Lake Erie Coastline Vegetative Study

Coastal Zone
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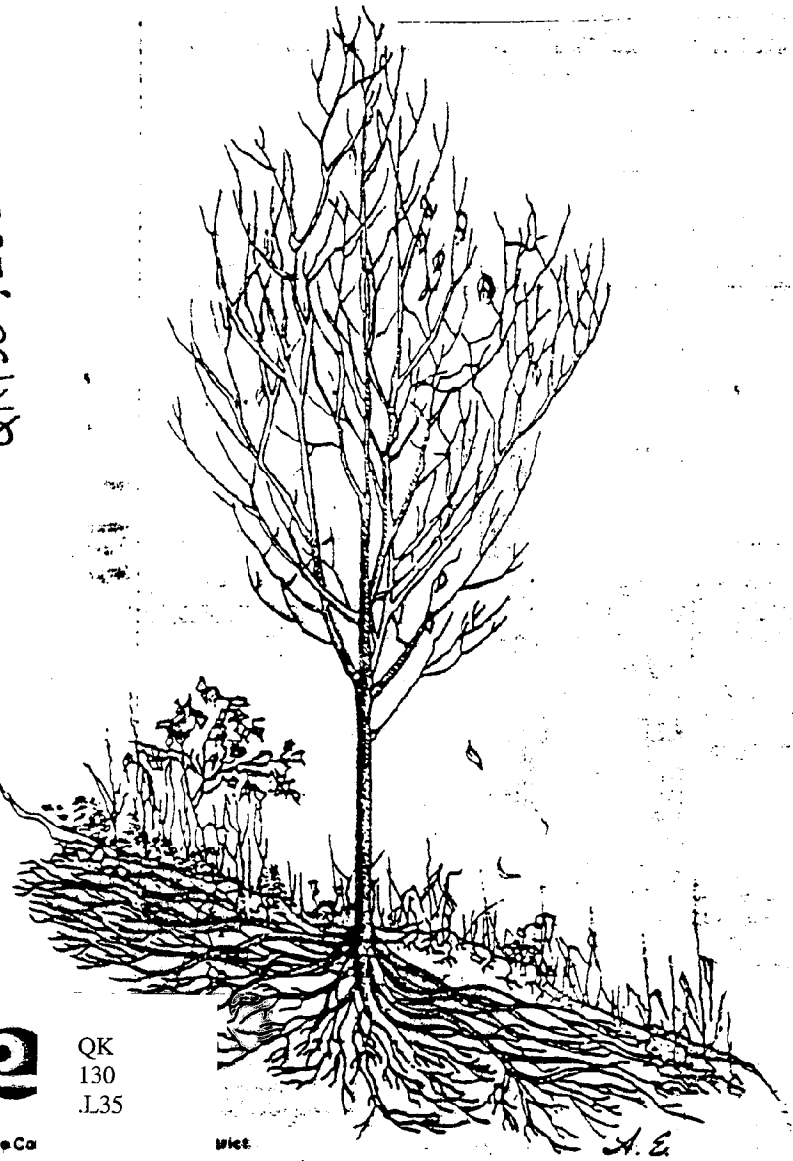
Pennsylvania Coastal Zone Management Program
QK130 .L35



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VEGETATIVE STUDY REPORT

I INTRODUCTION TO THE LAKE ERIE COASTAL ZONE VEGETATION STUDY The purpose of this study is to investigate the role of vegetation in stabilizing the bluffs along Pennsylvania's Lake Erie shoreline and to gather sufficient information to determine the vegetative species best adaptive to the various bluff conditions existing in the Lake Erie Coastal Zone. This information is also presented in a brochure titled "Vegetation - Its Role Along Pennsylvania's Lake Shoreline" which is used as a supplemental support document to the Site Analysis Report (SAR) Service. The study provides the research and findings needed to backup the data presented in the brochure. Also, the study will be used as the primary reference source by the DCZM in formulating vegetative recommendations during the development of individual property SAR reports.

This study contains the following information:

- Soils of the Erie Coastal Zone bluff study area
- General bluff makeup
- Locations of the sampling sites
- Methodology of the field assessment
- Analysis of the collected field data
- Species evaluation
- Determination of best species/mix
- Study conclusions

The information in this study and resulting brochure will provide a comprehensive approach to help the property owners understand and properly use vegetation in addressing the affects of bluff recession.

II HISTORY

Bluff recession along the Great Lakes has occurred since the glaciers scoured out the five basins as recently as 10,000 years ago. Yet, it is only within the last 50 years that this common geologic occurrence has become a major problem. This is due to the increasing number of residential, recreational, commercial, and industrial developments on or near the lake bluffs. Man's close proximity to this active geologic area has made him aware of the extensive erosion occurring and in many instances this erosion has been accelerated by his presence.

Shoreline erosion and flooding

The Pennsylvania shoreline bordering Lake Erie is approximately 63 miles long, much of which is comprised of high lake bluffs. A previous Coastal Zone Management study, "Shoreline Erosion and Flooding, Erie County," June 1975, has documented that bluff recession along the Pennsylvania Lake Erie shoreline ranges from 1/2 to 2 feet per year. This recession rate translates into 600,000 tons of sediment deposition into the Lake's littoral system each year and a correspondingly large

number of requests for assistance from shoreline property owners who are in danger of losing property and/or dwellings.

Experience has taught all those involved with bluff disturbances that there is usually no single or simple solution. However, time and a great deal of research have proven that a good vegetative cover can reduce soil erosion and provide greater stability for exposed bluff areas. A good stand of vegetation is one providing nearly 100% soil cover. Such a stand increases the soils' porosity allowing increased infiltration rates during rainstorms and reduces runoff. Since it is runoff that carries away soil particles, vegetation effectively reduces erosion. Plant roots provide stability against soil movement as they bind the soil particles together. Vegetation is not the whole solution to preventing erosion of the bluffs, but it can be used to address certain aspects of bluff recession.

This report is based upon an investigation to determine which types of vegetation grow on the lake bluffs under various conditions. Soil type, light, slope, pH, moisture, and specie frequency of occurrence were all considered. The database has allowed the determination of a best specie or species mix for various bluff conditions. Criteria for being considered a best specie was not based entirely on the plant's ability to thrive and grow on the bluff environment, but also on its ability to control surface erosion via soil cover, rooting ability and root depth.

III DESCRIPTION OF STUDY AREA (Soils, Site locations, General bluff make-up)

The area addressed by the study consisted of 48 miles of bluffs along the 63 miles of Pennsylvania Lake Erie shoreline. This shoreline extends from the Ohio State line to the New York State line on the northern border of Erie County, Pennsylvania. The area is entirely within the Lake Erie Coastal Zone. The shorelines of Presque Isle and the City of Erie were deemed exempt from the bluff studies; Presque Isle because of its lack of relief and the City of Erie because of the sheltering effects of Presque Isle.

Soils

Bluffs, which are referred to as "escarpments" in the Soil Survey of Erie County, are defined as "miscellaneous land types" which "occur on steep slopes that have formed as a result of stream cutting or lakeshore erosion. The degree of erosion varies. The tops of the escarpments have a cover of soil; but at the bases of the eroded slopes, there are outcrops of rocks. In some places, the soil material is underlain by quicksand. On most of the escarpments, the soil material resembles that of either the Berrien, Caneadea, Conotton, Ottawa, Platea, Wallington, or Williamson and Collamer soils. Because of the steep slopes and the effects of erosion, this mapping unit is in capability unit VIIe-2." 1

Berrien, Ottawa, Wallington and Williamson and Collamer soils are all fine sandy loams. Wallington and Williamson and Collamer soils also have a silt loam classification along with Caneadea and Platea. The Conotton soil series has several soil listings including: coarse sandy

loam, gravelly loam and gravelly sandy loam.

"Class VII soils have very severe limitations that make them unsuited to cultivation and that restricts their use largely to pasture, woodland, or wildlife." 2 Specifically, Class VIIe-2 is a steep to very steep, droughty, sandy soil; and, in the case of escarpments, is limited to wildlife use only. The soil survey recommends woodland use for escarpments, but the regularity of slumps and recessions precludes the propogation of anything other than some naturally occurring plants, shrubs and small hydrophilic trees.

Figure 1 is a General Soil map of Erie County and can present an overview of soil types found in the County and in the Study area.

Site locations

The site locations chosen (Figure 2) all displayed the heights, slopes, and soils characteristic of escarpments (bluffs) as defined previously. The bluffs displayed heights ranging from 5 to 180 feet, and slopes varying from 30 to 60 degrees. The bluff face, in most instances, exhibited 3 sections (upper, mid, lower) because of changes in the soil composition.

General bluff make-up

For the purposes of this report the bluff face will be divided up into the following sections:

The upper section- This is the most active and unstable part of the bluff. It begins immediately below the crest and extends downward vertically or nearly vertically for distances ranging from 3 to 25 feet. The most porous soil of the bluff is found in this section. In many instances the upper section undercuts the crest. A line of groundwater flow can usually be seen exiting the bluff face anywhere from the bottom of this section to halfway up. Generally, because of its extreme angle, plants do not grow well on this section. It will, however, support vegetation if seeds have a place to lodge and germinate. The soil above the wetted horizon is usually very dry and acidic.

