A COMPARISON OF RURAL AND URBAN FLUVIAL SYSTEMS AS A FUNCTION
OF LAND COVER CHANGES IN SUMMIT COUNTY, OHIO

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A COMPARISON OF RURAL AND URBAN FLUVIAL SYSTEMS AS A FUNCTION
OF LAND COVER CHANGES IN SUMMIT COUNTY, OHIO

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ABSTRACT

Population growth during the 20th century in Northeast Ohio has led to an overall increase in developed land cover and anthropogenic pollution such as fossil fuel combustion. Urban expansion and fossil fuel combustion result in an increase of polluted runoff into fluvial systems, which jeopardizes water quality, undermines infrastructure, and stresses local ecosystems that buffer floods. This study compares heavy metal pollution levels and land cover change during the 20th century in dammed impoundments within the rural Haskell Run watershed (Lake Butler), the rural Ritchie Run (Lake Litchfield), and the urban Mud Brook watershed (Old Mill Pond) in Northeast Ohio. Surficial sediment samples were collected from each impoundment to assess current pollution levels and sediment cores were collected for the past record of pollution. The two end-member watershed types have similar bedrock, glacial history, and climate, however, land cover differs greatly. Between 1985-2010, there was no land cover change in the rural Ritchie Run watershed, and in 2010, Ritchie Run had 3.4% developed land cover and 0.63% impervious cover. During the same period, the rural Haskell Run watershed increased by 1.37% in developed land cover, and in 2010, 12% of the Haskell Run watershed was developed land and 3.3% was impervious cover. Developed land cover, from 1985-2010, increased by 15.3% in the urban Mud Brook watershed, and in 2010, 74% was developed land cover and 23% was impervious cover. Old Mill Pond impoundment sediments were found to have higher heavy metal and ferrimagnetic concentrations, whereas, Lakes Butler and Litchfield sediments have comparatively lower heavy metal and ferrimagnetic concentrations. There is a moderate direct relationship

between heavy metal and ferrimagnetic content. Therefore, magnetics can be used as an inexpensive and rapid screening tool for heavy metal pollution studies. The Old Mill Pond sediment core records an increase in heavy metal and ferrimagnetic concentration in the early 20th century, peaking in the 1940s-1960s when Cuyahoga Falls experienced a doubling in population. Since the 1970s-1980s, after the Clean Air Act (1970) and Clean Water Act (1972) were enacted, the heavy metal and ferrimagnetic concentrations decreased to present-day. The study supports that more developed land cover and impervious surfaces in a watershed lead to higher levels of anthropogenic related pollutants in fluvial systems. Sediment cores and aerial photographs from Lakes Butler and Litchfield indicate a history of both delta progradation and flood events. Studies, such as this, can assist in informing local policy makers and land managers when considering the effects of urban expansion, preservation of ecosystems and undeveloped spaces, and the effectiveness of national and local environmental regulations.

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CHAPTER I

INTRODUCTION

1.1 Overview and Significance

Population growth and urban expansion within the Cuyahoga River watershed has contributed to an increase in developed land cover and anthropogenic pollution, namely fossil fuel combustion products. Land cover and pollution changes impact local fluvial systems and influence sediment delivery, geomorphology, and pollution levels captured in the sediment record. The goal of this research project is to evaluate differences in sediment delivery and sediment type from subwatersheds of the Cuyahoga River having contrasting land cover change histories. Numerous studies have successfully utilized sediment core, GIS, and watershed ecology analysis to assess the anthropogenic impacts of the 20th century land cover changes on the fluvial environment (Peck et al., 2007; Muller et al., 2009; Mann et al., 2013; Shaw, 2013; Kibene et al., 2014; Webb-Sullivan and Evans, 2014; Lin et al., 2015).

The two subwatersheds of the Cuyahoga River for this thesis, Haskell Run/Ritchie Run and Mud Brook, are both located in Summit County, Ohio (Figure 1). Haskell Run/Ritchie Run and Mud Brook have similar slopes, climate, glacial history, and underlying bedrock; however, they have contrasting land cover change histories. The Haskell Run/Ritchie Run watersheds have remained largely undeveloped and contain two dammed impoundments called Lake Butler and Lake Litchfield (Figure 2), whereas the middle Mud Brook watershed is highly developed and contains a dammed impoundment called Old Mill Pond (Figure 3). These impoundments provide sediment records spanning the last half-century.

Figure 1. Watersheds for the three study impoundments (Butler, Litchfield, and Old Mill Pond) within the Cuyahoga River watershed in Northeast Ohio (US Census, 2015; ESRI, 2017; USDA, 2017).

Figure 2. Aerial photo showing Lake Butler in the Haskell Run watershed and Lake Litchfield in the Ritchie Run watershed (ESRI, 2016).

My first hypothesis is that the Old Mill Pond sediment will contain elevated levels of heavy metals and ferrimagnetic particles due to increased urbanization in the Mud Brook watershed, whereas Lakes Butler and Litchfield sediment will have comparatively low levels of heavy metals and ferrimagnetic particles owing to less development in the Haskell Run/Ritchie Run watersheds. Combustion pollution often has high concentrations of coarse-grained ferrimagnetic particles (Evans & Heller, 2003). Thus, I have an additional research question that will determine if sediment magnetic properties can be used as a pollution proxy.

Since July 2003, there has been an increase in the frequency of heavy precipitation and flooding events in Northeast Ohio (Liberatore, 2013). Increased precipitation and flooding often leads to higher rates of sedimentation and higher energy conditions that transport larger particles. My second hypothesis is that increased sedimentation and larger grain sizes will occur in the impoundments of both watersheds due to more frequent flooding since 2003.

To address these hypotheses, land cover change through time was assessed. Sediment samples from each impoundment were collected and analyzed for grain size, physical properties, heavy metals, and magnetic properties. Changes to the shoreline of the deltas in each impoundment were assessed using a series of aerial photographs (Google, 2016; Summit County Fiscal Office, 2016; Summit County Parcel Viewer, 2016; USGS, 2016b).

With a changing regional climate, strategic planning based in scientific research is critical to support better-informed local policy regarding people and ecosystems (Cook et al., 2014). This study will afford new insights into sedimentation in the Cuyahoga River by examining watersheds with contrasting land cover.

Figure 3. Aerial photo showing Old Mill Pond in the middle Mud Brook watershed (ESRI, 2016).

1.2 Physical Setting of the Study Sites

Two watersheds, one rural and one urban, each with dammed impoundments, were selected for study (Figures 2 and 3). Both watersheds are located in Summit County, Ohio, and drain into the Cuyahoga River. Owing to their close proximity, the two watersheds have been subjected to similar increases in precipitation and flooding events since July 2003.

Haskell Run (Lake Butler) and Ritchie Run (Lake Litchfield) are two rural watersheds adjacent to each other. For the purposes of this project, they are both considered to be the rural endmember watershed type (Figure 2). The Lake Butler dam was constructed between 1958 to 1963, and the Lake Litchfield dam was built in 1975 and the water level was raised for boating around 1977-1978 (Cardwell, 2016; Bergdorf R., 2016). The Lake Butler dam is 95 m (310 ft) wide and 15 m (50.7 ft) tall with a normal pool area over 33,000 m² (8.2 acres). The Lake Litchfield dam is 114 m (375 ft) wide and 21 m (68.5 ft) tall and has a normal pool area over 105,000 m² (26 acres). Both dam structures are constructed of earthfill (ODNR, 2016).

Lakes Butler and Litchfield lie within Boy Scouts of America property (Camps Manatoc and Butler), established circa 1922 by Karl Butler and Dwight Ramsey (Davis, 2013). Camps Manatoc and Butler are located in Boston Township and are surrounded by the Cuyahoga Valley National Park. In the 1990s, the National Park Service proposed an easement to prevent the Boy Scout Council's campgrounds from being developed (Downing, 1992). In 1994, the National Park Service paid \$1.75 million to the Boy Scout Council to aid the organization in preserving its 600 acres and assisting in camp upkeep (Zapinski, 1994). Lake Butler receives water from Haskell Run, and Lake Litchfield is largely spring-fed from Ritchie Run. Both Haskell Run and Ritchie Run have remained relatively rural and undeveloped during the 20th century (Figures 4 and 5). On Wednesday, August 6, 1981, a tire fire occurred at the Park Tire Company located

near the headwaters of Haskell Run (Figure 6; Holies, 1981). The tire fire produced 9,000 gallons of tire oil and killed thousands of fish in Haskell Run (Holies, 1981). Barriers were constructed along Haskell Run to limit the tire oil from entering Lake Butler (Masek, 1981). A local witness (Randy Bergdorf) reported the tar from the fire was smoking until at least February 1982, and the director of the Boy Scout camp at the time (Wes Bergdorf) shut down the camp's drinking water pump until authorities cleaned the site (Henson and Montague, 1981). Other than the tire fire, there were no other major environmental spills or incidents that occurred on Haskell Run or Ritchie Run.

The middle Mud Brook watershed is largely urbanized and contains a dammed impoundment called Old Mill Pond. Old Mill Pond is located in Cuyahoga Falls near the intersection of Bath Road and State Road (Figure 7). To the best of my knowledge, there are no written records to indicate what year Old Mill Pond was dammed. The dam was not present on the 1905 Summit County Topography Map nor the 1910 Summit County Atlas. The dam, however, does appear on the 1936 Summit County Atlas. This indicates the dam was constructed between 1910 and 1936 (The Rectigraph Abstract and Title company, 1910; Sidwell Studio, 1936). ODNR (2016) reports that the concrete dam is approximately 3.1 m (10 ft) tall, and has a normal pool area of 64,750 m² (16 acres).

Though Mud Brook watershed was largely rural in the early 20th century, the Mud Brook study area has supported several industries, such as grain, cheese, and lumber factories, since the 19th century (The Rectigraph Abstract and Title company, 1874; Love and Giffels, 1999). The area, formerly located in Northampton Township, was often referred to as the Iron Bridge because of the industry and iron bridges in that area in the late 1800s (Seguin and Seguin, 2000; Bergdorf R., 2016; Hoffman, 2016). The 1910 Summit County Atlas shows that the majority of landowners in the Mud Brook study area were individuals; smaller plots of land can be seen already sectioned off for housing units (Figure 8).

1910

1931

1951

Figure 4. Map of the Haskell Run and Ritchie Run watersheds showing low impact farming or undeveloped land from the Summit County Atlases of 1910, 1936, and 1951 (The Rectigraph Abstract and Title company, 1910; Sidwell Studio 1936; Sidwell Studio 1951).

1994

2006

2015

Figure 5. Haskell Run and Ritchie Run in 1994, 2006, and 2015. Haskell Run (Lake Butler) and Ritchie Run (Lake Litchfield), as shown above, have experienced little urban development from 1994 through to 2015 (Summit County Parcel Viewer, 2016).

Figure 6. Figure from the newspaper account of the Park Tire Co. tire fire in the Haskell Run watershed on Wednesday, August 6, 1981 (The Cleveland Press, 1981).

Figure 7. Map showing Old Mill Pond and the surrounding development (ODNR, 2017).

In the 1910 atlas, the cheese factory and saw mill indicated by the 1874 atlas were no longer present. Some plots of land within the watershed, as indicated on the 1936 Summit County Atlas, were still owned largely by the same individuals; however, more industry, such as Cleveland Downs Inc., is also present between Lake Wyoga and Old Mill Pond. Seguin and Seguin (2000) suggest that a mill at Old Mill Pond was present at least until the late 1930s before a restaurant by the name of Senior's Old Mill Pond was built in the 1940s at the same location (Figure 9). The atlas shows that by 1951 more industry was present in the Mud Brook watershed, and a company called Brook Point IMR Co. owned the land to the northeast, adjacent to Old Mill Pond (Sidwell Studio, 1951). Cuyahoga Falls, around the time following World War II, experienced a doubling in population from approximately 25,000 people in the 1940s to about 50,000 people in the 1960s (Mann et al., 2013). Since the 1960s, expanding housing developments and industry around Old Mill Pond increased impervious surfaces in the Mud Brook watershed (Figure 10; USGS, 1967; USGS, 1979; Summit County Fiscal Office, 2016). Though there is no boating recreation on Old Mill Pond currently, other recreational activities have occurred within the watershed study site. The former Mud Run Gun Club shooting range was located approximately 1.46 km upstream of Old Mill Pond. The club ceased operations in the 1990s, and the land is now targeted for environmental remediation of lead contamination from lead ammunition pellets at the site (Wiandt, 2010). As evident from the aerial photos of Old Mill Pond from 1994 to 2015, the housing developments and industry in the Mud Brook watershed increased over the last 20 years and is likely to continue increasing into 2017 and 2018 (Figure 11). The home improvement company, Menards, plans to build in 2018 a new retail store adjacent to Old Mill Pond (Figure 11; Schleis, 2015; 2016; 2017). In addition, construction of 77 new condominiums on a 17-acre plot north east of Old Mill Pond has been proposed by Ryan Homes (Schleis, 2015; 2016; 2017). As of June 12, 2016, Google Earth aerial photos indicated that both projects are already underway.

1910

1936

1951

Figure 8. The middle Mud Brook watershed and old Mill Pond dam from 1910-1951 (The Rectigraph Abstract and Title company, 1910; Sidwell Studio, 1936; Sidwell Studio, 1951).

Figure 9. (Top) The “Iron Bridge” in Cuyahoga Falls, picture taken in the late 19th century (SCHS, 2008). (Bottom) A mill formerly on Old Mill Pond by State Rd. The photo was taken before 1940 (Seguin and Seguin, 2000).

1994

2006

2015

Figure 10. The middle Mud Brook watershed and old Mill Pond dam showing suburban development between 1994-2015 (Summit County Parcel Viewer, 2016). The red arrows indicate the location of the Old Mill Pond dam near the intersection of State and Bath roads.

1.3 Background

The geological and anthropogenic histories of the Haskell Run, Ritchie Run, and Mud Brook watersheds were researched to gain an understanding of the changes occurring throughout time in the three study watershed sites.

1.3.1 Northeast Ohio Geologic Setting

The bedrock formations in Northeast Ohio are siliciclastic rocks dating back to the Devonian (359 to 407 Ma), the Mississippian (322 to 359 Ma), and the Pennsylvanian (302 to 318 Ma) Periods (Szabo, 1986; Hacker, 2004; ODNR, 2006). The bedrock in the Haskell Run/Ritchie Run and Mud Brook study areas consists of the Pennsylvanian-aged Sharon sandstone, and the Mississippian Cuyahoga Formation contains small amounts of Devonian-age Ohio shale in the incised stream valleys (ODNR, 2006).

During the last glacial maximum, Northeast Ohio experienced glaciations in the late Wisconsinan stage 21,000 to 25,000 year BP (Szabo et al., 2003). In times of glacial retreat, a series of proglacial lakes (Lake Cuyahoga and Lake Independence) formed between the higher topography to the south and the ice to the north (Szabo et al., 2003). Lake Cuyahoga formed before the first advancement of Northampton ice, and Lake Independence formed before the second advancement of Northampton ice (Szabo, 1986). Numerous melt-water streams drained from the upland areas, which created deltas prograding into Lakes Cuyahoga and Independence (Szabo, 1986). The retreating and advancing ice lobes changed the fluvial drainage patterns, causing the ancestral Lake Erie levels to rise and fall (Szabo, 1986; Coakley, 1999; Anderson et al., 2012). About 12,500 year BP, the ice retreated from the Niagara peninsula, draining ancestral Lake Erie (Szabo et al., 2003). The low lake level led to extensive downcutting into the glacial deposits, ultimately shifting the continental divide southward towards present day Akron (Szabo et al., 2003). Post-glacial isostatic rebound of the Niagara Falls area raised Lake Erie's

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Figure 11. Figure from a news paper article report on the continued development surrounding Old Mill Pond. A 77 unit townhome complex and the hardware store Menards are already underway with construction, and are likely to be completed in 2018 (Schleis, 2015; 2016).

outlet, thus raising Lake Erie toward modern day lake levels (Coakley, 1999; Szabo et al., 2003; Anderson et al., 2012). In both the upper Haskell Run watershed and the middle Mud Brook watershed, the glacial deposits are largely ridge moraine deposits from the Wisconsin glacialiation 14,000 to 24,000 year BP (ODNR, 2005).

1.3.2. Northeast Ohio Anthropogenic Past

The Cuyahoga River Valley served as an important transportation route for native tribes, European traders, and explorers portaging between Lake Erie and the Tuscarawas River in the 17th century (Hacker, 2004). The European-American settlers came to Northeast Ohio beginning around 1800 Common Era (CE), ultimately transforming regional ecosystems, sediment yield, and fluvial patterns (Webb-Sullivan and Evans, 2014; Church and Ferguson, 2015). Wolman (1967) provides a conceptual model depicting the impact of land cover changes on sediment yield. The model suggests that around 1800 CE, much of the land cover in the eastern United States was forested and channel conditions were stable (Figure 12). During the 19th century, forests were clear-cut for agricultural purposes, resulting in increased sediment yield and channel aggradation. As farm fields reverted to secondary growth in the 20th century, sediment yield declined. In the 1960s, a surge of construction, such as highway building and suburban development, resulted in a spike in sediment yield and channel aggradation. With urbanized watersheds, sediment yield declines as sediment sources are covered, and channels are scoured and banks are eroded from the increased runoff from an urban watershed (Wolman, 1967; Church and Ferguson, 2015).

In 1827, the Ohio and Erie Canal was opened from Akron to Cleveland and brought industry, trade, and the beginnings of manufacturing to the Cuyahoga River Valley (Hacker, 2004). In the 1850s, Northeast Ohio began to transition to railroads, and canals became obsolete. The rubber industry in Akron began circa 1870s and lasted for about

Figure 12. Conceptual model depicting land use changes, channel conditions, and sediment yield response (Modified after Wolman, 1967).

100 years until it experienced a significant decline in the 1980s (Love and Giffels, 1999). The pollution from industrial expansion in the Akron area stressed the local waterways and ecosystems (Haney, 2004; Yuan et al., 2013).

Currently, the Akron-Cleveland metropolitan area has a population of around 2 million people (Yuan et al., 2013). Approximately 15% of that population live in the Cuyahoga River Valley (Hacker, 2004). The legacy sediment (LS) in waterways has become a subject of concern for scientists and environmentalists. LS is commonly understood to be sourced from high sediment input during episodic events rather than cumulative century-long anthropogenic sedimentation (Wohl, 2013; James, 2013; Webb-Sullivan and Evans, 2014; Wohl, 2015). Additionally, LS is defined as being composed mostly of alluvial and colluvial sediments sourced from terrigenous and fluvial environments that yield a significantly high sedimentation rate in the depositional record (James, 2013). The geomorphic and sedimentary distinction of LS and normal sediment loading equates to sediment delivery that exceeds sediment transport in the fluvial environment (James, 2013).

On December 27, 1974, the Cuyahoga Valley National Recreation Area, now Cuyahoga Valley National Park, the nation's third urban national park, was established, becoming Cuyahoga Valley National Park in 2000 (Harnapp, 1988; Mason, 1994; Hamin, 2001; Hacker, 2004). Mason (1994) suggests that the creation of Cuyahoga Valley National park and other similar parks in metropolitan areas in the 1970s was a national response by Congress to rising environmentalism in the United States. These parks provided recreation and green-space in highly urbanized areas such as the Akron-Cleveland region. In addition, the parks aided in preserving ecosystems threatened by urban sprawl. All three thesis study watershed sites ultimately drain into the national park and the Cuyahoga River.

1.3.3 Climate Change in Northeast Ohio

Developed land cover around the Akron area has induced an increase in fluvial energy from more impervious surfaces; however, climate change also plays a role in dictating local fluvial conditions. In the Akron-Canton area, the mean average temperature is approximately 49.8°F (~10°C), with July on average the warmest month at 72°F (~22°C) and January the coldest at 26.1°F (~ -3°C) (NOAA, 2016b). The total average precipitation rate is approximately 39.62 in/yr (~100 cm/yr) and the average snowfall, factored into the total precipitation, is 47.5 in/yr (~120 cm/yr), or about 5 in/yr (12.7cm/yr) of precipitation (NOAA, 2016b). Climate conditions in Northeast Ohio, however, are deviating from these long-term averages.

In Northeast Ohio and elsewhere globally, the frequency and magnitude of storms and floods are increasing (Pielke, 2005; Liberatore, 2013; Mann et al., 2013; Schillereff et al., 2014; Delaney, 2016). After July 2003, flooding has increased in Northeast Ohio (Liberatore, 2013). Four of the top ten wettest years in Akron from 1880-2016 occurred after July 2003: 2014, 2011, 2004, and 2003 (Table 1; Liberatore, 2013; NOAA, 2016b). Seven of the top ten flood events at Old Portage Path on the Cuyahoga River also occurred after July 2003 (Table 1; NOAA, 2016a). The USGS gage station records for the Cuyahoga River at Old Portage Path show more high-flow days over the past 13 years (2003 to 2016) than any other 13 year period in the last 95 years (Table 2; Figure 18). A mean daily discharge value of 80 cubic meters per second (cms) was selected to represent high-flow events (Liberatore, 2013). From July 2003 to February 2016, there have been 67 high-flow days, whereas other 13 year periods only have between 11 and 21 high-flow days (Table 2; Figure 13; USGS, 2016). The contiguous United States is warming, with 2015 being the warmest year on record within the last 135 years (NOAA, 2016c). From 1950 to 2009, 65% of record daily high temperatures occurred between 2000 and 2009

Table 1. Top ten historic crests of the Cuyahoga River (NOAA, 2016a) and wettest years in Akron, OH (NOAA, 2016b).

Historic Crests of the Cuyahoga River at Old Portage			Wettest Years 1900-2015		
Rank	Year	Height (m)	Rank	Year	Amount (cm/yr)
1	2013	4.4	1	1990	166.9
2	2004	4.2	2	2011	148.3
3	1979	4.1	3	2003	129.8
4	2011	4.0	4	1956	119.5
5	2014	3.9	5	1926	119.4
6	2003	3.9	6	1996	119.2
7	1976	3.7	7	2004	117.6
8	2011	3.5	8	2014	116.1
9	1959	3.5	9	2000	115.6
10	2005	3.4	10	1913	115.4

Table 2. Number of high flow events on the Cuyahoga River at Old Portage Path, Ohio in 13-year intervals since 1921(USGS, 2016a).

Years (~13 year periods)	Days Over 80 cms
2/2016-7/2003	67
7/2003-7/1990	11
7/1990-7/1977	19
7/1977-7/1964	11
7/1964-7/1951	21
7/1951-7/1938*	10
7/1938-10/1921*	21

* Missing data from 1/1936-2/1939

Figure 13. Mean daily discharge of the Cuyahoga River at the Old Portage Path gage station in Old Portage, Ohio. In 13 years since July 2003, there have been 67 high flow events (over 80 cms), more than any other 13 year period since 1921 (USGS, 2016a).

(U.S. EPA, 2014). As air temperature increases, more frequent and intense precipitation and flood events are expected as the hydrological cycle accelerates (U.S. EPA, 2014).

CHAPTER II

METHODS

Surface sediment samples and sediment cores were collected for this thesis study at the three impoundment sites: Lake Butler, Lake Litchfield, and Old Mill Pond. Discharge and total suspended sediment data were collected at Lake Butler. Sediment samples were analyzed in the lab for sediment properties, magnetic properties, and heavy metals. Watershed land cover change was processed and analyzed in the computer lab using ArcMap.

2.1 Field Methods

A total of 15 sediment cores and 40 surficial sediment samples were collected from Lakes Butler and Litchfield, and Old Mill Pond in March and May of 2016. The trapping efficiency and stream discharge of Lake Butler was measured in March and November of 2016.

2.1.1 Sediment Core Sampling

A modified Livingston piston corer was used to collect sediment cores from Lake Butler, Lake Litchfield, and Old Mill Pond (Figures 14-16; Tables 3-5). A Wildco grab sampler was used to collect two short surface cores from Old Mill Pond. The delta environments where streams entered each impoundment were selected for coring. Latitude and longitude of each core location was determined with a Garmin global positioning system (GPS).

Figure 14. Lake Butler surface sediment samples, core sites, and stream discharge measurement locations overlain on a 2015 aerial photo (ESRI, 2016a).

Figure 15. Lake Litchfield surface sediment samples and core sites overlain on a 2015 aerial photo (ESRI, 2016a).

Figure 16. Old Mill Pond surface sediment samples and core sites overlain on a 2015 aerial photo (ESRI, 2016a).

Table 3. Sediment cores collected from Lake Butler near Peninsula, OH.

Core	Latitude (DD)	Longitude (DD)	Core Length (m)	Sediment Comment	Location Comment
LB-16-C1-D1	41.232095	-81.522202	0.55	Core compacted. Original hole is 0.79m. Core sticks out at bottom.	Delta top (drive 1)
LB-16-C1-D2	41.232095	-81.522202	0.50	First few cm of core are fill from surface.	Delta top (drive 2)
LB-16-C4-D1	41.232025	-81.522297	0.93	Black and light tan-brown alternate layers.	Delta top (drive 1)
LB-16-C4-D2	41.232025	-81.522297	0.82	Mix of sand and silt, with organics.	Delta top (drive 2)
LB-16-C4-D3	41.232025	-81.522297	0.59	Silt and clay, sand, gravel pieces at the bottom 8cm.	Delta top (drive 3)
LB-16-C7-D1	41.232190	-81.523930	0.98	Mud, sand, and pebbles.	Lacustrine

Table 4. Sediment core samples at Lake Litchfield near Peninsula, OH.

Core	Latitude (DD)	Longitude (DD)	Core Length (m)	Sediment Comment	Location Comment
LL-16-C1	41.226039	-81.525002	1.39	Black alternating flood layers	Delta front
LL-16-C2	41.225984	-81.524774	0.89	Sandy, leafy layers, graded bedding	sub-aqueous levee
LL-16-C3	41.225969	-81.524785	0.59	100% sand	sub-aqueous levee
LL-16-C4	41.225969	-81.524785	0.10	Short, sandy core	sub-aqueous levee

Table 5. Sediment core samples at Old Mill Pond in Cuyahoga Falls, OH.

Core	Latitude (DD)	Longitude (DD)	Core Length (m)	Sediment Comment	Location Comment
OMP-16-C1	41.15530000	-81.50848333	0.14	Silty, clay composition, leaf debris	Short core, middle of lake
OMP-16-C2	41.15526900	-81.50841800	1.54	Brown and tan mud and sand	3 m south of site 1, lake core
OMP-16-C3	41.15526900	-81.50841800	1.66	Brown and tan mud and sand	Best lake core, same location as site 2
OMP-16-C4	41.15502100	-81.50785500	0.10	Brown and tan mud and sand	Delta front
OMP-16-C5	41.15502100	-81.50785500	0.95	Brown and tan mud and sand	Delta front (same location as C4)

2.1.2 Surface Sediment Sampling

A total of 13 to 14 surface sediment samples were collected from each lake with a Wildco grab sampler or a pole-mounted scoop (Figures 14-16; Tables 6-8). Latitude and longitude of each sample location was determined with a Garmin GPS. The water depth at each site was measured with a grab sampler rope, which was marked in 1 meter increments. Surficial sediment samples were located near core sites and longitudinally down the impoundment.

2.1.3 Trapping Efficiency and Stream Discharge of Lake Butler

On March 25 and November 21, 2016, the sediment trapping efficiency of Lake Butler was estimated by measuring the inflow and outflow discharge (Table 9). The inflow and outflow water discharge was measured with a Gurley Pygmy flow meter and meter stick. Total suspended sediment (TSS) concentrations were measured with the Ohio Sediment Stick (ODNR, 2014). Inflow measurements were made in Haskell Run near where it joins Lake Butler. Outflow measurements were made in the outflow culvert at the base of the dam. Suspended sediment discharge (Q_s) was determined by multiplying the water discharge (Q_w) at a particular location by the average suspended sediment concentration.

2.2 Lab Methods and Equipment

All sediment samples from Lake Butler, Lake Litchfield, and Old Mill Pond were processed in the laboratory. The samples were measured for magnetic properties, heavy metals, and physical sediment properties.

Table 6. Surface sediment samples collected from Lake Butler near Peninsula, OH on March 25, 2016.

Sample Number	Latitude (DD)	Longitude (DD)	Depth (m)	Sediment Comment	Location Comment
LB-G1	41.23340000	-81.52798333	6.40	1-2cm, tan clay on top of black organic layer.	Center, lake
LB-G2	41.23245000	-81.52433333	0.75	1-2cm, tan clay on top of black organic layer.	River Right, lake
LB-G3	41.23161667	-81.52466667	1.80	1-2cm, tan clay on top of black organic layer.	Center, lake
LB-G4	41.23216667	-81.52431667	1.40	1-2cm, tan clay on top of black organic layer.	River Left, lake
LB-G5	41.23241667	-81.52293333	1.00	1-2cm, tan clay on top of black organic layer.	Center, river
LB-G6	41.23200000	-81.52265000	0.00	1-2cm, tan clay on top of black organic layer.	Delta
LB-G7	41.23202000	-81.52263100	0.50	1-2cm, tan clay on top of black organic layer.	Near Delta
LB-G8	41.23224600	-81.52491600	1.15	1-2cm, tan clay on top of black organic layer.	Center, lake
LB-G9	41.23230000	-81.52573333	3.25	1-2cm, tan clay on top of black organic layer.	Center, lake
LB-G10	41.23206667	-81.52185000	-	Black gravel	Haskell Run, headcut nearby
LB-G11	41.23176667	-81.52153333	-	Sandy	Upstream
LB-G12	41.23033333	-81.52115000	-	Sandy	Mid-way upstream, sandy deposits
LB-G13	41.23033333	-81.52083333	-	Large gravel pieces/ pebbles	Most upstream in Haskell Run
LB-G14	41.23211667	-81.52226667	-	Sandy	Channel new core site 1 and 4

Table 7. Surface sediment samples collected from Lake Litchfield near Peninsula, OH taken May 15, 2016.

Sample Number	Latitude (DD)	Longitude (DD)	Depth (m)	Sediment Comment	Location Comment
LL-G1	41.22603900	-81.52500200	1.50	1-2 cm, tan/black organic clay	Same location as LL-16-C1
LL-G2	41.22572800	-81.52549200	1.40	1-2 cm, tan/black organic clay	In alcove area
LL-G3	41.22678333	-81.52666667	2.00	Yellow/grey clay over organic mud	Alluvial fan area
LL-G4	41.22693333	-81.52783333	5.50	Yellow/grey clay over organic mud	River center
LL-G5	41.22743333	-81.52851667	6.50	Yellow clay top 1-2 cm, black organic mud	River center
LL-G6	41.22868333	-81.52975000	4.50	Red clay at top 1-2 cm	River right, in alluvial fan
LL-G7	41.22870000	-81.52963333	2.50	Red clay top 1-2 cm	Near lake fork
LL-G8	41.22895000	-81.53151667	8.50	Black organic rich mud at top 1-2 cm	Near lake fork
LL-G9	41.22893333	-81.53165000	5.50	1-2 cm, tan/black organic clay	River left
LL-G10	41.22881667	-81.53248333	3.25	Top 1-2 cm of sediment is red	Alluvial fan in alcove
LL-G11	41.22903800	-81.53295700	4.00	Red/brown, silty	Taken from other side of the alcove
LL-G12	41.22995000	-81.53306667	11.00	Light brown clay/silt	Sample very minimal, middle of river
LL-G13	41.23111800	-81.53362200	8.50	1-2 cm, tan and black mud/clay	Near the culvert (river center)

Table 8. Surface sediment samples collected from Old Mill Pond in Cuyahoga Falls, OH taken May 9, 2016.

Sample Number	Latitude (DD)	Longitude (DD)	Depth (m)	Sediment Comment	Location Comment
OMP-G1	41.15530000	-81.50848333	0.27	Silty/clay, brown	G1 from C1 surface sample, short core
OMP-G2	41.15481667	-81.50801667	1.00	Silty/clay, brown	Near C5 location (by delta)
OMP-G3	41.15476667	-81.50706667	1.00	Silty/clay, brown	Going toward the outflow, river right
OMP-G4	41.15430000	-81.50706667	1.33	Silty/clay, brown color, organic matter	River center, in channel toward dam
OMP-G5	41.15398300	-81.50719400	1.20	Organic matter, medium sand to gravel	River left heading toward dam
OMP-G6	41.15338333	-81.50733333	0.50	Black, organic matter, med sand to pebbles	Near culvert
OMP-G7	41.15336300	-81.50727400	1.00	Black color, sulfur smell, coarse sand-pebbles	Near culvert
OMP-G8	41.15348333	-81.50768333	0.40	Organic matter, shells, pebbles	Where culvert and stream fork
OMP-G9	41.15365800	-81.50768600	1.40	Brown, silty/clay	River right toward dam direction,
OMP-G10	41.15508333	-81.50933333	0.10	Brown, silty/clay	Near the shore, lake left
OMP-G11	41.15612800	-81.50934800	0.40	Brown, silty/clay	North west of pond
OMP-G12	41.15618333	-81.50840000	0.46	Brown, silty/clay	Near the top, right section of the lake
OMP-G13	41.15618333	-81.50848333	0.51	Brown, silty/clay	2 m to the left of G12

Table 9. Lake Butler inflow and outflow discharge measurement locations.

Date	Latitude (DD)	Longitude (DD)	Location Comment
3/25/2016	41.23213	-81.521984	Inflow
3/25/2016	41.233108	-81.530014	Outflow
11/21/2016	41.231975	-81.521749	Inflow
11/21/2016	41.233108	-81.530014	Outflow

2.2.1 Magnetic Susceptibility (κ)

All sediment cores were measured for whole-core magnetic susceptibility (κ) at a 3 cm interval using a Bartington MS2C core logging sensor. Whole-core magnetic susceptibility (κ) is based on sample volume and is a measure of the concentration of ferrimagnetic material within a sample that is placed in a magnetic field (Evans and Heller, 2003). κ is measured in a field; therefore, a significant amount of diamagnetic and paramagnetic material can influence the measurement (Evans and Heller, 2003).

2.2.2 Lithology Analysis

The cores were spilt length-wise and visually described for grain size, composition, color, and sedimentary structures. The cores were then photographed. Half of each core was subsampled for further laboratory analysis. The other core halves were archived in the sedimentology refrigerator. To further identify sediment components, smear slides were made of the various lithologies from all three lakes. The slides were analyzed using a petrographic microscope.

2.2.3. Loss-On-Ignition

All surface samples and all cores, sampled at 1 cm intervals, were measured for loss-on-ignition (LOI) using the Dean (1974) method. LOI was used for measuring bulk density (dry or wet weight of sediment per unit volume) and organic matter content. 1 cubic centimeter (cc) of wet sediment was dried in the muffle furnace at 100°C for 24 hours. Samples were then burned at 550°C for 2 hours. The contents were weighed before drying, after drying, and after burning to calculate weight loss.

2.2.4. Grain Size Analysis

The Folk (1980) pipette method was used to measure grain size on representative mud samples from selected surface samples and cores. Approximately 30 g of wet mud was treated with 10 mL of 30% hydrogen peroxide twice a day for six days to oxidize organic matter. It is likely that not all the organic matter was eliminated from the sediment. All samples were then air-dried and weighed. The sediment was combined with 250 mL of sodium metaphosphate (PO_4) solution for 24 hours to prevent flocculation. Prepared samples were then added to a 1000 mL graduated cylinder and the water level was raised to 1000 mL using deionized water. The samples were well mixed and a timer was started when the stir bar broke the water surface. 20 mL aliquots were pipetted into pre-weighed jars at particular time intervals and cylinder depths to determine the mud grain size distribution (Table 10). After pipetting, the samples were wet sieved at 4Φ (0.0625 mm) to determine the percent sand and gravel. The grain size fractions in the jars were dried at 80°C for three days, cooled, and weighed.

Sand and gravel samples were sieved using a Tyler Rotap and following the methods of Folk (1980). Samples were sieved from -3Φ (8.0 mm) to 4Φ (0.0625 mm) in 0.5Φ increments to determine the grain size distribution. The very coarse sands (0Φ) were analyzed under a binocular microscope to determine the relative percent of anthropogenic particles to naturally occurring sand particles.

