}$ side. But still regularly seen on the grounds and in a wooded area immediately adjacent to the pond are deer, coyotes, foxes, black and copperhead snakes, as well as the expected squirrels, raccoons, opossums, birds, and geese.

Kristan (2008), who has owned a golf course for over 20 years, has found that the water feature on the grounds of a golf facility is one of the greatest assets for many reasons, including the beauty, the sense of flow from watery reflections, the added challenge to the golfer, and the plentiful and free source of water. In addition, his experience has been that the financial cost to maintain a pond is less than the maintenance cost of an equivalent area of turf.

In using the pond for irrigation, it is important that algae and other floating or suspended plants are kept from growing. Not doing so can result in clogged intakes and can alter the quality of the water. Chemicals can be used and are relatively inexpensive but do require periodic applications.

Kristan's solution has been to install Hybrid Grass Carp into the water. These fish cost about $8 to 15 each; approximately 6 are needed for the pond on his golf course. His course is approximately one-half acre surface, average four feet in depth, with a yield of two acre feet. The fish eat at least their weight each day and that is enough to keep the water clear. In the early spring, before the deeper water is warm enough to invigorate the carp, the shallow water warms and algae grows on the bottom;  the algae blooms float to the top and form the familiar pond scum. To discourage this early growth, a blue concentrate dye is added to the water for a few weeks until the water warms and the fish can be seen actively feeding. The cost for the dye is about $100 per year. As the fish are visible during feeding, it is easy to count and replace any that have died. Their life span is quite long but he adds a few every other year to maintain a youthful group.

Maintenance costs for the first 15 months usage have been minimal and have not been a cost increase over the landscaping and maintenance activities previously associated with this section of the club property. It is anticipated that removing silt or dredging the basins will be an expense but that has also been considered to be minimal based on the sizes of the basins and the availability of equipment and labor from club members. It was also considered to be an expense that would occur after the initial payback period was reached.

## Benefits Realized and Anticipated

The intent of this project to reduce pollution into the Neuse River buffer, provide a supply of non-potable water for irrigation of the tennis courts and golf course and provide water hazards for the gold course has been met. The solutions have produced and are anticipated to produce numerous benefits to the club including enhancing revenue, reducing pollution and improving the social aspects of the golf course. Specifically, the following 8 specific goals of the project have been met.

- Develop a sustainable water harvesting system enhancing the triple bottom line of social, environmental and economic consequences
- Reduce potable water purchases
- Reduce nitrogen, phosphorus, and total suspended solid levels in the Neuse River buffer
- Reduce the amount of fertilizer needed for golf course maintenance
- Add water hazards to the golf course
- Recharge the ground water
- Add an educational component for club members and visitors regarding water harvesting and cost effective management of a precious and vital resource
- Establish the potential to achieve LEED Green Building Rating System Credit under Water Use Reduction, Water Efficient Landscaping and Storm Water Management

Quantifiable results include economic, social and environmental impacts. The economic benefits are now being realized. The club began using the harvested water in 2011 for golf course irrigation. This has enabled the club to reduce water purchases in 2011 by over 1.5M gallons (a 32% decrease) from 2010 purchases, despite a 5% increase in club membership, a 40% increase in banquet food and beverage sales, and almost the same number of degree cooling days for 2011 compared to 2010 (7% decrease). Purchasing 1.5M gallons less water at $0.016 per gallon saved the club over $24,000 in 2011 and is above the amount initially projected to be saved annually when the financial payback period was calculated.

Significant pollution control has also resulted from this project. Stream bank erosion has been eliminated and the nitrogen, phosphorus and total suspended solid levels in the run-off have been reduced. The storm water BMP's (Best Management Practices) include the wetlands, wet detention pond and the dry detention basin, all of which are reducing pollutant offsite migration. Specifically, the wetlands drain 4.1 acres and treat the runoff from a portion of the pool decking, tennis courts with associated walking surfaces and related lawn areas. Approximately 2.6 acres of this area is impervious. As the runoff flows into the wetlands, this facility with its mixture of plants removes approximately 40% of the nitrogen from the storm water.

The wet detention pond has a drainage area of 16.2 acres and treats runoff from the club's roofs including condensate from the HVAC units, the pool decks, pool filter backwash, a portion of the golf course, and the overflow from the wetlands unit. In addition the pond receives a portion of the runoff from I-440. While stored in the wet pond, the nitrogen in the storm water is reduced by approximately 25%. During the summer season, this facility provides irrigation water for the golf course. The wet pond also slows downstream runoff velocities thereby reducing the erosion in the receiving stream channel.

The dry detention basin on the property's west side treats the runoff of a 6.5 acre section of the golf course. The basin fills during a rain event and dewaters over a one to two day period. This slows the storm water discharge and reduces downstream erosion. Approximately 10% of the nitrogen enriched water entering is removed while flowing through this device.

The nitrogen-enriched water, continuously recycled through the forebay and pond, has made it possible to reduce the amount of fertilizers used.

The social impact has also been substantial. The addition of the wetland, dry detention basin, forebay, and wet pond have added much-desired water hazards to the golf course and have greatly enhanced the value to the golf course users.

All goals as initially established have been met with an eventual LEED certification a component of additional construction of club buildings scheduled to begin in late 2012 or early 2013.

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