A Multiple Instrument, Sub-Surface Investigation of the Bradford Beach Shoreline in Milwaukee, Wisconsin

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Abstract
Geophysical studies were conducted at the north end of Bradford Beach on Lake Michigan in Milwaukee Wisconsin to assess the shallow subsurface geology. The location was chosen to supplement current research at the beach relating to bacterial studies, and the construction of water gardens near storm drains that discharge onto the beach. Characterization of the subsurface at this location and its hydrologic interaction with Lake Michigan is a key component in understanding the inflow of storm water runoff and developing environmental solutions to pollution control. Geophysical surveys included electrical resistivity, electromagnetic surveys, and ground penetrating radar. The geophysical data from the three surveys are consistent with each other and we interpret the results as 3.5 meters of sand with decreasing resistivity at depth overlaying an impervious subsurface of higher resistivity which is probably till or Devonian Antrim Shale. The low conductivity layer dips towards the south and shows little to no sedimentary variation and lacks distinct natural depositional structures. This layer is probably saturated sand above an impervious base layer of till or shale. This is consistent with the area being a man-made beach dating back to the 1930’s.

Geology
The Bradford Beach area is an urban beach in Milwaukee County on the shore of Lake Michigan (43°03′41.30″ N, 87°52′20.41″ W). The beach spans a total distance of approximately 700 meters and horizontally extends 125 meters to the waters edge from Lincoln Memorial Drive. Dolostone boulders and concrete rip-rap encompass the beaches north and south ends which were emplaced for erosion control. Across Lincoln Memorial Drive to the west is a 25-meter bluff of glacial deposits that rises up from where the natural shoreline used to be. The beach consists of a flat, southerly dipping region of coarse to medium grained sand that overlays either Wisconsinin age till or Devonian age Antrim Shale. The current beach was originally built in the 1930s, and through the years has seen different construction processes in an effort to help limit erosion and enhance visual appeal.

Methods
Students from the UWM Geosciences Department conducted the surveys in March and April 2008 as part of a geophysics seminar. Survey lines were positioned using both survey tapes and GPS units. The location on the beach was selected to be near several of the storm drain outlets that discharge onto the beach. The locations of all the survey lines are indicated on Figure 1.
Electrical Resistivity
DC resistivity soundings and DC resistivity profiles were conducted at the site. Two soundings were conducted at approximately 70 meters apart in a S/N orientation along a survey line near the middle of the beach. The sounding surveys were configured in a Wenner array with a maximum “a” spacing of 46 meters, using an ABEM Terrameter SAS 300/VES resistivity meter. The data was modeled using Interpex 1X1D resistivity software.

Resistivity profiling (imaging) was performed using a 16 electrode GF Instruments ARES-Automatic Resistivity System with 2 meter and 5 meter spacings in a Wenner-Schlumberger configuration. The array was located between the two soundings and covered a maximum horizontal distance of 30 and 75 meters respectively. The data was modeled using RESTIX 2-D software.

Electromagnetic
A Geonics EM31-MK2 Ground Conductivity Meter was used for all EM surveys. Survey lines were run in both North/South and East/West directions to target variations and changes in subsurface conditions. The conductivity meter was carried parallel to the survey line direction, and utilized an automatic data collection setup to record data on a 2 second time interval. Fiducial marks were recorded at intervals of 50 or 100 meters to facilitate correlation between lines. The initial EM lines were collected in both the vertical and horizontal mode, but after preliminary interpretation it became evident that the horizontal data was redundant, and so all other lines were collected only in the vertical mode. After collection, all data was processed with Geonics Dat31 software to correct for survey line distances.

Ground Penetrating Radar
GPR data was collected with a Geophysical Survey Systems Inc. SIR 3000 GPR unit with both 120 MHz and 500 MHz antennas. A total of 4 survey lines each 100 meters long were run along lines that had previously been sampled with resistivity and EM techniques. Survey lines spanned from Lincoln Memorial Drive to the waters edge (West/East), and along the North center of the beach (South/North). Fiducial marks were collected at 1-meter spacings to assist in correlating data.

Results
Resistivity Sounding
Resistivity sounding data produced well-defined vertical information about resistivity stratification and relative bedrock depth. Sounding data described a 4-layer stratification. For the southern sounding, Figure 2, the layers are interpreted as dry sand (0-0.5 m.), moist sand (0.5-3.5 m.), saturated sand or clay (3.5-10 m.), and dry bedrock below 10 m. The northern sounding, Figure 3, is more complex. There appears to be a moist soil or sand horizon just below the surface (0.5-1.0 meters), and dry sand from 1-3 meters. Below 3 meters the strata is a uniform material of 50-70 ohm-meters, which is probably the bedrock. The differences between the north and south sounding locations indicate lateral change of resistivity properties between survey points, but both sounding identify a boundary at approximately 3.5 meters.

Figure 2: DC electrical sounding data and interpretation for the south sounding.
Resistivity Profiling
Resistivity profile calculations produced a stratified model consistent with sounding data. Figure 4 presents the data for the 5 meter spacing survey, which senses to about 6 meters. Figure 5 presents data for the 2 meter spacing survey, which senses to about 3 meters in the center of the survey. The depths noted on the diagram are only a psuedodepth, which is an artifact of the data presentation. The resistivity at the surface is higher to the south, and the resistivities are lower at depth toward the south. The low resistivity at depth toward the south may be the results of a water plume from the storm drain to the east of the profile.
Figure 4: Resistivity profile (psuedosection) with 5 meter spacing. Top graph is raw data (apparent resistivity): bottom graph is interpreted layer parameters. It shows higher resistivity to the south and lower resistivity at depth. This profile is sensing to approximately 6 m. depth at the center.