The mid section- This section exhibits the gentlest slope of the bluff, generally proceeding at an angle of 20 to 45 degrees. The mid section appears as a bench along the bluff with a vertical height which may vary dramatically. At one site it may be only 3 feet, at others 40 feet or more. The length of this section is also variable. As a result of the groundwater exiting the bluff from the higher strata and surface runoff, this section is usually quite moist. The soils of the mid section are more permeable than the soils of the lower section, and if plant cover is not extensive, rills and gullies are created from seeps and springs. Fortunately, this section usually displays the most diversified and thickest plant growth. The pH factor varies from slightly acidic to neutral.

The lower section- This section begins below the mid section extending downward to the base of the bluff at a steep angle. The slope of this section is usually 45 degrees or greater and may be 3 to 20 feet in height. The soil moisture can vary from very dry to very wet, depending on the wave splash, section composition, and amount of groundwater movement. The lower section may be composed of different soil materials. It may consist of all soil (such as blue clay), all shale, or soil on a shale base. The low section's pH ranges from neutral to slightly alkaline.

An illustration of a lake bluff has been provided (Figure 3) to show the 3 sections found to be typical throughout the study area. Variations of height, length, and slope, however, did occur.

IV METHODOLOGY (Field Assessment)

Field studies were performed in order to establish a representative sampling of the entire Pennsylvania Lake Erie shoreline. These bluffs exhibited varying conditions of slope, soil type, soil pH, soil saturation, and insolation.

Site locations were chosen randomly. Usually a survey was made every 100 ft. (35 paces).

The first criteria was an overall bluff slope of 30 degrees or greater. Each section of the bluff face (upper, mid, lower) was then examined to determine: the slope of the section, soil type, soil pH, soil saturation, insolation, canopy cover, dominant vegetative species, stage of succession, and percentage of cover. Additional comments concerning the bluff sections and plant growth were made, as well as an estimation of overall bluff height.

A hand abney was used to establish the angle of the slopes. The overall slope was taken from a standing position. The slope of each section was measured by sitting or lying at the same angle as the section being measured, or by placing the abney on the average slope of the section.

Soil types were quantified based on the USDA Soil Conservation Service's Unified Soil Classification System. This classification system breaks soils down principally by texture (utilizing a few field indentification tests).

Soil pH was determined using a Cornell Soil pH Test Kit. Soil samples were stained with Chlor Phenol Red, and Bromthymol Blue in a white dish. The corresponding color change was compared to a color chart and pH noted. The kit was able to measure soil pH's from 5.0 to 7.2.

Soil saturation and insolation were measured using a Micronta Soil Moisture and Light Meter. This device measured both light and moisture. A solor panel of sort measured the light intensity, and a probe that could be inserted into the soil measured the saturation. Readout was on a scale of 1 to 10: 1 - the darkest or dryest; 10 - the brightest or most moist.

Canopy cover was estimated based upon the amount of foliar coverage or bluff cover that blocked out the sun's rays during the course of an average growing season day. Since all bluffs in the study area have northern exposures, none could have a true 0% canopy cover (as the bluff crest itself would block out light to certain sections); nonetheless, a canopy cover of 0% has been used for certain bluffs in this study and represents a very low-shade area.

Plant species were identified using the resources available to the Erie County Conservation District including the USDA Soil Conservation Service and the Botany Department of The Butler County Community College.

Comments concerning the bluff section dealt with geologic processes, such as the rate of recession, ie. active recession, man accelerated recession, recency of slump, and whether the slope was rilled or not. Comments concerning plant growth included: area and plant growth on the slope, whether the growth was sparse or thick, etc..

What plant was dominant and the amount of cover it provided was a judgment call. Often times 2 plants appeared to be growing and covering the same area. One was chosen over the other based upon an estimate that it provided 60% cover and the other plant only provided 40% cover. It should be noted that percent cover is not the percent of cover the dominant specie provides over that slope section, but the percent of cover it provides in reference to the other vegetation growing. For example, only 1 plant could be growing on a bluff section; it would be rated as 100% cover even though it might only occupy 10% of the bluff.

A photograph of each bluff site was taken to document sites and plant growth. Examining the pictures can best show the extent of growth a type of vegetation is achieving. Photographs were also taken of important plant and tree species for use in the brochure.

All data and information from each bluff site was recorded on a form prepared by the Erie County Conservation District and shown in Figure 4.

Data from the forms was then transferred to a relational database management computer program via Microrim's RBASE 4000 and the ECCD's Tandy 2000 computer. The database for the Vegetative Study was designed by Sean E. Gill of the Erie County Conservation District. Manipulation of the database allowed the development of the sections that follow.

V ANALYSIS OF FIELD DATA

Of the 100 bluff sites, only 4 did not have some sort of vegetation growing on 1 of the 3 slope sections. This would seem to indicate that plants will grow on the Lake Erie bluffs if given a chance. The 4 sites that did not have any growth had just suffered major recessions and enough time had not passed for plants to colonize the slope.

Since the bluffs generally exhibited 3 sections, it will be easier to examine the study results as they relate to these 3 individual sections. First of all, we will take a look at a general

overview of the bluff sites and the conditions present. Then the plant species growing under various conditions will be examined. The photos of bluff sites that accompanies this manuscript should be reviewed to get an idea of just how vegetated the bluffs are. Important plant species encountered are listed on the back of each photo. These photos will be invaluable when reviewing the computer program that contains the data for each site. Unfortunately, 2 of the site photos did not develop properly and are unavailable for viewing. (Site #'s 16, 100)

Table 1 is a general overview of bluff site characteristics including maximum, minimum and average values.

TABLE 1

	Maximum Value	Minimum Value	Average Value (Typical Bluff)
UPPER SECTION			
Slope:	90 degrees	26 degrees	68 degrees
Soil Saturation:	10	1	5
Soil pH:	7.2	5.0	6.386
Insolation:	10	2	8
Canopy Cover:	100%	0%	33%
Soil Type: CL-45 ML-11 SC-10 SL-1 SM-33			
MID SECTION			
Slope:	90 degrees	16 degrees	37 degrees
Soil Saturation:	10	1	8
Soil pH:	7.2	5.0	6.745
Insolation:	10	3	9
Canopy Cover:	90%	0%	23%
Soil Type: CH-5 CL-43 MH-2 ML-6 *RS-6 SC-33 SL-5			
LOWER SECTION			
Slope:	90 degrees	21 degrees	57 degrees
Soil Saturation:	10	0	5
Soil pH:	7.2	6.1	7.102
Insolation:	10	4	9
Canopy Cover:	100%	0%	16%
Soil Type: CH-57 CL-6 CO-1 MH-1 *RS-35			

*Wherever shale was encountered as the soil type, the symbol RS was used; the pH was not taken as nothing will grow on shale; the saturation was estimated.

As the photographs will indicate, it may be true that vegetation is growing on most of the bluffs; it is also true that it is not growing over all sections of the bluffs. Study results indicate that 75 bluffs contain 1 or more sections devoid of vegetation. The breakdown of denuded sections is as follows: upper section - 45 bluffs with no growth, mid section - 12 bluffs with no growth, lower section - 75 bluffs with no growth.

Forty-five (45) bluffs had upper sections with no growth. This is due primarily to the activeness of this section. If the face is actively receding, little plant life is going to be able to grow on it. Also, these sections are extremely steep. Vegetation cannot get established on 75-90 degree angles. The soil will usually support vegetation, as many steep slopes had plants and small trees growing on ledges only a few inches wide by a foot long. Vegetation will rarely root on a vertical slope.

Of the bluffs with mid section showing no growth, 6 were composed of shale and 4 others were bluffs with nothing growing at all. The 2 other non-vegetated slopes were victims of recent recessions. 88 bluffs had mid sections displaying vegetative growth, often lush and diversified.

The reason for no growth on lower sections of bluffs can be explained due to the steepness of the slope and the constant wave action. Also, 35 lower sections were made of shale which will not support vegetative growth under normal conditions. Wave action prevents vegetation from getting established. Most lower sections that were not shale were made of blueclay (CH on unified soil classification - 57 bluff sections) which seemed to support little growth and eroded easily.

The following 3 tables list the vegetative species found during this study under various bluff conditions. It should be emphasized that the species listed here were the dominant species (those showing the greatest percent cover). In many instances, other plants, shrubs or trees were present, and will be discussed later because they were probably dominant on other bluffs. A few species showed up over and over again. These are the species that can be expected to vegetate Lake Erie bluffs.

TABLE 2

DOMINANT SPECIES ON THE UPPER SECTION

SPECIE	# of bluffs dominant on
Andropogon	1
Black alder	2
Black locust	5
Canada bluegrass	1
Chicory	1
Coltsfoot	17
Crabgrass	1
Crownvetch	2
Eastern cottonwood	1
Elderberry	1
Flowering raspberry	3
Goldenrod	2
Horsetail	2
Jewelweed	2
Orchardgrass	1

Prairie junegrass	1
Red clover	2
Redtop	2
Sassafras	1
Staghorn sumac	1
Sweet white clover	3
White snakeroot	1
Yarrow	1
Yellow birch	1

TABLE 3

DOMINANT SPECIES ON THE MID SECTION

SPECIE	# of bluffs dominant on
Black alder	1
Black locust	1
Coltsfoot	26
Crownvetch	2
Eastern cottonwood	3
Flowering raspberry	1
Goldenrod	11
Horsetail	32
Jewelweed	2
Nightshade	1
Panicum	1
Perennial ryegrass	2
Plantain	2
Poplar	3
Red clover	1
Sweet white clover	1
White snakeroot	1

TABLE 4

DOMINANT SPECIES ON THE LOWER SECTION

SPECIE	# of bluffs dominant on
Coltsfoot	9
Eastern cottonwood	1
Goldenrod	2
Horsetail	12
Yarrow	1

A quick glance at the previous 3 tables leads one to believe that horsetail and coltsfoot are the 2 most common dominant species found on the Lake bluffs. This deduction is true. On virtually every vegetated bluff examined, either horsetail or coltsfoot, or both were present. These species were not always the dominant plants, but they were almost always present. Of the remaining dominants, goldenrod appeared the most. It was dominant on 15 bluff sections out of 300

sections surveyed. (5%).

