

**Shoreline Erosion in Deep Creek Lake, Maryland:
Patterns, Trends and Economic Implications**

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ABSTRACT

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Deep Creek Lake, Maryland was constructed in the 1930s as a reservoir for a hydro-electric project, but it also has been used for recreational purposes. Property ownership is attractive, but lakefront properties in particular are exposed to shoreline erosion. A particular issue is the State of Maryland's ownership of the shoreline and the buffer strip. While most of shoreline erosion occurs technically on state-owned land, not the lakeshore private property, erosion's most visible effects are property improvements damage or gradual decrease in the distance between the lake and the property improvement. In order to understand the magnitude of the problem, to observe patterns for shoreline erosion and to help better planning of development in the region, one of the objectives of the present study was to map and, to the extent possible, to quantify shoreline erosion on Deep Creek Lake. Another objective of the study was to collect information about actual erosion directly from owners of lakefront properties and to assess their experiences and perceptions of shoreline erosion hazards on their property. In order to achieve the first objective, the study used historical aerial photographs. The highest water marks on previously rectified aerial photographs were traced in ArcView 9.1. Digitized shorelines from multiple years were overlain, followed by the spatial adjustment of vectorized shoreline. For the second objective of the study, a survey of lakefront property owners was conducted. The result of the digitization procedure showed that in many sectors the shoreline receded from the original location, whereas in some sectors the shore protracted. The findings from the owners' survey (sample size=323; return rate: 67.4 percent) suggest that almost 70 percent of properties have undergone some form of erosion and that those owners who reported such events are more likely to be aware of potential causes and mechanisms of erosion on the shoreline of their property. The limitations of the study include the fact that a qualitative analysis of shoreline change cannot be descriptive enough if changes are only on a small scale and that self-reported data can overestimate the location and/or extent of erosion. The study found that there is erosion in Deep Creek Lake and the property owners are aware of the process, but additional information is needed in order to quantify the erosion, to map it and establish its patterns.

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Chapter 1. Introduction

Lakefront property ownership in Deep Creek Lake has been constantly attractive for buyers in search of vacation homes in this Western Maryland recreational area. On the local real estate market, lakefront houses and/or land come with the highest price tag in the entire area. Unfortunately, some lakefront owners face threats to the property and its financial value in the form of land loss or structure damage due to shoreline erosion. In technical terms, a property improvement is any kind of structure built by the owner on the property (such as a dock, a shed, a house, or another structure). Property losses are characterized by a gradual decrease in the distance between the lake and property improvements, which, if allowed to continue, diminish the resale value of the property and eventually threaten property improvements with collapse into the lake. The original boundary line was established by the electrical company which built the lake. Generally, the so-called “buffer strip” consists of at least 25 feet of land. The width of the buffer area varies with elevation and ranges from a few feet in sections where the lake shore is steep to several hundred yards when the land is a gradual slope away from the lake. A particular issue in Deep Creek Lake is the State of Maryland’s ownership of the shoreline and the buffer strip. While most of shoreline erosion occurs technically on state-owned land, not the lakeshore private property, erosion’s most visible effects are property improvements damage or gradual decrease in the distance between the lake and the property improvement. Residents whose properties appear to have been affected by shoreline erosion have voiced their concerns (Deep Creek Dispatch n/d; EMR, Inc., 2004) and some have applied for permits to build erosion protection structures on their property. Currently, the Maryland Department of Environment (MDE) reviews and approves or denies the shoreline erosion control structures. Subsequently, Deep Creek Lake Natural Resources Management Area (NRMA) permits the work if it has been

approved by MDE. Whether local government should take responsibility in assisting financially these owners is a controversial issue, and currently MDE does not share the costs of such projects.

Chapter 2. Context of Shoreline Erosion in Deep Creek Lake

2.1: Geographic Location

Deep Creek Lake is located in Garrett County, the westernmost county in Maryland, with an area of 662 square miles and a shoreline of approximately 65 miles. Garrett County has a population of approximately 29,909 (U.S. Census Bureau n/d), being the least populated county in Maryland. The Deep Creek Lake watershed is bounded by several mountains, including Marsh Mountain, Meadow Mountain, Snaggy Mountain, and Roman Nose Hill.

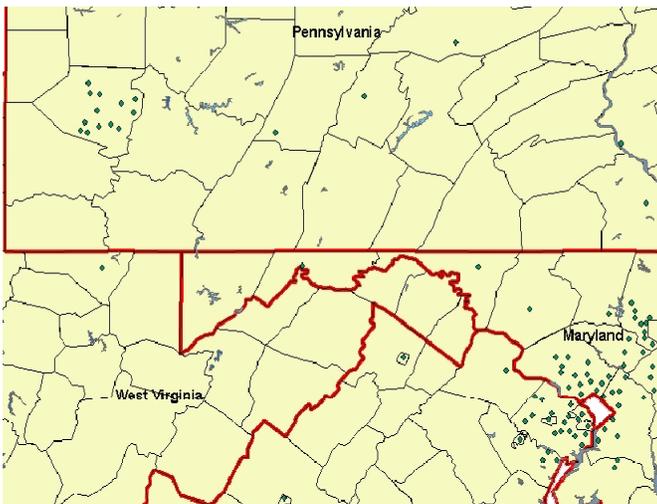


Figure 1: Deep Creek Lake, MD and surrounding states

The lake was created in 1928 by the Pennsylvania Electric Company, a private company that bought all the land and built the dam. Deep Creek Lake hydroelectric project was constructed on Deep Creek, a tributary of the Youghiogheny River, by flooding a section of Youghiogheny River valley. As a result, the lake is long, narrow and has a convoluted shoreline. Over the next few decades, the Deep Creek Lake region developed as a recreational resort, with

the human presence and activities on and around the lake intensifying in the last 15 years (EMR, Inc., 2004).

2.2: Overview of Potential Determinants of Shoreline Erosion

Erosion represents the process of weathering (i.e. the physical process - either mechanically or chemically - of changing the character of rock at or near the earth surface), followed by physical removal of rock particles from their original position (Tarbuck and Lutgens 1987). Based on how rock particles are removed, erosion can be induced by five different types of mechanisms: (1) rain and stream action, (2) the action of glaciers, (3) the action of wind, (4) action of waves, and (5) the action of forces within the Earth. Given the history and physical geography particularities of the region, the predominant natural cause of erosion in Deep Creek Lake appears to be the action of waves on the shoreline (Deep Creek Lake recreation and land use plan, 2001; EMR Inc., 2004). Shoreline erosion at Deep Creek Lake is rarely a single event as much as it is an ongoing process that doesn't get recognized as a problem until trees are toppled or lakefront property owners have to relocate shoreline-added structures or their embankment topples into the lake. On the other hand, the property owners are in many circumstances the ones removing, cutting and trimming soil-stabilizing vegetation along the shoreline (Carolyn Matthews, Manager, Deep Creek Lake NRMA, April 30, e-mail).

Major storms are rarely erosion-producing events in Deep Creek Lake. Lake level fluctuations (induced by hydroelectric project operations) represent a dominant influence of human factors on the process of erosion. In addition, because of the recreational nature of most human activities on the lake (boating and watercraft activities), especially during warm months, the action of waves in inducing shoreline erosion could be thus exacerbated (EMR, Inc., 2004; Canadian Coastguard/Erosion and Boatwake n/d).

2.3: Physical Characteristics

From the viewpoint of physical geography, topography and vegetation determine the characteristics of a landscape. The topography is the result of the nature of the rocks, their external or internal characteristics and the types of soils.

The elevation in Western Maryland increases gradually across the Coastal Plain and then more rapidly until the highest point and elevation are reached on the Allegheny Plateau, which is a sector of Appalachian Mountains. The Allegheny Plateau extends westward from Dan's Mountain through the rest of the state. The general aspect shows elongated ridges from southwest to northeast. The topographic elevation of Deep Creek Lake area is an expression of geologic history and the varying erosive rates of different rocks in time. This physical activity created an elevation that varies from 2,000 feet to more than 3000 feet above the sea level. Through the understanding of the topography other features influencing development in the area can be explained. The soils are strongly influenced by water level. It is especially true for soil drainage characteristics and adjacent with these, vegetation and even wildlife. Slope is an important factor in determining suitability of land for different uses.

Deep Creek Lake is located entirely within the Allegheny Plateau, the westernmost geographical region of Maryland. In geologic terms the Alleghenies are old hills, and their history started more than 500 millions years ago during the Paleozoic Era, in the Late Ordovician or Early Silurian, and Devonian period (Tarbuck and Lutgens 1987; Kiver and Harris 1999). For more than 200 million years, the ocean filled the region now occupied by the Appalachian Plateau and sediments from eroding uplands washed into area, slowly adding to the accumulative debris of marine skeletons. The abundance of fossils is evidence of the fact that this area was under the water. The geologic event known as Appalachian Orogeny, in the Carboniferous

period, with its Mississippian and Pennsylvanian epochs, occurred and the region was uplifted. The Pennsylvanian period, also called “The Coal Age”, followed occurring around 325-286 millions years ago. The shoreline included in this study is located on a syncline called the Casselman Basin. The Meadow Mountain is the eastern border of this formation. The sediments exposed here are brown colored sandstones and shales of Mauch Chunk formation. A very thick layer of Greenbrier Limestone underlies the lake and contributes with calcium carbonate to buffer the lake waters from acidic runoff due to the younger formations of sandstone, shale, and coal.

