EVALUATION OF BEST MANAGEMENT PRACTICES FOR UNDERGROUND UTILITY LINE INSTALLATION AND RESTORATION IN WETLANDS

Final Report to Maryland Department of the Environment
December 14, 2012

Prepared by Bruce Vasilas, Professor, University of Delaware

Edited by: Denise Clearwater
February, 2013

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EFFECTIVENESS OF BEST MANAGEMENT PRACTICES IN RESTORING TEMPORARY IMPACTS IN NONTIDAL WETLANDS

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INTRODUCTION

The Maryland Department of the Environment (MDE) regulates activities conducted in nontidal waters and their 100-year floodplains, and nontidal wetlands. Regulated activities include draining, excavating, filling, grading, shaping, changing the hydrology, and removing vegetation. Underground utility lines (i.e. sewer, gas, water) are often constructed in wetlands, floodplains, or adjacent to these systems. The impacts of construction and maintenance of utility lines to these systems may be direct (e.g. excavating, vegetation removal) or indirect (e.g. hydrologic alterations). Impacts may be temporary or long term. Inherent to construction of underground utility lines are ecosystem disturbances including excavating, filling, and removing vegetation. For wetlands, long-term hydrologic alterations are of particular concern as the suite of ecosystem services and the capacity of individual services are strongly tied to hydrologic characteristics (hydroperiod, hydrodynamics) of each wetland. Hydrologic alterations may impact plant communities and wildlife habitat, sediment transport, and the quality of surface waters and groundwater. Assessment of impacts should address the three phases associated with utility line construction and maintenance: construction, restoration, and right of way (R.O.W.) maintenance. Restoration includes backfilling of the trench, soil surface leveling, and seeding to establish groundcover to minimize runoff and soil erosion and to promote desirable plant succession. R.O.W. maintenance typically prevents the establishment of woody plant species.

To minimize impacts MDE has established best management practices (BMPs) for working in nontidal wetlands, wetland buffers, waterways, and 100-year floodplains. These BMPs include the following:

1. No excess fill, construction material, or debris shall be stockpiled or stored in nontidal wetlands, wetland buffers, waterways, and 100-year floodplains.
2. Place materials in a location and manner which does not adversely impact surface or subsurface water flow into or out of nontidal wetlands, wetland buffers, waterways, and 100-year floodplains.
3. Repair and maintain any serviceable structure or fill so there is no permanent loss of nontidal wetlands, wetland buffers, waterways, or permanent modification of the 100-year floodplain in excess of that lost under the originally authorized structure or fill.
4. Rectify any nontidal wetlands, wetland buffers, waterways, or 100-year floodplain temporarily impacted by any construction.
*5. All stabilization in the nontidal wetland and nontidal wetland buffer shall consist of the following species: Annual Ryegrass (Lolium multiflorum), Millet (Setaria italic), Barley (Hordeum sp.), Oats (Uniola sp.), and/or Rye (Secale cereal)…..**Kentucky 31 fescue shall***

not be utilized in wetland or buffer areas. *The area should be seeded and mulched to reduce erosion after construction activities have been completed.*
6. After installation has been completed, make post-construction grades and elevations the same as original grades and elevations in temporarily impacted areas.

The project described in this report was conducted to assess the effectiveness of MDE's BMPs for underground utility line installation in wetlands or adjacent to wetlands. Seven sites were evaluated in Maryland. In some cases the utility line went through a wetland; in other cases the utility line went through a wetland buffer. In the latter situation adjacent wetlands were assessed. At some sites only one wetland was directly impacted. At other sites multiple wetlands appeared to be impacted and were assessed. Three basic approaches were utilized to identify and quantify an appropriate control (non-disturbed condition):

1. A site was assessed prior to and after utility line installation and restoration.
2. A disturbed wetland was compared to a non-disturbed wetland. In this case *disturbance* refers only to the presence of a utility line. It does not imply that a non-disturbed wetland was in pristine condition. The control site was chosen for its similarity to the disturbed site on the basis of landscape position, wetland type, plant community composition, close proximity, and soil map unit.
3. A disturbed section(s) of a wetland was compared to a non-disturbed section(s).

Impact assessment focused on the following ecosystem units:

1. Plant community composition, especially in the context of wildlife habitat and soil conservation.
2. Soils, especially in the context of potential alterations to groundwater flow, erosion potential, and promoting favorable plant succession.
3. Groundwater chemistry.
4. Hydrology. Hydroperiod was assessed directly with automated monitoring wells. Changes in hydroperiod due to line installation and restoration were determined directly with monitoring wells and indirectly through soil morphology observations. Ranking sources of hydrologic input (precipitation, surface flow, groundwater discharge, overbank flow) and hydrodynamics was determined by evaluation of landscape position, proximity to surface waters, and soil characteristics; and visual observation of seeps and overbank flow.

MATERIALS AND METHODS

Seven sites were selected in Maryland for environmental assessment; three in Garrett County (GT1, GT2, GT3) in the Appalachian Plateau, one in Charles County (CH) in the Inner Coastal Plain, and three in Harford County (HR1, HR2, HR3). HR3 is in the Piedmont; HR1 and HR2 are in the Inner Coastal Plain but receive deposition from the Piedmont as evidenced by the presence of mica in their soils.

To assess the impact of underground utility line construction on the wetlands, two types of comparisons were conducted. In four cases (GT2, GT3, HR1, HR3) construction and restoration was completed prior to initiation of this project. At those sites disturbed areas (From this point on referred to as R.O.W.) were compared to areas in close proximity to the construction site but not directly impacted by the construction. GT3 and HR3 wetlands were large enough that undisturbed sections (control sites) were available in the same wetland that the utility line ran through. GT2 and HR2 were narrow linear wetlands parallel to streams. We attempted to make comparisons between disturbed and undisturbed areas within the same wetland, but the dimensions of these wetlands precluded an accurate assessment of all target parameters. Therefore, control sites were established in similar wetlands at similar elevations across the stream. In the other cases (GT1, HR2, CH) construction started during the course of this project. Therefore, most comparisons were pre-disturbance versus post-disturbance. At time of the last site visit restoration has been completed at GT1 for 15 months, at HR2 for 1 week, and at CH for 1 week. Therefore, assessments for HR2 and CH are incomplete. However, one advantage to assessing GT1, HR2, and CH is it allowed us to evaluate the construction and restoration practices as they occurred.

From the beginning we had to make a critical decision to our approach in data collection. Do we assess the R.O.W. or the adjacent wetland(s)? This decision was critical to the placement of monitoring wells and groundwater sampling wells. In some cases (GT1, GT2, GT3, HR3) most of the R.O.W. was wet or a large section of the R.O.W. was wet. In several cases (HR1, HR2, and CH) the R.O.W. was at a higher elevation than an adjacent floodplain wetland located between the R.O.W. and a stream. At CH the R.O.W. ran between two wetlands. Those two wetlands are now hydrologically connected via a restored stream channel cutting through the R.O.W. Although the R.O.W. at HR1 is at a higher elevation than the floodplain it is predominately wet. In some cases we felt that impacts to the adjacent floodplain were more important than direct impacts to the R.O.W. Therefore, we hydrologically monitored the adjacent floodplain. In some cases the floodplain was long and varied considerably in width. We chose to monitor a section that we felt was most representative of the floodplain. We also had to consider potential damage to the wells during line installation and restoration. At GT2 and HR3 wells were placed in the ROW. At GT1 and GT3 wells were placed outside the ROW; we were concerned for well damage during line installation (GT1) or from post-restoration off road vehicle damage (GT3). Two wells were placed in the GT3 wetland-one hydrologically above the R.O.W., one hydrologically below the R.O.W. At HR1 and HR2 wells were placed in the adjacent floodplain. At CH wells were placed in each of the two wetland systems. Monitoring wells were also placed in control sites at GT2, HR1, and HR3. Unfortunately, wells at HR1 were vandalized, and our data set covers less than 1 year.

The R.O.W. was characterized with respect to relative elevation (surveyed), width and the length of the section through the wetland. Obvious staging areas were usually outside of the wetland and much wider than the bulk of the R.O.W. They were not included in the R.O.W. dimension calculations. Although we will use the term R.O.W. and disturbance interchangeably in this report, we did not assume they were the same when calculating disturbance width. The true R.O.W. was visually obvious save at HR3 (meadow portion) and GT2. We did soil investigations to determine if the true R.O.W. width matched the width of the disturbance area. In general they matched closely. In discussions with two of the project foremen it became apparent that they would utilize the full width of the allotted R.O.W. as a larger space saved them time and therefore money.

Plant communities were assessed by methods outlined in the 1987 USACOE Wetland Delineation Manual (Environmental Laboratory 1987). Dominant plant species were determined using 30 foot radius circular plots, aerial or ground coverage, and the 50/20 Rule. Multiple plots were used for those wetlands with multiple plant communities. To determine wetland size, delineations were conducted according to procedures presented in 1987 USACOE Wetland Delineation Manual (Environmental Laboratory, 1987) and regional supplements.

The soil in the center of each wetland was characterized by a detailed description by NRCS standards (Schoeneberger et al. 2002). Pedons were extracted with a tiling spade and bucket auger. Soils were classified according to the soil descriptions. Soil compaction (increased bulk density) was measured in the spring with a penetrometer which measures resistance to penetration by the probe. Soil redox potential (Eh) and soil pH were measured early in the growing season at a depth of 10 inches in most plots and to a depth of 4 inches in the one plot that was inundated. Soil Eh was determined with a reference electrode (Ag/AgCl), five platinum electrodes, and a voltmeter; thresholds for anaerobic conditions were determined by the equation, Eh=595-60 (pH) according to National Technical Committee for Hydric Soils. (2003). Automated monitoring wells (Remote Data Systems) were installed according to US Army Corps of Engineers' standards (USACOE, 1993) in each wetland and programmed to record water table depth daily. Two monitoring wells were installed at GT2 and HR1, one in the disturbed wetland and one in the control wetland across the stream. Three monitoring wells were installed at HR3, one each in the woods section and meadow section of the r.o.w. and one in an undisturbed section of the meadow. One well was installed at GT1 just next to the r.o.w. At HR2, CH1, and CH2 one well was installed at each site in the adjacent wetland. At GT3 two wells were installed, one north of the R.O.W., one south of the R.O.W. Two or four simple wells (slotted PVC pipe) were installed at each site to facilitate groundwater sampling for chemical analysis. Wells were installed to a depth of 40 inches if possible. In some cases shallow bedrock or a shallow gravel lens precluded well installation to the desired depth. Water samples were collected from the simple wells and analyzed for pH, inorganic nitrogen, organic phosphorous, and inorganic phosphorous (orthophosphates). Water samples were taken monthly six times a year during the months when the water table was closest to the soil surface. At some sites the water table dropped below well depths during part of the year which limited the sampling period.

Amphibians often seek cover under woody debris allowing ecologists to use artificial cover to determine the presence of some species. We focused on the mole salamanders (Family Ambystomatidae) of which three species are in our area: eastern tiger salamander (*Ambystoma tigrinum tigrinum*), marbled salamander (*A. opacum*), and spotted salamander (*A. maculatum*). We targeted that family because those species are considered to be very sensitive to environmental changes. Because eastern tiger salamanders and spotted salamanders are extremely rare, we expected marbled salamanders to be the most common and to provide the most information for comparisons between sites. Ten (12"x12"x2") cover boards were placed at each site. Boards were placed in two transects with each board 30' apart. Because of the likelihood of extensive flooding, no boards were placed at HR2. The presence of salamanders was determined monthly. Boards were lifted quickly, and all amphibians were captured and placed in holding containers for identification. Once each individual was identified, the board was returned to its original position and captured individuals were placed directly adjacent to the board to prevent damage when the board is repositioned.

RESULTS AND DISCUSSION

Wetland Classification and Hydrology Classification

Classification of these wetlands is not clear cut. Although most of them flood, most of the water is supplied via groundwater discharge from toeslope seeps. Flooding from overbank flow from an adjacent stream can be intense, however those flooding events are infrequent and of short duration. In short, the wetland hydrology criteria-a water table within 12 inches of the soil surface for 14 consecutive days during the growing season-is met because of groundwater discharge, not because of overbank flow. So these wetlands perform hydrologically like slope wetlands, not riverine wetlands. We have chosen during classification to emphasize water source but acknowledge a landscape position that facilitates flooding. So we classified several of the sites as toeslope floodplains. This is an important distinction for disturbance assessment. The most common scenario was a floodplain between a perennial stream and a R.O.W. The R.O.W. may or may not be wet. However, the principle hydrologic gradient is perpendicular to the R.O.W. If the R.O.W. is impacting hydrology of the adjacent wetland, it would be by altering groundwater discharge to the wetland. The impact of utility line installation to the hydrologic condition of the R.O.W. was more clear-cut and is noted. Based on our monitoring well data, we also classified the hydroperiods as *seasonally-saturated* (a water table at a depth <12 inches for <50 % of the time) or *permanently-saturated* (a water table at a depth <12 inches for >50 % of the time). Short periods of inundation were found at all sites; no sites were permanently inundated. We chose to emphasize to saturation because of the recognized importance of a fluctuating water table to alternating periods of aerobic and anaerobic conditions, a scenario that promotes biogeochemical services. We chose the 12 inch depth threshold because capillary rise in these loamy soils is generally 10-12 inches. Several of these wetlands were quite large. One had large sections that were seasonally saturated, other sections were permanently saturated. We concentrated on those sections closest to the R.O.W. Several of the wetlands had both emergent and forested plant communities. We focused on the plant communities most likely to be impacted by the utility line installation and R.O.W. maintenance.

General Site Descriptions

General site characteristics and site comparisons are presented in Table 1. The R.O.W. width reflects the width of direct disturbance not the maintained true R.O.W. width. Soil investigations were used to determine if the vegetation disturbance width matched the soil disturbance width. In most cases they did. The value for HR2 does not include a 10 foot access road adjacent to and west of the R.O.W. The table also indicates whether the R.O.W. was wet. The comparison column indicates the type of control used to assess disturbance impacts.

Table 1. General site characteristics and types of disturbed: control comparisons. R.O.W. refers to the area directly disturbed by utility line installation.

Site	Wetland type	R.O.W. width	R.O.W. wet?	Comparison
GT1	Mineral soil flat	25-30 ft.	Yes	Pre-disturbed vs. post-disturbed
GT2	Toeslope floodplain	10-15ft.	Yes	Disturbed wetland vs. control wetland
GT3	Mineral soil flat	15 ft.	Yes	Disturbed section vs. undisturbed section
HR1	Toeslope floodplain	15-20 ft.	Yes	Disturbed wetland vs. control wetland
HR2	Toeslope floodplain	25-35 ft.	No	Pre-disturbed vs. post-disturbed
HR3	Toeslope floodplain	20ft.	Yes	Disturbed section vs. undisturbed section
CHa	Toeslope floodplain	20 ft.	No	Pre-disturbed vs. post-disturbed
CHb	Riparian	15 ft.	Yes	Pre-disturbed vs. post-disturbed

GT1 is located in Loch Lynn Heights in Garrett County. A raised railroad bed runs SE-NW along the north side of the wetland. The wetland is south of the railroad. The adjacent area to the NE is residential and light commercial (Photos 1 and 2). A school and ball fields are located to the SE. A gas line runs along the south side. The wetland extends south of the gas line. All observations were taken from the wetland area between the gas line and the railroad; this area is ~8.2 acres. From the gas line ROW to the base of the railroad bed the elevation drops 5 feet. The Little Youghiogheny River runs along west side and under the railroad. It floods supplying water to the NW corner of the wetland. Water is also supplied by numerous seeps, primarily from the south. Water flows S to N, then impounded by the railroad bed it flows E to W. Obviously, the hydrology of the site is complex (multiple sources and pathways). However, hydrologically the site could be classified as a mineral soil flat and a floodplain. Part of the wetland floods on a regular basis; part of the wetland does not flood. With respect to hydroperiod, most of the wetland is seasonally saturated. However, the section that received the sewer line is permanently saturated (Fig. 4). Inundation is caused primarily by flooding. Inundation due to a high water table is limited to November.-March. Vegetation is primarily emergent with a well-established shrub stratum. Trees are restricted to an area adjacent to the river and a row of *Pinus strobus* along the railroad that was obviously planted. The site had a hydric soil, hydrophytic vegetation, and met the hydrology indicator ‘saturation to the soil surface.’