The 3 tables that follow list all vegetative species recorded during the study (other than dominant) and the number of times they occurred in each section. These species were found to be providing at least 10% cover, as species providing less cover were not recorded.

TABLE 5

SPECIES IN ADDITION TO THE DOMINANTS ON THE UPPER SECTION (35)

SPECIE	# of occurrences
American hackberry	1
Basswood	3
Black locust	7
Black medic	4
Canada bluegrass	3
Coltsfoot	13
Common St. Johnswort	1
Eastern cottonwood	3
Flowering raspberry	3
Goldenrod	20
Hemlock	1
Horsetail	7
Jewelweed	3
Kentucky bluegrass	1
Lambsquarter	1
Nightshade	1
Orchardgrass	4
Panicum	2
Phragmites	1
Plantain	1
Pokeweed	1
Prairie junegrass	1
Queen Anne's lace	2
Red oak	1
Redtop	3
Sassafras	1
Sheep sorrel	1
Silky dogwood	4
Silver maple	1
Staghorn sumac	7
Timothy	1
White ash	2
willow	5
Yarrow	10

TABLE 6

SPECIES IN ADDITION TO THE DOMINANTS ON THE MID SECTION (49)

SPECIE	# of occurrences
Basswood	3
Black alder	12
Black locust	5
Black-eyed Susan	3
Black medic	1
Bracken fern	1
Brambles	3
Canada bluegrass	10
Chicory	1
Coltsfoot	50
Common St. Johnswort	3
Crownvetch	4
Curly dock	1
Eastern cottonwood	18
English ivy	1
Flowering raspberry	23
Goldenrod	57
Horsetail	19
Jewelweed	5
Kentucky bluegrass	1
Nightshade	4
Nutsedge	9
Orchardgrass	12
Ox-eye daisy	6
Panicum	1
Perennial ryegrass	2
Plantain	2
Prairie junegrass	1
Queen Anne's lace	17
Red clover	2
Red oak	1
Redosier dogwood	2
Redtop	15
Reed canarygrass	5
Sassafras	1
Sheep sorrel	2
Silky dogwood	4
Silver maple	2
Staghorn sumac	7
Strawberries	4
Sweet white clover	4
Tall fescue	3
Timothy	2
Virginia creeper	1
White ash	7
White snakeroot	2
Wild grapes	2
willow	27
Yarrow	33

TABLE 7

SPECIES IN ADDITION TO DOMINANTS ON THE LOWER SECTION (22)

SPECIE	# of occurrences
Basswood	1
Black locust	2
Canada bluegrass	1
Coltsfoot	18
Crownvetch	1
Eastern cottonwood	4
Flowering raspberry	7
Gray dogwood	1
Goldenrod	7
Horsetail	9
Jewelweed	2
Kentucky bluegrass	1
Nightshade	1
Perennial ryegrass	2
Queen Anne's lace	1
Redtop	1
Strawberry	1
Sweet white clover	1
White ash	1
willow	5
Yarrow	3

The preceeding tables indicate those few species that show up over and over again. They include Coltsfoot, Horsetail, Goldenrods, Yarrow, Flowering raspberry, Eastern cottonwood, and willows. These 7 species are definitely the most common plants growing on the Pennsylvania Lake Erie bluffs.

Table 8 summarizes the results of Tables 5, 6, and 7 while deleting all species that occurred on less than 5% of the sections surveyed. This table displays species that grow with some degree of regularity. This does not include dominant species, only species that occurred in addition to them.

TABLE 8

SUMMATION OF COMMONLY OCCURRING SPECIES (OTHER THAN DOMINANT)

SPECIE	# of occurrences	% (based on 300 sections)
Goldenrod	84	28
Coltsfoot	81	27
Yarrow	46	15
willow	37	12
Horsetail	35	12
Flowering raspberry	33	11
Eastern cottonwood	25	8
Queen Anne's lace	20	7
Redtop	19	6
Orchardgrass	16	5

Note: Black alder, Black locust, Canada bluegrass and Staghorn sumac occurred very near 5%.

Now that it is apparent which plant species grow on the bluffs, let's examine which species can be expected to propogate under extreme bluff conditions of slope, light, moisture, shade, and pH.

An extreme slope condition would be in the neighborhood of 75 - 90 degrees. Since the light meter used registered a 10 on most bluffs, it was assumed that the limiting insolation value is the case where not enough light is present. We will use a 4 to represent an extremely low insolation setting. To examine excessive soil moisture conditions, we will have to look at the dry end of the spectrum as any damp soil registered a 10. (Also, moister soils always exhibited better growth than dry ones as measured on the soil moisture probe.) A value of 3 or less will be considered excessive. Most plants grow well on neutral soils; therefore, an acid situation will be considered the limiting condition where pH is concerned (pH of 5.4 or less will be used as excessive.) Shade cover didn't seem to make a lot of difference, but we'll examine both ends of the spectrum designating 10% or less as low shade, 90% and greater as an extreme shade situation. Tables 9, 10, 11, 12 and 13 show the results.

TABLE 9

DOMINANT SPECIES GROWING UNDER EXTREME SLOPE (≥75 degrees)

SPECIE	# of occurrences	%(based on 95 sections)
Black locust	2	2
Coltsfoot	11	12
Eastern cottonwood	1	1
Goldenrod	1	1
Horsetail	1	1
Plantain	1	1
Prairie junegrass	1	1
Redtop	1	1
Sassafras	1	1
Sweet white clover	1	1
Yarrow	1	1

Ninety-five (95) sections had slopes equal to or greater than 75 degrees. Of these 95 sections, Coltsfoot was dominant on 11 (12%). Only this specie shows a significant adabtability to steep slopes.

TABLE 10

DOMINANT SPECIES GROWING UNDER EXTREMELY LOW INSOLATION (≤4 ON MICRONTA METER

SPECIE	# of occurrences	%(based on 5 sections)
Coltsfoot	1	20
White snakeroot	1	20
Yellow birch	1	20

Only 5 bluff sections had low light conditions and 3 different species were found growing. Due to the low occurrence of this condition, no real results can be assessed here.

TABLE 11

DOMINANT SPECIES GROWING UNDER LOW MOISTURE SATURATION (≤ 3 on MICTONTA METER)

SPECIE	# of occurrences	%(based on 38 sections)
Black locust	2	5
Chicory	1	3
Coltsfoot	6	16
Crownvetch	4	11
Flowering raspberry	1	3
Plantain	1	3
Prairie junegrass	1	3
Redtop	1	3
Sweet white clover	1	3
Yarrow	2	5

Thirty-eight (38) of 300 sections (13%) had low soil saturations. The most commonly found plant was Coltsfoot. Crownvetch was not very far behind, but its figures are somewhat misleading. Crownvetch will only grow well on dry soil and it was only found dominant on the 4 sections illustrated by this table. It should also be noted that these 4 sections represent 2 bluffs where the Crownvetch was dominant on both the upper and mid sections.

TABLE 12

DOMINANT SPECIES GROWING UNDER LOW pH (≤5.4)

SPECIE	# of occurrences	%(based on 28 sections)
Andropogon	1	4
Chicory	1	4
Coltsfoot	9	32
Crownvetch	2	7
Flowering raspberry	1	4
Horsetail	1	4
Nightshade	1	4
Prairie junegrass	1	4
Redtop	1	4
Yarrow	1	4

Only 9% of bluff sections contained excessively acidic slopes, but coltsfoot proved once again to be the most common specie.

TABLE 13

DOMINANT SPECIES GROWING UNDER EXTREME CANOPY COVER

SPECIE	CANOPY ≤10% #of occurrences	CANOPY ≥90% #of occurrences	CANOPY ≤10% %(152 sections)	CANOPY ≥90% %(19 sections)
Black alder	1	0	<1	0
Black locust	4	1	3	5
Chicory	1	0	<1	0
Coltsfoot	15	4	10	21
Crabgrass	1	0	<1	0
Crownvetch	4	0	3	0
Eastern cottonwood	2	0	1	0
Goldenrod	7	0	5	0
Horsetail	32	0	21	0
Jewelweed	0	2	0	11
Panicum	1	0	<1	0
Perennial ryegrass	1	0	<1	0
Plantain	2	0	1	0
Red clover	3	0	2	0
Staghorn sumac	1	0	<1	0
Sweet white clover	3	0	2	0
White snakeroot	0	2	0	11
Yarrow	2	0	1	0
Yellow birch	0	1	0	5

Once again, Coltsfoot proves to be a very versatile specie. Only horsetail is more common on low canopy cover situations and Coltsfoot is the most commonly occurring specie on shaded bluffs. Horsetail is one of the most common dominant bluff species and the results of this table indicate that it will do very well on bluffs with plenty of sunshine. Jewelweed and White snakeroot seem to show some promise in shaded areas; Goldenrod will fare well in direct sunlight.

