Proposed Remedial Action Plan - GE Main Plant - Supporting Information

SUMMARY of AGRONOMIC COVER SYSTEM PILOT

GE began pursuing an engineered agronomic cover system (Phyto-cover) in the late 1990s at the GE Main Plant within the 120- acre area of former landfills. GE and a phyto-remediation consultant evaluated the opportunity for an enhanced cover system for the three former landfills at the Main Plant.

By the mid-1990s, full-scale testing of phyto-cover systems was already in progress throughout the United States at existing municipal landfill sites. Implementation at both municipal and industrial landfill sites has since been initiated based on the earlier pilot-scale evaluations. The phyto-cover systems were developed and tested by the Alternative Cover Assessment Program (ACAP) as part of the Remediation Technologies Demonstration Forum (RTDF) of the United States Environmental Protection agency (USEPA). The initial development and pilot phase for the phyto-cover at the GE site was modeled after this ACAP program under peer review and support of scientists at the USEPA. Plant materials and initial pilot-scale plot design were obtained from, and developed through collaboration with colleagues at New York State College of Environmental Science & Forestry (SUNY-ESF).

As detailed briefly in the text Section 4.3 discussion box, an agronomic or phyto-cover is an integrated plant and soil system that has a sufficiently deep soil profile, with abundant vegetative cover (and roots) and an adequate water holding capacity, so that most of the precipitation and surface percolation are removed by evaporative losses from the soil surface and transpiration by the vegetation

The agronomic cover system utilizes various ecological means, including the installation of grasses, plants, trees and other vegetative materials, in conjunction with additions of soil from proximal sources, where necessary, for covering surface and subsurface materials in-place. The selection of plant materials is critical to the success of any phyto-cover system. The plants used in the Main Plant pilot-scale testing at the former landfills were selected based on engineering qualities (had the ability to develop large root masses and pump large quantities of water) or for ecological reasons (enhanced the community characteristics of the landfill ecosystem).

The purpose of the phyto-cover system pilot was twofold; 1) to establish relevant background information gathered over the years of investigation at the Main Plant Site; and 2) to apply that knowledge in the design and testing of field plots over small areas of the former landfills (~10%) in order to optimize the final design of an ecologically-based phyto-cover for the former landfills. The design objectives of the final phyto-cover are to reduce infiltration of precipitation, thereby retarding lateral migration of shallow ground water, and reducing seep water. The phyto-cover system would also serve to limit soil erosion and create a physical barrier between the surface environment and subsurface material below. An integral component to this final design is to limit massive destruction of a fully functional native ecosystem, which contributes all of the formentioned engineering functions into the existing cover on the former landfills. Not only do the existing ecosystems provide some ecological function, with a rich and biologically diverse floral and faunal community existing over the former landfills, they also provide engineering function by controlling infiltration and migration of shallow groundwater where sufficient soils and healthy vegetation already exist (a majority of the former landfills footprint).

