Water Harvesting

Reducing Pollution & Enhancing Revenue to Protect the Triple Bottom Line

By Albert Weaver III and Carl Simmons

During mid-2007, the eastern U.S. experienced a severe drought. As a result, many locales implemented mandatory water saving and reduction methods. In Raleigh, NC, water restrictions applied especially to the use of water for irrigation and limited water used for that purpose to alternate days of the week. In addition, the area enacted restrictions on filling swimming and wading pools.

The project that is the focus of this case study arose from too little and too much water on the same property. One was uncontrolled runoff causing erosion with its deleterious effects; the second offered a paucity of potable water. This situation led to incorporation of a water harvesting system as a water management solution for a 4,000-member social club situated on 45 acres in Raleigh, NC. A recreational and social club must maintain an adequate supply of water for swimming pools, golf courses, kitchen and cooking facilities, and shower and bathing facilities. This club uses about 4 million gallons of water annually for all purposes and, before this project, used potable water exclusively for its watering needs.

Problems Identified

The Clean Water Act of 1972 and subsequent legislation also affected the club's water use. The act seeks to restore and maintain the physical, chemical and biological integrity of U.S. waters. Before 2007, yet still in effect in 2007, EPA enacted efforts to reduce the amount of nitrogen and phosphorus runoff 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 designated the Neuse River basin as nutrient-sensitive waters, which makes it subject to basin-specific Nutrient Sensitive Waters Management Strategies (NC Department of Environment and Natural Resources, 2008). Rules are specific to riparian buffer protection, agriculture, and nutrient and storm water 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* is a term used by U.S. Department of Agriculture's Forestry Service and other sources;

IN BRIEF

- **This case study at a social club reduced nitrogen and phosphorus pollution of a major drinking water source; assurance of a more reliable supply of nonpotable water for irrigating the golf course and tennis courts; and the addition of previously nonexistent water features on the golf course.**
- **The resulting water harvesting system using stormwater, irrigation overwash, HVAC system condensate and swimming pool backwash, supplies nonpotable irrigation water with a projected 5-year cost recovery that protects the triple bottom line, the essence of a sustainable development.**

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Erosion on the golf course was one of the concerns that prompted the project.

they consist of forest and grass or shrubs designed to intercept surface runoff and subsurface flow, and have been shown to effectively control nonpoint source pollution by removing nutrients, especially nitrogen and sediment.

On-site continuous surveys were initiated on club 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. Results were compiled into a master's thesis for the School of Biological and Agricultural Engineering at NC State University. In the thesis, Skipper notes:

> 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 club property for 15 months. Skipper (2008) notes 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, NC, 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, loads and exports among land uses, as well as compare upstream sub watersheds to the downstream outlet.

Table 1 presents several monitoring results from Skipper's (2008) survey. The results also include 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 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. Formed by the confluence of the Flat and Eno rivers near Raleigh, NC, the river is the longest in the state and the widest river in the U.S.—6 miles across at its widest point (Neuse River Keeper Foundation, 2010).

Additional problems with the river include the presence of the bacteria dinoflagellate Pfieseria piscicida, which blooms with increased nutrient levels; nitrogen is a primary reason for these increased 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 (NC Department of Environment and Natural Resources, 2008).

Table 1

Average Pollutant Loads in Storm Water Runoff From Club Property

Pollutant	TKN	$NO_3 + NO_2$	TN	NH_3-N	TP	Ortho-P	TSS
kg/ha	0.16	0.09	0.24	0.023	0.036	0.022	11.5
lb/acre	0.14	0.08	0.21	0.021	0.032	0.019	10.3

Note. *1 hectare = 2.471 acres*
TKN = Total kjehldahl nitrogen
$NO_3 + NO_2$ = Nitrate-nitrite
TN = Total nitrogen
NH_3-N = Ammonia-nitrogen
TP = Total phosphorous
Ortho-P = Orthophosphate
TSS = Total suspended solids

Nonpotable Water Needs Quantified

Nonpotable water needs for this club include irrigation of the nine-hole golf course and clay tennis courts. Potable water was used for irrigation, and watering the approximately 25-acre Bermuda grass golf course was performed sporadically, depending on the amount of rainfall. When it was necessary to water the course, 43 sprinkler heads supplied water at 30 gallons-per-minute at 55 psi, using two heads simultaneously for 20 minutes before another two were activated. This usage cycle consumed approximately 26,000 gallons of water.