Everything in the study up to this point has been documenting the bluff conditions, such as insolation, soil composition, canopy cover, soil pH and soil saturation and showing where each plant is growing. The data shows, at this point, that most every species is found to grow under all the conditions with the exception of soil saturation.

A quick look at Tables 9, 11, 12, and 13 bears out this fact. Even a very low moisture saturation as shown in Table 11 will support species that provide very good soil stabilization, such as locust, Crownvetch, Flowering raspberry and Redtop. The bluffs where excessive moisture was present usually exhibited active recession because the water movement out through the face carried soil particles with it. In many cases excessive moisture can be determined just by visual observation. Where doubt exists on soil saturation, the Micronta Soil Moisture and Light Meter should be used. (See Section VI Methodology)

A low pH should not be considered a limiting factor because of the ease of adjusting pH upward by the application of ground limestone as a soil amendment.

The presence of an extreme canopy cover always indicated a stable bluff on the sections studied. The size and age of the trees that created extreme canopy cover further proves a relatively long period of time between slumps. The study shows over and over again that moisture is the most significant limiting factor.

With this limiting factor in mind, the next section of this report will deal with species evaluation and recommendations. You will find in this section of the study that the best species mix will be related to the extent of soil saturation.

VI SPECIES EVALUATION

This section will attempt to analyze the most common bluff species in terms of their compatability to the bluff environment, the erosion control and soil stabalization they provide and the species availability for planting.

The first prerequisite above appears somewhat redundant. Obviously, if the species are common to the bluffs, they must be suitable to the bluff environment. This is true, but additional plant species are going to be evaluated here: species that have readily available seed sources and have been used in the past for conservation plantings.

Erosion control and soil stabalization capabilities are determined: by the species rooting system, the degree of soil coverage provided, and the amount of time the specie takes to establish itself. Since bluff recession occurs so frequently, it is important to have a specie that establishes quickly.

Species availability is very important. One plant type could flourish naturally on the Lake bluffs; but if there are no commercial seed sources, it would be relatively difficult to introduce this specie. The following species will be examined based on the previously explained criteria:

1. Black alder
2. Black locust
3. Canada bluegrass
4. Coltsfoot
5. Crownvetch
6. Goldenrod
7. Horsetail
8. Jewelweed
9. Nightshade
10. Orchardgrass
11. Eastern cottonwoods
12. Red clover
13. Perennial ryegrass
14. Staghorn sumac
15. Sweet white clover
16. Flowering raspberry
17. White snakeroot
18. Yarrow
19. willow
20. dogwoods (Silky,Redosier, Graystem)
21. White ash
22. Queen Anne's lace
23. Nutsedge
24. Reed canarygrass
25. Timothy
26. Tall fescue
27. Redtop
28. "Rem Red" Amur honeysuckle
29. "Arnot" bristly locust
30. Halls Japanese honeysuckle

These species are either very common and well adapted to the Lake Erie bluffs, or are recommended species for bluff plantings. Note that a few plants that were found dominant will not be evaluated. This is so (1) because either these species were only dominant once and were never seen again on a bluff, or (2) because they were providing a very low percent of cover.

1. European black alder - was found on 6% of the section sites and 3 times as a dominant. Black alder is a tree specie that can grow to 50 feet in height. On the bluffs, it did not exceed 15 feet, but grew fairly well. Black alder will tolerate the following site conditions: low fertility, acid, loamy and sandy soils, droughty areas, extreme sunlight and moderately well-drained soils. It has poor shade tolerance and will grow from a seedling to 12' - 15' in 4 to 6 years. As with most trees, it has an excellent root system, but does not provide good soil cover. Seeds and seedlings are available from most nurseries. The specie does appear adapted to milder slopes (seen mostly on mid sections) and may hold the soil well if planted in conjunction with some herbaceous or ground cover providing plant.

2. Black locust - was found on 6.7% of the section sites and 6 times as a dominant. It is also a tree specie that grew predominately and most prevalently on bluff crests. Occasionally, it was found on the bluff itself where it might germinate on any of the 3 sections. This specie was often seen growing from small ledges on otherwise vertical slopes. As with Black alder, Black locust's roots are extensive and hold the soil well but provide no ground cover. Black locust will tolerate loamy and sandy, dry to moderately well-drained soils that are slightly acid. It is a rapidly growing deciduous tree that exhibits growth characteristics similar to Black alder. This is a specie that has potential when used with a plant that provides ground cover and is

commercially available at Musser Forest, Inc., Indiana, Pa. 15701. Most nurseries should be able to provide this specie.

3. Canada bluegrass - is a grass specie very similar to Kentucky bluegrass but smaller. It was found on 5% of section sites and once as a dominant. It is capable of producing very dense stands (as it did on some sites) and has a fair root system. This specie prefers gentler slopes of 0-40 degrees and will grow on clayey, loamy or sandy soils where the pH is slightly acid to neutral. It will withstand some shade, but will perform better in sunlight. It prefers a moderately well-drained soil. On bluffs with such conditions, it can be expected to do very well. Its best application would probably be in combination with other plants, trees, or shrubs, and grasses. Seed and/or sod is readily available commercially.

4. Coltsfoot - is a herbaceous plant that was the most dominant and grew under the widest range of bluff conditions, i.e. slope, pH, soil type, saturation, insolation and canopy cover. It was dominant on 52 sections and present on 44.3% of bluff sections overall. This specie is most adapted to the bluff environment based on the results of this study. It is a pioneer plant specie with extremely rapid growth capable of vegetating a bluff section in a few months (3-4 months). It provides good soil cover (not as dense as grasses) but only has a single long root that provides limited soil stabalization. Another drawback to this specie is that there are no commercial sources.

5. Crownvetch - is a herbaceous legume that was found on 3% of section sites and was dominant on 4 section slopes. Crownvetch will grow in shallow, low fertility, acid soils of all denominations (clayey, loamy and sandy). It is an excellent drought tolerant, poor shade tolerant specie that requires a well-drained soil. It will grow to 3 feet in height, but will require 2 to 3 years to provide dense cover and is slow to grow the first year. The specie is excellent for stabalizing steep slopes, but its adaptability to Lake bluffs is limited due to the wetness of most of them. Seed is commercially available for this specie.

6. Goldenrod - is a common perennial herbaceous plant that will grow under most bluff conditions. It was the most common (other than dominant) plant specie recorded during the survey. It was found on 33% of slope sections and was dominant 15 times. Goldenrod will grow in all 3 soil types under slightly acid conditions. It has poor shade tolerance and will propogate in moderately well-drained to somewhat poorly drained soil. It will grow to 5 feet high and provide a dense cover with a well-developed root system. It dies off every year, but the stalks remain standing until excess snowflall collapses them. This is another excellent specie for vegetating Lake bluffs, but seed is not commercially available.

7. Horsetail - is a primitive plant that was the most common dominant specie encountered on the mid section during the site surveys. This specie showed up 46 times as a dominant and 27% overall. Horsetail could be found growing on average slopes (0-45 degrees) in all soil types under slightly acid conditions. This pioneer specie did best in full sunlight and under a soil saturation of somewhat poorly drained and drier. This plant is capable of vegetating an entire slump area with

fairly dense cover in only a few months. It has poor shade tolerance and only an average root system. Also, this naturally occurring plant has no known commercial seed source.

8. (Spotted) Jewelweed) - is a common herbaceous plant seen along shady roadsides with orange flowers and its famous "touch-me-not" exploding seed pods. This specie is very succulent and its juices are a proclaimed remedy for poison ivy and insect bites. Not an extremely common plant, during our surveys it showed up 4.7% of the time and 4 times as a dominant. This specie does very well in somewhat poorly drained soils to poorly drained soils of clayey loamy or sandy content. It is a very shade-tolerant specie and will propogate in a slightly acid soil on a milder slope. It can produce a fairly dense stand within a few months of up to 3 feet tall with a good root system. This specie could be utilized on shady wet slopes; but, being a native plant, there is no commercial seed source.

9. (Bitter) Nightshade) - is a viney plant specie bearing bright red poisonous berries. This specie was dominant on 1 site section and present on 2.3% of sections. This plant can produce a good cover with a fair root system on average slopes (0 - 45 degrees) having dry to moderately well-drained soils. It will grow in low fertility, clayey, loamy, or sandy, acid soils where there is moderate shade to full sunlight. It requires only a few months to reach maturity, but being poisonous, it is not looked upon favorably by the commercial plant industry; thus, there are no seeds available.

10. Orchardgrass - is a common perennial cool season grass that is often used as hay forage. It was found on 5.7% of section sites and once as a dominant. It is a tall growing bunch grass specie that forms dense stands with an excellent root system. It was found on all slopes, but preferred 0-40 degree inclines. It grew in all soil types and under all pH conditions, but made its best showing on pH's closer to neutral. The specie propogated under all moisture conditions, but did best on well-drained to somewhat poorly drained soils where there was low shade situations. Orchardgrass definitely enjoys the sunshine. There is an absolute plethora of seed sources for this grass type.