Photo 1. GT1, showing surrounding land use. Arrow indicates study area.

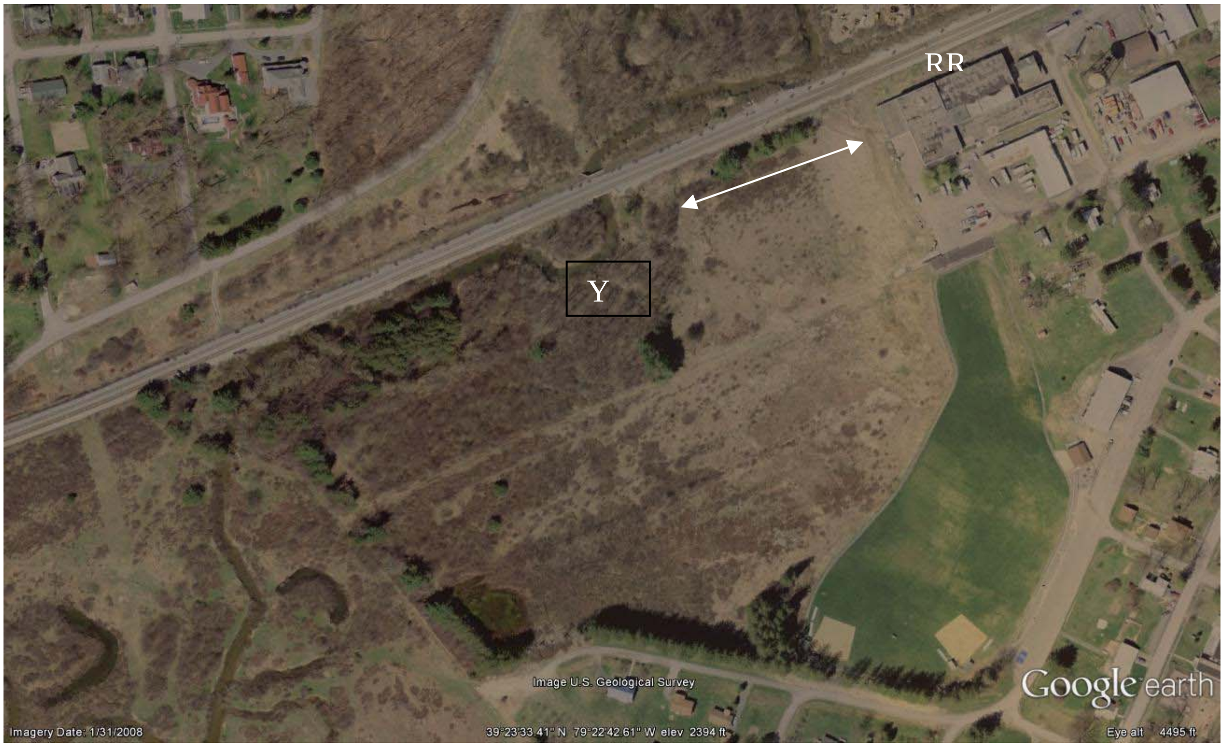


Photo 2. GT1. Arrow indicates R.O.W. The railroad (RR) and Youghiogheny River (YR) are evident.

GT2 is located in Mt. Lake Park in Garrett County. The site is bound by Rte. 135 on north side. A residential area is on the east side (Photos 3 and 4). A steep wooded slope is to the west side. The area above the slope is undeveloped. A tributary of the Little Youghiogheny River runs under Rte. 135 and splits the wetland (Photo 5) as it runs N-S through primarily residential areas. All observations were collected from a well-defined wetland (~0.34 acres) just south of Rte. 135. A narrow wetland corridor (<25 ft.) follows the stream south through primarily residential areas. We classified the wetland as a slope. Hydrology is supplied by toeslope seeps located to the NW and NE. Water flows NW and NE toward the stream. There was little evidence of overbank flow but inundation was common. The hydroperiod would be classified as permanently saturated (Fig. 5). An 8" gas line runs parallel and west of the stream. The disturbance comparison was disturbed side (west of stream) versus undisturbed side (east of stream, control). Both the disturbed plot and the control plot had a hydric soil, hydrophytic vegetation, and met the hydrology indicator 'saturation to the soil surface.'

Photo 3. GT2 showing surrounding land use. Arrow indicates study site.

Photo 4. GT2. Disturbed side (D) is to the left of the stream. Control side (C) is to the right. R.O.W. runs parallel to stream.


Photo 5. GT2. View of the R.O.W. Stream is visual to the left.

GT3 is located just north of McHenry in Garrett County. The Garrett County airport is located 1,300' to the east. The wetland is just east of Pysell Road. A low density residential area is west of Pysell Road. Most of the surrounding area is undeveloped and wooded (Photos 6 and 7). The entire wetland is buffered by woods. The wetland is much longer than wide, runs in a N-S direction, and is ~5.2 acres in size. Disturbed area (water line) runs E-W, splitting the wetland in half (Photo 7). Two significant disturbances have occurred subsequent to the water line and sewer line installation. Off road vehicular traffic has compacted and rutted the R.O.W. as well as a path running N-S, further splitting the wetland (Photo 8**)**. Therefore, the wetland has four distinct quadrants. Most of wetland is emergent but extends well into woods, esp. on E and W sides. A shallow ditch runs N-S just east of SE quadrant-flowing water. The wetland would be classified as a mineral soil flat, however there is some hydrologic input from seeps at the north end and on both the east and west sides on the north end, and groundwater runs through the wetland in a N-SE direction. The elevation in the wetland varies by 4 feet with the lowest point in the row and the highest point north of the R.O.W. Groundwater flow is also impacted by the presence of an aquitard (fragipan). Overall the wetland is seasonally saturated (Fig. 6). However ruts on the north end are inundated (1-2 inch depth) in the spring and most of the R.O.W. is permanently inundated (up to 80% of the area and up to 10 inches deep) (Photo 23). The disturbance comparison was disturbed versus undisturbed. Both the disturbed plot and the control plot had a hydric soil, hydrophytic vegetation, and met hydrology indicators 'saturation to the soil surface' (undisturbed) and 'ponding' (R.O.W.).

Photo 6. GT3, showing surrounding land use. Arrow indicates study area. Airport is visible to the right. The R.O.W. from the study site to the airport is also visible.

Photo 7. GT3. Arrow indicates R.O.W.

Photo 8. GT3. Impacts of off-road vehicular traffic are evident.

HR1 is on the Bosley Conservancy (350 acres) owned by The Izaak Walton League of America. The surrounding area is residential and commercial (Photos 9 and 10). The R.O.W. runs parallel to and south of Otter Creek (a tributary of Bush River) and north of Hanson Road in

Abingdon, Harford County. The primary wetland area is a floodplain between the row and the creek (Photo 11). Parts of the R.O.W. is wet due to compaction and backslope seeps (Photos 11 and 25. The floodplain receives water from toeslope seeps below the R.O.W., surface flow from backslope seeps located just above the R.O.W, culverts in the R.O.W. as well as overbank flow. The R.O.W. receives water from backslope seeps. The R.O.W. receives runoff but there is no indication that it receives water from overbank flow. We classified the floodplain as a toeslope wetland and the R.O.W. a backslope wetland. The floodplain hydroperiod is seasonally saturated (Fig. 7.) although it was close to meeting the threshold for permanently saturated. Wells were vandalized so we have limited data. However the period that we have well data for received close to normal rainfall. We did not have a well in the R.O.W. however our conclusion is that it is permanently saturated. A 24-inch and 36-inch sewer line was installed in a level R.O.W and. is present on a stream valley slope. Culverts were installed perpendicular to and above the sewer line to prevent hydrologic damage to the line. Some of the backslope groundwater discharge is diverted by the culverts, but the R.O.W. is still a wetland and frequently displays inundation in traffic ruts. The control site was a floodplain wetland on the other side of the stream. All three plots had a hydric soil, hydrophytic vegetation, and met the hydrology indicator ‘saturation to the soil surface.’

Photo 9. HR1, showing surrounding land use. Arrow indicates study area. The stream and R.O.W. are visible.

Photo 10. HR1 floodplain.

Photo 11. HR1. R.O.W. is in the foreground. Arrow indicates backslope seep.

HR2 is contained within the Bush Declaration Natural Resources Management Area in Edgewood, Harford County (Photos 12 and 13). Bush is bordered to the north by Route 7 and to the south by Route 40. The Bush Valley Landfill is located to the south. The surrounding area is residential and commercial (Photo 12). The R.O.W. runs parallel to a stream, Bynum Run. There are two wetland types near the R.O.W. South of the R.O.W. are several large, impounded, permanently inundated wetlands (Photo 13). A floodplain runs between the R.O.W. and the stream. We targeted the floodplain for this study. Most of the R.O.W. extending from Route 7 south until it curves east was not wet-it lacked a hydric soil. It was that section of the R.O.W. that we targeted. A section further east did have a hydric soil. However, we did observe occasional flooding of the R.O.W. near Route 7. The pre-disturbed R.O.W. had hydrophytic vegetation and parts of it showed episaturation due to compaction caused by installation of an earlier sewer line. The lack of a hydric soil indicator could be due to a lack of hydrology or the relatively young age of the soil which developed from backfill material.

The floodplain receives water from toeslope seeps as well as overbank flow. We consider it to be a toeslope floodplain. The hydroperiod is seasonally saturated (Fig. 8). The floodplain has hydrophytic vegetation and meets the hydrology indicator 'saturation to the soil surface'. It does meet a hydric soil indicator in spots. Some pedons did not meet a hydric soil indicator. This is probably due to the dynamic nature of the floodplain. This site frequently receives very high energy floods which removes the organic matter required for the formation of redoximorphic features. Drift lines are extensive and we have personally observed flooding so intense that it prevented us from reaching the plot.

Photo 12. HR2, showing surrounding land use. Arrow indicates study area.

Photo 13. HR2. Arrow indicates R.O.W. Impounded, permanently inundated wetland is obvious below the arrow. Floodplain lies between arrow and stream (Bynum Run).

Photo 14. HR2. Floodplain.

HR3 is entirely within Blakes Venture Park, a 42 acre county park in Forest Hill, Harford County (Photos 15 and 16). The park contains natural areas and ball fields. The surrounding area is primarily residential and secondarily commercial (Photo 15). The study site was a large wetland in the center of the park. It is primarily emergent (wet meadow) but extends into the woods (Photo 26). A stream, Bynum Run meanders through the wetland (Photos 17 and 18). Beaver activity has undoubtedly increased hydrologic inputs to the site. The meadow receives significant water inputs from groundwater discharge from toeslope seeps at the meadow/woods interface. Backslope seeps were also found further into the woods. The dominant soil in the woods contains an aquitard (fragipan). Groundwater readily flows on top of these fragipans until reaching a discharge site. Since the R.O.W. runs in the same direction as groundwater flow, it would not be expected to affect groundwater discharge. The hydroperiod is permanently saturated (Fig. 9, but inundation was frequent). A multi-use raised trail runs NW-SE and splits the wetland (Photo 16). The R.O.W. runs NW-SE through the woods and splits the marsh (Photo 16). All observations were taken NE of the trail, an area ~6.4 acres in size. The disturbance comparison was disturbed versus undisturbed (both in the woods and in the meadow). There were three undisturbed plots-two in the marsh, one in the woods. There were two disturbed plots-one in the marsh and one in the R.O.W. through the woods. All plots had hydric soils, hydrophytic vegetation, and met the hydrology indicator ‘saturation to the soil surface.

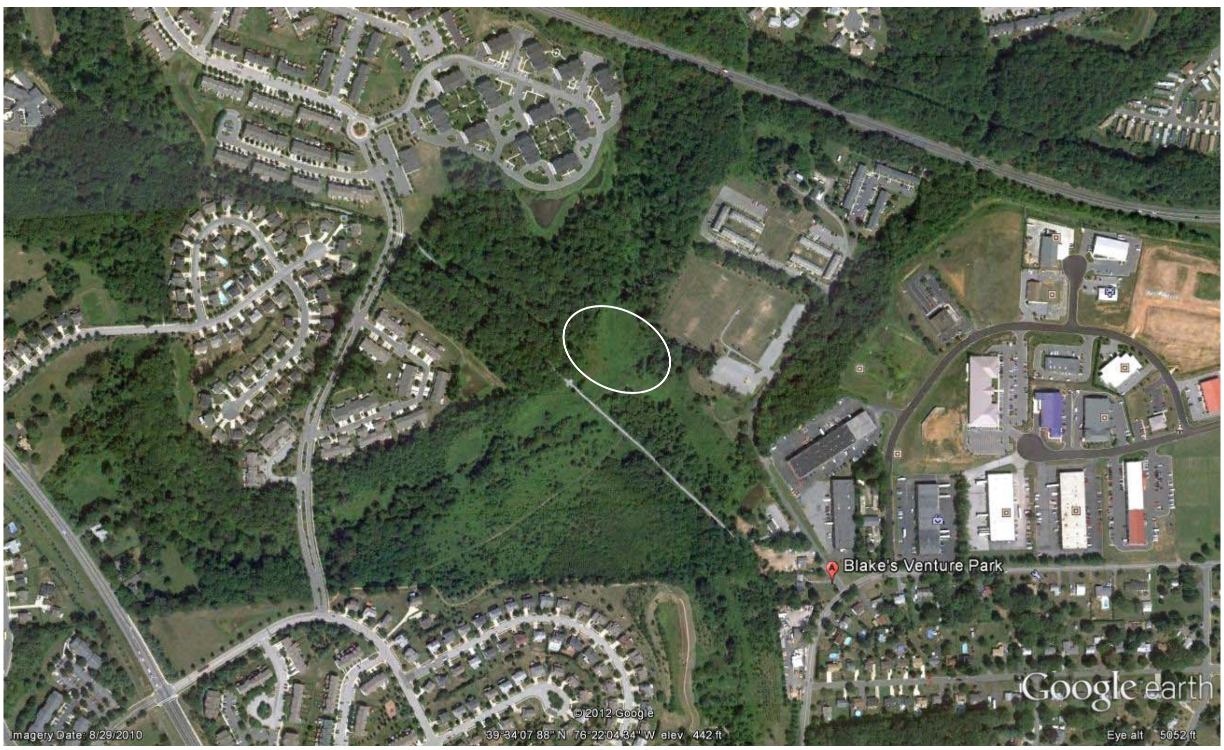


Photo 15. HR3. Oval polygon indicates study area. Raised multiuse trail in visible just below oval.

Photo 16. HR3. Study area. Arrow indicates R.O.W. A stream is visible running between the multi-use trail and the R.O.W.

Photo 17. HR3. Stream running through the wet meadow.


Photo 18. HR3. Wet meadow.