The five major factors in the formation of soils are parent material, climate, living organisms, topography, and time. There are 6 types of soil associations ((Stone and Matthews 1974) in Garrett County, MD: 1) *Calvin-Gilpin* (29%); 2) *Gilpin-Cookport-Dekalb* (9%); 3) *Gilpin-Wharton-Dekalb* (5%); 4) *Lickdale-Armagh-Peat* (1%); 5) *Dekalb-Calvin-Gilpin* (14%); and 6) *Dekalb-Gilpin-Cookport* (42%). In and around the study area, three major associations of soils, *Calvin-Gilpin*, *Dekalb-Calvin-Gilpin*, and *Dekalb-Gilpin-Cookport* are identified. These associations have in common specific characteristics such as gently sloping to steep, moderately deep, and good drainage soils; most are very stony loams or silt loams. The area South to the lake is represented by the *Calvin-Gilpin* association, but also has 30 percent of less extensive soils. In the area surrounding the Northern sector of the lake, *Dekalb-Calvin-Gilpin* and *Dekalb-Gilpin-Cookport* are the most dominant associations. The *Dekalb-Gilpin-Cookport* association occupies almost 42 percent of the county and more than 60 percent of the Northwestern sector. Except for isolated areas, this association is not used for cultivated crops. Small areas were used for forage crops and pasture, but generally the association is used for woodland, wildlife habitat, watershed protection, and outdoor recreation.

Ranking second in importance after the geological aspects in the erosion process of the area of study, the climate, through its components (precipitation, temperature, and seasonal variability), acts upon the bedrock. Garrett County has a humid, temperate, continental climate. The climate is fairly uniform throughout the county, although there are local differences in weather at different elevations and in relation to the lake. Average monthly temperatures in winter are below freezing and average monthly temperatures in summer are typically over 20° C. Overall, there are no significant differences among soils of the county caused by climate alone (Stone and Matthews 1974). As mentioned, storms rarely occur.

Approximately 90 percent of the Deep Creek Lake shoreline's natural character has been impacted by residential and commercial development to various degrees (Deep Creek Lake recreation and land use plan, 2001). In early development areas, wherever smoother slopes allowed, the shoreline is completely deforested and replaced with grassy patches, while there are several areas of the lake that still maintain their natural appearance with minimum or no disturbance. The forest cover along the buffer strip is generally fragmented.

2.4: Lake Level Regulations

In 1968, the Pennsylvania Electric Company (PENELEC), at that time owner of the lake and surrounding properties, was issued by the Federal Energy Regulatory Commission (FERC) a license to operate the Deep Creek Lake hydroelectric project. PENELEC, as the lake owner at that time, had established its own policies and procedures for managing the lake, which also extended over the recreation area and the access to Deep Creek Lake.

Lake management regulations were promulgated through a public process beginning in 1981 and were updated in 1986, 1988, 1989, and 2000. These regulations (COMAR Title 08,

2006) are still in effect and provide the basis for lake management operations conducted by the Maryland Department of Natural Resources (DNR).

In 1991, FERC determined that the federal government should not maintain jurisdiction over the Deep Creek Lake project. Therefore, the water appropriation permit issued by the State of Maryland in 1994 guided the maintenance of the lake levels and discharges for generation of hydroelectric power. In 1999, General Public Utility, PENELEC's holding corporation and the State of Maryland started to negotiate the purchase of the bottom, buffer zone properties and other parcels owned by the power company. The sale was completed in 2000, but the State of Maryland did not buy the dam, intake tunnel, and power plant. These assets were sold to Sithe Energies at the time, currently the owner being Brookfield Power.

Discharges from Deep Creek Hydroelectric Station enter the Youghiogheny River. This water discharge has the potential to affect recreational activities on the lake through changes in the lake's water level, as well as downstream environment of the river. Because the interests of various users of Deep Creek Lake's resources are potentially conflicting, a plan was developed during the re-licensing and permitting process, to find balanced solutions to a variety of complex environmental and recreational issues in conjunction with economical operation of the power plant.

The plan is implemented through the Water Appropriation and Use Permit for Deep Creek Lake Station (Deep Creek Lake recreation and land use plan, 2001), which requires the release or retention of water for various in-lake and downstream uses. The scheduled release is every Monday and Friday and one Saturday per month during the whitewater recreation season (April 15-October 15). These releases are to last at least 3 hours when sufficient water is available and they cannot be curtailed unless the lake level is 1 foot or more below the lower

operating rule band (for Friday release) or below the lower rule band (for Monday and Saturday release). The permit also requires the owner of the power plant to make releases to maintain river water temperature below 25⁰C for trout habitat during the summer.

2.5: Recreational Watercraft Activities

Three basic types of boats are utilized on Deep Creek Lake: power boats, sail boats and human powered boats. Boating activity is at a peak during spring and summer weekends. According to a 2004 carrying capacity study (EMR, Inc., 2004), overall boating activity during non-peak times was well within carrying capacity limits. Water skiing, wake boarding and tubing are popular at Deep Creek Lake. Windsurfing also occurs. These uses also tend to be at their highest levels during the peak boating periods of spring/summer weekends. The operation of personal water craft is restricted on the lake during summer peak-use boating periods. As a particularly interesting note, according to the present study, the lakefront property owners in general tend to believe that the usual level of recreational boating on the lake, besides other nuisances, induces waves that affect the shoreline by producing erosion.

2.6: Lakefront Property Hazards

Being primarily a recreational area, the lakefront was particularly attractive for building residential and commercial structures. The Garrett County Planning and Zoning establishes private property development setbacks from adjacent property and from the water line.

According to Phillips and Rasid (1996) the types of erosion damages commonly found in inland lakes are: beach erosion and loss of land/property; loss of trees/landscaping; and damage to lakeshore structures (such as boating docks, retaining wall or even public roads). The literature on lakeshore engineering (Carter et al. 1987; Charlier and de Meyer 1997; Gibson et al. 2002) suggests that the extent of lakefront property damage can be determined by three factors

occurring in various combinations: 1) the natural erodibility of the land; 2) the distance at which property improvements are set back from the shore; and 3) the presence of an erosion control structure. Natural erodibility can be determined by the Universal Soil Loss Equation (USLE). This equation predicts the long term average annual rate of erosion on a field slope by using numerical estimate of rainfall pattern, soil type, topography, crop system and management practices (Charlier and de Meyer 1997). It only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion. In theory, a high degree of erodibility could be used as a deterrent to erecting structures on that section of the shore, and could also determine the width of the setback regulated by the authority issuing the permit.

Because the buffer strip of the shoreline is actually owned by Maryland DNR, the state regulates the kind of shore erosion control measures that can be applied in case of damage-causing erosion. DNR, through Deep Creek Lake Natural Resources Management Area (NRMA) previews each individual application in order to be assured there is no other recourse to stabilization than building a shoreline erosion control structure. If less invasive alternatives are not going to rectify the situation then the permit application is forwarded to the Maryland Department of Environment (MDE). MDE reviews the application, inspects the site and approves or declines the request for shoreline erosion control structures.

2.7: Study Site

The shoreline on Deep Creek Lake is 65 miles long and most of it is occupied by structures owned by almost 2,000 individual owners of residential and commercial properties, as well as the Deep Creek Lake State Park. Generally the lake can be divided into three sectors, Northern, Central, and Southern (EMR, Inc., 2004). Different sections of the lake are also referred to

according to the name of prominent geographic landmarks such as McHenry and Thayerville (areas with the most intense residential development) or Turkey Neck (an area with intense boating). According to the zip code of the physical address of the property, there are 3 sections: McHenry (21541), Oakland (21550), and Swanton (21561) (Figure 2).