11. Eastern cottonwood)- is a very common tree specie that was encountered on the bluffs as seedlings, saplings and young individuals. It was dominant 5 times and occurred on 10% of site sections. Everytime it was dominant, it was in seedling form where it frequently displayed 25 or more seedlings to the square foot. The trees could never be expected to grow that dense, but it does emphasize the cottonwood's ability to pioneer bluffs and when grown, its extensive root system holds the soil well. The specie is hydrophilic and will grow on poorly drained soils under all pH's, but showed a definite preference for neutral or near neutral hydrogen ion concentrations. It fared well in all soil types and displayed a liking for sunshine. When used in combination with a ground cover crop, it could be just the ticket for wet bluffs. The specie is extremely common and readily available at all nurseries.

12. Red clover - is a short-lived perennial legume that is frequently used as a forage crop. It is easy to establish on all soil types and will grow on acidic and wet soils up to somewhat poorly drained. Red

clover was found on 1.7% of site sections and was dominant on 3 sections. In each dominant case, it originated from the back yard of a landowner occupying the bluff crest. It created a dense cover, but had only a fair root system. The specie is shade intolerant and grew well on slopes from 0-60 degrees. Because it is easy to establish and quick growing, this specie may work well on the steeper parts of bluffs.

13. Perennial ryegrass - is a perennial bunchgrass specie that is not quite as winter hardy as orchardgrass. Ryegrass grows in medium fertility, slightly acid, clayey and loamy soils. It has poor shade tolerance, but will propogate in a somewhat poorly drained soil. It can produce complete cover in a few months and has a shallow but fibrous root system. It was found to grow on slopes up to 40 degrees and can be purchased at any seed dealership. Ryegrass was found on 2% of slope sections and twice as a dominant. Its best application may be as a means of providing quick cover while other species are taking root.

14. Staghorn sumac - is a large shrub that grows to a height of 10 to 15 feet. It was found on 5% of sections and once as a dominant. It will grow on most slopes if given a chance. Sumac, like Black locust, was often seen growing from ledges on otherwise vertical upper sections. This shrub grows in medium fertility, slightly acid, loamy soils. It will tolerate drought and moderately well-drained soil, but not shade. One-year-old seedlings will mature in 4 to 6 years. On bluffs that meet the above conditions, Staghorn sumac may provide some benefits due to its root system when used in conjunction with a cover crop.

15. Sweet white clover - is a biennial legume used primarily for soil improvement and stabalization or as a nectar producing flower for honey bees. It was found on 9 sections (3%) and of these, 4 times as a dominant. This clover specie does best on milder slopes (0-35 degrees) and when in direct sunlight. It will grow on loamy to sandy, slightly acid, moist soils. This specie can produce a fairly dense stand up to 5 feet high and possesses a fair root system. The sites where this specie was dominant appeared to have been planted by man. The Sweet white clover had grown into a good stand and was doing a good job of slope stabalization. Seed is available from most dealers and nurseries.

16. Flowering raspberry - is a pioneering bramble type of plant that produces pink fruit similar to red raspberries. It was fairly common on bluffs showing up 12.3% of the time and 4 times as a dominant. The specie preferred slopes in the range of 0 to 45 degrees, but was sometimes found on steeper ones. It could be found on all soil types (loamy preferred) under all pH's (slightly acid to neutral preferred) and on up to somewhat poorly drained soils. It was under all canopy situations, but appeared most under well lit conditions. The specie can produce fair to good cover in a short time (few months) and has an extensive root system. It appears to be well adapted to the bluff environment, but the seeds or nursery stock cannot be purchased. It is possible that any bramble type of plant may work as well (blackberries, red raspberries, black raspberries, etc.), and these may be purchased from most nurseries.

17. White snakeroot - is a herbaceous specie that only occurred on a few sites, but is notable because it is shade tolerant and will grow well on somewhat poorly drained soils. It was even noted growing on poorly drained areas with some standing water and overland flow. This plant occurred only on 1.3% of section sites and as a dominant twice. It grew on clayey, loamy, and sandy soils that were near a neutral pH and in the shade. The micronta light meter still registered a "10" in these areas, but the heavy canopy created a shady setting. White snakeroot matures in 1 growing season and can provide good cover 2 to 3 feet high. It has an excellent fibrous root system even when young, but being a wild specie, is not available commercially.

18. Yarrow - is another herbaceous plant that occurred very often during the survey and is noted by its somewhat parsley-like leaves and small clustered white flowers. This specie was dominant on 2 slopes and seen 16% of the time. It was rarely seen growing thick enough to provide good cover, but it does possess a respectable root system. It is common enough on the bluffs that it must be well adapted to life there, but seed unavailability precludes trying to establish it. Yarrow was found on all inclines from 0 degrees to 35 degrees with the majority on the lower end of the scale. A sunlit area was preferred on a moist loamy to sandy soil. It grew under all pH conditions, but appeared most often near neutral.

19. willow - is a very common water-loving tree specie. It is an excellent tree to plant on the bluffs due to its acceptability of that environment and its well-developed root system. Willow seedlings, sapling and trees appeared 12.3% of the time during the study. It was never a dominant, but appeared very often and would do well when planted with a ground cover-providing plant specie. Willows were found on slopes ranging from 0 to 40 degrees in medium fertility, slightly acid, clayey, loamy and sandy soils. It has a poor drought tolerance, good shade tolerance and grows well on poorly drained soils. Willows are traditional trees for providing effective erosion control on wet areas and along streams. They can be purchased at any nursery.

20. Redosier, Silky/Graystem dogwood - is a decidius fruitbearing shrub that is beneficial for erosion protection and wildlife food and habitat. Three different species were found during the bluff surveys including: Silky (2.7%), Redosier (0.7%) and Graystem (0.3%). All 3 species grow in medium fertility, slightly acid, clayey, loamy and sandy soils. They have fair shade and drought tolerance and prefer milder slopes. Graystem requires a well drained soil; Silky and Redosier can tolerate a poorly drained soil. Even though they were not common species during the survey, they should offer good stabalization on slopes with the above characteristics when used in conjunction with a cover crop. Dogwoods grow 8 to 12 feet high, have an excellent root system, and are readily available.

21. White ash - is a fairly common decidious tree that was seen on 3.3% of section sites. This specie grows on gentler slopes (up to 40 degrees) on clayey, loamy or sandy soils that may be slightly acidic. White ash has fair shade tolerance, but was found most often in the sunlight on moist soils up to somewhat poorly drained. It offers promise for

vegetating bluffs due to its soil stabalizing root system, adaptability to bluff environment, commercial availability and when used with a herbaceous or grass specie, for cover.

22. Queen Anne's lace - is the common "wild carrot" seen virtually on every hill and dale. It appeared on 6.7% of bluff sections wherever gentle slopes and slightly acid loamy soils prevailed. It would tolerate somewhat poorly drained soils but would not tolerate shade. This specie grows up to 3 tall and can provide a good cover with adequate soil stabalization due to its single carrot-like root. Being a wild plant specie, it is not available commercially.

23. Nutsedge - is a common specie of sedge found on 3.3% of section sites that had a distinct liking for poorly drained soils. Study results indicate it prefers slightly acid to acid, loamy to sandy soils on mild slopes in full sunlight. On some bluffs, it was found to be growing very thick even in standing water. This specie is considered to be a noxious weed and once established, it is very hard to get rid of. For this reason, it is not offered by seed dealers. Nutsedge has a very good root system and it would perform well if it was obtainable. Some sedges are commmercially available and may be usable if they exhibit preferences and characteristics similar to nutsedge.

24. Reed canarygrass - is a tall (4 foot) sod-forming perennial grass that was found on only 1.7% of section sites. It is a common conservation planting that excells on extremely poor drainage areas and produces a dense stand with an excellent root system. It should work very well on wet bluffs up to 45 degrees of loamy, slightly acid content. It seems to enjoy sunlight, but was found under up to 60% canopy cover. Since it is such a common conservation planting, it is available at just about all seed dealers.

25. Timothy - is a common bunch grass with a relatively shallow but fibrous root system. It is often used for hay forage and was found on only 1% of section slopes. Timothy, like Reed canarygrass, is a common planting with readily available seed sources. During the study, it was found on average slopes (0-45 degrees) of loamy, acid soils that were well drained to moderately well drained. It occurred under limited canopy cover and in nearly full sunlight. Timothy grows to 3 feet high and can form excellent cover. Under the proper conditions, it could provide adequate stabalization.

26. Tall fescue - is a deep-rooted, long-lived, sod-forming grass that spreads by seeds and short underground stems. It is the most common conservation planting in the Northeast; and while found on only 1% of slopes, it had been introduced by man in each case. It has an excellent root system and produces an effective cover in the establishment year. Tall fescue grows in low-fertility, acid, clayey, loamy and sandy soils and will tolerate somewhat poorly drained areas. It has fair shade tolerance and good drought tolerance. Kentucky 31 is the most common variety and can be found at any and all seed dealerships.

27. Redtop - is a fast-starting, sod-forming grass that achieves a height of 18" at maturity. It provides effective cover the first year and will grow on poorly drained soils. This specie was found on 7% of

section sites and twice as a dominant. It is a common component of seeding mixtures for disturbed sites in the Northeast. It will grow in low feritility, very acid, clayey, loamy and sandy soils. It has poor shade tolerance, fair drought tolerance and good cold tolerance. Redtop is readily available and should provide good results when used in combination with other species.

28. "Rem Red" Amur honeysuckle - is a berry-bearing shrub that grows to a height of 8 to 12 feet. It was not encountered during the study, but is known to have been used during the past for bluff stabalization. This honeysuckle specie grows in medium fertility, slightly acid, clayey, loamy and sandy soils. It has fair drought tolerance, fair shade tolerance and will tolerate somewhat poorly drained soils. It can provide good cover and soil stabalization when used in conjunction with cover crop species and is readily available at nurseries.

