FINAL REPORT

WETLAND RESTORATION FOR SCIENCE EDUCATION GLADE SPRING, VIRGINIA

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EXECUTIVE SUMMARY

Historically, wetlands have been perceived as wasted lands that limit the progress of development. An increase in education and public awareness has altered this misconception, and wetlands are now being viewed as a valuable natural resource. The mission of the Glade Spring Wetland Restoration and Enhancement Design Project was to improve and enlarge an existing wetland for use as an outdoor educational facility, teaching the community about the ecology, functions and values of wetlands.

Site alterations were made to aid in the wetland restoration. These alterations included the installation of a livestock crossing, extensive fencing, drainage removal, and planting trees. The wetland restoration aspect of the project was a success in fostering wetland reestablishment. However, in order to create an effective educational facility, further site improvements were necessary. A specific decision sequence for the development of the enhanced wetland was therefore established. The site evaluation, design criteria, project plan, construction plan, and management plan (including monitoring and other considerations) were all integral steps of the developed decision sequence. The final design included a dike with an 8:1 side slope, and a 0.28-acre constructed wetland basin. The implemented engineering designs will serve to enlarge the existing wetland as well as to increase the diversity of the wetland flora and fauna.

Site History

The Wetland Restoration and Enhancement Project site is located on property of Virginia Tech's Southwest Virginia Agriculture Research and Extension Center at Glade Spring, approximately 90 minutes south of Blacksburg and 15 minutes north of Abingdon (see Figure 1). Currently, there is approximately 0.6 acres of existing wetland on the 4-acre site. The water source for the wetland is a seep located at the base of a hill. It is expected that the water table intersects the hill at that point, and the water is flowing west from adjacent lands (Gale Heffinger, personal communication, Abingdon, Va, 30 Jan 1998). For at least 10 years, the site has been drained for agricultural use and the wet areas utilized as cooling troughs for cows and sheep. The result was a compacted and degraded wetland. Sewer line installation in 1995 and culvert replacement in 1997 further degraded the wetland. The Research Farm, in consultation with the Natural Resources Conservation Service (NRCS), hired a contractor to build a fence to keep out cattle and sheep from the wetland, build a stream crossing, and install alternative watering methods. Together they realized that this site was their opportunity to provide a wetland educational facility for area schools. A coalition of parties with similar interests in education and soil and water conservation was formed to take on the project. This coalition includes the Adopt-A-Watershed program, the Holston River Soil and Water Conservation District, Patrick Henry High School, and the Virginia Water Resources Research Center.

Wetland Restoration and Functions

Wetland restoration is the rehabilitation of a degraded wetland or a hydric soil area that was previously a wetland (Soil Conservation Service, 1992b). As stated by Novotny and Olem (1994), the most comprehensive definition for wetlands was advanced by the U.S. Fish and Wildlife Service:

> Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have one or more of the following attributes: 1) at least periodically, the land supports predominantly hydrophytes, 2) the substrate is predominantly undrained hydric soils, or 3) the substrate is nonsoil (organic matter) with water or covered by shallow water at some time during the growing season each year.

Wetlands are legally protected due to the goods and services they provide that benefit human needs (wetland values). They perform multiple beneficial functions by means of physical, chemical, and biological processes (NCHRP, 1996). These functions include flood conveyance and storage, barriers to waves and erosion, sediment control, habitat for wildlife including waterfowl and rare and endangered species, water supply and water quality improvement, food

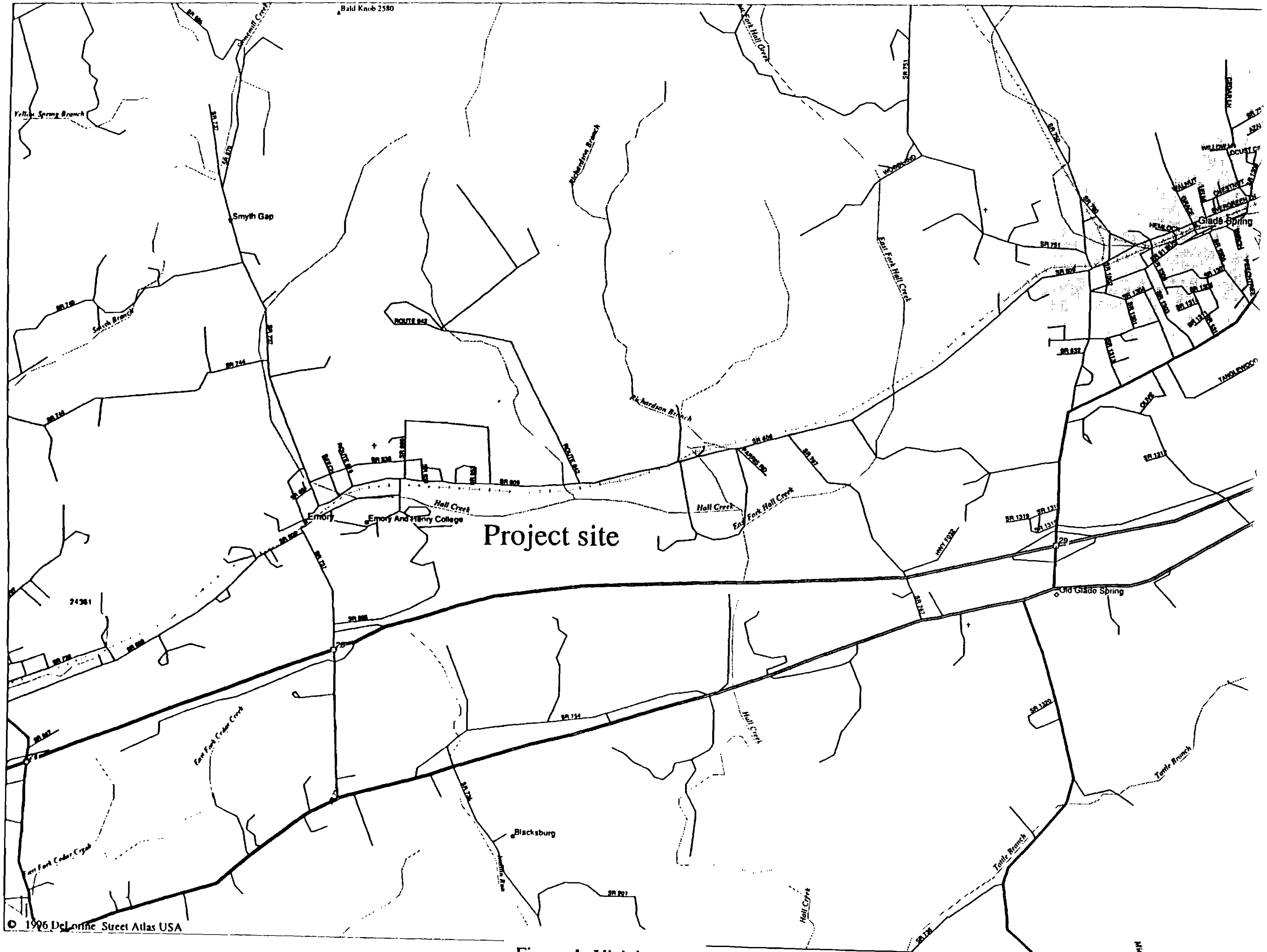


Figure 1. Vicinity map

and timber production, historic and archaeological values, education and research, recreation, and aesthetic values (NCHRP, 1996).

Goals and Objectives

The mission of the Glade Spring Wetland Restoration and Enhancement Project is to improve and enlarge the existing wetland for use as an outdoor educational facility to teach the community about wetland ecology, functions and values. Primary use of the facility will be by teachers and their classes in Southwest Virginia. A secondary purpose would be to provide researchers the opportunity to study the wetland restoration process and monitor associated stream habitat improvement.

Two components of the project have been identified; wetland restoration, and wetland enhancement. The definition used in this project for wetland restoration is the removal of damaging factors to the wetland and protection of the site to assure that natural succession can occur which will restore functions of the wetland. Wetland enhancement in this study encompasses additions to an existing wetland to provide specific functions and values deemed important to the site.

Wetland Restoration

The wetland restoration aspect of the project has been completed. First, a livestock crossing and fence were installed to enhance wetland performance by preventing farm animals from grazing on the wetland site (Figure 2). This enabled native wetland plant species to rejuvenate from the existing seed bank.

Figure 2. Livestock crossing

Second, ditches had been created to drain the wetland when the site was under agricultural use; these ditches were partially removed to rehabilitate the area. Photographs illustrating the drainage removal process are illustrated in Figure 3. The removal of the ditches appears to have increased infiltration on site based on data collected from water table observation wells.

Figure 3. Three stages of berm removal: before, during, and after (pictured from left to right)

The last step taken to restore the existing wetland was to plant trees to provide a food source to wildlife, increase stream habitat quality and streambank stability, screen the site from sight and noise, and act as windbreaks. Along the south side of Hall Creek, four tree species were planted in the following order outward from the bank: red osier dogwood, American hornbeam, elderberry, and hackberry. A few green ash seedlings were also planted on the north side of Hall Creek. In the northwestern corner of the property, to provide a screen, upland tree species were planted including black walnut, white pine, and black gum. Other species were planted in the southwest corner and the eastern portion of the property, between the fence and the Treasure Mountain drainage, in order to improve fall color and wildlife habitat value. These included yellow poplar, willow oak, sugar maple, sycamore, bald cypress, river birch, pin oak, red maple, water oak, and water willow. Table 1 defines the vegetative index as a means to identify quality of wetland vegetation (it rates the percent occurrence of species in wetland versus upland habitats). A list of the trees planted can be seen in Table 2, along with their Latin names and vegetative indices. Table 3 provides a list of trees we could consider for future planting projects.

Table 1. Vegetative index

Vegetative Index	
Goal: Greater than 50% obligate or facultative wetland plants	
Vegetation Category	**% occurrence in wetlands**
Obligate wetland (OBL)	>99
Facultative wetland (FACW)	67-99
Facultative (FAC)	33-67
Facultative upland (FACU)	<33
Obligate upland (Upland)	<1

Table 2. Trees planted to date

Common names	Latin names	Comments / Veg. Index
Bald Cypress	*Taxodium distichum*	OBL
Red Osier Dogwood	*Cornus stolonifera*	FACW+
River Birch	*Betula nigra*	FACW
Pin Oak	*Quercus palustris*	FACW
Elderberry	*Sambucus canadensis*	FACW, FAC
Red Maple	*Acer rubrum*	FAC
Water Oak	*Quercus nigra*	FAC
Black Gum	*Nyssa sylvatica*	FAC
Hackberry	*Celtis occidentalis*	FAC, FACU
Water Willow	*Decodon verticillatus*	Streambanks
Black Walnut	*Juglans nigra*	FACU
Sugar Maple	*Acer saccharinum*	Moist soil
American Hornbeam	*Carpinus caroliniana*	Moist woods
Sycamore Maple	*Acer pseudoplatanus*	Woods
White Pine	*Pinus strobus*	FACU
Yellow Poplar	*Populus sp.*	River valleys
Willow Oak	*Quercus phellos*	Moist soil

Table 3. Trees recommended for future plantings

Common names	Latin names	Comments
Green Ash	*Fraxinus pennsylvanica*	FACW
Sweet Gum	*Liquidambar styraciflua*	Moist woods
Northern Red Oak	*Quercus rubra*	Woods
Black Ash	*Fraxinus nigra*	Marsh
Red Ash	*Fraxinus pennsylvanica*	Marsh
Northern White Cedar	*Thuja occidentalis*	FACW
American elm	*Ulmus americana L.*	FACW-
Silver maple	*Acer saccharinum*	FACW
Basket/Swamp chestnut	*Quercus michauxii*	FACW, stream borders
Sweet bay/Swamp magnolia	*Magnolia virginiana*	FACW+, FACW
Northern arrowwood	*Viburnum recognitum*	FACW-, FACW
Silky dogwood	*Cornus amomum*	FACW
Gray-stem dogwood	*Cornus sp.*	FAC, native

Wetland Enhancement

Further improvements to the site were needed to create an effective educational facility. A specific decision sequence for the development of the enhanced wetland was established:

1. Site evaluation
2. Design criteria
3. Design options
4. Project plan
5. Construction plan
6. Management plan
7. Monitoring
8. Other Considerations

Site Evaluation

Watershed delineation and peak flow analysis, wetland delineation, water budget/water quantity, water quality, and soil properties are the five components of the wetland enhancement site evaluation that will be discussed.