Figure 5: Resistivity Profile (psuedosection) with 2 meter spacing. Top graph is raw
data (apparent resistivity): bottom graph is interpreted layer parameters. It shows higher resistivity to the south and lower resistivity at depth. This profile is sensing to approximately 3 m. depth at the center.

**Electromagnetic**

The electromagnetic lines were run parallel and perpendicular to the beach. All data reported in figures 6 and 7 are for vertical dipole orientation. This provides a sensing depth of approximately 6 meters. The conductivity values are an integrated average over that depth. Lines 1 through 4 are parallel to the beach from south to north, starting at the roadway (line 1) and progressing to the waters edge (line 4). The north end of all lines is where all the other electrical surveys were made (250-500 meters). The large fluxuations on line 1 are attributed to cultural features along the road. Lines 2-4 from 250-500 meters show very little variation, which is interpreted as fairly uniform subsurface material to a depth of 3-4 meters. There are no indications of cultural features such as drainpipes. The survey lines run perpendicular to the road, Figure 7, show a steady decrease in conductivity values moving away from the road toward the water. There are some indications of variations at depth along the profile from 25 to 60 meters, but the remaining area is very uniform. (60-100m.).

![EM data graph](image)

Figure 6 EM data South to North. Line 1 is along the sidewalk. The large fluxuations are caused by cultural features. Lines 3 and 4 are more representative of subsurface values on the beach. See Figure 1 for line locations.
Ground Penetrating Radar

The GPR profiles coincided with transects from other techniques. Figure 8 presents data collected with the 500 MHz antenna parallel to the beach as noted on Figure 1. There is a primary reflector at approximately 3.0 meters with minimal depositional characteristics in the main sand body. A thinning or dipping of this horizon of about .5 meters is noted between the south and north endpoints. There are near surface sediment structures visible from about 60-100 meters, probably from sand blowing from the south to the north and depositing the sand similarly to sand dune development. Data collected with the 120 MHz antenna (not pictured) show similar structures, but with less resolution. Figure 9 shows a profile from Lincoln memorial Drive to the beach (west-east). The first 10 meters is on the grass area near the road. A major reflector is seen at 60-70 nanoseconds (3-4 meters). Some near surface onlap sediment structures are also evident (10-30 ns) especially to the east end of the line.
Figure 8: South to North (parallel to beach.)  500 MHz antenna, Dielectric constant = 7.1
Processing: Distance correction applied (rubberbanding), Field applied gain removed, automatic gain applied.

Figure 9: West to East (from street to beach).  500 MHz antenna, Dielectric constant = 7.1
Processing: Distance correction applied (rubberbanding), Field applied gain removed, automatic gain applied. Depth scale is in Nanoseconds. Horizontal distance is 100 meters. The
major reflector is at 3.5 meters. First ~10 meters is on grass. Some near surface sediment structures are evident down to 25 ns.

Conclusions
Bradford Beach was modeled as a layered system consisting of a southward dipping body sand body approximately 3.5 meters thick that thins to the north. Within this sand body there are varying levels of saturation described by profile and sounding models. These variations may relate to influx of water from the storm drain discharge. The beach exhibited very little natural sedimentary history noted by the lack of depositional structures in the sand based on the GPR data. Natural beach sand was either removed, or altered through reconstruction processes that occurred a long ago as the 1930’s. Bedrock below the sand body was determined through multiple techniques to be located at approximately 3.5 meters and from regional geology was characterized to be Antrim Shale, or possibly Wisconsinin till.

This geophysical study was completed before the construction of the water gardens. Future geophysical studies after the gardens are completion could offer insight on the hydrological subsurface interaction and effectiveness of garden design.

Acknowledgments
Special thanks do to Dave Hart of the Wisconsin Geological and Natural History Survey for the use of the WGNHS SIR 3000 GPR unit, as well as his expertise with post data corrections and manipulations. The following students contributed to the data collection and interpretation: Mike Baierlap, Bonnie Bills, Ben Dickinson, Katherine LeCroix, Scott Fedak, Joe Oszuscik, and Jeanne Ramponi.

References
L.J. Beversdorf, S.M.Bornstein-Forst, S.L.McLellan, 2006, The potential for beach sand to serve as a reservoir for Escherichia coli and the physical influences on cell die-off. Journal of Applied Microbiology (102) pp1372-1381
Bradford Beach to get a cleanup

Rain gardens, dunes, native plantings, swales included

By STEVE SCHULTZE
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Posted: Sept. 18, 2007

By this time next year, Bradford Beach should be sporting a new look, with $1.2 million in rain gardens, dunes and grassy swales installed as a means of diverting bacteria-laden storm water runoff from the sand.

Low spots near the beach that now are mowed will be shaped into basins with native plantings to help hold and absorb excess rainwater, and nearby berms will be planted with dune grass.

The beach parking lot will be altered slightly - about six feet will be shaved from the lake side and added to the west side of the lot.

On the lake side of the lot, a long swale - or shallow trough - will also help filter the runoff and keep it from the beach. A rain garden planted in shrubs and small plants and surrounded by a low wall will be built south of the Bradford bathhouse.

The combined impact of the installations should cut about 90% of storm water from reaching the beach, said Stevan Keith, a county environmental engineer. The storm water is directed toward the beach by a series of seven storm sewer outfalls that drain the bluff overlooking Bradford.

The project should cut down on the bacteria left on the beach after a storm, as well as restoring a more natural look, Keith told the Milwaukee County Board Parks Committee on Tuesday.