CHa and **CHb** are located just west of McDaniel Road northwest of Waldorf, Charles County (Photos 19 and 20). Most of the surrounding area is wooded and undeveloped (Photo 19). Small residential areas are present within the wooded areas. We have chosen to use the designations CHa and CHb instead of CH1 and CH2 to emphasize that these are two wetlands hydrologically connected and impacted by the same utility line. CHa is a floodplain on the south side of a stream, Piney Branch (Photos 21 and 22). Because of stream meandering and because the stream is deeply incised in sections, the entire stream corridor is not wet. Rather you have a series of wetlands separated by short stretches of uplands. The wetland section we assessed is ~0.7 acres. Its major source of water is from groundwater discharge from toeslope seeps. It also receives overbank flow. Parts receive streamflow from CHb. CHb is a riparian wetland divided by a tributary of Piney Branch (Photos 21 and 23). It is also south of Piney Branch. The R.O.W. is adjacent to the north end of CHb for a stretch of 240 feet. The CHb stream crosses the R.O.W. That section of the streambed was restored and stabilized (Photo 30). We chose to monitor that section of the floodplain (CHa) east of CHb because we thought it was more representative of the entire floodplain. The hydroperiods are classified as seasonally saturated for CHa (Fig. 10) and permanently saturated for CHb (Fig. 11). CHa receives overbank flow, CHb is frequently inundated. CHa is a toeslope floodplain. CHb receives most of its water from backslope seeps so in many ways it behaves like a slope wetland. However its water level is significantly impacted by stream flow so we are classifying it as riparian. Most of the R.O.W. is not wet (Photos 28 and 29). However the section adjacent to CHb is wet. The section adjacent to CHa is not wet

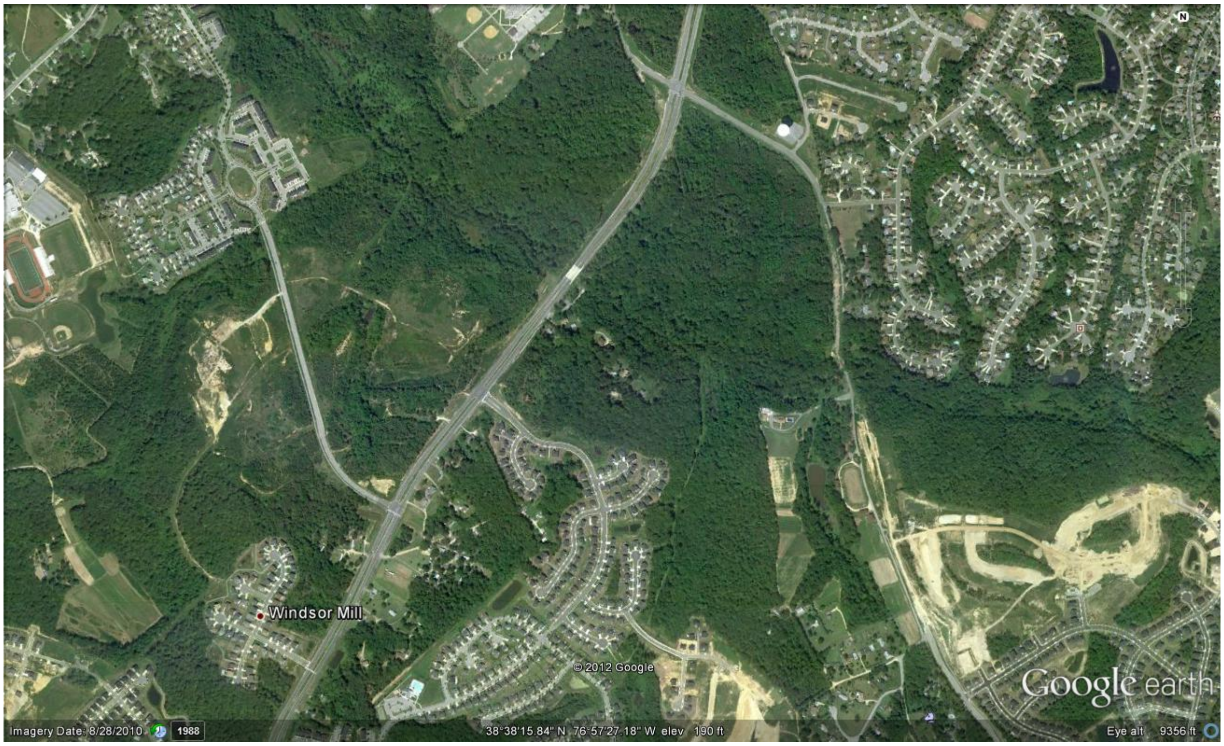


Photo 19. CH, showing surrounding land use.

Photo 20. CHa and CHb. Study area locations indicated. Arrow indicates R.O.W.


Photo 21. CHa. Floodplain. Stream is evident in the background.


Photo 22. CHb. Riparian wetland.

Description of Utility Line, Installation Techniques, and Restoration Techniques

These descriptions are based on pre-construction plans. They do not reflect our personal observations.

GT1….. A sewer line was constructed parallel to the railroad and just south of the pines during the fall of 2010 through early spring of 2011 to rehabilitate an existing sanitary sewer collection system that is over 70 years old. The authorized impact included the temporary disturbance of 17,190 square feet of emergent wetlands. It was restored (seeded) in spring 2011. The disturbance comparison was pre-disturbed versus post-disturbed. Plans describing stabilization and the size of the sewer line were lost, however, it is believed to be comparable to sewer improvements to the Mountain Lake Park system with an 8 inch line. Plans for this project required excavated material to be backfilled over the trench and compacted. The upper three inches of soil were to be raked, disced, and temporarily seeded with annual rye grass. The permanent seed mix was Kentucky 31 Tall Fescue, birdsfoot trefoil, and annual ryegrass.

GT2….An 8" gas line was installed to replace a 6" line. Disturbance: 1-gas line; 2-gas line repair. The authorized impacts were the temporary disturbance of 3000 square feet of emergent wetlands to replace steel pipeline with plastic pipeline or insertion of plastic line into the steel line. Staging areas were located outside of the wetland. The work limits were 50 feet wide through the wetland. Plans were lost for this project during the course of the study. Stabilization and restoration specifications used by the permittee as of 2011 required segregation of topsoil to be replaced back over the trench to pre-construction elevations. Standard BMPs were required in the authorization.

GT3…. Authorized impacts included the temporary disturbance of 7,520 square feet of emergent wetland to install water and 2" and 4" sewer lines to serve Garrett County Airport. The top of the encasement for the lines was at least three feet below the stream invert. Restoration techniques were to stockpile the top 12" of topsoil, and replace the material over the installed water and sewer lines to the original elevation of the wetland, and re-seed the area with a wetland seed mix. Mats were to be used to minimize disturbance from construction equipment.


Photo 23. GT3. R.O.W. is inundated. No inundation is evident to the right or left.


Photo 24. GT3, undisturbed section.

HR1. A 36 inch sewer main (Bynum Run Interceptor) was installed. Construction plans called for a construction easement of ten feet and a permanent easement of 20 feet. The total disturbed area was 2.77 acres. The authorized impacts included the temporary disturbance of 10,200 square feet of forested wetlands and 32,735 square feet of emergent wetlands. Wooden mats were used as construction platforms in wet areas. The top 6 inches of topsoil was stripped and salvaged prior to trenching. Trench depth was 16-21 feet. A sleeve of crushed stone was placed around the pipe. Backfill above the crushed stone was native soil sufficiently dry enough to achieve at least 80% compaction. The upper 6 inches of backfill was native topsoil. The top 2 inches of backfill was not compacted. The disturbed area was restored to its original grade, then seeded to annual ryegrass and mulched with small grain straw. The permanent seeding mixture was reed canarygrass, redtop, and birdsfoot trefoil.

Photo 25. HR1, R.O.W. Floodplain is downslope to the right. Seeps to the left keep the R.O.W. wet.

HR2. The authorized impacts included the temporary disturbance of 14,478 square feet or emergent nontidal wetlands for installation of a 36-inch parallel sewer. A new 42-inch diameter sewer main was installed parallel to an existing 36-inch sewer main. Depth of the trench ranged from 8 to 23 feet. The utility was installed via open-cut trench using excavators for digging and in-trench compaction equipment. A front-end loader was used to transport materials on site. A sleeve of crusher run aggregate (CR-6) was placed around the pipe. Backfill above the CR-6 was native soil sufficiently dry enough to achieve at least 85% compaction. The native wetlands soil was restored to surface of wetland areas and topsoil was restored to lawn areas. Four impervious clay dams were installed downhill from wetlands areas to keep the trench from draining wetlands. Straw matting was used for temporary restoration. Permanent restoration included restoring disturbed areas to original grades, restoring wetlands surface soils and topsoil as appropriate, seeding with annual ryegrass, millet, barley, oats, and/or rye for wetlands and wetlands buffers with straw mulch. Seed for Non-wetlands area were seeded to fescue. Construction started in August 2011; restoration was completed in October 2012 in the area of the study site. An access road west of the R.O.W. averaged 9 feet in width. The R.O.W. width varied from 25 feet to 40 feet.


Photo 26. HR2. R.O.W. prior to restoration.

Photo 27. R.O.W. after seeding.

HR3

The site contains an 8" sewer line installed prior to the 1991 implementation of State nontidal wetland regulations. A parallel 12" sewer was installed to address an overflow problem, and was installed during the early 1990's. In the mid-1990's, an 8" sewer line to serve an adjacent residential development was installed for a perpendicular connection to the line parallel to Bynum Run with a temporary impact to 2,500 square feet of emergent nontidal wetlands.

A raised board walk was installed through the wetlands circa 2000 with both permanent (3,915 square feet of emergent wetlands) and temporary impacts of 1,945 square feet of emergent wetlands. Temporary impacts associated with the boardwalk were for construction access.

The temporary road consisted on wetland mats to support equipment over a vegetated path.

Standard BMPs for the perpendicular sewer were applied.

The study area also contains a reforestation site with plantings of winterberry, elderberry, silky dogwood, green ash, and pin oak. No plantings were allowed within 20 feet of any utility. A wetland seed mix of switchgrass, redtop, Japanese millet, and annual ryegrass was used. This information was shown on plans with the 1999 authorization of the boardwalk.

Plantings were completed for a second mitigation site east of the boardwalk in 2008. Plantings consisted of red maple (*Acer rubrum)*, sweet gum (*Liquidambar styraciflua*), swamp white oak (*Quercus bicolor*), willow oak (*Q. phellos*), shadblow serviceberry (*Amelanchier canadensis)* and sweetbay magnolia (*Magnolia virginiana*).

CH. . The authorized impacts included the temporary disturbance of 40,151 square feet of emergent wetlands in a predominantly forested floodplain. A 42-inch sewer line was installed. Prior to trenching topsoil was scraped and segregated. Depth of trench-9-30 feet. A1 foot stone envelope was placed around the pipe. Native soil was backfilled and topped with native topsoil. Disturbed areas in wetlands were restored to original contours and elevations and seeded to annual rye and millet. Non-wetland areas were seeded to tall fescue and mulched with small grain straw. Stream channels through the R.O.W. were restored to the original contours and stabilized with riprap. Construction started in winter 2011, restoration was completed in fall 2012.


Photo 28. CHa and CHb. R.O.W. after leveling.


Photo 29. CHa and CHb. R.O.W. after seeding.

Photo 30. CHb. Stream flows through CHb and into CHa. Riprap used to stabilize the streambed where it crosses the R.O.W. is evident in the background.

Plant Community and Wildlife Habitat Impacts

Plant community composition is presented in Tables 2-8. Because of the recognized importance of multiple strata to wildlife habitat, each stratum was addressed individually. A stratum was recognized as established if it represented at least 5% groundcover. Strata representing <5% groundcover are presented but are not included in the calculated strata number and can't contain a dominant species. Other characteristics of interest were plant diversity (total number of species represented), number of dominant plant species as it is an indicator of homeostasis, total groundcover which impacts soil conservation and sediment transport, number of invasive species as listed by the Maryland Invasive Species Council (MISC), and presence of mast species. In addition, native species considered to be beneficial to wildlife according to Cole et al. (1996) were noted. In that publication species are assigned a wildlife beneficial rating of excellent, good, or fair.

GT1 had six plant plots including two pre-disturbed plots and four post-disturbance plots. Sewer line construction occurred in the winter and early spring of 2011. The post-disturbance 2011 plot reflects the success of the restoration seeding that year. Three post-disturbance 2012 plots reflect colonization of species from the local seed bank. Three plots were used as there were multiple plant communities. For the pre-disturbance plots there were 6-10 total species, 2-5 dominant species, and no invasive species. Plot 1 only had a shrub stratum which contained two soft mast species, *Amelanchier bartamiana* and *Viburnum recognitum*. Both plots had excellent herbaceous groundcover, 83% and 100%. The post-disturbance 2011 plot was dominated by the seeded species, *Lolium multiflorum,* and a re-colonized species, *Juncus effusus.* Total herbaceous groundcover was 84%, a high number for a newly-established stand and high enough to ensure soil conservation. Post-disturbance 2012 plots showed an encouraging increase in plant diversity, 9-12 total species per plot with no invasive species. Only one or two species were dominant. However we can expect an increase in the number of dominant species within the next several years. Total herbaceous groundcover was 63% to 87%. By all metrics re-vegetation practices were successful.

Table 2. Plant community composition for GT1. Dominant species in bold print. Native species with recognized benefit to wildlife are designated with E (excellent), G (good), or F (fair).		
Pre-disturbed Plot 1	Pre-disturbed Plot 2	Post-disturbed 2011
Shrub		
Total: 12%		
Viburnum recognitum		
Amelanchier bartamiana E		
Herbaceous		
Total: 100%	Total: 83%	Total: 84%
Holcus lanatus	***Juncus effusus***	***Lolium multiflorum***
Solidago rugosa	***Phalaris arundinacea***	***Juncus effusus***
Solidago graminifolia	*Asclepias incarnata*	
Hypericum densiflorum	*Carex frankii* E	
Viburnurnum recognitum	*Carex tribuloides* E	
Scirpus cyperinus	*Carex stricta* E	
Carex tribuloides E		
Scirpus atrovirens		
Post-disturbed 2012 Plot 1	Post-disturbed 2012 Plot 2	Post-disturbed 2012 Plot 3
Herbaceous		
Total: 82%	Total: 63%	Total: 87%
Juncus effuses	***Plantago lanceolata***	***Juncus effusus***
Phalaris arundinacea	***Juncus effusus***	*Phalaris arundinacea*
Scirpus atrovirens	*Anthoxanthum odoratum*	*Carex frankii* E
Solidago graminifolia	*Carex tribuloides* E	*Carex tribuloides* E
Carex tribuloides E	*Trifolium repens*	*Carex stricta* E
Solidago rugosa	*Solidago graminifolia*	*Asclepias incarnate*
Verbena hastate	*Carex frankii* E	*Anthoxanthum odoratum*
Carex stricta E	*Eleocharis sp.*	*Eleocharis sp.*
Anthoxanthum odoratum	*Lolium multiflorum*	*Cicuta maculate*
Eleocharis sp.	*Solidago rugosa*	
Cicuta maculate		
Trifolium repens		


Photo 31. GT1, R.O.W., one year after restoration.


Photo 32. GT1, R.O.W, 18 months after restoration.

GT2 had four plots reflecting two plant communities in both the disturbed side and control side. Control Plot 1 and Disturbed Plot 1 had similar plant communities, both restricted to one stratum (herbaceous)) with 100% groundcover. Disturbed Plot 1 had 10 total species and 4 dominant species; Control Plot 1 had 10 total species and 2 dominant species. Seven species were common to both plots and there were no invasive species. Control Plot 2 and Disturbed Plot 2 each had a shrub stratum and little plant diversity resulting from shading by the dominant shrub species, *Alnus rugosa*, and the dominant herbaceous species, *Symplocarpus foetidus.* By all metrics, re-vegetation efforts at this site were successful.