Watershed Delineation and Peak Flow Analysis

A topographic map was acquired for purposes of tracing the watershed boundary (see Figure 4). The area encompassed by the wetland boundary was determined to be 495 acres. The curve numbers and appropriate areas were identified using ArcView Geographic Information System data from the Holston River watershed (acquired from TVA) (See Figure 5).

Figure 4. Watershed delineation

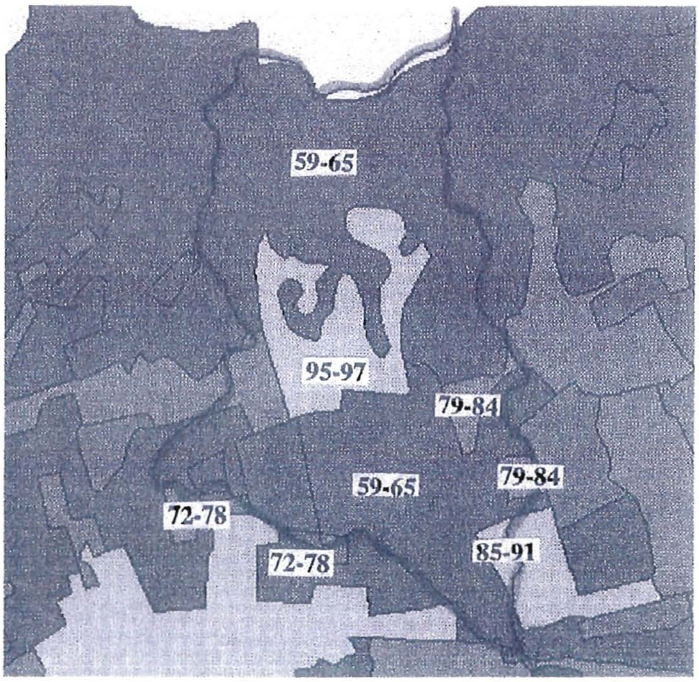
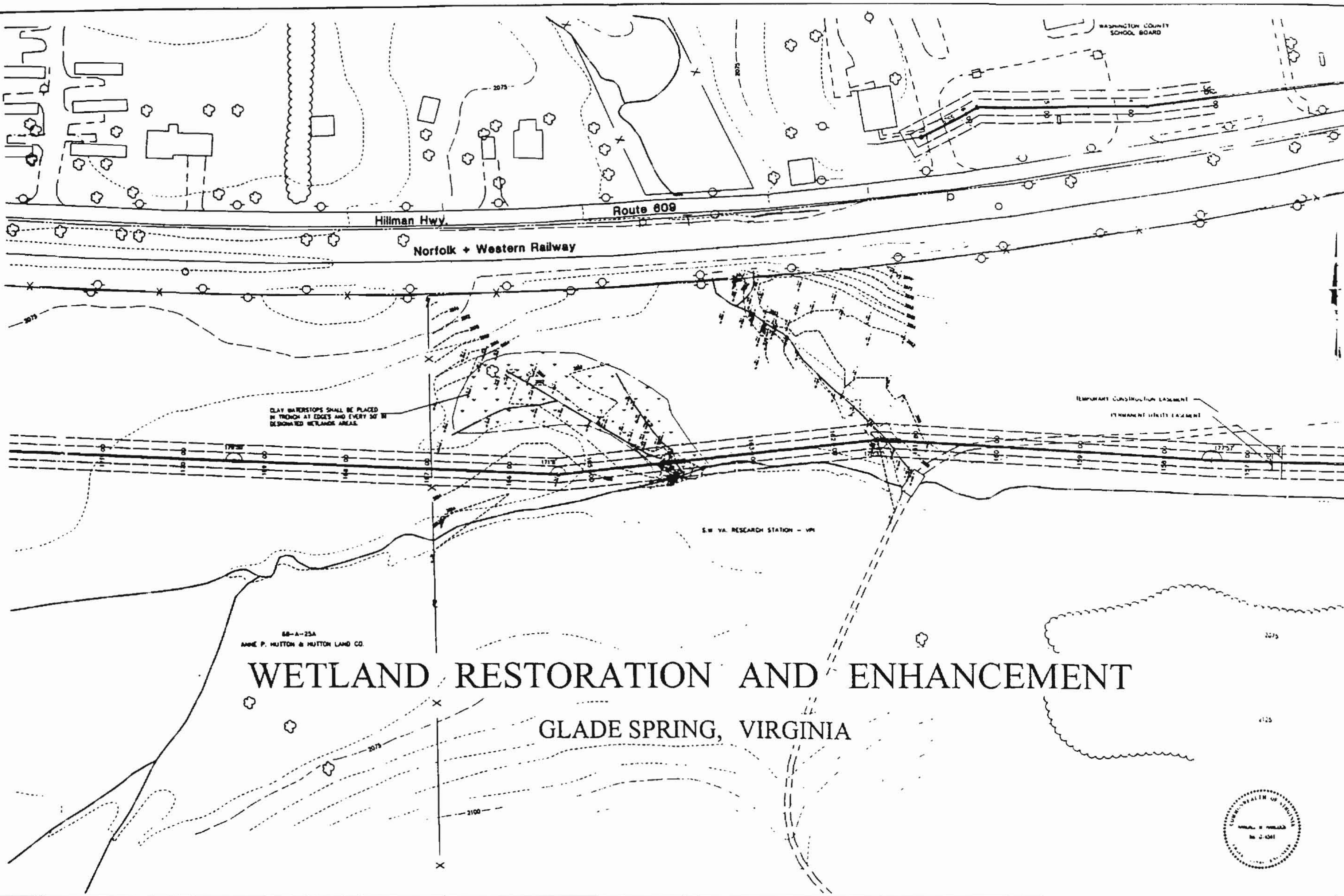


Figure 5. Identification of curve numbers within the watershed boundary



Draper Aden Associates CONSULTING ENGINEERS	DESIGNED RMH DRAWN MBB CHECKED JSL DATE 10/15/93	PLAN EMORY–MEADOWVIEW REGIONAL WASTEWATER COLLECTION SYSTEM WASHINGTON COUNTY, VIRGINIA	REVISIONS: 4-12-94	SCALE: 1" = 50' PLAN № T-6772	SHEET 15OF

Watershed information is primarily important to the calculation of peak flow. The information was acquired, and peak flow calculated, but the results were not applied to the constructed wetland design because of the uncertain influence of storm water on an off-stream wetland.

Wetland Delineation

A topographic map of the site established before any modifications took place is shown in Figure 6. The topographic map was created initially by Draper Aden & Associates (Blacksburg, Va.) for a sewer line installation through the site along Hall Creek. This map indicates the wetland delineation boundary established by their personnel. Draper Aden & Associates included survey points from our data collection in the database for their drawing, and additional topographic lines were created.

The wetland was also delineated by a NRCS team to establish whether or not the site was eligible for the Wetland Reserve Program (WRP), a source of funding for this project. Review of the hydrology, hydrophytes, and hydric soils led to its classification as a shrub/scrub wetland with potential for a forested wetland (John D. Myers, letter to Frank Smith, 26 February 1998).

Water Budget/ Water Quantity

A water budget or balance accounts for the inflow, storage, and outflow of water (Soil Conservation Service, 1992b). The Glade Spring annual wetland water balance is illustrated in Figure 7. This figure illustrates the water flow of a typical wetland while detailing the water budget data acquired for the design of the constructed wetland.

Four water table observation wells, a six-inch H flume, and a standard rain gauge were installed in April 1997 to take the water quantity measurements that were used to characterize the hydrology of the Glade Spring wetland site. The H-flume and a March-McBirney flow meter were used to measure the surface water flow of the seep at the far end of the site and Treasure Mountain drainage, respectively. Measurements collected during the growing season can be found in Appendix A.

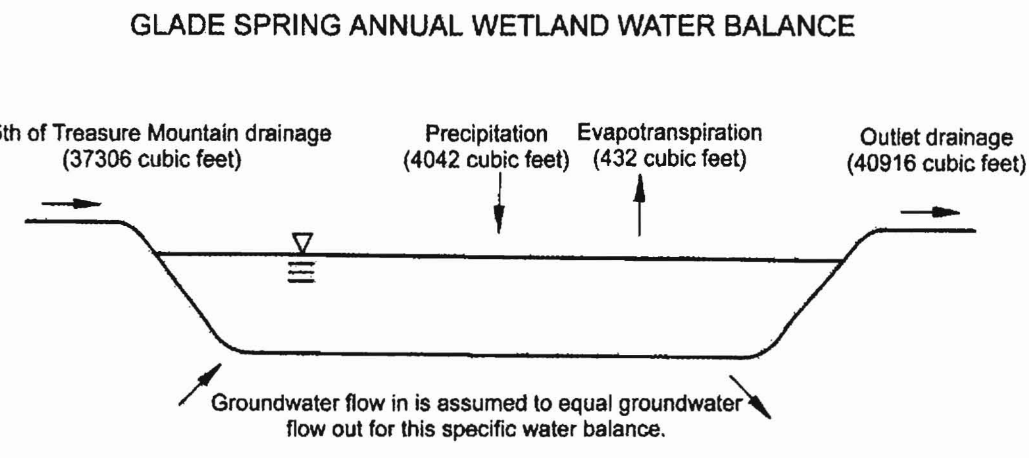


Figure 7. Glade Spring annual wetland water balance

Water Quality

Water quality samples were taken at least once a month for a complete growing season starting in April and ending in October of 1997. These samples were tested for nutrients, indicator organisms, and metals. In addition, a few samples were taken for pesticide analysis, though no pesticides were detected in these samples. The average and range of contaminant concentrations seen in the seep are shown in Table 4, while Table 5 shows the same information as seen in the samples taken from the Treasure Mountain drainage. The tables show that no exceedances occurred of maximum allowed standards for the tested contaminants set by EPA, except for nitrates in the seep and fecal coliforms in both the seep and the Treasure Mountain drainage.

The high concentration of nitrates would be of concern if the water were to be used for drinking, or if eutrophication was a problem, but neither of these issues were relevant to this site. The maximum concentration of 12.3 mg/L of nitrates is very close to meeting the human health standard of 10 mg/L. There were no criteria found for nitrates with regard to aquatic life, but wetland vegetation should be able to use the dissolved nitrates for growth and prevent excessive discharge downstream.