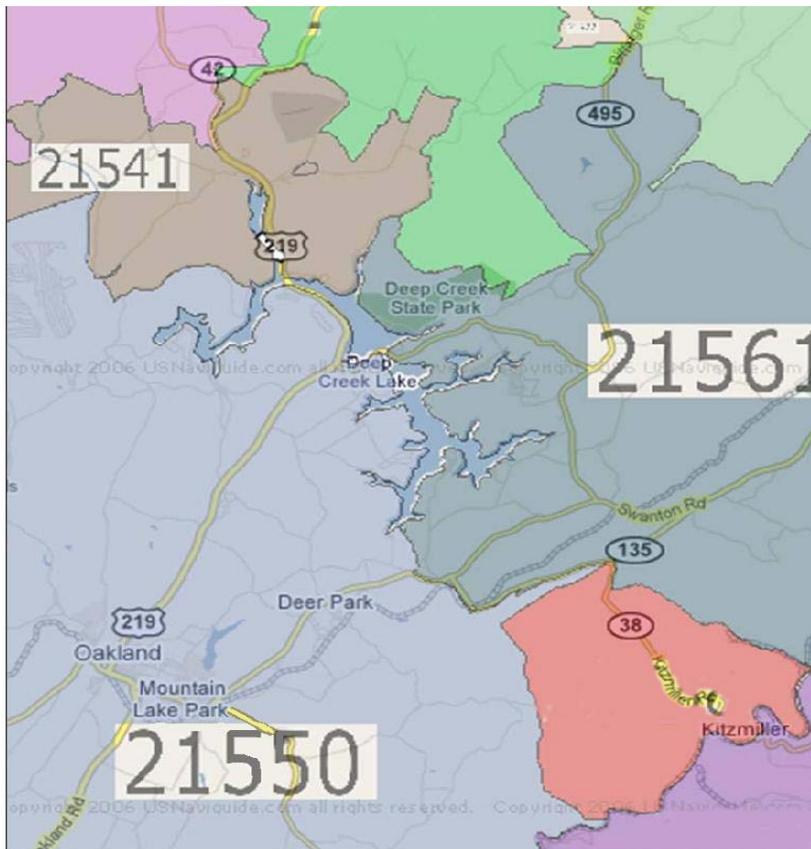


Figure 2. Zip codes for Deep Creek Lake, Maryland

2.8: Exploring Owner Perceptions of Shoreline Erosion Hazards

Deep Creek Lake was created originally as a resource for hydroelectric power for the region's development and only later did it become a recreational point of interest. The ownership over the shoreline appears a particular, potentially conflict-generating combination.

While individuals own lakefront properties, a buffer strip of variable width is owned by the state. To add to the complexity of the situation, the region is currently viewed as an income generator for the entire Garrett County, with profits coming from recreational activities. All these elements have led to more or less open conflicts of interests between the state, the operator of the hydroelectric project, and the individual owners. This situation is not unique to Deep Creek Lake. In previous studies (Charlier and de Meyer 1997; Dilley and Rasid 1990; Phillips and Rasid 1996) attempts were made to explore what the owners think about this kind of situation and how a compromise can be reached between public interest and individual interest. However, these studies focused on larger bodies of water, where national and international interests intersect. To date, no previous study was found to explore issues of local or regional importance.

Chapter 3. Goals and Objectives

Information about erosion occurrence in Deep Creek Lake is mostly anecdotal, and there has been no systematic attempt so far to demonstrate that erosion has indeed occurred, and if it indeed exists, to map it or to better understand its determining causes. The Deep Creek Lake Recreation and Land Use Plan issued in 2001 recommended that a scientific study of this topic be undertaken, and the owners' association publicly supported the idea Deep Creek Dispatch n/d). The goal of this study is to fill in the gap in knowledge regarding shoreline erosion in Deep Creek Lake and its consequences.

The first objective of this project is to map and, to the extent possible, to quantify shoreline erosion on Deep Creek Lake. The result could potentially offer a more accurate understanding of the magnitude of the problem, suggest patterns for shoreline erosion and help better planning of development in the region.

The second objective of the study is to collect information about actual erosion from owners of lakefront properties in Deep Creek Lake. In addition, the study will assess their experiences and perceptions of shoreline erosion hazards on their property and what possible correlation could be found between these experiences and perceptions of the physical process of erosion (Kreutzwiser 1987). Such assessment will hopefully be relevant for the management of the shoreline on Deep Creek Lake and possibly in other similar areas, because it could lead to a clearer understanding of responsibilities of both the local government agencies and the owners, and hence to less conflict of interests.

Chapter 4. Study Methods

4.1: Digitization of Shoreline Erosion in Deep Creek Lake

Direct measurement of the distance between the shoreline and one arbitrary point on the ground, and comparison of successive measurements over time could offer an exact understanding of the extent and location of erosion. However direct field measurements are impractical and expensive, especially for smaller inland lakes like Deep Creek Lake. Digital analysis of high resolution photographs taken over defined temporal periods has been used as a practical alternative to direct measurements in estimating actual and projected recession of the shoreline (Fisher and Overton n/d; Gibeaut et al.n/d; Gibson et al. 2002; Hughes n/d). However currently there are no digital maps available for Garrett County, Maryland (where Deep Creek Lake is located) therefore this study will test a different approach.

Historical aerial photos for Garrett County, MD from different years (1938, 1962, and 1988) were used. The photographs were obtained from a personal collection (John Ninesteel, Frostburg State University, Maryland) as scanned versions of the original and were geo-referenced (state plane coordinate system). No additional information was provided about the photographs. The shoreline was then digitized in ArcView 9.1 (ESRI, 2005). Figure 3 exemplifies the outcome of this step for the 1938 aerial photographs. On these digitized images the shoreline was mapped through onscreen digitization techniques (Gibson et al. 2002) by tracing the highest water marks on previously rectified aerial photos (Figure 4). A digital elevation model (DEM) (resolution 30 m) was downloaded in September 2005 from the United States Geological Survey (USGS), and for the purpose of capturing the slope line an attempt to interpolate a 3D line off the active surface was made (Figure 5).