Table 3. Plant community composition for GT2. Dominant species in bold print. Native species with recognized benefit to wildlife are designated with E (excellent), G (good), or F (fair).	
Control Plot 1	Disturbed Plot 1
Herbaceous	
Total: 100%	Total: 100%
Phalaris arundinacea	***Carex stricta*** E
Leersia oryzoides	***Phalaris arundinacea***
Typha latifolia G	***Onoclea sensibilis***
Scirpus atrovirens	***Solidago graminifolia***
Dipsacus sylvestris	*Solidago graminifolia*
Juncus effuses	*Dipsacus sylvestris*
Carex stricta E	*Scirpus atrovirens*
Verbena hastate	*Typha latifolia* G
Impatiens capensis	*Juncus effusus*
Solidago graminifolia	*Veronica noveboracensis*
Control Plot 2	Disturbed Plot 2
Shrub	
Total: 62%	Total: 50%
Alnus rugosa	***Alnus rugosa***
Sambucus canadensis E	
Herbaceous	
Total: 33%	Total: 25%
Symplocarpus foetidus	***Symplocarpus foetidus***
Impatiens capensis	

GT3 had three plots, two undisturbed and one disturbed. Most of the wetland was emergent but it extended into the woods. Vegetation in the r.o.w. was similar in the woods and in the meadow. Therefore, one disturbed plot was used. The undisturbed woods had 4 strata, 6 species, 3 dominant species and multiple hard mast (*Pinus strobus*, *Picea abies*) and soft mast (*Rubus hibiscus*, *Prunus serotina*, *Rubus hibiscus*) species. *Picea abies* was obviously planted and arranged in rows. The undisturbed meadow had only a herbaceous stratum, 9 total species, 3 dominant species, two soft mast species (*Rubus hibiscus*, *Amelanchier bartamiana*), and >100% groundcover. The disturbed area had 4 species (all herbaceous), 3 dominant species, and no mast species. Groundcover was only 35% as there were extensive non-vegetated areas. There were no invasive species in any of the plots. This site represents a failure in re-vegetation efforts in both a soil conservation standpoint and a wildlife habitat standpoint. My conclusion is that the failure is due primarily to vehicular traffic and does not necessarily reflect the original re-vegetation efforts.

Table 4. .Plant community composition for GT3. Dominant species in bold print. Native species with recognized benefit to wildlife are designated with E (excellent), G (good), or F (fair).		
Undisturbed woods	Undisturbed meadow	Disturbed area
Tree		
Total 60%		
Acer rubrum G		
Picea abies		
Pinus strobus E		
Prunus serotina E		
Sapling		
Total 35%	Total 3%	
Acer rubrum G	*Acer rubrum* G	
	Amelanchier bartamiana E	
Shrub		
Total 5%		
Vaccinium corymbosum E		
Herbaceous		
Total 42%	Total 120%	Total 35%
Vaccinium corymbosum E	***Rubus hispidus*** E	***Phalaris arundinacea***
Rubus hispidus E	***Phalaris arundinacea***	***Juncus effusus***
	Solidago graminifolia	***Echinoclea walteri***
	Solidago caesia	*Scirpus atrovirens*
	Solidago rugosa	
	Juncus effusus	
	Cicuta maculate	

HR1 had three vegetation plots; one in the R.O.W., one in the wetland between the R.O.W. and the stream, and a control wetland on the other side of the stream. The control plot had 4 strata, 10 species, 7 dominant species, 1 invasive (*Rosa multiflora*), and 4 soft mast species. The wetland plot next to the R.O.W. had 4 strata, 12 species, 8 dominant species, 2 invasive species (*Rosa multiflora, Lonicera japonica*), and 4 soft mast species. There were 10 species common to the two plots. Based on this comparison I conclude that the utility line construction had no long-term impact on the adjacent wetland. The R.O.W. plot was entirely emergent with 11 species, 2 dominant species, 2 invasive species, and 3 soft mast species (*Polygonum spp.*). It had excellent total groundcover (88%), however, the most dominant species was an invasive (*Microstegium vimineum*). This does not represent a successful re-vegetation effort.

Table 5. Plant community composition for HR1. Dominant species in bold print. * indicates an invasive species of concern by MISC. Native species with recognized benefit to wildlife are designated with E (excellent), G (good), or F (fair).		
Control	Adjacent to R.O.W.	R.O.W.
Trees		
Total: 63%	Total: 65%	
Liquidambar styraciflua F	***Betula nigra***	
Acer rubrum G	***Liquidambar styraciflua*** F	
Betula nigra	***Plantatus occidentalis*** F	
Plantatus occidentalis F	*Acer rubrum* G	
	Liriodendron tulipifera F	
Saplings		
Total: 16%	Total: 22%	
Acer negundo	***Acer negundo***	
Fraxinus pennsylvanica E	***Acer rubrum*** G	
Acer rubrum G	*Fraxinus pennsylvanica* E	
Shrubs		
Total: 34%	Total: 30%	
Lindera benzoin F	***Lindera benzoin*** F	
Acer negundo	***Acer negundo***	
	*Rosa multiflora**	
Woody vine		
	Total: 2%	
	Toxicodendron radicans E	
Herbaceous		
Total: 24%	Total: 10%	Total: 88%
Boehmeria cylindrica	***Toxicodendron radicans*** E	***Microstegium vimineum*** *
Toxicodendron radicans E	***Lindera benzoin*** F	***Cinna arundinarea***
Acer negundo	***Lonicera japonica*** *	*Scirpus atrovirens*
Rosa multiflora *	*Boehmeria cylindrical*	*Aster pilosus*
	Acer negundo	*Boehmeria cylindrical*
		Polygonum cespitosum
		Polygonum sagittatum
		Polygonum perfoliatum *
		Polygonum hydropiperoides
		Impatiens capensis
		Onoclea sensibilis

HR2 had three vegetation plots; a pre-disturbed R.O.W., a post-disturbed R.O.W.., and an adjacent wetland between the R.O.W. and the stream. Assessment of this site is difficult because a sewer line was installed previously. This year the old line is being removed and replaced with a new line. Therefore the ‘pre-disturbed’ plot reflects impacts from the first line. At this time construction of the second line has not been completed so no post-disturbance plant community assessment is available. The adjacent wetland had 4 strata, 20 species, 5 dominant species, 4 invasive species, and 72% groundcover. That level of groundcover is impressive for a very dynamic floodplain; however the presence of 4 invasive species is not encouraging. It is not

possible to assess if the presence of the invasives is due to the original line; the presence of *Festuca rubra* is probably due to the original restoration efforts. The R.O.W. has only emergent vegetation, 13 species, 3 dominant species, 4 invasive species, and 90% groundcover. There were 4 soft mast species, but three were invasives.

Table 6. Plant community composition for HR2. Dominant species in bold print. * indicates an invasive species of concern by MISC. Native species with recognized benefit to wildlife are designated with E (excellent), G (good), or F (fair).

Undisturbed, adjacent	Pre-disturbed row	Post-disturbed row
	Tree	
Total: 40%		
Acer negundo		
	Sapling	
Total: 9%		
Acer negundo		
	Shrub	
Total: 15%		
Lindera benzoin F		
Faxinus pennsylvanica E		
Acer negundo		
	Herbaceous	
Total: 72%	Total: 90%	
Lysimachia nummularia	***Polygonum cespitosum***	
Pilea pumila	***Microstegium vimineum*** *	
Boehmeria cylindrical	***Phalaris arundinacea***	
Hemerocallis fulva	*Sicyos angulatus*	
Festuca rubra	*Polygonum cuspidatum* *	
Boehmeria cylindrical	*Actinomeris alternifolia*	
Hemerocallis fulva *	*Rosa multiflora* *	
Urtica dioica	*Boehmeria cylindrical*	
Symplocarpus foetidus	*Impatiens capensis*	
Microstegium vimineum *	*Galium tinctorium*	
Polygonum perfoliatum *	*Erechtites hieracifolia*	
Polygonum cuspidatum *	*Rumex obtusifolius*	
Polygonum sagittatum	*Polygonum perfoliatum* *	
Rosa multiflora *		
Polygonum hydropiper		
Polygonum cespitosum		
Impatiens capensis		

HR3 had five vegetation plots. The wetland was predominately wet meadow but extended well into woods. The R.O.W. goes through the woods and the meadow. Vegetation in the R.O.W. was significantly different in the woods section than in the meadow section. In addition, there were two distinct plant communities in undisturbed portions of the meadow. Undisturbed meadow Plot 1 had 11 species (all emergent), 4 dominant species, and 98% groundcover. Only one species (*Microstegium vimineum*) is considered invasive by M.I.S.C.;

however, *Arthraxon hispidus* was dominant and is banned in Connecticut and prohibited in Massachussetts as a potentially invasive species. Undisturbed meadow Plot 2 had 11 species (mostly emergent), 2 dominant species, and 100% groundcover. One invasive was present (*Microstegium vimineum*), as was *Arthraxon hispidus*. *Ilex verticillata* was present in the shrub stratum. The disturbed meadow plot had 8 species (all emergent), 3 dominant species including *Arthraxon hispidus*, and 98% groundcover. Interestingly, *Microstegium vimineum* was not present in the disturbed plot. The undisturbed woods plot had 4 strata, 7 species, 5 dominant species, a valued hard mast species (*Quercus alba*), two soft mast species (*Viburnum recognitum*, *Smilax rotundifolia*), and no invasive species. The R.O.W. woods plot was entirely emergent with 10 species, 1 dominant species, and 98% groundcover. There were two invasive species (*Microstegium vimineum* , dominant, and *Rosa multiflora*). In addition, just outside of the wetland *Phragmittes australis* was dominant in the R.O.W.

Table 7. Plant community composition for HR3. Dominant species in bold print. * indicates an Invasive species of concern by MISC. Native species with recognized benefit to wildlife are designated with E (excellent), G (good), or F (fair).

Undisturbed meadow 1	Undisturbed meadow 2	Disturbed meadow
	Shrub	
	1% *Ilex verticillata*	
Total 98%	Total 100%	Total 99%
Microstegium vimineum *	***Microstegium vimineum*** *	***Arthraxon hispidus***
Leersia oryzoides G	***Erechtites hieracifolia***	***Juncus effusus***
Arthraxon hispidus	*Arthraxon hispidus*	***Leersia oryzoides*** G
Polygonum sagittatum	*Leersia oryzoides* G	*Cinna arundinacea*
Impatiens capensis	*Scirpus cyperinus*	*Solidago graminifolia*
Juncus effuses	*Polygonum sagittatum*	*Polygonum sagittatum*
Scirpus cyperinus	*Juncus effuses*	*Verbena hastate*
Verbena hastate	*Impatiens capensis*	*Cyperus strigosus*
Solidago rugosa	*Verbena hastate*	
Solidago graminifolia	*Solidago graminifolia*	
Erechtites hieracifolia	*Solidago rugosa*	
Undisturbed woods	R.O.W. through woods	
	Tree	
Total 55%		
Quercus alba E		
Acer rubrum G		
Nyssa sylvatica E		
Liriodendron tulipifera F		
	Sapling	
Total 15%		
Nyssa sylvatica E		
	Shrub	
Total 10%		

Viburnum recognitum		
	Woody vines	
Total 1%	Total 1%	
Smilax rotundifolia E	*Rubus sp.*	
	Herbaceous	
Total 15%	Total 98%	
Thelypteris noveboracensis	***Microstegium vimineum*** *	
Nyssa sylvatica E	*Solidago graminifolia*	
	Solidago rugosa	
	Juncus effuses	
	Polygonum sagittatum	
	Cyperus strigosus	
	Rosa multiflora *	
	Cinna arundinacea	
	Impatiens capensis	
	Onoclea sensibilis	

CH had three plots: a pre-disturbed R.O.W., CHa a floodplain between the R.O.W. and Piney Branch, and CHb a riparian wetland divided by a tributary of Piney Branch. The R.O.W. is adjacent to the north end of CHb. At the last field visit (10/24/12) the R.O.W. had been recently seeded and *Lolium multiflorum* was just getting established. Trees had been planted adjacent to the stream crossing the R.O.W . The pre-disturbance R.O.W had two strata (tree and herb), 9 species, 3 dominant species, and 75% herbaceous groundcover. There was one invasive species- *Microstegium vimineum*. CHa had two strata (tree and herb), 10 species, 3 dominant species, and 70% groundcover. There were two invasive species including a dominant species (*Microstegium vimineum*). CHb was emergent in the center, with a ring of saplings just upslope (but still in the wetland, and a ring of trees just outside the ring of saplings. *Microstegium vimineum* was a dominant invasive.

Table 8. Plant community composition for CHa and CHb. Dominant species in bold print. * indicates an invasive species of concern by MISC. Native species with recognized benefit to wildlife are designated with E (excellent), G (good), or F (fair).

CHa floodplain	Pre-disturbed R.O.W.	CHb riparian
	Tree	
Total 50%	Total 50%	Total 5%
Acer rubrum G	***Platanus occidentalis*** F	***Acer rubrum*** G
Fagus grandifolia E	***Fagus grandifolia*** E	*Platanus occidentalis* F
Liquidambar styraciflua F	*Liquidambar styraciflua* F	
Quercus falcata E	*Betula nigra*	
	Acer rubrum G	
	Sapling	
Total 0%	Total 0%	Total 6%
		Platanus occidentalis F
		Acer rubrum G

	Shrub	
Total 0%	Total 0%	Total 1%
		Cephalanthus occidentalis G
		Sambucus canadensis E
	Vine	
Total 0%	Total 0%	Total <1%
		Rubus sp.
	Herb	
Total 70%	Total 75%	Total 100%
Microstegium vimineum *	***Microstegium vimineum*** *	***Microstegium vimineum*** *
Lindera benzoin F	*Boehmeria cylindrical*	*Polygonum sagittatum*
Fagus grandifolia E	*Solidago graminifolia*	*Scirpus cyperinus*
Dicanthelium clandestinum	*Fagus grandifolia* E	*Juncus effusus*
Cinna arundinarea	*Setaria faberi*	*Boehmeria cylindrica*
Murdannia keisak		*Pilea pumila*
Juncus effuses		*Urtica dioica*

Salamanders: Only one individual of the Ambystomatidae Family was found-a spotted salamander (*Ambystoma maculatum*) along the edge of the R.O.W.in the woods at HR3. Eastern red-backed salamanders (*Plethodon cinereus*) were common at GT3. No other salamanders were found there. None were found at GT1 or GT2. Two northern dusky salamanders (*Desmognalthus fuscus*) were found at CHa. One eastern red-backed salamander was found at CHb outside of the wetland and in the undisturbed section of the woods at HR3. Obviously, from such a small sample size we can't draw conclusions. The scarcity of salamanders was surprising. It may be that flood events at some of the sites are too severe to be good habitat.

Soil Impacts

Soil classifications for undisturbed areas are presented in Table 9. Identification of soils in undisturbed areas gives us insight into the nature of the soils in the R.O.W. prior to disturbance as long as the R.O.W. and undisturbed area occupy similar landscape positions and experience similar hydrologic conditions. No attempt was made to classify the R.O.W. soils as they are so young they are not in equilibrium with the environment. Classifications were based initially on the map units in the soil survey and then verified or refuted by on-site pedon descriptions. In most case, the pedons matched soil series described in the map units. There were two discrepancies. At GT1 most of the wetland had soils that matched the series Atkins. However, the soil in the area adjacent to the R.O.W. did not match a series, it had a much thicker A horizon (topsoil) due to near continuous saturation. At CHb the wettest part of the wetland had soils similar to the series Lenni. The match was not perfect, but most of the critical characteristics were close enough that we have chosen to use the Lenni tag.

Table 9. Soil classifications in undisturbed areas at the wetland sites. Dominant series in bold lettering.

Site	Series	Taxon (great group)	Drain.class	Textural class
GT1, GT2	**Atkins silt loam**	Fluvaquentic Endoaquepts	PD	Fine-loamy
GT1	None	Fluvaquentic Humaquepts	PD	Coarse-loamy

GT3	**Nolo silt loam**	Typic Fragiaquults	PD	Fine-loamy
HR1, HR2, HR3	**Hatboro silt loam**	Fluvaquentic Endoaquepts	PD	Fine-loamy
HR3	Glenville	Aquic Fragiudults	SPD	Fine-loamy
CHa, CHb	**Potobac**	Fluvaquentic Endoaquepts	PD	Coarse-loamy
CHa, CHb	Issue	Fluvaquentic Dystrudepts	SPD	Coarse-loamy
CHb	Lenni	Typic Endoaquults	PD	Fine

Drainage class: PD=poorly drained, SPD=somewhat poorly drained

Soil series identification also helps us characterize the sites hydrologically. Nolo and Glenville have fragipans, a type of aquitard. Groundwater will flow laterally above the fragipan and discharge downslope. All the series save Glenville and Issue are hydric. They are somewhat poorly drained and gradually interface with hydric soils. Glenville is found in the woods at HR3 just upslope from the wetland. Issue is found adjacent to Potobac on terraces and drier sections of the floodplain at CH.