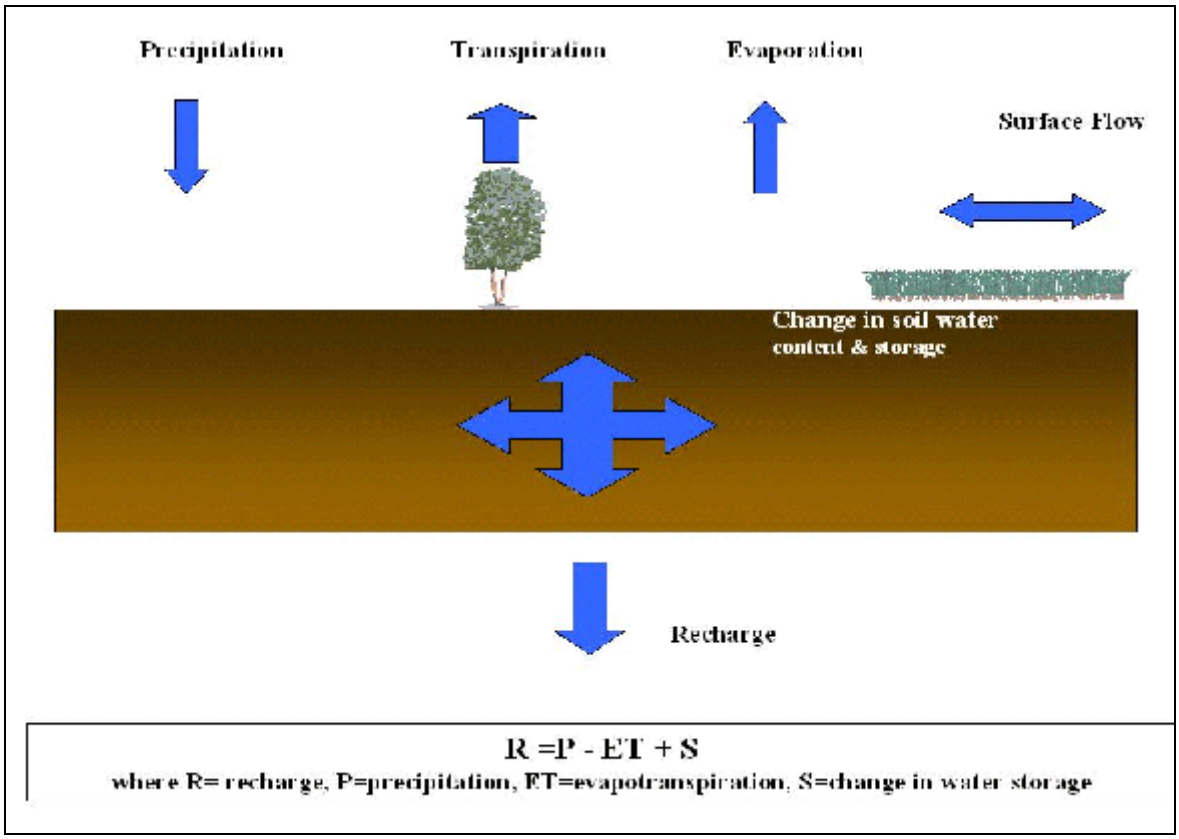

Figure 1. Conceptual model of near-surface water balance. The Phyto-cover will serve to maximize ET and surface flow, and minimize recharge (leachate generation).

Prior to the full-scale field pilot program within the Main Plant former landfills, crucial design information was needed in order to match the existing, thriving ecosystem to achieve the optimal cover system. This information was attained through review of regional and local environmental conditions, assessment of existing data and the gathering of new data, as necessary. The initial data collection consisted of reviewing regional and local meteorological, climatologic and atmospheric conditions, physical site characterization, and the present ecological communities in and around the former landfills. The meteorological, climatologic and atmospheric data, collected from a micro-meteorological weather station installed on the former East Landfill in 1999, included collection of local annual and average precipitation (rain and snow), annual and average air temperatures, wind speed, relative humidity, solar radiation, etc. Regional and long-term climatic and meteorological data were obtained from the University of Albany archives and the Albany Regional Airport weather station. Site-specific physical characterization included the review of existing soil parameters (soil textural class, permeability, organic content, water storage potential, etc.), general geology, hydrogeology and other relavent natural resources. The ecological information reviewed included existing and dominant tree, grass and plant species, existing fauna habitats already well established and a review of endangered species present and potentially living in this community. Similar to design methods utilized by the ACAP program, the site-specific and local data are used in modeling programs (i.e., H.E.L.P. Model) to predict the expected water balance and subsurface hydrologic flow characteristics in these locations.

In early 1999, GE initiated the field pilot study with the design and planting of five vegetation plots and installation of on-site data monitoring and collection equipment. This equipment collected the meteorological, atmospheric and

physical information for site-specific conditions, similar to the data gathered through the initial file research for local and regional conditions. The monitoring equipment installed included a 3 meter (10 foot) tall tripod tower equipped with a micro-meteorological weather station and datalogger to store data collected in real time. The weather station was located adjacent to an existing stand of trees within the center of the former East Landfill. The ambient atmospheric data that were collected included wind speed and direction, precipitation (rain and snow) quantities, air temperature, relative humidity, and solar radiation. In addition, soil data collection equipment, including lysimeters, was installed within undisturbed soil profiles in three locations on the former East Landfill. This enabled the collection of in-situ data on subsurface soil conditions including soil moisture content, temperature and water flux. Root conditions and proliferation were also documented during installation of soil equipment. A sap flow data collection system was installed on both native trees as well as the planted field plots to examine sap flow and enable the computation of water balance (together with data from local soils) and water usage efficiencies. All of these data for a provide a quantitative basis for design of the final phyto-cover system.