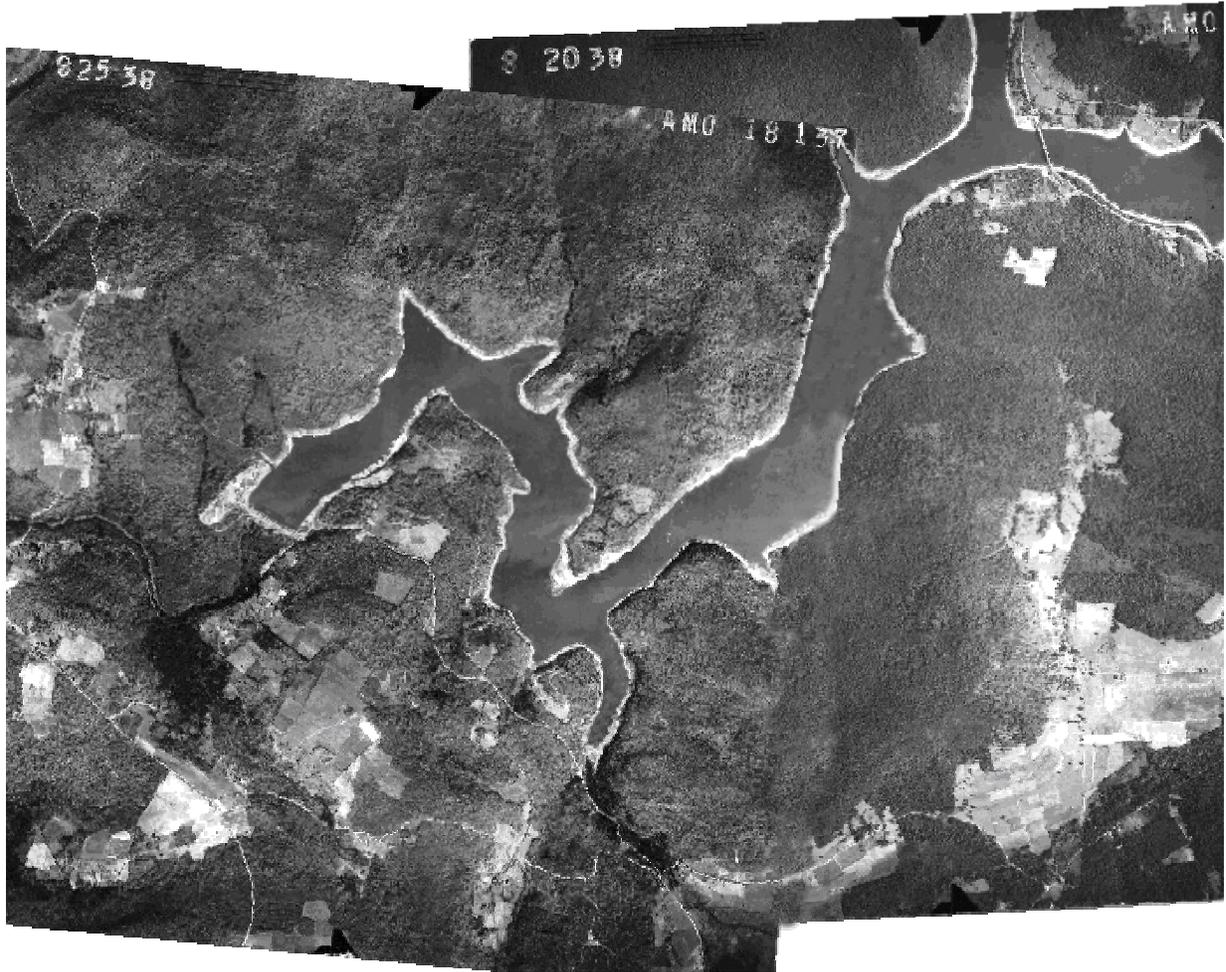


Figure 3. Geo-referenced 1938 Deep Creek Lake aerial photograph

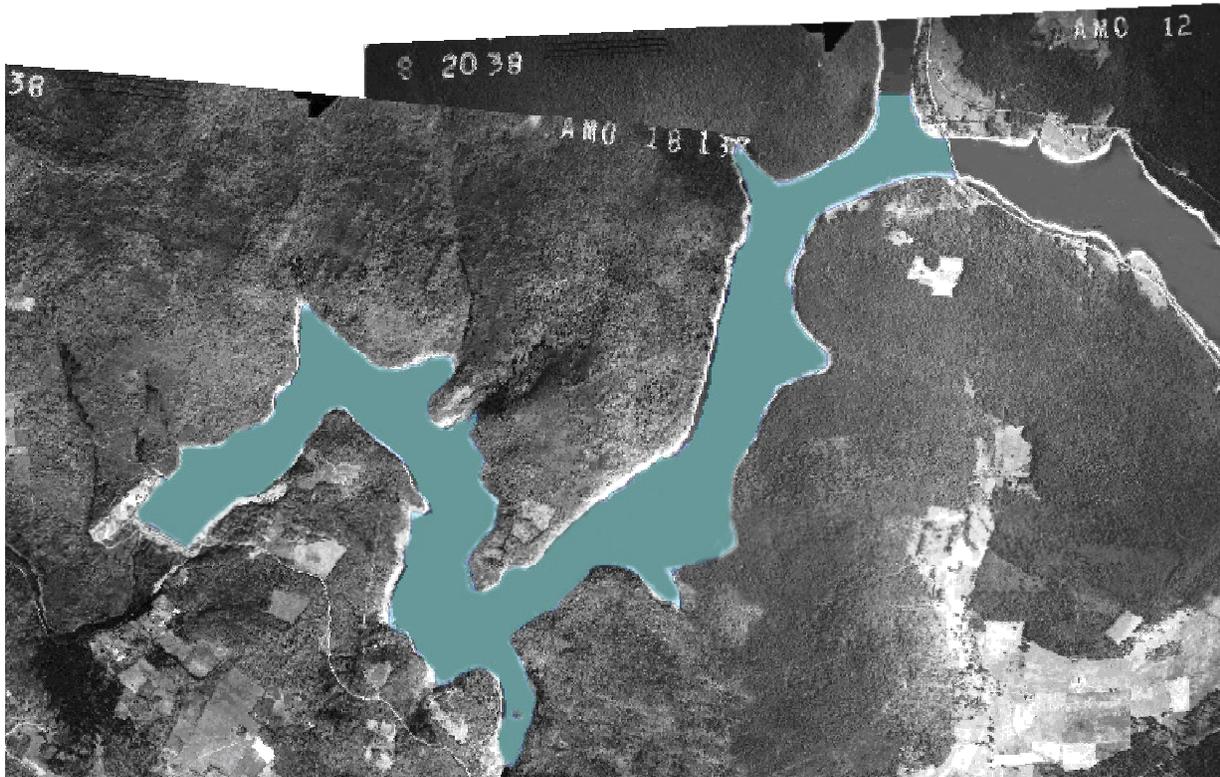


Figure 4. Lakeshore tracing on Digitized 1938 Deep Creek Lake aerial photograph

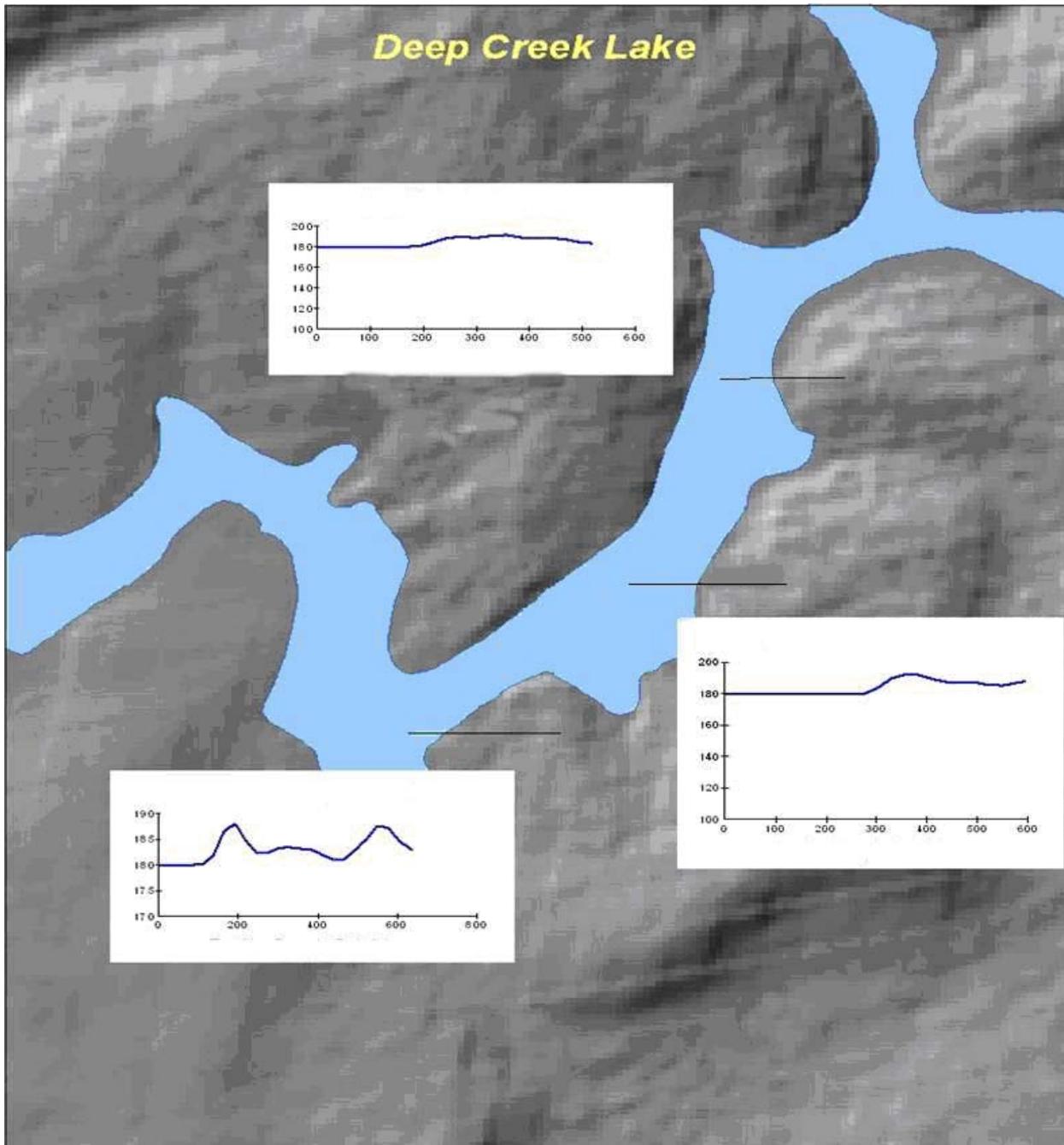


Figure 5. Linear interpolation of the shoreline DEM with the digitized 1938 Deep Creek Lake shoreline

Having a resolution of 30 x 30 m, the 3D image displayed an excessively coarse appearance, rendering the DEM image inappropriate for the purposes of this study. Due to this

technical detail, the subsequent steps were performed on original digitized aerial photographs. Digitized shorelines from multiple years were overlain in ArcView, followed by the spatial adjustment of vectorized shoreline (with the purpose of controlling for errors in interpretation of regression/advancement of the shoreline). A qualitative assessment of shoreline change was conducted in order to determine where and how much erosion occurred over time. Although the entire lakeshore was digitized, only one particular section- Northwestern- was examined in more depth, because anecdotal reports most often referred to this particular section (Figure 6).