29. "Arnot" bristly locust- is a perennial shrub that grows to heights of 4 to 6 feet and forms a thicket by root suckers. This deciduous shrub requires well-drained areas, and is drought tolerant. It has poor shade tolerance, but is excellent for slopes ranging from 0-75 degrees. It grows in low-fertility, very acid, loamy and sandy soils. It is commercially available.

30. Halls Japanese honeysuckle - is an agressive semi-evergreen vine that is 12-15" high, with an excellent root system for covering large areas. This honeysuckle will grow on low-fertility, acid clayey, loamy and sandy soils. It has excellent shade tolerance, good drought tolerance, and fair tolerance of poorly-drained areas. This specie may help to secure slopes ranging from 0-60 degrees, and has been used elsewhere as a conservation plant. It is commercially available.

VII DETERMINATION OF BEST SPECIE/PARTICULAR SITUATION

Determining a best specie to plant on the Lake bluffs is an impossible task. Bluff conditions vary so greatly from site to site that no single specie can be expected to perform admirably in all situations. The best way to recommend species to plant on a given bluff is to examine the conditions of the bluff and then enter the database accummulated during this study based on those conditions. The program will yield prospective plant specie candidates for success on that particular bluff.

The above procedure is recommended for individual bluffs. On a more general basis, there are some species that can be recommended. A mix of Coltsfoot and Goldenrod would be ideal. The 2 grew on the highest percentage of bluffs examined. Add willow trees for deeper soil stabalization and the problem of vegetating a slope is solved.

Coltsfoot and Goldenrod are the most adapted species to the bluff environment. Yet seeds cannot be acquired commercially so the species cannot be easily introduced. Any specie that does not have a readily available source cannot be recommended as a "best specie." Of the species evaluated in the preceeding section, 8 are not commercially available and thus are not included in our list of recommended species. It is unfortunate because the 8 species included some of the species

best adapted to the bluff environment.

Of the remaining 22, 8 are trees or shrubs which will do an excellent job of deep soil stabalization, but cannot be recommended by themselves as they lack sufficient soil cover. Crownvetch has limited application because bluffs are generally too wet. Red clover and Sweet white clover grew well, but are too short lived.

This leaves a handful of grasses including: Canada bluegrass, Orchardgrass, Perennial ryegrass, Reed canarygrass, Timothy, Tall fescue and Redtop. It should be noted that during the study, the summation of all of these grasses found on the bluff slopes totalled 22.7%. They rarely appeared as dominants and where they did occur, they usually occupied only a small area of the bluff, which leads us right back to where we started. There is no single specie alone that will vegetate and stabalize the bluffs.

However, mixtures of grasses,legumes, shrubs and trees can be recommended that will probably do the job. The grasses just looked at would be excellent as a seed mixture for the entire bluff. Plant some honeysuckle or Black locust on the crest, some dogwood, Black alders and willow on the slopes and the resultant should be a vegetated, fairly stable bluff.

The following tables list possible mixes for bluffs based solely on drainage. When all 3 drainage conditions exist on a single bluff, it may be necessary to use a different mixture on each of the 3 sections of the bluff. It would prove too difficult to explain in this study the processes involved in identifying a specific soil type and how it relates to drainage (ie. well-drained, somewhat poorly-drained, etc.) to the unqualified observer. However, the Erie County Conservation District can provide a brief instructional lesson in the field to the DCZM staff specialist which would allow that person to make a qualified judgment of soil composition and drainage in the SAR report.

TABLE 14

SPECIES TO PLANT ON A WELL DRAINED TO MODERATELY WELL DRAINED BLUFF
(GRAVEL - SAND - SILT MIXTURES)

1. Tall fescue
2. Orchardgrass
3. Canada bluegrass
4. Perennial ryegrass
5. Timothy
6. Redtop
7. Crownvetch
8. Sweet white clover
9. Red clover
10. Staghorn sumac
11. Graystem dogwood
12. Black locust
13. White ash

TABLE 15

SPECIES TO PLANT ON MODERATE WELL DRAINED TO SOMEWHAT POORLY DRAINED BLUFF (SILTY SANDS - SAND SILT MIXTURES)

1. Tall fescue
2. Canada bluegrass
3. Orchardgrass
4. Perennial ryegrass
5. Redtop
6. Red clover
7. Sweet white clover
8. Reed canarygrass
9. Eastern cottonwood
10. willow
11. "Rem Red" Amur honeysuckle
12. Black alder
13. Silky dogwood
14. Redosier dogwood

TABLE 16

SPECIES TO PLANT ON SOMEWHAT POORLY DRAINED TO POORLY DRAINED BLUFF (SILT AND CLAY MIXTURES)

1. Reed canarygrass
2. Redtop
3. Tall fescue
4. Perennial ryegrass
5. willow
6. Eastern cottonwood
7. Silky dogwood
8. "Rem Red" Amur honeysuckle

The 3 previous tables are only meant to be a starting point regarding what one should plant on a bluff with a given drainage characteristic. The species listed should do well and not all listed need be planted, but by planting all, you will eliminate any gaps that might develop due to misjudging the drainage condition. For the grasses and legumes planted by seed, the mixture should highlight the most adapted species to that bluff and approximate 40 to 50 lbs. per acre. For example, on a well drained soil one might mix the following for a 1-acre bluff:

TABLE 17

MIXTURE FOR WELL-DRAINED SOIL (1-ACRE BLUFF)

Perennial ryegrass	6 lbs.
Redtop	4 lbs.
Tall fescue	12 lbs.
Orchardgrass	6 lbs.
Canada bluegrass	6 lbs.
Crownvetch	6 lbs.
Sweet white clover	4 lbs.
Red clover	6 lbs.
	50 lbs.

On a wetter soil, Reed canarygrass would be emphasized over Tall fescue and Crownvetch swapped for a more water adapted specie. Plant trees and shrubs according to the recommendations of the nursery at which

they were purchased.

It has been emphasized before that there is no 1 specie for every situation; yet, there is that "typical lake bluff"* spoken of in the first few sections and the following mixture is recommended as a general bluff planting. *See Table 1 Average Values

First, create a "greenbelt" along the crest by planting Black locust and/or "Rem Red" Amur honeysuckle. Seed the upper, mid and lower sections with the following mixture:

TABLE 18

MIXTURE FOR "TYPICAL" OR MODERATELY WELL-DRAINED OR SOMEWHAT POORLY DRAINED BLUFF (1-ACRE BLUFF)

Tall fescue	10 lbs.
Reed canarygrass	15 lbs.
Perennial rye	15 lbs.
Redtop	4 lbs.
Orchardgrass	8 lbs.
Canada bluegrass	6 lbs.
Sweet white clover	4 lbs.
	62 lbs./acre

TABLE 19

MIXTURE FOR SOMEWHAT POORLY TO POORLY-DRAINED BLUFF (1-ACRE BLUFF)

Reed canarygrass	10 lbs.
Redtop	6 lbs.
Tall fescue	30 lbs.
Perennial ryegrass	10 lbs.
	56 lbs./acre

It should be realized that if the upper section is much over 45 degrees, there will probably be little growth (hydroseeding is recommended on steep slopes, i.e. over 45 degrees) and if there is much wave attack on the lower section, there will be little establishment there also.

Plant on every section (if possible) willow, Eastern cottonwood and Black alders. Use, as a minimum, 1-year old seedlings and space them every 4 feet in rows up the slope. However, if the upper section is too steep, it may be advisable to reshape the section to a 30 degree slope for vegetating. Although Black locust and Staghorn sumac will grow on steep sections if they are planted on ledges. Also, if severe wave attack is occurring, plant the trees above the bluff slope where the

waves are breaking. A shoreline protection structure (groin, revetment, seawall) may be necessary to get any growth on the lower section.

Introduce Silky dogwood and "Rem Red" Amur honeysuckle to the wetter sections of the bluff once the trees are established.

The above constitutes a best mix of species for most bluff situations. Hopefully, the natural vegetation that is not available commercially, but is found to be performing so well will grow in with the established species further helping the bluff stabalization cause.

It is important to get some type of vegetative cover on a bluff devoid of vegetation to prevent serious erosion. In almost every case, an expert should be consulted before proceeding. It may be necessary or advisable to reshape the bluff before revegetating it. After this has been determined, the general process would be (1) to seed the entire bluff with the recommended fast growing grasses and legumes to establish a good vegetative cover (2) plant the recommended shrubs-vines after a good cover is established, and (3) plant the larger growing trees.

Careful consideration should be given whether or not to plant large trees. In many cases, large trees can cause problems to the bluff because of the wind "rocking" the trees and causing movement of the soil on the bluff. Also, many people do not want to block the view of the lake.

VIII CONCLUSION

A variety of plants, grasses, shrubs and trees were found to be growing on the bluffs: 58 different species in all. The most frequently encountered species included (in order of decreasing occurrence):

1.	Coltsfoot	(found on 44% of bluff sections)
2.	Goldenrod	(33%)
3.	Horsetail	(27%)
4.	Yarrow	(16%)
5.	Flowering raspberry	(12%)
6.	willow	(12%)
7.	Eastern cottonwood	(10%)
8.	Queen Anne's lace	(7%)
9.	Black locust	(7%)
10.	Redtop	(7%)
11.	Orchardgrass	(6%)
12.	Black alder	(6%)
13.	Canada bluegrass	(5%)
14.	Staghorn sumac	(5%)

Of these common species, Coltsfoot, Goldenrod, willow and cottonwood provided the best cover and appeared to be doing the best job of bluff stabalization. They were also the first species (along with Horsetail, Yarrow and Flowering raspberry) to colonize a recently slumped bluff.