2.2.5 Magnetic Analysis

All surface samples and representative down core lithologies were measured for magnetic concentration, grain size, and mineralogy parameters. Sediment samples were air-dried, disaggregated, and packed into 5.28 cm^3 plastic boxes. To measure high (4.75 kHz) and low (0.47 kHz) frequency magnetic susceptibility (χ_{hf} , χ_{lf}), a Bartington Instruments susceptibility meter with a field of 80 A/m was used. Magnetic susceptibility

Table 10. Time intervals and depths in the graduated cylinder for extracting silt and clay of known sizes. (Folk, 1980).

Phi Φ	Time (hrs:min:sec)	Depth (cm)
5	0:01:45	10
6	0:06:58	10
7	0:28:00	10
8	1:51:00	10
9	3:42:00	5

is a concentration parameter where larger values indicate greater ferrimagnetic concentration. Averages of three readings for each sample were recorded at both high and low frequencies. The frequency dependence, a magnetic grain size parameter, for each sample was calculated by the following equation:

$$\text{Frequency Dependence} = ((\chi_{lf} - \chi_{hf})/\chi_{lf}) * 100 \quad (\text{Eq. 1})$$

A Molspin spinner magnetometer was utilized for measuring remanent magnetization. A D-Tech 2000 AF demagnetizer was used to impart each sample with an anhysteretic remanent magnetization (ARM) at 100 mT. ARM is a measure of the amount of ferrimagnetic material in the sample and is biased toward stable single domain (SSD) particles (Evans and Heller, 2003). Next, samples were demagnetized to 40 mT on the AF demagnetizer and measured on the Molspin. Isothermal remanent magnetization (IRM) was imparted at 1 T utilizing the ASC impulse magnetizer. The saturation isothermal remanent magnetization (SIRM) is the maximum magnetic remanence acquired by a sample exposed to a saturating magnetic field (Evans and Heller, 2003). For this study, the 1 T field was considered to yield the SIRM. A direct current (DC) demagnetization of the SIRM was achieved using an ASC impulse magnetizer at -100 mT and -300 mT. From these measured remanents, the S-ratio, a magnetic mineralogy parameter, was calculated.

2.2.6 Heavy Metals

The total digestion procedure of Lacey et al. (2001) was performed on representative samples to determine the total concentration of lead (Pb), zinc (Zn), copper (Cu), and chromium (Cr) in the sediment. The concentrations of Pb, Zn, Cu, and Cr was determined with a Perkin-Elmer 7000 Atomic Absorption Spectrometer (AA). Instrument

concentration readings were then converted from mg/L to µg/g by using the following equation:

$$\text{Metal concentration (}\mu\text{g/g)} = \text{AA conc. (mg/L)} * (50 \text{ mL soln/sed wt g}) * (1000\mu\text{g/1 mg}) * (1\text{L}/1000\text{g}) \quad (\text{Eq. 2})$$

Four replica samples, two acid blanks, and two samples of National Institute of Standards and Technology (NIST) Buffalo River reference material #8704, were measured. The acid blanks were processed to check for contamination during the total digestion process (Table 11). The blank samples were below detection for all four metals, indicating that there was no contamination. The Buffalo River reference material #8704 was processed to determine the effectiveness of the total digestion method with known values for heavy metals.

Initially, the Pb and Cr concentrations for Buffalo River reference material #8704 (BRS) had anomalous percent recovery rates of 145% for Pb and 81% for Cr. The AA was found to have a drain blockage that affected the sample input and sample readings. The blockage was fixed, and the all samples were remeasured for new Pb and Cr concentrations. The new percent recovery was 99% for Pb and 91% for Cr the BRS. The close agreement between measured and reported BRS metal concentrations indicate an effective total digestion processes (Table 11).

2.3 GIS Procedures

GIS procedures were conducted using ArcMap to establish land cover percentages and areas and quantify land cover changes from 1985 to 2010 in Haskell Run, Ritchie Run, and Mud Brook watersheds. Additionally, the shorelines at the deltas for Lake Butler, Lake Litchfield, and Old Mill Pond were assessed.

Table 11. A. Two acid blanks and Buffalo River reference material #8704 denoting the concentrations of lead (Pb), zinc (Zn), copper (Cu), and chromium (Cr). B. Known Buffalo River heavy metal concentrations for samples #8740 in Pb, Zn, and Cr (National Institute of Standards and Technology, 2000). C. The recovery percentage of the tested values for Buffalo River standard #8704.

A.						
Sample	Sediment (g)	Pb Concentration ($\mu\text{g/g}$)	Zn Concentration ($\mu\text{g/g}$)	Cu Concentration ($\mu\text{g/g}$)	Cr Concentration ($\mu\text{g/g}$)	
Blank 1	0	0.025	0.031	-0.001	0.006	
Blank 2	0	0.028	0.029	-0.001	0.003	
BRS 1	0.197	153.6	444.4	104.3	113.5	
BRS 2	0.199	142.7	403.8	98.2	108.3	
B.						
	Pb ($\mu\text{g/g}$)	Zn ($\mu\text{g/g}$)	Cu ($\mu\text{g/g}$)	Cr ($\mu\text{g/g}$)		
Buffalo River #8704	150 ± 17	408 ± 15	-	121.9 ± 3.8		
C.						
	Pb %	Zn %	Cu %	Cr %		
Buffalo River #8704						
BRS 1	102.4	108.9	-	93.1		
BRS 2	95.1	99.0	-	88.8		
Average	98.8	103.9	-	91.0		

2.3.7 Land Cover Change

Land cover changes in both the Mud Brook and Haskell Run/Ritchie Run watersheds were quantified utilizing ArcGIS software. All three sites are subwatersheds of the Cuyahoga River. The subwatershed study sites were delineated utilizing the GIS pour point method with a 1/9th arc second Digital Elevation Model (DEM) raster file (Parmenter and Melcher, 2012). First, the DEMs projected coordinates were changed to NAD 1983 (2011) StatePlane Ohio North FIPS 3401 (US Feet). Flow direction in each site area was determined from the DEMs. Flow accumulation (accumulated flow from each cell to the next) was calculated from the new filled DEM identifying flow within the area. The watershed boundaries for all three subwatersheds was not accurate initially. The watersheds were edited and reshaped based on a visual assessment of ridges and elevation changes using the ESRI topography map, current aerial photos, and the Summit County Fiscal Office defined watershed boundaries (Table 12). The Lake Butler subwatershed flows from the headwaters of Haskell Run to the lake dam. The Lake Litchfield subwatershed mainly flows from the headwaters of Ritchie Run to the lake dam. Old Mill Pond/Mud Brook subwatershed starts at Lake Wyoga and flows to the Old Mill Pond dam.

The data sets used for land cover change analysis were from NOAA Digital Coast for the years 1985, 1996, 2001, 2006, and 2010 (Table 12; Digital Coast, 2016a). The Mud Brook, Haskell Run, and Ritchie Run subwatershed boundaries were used to clip the land cover data sets to analyze only the land cover within each subwatershed. The cell sizes for the land cover data was 30 X 30 meters. Land cover data was classified using the NOAA Digital Coast C-CAP classification system. The four main reclassified groups of land cover assessed were: developed, farmland, undeveloped, and open water (Digital Coast, 2016b). Developed land in this study is comprised of five classes: high intensity, medium intensity, low intensity, open spaces, and barren land. For the purposes of this

Table 12. GIS data types, sources, and their purpose to complete the thesis.

Data Type	Source*	Source Website	Purpose
Aerial photos for 1994, 2000, 2005, 2006, 2010, watershed boundaries, 2000 drainage	Summit County Fiscal Office (2016)	https://fiscaloffice.summitoh.net/index.php/documents-a-forms/viewcategory/40-gis-data-downloads . 1994 data was not available for download on the Summit County site. Missing data was used from U.A. Geoscience department server.	Used to determine shoreline changes for impoundments; Sub-divide watersheds; Established general flow of watersheds
Aerial Imagery 2003	USGS Earth Explorer (USGS, 2016b)	http://earthexplorer.usgs.gov/	Determine shoreline changes for impoundments
Aerial Imagery 2012, Topo Map	ESRI Basemap (2016a)	Basemap from ArcMap 10.4	Determine shoreline changes for impoundments
Aerial Imagery 2014	Google Earth (2016)	https://earth.google.com/	Determine shoreline changes for impoundments
Aerial Imagery 2015	Summit County Parcel Viewer (2016)	http://summitmaps.summitoh.net/PropertyResearch/	Determine shoreline changes for impoundments
Aerial Imagery 2016	Google Earth (2016)	https://earth.google.com/	Determine shoreline changes for impoundments
Digital Elevation Model (DEM)	USGS (National Map)	http://nationalmap.gov/viewer.html	Used to determine surface elevation to make subwatersheds
Topographic Map	ESRI (2016b)	Topographic map from ArcMap 10.4	Used to determine surface elevation to edit subwatershed boundaries
Land cover data 1985, 1996, 2001, 2006, 2010	NOAA (Digital Coast, 2016a)	https://coast.noaa.gov/dataregistry/search/collection	Used to determine land cover changes over time in the study areas
Cuyahoga River Watershed Shapefile	USDA (2017)	https://www.nrcs.usda.gov/wps/portal/nrcs/detail/oh/technical/?cid=nrcs144p2_029586	Used for creating location map
Northeast Ohio County Boundaries	US Census (2015)	https://www.census.gov/geo/maps-data/data/cbf/cbf_counties.html	Used for creating location map

*Complete references available in the reference section

study, barren land in the final assessment was included in the developed category owing to its runoff potential. Farmland consists of the classes cultivated crops and pasture/hay. Undeveloped land includes the remaining categories (i.e., grassland/herbaceous, deciduous forest, evergreen forests, mix forest, and palustrine forest, scrub, and emergent wetlands) except for open water. Land cover classes within each subwatershed were then assessed by total area and total percent to quantify the amount of land cover change over time.

Impervious land cover values were determined by multiplying a specific coefficient for each land cover class by the area for each site. Land cover class coefficients were calculated using NOAA's Impervious Surface Analysis Tool (ISAT) accounting for high, medium, and low values based on the population density or people per square mile (Table 13). High population density for the ISAT method is $>2,500$ people/mi², medium population density is $<2,500$ to >500 people/mi², and low population density is <500 people/mi² (Digital Coast, 2017).

2.3.8 Shoreline Assessment

Aerial photos from 1994, 2000, 2003, 2005, 2006, 2010, 2012, 2014, 2015, and 2016 were used to assess changes in the delta shorelines within each impoundment (Table 12; ESRI, 2016; Google, 2016; Summit County Parcel Viewer, 2016; Summit County Fiscal Office, 2016; USGS, 2016b). The aerial photo from 2015 was georeferenced from Summit County (Summit County Parcel Viewer, 2016) and years 2014 and 2016 were georeferenced from Google Earth (Google, 2016). Images were georeferenced by utilizing the ArcMap georeferencing tool. At least eight reference points were identified with the first order polynomial transformation and maximum residual distance of 0.9 meters, modified from the procedure of Delaney (2016).

Table 13. Impervious coefficients derived from population density (population/ sq. mi.) from the NOAA Impervious Surface Analysis Tool (ISAT) and NLCD (2006) impervious data. Population classifications: Low: ≤ 500 ; Medium: > 500 and ≤ 2500 ; High: > 2500 (Digital Coast, 2017).

Land Cover Code	Land Cover Class Name	Impervious coefficients based on population density		
		High	Medium	Low
0	Unclassified	0.00	0.00	0.00
2	Developed, High Intensity	76.45	76.61	76.36
3	Developed, Medium Intensity	49.21	49.02	48.99
4	Developed, Low Intensity	25.72	25.55	25.57
5	Developed, Open Space	11.15	10.95	10.93
6	Cultivated Crops	3.21	2.59	2.44
7	Pasture/Hay	2.06	1.51	1.40
8	Grassland/Herbaceous	9.30	8.74	8.47
9	Deciduous Forest	2.18	1.88	1.77
10	Evergreen Forest	1.44	1.23	1.20
11	Mixed Forest	2.74	2.22	2.08
12	Scrub/Shrub	3.86	3.50	3.28
13	Palustrine Forested Wetland	1.16	0.96	0.92
14	Palustrine Scrub/Shrub Wetland	1.31	1.27	1.26
15	Palustrine Emergent Wetland	1.46	1.44	1.46
20	Bare Land	14.91	14.73	14.49
21	Open Water	0.82	0.89	1.00

Poor: Photos have adequate to poor view of the delta and water level indicator. Vegetation and tree shadow blocks the shoreline. Pixel size is greater than 0.5 meters (USGS, 2016b).

Good to Fair: Photos have decent view of delta, shoreline, and water level indicator. Resolution depends upon georeferencing scale. Significant vegetation blocks shorelines (years 2014 & 2016). Pixel size is between 0.2-0.5 meters (Summit County Parcel Viewer, 2016).

Excellent: Photos have overall distinct view of delta, shoreline, and water level indicator. Sometimes tree shadow or vegetation can impair view. Pixel size is less than 0.2 meters. (Summit County Fiscal Office, 2016).

Figure 17. Examples of poor, good to fair, and excellent photo quality for Old Mill Pond. Refer to Table 14 for photo quality ranking of all photo years.

Table 14. Aerial orthophotos used to assess shoreline change, organized by year.

Year of Photo	Photo Source	Quality
1994	Summit County Fiscal Office, 2015	Good-Fair Quality: Resolution is fair. Deltas, shorelines, and streams can be seen clearly.
2000	Summit County Fiscal Office, 2015	Excellent Quality: Resolution was excellent. Delta and water level indicators could be seen clearly.
2003	USGS Earth Explorer	Poor Quality: Resolution poor. Vegetation covered delta shorelines. Some general characteristics could be determined (e.g., stream path in Lake Butler).
2005	Summit County Fiscal Office, 2015	Excellent Quality: Resolution was excellent. Delta and water level indicators could be seen clearly.
2006	Summit County Fiscal Office, 2015	Excellent Quality: Resolution was excellent. Delta, shorelines, and water level indicators could be seen clearly.
2010	Summit County Fiscal Office, 2015	Excellent Quality: Resolution was excellent. Delta, shorelines, and water level indicators could be seen clearly.
2012	ESRI, 2016	Good to Excellent Quality: Resolution was generally excellent, however some images were affected by tree shade.
2014	Google, 2016	Good to Fair Quality: Resolution depended upon georeferencing scale. Vegetation prevented some shorelines to be seen.
2015	Summit County Parcel Viewer, 2016	Good to Fair Quality: Resolution depended upon georeferencing scale.
2016	Google, 2016	Good to Fair Quality: Resolution depended upon georeferencing scale. Some sections of the delta were blocked by vegetation.

Photo quality and tree shadows greatly affected the visibility of the shoreline (Figure 17, Table 14). The delta shorelines were digitized utilizing the polygon tool primarily at scales between 1:150 and 1:400. Depending on the image quality, the scale would vary to make viewing the shoreline easier. Variations in the impoundment water level affects shoreline position; therefore, a fixed object or shoreline was identified at each site to compare relative lake level changes between photo years. At Lake Butler, a shoreline section between two trees from the year 2000 was used for a lake level indicator. At Lake Litchfield, a rounded shoreline section near the delta from the year 2000 was used. At Old Mill Pond a concrete-type structure near the delta was utilized. For each year, the lake level was denoted as deeper, shallower, or the same relative to the position of the shoreline reference year or if the object was observed in the photo. A problem lies in the time periods when the photos were taken. These photos are from one day in a year. The impoundment level could be higher or lower due to changes in the precipitation and stream discharge rates on that day. Lake Butler was drained in 2015, and thus the impoundment water level appears different than other years. Regarding sediment deposits, there was no significant deposition of sediment in any particular year after 2003. The delta, however, did show progradation from 1994 to 2016 as indicated by the delta environment transition from subaqueous delta front to delta top.

CHAPTER III

RESULTS

3.1 Lake Butler

Surficial and core sediment properties in addition to the trapping efficiency were measured and analyzed for Lake Butler. The shorelines at the Lake Butler delta were assessed from 1994 to 2016. Haskell Run watershed land cover changes were evaluated from 1985 to 2010.

3.1.1 Surface Samples

Seven samples were collected from Lake Butler, two from the delta at the head of the impoundment, and five from Haskell Run which flows into Lake Butler (Table 15). The impoundment samples consisted of a tan clay overlying an organic black mud. The stream samples ranged from medium sand to granule size. Porosity (the water percentage for a fully saturated sample), organic matter content, dry bulk density, mass-corrected susceptibility (χ), and visual grain size were evaluated for all surface samples (Table 15). Sand and gravel samples had low porosity (24-52%), low organic content (1.9-4.5%), and a high dry bulk density, whereas mud samples had high porosity (57.3-73.4%), high organic content (6.1-14.1%), and lower dry bulk density (0.3-0.5 g/cm³). All samples had a uniform mass-corrected susceptibility (χ_{it}), ranging from 20.2-38.0 10⁻⁸ m³ kg⁻¹, with one outlier at sample G13 (68.5 10⁻⁸ m³ kg⁻¹) from upstream in Haskell Run. The grain size for sample G14, collected where Haskell Run meets Lake Butler, was measured to be poorly sorted coarse sand (Table 16). Three surface samples (G4,5,7) were analyzed for Pb, Zn, Cu, and Cr heavy metal concentrations (Table 17). Pb concentrations ranged between 10-

Table 15. Magnetic and physical properties of Lake Butler surface samples collected March 25, 2016.

Sample Number	Depth (m)	X_{lf} ($10^{-8} \text{ m}^3 \text{ kg}^{-1}$)	X_{hf} ($10^{-8} \text{ m}^3 \text{ kg}^{-1}$)	X_{fd} (%)	Organic Matter (%)	Dry Bulk Density (g/cm^3)	Water Content (%)	Visual Grain Size	Location
LB-G1	6.40	25.3	24.7	2.2	12.5	0.331	73.4	Clay	Center, lake
LB-G2	0.75	20.2	19.5	-	14.1	0.494	62.9	Clay	River Right, lake
LB-G3	1.80	28.0	27.1	3.1	7.9	0.663	54.7	Clay	Center, lake
LB-G4	1.40	24.8	24.3	2.2	10.1	0.630	57.3	Clay	River Left, lake
LB-G5	1.00	27.6	27.2	1.6	11.6	0.534	60.9	Clay	Center, river
LB-G6	0.00	27.4	26.7	2.6	6.1	0.730	50.7	Clay	Delta
LB-G7	0.50	30.3	29.5	2.6	7.0	0.538	60.5	Clay	Near delta
LB-G8	1.15	32.7	32.2	1.5	13.3	0.412	67.8	Clay	Center, lake
LB-G9	3.25	22.6	21.9	3.1	5.5	0.574	59.1	Clay	Center, lake
LB-G10	0.00	38.0	37.2	2.1	4.5	1.403	52.0	Gravel	Haskell Run, headcut nearby
LB-G11	0.00	22.3	21.4	3.9	2.6	0.724	60.5	Coarse sand	Upstream on Haskell Run
LB-G12	0.00	37.1	36.0	3.0	4.5	1.307	29.0	Coarse sand	Mid-way upstream Haskell Run
LB-G13	0.00	68.5	68.4	0.1	1.9	1.087	26.1	Granuels	Most upstream in Haskell Run
LB-G14	0.00	28.0	26.9	3.9	2.4	1.423	26.7	Medium to coarse sand	Haskell Run and lake meet

Table 16. Lake Butler summary table of grain size analysis for representative samples. The D_{50} is the median. The σ is the sorting for the sand samples.

Sample	Dry Bulk Density (g/cm ³)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	D_{50} Φ	Wentworth Size Class	σ Φ	Sorting Value
LB-G14	1.423	3.1	95.2	1.7	-	1.07	Coarse sand	1.06	Poorly sorted
LB-C4 10cm	0.888	-	2.2	64.9	32.9	6.87	Medium silt	-	-
LB-C4 35cm	1.327	-	50.4	25.1	24.5	4.07	Very fine sand	-	-
LB-C4 200cm	0.974	-	1.6	66.1	32.3	7.29	Fine silt	-	-

Table 17. Heavy metal concentrations for selected Lake Butler sediment samples.

Sample	Pb Concentration (µg/g)	Zn Concentration (µg/g)	Cu Concentration (µg/g)	Cr Concentration (µg/g)
Surface				
LB-G4	35.3	153.2	23.3	56.9
LB-G5	26.1	139.3	26.1	55.3
LB-G5 Rep	26.3	132.4	28.1	57.9
LB-G7	10.6	155.8	27.1	58.8
Core				
LB-C4 0cm	8.5	119.0	16.8	46.8
LB-C4 50cm	19.1	169.6	20.9	61.8
LB-C4 101cm	16.8	252.0	14.6	49.8
LB-C4 150cm	19.3	709.4	35.1	62.4
LB-C4 200cm	13.5	124.5	32.4	52.0

35 µg/g, Zn concentrations were between 132-156 µg/g, Cu concentrations were between 23-28 µg/g, and Cr concentrations ranged from 55-58 µg/g. These samples were also tested for magnetic properties including ferrimagnetic concentration, magnetic grain size, and mineralogy (Table 18). The magnetic concentration parameters SIRM, χ_{lf} , and χ_{ARM} are largely a measure of the ferrimagnetic (low coercively) mineral content in a sample (Evans and Heller, 2003). The saturation isothermal remanent magnetization (SIRM) for these surface samples is on average $2,400 \cdot 10^{-6} \text{ Am}^2 \text{ kg}^{-1}$, the magnetic susceptibility (χ_{lf}) is on average $28 \cdot 10^{-8} \text{ Am}^3 \text{ kg}^{-1}$, and the anhysteretic remanent magnetization (χ_{ARM}) is on average $1.1 \cdot 10^{-6} \text{ m}^3 \text{ kg}^{-1}$. The S-ratio, a magnetic mineralogy indicator, is approximately 0.9 suggesting that both ferrimagnetic minerals (e.g., magnetite) and high coercively mineral (e.g., hematite or goethite) are present.

3.1.2 Trapping Efficiency

The sediment trapping efficiency of Lake Butler was determined by collecting inflow and outflow data on two dates (March 25 and November 21, 2016). Water discharge (Q_w) and total suspended sediment (TSS) concentrations were measured so that suspended sediment discharge (Q_s) could be calculated for the inflow and outflow (Appendix A). The lake was drained before the March data collection to repair a valve. Water level at that time was approximately a foot below normal level. In November, the lake was at the normal pool lake level. In March, water discharge at the inflow was $0.055 \text{ m}^3/\text{s}$ and the outflow was $0.061 \text{ m}^3/\text{s}$ (Appendix A). The difference in discharge between the two sites is not significant and therefore the lake was not draining. Inflow TSS was higher in Haskell Run and on average lower in the lake and at the outflow culvert. During this time, the outflow Q_s was about 1.32 g/sec. In November, discharge at the inflow and outflow sites were low (inflow = 0.016 ; outflow = $0.011 \text{ m}^3/\text{s}$). November TSS was lower than in March, indicating the water was less turbid in November. Q_s values in the lake were

Table 18. Magnetic properties for Lake Butler surface samples and core samples.

Sample	Sample Depth (cm)	Sample Wt (kg)	DBD (g/cm ³)	Organic Matter (%)	χ_{if} (10 ⁻⁸ m ³ kg ⁻¹)	χ_{hf} (10 ⁻⁸ m ³ kg ⁻¹)	χ_{fd} (%)
Surface							
LB-G4	1.40	0.0063	0.630	10.1	24.8	24.3	2.15
LB-G5	1.00	0.0062	0.534	11.6	27.6	27.2	1.57
LB-G7	0.50	0.0063	0.538	7.0	30.3	29.5	2.64
Core							
LB-C4 0cm	0.00	0.0060	0.805	10.1	27.9	27.4	1.79
LB-C4 50cm	50.00	0.0056	0.943	6.3	24.0	23.6	1.67
LB-C4 101cm	101.00	0.0060	0.935	6.0	29.5	28.6	3.05
LB-C4 150cm	150.00	0.0058	0.857	7.4	27.0	26.6	1.48
LB-C4 200cm	200.00	0.0060	0.974	5.1	35.5	34.5	2.82

Table 18. Magnetic properties for Lake Butler surface samples and core samples (cont'd).

Sample	χ_{ARM} ($10^{-6} \text{ m}^3 \text{ kg}^{-1}$)	$\chi_{\text{ARM}_{40\text{mT}}}$ $10^{-6} \text{ m}^3 \text{ kg}^{-1}$	IRM _{40mT} Convertered ($10^{-6} \text{ Am}^2 \text{ kg}^{-1}$)	SIRM Convertered ($10^{-6} \text{ A}^2 \text{ m}^2 \text{ kg}^{-1}$)	bIRM Demag _{-100mT} Convertered ($10^{-6} \text{ A}^2 \text{ m}^2 \text{ kg}^{-1}$)	bIRM Demag _{-300mT} Convertered ($10^{-6} \text{ A}^2 \text{ m}^2 \text{ kg}^{-1}$)
Surface						
LB-G4	1.295	0.455	801.97	2404.23	-1529.70	-2163.80
LB-G5	1.064	0.316	809.93	2441.63	-1535.34	-2188.38
LB-G7	1.338	0.463	869.12	2445.51	-1618.00	-2234.95
Core						
LB-C4 0cm	0.910	0.293	774.94	2362.39	-1484.67	-2124.73
LB-C4 50cm	1.342	0.479	784.49	2209.06	-1544.44	-1973.87
LB-C4 101cm	1.239	0.415	987.87	2729.14	-1916.19	-2453.88
LB-C4 150cm	1.442	0.506	967.59	2569.90	-1867.25	-2342.75
LB-C4 200cm	1.397	0.499	1327.79	3810.66	-2799.35	-3561.50

Table 18. Magnetic properties for Lake Butler surface samples and core samples (cont'd).

Sample	S-ratio	SIRM/ χ (10^2 A/m)	χ_{ARM}/χ
Surface			
LB-G4	0.900	96.94	5.221
LB-G5	0.896	88.46	3.855
LB-G7	0.914	80.71	4.417
Core			
LB-C4 0cm	0.899	84.67	3.261
LB-C4 50cm	0.894	92.04	5.593
LB-C4 101cm	0.899	92.51	4.199
LB-C4 150cm	0.912	95.18	5.341
LB-C4 200cm	0.935	107.34	3.934

also comparatively low, signifying more sediment was being transported in March than in November.

3.1.3 Sediment Cores

Sediment cores were collected from Lake Butler in March and May of 2016. Cores were taken from the delta top (LB-16-C1 and LB-16-C4) and from the pro-delta lake floor (LB-16-C7). Cores were evaluated for visual lithology, organic matter content, dry bulk density, grain size, heavy metal concentrations, and magnetic properties.

Delta top core LB-16-C4 is 249 cm long and can be divided into three main sections: 249-203 cm, 203-45 cm, and 45-0 cm (Figures 18 and 19). From 249 to 203 cm core depth, the lithology is primarily medium sand with granules in the bottom 8 cm. The granules at the bottom 8 cm are similar to the granules found in the channel of Haskell Run (sample G13). The whole-core susceptibility (κ) in this section is the highest in the entire core. The organic matter content increases slightly up core, with a peak value in a wood debris layer. Bulk density at the bottom 8 cm of C4 is 1.7 g/cm³, then gradually decreases ~1.2 g/cm³. Between 203-45 cm, there are three lithologies present; however, κ is uniform throughout the section. The predominant lithology is a dark grey clay.

In the clay units, organic matter and dry bulk density remain constant. The D_{50} of the sediment at 200 cm core depth was determined to be fine silt (Table 16). Sand is present at 147-142 cm and 80-76 cm core depth, accompanied by a decrease in organic matter content and a slight increase in dry bulk density. Layers of woody debris are present at 114-105 cm and at 76-74 cm. In these woody debris layers, there is an organic matter increase and a dry bulk density decrease. Between 45-0 cm core depth, there are three lithologies present: sand, black clay, and mud. In this section, at 35 cm, the sediment contains 50% sand and 25% silt and 25% clay with a high dry bulk density and a low

Figure 18. Detailed lithology description for Lake Butler sediment core LB-16-C4.

Figure 19. Lithology, whole core susceptibility (κ), organic matter, and dry bulk density for Lake Butler delta top core LB-16-C4. See figure 18 for lithology description.

Figure 20. Down core profiles of Lake Butler delta top core (C4) showing lithology, magnetic concentrations (SIRM), and Pb, Zn, Cu, and Cr heavy metal concentrations.

organic matter content (Table 16). The κ profile is uniform throughout this section, whereas, organic matter content and dry bulk density are variable.

Heavy metal concentrations for Pb, Zn, Cu, and Cr were analyzed for five down core samples in core C4 (Figure 20; Table 17). From 200 to 50 cm core depth, Pb and Cr concentrations are largely uniform, and at the top of the core, both metal concentrations drop slightly. Cu concentrations are slightly larger between 200-150 cm than between 100-0 cm. Zn concentration throughout the core is uniform, except at 150 cm depth, where the concentration increases to 709 $\mu\text{g/g}$. There are no corresponding increases in Pb, Cu, or Cr metal concentrations at 150 cm core depth.

The magnetic concentration parameters χ_{ir} , SIRM and χ_{ARM} are uniform and low throughout the core, indicating low concentrations of ferrimagnetic minerals are present (Figures 21 and 22; Table 18). Three of the five downcore samples have less than 2% frequency dependence, indicating that they do not contain superparamagnetic grains (SPM). The other two samples are above 2%, indicating that they contain superparamagnetic grains (Figure 23). The magnetic grain size parameters χ_{ARM}/χ and SIRM/χ show little variation down core. The S-ratio indicates most samples plot at about 0.9, indicating that there is a mixture of high and low coercively minerals present.

The second delta top core (C1) was taken close to C4. The core was not as long as C4; however, the core data show similar trends in κ , organic matter, and bulk density (Appendix B). Throughout the core, κ was uniform. The woody debris layers, between 115-90 cm, were high in organic matter content (20%) and had a low bulk density (0.5 g/cm^3). Interbedded sand and clay layers were present between 90-47 cm, having a low organic matter content (1-7%) and bulk density around 1.0 g/cm^3 . Silty mud and clay layers in the uppermost 47 cm showed moderate levels in organic matter and dry bulk density.

Figure 21. Lithology and magnetic concentration profiles for Lake Butler delta top core C4. See Figure 18 for lithology key.

Figure 22. Lithology, magnetic grain size ($\chi_{fd}\%$ and χ_{ARM}/χ), SIRM/ χ , and magnetic mineralogy (S-ratio) profiles for Lake Butler delta top core C4. See Figure 18 for lithology key.

Figure 23. Dearing Plot for surficial samples and core samples from the three site impoundments.

Figure 24. Detailed lithology description for core pro-delta Lake Butler core LB-16-C7.

The pro-delta lake floor core (C7) is 98 cm long and can be divided into three sections: 98-74 cm, 74-34 cm, and 34-0 cm (Figures 24 and 25). From 98-74 cm, the lithology is composed of granules in the bottom 2 cm overlying red/brown clay, and sandy/clay layers. In this section, magnetic susceptibility is high organic matter content is uniform at 7%. The dry bulk density decreases in the clay layers and increases in the sand. Between 74-34 cm core depth, there are woody debris, sand, and clay layers. The κ remains uniform in this section, whereas, the organic matter content and dry bulk density display greater variations. In the uppermost 34 cm, the lithology present is silty mud/clay. The κ , organic matter content, and dry bulk density fluctuates, but are generally uniform in value.

3.1.4 Shoreline Change

To document changes in sediment deposition and shoreline progradation from 1994 to 2016, aerial photographs of the delta at the upstream end of Lake Butler were examined (Figures 26-30). Due to the varying lake level in Lake Butler, the water level on each photograph was compared to the lake level in the year 2000 photograph. In 1994, Haskell Run enters Lake Butler on the left side of the valley. The lake level was higher in 1994 relative to the 2000 water line (Table 19). By 2000, Haskell Run enters Lake Butler on the right side of the valley. In the 2003 photo, it is difficult to see the water level due to the poor photo quality; however, it is known that the photograph was taken in July 2003, after a major regional flooding event (USGS, 2016b). Haskell Run continues to enter Lake Butler from the right side of the valley from 2005 to 2016. The lake level increases in 2005 then drops in 2006, possibly due to the time of the year (early spring) rather than due to flooding. In 2010, although lake level is low, the C4 core site is now clearly on the delta top environment. Since 2010, lake level is lower than in the years prior to 2010.

Figure 26. Haskell Run and the Lake Butler delta in 1994 and 2000. The rightmost red dot is the LB-16-C4 core location and the leftmost dot is the LB-16-C1 core location. The red line feature is the year 2000 shoreline reference point to determine relative water level change (Summit County Fiscal Office, 2016).

Figure 27. Haskell Run and the Lake Butler delta in 2003 and 2005. The rightmost red dot is the LB-16-C4 core location and the leftmost dot is the LB-16-C1 core location. The red line feature is the year 2000 shoreline reference point to determine relative water level change (Summit County Fiscal Office, 2016; USGS, 2016b).

Figure 28. Haskell Run and the Lake Butler delta in 2006 and 2010. The rightmost red dot is the LB-16-C4 core location and the leftmost dot is the LB-16-C1 core location. The red line feature is the year 2000 shoreline reference point to determine relative water level change (Summit County Fiscal Office, 2016).

Figure 29. Haskell Run and the Lake Butler delta in 2012 and 2014. The rightmost red dot is the LB-16-C4 core location and the leftmost dot is the LB-16-C1 core location. The red line feature is the year 2000 shoreline reference point to determine relative water level change (Google, 2016; Summit County Fiscal Office, 2016).

Figure 30. Haskell Run and the Lake Butler delta in 2015 and 2016. The rightmost red dot is the LB-16-C4 core location and the leftmost dot is the LB-16-C1 core location. The red line feature is the year 2000 shoreline reference point to determine relative water level change (Google, 2016; Summit County Parcel Viewer, 2016).

Table 19. Lake Butler lake level relative to the year 2000 water level.

Year	Water Level
1994	Deeper
2000	Reference year
2003	Same/ Slightly deeper
2005	Deeper
2006	Same
2010	Shallower
2012	Shallower
2014	Shallower
2015	Similar
2016	Shallower

3.1.5 Land cover

Land cover classification for this study was divided into four main categories: developed, farmland, undeveloped, and open water. Quantifying undeveloped and developed land cover change over time was the focus for land cover analysis. However, assessing changes in farmland is also important for watershed health and determining what pollutants or sediments are entering the watershed (Shi et al., 2017). Land cover area, land cover area change, impervious cover, and impervious cover change were tabulated for Lake Butler for five different years (Figure 31; Table 20; Appendix E). The total area of the Haskell Run watershed is 2,881,800 m². From 1985-2010, there was an overall 1.37% increase (+39,600 m²) in developed land, 0.87% decrease (-25,200 m²) in farmland, and 0.50% decrease (-14,400 m²) of undeveloped land. The greatest amount of change during 1985-2010 period occurred between 1996-2001 (Table 20). From 1985-2010, the overall increase in impervious surfaces was 12,712 m² (0.44%). The majority of the land use change was converting farmland and undeveloped land into developed land. The change occurred at the eastern edge of the Haskell Run watershed by Akron Cleveland Road. The location of this change is also outside the Cuyahoga Valley National Park boundaries.

3.2 Lake Litchfield

Surficial and core sediment properties were determined from Lake Litchfield. Lake Litchfield delta shorelines from 1994 to 2016 were assessed. Land cover changes were quantified for the Ritchie Run watershed between 1985 and 2010.

3.2.1 Surface Samples

Thirteen surface samples were collected from the Lake Litchfield impoundment (Table 24). The impoundment samples consisted largely of tan clay overlying an organic

Figure 31. Land cover change in the Haskell Run watershed from 1985-2010 (Digital Coast, 2016a). The percent impervious cover is also presented for each year.

Table 20. Haskell Run land cover and land cover change summary table for the years 1985, 1996, 2001, 2006, and 2010. A) Total area land cover and area land cover change (m²), B) Percent land cover and percent land cover change, C) Total area of impervious surfaces and impervious surface area change (m²), D) Percent impervious surfaces and percent impervious change. The total area of the Haskell Run watershed is 2,881,800 m² (Digital Coast, 2016a; Digital Coast, 2016b).

