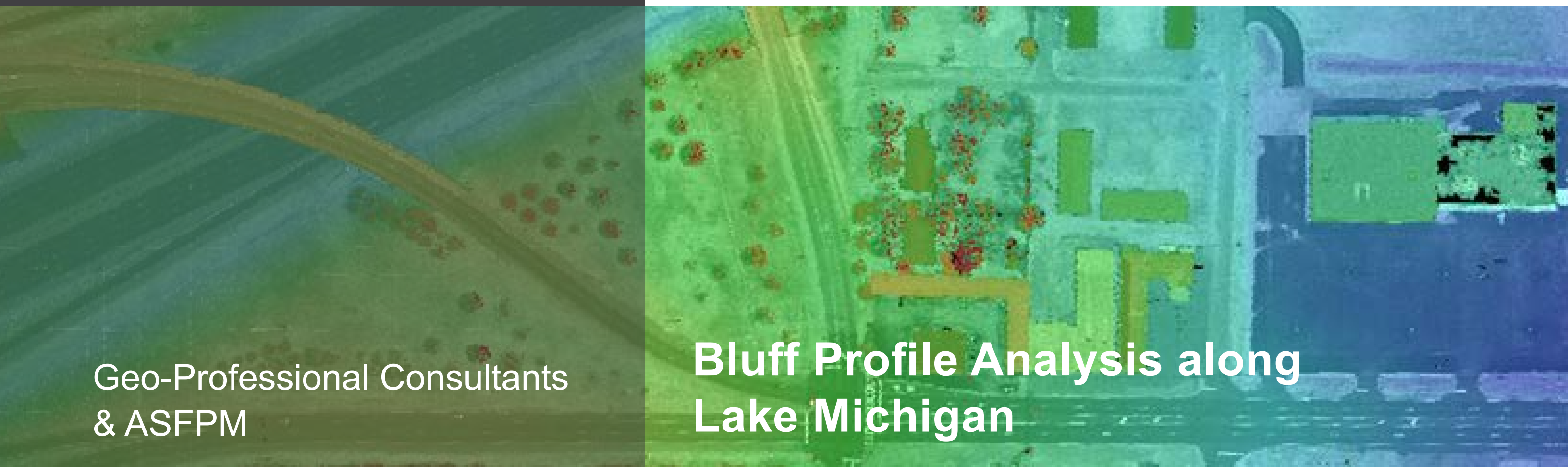
Case Study



Bluff Profile Analysis along Lake Michigan

Geo-Professional Consultants & ASFPM

Dr. David Mickelson
Geo-Professional Consultants

Geo-Professional Consultants, LLC offers consulting services in the areas of earth surface processes (geomorphology), interpretation of glacial deposits, and shore erosion problems.

1-608-257-1825
geoprofs@yahoo.com
www.GeoProfs.com

Jeffrey Stone
ASFPM

The mission of ASFPM is to promote education, policies, and activities that mitigate current and future losses, costs, and human suffering caused by flooding, and to protect the natural and beneficial functions of floodplains - all without causing adverse impacts.

1-608-828-3000
jeff@floods.org
www.Floods.org

"LP360 made it possible to measure about 100 profiles in only a few weeks where the same work in the field would've taken all summer!"

Challenge

Much of the Lake Michigan shoreline in Wisconsin has a coastal bluff varying in height from less than 20 feet to over 140 feet. These bluffs erode in a number of ways and at varying rates (Figure 1). Over 175 profiles of these bluffs were measured and analyzed for slope stability in the mid-1970s and again in the mid-1990s. These profiles were measured with a hand held inclinometer and tape and are stored as XY plots on paper. These profiles were also located as accurately as possible on aerial photos, but they were not located in a GIS. Our challenge was to re-measure these bluff profiles in a relatively short time and on a small budget so that we could document the changes that have taken place on the bluffs during the last 40 years and to use this input as a basis to determine bluff stability over time.