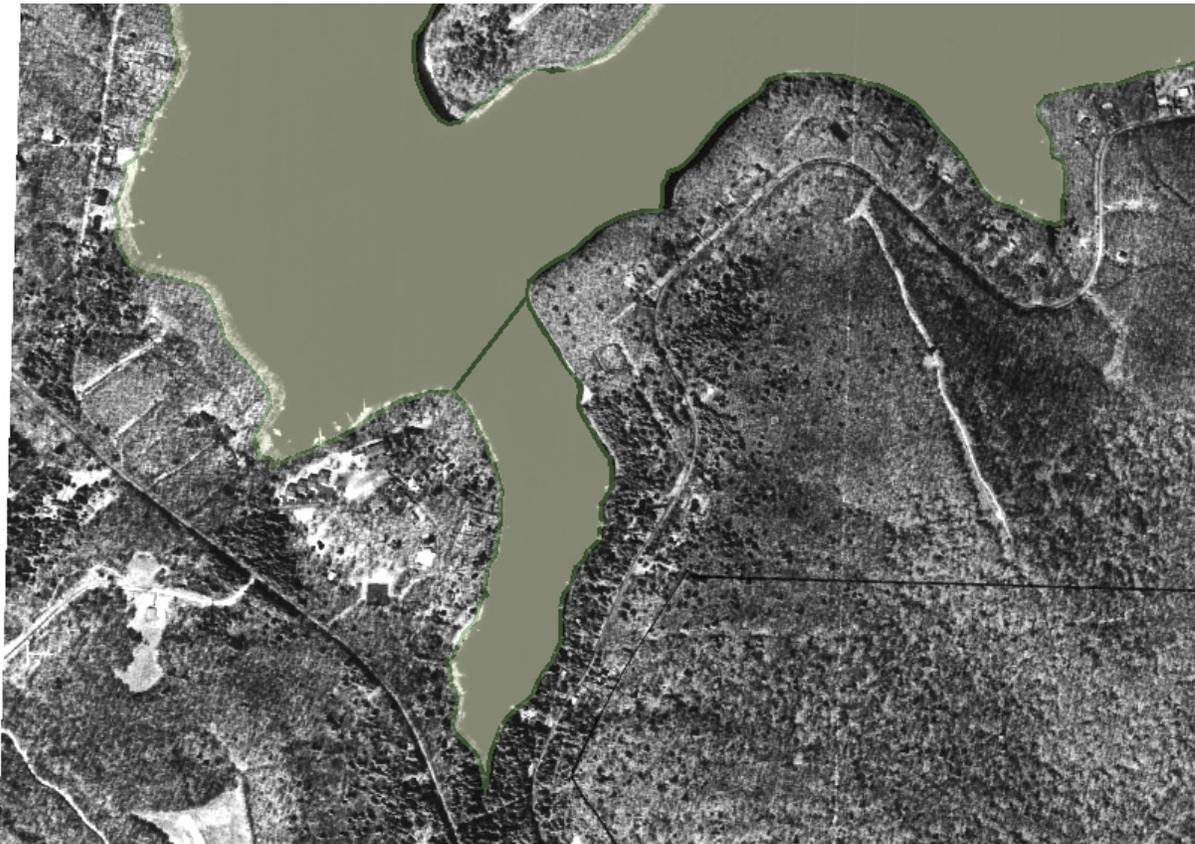


Figure 6. Spatial adjustment for the 1988 shoreline of Deep Creek Lake (Northwestern)

4.2: Survey of Property Owners to Determine Experiences and Perceptions of Shoreline Erosion Hazards

The second goal of this study was to survey lakefront property owners about erosion and to measure perceptions about the causes of shoreline erosion problems as well as their attitudes regarding the responsibility for shoreline control interventions. This part of the study was accomplished using a cross-sectional design to determine owners' attitudes. The rationale for using a quantitative tool for measuring attitudes was to obtain results that may be a useful reference in the near future, if recommendations from this study will be implemented. An innovative component was added to this study, consisting of a comparison of results from the shoreline digitization and location of self-reported erosion, thus attempting to validate both techniques. In other words, if images suggest that a shoreline change occurred in a certain sector of the lakeshore and in the same time a significant proportion of the survey respondents reported erosion in the same location, then both techniques validate each other and can be used in the future to determine lakeshore erosion.

The primary population to be studied consisted of owners of lakeshore properties or of other shoreline structures, such as dock slips, in Deep Creek Lake, MD. A list of property owners was identified at the Deep Creek Lake NRMA, containing approximately 90-95% of all owners of lakefront properties (Carolyn Matthews, Manager, Deep Creek Lake NRMA, personal communication). The list is updated every year. The 2006 list contained 1,994 names, from which a random sample of 323 owners was drawn. The sample size was such to ensure a 95% confidence interval with 5% margin of error, typical for this type of survey (Dillman 2000).

Data presented in this paper were collected using the survey method. A self-administered questionnaire was mailed to the study group in January and February 2007, following an

implementation procedure with proven effectiveness (Dillman 2000). The Institutional Review Board of the West Virginia University approved the study instrument and method (Appendix A).

The questionnaire used to collect data for this study was one that has been developed, implemented, and tested in a previous study of a similar population in Lake of the Woods (Phillips and Rasid 1996). It comprised a section with demographic questions and another section containing items to measure attitudes and perceptions regarding shoreline erosion in Deep Creek Lake. The study questionnaire focused on owners' direct experience of the shoreline erosion, their understanding of the problem and their perceptions of the causes that could result in property loss. The questionnaire was derived from the working hypothesis that hazard perception and attitude are influenced by respondent's own experience of the hazard (Rowntree 1974). With permission and feedback from one of the authors (Prof. Harun Rasid, University of Wisconsin), in addition to modifications of the layout of the original questionnaire, several sections were adapted to the local area profile and items were added that were relevant to specific elements in Deep Creek Lake (Appendix B).

The study instrument was reviewed by the president of the Property Owners Association of Deep Creek Lake, MD, and the Lake Manager of the Deep Creek Lake NRMA. The two reviewers represent the interests of the two major categories involved in the survey, the owners of lakefront properties and the owner and regulatory board for the shoreline itself.

In order to assess its reliability, the questionnaire was pre-tested with 5 owners having characteristics similar to the subjects in the study group. Questions asked during the pretest attempted to establish whether the content is appropriate to the study population and to identify other respondent-friendly features. Following the pre-test, only minor changes were incorporated in the final version of the questionnaire.

The 4-page survey questionnaire, containing mostly closed-ended items, was divided into four sections. One section of the questionnaire consisted of questions meant to characterize the owner and the property, such as the length of the property ownership, the section of the lakeshore where the property is located (zip code), the type of property (residential/commercial), and the type of occupancy (seasonal or year-round). Another section explored the owners' personal experience of property shoreline hazards (what kind of processes, if any, attributable to erosion they experienced) and whether any action was taken (such as erosion-related incidents reported to DNR and/or applications for permit to build control structure and/or construction of said structure). Another section assessed lakefront property owners' understanding and perceptions of the causes of shoreline erosion (such as erosion-prone natural characteristics of the shore, lake level fluctuations, wave-generating summertime watercraft activities, and inadequate building setback). A final section of the questionnaire asked the owners about their preference for controlling and reducing shore property hazards and who should bear the responsibility for the application of solution measures. The study instrument was designed to measure attitudes regarding potential causes for erosion and proposed control methods by using a 5-point subjective, Likert rating scale: *extremely important/effective*, *very important/effective*, *moderately important/effective*, *slightly important/effective*, and *not at all important/effective*. Each category was assigned a score from 5 (*extremely important/effective*) to 1 (*not at all important/effective*).

As mentioned above, the questionnaire in its final version was mailed to 323 owners, at the address under which the owner is listed in the abovementioned database, which is the person's permanent address and, in most cases, not the local address where the lakefront property is located. The implementation of the survey followed the steps described by Dillman (2000)

and consisted of two separate mailings. The first mailing included the survey questionnaire, a cover letter from the principal investigator, a letter from the president of the Property Owners Association (POA) of Deep Creek Lake, and a stamped self-addressed return envelope. Ten days after the first mailing, all non-respondents were sent a replacement packet with the same content as the first mailing. Steps to increase the response rate as much as possible were taken, such as mailing the questionnaire along with a cover letter co-signed by the president of the POA, actively involved in the area, and including a stamped, self-addressed envelope for returning the questionnaire. No incentive was provided for this survey.

All statistical analysis for this study was performed using SPSS[®] Base 15.0 for Windows (2006, SPSS Inc, Chicago, IL). Descriptive statistics were first calculated and analyzed for the following variables: length of the property ownership, the section of the lakeshore where the property is located (zip code), the type of property (residential/commercial), and the type of occupancy (seasonal or year-round). Using median scores, the respondent were grouped by the zipcode of their Deep Creek Lake property address and compared for overall attitudes and perceptions by using the chi-square test or a non-parametric test. For all analyses described here the statistical significance was set at a $p < 0.05$.

The specific goal of the survey was to obtain direct information regarding the existence, location, and extent of erosion, and to examine whether or not there is a parallel between the results of digitized shoreline change analysis and self-reported data on erosion.

Chapter 5. Results

5.1: Shoreline Erosion in Deep Creek Lake

Shoreline in the Northwestern sector of Deep Creek Lake, Maryland appears to have receded over the years from 1938 until 1988, as Figure 7 demonstrates, which also shows that the process is not uniformly distributed around the lake. In some sections, the process may have stabilized after a certain time, whereas in others it may have been constant or it may have started a long time after the lake was created.