A)									
Land Cover Class Name	Total Area (m ²)				Area Change (m ²)				
	1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	1985-2010
<u>Reclassified Groups</u>									
Developed	296,100	296,100	327,600	328,500	335,700	0	31,500	900	7,200
Farmland	89,100	83,700	63,900	63,900	63,900	-5,400	-19,800	0	0
Undeveloped	2,456,100	2,461,500	2,449,800	2,448,900	2,441,700	5,400	-11,700	-900	-7,200
Open Water	40,500	40,500	40,500	40,500	40,500	0	0	0	0
Total	2,881,800	2,881,800	2,881,800	2,881,800	2,881,800	0	0	0	0
B)									
Land Cover Class Name	Percent Total (%)					Percent Change (%)			
	1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	1985-2010
<u>Reclassified Groups</u>									
Developed	10.27	10.27	11.37	11.40	11.65	0.00	1.09	0.03	0.25
Farmland	3.09	2.90	2.22	2.22	2.22	-0.19	-0.69	0.00	0.00
Undeveloped	85.23	85.42	85.01	84.98	84.73	0.19	-0.41	-0.03	-0.25
Open Water	1.41	1.41	1.41	1.41	1.41	0.00	0.00	0.00	0.00
Total	100	100	100	100	100	0.00	0.00	0.00	0.00
C)									
Land Cover Class Name	Area of Impervious Cover (m ²)					Change in Impervious Cover (m ²)			
	1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	1985-2010
<u>Reclassified Groups</u>									
Developed	79,636.77	79,736.49	90,659.70	90,889.83	93,995.55	99.72	10,923.21	230.13	3,105.72
Farmland	1,528.20	1,396.44	913.32	913.32	913.32	-131.76	-483.12	0.00	0.00
Undeveloped	47,032.47	47,087.28	46,096.29	46,080.36	46,001.34	54.81	-990.99	-15.93	-79.02
Open Water	405.00	405.00	405.00	405.00	405.00	0.00	0.00	0.00	0.00
Total	128,602.44	128,625.21	138,074.31	138,288.51	141,315.21	22.77	9,449.10	214.2	3026.7
D)									
Land Cover Class Name	Percent Impervious Surfaces (%)					Percent Impervious Change (%)			
	1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	1985-2010
<u>Reclassified Groups</u>									
Developed	2.763	2.767	3.146	3.154	3.262	0.003	0.379	0.008	0.108
Farmland	0.053	0.048	0.032	0.032	0.032	-0.005	-0.017	0.000	0.000
Undeveloped	1.632	1.634	1.600	1.599	1.596	0.002	-0.034	-0.001	-0.003
Open Water	0.014	0.014	0.014	0.014	0.014	0.000	0.000	0.000	0.000
Total	4.463	4.463	4.791	4.799	4.904	0.001	0.328	0.007	0.105

Table 21. Magnetic and physical properties of Lake Litchfield surface samples and core samples.

Sample	Depth	χ_{lf}	χ_{hf}	χ_{fd}	Organic Matter	Dry Bulk Density	Water Content	Visual Grain Size	Location
Number	(m)	($10^{-8} \text{ m}^3 \text{ kg}^{-1}$)	($10^{-8} \text{ m}^3 \text{ kg}^{-1}$)	(%)	(%)	(g/cm^3)	(%)		
LL-G1	1.50	26.3	25.7	2.2	4.7	0.620	57.0	Clay	Same location as core 1, near inflow
LL-G2	1.40	31.9	31.7	0.6	4.9	0.452	66.5	Clay	Other side C1 in alcove area
LL-G3	2.00	23.6	23.1	2.1	10.5	0.333	73.1	Clay	Alluvial fan area
LL-G4	5.50	23.6	22.9	3.0	5.0	0.650	55.5	Clay	River center
LL-G5	6.50	19.2	18.9	-	5.6	0.291	76.2	Clay	River center
LL-G6	4.50	19.4	18.5	-	6.7	0.314	74.6	Clay	River right, in alluvial fan
LL-G7	2.50	20.4	20.2	1.0	7.6	0.313	74.7	Clay	Near bank of shore, lake fork
LL-G8	8.50	17.6	17.4	-	6.4	0.350	72.7	Clay	Near convergence of lake fork
LL-G9	5.50	17.8	16.9	-	7.2	0.311	74.9	Clay	River left
LL-G10	3.25	20.1	19.7	2.0	7.5	0.357	71.7	Clay	Alluvial fan in alcove
LL-G11	4.00	21.2	20.4	3.8	6.6	0.372	70.6	Clay	Compare with G10, other alcove
LL-G12	11.00	18.3	17.7	-	5.0	0.603	58.4	Clay	Middle of lake near put-in
LL-G13	8.50	18.3	17.8	-	5.7	0.407	68.3	Clay	Near the culvert (river center)

Table 22. Heavy metal concentrations for selected Lake Litchfield sediment samples.

Sample	Pb Concentration (µg/g)	Zn Concentration (µg/g)	Cu Concentration (µg/g)	Cr Concentration (µg/g)
Surface				
LL-G1	19.9	88.5	24.0	52.3
LL-G1 Rep	21.3	92.0	22.8	51.7
LL-G2	20.4	79.3	15.8	44.8
LL-G8	21.1	126.6	29.1	84.8
Core				
LL-C1 2cm	16.3	90.5	24.4	44.7
LL-C1 30cm	33.4	100.5	32.9	55.7
LL-C1 60cm	24.6	104.4	28.8	53.4
LL-C1 90cm	22.7	84.7	20.7	45.3
LL-C1 120cm	10.5	68.5	24.5	42.3

black mud; however, samples G5,6,7 had a distinctive red color. Samples were evaluated for porosity, organic matter content, dry bulk density, mass-corrected susceptibility (χ), visual grain size, heavy metal concentrations, and magnetic properties (Tables 21 and 22). These clay-rich samples had porosities between 55.5-76%, low organic matter between 4.9-10.5%, and low bulk densities ranged from 0.290-0.630 g/cm³. Magnetic susceptibility ranged between 17.6-31.7 10⁻⁸ m³ kg⁻¹.

Surficial samples G1,2, and 8 were analyzed for heavy metal concentrations (Table 25). The average metal concentrations were: Pb = 21 µg/g, Zn = 97 µg/g, Cu = 23 µg/g, and Cr = 58 µg/g. G8 had a high Zn concentration of 127 µg/g. These samples were also tested for magnetic properties including ferrimagnetic concentration, magnetic grain size, and mineralogy (Appendix C). The SIRM for these samples is on average 2,200 10⁻⁶ m³kg⁻¹, the average χ_{lf} is 25.3 10⁻⁸ m³ kg⁻¹, and the average χ_{ARM} is 0.9 10⁻⁶ m³ kg⁻¹. The S-ratio for the samples were at or about 0.9, indicating a mixture of high and low coercivity minerals are present. Most of these surficial samples had frequency dependence at or above 2% indicating the presence of SPM grains.

3.2.2. Sediment Cores

Four sediment cores were collected from Lake Litchfield in May 2016. One core was extracted from the delta slope (LL-16-C1), and the remaining cores were collected from the subaqueous levee where Ritchie Run enters Lake Litchfield (Figure 15).

The delta slope core, LL-16-C1, is 138 cm long and can be divided into three main sections: 138-118 cm, 118-78 cm, and 78-0 cm (Figures 32 and 33). Between 138-118 cm core depth, the lithology is a yellow/brown medium sand. There is a general decreasing trend up core in the whole-core susceptibility and dry bulk density profiles, and a slight increase in the organic matter content (Figure 33). Between 118-78 cm core depth, there are three lithologies present: clay, sand, and silty mud. In the clay layers, κ and dry bulk

Table 23. Lake Litchfield summary table of grain size analysis for representative samples. The D_{50} is the median.

Sample	Dry Bulk Density (g/cm ³)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	D_{50} Φ	Wentworth Size Class
LL-C1 15-20cm	0.861	-	1.2	67.3	31.6	6.83	Medium silt
LL-C1 30cm	0.970	-	0.6	80.6	18.8	6.61	Medium silt
LL-C1 45cm	0.920	-	1.1	63.8	35.1	7.03	Fine silt
LL-C1 90cm	1.340	-	10.6	61.6	27.7	6.22	Medium silt

Figure 32. Detailed lithology description for Lake Litchfield pro-delta core LL-16-C1.

Figure 33. Lithology, whole core susceptibility (κ), organic matter, and dry bulk density for Lake Litchfield pro-delta core LL-16-C1. See Figure 32 for lithology descriptions.

Figure 34. Down core profiles of Lake Litchfield pro-delta core (C1) showing lithology, magnetic concentration (SIRM), and Pb, Zn, Cu, and Cr heavy metal concentrations.

Figure 35. Lithology and magnetic concentration profiles for Lake Litchfield pro-delta core C1. See Figure 32 for lithology key.

Figure 36. Lithology, magnetic grain size ($\chi_{fd}\%$), χ_{ARM}/χ , SIRM/ χ , and magnetic mineralogy (S-ratio) profiles for Lake Litchfield core C1. See Figure 32 for lithology description.

Figure 37. Detailed lithology description for Lake Litchfield sediment core LL-16-C2.

Figure 38. Lithology, whole core susceptibility (κ), organic matter, and dry bulk density for Lake Litchfield core C2. See Figure 37 for lithology descriptions.

Figure 39. Lake Litchfield delta in 1994 and 2000. The leftmost dot is core LL-16-C1 and the rightmost dots are cores LL-16-C2 and C3 at the subaqueous delta. The red line is the year 2000 shoreline reference to determine relative water level change. Arrow shows delta progradation (Summit County Fiscal Office, 2016).

Figure 40. Lake Litchfield delta in 2003 and 2005. The leftmost dot is core LL-16-C1 and the rightmost dots are cores LL-16-C2 and C3 at the subaqueous delta. The red line is the year 2000 shoreline reference to determine relative water level change. Arrow shows delta progradation (Summit County Fiscal Office, 2016; USGS, 2016b).

Figure 41. Lake Litchfield delta in 2006 and 2010. The leftmost dot is core LL-16-C1 and the rightmost dots are cores LL-16-C2 and C3 at the subaqueous delta. The red line is the year 2000 shoreline reference to determine relative water level change. Arrow shows delta progradation (Summit County Fiscal Office, 2016).

Figure 42. Lake Litchfield delta in 2012 and 2014. The leftmost dot is core LL-16-C1 and the rightmost dots are cores LL-16-C2 and C3 at the subaqueous delta. The red line is the year 2000 shoreline reference to determine relative water level change. Arrow shows delta progradation (Summit County Fiscal Office, 2016).

Figure 43. Lake Litchfield delta in 2015 and 2016. The leftmost dot is core LL-16-C1 and the rightmost dots are cores LL-16-C2 and C3 at the subaqueous delta. The red line is the year 2000 shoreline reference to determine relative water level change. Arrow shows delta progradation (Google, 2016; Summit County Parcel Viewer, 2016).

Table 24. Lake Litchfield lake level relative to the year 2000 water level.

Year	Water Level
1994	Similar/deeper
2000	Reference year
2003	Unsure
2005	Deeper
2006	Shallower
2010	Similar
2012	Deeper
2014	Similar
2015	Deeper
2016	Unsure

density decrease, whereas organic matter increases. At 90 cm core depth, the D_{50} was measured to be medium silt (Table 23). At the upper most 78 cm, the lithologies present are clay, sand, and woody debris. Between 78-0 cm core depth, the organic matter and dry bulk density profiles display pronounced variation. An interval of alternating black and red clay, between 61-72 cm, exhibits a large increase in organic matter content (13%) and decrease in bulk density (0.3 g/cm^3). Grain size analysis of the samples from 45 cm, 30 cm, and 20 cm core depth had D_{50} values within the medium or fine silt range. Five downcore samples were tested for Pb, Zn, Cu, and Cr heavy metal concentrations (Figure 34). Zn, Cu, and Cr concentrations remained low and uniform throughout the core. Pb concentrations increase up core and then decreased at the core top.

The χ_{ARM} values for the five downcore samples are at or below $1.0 \cdot 10^{-6} \text{ m}^3 \text{ kg}^{-1}$ and SIRM values are less than $2,439 \cdot 10^{-6} \text{ m}^3 \text{ kg}^{-1}$, indicating low concentrations of ferrimagnetic low coercivity minerals (Figure 35). Two of the five samples have greater than 2% frequency, indicating that the samples contain superparamagnetic grains. The remaining samples contain stable single domain grains (Figures 23 and 36). The S-ratio values are at or about 0.9 signifying a mixture of high and low coercively minerals.

A second core was obtained at the subaqueous levee, where Ritchie Run enters the impoundment. Core LL-16-C2 is 88.5 cm long and is comprised largely of sand (Figures 37 and 38). Organic matter content is consistently low ($\sim 1\%$) and the dry bulk density is high ($\sim 1.3 \text{ g/cm}^3$). A layer of gravel is present between 56.5-54 cm core depth. Although the κ increases in the gravel layer, the organic matter content and dry bulk density are similar to the sand lithology. There are woody debris layers at 30-25 cm and 74-70 cm core depth with corresponding decreases in bulk density and increases in organic content (Figure 38). The other two subaqueous levee cores, C3 and C4, recovered similar lithology to C2 (Appendix D).

3.2.3 Shoreline Change

Aerial photographs of the delta at the upstream end of Lake Litchfield were analyzed to document sediment deposition changes and shoreline progradation from 1994 to 2016 (Figures 39-43). Lake level fluctuates in Lake Litchfield; therefore, each photograph year was compared to the year 2000 water level indicator. In 1994, the river mouth is set back into the stream valley. The water level is higher in 1994, 2005, 2012, and 2015 compared to the year 2000 waterline reference (Table 24). A reference point was marked on the map for 1994, 2000, 2003, 2005, 2010, and 2015 to track the growth rate of the river mouth (Table 25). From 1994-2000, the mouth of the river advanced approximately 33 meters. It was thought that with the evidence from Delaney (2016) and Liberator (2013) there would be a faster delta growth rate in Lake Litchfield after 2003 with increased regional flooding. After analysis, however, it was determined there was no significant increase after 2003 in the prograding delta. The total delta growth from 1994-2015 was approximately 74.5 meters. In August of 2016, Lake Litchfield was drained to repair a valve, which exposed the lakebed and shoreline features. During a data collection trip in September 2016, photos were captured of the exposed delta and sedimentary structures. This was the first time the lake was drained in its 40-year history.

3.2.4 Land cover

Percent area of land cover and percent area land cover change were tabulated and analyzed for Lake Litchfield (Figure 44; Table 26; Appendix E). The total area of the Ritchie Run watershed is 1,665,000 m². From 1985-2010, the Ritchie Run watershed had no change in developed, farmland, undeveloped, or open water land cover. As of 2010, 3.4% (55,800 m²) of the watershed was developed, 3.5% (58,500 m²) was farmland, and 86% (1,437,300 m²) was undeveloped land cover. Due to land cover classes not changing, there was no change in impervious surfaces from 1985-2010. Of the total watershed,

Table 25. Delta growth from 1994 to 2015 at Lake Litchfield.

Year	Month	Distance from Reference Point (m)	Delta growth/month (meters/month)
1994	April	40	-
2000	April	72.5	0.45
2003	July	72.5	0.00
2005	April	76.5	0.17
2010	April	99.2	0.38
2015	April	114.5	0.26

Figure 44. Land cover change from 1985-2010 in the Ritchie Run watershed (Digital Coast, 2016a). The percent impervious cover is also presented for each year.

Table 26. Ritchie Run land cover and land cover change summary table for the years 1985, 1996, 2001, 2006, and 2010. A) Total area land cover and area land cover change (m²), B) Percent land cover and percent land cover change, C) Total area of impervious surfaces and impervious surface area change (m²), D) Percent impervious surfaces and percent impervious change. The total area of the Haskell Run watershed is 1,665,000 m² (Digital Coast, 2016a; Digital Coast, 2016b).

A)	Total Area (m ²)					Area Change (m ²)				
Land Cover Class Name	1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
Reclass Groups										
Developed	55,800	55,800	55,800	55,800	55,800	0	0	0	0	0
Farmland	58,500	58,500	58,500	58,500	58,500	0	0	0	0	0
Undeveloped	1,437,300	1,437,300	1,437,300	1,437,300	1,437,300	0	0	0	0	0
Open Water	113,400	113,400	113,400	113,400	113,400	0	0	0	0	0
Total	1,665,000	1,665,000	1,665,000	1,665,000	1,665,000	0	0	0	0	0
B)	Percent Total (%)					Percent Change (%)				
Land Cover Class Name	1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
Reclass Groups										
Developed	3.35	3.35	3.35	3.35	3.35	0.00	0.00	0.00	0.00	0.00
Farmland	3.51	3.51	3.51	3.51	3.51	0.00	0.00	0.00	0.00	0.00
Undeveloped	86.32	86.32	86.32	86.32	86.32	0.00	0.00	0.00	0.00	0.00
Open Water	6.81	6.81	6.81	6.81	6.81	0.00	0.00	0.00	0.00	0.00
Total	100	100	100	100	100	0.00	0.00	0.00	0.00	0.00
C)	Area of Impervious Cover (m ²)					Change in Impervious Cover (m ²)				
Land Cover Class Name	1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
Reclass Groups										
Developed	10,447.02	10,447.02	10,447.02	10,447.02	10,447.02	0.00	0.00	0.00	0.00	0.00
Farmland	819.00	819.00	819.00	819.00	819.00	0.00	0.00	0.00	0.00	0.00
Undeveloped	27,878.85	27,878.85	27,878.85	27,878.85	27,878.85	0.00	0.00	0.00	0.00	0.00
Open Water	1,134.00	1,134.00	1,134.00	1,134.00	1,134.00	0.00	0.00	0.00	0.00	0.00
Total	40,278.87	40,278.87	40,278.87	40,278.87	40,278.87	0.00	0.00	0.00	0.00	0.00
D)	Percent Impervious Surfaces (%)					Percent Impervious Change (%)				
Land Cover Class Name	1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
Reclass Groups										
Developed	0.63	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.00	0.00
Farmland	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00
Undeveloped	1.67	1.67	1.67	1.67	1.67	0.00	0.00	0.00	0.00	0.00
Open Water	0.07	0.07	0.07	0.07	0.07	0.00	0.00	0.00	0.00	0.00
Total	2.42	2.42	2.42	2.42	2.42	0.00	0.00	0.00	0.00	0.00

2.42% is considered impervious cover, with 0.63% coming from developed land cover and 1.67% from undeveloped land cover. The main contribution for developed land cover in the Ritchie Run watershed is largely the Boy Scout camp and parts of Truxell Road.

3.3 Old Mill Pond

Surficial and core sediment properties were analyzed from the Old Mill Pond impoundment. Shorelines at the Old Mill Pond delta were assessed from 1994 to 2016. Land cover changes were determined for the Mud Brook watershed from 1985 to 2010.

3.3.1 Surface Samples

Thirteen surface samples were collected from the Old Mill Pond impoundment. Eleven samples were collected from the impoundment, and two were collected in the culvert closest to the dam (Figure 45). The impoundment surficial sediment is an organic-rich clay that changes to sand and gravel closer to the dam and culvert. Porosity, organic matter content, dry bulk density, mass-corrected susceptibility, and visual grain size were measured on all surface samples (Table 27). Mud samples have porosities between 70-77%, organic matter content between 10.3-11.3%, bulk density of about 0.32 g/cm³, and a susceptibility range of 41-104 10⁻⁸ m³ kg⁻¹. The mud sample G4, collected in the river channel heading toward the dam, had a notably higher susceptibility of 104 10⁻⁸ m³ kg⁻¹ when compared to the other mud samples. Sand and pebble-dominated samples had porosities between 23-32%, organic matter content of 3.4-4.8%, dry bulk density between 1.26-1.56 g/cm³, and susceptibility that ranged from 73-139 10⁻⁸ m³ kg⁻¹. Grain size was determined for samples G3,7,8,9, and 12 (Table 28; Appendix F). The culvert samples G7 and G8 were very poorly sorted, very coarse sand to coarse sand. The D₅₀ for G3, 9 and 12 were determined to be fine silt to very fine silt.

Table 27. Magnetic and physical properties of Old Mill Pond surface samples and core samples.

Sample	Depth	χ_{ir}	χ_{hf}	χ_{fd}	Organic Matter	Dry Bulk Density	Water Content	Visual Grain Size	Location
Number	(m)	($10^{-8} \text{ m}^3 \text{ kg}^{-1}$)	($10^{-8} \text{ m}^3 \text{ kg}^{-1}$)	(%)	(%)	(g/cm^3)	(%)		
OMP-G1	0.27	46.3	45.2	2.3	11.0	0.323	74.0	Silty clay	C1 surface sample, short core
OMP-G2	1.00	59.4	58.3	1.9	11.2	0.278	77.1	Silty clay	Near C5 location (by delta)
OMP-G3	1.00	50.5	49.4	2.2	10.3	0.344	73.1	Silty clay	Toward outflow, river right
OMP-G4	1.33	104.4	103.1	1.2	11.1	0.383	70.7	Silty clay	Toward dam, river center
OMP-G5	1.20	139	137.5	1.1	3.4	1.559	22.6	Gravel	River left, heading toward dam
OMP-G6	0.50	73.8	72.0	2.4	4.8	1.261	32.5	Medium sand	Near culvert, impoundment forks
OMP-G7	1.00	112	108.8	2.9	4.0	1.531	24.0	Coarse sand	Closest to the culvert
OMP-G8	0.40	106.5	103.4	2.9	3.7	1.260	31.0	Very coarse sand	Where culvert and stream fork
OMP-G9	1.40	70.1	68.5	2.3	10.9	0.363	71.1	Silty clay	River right, channel toward dam
OMP-G10	0.1	49.6	48.3	2.6	10.8	0.313	74.6	Silty clay	Near shore to the medical center
OMP-G11	0.4	71.8	71.0	1.1	11.0	0.327	73.6	Silty clay	Toward top of lake, near pipe
OMP-G12	0.46	42.8	41.5	3.0	10.7	0.335	73.0	Silty clay	Near top, right of lake, near pipe
OMP-G13	0.51	41.6	40.3	3.1	11.3	0.316	74.6	Silty clay	2 m to the left of G12

Table 28. Old Mill Pond summary table of grain size analysis for representative samples. The D_{50} is the median. The σ is the sorting for the sand samples.

Sample	Dry Bulk Density (g/cm ³)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	D ₅₀ Φ	Wentworth Size Class	σ Φ	Sorting Value
OMP-C3 20cm	0.756	-	1.7	66.2	32.1	6.91	Medium silt	-	-
OMP-C3 80cm	0.732	-	0.7	51.4	47.4	7.87	Fine silt	-	-
OMP-C3 110cm	0.539	-	8.8	46.2	45.1	8.00	Very fine silt	-	-
OMP-C3 160cm	0.988	-	1.6	52.7	45.6	7.63	Fine silt	-	-
OMP-C5 10cm	0.61	-	14.7	50.1	35.2	6.86	Medium silt	-	-
OMP-C5 25cm	0.865	-	5.2	62.0	32.8	6.73	Medium silt	-	-
OMP-G3	0.344	-	3.1	58.3	38.5	7.29	Find silt	-	-
OMP-G7	1.260	47.1	52.4	0.5	-	-0.76	Very coarse sand	2.09	Very poorly sorted
OMP-G8	0.363	12.1	87.1	0.8	-	0.86	Coarse sand	1.36	Poorly sorted
OMP-G9	0.363	-	11.0	48.2	40.8	7.80	Fine silt	-	-
OMP-G12	0.335	-	1.3	55.9	42.8	7.51	Fine silt	-	-

Table 29. Heavy metal concentrations for selected Old Mill Pond sediment samples.

Sample	Pb Concentration (µg/g)	Zn Concentration (µg/g)	Cu Concentration (µg/g)	Cr Concentration (µg/g)
Surface				
OMP-G1	48.8	213.6	40.6	68.1
OMP-G3	31.2	232.9	61.9	65.8
OMP-G4	4.6	217.7	51.8	58.2
OMP-G7	56.3	93.4	14.1	24.1
OMP-G8	28.4	92.7	10.6	18.6
OMP-G9	48.5	257.8	61.1	67.4
OMP-G11	21.1	168.2	32.3	45.8
OMP-G12	42.9	222.8	54.6	69.8
Cores				
OMP-C3 1cm	42.1	213.1	53.9	58.9
OMP-C3 20cm	29.7	213.7	47.8	58.6
OMP-C3 40cm	55.8	187.6	46.0	57.8
OMP-C3 60cm	74.5	199.8	44.0	61.3
OMP-C3 80cm	113.0	263.0	51.5	136.0
OMP-C3 80cm R	121.8	261.4	48.3	133.2
OMP-C3 100cm	93.8	223.6	51.5	75.4
OMP-C3 110cm	93.6	238.4	47.3	97.3
OMP-C3 120cm	41.3	183.3	40.5	74.8
OMP-C3 120cm R	38.1	188.4	39.1	72.0
OMP-C3 140cm	32.1	200.3	28.5	54.0
OMP-C3 160cm	23.5	113.7	22.1	50.7

Figure 45. Old Mill Pond surface sediment values for A) dry bulk density (g/cm^3), B) susceptibility frequency dependance (%), C) magnetic susceptibility ($10^{-8} \text{ m}^3 \text{ kg}^{-1}$), and D) Pb content ($\mu\text{g/g}$). Arrows indicate location of drainage pipe and culvert (ESRI, 2016a).

Eight grab samples (G1,3,4,7,8,9,11,12) were analyzed for Pb, Zn, Cu, and Cr heavy metal concentrations (Table 29). Pb concentrations ranged between 21-56 $\mu\text{g/g}$, with one sample (G4) having a low concentration of 4.6 $\mu\text{g/g}$. Zn concentrations were between 192-257 $\mu\text{g/g}$. Cu concentrations were between 10-62 $\mu\text{g/g}$, and Cr concentrations ranged from 18-70 $\mu\text{g/g}$. Except for Pb concentration, the sandy culvert samples (G7 and G8) had noticeably lower Zn, Cu, and Cr concentrations compared to all the other samples.

The surficial sediment samples measured for heavy metals were also analyzed for magnetic properties (Appendix C). The magnetic concentration of the had an average SIRM of $5,852 \cdot 10^{-6} \text{ Am}^2 \text{ kg}^{-1}$, an average χ_{if} of $76 \cdot 10^{-8} \text{ m}^3 \text{ kg}^{-1}$, and the χ_{ARM} average was $2.3 \cdot 10^{-6} \text{ m}^3 \text{ kg}^{-1}$. These values are indicative of high ferrimagnetic concentration in the mud samples. The sand samples from the culvert (G7 and 8) exhibited significantly higher ferrimagnetic concentrations than the mud samples. The SIRM for G7 and G8 was $12,782 \cdot 10^{-6} \text{ Am}^2 \text{ kg}^{-1}$ and $10,045 \cdot 10^{-6} \text{ Am}^2 \text{ kg}^{-1}$, respectively. The S-ratio for all samples was above 0.92, indicating ferrimagnetic, low coercively minerals. The concentration of ferrimagnetic minerals was highest where the Mud Brook channel narrows approaching the dam at the culvert.

3.3.2 Sediment Cores

Sediment cores were collected from Old Mill Pond in May 2016. Cores were taken from the middle of the impoundment (OMP-16-C1-C2) and near the subaqueous levee of a small stream entering the eastern side of the impoundment (Figure 16). Cores were analyzed for visual lithology, whole-core susceptibility, organic matter content, bulk density, grain size, heavy metal concentration, and magnetic properties.

The longest core from the middle of the impoundment, OMP-16-C3, is 165.5 cm long and can be divided into three sections: 165.5-150 cm, 150-70 cm, and 70-0 cm (Figure 46 and 47). Overall, in the whole core, the susceptibility ranges from $12\text{-}21 \cdot 10^{-5}$ Relative

Figure 46. Detailed lithology description for core Old Mill Pond sediment core OMP-16-C3.

SI Units, organic matter ranges from 8-12%, and bulk density ranges from 0.4-1.0 g/cm³. In the first interval, between 165.5-150 cm core depth, susceptibility increases up core, whereas, organic matter content and dry bulk density are uniform. Within this section, compacted mud containing roots is present in addition to a red sandy layer between 154.5-153 cm core depth (Figure 46). Within the lower section, from 165.5 to 160 cm, rounded grey clay clasts are present in a brown, compacted mud. Grain size analyzed at 160 cm indicates the D_{50} is fine silt (Table 28). Between 150-70 cm, the lithologies present are clay, iron-stained sand, silt, and woody debris. The D_{50} at 110 cm and 80 cm core depth was measured to be very fine silt and fine silt, respectively (Table 28). Iron-stained sand layers, that also contain organic matter, have lower dry bulk density and increased organic matter and susceptibility. The clay units within this section have an increase in susceptibility dry bulk density, and a decrease in organic matter. Between 70-0 cm, the predominant lithology is mud with variable susceptibility and a uniform organic matter and bulk density. A sand and woody debris layer, between 39-33 cm core depth, has high susceptibility and organic matter. In the uppermost 13 cm, the susceptibility and dry bulk density decrease, whereas organic matter increases.

Heavy metal concentrations for Pb, Zn, Cu, and Cr were measured on 10 core C3 subsamples (Figure 48; Table 29). Between 160-120 cm, all heavy metal concentrations are low. In the entire core, the lowest heavy metal concentration for all metals occurred at 160 cm core depth. From 120 to 80 cm core depth, there is a gradual increase in all metal concentrations, with peak concentrations occurring at 80 cm for all metals. From 70 to 0 cm, there is an overall decline in metal concentrations. Copper concentration is steadily increasing up core and at the surface, and has similar concentration to that of the 80 cm core depth. Zinc concentration remain uniform in the upper 60 cm.

Magnetic properties of concentration, grain size, and mineralogy were determined for the ten core subsamples (Figures 49 and 50; Appendix C). The average χ_{ARM} was

Figure 48. Down core profiles of Old Mill Pond middle impoundment core (C3) showing lithology, magnetic concentrations (SIRM), and Pb, Zn, Cu, and Cr heavy metal concentrations.

Figure 49. Lithology and magnetic concentration profiles for Old Mill Pond core C3. See Figure 46 for lithology key.

Figure 50. Lithology, magnetic grain size ($\chi_{fd}\%$, χ_{ARM}/χ , $SIRM/\chi$) and magnetic mineralogy (S-ratio) profiles for Old Mill Pond core C3. See Figure 46 for lithology key.

$2.6 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$, the average χ_{fr} was $46 \times 10^{-8} \text{ m}^3 \text{ kg}^{-1}$, and the average SIRM was $6,100 \times 10^{-6} \text{ Am}^2 \text{ kg}^{-1}$ for the core samples. These ferrimagnetic concentration values indicate that the core contains high concentrations of ferrimagnetic particles. Between 120-80 cm core depth, where the heavy metals concentration was high, there is also a high concentration of ferrimagnetic particles (Figure 48). Throughout the core the magnetic grain size is uniform except the coarse magnetic grain sizes found at the bottom of the core at 160 cm core depth (Figure 49). The S-ratio for this deep sample at 160 cm is 0.84, indicating a high proportion of high coercivity minerals (Figure 50). The remaining core samples have an S-ratio of about 0.93, which indicates the mineralogy is dominated by low coercivity, ferrimagnetic minerals.

A second core (OMP-16-C2), was obtained from the middle of the impoundment at the same location as C3. Core C2 has similar down-core trends in susceptibility, organic matter, and bulk density as C3 (Appendix D). Core C2, however, does not extend as deep as C3 and therefore was studied for heavy metal content.

A core was obtained from the subaqueous levee of a small stream entering the eastern side of the impoundment (OMP-16-C5). This core is 94.5 cm long and can be divided into three main sections: 94.5-50 cm, 50-30 cm, and 30-0 cm (Figures 51 and 52). Between 94.5-50 cm, main lithology is a brown silty/clay with a layer of yellow clay 61-60 cm core depth. Susceptibility, organic matter content, and dry bulk density are largely uniform throughout this section (Figures 51 and 52). Between 50-30 cm core depth, brown silty/clay with organic matter is present. In this section, the susceptibility, dry bulk density, and organic content remains uniform. In the uppermost 30 cm, there is a decrease in susceptibility and bulk density. It was observed that fine sand is present between 30-12 cm, accompanied by an increase in bulk density; however, the D_{50} at 10 cm and 25 cm core depths was determined to be a medium silt (Table 28). Organic mud is present from 12-0 cm accompanied by an increase in organic matter. Five down core samples

Figure 51. Detailed lithology description for Old Mill Pond sediment core OMP-16-C5.

Figure 52. Lithology, whole core susceptibility (κ), organic matter, and dry bulk density, for Old Mill Pond sediment core OMP-16-C5. See Figure 51 for lithology descriptions.

Figure 53. Old Mill Pond delta in 1994 and 2000. The leftmost red dot is the OMP-16-C3 core location and the rightmost dot is the OMP-16-C5 core location. The feature within the red circle is a stationary object used determine relative water level change (Summit County Fiscal Office, 2016).

Figure 54. Old Mill Pond delta in 2003 and 2005. The leftmost red dot is the OMP-16-C3 core location and the rightmost dot is the OMP-16-C5 core location. The feature within the red circle is a stationary object used determine relative water level change (Summit County Fiscal Office, 2016; USGS, 2016b).

Figure 55. Old Mill Pond delta in 2006 and 2010. The leftmost red dot is the OMP-16-C3 core location and the rightmost dot is the OMP-16-C5 core location. The feature within the red circle is a stationary object used determine relative water level change (Summit County Fiscal Office, 2016).

Figure 56. Old Mill Pond delta in 2012 and 2014. The leftmost red dot is the OMP-16-C3 core location and the rightmost dot is the OMP-16-C5 core location. The feature within the red circle is a stationary object used determine relative water level change (Google, 2016; Summit County Fiscal Office, 2016).

Figure 57. Old Mill Pond delta in 2015 and 2016. The leftmost red dot is the OMP-16-C3 core location and the rightmost dot is the OMP-16-C5 core location. The feature within the red circle is a stationary object used determine relative water level change (Google, 2016; Summit County Parcel Viewer, 2016).

Table 30. Lake water level relative to the concrete structure in Old Mill Pond.

Year	Water Level
1994	Shallower
2000	Deeper
2003	Shallower
2005	Shallower
2006	Deeper
2010	Deeper
2012	Deeper
2014	Shallower
2015	Deeper
2016	Shallower

were measured for magnetic susceptibility and plotted below 2% frequency dependence indicating the absence of SPM grain sizes.

3.3.3 Shoreline Change

The deltaic area of a small stream entering the east side of the impoundment was observed on aerial photographs between 1994 and 2016 (Figures 53-57). A stationary object present in the impoundment observed in 1994, 2003, 2005, and 2014 was utilized to assess lake level changes (Table 30). Lake level variation made it difficult to detect if the delta has prograded over time. Prior to 2003, however, the inflow was directed to the south, whereas post-2003, the inflow and delta sedimentation was directed to the west.

3.3.4 Land cover

Land cover area, land cover area change, impervious cover, and impervious cover change were tabulated and analyzed for the Mud Brook subwatershed containing Old Mill Pond (Figure 58; Table 31; Appendix E). The total area of the Mud Brook watershed is 8,439,300 m². Between 1985-2010, there was an 15.3% overall increase in developed land (+1,291,500 m²), a 13.05% decrease of undeveloped land (-1,101,600 m²), and a 2.21% decrease in farmland (-186,300 m²). The greatest land cover change over the 25-year period occurred between 1996-2001, with a decrease in undeveloped land by 7.28% (-614,700 m²), a decrease in farmland by 0.15% (-12,600 m²), and an increase in developed land by 7.44% (+628,200 m²). The impervious surface data shows that from 1985-2010, there was an overall increase in impervious area of 467,583 m² (5.54%) of the Mud Brook watershed. As of 2010, the Mud Brook watershed has 74% developed land cover, 3.2% farmland, and 22% undeveloped land cover. Of the total watershed, 24% is impervious surface, mainly attributable to developed land cover. Most of the developed land cover is from housing and shopping centers built within the Mud Brook watershed.

Figure 58. Land cover change in the Mud Brook watershed from 1985-2010 (Digital Coast, 2016a). The percent impervious cover is also presented for each year.

Table 31. Old Mill Pond land cover and land cover change summary table for the years 1985, 1996, 2001, 2006, and 2010. A) Total area land cover and area land cover change (m²), B) Percent land cover and percent land cover change, C) Total area of impervious surfaces and impervious surface area change (m²), D) Percent impervious surfaces and percent impervious change. The total area of the Haskell Run watershed is 8,439,300 m² (Digital Coast, 2016a; Digital Coast, 2016b).