Solution

To achieve this goal we obtained and processed 2012 USACE LIDAR data for much of Wisconsin's Lake Michigan shore. Using LP360 for ArcGIS (QCoherent Software, LLC) we re-projected to a Wisconsin coordinate system and performed verification of LIDAR classification quality (e.g. bare earth, trees, buildings). LP360 also allowed for rapid drawing of profiles from bluff top to lake edge. Correctly classified LIDAR points easily allow the separation of bare earth and other features such as trees and buildings. Figure 2a shows a profile with vegetation included and Figure 2b shows the ground surface with vegetation filtered out and a line draped to the surface to make it more easily visible.

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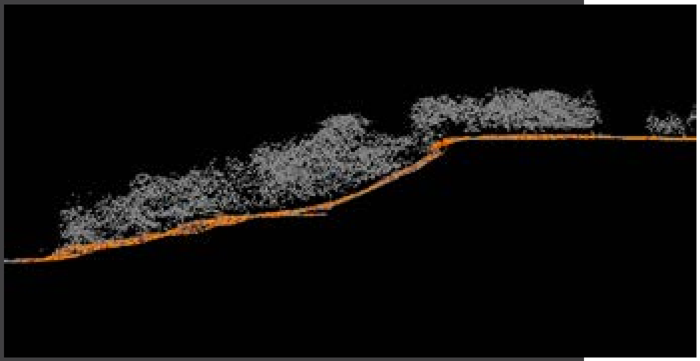
The output is a picture of the profile stored as a JPEG file (less useful) (Figure 3) or XY values (Figure 4) along the slope stored in an Excel spreadsheet (more useful).

Figure 1 (Above)- Oblique aerial photo of profile 12-15 on Lake Michigan shoreline

We measured 175 bluff profiles between Kenosha and Port Washington, Wisconsin, and they are in the process of being analyzed for lowest factor of safety which is a measure of how stable the bluff slope is. We tried to measure profiles at locations of profiles measured between 1976 and 1978 and again in 1995 but because the locations of these older profiles were marked only on aerial photos, and not using GPS, their locations cannot be verified to be exactly correct. Also, because there is no spatial control of previous profiles this comparison cannot be used to measure bluff top recession rates. It is possible, however, to conclude based on all of the profiles that slopes are more stable, have more gentle slopes, and have more sediment accumulated at the toe of the bluff than was there in the mid-1970s or mid-1990s (Figure 5). Presumably, this is because of generally low lake levels over the past few decades. (Since the late 1990s the level of Lake Michigan has been at or below the long-term average of all of the time between 1970 and 2014.)

Figure 2a (Below, Left) - Profile of ground surface and vegetation from 2012 USACE LIDAR using LP360

Figure 2b (Below, Right) - Profile of draped ground line with vegetation filtered out using LP360



A total of 175 profiles have been constructed from the 2012 LIDAR data. Of these, 105 profiles were in the same location as a profile that was measured in 1995. In order to compare slope stability in 1995 and 2012, we are in the process of analyzing them for factor of safety. Slopes can fail (have a landslide) on various surfaces. Our analysis is done to find the 10 most likely failure or rupture surfaces in a given slope. Of these, the one with the lowest safety factor is most likely to fail. If the lowest factor of safety is above 1.00 then it is generally assumed that the slope is reasonably stable. The higher the lowest factor of safety the more stability there is. If the factor of safety is below 1.00 the slope is considered unstable and likely to fail. The factor of safety cannot predict when failure will take place, but that it is likely at some point in the future under existing conditions. We are still attempting to find the engineering properties used when the 1976 profiles were reanalyzed 1995. We also have about 20 profiles for which the engineering properties are missing for both the 1976 and 1995 calculations.

