PATHFINDER GEOLOGICAL, INC.

- Environmental and Geological Consulting Services -

September 27, 1999

Mr. Edward J. Cunniff, Jr.
Great Lakes Shores
[redacted]

Subject: Recommendations for vegetative stabilization for bluffs on Great Lakes Shores Inc., shoreline property, Lexington , MI

Dear Mr. Cunniff:

We are pleased to submit the following recommendations for vegetative stabilization of the bluffs on the Great Lakes Shores, Inc., shoreline property. These recommendations are based on observations made during site visits to Great Lakes Shores and other localities along the Lexington Bluff area in Sanalac County, evaluation of areal photographs, and discussions with soil specialists and botanist from the MDNR, Michigan State Extension Service, as well as local horticultural experts and nurserymen.

Project Background

The Great Lakes Shores, Inc., shoreline property is classified as Lexington Bluff Shoretype which consists of 12 to 40 foot bluffs composed of variable mixtures of clay with boulders, sand and gravel. The exposed portions of the bluffs in the project area are composed primarily of layered clays. The slopes of the bluff face average between 40 and 60 degrees.

Mass-wasting of the bluff and beach erosion have been historic problems in the area. Extensive erosion of beach and slumping along the bluff have occurred in the Great Lakes Shores property over the past 10 to 30 years. Much of the bluff face is devoid of significant vegetation. Fresh erosion scarps indicate small scale slumping is on-going across the bluff face. The toe of the bluff has been reinforced by a seawall and jettys in an effort to reduce undercutting and mitigate beach erosion.

Dynamics of Mass Wasting

Mass wasting is the bulk movement of earth material under the influence of gravity. The stability of a slope is a function of the cohesiveness or internal friction of the sediment and the downward pull of gravity. The angle of repose is the is maximum angle at which material can accumulate before the downward pull of gravity overcomes the forces of friction that hold material on the slope. Any change in slope angle, such as those that produced by undercutting, or erosion from the toe of the slope will increase the downward pull of gravity on the slope. Similarly, any activity or event that reduces the internal friction or cohesion of the sedimentary material within the slope will decrease the materials ability to resist the downward pull of gravity, and also increase the likelihood of slope failure.

Slumping, a common form of mass wasting, results when a portion of the slope breaks away from adjacent material and rotates outward and downward as a coherent mass. Slumping

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generally occurs when either the sediment becomes saturated with water and looses its internal cohesion, or undercutting over steepens a slope.

The clay subsoil typical of the Lexington bluffs is relatively cohesive, allowing the angle of repose to remain greater than in areas where sandy, less cohesive soil types are present. However, erosive process along the shoreline have increased slope steepness in the project area. Although the clay subsoil is relatively cohesive, it has very low permeability. Clays tend to become weak and slippery when saturated. Infiltrating groundwater hydrates the clay adding weight to the slope, and acting as a lubricant within the layers of clay. The additional weight, in combination with increased hydrostatic pressure within the sediment, drastically reduces the ability of the slope to resist the pull of gravity, and slumping results.

Certain human activities will also increase the likelihood of slumping. In addition to the water infiltrating the sediment from normal precipitation, additional water is added to the bluff area from septic run-off and the watering of lawns. This infiltrating groundwater moves toward the bluff through interflow along the surface of the less permeable subsurface clay layers.

As much surface water run-off as possible should be diverted away from the slope by drains. The drains already in place should be maintained and if necessary additional drains should be considered. Small rills have developed to accommodate run-off along the slope face. These rills, as long as they remain small will help remove surface run-off from the slope, and not significantly contribute to slumping.

Vegetation and Slope Stability

The role of vegetation in stabilizing slopes is somewhat complex and depends on the extent and type of vegetative cover. Slopes that are vegetated with trees and shrubs are generally more resistant to the forces of mass wasting than either non-vegetated, or densely grass covered slopes of similar composition. Fast growing trees and shrubs produce the deep, complex root systems necessary to stabilize soil. Larger, fast growing plants are also more effective at removing excess water from the sub-soil through transpiration, reducing hydrostatic pore pressure and increasing cohesion within the sediment.