The improvements should "help stabilize the soil and act as natural treatment devices," Keith said.

The beach-scaping efforts follow studies by a University of Wisconsin-Milwaukee researcher that identified the storm sewer pipes as a source of bacteria found in the beach sand.

The county studied moving the Bradford storm sewer outfalls that empty rainwater near the beach and its parking lots, which has been identified as one source of potentially harmful bacteria in the sand. But that proved too costly. The county approved the funding for the project in 2006. The work must be done next year to meet terms of a state-issued storm water permit, Keith said.

An additional $50,000 toward the project will be contributed by the state and $15,000 by the Milwaukee Metropolitan Sewerage District. The parks panel approved applications for the state and MMSD grants.

Some similar measures at McKinley Beach are also planned. The Parks Department is seeking $300,000 in its 2008 budget request for some beach improvements there.

Water garden possible

Also Tuesday, a plan for a separate $650,000 "water garden" project at Bradford Beach to be paid for through private donations was advanced by the Parks Committee.

The money would go toward construction of a series of low concrete and stone benches along the north flank of the North Point snack bar parking lot. Visitors could hand pump water from low-capacity wells drilled there, and the water would flow along the benches. A nearby children's sandbox with a timber deck would also be built.

The water garden would "expand recreational opportunities in an area of high public interest with a subtle, yet artistic flair," according to a county analysis of the project. It should improve shoreline erosion-control measures, the analysis said.

The committee recommended that the parks department negotiate a contract for the project with Friends of Bradford Beach, a citizens group. Proof that the full $650,000 has been raised would be required before the water garden could be built.

Parks Director Sue Black said the two projects would complement one another and help beautify the lakefront.
Geologic Overview of the West Bend Area including Riverside Park, Glacial Blue Hills Recreation Area, and Cedarburg Bog

Below is a section of a map from the Quaternary Geology of Ozaukee and Washington Counties, Wisconsin from Mickelson and Syverson (1997). It provides a reference for the surface geology that will be seen at the three stops near West Bend.

A transect from west to east would show the Kettle Moraine just to the west of West Bend. This is the junction point between the Green Bay Lobe and the Lake Michigan Lobe of the Wisconsin Glaciation. The kettle moraine area is collapsed outwash and till that piled up between the two lobes. The Glacial Blue Hills Recreation Area is located in this region.

From West Bend eastward to Newburg, the Milwaukee River flows through glacial lake deposits, as it does at Riverside Park. The deposits originated in small glacial lake in the Lake Michigan lobe. The extreme meandering nature of the river at Riverside Park can be attributed the very flat terrain.

The Cedarburg Bog also resides in the area of the Lake Michigan Lobe, to the east and south of West Bend. It is a slightly elevated area that is a groundwater recharge area for the region.
Riverside Park is located near downtown West Bend and carved by the Milwaukee River. Coincidentally the name of the town West Bend was given because of the fact that the Milwaukee River “bends” to the West in that area. Today Riverside Park is a venue for festivals and celebrations and 60 acres of previously flooded terrain are now park land area for relaxation and recreation.

In 1870, the Woolen Mills Dam was constructed as a wooden dam in the Milwaukee River. The original dam was about 16 feet high and used to power the mills in the area (Wisconsin Department of Natural Resources (WDNR)). In 1919, the dam was rebuilt by Wisconsin Power as a concrete hydroelectric facility. Around 1960, the dam started to
crumble and create some serious safety issues for the public. Some of the hazards were poor water quality, low fish diversity, and heavy metal accumulations that contaminated the water. The plan was to keep the dam and repair it in the early 1980s but the repair costs were above three million dollars. The city and WDNR together decided that a removal of the dam would be less costly and better for the environment (WDNR).

After a successful removal, previously flooded areas were seeded with native plant seed and parts of the river channel were reconstructed. Throughout the years following the removal of the dam the fish habitat has improved greatly. The excessive amount of carp has decreased and the small mouth bass population has increased. The water quality has improved and the oxygen level of the water has increased (WDNR). Perhaps the most obvious benefit to the people of West Bend resulting from the removal of the dam has been the increase of park space and recreational opportunities at the park. Baseball fields
were built at the newly revived park, as well as trails, canoe loading docks and playground areas for families. The annual Kettle Moraine Jazz Festival is held at the Riverside Park as well.

References Cited


A special thanks to the Washington County Historical Society for providing resources on the dam.
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Woolen Mills-area dams date back to 1870

There has been a dam across the
waukee River in the general loca-
tion of the existing Woolen Mills dam
since 1870.
The following history of the dam
comes from the 1978 engineering fe-
sibility study conducted for the city
by Owen Ayres and Associates, Inc.,
Eau Claire:
The existing dam was constructed
in 1870 to replace the original flour
and feed mill dam constructed in
1876. The original dam served as a
cofferdam while the new dam was
whether or not the earth embank-
ments were overturned.
The flood of the Woolen Mills ware-
house is reported to have had a depth
of nearly four feet of water during the
1934 flood.
During the 1930s and 1930s a hydro-
electric plant was located on the left
embankment of the dam. This struc-
ture was later abandoned. Parts of
the powerhouse structure still remain
buried within the embankment.
Ownership of the dam was trans-
ferred to the City of West Bend on

Size of pond: 66.7 acres (0.104 sq.
Size of pond and watershed: 144,512
Watershed of Milwaukee River up
the Woolen Mills Dam includes
portions of Dodge, Fond du Lac,
Sheboygan and Washington counties.
Total watershed for Milwaukee River
system: 403.8 sq. miles.
Area of pond less than 3 feet deep:
Maximum depth: 14 feet (in natu-
emergerd vegetation.
Water volume: 436.7 acre-feet.
Water exchanged in pond every 2
days.
The most abundant fish species in
the pond are carp, bullheads and
minnows. The carp have been a
serious fish management problem.
Other fish comprise a small percent-
age of the fish population.