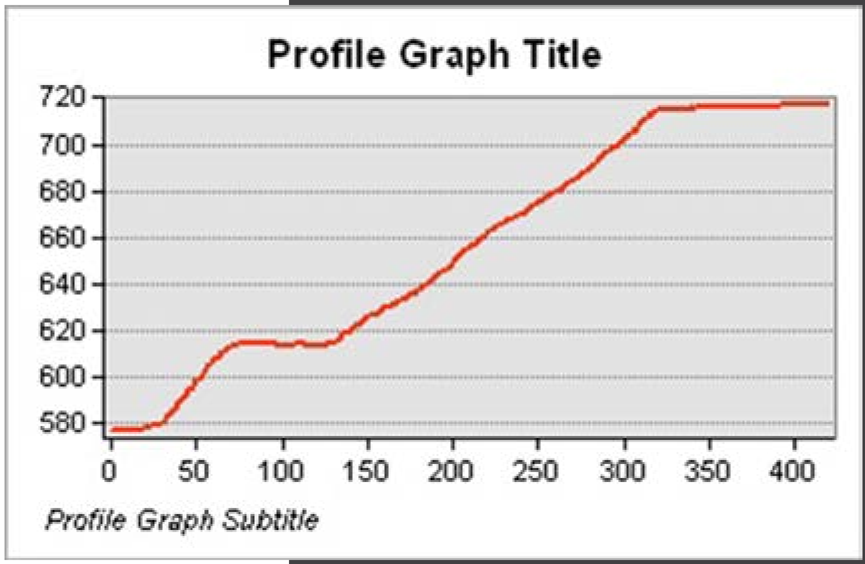


Figure 3 - Example of JPEG image of bluff produced using LP360

X	Y
419.2	717.1
419.2	717.1
419.1	717.1
418.3	717.1
416.6	717.0
417.7	717.0
416.1	717.0
414.6	717.0
413.9	717.0
412.1	716.9
411.5	716.9
411.5	716.9
411.7	716.9
411.4	716.9
409.3	716.9
408.9	716.9
406.4	716.9
406.9	716.9
407.5	716.9
405.3	716.8
404.6	716.8
404.5	716.8
403.8	716.8
402.3	716.8
402.8	716.8

(many points not shown in this figure)

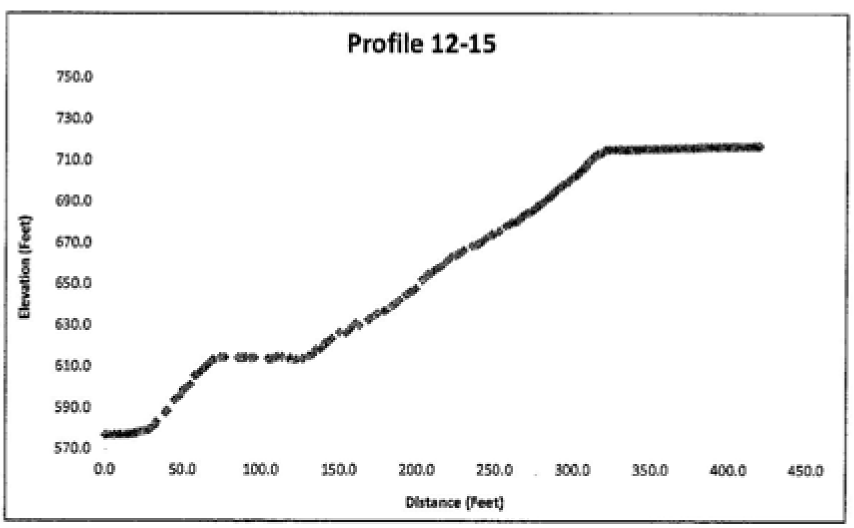


Figure 4 - Example of Excel file of bluff elevation and distances. The data column has been truncated. These files are used for the factor of safety calculations.

The bluffs have definitely become more stable since 1995. In 1995, of the 105 profiles analyzed to date, the slope with the highest value of the lowest factor of safety was 3.30, but in 2012 that value was 3.82. In 1995, 54 of the 105 profiles had lowest factor of safety’s greater than 1.00. In 2012 81 profiles had lowest

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factor of safety greater than 1.0. Of the 105 profiles that were analyzed from 1995 and 2012, 71 increased their lowest factor of safety, thus becoming more stable. Of the 105 profiles, 29 became less stable. Five profiles had the same factor of safety at both times of measurement.

This project has analyzed slopes from the Wisconsin – Illinois state line north to the city of Port Washington.