Table 10 presents characteristics of surface horizons, A horizons (topsoil), and O (organic horizons for the sites. The table is redundant in cases where the surface horizon is an A horizon. In an undisturbed soil the surface horizon would be an O or an A. In very wet soils a thick O would be found directly above an A. The presence of a horizon other than an O or A at the surface indicates disturbance. O and A horizons are important in that they supply carbon essential to nutrient cycling and provide a quality seedbed for re-vegetation efforts. Restoration efforts should include the application of topsoil as the top layer of soil. O horizons will form in the disturbed soil if they were present in the pre-disturbed soil and post-disturbance hydrology is as wet or wetter than pre-disturbance hydrology. Surface O horizons were found at GT1 and GT2 in undisturbed plots. It is not unusual to find O horizons lacking in these floodplain soils. Buried O horizons were found at HR2 (undisturbed) and HR1 (disturbed). The former burial resulted from natural deposition common to floodplains. The latter resulted from backfilling with subsoil on top of the O (and A horizon). Soils lacking surface O or A horizons were found at GT1, GT3, and HR1; all in the R.O.W.

Table 10.Texture, structure, and depths (inches) for select soil horizons.								
		Horizons						
Site	Plot	Surface			A			O
		Desig.	Text.	Struct.	Depths	Text.	Struct.	Depths
GT1	Undist. 1, R.O.W.	Oi	M	-	0.5-37	SiL	2,m gr.	0-0.5
GT1	Undist. 2	Oe	MP	-.	1-10	SiL	2,m gr.	0-1
GT1	Dist. R.O.W.	C	SiL	1,m gr.	2.5-12	SiL	2,m gr.	-
GT2	Undist. 1	A	MSiL	1,f gr.	0-2	MSiL	1,f gr.	10-15
GT2	Undist. 2	Oe	MP	-	2.5-4.5	MSiL	1,m gr.	0-2.5
GT2	Dist. R.O.W.	A	MSiL	1,f gr.	0-0.5	MSiL	1,f gr.	-
GT3	Undist.	Ap	SiL	2,m gr.	0-5	SiL	2,m gr.	-
GT3	Dist. R.O.W.	CB	SiL	3,c pl.	4-7	L	2,m sab.	-
HR1	Undist. 1	A	MSiL	1,f gr.	0-1	MSiL	1,f gr.	-
HR1	Undist. 2	Ap	L	2,m gr.	0-2	L	2,m gr.	-
HR1	Dist. R.O.W.	CB	SL	3,c pl.	22-30	SiL	Massive	22-30
HR2	Undist. 1	A	SiL	3,c pl.	0-2	SiL	3,c pl.	48-53
HR2	Undist. 2	A	L	2,m gr.	0-2.5	L	2,m gr.	-
HR2	Dist. R.O.W.	A	L	1,m sbk.	0-8	L	2,m sbk.	
HR3	Undist. MDW	A	SiL	3, m gr.	0-6	SiL	3, m gr.	-
HR3	Undist. WDS	A	SiL	2,m gr.	0-0.5	SiL	2,m gr.	-
HR3	Dist. MDW, R.O.W.	A	MSiL	2,f gr.	0-4	MSiL	2,f gr.	-
HR3	Dist. WDS, R.O.W.	A	SiL	2,m gr.	0-4	SiL	2,m gr.	-
CHa	Undist,	A	SiL	2, m gr.	0-6	SiL	2, m gr.	-
CHb	Undist.	Oi	M	-	0.5-3	MSiL	1,f gr.	0-0.5
CH	Dist. R.O.W.	BC	GrSL	1&2, f&m sbk	-	-	-	-

Texture: M=muck, MP=mucky peat, SiL=silt loam, MSiL=mucky silt loam, L=loam, SL=sandy loam, GR=gravelly. Structure: strength, size, shape. Strength: 1=weak, 2=moderate, 3=strong. Size: f=fine, m=medium, c=coarse. Shape: gr.=granular, pl.=platy, sab.=subangular blocky. Massive structure is not assigned a size or strength.

There are three very different examples to note. Both pertain to R.O.W.s assessed soon after restoration seeding. The HR2 R.O.W. had an excellent seedbed. The A horizon was 8 inches thick starting at the surface. It had sub-angular blocky structure, which is not ideal but the structure was weak. We can expect granular structure to form over time. The CH R.O.W. was high in gravel, high enough that we could not get a spade deeper than 6 inches. So we do not know what the soil is like below that surface layer. The surface layer is subsoil, B and C material) with a gravelly sandy loam texture. This seedbed is not favorable to seedling establishment or soil conservation. At GT1 a thick A horizon was buried by 2.5 inches of C material. Again, while not ideal, the system will work if the plant roots can quickly get down to the A horizon. Fortunately, seeding was successful, and one year after seeding the groundcover was excellent and non-planted species were getting established. We expect this restoration to be successful.

Soil structure results from forces applied to the soil. These forces include freezing and thawing, wetting and drying, vehicular traffic, and flooding. The types and depths that specific soil structure types are found reflect the types of forces imposed. Freezing and thawing, and wetting and drying tend to apply uniform pressure to a soil horizon resulting in granular (rounded) or subangular blocky structural units. High organic matter content promotes granular structure; high clay content promotes subangular blocky structure. Pressure applied downward to the soil promotes platy structure. Plowing produces plates at depths of 4-10 inches. Heavy equipment traffic or inundation produces plates starting at or close to the soil surface. The lower the organic matter content in the soil, the stronger (more rigid) the plates. Plates can impede root growth and infiltration-resulting in episaturation, more runoff, and a decrease in groundwater recharge capacity. Granular structure promotes root growth and infiltration.

Penetrometers measure resistance by soil horizons to penetration. It is an indirect measurement of bulk density (soil dry weight per unit volume). The higher the resistance, the higher the bulk density, and the greater the compaction. High bulk density can restrict root growth, and restrict air and water movement in the soil which can impede biogeochemical cycling. Measurements were taken when the soil was saturated to reduce variability. Resistance (but not bulk density) increases as the soil dries. Therefore, the values presented represent the lowest resistance values. Values presented below reflect the average or range of five individual readings. In some cases there was extensive spatial variability (e.g. HR1) so multiple locations are presented individually. Since bulk density may not be uniform within a horizon a range in resistance is given. For example, from 8-16 inches resistance varied from 70-120. At resistance exceeding values of 200 it often became difficult to push the probe any deeper. We recorded that as *refusal*. Usually we can tell if the probe is hitting a rock. Some compaction is natural and results from the accumulation of clay at depths commonly in the range of 8-12 inches. Resistance approaching 200 in the upper foot is most likely due to construction and vehicular traffic; it can impede root growth of herbaceous plants and cause perching of water. Therefore it can change the hydrology from an endosaturated condition to an episaturated condition. This has implications with respect to biogeochemical cycling.

At CHa and CHb near-surface gravel prevented us from inserting the probe deeper than 3 inches. Therefore, we have no post-disturbance readings. HR1 had significant spatial variability. In some spots refusal occurred at a depth of 17 inches, in other spots it was as shallow as 4 inches. The post-disturbed R.O.W. at HR2 was an excellent seedbed with resistance values 60-150 in the upper 17 inches. At HR3 both the disturbed meadow and disturbed woods had compaction; it was worst in the woods. The post-disturbed R.O.W. at GT1 was also an excellent seedbed with no compaction. The R.O.W. at GT2 had resistance values no higher than 120 in the upper 24 inches. Shallow compaction in the R.O.W. at GT3 was so severe that it caused permanent inundation (Photo 23). We feel that this compaction is most likely due to off-road vehicular traffic.

Table 11. Impact of disturbance on soil compaction.					
		Undisturbed		Disturbed	
Site	Comparison	Depth	Resistance	Depth	Resistance
		inches	lbs/sq. in.	inches	lbs/sq. in.
CHa	Pre-dist. vs. post-dist.	0-22	70-120		
		22+	180		
CHb	Pre-dist. vs. post-dist.	0-27	<80		
HR1 #1	R.O.W. vs. control	0-27	50-110	0-17	80-150
				17	Refusal
HR1 #2	R.O.W. vs. control			0-4	120-150
				4	Refusal
HR2 #1	R.O.W. vs. control	0-3	40-100	0-27	60-120
		3-6	100-190		
		6-27	180-220		
HR2 #2	R.O.W. vs. control			0-17	80-150
				17-27	180-200
HR3, woods	R.O.W. vs. control	0-16	60-120	0-4	200
		16-27	180-200	4-6	60-120
				6-27	120-200
HR3, meadow	R.O.W. vs. control	0-27	40-90	0-10	60-100
				10-27	175-200
GT1, R.O.W.	Pre-dist. vs. post-dist.	0-14	10-20	0-27	80-110
		14-24	90-110		
GT2	R.O.W. vs. control	0-8	45-50	0-13	40-70
		8-10	100	13-24	80-120
		10-24	60-70	24-27	180
GT3 #1	R.O.W. vs. control	0-10	50-60	0-7	80-100
		10-13	70-80	7-11	185-205
		13-27	60-70	11-27	85-120
GT3 #2	R.O.W. vs. control			0-8	85-110
				8	Refusal

Photo 33. GT1. Soil from restored R.O.W. Topsoil was clearly buried.

Photo 34. HR1. Spade slices from R.O.W. show variability in the soils.

Photo 35. HR2. Soil from post-seeded R.O.W. Brown colors indicating organic matter and granular structure are characteristics of a good seedbed.

Hydrology Impacts

Long-term precipitation averages and rainfall data during the course of this project are presented in Table 12 and Figures 1-3. Of particular note, from November 2010 to July 2012, Harford County had only one month with average or above average precipitation. It was an extraordinarily dry period. Garrett County had close to normal precipitation patterns. Charles County had large fluctuations in monthly precipitation; but when viewed in six month blocks, precipitation was close to normal but somewhat drier in 2012.

Table 12. 30-year precipitation averages.

Month	Harford Co.	Garrett Co.	Charles Co.
January	3.06	3.53	3.41
February	2.46	3.20	2.72
March	3.67	3.97	3.92
April	3.50	4.07	3.41
May	4.52	4.90	4.57
June	3.98	4.64	3.60
July	4.01	4.96	4.01
August	3.98	4.15	3.71
September	3.92	3.60	4.31
October	3.53	3.06	3.63
November	3.12	3.65	3.32
December	3.21	3.64	3.34
Total	42.95	47.37	43.94

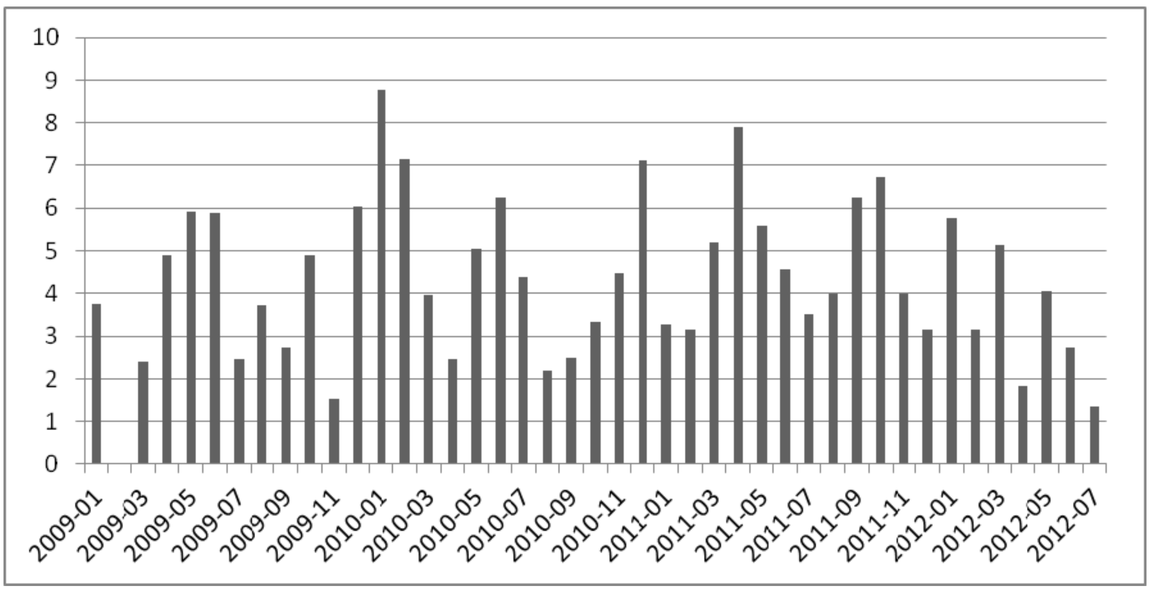


Fig. 1. Monthly precipitation data (inches) for Garrett Co.

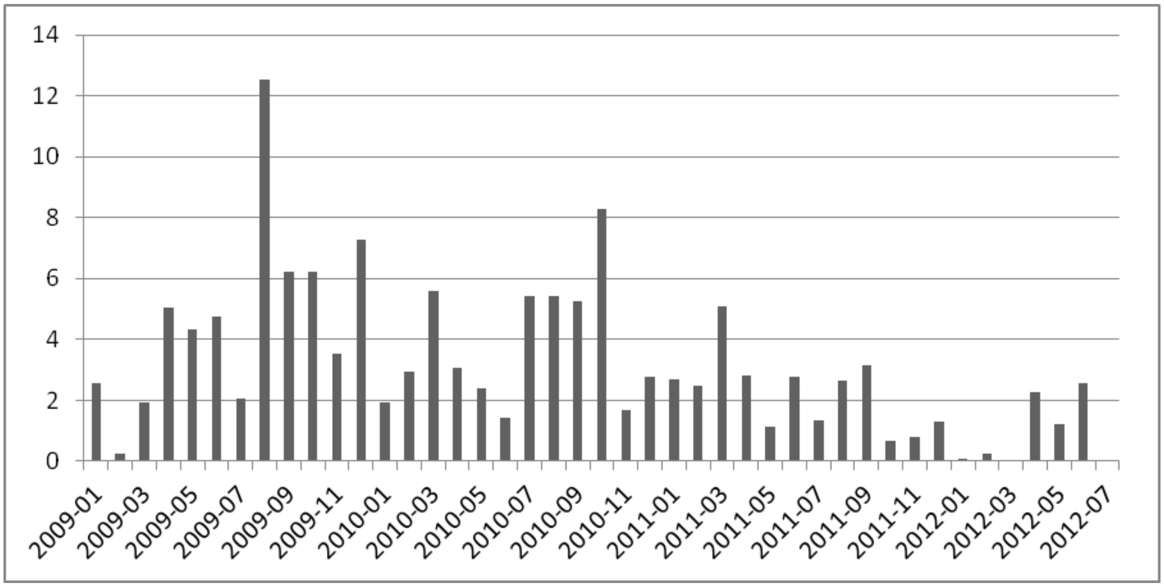


Fig. 2. Monthly precipitation data (inches) for Harford County.