Table 4. Average and range of contaminant concentration for the Glade Spring seep

Average and Range of Contaminant Concentrations Comprising Biological, Nutrient, and Metals Analysis as Compared to National Statndards							
	Concentration of samples			Aquatic Life		Human Health	
Test	Min	Max	Avg	Fresh Acute Criteria*	Fresh Chronic Criteria*	Water and Fish Ingestion	Drinking Water Standard
Cadmium (ug/L)	BDL	0.15	0.04	39	11	10	5
Copper (ug/L)	1	3	2	18	12	170000	1000
Fecal coliforms (colonies/100ml)	0	470	108	-	-	-	Absent
Lead (ug/L)	BDL	2	1.3	8.2	32	50	15
Nitrates (mg/L)	1.2	12.3	3.8	-	-	10	0.01
pH	6.5	7.8	7.2	-	6.5-9.0	5.0-9.0	6.5-8.5
Phosphorus (mg/L)	BDL	0.2	0.1	-	-	-	-
Zincd (ug/L)	0.02	0.04	0.03	320	47	5000	5000

BDL = Below Detection Level

*Values for maximum allowable concentrations for drinking water (drinking water standard):

Metals: Water Quality Assessment Ed. By D. Chapman, 2nd edition, 1996

All other tests: EPA Quality Criteria For Water 1986

Table 5. Average and range of contaminant concentration for Treasure Mountain drainage waters

Average and Range of Concentration of Contaminants Comprising Biological, Nutrient, and Heavy Metal Analysis Compared to National Standards for Glade Spring Wetland Treasure Mountain Drainage.							
	Concentration of samples			Aquatic Life		Human Health	
Test	Minimum	Maximum	Average	Fresh Acute Criteria*	Fresh Chronic Criteria*	Water and Fish Ingestion*	Drinking Water Standard**
Cadmium (ug/L)	BDL	0.11	0.05	39	11	10	5
Copper (ug/L)	BDL	5	2	18	12	170000	1000
Fecal Coliforms (colonies/100mL)	0	3600	755	-	-	-	Absent
Lead (ug/L)	BDL	7	1.7	8.2	32	50	15
Nitrates (mg/L)	1.3	5.7	2.9	-	-	10	0.01
pH	6.7	7.8	7.2	-	6.5-9.0	5.0-9.0	6.5-8.5
Phosphorus (mg/L)	BDL	0.1	0.04	-	-	-	-
Zinc (ug/L)	0.02	0.05	0.3	320	47	5000	5000

BDL = Below Detection Limit
**Values for maximum allowable concentrations for drinking water (drinking water standard):
For metals (Cadmium, Copper, Lead, and Zinc): Water Quality Assessment.
Edited by D. Chapman, second Edition, 1996.
For all other tests: EPA Quality Criteria For Water 1986.

Past watershed land uses were investigated to better understand the water quality data. In the last 50 years, the primary use of the watershed was as a dairy farm. The area was named Treasure Mountain in honor of the failed golf course in the area from the 1960s. Later, in the early 1970s and 1980s, a few houses were built. Since the watershed has karst topography, the water quality may be influenced by household septic tanks. However, it does not appear that the current rural residential and pasture land uses greatly affect water quality, and such an assumption matches the low contaminants seen in water samples tested over the summer months. Future land use is assumed to be gradual urbanization as development fills in the I-81 corridor between Abingdon and Marion, Va.

Soil Properties

Within this boundary, the soil types were identified using U.S. Department of Agriculture, NRCS databases located at the Abingdon NRCS office. The soil in the wetland area was Clubcaf silt loam (Hydrologic group D), and in the upland areas immediately adjacent, a Wyrick-Marbie Complex (7-15% slope).

Clubcaf soils are frequently flooded for long durations usually between December and April (according to NRCS soil reports acquired from the Abingdon office). Hydrologic group D soils generally have very slow infiltration rates when thoroughly wet and can be assumed to have an infiltration rate of 0.1 mm/day (Schwab et al., 1993).

Clubcaf silt loams are good for wetland plants and wildlife. A typical Clubcaf soil has a deep subsoil with root zones greater than 60 inches. However, it does have limitations for use as a construction material. Moderate limitations are to be considered for the construction of ponded areas in Clubcaf soils due to slow seepage and recharge rates for excavated ponds. Construction limitations are severe for embankments, dikes, and levees, therefore, great precautions should be made when using Clubcaf soils as fill for an earthern water control structure (NRCS soil reports).

The Wyrick portion of the upland soil complex on-site has only slight limitations for dikes, and contains 15-60% clay depending upon location in the soil profile (NRCS, 1998). It may be a less expensive option for use in dike construction as compared to hauling material from off-site sources.

Design Criteria

Six basic design criteria were established for the enhancement of the Glade Spring Wetland. The design criteria are used to specify the basic conditions required for the wetland to perform the desired functions. First, the most important requirement is to ensure hydrology adequate to sustain the wetland flora throughout the created wetland site. Second, diversity of wetland flora and fauna must be promoted especially if the site is to be used as a teaching tool. Third, the wetland must be fully developed in order to ensure an adequate life span for the project. For the wetland enhancement design to be eligible for the Wetland Reserve Program's (WRP) 10 year cost share agreement, which pays for 75% of all practices necessary to restore the wetland, the wetland must be designed for and maintained for a minimum 10-year period after installation. Also specified by the WRP program are that less than 30% of the site be ponded (allowed for in this design due to the large site size in comparison to the constructed wetland basin, and the low expectation for dike effectiveness in ponding) and that only 5% of the site be cropped as wildlife food (small grains). Wildlife crops were not included in the design due to the small site size relative to wildfowl needs. Fourth, to ensure that the design can be feasibly implemented, construction limitations must be foreseen. Construction materials and equipment available for excavation must be considered when designing the site. Fifth, the available funding of the project must also be weighed against the cost projected with implementation of the wetland design. Last, the wetland enhancement project should provide a pleasing aesthetic experience for users of the proposed wetland educational facility.

Design Options

The original intent of the wetland enhancement component of the project was to focus on the values of water quality, education, aesthetics, and habitat for waterfowl, mammals, and rare and endangered species. Due to the small area of the site, we did not design specifically for any species, but intend that the site have the necessary features required by wetland flora and fauna. In the future, if greater space is acquired to expand this project, habitat could be specifically designed for different species.

We considered in-stream and off-stream options for the pond. The in-stream option was initially preferred because it would have greatly reduced the excavation volumes (the streambanks are high) and water supply (from the Treasure Mountain drainage) would have been assured without complicated engineered structures. However, the in-stream option was rejected based on the realization that a dam placed in the drainage from a 500-acre watershed would have to be significantly larger and stronger than we intended it to be, in order to prevent failure during peak flow events (John D. Myers, personal communication with Rebecca Bohdan, NRCS Richmond, Va., 11 March 1998) and would most likely be rejected in a permitting process (Nancy Norton, personal communication, Abingdon DEQ office, 3 February 1998). Furthermore, the culverts immediately upstream from the ponded area could not be influenced by the design because they serve the railroad.

The installation of several basins was considered in order to demonstrate different vegetation complexes in the wetland for the educational facility. However, due to space limitations, each pond would be small and the detention times within each basin would be shorter than required for pollution removal. While this facility is intended to be for educational purposes, the function of pollutant removal was retained by the creation of one large pond, in case land uses changed in the future and more nonpoint source pollutants entered the water. It was decided that the one basin design could have sufficient variability in topography to allow for a large diversity of habitat.

Multiple berms in the seep drainageway was an option considered in order to better direct flow and prevent flooding in established wooded areas. However, the difficulty of getting heavy equipment in the wetter portions of the site, in order to create multiple berms, was deemed too great a problem.

The source of material to build the dike was also an issue. In the cost estimate, we assumed the pond and the dike would be built at the same time. This scenario is more economical due to the mobilization costs of a contractor and the possible use of the excavated Clubcaf series soil to build the dike. The excavated soil is not recommended by the NRCS/USGS soils database for building dikes and berms, yet the shallow slopes used for the dike (discussed in more detail later), should allow the Clubcaf soil to be used for construction. Other options for dike material would be the on-location upland soils more suitable for dike construction, or an off-site source of impermeable clay or more suitable soils. A further option would be to use the Wyrick soils as a "key" to hold the Clubcaf soils. It is possible that an excavation from the Wyrick slopes could be filled by the soil excavated from the ponded area, but the erosive potential of the soils in that placement would need to be considered. An off-site source for sediment materials would be the least desirable alternative due to the higher cost of its transportation.

There were various options for the water level control structure. This unit must allow for regulation of the water level (both rise and dewatering), and it must be a simple low maintenance design. Options reviewed included a stoplog structure, an overflow spillway, a mechanical spillway, valves, a perforated riser, a flashboard culvert, and a swiveling pipe (Hammer, 1992). An inlet valve was chosen to provide inexpensive water level control, while an overflow spillway could provide an aesthetically pleasing yet inexpensive outlet during both normal and flood-stage flows.

Different valve options were investigated, including gate valves, solenoid valves, butterfly valves, and ball valves. Gate valves had the advantages of simple and unrestricted flow, but were ruled out because the control device would be conspicuous. The solenoid device was eliminated because it would require a power source and be more costly, and butterfly valves were also found to be too expensive. Among ball valves, brass provides a heavy duty and corrosion resistant design. A simple handle was sought that was inconspicuous for the final design choice.

One further design alternative scenario was the choice of the material for the inflow pipe. Materials considered included PVC, polyethylene, and commercial steel. Commercial steel would be the most resistant to degradation, but it is heavier and more awkward to handle. Polyethylene can be used, but it is the least resistant to degradation (approximately 20 years lifespan) and primarily comes in rolls that distort the shape of the pipe. Since the slope of the pipe must be precise, this option was rejected. PVC was eventually chosen due to its use in other applications to carry fluids, its relatively low cost, ease in transport, and straight lengths.

Project Plan

Objectives and Specifications

The project objectives were to enlarge the wetland and enhance the educational facility by increasing the potential for ecosystem diversity. An earthern dike and a ponded area were designed to provide for these objectives. These design features and their specifications are presented below, and partially illustrated in Figure 8. All design calculations are located in Appendix A, in order of appearance within the project plan.

Dike Construction

The purpose of the dike construction is to block seep drainage and divert water over a greater portion of the site. The location of the dike was of initial concern. A sewer line is buried approximately 7 to 8 feet deep on the wetland site running parallel to Hall Creek. A 20-foot easement (10 ft on either side) has been established surrounding the sewer line. The easement prohibits the erection of structures and other work that may damage the lines or prohibit access to perform maintenance and repairs (R. Hancock, personal communication, Blacksburg, Va., 17 February 1998). The dike cannot be constructed overtop this easement; therefore, the dike was designed to be created directly outside of the easement area. Also, care is needed when using heavy machinery and equipment in the vicinity of the sewer line.

The design of the dike included choosing a side slope, a top width, and the dike's height (see Appendix, Calculation 1). An emergency spillway was also included in the design in case of a large storm event (though there is limited soil surface feeding this site in terms of runoff, and the seep is not expected to produce large amounts of water at any one time).