DNR OPINION OF POND
(from 1974 records)
One of the early versions of the Woolen Mills dams is viewed by West Bend residents in this undated photograph from the archives of the Washington County Historical Society.

Woolen Mills-area dams date back to 1870
An Excerpt from the River Alliance of Wisconsin Webpage:

http://www.wisconsinrivers.org/

One case study on the affects of dam removals is the Woolen Mills Dam on the Milwaukee River. This dam had a head of 14’ and flowed 70 acres of floodplain. After several unsuccessful attempts to obtain outside funding to replace the dam, the City of West Bend asked the DNR to help them develop a removal plan which included development of additional parkland within the former impoundment. In May of 1988 the dam was removed.

After removal, the area was seeded with smartweed and barnyard grass to stabilize the exposed sediments. Over the next few years, trails and parklands were developed throughout the area. At the upper end of the impoundment, approximately 1000’ of the river channel was reconstructed. That area was found to be artificially wide and shallow due to deposition of larger bedload material when impounded.

Fish habitat response was very good and took approximately 3 years to occur naturally. That change was best illustrated by the response of study reach at the lower end of the impoundment. Steady improvement was observed in habitat quality rating as riverbanks stabilized and course substrate was exposed.

The fish community at Woolen Mills also responded well. Carp catch per unit effort plummeted, smallmouth bass catch increased significantly and the Index of Biotic Integrity improved as well. Angler response was also good. Angler use in the Woolen Mills reach in 1990 was 192 hours/acre compared to 18 hours/acre in an impounded reach a short distance upstream.

The River Alliance of Wisconsin on Dams

What's Wrong with Dams?
The River Alliance is not "anti-dam." We recognize that in many cases dams provide important societal benefits. But some dams are more useful than others. By their very existence, dams have a detrimental impact on rivers and streams. For example, dams:

- Alter natural flow pattern
- Fragment habitat
- Block migration corridors
- Degrade water quality by altering temperatures and oxygen levels
- Fluctuate water levels, either stranding or flooding fish and wildlife
- Hold back silt, debris and nutrients
Dam Removal

While about 200 hydropower facilities inhabit Wisconsin's rivers, the vast majority of dams in the state do not generate any hydropower. Today, many of our dams have outlived their economic viability, have become public safety hazards and pose significant financial burdens to local communities and other dam owners. In fact, according to the Wisconsin Department of Natural Resources, about 10% (~ 380) of Wisconsin's dams are functionally obsolete. Here are some facts about restoring rivers through selective dam removal:

- Dam removal, on average, costs 3 to 5 times LESS than dam repair.
- Dam removal eliminates the on-going costs of dam maintenance and operation, liability insurance, and repeated dredging of silted-in impoundments.
- Dam removal improves water quality, both in the former impoundment and downstream.
- Former impoundments (artificial lakes/ponds) often revegetate within ONE growing season following removal.
- Dam removal allows fish and other species to access important spawning, resting, feeding, and nursery sites.
- Dam removal restores more natural water temperatures and oxygen levels.
- Dam removal improves recreational and aesthetic opportunities -- from canoeing and kayaking to fishing and wildlife watching.

Increasingly, the combination of financial, safety and environmental issues are influencing dam owners and communities to consider dam removal as an alternative to costly repairs of old, obsolete dams. The Wisconsin Department of Natural Resources (DNR) estimates that between 300 and 400 communities across the state are facing, or will face in the near future, the decision of whether to repair or remove an old dam. These community decisions are often made with inaccurate and incomplete information. Those interested in the continued presence of dams are generally well represented, and the DNR provides neutral technical and regulatory information from a safety perspective.

Source:  http://www.wisconsinrivers.org/
The Blue Hills Woods encompasses over 300 acres of rolling wooded hills, ponds, kettles, and scenic views. The area extends from Hwy 33 to County D on the northwest side of West Bend. Created by the withdrawal of the glaciers during the last Ice Age, the Blue Hills offers the opportunity to experience the beauty of the Kettle Moraine five minutes from downtown West Bend. The Glacial Blue Hills Recreation Area is located within this corridor. Winding through the Recreation Area and the woods is the National Scenic Ice Age Trail, one of only eight such National Scenic Trails in the country. [http://www.bluehillsconservancy.org/](http://www.bluehillsconservancy.org/)

The glacial environmental corridor, with trailheads on West Washington Street, Park Avenue, and Beaver Dam Road, is a native hardwood forest. The Ice Age National Scenic Trail meanders along the rolling glacial landscapes, disappearing below the dense forest canopy. Within the Corridor is Glacial Blue Hills Recreation Area.
Glacial Blue Hills Recreation Area is rugged and primitive, offering a wilderness-like experience for the visitor. Glacial Blue Hills offers highline views of the woodland valley, presents clues to the most recent glaciation, and yields access to the park’s interior solitude, while affording the unique chance to hike, mountain bike, explore via orienteering, and nap among nature’s conversation. Trailheads and parking lot are located on Beaver Dam Road.

www.ci.westbend.wi.us/Departments/PRF/GlacierBlueHills.htm

ORIENTEERING COURSE

Glacial Blue Hills Recreation Area offers two self-guided orienteering courses. Orienteering is navigating over land using topographical map and compass. The main emphases is using the lay of the land to guide the participant around a course consisting of a number of checkpoints called controls. Orienteering satisfies the mystery of exploring and is a fun activity for the whole family.