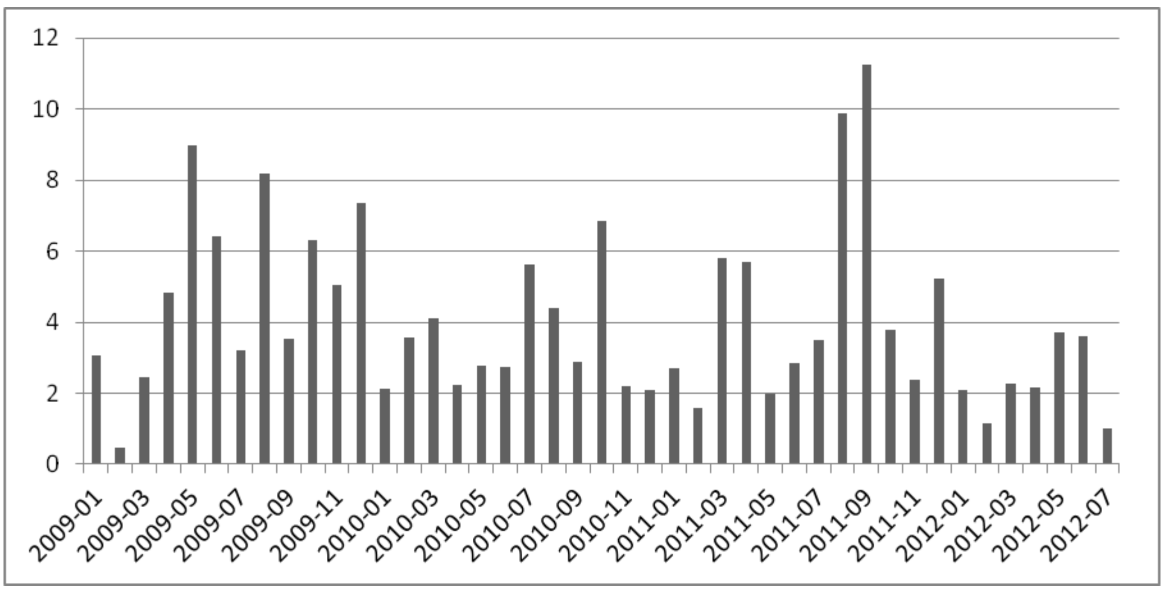
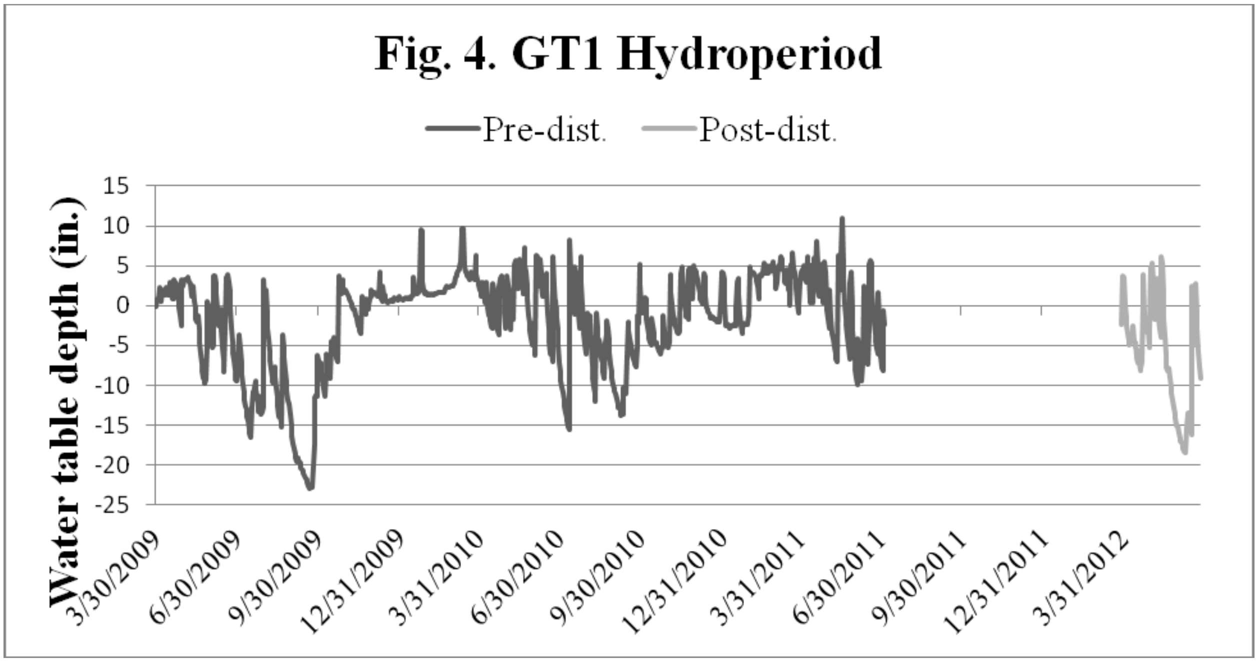


Fig. 3. Monthly precipitation data (inches) for Charles County.

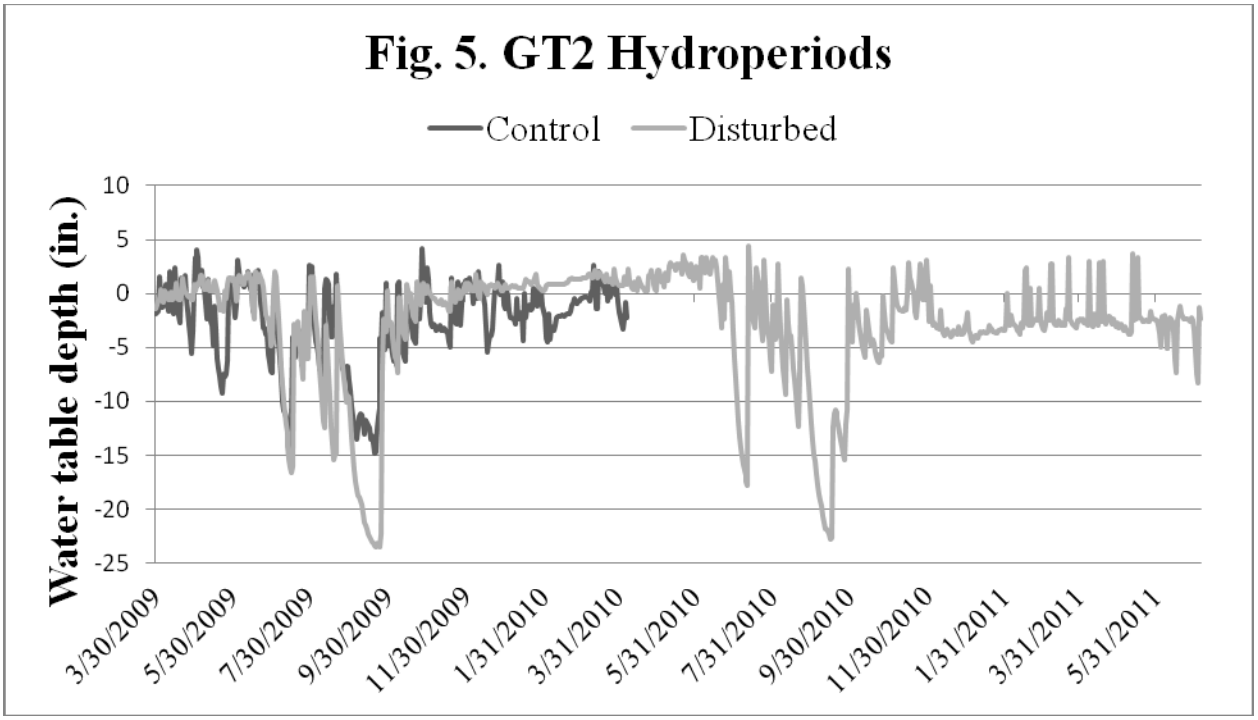
To maximize available resources we had to make choices with respect to the number of monitoring wells per site as well as the placement of wells in each site. In some cases we had to pull a well from one site and re-install it at another site. One well failed, two were vandalized. However, we are confident that in most cases we have enough data to make solid conclusions. We also utilized soil morphology observations to supplement the well data as soil morphology reflects long-term hydrologic conditions.

GT1 is a large wetland; most is seasonally saturated, but the R.O.W. is permanently saturated. One well was placed just outside the R.O.W. (Fig. 4). It was pulled in the summer of 2011 (pre-disturbance) and re-installed in March 2012 (post-disturbance). The data indicate that the disturbance had no significant effect on hydrology. This is not surprising. Water flows S to

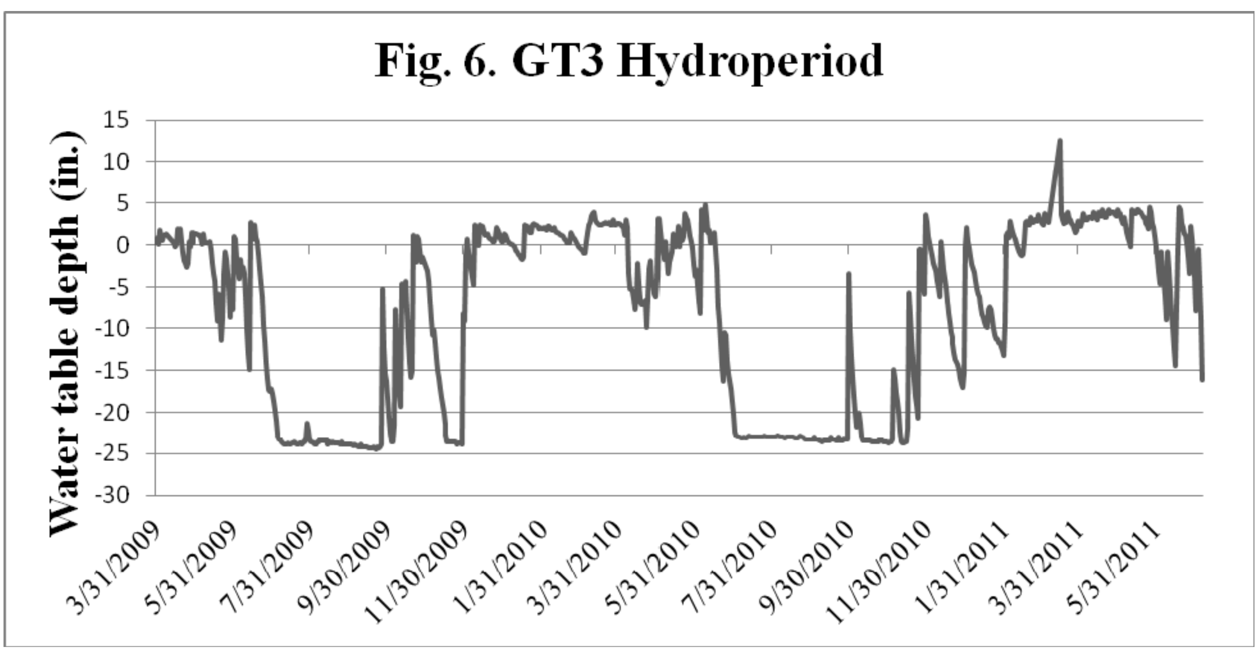
N, then impounded by the railroad bed it flows E to W. toward the river. When the river floods, water flows W to E. The R.O.W. runs parallel to the railroad and perpendicular to overbank flow. It should not alter overbank flow. If it altered S to N flow, the effect would be minor since the R.O.W. is in close proximity to the railroad and its major impounding effects.



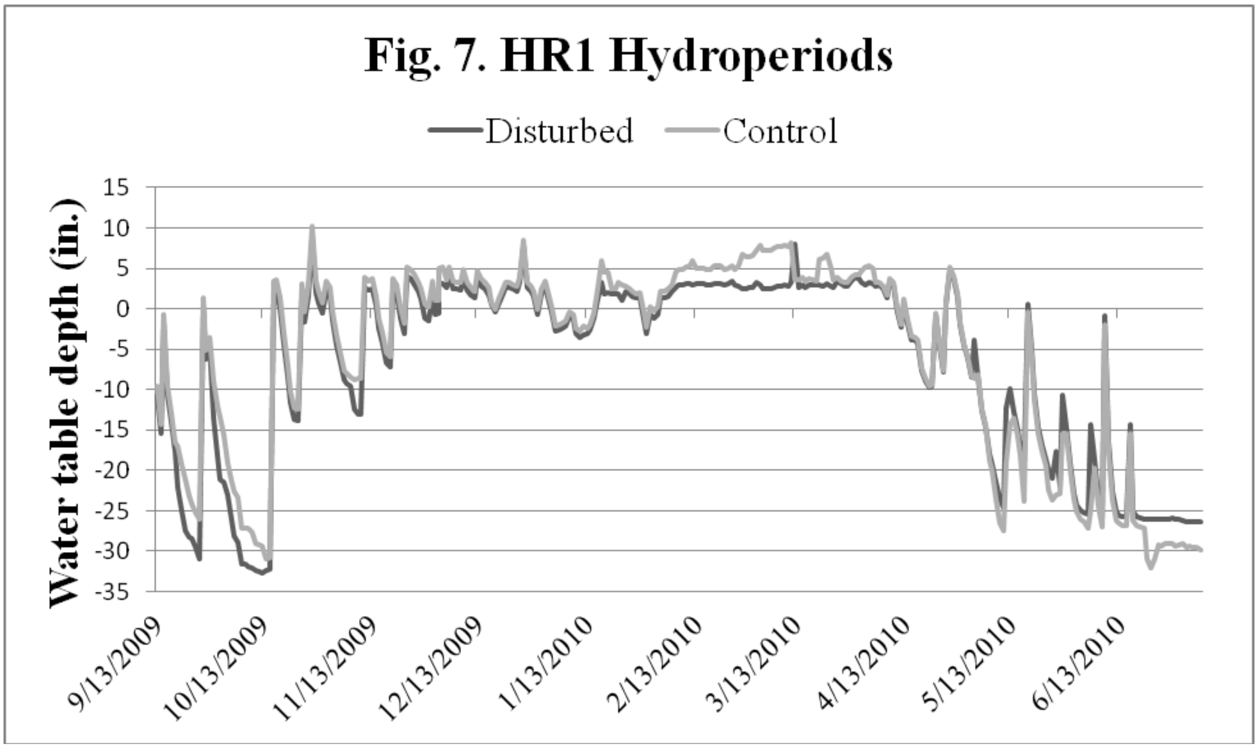
GT2 had a well in the disturbed side and a well in the control side, one on each side of the stream. After one year the control well was pulled to replace a failing well at GT3. However, over the first year the two wells showed similar hydroperiods (Fig. 5). Both were permanently saturated. The disturbed side was slightly wetter. However, in both cases the water table stayed within -5 inches to +5 inches most of the year. Therefore, we do not expect biogeochemical services to be affected.