Each monitoring and datalogger system is powered by solar panel arrays with battery back-up. Data are stored in the dataloggers and downloaded to a laptop PC periodically. Figure 2 shows a schematic of a data collection system. A micro-meteorogical weather station was installed within a grassland community at the former East Landfill, while a sap flow monitoring system was installed in a proximal tree stand. Soil data arrays, together with lysimeters were installed into undisturbed soil profiles adjacent to the weather station (grass cover) and in the tree stand (under canopy). The lysimeters and soil arrays were then used to compare the water movement through the different soil profiles (grass versus tree cover) and assess the varying amount of precipitation reaching each soil (under canopy – tree; open – grass).

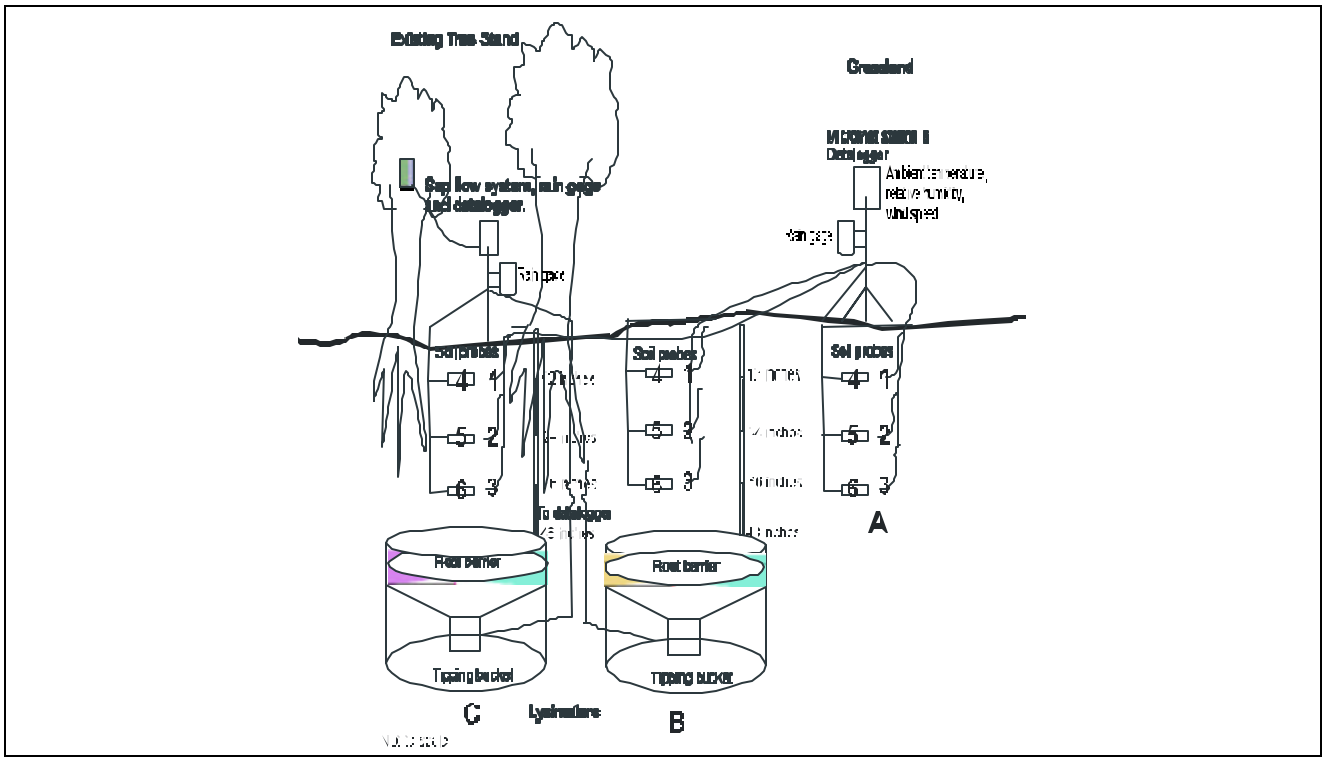

Figure 2. A schematic illustration of the empirical data collection system installed on the former East Landfill in

1999.