Map and compass are available at the Recreation Department office located at 1115 S. Main Street. A refundable $10.00 deposit is required for each compass checked out at the Department office. Office hours are 8:00 a.m. to 4:30 p.m. Monday through Friday.
Cedarburg Bog UWM Field Station
3095 Blue Goose Road
Saukville, WI
Dr. Doug Cherkauer

Access: From the intersection of County Highway Y and State Highway 33 in Newburg, go east on 33 2.6 miles to a parking area on the south side of the road. A trail leads to a pier on Watts Lake. For access to Mud Lake and the heart of the bog, go south on Y 4.2 miles, then east on Cedar-Sauk Road, 0.75 miles to a pull-off on the north side of the road. Walk north along a boggy, unimproved trail to the lake. A kayak or canoe is required to reach the interior. Access to UW-Milwaukee land is available to groups by contacting the UWM Field Station on Blue Goose Road at (262)675-6844.

Description: Cedarburg Bog is the most intact large bog in southeastern Wisconsin and composed of a mosaic of vegetation types. Once part of a large glacial lake, the bog is a relict community - a southern example of the type more commonly found in northern Wisconsin. There are six lakes remaining within the bog, all with varying sizes and depths. The 245-acre Mud Lake is the largest, followed by the 34-acre Long Lake. Surrounding the lakes are areas of emergent aquatic vegetation while just outside this zone is a successional shrub-carr area. Most unusual is a string or "patterned" bog, unique here because it lies far south of its usual range in North America. It is composed of ridges of stunted cedar and tamarack that lie in an open flat sedge mat. The meadow vegetation consists of narrow-leaved sedges, pitcher plant, bogbean, water horsetail, arrow-grass, orchids, and the insectivorous sundew and bladderwort. A conifer-swamp hardwood forest is adjacent to the bog. There is a very diverse flora and fauna; many that are more common in northern boreal forests and that are at their southern range limit here. Cedarburg Bog is owned by the DNR and University of Wisconsin and was designated a State Natural Area in 1952.

http://www.dnr.state.wi.us/org/LAND/er/sna/sna2.htm
Natural Areas

Cedarburg Bog

The Cedarburg Bog is one of the largest and most diverse wetlands in southern Wisconsin. Its 2500 acres contain deep and shallow bog lakes, submerged and emergent aquatic communities, a small stream, deep and shallow marshes, sedge communities, shrub carrs, swamp hardwoods and large expanses of cedar-tamarack swamp forest. The southernmost string bog in North America lies in the heart of the bog. String bog is a type of patterned vegetation typically found in the large peatlands of northern Canada. In the Cedarburg Bog over 35 higher plant species and 19 species of breeding birds reach or are near the southern extent of their range in Wisconsin. The pH of the Cedarburg Bog is nearly neutral, a result of the region's calcareous groundwater. Access into the heart of the bog is provided by a boardwalk, and a guidebook to the Bog is available. A quantitative survey of the vegetation in the Cedarburg Bog was completed in 1991. The uniqueness of the bog has been recognized by its inclusion in the Wisconsin Natural Area System, and it is also registered as a National Natural Landmark by the Department of the Interior. The Cedarburg Bog Natural Area is also an Experimental Ecological Reserve, part of the National EER network.

Sapa Bog

In 1983 the Nature Conservancy purchased, and donated to the Field Station, 12 acres of acidic bog called the Sapa Spruce Bog and 11 acres of swamp hardwood. This pristine bog adjacent to the Field Station is the southernmost black spruce bog in the state. It contains southern outliers of many plant species and represents a very different wetland community from that contained in the Cedarburg Bog. A plant species list for the Sapa Bog is available. Access to this bog is allowed for research purposes only.

Upland Habitats at the Field Station

The Field Station owns almost 80 acres of one of the finest mature beech-maple forests remaining in southeastern Wisconsin. A recent acquisition of 18 acres of high quality beech-maple forest adjacent to the Field Station was purchased by the Nature Conservancy in 1991 for eventual donation to the Station. This parcel is being managed by the Station. Like the Cedarburg Bog, the beech-maple forest has been designated a State Natural Area, and is classified as a National Natural Landmark by the Department of Interior.

Approximately 110 acres of old agricultural fields in various stages of succession (including 15 acres still being cropped in hay) are available for experimental research. A history of the use and management of the agricultural and old field areas is maintained as part of our data base. Three of the old field areas are maintained permanently in herbaceous vegetation. Long-range plans for these fields include the introduction of native plants to increase species and community diversity. Prairie species have been planted in several fields. [http://www.uwm.edu/Dept/fieldstation/natareas.html](http://www.uwm.edu/Dept/fieldstation/natareas.html)
From a geologic and groundwater perspective the Cedarburg Bog is an important groundwater recharge zone for both the Pleistocene drift and the Silurian dolomite aquifer. The outline of the watershed is noted in Figure 1 below. The Bog sits on a variety of glacial deposits, but because it is elevated, as noted in figures 2 and 3 (or 3 and 4), it is a recharge area of importance.