A separate water meter for irrigation use was not installed when the club was built in 1960 or thereafter when the water irrigation system was added in the late 1990s. Therefore, the cost of water to the club included both potable water for irrigation and an equal cost for discharge to the sewage system. Although the water was not being discharged to the sewage system, the cost still applied because 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 U.S.

Tennis courts are watered three 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 from April through September. This was determined from the club's water usage records, which encompassed 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 committee was formed in summer 2008 to find solutions to address the identified problems, focusing especially on Raleigh's water use restrictions. The authors served on this committee. The committee consisted of club members with architectural, engineering, environmental science and plumbing backgrounds and expertise. An initial review suggested that drilling a well might be a solution. However, at a cost of $20,000 to $25,000 and with no guarantee of success in producing an adequate supply of water, that solution was tabled in favor of taking advantage of the water available from storm water runoff. The club receives about 39 in. of rainfall annually.

Other problems the committee identified included the lack of water features on the golf course; erosion of creek banks in an adjoining club-owned nature park; and use of labor-intensive, 550-gallon cisterns to capture water from roof runoff and manual redistribution of that water to the tennis courts and golf course. Lack of water features ("hazards") on the golf course was a key component in successfully marketing this concept to club members and the primary piece of the social aspect of the triple bottom line. Thus, as the project progressed, a sustainable development was unfolding

Table 2

Storm Water Runoff Drainage to Wetland, Forebay & Pond East Side

	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 ft	2695	4309
Area provided (ft^2)	11,777	15,188

Note. *Calculations sized the wetland and ponds solely for storm water runoff.*

that would reduce pollution, enhance revenue and provide new amenities on the golf course.

The amount of water the property receives from storm events was determined and was the basis for 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) 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 Natural Resource Conservation Service (NRCS) in 1986. The curve is an empirical formula developed by the U.S. Department of Agriculture's NRCS and is a hydrological parameter used to predict runoff or infiltration after rainfall. (SCS refers to the organization's former 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)" (NC Department of Environment and Natural Resources, 2007). The method was used to calculate the volume of water generated from storm events and the size of the containment basins for this project. Key equations used follow.

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. Based on the data presented in Table 2 (p. 59), runoff volume was calculated:

$$\text{Volume} = 3{,}630 \times R_d \times R_v \times A$$

Where:

V = volume of runoff to be controlled by the design storm in ft³

R_d = rainfall depth in inches

A = area acres

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

As this solution was explored, it became apparent not only that could the storm water runoff be used to irrigate the golf course and tennis courts, but also that other water sources could be used. For example, two metal-roofed tennis shelters each yield about 550 gallons of water for every 1-in. rainfall event. In addition, the club has a 27,000 sq. ft 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 from May through September (when pools are operational). Pool splash-out was viewed as another source to be harvested; while not quantified, it was viewed as being worth the cost of capture.

While this project was being explored, the club was renovated and its HVAC system was upgraded 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, overwash 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 four-lane highway adjacent to the club property that 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.