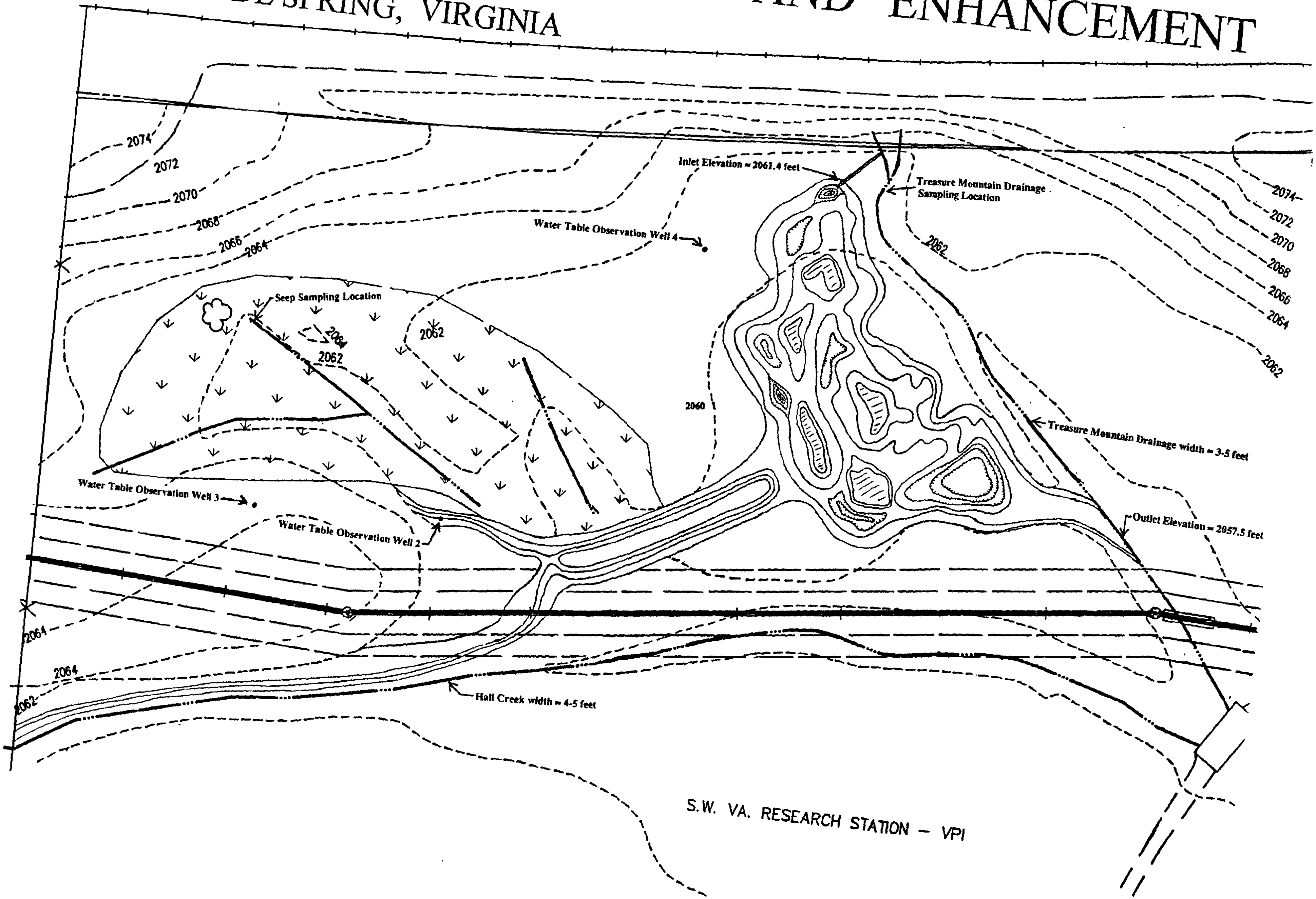
It was recommended, by the NRCS delineation team, that an 8:1 side slope be used for the dike (J. Myers, personal communication, Richmond, Va., 11 March 1998). It is expected with this shallow slope that the excavated Clubcaf soil from the constructed wetland basin can partially be used for the dike construction if a core of Wyrick soil from an upland slope is used to slow seepage through the dike. It is unlikely that excavation to an impermeable layer will be possible due to the depth of Clubcaf silt loams in the area, and wetness in the area of excavation. The shallow slope and large base of the dike will prevent slippage, while geotextile engineering fabric could be used to reinforce portions of the foundation and the upstream face of the dike.

The top width of the dike was assumed to be 10 feet. The top width considers the ability of equipment to cross the dam during construction and for maintenance purposes. Furthermore, berm widths of 3 to 5 meters and greater than 4:1 side slopes rarely have serious muskrat damage (Hammer, 1992).

Hand compaction (manually directed power tampers likely) will be used for the dike, and layers will be spread to a uniform 2 inch thickness. The compaction degree is specified as Class C; each layer is compacted by a specified number of passes of a roller. Soil moisture is specified only to the degree that the soil forms a ball when squeezed, but no water runs out. Sand bags should be used to divert water while construction takes place. After each layer is compacted, it will be scarified parallel to the axis of the fill. If the soil needs to be moistened, it can be watered then mixed using available equipment (disking, blading, etc.) to achieve uniformity of soil moisture (Soil Conservation Service, 1992a). If the Clubcaf silt loam is used, it may need to dry before the next layer is placed.

WETLAND RESTORATION AND ENHANCEMENT

GLADE SPRING, VIRGINIA



Before construction five inches of topsoil will be stockpiled. The topsoil will be replaced and firmed on top of the dike after all other earth work construction takes place. Geojute was chosen to be placed over the entire surface area of the dike to prevent significant erosion prior to vegetative establishment from the seed bank provided in topsoil.

The total height of the dam designed is 1.75 feet. This dike height includes a 10% addition for settlement and was designed to impound one foot elevation of water. The emergency spillway is located at the one-foot water level. This impounded height would not affect surface area much beyond the existing drainage channels, and the water height will not reach the neighbor's property.

A dike need only be sufficient to redirect water flow, though much of the water may permeate through the bank due to the lack of impermeable material in the dike or below the dike. Since the sources of the water to be impounded by the dike are the seep and only a small amount of runoff from surrounding lands, it is not expected that erosion will be significant once a vegetative cover is established.

Emergency spillway for dike

The design of the emergency spillway includes selecting a vegetative cover, choosing a cross-section shape, and designing for a permissible velocity (one that will not cause erosion or damage the grass) given an assumed flow rate and amount (see Appendix A, Calculation 2).

The first step in the design of the emergency spillway for the dike was to select a grassed water-way cover. Reed canary grass was chosen for the emergency spillway due to the quick-growing nature of this erosion controlling land cover. Reed canary grass is also useful to wildlife by providing seeds for food, protecting nests and dens, and providing escape cover. However, the choice is subject to change because reed canary grass is deemed to be an invasive species (Doug Ogle, personal communication, Glade Spring, Va., 23 May 1997). Reed canary grass has a retardance of A, as defined by Schwab et al. (1993). The selected grass has an excellent stand, approximately 3-ft if not mowed, helpful in reducing flow velocities over the vegetated spillway.

The emergency spillway was designed in a parabolic shape to provide a natural look of drainage to the dike. The flow of the seep is the only measured flow recorded at the site, therefore the maximum measured flow of the seep was increased ten times as a safety factor and used in the design procedure (Appendix A). A permissible velocity of 0.9 m/s was chosen since Clubcaf series soils are easily eroded. The spillway is placed at the maximum desired ponded elevation on the face of the dike (1 ft). Dimensions of the spillway can be found in Appendix A.

Constructed Wetland

The three objectives of our constructed wetland design were water quality improvement, wildlife habitat enhancement, and aesthetic design for recreation and education. The specifications we designed for in order to achieve these objectives, once a location was decided for placement of the constructed wetland basin, were the following: (1) maintain water depths of less than 18 in. over 75% of the area to maximize quality of habitat for wildlife (especially ducks and geese) (Soil Conservation Service, 1977); (2) provide enough water to the basin so that an outlet flow can be achieved despite evapotranspiration and infiltration; (3) design for the minimum pipe diameter that could allow flow through the pipe (placed on a 1.3% slope) at a rate sufficient to overcome friction within the intake structures; (4) provide water detention time within the basin of greater than seven days to achieve some benefit of pollutant removal (Wile et al., 1985); (5) remove excess water at a rate greater than ½ in. per day for safety and plant growth reasons (Soil Conservation Service, 1977); (6) allow for sedimentation in order to increase the time between dredgings.

Basin Placement

The west and east sides of the Treasure Mountain Drainage were considered for off-stream wetland basin placement. Both had steep streambanks and would require significant excavation due to the desire to create a low-maintenance site and avoid the use of pumps. The west side of the drainage was chosen in order to connect the new wetland basin to the original wetland, and thus increase its effective size. The fall was surveyed along the Treasure Mountain Drainage, and it was determined that a 3.9-ft fall was available for the design of the constructed wetland.

Basin shape and topography

A 0.28-acre basin was designed with variable depth, variable edge, and variable slopes within the wetland to promote habitat diversity and enhance the aesthetics of the design. Along the shoreline the slopes will range between 10:1 and 20:1 as recommended by Crawford and Rossiter. The depth does not exceed 3-ft. for reasons of safety, cost, and vegetation requirements. Part of the topographical variation included the creation of islands that increase the circuitous nature of water flow, provide protected nesting sites, and enhance cover diversity. The majority of the pond was shaped for depths of 2-in. and 6-in., with a few areas of depths 1-ft, 1.5-ft, and 3-ft. This follows the first specification mentioned above; greater than 75% of the ponded surface area is of less than 18-in. depth.

Detention Time

Constructed wetlands' primary problem is short-circuiting (Wile et al., 1985). Short-circuiting is when water does not mix within the wetland basin, and takes a shorter route through the wet pond than is desired for the detention time necessary to remove pollutants to any extent. In most cases, the detention time required for constructed wetland design ranges from 8 to 10 days (Wile et al., 1985). Careful grading must be accomplished on site to negate this problem. Installation of baffles or islands also improves detention time. For this design, a simplified detention time calculation (see Appendix A, Calculation 3) was used in conjunction with the water balance in the following section to assess water quantity within the constructed wetland basin, and calculate an adequate inflow rate off the Treasure Mountain drainage (see Appendix A, Calculation 3 for details).

Water Quantity Assessment and Control

Three of the specifications for the constructed wetland were interdependent. The amount of flow diverted from the Treasure Mountain drainage to fill the basin would depend upon the site water balance, affect the detention time, and cause changes to the inflow pipe size. First, a spreadsheet was set up to calculate the monthly water budget using the data we collected for precipitation, evapotranspiration, Treasure Mountain flow rate, seep flow rate, and the estimate of infiltration rate. The monthly water balance over the growing season was used to estimate the amount of flow from the Treasure Mountain drainage that would need to be supplied to the wetland basin, and to calculate the estimated flow that would need to be carried by the outflow spillway (Appendix A, Calculation 3).

Inlet Design

The result of the water balance/detention time analysis was the decision to use a multi-slot flow divider to remove 1/5 of the Treasure Mountain drainage flow, regardless of its quantity (Figure 8). To carry 0.33 ft^3/sec capacity flow (the maximum baseflow we measured in the Treasure Mountain drainage), an 11-slot structure was chosen with dimensions 14-in. wide x 24-in. long x 7 ¾-in. deep (Brakensiek, 1979). This would be fabricated out of 24-gage sheet metal in the BSE machine shop. The pipe carrying flow from the outlet of the multi-slot divisor to the constructed wetland basin was sized for a minimum diameter necessary to carry the flow, given slope, friction within the pipe and other structures, and certain safety factors. The mechanical energy equation was used in this procedure (Appendix A, Calculation 4). The invert elevation of the pipe on the stream-side is 2161.4-ft., while the invert elevations of the pipe on the basin side is 2060.8-ft. The energy produced by the head within the pipe must be greater than the frictional forces created within the pipe. Multiple iterations of the calculations were performed to achieve the proper sizing. The result was a 2-in. nominal diameter pipe, PVC. The velocity of the flow exiting from a pipe of 1.3% slope, and 2 in. diameter, is 0.914 ft/sec (Schwab et al., 1993). To prevent erosion beneath the pipe outlet, flat rock or concrete will be placed below the outlet of the pipe.

Another water control structure included in the design is a one-way brass ball valve needed to completely or partially shut off flow to the wetland pond if necessary for maintenance or vegetative management (see Figure 9 for a diagram of these control structures). This valve should be closed during installation and construction of the basin. Plant establishment requires minimal flooding (typically two weeks) during the first year. Germination often requires a drawdown in early, mid, or late spring depending on the species, and this drawdown is important if the natural seedbank is to provide reliable cover (Weller, 1994). If invasive species become a problem, water level management can discourage their survival. Or if excessive flooding occurs, drainage can rehabilitate stressed vegetation. Drainage can also discourage aquatic furbearers if they become problematic (too much herbivory or digging in water control structures) (Weller, 1994), and a temporary drawdown in summer may suppress mosquito larvae (Batzer and Resh, 1994).