A)									
Land Cover Class Name	Total Area (m ²)				Area Change (m ²)				
	1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	1985-2010
<u>Reclass Groups</u>									
Developed	4,923,000	5,319,000	5,947,200	6,075,000	6,214,500	396,000	628,200	127,800	1,291,500
Farmland	456,300	306,000	293,400	287,100	270,000	-150,300	-12,600	-6,300	-186,300
Undeveloped	2,984,400	2,738,700	2,124,000	2,005,200	1,882,800	-245,700	-614,700	-118,800	-1,101,600
Open Water	75,600	75,600	74,700	72,000	72,000	0	-900	-2,700	-3,600
Total	8,439,300	8,439,300	8,439,300	8,439,300	8,439,300	0	0	0	0
B)									
Land Cover Class Name	Percent Total (%)					Percent Change (%)			
	1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	1985-2010
<u>Reclass Groups</u>									
Developed	58.33	63.03	70.47	71.98	73.64	4.69	7.44	1.51	15.30
Farmland	5.41	3.63	3.48	3.40	3.20	-1.78	-0.15	-0.07	-2.21
Undeveloped	35.36	32.45	25.17	23.76	22.31	-2.91	-7.28	-1.41	-13.05
Open Water	0.90	0.90	0.89	0.85	0.85	0.00	-0.01	-0.03	-0.04
Total	100	100	100	100	100	0.00	0.00	0.00	0.00
C)									
Land Cover Class Name	Area of Impervious Cover (m ²)					Change in Impervious Cover (m ²)			
	1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	1985-2010
<u>Reclass Groups</u>									
Developed	1,464,859.26	1,586,622.24	1,825,093.35	1,867,270.32	1,967,707.62	121,762.98	238,471.11	42,176.97	502,848.36
Farmland	10,185.21	6,292.44	5,975.82	5,880.69	5,525.28	-3,892.77	-316.62	-95.13	-4,659.93
Undeveloped	67,573.71	64,048.59	40,849.11	39,158.28	37,000.44	-3,525.12	-23,199.48	-1,690.83	-30,573.27
Open Water	672.84	672.84	664.83	640.80	640.80	0.00	-8.01	-24.03	-32.04
Total	1,543,291.02	1,657,636.11	1,872,583.11	1,912,950.09	2,010,874.14	114,345.09	214,947.00	40,366.98	467,583.12
D)									
Land Cover Class Name	Percent Impervious Surfaces (%)					Percent Impervious Change (%)			
	1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	1985-2010
<u>Reclass Groups</u>									
Developed	17.36	18.80	21.63	22.13	23.32	1.44	2.83	0.50	5.96
Farmland	0.12	0.07	0.07	0.07	0.07	-0.05	0.00	0.00	-0.06
Undeveloped	0.80	0.76	0.48	0.46	0.44	-0.04	-0.27	-0.02	-0.36
Open Water	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Total	18.29	19.64	22.19	22.67	23.83	1.35	2.55	0.48	5.54

The small section that has consistently remained undeveloped over time lies along Mud Brook (Figure 58). This area is likely subject to flooding and therefore is unsuitable for development.

CHAPTER IV

DISCUSSION

4.1 The Impact of Watershed Development on Pollution in Fluvial Systems

My first hypothesis states that the sediments from Old Mill Pond, located in the urban Mud Brook watershed, would have greater heavy metal and ferrimagnetic particle concentrations than sediment from Lakes Butler and Litchfield located in rural Haskell Run and Ritchie Run watersheds. As of 2010, the land cover data reveals that the Mud Brook watershed has 74% developed land cover, whereas Haskell Run has 12% and Ritchie Run has 3% (Tables 20, 25, and 31; Appendix E). The impervious surfaces of Mud Brook, Haskell Run, and Ritchie Run are 24%, 5%, and 2.4%, respectively. Furthermore, as of 2012, the population in the Mud Brook watershed is approximately 5,757 people, whereas Haskell Run and Ritchie Run have a combined population of approximately 672 people (U.S. Census Bureau, 2012). Owing to the contrasting watershed development, these sites provide ideal locations to test the above-mentioned hypothesis.

Heavy metals tested for this project were lead, zinc, copper, and chromium, all of which are commonly associated with anthropogenic pollution. The surface samples and the uppermost 20 cm of sediment cores that were measured for heavy metal concentration are considered to represent present-day conditions. Old Mill Pond sediments have higher heavy metal concentrations of Pb, Zn, and Cu than Lakes Butler or Litchfield (Figure 59). The Cr concentrations are similar between the three impoundment sites. For all metals, Old Mill Pond sediment exhibited a wider range of metal concentrations than

Figure 59. Box and whiskers plot of Pb, Zn, Cu, and Cr heavy metal concentrations for Lake Butler (n=5), Lake Litchfield (n=5), and Old Mill Pond (n=10). The consensus-based threshold effect concentration (TEC) for each metal are indicated by the dashed horizontal line (MacDonald et al., 2000).

Lakes Butler or Litchfield. Both Lake Butler and Lake Litchfield sediment have similar and low heavy metal concentrations. These data support the hypothesis that Old Mill Pond sediment contains higher levels of anthropogenic heavy metal concentrations than the rural impoundments of Lakes Butler and Litchfield. The higher heavy metal concentrations in Old Mill Pond are attributed to increased watershed development and human activities adversely affecting the fluvial environment.

The consensus-based threshold effect concentration (TEC) and probable effect concentration (PEC) are toxicity levels on “sediment-dwelling organisms” of various pollutants in freshwater sediments (MacDonald et al., 2000). MacDonald et al. (2000) explain that TECs identify contaminant concentrations in freshwater sediments below which adverse effects on benthic organisms are unlikely, and “predict the absence of toxicity.” The PEC determines the level at which the toxicity of contaminant in the sediment will likely have “adverse effects on sediment-dwelling organisms” (MacDonald et al., 2000). None of the surficial sediment samples from the three impoundments approached the PEC for Pb, Zn, Cu, or Cr. Most samples from Old Mill Pond were between the TEC and PEC (Figure 59). Lakes Butler and Litchfield sediment samples were below the TEC for Pb and Cu. For Zn, Lake Butler samples were above the TEC, whereas Lake Litchfield was below the TEC. The majority of the samples from all of the impoundments were above the TEC for Cr.

When examining surface sediment Pb concentrations at Old Mill Pond, the highest lead concentrations are located either adjacent to the drainage pipe at the northeast corner of the lake or by the culvert toward the south end of the impoundment where the channel narrows (Figure 45). The drainage pipe and culvert receive runoff from roadways and parking lots. The higher Pb concentrations are thus likely related to increased pollution from these impervious surface areas. The Pb concentrations did not approach the PEC, however samples did surpass the TEC.

Chromium naturally occurs in the earth's crust in oxidation states from Cr(III) to Cr(VI), where Cr(III) is the most stable and often found in the ore ferrochromite (Jacobs and Testa, 2005; Tchounwou et al., 2014). Industrial activity such as stainless steel welding, metal processing, and ferrochrome/chrome pigment production are common sources of Cr (VI) to the environment (Tchounwou et al., 2014). Interestingly, the surficial sediment Cr concentrations are similar at Old Mill Pond, Lake Butler, and Lake Litchfield (Figure 59). The average Cr concentration for all three impoundments is approximately 55 µg/g (Tables 17, 22, and 29). Other Northeast Ohio lake sediment research of Cr include studies of Silver Lake, Summit Lake, Rex Lake, and Brady Lake (Haney, 2004; Shaw, 2013; Mitchell, 2015; Grochocki, 2017). In sediment that accumulated prior to the Euro-American Settlement in Northeast Ohio, Cr concentrations range from 20 to 60 µg/g, which reflect the natural background chromium concentration. Though on the higher end, the Cr concentrations for Old Mill Pond, Lake Butler, and Lake Litchfield are within the background concentration range for chromium. Therefore, the similar Cr concentrations at Old Mill Pond, Lake Butler, and Lake Litchfield likely represent natural sources of Cr rather than anthropogenic activity.

It can be concluded that urban watersheds generally have higher levels of heavy metals in impoundment sediments than in rural watersheds because heavy metal pollution is linked to greater anthropogenic activity and higher percentages of developed land cover and impervious surfaces. There is an established link between developed and agricultural land use as a source for higher non-point source pollution levels, whereas forests and grasslands typically have lower pollution levels (Shi et al., 2017). Copper is often used in plumbing and wiring (Smol, 2008). Zinc and lead are both present in coal-fired power plant emissions (Lee and Lehmden, 1973). Zinc is also found in galvanized metals and as an accelerator agent for the vulcanization process in tire manufacturing (Callendar and Rice, 2000). Lead is found in relatively low amounts naturally, but it is often associated

with anthropogenic activity such as fossil fuel combustion, manufacturing, mining, and lead pipes for municipal water (Lee and Lehmden, 1973; Tchounwou et al., 2014). Lead shot-gun pellets and sinkers used in recreational hunting and fishing can also be a source for lead contamination especially if the ammunition and sinkers are left in the field (Haig et al., 2014). Located 1.46 km upstream of Old Mill Pond, was the former Mud Run Gun Club that had contaminated the soil with lead shot-gun pellets (Wiandt, 2010; Schleis, 2017). It is unknown if this upstream lead source has any influence on the lead concentration present in Old Mill Pond surface sediment.

Mitchell (2015) studied the sediment in Rex Lake, a kettle lake in Summit County, New Franklin, OH, in a rural area where the population density, as of 2015, is 1,096 people/mi². The population density in Cuyahoga Falls, where Old Mill Pond is located, is 1,925 people/mi² (Census Bureau, 2015). In addition to having almost double the population, the Old Mill Pond watershed contains more developed land cover than the rural Rex Lake watershed. However, the Pb levels in Rex Lake surface sediment are slightly higher than Old Mill Pond surface sediment. Rex Lake modern day Pb sediment concentrations range from 42-94 µg/g (Mitchell, 2015), whereas Old Mill Pond Pb modern day sediment concentrations range from 21-56 µg/g (Table 31). Mitchell (2015) attributed the rise in lead concentration between 1900-1980 to increased lake recreation, the use of motorized boats, and the building of hotels and houses around the lake. In the Mud Brook watershed, impervious surfaces and development contribute anthropogenic pollution to Old Mill Pond; however, no boating occurs on Old Mill Pond. The variance in human activities, and not the population density in the watershed, may account for the differences in Pb concentration between Rex Lake and Old Mill Pond.

In summary, Old Mill Pond present-day heavy metal concentrations are between the PEC and TEC, indicating that the contaminants are not above the level for which there are adverse effects on benthic organisms, yet toxins are also not below the threshold

of adverse effects (MacDonald et al., 2000). For Lakes Butler and Litchfield, Pb and Cu concentrations were below the TEC. Lake Litchfield Zn concentrations were well below the TEC, whereas Lake Butler exhibited higher levels of Zn above the TEC. Old Mill Pond, Lake Butler, and Lake Litchfield Cr concentrations were above the TEC and attributed largely to background sources.

4.2 Sediment Magnetism as a Pollution Proxy

Heavy metal analysis on sediment is instrumental for assessing pollution; however, the process is time-consuming and expensive. For this reason, sediment magnetism was studied to determine if magnetic parameters could be used as a heavy metal proxy. Anthropogenic pollution, such as combustion products from gasoline or coal, is often highly magnetic and produces ferrimagnetic particles that are distinct from naturally occurring pedogenic ferrimagnetic particles (Evans and Heller, 2003). Sediment magnetic properties have the advantage of being less time-consuming and inexpensive to measure.

Old Mill Pond sediment exhibits higher magnetic concentration compared to Lakes Butler and Litchfield (Figure 60). Magnetic susceptibility is generally considered a ferrimagnetic concentration parameter; however, susceptibility also depends on paramagnetic and diamagnetic content as well as the presence of superparamagnetic particles. Magnetic remanence parameters SIRM and χ_{ARM} only measure the remanence-bearing particles in a sample. The SIRM and χ_{ARM} measurements are similar to susceptibility in that greater values are found with Old Mill Pond sediment compared to Lakes Butler and Litchfield. The corresponding SIRM and heavy metal concentration values show a moderate direct relationship between ferrimagnetic and heavy metal concentration (Figure 61). Two sandy surface samples from Old Mill Pond (G7 and G8) were not plotted because all other samples were mud, and it is best not to mix

Figure 60. Box and whiskers plots of magnetic susceptibility (χ) ranges, a sediment magnetic parameter, for all surface samples for Lake Butler (n=14), Lake Litchfield (n=13), and Old Mill Pond (n=13).

Figure 61. SIRM, a magnetic concentration parameter, versus heavy metal concentration of Pb, Zn, Cu, and Cr for Lake Butler, Lake Litchfield, and Old Mill Pond long core and surface sediment samples.

contrasting lithologies. Zinc ($r^2 = 0.62$) and copper ($r^2 = 0.58$) display a moderate positive relationship between metal concentration and SIRM, whereas chromium ($r^2 = 0.48$) and lead ($r^2 = 0.31$) had weaker relationships. These data show that the rapid and inexpensive magnetic concentration measurements can be used in a general way as a proxy for heavy metal concentration. However, given the scatter in the data of this study, some pollution “hot spots” will be missed by the magnetic proxy. Furthermore, certain high magnetic concentration readings will not exhibit elevations of heavy metal concentration. Therefore, magnetic parameters as a pollution proxy has limitations, but overall can provide a quick site assessment tool.

Sand characterizes the surface sediment in the culvert and where the impoundment narrows by the dam at Old Mill Pond (Figure 45). The sand accumulates in these higher velocity areas, whereas mud accumulates in the wider impoundment area that has relatively lower velocity. Coarse-grained ferrimagnetic material, such as steel from anthropogenic sources (e.g., cars and construction) can be washed into the culvert from the parking lots and roadways. Clay particles tend to adsorb heavy metals (Konhauser, 2007). Due to both adsorption and flow velocity processes, the sand in Old Mill Pond has higher ferrimagnetic particle concentrations but lower heavy metal concentrations.

Additional magnetic parameters were analyzed in an attempt to differentiate sediment sources for each impoundment. The frequency dependence of susceptibility has been utilized to distinguish pedogenic sources from pollution sources (Dearing, 1999; Figure 62). Samples that plot above 2% frequency dependence contain superparamagnetic particles often of pedogenic origin (Dearing, 1999; Evans and Heller, 2003). Samples with less than 2% frequency dependence do not contain superparamagnetic particles. High concentrations of coarse-grained magnetic particles, stable single domain (SSD), are often associated with fossil fuel combustion (Dearing, 1999). In addition, enhanced Ohio soils tend to have a frequency dependence of 4-5% (Peck, 2017).

Figure 62. Modified Dearing Plot for surficial samples and core samples from the three site impoundments.

Of the 59 surface and core samples, 20 plot below the 2% line, and 39 plot above the 2% line (Figure 62). Of the 20 samples that plot below the 2% line, the samples from Old Mill Pond have higher concentrations of coarse-grained particles than Lakes Butler and Litchfield. The remaining 39 samples plot above the 2% line, indicating the presence of super paramagnetic (SPM) grains. These SPM grains may be pedogenically generated and washed into the impoundments. Alternatively, iron precipitation under oxic conditions can coat detrital mineral grains with magnetic mineralogies having SPM size (Evans and Heller, 2003). Another possibility that explains the SPM grain sizes could be reductive diagenesis, which occurs in reducing conditions when iron oxides undergo dissolution and create iron sulfides. This process can dissolve larger SSD magnetic grains into smaller SPM grains. Evidence to support this possibility includes freshly split cores were black in color and smelled of hydrogen sulfide. Months later, the sediment cores turned brown and red suggesting the oxidation of mono-sulfide minerals.

Combustion often produces low coercivity (i.e., ferrimagnetic) particles. The S-ratio is an indicator of magnetic mineralogy. When S-ratio values are greater than 0.9, ferrimagnetic minerals dominate the sample, whereas values less than 0.9 have a significant portion of high coercivity canted-antiferromagnetic particles (Evans and Heller, 2003). The S-ratio for all Old Mill Pond samples, except for one, are above 0.9 and indicate that ferrimagnetic minerals dominate the sediment at Old Mill Pond (Figure 50). Half of the Lakes Butler and Litchfield samples have S-ratios lower than 0.9, indicating a high coercivity mineral assemblages, such as hematite staining detrital grains.

4.3 Historical Changes Recorded in the Impoundment Sediment

Not only does the present-day surface sediment vary between urban Old Mill Pond and rural Lakes Butler and Litchfield, but there also are differences in the down core sediment profiles. In order to date approximate time intervals in the sediment cores, a linear sedimentation rate was established for each core by taking the impoundment sediment thickness (in cm) and dividing it by the age difference between the year the dam was constructed and the year of core collection (2016). The resulting linear sedimentation rates for each lake are as follows: Lake Butler = 3.80 cm/yr, Lake Litchfield = 3.00 cm/yr, Old Mill Pond = 1.56 cm/yr. The Old Mill Pond core provides a record of pollution history in Cuyahoga Falls. The cores from Lakes Butler and Litchfield show their respective deltas prograding over time. All three impoundment cores have three time general periods: Pre-Dam Period, Early Impoundment Period, and Late Impoundment Period.

4.3.1. Lake Butler

The Pre-Dam Period for Lake Butler is pre-1962, the Early Impoundment Period is from ~1962 to 1982, and the Late Impoundment Period is 1982 to 2016.

Pre-Dam Period (pre-1962)

Lake Butler lies within the rural watershed of Haskell Run. The Lake Butler dam was constructed between 1959-1962 (Bergdorf R., 2016). The linear sedimentation rate for core C4 is 3.80 cm/yr. Three general time periods (Pre-Dam, Early Impoundment, and Lake Impoundment) can be identified based on down-core sedimentary changes. The earliest time period, referred to as the Pre-Dam Period, is represented by the lowermost lithology unit in C4 (Figure 63). From 249 to 202 cm core depth, sand and gravel, displaying high dry bulk density and low organic matter, are present (Figure 63). The

Figure 63. Summary figure for Lake Butler delta top core (LB-16-C4) showing lithology, dry bulk density (DBD), saturation isothermal remanent magnetization (SIRM), and Pb and Zn concentrations. Time periods and approximate dates are listed to the right. The threshold effect concentration (TEC) is denoted by the vertical blue-dashed line and probable effect concentration (PEC) is denoted by the vertical solid red line for Pb and Zn (MacDonald et al., 2000).

basal gravel indicates higher energy conditions similar to that observed in the present-day Haskell Run where gravels cover the channel floor (Table 6). Therefore, the basal gravel unit in the core is inferred to represent pre-dam conditions when the core site was a fluvial environment. The sand and gravel granules at the bottom of the delta top core (C4) are a similar size to the Haskell Run G13 sample collected upstream in a higher energy environment. The sand and gravel unit has an abrupt contact with an overlying clay lithology at 202 cm.

Early Impoundment Period (~1962-1982)

From 202-118 cm core depth, the lithology is predominantly a clay with moderate dry bulk density (Figure 63). The linear sedimentation rate dates this core interval to be approximately 1962 to 1982, which is referred to as the Early Impoundment Period. The clay lithology indicates a low energy depositional environment inferred to be the slack-water of the Lake Butler dam impoundment. During this time, the core site would have been located farthest from where Haskell Run entered the impoundment. The river mouth delta did not have the time to prograde into the lake at this point, and thus the clays were deposited in the low energy delta front environment. The sand layer from 147.5-142 cm may represent a flood event. In this time period, only two heavy metal samples were measured. Except for zinc, the heavy metal concentration values were low. Zinc, however, had a high concentration at 150 cm core depth (Figure 63).

In August 1981, a tire fire occurred in the Haskell Run watershed in Hudson, Ohio, upstream from Lake Butler (The Cleveland Press, 1981). News reports state that Haskell Run was exposed to a portion of the 9,000 gallons of tire oil resulting from the fire (Holies, 1981). However, the tire oil was said not to have affected Lake Butler (Holies, 1981). Given the great uncertainty in using a linear sedimentation rate to date the core, the high Zn concentration may or may not be temporally related to the 1981 tire fire.

Future research could investigate in greater detail the Zn metal concentration and also analyze for other burned tire product chemical signatures surrounding the 150 cm Zn peak to attempt to resolve the anomalously high Zn concentration. A sediment core could also be taken upstream in Haskell Run at a deposition center (i.e., floodplain marsh) to look for evidence of the tire fire.

Late Impoundment Period (1982-2016)

The sediment above 118 cm core depth represents the Late Impoundment Period. This period spans from 1981 to 2016. Above 118 cm core depth, the clay lithology is interbedded with sandy layers and woody debris layers (Figure 63). Dry bulk density in this section exhibits pronounced fluctuations. Heavy metal concentrations are generally low and declining toward the core top. The interbedded wood and sand lithologies appear to be a combination of two processes--flooding and delta progradation. At 50 cm core depth, there is a change from clay to a sandy clay mixture (Figure 63). In core C4 this depth dates approximately to 2003. This shift from clay deposited under low energy to sand deposited under high energy may be attributed to the increase in regional flooding after July 2003, as suggested by Liberator (2013) and Delaney (2016). The aerial photos do not show explicitly that after 2003 there was greater deposition of sediment at the delta mouth; however, delta progradation was occurring. The aerial photos from 1994 to 2016 show that the delta is prograding and that by 2010 the C4 core site transitions from delta front to delta top. The uppermost 22 cm of the core is a brown silt that accumulates in a delta top environment. As the delta prograded closer to the C4 core site, smaller flood events may be recorded in sediment record of C4 to a greater extent than when the delta is farther from the core site. This can be explained by the sediments being closer to the source, and thus more sediment can accumulate more rapidly.

Figure 64. Summary figure for the Lake Litchfield delta front core (LL-16-C1). This figure shows the lithology, dry bulk density (DBD), saturation isothermal remanent magnetization (SIRM), and Pb and Zn concentrations. Time periods and approximate dates are listed to the right. The threshold effect concentration (TEC) is denoted by the vertical blue-dashed line and probable effect concentration (PEC) is denoted by the vertical solid red line for Pb and Zn (MacDonald et al., 2000).

4.3.2. Lake Litchfield

The Pre-Dam Period for Lake Litchfield is pre-1978, the Early Impoundment Period is between ~1978 and 1990, and the Late Impoundment Period is from 1990 to 2016.

Pre-Dam Period (Pre-1978)

Rural Ritchie Run contains the Lake Litchfield impoundment situated within the Manatoc Boy Scout Camp. The Lake Litchfield dam was installed between 1977-1978 (Bergdorf, R., 2016). The linear sedimentation rate for Lake Litchfield sediment core C1 was determined to be 3.00 cm/yr. Three general time periods can be identified based upon the down core sedimentary changes. The Pre-Dam Period is represented by the lowermost lithology unit in C1 (Figure 64). Between 139.5-118 cm core depth, sand with high dry bulk density is present. The sand unit implies deposition under high energy conditions and is interpreted to represent a riverine environment before the dam was constructed. At 118 cm core depth, there is an abrupt contact between the sand unit and the overlying clay unit. Early Impoundment Period (1978-1990)

The lithology from 118-78 cm core depth is predominantly clay and silt with interbedded sand layers (Figure 64). This period is referred to as the Early Impoundment Period and is estimated to span from 1978 to 1990 using the linear sedimentation rate. The mud layers indicate low energy associated with the slack water of the Lake Litchfield impoundment. The interbedded layers of sand indicating high energy conditions that are possibly associated with flood events. There is an increase in SIRM at 90 cm core depth, indicating greater ferrimagnetic concentration. Heavy metal concentrations are low in the Early Impoundment Period and throughout the entire core.

Figure 65. Sedimentary structures at Lake Litchfield delta on November 21, 2016. A) Longitudinal view of the subaqueous delta where core 2 was collected. B) The exposed delta rollover and delta front. C) Closer image showing the sedimentary structures of the topset/foreset contact.

Late Impoundment Period (1990-2016)

The Late Impoundment Period, spanning from 1990 to 2016 is represented by the sediment above 78 cm core depth (Figure 64). The lithology is predominantly clay with interbedded sand and woody debris layers. Between 72-61 cm, a red/black clay with highly variable in dry bulk density is present. Throughout the Late Impoundment Period, the dry bulk density profile shows pronounced fluctuations. The variations in dry bulk density and lithology is interpreted to represent flooding events as the delta progrades closer to the core site. Aerial photos from 1994 to 2016 indicate that the delta is prograding into the impoundment (Figures 39-43). The uppermost 8 cm of sand may be the result of increased regional flooding and the close proximity of the delta.

In August 2016, Lake Litchfield was drained to repair the outflow valve in the dam, which exposed the delta and core site C1. Deltaic sedimentary structures were readily observed at this time (Figure 65). The delta topset/foreset contact rollover show progradation as the delta at the mouth of Ritchie Run builds into the dammed impoundment over time. The water level in Lake Litchfield has not drastically changed since the dam was installed in 1978; therefore, the prograding delta reflects the decrease in stream energy as Ritchie Run enters the wide dam pool. At the exposed subaqueous delta and in core C2, layers of leaves were observed (Figures 64 and 65). According to Bilby and Heffner (2016), leaf-litter travel distance depends largely on wind speed in addition to forest age, tree type, and topography of the riparian area. The leaf layers may represent leaves washing downstream each fall and possibly during high flow events. To determine if leaf layers in the impoundment delta sediments have any chronostratigraphic or flood relevance, a monitoring experiment could be conducted using a marker to measure sediments over several years.

Water level and sediment supply are the two main factors that affect shoreline changes (Davison-Arnott, 2010). The lake level, until the late summer of 2016, had not

changed drastically since the lake was dammed in 1978 (Bergdorf C., 2016). The aerial photos indicate a regressive shoreline, or prograding delta, building out into the lake since at least 1994 (Figures 39-43). The aerial photos were further analyzed to determine the progradation rate of the delta before and after 2003 (Table 26). The shoreline was expected to have a higher growth progradation after 2003, owing to the increase in flood frequency in Northeast Ohio. Two years were assessed before 2003 (1994 and 2000), and seven years were assessed after 2003 (2005, 2006, 2010, 2012, 2014, 2015, 2016). The pre- and post-2003 progradation rates were 0.30 m/mo and 0.32 m/mo, respectively (Table 28). Thus, the delta in Lake Litchfield did not appear to respond to the increased flood frequency after 2003. Delaney (2016) studied a dammed impoundment within the Yellow Creek, Ohio, watershed that showed greater delta sedimentation after 2003 than prior to 2003. The Yellow Creek dam pool, however, was shallower than Lake Litchfield. It is possible that the deeper Lake Litchfield impoundment accounts for any increase in sediment supply in the subaqueous part of the delta that is not resolved in the aerial photographs. To determine the sedimentation in the subaqueous delta at Lake Litchfield, a volumetric sediment analysis could be conducted by collecting numerous cores at the subaqueous delta and quantifying the amount of sediment depositing at the delta over time.

4.3.3. Old Mill Pond

The Pre-Dam Period for Old Mill Pond is pre-1920, the Early Impoundment Period is from ~1920 to 1971, and the Late Impoundment Period is 1971 to 2016.

Pre-Dam Period (Pre-1920)

Old Mill Pond is a small impoundment that lies within the Mud Brook watershed. The Old Mill Pond dam was constructed between 1910-1936, which for this thesis

Figure 66. Summary figure for Old Mill Pond sediment core 3 showing lithology, dry bulk density (DBD), saturation isothermal remanent magnetization (SIRM), and Pb and Zn concentrations. Time periods and approximate dates are listed to the right. The threshold effect concentration (TEC) is denoted by the vertical blue-dashed line and probable effect concentration (PEC) is denoted by the vertical solid red line for Pb and Zn (MacDonald et al., 2000).

is approximated as 1920 (The Rectigraph Abstract and Title company, 1910; Sidwell Studio, 1936). A linear sedimentation rate was determined for Old Mill Pond to be 1.56 cm/yr. There are three general time periods (Pre-Dam, Early Impoundment, and Late Impoundment) that can be identified by sedimentary changes in C3. The earliest of these periods is the Pre-Dam Period, which is represented by sediment from 165.5 to 150 cm core depth (Figure 66). From 165.5 to 150 cm core depth, the main lithology is a compacted silty mud with decomposing leaves, wood, and roots. These sediments have high dry bulk density. In the lowermost 5.5 cm (165.5-160 cm), there are small clay clasts present, which may indicate an erosion boundary in a fluvial environment. One heavy metal and SIRM sample were tested from this period and were found to be the lowest in the entire core (Figure 66). The boundary between the Pre-Dam Period and the Early Impoundment Period is marked by the increase in ferrimagnetic and heavy metal concentrations and a lithology change from compacted mud to organic-rich clay at 150 cm (Figure 66).

Early Impoundment Period (1920-1971)

From 150-70 cm core depth, the lithology is interbedded mud and sand, with a fluctuating dry bulk density (Figure 66). The Early Impoundment Period spans from 1920 to 1971 as determined by the linear sedimentation rate. The clay unit between 150-140 cm core depth indicates a change in environments from a possible wetland (muds with roots) to the slack water of the Old Mill Pond dam impoundment. Between 150-70 cm core depth, Pb concentrations increase to a maximum of 121 $\mu\text{g/g}$ at about 1965 (80 cm). Between the 1940s-1960s, the city of Cuyahoga Falls experienced a doubling in population from about 25,000 to 50,000 (Mann et al., 2013). Approximately 1.46 km upstream of Old Mill Pond, the Mud Run Gun Club was located and resulted in lead contamination of the soil from spent ammunition (Wiandt, 2010). The historical activity

of the gun club is unknown, but it ceased operation in the 1990s (Wiandt, 2010). The increased population, urban expansion, and change in watershed activities are likely to account for the increased level of pollution in the Old Mill Pond sediment core. The sand layers within the Early Impoundment Period may be related to increased erosion from the construction that accompanied the population growth, or they may have been deposited during high flow events.

Late Impoundment Period (1971-2016)

The Late Impoundment Period is represented by sediment above 70 cm core depth. The period spans from 1971 to 2016. In this time period, the lithology is predominantly a silty mud with moderate dry bulk density deposited in the low energy slack water of the dam impoundment (Figure 66). Sand and organic debris is interbedded within this section possibly as a result of a flood. This period is also characterized by a decline of heavy metals and ferrimagnetic particles, possibly due to changing watershed activities and the enactment and enforcement of the Clear Air Act (1970) and Clean Water Act (1972). The time series of aerial photos from 1994 to 2016 do not show significant changes accounted for by the increase in regional flooding after 2003.

4.4 Broader Implications for Sedimentation, Land Use, and Climate Change

In parts of the United States, such as the upper Midwest, the intensity of storms and resultant floods have noticeably increased in the last century (Pielke, 2005; Liberatore 2013; Schillereff et al. 2014). A local resident, Tom Quick, of Peninsula, OH, observed a major flood in July 2003 that caused notable damage to infrastructure in the area around Lakes Butler and Litchfield. Since then, Mr. Quick has observed an increase in flooding that often undermines the Cuyahoga Valley Scenic Rail Road train tracks and washes out

roads and trails within Cuyahoga Valley National Park (Quick, 2017). The USGS stream gage station at Old Portage on the Cuyahoga River records the increase in flooding events since July 2003 (Figure 13). In addition to floods, there has been a marked change in the sediment load of the Cuyahoga River. Mann et al. (2013) document the increased Cuyahoga River sediment load associated with more frequent floods after July 2003. Wolman (1967) suggests that land use changes also impact sedimentation and fluvial channel morphology. The increase in urban land cover in the Mud Brook watershed from 1985 to 2010 is likely to continue given the building of proposed new shopping centers and housing developments. The Haskell Run/Ritchie Run watersheds are likely to maintain their undeveloped land cover because the watersheds lie within the boundaries of Cuyahoga Valley National Park. However, the less developed watersheds will still be at risk for more flooding damage with any increase in regional flooding. With more impermeable surfaces in urban watersheds and more frequent storms, the consequences will ultimately be higher volumes of runoff and greater flooding. Anticipating and planning the effects of increased urban development and flooding is a necessity in Northeast Ohio for the safety of people and infrastructure, and for the preservation of vital ecosystems such as wetlands, forests, and waterways (Cook et al. 2014; Stapanian et al. 2016).

Techniques to manage high sediment yields or contaminants spreading throughout the Cuyahoga River watershed should focus on protecting current wetlands in addition to constructing wetlands to trap sediment, sustain forested areas, reduce impervious surfaces, and prevent further erosion especially in incised banks. Dammed impoundments capture a stream's sediment load and limit sediment and associated pollutants from traveling downstream. When dam pools reach sediment storage capacity, the stream sediment load bypasses the impoundment and impacts downstream ecosystems. Lakes Butler (6.4 m deep) and Litchfield (11 m deep) have large dam pools, therefore exceeding

the sediment storage capacity will not be a problem in the foreseeable future. This inference is supported by limited sediment accumulation observed in Lake Litchfield when the lake was drained in 2016. Old Mill Pond, however, is only 1.4 m deep and sediment bypass is likely occurring. Wetlands and retention ponds being built around Old Mill Pond are therefore critical to limiting sediment from entering Mud Brook. Wetlands also provide natural bioremediation, including treatment of municipal waste-water effluent, a common cause of urban point-source pollution in fluvial systems (Konhauser, 2007; Ghermani and Fichtman, 2015; Lane et al., 2016).

Assessment of the differences in sediment yield and sediment type loading into the Cuyahoga River is of value for land managers, local governments, citizens, and scientists, especially those involved with habitat preservation, sediment pollution prevention, and dredging of the Port of Cleveland. Cuyahoga Valley National Park (CVNP) is a land conservation agency committed to ecosystem preservation in the Cuyahoga River Valley (Hamin, 2001). Local waterways surrounding CVNP and the Cuyahoga Valley have experienced higher sediment delivery from increased regional flooding since 2003 (Mann et al., 2013; Liberatore, 2013).

There is a growing need in urban societies for assigning a “value” to the landscape to further illustrate habitat importance. Song et al (2015) suggest that conducting an “economic valuation” assessment with various land-use types might be useful in convincing governments and citizens to take note of their green space and the importance of habitat preservation now and in the future.

CHAPTER V

CONCLUSIONS

This study of Lake Butler, Lake Litchfield, and Old Mill Pond sediment and watershed land cover determined the following:

- Heavy metal and ferrimagnetic concentrations are higher in the sediment of urban Old Mill Pond than in the sediment of rural Lakes Butler and Litchfield. As of 2010, Mud Brook had the highest percentage of developed land cover (74%), whereas Haskell Run and Ritchie Run has 12% and 3.4% developed land cover, respectively. In the down core sediment profile of Old Mill Pond, the heavy metal concentration values increased and peaked between the 1940s-1960s during the time of major population growth in the city of Cuyahoga Falls. Since the early 1980s, there is a decrease in heavy metal concentration to the top of the core after the enactment and enforcement of the Clear Air Act (1970) and Clean Water Act (1972). In addition, changing land use and anthropogenic activity (e.g., presence of a gun club) may also contribute to the changing Pb concentration.
- A direct relationship was found between heavy metal and ferrimagnetic concentrations. Zinc ($r^2=0.62$) and copper ($r^2=0.58$) display a moderate positive relationship, whereas chromium ($r^2=0.48$) and lead ($r^2=0.31$) had weaker relationships. Magnetics can generally be used as a pollution proxy; however, due to the scatter of the data, some samples with low magnetic concentration could have high metal content, and other samples with high magnetic content could have low metal concentrations.
- Following the increase of flood frequency beginning in 2003, there is no apparent increase in the progradation rate of the subaerial delta top building into the impoundment. However, a future study of changes in the sediment accumulation of the subaqueous

delta environment may provide a more accurate measure of the watershed response to increased flooding. The sediment cores from Lakes Butler and Litchfield become coarser-grained at the top because the prograding delta brought the sediment source closer to the core site.

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APPENDICES

APPENDIX A

HASKELL RUN DISCHARGE AND TOTAL SUSPENDED SEDIMENT

On March 25 and November 21, 2016, the sediment trapping efficiency of Lake Butler was estimated by measuring the inflow and outflow discharge. The inflow and outflow water discharge was measured with a Gurley Pygmy flow meter and meter stick. Total suspended sediment (TSS) concentrations were measured with the Ohio Sediment Stick (ODNR, 2014).

Table A1.Haskell Run discharge into Lake Butler on March 25, 2016.