Unfortunately, the higher frequency species showing adaptation to the bluff environment are native species that have no commercial seed sources. Of the frequently encountered species, only the last 6 listed along with willows and cottonwoods are available from nurseries. Species without commercial availability are more difficult to use for bluff planting.

There are available species that were found on the bluffs. They were not as common as some other species, but did a good job where they were found. There are also some traditional conservation plantings that should be well suited to the bluff environment. Recommended commercially available species for planting on the bluff include:

GRASSES & LEGUMES:	Tall fescue
	Canada bluegrass
	Orchardgrass
	Perennial ryegrass
	Reed canarygrass
	Redtop
	Red clover
	Sweet white clover
	Crownvetch
	Timothy
SHRUBS:	Silky dogwood
	Redosier dogwood
	Graystem dogwood
	Staghorn sumac
	"Rem Red" Amur honeysuckle
	"Arnot" bristly locust
	Halls Japanese honeysuckle
TREES:	Black alder
	Black locust
	Eastern cottonwood
	willow
	White ash

These listed species were evaluated under the bluff conditions of slope, soil type, soil moisture, soil pH, insolation and canopy cover. The importance of these conditions is as follows:

Slope - The results of the study indicate that as the steepness of the slope increases, the existance of vegetation decreases. Slopes under 45 degrees usually support a good vegetative cover. Slopes over 45 degrees declined in vegetation up to 75 degrees with slopes over this steep angle exhibiting almost no growth at all. These steep slopes always revealed active recession and, in almost all cases were caused by water, ie. wave splash, excessive surface water or ground water movement out through the face. Because of this constant recession, vegetation never has a change to get established.

Soil pH - The lowest pH recorded on the 300 sections of the bluffs was 5.0 and the highest was found to be 7.2. This range of pH does not

present a serious limiting factor. The study shows that good vegetative cover was found at both extremes of this range.

Insolation - Since only 5 bluff sections out of 300 were found to have low light conditions, we must draw the conclusion that insolation is not a limiting factor on the Pennsylvania Lake Erie shoreline.

Canopy Cover - We have stated before in this study that extreme canopy cover indicates a stable bluff with mature trees growing in place for many years (50 - 100 years). The presence of natural ground covering vegetation, though sometimes sparse, does not indicate a serious limitation. Several of the recommended species in this study have fair to excellent shade tolerance, ie. Tall fescue, Halls Japanese honeysuckle.

Soil Type - With the exception of 2 soil types, shale (RS) and blueclay (CH), all the other classes of soil were able to support a good vegetative cover. These 2 soil types were always found in the lower section. Shale is somewhat impervious and will not allow rooting of vegetation. However, we must consider this a plus factor because the presence of shale or bedrock usually provides a stable base of the bluff. The 5 bluff sections where blueclay was found had very little vegetation. Blueclay is very easily eroded and always demonstrated ground water movement, wave splash, or surface water erosion.

Soil Saturation - The preceding 5 limiting factors demonstrated that if excessive soil saturation is controlled, a good vegetative cover can be established on the bluffs. Even a very steep slope is no exception because the cause of the steepness is water related. If the Penn-Lake Erie shoreline is to be revegetated, the various causes of these water related problems must be addressed. Because of the complex nature of these problems, the casual observer or property owner should not attempt corrective measures without consulting The Division of Coastal Zone Management.

The goal of vegetating bluffs is to achieve a dense growth covering the surface and to develop a patterned, deeper rooted growth of shrubs and trees. Grasses and legumes will hold the surface soil while shrubs and trees will go deeper, possibly even penetrating the slippage zone and preventing the slippage of different soil layers.

In all cases, shoreline property owners should first contact The Division of Coastal Zone Management, DER, to request the SAR Service, which when completed, will provide specific recommendations on vegetation species by the Erie County Conservation District or the U.S.D.A. Soil Conservation Service.

Vegetation is not the complete solution to bluff recession, but it and some other common-sense land use practices can increase bluff stability.

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3. Soil Survey of Erie County Pennsylvania, USDA Soil Conservation Service, December 1960.

4. The Great Lakes Research Institute, Shoreline Erosion and Flooding-Erie County, Pennsylvania Department of Environmental Resources, Division of Coastal Zone Management, 1975

5. The Penn State Agronomy Guide 1985-1986, The Pennsylvania State University, College of Agriculture Extension Service, University Park, Pa., 1985

X FOOTNOTES

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2. et. al., p. 17.