Table 3 lists the water sources and the estimated annual water volume from each source using a basis of 39 in. of rainfall per year at this location (where applicable). Some capture efficiencies were measured. For those not measured, the efficiencies are based on data from *The Texas Manual on Rainwater Harvesting*, 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 ft²)	Capture efficiency (%)	Estimated annual volume (gal)[a]
Ground—pervious[b]	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 ft²	90	590,773
Roofs—metal	1,200 ft²	100	29,174
Tennis court overwash	20,160 ft²	10	1,633
Total water available			7,337,084

Note. *[a]Estimated volume includes evaporative losses occurring during runoff. [b]Volume estimated based on rainfall events of duration and volume exceeding ground percolation expectations where pervious surfaces included.*

Table 4

Actual & Projected Water Consumption & Costs, 2003-2014

Year	100's ft³	Gal	Cost	Cost/gal	% Increase annual cost/gal
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[a]	5830	4,360,840	57,048	0.013	23.1
2011[b]	5849	4,375,000[c]	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

Note. *[a]A second pool with a water volume of 145,000 gal was added in 2010. [b]Years 2011-2014 are based on linear regression projections and historic valuations based on actual consumption and costs for years 2003-2010. [c]Stabilized water consumption for years 2011-2014 based on maintaining the club membership cap of 900 members.*

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 dishwashing machine, and toilet facility discharges. Some of these (e.g., 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 food waste) are considered gray water.

Reports from American Water Works Association, Water Reuse Association and Water Environmental Federation provide additional data on gray water use and prohibitions on its use. For example, Sheikh (2010) noted that about 7% of U.S households were using gray water in 2006 and estimates that 10% may be using it by 2030. Where prohibitions do exist, the arguments against using gray water cite elevated levels of sodium, boron, nitrogen, phosphorus, fecal coliform, chlorine residuals, bleach compounds and malodorous smells. Sheikh reported on five states with regulations that govern the use of gray water, and North Carolina is one of those states.

Business Model

The committee determined that a business model was critical to project continuation. This included not only showing a cost-benefit analysis which established that the project could pay for itself in an acceptable time frame while balancing social, environmental and economic consequences.

As the project developed, water usage data were available through the latter part of 2008; those data were updated through 2010 for this article. Data for years 2011 through 2014 are forecast based on prior years' usage.

Knowing the historic water usage volume and costs allowed the designers and planners to project and quantify future costs. Based on this, it also 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 FY03 through FY08, the authors conservatively projected future water consumption cost increases of 10% per year. As the note to Table 4 explains, this value was 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 cited earlier. Table 5 presents the project's preliminary construction budget.

Reducing the nitrogen migrating offsite from applying fertilizer 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 irrigating the golf course and tennis courts. When the business model was developed, it was anticipated that the nitrogen credit could be sold and that it would be worth $70,000 to this club's property. (As of Jan. 1, 2011, nitrogen credits for the Neuse River are valued at $20.59 per lb.) Management strategy also was influenced by the amount of nitrogen credit following project completion. Table 6 (p. 62) presents allowable values available.

Roof drainage captures HVAC condensate from 15 units plus rainfall.

After the preliminary budget was developed, the committee could determine the project's economic feasibility. By using the cost of water (Table 4) and assuming that more than 1 million gallons per year could be obtained from water harvesting for irrigation, then a cost reduction or positive revenue stream could be determined. In addition, the nitrogen offset credit was assumed to be $70,000 and was treated as an income stream. These values were compared to the cost of building the pond and wetlands using the following algorithm.

The payback period and return on investment are the two primary means of determining whether a capital project is financially feasible. For this project, the payback method was used. The equation on p. 62 was used to determine the payback period.

Table 5

Preliminary Construction Budget

Item	Units	Qty	Unit price $	Total $
Clearing	Acres	1.5	12,000	18,000
Erosion control	Ls[a]	1	8,000	8,000
Grading	Cy[b]	6,000	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

Note. *[a]Ls = lump sum. [b]Cy = cubic yards.*

Table 6

Nutrient Removal Efficiencies for Best Management Practices Used Under Neuse River Storm Water Rules

Best management practice	Total nitrogen	Total phosphorus
Wet pond	25	40
Storm water wetland	40	40
Sand filter	35	45
Bio-retention	35	45
Grass swale	20	20
Vegetated filter strip w/level spreader[a]	20	35
50-ft restored riparian buffer w/level spreader	30	30
Dry detention	10	10

Note. [a]*Without internal water storage.*

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

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

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

Of interest is the comparison of projected costs versus actual costs. As the note to Table 7 explains, some projected costs were not incurred because club members donated some services and materials.