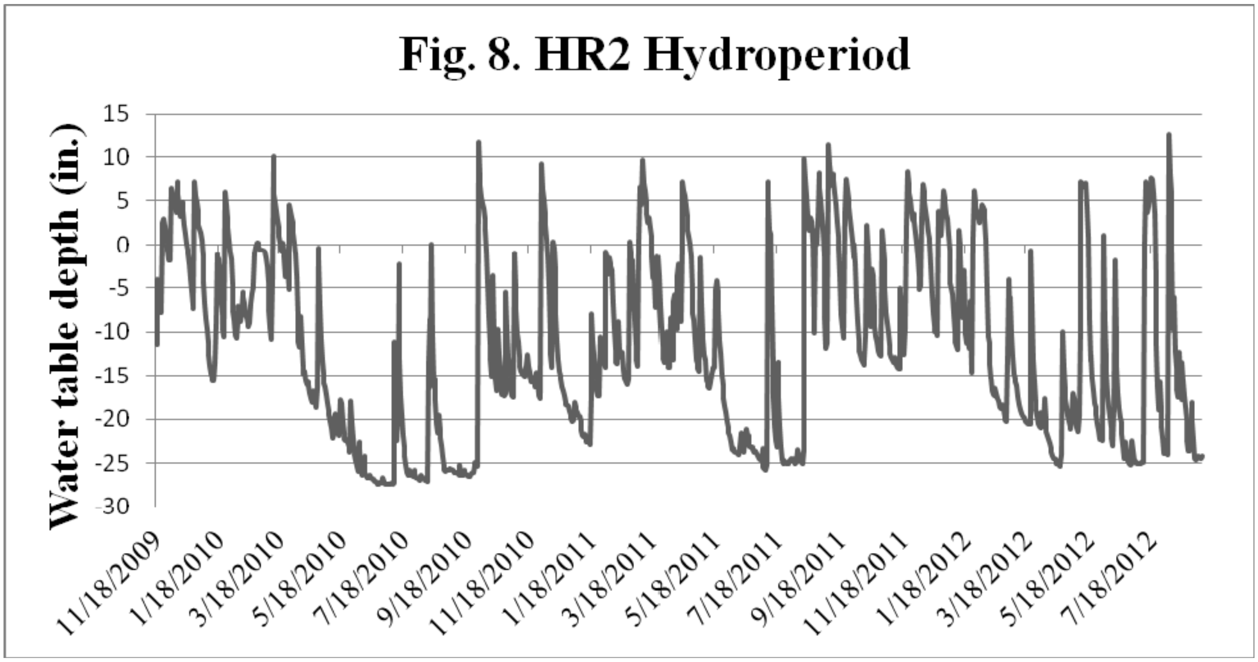
GT3 had two wells, one north of the R.O.W., one south of the R.O.W. Water flows through the wetland north to south. Only one hydroperiod is shown (Fig. 6). Because the two hydrographs were virtually identical indicating that the R.O.W. had no impact on water flow through most of the wetland. The hydrology of the R.O.W. was significantly altered by line installation and, probably to a greater extent, by post-restoration off-road vehicular traffic. The R.O.W. was severely compacted near the surface and contained deep vehicle ruts. Most of the R.O.W. was permanently inundated. The rest of the wetland was hydrologically characteristic of a typical mineral soil flat-seasonally saturated with short-term inundation. Extended inundation was found only in deep vehicle ruts.



HR1 had two wells; one placed in the floodplain downslope from the R.O.W., one placed in a control floodplain across the stream. Both wells were vandalized after 10 months. However, available data for the two sites shows similar hydroperiods (Fig. 7). Since the wells were operating during a period of near-normal precipitation, we can conclude that the R.O.W. had no impact on hydrology of the floodplain. Most of the R.O.W. was wet with deep ruts and soil compaction. We believe that the R.O.W. was wet pre-disturbance, but is wetter post-disturbance. Some of that is undoubtedly due to compaction and deep ruts present at this time. However, there is probably greater stormwater inputs due to increased development upslope.

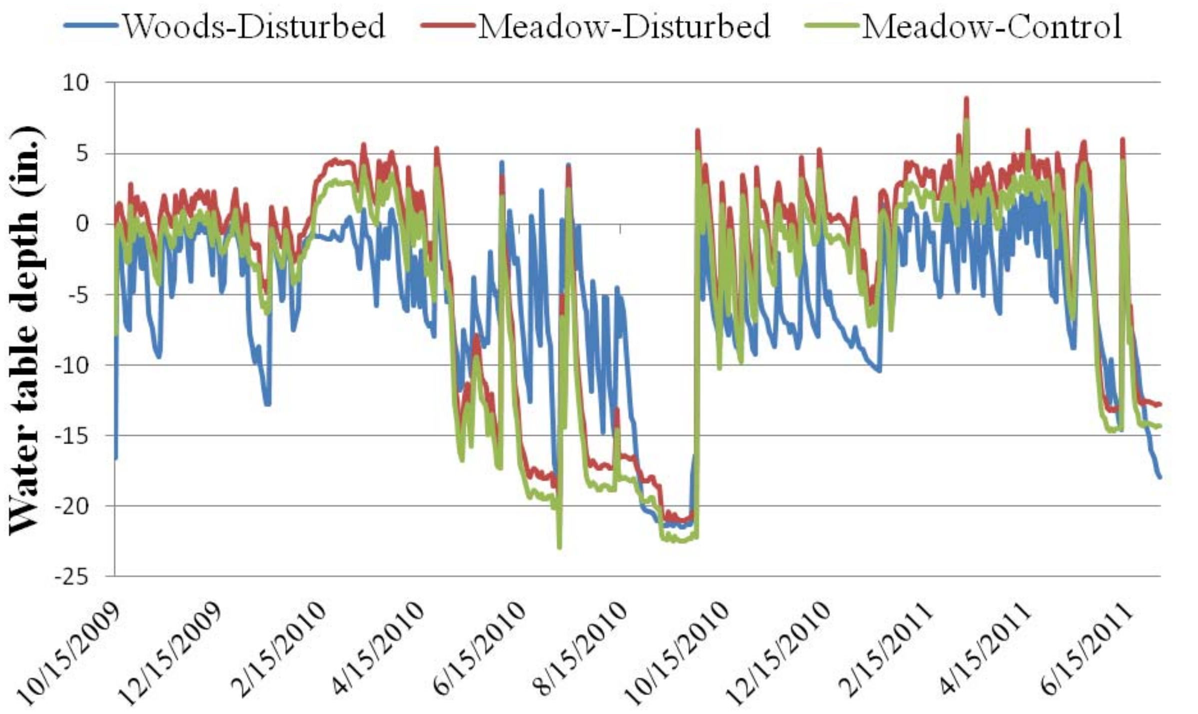


HR2 had one well in the floodplain downslope of the R.O.W. Restoration was completed in October 2012 so we have no post-disturbance hydrologic data. During the construction period (post July 2011) it appears that the construction activities increased the frequency and magnitude of water table fluctuations (Fig. 8). However, it was still seasonally saturated. We expect hydrology to revert to normal. Water is supplied to the floodplain primarily from groundwater discharge. The groundwater has to flow past the R.O.W., but probably above the sewer line. Our soil investigations did not find any soil factors above the sewer line that we expect to impede groundwater flow.



HR3 has two wetland components, a wet woods and a wet meadow, that are contiguous. The R.O.W. runs through both components and parallel to the main path of water flow. Three wells were used; one in the woods R.O.W., one in the meadow R.O.W., and one in a control section of the meadow (Fig. 9). The meadow R.O.W. and the meadow control had near-identical hydroperiods. The woods R.O.W. had a slightly drier but more dynamic hydroperiod than the meadow R.O.W. With the available data we can’t conclusively determine whether the disturbance in the woods impacted hydrology. Anecdotal evidence indicates that the R.O.W. section of the woods was slightly wetter than undisturbed wetland sections of the woods. There were a number of active seeps in that section of the R.O.W. Groundwater discharge from those seeps were likely accentuated by the disturbance. We can conclude that hydrology of the wet meadow was not impacted. The two meadow wells gave similar results, and the two paths of water flow into the wetland, groundwater discharge from the north and overbank flow from the south, were perpendicular to the R.O.W.

Fig. 9. HR3 Hydroperiods



CHb is hydrologically upslope from **CHa**. The two wetlands are separated by the R.O.W. CHb discharges water into CHa via a stream. Most of the water entering CHa is via groundwater discharge via toeslope seeps. Groundwater flow is perpendicular to the R.O.W. This groundwater has to flow past the R.O.W. to enter CHa. It is our conclusion that the groundwater is flowing over the sewer line and is not impeded by the line. Hydroperiods are presented in Figures 10 and 11. No post-disturbance data is available. Construction occurred throughout 2012. It appears that CHa, and to a lesser extent, CHb had lower water tables during construction. Did construction interrupt the flow of water into CHa? We can’t know for sure. However, it should be noted that Charles County was experiencing a drought during that time. Based on our monitoring of Piedmont slope wetlands, we can conclude that the drought would be expected to have a greater impact on a wetland dependent on toeslope discharge (CHa) than one based on backslope discharge (CHb). Also, if the R.O.W. was impeding water flow into CHa it should also impede water flow out of CHb, and there is no evidence of that. Our conclusion is that the R.O.W. is not altering water flow. It should also be noted that the stream channel crossing the R.O.W. was restored and stabilized.

Fig. 10. CHa Hydroperiod

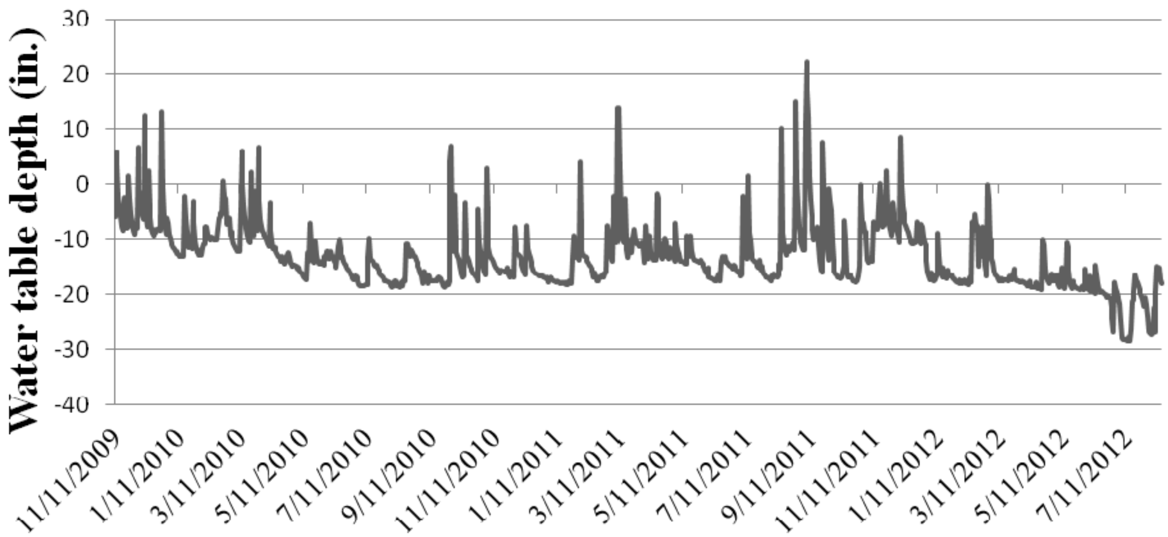
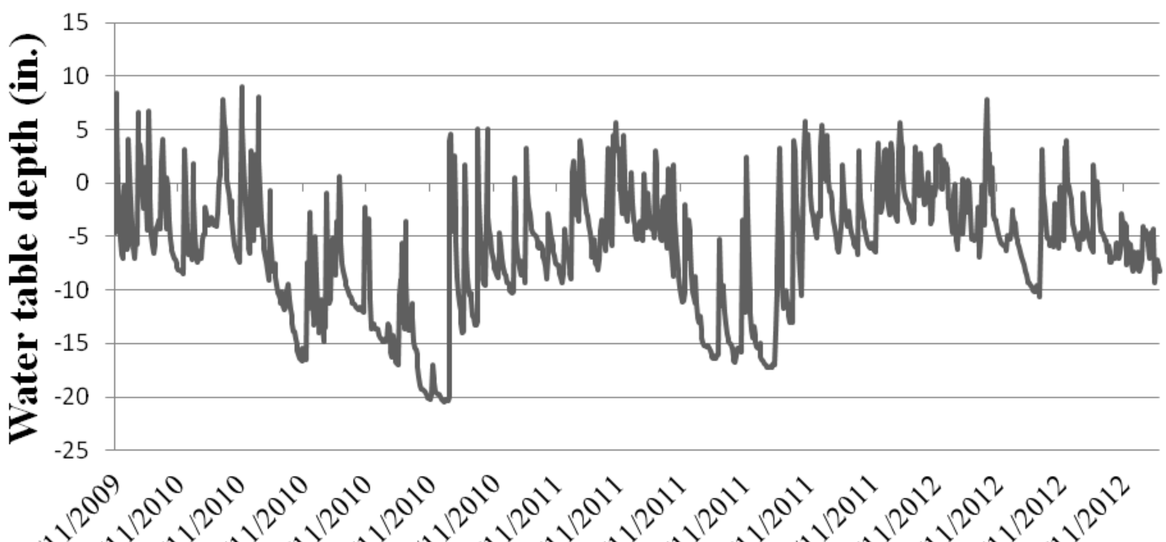


Fig. 11. CHb Hydroperiod



In previous research projects we found that hydric soil indicators can be used not only to help in the identification of wetlands but also to characterize hydroperiods. For example, F3. Depleted Matrix forms in hydrologic conditions characterized as seasonally saturated with a fluctuating water table. A11. Depleted Below Dark Surface is found in conditions similar to or slightly wetter than F3. In fact F3 and A11 are commonly found in the same pedon. Conversely, F2. Loamy Gleyed Matrix and F6. Redox Dark Surface form in soils that stay saturated for extended periods of time. F19. Piedmont Flood Plain Soils was developed specifically for flood plains where the dynamic nature of the system retards the development of redoximorphic features. However it is the nature of most floodplains in the Piedmont that they stay saturated for short duration similar to conditions for F3. In fact at these sites most of the hydrologic input is from groundwater discharge, which tends to be seasonal, as opposed to overbank flow. We commonly find F3 just upslope of F19 in these sites. Therefore, the indicators can provide insight as to the original hydroperiod and whether the disturbance had any long-term impacts on hydrology. Obviously, the latter information can't be obtained until several years after the disturbance so that the disturbed soil has time to form redoximorphic features.

The hydric soil indicators found in this study are presented in Table 13. At GT1, A11 and F6 were found in undisturbed sections of the wetland; A11 was found upslope of the R.O.W., F6 was found next to the R.O.W . and in the pre-disturbed R.O.W. No indicator was found in the post-disturbed R.O.W. This is not surprising; the 'new' soil is too young to develop redoximorphic features. We expect F6 to form there with age. At GT2 F3 was found on the disturbed side (including outside of the R.O.W.); F2 was found on the control side. Well data (Fig. 5) does indicate that the control side was actually wetter. At GT3 F3 was found in all plots. At HR1 F3 and F19 were found in the floodplain downslope from the R.O.W. and the control floodplain. This indicates that hydrology of the floodplain was not significantly altered by the utility line construction. The soil just upslope and just downslope of the R.O.W. met F3. The R.O.W. met F3 and F6. There was considerable soil variability in the R.O.W. (Photo 18). F3 was found in most of the pedons; pedons in micro-depressions that became inundated met F6. We conclude that even with the culverts, the entire R.O.W. was wet, construction made some areas wetter. At HR2 most of the R.O.W. pre-disturbance did not meet a hydric soils indicator. Indicators were not found in the post-disturbance R.O.W. That was expected; unless they backfilled with hydric soils, the new soil would not have time to form indicators. As mentioned previously, except in small pockets, most of the R.O.W. was not wet. Considerable variability was found in the floodplain. Many pedons lacked indicators. Again, this is not surprising. Flooding is so intense at that site that scouring removes organic matter which is required to form the indicators. Several pedons, however, met F3 and F19. At HR3 F3 was found in all plots. Based on this information we can conclude that construction had no long term impact to the hydrology of GT2, GT3, HR1, or HR3.

Table 13. Hydric soil indicators

	R.O.W.			Wetlands	
	Pre-dist.	Post-dist.	Control[a]	Adjacent[b]	Control[c]
GT1	F6	None	F6	A11; F6	-
GT2	-	F3	F3	F3	F2
GT3	-	F3	F3	F3	-
HR1	-	F3, F2	F3	F3, F19	F3, F19
HR2	None	None	Control	F3, F19	-
HR3-WDS	-	F3	F3	F3	-
HR3-MDW	-	F3	F3	F3	-
CHa	None	-	None	F3	-
CHb	F3	-	F3	F3, A11	-

[a] R.O.W.-Control: Pedon located just outside of R.O.W.
[b] Wetland-Adjacent: Pedon located in wetland next to R.O.W.
[c] Wetland-Control: Pedon located in wetland on other side of stream.