Continuous ground covers, including dense grasses with shallow root systems, tend to decrease water run-off and increase the rate of water infiltration on the slope face. Dense ground covers can actually increase the likely hood of slope failure.

Special Considerations

Several considerations must be taken into account in determining the most appropriate type of planting to stabilize the bluff. Growing conditions on the bluff face are extreme. The soil in the immediate area are Melita type soils. These soils are very low in fertility and have very low moisture-holding capacity. So while the low permeability of the underlying clay sub-soil results in poor drainage during the spring, the top soil is subject to draughty conditions for much of the growing season.

On the steep slope face, top-soil is easily eroded and nonexistent in many areas. So the plants selected for re-vegetation on the slope must be capable of surviving in the low fertility sub-soil, as well as undergoing periods of both saturated and extremely dry soil conditions. This will rule out many nursery-grown plants that have been adapted to more optimal growing conditions. They will simply not be hardy enough to survive conditions on the bluff face.

Another important consideration in selecting plants for the bluff entails the expectations of association members that have become accustomed to the appearance of the relatively denuded bluff and shoreline area. Some association members have expressed concern that their lake view will be obscured by trees and dense foliage. In several areas, the native tree and shrubs that are recolonizing the bluff have been severely cut back to prevent their establishment.

To prevent the "unauthorized" removal of vegetation along the shoreline, it is evident that some compromise must be struck between optimal stabilization of the bluff and preserving the lake view. While moderate pruning to preserve the lake view will not harm the plants, extreme pruning will reduce both the rate of root growth and the rate of water up-take through transpiration. For vegetative stabilization to be successful, large plants must be allowed to grow to a reasonable height, otherwise the complex root systems necessary to stabilize the soil will not develop.

Vegetative Stabilization

Effective stabilization does not require uniform coverage of the slope by dense vegetation. Trees can be spaced along the top of the bluff, and lower branches pruned to preserve a view of the lake from the road. Taller tree and shrub species can be planted near the base of the bluff and upper branches trimmed to a height level with the top of the bluff.

Shrubs should be vertically arranged to concentrate lower growing species near the top of the bluff with taller species or varieties planted on the contour further down the slope. With proper planning, vegetation planted on the slope face will be able to grow to a reasonable height without obscuring the lake view from the top of the bluff.

It is important that the planting scheme provide a mixture of plants with variable heights and root depths. This will result in the maximum stabilization without reducing run-off or increasing water infiltration on the slope. Larger tree and shrub varieties with extensive root systems should be planted at strategic locations at the top and near the base of the bluff. Shrubs should be planted in clusters. Smaller plants, wildflowers and grasses need to be planted between larger trees and shrubs. Continuous plantings of dense ground covers should be avoided.

Recommendations for specific plant types

We have compiled the following list of suitable plant species for vegetative stabilization of the bluff. The list includes a variety of species that are adaptable to the soil conditions present on the bluff area. Priority has been given to indigenous species, but some non-indigenous species have also been included for your consideration. Non-indigenous species are marked with an asterix (*). The maximum height of each species is also included.

The selection of a variety of plants from the following list should provide a foundation planting for stabilization of the bluff. Selecting a variety of native plant species will naturalize the shoreline and provide low-maintenance growth. Occasional trimming may be required on the upper branches of mid-level shrubs and taller trees planted at the base of the bluff. The lower branches of trees planted at the top of the bluff may be pruned to preserve the lake view.

Please remember that the individual plants most likely to survive are those best adapted to the locality, ie. the plants that are already growing and thriving there. Many nursery grown plants

will not be able to adjust to the harsh climatic and soil conditions of the bluff. Any shrub or tree that currently is growing in the bluff face should be allowed to remain in place if at all possible.

Plant List

Trees and Shrubs

Willow Family (Salicacae)
Willows (*Salix*) - Shrub to tree size. Willows are very fast growing and hardy, but must be planted during moist weather so roots do not dry out before they get established.

Poplars, Aspens, and Cottonwoods (*Populus*) - These are trees and are very fast growing in moist soils.