Construction was completed in November 2010 and a certificate of completion was issued by the City of Raleigh's Stormwater Utility Division on Jan. 1, 2011. The following discussion describes the physical features of the completed project.

Wetland & Ponds Physical Features

Maintaining a 50-ft-wide buffer from all sides of the Neuse River buffer was one constraint on the pond location and is a regulatory-specified method of reducing the amount of runoff into a water resource. As noted, riparian buffers are vegetated areas next to water resources that reduce pollutant movement into surface waters and provide bank stabilization, as well as provide aquatic and wildlife habitats. They are typically 25 to 50 ft on each side of perennial streams; North Carolina prohibits construction or related activities within 50 ft 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 four basins and is oriented in a general water flow direction of west to east on the property's higher elevations. The four basins, shallow land and shallow water areas cover 11,777 sq. ft and include a forebay with 1,178 sq. ft, two shallow pools and a deep pool (1,175 sq. ft).

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 pond's forebay. Water also enters the forebay from the backwash of the three swimming pools, splash out from three pools, main building roof drains that serve the 27,000-sq.-ft roof, two tennis court pavilions with metal roof surface areas of 2,400 sq. ft in aggregate, HVAC condensate discharge from the 15 main-building roof units, and storm water runoff from both pervious and imperious portions of the property with elevations greater than 440 ft. The depth of the forebay ranges from 435.5 to 440 ft, giving a maximum water depth of 4.5 ft.

A bermed area exists between the forebay and main pond; this is an access area for the golf course, and it is where underground utilities lines for the potable water for the buildings and structures on the lower portions of the property are located.

Water then flows from the forebay to the pond. The pond has 19,383 ft^3 (145,000 gallons) capacity; it also receives water from the forebay, from the discharge of the four-lane highway on its east side, and from storm water runoff from elevations greater than 435 ft on the pond's south and west sides.

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 four-lane highway east of the club's property. Water flow to the 6,065 ft^3 (45,369 gallons) capacity pond on the property's west side is fed entirely from storm water runoff and it has similar construction to the east side pond.

Maintenance

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

The wet detention basin, pretreatment areas including forebays and the vegetated filters where provided, and the wetlands require attention specific to the installation of plants, grasses and trees. These recommendations apply:

•Immediately after establishing the wet detention basin, water the plants on the vegetated shelf and basin perimeter twice weekly if needed, until the plants become established (commonly 6 weeks).

•Do not fertilize any portion of the wet detention pond after the first initial fertilization unless required to establish the plants on the vegetated shelf.

•Maintain stable ground cover in the drainage area to reduce the sediment load to the wet detention basin.

•Once the storm water wetland is constructed, conduct biweekly inspections and water wetland plants biweekly until vegetation becomes established (commonly 6 weeks).

•Do not fertilize any portion of the storm water wetland after the first initial fertilization required to establish the wetland plants.

•Maintain stable ground cover in the drainage area to reduce the sediment load to the wetland.

After construction is complete, management must address ongoing routine and preventive maintenance needs for the ponds, forebay and wetlands associated with a water harvesting system. Key items to address include:

•presence of trash and debris;
•bare soil and erosive gullies;
•vegetation too short or too long;
•clogged inlet device pipes or swales;
•clogged outlet device piping;
•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;
•clogged screens or filters;
•pump not operating properly;
•mosquitos.

Inspection frequency to identify and schedule maintenance is based on the occurrence of significant falling weather events as well as a predetermined time interval. In general, inspect the wet detention pond, once it is established, once a month and within 24 hours after every storm event greater than 1 in. (or 1.5 in. if in a coastal area). Store records of operation and maintenance in a known location so they are available upon request.

Roofing systems employed to capture falling weather also should be checked routinely. To ensure operation as designed, a licensed P.E., 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.