The full-scale field pilot was initiated in mid 1999 with the installation of five phyto plot cover system plantings. These initial plantings consisted of various hybrid willow and polar trees, which as previously detailed, have extremely high water removal capacities through their root system. Each test plot was specifically designed with different tree planting densities (number of trees per acre peer plot), tree clone variations and planting depths (depth to main root mass) and surficial soil cover type and thicknesses. Test plots were studied using the monitoring equipment that gathered information on the relative performance of each of the pilot plot designs, and provided information critical to the optimum design of subsequent plantings. This iterative process was repeated again in 2003, when information from the 1999 plots was used to create a second generation of pilot plantings. In this way, GE has been able to test plant type, soil cover thickness, and soil amendments to evaluate the optimal designs and planting preparation conditions.

During installation of field pilot test plots in 2000 and 2002, slower growing hardwoods and other species native to the upland ecosystem created by the landfilling process (that converted wet, silty river bottom lands to dry, sandy uplands) were added to new and previously planted areas. The addition of the native species brought into focus the bi-modal objectives of the phyto-cover system designs for the Site which centered on the rapidly growing hybrids serving an engineering purpose in controlling shallow water movement. As pioneer species, they also filled the role of nursery plants for the more slowly growing native species. In contrast, the native species, selected due to their presence on site, and because they occurred on other local sites that had similar ecological conditions as the newly created former landfill uplands, were planted to be the mid-successional cohort at the site. The hybrids selected for the Site plots were for the most part sterile male clones, with a life expectancy of around 30 years. The natives will outlive these, and replace the hybrids in the landscape over time.

