APPENDIX D
RESTORATION PLAN STUDIES & EXAMPLES

Species Search Lists – Timed Wander Approach

Disturbed Oak Pine Forest (30-70 years)
Eupatorium rugosum
Agropyron repens
Solidago canadensis
Celastrus orbiculatus
Acer rubrum
Poa pratensis
Rhus radicans
Pinus strobus
Quercus velutina
Rhamnus cathartica
Prunus serotina
Lonicera tatarica
Dactylis glomerata
Chenopodium album
Alliaria officinalis
Oxalis stricta
Parthenocissus inserta
Plantago lanceolata
Galium asprellum
Solanum dulcamara
Ambrosia artemisiifolia elatior
Rubus allegheniensis
Aster laevis
Panicum sp.
Rubus occidentalis
Hackelia virginiana
Vitis riparia
Quercus coccinea
Acer rubrum
Pinus rigida
Symplocarpus foetidus
Polygonum persicaria
Polygonum punctatum
Onoclea sensibilis
Circaea luteiana
Polygonum lapathifolium
Impatiens capensis
Populus deltoides
Robinia pseudoacacia
Rhus radicans
Lonicera maackii
Rubus sp.
Phytolacca americana
Cardamine pensylvanica
Agrostis perennans
Veronica americana
Sorbus americana
Quercus coccinea

Quercus velutina
Quercus rubra
Athyrium filix-femina
Podophyllum peltatum

Forested Wetland (30-50 years)
Osmunda claytoniana
Athyrium filix-femina
Impatiens pallida
Prunus serotina
Eupatorium perfoliatum
Eupatorium rugosum
Acer rubrum
Osmunda regalis
Parthenocissus inserta
Celastrus orbiculatus
Vitis riparia
Pilea pumila
Acalypha rhomboidea
Rosa multiflora
Symplocarpus foetidus
Lindernia benzoin
Polygonum virginianum
Carex stricta
Quercus rubra
Cornus racemosa
Quercus coccinea
Populus deltoides
Viburnum dentatum
Aster simplex
Rubus occidentalis
Rubus allegheniensis
Amphicarpaea bracteata
Thalictrum dasycarpum
Clematis virginiana
Thelypteris noveboracensis
Fraxinus pennsylvanica
Lonicera tatarica
Polygonum virginianum
Trillium flexipes
Hepatica americana
Arisaema triphyllum
Solidago gigantea
Solidago patula
Circaea lutieana
Viola lanceolata
Carex bebbii
Lycopus americanus
Aster laevis
Geranium maculatum
Populus deltoides

Fraxinus nigra
Solanum dulcamara
Ribes missouriense
Cardamine pensylvanica
Ulmus americana
Veronica americana
Thalictrum dasycarpum hypoglaucum
Oxalis stricta

Upland Mesic Forest
Prunus serotina
Acer rubrum
Lindera benzoin
Thelypteris noveboracensis
Prunus virginiana
Tilia americana
Osmunda claytoniana
Alliaria officinalis
Rhus radicans
Onoclea sensibilis
Fraxinus americana
Parthenocissus inserta
Aralia nudicaulis
Celastrus orbiculatus
Rosa multiflora
Onoclea sensibilis
Cardamine pensylvanica
Veronica americana
Carex sparganioides
Polygonum virginianum
Prunus virginiana
Spiraea alba
Carex blanda
Rubus allegheniensis
Quercus rubra
Corylus americana
Lysimachia terrestris
Glyceria striata
Carex sp.
Lonicera tatarica
Betula populifolia
Quercus velutina
Viola sp.
Mitchella repens
Viola striata
Solidago patula
Aster laevis
Thalictrum dasycarpum
Nemopanthus mucronata

Disturbed Mesic Forest (20-30 years)
Osmunda cinnamomea
Eupatorium rugosum
Impatiens capensis
Alliaria officinalis
Acer rubrum
Solanum dulcamara
Osmunda regalis
Rubus allegheniensis
Celastrus orbiculatus
Pilea pumila
Onoclea sensibilis
Polygonum virginianum
Symplocarpus foetidus
Athyrium filix-femina
Carex sp.
Prunus serotina
Carex pensylvanica
Thalictrum dasycarpum
Oxalis stricta
Acalypha rhomboidea
Solidago canadensis
Glyceria striata
Eupatorium purpureum
Polygonella articulata
Phytolacca americana
Onoclea sensibilis
Clematis virginiana
Apios americana
Cornus amomum
Polygonum virginianum
Thelypteris noveboracensis
Geum canadense
Populus grandidentata
Rosa multiflora
Osmunda regalis
Amphicarpaea bracteata
Aster puniceus
Cirsium arvense
Echinocystis lobata
Urtica dioica
Carex stricta

North Powerline Easement
Impatiens capensis
Osmunda claytoniana
Alliaria officinalis
Celastrus orbiculatus
Eupatorium rugosum
Cirsium arvense

Acer rubrum
Pilea pumila
Polygonella articulata
Phragmites communis
Solidago canadensis
Rubus allegheniensis
Polygonum convolvulus
Glyceria striata
Sambucus canadensis
Urtica dioica
Rhus glabra
Phytolacca americana
Geum canadense
Oxalis stricta
Lobelia siphilitica
Symplocarpus foetidus
Prunella vulgaris
Erigeron annuus
Solidago graminifolia
Polygonum punctatum
Juncus tenuis
Galium sp.
Corylus americana
Eupatorium purpureum
Polygonum arifolium pubescens
Lythrum salicaria
Aster pilosus
Agrostis stolonifera
Rubus occidentalis
Vitis riparia

Powerline Corridor
Rubus allegheniensis
Solidago graminifolia
Solidago canadensis
Polygonum orientale
Phytolacca americana
Osmunda claytoniana
Osmunda regalis
Asclepias syriaca
Celastrus orbiculatus
Prunus serotina
Parthenocissus inserta
Clematis virginiana
Galium aparine
Alliaria officinalis
Impatiens capensis
Cornus racemosa
Pilea pumila
Spiraea alba
Vitis riparia

Amphicarpaea bracteata
Geum canadense

Older Forested Wetlands (Part of Forested Wetland polygon; area around transects E2-E3)

Eupatorium rugosum
Vitis riparia
Arctium lappa
Impatiens capensis
Pilea pumila
Geum canadense
Alliaria officinalis
Thalictrum dasycarpum
Solanum dulcamara
Symplocarpus foetidus
Eupatorium purpureum
Prunus serotina
Phragmites communis
Rubus allegheniensis
Parthenocissus inserta
Osmunda claytoniana
Clematis virginiana
Athyrium filix-femina
Lindera benzoin
Solidago canadensis
Acer rubrum
Osmunda regalis
Trillium flexipes
Celastrus orbiculatus
Viburnum opulus
Carex sp.
Cornus amomum
Ulmus americana
Aster umbellatus
Glyceria striata
Polygonum virginianum
Fraxinus americana
Circaea lutieana
Viburnum dentatum
Thelypteris noveboracensis
Osmunda regalis spectabilis
Carex pensylvanica
Maianthemum canadense
Hamamelis virginiana
Sambucus canadensis
Aster cordifolius
Carex blanda
Quercus rubra
Viburnum dentatum
Geranium maculatum
Streptopus roseus

Smilacina racemosa
Polystichum acrostichoides
Corylus americana
Carpinus caroliniana
Arisaema triphyllum
Mitchella repens
Carex sp.
Brachyelytrum erectum
Ostrya virginiana
Carex pensylvanica
Galium sp.
Sassafras albidum
Populus deltoides
Rhus radicans
Onoclea sensibilis
Adiantum pedatum
Prunus serotina
Quercus alba
Betula papyrifera
Solidago flexicaulis
Aralia nudicaulis
Rubus flagellaris

Pines Stand/Old Pasture
Pinus strobus
Prunus serotina
Solidago canadensis
Solidago ulmifolia
Gaultheria procumbens
Acer rubrum
Aster divaricatus
Veronica americana
Vaccinium angustifolium
Mitchella repens
Hamamelis virginiana
Quercus alba
Agrostis perennans
Carex pensylvanica
Rubus occidentalis
Solidago caesia
Fraxinus americana
Lonicera tatarica
Rhamnus cathartica
Celastrus orbiculatus
Aster laevis
Athyrium filix-femina michauxii
Carex blanda
Clematis virginiana
Lotus corniculatus
Galium sp.
Viola papilonacea

Parthenocissus inserta
Solidago graminifolia nuttallii
Betula populifolia
Festuca rubra
Aster laevis
Populus deltoides
Potentilla simplex
Osmunda claytoniana
Dianthus armeria
Solidago sp.
Hieracium florentinum
Oxalis stricta
Dactylis glomerata
Lobelia inflata
Viola sagittata
Hypericum perforatum
Solidago nemoralis
Rumex acetosella
Alliaria officinalis
Fraxinus americana
Maianthemum canadense interius
Amelanchier sp.
Monotropa uniflora
Agrostis perennans
Solidago nemoralis
Juncus tenuis
Dactylis glomerata
Danthonia spicata

Northern Drainage Ditch system
Solanum dulcamara
Leersia oryzoides
Epilobium coloratum
Impatiens capensis
Aster umbellatus
Eupatorium perfoliatum
Scirpus cyperinus
Berberis thunbergii
Symplocarpus foetidus
Aster laevis
Lonicera tatarica
Bidens frondosa
Glyceria striata
Vitis riparia
Onoclea sensibilis
Iris versicolor
Betula populifolia
Aster divaricatus
Equisetum arvense

Old field
Prunella vulgaris
Quercus rubra
Solidago caesia
Agrostis perennans
Hieracium florentinum
Phleum pratense
Solidago canadensis
Sassafras albidum
Viburnum opulus
Galium sp.
Rudbeckia hirta
Prunus serotina
Andropogon gerardii
Panicum cryptandous
Quercus alba
Solidago graminifolia nuttallii
Lonicera tatarica
Rubus allegheniensis
Quercus coccinea
Lespedeza hirta
Andropogon scoparius
Spiraea alba
Elaeagnus angustifolia
Salix sp.
Populus tremuloides
Centaurea maculosa
Rhus radicans
Vicia cracca
Eragrostis spectabilis
Poa pratensis
Plantago lanceolata
Dactylis glomerata
Aster pilosus
Asclepias syriaca
Daucus carota
Solidago juncea
Cornus racemosa
Juniperus virginiana
Asparagus officinalis
Onoclea sensibilis
Vitis riparia
Eupatorium purpureum
Lysimachia ciliata
Solidago nemoralis
Aster ericoides
Quercus velutina
Juncus tenuis

City Disturbed Forest
Eupatorium rugosum
Viburnum dentatum
Osmunda claytoniana
Solidago gigantea
Alliaria officinalis
Impatiens capensis
Cornus racemosa
Acer rubrum
Athyrium filix-femina michauxii
Viola sp.
Juncus tenuis
Onoclea sensibilis
Prunus serotina
Fraxinus americana
Viburnum lentago
Convallaria majalis
Celastrus orbiculatus
Trillium flexipes
Symplocarpus foetidus
Ulmus americana
Osmunda regalis
Pilea pumila
Carex pensylvanica
Parthenocissus inserta
Rhus radicans
Pinus rigida
Aralia nudicaulis
Carex blanda
Mitchella repens
Rhamnus cathartica
Corylus americana
Maianthemum canadense
Boehmeria cylindrica
Thelypteris noveboracensis
Fraxinus americana
Lindera benzoin
Pilea pumila
Geum canadense
Glyceria striata
Carex sp
Pinus strobus
Pinus resinosa
Thalictrum dasycarpum
Prunus virginiana
Solanum dulcamara
Apios americana
Vitis riparia
Polygonum virginianum
Rhus radicans
Lonicera tatarica

Carex bebbii
Veronica americana
Lysimachia ciliata
Polygonum punctatum
Carex sp.
Quercus alba
Quercus prinoides
Aster lateriflorus
Phragmites communis

Red Maple Stand East of Trailer Park
Alliaria officinalis
Impatiens capensis
Acer rubrum
Prunus serotina
Celastrus orbiculatus
Rubus allegheniensis
Eupatorium rugosum
Rubus allegheniensis
Rubus occidentalis
Vitis riparia
Polygonum virginianum
Ulmus americana
Pilea pumila
Carex sp.
Streptopus roseus
Rubus flagellaris
Arctium lappa
Sorbus americana
Athyrium filix-femina
Lonicera tatarica
Juncus tenuis
Fraxinus americana
Glyceria striata
Fragaria virginiana
Geum canadense
Symplocarpus foetidus

Degraded Oak/Pine Forest
Carex pensylvanica
Quercus alba
Carex stricta
Polygonum punctatum
Lonicera tatarica
Alliaria officinalis
Parthenocissus inserta
Prunus serotina
Trillium flexipes
Eupatorium rugosum
Aster laevis
Carex blanda

Chenopodium murale
Celastrus orbiculatus
Quercus velutina
Pinus rigida
Rubus occidentalis
Rubus allegheniensis
Quercus macrocarpa
Hackelia virginiana
Polygonum pensylvanicum
Oxalis stricta
Polygonum convolvulus
Cornus racemosa
Quercus muhlenbergii
Polygonum pensylvanicum
Solidago juncea
Sorbus americana
Catalpa speciosa.
Erechtites hieracifolia
Malus sp.
Betula populifolia
Osmunda regalis
Arisaema triphyllum

Trailer Park
Picea pungens
Pinus resinosa
Festuca elatior
Vitis riparia
Poa pratensis
Celastrus orbiculatus
Picea abies
Salix babylonica
Acer rubrum
Acer saccharinum
Taraxacum officinale
Poa pratensis
Hackelia virginiana
Lonicera tatarica
Rhamnus cathartica
Achillea millefolium
Verbascum thapsus
Asclepias syriaca
Daucus carota
Populus deltoides
Lythrum salicaria
Cirsium arvense
Lepidium virginicum
Setaria glauca
Oxalis stricta
Plantago major
Betula papyrifera

Juglans nigra
Aster laevis
Athyrium filix-femina michauxii
Asclepias syriaca
Malus sp.
Oenothera biennis
Festuca rubra
Catalpa speciosa
Aristida purpurascens
Acalypha rhomboidea
Verbena bracteata
Bromus japonicus
Centaurea maculosa
Echinochloa crusgalli
Panicum capillare
Leptochloa indica
Erechtites hieracifolia
Brassica kaber
Polygonum aviculare
Erigeron annuus
Berteroa incana
Ulmus pumila
Dactylis glomerata
Sporobolus vaginiflorus
Cyperus strigosus
Ambrosia artemisiifolia elatior
Galium sp.
Eragrostis neomexicana
Rumex crispus
Rosa multiflora
Erigeron canadensis
Agropyron repens
Phytolacca americana
Spiraea tomentosa rosea
Robinia pseudoacacia
Panicum villosissimum
Eragrostis spectabilis
Andropogon scoparius
Setaria faberi
Lotus corniculatus
Lythrum salicaria
Mock orange bush
Lespedeza capitata
Hypericum perforatum
Rudbeckia hirta
Physostegia virginiana
Panicum virgatum
Quercus alba
Festuca rubra
Ceanothus americanus
Carex sp.

Digitaria sanguinalis
Potentilla simplex
Iris siberica
Panicium sp.
Trifolium arvense
Thuja occidentalis
Panicum dichotomiflorum
Salsola kali
Artimis sp.
Forsythia sp.
Ligustrum vulgare
Bromus inermis
Campsis radicans
Gleditsia triacanthos
Cirsium vulgare
Melilotus officinalis
Eupatorium perfoliatum
Erechtites hieracifolia
Viola papilonacea
Melilotus officinalis
Eragrostis pectinacea
Acer negundo
Leonurus cardiaca

Black Locust/Wild Black Cherry dominated area
Prunus serotina
Robinia pseudoacacia

(no other species described)

Old Field/Scattered Cottonwoods on Spoil Piles
Populus deltoides

(no other species described)

Quaking Aspen/Dense Shrub area
Populus tremuloides
Rubus sp.
Cornus racemosa

(no other species described)

Red Oak Dominated area
Quercus rubra

(no other species described)

STREAM HABITAT AND AQUATIC MACROINVERTEBRATE ASSESSMENT

Albany Pine Bush Landfill Project

December 6, 2006

(AES Project # 06-0590)

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Table of Contents

Tables

Figures

Appendices

1.0 INTRODUCTION

On September 26th, 27th and 28th, 2006 Applied Ecological Services, Inc. (AES) and Clough Harbour & Associates (CHA) ecologists conducted comprehensive baseline surveys of stream habitat and sampled aquatic macroinvertebrate communities in onsite and offsite (reference) stream and wetland systems as a component of the Albany Pine Bush Landfill Project in Albany County, New York. The purpose of this investigation is to provide baseline data that can be used to identify existing conditions and provide information needed to conduct restoration activities on the site. Two stream systems and four wetlands complexes were investigated. The first stream is an unnamed tributary to Rensselaer Lake that originates at a wetland mitigation pond and flows southeast just east of the Rapp Road Landfill. The second stream is an offsite reference tributary to Rensselaer Lake located to the east. Macroinvertebrates were sampled from three wetlands complexes just north of the landfill including a mitigation pond, button bush swamp, and bog/vernal pool. Macroinvertebrates in a fourth, offsite reference sedge meadow, were also sampled. Figures 1 and 2 depict the location of the streams and wetlands discussed above. The offsite reference sedge meadow is not shown on the figures.

Prior to conducting the field reconnaissance, the unnamed stream just east of the landfill was divided into six reaches from southeast to northwest beginning at the streams intersection with Rapp Road and continuing upstream to the mitigation pond (Figure 1). A stream reach is defined as a stream segment having fairly homogenous hydrology, geomorphology, and riparian cover as well as land use characteristics. This method of lumping portions of the stream with similar characteristics into reaches allows for more useful collection, analysis, and comparison of the data.

2.0 METHODS

2.1 Aquatic Habitat Assessment

Habitat within each stream reach comprising the unnamed tributary was assessed using the Qualitative Habitat Evaluation Index (QHEI). The index was developed by the Ohio EPA for streams and rivers in Ohio but is also useful throughout most other parts of the country. The QHEI is a repeatable physical habitat index designed to provide empirical, quantified evaluation of the general lotic macrohabitat characteristics of a stream segment that are important to warm water faunas such as fish and macroinvertebrates. Studies using QHEI scores and fish/macroinvertebrate data have shown high correlation; poor QHEI scores generally have poor fish/macroinvertebrate communities and vise versa. The QHEI is composed of six metrics including substrate composition, in-stream cover, channel morphology, riparian zone and bank erosion, pool/glide and riffle-run quality, and map gradient. Each metric is scored individually then summed to provide the total QHEI score. The best possible score is 100. QHEI scoring sheets for each stream reach can be found in Appendix A.

QHEI scores greater than 60 generally support average quality fish and macroinvertebrate communities. Scores greater than 80 typify pristine habitat conditions that have the ability to support exceptional warm water faunas. Table 1 below summarizes the QHEI score classifications. Areas with habitat scores lower than 60 may support warm water faunas but usually have significant degradation.

Table 1. QHEI score classifications

QHEI	Class	Usual Characteristics
80-100	Excellent	Comparable to pristine conditions; exceptional assemblage of habitat types; sufficient riparian zone
60-79	Good	Impacts to riparian zone
30-59	Fair	Impacts to riparian zone; channelization; most in-stream habitat gone
0-29	Poor	All aspects of habitat in degraded state

2.2 Macroinvertebrate Sampling

Macroinvertebrates were sampled using a standard D-frame kick net that was also used for jabbing, dipping, and sweeping around instream habitat. In addition to D-frame sampling, macroinvertebrates were hand picked from instream habitat using forceps. Each site and/or stream reach was sampled for approximately 10-15 minutes. All collected organisms were placed in small plastic containers with rubbing alcohol for preservation and later identification in a laboratory.

In the laboratory, all organisms obtained from each sampling site and/or stream reach were identified to at least the family level by CHA and recorded on data sheets (see Appendix B). A reference collection was also assembled by CHA and checked by AES for consistency among identifications. The resulting data was used to evaluate the general overall water quality and biological health of the stream and wetland systems by using known tolerance to organic pollution for each taxa. Macroinvertebrates provide valuable information related to pollution because they integrate cumulative effects of sediment/nutrient pollution and respond to habitat degradation.

3.0 RESULTS

3.1 Aquatic Habitat Assessment

QHEI scores along the stream Reaches 1-5 comprising the unnamed tributary ranged from a high of 55 (Fair) at Reach 2 to a low of 40 (Fair) at Reach 6 (Table 2; Appendix A). Other reaches scored between 43.5 and 50 (Fair). The offsite reference reach scored 47.5, a result comparable to conditions documented along the onsite unnamed tributary. Stream Reach 6 is a very small tributary that joins the unnamed tributary just south and east of the landfill. Because of its small size, a QHEI was not conducted on this reach. A general description of the criteria used to complete the QHEI analysis and conditions observed are summarized below.

Table 2. QHEI scores for Reaches 1-5 on unnamed tributary and offsite reference stream reach.