References;


Figure 1  Location of the Cedarburg Bog watershed and the Field Station site, Ozaukee County, Wisconsin.
Figure 3: Regional topography and subsurface geology in the Cedarburg Bog Area, Washington and Ozaukee Counties, Wisconsin. Cross-section location on Figure 1. (modified from Mulica, 1973)
Figure 4  Generalized direction of groundwater flow in the Cedarburg Bog Area, Ozaukee County, Wisconsin. (from Mulica, 1973)
Klode Park is a recreation and beach area situated on a bluff along the shore of Lake Michigan. This site provides us with insight into the unique and ongoing problems inherent in an inhabited coastal environment, specifically that of Lake Michigan. Since its acquisition in 1929, Klode Park has experienced a lengthy series of erosional problems. Each of these erosional events has been followed by changes in landscape design and aesthetics. None of the erosional events compare in scale, however to those which occurred over a period of a few months between 1986 and 1987. In spring of 1987 the bluff at Klode failed catastrophically, causing a 250-by 100-foot chunk of bluff to slide from a height of 60 feet, 200 feet out into Lake Michigan. We will look first at the conditions that contributed to and led to the bluff failure and then at the measures taken to stabilize the bluff and surrounding beach.

A significant part of Klode's problem lies within the bluff stratigraphy. Klode's bluff is made up of lake sediment layers sandwiched between glacial till units deposited approximately 13,000 years ago by the Lake Michigan lobe of the Wisconsinan glacier. The oldest till unit's composition is 44% clay, 41% silt, and 15% sand. Above this till unit lay a number of thin lake sediment layers containing mixtures of silt and sand lenses. The uppermost till present is the Ozaukee member, a red unit composed of fine-grained silty clay or silty clay loam. Much of this uppermost till member is fractured and is host to a perched water table. Characteristic of bluff soils are low infiltration capacity, low permeability, poor drainage, and excess pore pressure. These properties produce decreased slope stability on the bluff face at Klode and along many of Lake Michigan's
bluffs. Groundwater seepage within the bluff units weakens the cohesive structures of the soils and facilitates failure. Excessive precipitation levels feed the groundwater system, thus becoming a significant bluff stability factor as well.

The most obvious source of erosion along Lake Michigan is, of course, the constant action of waves. Wave height is a function of water level, or depth, combined with fetch. Fetch is the distance wind is able to travel uninterrupted. Wave energy increases considerably as the amount of fetch and/or water depth increases. Bathymetry studies indicate a steep near-shore slope off of Klode's beach. The slope provides for deep offshore waters that combine with a high fetch to lend considerable force to the waves that act against the Klode beach area and bluff toes.

When record precipitation levels fell in the autumn months of 1986, the water level in Lake Michigan rose rapidly. In a winter storm that produced strong winds and precipitation, waves overtopped and battered a cement seawall that had been in place for over 25 years. This seawall protected the North Shore Water Intake Pump Station, a facility that provides services to approximately 40,000 North Shore citizens. Temporary rip-rap structures were installed to save the pump station. In January of 1987, emergency revetment work was performed in the vicinity of the pump facility at a cost of $70,000. Support work was completed with the construction of a 450-ton armor stone retaining wall at the bluff toe. Seven hundred tons of crushed stone were placed between the wall and the pump facility, protecting 265 feet of shoreline. The emergency protection, however, left the northern adjacent bluff unprotected.

Another large storm event in March 1987 raised the Lake Michigan water level to its 100-year flood stage level of 584.3 feet. At this time Klode Park had 480 feet of shoreline. The sand and gravel beach area was 20-35 feet wide and sloped at an angle between 7% and 9%. The bluff behind the beach was 75-80 feet high and sloped toward the lake at 22%. The bluff slope was approximately 90% vegetated. During the spring's stormy season a high level of groundwater seepage was reported, hinting to the saturation of bluff soil and to the possible instability of the bluff. In addition to noted seepage, slumping and bluff toe erosion were also increasing the possibility of bluff failure.

Indeed, during the night hours of April 14, 1987, a massive section of Klode's bluff failed. For hours following the initial major failure event, land continued to slide into the lake. The landslide did not affect or endanger the pump facility near the south end of the park, but did put the bluff area to the north into imminent danger of failure. Engineers assessing the situation calculated a factor of safety of 1.1 for the fallen bluff. Factor of safety is a calculation derived by dividing the resisting forces by the driving forces of the bluff face (Figure 1). A factor of safety greater than one signifies a stable bluff and is normally considered a "safe" number. A factor of safety equal to one indicates a marginally stable face.
With the unsatisfactory result calculated for the failed bluff, five bluff stabilization alternatives were offered by engineers:

1. Regrade bluff to form more gentle slope down to shoreline;
2. Enforce bluff toe with fill;
3. Build retaining wall at toe;
4. Construct "fingerlike" concrete/stone structures from shoreline;
5. Do nothing.

Due to the possible dangers presented to private property to the north and the pump station to the south, the "Do nothing" approach was immediately deemed unacceptable. Regrading the bluff and adding 40 cubic yards of fill per linear foot at bluff toe would, according to engineers, increase the bluffs factor of safety to a stable 1.36.

It was the wish, however, of Whitefish Bay Village administrators to restore the park area for recreational uses. This wish eliminated the second of the five options. It did, however, lead to the discovery that tunnel boring machine spoils were available for use from the Milwaukee Metropolitan Sewerage District's Deep Tunnel Project at no cost to the village, provided the spoils could be accepted by autumn of 1987. Though the village had paid $100,000 in June of 1987 to the Southeast Wisconsin Regional Planning Commission (SEWRPC) to become involved in the solution process, not enough time existed for SEWRPC to submit a recommendation. Without the expertise SEWRPC offered, village officers were forced to educate themselves on the basics of shoreline protection and bluff stabilization. Lengthy discussions were held with the engineering firm to decide upon three possible, viable long-term solutions.