Outlet Design

There are several factors that dictate the design of the outlet structures. First, continuous flow is desired to prevent stagnation of the water, primarily of concern for mosquito control and oxygen renewal. Such flow must also be reliable, with stable surface water elevations in order to maintain plant communities. The outlet must remove excess water that may flood vegetation or destroy outlet structures. The rate of water removal is desired to be greater than or equal to ½-in. in 24-hrs (Soil Conservation Service, 1977), which can occur in this design even if the basin area becomes five times greater than normal. The calculations are performed in Appendix A, Calculation 5 for a parabolic-shape spillway of dimensions 2-in. deep, 10-ft. wide, and 50-ft. long.

Because the outflow spillway is designed to carry continuous flow, a stream channel is simulated. First, geotextile membrane is placed in the channel to protect against erosion. Since geotextile membrane is vulnerable to UV radiation, it will need to be covered by 10 to 15-cm

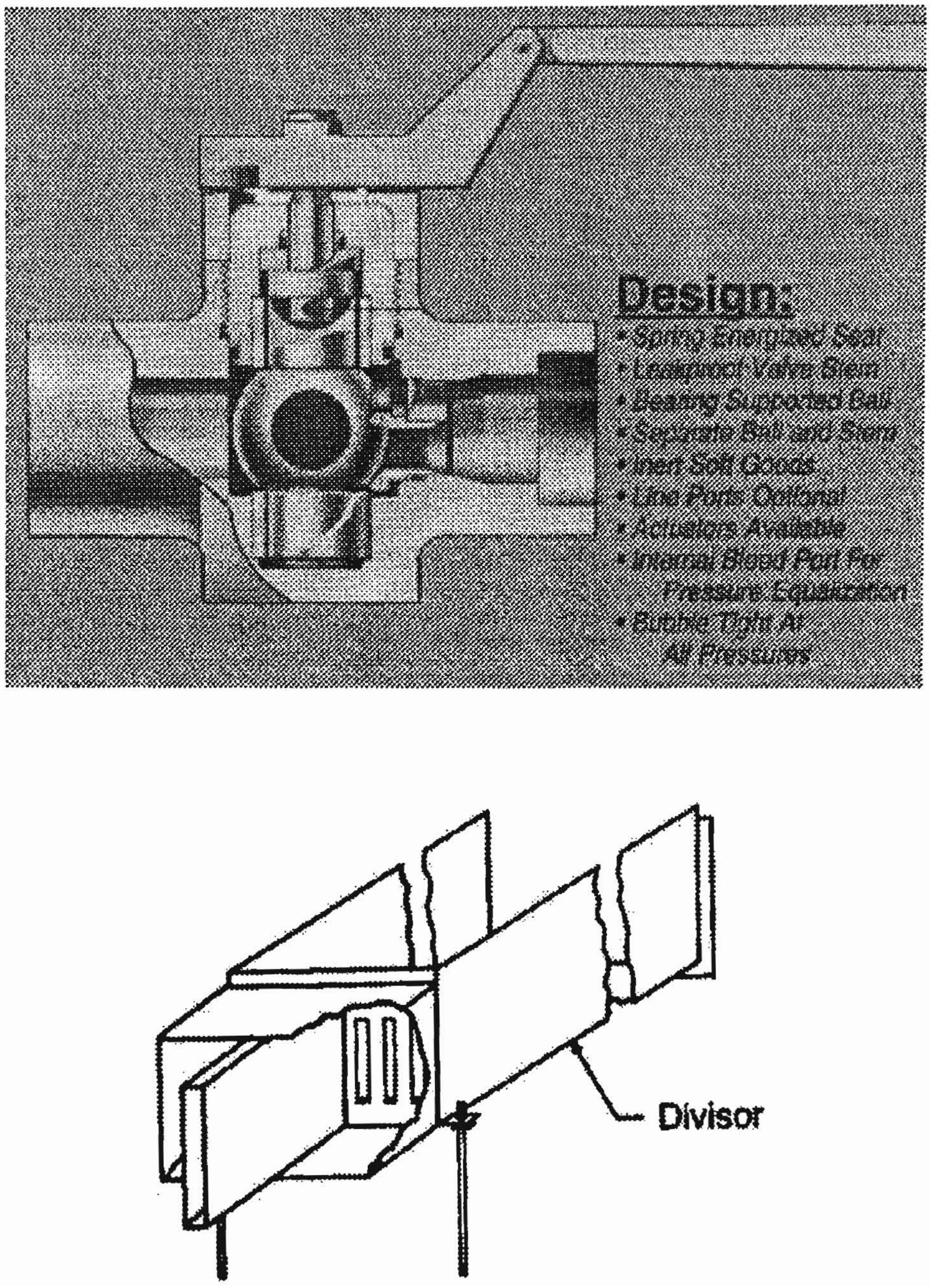


Figure 9. Inlet flow control structures: 2-in. diameter brass ball valve (Specialty Ball Valve Engineering (Thomas Register, 1994)), multislot divisor (Brakensiek et al., 1979)

of soil after installation (the topsoil stockpiled earlier). The channel bottom will be lined with river rock for further armor. If river rock is too expensive, sprigged stoloniferous marsh plants may be used which can tolerate constant inundation. Other vegetation can grow along the edges of the channel where flow will not be continuous.

Sedimentation

Sedimentation basins were included in the design below the outlet of the intake pipe and in the area of the drainage diverted by the dike into the constructed pond. Peak runoff was calculated for twice the area of the wetland site, using the C factor and intensity rate used in the calculation made for peak runoff from the entire watershed. An average was calculated of the total suspended solids results from the Treasure Mountain drainage water quality sample analysis, and this combined with peak runoff led to an estimate for sediment mass to be deposited in the constructed pond in the 10-year life span required by the WRP. The mass of soil was transformed to volume using the average moist bulk density of Clubcaf series soils. The expected sedimentation volume, 7.7 ft^3 of soil, was assumed to be deposited at each inlet location. Therefore, additional sedimentation allowances were made in those locations. The additional excavation at those locations is significantly greater than the sedimentation allowance required: 56 ft^3 is allowed for sedimentation below the intake pipe outlet, and 94 ft^3 is allowed below the dike-diverted drainage. Dredging should not need to occur within the first 10 years of the constructed wetland's lifespan.

Overall Comments

It is unknown at this time what water surface elevations and hydroperiod will result from the design. The uncertainty of the water budget is the primary factor of concern. Depending upon the subsurface characteristics of the soils and the water table influence post-excavation, several scenarios might result. The first is for the design to react as expected, with little influence from the subsurface-source waters, and low infiltration. Perhaps more inflow would occur than expected, yet it is not foreseen that this would be significant enough to exceed the design capacity. A second scenario would be that no inflow would come from the seep, more infiltration may occur than expected, and the result would be stagnation and insufficient ponding. A third scenario, perhaps less likely, would be that the constructed wetland basin drains the water from adjacent soils faster than its current rate. This would be a negative impact on the site. A fourth scenario that might result is for water surface elevations to fluctuate too much to allow adequate establishment of wetland vegetation.

Construction Plan

The contractors selected by the bidding process should have demonstrated experience in wetland construction. This would enable a reasonable cost estimate, especially assuming they already own the proper equipment. The disadvantage is that the mobilization and travel expenses would be higher than if someone with a backhoe could be hired to complete the project. Supervision of the construction will need to be overseen by a qualified NRCS engineer, with periodic site visits by members of the design committee. One or more pre-construction meetings with the contractor should occur both in the office and on-site to maximize communication (Erwin, 1990). The variable topography may appear an "untidy" job and the contractor/excavator may need convincing to produce the results desired (Clewell and Lea, 1990).

Prior to excavation of the basin, a test area should be dug to the proper depth to investigate water table interactions and infiltration rates apparent at that depth. If seepage meters are available, they should be used to investigate the subsurface hydrology in the area.

If the Clubcaf loam is not suitable for building the dike, the material will need to be excavated from the upland area in the northeastern corner of the site, as long as the removal of fill does not impact the stability of the railroad. The depth to bedrock in this upland area should be measured.

Further investigation into environmental impact of the project may be warranted including an archaeological and historical site background check, notice of any zoning or water rights, presence of hazardous wastes and substances, or presence of threatened and endangered species that may be relevant to this project.

Construction staging areas

The staging area for the equipment will be on the eastern side of the livestock fencing along Hall Creek. This area will likely be made into a small parking lot in the future. No clearing or grubbing will be needed, and disturbance should be minimized.

Equipment Needed

Due to the wet nature of the soils in the area under construction, the contractor must be prepared with appropriate equipment. The various operations needed include clearing a foundation, obtaining material, placing material, and shaping and compacting. When dealing with shallow water, the equipment changes to draglines with timber mats; tracked machinery; a highline arrangement with a winch, cable (distances 1500 ft), bucket (capacity 3 to 10 cubic yards), and deadman; or a clamshell (Johnson and McGuinness, 1975).

Material Disposal, Clean-Up Process

The waste from the basin excavation should be placed in the northeastern corner of the site, potentially filling in areas removed for the dike. The spoil should be sloped and contoured to blend into the surroundings, and stabilized with vegetation. Complete removal of trash, equipment, and stakes must take place after construction.

Sediment and Erosion Control Plan

In accordance with the Virginia Erosion and Sediment Control Handbook, sediment barriers, site preparation for vegetative establishment, and temporary vegetative cover are the three main erosion control practices that should be considered during construction.

<u>Silt Fences</u>

Silt fences should be installed as sediment barriers. As defined by the Virginia Erosion and Sediment Control Handbook, a silt fence is a temporary sediment barrier consisting of a synthetic filter fabric stretched across and attached to supporting posts, and entrenched (DSWC, 1992). The purpose of the silt fence is to intercept and detain small amounts of sediment from disturbed areas during construction operations in order to prevent sediment from leaving the site and to decrease the velocity of sheet flows and low-to-moderate level channel flows (DSWC, 1992). Silt fences should be installed on the site below the proposed area of construction where sheet or rill erosion would occur. A woven synthetic fiber (pervious sheet of propylene, nylon, polyester or ethylene yarn) should be chosen with a typical flow rate of 0.3 gallons per square foot per minute, a 97% filter efficiency, and ultraviolet ray inhibitors and stabilizers to provide a minimum of six months of expected usable construction life at a temperature range of 0° F to 120° F (DSWC, 1992). Wooden pine stakes with a minimum diameter and length should be utilized for construction of the silt fence (DSWC, 1992). Installation instructions should be followed as outlined in the Virginia Erosion and Sediment Control Handbook.

Site Preparation for Vegetation Establishment

Specific components within the wetland topsoil should be preserved including the organic matter, water holding capacity, and nutrients. The topsoil shall be stripped to a depth of 5 inches and stockpiled in such a manner that natural drainage is not obstructed and no off-site sediment damage shall result. The stockpile should be stabilized or protected in accordance with the Virginia Erosion and Sediment Control Handbook MS #2. The side slope of the stockpile shall not exceed 2:1 (DSWC, 1992). Perimeter controls must be placed around the stockpile immediately; and seeding of the stockpile shall be completed within 7 days of the formation of the stockpile if it is to remain dormant for longer than 30 days (DSWC, 1992). After grading the areas to be topsoiled, the subgrade shall be loosened by discing or scarifying to a depth of at least 2 inches to ensure bonding of the topsoil and subsoil (DSWC, 1992). The topsoil should be compacted enough to ensure good contact with the underlying soil. Replacement of topsoil should not take place during frozen or muddy conditions.