Reach	Substrate Score	In-stream Cover Score	Channel Morphology Score	Riparian/ Bank Erosion Score	Pool Score	Riffle Score	Gradient Score	Total Score
Max. Possible Score	**20**	**20**	**20**	**10**	**12**	**8**	**10**	**100**
Reach 1	9	11	14	10	3	0	8	**55**
Reach 2	9	6	8	9.5	3	0	8	**43.5**
Reach 3	9	5	7	8	3	0	8	**40**
Reach 4	9	10	10	9	3	0	8	**49**
Reach 5	8	10	10	6.5	3	0	8	**45.5**
Offsite Reference Reach	16	6	6	8.5	3	0	8	**47.5**

Note: No QHEI completed for stream Reach 6.

Substrate: The substrate among all reaches comprising the unnamed tributary stream is considered average quality at best. The most common substrates are muck/silt and sand but they do not appear to cover or embed other substrates. The offsite reference reach has slightly higher substrate value because it contains less silt and a variety of different substrate types.

Instream Cover: In-stream cover is less than adequate in most reaches to support high quality aquatic faunas. Although cover is between 25% and 75% of the stream along most reaches, most of this comes from logs/woody debris. The offsite reference reach also follows this instream cover pattern.

Channel Morphology: Channel morphology refers to the quality of the stream channel that relates to the creation and stability of habitat. Channel morphology is poor within all reaches (including the offsite reference stream) except Reach 1 where natural meanders are still present. Poor conditions are the result of low to no sinuosity, poor riffle-pool development, and low channel stability that appear to be the result of past channelization activities.

Riparian Condition: The riparian zones are generally wide (> 150 feet) and comprised primarily of open or forested floodplain. Bank erosion associated with riparian areas is minimal to moderate in most reaches.

Riffles and Pools: High quality riffles and pools are almost non-existent within the study reaches. This is common in sand and silt dominated steams. Where small riffles do exist, they are shallow and not adequate to support fishes and other faunas.

Gradient: Stream gradient was calculated from a USGS 7.5-minute topographic map by measuring the elevation change through a reach. Low gradient streams generally change in elevation between 0 feet and 5 feet over a mile. Moderate and high gradient streams change an average of 5 feet to 30 feet. All of the stream reaches, including the reference reach, drop about 6 feet in elevation over a mile. This represents a rather low gradient stream.

3.2 Macroinvertebrate Sampling

Table 3 presents macroinvertebrate taxa richness and general tolerance to pollution of the overall macroinvertebrate community at each location. Tolerance values were obtained from the "Quality Assurance Work Plan for Biological Steam Monitoring in New York State" produced by the New York State Stream Biomonitoring Unit: NYS Department of Environmental Conservation. According to the document, most tolerance values used are derived from calculations made by Hilsenhoff (1987) that were used to calculate the Hilsenhoff Biotic Index (HBI). The HBI was designed to rapidly assess the degree of organic pollution in streams. It is calculated by multiplying the number of organisms collected by their tolerance value, summing the products, and dividing by the total number of organisms collected. While the HBI was developed to measure organic pollution, it has been applied to evaluate general impairment of aquatic insect communities because insects that are tolerant of organic pollution are often tolerant of thermal and siltation as well. The reverse is also true; insects that are intolerant of organic pollution are often intolerant of other types of pollution including thermal and siltation. Table 3 correlates the HBI score with water quality. Tables 4 and 5 present the taxa richness and HBI scores for each survey site and/or stream reach.

The results of the macroinvertebrate survey indicate that stream reaches exhibit fair to poor water quality while the wetland complexes exhibit good to very good water quality despite having fewer overall taxa richness than streams. Poor conditions documented in the stream reaches could also be the result of poor habitat conditions and low oxygen levels that have resulted from channelization activities.

Table 3. Water Quality Correlation to Hilsenhoff Biotic Index.

Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very Good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly Poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very Poor	Severe organic pollution likely

TABLE 4. Macroinvertebrate taxa richness and pollution tolerance of macroinvertebrate communities within stream Reaches.

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Offsite Reference Reach
Taxa Richness (# species)	13	12	12	10	10	8	5
Hilsenhoff Biotic Index	7.23 (Poor)	5.87 (Fairly Poor)	5.35 (Fair)	5.08 (Fair)	6.73 (Poor)	5.57 (Fair)	6.5 (Fairly Poor)

TABLE 5. Macroinvertebrate taxa richness and pollution tolerance of macroinvertebrate communities within wetland complexes.

	Mitigation Pond	**Button Bush Swamp**	**Bog/Vernal Pond**	**Offsite Reference Sedge Meadow**
Taxa Richness (# species)	8	8	7	10
Hilsenhoff Biotic Index	4.47 (Good)	4.03 (Very Good)	4.94 (Good)	4.68 (Good)

4.0 SITE PHOTOGRAPHS

Photo 1. Stream Reach 1 facing upstream.

Photo 2. Stream Reach 2 facing upstream.

Photo 3. Stream Reach 3 facing upstream.

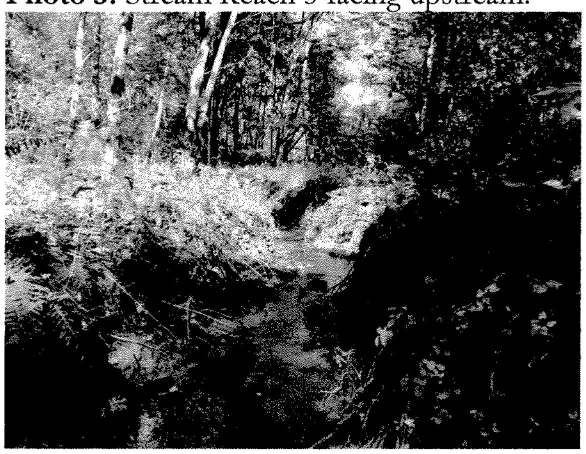


Photo 4. Stream Reach 4 facing upstream.

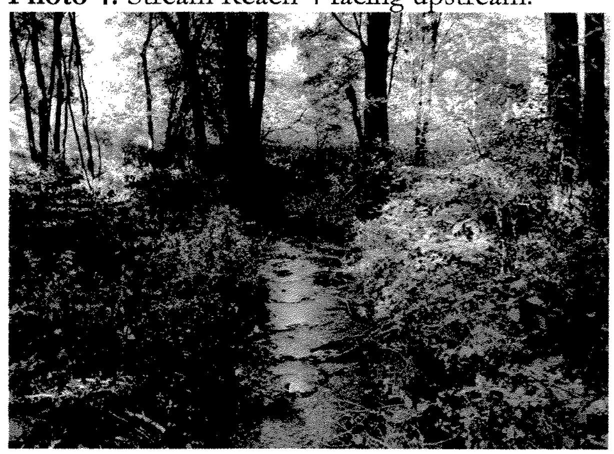


Photo 5. Stream Reach 5 facing upstream.

Photo 6. Stream Reach 6 (tributary to Reach 2)

Photo 7. Offsite Reference Stream

Photo 8. Wetland # 1: Mitigation Pond

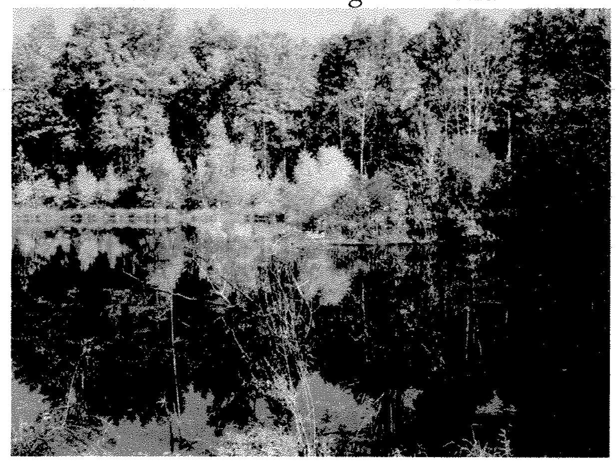


Photo 9. Wetland # 2: Buttonbush Swamp

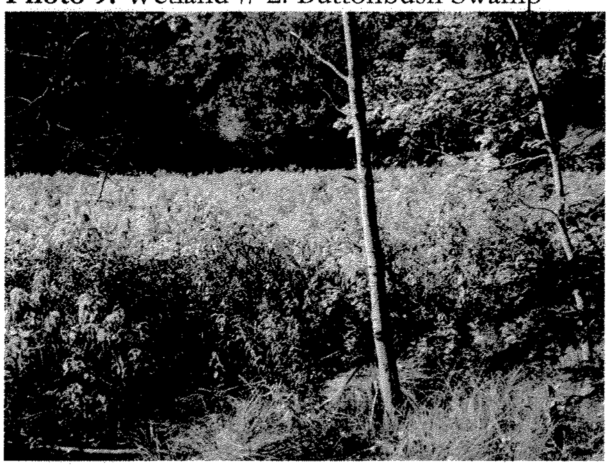


Photo 10. Wetland # 3: Bog facing north.

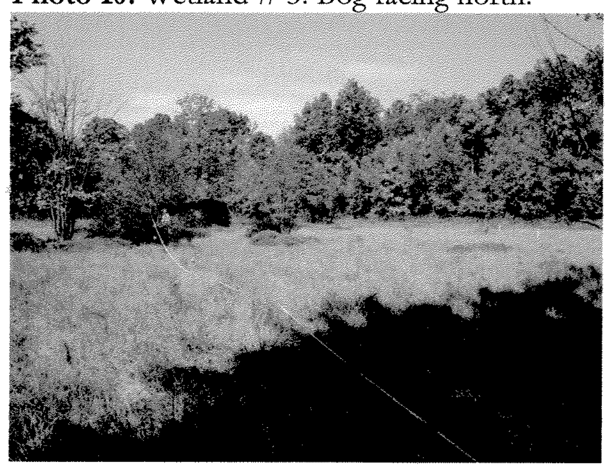
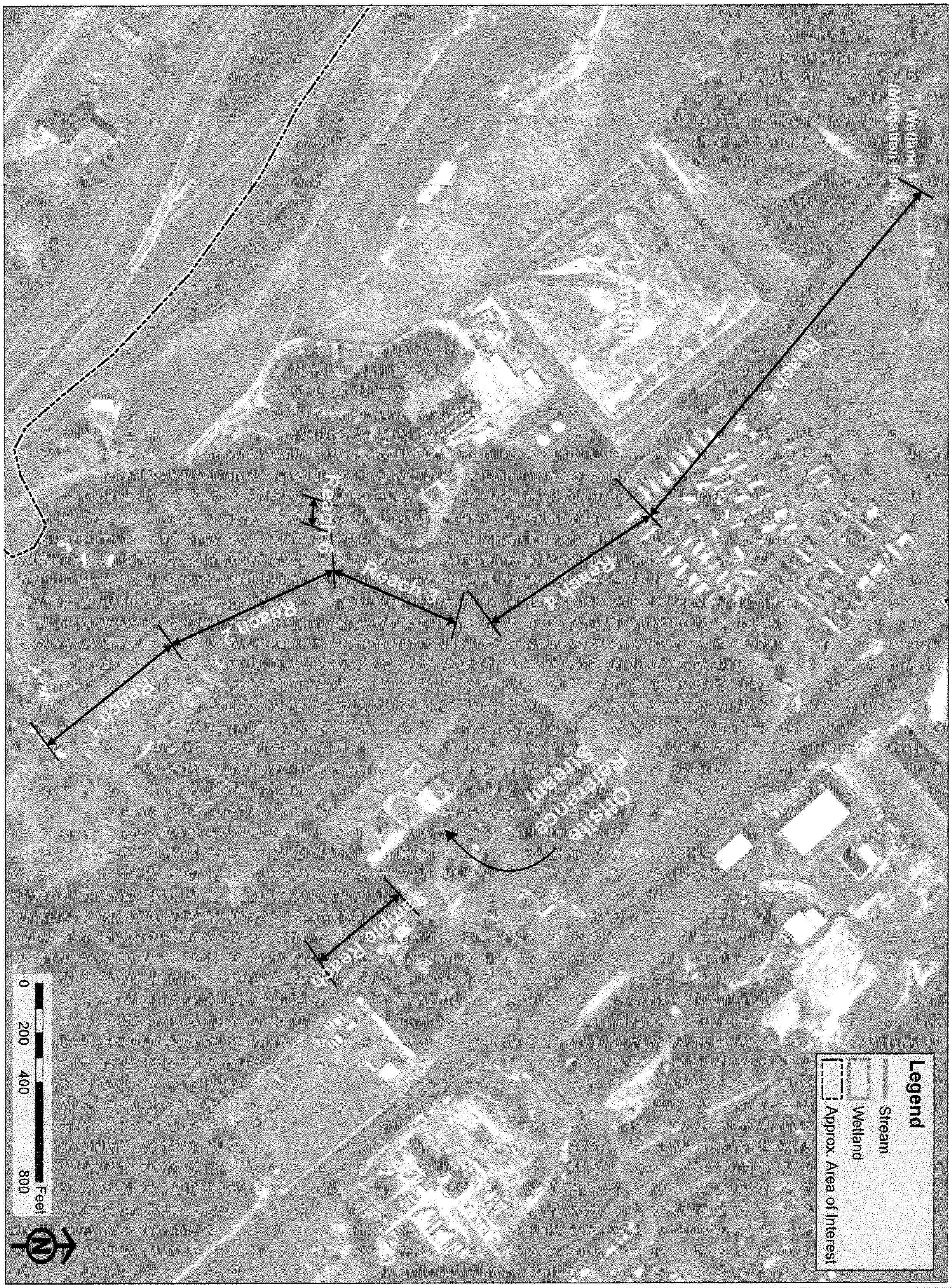


Photo 11. Offsite reference sedge meadow.

Figure 1. Stream Reach Locations



Applied Ecological Services, Inc.

Figure 1. Stream Reach Locations

Mapped by: jlc | AES Project Number: 06-0590
Field Work: | File Name: topo2of2.mxd
Checked by: | Date: 11.29.06

Albany Pine Bush Landfill
Albany County, New York
Clough Harbour & Associated, LLP
III Winners Circle, P.O. Box 6259
Albany, New York 12205-0269

Revisions:

No.	By	Date	Description
1			
2			
3			
4			
5			

Coordinate System
UTM
North American Datum NAD 83
Zone 18 N
Units meters

Data
Source Data: NRCS, 1994-1997 imagery
Aerial Published 2002

1 inch equals 175 feet
When Printed at 24"X36"

Figure 2. Wetland Locations

Revisions:			
No.	By	Date	Description
1			
2			
3			
4			
5			

Coordinate System
UTM
North American Datum (NAD) 83
Zone: 18 N
Units: meters

Data
Source/Date: NRCS, 1994-1997 mosaic
Aerial Published 2002

1 inch equals 175 feet
When Printed at 24"X36"

Albany Pine Bush Landfill
Albany County, New York
Clough Harbour & Associated, LLP
III Winners Circle, P.O. Box 6259
Albany, New York 12205-0269

Figure 2. Wetland Locations

Mapped by: jlc	AES Project Number: 06-0590
Field Work:	File Name: topo1of2.mxd
Checked by:	Date: 11.29.06

Applied Ecological Services, Inc.

APPENDIX A

QHEI SCORE SHEETS

STREAM: Offsite Reference RIVER MILE: ______ DATE: 9/27/2006 QHEI SCORE **47.50**

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE **16.00**

TYPE	POOL	RIFFLE	TYPE	POOL	RIFFLE
[ ] [ ] BLDER/SLAB(10)			[ ] [ ] GRAVEL(7)	X	
[ ] [ ] BOULDER(9)			[X] [X] SAND(6)		
[ ] [ ] COBBLE(8)			[ ] [ ] BEDROCK(5)		
[ ] [ ] HARDPAN(4)			[ ] [ ] DETRITUS(3)	X	
[ ] [ ] MUCK/SILT(2)	X		[ ] [ ] ARTIFIC(0)	X	

TOTAL NUMBER OF SUBSTRATE TYPES: [X] >4(2) [ ] <4(0)

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [ ] RIP/RAP(0) [X] TILLS(1) [ ] HARDPAN(0) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2)

SILT COVER (one): [ ] SILT-HEAVY(-2) [ ] SILT-MOD(-1) [X] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [ ] EXTENSIVE(-2) [ ] MODERATE(-1) [ ] LOW(0) [X] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER: COVER SCORE **6.00**

TYPE (Check all that apply)

[ ] UNDERCUT BANKS(1) [ ] DEEP POOLS(2) [ ] OXBOWS(1)
[X] OVERHANGING VEGETATION(1) [ ] ROOTWADS(1) [ ] AQUATIC MACROPHYTES(1)
[ ] SHALLOWS (IN SLOW WATER)(1) [X] BOULDERS(1) [X] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

[ ] EXTENSIVE >75%(11)
[ ] MODERATE 25-75%(7)
[X] SPARSE 5-25%(3)
[ ] NEARLY ABSENT <5%(1)

COMMENTS: Boulders are artificial (riprap near bridge)

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE **6.00**

SINUOSITY: [ ] HIGH(4) [ ] MODERATE(3) [X] LOW(2) [ ] NONE(1)

DEVELOPMENT: [ ] EXCELLENT(7) [ ] GOOD(5) [ ] FAIR(3) [X] POOR(1)

CHANNELIZATION: [ ] NONE(6) [ ] RECOVERED(4) [ ] RECOVERING(3) [X] RECENT OR NO RECOVERY(1)

STABILITY: [ ] HIGH(3) [X] MODERATE(2) [ ] LOW(1)

MODIFICATION/OTHER: [ ] SNAGGING [ ] IMPOUND [ ] RELOCATION [ ] ISLAND [ ] CANOPY REMOVAL [ ] LEVEED [X] DREDGING [X] BANK SHAPING [ ] ONE SIDE CHANNEL MODIFICATION

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) RIPARIAN SCORE **8.50**

River Right Looking Downstream

RIPARIAN WIDTH (per bank) — L R (per bank)
- L [ ] R [X] WIDE >150 ft.(4)
- L [X] R [ ] MODERATE 30-150 ft.(3)
- L [ ] R [ ] NARROW 15-30 ft.(2)
- L [ ] R [ ] VERY NARROW 3-15 ft.(1)
- L [ ] R [ ] NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY — L R (most predominant per bank)
- L [X] R [X] FOREST, SWAMP(3)
- L [ ] R [ ] OPEN PASTURE/ROW CROP(0)
- L [ ] R [ ] RESID.,PARK,NEW FIELD(1)
- L [ ] R [ ] FENCED PASTURE(1)

L R (per bank)
- L [ ] R [ ] URBAN OR INDUSTRIAL(0)
- L [ ] R [ ] SHRUB OR OLD FIELD(2)
- L [ ] R [ ] CONSERV. TILLAGE(1)
- L [ ] R [ ] MINING/CONSTRUCTION(0)

BANK EROSION — L R (per bank)
- L [ ] R [ ] NONE OR LITTLE(3)
- L [X] R [X] MODERATE(2)
- L [ ] R [ ] HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY NO POOL = 0 POOL SCORE **3.00**

MAX.DEPTH (Check 1): [ ] >4 ft.(6) [ ] 2.4-4 ft.(4) [ ] 1.2-2.4 ft.(2) [X] <1.2 ft.(1) [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): [ ] POOL WIDTH>RIFFLE WIDTH(2) [X] POOL WIDTH=RIFFLE WIDTH(1) [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): [ ] TORRENTIAL(-1) [ ] EDDIES(1) [ ] FAST(1) [ ] INTERSTITIAL(-1) [X] MODERATE(1) [ ] INTERMITTENT(-2) [ ] SLOW(1)

COMMENTS:

RIFFLE SCORE **0.00**

RIFFLE/RUN DEPTH: [ ] GENERALLY >4 in. MAX.>20 in.(4) [ ] GENERALLY >4 in. MAX.<20 in.(3) [ ] GENERALLY 2-4 in.(1) [X] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: [ ] STABLE (e.g., Cobble,Boulder)(2) [ ] MOD.STABLE (e.g., Pea Gravel)(1) [ ] UNSTABLE (Gravel, Sand)(0) [X] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: [ ] EXTENSIVE(-1) [ ] NONE(2) [ ] MODERATE(0) [X] NO RIFFLE(0) [ ] LOW(1)

COMMENTS:

6) GRADIENT (FEET/MILE): 6.00 % POOL 5.00 % RIFFLE 0.00 % RUN 95.00 GRADIENT SCORE **8.00**

STREAM: Rapp Road Landfill Ditch **RIVER MILE:** Reach 1 **DATE:** 9/26/2006 **QHEI SCORE** 55.00

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present)

SUBSTRATE SCORE 9.00

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)		
[ ]	[ ]	BOULDER(9)			X	[ ]	SAND(6)	X	
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[ ]	DETRITUS(3)	X	
X	[ ]	MUCK/SILT(2)	X		[ ]	[ ]	ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [X] <4(0)

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [ ] RIP/RAP(0) [X] TILLS(1) [ ] HARDPAN(0) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2)

SILT COVER (one): [ ] SILT-HEAVY(-2) [X] SILT-MOD(-1) [ ] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [ ] EXTENSIVE(-2) [ ] MODERATE(-1) [ ] LOW(0) [X] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: No gravel or cobble to measure embeddedness

2) INSTREAM COVER:

COVER SCORE 11.00

TYPE (Check all that apply)

- [X] UNDERCUT BANKS(1)
- [X] OVERHANGING VEGETATION(1)
- [ ] SHALLOWS (IN SLOW WATER)(1)
- [ ] DEEP POOLS(2)
- [X] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [ ] AQUATIC MACROPHYTES(1)
- [X] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

- [ ] EXTENSIVE >75%(11)
- [X] MODERATE 25-75%(7)
- [ ] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE)

CHANNEL SCORE 14.00

SINUOSITY: [ ] HIGH(4) [X] MODERATE(3) [ ] LOW(2) [ ] NONE(1)

DEVELOPMENT: [ ] EXCELLENT(7) [ ] GOOD(5) [X] FAIR(3) [ ] POOR(1)

CHANNELIZATION: [X] NONE(6) [ ] RECOVERED(4) [ ] RECOVERING(3) [ ] RECENT OR NO RECOVERY(1)

STABILITY: [ ] HIGH(3) [X] MODERATE(2) [ ] LOW(1)

MODIFICATION/OTHER: [ ] SNAGGING [ ] RELOCATION [ ] CANOPY REMOVAL [ ] DREDGING [ ] ONE SIDE CHANNEL MODIFICATION [ ] IMPOUND [ ] ISLAND [ ] LEVEED [ ] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank)

RIPARIAN SCORE 10.00

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	
X	X	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[ ]	[ ]	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
X	X	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[ ]	[ ]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[ ]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
X	X	NONE OR LITTLE(3)
[ ]	[ ]	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0 POOL SCORE 3.00

MAX.DEPTH (Check 1): [ ] >4 ft.(6) [ ] 2.4-4 ft.(4) [ ] 1.2-2.4 ft.(2) [X] <1.2 ft.(1) [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): [ ] POOL WIDTH>RIFFLE WIDTH(2) [X] POOL WIDTH=RIFFLE WIDTH(1) [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): [ ] TORRENTIAL(-1) [ ] FAST(1) [X] MODERATE(1) [ ] SLOW(1) [ ] EDDIES(1) [ ] INTERSTITIAL(-1) [ ] INTERMITTENT(-2)

COMMENTS: No riffles. Pool witdth measrued against run width.