Distance (m)	Segment Width (m)	Water Depth (m)	Clicks/min*	Description	Area (m ²)	Velocity (m/s)	Discharge (m ³ /s)
0	0	0.00	0	Zero water	0.000	0.000	0.000
0.1	0.15	0.05	10	-	0.008	0.051	0.000
0.2	0.1	0.08	29	Scarp	0.008	0.147	0.001
0.3	0.1	0.15	36	½ way down scarp	0.015	0.183	0.003
0.4	0.1	0.26	44	More gravel	0.026	0.224	0.006
0.5	0.1	0.28	44	Gravel	0.028	0.224	0.006
0.6	0.1	0.26	44	Gravel	0.026	0.224	0.006
0.7	0.1	0.25	47	Gravel	0.025	0.239	0.006
0.8	0.1	0.23	50	Gravel	0.023	0.254	0.006
0.9	0.1	0.21	47	Gravel	0.021	0.239	0.005
1	0.1	0.20	44	Noticeably more gravel	0.020	0.224	0.004
1.1	0.1	0.18	43	-	0.018	0.218	0.004
1.2	0.075	0.22	41	-	0.017	0.208	0.003
1.25	0.05	0.22	35	Base of scarp	0.011	0.178	0.002
1.3	0.075	0.16	29	-	0.012	0.147	0.002
1.4	0.08	0.02	0	-	0.002	0.000	0.000
1.43	0	0.00	0	End	0.000	0.000	0.000
Total Discharge							0.055

*Bold text measured values. Plain text interpolated values.

Table A2. Outflow discharge of Lake Butler. Measurements taken at a culvert on March 25, 2016.

Trial	Diameter (m)	Water Width (m)	Water Depth (m)	Clicks/min	Description	Water Area (m ²)	Velocity (m/s)	Discharge (m ³ /s)
1	1.53	0.75	0.1	191	Middle of culvert, leaf debris in flow	0.063	0.970	0.061
2	1.53	0.75	0.1	190	middle of culvert	0.063	0.965	0.061

Table A3. Haskell Run discharge into Lake Butler on November 21, 2016.

Distance	Segment	Width	Water						
(m)	(m)	(m)	Depth	Clicks/min*	Description	Area	Velocity	Discharge	
			(m)			(m ²)	(m/s)	(m ³ /s)	
0	0		0.00	0	Vertical bank	0.000	0.000	0.000	
0	0		0.13	8	-	0.000	0.041	0.000	
0.1	0.15		0.19	16	-	0.028	0.081	0.002	
0.2	0.07		0.21	16	-	0.015	0.081	0.001	
0.24	0.08		0.24	19	-	0.019	0.097	0.002	
0.36	0.11		0.32	21	-	0.035	0.107	0.004	
0.46	0.07		0.29	19	-	0.020	0.097	0.002	
0.5	0.08		0.25	18	-	0.020	0.091	0.002	
0.6	0.15		0.22	16	-	0.033	0.081	0.003	
0.7	0		0.155	8	-	0.000	0.041	0.000	
0.7	0		0.00	0	Vertical bank	0.000	0.000	0.000	
						Total Discharge		0.016	

*Bold text measured values. Plain text interpolated values.

Table A4. Outflow discharge of Lake Butler. Measurements taken at a culvert on Novmeber 21, 2016.

Trial	Diameter (m)	Water		Clicks/min	Description	Water		Velocity (m/s)	Discharge (m ³ /s)
		Width (m)	Depth (m)			Area (m ²)			
1	1.53	0.56	0.06	77	Middle of culvert, leaf debris in flow	0.028	0.391	0.011	
2	1.53	0.56	0.06	75		middle of culvert	0.028	0.381	0.011

Table A5. River inflow and culvert outflow from Lake Butler. A. Measurements taken March 25, 2016. B. Measurements taken November 21, 2016.

A.				
Site	Ohio Sediment Stick (in)	TSS (mg/l)	Qw (m ³ /s)	Qs (g/sec)
Inflow	10.7	29.7	-	-
Inflow	9.4	36	-	-
Inflow	10.5	31	-	-
Inflow	12	26.5	-	-
Inflow Average:	10.7	30.8	0.055	1.69
Lake	15.8	18.1	-	-
Lake	10	33.7	-	-
Lake Average:	12.9	25.9	-	-
Outflow	13	23.8	-	-
Outflow	12	21.6	-	-
Outflow	13.8	19.7	-	-
Outflow Average:	12.9	21.7	0.061	1.32
B.				
Site	Ohio Sediment Stick (in)	TSS (mg/l)	Qw (m ³ /s)	Qs (g/sec)
Inflow	36	>5	-	-
Inflow	36	>5	-	-
Inflow Average:	36	>5	0.016	0.08
Lake	18.5	15	-	-
Lake	23.8	11	-	-
Lake	23.5	11	-	-
Lake Average:	21.9	12.3	-	-
Outflow	25	10.1	-	-
Outflow	24.7	10.3	-	-
Outflow	27	9.1	-	-
Outflow Average:	25.6	9.8	0.011	0.11

APPENDIX B
SEDIMENT CORE LOSS-ON-IGNITION AND WHOLE CORE SUSCEPTIBILITY
(K) FOR LAKE BUTLER, LAKE LITCHFIELD, AND OLD MILL POND

Dry bulk density, wet bulk density, organic matter content, water content, and whole-core magnetic susceptibility (κ) measurements were conducted on all cores from Lake Butler, Lake Litchfield, and Old Mill Pond.

Table B1. LOI data for Lake Butler core 1.

Core-Drive	Depth in Drive	Depth in Core	Corrected Depth in Core	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(cm)	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
LB-16-C1-D1	0.5	0.5	0.725	7.2	1.491	0.949	36.4
	1.5	1.5	2.175	7.2	1.495	0.946	36.7
	2.5	2.5	3.625	6.2	1.625	1.046	35.6
	3.5	3.5	5.075	6.1	1.546	1.001	35.3
	4.5	4.5	6.525	6.9	1.467	0.865	41.0
	5.5	5.5	7.975	6.8	1.488	0.876	41.1
	6.5	6.5	9.425	6.8	1.422	0.853	40.0
	7.5	7.5	10.875	6.8	1.426	0.818	42.6
	8.5	8.5	12.325	7.4	1.412	0.810	42.6
	9.5	9.5	13.775	6.5	1.510	0.928	38.5
	10.5	10.5	15.225	7.8	1.337	0.768	42.6
	11.5	11.5	16.675	6.4	1.403	0.877	37.5
	12.5	12.5	18.125	6.9	1.395	0.857	38.6
	13.5	13.5	19.575	6.3	1.508	0.956	36.6
	14.5	14.5	21.025	7.0	1.449	0.859	40.7
	15.5	15.5	22.475	6.6	1.428	0.882	38.2
	16.5	16.5	23.925	7.6	1.457	0.860	41.0
	17.5	17.5	25.375	7.2	1.469	0.888	39.6
	18.5	18.5	26.825	6.0	1.602	1.063	33.6
	19.5	19.5	28.275	6.2	1.614	1.082	33.0
	20.5	20.5	29.725	6.2	1.578	1.029	34.8
	21.5	21.5	31.175	6.4	1.563	1.000	36.0
	22.5	22.5	32.625	5.4	1.569	1.073	31.6
	23.5	23.5	34.075	6.8	1.473	0.923	37.3
	24.5	24.5	35.525	5.6	1.674	1.126	32.7
	25.5	25.5	36.975	6.1	1.691	1.134	32.9
	26.5	26.5	38.425	5.4	1.530	1.007	34.2
	27.5	27.5	39.875	8.3	1.398	0.797	43.0
	28.5	28.5	41.325	8.3	1.421	0.863	39.3
	29.5	29.5	42.775	6.0	1.635	1.078	34.1
	30.5	30.5	44.225	5.7	1.626	1.080	33.6
	31.5	31.5	45.675	3.4	1.746	1.248	28.5
	32.5	32.5	47.125	6.2	1.521	0.954	37.3
	33.5	33.5	48.575	6.3	1.603	1.024	36.1
	34.5	34.5	50.025	6.3	1.579	0.983	37.7
	35.5	35.5	51.475	6.6	1.474	0.875	40.6
	36.5	36.5	52.925	7.1	1.493	0.877	41.3
	37.5	37.5	54.375	7.6	1.396	0.807	42.2
	38.5	38.5	55.825	6.7	1.446	0.780	46.1
	39.5	39.5	57.275	6.3	1.528	0.885	42.1

Table B1. (Cont) LOI data for Lake Butler core 1.

Core-Drive	Depth in Drive	Depth in Core	Corrected Depth in Core	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(cm)	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
LB-16-C1-D1	40.5	40.5	58.725	5.8	1.595	1.020	36.1
	41.5	41.5	60.175	5.2	1.627	1.098	32.5
	42.5	42.5	61.625	5.4	1.643	1.109	32.5
	46.5	46.5	67.425	3.7	1.572	1.133	27.9
	47.5	47.5	68.875	7.6	1.335	0.853	36.1
	48.5	48.5	70.325	5.4	1.495	1.014	32.2
	49.5	49.5	71.775	8.1	1.407	0.838	40.4
	50.5	50.5	73.225	6.1	1.593	1.023	35.8
	51.5	51.5	74.675	5.8	1.490	0.978	34.4
	52.5	52.5	76.125	6.4	1.374	0.829	39.7
	53.5	53.5	77.575	5.4	1.551	1.029	33.7
	54.5	54.5	79.000	1.6	1.540	1.230	20.1
LB-16-C1-D2	0.5	Hole fill	-	3.3	1.606	1.121	30.2
	1.5	Hole fill	-	4.8	1.581	1.039	34.3
	3.5	80.0	80.000	0.7	1.734	1.427	17.7
	4.5	81.0	81.000	0.7	1.720	1.408	18.1
	5.5	82.0	82.000	2.2	1.669	1.386	17.0
	6.5	83.0	83.000	0.7	1.772	1.447	18.3
	7.5	84.0	84.000	1.6	1.645	1.318	19.9
	8.5	85.0	85.000	8.2	1.400	0.900	35.7
	9.5	86.0	86.000	6.5	1.619	1.031	36.3
	10.5	87.0	87.000	9.3	1.370	0.806	41.2
	15.5	92.0	92.000	7.8	1.408	0.862	38.8
	16.5	93.0	93.000	8.0	1.391	0.845	39.3
	17.5	94.0	94.000	19.7	0.973	0.396	59.3
	18.5	95.0	95.000	16.2	1.022	0.493	51.8
	19.5	96.0	96.000	8.6	1.392	0.838	39.8
	20.5	97.0	97.000	7.2	1.565	0.984	37.1
	21.5	98.0	98.000	4.5	1.312	0.928	29.3
	22.5	99.0	99.000	14.2	1.326	0.713	46.2
	23.5	100.0	100.000	12.7	1.375	0.740	46.2
	24.5	101.0	101.000	8.5	1.478	0.860	41.8
	25.5	102.0	102.000	9.1	1.533	0.872	43.1
	26.5	103.0	103.000	8.7	1.494	0.842	43.6
	27.5	104.0	104.000	9.6	1.366	0.729	46.6
	28.5	105.0	105.000	8.8	1.419	0.782	44.9
	29.5	106.0	106.000	7.9	1.424	0.857	39.8

Table B1. (Cont) LOI data for Lake Butler core 1.

Core-Drive	Depth in Drive	Depth in Core	Corrected Depth in Core	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(cm)	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
LB-16-C1-D2	30.5	107.0	107.000	3.0	1.674	1.242	25.8
	31.5	108.0	108.000	9.7	1.364	0.829	39.2
	32.5	109.0	109.000	10.8	1.258	0.697	44.6
	33.5	110.0	110.000	6.5	1.577	1.022	35.2
	34.5	111.0	111.000	6.8	1.480	0.944	36.2
	35.5	112.0	112.000	6.1	1.682	1.096	34.8
	36.5	113.0	113.000	9.0	1.536	0.910	40.8
	37.5	114.0	114.000	6.8	1.614	1.022	36.7
	38.5	115.0	115.000	9.1	1.582	0.940	40.6
	39.5	116.0	116.000	7.6	1.512	0.921	39.1
	40.5	117.0	117.000	7.5	1.473	0.897	39.1
	41.5	118.0	118.000	7.6	1.508	0.909	39.7
	42.5	119.0	119.000	9.4	1.461	0.811	44.5
	43.5	120.0	120.000	8.4	1.367	0.761	44.3
	44.5	121.0	121.000	6.8	1.539	0.948	38.4
	45.5	122.0	122.000	7.1	1.561	0.968	38.0
	46.5	123.0	123.000	6.5	1.621	1.038	36.0
	47.5	124.0	124.000	6.7	1.609	1.043	35.2
	48.5	125.0	125.000	6.7	1.492	0.946	36.6
	49.5	126.0	126.000	6.7	1.627	1.014	37.7

Table B2. Whole-core susceptibility (κ) for Lake Butler core 1.

Core-Drive	Depth in Drive	Depth in Core	Corrected Depth in Core	κ (10^{-5} Relative SI Units)	Edited κ (10^{-5} Relative SI Units)
	(cm)	(cm)	(cm)		
LB-16-C1-D1	0.0	0.0	-	9.3	-
	3.0	3.0	4.4	11.4	11.4
	6.0	6.0	8.7	10.4	10.4
	9.0	9.0	13.1	10.5	10.5
	12.0	12.0	17.4	11.0	11.0
	15.0	15.0	21.8	10.7	10.7
	18.0	18.0	26.1	11.5	11.5
	21.0	21.0	30.5	12.5	12.5
	24.0	24.0	34.8	12.9	12.9
	27.0	27.0	39.2	13.1	13.1
	30.0	30.0	43.5	15.5	15.5
	33.0	33.0	47.9	15.9	15.9
	36.0	36.0	52.2	13.2	13.2
	39.0	39.0	56.6	13.1	13.1
	42.0	42.0	60.9	14.3	14.3
	45.0	45.0	65.3	10.9	10.9
	48.0	48.0	69.6	13.7	13.7
	51.0	51.0	74.0	14.7	14.7
	54.0	54.0	-	11.4	-
LB-16-C1-D2	0.0	76.5	-	8.0	-
	3.0	79.5	-	11.6	-
	6.0	82.5	82.5	12.9	12.9
	9.0	85.5	85.5	14.3	14.3
	12.0	88.5	88.5	13.9	13.9
	15.0	91.5	91.5	14.5	14.5
	18.0	94.5	94.5	15.7	15.7
	21.0	97.5	97.5	16.4	16.4
	24.0	100.5	100.5	13.2	13.2
	27.0	103.5	103.5	12.9	12.9
	30.0	106.5	106.5	13.3	13.3
	33.0	109.5	109.5	15.2	15.2
	36.0	112.5	112.5	16.3	16.3
	39.0	115.5	115.5	14.7	14.7
	42.0	118.5	118.5	14.1	14.1
	45.0	121.5	121.5	14.8	14.8
	48.0	124.5	124.5	14.3	14.3
	51.0	127.5	-	9.0	-

Table B3. LOI data for Lake Butler core 4.

Core-Drive	Depth in Drive (cm)	Depth in Core (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water Content (%)
LB-16-C4-D1	0.5	0.5	10.1	1.332	0.805	39.6
	1.5	1.5	6.8	1.443	0.880	39.0
	2.5	2.5	6.8	1.387	0.828	40.3
	3.5	3.5	6.3	1.582	1.035	34.6
	4.5	4.5	5.7	1.561	1.000	35.9
	5.5	5.5	6.0	1.588	1.004	36.8
	6.5	6.5	5.4	1.608	1.022	36.4
	7.5	7.5	5.2	1.675	1.098	34.4
	8.5	8.5	5.8	1.584	1.005	36.6
	9.5	9.5	7.2	1.415	0.789	44.2
	10.5	10.5	6.4	1.521	0.888	41.6
	11.5	11.5	7.4	1.469	0.839	42.9
	12.5	12.5	7.3	1.366	0.688	49.6
	13.5	13.5	7.1	1.433	0.785	45.2
	14.5	14.5	7.7	1.315	0.716	45.6
	15.5	15.5	5.5	1.589	0.996	37.3
	16.5	16.5	5.1	1.643	1.086	33.9
	17.5	17.5	5.5	1.549	0.963	37.8
	18.5	18.5	5.9	1.407	0.841	40.2
	19.5	19.5	6.3	1.510	0.890	41.1
	20.5	20.5	5.1	1.520	0.948	37.6
	21.5	21.5	5.5	1.591	1.024	35.6
	22.5	22.5	5.7	1.568	0.987	37.1
	23.5	23.5	6.1	1.524	0.969	36.4
	24.5	24.5	7.3	1.461	0.810	44.6
	25.5	25.5	6.4	1.447	0.858	40.7
	26.5	26.5	6.2	1.577	1.015	35.6
	27.5	27.5	5.9	1.590	1.024	35.6
	28.5	28.5	7.3	1.439	0.830	42.3
	29.5	29.5	6.3	1.397	0.854	38.9
	30.5	30.5	6.1	1.585	0.978	38.3
	31.5	31.5	7.1	1.567	0.934	40.4
	32.5	32.5	7.0	1.472	0.884	39.9
	33.5	33.5	6.9	1.580	0.969	38.7
	34.5	34.5	4.4	1.801	1.301	27.8
	35.5	35.5	3.2	1.721	1.327	22.9
	37.5	37.5	6.8	1.527	0.957	37.3
	38.5	38.5	6.5	1.573	0.970	38.3
	39.5	39.5	6.9	1.545	0.900	41.7
	40.5	40.5	6.7	1.528	0.894	41.5

Table B3. (Cont) LOI data for Lake Butler core 4.

Core-Drive	Depth in Drive (cm)	Depth in Core (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water Content (%)
LB-16-C4-D1	41.5	41.5	6.9	1.513	0.886	41.4
	42.5	42.5	6.7	1.548	0.936	39.5
	43.5	43.5	6.5	1.53	0.963	37.1
	44.5	44.5	6.3	1.529	0.952	37.7
	46.5	46.5	6.2	1.605	1.033	35.6
	47.5	47.5	6.0	1.605	1.011	37.0
	48.5	48.5	7.3	1.472	0.848	42.4
	49.5	49.5	6.9	1.511	0.860	43.1
	50.5	50.5	6.3	1.571	0.943	40.0
	51.5	51.5	6.3	1.507	0.885	41.3
	52.5	52.5	6.4	1.519	0.906	40.4
	53.5	53.5	7.1	1.5	0.886	40.9
	54.5	54.5	5.9	1.569	0.936	40.3
	55.5	55.5	5.4	1.677	1.106	34.0
	56.5	56.5	5.2	1.674	1.124	32.9
	57.5	57.5	5.2	1.77	1.091	38.4
	58.5	58.5	5.4	1.664	1.067	35.9
	59.5	59.5	6.2	1.661	1.031	37.9
	60.5	60.5	6.2	1.599	0.999	37.5
	61.5	61.5	7.5	1.449	0.843	41.8
	63.0	63.0	7.6	1.388	0.824	40.6
	64.5	64.5	8.5	1.396	0.696	50.1
	65.5	65.5	6.6	1.508	0.861	42.9
	66.5	66.5	7.2	1.545	0.899	41.8
	67.5	67.5	6.7	1.562	0.935	40.1
	68.5	68.5	8.2	1.234	0.612	50.4
	69.5	69.5	9.0	1.367	0.655	52.1
	70.5	70.5	7.2	1.482	0.793	46.5
	71.5	71.5	8.1	1.44	0.801	44.4
	72.5	72.5	7.1	1.496	0.848	43.3
	73.5	73.5	6.9	1.516	0.945	37.7
	74.5	74.5	6.1	1.619	1.058	34.7
	76.5	76.5	7.9	1.323	0.796	39.8
	78.5	78.5	1.3	1.762	1.410	20.0
	79.5	79.5	6.2	1.646	1.079	34.4
	80.5	80.5	10.7	1.334	0.721	46.0
	82.5	82.5	6.0	1.627	1.037	36.3
	83.5	83.5	6.9	1.545	0.956	38.1
	84.5	84.5	5.6	1.619	1.062	34.4

Table B3. (Cont) LOI data for Lake Butler core 4.

Core-Drive	Depth in Drive (cm)	Depth in Core (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water Content (%)
LB-16-C4-D1	85.5	85.5	5.8	1.637	1.078	34.1
	86.5	86.5	5.7	1.675	1.129	32.6
	87.5	87.5	5.6	1.693	1.133	33.1
	88.5	88.5	7.0	1.515	0.870	42.6
	89.5	89.5	5.0	1.711	1.151	32.7
	90.5	90.5	7.2	1.591	0.986	38.0
	91.5	91.5	6.6	1.631	1.017	37.6
	92.5	92.5	4.9	1.644	1.158	29.6
LB-16-C4-D2	0.5	100.5	7.1	1.549	0.935	39.6
	1.5	101.5	6.0	1.623	1.011	37.7
	2.5	102.5	5.8	1.630	1.078	33.9
	3.5	103.5	5.1	1.749	1.194	31.7
	4.5	104.5	5.9	1.644	1.069	35.0
	5.5	105.5	8.9	1.466	0.879	40.0
	6.5	106.5	8.3	1.502	0.917	38.9
	7.5	107.5	8.6	1.484	0.912	38.5
	13.5	113.5	22.5	1.137	0.516	54.6
	14.5	114.5	7.3	1.621	1.031	36.4
	15.5	115.5	8.1	1.553	0.922	40.6
	16.5	116.5	9.6	1.474	0.847	42.5
	17.5	117.5	9.1	1.501	0.869	42.1
	18.5	118.5	7.7	1.556	0.933	40.0
	19.5	119.5	8.0	1.519	0.877	42.3
	20.5	120.5	9.0	1.462	0.807	44.8
	21.5	121.5	7.3	1.554	0.936	39.8
	22.5	122.5	6.9	1.612	0.990	38.6
	23.5	123.5	6.9	1.465	0.858	41.4
	24.5	124.5	6.8	1.456	0.863	40.7
	25.5	125.5	6.2	1.568	1.021	34.9
	26.5	126.5	6.9	1.593	1.004	37.0
	27.5	127.5	6.5	1.524	0.966	36.6
	28.5	128.5	7.1	1.555	0.969	37.7
	29.5	129.5	6.9	1.576	0.992	37.1
	30.5	130.5	7.2	1.590	0.990	37.7
	31.5	131.5	7.2	1.550	0.927	40.2
	32.5	132.5	6.3	1.562	0.984	37.0
	33.5	133.5	6.0	1.658	1.073	35.3
	34.5	134.5	6.2	1.624	1.049	35.4
	35.5	135.5	6.5	1.577	0.999	36.7

Table B3. (Cont) LOI data for Lake Butler core 4.

Core-Drive	Depth in Drive (cm)	Depth in Core (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water Content (%)
LB-16-C4-D2	36.5	136.5	6.3	1.516	0.934	38.4
	37.5	137.5	6.6	1.582	0.985	37.7
	38.5	138.5	6.0	1.621	1.027	36.6
	39.5	139.5	6.2	1.542	0.966	37.4
	40.5	140.5	5.9	1.631	1.041	36.2
	42.0	142.0	8.8	1.435	0.752	47.6
	43.5	143.5	6.1	1.588	0.983	38.1
	44.5	144.5	5.7	1.355	0.945	30.3
	45.5	145.5	5.5	1.582	0.949	40.0
	46.5	146.5	6.0	1.585	0.965	39.1
	47.5	147.5	6.6	1.537	0.939	38.9
	48.5	148.5	5.7	1.638	1.061	35.2
	49.5	149.5	5.5	1.676	1.095	34.7
	50.5	150.5	7.4	1.468	0.857	41.6
	51.5	151.5	5.3	1.658	1.067	35.6
	52.5	152.5	5.8	1.517	0.903	40.5
	53.5	153.5	4.9	1.636	1.081	33.9
	54.5	154.5	5.9	1.615	1.017	37.0
	55.5	155.5	6.5	1.572	0.961	38.9
	56.5	156.5	5.8	1.522	0.931	38.8
	57.5	157.5	5.8	1.542	0.929	39.8
	58.5	158.5	5.6	1.606	1.009	37.2
	59.5	159.5	6.3	1.547	0.959	38.0
	60.5	160.5	5.5	1.639	1.061	35.3
	61.5	161.5	6.4	1.480	0.892	39.7
	62.5	162.5	5.3	1.593	0.988	38.0
	63.5	163.5	4.8	1.634	1.075	34.2
	64.5	164.5	5.3	1.673	1.091	34.8
	65.5	165.5	5.8	1.634	1.043	36.2
	66.5	166.5	6.2	1.614	0.984	39.0
	67.5	167.5	5.8	1.505	0.846	43.8
	68.5	168.5	5.1	1.655	1.070	35.3
	69.5	169.5	4.8	1.601	1.027	35.9
	70.5	170.5	4.8	1.627	1.065	34.5
	71.5	171.5	5.6	1.550	0.979	36.8
	72.5	172.5	6.9	1.546	0.914	40.9
	74.0	174.0	6.3	1.448	0.824	43.1
	75.0	175.0	6.0	1.571	0.930	40.8
	76.5	176.5	5.6	1.540	0.924	40.0

Table B3. (Cont) LOI data for Lake Butler core 4.

Core-Drive	Depth in Drive (cm)	Depth in Core (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water Content (%)
LB-16-C4-D2	77.5	177.5	5.3	1.559	0.946	39.3
	78.5	178.5	5.0	1.695	1.130	33.3
	79.5	179.5	5.7	1.618	1.021	36.9
	80.5	180.5	5.4	1.591	1.015	36.2
	81.5	181.5	5.5	1.652	1.086	34.3
LB-16-C4-D3	0.5	190.5	5.1	1.760	1.219	30.7
	1.5	191.5	4.4	1.703	1.145	32.8
	2.5	192.5	4.7	1.612	1.035	35.8
	3.5	193.5	5.4	1.603	1.011	36.9
	4.5	194.5	5.8	1.570	0.977	37.8
	6.0	196.0	6.1	1.608	1.008	37.3
	7.5	197.5	4.4	1.628	1.020	37.3
	8.5	198.5	4.6	1.690	1.120	33.7
	9.5	199.5	4.7	1.673	1.108	33.8
	10.5	200.5	5.1	1.568	0.974	37.9
	12.5	202.5	4.9	1.831	1.324	27.7
	13.5	203.5	6.2	1.689	1.158	31.4
	14.5	204.5	7.9	1.717	1.144	33.4
	15.5	205.5	5.4	1.695	1.212	28.5
	16.5	206.5	5.1	1.766	1.285	27.2
	17.5	207.5	5.9	1.711	1.225	28.4
	19.5	209.5	9.0	1.569	1.035	34.0
	20.5	210.5	4.7	1.764	1.331	24.5
	21.5	211.5	4.4	1.824	1.376	24.6
	22.5	212.5	4.4	1.841	1.394	24.3
	23.5	213.5	4.9	1.629	1.236	24.1
	24.5	214.5	4.5	1.814	1.389	23.4
	25.5	215.5	4.3	1.889	1.457	22.9
	26.5	216.5	4.2	1.807	1.387	23.2
	27.5	217.5	4.0	1.857	1.440	22.5
	28.5	218.5	3.7	1.885	1.502	20.3
	29.5	219.5	3.8	1.869	1.466	21.6
	30.5	220.5	3.9	1.813	1.414	22.0
	31.5	221.5	3.4	1.889	1.500	20.6
	32.5	222.5	3.2	1.852	1.484	19.9
	33.5	223.5	3.3	1.907	1.533	19.6
	35.0	225.0	4.2	1.854	1.488	19.7
	36.5	226.5	2.4	1.926	1.654	14.1
	37.5	227.5	3.1	1.911	1.583	17.2

Table B3. (Cont) LOI data for Lake Butler core 4.

Core-Drive	Depth in Drive (cm)	Depth in Core (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water Content (%)
LB-16-C4-D3	38.5	228.5	2.8	1.859	1.533	17.5
	39.5	229.5	2.4	1.847	1.523	17.5
	40.5	230.5	2.8	1.683	1.380	18.0
	41.5	231.5	3.0	1.942	1.584	18.4
	42.5	232.5	3.2	1.869	1.525	18.4
	43.5	233.5	3.0	1.944	1.580	18.7
	44.5	234.5	2.9	1.995	1.637	17.9
	45.5	235.5	3.1	1.930	1.579	18.2
	46.5	236.5	3.0	1.697	1.378	18.8
	47.5	237.5	2.1	1.895	1.614	14.8
	48.5	238.5	2.3	1.876	1.574	16.1
	49.5	239.5	2.1	1.824	1.552	14.9
	50.5	240.5	2.1	1.703	1.480	13.1
	51.5	241.5	2.9	1.783	1.467	17.7
	52.5	242.5	2.6	1.936	1.584	18.2
	53.5	243.5	3.1	1.986	1.612	18.8
	54.5	244.5	2.9	1.895	1.551	18.2
	55.5	245.5	2.9	1.845	1.504	18.5
	56.5	246.5	2.7	1.999	1.654	17.3
	57.5	247.5	2.4	2.018	1.663	17.6
	58.5	248.5	1.7	1.620	1.451	10.4

Table B4. Whole-core susceptibility (κ) for Lake Butler core 4.

Core-Drive	Depth in Drive (cm)	Depth in Core (cm)	Corrected Depth in Core (cm)	κ (10^{-5} Relative SI Units)	Edited κ (10^{-5} Relative SI Units)	Edited κ^* ($\kappa/2$) (10^{-5} Relative SI Units)
LB-16-C4-D1	0	0	0	10.4	-	-
	3	3	3	21.0	21.0	10.50
	6	6	6	20.7	20.7	10.35
	9	9	9	19.0	19.0	9.50
	12	12	12	16.7	16.7	8.35
	15	15	15	19.6	19.6	9.80
	18	18	18	21.1	21.1	10.55
	21	21	21	20.5	20.5	10.25
	24	24	24	21.1	21.1	10.55
	27	27	27	24.3	24.3	12.15
	30	30	30	24.7	24.7	12.35
	33	33	33	26.2	26.2	13.10
	36	36	36	29.4	29.4	14.70
	39	39	39	27.3	27.3	13.65
	42	42	42	25.6	25.6	12.80
	45	45	45	27.3	27.3	13.65
	48	48	48	23.3	23.3	11.65
	51	51	51	21.4	21.4	10.70
	54	54	54	24.3	24.3	12.15
	57	57	57	27.9	27.9	13.95
	60	60	60	28.6	28.6	14.30
	63	63	63	23.4	23.4	11.70
	66	66	66	19.5	19.5	9.75
	69	69	69	17.4	17.4	8.70
	72	72	72	21.2	21.2	10.60
	75	75	75	26.4	26.4	13.20
	78	78	78	26.0	26.0	13.00
	81	81	81	25.5	25.5	12.75
	84	84	84	24.1	24.1	12.05
	87	87	87	22.6	22.6	11.30
	90	90	90	20.7	20.7	10.35
	93	93	-	11.2	-	-
LB-16-C4-D2	0	100	-	8.7	-	-
	3	103	103	26.4	26.4	13.20
	6	106	106	27.4	27.4	13.70
	9	109	109	23.4	23.4	11.70
	12	112	112	20.4	20.4	10.20
	15	115	115	25.3	25.3	12.65
	18	118	118	25.1	25.1	12.55

Table B4. (Cont) Whole-core susceptibility (κ) for Lake Butler core 4.

Core-Drive	Depth in Drive (cm)	Depth in Core (cm)	Corrected Depth in Core (cm)	κ (10^{-5} Relative SI Units)	Edited κ (10^{-5} Relative SI Units)	Edited κ^* ($\kappa/2$) (10^{-5} Relative SI Units)
LB-16-C4-D2	21	121	121	24.8	24.8	12.40
	24	124	124	25.6	25.6	12.80
	27	127	127	27.4	27.4	13.70
	30	130	130	25.6	25.6	12.80
	33	133	133	25.2	25.2	12.60
	36	136	136	25.7	25.7	12.85
	39	139	139	24.6	24.6	12.30
	42	142	142	22.8	22.8	11.40
	45	145	145	23.8	23.8	11.90
	48	148	148	25.2	25.2	12.60
	51	151	151	25.9	25.9	12.95
	54	154	154	24.7	24.7	12.35
	57	157	157	25.8	25.8	12.90
	60	160	160	24.6	24.6	12.30
	63	163	163	23.6	23.6	11.80
	66	166	166	24.1	24.1	12.05
	69	169	169	24.2	24.2	12.10
	72	172	172	25.1	25.1	12.55
	75	175	175	27.2	27.2	13.60
	78	178	178	25.6	25.6	12.80
	81	181	181	26.3	26.3	13.15
	84	184	184	19.2	19.2	9.60
	87	187	-	4.1	-	-
LB-16-C4-D3	0	190	-	9.3	-	-
	3	193	193	25.0	25.0	12.50
	6	196	196	32.6	32.6	16.30
	9	199	199	33.8	33.8	16.90
	12	202	202	47.9	47.9	23.95
	15	205	205	82.6	82.6	41.30
	18	208	208	66.6	66.6	33.30
	21	211	211	57.5	57.5	28.75
	24	214	214	62.6	62.6	31.30
	27	217	217	66.0	66.0	33.00
	30	220	220	66.3	66.3	33.15
	33	223	223	63.8	63.8	31.90
	36	226	226	55.9	55.9	27.95
	39	229	229	65.5	65.5	32.75
	42	232	232	77.7	77.7	38.85

Table B4. (Cont) Whole-core susceptibility (κ) for Lake Butler core 4.

Core-Drive	Depth in Drive (cm)	Depth in Core (cm)	Corrected Depth in Core (cm)	κ (10^{-5} Relative SI Units)	Edited κ (10^{-5} Relative SI Units)	Edited κ^* ($\kappa/2$) (10^{-5} Relative SI Units)
LB-16-C4-D3	45	235	235	67.6	67.6	33.80
	48	238	238	61.3	61.3	30.65
	51	241	241	58.5	58.5	29.25
	54	244	244	59.2	59.2	29.60
	57	247	247	64.5	64.5	32.25
	60	250	-	51.4	-	-

Table B5. LOI data for Lake Butler core 7.

Core-Drive	Depth (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water Content (%)
LB-16-C7	0.5	6.0	1.539	0.926	39.8
	1.5	6.1	1.472	0.881	40.1
	2.5	5.9	1.498	0.900	39.9
	3.5	6.4	1.403	0.771	45.0
	4.5	5.9	1.462	0.843	42.3
	5.5	6.0	1.477	0.873	40.9
	6.5	6.6	1.483	0.890	40.0
	7.5	7.8	1.423	0.785	44.8
	8.5	7.0	1.408	0.714	49.3
	9.5	6.8	1.405	0.703	50.0
	10.5	6.1	1.445	0.802	44.5
	11.5	5.7	1.476	0.841	43.0
	12.5	5.4	1.505	0.926	38.5
	13.5	7.5	1.364	0.706	48.2
	14.5	6.2	1.438	0.790	45.1
	15.5	4.4	1.627	1.091	32.9
	16.5	6.1	1.505	0.900	40.2
	17.5	6.1	1.440	0.754	47.6
	18.5	4.9	1.552	0.953	38.6
	19.5	6.1	1.436	0.831	42.1
	20.5	6.4	1.457	0.813	44.2
	21.5	6.4	1.425	0.752	47.2
	22.5	5.8	1.470	0.790	46.3
	23.5	5.7	1.386	0.771	44.4
	24.5	5.4	1.518	0.948	37.5
	25.5	5.3	1.507	0.931	38.2
	26.5	5.5	1.509	0.879	41.7
	27.5	5.1	1.520	0.930	38.8
	28.5	4.6	1.561	1.034	33.8
	29.5	5.1	1.497	0.910	39.2
	30.5	6.3	1.466	0.805	45.1
	31.5	6.5	1.361	0.680	50.0
	32.5	6.2	1.367	0.722	47.2
	33.5	7.2	1.326	0.636	52.0
	34.5	7.9	1.412	0.734	48.0
	35.5	6.5	1.423	0.803	43.6
	36.5	9.4	1.392	0.681	51.1
	37.5	10.0	1.351	0.580	57.1
	38.5	7.1	1.411	0.763	45.9
	39.5	7.0	1.442	0.799	44.6
	40.5	5.8	1.502	0.921	38.7
	41.5	6.1	1.513	0.906	40.1

Table B5. (Cont) LOI data for Lake Butler core 7.