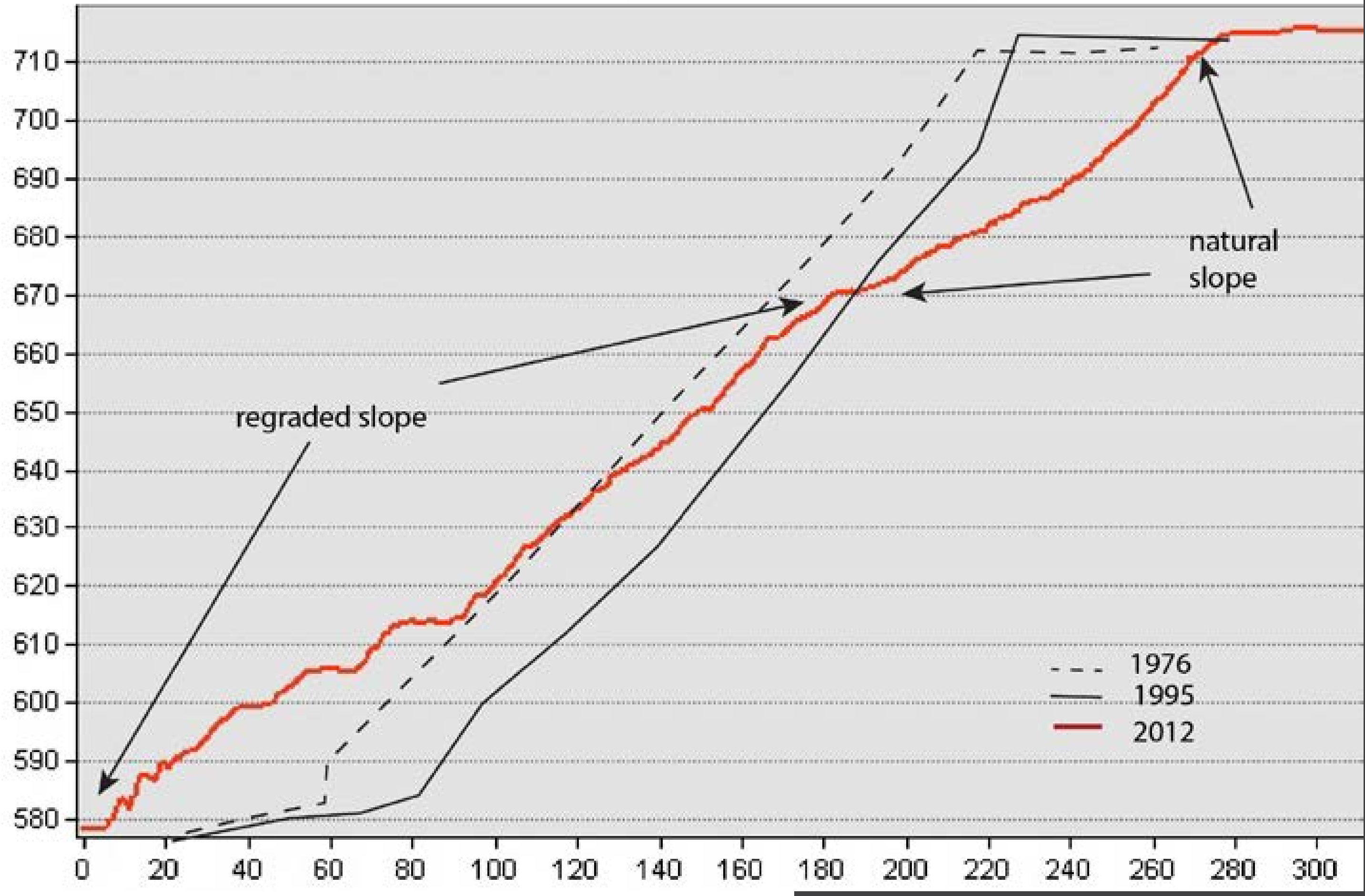

Figure 5 – Example of slope comparison over time

Summary

In summary, LP360 made it possible to measure about 100 profiles in only a few weeks where the same work in the field would've taken all summer! This allowed much more time for compilation of data and later analysis. In addition, our profiles are now located in a GIS.

QCoherent Software
9668 Madison Blvd., Suite 202
Madison, AL 35758

1-256-461-8289
info@LP360.com

www.LP360.com