RIFFLE SCORE 0.00

RIFFLE/RUN DEPTH: [ ] GENERALLY >4 in. MAX.>20 in.(4) [ ] GENERALLY >4 in. MAX.<20 in.(3) [ ] GENERALLY 2-4 in.(1) [X] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: [ ] STABLE (e.g., Cobble,Boulder)(2) [ ] MOD.STABLE (e.g., Pea Gravel)(1) [ ] UNSTABLE (Gravel, Sand)(0) [X] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: [ ] EXTENSIVE(-1) [ ] MODERATE(0) [ ] LOW(1) [ ] NONE(2) [X] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 6.00

% POOL 15.00 % RIFFLE 0.00 % RUN 85.00 GRADIENT SCORE 8.00

STREAM: Rap Road Landfill Ditch RIVER MILE: Reach 2 DATE: 9/26/2006 QHEI SCORE 43.50

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE 9.00

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)		
[ ]	[ ]	BOULDER(9)			[X]	[ ]	SAND(6)		
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[ ]	DETRITUS(3)		
[X]	[ ]	MUCK/SILT(2)	X		[ ]	[ ]	ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [X] <4(0)

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [ ] RIP/RAP(0) [X] TILLS(1) [ ] HARDPAN(0) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2)

SILT COVER (one): [ ] SILT-HEAVY(-2) [X] SILT-MOD(-1) [ ] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [ ] EXTENSIVE(-2) [ ] MODERATE(-1) [ ] LOW(0) [X] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: No gravel or cobble to measure embeddedness

2) INSTREAM COVER: COVER SCORE 6.00

TYPE (Check all that apply)

- [ ] UNDERCUT BANKS(1)
- [X] OVERHANGING VEGETATION(1)
- [ ] SHALLOWS (IN SLOW WATER)(1)
- [ ] DEEP POOLS(2)
- [X] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [ ] AQUATIC MACROPHYTES(1)
- [X] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

- [ ] EXTENSIVE >75%(11)
- [ ] MODERATE 25-75%(7)
- [X] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE 8.00

SINUOSITY: [ ] HIGH(4) [ ] MODERATE(3) [X] LOW(2) [ ] NONE(1)

DEVELOPMENT: [ ] EXCELLENT(7) [ ] GOOD(5) [X] FAIR(3) [ ] POOR(1)

CHANNELIZATION: [ ] NONE(6) [ ] RECOVERED(4) [ ] RECOVERING(3) [X] RECENT OR NO RECOVERY(1)

STABILITY: [ ] HIGH(3) [X] MODERATE(2) [ ] LOW(1)

MODIFICATION/OTHER: [ ] SNAGGING [ ] RELOCATION [ ] CANOPY REMOVAL [X] DREDGING [ ] ONE SIDE CHANNEL MODIFICATION [ ] IMPOUND [ ] ISLAND [ ] LEVEED [X] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) RIPARIAN SCORE 9.50

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
X	X	WIDE >150 ft.(4)
		MODERATE 30-150 ft.(3)
		NARROW 15-30 ft.(2)
		VERY NARROW 3-15 ft.(1)
		NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
X	X	FOREST, SWAMP(3)			URBAN OR INDUSTRIAL(0)
		OPEN PASTURE/ROW CROP(0)			SHRUB OR OLD FIELD(2)
		RESID.,PARK,NEW FIELD(1)			CONSERV. TILLAGE(1)
		FENCED PASTURE(1)			MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
X		NONE OR LITTLE(3)
	X	MODERATE(2)
		HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY NO POOL = 0 POOL SCORE 3.00

MAX.DEPTH (Check 1): [ ] >4 ft.(6) [ ] 2.4-4 ft.(4) [ ] 1.2-2.4 ft.(2) [X] <1.2 ft.(1) [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): [ ] POOL WIDTH>RIFFLE WIDTH(2) [X] POOL WIDTH=RIFFLE WIDTH(1) [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): [ ] TORRENTIAL(-1) [ ] FAST(1) [X] MODERATE(1) [ ] SLOW(1) [ ] EDDIES(1) [ ] INTERSTITIAL(-1) [ ] INTERMITTENT(-2)

COMMENTS: No riffles. Pool width measured against run width

RIFFLE SCORE 0.00

RIFFLE/RUN DEPTH: [ ] GENERALLY >4 in. MAX.>20 in.(4) [ ] GENERALLY >4 in. MAX.<20 in.(3) [ ] GENERALLY 2-4 in.(1) [X] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: [ ] STABLE (e.g., Cobble,Boulder)(2) [ ] MOD.STABLE (e.g., Pea Gravel)(1) [ ] UNSTABLE (Gravel, Sand)(0) [X] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: [ ] EXTENSIVE(-1) [ ] MODERATE(0) [ ] LOW(1) [ ] NONE(2) [X] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 6.00 % POOL 5.00 % RIFFLE 0.00 % RUN 95.00 GRADIENT SCORE 8.00

STREAM: Rapp Road Landfill Ditch RIVER MILE: Reach 3 DATE: 9/26/2006 QHEI SCORE 40.00

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE 9.00

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)		
[ ]	[ ]	BOULDER(9)			[X]	[ ]	SAND(6)	X	
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[ ]	DETRITUS(3)		
[X]	[ ]	MUCK/SILT(2)	X		[ ]	[ ]	ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [X] <4(0)

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [ ] RIP/RAP(0) [X] TILLS(1) [ ] HARDPAN(0) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2)

SILT COVER (one): [ ] SILT-HEAVY(-2) [X] SILT-MOD(-1) [ ] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [ ] EXTENSIVE(-2) [ ] MODERATE(-1) [ ] LOW(0) [X] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: No gravel or cobble to measure embeddedness

2) INSTREAM COVER: COVER SCORE 5.00

TYPE (Check all that apply)

[ ] UNDERCUT BANKS(1) [ ] DEEP POOLS(2) [ ] OXBOWS(1)
[X] OVERHANGING VEGETATION(1) [ ] ROOTWADS(1) [ ] AQUATIC MACROPHYTES(1)
[ ] SHALLOWS (IN SLOW WATER)(1) [ ] BOULDERS(1) [X] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

[ ] EXTENSIVE >75%(11)
[ ] MODERATE 25-75%(7)
[X] SPARSE 5-25%(3)
[ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE 7.00

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
[ ] HIGH(4)	[ ] EXCELLENT(7)	[ ] NONE(6)	[ ] HIGH(3)
[ ] MODERATE(3)	[ ] GOOD(5)	[ ] RECOVERED(4)	[ ] MODERATE(2)
[X] LOW(2)	[ ] FAIR(3)	[X] RECOVERING(3)	[X] LOW(1)
[ ] NONE(1)	[X] POOR(1)	[ ] RECENT OR NO RECOVERY(1)	

MODIFICATION/OTHER: [ ] SNAGGING [ ] IMPOUND [ ] RELOCATION [ ] ISLAND [ ] CANOPY REMOVAL [ ] LEVEED [ ] DREDGING [ ] BANK SHAPING [ ] ONE SIDE CHANNEL MODIFICATION

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) RIPARIAN SCORE 8.00

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[X]	[X]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[ ]	[ ]	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[X]	[X]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[ ]	[ ]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[ ]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[ ]	[ ]	NONE OR LITTLE(3)
[ ]	[ ]	MODERATE(2)
[X]	[X]	HEAVY OR SEVERE(1)

COMMENTS: Headcut at upstream point of reach

5) POOL/GLIDE AND RIFFLE/RUN QUALITY NO POOL = 0 POOL SCORE 3.00

MAX.DEPTH (Check 1)

[ ] >4 ft.(6)
[ ] 2.4-4 ft.(4)
[ ] 1.2-2.4 ft.(2)
[X] <1.2 ft.(1)
[ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)

[ ] POOL WIDTH>RIFFLE WIDTH(2)
[X] POOL WIDTH=RIFFLE WIDTH(1)
[ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)

[ ] TORRENTIAL(-1) [ ] EDDIES(1)
[ ] FAST(1) [ ] INTERSTITIAL(-1)
[X] MODERATE(1) [ ] INTERMITTENT(-2)
[ ] SLOW(1)

COMMENTS: No true riffles. Pool width measured against run width

RIFFLE SCORE 0.00

RIFFLE/RUN DEPTH

[ ] GENERALLY >4 in. MAX.>20 in.(4)
[ ] GENERALLY >4 in. MAX.<20 in.(3)
[ ] GENERALLY 2-4 in.(1)
[X] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE

[ ] STABLE (e.g., Cobble,Boulder)(2)
[ ] MOD.STABLE (e.g., Pea Gravel)(1)
[ ] UNSTABLE (Gravel, Sand)(0)
[X] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS

[ ] EXTENSIVE(-1) [ ] NONE(2)
[ ] MODERATE(0) [X] NO RIFFLE(0)
[ ] LOW(1)

COMMENTS:

6) GRADIENT (FEET/MILE): 6.00 % POOL 5.00 % RIFFLE 0.00 % RUN 95.00 GRADIENT SCORE 8.00

STREAM: Rapp Road Landfill Ditch RIVER MILE: Reach 4 DATE: 9/26/2006 QHEI SCORE **49.00**

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present)

SUBSTRATE SCORE **9.00**

TYPE		POOL	RIFFLE	TYPE		POOL	RIFFLE
[ ]	[ ] BLDER/SLAB(10)			[ ]	[ ] GRAVEL(7)		
[ ]	[ ] BOULDER(9)			[X]	[ ] SAND(6)	X	
[ ]	[ ] COBBLE(8)			[ ]	[ ] BEDROCK(5)		
[ ]	[ ] HARDPAN(4)			[ ]	[ ] DETRITUS(3)		
[X]	[ ] MUCK/SILT(2)	X		[ ]	[ ] ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [X] <4(0)

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [X] TILLS(1) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2) [ ] RIP/RAP(0) [ ] HARDPAN(0)

SILT COVER (one): [ ] SILT-HEAVY(-2) [ ] SILT-NORM(0) [X] SILT-MOD(-1) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [ ] EXTENSIVE(-2) [ ] LOW(0) [ ] MODERATE(-1) [X] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: No gravel or cobble to measure embeddedness

2) INSTREAM COVER:

COVER SCORE **10.00**

TYPE (Check all that apply)

- [ ] UNDERCUT BANKS(1)
- [X] OVERHANGING VEGETATION(1)
- [ ] SHALLOWS (IN SLOW WATER)(1)
- [ ] DEEP POOLS(2)
- [X] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [ ] AQUATIC MACROPHYTES(1)
- [X] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

- [ ] EXTENSIVE >75%(11)
- [X] MODERATE 25-75%(7)
- [ ] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE)

CHANNEL SCORE **10.00**

SINUOSITY: [ ] HIGH(4) [ ] MODERATE(3) [X] LOW(2) [ ] NONE(1)

DEVELOPMENT: [ ] EXCELLENT(7) [ ] GOOD(5) [X] FAIR(3) [ ] POOR(1)

CHANNELIZATION: [ ] NONE(6) [ ] RECOVERED(4) [X] RECOVERING(3) [ ] RECENT OR NO RECOVERY(1)

STABILITY: [ ] HIGH(3) [X] MODERATE(2) [ ] LOW(1)

MODIFICATION/OTHER: [ ] SNAGGING [ ] RELOCATION [ ] CANOPY REMOVAL [X] DREDGING [ ] ONE SIDE CHANNEL MODIFICATION [ ] IMPOUND [ ] ISLAND [ ] LEVEED [X] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank)

RIPARIAN SCORE **9.00**

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
X	X	WIDE >150 ft.(4)
		MODERATE 30-150 ft.(3)
		NARROW 15-30 ft.(2)
		VERY NARROW 3-15 ft.(1)
		NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
X	X	FOREST, SWAMP(3)			URBAN OR INDUSTRIAL(0)
		OPEN PASTURE/ROW CROP(0)			SHRUB OR OLD FIELD(2)
		RESID.,PARK,NEW FIELD(1)			CONSERV. TILLAGE(1)
		FENCED PASTURE(1)			MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
		NONE OR LITTLE(3)
X	X	MODERATE(2)
		HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0 POOL SCORE **3.00**

MAX.DEPTH (Check 1): [ ] >4 ft.(6) [ ] 2.4-4 ft.(4) [ ] 1.2-2.4 ft.(2) [X] <1.2 ft.(1) [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): [ ] POOL WIDTH>RIFFLE WIDTH(2) [X] POOL WIDTH=RIFFLE WIDTH(1) [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): [ ] TORRENTIAL(-1) [ ] FAST(1) [X] MODERATE(1) [ ] SLOW(1) [ ] EDDIES(1) [ ] INTERSTITIAL(-1) [ ] INTERMITTENT(-2)

COMMENTS: No riffles. Pool width compared to run width

RIFFLE SCORE **0.00**

RIFFLE/RUN DEPTH: [ ] GENERALLY >4 in. MAX.>20 in.(4) [ ] GENERALLY >4 in. MAX.<20 in.(3) [ ] GENERALLY 2-4 in.(1) [X] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: [ ] STABLE (e.g., Cobble,Boulder)(2) [ ] MOD.STABLE (e.g., Pea Gravel)(1) [ ] UNSTABLE (Gravel, Sand)(0) [X] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: [ ] EXTENSIVE(-1) [ ] MODERATE(0) [ ] LOW(1) [ ] NONE(2) [X] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 6.00

% POOL 10.00 % RIFFLE 0.00 % RUN 90.00 GRADIENT SCORE **8.00**

STREAM: Rapp Road Landfille Ditch RIVER MILE: Reach 5 DATE: 9/28/2006 QHEI SCORE **45.50**

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE **8.00**

TYPE		POOL	RIFFLE
[ ] [ ]	BLDER/SLAB(10)		
[ ] [ ]	BOULDER(9)		
[ ] [ ]	COBBLE(8)		
[ ] [ ]	HARDPAN(4)		
[X] [ ]	MUCK/SILT(2)	X	
[ ] [ ]	GRAVEL(7)		
[X] [ ]	SAND(6)		
[ ] [ ]	BEDROCK(5)		
[ ] [ ]	DETRITUS(3)	X	
[ ] [ ]	ARTIFIC(0)		

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [ ] RIP/RAP(0) [X] TILLS(1) [ ] HARDPAN(0) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2)

SILT COVER (one): [ ] SILT-HEAVY(-2) [X] SILT-MOD(-1) [ ] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [ ] EXTENSIVE(-2) [ ] MODERATE(-1) [X] LOW(0) [ ] NONE(1)

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [X] <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER: COVER SCORE **10.00**

TYPE (Check all that apply)

[ ] UNDERCUT BANKS(1) [X] OVERHANGING VEGETATION(1) [ ] SHALLOWS (IN SLOW WATER)(1) [ ] DEEP POOLS(2) [X] ROOTWADS(1) [ ] BOULDERS(1) [ ] OXBOWS(1) [ ] AQUATIC MACROPHYTES(1) [X] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

[ ] EXTENSIVE >75%(11) [X] MODERATE 25-75%(7) [ ] SPARSE 5-25%(3) [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE **10.00**

SINUOSITY: [ ] HIGH(4) [ ] MODERATE(3) [X] LOW(2) [ ] NONE(1)

DEVELOPMENT: [ ] EXCELLENT(7) [ ] GOOD(5) [X] FAIR(3) [ ] POOR(1)

CHANNELIZATION: [ ] NONE(6) [ ] RECOVERED(4) [X] RECOVERING(3) [ ] RECENT OR NO RECOVERY(1)

STABILITY: [ ] HIGH(3) [X] MODERATE(2) [ ] LOW(1)

MODIFICATION/OTHER: [ ] SNAGGING [ ] RELOCATION [ ] CANOPY REMOVAL [X] DREDGING [ ] ONE SIDE CHANNEL MODIFICATION [ ] IMPOUND [ ] ISLAND [ ] LEVEED [X] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) RIPARIAN SCORE **6.50**

River Right Looking Downstream

RIPARIAN WIDTH (per bank) — L R (per bank): [ ] [ ] WIDE >150 ft.(4) [ ] [ ] MODERATE 30-150 ft.(3) [ ] [ ] NARROW 15-30 ft.(2) [X] [X] VERY NARROW 3-15 ft.(1) [ ] [ ] NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY — L R (most predominant per bank): [ ] [X] FOREST, SWAMP(3) [ ] [ ] OPEN PASTURE/ROW CROP(0) [ ] [ ] RESID.,PARK,NEW FIELD(1) [ ] [ ] FENCED PASTURE(1)

L R (per bank): [ ] [ ] URBAN OR INDUSTRIAL(0) [X] [ ] SHRUB OR OLD FIELD(2) [ ] [ ] CONSERV. TILLAGE(1) [ ] [ ] MINING/CONSTRUCTION(0)

BANK EROSION — L R (per bank): [X] [X] NONE OR LITTLE(3) [ ] [ ] MODERATE(2) [ ] [ ] HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** POOL SCORE **3.00**

MAX.DEPTH (Check 1): [ ] >4 ft.(6) [ ] 2.4-4 ft.(4) [ ] 1.2-2.4 ft.(2) [X] <1.2 ft.(1) [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): [ ] POOL WIDTH>RIFFLE WIDTH(2) [X] POOL WIDTH=RIFFLE WIDTH(1) [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): [ ] TORRENTIAL(-1) [ ] FAST(1) [X] MODERATE(1) [ ] SLOW(1) [ ] EDDIES(1) [ ] INTERSTITIAL(-1) [ ] INTERMITTENT(-2)

COMMENTS:

RIFFLE SCORE **0.00**

RIFFLE/RUN DEPTH: [ ] GENERALLY >4 in. MAX.>20 in.(4) [ ] GENERALLY >4 in. MAX.<20 in.(3) [ ] GENERALLY 2-4 in.(1) [X] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: [ ] STABLE (e.g., Cobble,Boulder)(2) [ ] MOD.STABLE (e.g., Pea Gravel)(1) [ ] UNSTABLE (Gravel, Sand)(0) [X] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: [ ] EXTENSIVE(-1) [ ] MODERATE(0) [ ] LOW(1) [ ] NONE(2) [X] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 6.00 **% POOL** 20.00 **% RIFFLE** 0.00 **% RUN** 80.00 GRADIENT SCORE **8.00**

APPENDIX B

MACROINVERTEBRATE DATA SHEETS

LABORATORY DATA SHEET

River/Stream/Wetland: Rapp Road Landfill Stream

Station Number: Reach 1

Date: September 26, 2006

Sample Type: D-framed kick net

Subsample: entire ½ ¼ 100

Sorted by: David MacDougall, October-November 2006

	Sub.	Total		Sub.	Total
Nemertea			Coleoptera		
			Dytiscidae		3
Platyhelminthes					
Oligochaeta			Megaloptera		1
Hirundinea			Trichoptera		
			Hydropsychidae		7
Mollusca			Glossosomatidae		1
Physella integra		278			
Planarbula armigera		5			
Sphaerium sp.		1	Other Diptera		
Musculium sp.		1	Tipulidae		10
Crustacea					
Isopoda		15			
			Chironomidae larvae		37
			pupae		5
Ephemeroptera			total		42
Plecoptera					
Other Insecta					
Hemiptera – Gerris remigis		3			
Arachnida - Araneae		2			