Core-Drive	Depth	Organic	Wet bulk	Dry Bulk	Water
	(cm)	Matter	Density	Density	Content
		(%)	(g/cm ³)	(g/cm ³)	(%)
LB-16-C7	42.5	4.8	1.527	0.996	34.8
	43.5	6.7	1.400	0.810	42.1
	44.5	11.4	1.336	0.595	55.5
	45.5	6.2	1.443	0.853	40.9
	46.5	5.0	1.469	0.914	37.8
	47.5	6.9	1.531	0.878	42.7
	48.5	7.0	1.421	0.800	43.7
	49.5	5.2	1.487	0.897	39.7
	50.5	6.6	1.347	0.667	50.5
	51.5	4.8	1.514	0.924	39.0
	52.5	5.6	1.494	0.917	38.6
	53.5	5.5	1.535	0.907	40.9
	54.5	6.1	1.431	0.820	42.7
	55.5	7.3	1.294	0.593	54.2
	56.5	6.3	1.414	0.764	46.0
	57.5	6.4	1.381	0.724	47.6
	58.5	6.1	1.383	0.738	46.6
	59.5	6.1	1.468	0.866	41.0
	60.5	6.9	1.302	0.652	49.9
	61.5	7.5	1.332	0.628	52.9
	62.5	5.8	1.406	0.796	43.4
	63.5	5.9	1.364	0.710	47.9
	64.5	5.9	1.463	0.817	44.2
	65.5	7.8	1.271	0.486	61.8
	66.5	5.9	1.406	0.717	49.0
	67.5	8.6	1.285	0.526	59.1
	68.5	7.6	1.196	0.503	57.9
	69.5	6.0	1.371	0.682	50.3
	70.5	5.6	1.514	0.853	43.7
	71.5	7.0	1.120	0.473	57.8
	72.5	5.9	1.429	0.764	46.5
	73.5	5.2	1.370	0.782	42.9
	74.5	5.8	1.484	0.873	41.2
	75.5	4.8	1.471	0.972	33.9
	76.5	6.3	1.441	0.882	38.8
	77.5	5.5	1.593	1.043	34.5
	78.5	5.7	1.565	1.004	35.8
	79.5	5.5	1.556	1.016	34.7
	80.5	5.3	1.461	0.955	34.6
	81.5	5.9	1.478	0.920	37.8

Table B5. (Cont) LOI data for Lake Butler core 7.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
LB-16-C7	82.5	6.2	1.424	0.858	39.7
	83.5	5.7	1.384	0.887	35.9
	84.5	6.1	1.399	0.782	44.1
	85.5	6.0	1.359	0.756	44.4
	86.5	6.1	1.421	0.826	41.9
	87.5	5.6	1.405	0.844	39.9
	88.5	5.2	1.392	0.890	36.1
	89.5	5.4	1.349	0.865	35.9
	90.5	5.4	1.430	0.886	38.0
	91.5	5.7	1.338	0.849	36.5
	92.5	5.4	1.501	1.017	32.2
	93.5	5.5	1.463	0.997	31.9
	94.5	5.3	1.642	1.151	29.9
	95.5	5.2	1.490	1.042	30.1
	96.5	5.4	1.759	1.283	27.1
	97.5	5.0	1.518	1.087	28.4

Table B6. Whole-core susceptibility (κ) for Lake Butler core 7.

Core-Drive	Depth in Drive	Depth in Core	Corrected Depth in Core	κ	Edited κ
	(cm)	(cm)	(cm)	(10^{-5} Relative SI Units)	(10^{-5} Relative SI Units)
LB-16-C7	0	0	-	1.5	-
	3	3	3	8.3	8.3
	6	6	6	10.8	10.8
	9	9	9	11.3	11.3
	12	12	12	10.5	10.5
	15	15	15	11.7	11.7
	18	18	18	12.5	12.5
	21	21	21	11.1	11.1
	24	24	24	10.9	10.9
	27	27	27	12.9	12.9
	30	30	30	13.9	13.9
	33	33	33	11.8	11.8
	36	36	36	10.5	10.5
	39	39	39	12.7	12.7
	42	42	42	14.4	14.4
	45	45	45	14.8	14.8
	48	48	48	14.4	14.4
	51	51	51	13.9	13.9
	54	54	54	13.6	13.6
	57	57	57	12.5	12.5
	60	60	60	11.2	11.2
	63	63	63	11.8	11.8
	66	66	66	10.3	10.3
	69	69	69	9.2	9.2
	72	72	72	11.6	11.6
	75	75	75	16.3	16.3
	78	78	78	22.8	22.8
	81	81	81	25.3	25.3
	84	84	84	25.6	25.6
	87	87	87	22.5	22.5
	90	90	90	22.5	22.5
	93	93	93	24.0	24.0
	96	96	96	25.1	25.1
	99	99	-	18.7	-

Table B7. LOI data for Lake Litchfield core 1.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
LL-16-C1	0.5	5.1	1.515	0.904	40.3
	1.5	4.9	1.569	1.026	34.6
	2.5	4.7	1.584	1.015	35.9
	3.5	4.9	1.421	0.899	36.7
	4.5	5.2	1.557	0.946	39.2
	5.5	4.6	1.487	0.912	38.7
	6.5	4.3	1.580	1.011	36.0
	7.5	4.5	1.558	0.978	37.2
	8.5	5.4	1.483	0.912	38.5
	9.5	2.8	1.657	1.161	29.9
	10.5	4.3	1.610	1.027	36.2
	11.5	5.6	1.484	0.915	38.3
	12.5	4.2	1.592	1.050	34.0
	13.5	5.3	1.560	0.938	39.9
	14.5	6.0	1.227	0.598	51.3
	15.5	4.6	1.480	0.847	42.8
	16.5	4.3	1.591	0.996	37.4
	17.5	5.5	1.511	0.861	43.0
	18.5	5.1	1.385	0.749	45.9
	19.5	3.6	1.552	0.996	35.8
	20.5	4.4	1.461	0.861	41.1
	21.5	5.9	1.281	0.596	53.5
	22.5	3.3	1.604	1.084	32.4
	23.5	3.7	1.641	1.083	34.0
	24.5	4.7	1.432	0.854	40.4
	25.5	4.1	1.543	1.013	34.3
	26.5	3.8	1.619	1.074	33.7
	27.5	5.0	1.541	0.969	37.1
	28.5	4.7	1.592	0.986	38.1
	29.5	5.3	1.520	0.924	39.2
	30.5	4.6	1.568	0.970	38.1
	31.5	3.7	1.655	1.143	30.9
	32.5	4.0	1.663	1.110	33.3
	33.5	3.9	1.514	0.990	34.6
	34.5	1.5	1.774	1.368	22.9
	35.5	4.1	1.615	1.064	34.1
	36.5	3.8	1.574	1.051	33.2
	37.5	2.0	1.761	1.319	25.1
	38.5	4.3	1.644	1.085	34.0

Table B7. (Cont) LOI data for Lake Litchfield core 1.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
LL-16-C1	39.5	4.0	1.636	1.069	34.7
	40.5	4.7	1.537	0.937	39.0
	42.0	6.2	1.376	0.694	49.6
	43.0	6.1	1.395	0.773	44.6
	44.0	8.2	1.219	0.478	60.8
	45.0	4.9	1.500	0.920	38.7
	46.5	6.4	1.395	0.761	45.4
	47.5	5.9	1.256	0.613	51.2
	48.5	4.5	1.572	0.985	37.3
	49.5	3.7	1.712	1.176	31.3
	50.5	3.7	1.610	1.086	32.5
	51.5	3.7	1.655	1.158	30.0
	52.5	3.9	1.703	1.166	31.5
	53.5	4.1	1.632	1.054	35.4
	54.5	3.5	1.671	1.140	31.8
	55.5	1.9	1.784	1.366	23.4
	56.5	4.7	1.669	1.089	34.8
	57.5	4.0	1.680	1.114	33.7
	58.5	5.0	1.582	0.993	37.2
	59.5	5.0	1.407	0.898	36.2
	61.0	7.1	1.341	0.590	56.0
	62.5	4.8	1.566	0.962	38.6
	63.5	4.7	1.595	1.015	36.4
	64.5	13.3	1.158	0.368	68.2
	65.5	5.7	1.430	0.861	39.8
	66.5	5.3	1.586	0.970	38.8
	67.5	6.0	1.434	0.856	40.3
	68.5	4.9	1.562	0.993	36.4
	69.5	5.4	1.653	1.028	37.8
	70.5	4.7	1.614	1.061	34.3
	71.5	6.8	1.440	0.780	45.8
	72.5	5.2	1.556	0.908	41.6
	73.5	6.2	1.366	0.731	46.5
	74.5	5.3	1.530	0.893	41.6
	75.5	5.5	1.344	0.887	34.0
	76.5	4.7	1.738	1.246	28.3
	77.5	4.1	1.723	1.272	26.2
	78.5	3.3	1.718	1.271	26.0
	79.5	2.9	1.838	1.400	23.8

Table B7. LOI data for Lake Litchfield core 1.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
LL-16-C1	80.5	3.1	1.738	1.324	23.8
	81.5	3.1	1.683	1.263	25.0
	82.5	3.5	1.607	1.208	24.8
	83.5	3.4	1.797	1.337	25.6
	84.5	3.2	1.444	1.071	25.8
	85.5	3.2	1.657	1.236	25.4
	86.5	3.4	1.828	1.371	25.0
	87.5	3.2	1.842	1.410	23.5
	88.5	3.3	1.712	1.331	22.3
	89.5	3.2	1.803	1.354	24.9
	90.5	3.2	1.756	1.340	23.7
	91.5	3.4	1.815	1.371	24.5
	92.5	3.3	1.822	1.381	24.2
	93.5	3.2	1.818	1.374	24.4
	94.5	3.3	1.879	1.433	23.7
	95.5	2.8	1.865	1.456	21.9
	96.5	2.6	1.728	1.346	22.1
	97.5	3.1	1.808	1.364	24.6
	98.5	3.2	1.750	1.290	26.3
	99.5	3.1	1.766	1.328	24.8
	100.5	3.0	1.846	1.422	23.0
	101.5	2.5	1.843	1.454	21.1
	102.5	1.7	1.842	1.498	18.7
	103.5	2.0	1.829	1.477	19.2
	105.5	4.0	1.759	1.329	24.4
	106.5	4.3	1.716	1.270	26.0
	107.5	4.3	1.722	1.290	25.1
	108.5	4.0	1.731	1.305	24.6
	109.5	4.3	1.652	1.207	26.9
	110.5	3.3	1.794	1.377	23.2
	111.5	3.4	1.684	1.270	24.6
	112.5	5.9	1.574	1.090	30.7
	113.5	5.7	1.599	1.120	30.0
	114.5	3.5	1.716	1.302	24.1
	116.5	4.6	1.646	1.167	29.1
	117.5	2.8	1.654	1.291	21.9
	118.5	2.8	1.689	1.304	22.8
	119.5	3.1	1.877	1.442	23.2
	120.5	3.5	1.773	1.338	24.5

Table B7. LOI data for Lake Litchfield core 1.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
LL-16-C1	122.5	2.3	1.882	1.500	20.3
	123.5	2.3	1.773	1.456	17.9
	124.5	2.1	1.863	1.531	17.8
	125.5	2.2	1.945	1.598	17.8
	126.5	2.3	1.584	1.283	19.0
	127.5	2.5	1.734	1.384	20.2
	128.5	4.3	1.603	1.180	26.4
	129.5	2.2	1.776	1.424	19.8
	131.5	2.2	1.656	1.401	15.4
	132.5	2.1	1.640	1.369	16.5
	133.5	2.4	1.707	1.391	18.5
	134.5	2.2	1.812	1.470	18.9
	135.5	2.2	1.759	1.437	18.3
	136.5	2.6	1.877	1.474	21.5
	137.5	1.9	1.630	1.380	15.3
	138.5	1.7	1.880	1.614	14.1

Table B8. Whole-core susceptibility (κ) for Lake Litchfield core 1.

Core-Drive	Depth in Core	Corrected Depth	κ	Edited κ
	(cm)	in Core (cm)	(10^{-5} Relative SI Units)	(10^{-5} Relative SI Units)
LL-16-C1	0	-	4.3	-
	3	3	13.6	13.6
	6	6	16.2	16.2
	9	9	16.6	16.6
	12	12	17.5	17.5
	15	15	13.6	13.6
	18	18	12.0	12.0
	21	21	11.4	11.4
	24	24	11.4	11.4
	27	27	14.3	14.3
	30	30	16.0	16.0
	33	33	16.0	16.0
	36	36	20.8	20.8
	39	39	24.5	24.5
	42	42	18.8	18.8
	45	45	12.1	12.1
	48	48	12.5	12.5
	51	51	15.2	15.2
	54	54	19.4	19.4
	57	57	23.4	23.4
	60	60	17.1	17.1
	63	63	12.7	12.7
	66	66	12.0	12.0
	69	69	14.4	14.4
	72	72	14.4	14.4
	75	75	14.7	14.7
	78	78	25.2	25.2
	81	81	30.4	30.4
	84	84	30.0	30.0
	87	87	29.5	29.5
	90	90	28.6	28.6
	93	93	28.4	28.4
	96	96	31.3	31.3
	99	99	30.8	30.8
	102	102	35.7	35.7
	105	105	40.2	40.2
	108	108	32.1	32.1
	111	111	28.4	28.4

Table B8. (Cont) Whole-core susceptibility (κ) for Lake Litchfield core 1.

Core-Drive	Depth in Core	Corrected Depth in Core	κ	Edited κ
	(cm)	(cm)	(10^{-5} Relative SI Units)	(10^{-5} Relative SI Units)
LL-16-C1	114	114	25.0	25.0
	117	117	27.2	27.2
	120	120	33.1	33.1
	123	123	38.4	38.4
	126	126	43.4	43.4
	129	129	44.1	44.1
	132	132	46.7	46.7
	135	135	46.4	46.4
	138	138	42.2	42.2
	141	-	23.4	-

Table B9. LOI data for Lake Litchfield core 2.

Core-Drive	Depth (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water Content (%)
LL-16-C2	1.5	0.5	1.658	1.361	17.9
	2.5	0.5	1.739	1.404	19.3
	3.5	0.5	1.651	1.345	18.5
	4.5	0.4	1.553	1.251	19.4
	5.5	0.8	1.632	1.327	18.7
	6.5	1.0	1.553	1.241	20.1
	7.5	0.9	1.739	1.384	20.4
	8.5	1.7	1.641	1.297	21.0
	9.5	1.7	1.669	1.317	21.1
	10.5	1.5	1.658	1.370	17.4
	11.5	4.7	1.338	0.913	31.8
	12.5	1.1	1.588	1.303	17.9
	13.5	0.8	1.448	1.184	18.2
	14.5	1.0	1.607	1.298	19.2
	15.5	0.8	1.729	1.390	19.6
	16.5	0.5	1.680	1.350	19.6
	17.5	0.5	1.764	1.433	18.8
	18.5	0.4	1.687	1.374	18.6
	19.5	0.9	1.698	1.386	18.4
	20.5	0.8	1.601	1.325	17.2
	21.5	0.9	1.526	1.265	17.1
	22.5	0.9	1.314	1.121	14.7
	23.5	0.7	1.699	1.379	18.8
	24.5	0.8	1.700	1.369	19.5
	25.5	5.1	1.003	0.730	27.2
	26.5	4.4	1.357	0.960	29.3
	30.5	1.1	1.644	1.331	19.0
	31.5	1.4	1.577	1.255	20.4
	32.5	1.9	1.516	1.241	18.1
	34.5	1.5	1.549	1.257	18.9
	35.5	0.8	1.526	1.251	18.0
	36.5	1.0	1.610	1.306	18.9
	37.5	1.3	1.544	1.254	18.8
	38.5	0.5	1.660	1.341	19.2
	39.5	0.7	1.676	1.356	19.1
	40.5	0.8	1.630	1.316	19.3
	41.5	0.8	1.641	1.317	19.7
	42.5	1.4	1.653	1.328	19.7
	43.5	1.5	1.678	1.371	18.3
	44.5	1.3	1.596	1.272	20.3
	45.5	1.1	1.639	1.311	20.0
	46.5	1.1	1.653	1.335	19.2

Table B9. (Cont) LOI data for Lake Litchfield core 2.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
LL-16-C2	47.5	0.8	1.683	1.349	19.8
	48.5	1.3	1.573	1.275	18.9
	49.5	1.4	1.584	1.269	19.9
	50.5	1.0	1.586	1.291	18.6
	51.5	1.0	1.425	1.182	17.1
	52.5	1.0	1.630	1.337	18.0
	53.5	0.7	1.606	1.314	18.2
	54.5	1.1	1.653	1.330	19.5
	55.5	1.7	1.512	1.264	16.4
	56.5	1.0	1.550	1.263	18.5
	57.5	0.9	1.548	1.265	18.3
	58.5	0.9	1.620	1.321	18.5
	59.5	1.5	1.632	1.296	20.6
	60.5	0.8	1.489	1.215	18.4
	61.5	1.5	1.634	1.299	20.5
	62.5	1.5	1.539	1.247	19.0
	63.5	1.1	1.271	1.035	18.6
	64.5	0.9	1.730	1.391	19.6
	65.5	0.9	1.704	1.380	19.0
	66.5	0.9	1.569	1.231	21.5
	67.5	1.3	1.658	1.322	20.3
	68.5	1.2	1.655	1.293	21.9
	69.5	2.0	1.695	1.297	23.5
	70.5	2.4	1.597	1.185	25.8
	71.5	2.9	1.337	0.986	26.3
	72.5	6.3	1.564	1.045	33.2
	73.5	3.7	1.518	1.101	27.5
	74.5	1.6	1.679	1.313	21.8
	75.5	1.0	1.697	1.364	19.6
	76.5	1.3	1.577	1.271	19.4
	77.5	0.9	1.667	1.338	19.7
	78.5	1.1	1.771	1.392	21.4
	80.5	1.5	1.287	1.015	21.1
	81.5	1.5	1.707	1.372	19.6
	82.5	1.9	1.513	1.220	19.4
	83.5	1.9	1.510	1.233	18.3
	84.5	2.0	1.614	1.288	20.2
	85.5	1.8	1.332	1.089	18.2
	86.5	1.8	1.298	1.074	17.3
	87.5	1.9	1.538	1.223	20.5
	88.5	1.9	1.511	1.271	15.9

Table B10. Whole-core susceptibility (κ) for Lake Litchfield core 2.

Core-Drive	Depth in Core (cm)	Corrected Depth in Core (cm)	κ (10^{-5} Relative SI Units)	Edited κ (10^{-5} Relative SI Units)
LL-16-C2	0	-	4.0	-
	3	3	23.2	23.2
	6	6	27.0	27.0
	9	9	14.4	14.4
	12	12	14.7	14.7
	15	15	20.7	20.7
	18	18	42.3	42.3
	21	21	40.6	40.6
	24	24	26.0	26.0
	27	27	16.7	16.7
	30	30	10.7	10.7
	33	33	12.3	12.3
	36	36	11.9	11.9
	39	39	9.2	9.2
	42	42	8.1	8.1
	45	45	9.0	9.0
	48	48	10.3	10.3
	51	51	11.9	11.9
	54	54	16.8	16.8
	57	57	13.4	13.4
	60	60	12.5	12.5
	63	63	11.8	11.8
	66	66	12.7	12.7
	69	69	12.2	12.2
	72	72	11.9	11.9
	75	75	9.4	9.4
	78	78	10.3	10.3
	81	81	10.6	10.6
	84	84	13.7	13.7
	87	87	13.8	13.8
	90	90	9.0	9.0
	93	-	1.5	-

Table B11. LOI data for Lake Litchfield core 3.

Core-Drive	Depth (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water (%)
LL-16-C3	0.5	1.0	1.730	1.371	20.8
	1.5	0.9	1.677	1.370	18.3
	2.5	1.3	1.631	1.337	18.0
	3.5	1.0	1.678	1.329	20.8
	4.5	1.0	1.635	1.291	21.0
	5.5	1.2	1.634	1.288	21.2
	6.5	0.9	1.617	1.270	21.5
	7.5	0.7	1.721	1.362	20.9
	8.5	0.5	1.669	1.333	20.1
	9.5	0.5	1.811	1.441	20.4
	10.5	0.5	1.587	1.276	19.6
	11.5	0.7	1.699	1.364	19.7
	12.5	0.6	1.634	1.326	18.8
	13.5	0.7	1.418	1.171	17.4
	14.5	0.9	1.637	1.349	17.6
	15.5	0.9	1.560	1.291	17.2
	16.5	1.1	1.590	1.307	17.8
	17.5	0.7	1.594	1.297	18.6
	18.5	1.2	1.432	1.230	14.1
	19.5	0.9	1.514	1.271	16.1
	20.5	0.7	1.535	1.269	17.3
	21.5	0.9	1.655	1.362	17.7
	22.5	1.1	1.487	1.233	17.1
	23.5	0.9	1.698	1.386	18.4
	24.5	0.7	1.641	1.322	19.4
	25.5	1.5	1.722	1.346	21.8
	27.5	0.5	1.721	1.367	20.6
	28.5	0.7	1.688	1.342	20.5
	29.5	0.5	1.819	1.446	20.5
	30.5	0.4	1.757	1.405	20.0
	31.5	0.5	1.640	1.307	20.3
	32.5	0.5	1.539	1.262	18.0
	33.5	0.4	1.669	1.337	19.9
	34.5	0.5	1.726	1.390	19.5
	35.5	0.6	1.768	1.428	19.2
	36.5	0.6	1.784	1.441	19.2
	37.5	0.7	1.672	1.355	19.0
	38.5	2.0	1.420	1.092	23.1
	39.5	1.7	1.588	1.261	20.6
	40.5	2.7	1.494	1.150	23.0

Table B11. (Cont) LOI data for Lake Litchfield core 3.

Core-Drive	Depth (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water (%)
LL-16-C3	42.5	0.7	1.635	1.338	18.2
	43.5	0.8	1.448	1.198	17.3
	44.5	0.9	1.597	1.339	16.2
	45.5	0.8	1.471	1.198	18.6
	46.5	0.8	1.731	1.390	19.7
	47.5	0.9	1.670	1.315	21.3
	48.5	0.8	1.662	1.324	20.3
	49.5	0.6	1.787	1.432	19.9
	50.5	0.7	1.698	1.360	19.9
	51.5	0.6	1.763	1.413	19.9
	52.5	0.4	1.714	1.365	20.4
	53.5	0.4	1.763	1.418	19.6
	54.5	0.6	1.748	1.427	18.4
	55.5	0.7	1.660	1.348	18.8
	56.5	1.4	1.678	1.358	19.1
	58.5	4.0	1.519	1.160	23.6

Table B12. Whole-core susceptibility (κ) for Lake Litchfield core 3.

Core-Drive	Depth in Core (cm)	Corrected Depth in Core (cm)	κ (10^{-5} Relative SI Units)	Edited κ (10^{-5} Relative SI Units)
LL-16-C3	3	-	10.7	-
	6	6	9.4	9.4
	9	9	8.3	8.3
	12	12	7.9	7.9
	15	15	10.5	10.5
	18	18	12.2	12.2
	21	21	13.4	13.4
	24	24	13.6	13.6
	27	27	14.5	14.5
	30	30	13.4	13.4
	33	33	12.6	12.6
	36	36	10.3	10.3
	39	39	11.8	11.8
	42	42	13.9	13.9
	45	45	14.3	14.3
	48	48	15.3	15.3
	51	51	13.9	13.9
	54	54	13.2	13.2
	57	57	10.8	10.8
	60	-	3.9	-

Table B13. LOI data for Old Mill Pond core 2.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
OMP-16-C2	0.5	9.4	1.328	0.608	54.2
	1.5	9.6	1.179	0.542	54.0
	2.5	9.7	1.319	0.589	55.3
	3.5	9.5	1.283	0.582	54.6
	4.5	9.5	1.326	0.602	54.6
	5.5	9.8	1.310	0.589	55.0
	6.5	9.7	1.275	0.579	54.6
	7.5	9.7	1.275	0.579	54.6
	8.5	10.0	1.374	0.638	53.6
	9.5	9.2	1.391	0.642	53.8
	10.5	8.9	1.319	0.629	52.3
	11.5	8.7	1.399	0.681	51.3
	12.5	8.5	1.433	0.715	50.1
	13.5	8.5	1.450	0.71	51.0
	14.5	8.4	1.391	0.694	50.1
	15.5	8.4	1.428	0.711	50.2
	16.5	8.3	1.352	0.678	49.9
	17.5	8.2	1.147	0.571	50.2
	18.5	7.8	1.459	0.755	48.3
	19.5	7.7	1.449	0.763	47.3
	20.5	7.7	1.336	0.692	48.2
	21.5	7.2	1.464	0.801	45.3
	22.5	6.9	1.360	0.734	46.0
	23.5	6.8	1.360	0.734	46.0
	24.5	7.0	1.372	0.741	46.0
	25.5	6.8	1.504	0.822	45.3
	26.5	6.7	1.495	0.809	45.9
	27.5	6.5	1.447	0.794	45.1
	28.5	6.6	1.484	0.819	44.8
	29.5	6.5	1.478	0.816	44.8
	30.5	6.6	1.490	0.816	45.2
	31.5	6.6	1.485	0.807	45.7
	32.5	6.6	1.462	0.805	44.9
	33.5	6.7	1.482	0.819	44.7
	34.5	7.1	1.460	0.82	43.8
	35.5	7.2	1.471	0.822	44.1
	36.5	7.4	1.459	0.802	45.0
	37.5	7.2	1.572	0.873	44.5
	38.5	7.4	1.461	0.794	45.7
	39.5	7.5	1.428	0.786	45.0

Table B13. (Cont) LOI data for Old Mill Pond core 2.

Core-Drive	Depth (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water Content (%)
OMP-16-C2	40.5	7.5	1.417	0.762	46.2
	41.5	7.2	1.404	0.763	45.7
	42.5	7.0	1.476	0.810	45.1
	43.5	7.0	1.504	0.825	45.1
	44.5	7.0	1.465	0.817	44.2
	45.5	7.2	1.388	0.777	44.0
	46.5	7.0	1.458	0.818	43.9
	47.5	6.9	1.508	0.837	44.5
	48.5	6.8	1.479	0.847	42.7
	49.5	6.8	1.502	0.840	44.1
	50.5	6.3	1.442	0.811	43.8
	51.5	6.2	1.497	0.833	44.4
	52.5	6.3	1.487	0.828	44.3
	53.5	6.5	1.446	0.801	44.6
	54.5	6.2	1.484	0.801	46.0
	55.5	6.4	1.469	0.807	45.1
	56.5	6.5	1.492	0.834	44.1
	57.5	6.6	1.465	0.808	44.8
	58.5	6.5	1.509	0.827	45.2
	59.5	7.1	1.471	0.786	46.6
	60.5	7.1	1.415	0.757	46.5
	61.5	7.5	1.374	0.711	48.3
	62.5	7.1	1.464	0.765	47.7
	63.5	7.0	1.419	0.752	47.0
	64.5	6.8	1.465	0.805	45.1
	65.5	6.7	1.495	0.836	44.1
	66.5	6.8	1.476	0.823	44.2
	67.5	7.1	1.507	0.850	43.6
	68.5	7.1	1.445	0.773	46.5
	69.5	6.9	1.500	0.826	44.9
	70.5	7.1	1.469	0.818	44.3
	71.5	7.4	1.474	0.815	44.7
	72.5	7.5	1.402	0.761	45.7
	73.5	7.3	1.489	0.832	44.1
	74.5	7.4	1.491	0.848	43.1
	75.5	7.1	1.540	0.868	43.6
	76.5	7.7	1.474	0.822	44.2
	77.5	7.4	1.492	0.837	43.9
	78.5	7.7	1.432	0.797	44.3

Table B13. (Cont) LOI data for Old Mill Pond core 2.

Core-Drive	Depth (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water Content (%)
OMP-16-C2	79.5	8.4	1.413	0.758	46.4
	80.5	8.4	1.515	0.836	44.8
	81.5	8.5	1.406	0.703	50.0
	82.5	8.6	1.400	0.709	49.4
	83.5	8.6	1.455	0.759	47.8
	84.5	8.7	1.438	0.767	46.7
	85.5	8.8	1.440	0.770	46.5
	86.5	8.6	1.448	0.778	46.3
	87.5	8.5	1.474	0.764	48.2
	88.5	8.7	1.464	0.805	45.0
	89.5	8.8	1.447	0.800	44.7
	90.5	8.6	1.452	0.777	46.5
	91.5	9.0	1.429	0.776	45.7
	92.5	8.9	1.371	0.732	46.6
	93.5	8.5	1.373	0.719	47.6
	94.5	8.1	1.459	0.787	46.1
	95.5	8.3	1.310	0.662	49.5
	96.5	7.7	1.326	0.691	47.9
	97.5	7.3	1.340	0.735	45.1
	98.5	6.9	1.378	0.795	42.3
	99.5	7.3	1.445	0.813	43.7
	100.5	7.5	1.408	0.776	44.9
	101.5	7.3	1.453	0.827	43.1
	102.5	8.0	1.442	0.766	46.9
	103.5	8.0	1.457	0.776	46.7
	104.5	7.8	1.462	0.793	45.8
	105.5	8.7	1.394	0.713	48.9
	106.5	9.1	1.342	0.661	50.7
	107.5	8.6	1.393	0.701	49.7
	108.5	8.6	1.400	0.689	50.8
	109.5	9.3	1.357	0.605	55.4
	110.5	9.5	1.311	0.570	56.5
	111.5	9.3	1.358	0.624	54.1
	112.5	8.9	1.341	0.638	52.4
	113.5	9.1	1.350	0.637	52.8
	114.5	8.1	1.396	0.695	50.2
	115.5	7.6	1.409	0.719	49.0
	116.5	7.2	1.459	0.789	45.9
	117.5	7.0	1.498	0.854	43.0

Table B13. (Cont) LOI data for Old Mill Pond core 2.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
OMP-16-C2	118.5	7.2	1.512	0.857	43.3
	119.5	7.3	1.374	0.737	46.4
	120.5	7.0	1.441	0.814	43.5
	121.5	7.0	1.476	0.823	44.2
	122.5	7.1	1.414	0.775	45.2
	123.5	7.2	1.449	0.808	44.2
	124.5	5.5	1.566	0.965	38.4
	125.5	9.9	1.351	0.604	55.3
	126.5	11.0	1.244	0.489	60.7
	127.5	11.0	1.200	0.428	64.3
	128.5	10.7	1.243	0.542	56.4
	129.5	11.5	1.276	0.480	62.4
	130.5	11.5	1.270	0.495	61.0
	131.5	10.0	1.427	0.697	51.2
	132.5	10.4	1.358	0.628	53.8
	133.5	10.6	1.374	0.624	54.6
	134.5	10.2	1.386	0.650	53.1
	135.5	10.2	1.380	0.659	52.2
	136.5	10.6	1.351	0.625	53.7
	137.5	9.8	1.350	0.625	53.7
	138.5	10.2	1.311	0.615	53.1
	139.5	9.5	1.337	0.623	53.4
	140.5	8.2	1.365	0.670	50.9
	141.5	6.1	1.545	0.977	36.8
	142.5	9.4	1.343	0.631	53.0
	143.5	9.0	1.514	0.862	43.1
	144.5	10.8	1.320	0.713	46.0
	145.5	8.7	1.477	0.855	42.1
	146.5	9.9	1.367	0.694	49.2
	147.5	10.1	1.308	0.631	51.8
	148.5	9.8	1.387	0.660	52.4
	149.5	11.3	1.471	0.787	46.5
	150.5	9.1	1.584	1.040	34.3
	151.5	8.4	1.672	1.125	32.7
	152.5	12.0	1.511	0.886	41.4
	153.5	11.4	1.496	0.878	41.3

Table B14. Whole-core susceptibility (κ) for Old Mill Pond core 2.

Core-Drive	Depth in Core (cm)	Corrected Depth in Core (cm)	κ (10^{-5} Relative SI Units)	Edited κ (10^{-5} Relative SI Units)
OMP-16-C2	0	-	8.7	-
	3	3	13.3	13.3
	6	6	15.1	15.1
	9	9	16.7	16.7
	12	12	18.0	18.0
	15	15	18.4	18.4
	18	18	18.5	18.5
	21	21	18.4	18.4
	24	24	18.6	18.6
	27	27	18.7	18.7
	30	30	18.8	18.8
	33	33	20.1	20.1
	36	36	21.5	21.5
	39	39	21.6	21.6
	42	42	21.4	21.4
	45	45	20.2	20.2
	48	48	21.4	21.4
	51	51	18.7	18.7
	54	54	19.1	19.1
	57	57	17.1	17.1
	60	60	16.9	16.9
	63	63	17.9	17.9
	66	66	18.7	18.7
	69	69	19.3	19.3
	72	72	20.4	20.4
	75	75	21.1	21.1
	78	78	21.9	21.9
	81	81	23.0	23.0
	84	84	23.8	23.8
	87	87	24.7	24.7
	90	90	25.7	25.7
	93	93	22.8	22.8
	96	96	21.3	21.3
	99	99	22.1	22.1
	102	102	22.9	22.9
	105	105	22.1	22.1
	108	108	19.5	19.5
	111	111	18.0	18.0
	114	114	18.7	18.7

Table B15. LOI data for Old Mill Pond core 3.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
OMP-16-C3	0.5	10.5	1.211	0.516	57.4
	1.5	10.0	1.274	0.542	57.5
	2.5	10.0	1.133	0.482	57.5
	3.5	9.9	1.116	0.474	57.5
	4.5	8.3	1.368	0.396	71.1
	5.5	9.6	1.152	0.501	56.5
	6.5	9.5	1.096	0.483	55.9
	7.5	10.0	1.252	0.568	54.6
	8.5	9.7	1.354	0.620	54.2
	9.5	9.3	1.332	0.616	53.8
	10.5	9.1	0.949	0.453	52.3
	11.5	9.2	1.257	0.597	52.5
	12.5	8.9	1.268	0.621	51.0
	13.5	8.8	1.388	0.678	51.2
	14.5	8.7	1.309	0.663	49.4
	15.5	8.5	1.309	0.662	49.4
	16.5	8.3	1.205	0.618	48.7
	17.5	8.2	1.348	0.685	49.2
	18.5	8.3	1.390	0.715	48.6
	19.5	7.9	1.316	0.695	47.2
	20.5	7.8	1.413	0.756	46.5
	21.5	7.6	1.281	0.675	47.3
	22.5	7.5	1.077	0.574	46.7
	23.5	7.3	1.223	0.659	46.1
	24.5	7.2	1.385	0.734	47.0
	25.5	7.2	1.260	0.681	46.0
	26.5	7.4	1.175	0.653	44.4
	27.5	7.3	1.467	0.818	44.2
	28.5	7.3	1.369	0.753	45.0
	29.5	7.2	1.392	0.769	44.8
	30.5	6.9	1.380	0.765	44.6
	31.5	6.8	1.428	0.803	43.8
	32.5	7.3	1.382	0.767	44.5
	33.5	7.3	1.457	0.822	43.6
	34.5	7.5	1.432	0.796	44.4
	35.5	7.9	1.371	0.747	45.5
	36.5	8.0	1.480	0.822	44.5
	37.5	7.9	1.406	0.761	45.9
	38.5	7.8	1.453	0.799	45.0
	39.5	7.5	1.434	0.795	44.6

Table B15. (Cont) LOI data for Old Mill Pond core 3.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
OMP-16-C3	40.5	7.4	1.432	0.797	44.3
	41.5	7.2	1.455	0.814	44.1
	42.5	7.4	1.471	0.813	44.7
	43.5	7.3	1.421	0.796	44.0
	44.5	7.3	1.517	0.854	43.7
	45.5	7.4	1.433	0.800	44.2
	46.5	7.0	1.457	0.826	43.3
	47.5	7.0	1.416	0.802	43.4
	48.5	6.6	1.410	0.791	43.9
	49.5	6.5	1.404	0.785	44.1
	50.5	6.4	1.442	0.812	43.7
	51.5	6.7	1.441	0.807	44.0
	52.5	6.7	1.343	0.743	44.7
	53.5	6.7	1.392	0.765	45.0
	54.5	7.3	1.320	0.669	49.3
	55.5	7.3	1.303	0.668	48.7
	56.5	7.2	1.351	0.718	46.9
	57.5	7.3	1.388	0.724	47.8
	58.5	7.3	1.379	0.711	48.4
	59.5	7.0	1.345	0.698	48.1
	60.5	7.3	1.417	0.763	46.2
	61.5	7.0	1.406	0.790	43.8
	62.5	6.9	1.531	0.875	42.8
	63.5	6.8	1.426	0.806	43.5
	64.5	7.2	1.446	0.803	44.5
	65.5	7.0	1.390	0.803	42.2
	66.5	7.0	1.513	0.885	41.5
	67.5	7.3	1.418	0.805	43.2
	68.5	7.6	1.380	0.772	44.1
	69.5	7.6	1.467	0.819	44.2
	70.5	7.5	1.361	0.772	43.3
	71.5	7.6	1.375	0.779	43.3
	72.5	7.4	1.504	0.849	43.6
	73.5	7.4	1.428	0.793	44.5
	74.5	7.4	1.108	0.620	44.0
	75.5	8.4	1.407	0.739	47.5
	76.5	8.6	1.381	0.759	45.0
	77.5	8.7	1.450	0.796	45.1
	78.5	8.8	1.393	0.702	49.6

Table B15. (Cont) LOI data for Old Mill Pond core 3.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
OMP-16-C3	79.5	9.0	1.403	0.709	49.5
	80.5	8.6	1.393	0.732	47.5
	81.5	8.8	1.425	0.759	46.7
	82.5	8.7	1.403	0.743	47.0
	83.5	8.6	1.417	0.730	48.5
	84.5	9.0	1.482	0.836	43.6
	85.5	9.4	1.411	0.765	45.8
	86.5	9.4	1.319	0.650	50.7
	87.5	9.0	1.432	0.767	46.4
	88.5	8.3	1.476	0.810	45.1
	89.5	8.7	1.420	0.782	44.9
	90.5	8.7	1.464	0.804	45.1
	91.5	8.4	1.347	0.666	50.6
	92.5	7.8	1.480	0.778	47.4
	93.5	7.7	1.499	0.834	44.4
	94.5	7.5	1.503	0.849	43.5
	95.5	7.6	1.469	0.837	43.0
	96.5	7.9	1.435	0.811	43.5
	97.5	7.8	1.474	0.832	43.6
	98.5	6.8	1.560	0.930	40.4
	99.5	8.1	1.441	0.780	45.9
	100.5	8.4	1.428	0.776	45.7
	101.5	9.1	1.381	0.723	47.6
	102.5	8.9	1.421	0.730	48.6
	103.5	10.8	1.308	0.566	56.7
	104.5	10.7	1.213	0.484	60.1
	105.5	10.1	1.279	0.542	57.6
	106.5	10.4	1.273	0.521	59.1
	107.5	9.3	1.305	0.593	54.6
	108.5	9.5	1.347	0.631	53.2
	109.5	9.9	1.240	0.535	56.9
	110.5	10.8	1.303	0.539	58.6
	111.5	8.4	1.340	0.655	51.1
	112.5	8.3	1.399	0.700	50.0
	113.5	7.8	1.412	0.731	48.2
	114.5	7.1	1.505	0.865	42.5
	115.5	6.8	1.377	0.764	44.5

Table B15. (Cont) LOI data for Old Mill Pond core 3.