Table 7

Actual Construction Costs

Engineering and design	$11,835
General contractor	$143,649
Landscape contractor[a]	$1,005
Irrigation contractor	$14,537
Permits and fees	$1,632
Total	**$172,658**

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

Embankments and dams must be properly maintained to ensure system integrity. Bands and embankments should be inspected once a year by a dam safety expert. The measuring device used to determine the sediment elevation should deliver accurate depth reading and not readily penetrate into accumulated sediments.

Sedimentation control and removal are based on the permanent pool depth of the pond. The NC Department of Natural and Environmental Resources (2007) offers and recommends design parameters (Figure 1, p. 64) to establish maintenance criteria for sediment removal. As noted, "When the permanent pool depth reads x ft in the main pond, the sediment shall be removed. When the permanent pool depth reads x ft in the forebay, the sediment shall be removed."

Perceived and sometimes real problems associated with pond and wetland maintenance include insects, 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, a site can create an environment not conducive to a mosquito habitat. During this project, mature vegetation was removed from both the ponds and wetlands sites. Although some trees remain near the water bodies, photographs of the completed design show open areas on at least two of the four directional quadrants.

Approximately 35 soft and hardwood trees with calipers as great as 24 in. were removed in the pond and wetland area; however, the environment remains conducive to a robust and active wildlife population (e.g., deer, coyotes, foxes, black and copperhead snakes, squirrels, raccoons, opossums, birds, geese).

David Kristan (personal communication) who has owned a golf course for more than 20 years has found that the water feature on the grounds of a golf facility is a great asset for many reasons, including the beauty, the sense of flow from watery reflections, the added challenge to golfers, and the plentiful and free source of water. In addition, his experience indicates 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 to prevent growth of algae and other floating or suspended plants, as they can clog intakes and alter wa-

Completed pond in the background and forebay has helped the club conserve water.

ter quality. Chemicals can be used and are relatively inexpensive but do require periodic applications.

Kristan's solution has been to place hybrid grass carp into the water. The fish eat at least their weight each day, which keeps 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 Kristan adds a few every other year to maintain a youthful group.

Following project completion including the planting of wetland grasses and plants, algae appeared as expected in the main irrigation pond. Five hybrid grass carp were added to the pond and a 24-in.-high plastic fence was installed on the pond side of the littoral shelf (10-ft zone with 5º slope toward the pond at the top of normal pool elevation where wetland plants and grasses were placed). Fencing keeps the fish from pulling wetland plants out of the ground. It will be removed after the plants have been in place for 18 months with the expectation that their root systems will be sufficiently developed at that time to withstand any foraging by the fish. Adding 300 ft of fencing and fish cost $550.

Maintenance costs for the first 15 months of use have been minimal and have not been a cost increase over the landscaping and maintenance activities previously associated with this section of club property. It is anticipated that removing silt or dredging the basins will be an expense, but that has been deemed to be minimal based on basin sizes 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 & Anticipated

This project was initiated to reduce pollution into the Neuse River buffer, provide a supply of nonpotable water for irrigation of the tennis courts and golf course, and provide water features for the golf course. The solutions have produced and are anticipated to produce numerous benefits to the club including enhanced revenue, reduced pollution and improved social aspects of the golf course. Specifically, these project goals have been met:

1) Develop a sustainable water harvesting system enhancing the triple bottom line of social, environmental and economic consequences.

2) Reduce potable water purchases.

3) Reduce nitrogen, phosphorus and total suspended solid levels in the Neuse River buffer.

4) Reduce the amount of fertilizer needed for golf course maintenance.

5) Add water features to the golf course.

6) Recharge the groundwater.

7) Add an educational component for members and visitors about water harvesting and cost-effective management of a precious and vital resource.

8) 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. As a result, the club reduced water purchases in 2011 by more than 1.5 million 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 1.5 million gallons less water at $0.016 per gallon saved the club more than $24,000 in 2011 and is higher than the amount initially projected to be saved annually when the financial payback period was calculated (Figure 2, p. 65).