LABORATORY DATA SHEET

River/Stream/Wetland: Rapp Road Landfill Stream

Station Number: Reach 2

Date: September 26, 2006

Sample Type: D – framed kick net

Subsample: entire ½ ¼ 100

Sorted by: David MacDougall, October – November 2006

	Sub.	Total		Sub.	Total
Nemertea			Coleoptera		
			Dytiscidae		5
Platyhelminthes					
Oligochaeta			Megaloptera		
Hirundinea			Trichoptera		
			Hydropsychidae		1
Mollusca					
Planorbula armigera		1			
Physella integra		15			
Musculium sp.		1	Other Diptera		
Sphaerium sp.		1	Athericidae		1
Lymnaea stagnalis		1	Tipulidae		1
Crustacea					
Isopoda		27			
			Chironomidae larvae		1
			pupae		
Ephemeroptera			total		
Plecoptera					
Other Insecta					
Hemiptera – *Gerris remigis*		3			

LABORATORY DATA SHEET

River/Stream/Wetland: Rapp Road Landfill Stream

Station Number: Reach 3

Date: September 26, 2006

Sample Type: D – framed kick net

Subsample: entire ½ ¼ 100

Sorted by: David MacDougall, October-November 2006

	Sub.	Total		Sub.	Total
Nemertea			Coleoptera		
			Dytiscidae		3
Platyhelminthes					
Turbellaria - Planaria		9			
Oligochaeta			Megaloptera		
Hirundinea			Trichoptera		
			Hydropsychidae		4
Mollusca			Limnephilidae		2
Physella integra		2			
Musculium sp.		2			
			Other Diptera		
			Tipulidae		4
			Stratiomyidae		3
Crustacea					
Isopoda		15			
			Chironomidae larvae		3
			pupae		
Ephemeroptera			total		
Baetidae		1			
Plecoptera					
Other Insecta					
Hemiptera – *Gerris remigis*		1			

LABORATORY DATA SHEET
River/Stream/Wetland: Rapp Road Landfill Stream
Station Number: Reach 4
Date: September 26, 2006
Sample Type: D – framed kick net
Subsample: entire ½ ¼ 100
Sorted by: David MacDougall, October – November 2006

	Sub.	Total		Sub.	Total
Nemertea			Coleoptera		
Platyhelminthes					
Turbellaria - Planaria		23			
Oligochaeta			Megaloptera		4
Hirundinea			Trichoptera		
			Glossosomatidae		1
Mollusca			Hydropsychidae		1
Lymnaea stagnalis		1			
			Other Diptera		
			Tipulidae		9
			Athericidae		1
Crustacea					
Isopoda		83			
			Chironomidae larvae		2
			pupae		
Ephemeroptera			total		
Baetidae		3			
Plecoptera					
Other Insecta					

LABORATORY DATA SHEET
River/Stream/Wetland: Rapp Road Landfill Stream
Station Number: Reach 5
Date: September 26, 2006
Sample Type: D – framed kick net
Subsample: entire ½ ¼ 100
Sorted by: David MacDougall, October-November

	Sub.	Total		Sub.	Total
Nemertea			Coleoptera		
			Dytiscidae		5
Platyhelminthes					
Oligochaeta		1	Megaloptera		3
Hirundinea			Trichoptera		
Mollusca					
Musculium sp.		100			
Sphaerium sp.		82			
			Other Diptera		
			Ptychopteridae		68
			Stratiomyidae		2
Crustacea					
Isopoda		1			
			Chironomidae larvae		2
			pupae		
Ephemeroptera			total		
Plecoptera					
Other Insecta					
Hemiptera – *Gerris remigis*		1			

LABORATORY DATA SHEET

River/Stream/Wetland: Rapp Road Landfill Stream

Station Number: Reach 6

Date: September 28, 2006

Sample Type: D – framed kick net

Subsample: entire ½ ¼ 100

Sorted by: David MacDougall, October – November 2006

	Sub.	Total		Sub.	Total
Nemertea			Coleoptera		
Platyhelminthes					
Oligochaeta			Megaloptera		
Hirundinea			Trichoptera		
Mollusca					
Planorbula armigera		1			
Sphaerium sp.		20			
Musculium sp.		8	Other Diptera		
Lymnaea stagnalis		3			
Physella integra		8			
Crustacea					
Isopoda		62			
			Chironomidae larvae		5
			pupae		
Ephemeroptera			total		
Plecoptera					
Other Insecta					
Hemiptera – *Gerris remigis*		1			

LABORATORY DATA SHEET

River/Stream/Wetland: Rapp Road Landfill – Offsite Reference Stream

Station Number: N/A

Date: September 26 & 27, 2006

Sample Type: D – framed kick net

Subsample: entire ½ ¼ 100

Sorted by: David MacDougall, October – November 2006

	Sub.	Total		Sub.	Total
Nemertea			Coleoptera		
Platyhelminthes					
Oligochaeta			Megaloptera		
Hirundinea			Trichoptera		
Mollusca					
Physella integra		1			
			Other Diptera		
			Ptychopteridae		2
			Tipulidae		1
Crustacea					
			Chironomidae larvae		3
			pupae		1
Ephemeroptera			total		4
Plecoptera					
Other Insecta					
Hemiptera: Notonectidae		1			

LABORATORY DATA SHEET

River/Stream/Wetland: Rapp Road Landfill - Mitigation Pond

Station Number: Wetland # 1

Date: September 27, 2006

Sample Type: D – framed kick net

Subsample: entire ½ ¼ 100

Sorted by: David MacDougall, October – November 2006

	Sub.	Total		Sub.	Total
Nemertea			Coleoptera		
			Dytiscidae		2
Platyhelminthes					
Oligochaeta			Megaloptera		
Hirundinea			Trichoptera		
Mollusca					
			Other Diptera		
			Dixidae		33
Crustacea					
			Chironomidae larvae		
			pupae		
Ephemeroptera			total		
Plecoptera					
Other Insecta					
Hemiptera: Notonectidae		30			
Hemiptera: Corixidae		31			
Odonata: Anisoptera: Aeshnidae		18			
Odonata: Anisoptera: Libellulidae					
Celithemis sp.		9			
Odonata: Zygoptera: Lestidae		72			
Hemiptera: Belostomatidae		1			

LABORATORY DATA SHEET
River/Stream/Wetland: Rapp Road Landfill – Button Bush Swamp
Station Number: Wetland # 2
Date: September 27, 2006
Sample Type: D – framed kick net
Subsample: entire ½ ¼ 100
Sorted by: David MacDougall, October – November 2006

	Sub.	Total		Sub.	Total
Nemertea			Coleoptera		
			Dytiscidae		1
Platyhelminthes					
Oligochaeta			Megaloptera		
Hirundinea			Trichoptera		
Mollusca					
Planorbula armigera		10			
			Other Diptera		
			Dixidae		9
Crustacea					
			Chironomidae larvae		
			pupae		
Ephemeroptera			total		
Plecoptera					
Other Insecta					
Odonata: Anisoptera: Aeshaidae		4			
Hemiptera: Notonectidae		11			
Hemiptera: Corixidae		1			
Odonata: Zygoptera: Lestidae		3			
Odonata: Anisoptera: Libellulidae					
Libellulinae: *Leucorrhinia sp.*		2			

LABORATORY DATA SHEET					
River/Stream/Wetland: Rapp Road Landfill – Bog/Vernal Pond Reference Site					
Station Number: Wetland # 3					
Date: September 27, 2006					
Sample Type: D – framed kick net					
Subsample: entire ½ ¼ 100					
Sorted by: David MacDougall, October – November 2006					
	Sub.	Total		Sub.	Total
Nemertea			Coleoptera		
			Dytiscidae		2
Platyhelminthes					
Oligochaeta			Megaloptera		
Hirundinea			Trichoptera		
			Phryganeidae - *Ptilostomis*		2
Mollusca					
			Other Diptera		
			Dixidae		1
Crustacea					
			Chironomidae larvae		
			pupae		
Ephemeroptera			total		
Plecoptera					
Other Insecta					
Odonata: Anispotera: Aeshnidae		10			
Hemiptera: Notonectidae		36			
Hemiptera: Belostomatidae		1			
Odonata: Zygoptera: Coenagrimidae		1			

LABORATORY DATA SHEET					
River/Stream/Wetland: Rapp Road Landfill – Offsite Reference Sedge meadow					
Station Number: Wetland # 4					
Date: September 27, 2006					
Sample Type: D – framed kick net					
Subsample: entire ½ ¼ 100					
Sorted by: David MacDougall, October – November 2006					
	Sub.	Total		Sub.	Total
Nemertea			Coleoptera		
			Dytiscidae		19
Platyhelminthes					
Oligochaeta			Megaloptera		
Hirundinea			Trichoptera		
Mollusca					
Planorbula armigera		8			
			Other Diptera		
			Dixidae		3
Crustacea					
			Chironomidae larvae		
			pupae		
Ephemeroptera			total		
Plecoptera					
Other Insecta					
Hemiptera: *Ranatra elongata*		3			
Odonata: Anisoptera: Aeshnidae		4			
Hemiptera: Notonectidae		21			
Hemiptera: Corixidae		29			
Odonata: Anisoptera: Libellulidae					
Libellulinae: *Leucorrhinia sp.*		12			
Odonata: Anisoptera: Libellulidae					
Libellulinae: *Libellula sp.*		2			
Odonata: Zygoptera: Lestidae		16			

H:060590:012207

A review of the impacts and risks for use of native grass, forb, shrub and tree species plantings when used to stabilize and close domestic solid waste landfill caps.

prepared for

The Albany, New York Landfill

by

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TABLE OF CONTENTS TOC \o "1-3"

INTRODUCTION

This is a technical review of the scientific literature to address the following questions and purposes:

- Can native prairie grasses, wildflowers, forbs and trees be used safely for the final revegetation and stabilization of the Albany landfill cap?
- Will native species grow on geotextile protected clay caps?
- Will these plant species contribute, cause, or exacerbate failure of the geotextile clay cap? If so, by what proven mechanisms?
- Are native plant species equal or superior to stabilize and reduce the risks of failure of geotextile clay caps?
- What are the growth and survival characteristics of native prairie grasses, flowers, shrubs and trees that confirm native species are compatible with landfill cap closure?
- What characteristics of soil and landfill cap management will augment or detract from native species use for landfill cap closures?

OVERVIEW OF SITE CLOSURE PLAN

When landfills are closed with a geotextile clay liner (GCL) and upper barrier protection subsoils to prevent water entry and subsequent mobilization of contaminants, the long-term integrity of the cap system is the paramount concern. Usually, GCLs are covered by a minimum of three or four 6 inch soil lifts that are compacted in place, after clean compacted fill soil of variable thickness was placed on top of the waste. In general, above the waste a lower barrier protection layer of fill soil, often 24” thick, supports a composite plastic liner of 60 mils thickness. On top of the composite liner, a gravel or drainage composite layer is connected to a subsurface drainage system within the cap to move water off the landfill cap safely. Then an upper barrier protection layer (UPBL) of 18 to 24 inches of more permeable soils with an uppermost layer of six inches of humified topsoil completes the cap. Sometimes the geotextile membrane is a bentonite blanket contained between 2 woven geotextile fabric layers rather than a synthetic plastic membrane. The majority of landfill closures then plant the surface to a typical aggressive lawn or roadside grass mix that is not native. When a cap's barrier is either compacted clay or a bentonite blanket, it is important to regulate shrink/swell potential of these soil materials to lower the risk of failure of the clay barrier during cycles of drought and re-wetting. In arid environments, irrigation has been used to control clay shrinkage by moisture and maintain the integrity of the clay layer.

After closure and stabilization, some landfill caps have been converted to open space, parks, even parking lots. Recreational facilities, bicycle paths, walking trails, irrigated lawn, and even floating slab buildings have been installed on thicker caps even those without synthetic or compacted barriers to water penetration, especially in Europe. Presently, North America's largest closed domestic landfill at Fresh Kills, Staten Island, New York is being planned for a succession of land uses that will include the required facilities and infrastructure for recreational uses on a thousand acres of waste footprint of that closed landfill facility. The Penn and Fountain landfill closures on Long Island also feature a close integration with the Jamaica Bay recreational area through the use of specialized soils in the cap above the impermeable layers created to promote the growth of native species. These facilities depart significantly from the typical closure model in three ways: (1) Native species only are used in the vegetation of the caps; the strategy is to promote native species reclamation and retard invasion by alien plant species that prefer rich agronomic soils, (2) Exceptional care has been taken to mimic the chemical and physical qualities of the native subsoil and topsoils of the region in these caps, and (3) Native grasses, forbs, shrubs and trees are the landfill cap vegetation in place of the customary lawn grass.

ASSUMPTIONS

Several assumptions were made during this review as follows:

If native species can be used for site stabilization rather than the common alien grasses this may reduce long term maintenance, obviate any need for irrigation or other annual maintenance and will provide a more attractive successor land use. We assumed it is desirable to naturalize landfills with native vegetation in park-like settings as this will also attract native wildlife that the public deems to be valuable. One explicit goal is to convert perceived public liabilities into valued public assets.

Review of Technical Literature

We summarize the relevant published technical literature and AES experience that addresses the questions and information needs that respond to the questions posed in the introduction.

Demonstration of Regulatory Compliance

This report explores if a native landscape design is consistent with the closure and regulatory intent for this site. The use of native grass, forb, tree, and shrub plantings on caps must provide stabilization and safe conditions before enhancement of the closed site. Regulators require that closure engineering, plant ecological/soil conditions, and ecological restoration strategies are reviewed for appropriateness (e.g. Viessman and Hammer 1985; Northeastern Illinois soil erosion and sedimentation control steering committee 1989; Mariner and Mertz-Irwin 1991; Spooner et al. 1992 etc.) The USEPA often addresses non-point source water quality management (USEPA 1983; Cunningham 1988). In some cases the US Fish and Wildlife Service or state Department of Natural Resources may become involved if there are rare, threatened or endangered species, wetland or watershed issues at a site. The typical regulatory concerns usually includes a point by point discussion of the performance of conventional vs. alternative native planting landscape designs with criteria associated with site closure, to wit:

- **Vegetation shall be promoted on all reconstructed surfaces to minimize wind and water erosion of the final protective covers**.

  Stabilization against wind and water erosion, and protection of the capping system, to prevent exposure of the geomembrane and drainage structure is of primary concern during site planning, design and regulatory reviews. Soil bioengineering using locally adapted native plants create stronger and more stable plantings. Native plants are adapted and grow best under the local conditions of ecological severity and extremes as exist on a clay cap slope or top. Native species have shown the most success in stabilization of extreme slopes and poor substrates during wind and water erosion events and especially during extreme drought. Consequently, natives have been recommended for regional use in stressed growing conditions that include road cuts, landfills, mined lands, and other severely-stressed settings, (Horton 1949; Weaver 1954; Plummer 1970; Johnson et al 1971; USDA Soil Cons. Svs. 1972; Gillick and Scott 1975; Hall and Ludwig 1975; USEPA 1975; Edmunson 1976; Dehgan et al 1977; Bennet et al 1978; Kuenstler et al 1978; Monsen 1978; Leone et al 1979; Schiechtl 1980; Diekelmann and Schuster 1982; Hunt 1983; Shimell 1983; Bowen 1985; Peven 1985; Henderson 1987; Gray and Leiser 1989; Apfelbaum 1991; Mariner and Mertz-Irwin 1991, etc.). The excellent performance of native species under severe drought stress is especially significant because the underdrain layer above the geomembrane below the UPBL restricts the available reserves of soil pore water to only the water storable in the permeable soils of this UPBL layer and whatever topsoil has been applied. Typically, the UPBL soils are permeable silty sands with a modest capacity for water storage (i.e. the field capacity) between precipitation events, typically 1.5 – 2.0 inches per foot. In natural soil profiles, there is a measurable capacity to renew this supply by upward wicking of waters from deep subsoils during droughts. This does not exist in landfill caps because the drainage layer above the geomembrane does not store water and the geomembrane or compacted clay barrier prevents access to any pore waters under this barrier.

Limited end-use opportunities often result from the design criteria for plantings done only to lower the risk of failure of the cap. Recently, a series of projects to design closure plantings for multiple benefits and uses have proceeded in the country, most notably in the boroughs of New York. The recently completed Penn and Fountain projects in Brooklyn and the planned Fresh Kills Lifescape project on Staten Island illustrate the direction of landfill capping and closures in New York State. These regional projects are building on experiences at the St. Johns Landfill in Portland, Oregon and Countryside Landfill in Grayslake, Illinois, all of which have used soil bioengineering and plantings with native grasses, wildflowers, shrubs and trees to achieve site stabilization, improved plant and animal diversity and numerous new recreational end-use opportunities that conventional alien species plantings and standard soil caps do not provide. These and other plantings on high risk sites with steep slopes or severe conditions have very favorable outcomes without loss of the engineering integrity of the design and no environmental or regulatory concerns (Handel 1989; Wong and Yu 1989; AES 2004).

- **Vegetation shall be compatible with the climatic conditions.**

The use of native grasses, forbs, shrubs and trees for slope stabilization to address the regional climatic swings typical of New York growing seasons provides a very different end product and opportunity set. A closure planting program for the Albany site could use native species best adapted to the high exposure, windswept, and extreme droughty slopes and regional climate (Tables

1 and 2). Allowance for the droughty conditions typical of the rare scrub oak-long-leaf pine association next to the landfill is possible with native species that grow, prosper, and flower under all local conditions. Conventional landfill closure plantings of alien cool season grass species, such as tall fescue (*Festuca elatior*) and Eurasian brome (*Bromus inermis*) actively grow only in spring and fall under cool moist conditions and are dormant or have minimal growth at other times of the year unless irrigated. One consequence of a cool season community that shuts down in droughts of summer is a habitat that is not nearly as attractive to wildlife as compared to native landscapes because food sources, particularly insect populations, tend to collapse under drought in the cool season communities.

The adaptability of native plants to drought, very wet conditions, extreme winter exposures and very poor nutrition is documented thoroughly in hundreds of technical papers (Hilgard 1906; Hursh and Haasis 1931; Biswell 1935; Weaver and Albertson 1936; Albertson and Weaver 1942; Albertson 1943; Weaver and Weaver and Albertson 1944; Partch 1949; Osaki et al. 1998; etc). Native species have much higher tolerance to variable and extreme climatic conditions (Weaver 1954; 1956; and 1968). Weaver's (1968) "Prairie Plants and Their Environment" is a masterful reference that details summaries of fifty years of research on hundreds of native species through out the Midwest including the response of the prairie ecological system to the great drought and severe wet periods. Without equivocation, this study documents the unprecedented tolerance and survivability of many of the native grasses and wildflowers included in the example planting plan lists (Table 1). The studies also document the death and failures of many cool season grasses, including bluegrass (*Poa pratensis*) and brome grass, during drought. Native species are the clear choice for the stressful condition of landfill caps.

- **Vegetation shall require little maintenance.**

  Native grasses, forbs, shrubs, and trees not only survive and prosper in inhospitable environments, but they require very little maintenance, compared to cool season plantings especially during later years after establishment (Breyer and Pollard 1980; Duebbert 1981; Diekelmann and Schuster 1982; Mariner and Mertz-Irwin 1991; etc). Some clay-capped landfills require seasonal mowing, noxious weed control and regular fertilization programs to maintain cool season grass stands. Native species stands are not nearly as vulnerable to noxious weed invasions; often, alien weeds establish dense monocultures on landfills planted with cool season grasses (Apfelbaum, personal observations; AES 2004). Native grasses and wildflowers are well-adapted to withstand stress and resist mortality that open landfill surfaces to weed invasions. For example, the major native grasses have a photosynthetic pathway (C4) that conserves water (unlike cool season grasses) and have leaf stomata adapted to conserve water. They also have pubescence and revolute leaf margins that contribute to greater water conservation. They require less energy for cooling, sustained growth and basal metabolic needs (Weaver 1968). These adaptations decrease maintenance needs, such as mowing or irrigation. A typical landfill management for native grass and wildflower plantings is mowing to the height of 6 inches when the vegetation reaches about one foot during the first growing season. This prevents most alien weeds from producing seeds. However, perennial native grasses and flowers are too small to be injured by a 6 inch mowing. No watering or fertilizing is recommended, because this benefits the weedy species. Native perennials are adapted to the natural conditions and require no watering or fertilizer (Larson 1991). During the second growing season mowing to a height of 6 inches should continue if weed species have survived. Since soil disturbance is essential for the weeds to continue to survive, it is only rarely used. Areas vacated by a mature annual weed leaves a disturbed soil from which many weed seeds in the soil can emerge (Larson 1991). After year two, mowing can be conducted but only to control noxious weeds that may be present. Otherwise, direct herbicide treatment on persistent noxious weeds becomes the principal management strategy after the fist few years, but this is needed very rarely in native species plantings.

- **Vegetation shall consist of a diverse mix of native and introduced species that is consistent with the post closure land use.**

A native planting program integrates the best characteristics of quick establishing nonnative cool season annual nurse grasses (e.g. oats (*Avena sativa*) and barley (*Hordeum vulgare*)) with long-lived and durable native species plantings. This combination is proven to accomplish early success and stabilization of the capped landfill slopes and top. It will also provide the rapid amelioration of site conditions required for the success of plantings. The plantings will succeed from quick growing annual cover crops as dominants within several weeks after planting, through a cool season growth phase to succeed into a native plant community dominated by grasses and wildflower. A cool season grass understory with successional natives (e.g. Canada wildrye, *(Elymus canadensis*)) will be retained to provide early spring greenups.