Surface roughening should take place, prior to seeding for the establishment of vegetative cover, in order to reduce runoff velocity and erosion and increase infiltration (DSWC, 1992). Surface roughening provides a rough soil surface with horizontal depressions created by operating a tillage or other suitable implement on the contour, or by leaving slopes in a roughened condition by not fine-grading them (DSWC, 1992). The rough, loose soil surfaces give fertilizer (if any are applied) and seed some natural coverage. These niches in the surface provide microclimates, generally cool with a favorable moisture level, which aid in seed germination (DSWC, 1992).

Temporary Vegetative Cover

Temporary vegetative cover on disturbed areas, produced by seeding with appropriate rapidly growing annual plants, is necessary to reduce damage from sediment and runoff to downstream or off-site areas, and to provide protection to bare soils exposed during construction until permanent vegetation can be established (DSWC, 1992). However, a suitable non-invasive plant material should be used. A guideline for temporary seeding can be found in the Virginia Erosion and Sediment Control Handbook (STD & SPEC 3.31 Temporary Seeding) (DSWC, 1992).

Cost-accounting

Costs normally include labor, equipment, materials, supervision, and overhead charges. The cost of excavation is assumed to include labor, equipment, materials, and overhead charges. Supervision and other labor will be assumed donated by those agencies and groups involved with this project.

Management Plan

The WRP agreement specifies that it is the landowner's responsibility to maintain the site for 10 years after restoration practices are installed. Regular maintenance will be needed on site. First, the intake pipe structures should be cleaned of lodged debris and excessively accumulated

Dike Total		$1,767
Fill from constructed wetland, grading, and compaction; topsoil stockpiling and replacement (350 cubic yds)	$1,610	
Reed canary grass seeding and mulching in emergency spillway (20 sq. yds)	$8	
Geojute over entire surface area (170 sq. yds)	$149	
Constructed Wetland Total		$7,825
Flow splitter and concrete collection box	$375	
One-way brass ball valve for 2 in. diam. pipe	$48	
Inlet pipes: PVC, 2 in. diam., 40 ft length, and couplings	$16	
Rip-Rap: flat stone (30 sq. ft)	$25	
Total excavation and grading using bucket dragline, topsoil stockpiling and replacement (1580 cubic yds)	$7,268	
Geotextile engineering fabric (3.5 oz, 60 sq. yds)	$78	
Cobbles (3 cubic yds)	$15	
TOTAL PROJECT COST		**$9,592**

Project Element	Estimated Cost	Funding Acquired	Funding Needed
Dike	$1,767	$1,097	$670
Constructed Wetland	$8,107	$2,875	$5,232
Site access: farm road stabilization, parking	$8,000	$0	$8,000
Educational facilities	$15,000	$0	$15,000
Educational materials	$1,400	$1,400	$0
Planting trees and other wetland vegetation	$480	$480	$0
Maintenance	$9,000	Volunteer	$0

Table 6. Cost analysis for the Glade Spring enhancement project

(VMRC), and the Department of Environmental Quality. One permit potentially applicable to the project is the VMRC joint permit (turn-around time 4-6 weeks). An application to this permit would be distributed to all interested parties for review and comment, but may not waive the application for other permits. Following advice from contacts at the Department of Environmental Quality, the proposed design is not in-stream in order to avoid the need for most and potentially all permits. Furthermore, full diversion of the flow from the Treasure Mountain drainage was avoided and the outlet of the ponded area drains back to Treasure Mountain's drainage before it joins with Hall Creek.

Wildlife habitat plan

The design of the constructed wetland area must consider wildlife habitat requirements in terms of food, drinking water, resting areas, escape cover, and reproductive habitat. Mallards, galligoles, and black ducks (puddle ducks) nest within 150-yds of water 8-18 in. deep with herbaceous vegetation as cover. Wood ducks (also classified as puddle ducks) require tree cavities and greater than 1 acre of brood habitat per nesting pair, water depths greater than 5-in., and a 1:3 ratio of open water to cover. Diving ducks including ring-necked ducks and hooded mergansers frequent fresh water with depths greater than 2-ft. Wading birds, including great blue herons, green herons, black-crowned night herons, great egrets, and snowy egrets require an average 1-ft. depth of water, and mud flats are particularly desirable. Their food sources include fish, reptiles, and amphibians. Snow geese, Canada geese, and swans prefer islands for nesting. Muskrat require abundant wetland vegetation and stable water levels, both muskrat and beaver require a tree border, otter feed on aquatic vertebrates, and mink prefer open water.

Wetland habitat is enhanced by snags, fallen trees, and brush piles. Nesting and roosting boxes can be provided in the absence of snags, tree cavities, and other needed habitat; but the wildlife enhancement of the site must be weighed against the aesthetic deviation from natural habitat. The cost of constructed boxes may be similar to the cost of importing logs and brush from off-site sources. Native amphibians (salamanders, newts, frogs), reptiles (especially the bog turtle), small mammals, invertebrates, and songbirds and other small birds are desirable, and future monitoring will determine the success of the site at attracting these species and if future introductions are needed (Crawford and Rossiter).

Several federally listed or proposed endangered and threatened species were listed for Washington County, including the Appalachian Bewick's wren, gray bat, and Virginia northern flying squirrel. Endangered vascular plants included the fraser fir, mountain bittercress, Schweinitz'a sedge, Blue Ridge St. John's wort, Gray's lily, mountain rattlesnake root, Carey saxifrage, and Carolina saxifrage. Prior to construction, the site must be surveyed for these species and their habitat to prevent any damage.

Vegetation selection

The goal of a wetland creation or enhancement project is to have greater than 50% obligate or facultative wetland plants on site. The tree species planted to date were not all wetland species, but intended to provide cover along the streambanks, wildlife food and nesting requirements, and screening from the road and railroad. Primarily, the seed bank and adjacent wetland communities should create adequate plant establishment in disturbed sites after construction. If adequate establishment is not obtained, the species listed in Table 7 (the list is not a complete one) are provided as a reference for future planting efforts. A diversity of vegetation is desirable, including marginal nonpersistent emergent plants which are a large seed crop for birds, deeper water persistent emergents which provide nest sites and tubers as food, and submergent plants which are both a food source and a substrate for invertebrates (Weller, 1994). One local source for wetland species (including Spiraea spp.) is the stream beside the Emory & Henry College athletic fields, and Dr. Ogle can provide contact names in order to acquire permission to harvest plants (Doug Ogle, email communication, 24 Sept 1997).

Educational facilities

The intention of the Glade Spring Wetland Site is for it to be used as an outdoor classroom, therefore, it is necessary to ensure that the site is not degraded. To ensure low impact of visitors upon the wetland site, several conditions should be established. The Research Farm should be notified of the date and time of intended visitations. No motorized vehicles will be used in the wetland (Kusler). Hours of use of the site will be limited due to nesting seasons (Kusler). Trails, bridges, boardwalks, and ramps for handicap access will be constructed and installed to control foot traffic over sensitive areas of the site. No hunting, picking or collecting will be allowed on site unless permitted by authority. Furthermore, visitors will be required to stay on marked trails, be quiet, and not litter (Kusler).

Over the drier areas on-site rock or mulch trails will be laid, with or without wooden edge borders. Over the wet spots wood boardwalks will be installed, likely with pre-made concrete footings. Railings will be installed on all boardwalks and bridges. Bottom rails with no more than a 6-in. gap are needed to protect children from falling into the water (Kusler). In some areas, moveable pads constructed of 2x4's could be laid during especially wet periods. Figures 10 and 11 illustrate examples of walkways and bridges that are typically used. Permits are not needed for trails and interpretive markers. However, permits may be needed for the construction of larger boardwalks.

Table 7. Desirable wetland herbaceous species

Common Name	Latin Name	Comments / Veg. Index
St. John's wort	*Hypericum densiflorum*	FAC+, FACW
Smooth alder	*Alnus serrulata*	OBL
Common winterberry	*Ilex verticillata*	FACW+, FACW
Ninebark	*Physocarpus opulifolius*	FACW-, FACW, streambanks
Narrow-leaved meadowsweet	*Spiraea alba*	FACW+, OBL, wet meadow, swamp/marsh
Steeplebush/Hardhack	*Spiraea tomentosa*	FACW, FAC, wet meadow, swamp/marsh
Va. sweet-spires/Va. Willow	*Itea virginica*	OBL, FACW
Swamp azalea	*Rhododendron viscosum*	OBL, FACW
Broad-leaf arrowhead	*Sagittaria latifolia*	<50 depth, OBL, max. 12 in. depth
Yellow water-lily	*Nuphar spp*	OBL
Highbush blueberry	*Vaccinium corymbosum*	FACW
Swamp rose	*Rosa palustris*	OBL
Water weeds	*Elodea spp*	D. Ogle recommendation
Sedges	*Carex spp.*	OBL
Marsh marigold	*Calha palustris*	OBL
Sweet flag	*Acorus calamus*	OBL
Water lilies	*Nymphaea spp*	OBL
Spike rush	*Eleocharis spp*	D. Ogle
Beak rushes	*Rhynchospora spp*	D. Ogle
Peat mosses	*Sphagnum spp*	D. Ogle
Stoneworts	*Chara spp*	D. Ogle
Glassworts	*Salicornia spp.*	D. Ogle
Creeping bent grass	*Agrostis stolonifera*	FACW
Giant cane	*Arundinaria gigantea*	FACW
Virginia rye grass	*Elymus virginicus*	FAC
Switchgrass	*Panicum virgatum*	FACW
Common three square	*Scirpus americanus*	Max. 6 in. depth
Softstem bulrush	*Scirpus validus*	Max. 12 in. depth
Buttonbush	*Cephalanthus occidentalis*	Max. 2 ft. depth
Swamp rosemallow	*Hibiscus moscheutos*	Max. 3 in. depth
Rice cutgrass	*Leersia oryzoides*	Max. 3 in. depth
Arrow-arum	*Peltandra virginica*	Max. 12 in. depth
Pickerel week	*Pontederia cordata*	Max. 12 in. depth
Water plantain	*Alisma plantage-aquatica L.*	D. Ogle
Duckweeds	*Lemna spp.*	D. Ogle
Big duckweeds	*Spirodea spp.*	D. Ogle
American lotus	*Nelumbo lutea*	D. Ogle
Lizard's tail	*Saururus cernuus*	Max. 6 in. depth

Several signs and interactive exhibits will be needed on-site. First, an entrance sign will be used to identify the site (see Figure 12). This sign will include general information about wetland functions and values and more detailed information particularly relevant to the site (wetland species of plants and animals located on-site, site history including before and after restoration/enhancement photographs, and a trail map). Markers will identify points of interest along the trail. Within the printed Self-Guided Nature Trail and Wetland Walk brochure (rough example in Appendix B), explanations of the trail markers' significance will appear.

Educational programs can take place on-site, targeted for different age groups and interests. The Patrick Henry School Library will be stocked with wetland educational publications, videos, and activity suggestions for the field and the classroom. Associated materials will be accessible on the Virginia Water Resources Research Center web page.

Figure 10. Sample of a walkway seen at the Fenwick Wetlands Trail located in Craig County, Va., managed by the New Castle Ranger District

Figure 11. Sample of a bridge built for the Fenwick Wetlands Trail in Craig County, Va.