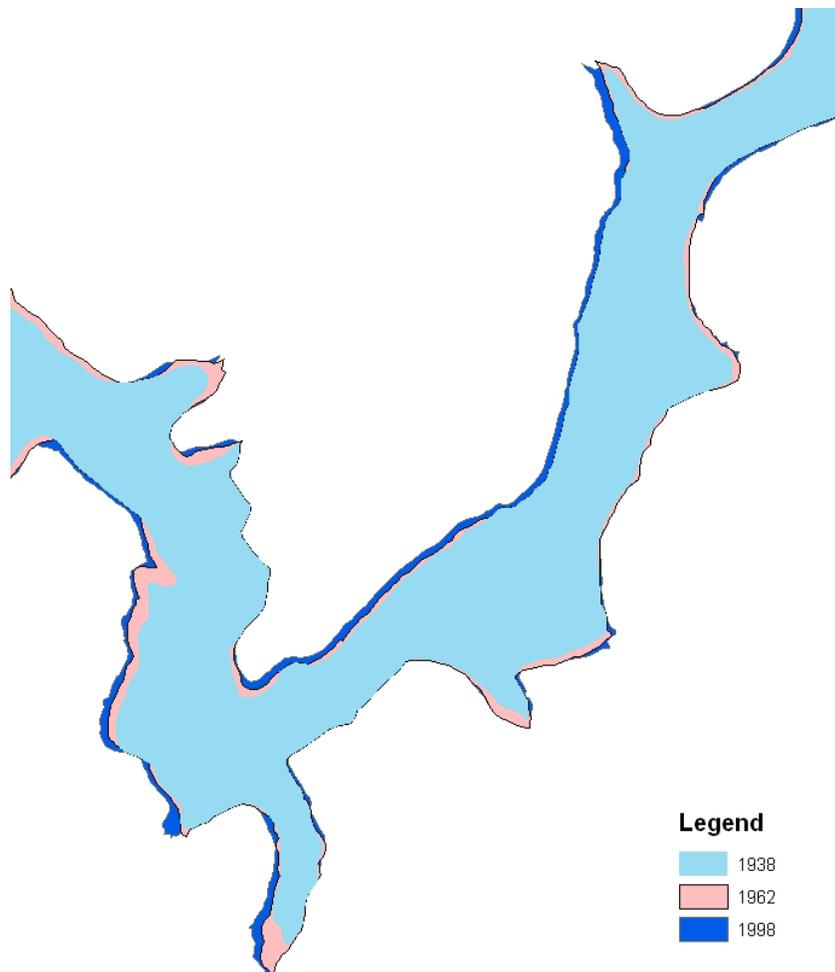


Figure 7. Overlays of 1938 (light blue), 1962 (pink), and 1988 (dark blue) Deep Creek Lake shoreline

5.2: Owners Experiences and Perceptions of Shoreline Erosion in Deep Creek Lake

Of the 323 owners surveyed in the sample, the questionnaire was returned by 221 respondents. Among these, one indicated that the address was no longer valid and nine were excluded as non-eligible (no longer owned a property in Deep Creek Lake). Overall the return rate was determined to be 67.4 percent. Without the survey, the only information about owners consisted of the address of their main residence, therefore, little comparison between respondents and non-respondents was possible. Based on the zipcode where the survey was mailed, most respondents were from Maryland (51 percent), followed by Pennsylvania (21 percent), and Virginia (16 percent), whereas non-respondents were from Maryland (50 percent), Pennsylvania 25 percent), and Virginia (11 percent).

Description of respondents and their properties

A general characterization of the ownership is presented in Table 1.

Table 1. Characteristics of the lakeshore property ownership in Deep Creek Lake, Maryland

Length of Property Ownership (years)			Current Type of Property Use (%)		Use of Individual Property (%)		Length of Shoreline (feet)		
<i>(n=221)</i>			<i>(n=221)</i>		<i>(n=221)</i>		<i>(n=221)</i>		
Mean	Median	SD	Individual Use	Commercial /Rental	Vacation Home	Main Residence	Mean	Median	SD
21.6	17.0	18.3	90.0	10.0	81.5	18.5	143.8	100.0	230.5

Most respondents (over 75 percent) owned their lakefront property for more than 33 years, whereas 25 percent became owners in the last 7 years or less (data not presented). A large majority of respondents owns a private vacation residence and only 10 percent owns commercial property on the lake shore (defined as real estate used for business). Most of the private residences are in fact second homes and only a small proportion of the respondents live all year round in their Deep Creek Lake homes. Examining the length of the property's shoreline, it

appears that 50 percent of the respondents have at least 100 feet of shoreline (with a minimum of 13 and a maximum of 3,000 feet).

The distribution of respondents by the zip code of their local address (Figure 8) indicates that most properties are located in Swanton, followed by Oakland and McHenry.

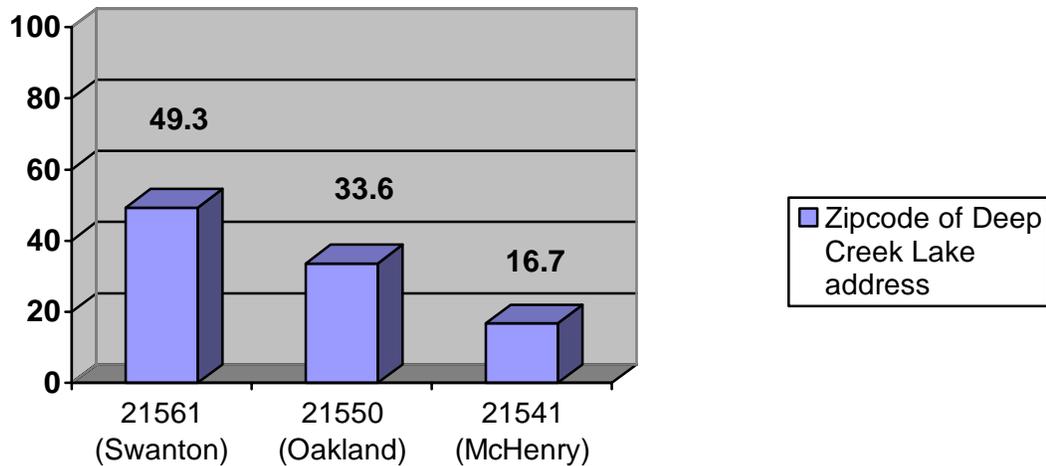


Figure 8. Distribution of respondent Deep Creek Lake addresses

Experience with erosion

A very important section of the questionnaire collected information about existence of erosion and/or events highly suggestive of shoreline erosion. Almost 69 percent of respondents answered that they had erosion on the shore of their lakefront property, whereas 24.4 percent reported that they did not have erosion and 7.2 percent were not sure. Based on the zipcode of the property location of those who had erosion on their property, 19.9 percent of the respondents have property in McHenry (21541), 32.1 percent in Oakland (21550), and 48.2 percent in Swanton (21561). A Chi-square test performed to analyze differences between these three groups showed no statistical significance.

Owners' experience with erosion was further explored by asking them to indicate the occurrence of changes and/or events that could be considered proxy measures of erosion. The rationale for adding this item was to explore the respondents' correct understanding of "erosion" by eliciting responses to specific events. Figure 9 describes this distribution.

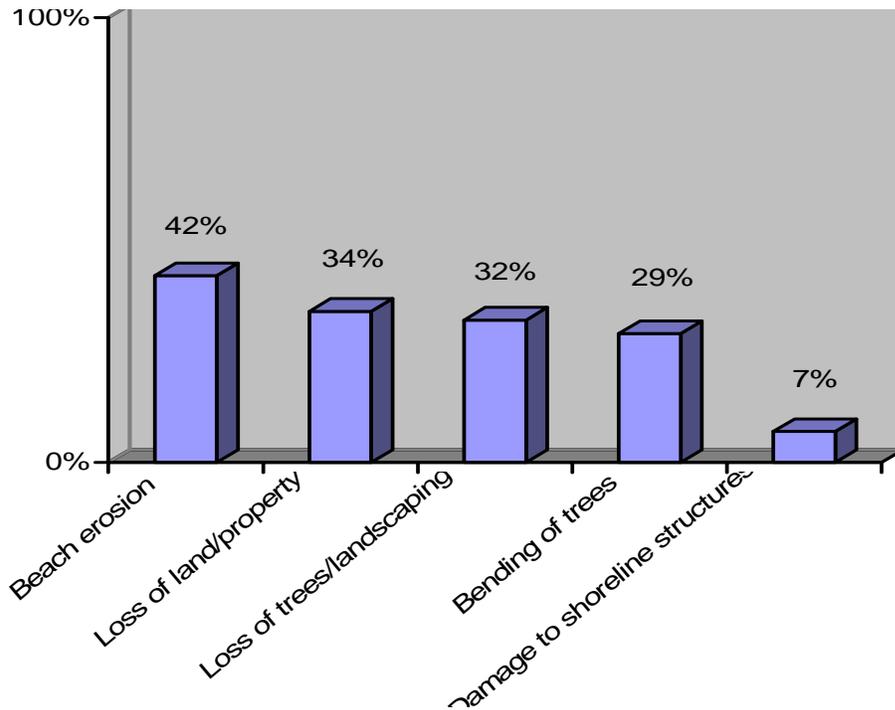


Figure 9. Distribution of erosion-related events in Deep Creek Lake

When responses to these categories were cross-referenced with the answers indicating the occurrence of generic "erosion" on their property, beach erosion was specifically experienced by almost 61 percent; loss of land, by 49.6 percent; loss of trees, by 46.9 percent; bending of trees, by almost 42 percent; damage to shoreline structure, by almost 10 percent; and other kind of erosion (such as degradation of an erosion-control measure, i.e. a retaining wall; hillside sliding; erosion occurring only after the construction of a retaining wall on adjacent property) by 9 percent of respondents. Since the respondents had the option of more than one answer, these

results indicate that some properties experienced more than one type of change indicative of erosion. Overall, the responses indicate that the owners responded affirmatively to the generic question about erosion and also identified one of the possible erosion-related events in equal proportions, suggesting that the 69 percent erosion in general is not an overestimation.