The native species planting strategy provides a quality, diverse landscape and wildlife habitat that will support light recreational uses including a regional greenway trail system integrated with the project site. The high diversity of species used in native landscaping provides a complimentary, interesting, and aesthetically pleasing setting for greenway trails, attractive to native wildlife which improves recreational experiences. The resulting biodiversity of a native-restored site is very important for maintenance of the regionally rare populations of many plants and animals. The native species cap closure planting design is consistent with national proposals for protection and restoration of biological diversity (Beecher 1942; Jacobs 1975; Wilson 1988; etc.). Also, because of the very low maintenance needs of established native plant cover, little disruption of the planting will occur. The potential to disrupt recreational uses is low. Reduced maintenance of the planting during the initial establishment period leads to less soil compaction owing to mowing conventional covers to create a low growing community. Conventional mowing management of the slopes underlain by heavy clay substrates can damage soil profiles, promote weedy vegetation and limit human uses, (e.g. surface soil sheer during mowing vehicle turns, compaction and rutting and potential surface water routing changes [See Goran et al. 1983.]). These problems are reduced markedly in low maintenance native species plantings.

The native plant species recommended for caps have high wildlife food and cover values (See Tables 1, 2.); most native prairie grass and wildflower species have moderate to high wildlife cover and food value. The information used to generate these tables is from personal observations and years of site monitoring of native species and conventionally-planted caps for numerous clients (Apfelbaum, Applied Ecological Services, Inc. 2004, unpublished observations and data) and from a plethora of articles, books, and technical papers on the wildlife value of native grasses and wildflowers. Example information sources are identified in the Bibliography and include: Weaver 1968;

Robel 1981; Diekelmann and Shuster 1982; Dove 1983a, 1983b, 1984a, 1984b Farmland Committee 1985; Henderson 1987; etc).

- **Vegetation shall be tolerant of the outgassing often generated in capped sites.**

  Most research projects comparing the vulnerability of plants to landfill out-gas have suggested that native prairie grasses and flowers are more tolerant than cool season grasses (Flower et al 1981; Peven 1985; Card 1992;). However, with well designed clay and geomembrane capping systems, vegetative covers are subjected to little out-gas exposure except near well heads for the recovery of landfill gas. Native species also are often the most tolerant plants to other environmental contaminants including excess heavy metals and insufficient trace elements (Lepper 1978; Kabata-Pendia and Pendia 1984; Peven 1985; Eisler 1990; Arthur et al. 1992).

  Studies conducted on out-gas and plant relationships suggest if caps are built to specifications, vegetation establishment, growth and success are unaffected. In poorly capped landfills some plant species have died and failed to provide long-term soil stability (Deuber 1936; Arthur et al 1981). In fact, plant mortalities are used to detect gas leaks on landfills and from gas pipelines (Eyon 1967). Tolerance to gas in the soil relates directly to its composition and concentration, timing of exposures, plant phenology and the presence of other metabolic gases such as oxygen and carbon dioxide as well as toxic gases such as methane and hydrogen sulfide. If seed sources are near, native prairie plants are often the first to invade landfill environments. Some observers have concluded that not only are some native plants tolerant of landfill gasses, but also to other stressful environmental conditions on landfills. (Leonard and Pinckard 1946; Gilman et al 1978; Flower et al. 1978,1981; Gilmanm et al 1981; Morgan and Sullivan 1981; Shimell 1983, etc).

Crook (1992) investigated the feasibility of planting trees on clay-capped landfills and other containment sites. He concluded that planting even trees on sites is unlikely to violate clay caps in an out-gassing environment or over heavily compacted clay caps because most tree species require a soil atmosphere with 18% oxygen or more and die with less than 12% soil oxygen. He identified that carbon dioxide, methane, or ethylene in concentrations of 5-10% or greater in soil voids will kill most trees. Stonell (1986) identified that clay caps can become weakened in drought and that tree roots are capable of drying clays below the moisture content which induces cracking. They found tree roots generally confined to the top 300 mm of soil, but others have suggested that roots can desiccate to soil depths of 700 mm. They recommended that if trees planted on a clay cap, that they only be planted in locations with soil or rooting medium of a minimum 1 meter in thickness. In Britain, the Department of Environment (1984) reports that it is possible to control tree root growth on landfills by maintaining low fertility in deeper soil layers, or by compacting the base layers of final soil cover. Robinson and Handel (1995) showed there is no theoretical or empirical basis to disallow tree plantings on clay-capped sites. They excavated 30 trees and shrubs growing on a clay-lined municipal sanitary landfill invaded by trees for seven years after closure. All trees had shallow roots, including species that grow typically with tap roots. Only occasionally were small feeder roots found in the upper 1 cm of the clay caps. They concluded that thorough compaction of a clay cap created a substrate with material densities well above those roots will penetrate. Compaction alone stopped root growth; mean penetrometer resistance values above 2.0 Mpa control root potential penetration (Hermann 1977; Atkinson and Mace-Dawson 1991; McMichael and Persson 1991; and Atwell 1993). (Glinski and Lipiec 1990; Campbell and O'Sullivan 1991; Bennie 1991; and Bengough 1991). Dobson and Moffat (1995) reached the same conclusions regarding the root growth for trees or shrubs on compacted clay caps. In friable native soils, they found 90% of trees and shrub roots in the upper 0.6 meters of soils, and substantially less on compacted clay caps roots. They also concluded that tree roots and subsequent evapotranspirational water losses are extremely unlikely to be the primary cause of dessiccation cracking in a clay cap owing to their inability to extract more than a few percent of the total moisture held in clays with sufficient density to have the requisite low permeability of 1 x 10^{-7} to 10^{-9} cm/s. Where high density polyethelene liners or mineral materials were used in caps and the upper barrier protection material was compacted to a bulk density of 1.8 grams/cubic centimeter, there was no evidence that tree or other plant roots were able to penetrate. The authors conclude that with proper planning and installation, trees and shrubs may be grown successfully without violating clay cap integrity. In addition they contend that clay capped facilities can be designed to provide more ecologically diverse and valuable vegetation, if this is a discrete goal of closure projects, and is supported by good bioengineering, design, and site examination.

April and Sims (1990) examined the usefulness of providing enhanced treatment of toxic organic chemicals using eight deep rooted prairie grasses (big and little bluestems, indian grass, switch grass, Canada wild rye, side oats grama, western wheat grass and blue grama). This study involved planting prairie grasses on a highly permeable sand top soil over a site with four polycyclic aromatic hydrocarbons (PAHs). The extent of PAH disappearance in vegetated soil was significantly greater than in unvegetated soils. They concluded that where deep soil penetration is desired, these plants can be a low cost, effective, and low maintenance alternative for addressing PAH contaminated soils. They believed increased soil-microbial activity, improved physical and chemical properties of the contaminated soils, and increased the contact between microbes associated with the root and the toxic compounds in the contaminated soils were the primary mechanisms of detoxification.

Native prairie grasses and wildflowers have typically not been used on landfills or clay capped sites. We believe this has occurred because of the simplicity, lower seed cost and convention of using nonnative grasses and clovers in all aspects of re-vegetation associated with disturbed landscapes, especially mined lands and road right-of-ways. The misconception that the root penetration depth or required rooting depth is too deep, has also prevented the use of native plants until recently. This misconception may have led professionals to conclude native plant materials would compromise the clay cap and contribute to its failure. Cool season and native prairie grasses experience different opportunities for root growth and achieve different rooting depths depending on the nature of the substrate in which they grow (Weaver 1968; Bohm 1979; Atkinson and Mackie-Dawson 1991). In loose uncompacted soils both native and alien species may grow roots many meters deep. However, in heavily compacted soils and even where mere inches of topsoil and subsoil occur on impermeable bedrock, cool season and native prairie grasses and forbs will grow but will have poor vertical root development. Under compacted soil conditions, such as on a clay cap, the major difference between these groups of plants is the markedly greater and denser root mass of native plants that increases the ability of these plants to tolerate physiological stresses, such as drought, (Atkinson and Mackie-Dawson 1991) and may contribute to greater cap stability (Browning 1990). A primary focus of much recent research has been on rooting depth and potential violation of the integrity of the landfill cap (Flower et al 1978; Gilman 1979; Leone et al 1979; Stalter 1979; Gilman 1980; Lutton 1982; Gilman et al 1985; Ettala

1987; Attala 1988; Wong and Yu 1989, etc). These studies have generally indicated that root penetration of clay caps does not occur for a number of reasons:

High Compaction of clay substrates impedes root penetration of caps except perhaps in cracks that develop in the caps because of thermal contraction (Andersland and Al-Moussawi 1987).

Prevailing research results suggest that root growth does not represent a threat to clay caps. In fact, a geomembrane system only reinforces resistance to root penetration. Based on studies of how roots direct growth, and how root morphology changes in response to natural soil profile changes, we believe strongly that well compacted clay caps (even without the presence of a geomembrane system) will provide an effective barrier to root penetration. In order to grow, a root pushes through the soil with an extending root tip with a diameter of 0.1 to 3mm. To move through soil, which generally contains pores of 0.002 to 0.2 mm or less, the root grows by turgor (osmotic-hydraulic) pressure. It must therefore push aside soil materials. Consequently, nonporous soils (such as compacted clays (even without a geomembrane barrier) represent a formidable barrier. On engineered clay caps with heavy soil compaction and on compacted mined sites, the lack of woody plant and herbaceous plant growth is related to the inability of roots to penetrate the substrates. Various methods for subsoil ripping and other soil preparation treatments are required to reduce compaction before plant growth will even occur, (Brown et al 1968; Brandshaw and Chadwick 1980; Malcom 1990; Apfelbaum 1991, etc). High Bulk densities in naturally occurring soils ≥ 1.5-1.8 mg/cm^2 retard root growth profoundly. On compacted landfill caps, bulk densities may be much greater and thus would be expected to be an effective barrier to root penetration. Resistance to root growth is also related to the average soil pore sizes. Soils with high bulk density values, especially highly compacted clay substrates, have a very small average soil pore size that restricts root penetration on caps. Resistance to root penetration increases directly in the vicinity of root growth owing to displaced soil materials. This increased soil compaction in the growing region in an already compacted soil environment results in cessation of continued root growth in the direction of increased bulk density. This limits root growth to upper shallow topsoils. Typically, plant root growth is restricted to spreading in these environments.

At the Fresh Kills landfill, research documented that even where thermal expansion related soil cracks formed in the landfill cap, root invasion did not occur for a number of reasons. Apparent impediments to root growth into existing landfill cap cracks were correlated with the layer of anoxic, nutrient poor sand, (drainage layer), probably suffused with methane, carbon dioxide, and other inhibitory gasses. Research found that thin probing taproots might penetrate through breaks or pores in the clay cap but that they would die back rather than increase in length or thickness. In fact, if gases are present in the fractured soils in sufficient concentration, root growth even above the clay cap is inhibited. Rather than the plant challenging the integrity of the clay cap, in a typical clay cap, plants cannot overcome these stressful conditions. Since clay caps are also nutrient poor, but inhibit nutrient uptake (owing to clay colloid binding capacity [Brady 1974]), root growth into caps should be minimal. Depth of root growth has demonstrated that root architecture is almost always controlled by the nature of the substrate in which the plants grow. Deep rooting plants in native soils have been well documented (Meinzer 1927; Coile 1951; Kreutzer 1961; Bibelriether 1966; Sutton 1969,1991; Russell 1973; Savill 1976; Foster 1993), while extreme shallow-surficial roots have been documented in compacted or geologically constrained soils.

Heavily compacted soils have been altered by tillage and subsoil loosening to achieve substantially greater rooting depth, plant production, increased soil porosity, and increased hydraulic conductivity (Harrison, Cameron and McLaren 1994). These techniques are the opposite of those used on GCC and GCL capped sites. These and other studies have demonstrated benefits of subsoil loosening and tillage are reversible by engineered compaction, altering soil textural composition, and by altering the chemistry of soil (CEC, pH, etc.). Native uncompacted soils and subsoils compared to engineered soil cap systems, will sustain very different plant growth by the same plant species. Root growth and above ground plant growth are significantly diminished in compacted soils, whether native or engineered.

- **Temporary erosion control measures, including but not limited to mulch straw, netting and chemical soil stabilizers, shall be undertaken while vegetation is being established.**

  The site stabilization strategy employed on most clay capping projects includes use of short lived and quickly establishing annual cover crops and a mulching system involving several options. The annual plants are seeded simultaneously with biennial and long and short lived perennial species. With this planting strategy, all species are potentially seeded simultaneously and will consequently respond to conditions for germination as they become suitable. Because of the seasonal nature for planting native prairie grass and flower species, if slopes are readied for final planting but the season is not proper for planting natives, then a cover cropping system is included. Once established, the native prairie seeded will be no-till drilled. The drilling of the native species seeds will be conducted directly into the established cover crop grass to cause minimal soil disruption.

  This same planting strategy was employed in the reclamation and revegetation of mined lands in Wisconsin; it has been very successful in the extreme environment of high waste rock dumps which have the same risk of erosion and plant exposure as on regional landfill tops and slopes, especially south and west aspect slopes (Ludwig and Apfelbaum, In Press; Burris and Apfelbaum 1992).

The mulching system can include erosion netting, erosion bats, and straw checks and blown straw if and where necessary to maximize erosion control. If hydromulching does occur, a tackifier such as Guar Gum is a very effective soil and mulch stabilizer. This tackifier produces a wet-resistant surface which reduces soil saturation, potential effects of slope failure from mass wasting and solufluction, and greatly reduces erosion of mulch and seed.

- **What evidence exists for root penetration of Geotextile clay caps and liners?**

Investigations of root penetration of GCL's and GCC's were done in lab and field settings. Melchior (1997) found lawn grasses, and weeds with fine roots (≤1 mm diameter) did penetrate bentonite mats during the first year where the GCC were installed over gravel and sand underdrainage layers. During year two, some liginified larger roots were also found to grow into the GCC. They speculated that if larger diameter lignified roots died and decomposed, then the remaining void could form open flow channels through the matting. However, they were not able to demonstrate this to occur in either field or laboratory experiments. The GCC was found to crack during drought but reseal during rehydration. Fine roots of grasses and weeds grew during wet periods, and ceased during dry down periods when the GCC developed vertical and horizontal "cracks". Under the experimental conditions, they found fine roots to grow completely through the mat in the first growing season.

They concluded that there is still a lack of convincing evidence and documented proof that bentonite mats (GCC and GCL) will work in caps. Use must be considered on a case by case basis. They also stated that new GCLs made with two bentonite layers divided by a middle geotextile, and prehydrated bentonite with organic additives, will improve performance. The lack of drying of the bentonite layer does not prevent root penetration by lawn grasses and other plants. They also identified a problem with GCC mats that did lead to failures that were completely unrelated to plant materials. They found that sodium in the sodium bentonite clay used in the GCC was prone to fail if irrigated with moderate to high carbonate waters containing calcium and magnesium. Then, the sodium cations were replaced by the calcium or magnesium; these chemical reactions reduced resealability of the GCC after modest or severe drought.

Technical Data Sheets for Geosynthetic clay lines (GCL's) (__Unpublished CETCO TR-310) found during a "tank scale" study that primary tap roots of weeds did not penetrate the GCL. Roots traveled directly downward, then turned 90 degrees upon encountering the GCL, and grew parallel to the surface of the GCL. They concluded the woven geotextile covering was "apparently sufficiently tightly knit to prevent penetration by tap roots". The study did find that fine root hairs that branched from the tap root were able to penetrate the GCL. The geotextile did not appear stretched or damaged by root penetration. They also tested permeability of the penetrated mat and found even with penetration that the permeability of the penetrated mat was consistent with "virgin" unpenetrated GCL.

Kargbo, Fanning, Inyang, and Duell (1993) have cautioned that the permeability of GCC and GCL's will increase in clay soils with the potential to produce acid sulfate. Where the potential for acid sulfate generation at the substrate interface with the underside of the GCC/GCL exists, this can increase permeability of the liner, result in mortality of vegetation exposed to strong acids, and enhance erosion risks of the cap. They suggest testing substrates that the GCC/GCL will be bedded on to ensure acid sulfate generation will not occur. Mobilization of metals from soils is typically associated with pyritic and other sulfur bearing minerals; under irrigated or excessively wet aerobic conditions in the near surface environment, the production of free sulfuric acid can occur. This study found that where clay acidification occurred below the GCC or GCL, topsoils failed to support the plant species applied as stabilization cover. Non-native species, such as lawn grasses, roadside, highway grass and clover mixes were especially intolerant of acidification. In fact, some of the most tolerant plant species included the native grasses such as little bluestem (*Andropogon scoparius*). Considerable work has been done on Geotextile Clay liners beneath landfilled materials. These studies have focused narrowly on the permeability of the liners and the chemical influence of leachates on liner performance and efficiency (Hoeks, Glas, Hofkamp and Ryhiner 1987).

Koerner and Daniel (1992) summarized the performance of all of the major categories of capping systems including GCC and GCL caps. They rated each cap and closure performance under environmental factors that complicate their design and influence success. Included were temperature extremes (freezing and thawing to significant depths), wet/dry cycles, potential for penetration by plant roots, burrowing animals (e.g. worms, insects, etc.), total differential settlement caused by compression of the waste or foundation soils, temporary or permanent surcharge by stockpiling materials, downslope slippage or creep, vehicle movements that drive over caps, wind and water erosion, deformation caused by earthquakes, long-term moisture changes if water moves in or out of wastes, and alterations caused by gas derived from volatile or decomposable wastes. Ratings presented in this paper suggested that GCL and GCC designs are marginally acceptable, or not recommended for use if any of these variables presents a threat to the barrier layer material. In combination with a geomembrane, a two layer barrier system (GCL and GCC) is acceptable and recommended as feasible and cost effective. This study also suggests that a single-layered geomembrane system will out-perform a geosynthetic clay liner and a clay capped liner system and may cost less in the long-term.

Bowerman and Redente (1998) document that few capping and liner systems employed anywhere in the world can escape biointrusions of the protective barriers especially in arid regions. They state that mice, ants, ground squirrels, prairie dogs, some plants pose a threat to barrier integrity and waste isolation and that engineered caps have been designed without consideration of the ecological principals and processes, which can be crucial to their performance. They stress that incorporation of ecological processes into barrier design is essential to lower risk of failure (Waugh and Richardson 1997). These authors summarize some newer capping technologies that include thicker caps, use of slow release herbicides to prevent root growth and other new ideas (Wing and Gee 1994).

CONCLUSIONS:

Biointrusion into a Geotextile clay cap or liner lacking the 24” fill soil and drainage layer above a GCL can occur, but such cap designs are now illegal for domestic waste landfills. Plants can violate a poorly compacted cap or if otherwise not constructed to specifications. Plant and animals have influenced water infiltration, channeling, soil pore space, aeration, physical and chemical properties, and the community eventually established on native soils and reclaimed mine sites. There is no reason to believe they cannot do the same on capped sites (Ellison 1946; Edwards and Lofty 1978, 1980; Kalisz and Stone 1984; Nyhan 1989; Sejkora 1989; Blom 1990; Blom et al. 1994; Gonzales et al. 1995). Compacted subsoils can be a temporal and spatial barrier to cap penetration. Some authors question the longevity of capping systems not designed with ecological processes in mind, contending that biointrusion is likely and perhaps inevitable. However, at the Albany landfill site, the probability of cap failure by root penetration is very remote; a far greater risk is likely if poor construction practices are allowed. While the chemical environment of the Albany cap including subsoil pH and acidification tendencies could be deleterious to GCC and GCL integrity, that is equally unlikely owing to soil chemistry.

Plant growth on the Albany cap will occur during wet periods then decrease or cease as cap desiccation occurs. Root die back can occur often during periods of desiccation. Roots will not grow into cracks, because root growth stops and cracking occur simultaneously during desiccation. During rehydration, the GCL reseals before plant root growth can respond to rewetting. Native vegetation has substantially higher rates of precipitation interception compared to the usually specified lawn species for the typical cap site. These interception rates substantially reduce the total annual water available for infiltration or runoff (Apfelbaum in preparation; Weaver 1968). Native vegetation is substantially more drought tolerant and survives extreme drought much better compared to alien cool season grass species.

Lawn grass species need fertilizer and irrigation in capped settings; native vegetation does not need these amendments, nor regular maintenance; this reduces maintenance costs. Fertilizer and irrigation water chemistries can alter the chemistry and physical integrity of the GCC or GCL altering pH, calcium-sodium ratios in the bentonite clay of the GCC or GCL. Native vegetation which does not require fertilization or irrigation, does not present these risks.

If acidification problems manifest on this site, native species are substantially more adaptable. Natives can endure greater changes in substrate chemistry than alien species. An acidified soil may resist replanting.

Native prairie vegetation has higher root mass densities than cool season nonnative lawn grasses; this allows prairie vegetation to provide greater soil stabilization. Native plants are especially resistant to downhill creep and mass soil movement. This can be important on landfills where material settlement occurs routinely.

Lawn and cool season grasses can encourage the presence of burrowing mammals, because no root structure is present in the subsoils. Prairie vegetation provides more above ground plant mass that is habitat cover. This attracts animals that utilize surface cover, rather than encourage burrowing species. Some mammals (e.g. woodchucks *Marmota monax*) burrow regardless of the above ground vegetation cover, especially along slope breaks and on side slopes. For these species, greater resistance to burrowing owing to the dense root masses below ground of native plants are important.