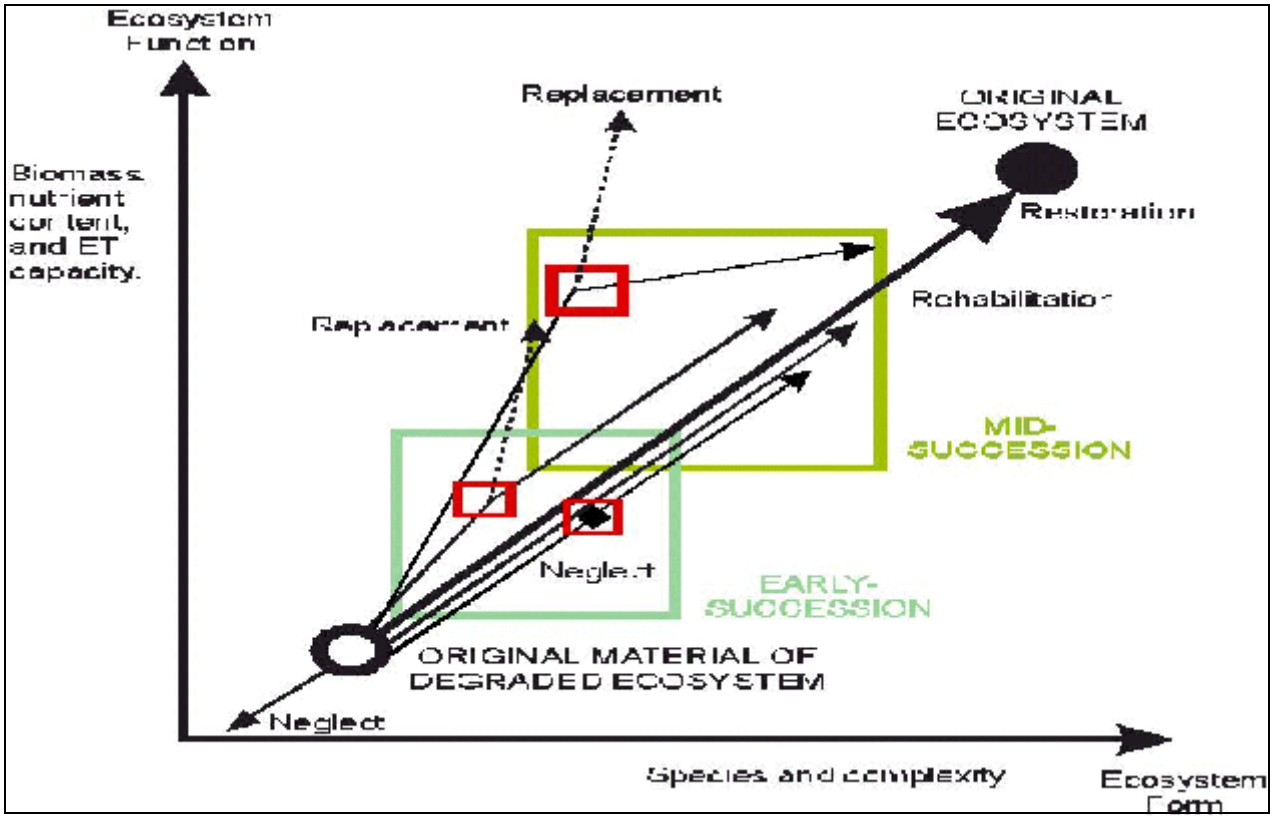

Figure 3. The successional process anticipated for the replacement of hybrids and damaged vegetation with introduced native species at the former GE landfills

The hybrids are very fast growers, and during the early stages of the cover system development, they provide the large leaf area and root mass that will drive high evapotranspiration. Over time, the hardwoods, with their large growth capacities and therefore, high leaf index (area of leafy vegetation compared to ground surface), will have very large capacity to evapotranspire huge volumes of water (approximately 36" annually).

To date, GE has planted 10 field trial pilot plots on each of the former East and West landfills, covering approximately 25 acres, including 9 acres of grassland re-establishment on the former tank farm dike areas. Within these areas, GE has planted approximately 20,000 hybrids and 2,000 native plants. The plots have had a range of objectives, including ecological restoration, clone-site testing (of hybrids), soil cover thickness evaluation, native species introduction, water balance quantification (including seep control), and grassland re-introduction. GE is collecting data from all test plots to quantify growth and survival of vegetation undergoing the various treatments, and to examine which treatments result in maximum evapotranspiration. Once the testing period is over, GE will continuedto actively manage the plots to ensure continued high levels of growth and survival of the planted vegetation, and to maximize the evapotranspiration. Native species survival and growth is also being monitored.

Pilot-scale Field Plots – Objectives and designs

The following section provides details as to the design and objectives of the pilot-scale field plots initiated in 1999. The initial thrust of the pilot program was to develop a list of rapidly growing, short rotation plants that were adapted for growth on the former landfills. A number of hybrid willows and poplars were selected from a research data base provided by colleagues at SUNY ESF that had exhibited good growth under agricultural conditions (the only conditions under which they had been grown at that time). To evaluate survival and growth under conditions typical of the former landfills, the selected species were then planted in a series of clone-site trials using completely randomized designs and factorial experimental set ups. For this purpose, three plots on the former East Landfill (EL1, EL2, and EL3) were selected and one on the former west landfill (WL1) that best reflected the conditions of the former landfills where additional cover would be required. The clone site trials were designed to answer the following questions: Which hybrid varieties would grow the best in the range of site soil chosen for the trials? Would the same root structure develop at depth in trees planted at 48 inches and at 12 inches depth in unamended soil? Would above ground biomass be the same after three years in plants planted at 48 inches and 12 inches? What soil amendments, if any, resulted in the best plant growth?

At the same time, GE was interested in whether planting hybrids adjacent to native stands of trees would result in a rapid colonization of the inter-plot space by native seedlings due to changes in micro-site conditions. In other words, with little effort could the rate of expansion of native tree stands be influenced? For this reason, a double row of hybrid willows and poplars were planted adjacent to an eastern cottonwood stand on the former West Landfill (WL2).

The results from these experiments, available after the 2002 growing season, became the basis for expanded experimentation on the ideal spacing for the Phyto-cover plantings. The research question was now which spacing of the successfully growing hybrids (selected on the basis of trials in EL1-EL3) would provide the best leaf area index (LAI). The LAI is a measure of leaf area to relative ground surface and a good approximation of transpiration capacity of vegetation (a LAI of 4 – 5 providing sufficient leaf cover to maximize transpiration). Plots EL7 and 8, planted in 2003 were designed to evaluate this important function. GE proposes to test the LAI's of plots planted

at three different densities to evaluate the best planting density. This density is also important, as the correct canopy density needs to be maintained to nurture the understory native species planted in 2001 and 2002. Plot EL2 was modified in 2001 to accommodate understory native species and has been monitored annually since then.