These three options were formally announced in June of 1987. Each option provided for different amounts of usable reclaimed land in the form of stabilized bluff and beach areas. Costs for the alternatives ranged from the "basic plan" at $800,000 to $2.8 million for a sophisticated peninsula-type solution. The design most favored initially would create a peninsula 1,500 feet long by 200 feet wide. Three breakwaters with additional breakwater/revetment combinations at the east end of fill and at the south end of the rock beach would create pocket beach areas and serve as bluff protection. This peninsula would also protect a 900-foot stretch of private shoreline property to the south of the park. In return for this protection, private landowners agreed to deed the lake-edge property to the park and pay a total of $300,000 toward the project. The estimated cost of adding this 6.5 acres to the park was $1.9 million.

What would have been Wisconsin's foray into the world of offshore erosion control measures was dismissed when one of the necessary property owners backed out of the agreement. When the three options were presented to Whitefish Bay residents, residents voted in favor of the cheaper, more modest concept. The $800,000 "pocket beach" plan called for three small offshore armor rock breakwaters, three steel groins, a graded bluff area, walking path, and a total of 1.5 acres of recreational land in the form of a bluff-toe grass area and a sand beach (Figures 2 and 3). The sand beach was to be 450 feet wide and extend 150 feet into Lake Michigan. The pocket beach design was limited in scope
to original park boundaries and to immediately adjacent land parcels. The protection system was modeled on a 1:20 scale in the Canadian National Research Laboratory in Ottawa, Ontario.

Design features were specified as follows:

- **Erosion protection:** The goal was to protect the bluff during a maximum level storm event producing a lake level two feet higher than the previously recorded high. Protection of the North Shore Pumping Station was the prime motivation for this specification;
- **Fill material:** 30,000 cubic yards of deep tunnel limestone spoil provided at no cost to the village (value of fill was estimated at $20.00 per cubic yard.);
- **Sand beach:** 15,400 cubic yards of "birdseye" sand specified to assure retention of swimming beach;
- **Breakwater structures:** 7,000 tons of armor stone rocks delivered from Michigan's Upper Peninsula;
- **Drainage system:** installed in bluff to capture groundwater.

Total construction costs of the project were calculated at approximately $1,250,000. When contributions from North Shore Water Commission and savings from using tunnel spoil were subtracted, the net cost to the Village of Whitefish Bay (construction costs only) was $840,925. In 1988 that cost translated into an extra $14.55 for the owner of a $100,000 assessed home.

Construction was completed and the park reopened in July of 1988. However, as early as March, 1989, erosion had already destroyed the new grading and left four- to eight-foot scarps along the shoreline at Klode Park. While the original engineers claimed that the scarps were part of the natural drifting process and would diminish as the beach and bluff returned to a state of equilibrium with the lake, another company was hired to once again repair the area. At this time it was recommended that a fieldstone wall be built at the north area to accommodate necessary regrading between the landscaped area and 150 feet of beach. In addition, it was suggested a retaining wall similar to the one already in place would provide necessary additional stability to the bluff and park.

While performing regrading work in May of 1989, workers discovered that along private properties on each end of the park, geometries prevented grading of tunnel boring machine spoils (TBM) areas to anything near the required 5:1 slope. Thus, it was predicted, scarps would ultimately reoccur with wave action. In June 1989 three- to four-foot waves reformed the scarp in previously regraded portions of the TBM beach "cells." While the 5:1 slopes were adversely affected by wave damage during this event, areas which sloped at a rate of 8:1 exhibited no scarps.

Due to inconsistencies in the modeled behavior of the beach protection device installed at Klode and the actual performance of the plan, a study was performed in 1993 to determine the reasons for the reoccurring problems.
Several were found:
- North and south beaches were modeled using beach fill material equivalent in scale to "birdseye sand." However, the north beach cell was created out of TBM spoils. Such a beach was never modeled. Thus, behavior is more difficult to predict.
- Profile development following storm events was modeled at a 5:1 slope. However, storm events have consistently resulted in steeper scarps. It was also predicted that the buried revetment would become exposed and serve as shore protection during extreme events. Landscaping features that are inconsistent with the geometry presented in the model prevent this from occurring safely. Specifically, the curb and lawn at the north cell are located lakeward of the buried revetment. Wave action undercuts the TBM spoils and causes the beach to regress toward the curb and buried revetment. Engineers predict that the curb and lawn section will collapse if the buried revetment becomes exposed.

Current recommendations from engineers suggest that Whitefish Bay Village officers begin to consider alternatives for the TBM beach cell. The vertical scarp on this cell erodes at a rate of approximately 2 feet per year. At this rate, the buried revetment in this area may be exposed in two to four years. If this occurs, beach access will become a safety problem to the public. Regrading is no longer an option, prevented by the existing geometries of the landscaped bluff and beach areas.

Lake Michigan's shoreline is a dynamic environment—constantly changing in an attempt to reach a state of equilibrium. As long as we insist on inhabiting the bluffs around the lake we will be fighting to keep property and lives safe. While the property at Klode Park appears to be stable at the moment, Village officials are involved in litigation with adjacent property owners regarding some of the work done on the park bluff drainage plan. In order to have a truly successful shoreline stabilization project, cooperation with surrounding homeowners is essential. Perhaps part of our longterm solution could be borrowed from the state of California, where all beachfront property is public and owned by the state government. Only when all of the shoreline is considered to be a single environment, a single parcel, will real progress be seen in the battle against shoreline erosion.

REFERENCES
Cronin, V. (1996), Personal Communication.
W.F. Baird & Assoc., 1986 - 95, Unpublished reports
Whitefish Bay Library Archives Whitefish Bay Village Hall files

"FS" = Calculated Factor of Safety.
2. **KLODE PARK SHORELINE PROTECTION DESIGN.**
3. BREAKWATER/BEACH/GROIN CROSS SECTION

SECTION B-B
SCALE: HOR. 1"=50'
VERT. 1"=10'

- BY WARZYN ENG.
1987
Estabrook Park is a reasonably good place to see two members of the Middle Devonian Milwaukee Formation.