All vegetation covers on capped sites, even highly maintained lawn associations, will be invaded by weedy plants (Robinson and Handel 1993). This occurs rapidly if sources for bird and mammal disseminated seeds are present, or seeds/propagules can wash in during floods. Many weedy species are most invasive into highly maintained low diversity plantings such as lawns in contrast to native species plantings with dense root masses, and competitive growth forms. The current site design does not take into account this potential and tendency for site invasion and potential biointrusion.

Many native plant species representing low to tall, spring-fall flowering, unique colorization and texture are available for use in the final cover planting on the Albany site (Tables1A, 1B and 2). Some areas on the site may also be suitable for planting of trees and shrubs.

The depth of top soil and fill soil types envisioned for the Albany landfill suggests only fine roots will penetrate the GCL. These are very small diameter non-lignified roots. The capacity of the GCL to reseal will not be compromised by these roots and root hairs. The probability of GCL failure from penetration is very very low! All prairie plants, including shrubs and trees (Tables 1A, 1B, 2) are expected to be compatible with the proposed capping system.

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TABLE 1: This table summarizes the performance of representative herbaceous and woody) plant species that may be included in the sites planting plans. The criteria for valuing each species by the various attributes are identified in the Vegetation Criterion Key. The experience of ecologists with Applied Ecological Services and a multitude of references were used to classify species (see bibliography).

TABLE 1A. Identification of vegetation criteria used in evaluating compatibility with GCC/GCL.

CLAY CAP
VEGETATION CRITERIA KEY

COMPATIBILITY WITH THE DESIGN INTENT

1. Presence in the Region

   H – Found in the presettlement landscape.
   M – Was not found in the region at presettlement but has naturalized.
   L – Was not found in the region during presettlement.

2. Native

   Y – Plant native to the area.
   N – Plant is not native to the area

3. Habitat Value for Food

   H – Provides excellent food source for many species (i.e. seed, nectar).
   M – Provides food source for a few wildlife species.
   L – Provides no source of food for wildlife.

4. Habitat Value for Cover

   H – Provides excellent cover for nesting, breeding and protection.
   M – Provides some cover.
   L – No cover.

5. Seasonal Interest

   H – Colorful flowers, texture or stature.
   M – Compliments dominants
   L – Subdominant, not conspicuous

6. Non-Invasive

   H – Does not invade.
   M – Does invade if certain conditions are met.
   L – Invades areas by reseeding or root growth.

7. Soil Types

   B – Broad Range of Tolerance
   C – Clay Types
   L – Loam Types
   P – Peat Types
   S – Sand Types

ADAPTABILITY TO THE CAPPED SITE ENVIRONMENT

1. Root system type/depth

   B – Bulb
   R – Tap root
   R – Rhizome
   F – Fibrous
   S – Shallow 1-12”
   D – Deep 8-24”

2. Susceptibility to Gases

   H – Plant will not survive exposure to some gas.
   M – Plant may be affected by exposure to some gas.
   L – Plant is tolerant to gas.

3. Reaction to Higher Ground Temperatures

   H – Plant growth and survivability is strongly affected.
   M – Plants may be stressed.
   L – Plants are not affected.

4. Susceptibility to Ground Water Pollution

   H – Plants growth and survivability is strongly affected.
   M – Plants may be stressed.
   L – Plants are not affected.

5. Susceptibility to Surface Settlement

   H – Plant mortality due to root zone shearing.
   M – Plants may be stressed.
   L – Plants are not affected by root zone shearing.

6. Susceptibility to Wind Throw

   H – Plants are very sensitive to high winds.
   M – Plants may be stressed.
   L – Plants are not affected.

7. Adaptability to Soil Compaction

   H – Plants will adapt.
   M – Plants may adapt.
   L – Plants will not adapt.

8. Tolerance of Low Soil Oxygen Conditions

   H – Plants tolerate low oxygen conditions.
   M – Plants may be stressed by low oxygen conditions
   L – Plants will not survive low oxygen conditions.

9. Tolerance of Cover Soil Nutrients and pH.

H – Plants tolerant to variable nutrient and soil pH conditions.
M – Plants tolerate to certain conditions.
L – Plants restricted to a narrow range of conditions.

10. Adaptability to side Slope Conditions

Y – Plants tolerate side slope conditions.
N – Plants will not tolerate side slope conditions.

11. Height at Maturity

" – inches
' – feet

12. Erosion Control

H – Plant provides highly stable soil in the root zone.
M – Plant may provide erosion control.
L – Plant provides no soil stabilizing in root zone.

13. Resistant to Drought

H – Plant is highly adapted to drought conditions.
M – Plant may adapt to certain drought conditions.
L – Plant is not adapted to drought.

MAINTENANCE

1. Rate of Growth

F – Fast
M – Medium
S – Slow

2. Establishment Period

1 – One growing season.
1.5 – One and one half growing Seasons
2 – Two growing Seasons.

3. Longevity

L – Long lived perennial.
M – Short lived perennial.
S – Annual or biannual.

4. Susceptibility to Desiccation

H – Plants are highly susceptible to desiccation.
M – Plants may be susceptible to desiccation.
L – Plants are not susceptible to desiccation.

5. Susceptibility to Rodent/Rabbit Damage

H – Plants are vulnerable.
M – Plants may be vulnerable.
L – Plants are not vulnerable.

6. Susceptibility to disease and Insects

H – Plants are vulnerable.
M – Plants may be vulnerable.
L – Plants are not vulnerable.

7. Compatibility with the Climate

H – Plants are highly compatible.
M – Plants may be compatible.
L – Plants are not compatible.

TABLE 1B
CRITERIA AND SCORING USED IN TABLE 2

	1	2	3
EROSION CONTROL			
Rooting Depth	Deep	Shallow	Surface
Rooting Structure	Course	Fibrous	Densely fibrous
Rooting Habit	Horizontal Condensed	Horizontal Dispensed	Trailing clonal, stoloniferous, rhizomes
Adaptability to Gradient	Intolerant to gradient	May adapt	Rapid establishment
CLIMATE COMPATIBILITY			
Winter Extremes	Intolerant	Moderately tolerant	Tolerant
Summer Extremes	Intolerant	Moderately tolerant	Tolerant
MAINTENANCE			
Drought Tolerance	Intolerant	Moderately tolerant	Tolerant
Tolerance to Compacted Soils	Intolerant	Moderately tolerant	Tolerant
Disease/Insect Resistance	Vulnerable	Moderately resistant	Resistant
Longevity	Short-lived	Moderately-lived	Long-lived
DESIGN, POST-CLOSURE LAND USE			
Native to NE	Non-native	Native-rare	Native-common
Common to NE	Not present	Present	Common-naturalized
Habitat – Food Value	No value	Supports a few species	Supports many species
Habitat – Shelter	No value	Some cover	Excellent for nesting, protection
Seasonal interest	Not conspicuous	Showy flower or fruit display	Showy flower and fruit display
TOLERANCE OF GAS			
Tolerance of Low Soil Oxygen	Will not survive	Possibly stressed	Tolerant
Tolerance of Gases	Will not survive	Possibly stressed	Tolerant
Native to NE	Non-native	Native-rare	Native-common
PROTECTION OF COVER SYSTEM			
Root System Depth	Deep	Shallow	Surface

TABLE 2: An assessment of the suitability/compatibility of native prairie grasses and wildflowers and exemplenry trees and shrubs for planting in clay capped sites including sites with GCC and GCL. Rankings follow the criteria in Table 1A and 1B.

TABLE 2.

PLANT SPECIES	EROSION CONTROL				CLIMATE COMPATI-BILITY		MAINTENANCE				DESIGN, POST-CLOSURE AND USE						TOLERANCE OF GAS		
DECIDUOUS CANOPY TREES	Rooting Depth	Rooting Structure	Rooting Habit	Adaptability to Gradient	Winter Extremes	Summer Extremes	Drought Tolerance	Tolerance to Compacted Soils	Disease/Insect Resistance	Longevity	Native to N.E.	Common to N.E.	Habitat-Food Value	Habitat-Shelter	Seasonal Interest	Conspicuous Flower/Fruit	Tolerance to Low Soil Oxygen	Tolerance to Gases	Native to N.E.
Acer saccharum	3	3	1	1	3	3	3	3	2	3	3	3	3	2	3	1	3	3	3
Fraxinus americana	2	3	1	2	3	2	2	2	2	3	3	3	1	2	3	1	3	2	3
Fraxinus pennsylvanica	2	3	1	1	3	3	3	3	2	3	3	3	1	2	3	1	3	2	3
Quercus bicolor	2	3	1	1	3	3	3	3	3	3	3	3	3	2	3	2	3	2	3
Salix amygdaloides	2	3	3	1	3	3	3	3	2	1	3	1	3	2	1	1	3	2	3
Salix nigra	2	3	3	1	3	3	3	3	2	2	3	3	3	2	1	1	3	3	3
Tilia americana	1	1	2	3	3	1	1	1	2	3	3	3	1	2	3	1	2	2	3

PLANT SPECIES	EROSION CONTROL				CLIMATE COMPATI-BILITY		MAINTENANCE				DESIGN, POST-CLOSURE AND USE						TOLERANCE OF GAS		
DECIDUOUS UNDERSTORY TREES	Rooting Depth	Rooting Structure	Rooting Habit	Adaptability to Gradient	Winter Extremes	Summer Extremes	Drought Tolerance	Tolerance to Compacted Soils	Disease/Insect Resistance	Longevity	Native to N.E.	Common to N.E.	Habitat-Food Value	Habitat-Shelter	Seasonal Interest	Conspicuous Flower/Fruit	Tolerance to Low Soil Oxygen	Tolerance to Gases	Native to N.E.
Amelanchier canadensis	2	3	3	2	3	1	1	1	3	2	3	2	3	3	3	3	2	2	3
Cercis canadensis	2	3	3	3	2	3	3	2	3	2	2	3	1	2	3	3	2	2	2
Cornus mas	2	2	3	1	2	2	3	2	3	2	1	1	3	3	1	2	2	3	1
Crataegus crus-galli	1	2	1	3	3	3	3	2	2	2	1	3	2	3	3	3	2	2	1
Prunus virginiana	2	3	3	2	3	3	3	1	2	2	3	1	3	2	3	2	2	3	3
Ptelea trifoliata	2	2	3	3	3	3	3	1	3	2	3	1	2	2	2	1	1	3	3
Rhus copallina latifolia	2	1	3	3	2	3	3	1	3	1	1	1	3	2	3	3	2	3	1
Rhus glabra	2	3	3	3	3	3	3	1	3	1	3	3	3	2	3	3	2	3	3
Rhus typhina	2	3	3	3	3	3	3	1	3	1	3	3	3	2	3	3	2	3	3
Salix discolor	2	3	3	1	3	3	3	3	1	1	3	2	3	2	1	3	3	3	3
Viburnum lentago	2	3	3	3	3	3	3	1	3	1	3	2	3	2	3	2	2	3	1
Viburnum prunifolium	2	3	2	3	3	3	3	1	3	2	3	2	3	3	3	3	1	2	3
Zanthoxylum americanum	2	3	3	3	3	3	3	1	3	3	3	3	3	2	2	1	2	3	3

PLANT SPECIES	EROSION CONTROL				CLIMATE COMPATIBILITY		MAINTENANCE				DESIGN, POST-CLOSURE AND USE						TOLERANCE OF GAS		
DECIDUOUS SHRUBS	Rooting Depth	Rooting Structure	Rooting Habit	Adaptability to Gradient	Winter Extremes	Summer Extremes	Drought Tolerance	Tolerance to Compacted Soils	Disease/Insect Resistance	Longevity	Native to N.E.	Common to N.E.	Habitat-Food Value	Habitat-Shelter	Seasonal Interest	Conspicuous Flower/Fruit	Tolerance to Low Soil Oxygen	Tolerance to Gases	Native to N.E.
Aronia melanocarpa	3	3	3	3	3	3	3	3	3	1	3	2	2	2	3	2	3	3	3
Cornus amomum	3	3	3	1	1	3	3	3	2	1	3	2	3	2	2	2	3	2	3
Cornus racemosa	3	3	3	3	1	3	3	2	3	3	3	3	3	2	2	3	2	2	3
Cornus stolonifera	3	3	3	1	3	3	3	3	2	1	3	3	3	2	3	3	3	3	3
Corylus americana	2	3	3	3	3	2	2	2	3	3	3	2	2	2	2	1	1	3	3
Hamamelis vernalis	2	3	3	1	2	2	2	3	3	2	1	1	1	2	3	2	3	1	1
Rhus aromatica	3	3	3	3	3	3	3	1	2	2	1	2	3	2	3	2	1	3	1
Salix humilis	3	3	2	3	2	3	3	3	3	1	3	3	3	2	1	1	3	3	3
Salix lucida	3	3	2	1	2	3	3	3	1	1	3	2	3	2	1	1	3	3	3
Sambucus canadensis	3	3	3	2	3	3	3	3	2	2	3	3	3	2	1	3	3	3	3
Viburnum acerifolium	3	3	3	3	3	2	2	2	2	3	3	1	3	2	3	2	1	3	3
Viburnum dentatum	3	3	3	1	3	3	3	2	3	3	1	2	3	2	2	2	3	3	1
Viburnum trilobum	3	3	2	3	3	3	3	3	3	3	3	3	3	2	2	3	3	2	3
Viburnum lantana	3	3	3	3	3	3	3	2	3	3	1	1	3	2	1	3	1	3	1

PLANT SPECIES	EROSION CONTROL				CLIMATE COMPATI-BILITY		MAINTENANCE				DESIGN, POST-CLOSURE AND USE						TOLERANCE OF GAS		
PRAIRIE GRASSES AND FORBS	Rooting Depth	Rooting Structure	Rooting Habit	Adaptability to Gradient	Winter Extremes	Summer Extremes	Drought Tolerance	Tolerance to Compacted Soils	Disease/Insect Resistance	Longevity	Native to N.E.	Common to N.E.	Habitat-Food Value	Habitat-Shelter	Seasonal Interest	Conspicuous Flower/Fruit	Tolerance to Low Soil Oxygen	Tolerance to Gases	Native to N.E.
**Andropogon gerardii*	2	3	3	3	3	3	3	3	3	3	3	3	1	3	3	2	3	3	3
**Andropogon scoparius*	2	3	3	3	3	3	3	3	3	3	3	3	1	3	3	2	1	3	3
Anemone cylindrica	1	3	3	3	3	3	3	3	3	3	3	3	2	1	3	2	3	3	3
Argrostis alba	3	3	2	3	3	3	3	3	3	3	1	2	1	3	3		3	3	1
Aster azureus	3	2	2	3	3	3	3	3	3	3	3	3	1	1	3	2	2	2	3
Aster ericoides	3	3	3	3	3	3	3	3	3	3	3	2	2	2	3	2	3	3	3
Aster laevis	3	2	2	3	3	3	3	3	2	3	3	3	1	1	3	2	2	2	3
Aster novae-angliae	3	3	3	3	3	3	3	3	3	3	3	3	1	3	3	2	3	3	3
**Bouteloua curtipendula*	2	3	3	3	3	3	3	3	3	3	3	3	1	3	3	2	3	3	3
**Bouteloua gracilis*	2	3	3	3	3	3	3	3	3	3	3	3	1	3	3	2	3	3	3
**Bouteloua hirsuta*	2	3	3	3	3	3	3	3	3	3	3	3	1	3	3	2	3	3	3
**Buchloe dactyloides*	2	3	3	3	3	3	3	3	3	3	3	3	1	3	3	2	3	3	3
Coreopsis palmata	3	3	3	3	3	3	3	2	3	3	3	3	3	1	3	2	2	3	3
Desmodium canadense	1	1	1	3	3	3	3	3	3	3	2	2	2	1	2	3	3	3	3
Echinacea pallida	1	2	1	3	3	3	3	3	3	3	2	2	2	1	2	3	3	3	3
Elymus canadensis	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	3	3	3
Elymus villosus	2	3	3	3	3	3	3	2	3	3	3	3	3	3	3	1	3	1	3
Elymus virginicus	2	3	3	3	3	3	3	2	3	3	3	3	3	3	3	1	3	1	3

*** THESE SPECIES ARE INCLUDED AS EXAMPLES IN THE "DOWNTOWN OMAHA RIVERFRONT DESIGN DEVELOPMENT SUMMARY REPORT (UNEDITED).**

PLANT SPECIES	EROSION CONTROL				CLIMATE COMPATI-BILITY		MAINTENANCE				DESIGN, POST-CLOSURE AND USE						TOLERANCE TO GAS		
PRAIRIE GRASSES AND FORBS	Rooting Depth	Rooting Structure	Rooting Habit	Adaptability to Gradient	Winter Extremes	Summer Extremes	Drought Tolerance	Tolerance to Compacted Soils	Disease/Insect Resistance	Longevity	Native to N.E.	Common to N.E.	Habitat-Food Value	Habitat-Shelter	Seasonal Interest	Conspicuous Flower/Fruit	Tolerance to Low Soil Oxygen	Tolerance to Gases	Native to N.E.
Euphorbia corollata	3	3	3	3	3	3	3	3	3	3	3	3	2	1	3	2	3	3	3
Festuca rubra	3	3	2	3	3	3	3	2	3	3	1	3	1	2	3	1	3	3	1
Helianthus divaricatus	3	3	3	3	3	3	3	2	3	3	3	3	3	2	3	2	2	2	3
Helianthus laetiflorus	3	3	3	3	3	3	3	3	3	3	3	3	3	1	3	2	3	3	3
Lespedeza capitata	1	2	3	3	3	3	3	3	3	3	3	2	2	2	2	3	3	3	3
Monarda fistulosa	3	3	3	3	3	3	3	3	3	3	3	3	1	3	3	2	3	3	3
Panicum virgatum	2	3	3	3	3	3	3	3	3	3	3	3	1	3	3	3	3	3	3
Petalostemum purpureum	1	2	2	3	3	3	2	2	3	3	3	3	3	1	3	3	2	3	3
Phleum pratense	3	3	1	3	3	3	3	3	3	3	2	3	1	3	2	2	3	3	1
Potentilla arguta	3	3	1	3	3	3	3	3	3	3	3	3	3	1	3	2	1	2	3
Ratibida pinnata	3	3	3	3	3	3	3	3	3	2	3	3	3	1	3	2	1	3	3
Rudbeckia hirta	3	3	3	3	3	3	3	3	3	2	3	3	3	1	3	2	1	3	3
Rudbeckia triloba	2	3	3	3	3	3	3	1	3	3	3	3	2	1	3	2	2	2	3
Silphium terebinthinaceum	2	2	1	3	3	3	3	3	2	3	3	3	3	1	3	3	3	1	3
Solidago canadensis	3	3	3	3	3	3	3	3	3	2	3	2	2	2	3	2	3	3	3
Solidago nemoralis	3	3	2	3	3	3	3	3	2	3	3	3	2	1	3	2	1	3	3
Solidago rigida	3	2	1	3	3	3	3	3	3	3	3	3	3	1	3	2	1	3	3
Solidago speciosa	3	3	2	3	3	3	3	3	3	3	3	3	2	1	3	2	1	2	3
Sorghastrum nutans	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	1	3

ALBANY BUSH LANDFILL
Hydrologic & Water Quality Monitoring Schedule – April 17, 2007

Monitoring Plan:

The monitoring will include the 32 shallow 2-inch diameter piezometers (60-inch or longer as required) in the areas shown on the aerial photo monitoring plans. These include transect locations, wetland areas, fen, and vernal pond. Ten staff gages will be installed at the locations shown on the aerial photo. The piezometers and staff gages will be monitored once each month to provide data on the shallow groundwater and surface water elevation at the site. The datasondes can fit into the 2-inch diameter piezometers. In addition the datasonde will be used to measure water quality in the piezometer lowest in elevation or closest to the stream. If time permits water quality analysis from all piezometers is desirable.

The surface water will be monitored for flow volume using Telog recorders at two culvert locations on the stream adjacent to the landfill (shown on the aerial photo). One location is culvert 1 under Rapp Road and the other is culvert 3 behind the trailer court. Each telog unit should be placed about 20' upstream from the culvert entrance. The telog units continuously record water elevation at the culverts and using the surveyed culvert data the discharge volume versus time can be estimated. The Telog data will be downloaded monthly when the piezometers and staff gages are recorded.

Water quality will be measured at three stream locations using datasondes which record water temperature, dissolved oxygen, conductivity, pH, ORP (oxidation reduction potential), and chloride concentrations. At culvert 1 a datasonde will be deployed continuously to monitor water quality. The unit should be placed around 20' upstream from the culvert adjacent to the telog unit. The other datasonde will be used to measure water quality at culverts 3 and 8 on a revolving basis. This unit will be used to analyze the piezometer samples in between moves during the middle of the month. These units will be deployed for the time periods shown on the attached bar graph. The datasonde data will be downloaded monthly when the piezometers and staff gages are recorded.

The monitoring plan outlined above will provide both water quality and water discharge volume information from the site. The culvert surveys and discharge information will be used to develop a hydrologic model for the current conditions and the proposed restoration plan. The water quality information will be used to project improvements in water quality that may occur after restoration.