Species name	approximate height (maximum)
Black willow (*Slax nigra*)	40 ft.
Peachleaf willow (*Salix amygdaloides*)	60 ft.
Sandbar willow (*Silax exigua*)	30 ft.
Pussy willow (*Silxa discolor*)	shrub to tree (max. 25 ft.)
Bebb willow (*Silxa bebbiana*)	shrub to tree (max. 25 ft.)
*Corkscrew willow (*Salicaceae tortusoa*)	13 -20 ft. (Slow-growing specimen plant)
*Arctic willow (*Salix palas arctica*)	3-5 ft. (a creeping shrub)
Eastern Cottonwood (*Populus deltoides*)	75 - 100 ft.
Balsam poplar (*Populus balsamifera*)	60 -80 ft.
Quaking aspen (*Populus tremuloides*)	20-60 ft.
Bigtooth aspen (*Populus grandidentata*)	30-60 ft.

Sumac Family (Anacardiaceae)

Staghorn sumac (*Rhus typhina*)	Shrub to small tree (max. 25 ft.)
Winged sumac (*Rhus capallina*)	Shrub to small tree (max. 25 ft.)
Smooth sumac (*Rhus glabra*)	Shrub to small tree (max. 25 ft.)
*Tree of Heaven (*Ailanthua altissima*)	80 -100 ft.Fast growing, very hardy tree

Beech Family (Fragaceae) - Slow growing indigenous trees with shallow spreading root systems. Need surface moisture to grow.

American beech (*Fagus grandifolie*)	60 - 100 ft.
Red Oak	60 - 100 ft.
White Oak	60 - 100 ft.

Maple Family (Aceraceae) - Indigenous trees with medium growth rates. Maples require cool moist soils. Box elders are very hardy, rapid growers and do well in moist or dry soil conditions

Red maple *(Acer rubrum)*	75 - 80 ft.
Silver maple *(Acer saccharinum)*	60 - 80 ft.
Box Elder *(Acer negundo)*	50 - 70 ft.

Evergreens

Pine Family (Pinaceae) - Pines require moist, sandy soil conditions

White Pine (*Pinus strobus*)	75 - 100 ft

Cedar Family (Cupressaceae)

Common juniper (*Juniperus communis*)	hardy, sprawling shrub
Eastern red cedar (*Juniper virginiana*)	40 - 50 ft.

Medium to Large Plants and Wildflowers

*Yucca (*yucca filamentosa*) - thrive in various soil conditions, extensive deep roots

Common mullein (*Verascum thasus*)	1 - 8 ft.
Moth mullein (*Verbascum blaltaria*)	1 - 3 ft.
Canada goldenrod (*Solidago canadensis*)	1 - 3 ft.
Gumweed (*Grindelia squarrosa*)	.5 ft.
Wild daisy (Asters)	1 - 2 ft.
Common yarrow (*Archillea millefolium*)	1 - 2 ft.
Vervain (*Verbena hostata*)	
Queen Anne's Lace (*Daucus carota*)	1 - 3 ft
Canada thistle (*Cirsium arvenese*)	1 - 4 ft.
Bull thistle (*Cirsium vulgare*)	2 - 6 ft.
Chicory (*Cichorium intybus*)	1 - 5 ft.
Common dandelion (*Taraxqucum officinale*)	
Wild bergamont (Monarda fistulosa)	2 - 5 ft.
Silverrod (*Solidago bicolor*)	1 - 3 ft.
Goatsbeard (*Tragopogon dubius*)	1 - 3 ft.
Rough blazing star (*Liatris aspera*)	1 - 4 ft.

Milk weeds (Asclepias)

Common milkweed (*Asclepias syriaca*)
Butterfly Milkweed (*Asclepias tuberosa*)
Sand Milkweed (*Asclepias amplexicaulis*)

Morning Glories (Ipomoea)

Common morning glory (*Ipomoea purpurea*)
Ivyleaf morning glory (*Ipomoea hederocea*)

Verbenas

Hoary vervain (*Verbena stricta*)	1 - 4 ft.
Roce vervain (*Verbena canadensis*)	1 - 2 ft.