Core-Drive	Depth (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water Content (%)
OMP-16-C3	116.5	7.2	1.479	0.843	43.0
	117.5	7.2	1.479	0.831	43.8
	118.5	7.6	1.511	0.828	45.2
	119.5	7.2	1.482	0.801	46.0
	120.5	7.3	1.494	0.853	42.9
	121.5	7.3	1.520	0.876	42.4
	122.5	9.6	1.288	0.607	52.9
	123.5	11.2	1.246	0.516	58.6
	124.5	11.3	1.202	0.461	61.6
	125.5	11.1	1.151	0.433	62.4
	126.5	10.9	1.309	0.598	54.3
	127.5	10.2	1.315	0.598	54.5
	128.5	9.9	1.425	0.739	48.1
	129.5	10.3	1.350	0.604	55.3
	130.5	10.0	1.352	0.631	53.3
	131.5	10.0	1.356	0.641	52.7
	132.5	10.5	1.365	0.666	51.2
	133.5	10.3	1.349	0.629	53.4
	134.5	10.2	1.302	0.566	56.5
	135.5	9.8	1.306	0.599	54.1
	136.5	9.1	1.384	0.715	48.3
	137.5	9.0	1.359	0.654	51.9
	138.5	7.1	1.613	0.970	39.9
	139.5	9.4	1.408	0.790	43.9
	140.5	10.5	1.395	0.730	47.7
	141.5	11.3	1.429	0.820	42.6
	142.5	11.7	1.475	0.925	37.3
	143.5	11.8	1.485	0.932	37.2
	144.5	12.1	1.573	0.977	37.9
	145.5	12.9	1.472	0.867	41.1
	146.5	10.0	1.588	1.026	35.4
	147.5	10.3	1.554	0.982	36.8
	148.5	13.1	1.412	0.807	42.8
	149.5	12.5	1.465	0.849	42.0
	150.5	11.3	1.500	0.886	40.9
	151.5	11.3	1.462	0.861	41.1
	152.5	10.4	1.481	0.886	40.2
	153.5	11.0	1.485	0.854	42.5
	154.5	9.3	1.489	0.935	37.2

Table B15. (Cont) LOI data for Old Mill Pond core 3.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
OMP-16-C3	155.5	9.6	1.421	0.856	39.8
	156.5	9.5	1.556	0.930	40.2
	157.5	9.0	1.628	1.044	35.9
	158.5	9.9	1.515	0.938	38.1
	159.5	10.2	1.497	0.896	40.1
	160.5	9.4	1.580	0.988	37.5
	161.5	11.1	1.276	0.792	37.9
	162.5	11.0	1.524	0.916	39.9
	163.5	11.7	1.532	0.933	39.1
	164.5	10.3	1.571	0.979	37.7
	165.5	11.5	1.489	0.906	39.2

Table B16. Whole-core susceptibility (κ) for Old Mill Pond core 3.

Core-Drive	Depth in Core (cm)	Corrected Depth in Core (cm)	κ (10^{-5} Relative SI Units)	Edited κ (10^{-5} Relative SI Units)
OMP-16-C3	0	-	8.4	-
	3	3	12.6	12.6
	6	6	13.9	13.9
	9	9	14.6	14.6
	12	12	15.6	15.6
	15	15	15.9	15.9
	18	18	16.2	16.2
	21	21	16.1	16.1
	24	24	16.0	16.0
	27	27	16.7	16.7
	30	30	17.8	17.8
	33	33	18.8	18.8
	36	36	19.5	19.5
	39	39	18.9	18.9
	42	42	17.9	17.9
	45	45	17.6	17.6
	48	48	16.5	16.5
	51	51	15.4	15.4
	54	54	14.9	14.9
	57	57	15.0	15.0
	60	60	16.0	16.0
	63	63	17.2	17.2
	66	66	18.2	18.2
	69	69	18.6	18.6
	72	72	18.9	18.9
	75	75	19.1	19.1
	78	78	20.7	20.7
	81	81	21.3	21.3
	84	84	22.2	22.2
	87	87	21.0	21.0
	90	90	20.6	20.6
	93	93	20.3	20.3
	96	96	21.4	21.4
	99	99	21.3	21.3
	102	102	18.2	18.2
	105	105	14.5	14.5
	108	108	15.3	15.3

Table B16. (Cont) Whole-core susceptibility (κ) for Old Mill Pond core 3.

Core-Drive	Depth in Core (cm)	Corrected Depth in Core (cm)	κ (10^{-5} Relative SI Units)	Edited κ (10^{-5} Relative SI Units)
OMP-16-C3	111	111	16.1	16.1
	114	114	17.4	17.4
	117	117	18.0	18.0
	120	120	17.2	17.2
	123	123	14.3	14.3
	126	126	14	14
	129	129	15.1	15.1
	132	132	15.2	15.2
	135	135	13.9	13.9
	138	138	14.3	14.3
	141	141	16.1	16.1
	144	144	15.7	15.7
	147	147	13.1	13.1
	150	150	11.6	11.6
	153	153	11.4	11.4
	156	156	11.2	11.2
	159	159	10.7	10.7
	162	162	10.4	10.4
	165	-	3.8	-

Table B17. LOI data for Old Mill Pond core 5.

Core-Drive	Depth (cm)	Organic Matter (%)	Wet bulk Density (g/cm ³)	Dry Bulk Density (g/cm ³)	Water Content (%)
OMP-16-C5	0.5	11.4	0.969	0.431	55.5
	1.5	11.0	1.251	0.554	55.7
	2.5	10.9	1.127	0.512	54.6
	3.5	11.1	1.294	0.552	57.3
	4.5	10.8	1.283	0.583	54.6
	5.5	10.9	1.188	0.531	55.3
	6.5	11.1	1.195	0.513	57.1
	7.5	11.5	1.343	0.602	55.2
	8.5	10.6	1.213	0.540	55.5
	9.5	10.2	1.194	0.538	54.9
	10.5	9.7	1.275	0.610	52.2
	11.5	9.8	1.271	0.599	52.9
	12.5	9.6	1.423	0.707	50.3
	13.5	9.6	1.197	0.604	49.5
	14.5	9.1	1.352	0.671	50.4
	15.5	9.5	1.365	0.662	51.5
	16.5	9.2	1.179	0.599	49.2
	17.5	8.9	1.377	0.718	47.9
	18.5	8.9	1.515	0.798	47.3
	19.5	8.1	1.456	0.777	46.6
	20.5	8.1	1.455	0.781	46.3
	21.5	7.8	1.436	0.785	45.3
	22.5	8.0	1.436	0.802	44.2
	23.5	8.8	1.409	0.748	46.9
	24.5	7.2	1.431	0.804	43.8
	25.5	7.3	1.512	0.865	42.8
	26.5	7.3	1.425	0.821	42.4
	27.5	7.2	1.468	0.850	42.1
	28.5	7.4	1.386	0.799	42.4
	29.5	7.1	1.465	0.844	42.4
	30.5	6.9	1.567	0.878	44.0
	31.5	7.0	1.370	0.773	43.6
	32.5	6.8	1.494	0.833	44.2
	33.5	6.8	1.470	0.814	44.6
	34.5	6.7	1.466	0.806	45.0
	35.5	7.0	1.479	0.833	43.7
	36.5	6.8	1.490	0.824	44.7
	37.5	7.1	1.330	0.730	45.1

Table B17. (Cont) LOI data for Old Mill Pond core 5.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
OMP-16-C5	38.5	7.2	1.335	0.707	47.0
	39.5	7.2	1.310	0.704	46.3
	40.5	7.4	1.402	0.745	46.9
	41.5	7.7	1.345	0.692	48.6
	42.5	7.3	1.432	0.765	46.6
	43.5	7.2	1.463	0.796	45.6
	44.5	7.1	1.468	0.819	44.2
	45.5	6.9	1.478	0.836	43.4
	46.5	6.9	1.512	0.858	43.3
	47.5	7.0	1.519	0.869	42.8
	48.5	7.2	1.341	0.766	42.9
	49.5	7.1	1.516	0.876	42.2
	50.5	7.2	1.387	0.797	42.5
	51.5	6.9	1.506	0.878	41.7
	52.5	7.5	1.438	0.769	46.5
	53.5	7.4	1.389	0.796	42.7
	54.5	7.5	1.511	0.853	43.5
	55.5	7.6	1.479	0.826	44.2
	56.5	7.2	1.303	0.727	44.2
	57.5	7.8	1.398	0.709	49.3
	58.5	8.1	1.404	0.745	46.9
	59.5	7.2	1.486	0.852	42.7
	60.5	8.2	1.452	0.772	46.8
	61.5	8.7	1.388	0.710	48.8
	62.5	9.1	1.402	0.724	48.4
	63.5	8.2	1.422	0.758	46.7
	64.5	8.5	1.428	0.774	45.8
	65.5	8.6	1.468	0.807	45.0
	66.5	8.7	1.446	0.824	43.0
	67.5	9.2	1.425	0.729	48.8
	68.5	9.2	1.374	0.673	51.0
	69.5	9.0	1.442	0.770	46.6
	70.5	8.5	1.465	0.762	48.0
	71.5	7.6	1.439	0.803	44.2
	72.5	8.2	1.451	0.797	45.1
	73.5	8.2	1.357	0.758	44.1
	74.5	8.6	1.528	0.841	45.0
	75.5	7.8	1.437	0.747	48.0

Table B17. (Cont) LOI data for Old Mill Pond core 5.

Core-Drive	Depth	Organic Matter	Wet bulk Density	Dry Bulk Density	Water Content
	(cm)	(%)	(g/cm ³)	(g/cm ³)	(%)
OMP-16-C5	76.5	7.4	1.499	0.807	46.2
	77.5	7.3	1.445	0.826	42.8
	78.5	7.1	1.462	0.842	42.4
	79.5	7.0	1.438	0.839	41.7
	80.5	7.0	1.508	0.880	41.6
	81.5	7.2	1.500	0.856	42.9
	82.5	7.1	1.488	0.860	42.2
	83.5	6.8	1.510	0.873	42.2
	84.5	6.9	1.416	0.823	41.9
	85.5	6.7	1.455	0.852	41.4
	86.5	6.6	1.470	0.876	40.4
	87.5	6.6	1.568	0.922	41.2
	88.5	6.8	1.601	0.944	41.0
	89.5	7.1	1.468	0.870	40.7
	90.5	7.2	1.451	0.853	41.2
	91.5	6.8	1.491	0.873	41.4
	92.5	6.6	1.457	0.851	41.6
	93.5	7.1	1.490	0.842	43.5
	94.5	6.2	1.530	0.922	39.7

Table B18. Whole-core susceptibility (κ) for Old Mill Pond core 5.

Core-Drive	Depth in Core (cm)	Corrected Depth in Core (cm)	κ (10^{-5} Relative SI Units)	Edited κ (10^{-5} Relative SI Units)
OMP-16-C5	0	-	5.2	-
	3	3	12.3	12.3
	6	6	14.2	14.2
	9	9	14.8	14.8
	12	12	15.3	15.3
	15	15	16.3	16.3
	18	18	17.2	17.2
	21	21	19.0	19.0
	24	24	19.6	19.6
	27	27	19.9	19.9
	30	30	20.1	20.1
	33	33	18.4	18.4
	36	36	16.3	16.3
	39	39	15.5	15.5
	42	42	15.6	15.6
	45	45	16.5	16.5
	48	48	18.0	18.0
	51	51	18.8	18.8
	54	54	20.3	20.3
	57	57	20.5	20.5
	60	60	19.9	19.9
	63	63	20.9	20.9
	66	66	21.6	21.6
	69	69	20.8	20.8
	72	72	19.5	19.5
	75	75	19.8	19.8
	78	78	18.7	18.7
	81	81	18.9	18.9
	84	84	19.8	19.8
	87	87	19.9	19.9
	90	90	20.3	20.3
	93	93	19.3	19.3
	96	-	12.5	-
	99	-	2.4	-

APPENDIX C

SEDIMENT CORE AND SURFACE SAMPLE MAGNETIC PROPERTIES
FOR LAKE BUTLER, LAKE LITCHFIELD, AND OLD MILL POND

All surface samples and representative down core lithologies were measured for magnetic concentration, grain size, and mineralogy parameters. These parameters include susceptibility (χ), anhysteretic remanent magnetization (ARM), the saturation isothermal remanent magnetization (SIRM), isothermal remanent magnetization (IRM), S-ratio, χ_{ARM}/χ , and SIRM/χ .

Table C1. Magnetic properties for Lake Litchfield surface and core samples.

Sample	Sample Depth (cm)	Sample Wt (kg)	DBD (g/cm ³)	Organic Matter (%)	χ_{f} (10 ⁻⁸ m ³ kg ⁻¹)	χ_{hf} (10 ⁻⁸ m ³ kg ⁻¹)	χ_{fd} (%)
Surface							
LL-G1	1.50	0.0062	0.620	4.7	26.3	25.7	2.15
LL-G2	1.40	0.0065	0.452	4.9	31.9	31.7	0.63
LL-G8	8.50	0.0060	0.350	6.4	17.6	17.4	-
Core							
LL-C1 2cm	2.00	0.0064	1.015	4.7	33.0	32.6	1.21
LL-C1 30cm	30.00	0.0062	0.970	4.6	26.5	25.9	2.26
LL-C1 60cm	60.00	0.0061	0.898	7.1	27.0	26.6	1.48
LL-C1 90cm	90.00	0.0069	1.340	3.2	36.8	36.0	2.17
LL-C1 120cm	120.00	0.0074	1.338	3.5	47.8	47.2	1.26

Table C1. (Cont) Magnetic properties for Lake Litchfield surface and core samples.

Sample	χ_{ARM} ($10^{-6} \text{ m}^3 \text{ kg}^{-1}$)	$\chi_{\text{ARM}_{40\text{mT}}}$ $10^{-6} \text{ m}^3 \text{ kg}^{-1}$	$\text{IRM}_{40\text{mT}}$ ($10^{-6} \text{ Am}^2 \text{ kg}^{-1}$)	SIRM Converted ($10^{-6} \text{ A} \cdot \text{m}^2 \text{ kg}^{-1}$)	bIRM Demag $_{-100\text{mT}}$ Converted ($10^{-6} \text{ A} \cdot \text{m}^2 \text{ kg}^{-1}$)	bIRM Demag $_{-300\text{mT}}$ Converted ($10^{-6} \text{ A} \cdot \text{m}^2 \text{ kg}^{-1}$)
Surface	Surface					
0.972	LL-G1	0.371	685.45	2255.07	-1358.66	-2014.45
0.631	LL-G2	0.199	706.53	2336.38	-1352.76	-2106.56
1.252	LL-G8	0.464	471.94	1983.94	-833.36	-1694.49
Core	Core					
0.988	LL-C1 2cm	0.343	825.16	2361.72	-1591.34	-2150.22
0.987	LL-C1 30cm	0.361	756.96	2107.98	-1471.97	-1859.56
1.572	LL-C1 60cm	0.695	939.18	2780.01	-1925.38	-2550.80
1.114	LL-C1 90cm	0.239	1211.53	3215.76	-2333.37	-2932.81
0.585	LL-C1 120cm	0.167	747.77	1727.47	-1174.15	-1473.55

Table C1. (Cont) Magnetic properties for Lake Litchfield surface and core samples.

Sample	S-ratio	SIRM/ χ (10 ² A/m)	χ_{ARM}/χ
Surface			
LL-G1	0.893	85.74	3.697
LL-G2	0.902	73.24	1.977
LL-G8	0.854	112.72	7.114
Core			
LL-C1 2cm	0.910	71.57	2.993
LL-C1 30cm	0.882	79.55	3.726
LL-C1 60cm	0.918	102.96	5.824
LL-C1 90cm	0.912	87.38	3.027
LL-C1 120cm	0.853	36.14	1.223

Table C2. Magnetic properties for Old Mill Pond surface and core samples.

Sample	Sample Depth (cm)	Sample Wt (kg)	DBD (g/cm ³)	Organic Matter (%)	χ_{lf} ($10^{-8} \text{ m}^3 \text{ kg}^{-1}$)	χ_{hf} ($10^{-8} \text{ m}^3 \text{ kg}^{-1}$)	χ_{fd} (%)
Surface							
OMP-G1	0.27	0.0054	0.323	11.0	46.3	45.2	2.30
OMP-G3	1.00	0.0052	0.344	10.3	50.5	49.4	2.18
OMP-G4	1.33	0.0059	0.383	11.1	104.4	103.1	1.21
OMP-G7	1.00	0.0081	1.531	4.0	112.0	108.8	2.86
OMP-G8	0.40	0.0080	1.260	3.7	106.5	103.4	2.91
OMP-G9	1.40	0.0056	0.363	10.9	70.1	68.5	2.28
OMP-G11	0.40	0.0056	0.327	11.0	71.8	71.0	1.11
OMP-G12	0.46	0.0054	0.335	10.7	42.8	41.5	3.04
Core							
OMP-C3 1cm	1.00	0.0054	0.542	10.0	50.0	48.8	2.40
OMP-C3 20cm	20.00	0.0055	0.756	7.8	45.5	44.0	3.30
OMP-C3 40cm	40.00	0.0059	0.797	7.4	46.9	46.1	1.71
OMP-C3 60cm	60.00	0.0057	0.763	7.3	42.0	40.6	3.33
OMP-C3 80cm	80.00	0.0055	0.732	8.6	59.4	58.1	2.19
OMP-C3 100cm	110.00	0.0055	0.776	8.4	58.5	57.0	2.56
OMP-C3 110cm	110.00	0.0054	0.539	10.8	52.5	51.1	2.67
OMP-C3 120cm	120.00	0.0060	0.853	7.3	41.8	40.1	4.07
OMP-C3 140cm	140.00	0.0057	0.730	10.5	41.8	40.2	3.83
OMP-C3 160cm	160.00	0.0058	0.988	9.4	21.5	21.3	0.93

Table C2. (Cont) Magnetic properties for Old Mill Pond surface and core samples.

Sample	χ_{ARM} ($10^{-6} \text{ m}^3 \text{ kg}^{-1}$)	$\chi_{\text{ARM}_{40\text{mT}}}$ $10^{-6} \text{ m}^3 \text{ kg}^{-1}$	IRM $_{40\text{mT}}$ Converted ($10^{-6} \text{ A m}^2 \text{ kg}^{-1}$)	SIRM Converted ($10^{-6} \text{ A m}^2 \text{ kg}^{-1}$)	bIRM Demag. $_{100\text{mT}}$ Converted ($10^{-6} \text{ A m}^2 \text{ kg}^{-1}$)	bIRM Demag. $_{300}$ Converted ($10^{-6} \text{ A m}^2 \text{ kg}^{-1}$)
Surface						
OMP-G1	2.100	0.745	1876.66	4990.63	-3641.36	-4696.42
OMP-G3	2.434	0.827	2072.85	5494.31	-4055.25	-5144.45
OMP-G4	2.346	0.762	2684.35	6664.03	-4849.15	-6157.16
OMP-G7	2.064	0.518	6589.70	12782.80	-11292.28	-12852.93
OMP-G8	1.526	0.275	5729.12	10045.22	-9213.67	-9817.49
OMP-G9	2.528	0.811	2327.50	6166.38	-4529.86	-5746.67
OMP-G11	1.775	0.539	3120.87	6964.18	-5279.56	-6600.12
OMP-G12	2.380	0.836	1808.33	4837.92	-3525.87	-4521.07
Core						
OMP-C3 1cm	2.336	0.812	2106.05	5443.44	-4097.52	-5124.41
OMP-C3 20cm	2.155	0.737	1894.41	5002.95	-3760.95	-4681.13
OMP-C3 40cm	2.017	0.682	2046.34	5545.83	-4048.81	-5159.82
OMP-C3 60cm	2.040	0.748	1859.06	5148.69	-3806.33	-4789.16
OMP-C3 80cm	3.315	1.200	3240.71	9313.62	6711.31	-8678.77
OMP-C3 100cm	3.186	1.092	3112.90	9148.98	-6571.22	-8489.14
OMP-C3 110cm	4.175	1.446	2926.52	8558.87	-6077.39	-7945.07
OMP-C3 120cm	2.876	0.893	2013.41	5668.67	-4112.38	-5260.01
OMP-C3 140cm	2.913	0.961	2073.92	5596.05	-4046.44	-5241.68
OMP-C3 160cm	1.076	0.298	639.51	1648.66	-1062.35	-1387.59

Table C2. (Cont) Magnetic properties for Old Mill Pond surface and core samples.

Sample	S-ratio	SIRM/ χ (10 ² A/m)	χ_{ARM}/χ
Surface			
OMP-G1	0.941	107.79	4.536
OMP-G3	0.936	108.80	4.819
OMP-G4	0.924	63.83	2.247
OMP-G7	1.005	114.13	1.843
OMP-G8	0.977	94.32	1.433
OMP-G9	0.932	87.97	3.607
OMP-G11	0.948	96.99	2.472
OMP-G12	0.935	113.04	5.561
Core			
OMP-C3 1cm	0.941	108.87	4.672
OMP-C3 20cm	0.936	109.95	4.737
OMP-C3 40cm	0.930	118.25	4.300
OMP-C3 60cm	0.930	122.59	4.858
OMP-C3 80cm	0.932	156.79	5.581
OMP-C3 100cm	0.928	156.39	5.445
OMP-C3 110cm	0.928	163.03	7.952
OMP-C3 120cm	0.928	135.61	6.880
OMP-C3 140cm	0.937	133.88	6.970
OMP-C3 160cm	0.842	76.68	5.006

APPENDIX D

INDIVIDUAL SEDIMENT CORE LITHOLOGY AND SEDIMENT PROPERTIES FOR LAKE BUTLER, LAKE LITCHFIELD, AND OLD MILL POND

Lithology, organic matter content, dry bulk density, and whole-core susceptibility were analyzed on all cores for Lake Butler, Lake Litchfield, and Old Mill Pond.

Figure D1. Detailed lithology description for the Lake Butler delta top core LB-16-C1.

Figure D2. Lithology, whole core susceptibility (κ), organic matter, and dry bulk density for Lake Butler delta top core LB-16-C1. See Figure D1 for lithology description.

Figure D3. Detailed lithology description for Lake Litchfield sediment core LL-16-C3.

Figure D4. Lithology, whole core susceptibility (κ), organic matter, and dry bulk density for Lake Litchfield delta core LL-16-C3. See Figure D3 for lithology description.

Figure D5. Detailed lithology description for Old Mill Pond sediment core OMP-16-C2.

Figure D6. Lithology, whole core susceptibility (κ), organic matter, and dry bulk density for Old Mill Pond sediment core OMP-16-C2. See Figure D5 for lithology description.

APPENDIX E

LAND COVER CHANGE FOR HASKELL RUN, RITCHIE RUN, AND MUD BROOK

Haskell Run, Ritchie Run and Mud Brook watersheds were assessed for land cover change in the year 1985, 1996, 2001, 2006, and 2010 using NOAA's Coastal Change Analysis Program (C-Cap) (Digital Coast, 2016a). The cell sizes for the land cover data was 30 X 30 meters. Impervious land cover values were determined by multiplying a specific coefficient for each land cover class by the area for each site. Land cover class coefficients were calculated using NOAA's Impervious Surface Analysis Tool (ISAT) accounting for high, medium, and low values based on the population density or people per square mile.

Table E1. Total area land cover and area land cover change (m²) of land cover classifications of the Haskell Run watershed (Lake Butler) area for the years 1985, 1996, 2001, 2006, and 2010. The total area of the Haskell Run watershed is 2,881,800 m² (Digital Coast, 2016a).

Land Cover Code	Land Cover Class Name	Total Area (m ²)				Area Change (m ²)					
		1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
2	Developed, High Intensity	1,800	1,800	3,600	3,600	3,600	0	1,800	0	0	1,800
3	Developed, Medium Intensity	32,400	32,400	44,100	44,100	49,500	0	11,700	0	5,400	17,100
4	Developed, Low Intensity	229,500	230,400	243,000	243,900	245,700	900	12,600	900	1,800	16,200
5	Developed, Open Space	27,900	27,900	33,300	33,300	33,300	0	5,400	0	0	5,400
6	Cultivated Crops	27,000	21,600	1,800	1,800	1,800	-5,400	-19,800	0	0	-25,200
7	Pasture/Hay	62,100	62,100	62,100	62,100	62,100	0	0	0	0	0
8	Grassland/Herbaceous	57,600	57,600	45,900	45,900	45,000	0	-11,700	0	-900	-12,600
9	Deciduous Forest	2,213,100	2,221,200	2,221,200	2,220,300	2,206,800	8,100	0	-900	-13,500	-6,300
10	Evergreen Forest	120,600	120,600	120,600	120,600	120,600	0	0	0	0	0
11	Mixed Forest	10,800	10,800	10,800	10,800	10,800	0	0	0	0	0
12	Scrub/Shrub	33,300	30,600	30,600	30,600	37,800	-2,700	0	0	7,200	4,500
13	Palustrine Forested Wetland	15,300	15,300	15,300	15,300	15,300	0	0	0	0	0
14	Palustrine Scrub/Shrub Wetland	900	900	900	900	900	0	0	0	0	0
15	Palustrine Emergent Wetland	4,500	4,500	4,500	4,500	4,500	0	0	0	0	0
20	Bare Land	4,500	3,600	3,600	3,600	3,600	-900	0	0	0	-900
21	Open Water	40,500	40,500	40,500	40,500	40,500	0	0	0	0	0
<u>Reclassified Groups</u>											
2,3,4,5,20 6 & 7	Developed	296,100	296,100	327,600	328,500	335,700	0	31,500	900	7,200	39,600
	Farmland	89,100	83,700	63,900	63,900	63,900	-5,400	-19,800	0	0	-25,200
8,9,10,11,12,13,14,15	Undeveloped	2,456,100	2,461,500	2,449,800	2,448,900	2,441,700	5,400	-11,700	-900	-7,200	-14,400
	Open Water	40,500	40,500	40,500	40,500	40,500	0	0	0	0	0
21	Total	2,881,800	2,881,800	2,881,800	2,881,800	2,881,800	0	0	0	0	0

Table E2. Percent land cover and percent land cover change of land cover classifications of the Haskell Run watershed (Lake Butler) area for the years 1985, 1996, 2001, 2006, and 2010. The total area of the Haskell Run watershed is 2,881,800 m² (Digital Coast, 2016a).

Land Cover Code	Land Cover Class Name	Percent Total (%)					Percent Change (%)				
		1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
2	Developed, High Intensity	0.06	0.06	0.12	0.12	0.12	0.00	0.06	0.00	0.00	0.06
3	Developed, Medium Intensity	1.12	1.12	1.53	1.53	1.72	0.00	0.41	0.00	0.19	0.59
4	Developed, Low Intensity	7.96	8.00	8.43	8.46	8.53	0.03	0.44	0.03	0.06	0.56
5	Developed, Open Space	0.97	0.97	1.16	1.16	1.16	0.00	0.19	0.00	0.00	0.19
6	Cultivated Crops	0.94	0.75	0.06	0.06	0.06	-0.19	-0.69	0.00	0.00	-0.87
7	Pasture/Hay	2.15	2.15	2.15	2.15	2.15	0.00	0.00	0.00	0.00	0.00
8	Grassland/Herbaceous	2.00	2.00	1.59	1.59	1.56	0.00	-0.41	0.00	-0.03	-0.44
9	Deciduous Forest	76.80	77.08	77.08	77.05	76.58	0.28	0.00	-0.03	-0.47	-0.22
10	Evergreen Forest	4.18	4.18	4.18	4.18	4.18	0.00	0.00	0.00	0.00	0.00
11	Mixed Forest	0.37	0.37	0.37	0.37	0.37	0.00	0.00	0.00	0.00	0.00
12	Scrub/Shrub	1.16	1.06	1.06	1.06	1.31	-0.09	0.00	0.00	0.25	0.16
13	Palustrine Forested Wetland	0.53	0.53	0.53	0.53	0.53	0.00	0.00	0.00	0.00	0.00
14	Palustrine Scrub/Shrub Wetland	0.03	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00
15	Palustrine Emergent Wetland	0.16	0.16	0.16	0.16	0.16	0.00	0.00	0.00	0.00	0.00
20	Bare Land	0.16	0.12	0.12	0.12	0.12	-0.03	0.00	0.00	0.00	-0.03
21	Open Water	1.41	1.41	1.41	1.41	1.41	0.00	0.00	0.00	0.00	0.00
<u>Reclassified Groups</u>											
2,3,4,5,20 6 & 7	Developed	10.27	10.27	11.37	11.40	11.65	0.00	1.09	0.03	0.25	1.37
	Farmland	3.09	2.90	2.22	2.22	2.22	-0.19	-0.69	0.00	0.00	-0.87
	Undeveloped	85.23	85.42	85.01	84.98	84.73	0.19	-0.41	-0.03	-0.25	-0.50
8,9,10,11,12,13,14,15 21	Open Water	1.41	1.41	1.41	1.41	1.41	0.00	0.00	0.00	0.00	0.00
Total		100	100	100	100	100	0.00	0.00	0.00	0.00	0.00

Table E3. Total area of impervious surfaces and impervious surface area change (m²) of land cover classifications of the Haskell Run watershed (Lake Butler) area for the years 1985, 1996, 2001, 2006, and 2010. The total area of the Haskell Run watershed is 2,881,800 m². Haskell Run has a low population density. The land cover coefficient was multiplied by the area to obtain the values below (Digital Coast, 2016a; Digital Coast, 2016b).

Land Cover Code	Land Cover Class Name	Area of Impervious Cover (m ²)				Change in Impervious Cover (m ²)					
		1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
2	Developed, High Intensity	1,379.34	1,379.34	2,758.68	2,758.68	2,758.68	0.00	1,379.34	0.00	0.00	1,379.34
3	Developed, Medium Intensity	15,872.76	15,872.76	21,604.59	21,604.59	24,250.05	0.00	5,731.83	0.00	2,645.46	8,377.29
4	Developed, Low Intensity	58,683.15	58,913.28	62,135.10	62,365.23	62,825.49	230.13	3,221.82	230.13	460.26	4,142.34
5	Developed, Open Space	3,049.47	3,049.47	3,639.69	3,639.69	3,639.69	0.00	590.22	0.00	0.00	590.22
6	Cultivated Crops	658.80	527.04	43.92	43.92	43.92	-131.76	-483.12	0.00	0.00	-614.88
7	Pasture/Hay	869.40	869.40	869.40	869.40	869.40	0.00	0.00	0.00	0.00	0.00
8	Grassland/Herbaceous	4,878.72	4,878.72	3,887.73	3,887.73	3,811.50	0.00	-990.99	0.00	-76.23	-1,067.22
9	Deciduous Forest	39,171.87	39,315.24	39,315.24	39,299.31	39,060.36	143.37	0.00	-15.93	-238.95	-111.51
10	Evergreen Forest	1,447.20	1,447.20	1,447.20	1,447.20	1,447.20	0.00	0.00	0.00	0.00	0.00
11	Mixed Forest	224.64	224.64	224.64	224.64	224.64	0.00	0.00	0.00	0.00	0.00
12	Scrub/Shrub	1,092.24	1,003.68	1,003.68	1,003.68	1,239.84	-88.56	0.00	0.00	236.16	147.60
13	Palustrine Forested Wetland	140.76	140.76	140.76	140.76	140.76	0.00	0.00	0.00	0.00	0.00
14	Palustrine Scrub/Shrub Wetland	11.34	11.34	11.34	11.34	11.34	0.00	0.00	0.00	0.00	0.00
15	Palustrine Emergent Wetland	65.70	65.70	65.70	65.70	65.70	0.00	0.00	0.00	0.00	0.00
20	Bare Land	652.05	521.64	521.64	521.64	521.64	-130.41	0.00	0.00	0.00	-130.41
21	Open Water	405.00	405.00	405.00	405.00	405.00	0.00	0.00	0.00	0.00	0.00
Reclassified Groups											
2,3,4,5,20	Developed	79,636.77	79,736.49	90,659.70	90,889.83	93,995.55	99.72	10,923.21	230.13	3,105.72	14,358.78
6 & 7	Farmland	1,528.20	1,396.44	913.32	913.32	913.32	-131.76	-483.12	0.00	0.00	-614.88
8,9,10,11,12,13,14,15	Undeveloped	47,032.47	47,087.28	46,096.29	46,080.36	46,001.34	54.81	-990.99	-15.93	-79.02	-1,031.13
21	Open Water	405.00	405.00	405.00	405.00	405.00	0.00	0.00	0.00	0.00	0.00
Total		128,602.44	128,625.21	138,074.31	138,288.51	141,315.21	22.77	9,449.10	214.20	3,026.70	12,712.77

Table E4. Percent impervious surfaces and percent impervious change of the Haskell Run watershed (Lake Butler) area for the years 1985, 1996, 2001, 2006, and 2010. The total area of the Haskell Run watershed is 2,881,800 m² (Digital Coast, 2016a).