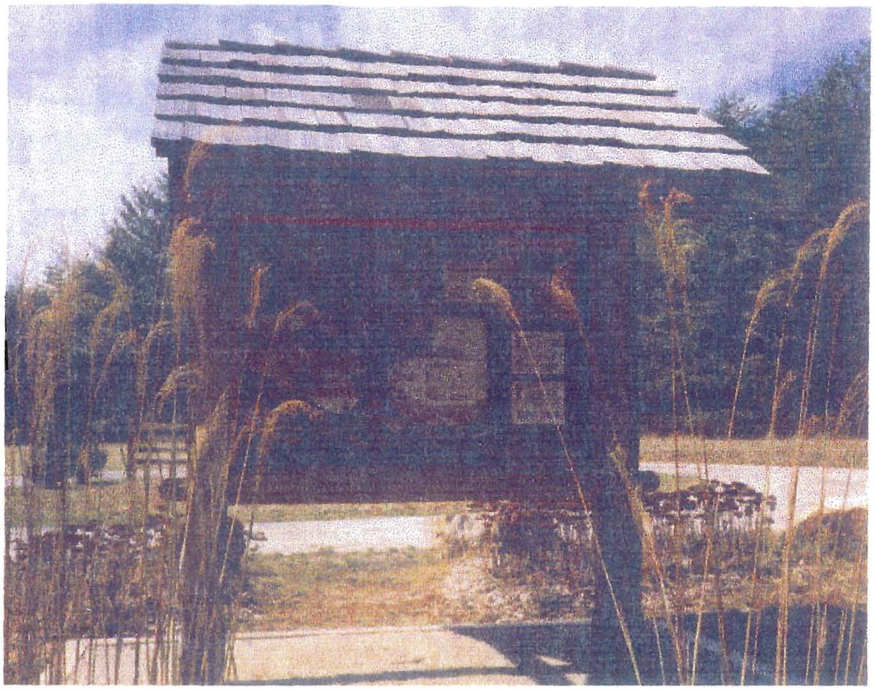


Figure 12. Sample of a welcome sign seen at the Fenwick Wetlands Trail, Craig County, Va

Future Use of the Site

The project will not succeed without local ownership. High-school students have been involved in the initial data collection on-site, in a few activities on-site, and in the tree planting projects. The wood shop class will be involved in the construction of the walkways. Hopefully, the site will be adopted by the high-school Science Club or 4H Club for purposes of maintenance, group monitoring projects including the Issak Walton League Save-Our-Streams program and Adopt-A-Watershed activities, and individual research projects.

Proposed Schedule of Construction and Design Implementation

Sufficient funding is available to construct the dike, plant additional vegetation, and begin the educational facility improvements and materials development. There is enough momentum in terms of funding and personnel that all aspects of the project should be completed within the next five years.

Assessment of Success and Future Recommendations

Partial wetland restoration and creation project failures are not uncommon. Failures occur due to the lack of scientific knowledge and staff expertise in design. Improper site conditions, such as water supply, depth, and velocity; and invasion by exotic species also contribute to partial failures of wetland projects. In particular, the hydrology of this site is very much unpredictable. There may be more infiltration than predicted, or improper grading of the wetland may create excessive channelization, and flow from the seep may never reach the pond as it infiltrates into the soil. The construction of this wetland will be more of an experiment than desired, for the cost involved, due to the uncertainty in water budget estimation. Therefore, after the completion of the construction phase of this project, a monitoring program should be established at the Glade Spring site to help educate future designers.

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Appendix A

Calculations

Calculation 1. Dike Design

Before designing the dike following assumptions were made:

w = 10 ft (top width)
s = 8:1 (side slope)
h = 1.75 ft (dike height including 10% addition for settlement to be withhold 1 foot of water behind the dike)

The following table was then used to calculate the volume earth needed to construct the dike:

Dam Volume Calculations													
Station (ft)	Actual Elevations (ft)			Adjusted Elevations Referenced from 2061.4 ft (ft)			Cross-Sectional Area (ft^3)			Total Cross-Sectional Area (ft^3)	Average Cross-Sectional	Length (ft)	Volume (ft^3)
	upstream side slope	middle	downstream side slope	upstream side slope	middle	downstream side slope	upstream side slope	middle	downstream side slope				
0.00													
											49.10	20.00	982.00
20.00	2061.00	2061.25	2061.00	0.40	0.15	0.40	15.05	19.00	15.05	49.10			
											48.40	26.88	1300.99
46.88	2060.80	2061.25	2061.40	0.60	0.15	0.00	16.45	19.00	12.25	47.70			
											59.65	34.37	2050.17
81.25	2060.00	2060.40	2060.00	1.40	1.00	1.40	22.05	27.50	22.05	71.60			
											64.40	43.75	2817.50
125.00	2060.90	2061.00	2060.30	0.50	0.40	1.10	15.75	21.50	19.95	57.20			
											57.20	6.25	357.50
131.25													
												Total Volume of Dike in cubic feet:	7508.18
												Total Volume of Dike Spillway in cubic feet:	65.60
												Total Volume of Topsoil Excavation in cubic feet:	1859.38
												Total Volume of Replacing Topsoil in cubic feet:	1859.38
												Total Volume of Earth Movement for Dike Construction in cubic feet:	11161.31
												Total Volume of Earth Movement for Dike Construction in cubic yards:	413.38

Cross-Section of Dike Design

Calculation 2. Dike Emergency Spillway

The Manning formula was used to determine the average velocity of flow less than or equal to the permissible velocity.

The equation states that:

$$v = \frac{R^{2/3}s^{1/2}}{n}$$

R = 0.28 m (hydraulic radius, Figure 7.5, Schwab, 1993)
s =.03 m/m (slope of channel)
n = 0.38 (roughness coefficient of the channel, Figure 7.3, Schwab, 1993)

v = 0.195 m/s

The continuity equation was used to determine the cross-sectional area needed to support the flow rate carried by the channel.

The equation states that:

$$q = av$$

q = 0.01 m^3/s (flow rate)
v = 0.195 m/s (average velocity of flow)

a = 0.051 m^2

The depth and top width of the emergency spillway were calculated by using the following equation:

$$a = \frac{2}{3}td$$

a = 0.051 m^2

t = 1.00 m
d = 0.076 m

Including freeboard:

T = 1.52 m (4.99 ft)

D = 0.176 m (0.58 ft)

Calculation 3. Monthly Water Budget Calculations

Precipitation

The needed parameters for the water budget were averaged on a monthly basis. Precipitation was averaged as the following table illustrates:

Precipitation Data for Abingdon, Virginia													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1948	326*	502	502	201	285	480							2296
1949	405	329	413	419	295	296	1302	909	211	267	274	329	5449
1950	698	520	465	149	888	721	502	322	256	86	232	281	5120
1951	334	263	442	399	506	407	528	193	265	125	380	403	4245
1952	484	195	424	213	369	376	591	399	160	77	462	274	4024
1953	372	427	447	330	480	351	407	126	289	49	86	327	3691
1954	693	109	479	313	364	270	405	308	168	184	254	415	3962
1955	241	478	907	303	183	323	386	247	134	214	272	201	3889
1956	229	666	565	465	333	191	588	284	418	180			3919
1956											265	551	816
1957	886	657	325	472	225	708	168	488	822	118	508	541	5918
1958	218	400	349	461	922	281	918	575	81	95	310	231	4841
1959	296	286	388	471	227	174	387	170	241	654	392	351	4037
1960	292	283	420	196	261	327	683	353	106	311	226	220	3678
1961	297	605	417	341	279	399	369	269	102	268	271	710	4327
1962	471	613	345										1429
1970	329	251	248	685	195	302	369	650		411	237	353	4030
1971	310	444	314	346	807	338	742	286	295	320	256	220	4678
1972	649	498	373	448	463	581	385	343	748	434	338	659	5919
1973	204	314	725	352	680	199	1083	449	163	386	413	651	5619
1974	636	562	650	386	678	526	320	187	385	212	365	598	5505
1975	466	424	975	226	469	459	358	405	566	176	280	416	5220
1976	410	414	356	90	295	611	379	467	595	720	169	427	4933
1979	699	504	300	380	320	739	517	219	515	259	341	255	5048
1980	422	148	584	351	408	175	550	298	358	295	286	154	4029
1981	160		228	470	712	501	484	265	578	261	135	400	4194
1982		617	441	300	269	788	755	794	318	297	455	301	5335
1983	226	213	266	490	597	249	391	304	235	348	288	486	4093
1984	258	533	384	316	747	265	542	186	104	156	386	334	4211
1985		319	185	227	472	287	538	467	29	263	828	127	3742
1986	353	452	212	93	595	123	354	487	577	309	311	433	4299
1987	440	430	302	708	262	392	383	305		95	267	414	3998
1988	282	316	191	451	312	128	503	304	393	262	364	222	3728
1989	379		392	295	359	461	433	206	840				3365
1990	375	502	532	421	672	277	526	611	377	542	154		4989
1991	434	500	837	176	615	424		291	324	49	447	620	4717
1992	197	345	397	278		457	469	303	263	310	211	592	3822
1993	330	295	662	314	283	68	291	509	507	203	356	612	4430
1994	460	790	759	360	358	387	541	443	187	269	199	190	4943
1995	573		316	163	559	459	137	151	383	304	536		3581
1996			441		840	522	307	415	511	371	467	461	4335
Average	4.01**	4.22	4.49	3.44	4.63	3.85	5.02	3.68	3.47	2.67	3.25	3.93	42.54
Minimum	1.60	1.09	1.85	0.90	1.83	0.68	1.37	1.26	0.29	0.49	0.86	1.27	8.16
Maximum	8.86	7.90	9.75	7.08	9.22	7.88	13.02	9.09	8.40	7.20	8.28	7.10	59.19

* Rainfall units are in 100ths of an inch
** Rainfall units are in inches
***All Data was downloaded from Abingdon, Virginia Climatological Data accessed from the internet from the Weather Bureau homepage

The averaged monthly precipitation measurements (ft/month) were then multiplied by the area within the constructed wetland perimeter (12977 ft^2) to result in a volume of precipitation per month (ft^3/month). These results representing precipitation will be illustrated later in the calculation of the monthly water budget.

Evapotranspiration
Evapotranspiration was averaged in a similar manner as precipitation. Values for evaporation were used from the Climatological Data Reports published by the National Weather Service (F.2.2). The averages were compiled from data collected at the Western Piedmont Philpott Dam in Henry County, Virginia from 1995-1997. These monthly averages were then multiplied by 0.8, the conversion factor to convert evaporation to potential evapotranspiration (PET) (Hammer, 1992). The following table lists the calculated averages:

Average Evapotranspiration Data		
Month	**Evaporation**	**Potential Evapotranpiration (PET)**
April	3.86	3.09
May	4.22	3.38
June	4.38	3.50
July	5.39	4.31
August	5.28	4.22
September	4.77	3.82
October	3.16	2.53
Annual Average	4.44	3.55

The averaged monthly evapotranspiration measurements (ft/month) were then multiplied by the constructed ponded surface area (12156 ft^2) to achieve in a volume of evapotranspiration per month (ft^3/month). These results representing evapotranspiration will be illustrated later in the calculation of the monthly water budget.

Ponded volume was calculated by knowing the surface areas between the topographic lines for the wetland pond (ft^2), then multiplying each by the appropriate depth (ft) to achieve volume

Treasure Mountain drainage inflow
Calculations were performed on cross-sectional areas and velocity measurements; the results are presented in the table below. An average of the total area and total flow volumes relevant to each month was made and used in the water budget calculation after conversion from ft^3/sec to ft^3/month.