Figure 1

Basin Diagram

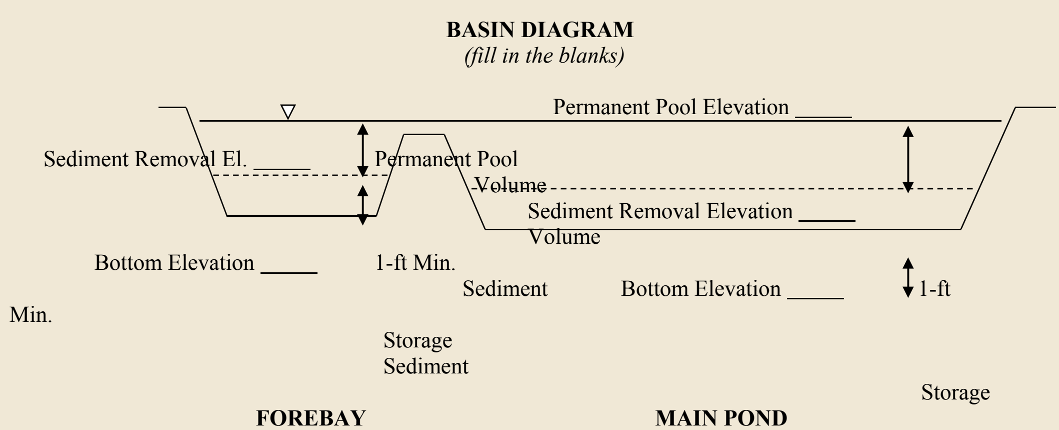
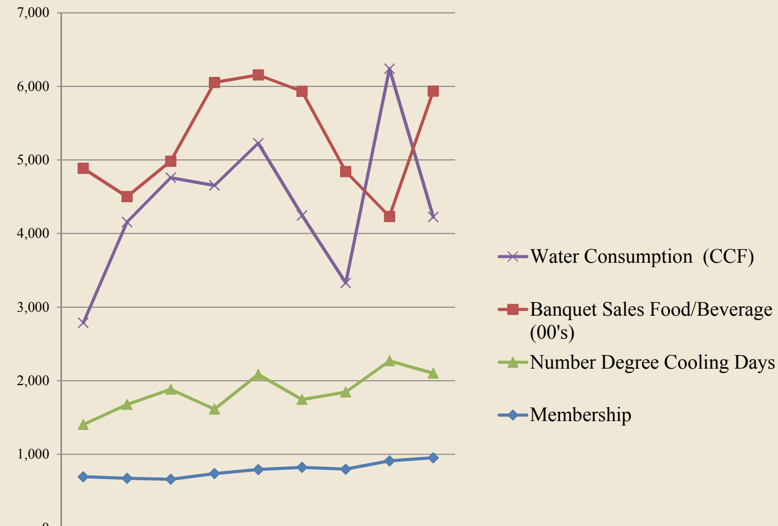


Figure 2
Water Consumption 2003-2011



	2003	2004	2005	2006	2007	2008	2009	2010	2011
Water Consumption (CCF)	2,786	4,157	4,759	4,654	5,228	4,247	3,329	6,240	4,225
Banquet Sales Food/Beverage (00's)	4886	4501	4983	6053	6155	5933	4843	4232	5936
Number Degree Cooling Days	1404	1677	1883	1613	2086	1745	1846	2270	2101
Membership	695	674	661	738	793	823	798	910	953

Significant pollution control also has resulted. Stream bank erosion has been eliminated, and the nitrogen, phosphorus and total suspended solid levels in the runoff have been reduced. The 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 are 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, pool decks, pool filter backwash, a portion of the golf course and the overflow from the wetlands. The pond also 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 1- to 2-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 also has been substantial. The addition of the wetland, dry detention basin, forebay and wet pond have added much-desired water features 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. **PS**

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