In general, analysis suggests that on the average, these erosion-related events are reported to have occurred in recent years (Table 2).

Table 2. Mean number of years since a specific erosion-related event has occurred

Beach erosion	Loss of land/property	Loss of trees/landscaping	Bending of trees	Damage to shoreline structures	Erosion problems elsewhere	Other erosion-related event
16.6	15.4	12.2	14.5	11.2	24.9	11.2

When asked if they ever had applied for a permit to address consequences of erosion, almost 30 percent of the respondents did not give an answer to the question. Of those who answered and indicated that they ever experienced erosion on their property, only 11 percent applied for a permit to address the change that occurred. However, when asked what type of protection measure was taken to address erosion-related events, those reporting various measures represented a larger percentage than those who applied for a permit. The most frequent type of protection measure taken by the owner was a retaining wall, followed by riprap and planting vegetation.

Regarding the application to obtain a permit to address erosion problems, the owners were asked to rate their experience and satisfaction with the process. Surprisingly (because only a small number indicated ever applying for such permit), of those who indicated ever experiencing erosion, 107 responded to this question. The mean satisfaction score was 4.2 (a

scale from 1 to 10 was given, with 1 being the lowest and 10 the biggest satisfaction score). A test for statistical significance (Mann-Whitney non-parametric test) was performed to determine if the satisfaction of those who indeed applied for a permit is different than of those who apparently did not apply, but still indicated their level of satisfaction. The result of 0.029 is smaller than the set p value of 0.05, supporting significant difference.

Perceived cause of erosion problems

When owners’ perceptions of the potential causes of erosion were explored, 61.6 percent indicated boat wakes to be extremely important, 58.9 percent considered wave action to be extremely important, and 26.5 percent saw lake level regulations to be extremely important. Other potential causes, such as inadequate building setback or beach width or tree cutting along the shore were considered slightly or not at all important by most respondents. Because of the nature of the data, a non-parametric test (Mann-Whitney) was performed to explore differences in the importance attributed to certain events in inducing erosion based on direct experience of erosion (Table 3).

Table 3. Relationship between the importance attributed to causes of erosion problems and experience of erosion on lakefront property

	Importance of wave action (n=185)	Importance of building setback (n=154)	Importance of beach width (n=149)	Importance of boat wakes (n=184)	Importance of lake level fluctuation (n=167)	Importance of tree cutting along the shore (n=158)	Importance of storm event (n=163)
Experienced erosion on property	75.1%*	74.5%*	71.8%	74.5%*	73.6%	72.2%	74.2%
Did not experience erosion on property	24.9%	25.5%	28.2%	25.5%	26.4%	27.8%	25.8%

* significant at $p < 0.05$

Solution preferences for shoreline erosion control

Owners' beliefs regarding the effectiveness of certain erosion control measures were also explored in the survey. Almost 38 percent believe that no wake zones are extremely important in controlling erosion in Deep Creek Lake, 33.6 percent believe that shore protection structure are extremely important and 25.6 percent believe that lake level regulations are extremely important. Other measures (setting specific building setback or beach width or preventing tree cutting along the shore) were perceived not at all or only slightly effective by most respondents. Exploring the differences in perceived effectiveness between those who ever applied for a permit to undertake shore protection structures and those who did not, it appears that they are statistically significant (Mann-Whitney test, $p = 0.04$).

Owners' attitude regarding financial responsibility for applying measures to control erosion in Deep Creek Lake was explored in the survey. Respondents were given the option to select more than one option from: individual property owner, Maryland DNR, MDE, or other party. By far (66.4 percent), most respondents hold Maryland DNR financially responsible, followed by the owners themselves (45.5 percent) and the MDE (28.9 percent). Other potential financial support was indicated by 11.4 percent of respondents, with examples such as grants from the County Commission to the owners for constructing erosion-control measures, the hydro-electrical power plant, users of lake as recreational resource (aka, tourists and renters). A quarter of the respondents indicated Maryland DNR and individual owner in the same time, suggesting respondents' belief that the financial burden could be shared.

Chapter 6. Summary and Conclusions

One of the objective of the present study was to map Deep Creek Lake shoreline on successive historical aerial photos and to detect development of erosion over time by comparing these digitized photographs. This section of the paper discusses the limitations of the technique for the particular circumstances of Deep Creek Lake and the usefulness of such an approach in similar studies.

Another objective of the present study was to collect information about actual erosion from owners of lakefront properties in Deep Creek Lake and to assess their experiences and perceptions of shoreline erosion hazards. A survey was conducted in order to achieve this objective, and the findings support the idea that the survey methodology is good for similar purposes.

6.1. Limitations

Limitations of the methods described include the fact that a qualitative analysis of shoreline change cannot be descriptive enough if changes are only on a small scale; and self-reported data on erosion can overestimate the location and/or extent of erosion.

6.2. Discussion of Results

Prior to digitization of the aerial photographs of Deep Creek Lake, a spatial arrangement of the area had to be performed, even though the images were first geo-referenced. This step alone is not sufficient for a good definition and spatial analysis of the area of study, because after geographic repositioning and definition of a certain projection, a slight spatial deviation still persists. The visible consequence is a spatial error that later requires a supplemental step of spatial repositioning of the shoreline. The following step consisted of visual interpretation of the shoreline and elimination of layer overlapping in ArcMap. In order to emphasize the changes

that occurred over time, the overlapping areas have been eliminated and only non-overlapping areas were kept.

Even though the shoreline change has been demonstrated with this technique, a particularity has to be taken into consideration. The oldest available photographs (1938) present an unusually broad shoreline, at least for the time of the year when they were taken. Although captured in the summer, at a time of typically highest lake levels, the lake appears much smaller, as if it was empty. On the other hand the archives of the hydro-electrical company did not record any particular event for that month and year. This peculiarity made the overlaying step somewhat tedious, but the final image captures the lines in such a way that the visualization and digitization of shoreline were made with minimum of error.

Without digital maps for the area in which Deep Creek Lake is located or other resources such as digitized topographic and soil maps, a thorough assessment of the entire 62 miles of shoreline appears unpractical. For example, a digital soil map would provide the best information to clarify why in some areas erosion occurred more often or at a faster rate, as the process of erosion relates to the physical and chemical characteristics of the soils. A detailed geological map at a large scale (1:24,000-1:48,000), although not as good as the soil map, would still be capable to substitute a soil map to explain erosion in particular areas, but current maps including Deep Creek Lake do not provide such detail. To the same extent, a land cover and/or land use maps would be useful, but only if they are at a detailed scale, in order to be able to explain for instance, why areas of the shoreline where vegetation was removed erode faster. The area in which Deep Creek Lake is located has only regional importance, therefore not much climatic data is usually available in a systematic form (the only meteorological station was

closed in the 1970s). The pattern of prevailing wind could potentially explain, at least in part, the extent of the erosion phenomenon in some areas.

The digitization technique has its informative value, in that it can indicate large sections of the shoreline where the process was slow but steady, or sectors in which a trend for new erosion may be evident. Collecting direct information from lakefront property owners, even through self-reports like an annual survey, could be a more practical and not very expensive alternative.

The survey return rate of 67.4 percent allows for generalization of results to the entire study area and population. It appears that erosion, taking forms such as beach erosion, loss of trees or property, indeed exists in Deep Creek Lake. The changes observed in the analysis of digitized imagery (besides being explained by the limitations of the technique itself) could be due to a process that is slow in most cases, yet still significant at the individual level of perception. On the average, current owners have been in the area for 21.6 years, which allows them to accurately date erosion-related events that occurred in the last 10-15 years. It was one of the goals of this study to determine where erosion is more often reported, but the lack of statistical significance of differences among the groups of owners having property addresses under one of the three zip codes does not allow for a definitive answer. It is possible that erosion, under different forms and rates, occurs everywhere around the lake. Also it is possible that more of those who did not experience erosion are in the non-respondent group (since the exact location of their Deep Creek Lake property could not be determined). The greatest limitation to collecting erosion information in this manner is inability to locate in greater detail a report on erosion. The present study divided 62 miles in three broad areas (defined by their

postal code), or the digitized images showed differences from one sector to another at a much detailed scale.