This upper layer is the Lindwurm Member. It was used as natural cement from about 1879 to about 1916.

The names of these rock formations are tied to the history of Estabrook Park and Lincoln Park. Lindwurm was the family name of the farm that was purchased by the city in 1907,
and later became Lincoln Park (Albano, 2007). Berthalet was the founder of the Milwaukee Cement Company. He discovered that the rock along the Milwaukee River could be turned into natural cement. This was before the days of Portland cement. He obtained the property rights along the Milwaukee River from Capital Dr. to Humboldt Dr., and in 1875 sold shares in his company, and started to quarry the rock that is now called the Berthalet Formation. In 1916 the city bought most of the 350 acres owned by the Milwaukee Cement Company, and named the area Estabrook Park (Peychal, 1996). The park received considerable improvements through the efforts of the WPA in the 1930’s which included straightening the river just north of the present park (Albino, 2007). The bottom line of all this is, what we see in Estabrook Park is not a natural channel for the river, but one that has had considerable modification over the years.

The Berthalet Member of the Milwaukee Formation is a dull gray dolomite (Figure 2).

Figure 2.

The upper portion is a hard layer, which was used for the cement. This layer also has many vugs filled with either asphalt or calcite (Brower, 1996). This is the top most layer of the bedrock that you walk on at the end of the boardwalk. The lower portion is fossiliferous, but may be hard to see because it is close to the river level.

**Lindwurm Member**

The Lindwurm Member of the Milwaukee Formation is predominately shale with some hard thin dolomitic limestone beds. It weathers to a blue gray clay. This can be seen under the boardwalk at low river stages. More of this rock member can be seen along the bike path near the urban Ecology Center at Riverside Park. The bike path was the former Milwaukee Road railroad tracks. The retaining walls that lined the former railroad bed appear to be made of the Lindwurm Member.
KNOWN FROM EXCAVATIONS AND MATERIAL IN THE GLACIAL DRIFT;
SILICEOUS GRAY SHALE AND ARGILLACEOUS DOLOMITE;
LARGE SILICEOUS CHONETES AND TENTACULITES; CHAROPHYTES.

GENERALLY HARD, BLUE-GRAY PYRITIFEROUS, CALCAREOUS SHALES; ONE 3" LAYER VERY HARD LIMESTONE FORMS BRINK OF WATERFALL AT TYPE LOCALITY; VERY FOSSILIFEROUS.

DULL GRAY DOLOMITE; UPPER FEW FEET VERY HARD WITH NUMEROUS CALCITIC AND ASPHALTIC VUGS; CEPHALOPODS COMMON; LOWER PART SHALY WITH DOLOMITE AT BASE; WEAVERS BUFF.

WHITE TO LIGHT BROWN DOLOMITE; LATTER BITUMINOUS IN ODOR; SOMETIMES VERY HARD BUT GENERALLY POROUS OR FRIABLE; FOSSILS RARE.

BROWN TO GRAY, BITUMINOUS IN PART, DOLOMITE; FOSSILS LIMITED BUT LARGE IN SIZE.

Feet

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References:

The following sources provided most of the information for the Estabrook Park site.


25th Wisconsin Undergraduate Field Conference, Urban and Shoreline Geology of Southeastern Wisconsin, 1996, Kean, W., and Webster, J. Eds.


Our Mission:
The mission of the River Revitalization Foundation is to establish a parkway for public access, walkways, recreation and education, bordering the Milwaukee, Menomonee and Kinnickinnic Rivers; to use the rivers to revitalize surrounding neighborhoods; and to improve water quality.

From the past to the future, we are committed to the return of this vital natural resource for all as Milwaukee’s urban rivers land trust.

Our Vision:
The River Revitalization Foundation advocates environmental conservation, public access and sensitive recreation in metro Milwaukee’s river watersheds.

To address critical land use issues and further the greenway concept, our primary focus includes ensuring:

1. Public access
2. Preservation of the River Valley
3. Preservation of green space in a dense urban area
4. Riparian buffers against encroaching development
5. Links with neighborhoods on both sides of the river
6. Conservation of critical habitat and wildlife areas

By convening partners with shared vision, values and mission, we can influence planning decisions made along this corridor.

Our Organizational Goals:
Our long-term goal is to recreate the urban landscape using the river as a focal point. As a land trust, we will impact the quality of life through neighborhood restoration, economic vitality, conservation of natural areas, and creation of public access to these natural areas and open spaces. “Green infrastructure” addresses this concept; by incorporating open space in urban planning, we have relief, through access to these spaces, from the intensity and pace of a dense urban environment. The community would be enhanced in many ways.

The indicators are:

1. Greenway established
2. Areas for passive recreation and fitness as well as environmental study
3. Protection of a linear corridor for wildlife habitat and migration, and aesthetic appreciation
4. Enhancement of the quality of life and pride in the nearby neighborhoods as well as for the Milwaukee community at large by protecting natural areas from encroaching development
5. Links created with the existing Oak Leaf Trail, connecting east side to northern communities with a trail to downtown, and to the lakefront
6. Connection with other efforts bringing pedestrians and cyclists to the Milwaukee River such as the proposed pedestrian bridge over the North Avenue dam and the “marsupial bridge” under the Holton Street viaduct
7. Opportunities for tourists to explore the natural river environment.
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