The emphasis in 2002 was to expand the phyto-plots of the successful hybrids to other areas of the former landfills. To achieve this, plots EL5 and EL6 were established. Plot EL6 also had another purpose. The path of the Poentic Kill, prior to its re-location for the expansion of the former East and West Landfills, occupied a channel just outside the current landfill boundary line to the east. A small seep is now apparent alongside the Poentic Kill where this old channel intersects the current channel (identified as Seep 8) on current GE submittals to NYDEC. Plot EL6 was located approximately above this seep area with the objective being to minimize the infiltration of a local source of seep recharge. Willow and poplar cuttings in EL6 were planted to depths of 18 inches. Rooting profiles were examined to evaluate whether these shallower plantings yielded the same ultimate rooting depths as the deeply planted hybrids (48 inches). In the same fashion, pilot plot EL4 was planted on the upland fill area above seeps 1 through 4. The design objective of the plantings in EL4, installed at depths of up to 10 feet, is to reduce the immediate recharge potential, and to intercept any shallow groundwater flowing towards the seeps. In conjunction with upland plantings, designed to reduce overall inputs to the shallow groundwater, these plantings in EL4 and EL6 will then over time, reduce seepage. The conceptual approach taken at EL4 and EL6 is shown in the schematic in Figure 4.

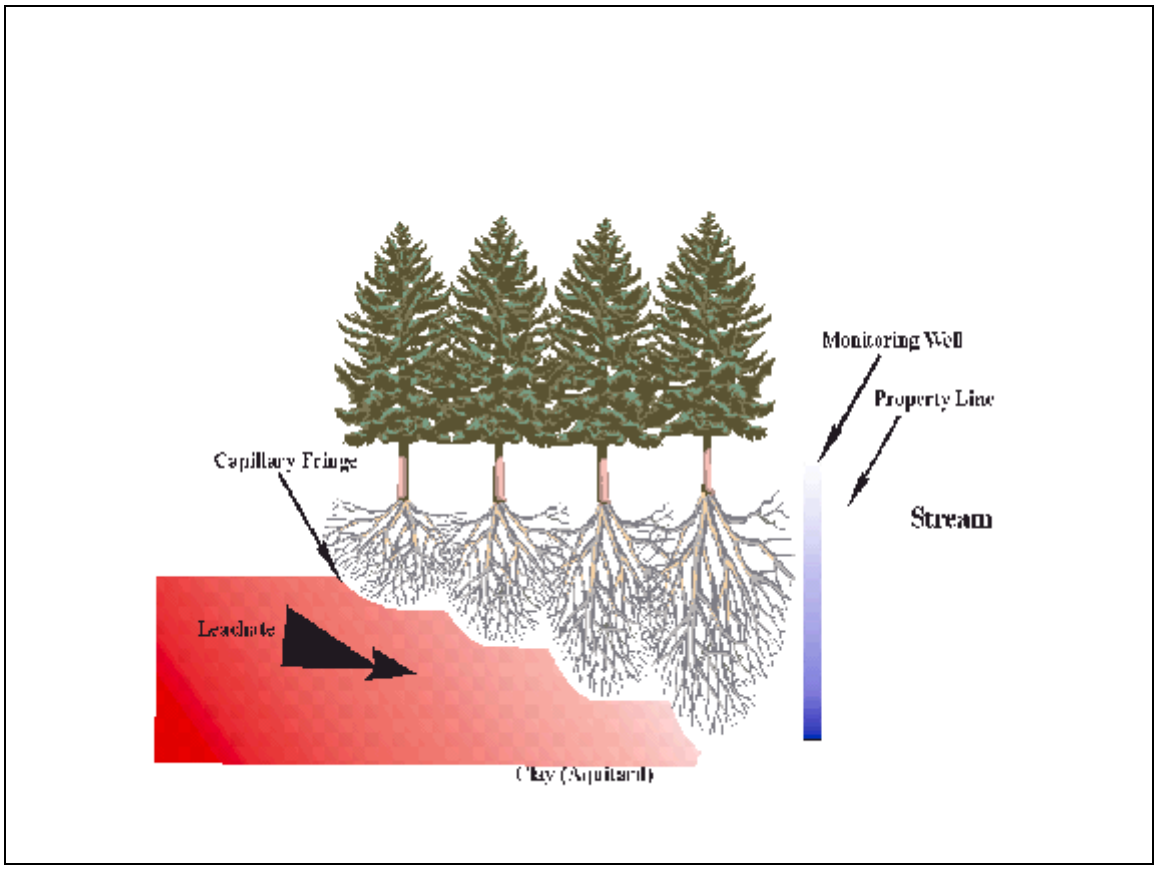

Figure 4. Schematic illustration of a riparian buffer planting system as was installed in plots El4 and EL6.