The results of this study confirm the hypothesis that hazard perception and attitude are influenced by respondent's own experience of the hazard. Those who experienced erosion believed that wave action in general or lake level regulations are instrumental in inducing erosion in Deep Creek Lake, more often than those who did not report erosion. This in fact confirms what owners have complained about for many years and what a previous carrying capacity study has determined. Also it appears that those who believe in the effectiveness of a certain erosion control measure, such as shoreline erosion control structures, are more likely to apply for such permit. This appears to be true regardless of the low level of satisfaction with the administrative process, either experienced directly or indirectly. On the other hand, some respondents observed that erosion of their lakefront occurred only when adjacent properties had erosion-control measures built on the shoreline. Finally, erosion and related factors affects some properties indirectly: sedimentation from erosion induces shallow shores in other areas, therefore making higher levels of the lake more desirable, with the effect that this apparently increasing erosion in steeper sections.

Regarding the involvement of authorities in the process, the finding that many respondents believe that the financial responsibility for applying erosion control measures can be shared is encouraging. Another example from the survey is that many respondents wish the administration to be more open in how it sees the preservation of the shoreline to be conducted. Many respondents complained about long processing times for applications requesting an erosion-control structure to be built on their property, only to be denied approval. The survey questionnaire did not ask property owners to specify the year of their experience with the

application. A more transparent set of guidelines for what can or can not be appropriate on their property will, in their view, improve cooperation with the authorities. It is true, on the other hand, that Deep Creek Lake NRMA now reviews the MDE application prior to its submission, to MDE to assure that the forms are filled out correctly and they will not be erroneously declined due to application errors.

6.3. Conclusions and Recommendations

Much of the process of analyzing shoreline changes on digitized images of Deep Creek Lake would have been significantly improved if digitized maps of the region would have been available. This is in fact a very important tool in today's water resources management and planning (Cech 2005), therefore one recommendation from the study for the Maryland DNR is to actively seek that the last undigitized county in Maryland receives attention.

A better determination of self-reported erosion would have been enabled by knowing owners' Deep Creek Lake addresses along with their main residence mailing addresses. Not being able to locate non-respondents on the lakeshore map is major limitation in establishing a pattern of erosion. However some trends are evident from the results of the study. In Deep Creek Lake, beach erosion and loss of land are the most frequent occurrences of erosion. At the same time, although their belief in the effectiveness of certain measures is clearly expressed, most owners do not choose to address these erosion-related events. Possible explanations could be found in the results of this study, including low level of satisfaction with the administrative process or perceived financial burden for the individual owner. Overall, a survey such as the one used in this study appears feasible and effective in collecting data regarding property issues.

Another recommendation from this study for the administration of Maryland DNR is to work closer with owners and their associations to actively educate them regarding the general

process of application for a permit, regarding the Maryland MDE regulations for shoreline protection and erosion control measures. Maryland MDE is primarily interested in preserving the natural beauty and ecology of the lakeshore, limiting interventions to the extent possible, but in the same time the owners of properties located on the shore are equally entitled to preservation of the integrity of their property.

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Appendix A: IRB Approval



MEMORANDUM

TO: Catalin Demain; Geography

FROM: Fred L. King
Associate Dean for
Research and Graduate Studies

DATE: November 20, 2006

RE: *Shorline Erosion in Deep Creek Lake, MD: Patterns, Trends and Economic Implications*

The Institutional Review Board for the Protection of Human Research Subjects (IRB) finds the above named research project qualifies as an exemption under category 2.

This finding will remain in effect only on the condition that the research is carried out *exactly* as described in the Application. Please submit an amendment to the IRB office if you intend to modify or change your study in any way. Any amendment must be reviewed and acknowledged before initiating any changes or modifications

Best wishes for the success of your research.

Phone: 304-293-4611
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Equal Opportunity/Affirmative Action Institution

Appendix B: Survey Questionnaire

DEEP CREEK LAKEFRONT PROPERTY OWNER SURVEY ON SHORELINE EROSION

This shoreline erosion survey is being conducted as part of the requirements for a Masters in Geography thesis at West Virginia University (Morgantown, WV). The study aims at surveying Deep Creek lakefront property owners' experience with shoreline erosion, their perceptions of the probable causes of shoreline erosion problems, and their understanding of responsibilities involved in preservation of shoreline. All information will be regarded as strictly confidential and will be used only for analytical purposes. For your convenience, we have tried to compile exhaustive lists of possible answers, but we realize that such a list is sometimes impossible to generate. As a result, you may find that the answer you most prefer is not already listed. This does not mean that your most preferred answer is incorrect; it simply means that it is not one of the most common. If you encounter such an item, feel free to use the "other" category and be as descriptive as possible. Please know that we greatly appreciate your input and value your honesty.

Demographic Information

1. How many years have you been the owner of your lakefront property at Deep Creek Lake? _____
2. Please indicate what the current use of your lakefront property at Deep Creek Lake is? **(Check only one answer)**
 Commercial/Rental Private
3. If you marked "Private", please indicate what type of dwelling is your lakefront property at Deep Creek Lake: **(Check only one answer)**
 Main residence (year-round) Second residence (vacation home)
4. What is the postal code (zip code) of the address at which your lakefront property in Deep Creek Lake is located? **(Check only one answer)**
 21541 (McHenry)
 21550 (Oakland)
 21561 (Swanton)
5. What is the approximate length of your property's shoreline? _____ feet
Check here if you do not know the answer.

Questions continue on back →

Experience with Erosion

Lake shoreline erosion refers to the process by which soil particles located along lakeshores become detached and transported away by wave energy.

6. Have you ever experienced shoreline erosion on your lakefront property in Deep Creek Lake?

Yes

No

Not sure

7. Following is a list of changes that may have occurred on the shoreline adjacent to your lakefront property. Please **check all that apply** and mark the year when the change became noticeable.

- | | |
|---|--|
| <input type="checkbox"/> Beach erosion _____ (year) | <input type="checkbox"/> Damage to shoreline structures (i.e., dock, shed) __ (year) |
| <input type="checkbox"/> Loss of land/Property _____ (year) | <input type="checkbox"/> Erosion problems elsewhere _____ (year) |
| <input type="checkbox"/> Loss of trees/landscaping _____ (year) | <input type="checkbox"/> Other: _____ (year) |
| <input type="checkbox"/> Bending of trees _____ (year) | |

If you did not experience any of the changes listed, check here and skip to Question # 10.

8. If you checked at least one answer in Question # 7, have you ever applied for a permit to undertake a protection measure to your eroded shoreline?

Yes

No

9. If you checked at least one answer in Question # 7, what protection measure, if any, have you undertaken: (**Check all that apply**)

Riprap

Relocation of damaged structure

Retaining wall

Insurance

Planting vegetation

Other:

If you did not take any measure, check here

Questions continue on page 3

Perceived Causes of Erosion Problems

10. Please rate the importance to you of *each* of the following factors in contributing to erosion problems in Deep Creek Lake: **(Check one box on each line)**

	Extremely Important	Very Important	Moderately Important	Slightly Important	Not at all Important
a. Wave action	<input type="checkbox"/>				
b. Inadequate building setback	<input type="checkbox"/>				
c. Inadequate beach width	<input type="checkbox"/>				
d. Boat wakes	<input type="checkbox"/>				
e. Lake level fluctuation	<input type="checkbox"/>				
f. Tree cutting along the shoreline	<input type="checkbox"/>				
g. Storm event	<input type="checkbox"/>				

Solution Preferences for Shoreline Erosion

11. How effective or ineffective do you believe the following solutions are as measures for shoreline erosion control in Deep Creek Lake?
(Check one box on each line)

	Extremely Effective	Very Effective	Moderately Effective	Slightly Effective	Not at all Effective
a. Regulate lake levels	<input type="checkbox"/>				
b. Designation of no wake zones	<input type="checkbox"/>				
c. Install shore protection structures	<input type="checkbox"/>				
d. Plant vegetation	<input type="checkbox"/>				
e. Land use regulations	<input type="checkbox"/>				
f. Adequate building setback	<input type="checkbox"/>				
g. Other measure (please describe): _____	<input type="checkbox"/>				

Questions continue on back →

12. Please indicate on a scale of 1-10 (with 1 being the lowest and 10 the highest) how satisfied you are with the current permit application process to undertake measures for shoreline stabilization in Deep Creek Lake. **(circle one)**

1 2 3 4 5 6 7 8 9 10

Check here if not applicable.

13. Please indicate whom you believe should be financially responsible for application of solution measures for shoreline stabilization?

(Check all that apply)

- Each lakefront property owner Maryland Department of Environment
 State of Maryland Dept. of Natural Resources Other (describe): _____

14. Do you have any other comments regarding shoreline erosion at Deep Creek Lake?

**Thank you very much for completing this survey.
Please return it in the enclosed postage-paid envelope to:
Catalin Demian
50 Price Hill Road
Morgantown, WV 26501**