Location	Deployed Monitoring Equipment	1-Apr	Apr 15 to Apr 20	1-May	May 15 to May 20	1-Jun	Jun 15 to Jun 20	1-Jul	Jul 15 to Jul 20	1-Aug	Aug 15 to Aug 20	1-Sep	Sep 15 to Sep 20	1-Oct	Oct 15 to Oct 20	1-Nov	Nov 15 to Nov 20
Culvert 1 (under Rapp Rd)	Datasonde (Approx 20' upstr)																
	Telog (Approx 20' upstr)																
Culvert 3 (behind trailer crt)	Datasonde (Approx 20' upstr)																
	Telog (Approx 20' upstr)																
Culvert 8 (under Rapp Rd)	Datasonde (Approx 20' upstr)																
Piezometers	Datasonde used to take analysis from all piezometers with water																

#06-0590 Albany Bush Landfill - Hydrologic Monitoring Equipment Requirements

As 0f 11/13/2006 Reference to Monitoring Plan Drawing - mon101106.dwg

Equipment	Deployment Location	Description	# of units	Location on Drawing
		Telog with Casing and datalogger		
Telog	Culvert 1	5 psi -Telog/casing/datalogger	1	yes
	Culvert 4		1	yes
		Total units =	2	

		Datasonde Water Quality Monitor (WQM) and datalogger		
WQ Monitoring	Culvert 1	Hydrolab Minisonde MS5 units and Recon logger		yes
	Culvert 4	deployed for extended periods at culverts		yes
	Culvert 8	purchase two MS5 units w/logger	2	yes
	piezometers	water quality analyzed using hydrolab		
		Total units =	2	

		Staff Gages		
Staff Gage	Culvert 1	Elevations marked (0-3.33')	1	yes
	Culvert 4	use metal fence or treated 2x4 post to hold gage	1	yes
	Culvert 8	0' at the ground (bottom) level	1	yes
	Wetland Pond		1	yes
	Wetland 2 - Buttonbush		1	yes
	Vernal Pond (VP)		2	yes
	Wetland 2 - Bog		1	yes
	Fen		1	yes
	Sedge Meadow		1	yes
		Total units =	10	
			20	

		60-inch Piezometers		
Piezometer	Transect E1	60-inch piezometer	5	yes
	Transect E2		3	yes
	Transect E5		4	yes
	Transect E4		4	yes
	Transect TP2		2	yes
	Transect DS1		2	yes
	Transect WL2 buttonbush		3	yes
	Transect VP		3	yes
	Transect WL 2 Bog		3	yes
	Transect SM		3	
		Total units =	32	

For Calibration
The culverts will require survey elevations at inlet and outlet, length of pipe, and entrance/outlet type.
GPS location on all monitoring locations.
Survey Elevations will be required for the staff gages.
Survey Elevations will be required for the piezometers.

Albany Bush Landfill – culverts (092606 site visit)

Culvert 1

2- 15" CMP pipes under Rapp Road

Culvert 2

24" CMP with bottom 8' sediment covered

Culvert 3

24" CMP

Culvert 4

18" CMP

Culvert 5

24" CMP

Culvert 6

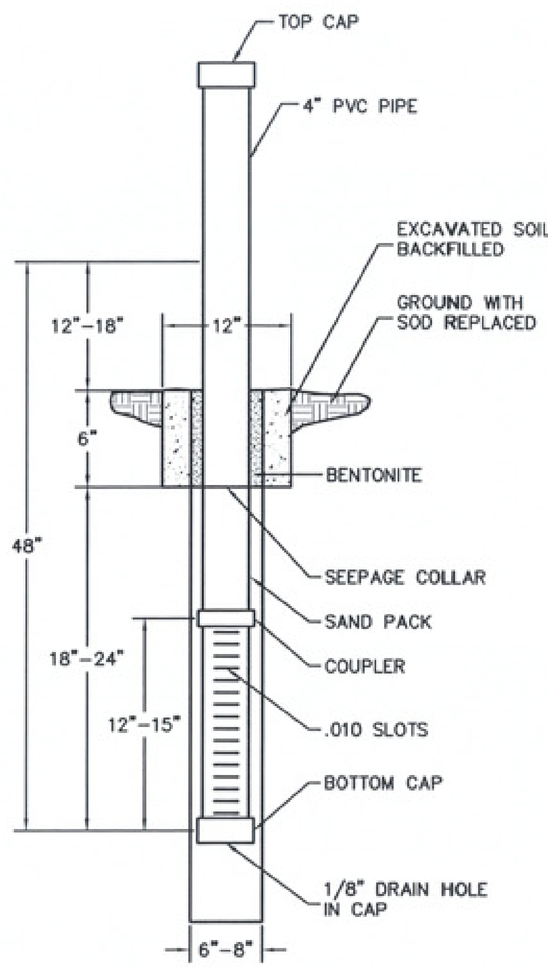
No picture or data

Culvert 7


10x16 rectangular riser (10" above outlet top) discharging through 12" plastic corrugated pipe

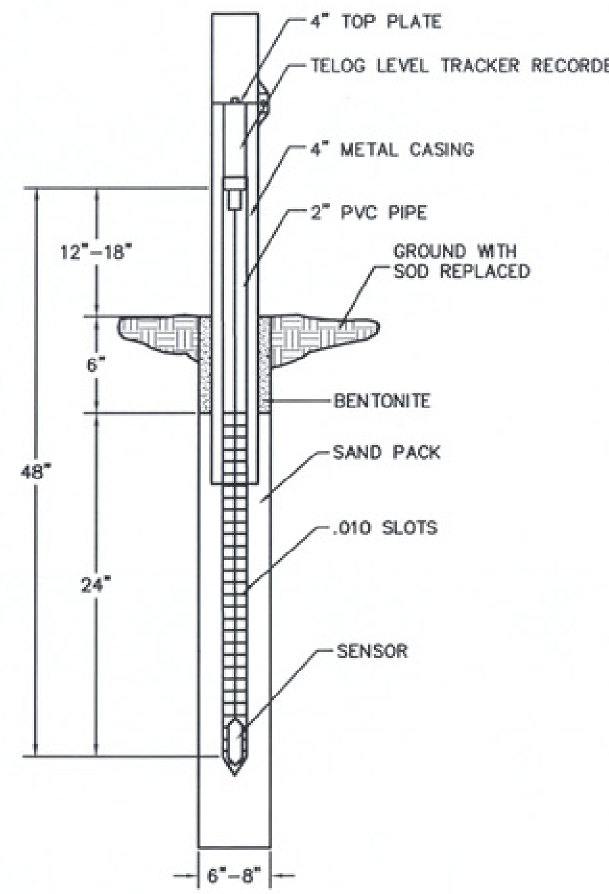
Culvert 8

Stream crossing under Rapp Road. No picture or data.



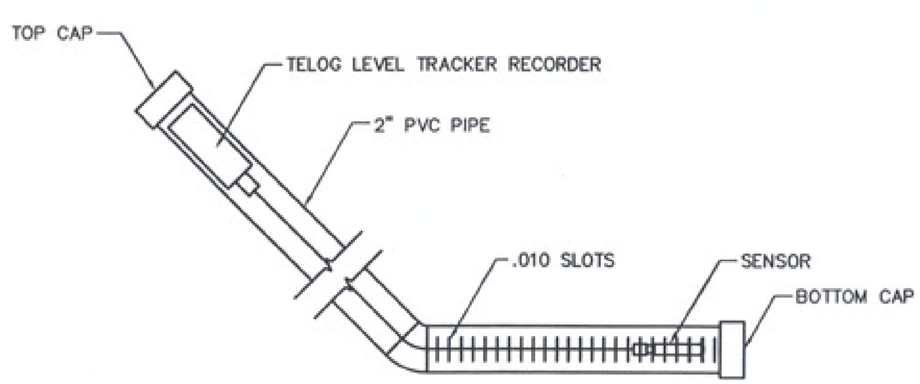
PIEZOMETER DETAIL

NOT TO SCALE



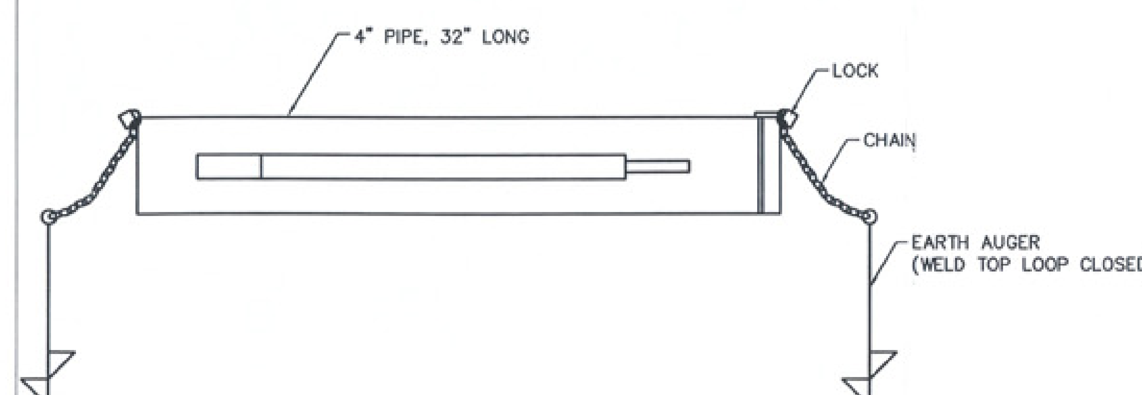
PIEZOMETER WITH TELOG DETAIL

NOT TO SCALE



TELOG HORIZONTAL DEPLOYMENT DETAIL

NOT TO SCALE



HYDROLAB DEPLOYMENT DETAIL

NOT TO SCALE

Revisions:			
No	By	Date	Description
1			
2			
3			
4			
5			
6			
7			
8			
9			

Standard Details

Drawn By: t.e.g.	AES Project No.: 06-0590
Checked:	File Name: tran100906.dwg
Approved:	Date: 10-09-2006

Albany Pine Bush Landfill

Albany, New York

Clough Harbour & Associates, LLP

III Winners Circle, P.O. Box 5269

Albany, New York 12205-0269

Sheet Number
1 of 1

Revisions:

No.	By	Date	Description
1			
2			
3			
4			
5			
6			
7			
8			
9			

Monitoring Plan

Drawn By: t.e.g.
Checked:
Approved:

AES Project No.: 06-0590
File Name: tran100906.dwg
Date: 10-09-2006

Albany Pine Bush Landfill

Albany, New York

Clough Harbour & Associates, LLP
III Winners Circle, P.O. Box 5269
Albany, New York 12205-0269

Sheet Number
1 of 1

Legend

E2 — Transect Location

Staff Gauge Location

Piezometer Location

0 300' 600' 1200'

SCALE: 1"= 600'

NORTH

Revisions:

Monitoring Plan-West

Drawn By: t.e.g.
Checked:
Approved:
AES Project No.: 06-0590
File Name: tran100906.dwg
Date: 10-09-2006

Albany Pine Bush Landfill
Albany, New York

Clough Harbour & Associates, LLP
III Winners Circle, P.O. Box 5269
Albany, New York 12205-0269

Sheet Number
1 of 1

APPLIED ECOLOGICAL SERVICES, INC.

17921 SMITH ROAD, P.O. BOX 256, BRODHEAD, WI 53520
PHONE: (608)897-8641 FAX: (608)897-8486
email: info@appliedeco.com

SPECIALISTS IN ENVIRONMENTAL MANAGEMENT AND RESEARCH

MEMO

TO: Steve Apfelbaum

FROM: Brad Herrick & John Larson

DATE: December 21, 2006

RE: Albany Landfill Vegetation Data Summary (AES# 06-0590)

Expansion Area Uplands (data sheet 1)
The understory of uplands are characterized by the native perennial *Eupatorium rugosum*, the aggressive non-native *Alliaria petiolata*, and the non-natives *Poa pratensis* and *Celastrus orbiculatus* with a combined 45% of the relative cover. *Prunus serotina* and *Rubus allegeniensis* dominated the shrub layer and *Prunus serotina*, *Quercus rubra*, and *Robinia pseudoacacia* were the most common tree species encountered. The total canopy intercept of 152% in the upland areas, indicates a dense canopy coverage with a shade suppressed ground story component. *Quercus rubra* is the dominant intercept species followed by *Acer rubrum* and *Prunus serotina*. Few trees have a DBH of greater than 12 inches indicative of a young woods.

Expansion Area Wetlands (data sheet 2)
Pilea pumila, *Phragmites australis*, *Osmunda cinnamomea*, and *Impatiens capensis* constitute almost 50% of the relative cover of the herbaceous vegetation in the wetland areas sampled. *Fraxinus pennsylvanica*, *Prunus serotina*, and the non-native *Berberis thunbergii* are dominant species in the shrub layer with *Acer rubrum* being the most common tree species. Similarly to the upland areas the wetlands display a close canopy system with a total intercept of 156%, with *Acer rubrum* constituting 40% of the relative percent intercept. *Prunus serotina* and *Vitis riparia* represent the second and third dominants in the canopy, respectively. Most trees are less than 12 inches DBH, with a few individuals of red maple, cottonwood and white pine achieving 20 inches DBH or greater. The red maple hardwood swamp community can be considered as a young woods.

Disturbed Areas & Trailer Park (data sheet 3)
The non-native species *Poa pratensis* and *Poa compressa* account for over 40% of the relative cover in the herbaceous layer, while *Celastrus orbiculatus*, *Vitis riparia*, and *Solidago canadensis* made up the next 20%. *Celastrus orbiculatus*, *Rubus strigosus* and to a lesser extent *Vitis riparia* are dominants in the shrub layer. Only four trees were observed within the sampling area, all being *Quercus coccinea*. These areas have an open canopy with only 43% total intercept and are comprised of *Acer rubrum* and the shrub/vine species *Vitis riparia* and *Rubus idaeus strigosus*.

Landfill Restoration and Weeds Transects (data sheet 4)
Panicum virgatum and *Poa pratensis* constitute 63% and 10% relative cover respectively in the prairie restoration plots on the landfill cap. *Poa pratensis*, *Festuca elatior*, and *Coronilla varia* equally account for over 85% combined relative cover in the landfill weed transects. No shrubs or trees were observed in these sampling areas.

Karner Blue Butterfly Prairie Habitat (data sheet 5)
The herbaceous plant community sampled in the Pine Bush prairie is dominated by *Andropogon scoparius* with over 53% relative cover. *Rubus flagellaris* and *Polygonum lapathifolium* account for an additional 28% relative cover. Few shrubs species and only a few individual trees were observed. *Prunus serotina* and *Quercus prinoides* were the most common shrub species. As would be expected, the prairie had a low canopy intercept (21%) with the dominant being *Prunus serotina*.

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Lupines were only occasionally observed as most had died back and were dormant at the time of sampling and thus under represented in the data.

Pine Bush Scrub Oak Forest (data sheet 6)

Vaccinium pallidum, *Rubus* sp., *Quercus bicolor*, and *Pteridium aquilinum latiusculum* account for over 87% relative cover of the understory vegetation. The shrub community is comprised almost entirely of *Quercus illicifolia.* Although, only a few small individuals (<10 inch DBH) of *Pinus rigida* were observed along the transect, it is the dominant canopy species in a closed canopy forest (163% total absolute intercept). *Quercus illicifolia* is the second most dominant species, entirely in the shrub layer.

Pine Bush Scrub Oak Thicket (PBSOT 1&2) (data sheet 7)

The herbaceous layer in the scrub oak thicket that has been brushed and burned (PBSOT 1&2) is relatively evenly dominated by Carex sp., *Andropogon scoparius*, *Pteridium aquilinum latiusculum*, *Quercus prinoides*, and *Quercus illicifolia* with a combined relative cover of 77%. *Quercus illicifolia* and *Populus tremuloides* are dominants in the shrub layer. These two species along with Pinus rigida comprise the highest relative canopy intercepts. However overall, this community has a low total canopy intercept (29%) indicative of an open to semi-open system.

Pine Bush Scrub Oak Thicket (not burned or brushed) (data sheet 8)

The unburned and unbrushed oak thicket community is dominated by, *Quercus prinoides*, *Carex pensylvanica*, and *Quercus ilicifolia* (77% relative cover) in the herbaceous layer and *Quercus ilicifolia* and *Quercus prinoides* in the shrub layer. Although only a handful of trees were observed, the shrub layer primarily of *Quercus ilicifolia*, *Quercus prinoides*, and *Quercus rubra* contributed the most to an overall very dense canopy cover (total intercept 163%), indicative of a closed/shady system.

Pine Bush Sedge Meadow (data sheet 9)

Carex stricta and *Rubus hispidus* account for over 56% of the herbaceous species relative cover in the sedge meadow. *Spiraea alba* is the dominant shrub species observed. The sedge meadow has a very low absolute canopy intercept (11%) and is comprised mostly of *Spiraea alba* in the interior and *Quercus prinoides.* towards the periphery.

Pine Bush Hanging Fen (data sheet 10)

Five species, *Carex pellita*, *Andropogon scoparius*, *Carex stricta*, *Rubus allegeniensis*, and *Osmunda regalis spectabilis* account for almost 60% of the relative cover in the hanging fen herbaceous community. *Spiraea alba* and *Rubus idaeus strigosus* are dominant in the shrub layer. These species also have the highest percent intercept although overall the canopy intercept was very low (18%).

Vernal Pool 1 (data sheet 11)

Aralia sp., *Rubus* sp., *Vaccinium corymbosum*, and *Quercus prinoides*, account for almost 75% of the relative cover in the herbaceous layer. *Vaccinium corymbosum* is also dominant in the shrub layer and *Acer rubrum* is the dominant tree species. Vernal Pool 1 has a closed canopy (137% absolute intercept) that is dominated by *Acer rubrum* and *Betula populiflolia.*

Vernal Pool Red Maple Swamp (data sheet 12)

Rubus sp. and *Osmunda regalis spectabilis* account for almost 50% of the herbaceous relative cover. While the shrub layer is minimal, there is a dense canopy (105% absolute intercept) dominated by *Vaccinium corymbosum*, *Acer rubrum*, and *Populus deltoides.*

Wetland (Pond) (data sheet 13)

With 30% relative cover, Osmunda claytoniana is the dominant herbaceous species present. Other important species include, *Vaccinium corymbosum* (10%), Daucus carota (7%) and Carex stricta (7%). *Alnus rugosa* is most common in the shrub layer, however the wetland is relatively void of shrubs. In addition, the canopy is relatively open (58% absolute intercept) with *Acer rubrum* and *Populus deltoides* the most common. Open water comprises over 60% of the transect.

Wetland (Button Bush Swamp) (data sheet 14)

The herbaceous relative cover in this wetland is dominated by *Lemna minor* (42%), *Lycopus americanus* (21%), and *Carex stricta* (17%). *Cephalanthus occidentalis* overwhelmingly dominates the shrub layer with almost the entire total intercept of 129%) comprised of *Cephalanthus occidentalis.*

Wetland (Bog) (data sheet 15)
Dominant herbaceous species in the bog include Sphagnum moss (51%), *Dulichium arundinaceum* (19%), and Carex stricta (19%). *Vaccinium corymbosum* is the only species in the shrub layer. The total canopy intercept (83%) is dominated by trees of *Acer rubrum* and *Betula populifolia.*

Seed Bank Data
Sixteen known species and 60 unknowns (repotted and being grown to an identifiable age) were identified from 41 seed bank samples. As of 12/5/06, 1,075 seedlings were collected. The seed bank samples are being cold-stratified over winter and the greenhouse germination will continue in March.