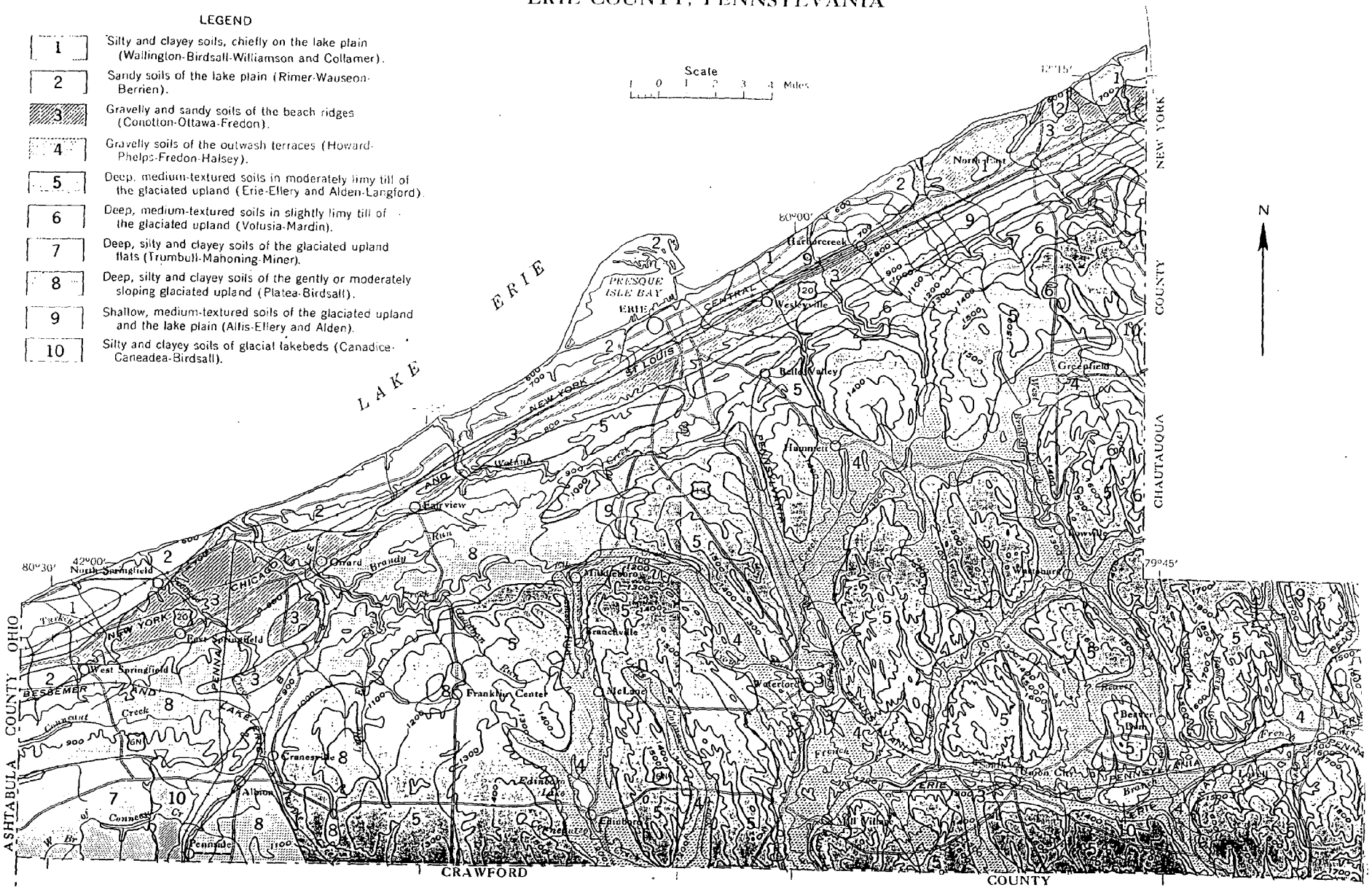
COMMON AND SCIENTIFIC NAMES OF SPECIES ENCOUNTERED DURING BLUFF STUDY

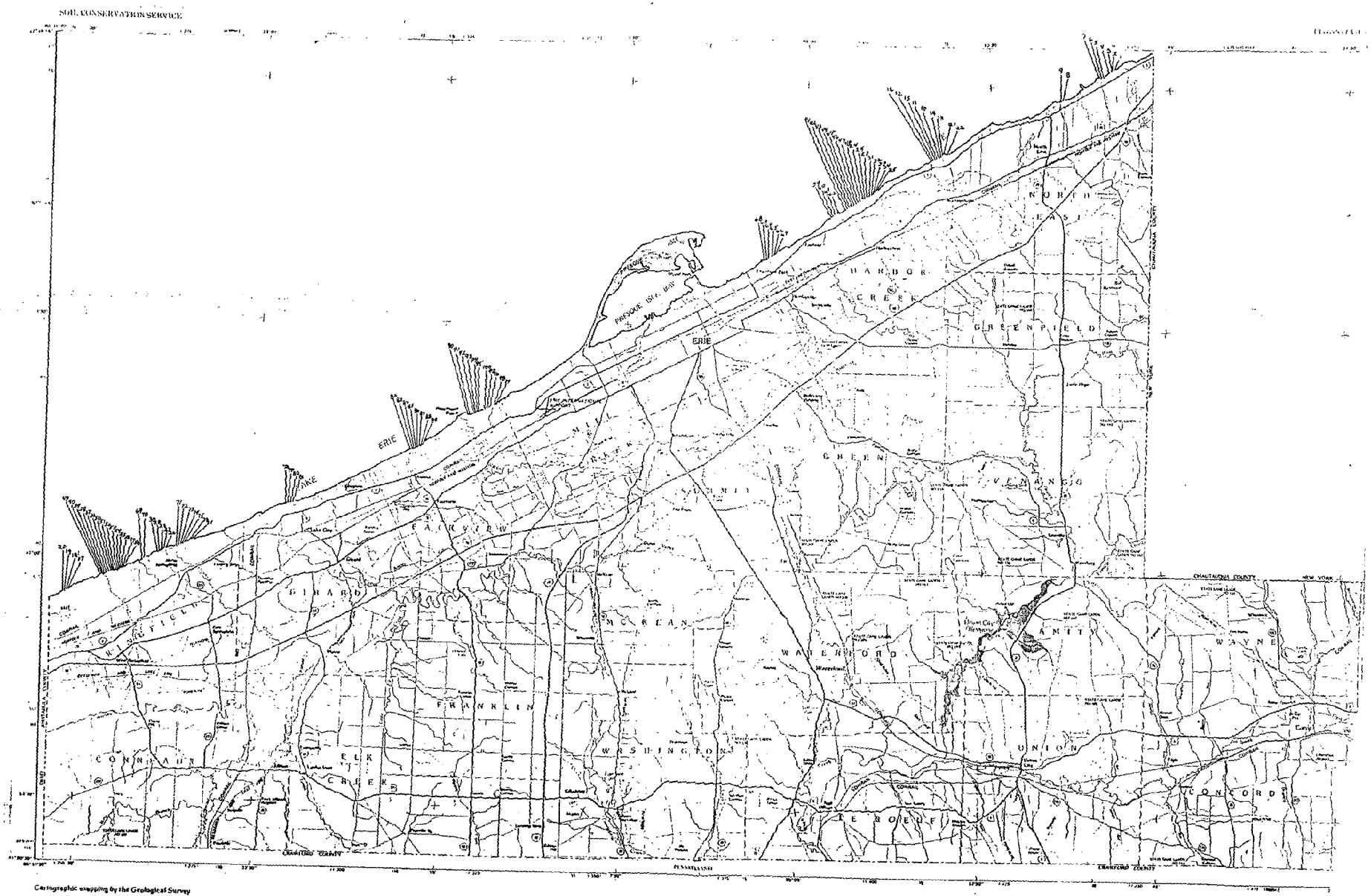
COMMON NAME	SCIENTIFIC NAME
1. American hackberry	Celtis occidentalis
2. Andropogon	Andropogon spp.
3. Basswood	Tilia americana
4. Black-eyed Susan	Rudbeckia hirta
5. Black locust	Robinia pseudoacacia
6. Bracken fern	Pteridium aquilinum
7. Brambles	Rubus spp.
8. Buckhorn plantain	Plantago lanceolata
9. Canada bluegrass	Poa compressa
10. Chicory	Cichorium intybus
11. Coltsfoot	Tussilago farfara
12. Common St. Johnswort	Hypericum perforatum
13. Crownvetch	Coronilla varia
14. Curled dock	Rumex crispus
15. Eastern cottonwood	Populus deltoides
16. Elderberry	Sambucus canadensis
17. English ivy	Glechoma hederacea
18. European black alder	Alnus glutinosa
19. Flowering raspberry	Rubus odoratus
20. Goldenrod	Solidago nemoralis
21. Graystem dogwood	Cornus racemosa
22. Hemlock	Tsuga canadeusis
23. Horsetail	Equisetum arvense
24. Jewelweed-spotted	Impatiens capensis
25. Kentucky bluegrass	Poa pratensis
26. Lambsquarter	Chenopodium album
27. Nightshade-bitter	Solanum dulcamara
28. Nutsedge	Carex spp.
29. Orchardgrass	Dactylus glomerata
30. Ox-eye daisy	Chrysanthemum leucanthemum
31. Panicum	Panicum spp.
32. Perennial ryegrass	Lolium perenne
33. Phragmites	Phragmites communis
34. Pokeweed	Phytolacca americana
35. Prairie junegrass	Koeleria cristata
36. Queen Anne's lace	Daucus carota
37. Red clover	Trifolium pratense
38. Red oak	Quercus rubra
39. Redosier dogwood	Cornus stolonifera
40. Redtop	Agrostis alba
41. Reed canarygrass	Phalaris arundinaceus
42. Sassafras	Sassafras albidum
43. Sheep sorrel	Rumex acetosella
44. Silky dogwood	Cornus amomum
45. Silver maple	Acer saccharinum
46. Small crabgrass	Digitaria ischaemum
47. Staghorn sumac	Rhus typhina
48. Sweet white clover	Melilotus alba
49. Tall fescue	Festuca arundinacea
50. Timothy	Phleum pratense

51. Virginia creeper	Parthenocissus quinquefolia
52. White ash	Fraxinus americana
53. White snakeroot	Eupatorium rugosum
54. Wild grapes	Vitis riparia
55. Wild strawberry	Fragana virginiana
56. Willow	Salix spp.
57. Yarrow	Achillea millefolium
58. Yellow birch	Betula alleghaniensis

GENERAL SOIL MAP

ERIE COUNTY, PENNSYLVANIA





SCALE 1:17,100 (approx.)

(FIGURE 2)

ERIE

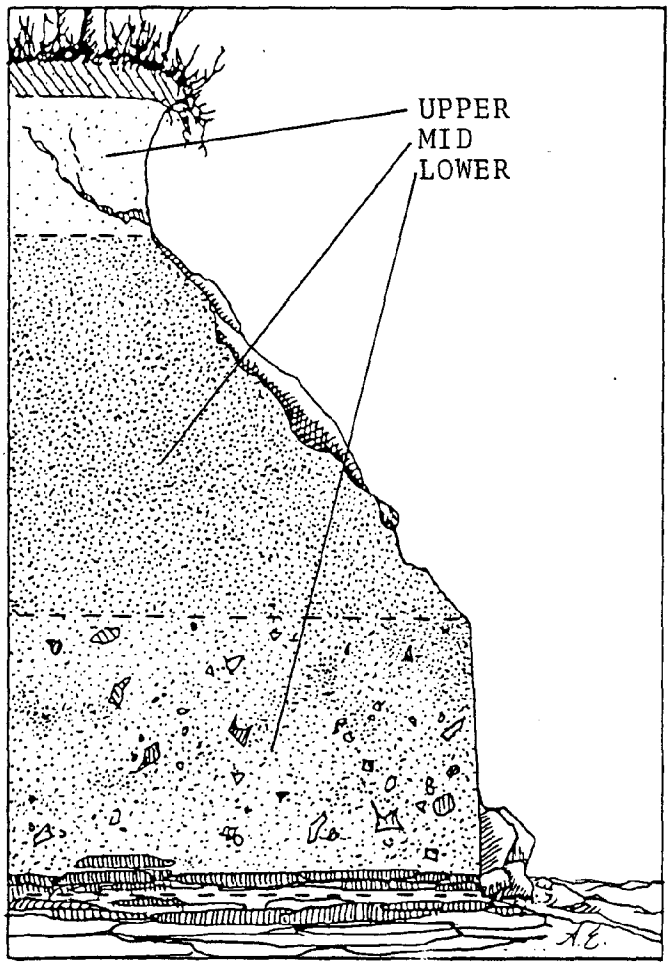


FIGURE 3

LAKE ERIE BLUFF VEGETATION ASSESSMENT WORKSHEET

Site # ____ Township _____ Tax Assessment Number _____

Owner: _____ Address: _____

Bluff Height: _____

Plant #1 _____ Stage: _____

Location: _____ Picture # _____

Comments: active recession
man accelerated rec.
recency of slump
native or introduced specie
etc.

Bluff Slope: _____ Soil Type: _____

Insolation: _____ Soil Saturation: _____

Canopy: None Sparse Dense Soil pH: _____

Other: _____

Plant #2 _____ Stage: _____

Location: _____ Picture # _____

Comments: _____

Bluff Slope: _____ Soil Type: _____

Insolation: _____ Soil Saturation: _____

Canopy: None Sparse Dense Soil pH: _____

Other: _____

Plant #3 _____ Stage: _____

Location: _____ Picture # _____

Comments: _____

Bluff Slope: _____ Soil Type: _____

Insolation: _____ Soil Saturation: _____

Canopy: None Sparse Dense Soil pH: _____

Other: _____

FIGURE 4

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