Measurement Date	Total Area (ft^2)	Total Flow Volume (ft^3/s)
04/01/97	1.01	0.213
04/22/97	1.92	0.318
04/22/97	1.82	0.202
05/22/97	2.01	0.083
06/10/97	2.32	0.129
06/17/97	2.47	0.042
06/23/97	2.18	0.111
07/07/97	2.21	0.066
07/13/97	2.12	0.033
08/21/97	2.29	0.003
10/02/97	2.94	0.012
10/02/97	0.40	0.058

Average flow rate = 0.110 ft^3/s = 0.003 m^3/s
Low flow rate = 0.02 ft^3/s = 0.0006 m^3/s

Seep inflow: H flume results
Stage was recorded on a weekly chart strip. Courtesy of Dr. Saied Mostaghimi's staff, these charts were digitized, the digitized data run through processing routines, and weekly average stage was specified as output. Monthly averages of these stages were calculated. These averages for stage (head) in feet were compared to a rating table for a 6-in. H flume for conversion to discharge in cubic feet per second (the rating table can be found in Brakensiek et al, 1979). These numbers were then used in the water budget calculation after conversion from ft^3/sec to ft^3/month.

H-Flume Data		
Month	Average stage	Average flow
April	0.2235	0.0530
May	0.2321	0.0585
June	0.2038	0.0431
July	0.1233	0.0146
Aug	0.1272	0.0173
Sept	0.1493	0.0233
Oct	0.0895	0.0080

Infiltration
The infiltration rate of the Clubcaf silt loam is 1 mm/hr, a general rate for hydrologic group D soils (Schwab et al., 1993). This was converted to ft/month and multiplied by the ponded surface area (12156 ft^2)

Subsurface Inflow and Outflow
These were assumed to be zero due to the uncertain nature of these flows, the high water table and hydric soils making the zero outflow a reasonable assumption, and the desirability of any inflow. The calculations made for the water budget were to know the minimum inflows necessary to keep a non-stagnated ponded area.

Outflow Spillway

This was calculated based on the principles of the water balance, succinctly described by the National Cooperative Highway Research Program's report on Guidelines for the Development of Wetland Replacement Areas (NCHRP, 1996):

> For any fixed volume in space, referred to as a "control volume," the law of mass conservation requires that, for an incompressible fluid during a given period of time, the inflow volume minus the outflow volume is equal to the change in storage, or:
>
> I-O = dS
>
> I=inflow
> O = outflow
> dS = change in storage

For the Glade Spring constructed wetland pond water balance:

I = Precipitation+Treasure Mountain Inflow+Seep Inflow
O = Evapotranspiration + Infiltration
dS = Ouflow spillway is sized to adequate capacity, and all flow is directed to it

Only a portion of the Treasure Mountain drainage was intended to be diverted. This portion was calculated iteratively, by assuming an initial percent removal of flow, then viewing the amount assigned by default to the outflow spillway by means of the water balance equation. This amount must first be positive, to achieve outflow. Next, the detention time (monthly), due to the amount of flow vs. ponded water volume the flow moves through, must be greater than 7 days, but not too large that long stagnation times resulted. Stagnation problems might also increase if friction from overland flow decreases the velocity of flow, but the overland flow rate is very difficult to estimate, and this was not considered in the overall analysis of flow rate (advice from S. Mostaghimi, personal communication, April 14, 1998). The detention time was calculated as follows:

$$\text{Time} = \frac{\text{Volume}(\text{ft}^3)}{\text{FlowofTM}(\text{ft}^3/_{\text{month}})} * \frac{30\,\text{day}}{1\,\text{month}}$$

The least percent removal of the Treasure Mountain flow was chosen for the design that caused the outflow spillway to carry flow and the detention times for each month to be greater than or equal to 7 days. The result was 20% removal of the Treasure Mountain flow. We deemed this to be acceptable to permitting agencies, especially because the outflow water was being returned to the same drainage.

The outlet velocity of the pipe should be approximated by the following equation:

$$v = \frac{1}{0.015}\left(\frac{d}{4}\right)^{2/3}\sqrt{s} = \frac{1}{0.015}\left(\frac{(2/12)}{4}\right)^{2/3}\sqrt{0.013} = 0.914 ft/\sec$$

v = velocity (ft/sec) (Schwab, 1993)
d = diameter of the pipe, ft
s = slope of the pipe, ft/ft

Final Monthly Water Budget Results

The following tables illustrate the water budget with an inflow of 1/5 of the Treasure Mountain Drainage and the detention time associated with it:

Monthly Water Budget for Glade Spring Wetland Restoration Project						
Month	Precip (ft3)	ET (ft3)	InTM (ft3)	InHflume (ft3)	Infiltration (ft3)	Outlet (ft3)
April	3720.07	375.38	126645.12	0.00	0.00	129989.82
May	5006.96	410.39	44461.44	0.00	0.00	49058.01
June	3871.47	425.95	48677.76	0.00	0.00	52123.29
July	5428.71	524.17	26516.16	0.00	0.00	31420.70
Aug	3979.61	513.47	1767.74	0.00	0.00	5233.89
Sep	3752.52	463.87	6428.16	0.00	0.00	9716.80
Oct	2887.38	307.30	6642.43	0.00	0.00	9222.51

Detention time			
InTM (ft3/month)	Volume (ft3)	Det time (months)	Det time (days)
126645.12	10647.64	0.08	2.52
44461.44	10647.64	0.24	7.42
48677.76	10647.64	0.22	6.56
26516.16	10647.64	0.40	12.45
1767.74	10647.64	6.02	186.72
6428.16	10647.64	1.66	49.69
6642.43	10647.64	1.60	49.69

Calculation 4. Pipe Design for Inflow to Constructed Wetland Basin

Before designing the pipe, the following assumptions were made:

Temperature of water = 10° C (minimum measured water temperature = 11° C)
Density of water = 1000 kg/m^3
Viscosity of water = 1.5674 * 10^{-3} kg/(m*s)
First iteration diameter of pipe = 4 in.
Equivalent length of pipe = 40-ft + 10-ft for a sharp-edged entrance given

The mechanical-energy balance equation was used: (Geankoplis, 1993)

$$\frac{1}{2\alpha}(v_{2av}^2 - v_{1av}^2) + g(z_2 - z_1) + \frac{(p_2 - p_1)}{\rho} + \Sigma F + W_s = 0$$

Because the velocities of inflow and outflow were approximately the same, and the pressure on each side of the pipe is set for atmospheric pressure, and there is no pump or fan; the head can be set equal to the negative of the friction factors (all in SI units).

$$-\Sigma F = 4f\frac{\Delta L}{D}\frac{v^2}{2} + Kent\frac{v^2}{2} + K_{ball,1/2open}\frac{v^2}{2} = g(z_2 - z_1)$$

$$-\Sigma F = 4(0.0065)\frac{12.19}{D}\frac{(0.0006/D^2)^2}{2} + 0.5\frac{(0.0006/D^2)^2}{2} + 9.5\frac{(0.0006/D^2)^2}{2} = 9.81(0.52)$$

The head was calculated based on a 40-ft length of PVC pipe and a 1.3% slope of the pipe. The fanning friction factor was achieved due to multiple iterations. First, the initial diameter was assumed. Then, Reynold's number was calculated based upon the flow taken from the Treasure Mountain drainage. This Reynold's number was used to find the fanning friction factor assuming a smooth pipe for the PVC material. The fanning friction factor was used in the above equations. Next, diameter was adjusted until each side of the equation matched. This means that the diameter of the pipe can carry the flow specified (the friction forces are overcome). A pipe diameter larger than this can be selected based on standard pipe sizes available for purchase and a 10% safety factor Since the result of this process was a 1.15-in. diameter pipe, with a safety factor this becomes 1.27-in. Pipe sizes of inner diameter greater than this are the 1-¼, the 1.5-in., and the 2-in. pipes. In April the largest baseflow quantity was seen (no storm events were measured). When this was run through the iterative process, and the diameter was calculated with a 10% safety factor, the result was 1.82-in. Therefore, the 2-in. pipe was chosen for the design.

Calculation 5. Constructed Wetland Overflow Spillway

The overflow spillway was designed specifically to drain ½-inch of ponded area in a 24 hour period. Before calculations were started the flow velocity within the spillway was assumed to be 3 m/s.

The continuity equation was used to determine the flow rate needed to support the velocity and area of the constructed basin that is to be drained by the channel.

The equation states that:

$$q = av$$

$a = 1129\ m^2$ (area of basin)
$v = 2.21 * 10^{-7}$ m/s (average velocity of flow)

$q = 0.000249\ m^3/s$ (flow rate)

The depth and top width of the overflow spillway were assumed to be 50.9 mm (0.167 ft or 2 in.) and 3.048 m (10 ft), respectively, for a 3 m/s velocity. These assumptions were then used to calculate flow through the outflow spillway using the following equation (Schwab et al., 1993):

$$a = \frac{2}{3}td$$

$t = 50.9$ mm
$d = 3.048$ m

$a = 0.103\ m^2$
$v = 3$ m/s

$q = 0.310\ m^3/s$

The flow rate calculated for this area was compared with the flow rate specified by the water balance analysis. The design flow value of $0.310\ m^3/s$ is much greater than the needed flow rate of $0.000249\ m^3/s$. In fact, even if the basin area was five times greater the design flow would still be adequate.

Appendix B

Sample Brochure

Thank you for visiting the Glade Spring Wetland. We hope that you enjoy your visit with us. To make it more accommodating to everyone, please follow all signs and do not litter.

Wetlands are transitional lands where the water table is usually at or near the soil surface. Wetlands have varying functions:

- Physical: flood control, groundwater recharge, and sediment trapping
- Chemical: waste treatment and pollution interception
- Biological: biological production and habitat
- Socioeconomic: food, fuel, timber, recreation, aesthetics, and education.

Special Attractions

The following numbers are associated with trail markers. Please read the caption at the associated trail marker.

1) The ***Hydrologic Regime***, or the dynamic and dominant presence of water, is the defining circumstance of a wetland. The water level is typically at, just below, or just above the ground's surface, creating the saturated conditions that lead to the development of hydric soils and the presence of hydrophytic plants.

2) ***Wetland diversity*** is very important to different species of plants and animals. Vegetation height and density, temperature gradients, water levels, food diversity, daily and seasonal fluctuations, and soil types all combine in vibrant, humming, synchronized concert to create the symphony that is a healthy and flourishing wetland.

3) ***Hydric Soils*** are saturated long enough during the growing season to create an anaerobic (low oxygen) state in the soil horizon. This lack of available oxygen limits the number of species that can survive there. Some wetland soils are dominated by organic material (partially decomposed plants) and are categorized as peats or mucks. Soils with a high mineral content (sand, silt, and clay), on the other hand, tend to form in warm, wooded wetlands and other locations that are water-saturated for only a portion of the growing season.

4) ***Wetland Plants,*** known as hydrophytic plants, have adapted to thrive in wetlands despite the stresses of an anaerobic and flooded environment. To succeed in their waterlogged environment, wetland plants must employ strategies such as long transporting tubes (emergent reeds), flotation (lilies), and buttressed trunks (cypress trees). Plants are often the most obvious indicators of a wetland.

5) ***Wildlife Habitat***

From bacteria to beaver, wetlands are both home and supermarket for a myriad of residents. The vegetative productivity attracts animals that utilize the wetland for food, shelter, spawning, nesting, or predatory opportunities.

Eighty percent of all breeding bird populations in the United States, along with more than half of the protected migratory bird species, rely on wetlands at some point of their life cycle.

6) ***Groundwater Monitoring*** is an important part of any wetland investigation. An extensive amount of data needs to be collected in order to characterize the groundwater flow of a wetland.

In the writing of this brochure Wow! The Wonders of Wetlands Educator's Guide (1995) was referred to and quoted. The publisher should be contacted before any publication of this brochure is made.

Self-Guided Nature Trail and Wetland Walk

Glade Spring, Virginia

WETLAND RESTORATION AND ENHANCEMENT

GLADE SPRING, VIRGINIA