Biogeochemistry/Water Quality Impacts

Soil redox potential (Eh) was measured according to standards set by the National Technical Committee for Hydric Soils (NTCHS) (Hydric Soil Technical Standard). The lower the Eh, the less oxygen in the system, and the greater tendency for the soil to donate electrons. This has implications for biogeochemical cycling. Under aerobic conditions (high Eh) oxygen is the preferred terminal electron acceptor (producing water). As Eh drops, nitrate is reduced to ammonium, then ferric iron is reduced to ferrous iron, then sulfate is reduced to sulfide. The NTCHS has set Eh thresholds that are a function of soil pH. Five Eh readings are taken at each site to account for significant inherent variability. If at least three of the Eh readings are below the threshold, the soil is considered to be anaerobic. Eh is affected by soil texture, soil water content, and compaction as well as soil pH. Therefore, disturbances that impact hydrology, promote compaction, or include backfilling with soil that differs in texture or pH from the original soil can affect Eh. For fine textured soils Eh is measured at a depth of 10 inches except for ponded sites in which a depth of 4 inches is used.

Table 14 presents a summary of the Eh results. In most cases the Eh results reflects our characterization of the sites and the water table data. Usually the wetlands were anaerobic and reduced in the early spring. Two exceptions were CHa and HR2 in 2012. Both are reflecting lower than normal water tables due to a drought and not disturbance impacts. R.O.W.s not considered wet (HR2 and CHa) were never reduced.

Table 14. Spatial and temporal variability in anaerobic conditions based on soil Eh.

			Right of way		Wetlands	
	Year	Pre-/Post-	Middle	Outside [a]	Adjacent[b]	Control[c]
GT1	2009	Pre-dist.	Yes	Yes	Yes	-
	2010	Pre-dist.	Yes	Yes	Yes	-
	2012	Post-dist.	Yes	Yes	Yes	-
GT2	2009	Post-dist.	Yes	Yes	Yes	Yes
	2010	Post-dist.	Yes	Yes	Yes	Yes
GT3	2009	Post-dist.	Yes	Yes	Yes	-
	2010	Post-dist.	Yes	Yes	Yes	-
HR1	2009	Post-dist.	Yes	Yes	Yes	Yes
	2010	Post-dist.	Yes	Yes	Yes	Yes
HR2	2010	Pre-dist.	No	No	Yes	-
	2011	Pre-dist.	No	No	Yes	-
	2012	Pre-dist.[d]	No	No	No	-
HR3-WDS	2010	Post-dist.	Yes	Yes	Yes	-
	2011	Post-dist.	Yes	Yes	Yes	-
HR3-MDW	2009	Post-dist.	Yes	Yes	Yes	-
	2010	Post-dist.	Yes	Yes	Yes	-
CHa	2010	Pre-dist.	No	No	Yes	-
	2011	Pre-dist.	No	No	Yes	-
	2012	Pre-dist.	No	No	No	-
CHb	2010	Pre-dist.	Yes	Yes	Yes	-
	2011	Pre-dist.	Yes	Yes	Yes	-
	2012	Pre-dist.	Yes	Yes	Yes	-

[a] R.o.w.-Outside: Pedon located just outside of r.o.w.
[b] Wetland-Adjacent: Pedon located in wetland next to r.o.w.
[c] Wetland-Control: Pedon located in wetland on other side of stream.
[d] Construction had started.

Water chemistry data are presented in Table 15. The *P value* indicates the probability that there is no treatment effect (disturbed versus control). In most environmental research studies a $P<0.05$ is considered significant. Consistent to the data set is high variability as indicated by high standard errors. High variability makes it more difficult to detect treatment differences. At each site four groundwater sampling wells were installed; two to sample water impacted by the disturbance, two to sample water not impacted by the disturbance. For each treatment a well was installed to sample water flowing into the area and a well was installed hydrologically downslope (outlet) in the area. The goal of this arrangement was to assess the ability of the site to remove orthophosphate and inorganic N from the water. To analyze the data we used two phases of statistics. First each well was considered as a separate treatment and an analysis of variance (ANOVA) was run. If that ANOVA found no significant treatment effect, inlet and outlet data were combined. Then a second ANOVA was run with two treatments-disturbed and control. In only one case (HR3, nitrate-N) did we detect a significant treatment effect. So except for HR3, nitrate-N the values below reflect the entire disturbed data set or the entire control data set. The ANOVA for disturbed versus control did not detect any differences in water chemistry. This indicates that the disturbance had no effect on water quality services. However, since the ANOVA for all four wells did not detect differences, we can conclude that these wetlands in the absence of disturbance have low functional capacity for water quality services. This is not surprising. These wetlands are very dynamic hydrologically so that water retention time is low.

The one site that we found a treatment effect, HR3 has two separate hydrodynamics. Groundwater flows over a fragipan in the woods and discharges via toeslope seeps at the woods/meadow interface. The water table is dynamic in the woods with vertical fluctuations characteristic of mineral soil flats. The water table is more static in the meadow with a greater retention time. Significantly higher nitrate levels were found in groundwater discharged from a seep in the R.O.W. close to the highest elevation in the wetland. By the time this groundwater had passed through part of the meadow, nitrate levels had reached control levels. So the disturbance is probably facilitating an increase in nitrate loading into the wetland, but the wetland is able to handle the additional load.

Table 15. Comparison of groundwater chemistry values for disturbed areas versus control areas.

Site	Disturbed			Control			P value
	N	Mean	SE	N	Mean	SE	
Orthophosphate							
GT1	22	0.35	0.361	24	0.35	0.445	0.9996
GT2	26	0.49	0.386	26	0.23	0.116	0.1949
GT3	18	0.30	0.291	20	0.22	0.092	0.6200
HR1	14	0.21	0.261	14	0.28	0.182	0.7733
HR3	14	0.20	0.103	14	0.25	0.142	0.6310
Ammonium-N							
GT1	22	3.46	4.897	24	3.38	3.831	0.9982
GT2	26	2.02	1.496	26	2.48	2.058	0.7733
GT3	18	2.03	1.776	20	1.78	1.578	0.9182
HR1	14	3.82	2.713	14	2.68	2.161	0.5790
HR3	14	1.62	1.234	14	1.97	1.486	0.8348
Nitrate-N							
GT1	22	4.34	6.080	24	5.88	7.635	0.514
GT2	26	5.92	5.245	26	8.21	6.961	0.5311
GT3	18	2.03	2.258	20	1.88	2.375	0.9850
HR1	14	7.72	10.080	14	5.50	8.859	0.8629
HR3-IN	7	7.67	3.436	7	1.99	3.581	0.0004
HR3-OUT	7	1.42	1.021	7	1.51	1.642	

CONCLUSIONS AND RECOMMENDATIONS

The conclusions presented here apply directly only to the sites assessed in this project. However, we feel confident in extrapolating these findings to situations with similar hydrologic conditions. In most of the cases the utility line was installed parallel to a stream with a floodplain between the R.O.W. and the stream. The major source of hydrology to the wetlands was groundwater discharge from slope seeps and water flow to the floodplain took a path perpendicular to the utility line. The impact of utility line installation followed by recommended restoration BMPs directly to wetlands or indirectly to adjacent wetlands is minimal with respect to hydrology and water quality services. Although perpendicular to the path of water flow to the wetland, it appears that the lines do not impact water flow.

In most cases installation and, and to a greater extent, maintenance of the R.O.W. permanently alters the plant community composition of the R.O.W. The alteration represents a degradation of wildlife habitat primarily be reducing the number of plant strata. It should be noted that the R.O.W. plant community after ~5 years does not reflect the seeding mixture used in restoration. Rather it reflects the composition of the seed bank. It also is impacted by hydrology and soil conditions (addressed below). Is this an issue? Not necessarily. The role of restoration seeding should be to encourage rapid groundcover (regardless of species) and to promote succession by favorable species. Plant community composition outside of the R.O.W. is not significantly altered. There was a significant range in the quality of soil in the R.O.W. This is one area in which I believe that improvements could be made that would promote more favorable plant succession. Some R.O.W.s had soils that were severely compacted near the surface or had high quantities of gravel near the surface. We detected only one instance where disturbance impacted water chemistry, in that instance high levels of nitrate were entering the wetland from a R.O.W. seep. However, the wetland was able to handle the nitrate loading and bring it down to background levels. It appears that these disturbances have minimal impact on water quality services.

We are convinced, based on the data collected on this project, that a primary factor mitigating the success of site restoration is soil management. There is a strong correlation between plant community diversity and percentage groundcover and penetrometer resistance in the upper 6" of soil. High penetrometer readings are due to compaction or the widespread distribution of gravel. It should be noted that when taking penetrometer readings we move the penetrometer if we hit gravel the first few times. If we keep hitting gravel we assume that the gravel is uniformly laterally distributed, and is a true soil feature and not an anomaly. The presence of near surface compaction or gravel results in a poor plant community-low plant density and low diversity. Low plant density will facilitate greater surface compaction caused by the impact of raindrops. This can cause surface sealing which promotes runoff. Accelerated runoff can promote soil erosion resulting in a greater soil volume occupied by gravel. The presence of gravel will cause the surface soil to dry out faster in the summer.

In general we were pleased with several findings that were fairly consistent across sites:

1. Disturbance outside of the R.O.W. was limited to GT3 and that was obviously due to off-road vehicular traffic.
2. Fescue was found in the wetland at only one site (HR2) and it obviously was not seeded during this latest restoration effort.
3. Efforts to return the R.O.W. to its original elevation were successful.
4. In general, hydrology of wetlands adjacent to the R.O.W.s does not appear to be impacted long-term by the disturbance. Otherwise, some short-term alterations were detected. These are unavoidable for certain hydrologic flow patterns.
5. Disturbance does not appear to have significant long-term impacts on water quality.

In other cases we found significant site to site variability. It would be helpful if we could identify the factors responsible for the variability:

1. Plant diversity and groundcover: These impact wildlife habitat and soil conservation.
2. Near surface soil characteristics: Specifically we were interested in soil organic matter content, soil texture, soil structure, and gravel content. These characteristics impact seedling establishment and plant succession, water infiltration, and soil conservation. A poor seedbed retards establishment of favorable plant species.

We found several strong relationships between soil characteristics and plant community composition in the R.O.W. We can split the sites into three groups:

1. GT2 and HR3 (meadow). These R.O.W.s are characterized by favorable topsoil characteristics (high in organic matter, low bulk density-low compaction levels, at the surface or just below an O horizon) and a favorable plant community (>99% groundcover, 8 or 9 established species, no invasives). It should be noted that *Arthraxon hispidus* was a dominant at HR3. Although not listed as an invasive, it has been identified as a species of potential concern. It should also be noted that *Microstegium vimineum* was dominant in the control section but not in the R.O.W. at HR3.

2. HR1 and GT3. These R.O.W.s are characterized by unfavorable surface soil characteristics (lacking topsoil-GT3, variable depth to topsoil-HR1, gravel near the surface-HR1, and compaction-both sites) and an unfavorable plant community. HR1 had good average groundcover (88%) but it was quite variable with some bare spots. It also had two invasive species (one dominant). GT3 had only 35% groundcover and four total species.

3. GT1, HR2, and CH. It is too soon to assess these sites. However, we can make several observations. GT1 had excellent topsoil buried by 2.5 inches of C material. So once the plant roots reach the topsoil this should not be a problem. The initial seeding took well and by year two near-complete and uniform groundcover and favorable plant succession was evident. HR2 had the best seed bed we saw-thick topsoil at the surface, good structure, no gravel. The seeding took well. We don't know it the recent storm (Sandy) impacted it. At CH seedlings were just emerging at our last visit. It's too soon to tell if the seeding took or if Sandy had an effect.

Based on the findings of this project we make the following recommendations:

1. Botanical success of the R.O.W. is strongly tied to the backfilling process as well as restoration practices. Beneficial seedbed characteristics include a minimum of 4 inches of topsoil at the surface, loamy textures, granular structure, and an absence of gravel. Soil texture and structure varies with depth, especially in the Coastal Plain. Soil organic matter obviously varies with depth. So during the trenching process soil materials are removed that vary in these characteristics. At some point a horizon rich in gravel or sand will be removed. During backfilling these soil materials should not be placed near the surface. They should not be within 12 inches of the surface. Below a depth of 12 inches these materials are not an issue. Construction and restoration plans called for ~6 inches of topsoil to be stripped and salvaged prior to trenching and later used as the top layer of backfill. In theory this is an excellent practice. However we found failures in the final result. In some cases it was obvious that during trenching topsoil was set aside and returned as the top layer during backfilling. In other cases the surface layer consisted of C material characterized by no organic matter, massive structure, and often high gravel content. Either contractors failed to ensure this BMP or they lacked the expertise to

identify topsoil. If a BMP calls for the removal and salvage of 6 inches of topsoil the contractor will scrape and salvage the upper 6 inches of the soil. In many wetlands the A horizon (topsoil) is thinner than 6 inches. So a mixture of subsoil and topsoil is applied to the surface. **A minimum of 4 inches of topsoil should be at the surface after the soil has settled post-restoration**. Positive examples include GT2, HR2, and HR3. GT1 had 2.5 inches of C material over topsoil.

2. Compaction should be kept to a minimum and the initial post-restoration elevation of the R.O.W. should be above the desired final grade. Soil material will always be left over after backfilling. The contractor can either remove the excess material from the site (at a cost) or compact the material to make it fit. Neither is desirable. Compaction can reduce infiltration and increase soil erosion, retard horizontal groundwater flow and discharge to adjacent wetlands, and restrict plant establishment and growth. The impacts depend on the depth of the compaction. Plans for several of the sites called for 80% or 85% compaction based on bulk density. For subsoil backfill that is probably appropriate, although we did find materials obviously compacted to a greater extent. Part of the problem with this standardized threshold is that it does not take into account inherent bulk density differences in soil materials. Subsoil has a higher bulk density than topsoil. Sandy materials have a higher bulk density than clayey materials. However, compacting sandy loams has less of a detrimental impact than compacting clay loams. Some surface compaction is necessary to promote a successful seedbed. A ‘fluffy’ seedbed is susceptible to erosion until the plants get established. However a 6 inch compacted topsoil layer is counter-productive and will lead to greater erosion susceptibility down the road.

With respect to the initial post-restoration elevation of the R.O.W., the key is to identify the final elevation after settling. The settling process is inherently a natural compaction process, another reason why topsoil compaction should be avoided. Settling will occur until the plant roots are established. Settling occurs as a result of raindrop action, freezing and thawing cycles, and wetting and drying cycles. An established root system stabilizes the soil against these forces. Therefore, if we recommend a slightly higher initial elevation to allow for settling, what is the appropriate increase in elevation? One contractor said he used 4 inches, another said he played it ‘by ear.’ The degree of settling is affected by soil organic matter content, texture, structure, and bulk density. Soils high in sand or high in bulk density tend not to settle as much. Our best estimate is that topsoil will settle by 33% to 50%. Note this estimate applies only to topsoil, not subsoil. Subsoil will not settle to the same degree. The low figure would be appropriate for sandy topsoil low in organic matter, the high figure would be for loamy topsoil high in organic matter.

LITERATURE CITED

Cole, C. A., T. L. Serfass, M. C. Brittingham, R. P. Brooks. 1996. Managing Your Restored Wetland. Penn State University Cooperative Extension.

Environmental Laboratory. 1987. Corps of Engineers Wetland Delineation Manual. U.S. Army Engineer Waterways Experiment Station. Vicksburg, MS, USA. Technical Report Y-87-1.

Heyer, R. W., M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster. 1994. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institute Press. Washington, USA.

Schoeneberger, P.J., D.A. Wysocki, D.A. Benham, and W.D. Broderson. 2002. Field Book for Describing and Sampling Soils. Ver. 2.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE, USA.

USDA, NRCS. 2010. Field Indicators of Hydric Soils in the United States, Version 7.0. L.M. Vasilas, G.W. Hurt, and C.V. Noble (eds.). USDA, NRCS in cooperation with the National Technical Committee for Hydric Soils, Fort Worth, TX.