Expansion Upland Summary Sheet 1

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Eupatorium rugosum	14	6.25	220.00	14.36	20.61
Alliaria petiolata	21	9.38	173.00	11.29	20.67
Poa pratensis	3	1.34	142.00	9.27	10.61
Celastrus orbiculatus	12	5.36	132.00	8.62	13.97
Osmunda cinnamomea	3	1.34	90.00	5.87	7.21
Fraxinus americana	9	4.02	79.00	5.16	9.17
Osmunda claytoniana	3	5.36	53.00	3.46	4.80
Prunus serotina	12	2.68	48.00	3.13	8.49
Athyrium filix-femina	6	0.45	38.00	2.48	5.16
Aster lateriflorus	1	2.27	30.00	1.96	2.40

*top ten species

Canopy Intercept**

Location & Species	Total Absolute % Intercept	Relative % Intercept	Absolute % Intercept
Expansion Area (E) Upland	152		
Quercus rubra		17	38
Acer rubrum		16	37
Prunus serotina		14	32

**top three species

Stem Density				Size Classes (DBH)									
Species	**<2in**	**2-4in**	**4-6in**	**6-8in**	**8-10in**	**10-12in**	**12-14in**	**14-16in**	**16-18in**	**18-20in**	**20in+**	**Total**	**Stems/ha**
Acer rubrum	7(3)	1(1)	2		1	1						12(4)	250(92)
Carpinus caroliniana		1	5									6	79
Celastrus orbiculatus	4											4	105
Cornus racemosa	7											7	184
Corylus americana	3											3	79
Crataegus sp.	3											3	79
Dead unknown	(2)	(1)	(2)									(5)	(92)
Fraxinus americana	5											5	132
Fraxinus pennsylvanica	1(4)	1	1									3(4)	52(105)
Hamamelis virginiana	32	1										33	855
Ilex verticillata	3(1)											3(1)	79(26)
Lindernia benzoin	6											6	158
Lonicera tatarica	4											4	105
Parthenocissus quinquefolia	5	6										11	211
Pinus rigida					1			1				2	26
Pinus strobus	3	8	1	2								14	224
Populus grandidentata					1							1	13
Prunus pennsylvanica	3											3	79
Prunus serotina	52(2)	8(1)	3	5	2							70(3)	1605(66)
Prunus virginiana	13											13	342
Quercus alba			1									1	13
Quercus coccinea				1								1	13
Quercus palustris		1		1								2	26
Quercus rubra	5(1)	4(2)	3		1	3			1		1	18(3)	303(52)
Quercus sp		1										1	13
Quercus velutina		1										1	13
Robinia pseudoacacia	1			1	1	1	2	1			1	8	118
Rubus allegeniensis	47											47	1237
Rubus occidentalis	1											1	26
Sambucus canadensis	1											1	26
Ulmus americana	1		1									1	26
Ulmus rubra	1	1(1)			1							2	39
Viburnum recognitum	1											3(1)	52(13)
Vitis riparia	1											1	26
												1	26
Total	**142(13)**	**20(6)**	**17(2)**	**10**	**8**	**5**	**2**	**2**	**1**	**0**	**2**	**290(21)**	
Total Stems/ ha	**3737(342)**	**263(79)**	**224(26)**	**132**	**105**	**66**	**26**	**26**	**13**	**0**	**26**		**6588(131)**

Expansion Wetland Summary

Sheet 2

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Pilea pumila	14	6.11	381.00	18.67	24.78
Phragmites australis	5	2.18	215.00	10.53	12.72
Osmunda cinnamomea	5	2.18	181.00	8.87	11.05
Impatiens capensis	15	6.55	166.00	8.13	14.68
Onoclea sensibilis	16	6.99	137.00	6.71	13.70
Celastrus orbiculatus	16	6.99	113.00	5.54	12.52
Athyrium filix-femina	6	2.62	108.00	5.29	7.91
Alliaria petiolata	10	4.37	68.00	3.33	7.70
Solidago canadensis	5	2.18	65.00	3.18	5.37
Rubus allegheniensis	6	2.62	58.00	2.84	5.46

*top ten species

Stem Density				Size Classes (DBH)									
Species	<2in	2-4in	4-6in	6-8in	8-10in	10-12in	12-14in	14-16in	16-18in	18-20in	20in+	**Total**	**Stems/ha**
Acer rubrum	1		6	1	4	3						**15**	**115**
Berberis thunbergii	10											**10**	**144**
Celastrus orbiculatus	1											**1**	**14**
Fraxinus americana		3	1									**4**	**29**
Fraxinus pennsylvanica	18											**18**	**259**
Lonicera tatarica	2											**2**	**29**
Pinus strobus							1				2	**3**	**22**
Populus deltoides											2	**2**	**14**
Prunus serotina	6							2	1		1	**10**	**115**
Quercus rubra		1										**1**	**7**
Ulmus americana		1										**1**	**7**
Viburnum recognitum	4(2)											**4(2)**	**58(29)**
Total	**38**	**5**	**7**	**1**	**4**	**3**	**1**	**2**	**1**	**0**	**5**	**71(2)**	
Total Stems/ ha	**547(29)**	**36**	**50**	**7**	**29**	**22**	**7**	**14**	**7**	**0**	**22**		**813(29)**

Canopy Intercept**

Location & Species	Total Absolute % Intercept	Relative % Intercept	Absolute % Intercept
Expansion Area (E) Wetland	156		
Acer rubrum		40	63
Prunus serotina		13	21
Vitis riparia		7	11

**top three species

Disturbed Areas & Trailer Park Summary

Sheet 3

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Poa pratensis	21	8.50	905.00	22.09	30.60
Poa compressa	12	4.86	785.00	19.17	24.02
Celastrus orbiculatus	7	2.83	268.00	6.54	9.38
Vitis riparia	18	7.29	245.00	5.98	13.27
Solidago canadensis	9	3.64	218.00	5.32	8.97
Phragmites australis	7	2.83	150.00	3.66	6.50
Rubus idaeus strigosus	4	1.62	137.00	3.34	4.96
Digitaria sanguinalis	7	2.83	111.00	2.71	5.54
Festuca elatior	8	3.24	106.00	2.59	5.83
Rubus allegheniensis	3	1.21	80.00	1.95	3.17

*top ten species

Stem Density				Size Classes (DBH)								
Species	<2in	2-4in	4-6in	6-8in	8-10in	10-12in	12-14in	14-16in	16-18in	18-20in	20in+	**Total**	**Stems/ha**
Betula populifolia	1											1	25
Celastrus orbiculatus	96											96	2400
Cornus racemosa	24											24	600
Dead unknown	(1)											(1)	25
Elaeagnus sp	3											3	75
Ligustrum vulgare	13											13	325
Parthenocissus quinquefolia	7											7	175
Populus deltoides	2											2	50
Prunus virginiana	2											2	50
Quercus coccinea					1			2			1	4	50
Rhamnus cathartica	1											1	25
Rhus glabra	1											1	25
Rhus typhina	1											1	25
Rubes allegeniensis	3											3	75
Rubus strigosus	92											92	2300
Salix sp	2											2	50
Vitis riparia	19											19	475
Vitis sp.	27											27	675
Total	**294(1)**	**0**	**0**	**0**	**1**	**0**	**0**	**2**	**0**	**0**	**1**	**298(1)**	
Total Stems/ ha	**7350(25)**	**0**	**0**	**0**	**13**	**0**	**0**	**25**	**0**	**0**	**13**		**7425**

Canopy Intercept**

Location & Species	Total Absolute % Intercept	Relative % Intercept	Absolute % Intercept
DS and TP	48		
Acer rubrum		13	6
Vitis riparia		12	6
Rubus idaeus strigosus		11	6

**top three species

Landfill Prairie Restoration Summary **Sheet 4**

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Panicum virgatum	10	16.67	720.00	63.44	80.10
Poa pratensis	5	8.33	115.00	10.13	18.47
Sorghastrum nutans	4	6.67	81.00	7.14	13.80
Andropogon gerardii	3	5.00	52.00	4.58	9.58
Ambrosia artemisiifolia elatior	4	6.67	28.00	2.47	9.13

*top five species

Landfill Weeds Summary

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Poa pratensis	8	15.69	32.40	31.67	47.36
Festuca elatior	7	13.73	29.70	29.03	42.76
Coronilla varia	5	9.80	25.40	24.83	34.63
Cirsium arvense	4	7.84	6.90	6.74	14.59
Ambrosia artemisiifolia elatior	2	3.92	5.00	4.89	8.87

*top five species

Pine Bush Karner Blue Butterfly Habitat Summary

Sheet 5

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Andropogon scoparius	20	20.41	815.00	53.51	73.92
Rubus flagellaris	5	5.10	229.00	15.04	20.14
Polygonum lapathifolium	5	5.10	206.00	13.53	18.63
Rubus hispidus	5	5.10	94.00	6.17	11.27
Digitaria sanguinalis	8	8.16	85.00	5.58	13.74

*top five species

Stem Density				Size Classes (DBH)									
Species	<2in	2-4in	4-6in	6-8in	8-10in	10-12in	12-14in	14-16in	16-18in	18-20in	20in+	**Total**	**Stems/ha**
Prunus serotina	8			1		(1)						**9(1)**	**425**
Quercus prinoides	13	2										**15**	**350**
Rubus idaeus strigosus	4											**4**	**100**
Vaccinium pallidum	3											**3**	**75**
Total	**27**	**2**	**0**	**1**	**0**	**(1)**	**0**	**0**	**0**	**0**	**0**	**31(1)**	
Total Stems/ ha	**1350**	**50**	**0**	**25**	**0**	**25**	**0**	**0**	**0**	**0**	**0**		**950**

Canopy Intercept**

Location & Species	Total Absolute % Intercept	Relative % Intercept	Absolute % Intercept
Prairie (PBKBH)	21		
Pinus rigida		30	6
Prunus serotina alive		42	9
Prunus serotina dead		16	3

**top three species

Pine Bush Scrub Oak Forest Summary

Sheet 6

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Vaccinium pallidum	6	15.38	242.0	36.07	51.45
Rubus (dewberry)	7	17.95	160.0	23.85	41.79
Quercus bicolor	9	23.08	110.0	16.39	39.47
Pteridium aquilinum latiusculum	4	10.26	75	11.18	21.43
Carex sp	2	5.13	22	3.28	8.41

*top five species

Stem Density				Size Classes (DBH)									
Species	<2in	2-4in	4-6in	6-8in	8-10in	10-12in	12-14in	14-16in	16-18in	18-20in	20in+	**Total**	**Stems/ha**
Betula populifolia	1	1										**2**	**150**
Crataegus sp.	2											**2**	**200**
Pinus rigida				2	(1)							**2(1)**	**100(50)**
Populus tremuloides	5	1(1)	(1)			1						**7(2)**	**600(200)**
Quercus illicifolia	53(4)											**53(4)**	**5300(200)**
Quercus prinoides	2											**2**	**200**
Toxicodendrum radicum	1											**1**	**100**
Total	**64(4)**	**2(1)**	**(1)**	**2**	**(1)**	**1**	**0**	**0**	**0**	**0**	**0**	**39(7)**	
Total Stems/ ha	**6400(400)**	**100(50)**	**0(50)**	**100**	**0(50)**	**50**	**0**	**0**	**0**	**0**	**0**		**6650(450)**

Canopy Intercept**

Location & Species	Total Absolute % Intercept	Relative % Intercept	Absolute % Intercept
Scrub Oak Forest (PBSOF1)	163		
Pinus rigida		45	73
Quercus ilicifolia		29	47
Betula populifolia		7	11

**top three species

Pine Bush Scrub Oak Thicket Summary — Sheet 7

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Carex sp.	11	13.75	375.0	19.77	33.52
Andropogon scoparius	7	8.75	292.0	15.39	24.14
Pteridium aquilinum latiusculum	15	18.75	279.0	14.71	18.24
Quercus prinoides	10	12.5	274	14.44	26.94
Quercus ilicifolia	6	7.5	250	13.18	20.68

**top five species

Stem Density				Size Classes (DBH)									
Species	<2in	2-4in	4-6in	6-8in	8-10in	10-12in	12-14in	14-16in	16-18in	18-20in	20in+	**Total**	**Stems/ha**
Dead unknown	(1)											**(1)**	**50**
Populus tremuloides	63(6)	2										**65(6)**	**3200(300)**
Quercus illicifolia	140(7)											**140(7)**	**7000(350)**
Quercus prinoides	5											**5**	**250**
Vaccinium pallidum	31											**31**	**1550**
Total	**239(14)**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**241(14)**	
Total Stems/ ha	**11950(700)**	**50**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		**12050(650)**

Canopy Intercept**

Location & Species	**Total Absolute % Intercept**	**Relative % Intercept**	**Absolute % Intercept**
Brushed Burned Scrub Oak (PPSOT 1&2)	29		
Quercus ilicifolia		50	15
Pinus rigida		21	6
Populus tremuloides		17	5

**top three species

Pine Bush Scrub Oak Thicket (not burned or brushed area) Summary

Sheet 8

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Quercus prinoides	4	8.00	145.0	30.21	38.21
Carex pensylvanica	4	8.00	117.0	24.38	32.38
Quercus ilicifolia	8	16.00	109.0	22.71	38.71
Pteridium aquilinum latiusculum	7	14	38	7.92	21.92
Andropogon scoparius	2	4	12	2.5	6.5

*top five species

Stem Density				Size Classes (DBH)									
Species	<2in	2-4in	4-6in	6-8in	8-10in	10-12in	12-14in	14-16in	16-18in	18-20in	20in+	**Total**	**Stems/ha**
Populus grandidentata	1	1(3)										**2(3)**	**150(150)**
Prunus serotina	4											**4**	**400**
Quercus illicifolia	69(5)	3										**72(5)**	**7050(500)**
Quercus prinoides	33											**33**	**3300**
Vaccinium corymbosum	2											**2**	**200**
Total	**109(5)**	**4(3)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**113(8)**	
Total Stems/ ha	**10900(500)**	**200(150)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		**11100(650)**

Canopy Intercept**

Location & Species	Total Absolute % Intercept	Relative % Intercept	Absolute % Intercept
Scrub Oak (PPSOT 3) Not burned or brushed	163		
Quercus ilicifolia		42	68
Quercus prinoides		12	19
Quercus rubra alive		11	18

**top three species

Pine Bush Sedge Meadow Summary — Sheet 9

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Carex stricta	9	16.07	48.36	44.52	60.59
Rubus hispidus	4	7.14	12.82	11.80	18.94
Spiraea alba	6	10.71	9.55	8.79	19.50
Thelyptris palustris	7	12.50	7.18	6.61	19.11
Vaccinium corymbosum	2	3.57	5.73	5.27	8.84

*top five species

Stem Density				Size Classes (DBH)									
Species	<2in	2-4in	4-6in	6-8in	8-10in	10-12in	12-14in	14-16in	16-18in	18-20in	20in+	**Total**	**Stems/ha**
Spiraea alba	35(9)											**35(9)**	**7000(1800)**
Vaccinium corymbosum	6											**6**	**1200**
Vaccinium pallidum	6											**6**	**1200**
Total	**47(9)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**47(9)**	
Total Stems/ ha	**9400(1800)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		**9400(1800)**

Canopy Intercept**

Location & Species	Total Absolute % Intercept	Relative % Intercept	Absolute % Intercept
Sedge Meadow (PBSM)	11		
Spirea alba		57	6
Quercus prinoides		30	3
Vaccinum sp.		11	1

**top three species

Sloping Fen Summary

Sheet 10

HERBACEOUS SPECIES*		AF	RF	AC	RC	IV
Carex pellita		3	8.82	165.0	17.90	26.72
Andropogon scoparius		2	5.88	160.0	17.35	23.24
Carex stricta		2	5.88	110.0	11.93	17.81
Rubus allegheniensis		4	11.76	102	11.06	22.83
Osmunda regalis spectabilis		1	2.94	80	8.68	11.62

*top five species

Stem Density				Size Classes (DBH)									
Species	<2in	2-4in	4-6in	6-8in	8-10in	10-12in	12-14in	14-16in	16-18in	18-20in	20in+	**Total**	**Stems/ha**
Acer rubrum	1											**1**	**200**
Rubus allegeniensis	5(1)											**5(1)**	**1000(200)**
Rubus strigosus	31(4)											**31(4)**	**6200(800)**
Spiraea alba	53											**53**	**10600**
Total	**90(5)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**90(5)**	
Total Stems/ ha	**18000(1000)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		**18000(1000)**

Canopy Intercept*

Location & Species	**Total Absolute % Intercept**	**Relative % Intercept**	**Absolute % Intercept**
Hanging Fen	18		
Rubus idaeus strigosus		47	8
Spirea alba		33	6
Rubus allegheniensis		13	2

*top three species

Vernal Pool 1 Summary Sheet 11

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Aralia sp.	1	7.69	10.0	22.73	30.42
Rubus sp.	1	7.69	10.0	22.73	30.42
Vaccinium corymbosum	3	23.08	7.0	15.91	38.99
Quercus prinoides	1	7.69	5	11.36	19.06
Carex stricta	1	7.69	3	6.82	14.51

*top five species

Stem Density				Size Classes (DBH)									
Species	<2in	2-4in	4-6in	6-8in	8-10in	10-12in	12-14in	14-16in	16-18in	18-20in	20in+	**Total**	**Stems/ha**
Acer rubrum	1(5)	6(5)	5	6	4							**22(10)**	**2300(1500)**
Betula populifolia	(3)											**(3)**	**600**
Vaccinium corymbosum	17(7)											**17(7)**	**3400(1400)**
Total	**18(15)**	**6(5)**	**5**	**6**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**39(20)**	
Total Stems/ ha	**3600(3000)**	**600(500)**	**500**	**600**	**400**	**0**	**0**	**0**	**0**	**0**	**0**		**6300(2900)**

Canopy Intercept**

Location & Species	Total Absolute % Intercept	Relative % Intercept	Absolute % Intercept
Vernal Pool 1	137		
Acer rubrum		58	79
Betula populifolia		25	34
Populus grandidentata		9	12

**top three species

Vernal Pool-Red Maple Swamp Summary

Sheet 12

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Rubus (dewberry)	1	5.26	40.0	28.70	33.43
Osmunda regalis	1	5.26	25.0	17.61	22.87
Prunus serotina	2	10.53	13.0	9.15	19.68
Lonicera tatarica	1	5.26	10	7.04	12.31
Vaccinium angustifolium	1	5.26	10	7.04	12.31

*top five species

Stem Density				Size Classes (DBH)									
Species	<2in	2-4in	4-6in	6-8in	8-10in	10-12in	12-14in	14-16in	16-18in	18-20in	20in+	**Total**	**Stems/ha**
Acer rubrum	2(1)	2										**4(1)**	**600(200)**
Betula populifolia	(3)	7(1)										**7(4)**	**700(700)**
Lonicera tatarica	8(1)											**8(1)**	**1600(200)**
Prunus serotina	4(1)											**4(1)**	**800(200)**
Rubus sp.	3											**3**	**600**
Total	**17(6)**	**9(1)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**26(7)**	
Total Stems/ ha	**3400(1200)**	**900(100)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		**4300(1300)**

Canopy Intercept**

Location & Species	Total Absolute % Intercept	Relative % Intercept	Absolute % Intercept
Vernal Pool 1 - Red Maple Swamp	105		
Vaccinium corymbosum		27	28
Acer rubrum		24	25
Populus deltoides		16	17

**top three species

Wetland (Pond) Summary

Sheet 13

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Osmunda claytoniana	1	3.57	90.0	29.90	33.47
Vaccinium corymbosum	1	3.57	30.0	9.97	13.54
Daucus carota	1	3.57	20.0	6.64	10.22
Carex stricta	1	3.57	20.0	6.64	10.22
Desmodium canadense	1	3.57	15	4.98	8.55
Onoclea sensibilis	1	3.57	15	4.98	8.55

*top six species

Stem Density				Size Classes (DBH)								
Species	<2in	2-4in	4-6in	6-8in	8-10in	10-12in	12-14in	14-16in	16-18in	18-20in	20in+	**Total**	**Stems/ha**
Acer rubrum	2	2				2						**6**	**400**
Alnus rugosa	24											**24**	**2400**
Betula populifolia		3										**3**	**150**
Populus tremuloides		1										**1**	**50**
Rubus allegeniensis	15											**15**	**1500**
Total	**41**	**6**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**45**	
Total Stems/ ha	**4100**	**300**	**0**	**0**	**0**	**100**	**0**	**0**	**0**	**0**	**0**	**4100**	**4500**

Canopy Intercept**

Location & Species	Total Absolute % Intercept	Relative % Intercept	Absolute % Intercept
Wetland 1 (Pond)	58		
Acer rubrum		35	20
Populus deltoides		22	13
Salix nigra		7	4

**top three species

Wetland (Button Bush) Summary

Sheet 14

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Lemna minor	6	17.14	285.0	41.67	58.81
Lycopus americanus	6	17.14	145.0	21.20	38.34
Carex stricta	3	8.57	115.0	16.81	25.38
Quercus velutina	1	2.86	20.0	2.92	5.78
Galium sp.	3	8.57	16	2.34	10.91

*top five species

Stem Density					Size Classes (DBH)							
Species	<2in	2-4in	4-6in	6-8in	8-10in	10-12in	12-14in	14-16in	16-18in	18-20in	20in+	**Total**	**Stems/ha**
Betula populifolia		1										**1**	**63**
Cephalanthus occidentalis	602											**602**	**75250**
Corylus americana	6											**6**	**750**
Pinus resinosa											1	**1**	**63**
Quercus alba						1						**1**	**63**
Quercus coccinea					1							**1**	**63**
Quercus illicifolia	1											**1**	**125**
Quercus velutina		1										**1**	**63**
Vaccinium corymbosum	24											**24**	**3000**
Total	**633**	**2**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**638**	
Total Stems/ ha	**79125**	**125**	**0**	**0**	**63**	**63**	**0**	**0**	**0**	**0**	**63**		**79440**

Canopy Intercept**

Location & Species	Total Absolute % Intercept	Relative % Intercept	Absolute % Intercept
Wetland 2 (Button bush)	129		
Cephalanthus occidentalis		52	67
Quercus alba		15	19
Pinis resinosa		8	11

**top three species

Wetland (Bog) Summary   Sheet 15

HERBACEOUS SPECIES*	AF	RF	AC	RC	IV
Sphagnum moss	11	26.19	1005.0	50.83	77.03
Dulichium arundinaceum	5	11.36	405.0	18.60	29.97
Carex stricta	9	21.43	385.0	19.47	40.9
Scirpus cyperinus	5	11.36	185.0	8.50	19.86
Chamaedaphne calyculata	3	6.82	55	2.53	9.34

*top five species

Stem Density				Size Classes (DBH)									
Species	<2in	2-4in	4-6in	6-8in	8-10in	10-12in	12-14in	14-16in	16-18in	18-20in	20in+	**Total**	**Stems/ha**
Betula populifolia		4										**4**	**133**
Nyssa sylvatica			1	1								**2**	**67**
Populus tremuloides			1									**1**	**33**
Vaccinium corymbosum	49											**49**	**3267**
Total	**49**	**4**	**2**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**56**	
Total Stems/ ha	**3267**	**133**	**67**	**33**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		**3500**

Canopy Intercept**

Location & Species	**Total Absolute % Intercept**	**Relative % Intercept**	**Absolute % Intercept**
Wetland 3 (Bog)	83		
Acer rubrum		28	23
Betula populifolia		16	14
Quercus coccinea		14	12

**top three species