Grasses and sedges - Grasses can have up to 90% of their weight below ground in their root systems where they store water and starch. They are useful in erosion control on slopes but should be planted in clumps, not as continuous ground cover or they can actually promote mass wasting during periods of saturation.

Sedge Family

Cyperoceal filiculmis	2 - 3 ft. tufts in sandy soil
Broom Sedge (*Andropogon virginicus*)	2 - 5 ft. native perennial

Grass family (Gramineae)

Beach Grass *(Ammophila breviligulata)*	1-3.5 ft. native to Great Lakes beeches
Canada wild rye *(Elymus canadensis)*	2.5 - 6 ft. very hardy native perennial
Sweet vernal grass *(Anthoxanthum odoratun)*	8in - 3.5 ft. native perennial
Purple top *(Triodia flava)*	2.5 - 7 ft. native perennial
Timothy *(Phleum pratense)*	1-3.5 ft
Quackgrass *(Agropyron repens)*	1 - 4 ft.
Poverty grass *(Danthonia spicata)*	0.3 - 2 ft
Nimblewill *(Muhlenbergia schreberi)*	2.5 - 7.5 ft.
Big bluestem *(Andropogon gerardi)*	2.5 - 5 ft. very hardy native perennial
Little Bluestem or Broom *(Andropogon scoparius)*	1.5 - 5 ft.
Sea oats *(Uniola paniculata)*	3 - 6 ft.
Porcupine grass *(Stipa spartea)*	2 - 5 ft.
Deer tongue grass *(Panicum clandestinum)*	

Plant Selection

Although selection of particular plants will depend on cost and availability, it is important to have a variety of plant types and heights. This will allow for tiering of the vegetation and maximize the complexity of the root network without impeding surface run-off from the slope.

Tree species from the poplar, maple, beech and pine families may be best suited for planting near the road at the top of the bluff. Trees species selected from the willow and beech families are best for the base of the slope. Willow trees may even grow at the beach level and facilitate the accumulation of sand in those areas.

Juniper may be considered for a low growing shrub at the crest of the bluff, particularly in areas where foot traffic is to be discouraged. Low growing shrubs, such as the arctic willow already purchased, and other medium-height plant species may be planted along the upper 6 feet of the bluff face.

Taller native varieties of shrub willow and sumac will do well in the middle to lower areas of the bluff face. Tiering plants in this manner will allow them the grow to their full height with a minimum of trimming. All of the shrubs should be planted in clusters with clumps of grasses and mid-sized plants planted between them.

It is also advisable to plant beach grass in the sand on the newly formed beaches. Although the recent accumulation of sand in this area is clearly a function of the lower lake levels, the presence of beach grass and other vegetation will help to stabilize the sand already there and facilitate the accumulation if more sand next season. If large willows can be established in that area they may even provide some protection for the sea-wall when lake levels rise, much as the large willow currently growing at the southern edge of the beach property has done.

Planting Schedule

Due to the extreme growing conditions on the bluff (low fertility clay soil, extremely low soil moisture in late summer and early fall) planting should be scheduled at times when conditions are most optimum for plant survival. Many of the recommended species are fast growing plants that require moist soil conditions while establishing root systems. If the roots dry out before they are established, the plants will die.

Late-summer to mid-fall are a periods of drought conditions over most of the bluff area. Since deep watering of newly transplanted specimens is not possible on steep slopes, planting should be done during the periods when soil moisture is at higher levels. Planting conditions are most favorable in mid-to-late fall when soil moisture increases and plants are entering their dormant stages; and in early spring, before plants enter their rapid growth phase.

We are aware that re-vegetating the bluff is a long-term project that your association will be completing in stages as resources become available. However, there are several vulnerable areas on the slope that show evidence of current slumping. If possible these areas should be given priority for planting vegetation.

Please give us advance notice of your proposed planting dates and a brief list of the type and number of plants you have obtained. We will stake appropriate locations on the bluff for the specimens you have available. Priority will be given to areas that are the least stable.

If you have any questions regarding this submittal,please feel free to call.

Sincerely,

Pathfinder Geological, Inc.

Ann C. Purdy, Ph.D.
Senior Geologist