This planting style was taken to another level in pilot plot EL9. In this case, GE suspected that flows to seep 6 may be concentrated along an old abandoned gravel layer associated with historic underground piping in the vicinity of the former petroleum storage areas on the former East Landfill. In this case, a series of double rows of long hybrid whips were planted to depths of up to 8 feet along the trace of the suspected gravel channel. As with all of the experimental plots, the deeply planted plots (EL4 and EL9) will be monitored over time to evaluate their effectiveness.

As discussed above, another focus of the pilot-scale field plots was to address the re-installation of native vegetation to the former landfills. In addition to EL2, 8 plots were selected on the former West Landfills for native vegetation restoration. In 2002, 6 plots (WL3 – 8) were planted alongside the state registered wetland west of the former landfills. The areas were selected due to the occurrence of large tracts of C&D rubble. The research question was: Can native plants survive and grow healthily on porous rubble with a covering of soil from proximal soil borrow areas. For this purpose GE selected sandy soils from a neighboring operational borrow source close to the site. The C&D rubble, and other areas of existing poor soil cover, and concomitant poor growth, were covered with approximately 12 inches of sandy soil and planted with a native vegetation seed mix. The seed mix was designed for the GE site, and consisted of native grasses, legumes, wildflowers, and other herbaceous species that could withstand periods of drought (cover soils at the site are generally fairly droughty and tend to become dry by late summer). GE also installed mid-successional trees and shrubs over select areas of the WL3 – 8 planting area.

Pilot plots WL9 and WL10 were designed to evaluate the minimum amount of soil cover required to overcome areas of persistent plant phytotoxicity that is apparent over small areas of the former West Landfill. These areas manifest as thin to non-existent vegetation cover by mid- to late-summer, and are coincident with thin soils, generally less than 12 inches thick. GE created a replicated experiment by adding soil to three different depths (8 inches, 12 inches, and 18 inches) over an area approximately 2 acres in size. An experimental control was also set up with no additional soil cover. These areas were then all treated similarly by tilling and adding soil amendment (compost). Each area was then seeded with the same restoration seed mix designed specifically for this pilot, and a mixture of hardwoods and native shrubs were planted. The final native pilot plot on the former East Landfill was prepared by soil additions in the fall of 2003. The plot is surrounded by existing eastern cottonwoods and black locust stands of intermediate height (up to 20 feet tall). These will be thinned this winter to allow light penetration into the interior EL10 plot. Native grasses, trees and shrubs will be planted in 2004. A final area planted in late 2003 was a backdrop to the landfill boundary on the north west side. Here the former landfills adjoin neighborhoods next to the Rotterdam Mall complex. GE has installed a green buffer consisting of conifers, typical of sandy upland areas in the north east USA. The buffer will act as a visual screen for neighboring inhabitants during winter, when many of the other vegetation have lost their leaves. The coniferous vegetation will also serve as forage and shelter for landfill wildlife.

Additional areas have been targeted for further experimental plantings in 2004, the designs of which will be based on the outcomes of earlier pilot plots. As has been demonstrated in this document, GE is expanding the experimental plantings by using site specific data to enhance design and tighten experimental layouts. It is anticipated that the final Phyto-cover design will be optimized for the various remaining areas, and will result in a complimentary mosaic of new and existing cover for the former landfill areas. The final cover will reduce the infiltration and percolation of precipitation by increasing evapotranspiration, and runoff. It will also result in increased stabilization of surface soils, and will contribute organic matter (through mortality and secretions) to the soils, thereby increasing soil fertility. Finally, by including mid-successional native species in the final design, the Phyto-cover will continue to enhance the richness and diversity of the fauna and provide forage and protection for the wildlife that already habits the former landfills at the GE site.