Land Cover Code	Land Cover Class Name	Percent Impervious Surfaces (%)					Percent Impervious Change (%)				
		1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
2	Developed, High Intensity	0.048	0.048	0.096	0.096	0.096	0.000	0.048	0.000	0.000	0.048
3	Developed, Medium Intensity	0.551	0.551	0.750	0.750	0.841	0.000	0.199	0.000	0.092	0.291
4	Developed, Low Intensity	2.036	2.044	2.156	2.164	2.180	0.008	0.112	0.008	0.016	0.144
5	Developed, Open Space	0.106	0.106	0.126	0.126	0.126	0.000	0.020	0.000	0.000	0.020
6	Cultivated Crops	0.023	0.018	0.002	0.002	0.002	-0.005	-0.017	0.000	0.000	-0.021
7	Pasture/Hay	0.030	0.030	0.030	0.030	0.030	0.000	0.000	0.000	0.000	0.000
8	Grassland/Herbaceous	0.169	0.169	0.135	0.135	0.132	0.000	-0.034	0.000	-0.003	-0.037
9	Deciduous Forest	1.359	1.364	1.364	1.364	1.355	0.005	0.000	-0.001	-0.008	-0.004
10	Evergreen Forest	0.050	0.050	0.050	0.050	0.050	0.000	0.000	0.000	0.000	0.000
11	Mixed Forest	0.008	0.008	0.008	0.008	0.008	0.000	0.000	0.000	0.000	0.000
12	Scrub/Shrub	0.038	0.035	0.035	0.035	0.043	-0.003	0.000	0.000	0.008	0.005
13	Palustrine Forested Wetland	0.005	0.005	0.005	0.005	0.005	0.000	0.000	0.000	0.000	0.000
14	Palustrine Scrub/Shrub Wetland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	Palustrine Emergent Wetland	0.002	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.000	0.000
20	Bare Land	0.023	0.018	0.018	0.018	0.018	-0.005	0.000	0.000	0.000	-0.005
21	Open Water	0.014	0.014	0.014	0.014	0.014	0.000	0.000	0.000	0.000	0.000
<u>Reclassified Groups</u>											
2,3,4,5,20 6 & 7	Developed	2.763	2.767	3.146	3.154	3.262	0.003	0.379	0.008	0.108	0.498
	Farmland	0.053	0.048	0.032	0.032	0.032	-0.005	-0.017	0.000	0.000	-0.021
	Undeveloped	1.632	1.634	1.600	1.599	1.596	0.002	-0.034	-0.001	-0.003	-0.036
8,9,10,11,12,13,14,15 21	Open Water	0.014	0.014	0.014	0.014	0.014	0.000	0.000	0.000	0.000	0.000
Total		4.463	4.463	4.791	4.799	4.904	0.001	0.328	0.007	0.105	0.441

Table E5. Total area land cover and area land cover change (m²) of land cover classifications of the Ritchie Run watershed (Lake Litchfield) area for the years 1985, 1996, 2001, 2006, and 2010. The total area of the Ritchie Run watershed is 1,665,000 m² (Digital Coast, 2016a).

Land Cover Code	Land Cover Class Name	Total Area (m ²)					Area Change (m ²)				
		1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
2	Developed, High Intensity	0	0	0	0	0	0	0	0	0	0
3	Developed, Medium Intensity	0	0	0	0	0	0	0	0	0	0
4	Developed, Low Intensity	29,700	29,700	29,700	29,700	29,700	0	0	0	0	0
5	Developed, Open Space	26,100	26,100	26,100	26,100	26,100	0	0	0	0	0
6	Cultivated Crops	0	0	0	0	0	0	0	0	0	0
7	Pasture/Hay	58,500	58,500	58,500	58,500	58,500	0	0	0	0	0
8	Grassland/Herbaceous	42,300	42,300	42,300	42,300	42,300	0	0	0	0	0
9	Deciduous Forest	1,285,200	1,285,200	1,285,200	1,285,200	1,285,200	0	0	0	0	0
10	Evergreen Forest	83,700	83,700	83,700	83,700	83,700	0	0	0	0	0
11	Mixed Forest	8,100	8,100	8,100	8,100	8,100	0	0	0	0	0
12	Scrub/Shrub	8,100	8,100	8,100	8,100	8,100	0	0	0	0	0
13	Palustrine Forested Wetland	4,500	4,500	4,500	4,500	4,500	0	0	0	0	0
14	Palustrine Scrub/Shrub Wetland	5,400	5,400	5,400	5,400	5,400	0	0	0	0	0
15	Palustrine Emergent Wetland	0	0	0	0	0	0	0	0	0	0
20	Bare Land	0	0	0	0	0	0	0	0	0	0
21	Open Water	113,400	113,400	113,400	113,400	113,400	0	0	0	0	0
<u>Reclass Groups</u>											
2,3,4,5,20 6 & 7	Developed	55,800	55,800	55,800	55,800	55,800	0	0	0	0	0
	Farmland	58,500	58,500	58,500	58,500	58,500	0	0	0	0	0
8,9,10,11,12,13,14,15	Undeveloped	1,437,300	1,437,300	1,437,300	1,437,300	1,437,300	0	0	0	0	0
	Open Water	113,400	113,400	113,400	113,400	113,400	0	0	0	0	0
21	Total	1,665,000	1,665,000	1,665,000	1,665,000	1,665,000	0	0	0	0	0

Table E6. Percent land cover and percent land cover change of land cover classifications of the Ritchie Run watershed (Lake Litchfield) area for the years 1985, 1996, 2001, 2006, and 2010. The total area of the Ritchie Run watershed is 1,665,000 m² (Digital Coast, 2016a).

Land Cover Code	Land Cover Class Name	Percent Total (%)					Percent Change (%)				
		1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
2	Developed, High Intensity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Developed, Medium Intensity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Developed, Low Intensity	1.79	1.79	1.79	1.79	1.79	0.00	0.00	0.00	0.00	0.00
5	Developed, Open Space	1.58	1.58	1.58	1.58	1.58	0.00	0.00	0.00	0.00	0.00
6	Cultivated Crops	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Pasture/Hay	3.53	3.53	3.53	3.53	3.53	0.00	0.00	0.00	0.00	0.00
8	Grassland/Herbaceous	2.56	2.56	2.56	2.56	2.56	0.00	0.00	0.00	0.00	0.00
9	Deciduous Forest	77.66	77.66	77.66	77.66	77.66	0.00	0.00	0.00	0.00	0.00
10	Evergreen Forest	5.06	5.06	5.06	5.06	5.06	0.00	0.00	0.00	0.00	0.00
11	Mixed Forest	0.49	0.49	0.49	0.49	0.49	0.00	0.00	0.00	0.00	0.00
12	Scrub/Shrub	0.49	0.49	0.49	0.49	0.49	0.00	0.00	0.00	0.00	0.00
13	Palustrine Forested Wetland	0.27	0.27	0.27	0.27	0.27	0.00	0.00	0.00	0.00	0.00
14	Palustrine Scrub/Shrub Wetland	0.33	0.33	0.33	0.33	0.33	0.00	0.00	0.00	0.00	0.00
15	Palustrine Emergent Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	Bare Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	Open Water	6.85	6.85	6.85	6.85	6.85	0.00	0.00	0.00	0.00	0.00
<u>Reclass Groups</u>											
2,3,4,5,20 6 & 7 8,9,10,11,12,13,14,15 21	Developed	3.35	3.35	3.35	3.35	3.35	0.00	0.00	0.00	0.00	0.00
	Farmland	3.51	3.51	3.51	3.51	3.51	0.00	0.00	0.00	0.00	0.00
	Undeveloped	86.32	86.32	86.32	86.32	86.32	0.00	0.00	0.00	0.00	0.00
	Open Water	6.81	6.81	6.81	6.81	6.81	0.00	0.00	0.00	0.00	0.00
Total		100	100	100	100	100	0.00	0.00	0.00	0.00	0.00

Table E7. Total area of impervious surfaces and impervious surface area change (m²) of land cover classifications of the Ritchie Run watershed (Lake Litchfield) area for the years 1985, 1996, 2001, 2006, and 2010. The total area of the Ritchie Run watershed is 1,665,000 m². Ritchie Run has a low population density. The land cover coefficient was multiplied by the area to obtain the values below (Digital Coast, 2016a; Digital Coast, 2016b).

Land Cover Code	Land Cover Class Name	Area of Impervious Cover (m ²)				Change in Impervious Cover (m ²)					
		1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
2	Developed, High Intensity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Developed, Medium Intensity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Developed, Low Intensity	7,594.29	7,594.29	7,594.29	7,594.29	7,594.29	0.00	0.00	0.00	0.00	0.00
5	Developed, Open Space	2,852.73	2,852.73	2,852.73	2,852.73	2,852.73	0.00	0.00	0.00	0.00	0.00
6	Cultivated Crops	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Pasture/Hay	819.00	819.00	819.00	819.00	819.00	0.00	0.00	0.00	0.00	0.00
8	Grassland/Herbaceous	3,582.81	3,582.81	3,582.81	3,582.81	3,582.81	0.00	0.00	0.00	0.00	0.00
9	Deciduous Forest	22,748.04	22,748.04	22,748.04	22,748.04	22,748.04	0.00	0.00	0.00	0.00	0.00
10	Evergreen Forest	1,004.40	1,004.40	1,004.40	1,004.40	1,004.40	0.00	0.00	0.00	0.00	0.00
11	Mixed Forest	168.48	168.48	168.48	168.48	168.48	0.00	0.00	0.00	0.00	0.00
12	Scrub/Shrub	265.68	265.68	265.68	265.68	265.68	0.00	0.00	0.00	0.00	0.00
13	Palustrine Forested Wetland	41.40	41.40	41.40	41.40	41.40	0.00	0.00	0.00	0.00	0.00
14	Palustrine Scrub/Shrub Wetland	68.04	68.04	68.04	68.04	68.04	0.00	0.00	0.00	0.00	0.00
15	Palustrine Emergent Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	Bare Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	Open Water	1,134.00	1,134.00	1,134.00	1,134.00	1,134.00	0.00	0.00	0.00	0.00	0.00
Reclass Groups											
2,3,4,5,20 6 & 7	Developed	10,447.02	10,447.02	10,447.02	10,447.02	10,447.02	0.00	0.00	0.00	0.00	0.00
	Farmland	819.00	819.00	819.00	819.00	819.00	0.00	0.00	0.00	0.00	0.00
	Undeveloped	27,878.85	27,878.85	27,878.85	27,878.85	27,878.85	0.00	0.00	0.00	0.00	0.00
8,9,10,11,12,13,14,15	Open Water	1,134.00	1,134.00	1,134.00	1,134.00	1,134.00	0.00	0.00	0.00	0.00	0.00
21	Total	40,278.87	40,278.87	40,278.87	40,278.87	40,278.87	0.00	0.00	0.00	0.00	0.00

Table E8. Percent impervious surfaces and percent impervious change of the Ritchie Run watershed (Lake Litchfield) area for the years 1985, 1996, 2001, 2006, and 2010. The total area of the Ritchie Run watershed is 1,665,000 m² (Digital Coast, 2016a).

Land Cover Code	Land Cover Class Name	Percent Impervious Surfaces (%)					Percent Impervious Change (%)				
		1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
2	Developed, High Intensity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Developed, Medium Intensity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Developed, Low Intensity	0.46	0.46	0.46	0.46	0.46	0.00	0.00	0.00	0.00	0.00
5	Developed, Open Space	0.17	0.17	0.17	0.17	0.17	0.00	0.00	0.00	0.00	0.00
6	Cultivated Crops	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Pasture/Hay	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00
8	Grassland/Herbaceous	0.22	0.22	0.22	0.22	0.22	0.00	0.00	0.00	0.00	0.00
9	Deciduous Forest	1.37	1.37	1.37	1.37	1.37	0.00	0.00	0.00	0.00	0.00
10	Evergreen Forest	0.06	0.06	0.06	0.06	0.06	0.00	0.00	0.00	0.00	0.00
11	Mixed Forest	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
12	Scrub/Shrub	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00
13	Palustrine Forested Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	Palustrine Scrub/Shrub Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	Palustrine Emergent Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	Bare Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	Open Water	0.07	0.07	0.07	0.07	0.07	0.00	0.00	0.00	0.00	0.00
<u>Reclass Groups</u>											
2,3,4,5,20 6 & 7	Developed	0.63	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.00	0.00
	Farmland	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00
	Undeveloped	1.67	1.67	1.67	1.67	1.67	0.00	0.00	0.00	0.00	0.00
8,9,10,11,12,13,14,15 21	Open Water	0.07	0.07	0.07	0.07	0.07	0.00	0.00	0.00	0.00	0.00
Total		2.42	2.42	2.42	2.42	2.42	0.00	0.00	0.00	0.00	0.00

Table E9. Total area land cover and area land cover change (m²) of land cover classifications of the Mud Brook watershed (Old Mill Pond) area for the years 1985, 1996, 2001, 2006, and 2010. The total area of the Mud Brook watershed is 8,439,300 m² (Digital Coast, 2016a).

Land Cover Code	Land Cover Class Name	Total Area (m ²)					Area Change (m ²)				
		1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
2	Developed, High Intensity	335,700	345,600	428,400	434,700	517,500	9,900	82,800	6,300	82,800	181,800
3	Developed, Medium Intensity	797,400	882,000	1,071,900	1,114,200	1,194,300	84,600	189,900	42,300	80,100	396,900
4	Developed, Low Intensity	2,743,200	3,019,500	3,316,500	3,372,300	3,373,200	276,300	297,000	55,800	900	630,000
5	Developed, Open Space	1,012,500	1,054,800	1,122,300	1,151,100	1,122,300	42,300	67,500	28,800	-28,800	109,800
6	Cultivated Crops	305,100	154,800	143,100	143,100	134,100	-150,300	-11,700	0	-9,000	-171,000
7	Pasture/Hay	151,200	151,200	150,300	144,000	135,900	0	-900	-6,300	-8,100	-15,300
8	Grassland/Herbaceous	215,100	229,500	56,700	60,300	60,300	14,400	-172,800	3,600	0	-154,800
9	Deciduous Forest	1,868,400	1,602,000	1,183,500	1,103,400	998,100	-266,400	-418,500	-80,100	-105,300	-870,300
10	Evergreen Forest	17,100	14,400	14,400	900	900	-2,700	0	-13,500	0	-16,200
11	Mixed Forest	6,300	6,300	6,300	5,400	5,400	0	0	-900	0	-900
12	Scrub/Shrub	177,300	184,500	184,500	182,700	181,800	7,200	0	-1,800	-900	4,500
13	Palustrine Forested Wetland	603,900	608,400	585,900	559,800	537,300	4,500	-22,500	-26,100	-22,500	-66,600
14	Palustrine Scrub/Shrub Wetland	54,000	53,100	53,100	53,100	65,700	-900	0	0	12,600	11,700
15	Palustrine Emergent Wetland	42,300	40,500	39,600	39,600	33,300	-1,800	-900	0	-6,300	-9,000
20	Bare Land	34,200	17,100	8,100	2,700	7,200	-17,100	-9,000	-5,400	4,500	-27,000
21	Open Water	75,600	75,600	74,700	72,000	72,000	0	-900	-2,700	0	-3,600
<u>Reclass Groups</u>											
2,3,4,5,20 6 & 7	Developed	4,923,000	5,319,000	5,947,200	6,075,000	6,214,500	396,000	628,200	127,800	139,500	1,291,500
	Farmland	456,300	306,000	293,400	287,100	270,000	-150,300	-12,600	-6,300	-17,100	-186,300
8,9,10,11,12,13,14,15	Undeveloped	2,984,400	2,738,700	2,124,000	2,005,200	1,882,800	-245,700	-614,700	-118,800	-122,400	-1,101,600
	Open Water	75,600	75,600	74,700	72,000	72,000	0	-900	-2,700	0	-3,600
21	Total	8,439,300	8,439,300	8,439,300	8,439,300	8,439,300	0	0	0	0	0

Table E10. Percent land cover and percent land cover change of land cover classifications of the Mud Brook watershed (Old Mill Pond) area for the years 1985, 1996, 2001, 2006, and 2010. The total area of the Mud Brook watershed is 8,439,300 m² (Digital Coast, 2016a).

Land Cover Code	Land Cover Class Name	Percent Total (%)					Percent Change (%)				
		1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
2	Developed, High Intensity	3.98	4.10	5.08	5.15	6.13	0.12	0.98	0.07	0.98	2.15
3	Developed, Medium Intensity	9.45	10.45	12.70	13.20	14.15	1.00	2.25	0.50	0.95	4.70
4	Developed, Low Intensity	32.51	35.78	39.30	39.96	39.97	3.27	3.52	0.66	0.01	7.47
5	Developed, Open Space	12.00	12.50	13.30	13.64	13.30	0.50	0.80	0.34	-0.34	1.30
6	Cultivated Crops	3.62	1.83	1.70	1.70	1.59	-1.78	-0.14	0.00	-0.11	-2.03
7	Pasture/Hay	1.79	1.79	1.78	1.71	1.61	0.00	-0.01	-0.07	-0.10	-0.18
8	Grassland/Herbaceous	2.55	2.72	0.67	0.71	0.71	0.17	-2.05	0.04	0.00	-1.83
9	Deciduous Forest	22.14	18.98	14.02	13.07	11.83	-3.16	-4.96	-0.95	-1.25	-10.31
10	Evergreen Forest	0.20	0.17	0.17	0.01	0.01	-0.03	0.00	-0.16	0.00	-0.19
11	Mixed Forest	0.07	0.07	0.07	0.06	0.06	0.00	0.00	-0.01	0.00	-0.01
12	Scrub/Shrub	2.10	2.19	2.19	2.16	2.15	0.09	0.00	-0.02	-0.01	0.05
13	Palustrine Forested Wetland	7.16	7.21	6.94	6.63	6.37	0.05	-0.27	-0.31	-0.27	-0.79
14	Palustrine Scrub/Shrub Wetland	0.64	0.63	0.63	0.63	0.78	-0.01	0.00	0.00	0.15	0.14
15	Palustrine Emergent Wetland	0.50	0.48	0.47	0.47	0.39	-0.02	-0.01	0.00	-0.07	-0.11
20	Bare Land	0.41	0.20	0.10	0.03	0.09	-0.20	-0.11	-0.06	0.05	-0.32
21	Open Water	0.90	0.90	0.89	0.85	0.85	0.00	-0.01	-0.03	0.00	-0.04
<u>Reclass Groups</u>											
2,3,4,5,20 6 & 7	Developed	58.33	63.03	70.47	71.98	73.64	4.69	7.44	1.51	1.65	15.30
	Farmland	5.41	3.63	3.48	3.40	3.20	-1.78	-0.15	-0.07	-0.20	-2.21
	Undeveloped	35.36	32.45	25.17	23.76	22.31	-2.91	-7.28	-1.41	-1.45	-13.05
8,9,10,11,12,13,14,15 21	Open Water	0.90	0.90	0.89	0.85	0.85	0.00	-0.01	-0.03	0.00	-0.04
Total		100	100	100	100	100	0.00	0.00	0.00	0.00	0.00

Table E11. Total area of impervious surfaces and impervious surface area change (m²) of land cover classifications of the Mud Brook (Old Mill Pond) area for the years 1985, 1996, 2001, 2006, and 2010. The total area of the Mud Brook watershed is 8,439,300 m². Mud Brook has a medium population density. The land cover coefficient was multiplied by the area to obtain the values below (Digital Coast, 2016a; Digital Coast, 2016b).

Land Cover Code	Land Cover Class Name	Area of Impervious Cover (m ²)					Change in Impervious Cover (m ²)				
		1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
2	Developed, High Intensity	257,179.77	264,764.16	328,197.24	333,023.67	396,456.75	7,584.39	63,433.08	4,826.43	63,433.08	139,276.98
3	Developed, Medium Intensity	390,885.48	432,356.40	525,445.38	546,180.84	585,445.86	41,470.92	93,088.98	20,735.46	39,265.02	194,560.38
4	Developed, Low Intensity	700,887.60	771,482.25	847,365.75	861,622.65	861,852.60	70,594.65	75,883.50	14,256.90	229.95	160,965.00
5	Developed, Open Space	110,868.75	115,500.60	122,891.85	126,045.45	122,891.85	4,631.85	7,391.25	3,153.60	-3,153.60	12,023.10
6	Cultivated Crops	7,902.09	4,009.32	3,706.29	3,706.29	3,473.19	-3,892.77	-303.03	0.00	-233.10	-4,428.90
7	Pasture/Hay	2,283.12	2,283.12	2,269.53	2,174.40	2,052.09	0.00	-13.59	-95.13	-122.31	-231.03
8	Grassland/Herbaceous	18,799.74	20,058.30	4,955.58	5,270.22	5,270.22	1,258.56	-15,102.72	314.64	0.00	-13,529.52
9	Deciduous Forest	35,125.92	30,117.60	22,249.80	20,743.92	18,764.28	-5,008.32	-7,867.80	-1,505.88	-1,979.64	-16,361.64
10	Evergreen Forest	210.33	177.12	177.12	11.07	11.07	-33.21	0.00	-166.05	0.00	-199.26
11	Mixed Forest	139.86	139.86	139.86	119.88	119.88	0.00	0.00	-19.98	0.00	-19.98
12	Scrub/Shrub	6,205.50	6,457.50	6,457.50	6,394.50	6,363.00	252.00	0.00	-63.00	-31.50	157.50
13	Palustrine Forested Wetland	5,797.44	5,840.64	5,624.64	5,374.08	5,158.08	43.20	-216.00	-250.56	-216.00	-639.36
14	Palustrine Scrub/Shrub Wetland	685.80	674.37	674.37	674.37	834.39	-11.43	0.00	0.00	160.02	148.59
15	Palustrine Emergent Wetland	609.12	583.20	570.24	570.24	479.52	-25.92	-12.96	0.00	-90.72	-129.60
20	Bare Land	5,037.66	2,518.83	1,193.13	397.71	1,060.56	-2,518.83	-1,325.70	-795.42	662.85	-3,977.10
21	Open Water	672.84	672.84	664.83	640.80	640.80	0.00	-8.01	-24.03	0.00	-32.04
Reclass Groups											
2,3,4,5,20 6 & 7 8,9,10,11,12,13,14,15	Developed	1,464,859.26	1,586,622.24	1,825,093.35	1,867,270.32	1,967,707.62	121,762.98	238,471.11	42,176.97	100,437.30	502,848.36
	Farmland	10,185.21	6,292.44	5,975.82	5,880.69	5,525.28	-3,892.77	-316.62	-95.13	-355.41	-4,659.93
	Undeveloped	67,573.71	64,048.59	40,849.11	39,158.28	37,000.44	-3,525.12	-23,199.48	-1,690.83	-2,157.84	-30,573.27
21	Open Water	672.84	672.84	664.83	640.80	640.80	0.00	-8.01	-24.03	0.00	-32.04
Total		1,543,291.02	1,657,636.11	1,872,583.11	1,912,950.09	2,010,874.14	114,345.09	214,947.00	40,366.98	97,924.05	467,583.12

Table E12. Percent impervious surfaces and percent impervious change of the Mud Brook watershed (Old Mill Pond) for the years 1985, 1996, 2001, 2006, and 2010. The total area of the Mud Brook watershed is 8,439,300 m² (Digital Coast, 2016a).

Land Cover Code	Land Cover Class Name	Percent Impervious Surfaces (%)					Percent Impervious Change (%)				
		1985	1996	2001	2006	2010	1985-1996	1996-2001	2001-2006	2006-2010	1985-2010
2	Developed, High Intensity	3.05	3.14	3.89	3.95	4.70	0.09	0.75	0.06	0.75	1.65
3	Developed, Medium Intensity	4.63	5.12	6.23	6.47	6.94	0.49	1.10	0.25	0.47	2.31
4	Developed, Low Intensity	8.31	9.14	10.04	10.21	10.21	0.84	0.90	0.17	0.00	1.91
5	Developed, Open Space	1.31	1.37	1.46	1.49	1.46	0.05	0.09	0.04	-0.04	0.14
6	Cultivated Crops	0.09	0.05	0.04	0.04	0.04	-0.05	0.00	0.00	0.00	-0.05
7	Pasture/Hay	0.03	0.03	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.00
8	Grassland/Herbaceous	0.22	0.24	0.06	0.06	0.06	0.01	-0.18	0.00	0.00	-0.16
9	Deciduous Forest	0.42	0.36	0.26	0.25	0.22	-0.06	-0.09	-0.02	-0.02	-0.19
10	Evergreen Forest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	Mixed Forest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Scrub/Shrub	0.07	0.08	0.08	0.08	0.08	0.00	0.00	0.00	0.00	0.00
13	Palustrine Forested Wetland	0.07	0.07	0.07	0.06	0.06	0.00	0.00	0.00	0.00	-0.01
14	Palustrine Scrub/Shrub Wetland	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
15	Palustrine Emergent Wetland	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
20	Bare Land	0.06	0.03	0.01	0.00	0.01	-0.03	-0.02	-0.01	0.01	-0.05
21	Open Water	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
<u>Reclass Groups</u>											
2,3,4,5,20 6 & 7	Developed	17.36	18.80	21.63	22.13	23.32	1.44	2.83	0.50	1.19	5.96
	Farmland	0.12	0.07	0.07	0.07	0.07	-0.05	0.00	0.00	0.00	-0.06
8,9,10,11,12,13,14,15	Undeveloped	0.80	0.76	0.48	0.46	0.44	-0.04	-0.27	-0.02	-0.03	-0.36
	Open Water	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Total		18.29	19.64	22.19	22.67	23.83	1.35	2.55	0.48	1.16	5.54

APPENDIX F

GRAIN SIZE DATA FOR SEDIMENT CORE AND SURFACE SAMPLES FOR LAKE BUTLER, LAKE LITCHFIELD, AND OLD MILL POND

The Folk (1980) grain size method was used on 19 repressive samples from the sediment cores and surface samples of all sites. The pipette method was used on mud samples. Sand and gravel samples were measured by using the rotap sieving method divided into 0.5 Φ increments.

Sample ID: LB-C4 200cm
Initial wt. (g) 15.147
End wt. (g) 15.367
% Error -1.452

phi Φ	Beaker (g)	Beaker and Sediment (g)	Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)	*50 (not 4 phi)	Cumulative % Coarser Than	Individual Wt %	S, M, C (%)
4	85.359	85.606	0.247	0.247	0.247	1.631	1.631	1.631
5	83.697	84.091	0.394	0.302	15.120	-	-	
6	85.940	86.289	0.349	0.257	12.870	13.624	15.101	
7	86.123	86.381	0.258	0.166	8.320	44.161	30.537	
8	85.640	85.837	0.197	0.105	5.270	64.631	20.470	66.107
9	84.953	85.135	0.182	0.090	4.520	69.664	5.034	32.262

D₅₀ 7.285

Sample ID: OMP-C3 160cm

Initial wt. (g) 17.087

End Wt. (g) 15.348

% Error 10.177

phi Φ	Beaker and		Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)		*50 (not 4 phi)	Cumulative		S, M, C (%)
	Beaker (g)	Sediment (g)					% Coarser Than	Individual Wt %	
4	87.005	87.283	0.278	0.278	0.278	0.278	1.627	1.627	1.627
5	86.947	87.340	0.393	0.301	0.301	15.070	10.346	8.719	
6	84.003	84.377	0.374	0.282	0.282	14.120	15.997	5.652	
7	86.131	86.416	0.285	0.193	0.193	9.670	42.471	26.474	
8	86.828	87.073	0.245	0.153	0.153	7.670	54.370	11.898	52.743
9	86.031	86.244	0.213	0.121	0.121	6.070	63.888	9.519	45.630

D₅₀ 7.633

Sample ID: LL-C1 45cm
Initial wt. (g) 15.179
End Wt. (g) 14.035
% Error 7.537

phi Φ	Beaker (g)	Beaker and Sediment (g)	Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)	*50 (not 4 phi)	Cumulative % Coarser Than	Individual Wt %	S, M, C (%)
4	82.735	82.900	0.165	0.165	0.165	1.087	1.087	1.087
5	89.466	89.835	0.369	0.277	13.870	7.620	6.533	
6	86.129	86.438	0.309	0.217	10.870	27.601	19.981	
7	84.550	84.793	0.243	0.151	7.570	49.580	21.979	
8	83.689	83.886	0.197	0.105	5.270	64.899	15.319	63.812
9	86.392	86.570	0.178	0.086	4.320	71.227	6.327	35.101

D₅₀ 7.027

Sample ID: LL-C1 90cm
Initial wt. (g) 17.414
End wt. (g) 15.019
% Error 13.753

phi Φ	Beaker (g)	Beaker and Sediment (g)	Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)	*50 (not 4 phi)	Cumulative % Coarser Than	Individual Wt %	S, M, C (%)
4	89.187	91.036	1.849	1.849	1.849	10.618	10.618	10.618
5	84.998	85.353	0.355	0.263	13.170	15.387	4.769	
6	86.302	86.558	0.256	0.164	8.220	47.189	31.802	
7	85.977	86.193	0.216	0.124	6.220	60.039	12.849	
8	85.001	85.179	0.178	0.086	4.320	72.245	12.207	61.628
9	84.388	84.547	0.159	0.067	3.370	78.349	6.103	27.755

D₅₀ 6.219

Sample ID: LB-C4 10cm
Initial wt. (g) 18.528
End wt. (g) 16.126
% Error 12.964

phi Φ	Beaker (g)	Beaker and Sediment (g)	Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)	*50 (not 4 phi)	Cumulative % Coarser Than	Individual Wt %	S, M, C (%)
4	83.313	83.719	0.406	0.406	0.406	2.191	2.191	2.191
5	85.363	85.769	0.406	0.314	15.720	13.255	11.063	
6	85.152	85.492	0.340	0.248	12.420	31.465	18.210	
7	87.849	88.112	0.263	0.171	8.570	52.709	21.245	
8	84.842	85.053	0.211	0.119	5.970	67.057	14.347	64.865
9	84.800	84.986	0.186	0.094	4.720	73.954	6.898	32.943

D_{50} 6.872

Sample ID: OMP-C3 110cm

Initial wt. (g) 16.253

End wt. (g) 15.693

% Error 3.446

phi Φ	Beaker and		Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)		*50 (not 4 phi)	Cumulative % Coarser Than	Individual Wt %	S, M, C (%)
	Beaker (g)	Sediment (g)							
4	86.830	88.253	1.423	1.423	1.423	1.423	8.755	8.755	8.755
5	84.916	85.293	0.377	0.285	0.285	14.270	3.776	-	
6	85.328	85.678	0.350	0.258	0.258	12.920	12.879	9.103	
7	83.641	83.938	0.297	0.205	0.205	10.270	30.748	17.869	
8	82.702	82.942	0.240	0.148	0.148	7.420	49.966	19.218	46.190
9	85.322	85.521	0.199	0.107	0.107	5.370	63.790	13.823	45.055

D₅₀ 8.002

Sample ID: OMP-C3 20cm

Initial wt. (g) 19.211

End wt. (g) 17.340

% Error 9.739

phi Φ	Beaker (g)	Beaker and Sediment (g)	Dry Sediment Only (g)	0.0916g Less		*50 (not 4 phi)	Cumulative % Coarser Than	Individual Wt %	S, M, C (%)
				Dispersant (g) (not 4 phi)	Dispersant (g) (not 4 phi)				
4	84.946	85.266	0.320	0.320	0.320	0.320	1.666	1.666	1.666
5	85.558	85.990	0.432	0.340	0.340	17.020	9.904	8.238	
6	84.795	85.162	0.367	0.275	0.275	13.770	27.108	17.204	
7	84.490	84.762	0.272	0.180	0.180	9.020	52.252	25.144	
8	85.910	86.123	0.213	0.121	0.121	6.070	67.868	15.616	66.203
9	89.180	89.366	0.186	0.094	0.094	4.720	75.015	7.146	32.132

D₅₀ 6.910

Sample ID: LB-C4 35cm
Initial wt. (g) 18.670
End wt. (g) 16.922
% Error 9.363

phi Φ	Beaker (g)	Beaker and Sediment (g)		Dry Sediment Only (g)		0.0916g Less Dispersant (g) (not 4 phi)		*50 (not 4 phi)	Cumulative % Coarser Than	Individual Wt %	S, M, C (%)
		Sediment (g)		Sediment Only (g)		Dispersant (g) (not 4 phi)					
4	87.801	97.203		9.402		9.402		9.402	50.359	50.359	50.359
5	85.032	85.274		0.242		0.150		7.520	18.861	-	
6	83.636	83.840		0.204		0.112		5.620	39.361	20.501	
7	89.436	89.601		0.165		0.073		3.670	60.401	21.040	
8	86.302	86.447		0.145		0.053		2.670	71.191	10.790	25.148
9	86.124	86.261		0.137		0.045		2.270	75.507	4.316	24.493

D₅₀ 4.065

Sample ID: OMP-C3 80cm

Initial wt. (g) 18.356

End wt. (g) 17.505

% Error 4.636

phi Φ	Beaker (g)	Beaker and Sediment (g)	Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)	*50 (not 4 phi)	Cumulative		S, M, C (%)
						% Coarser Than	Individual Wt %	
4	85.974	86.109	0.135	0.135	0.135	0.735	0.735	0.735
5	86.138	86.577	0.439	0.347	17.370	4.670	3.935	
6	85.963	86.359	0.396	0.304	15.220	16.470	11.800	
7	86.340	86.665	0.325	0.233	11.670	35.953	19.483	
8	84.010	84.276	0.266	0.174	8.720	52.143	16.190	51.408
9	86.078	86.313	0.235	0.143	7.170	60.650	8.507	47.857

D₅₀ 7.868

Sample ID: OMP G3
Initial wt. (g) 9.561
End wt. (g) 8.769
% Error 8.284

phi Φ	Beaker (g)	Beaker and Sediment (g)	Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)	*50 (not 4 phi)	Cumulative % Coarser Than	Individual Wt %	S, M, C (%)
4	85.177	85.476	0.299	0.299	0.299	3.127	3.127	3.127
5	83.262	83.523	0.261	0.169	8.470	8.551	5.424	
6	84.282	84.507	0.225	0.133	6.670	27.985	19.434	
7	84.524	84.717	0.193	0.101	5.070	45.260	17.275	
8	84.989	85.152	0.163	0.071	3.570	61.455	16.195	58.328
9	85.305	85.458	0.153	0.061	3.070	66.854	5.398	38.545

D₅₀ 7.293

Sample ID: OMP G12

Initial wt. (g) 10.452

End wt. (g) 9.954

% Error 4.765

phi Φ	Beaker and		Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)		*50 (not 4 phi)	Cumulative		Individual Wt %	S, M, C (%)
	Beaker (g)	Sediment (g)			% Coarser Than					
4	84.347	84.481	0.134	0.134	0.134	0.134	1.282	1.282	1.282	1.282
5	86.981	87.269	0.288	0.196	0.196	9.820	4.827	3.544	3.544	
6	86.929	87.176	0.247	0.155	0.155	7.770	24.695	19.868	19.868	
7	83.299	83.509	0.210	0.118	0.118	5.920	42.625	17.930	17.930	
8	84.809	84.989	0.180	0.088	0.088	4.420	57.162	14.538	14.538	55.880
9	85.119	85.282	0.163	0.071	0.071	3.570	65.400	8.238	8.238	42.838

D_{50} 7.507

Sample ID: LL-C1, 15-20cm

Initial wt. (g) 18.492

End wt. (g) 16.785

% Error 9.231

phi Φ	Beaker (g)	Beaker and Sediment (g)	Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)	*50 (not 4 phi)	Cumulative % Coarser Than	Individual Wt %	S, M, C (%)
4	86.673	86.888	0.215	0.215	0.215	1.163	1.163	1.163
5	50.416	50.839	0.423	0.331	16.570	9.340	8.177	
6	49.352	49.708	0.356	0.264	13.220	27.669	18.329	
7	50.431	50.689	0.258	0.166	8.320	54.478	26.810	
8	50.626	50.833	0.207	0.115	5.770	68.430	13.952	67.268
9	48.618	48.799	0.181	0.089	4.470	75.543	7.113	31.570

D₅₀ 6.833

Sample ID: LL-C1 30cm

Initial wt. (g) 18.868

End wt. (g) 17.680

% Error 6.296

phi Φ	Beaker (g)	Beaker and Sediment (g)	Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)	*50 (not 4 phi)	Cumulative % Coarser Than	Individual Wt %	S, M, C (%)
4	86.990	87.100	0.110	0.110	0.110	0.583	0.583	0.583
5	84.897	85.340	0.443	0.351	17.570	7.633	7.050	
6	84.676	85.044	0.368	0.276	13.820	31.725	24.093	
7	87.534	87.808	0.274	0.182	9.120	61.921	30.196	
8	84.000	84.214	0.214	0.122	6.120	81.195	19.274	80.612
9	86.720	86.905	0.185	0.093	4.670	90.511	9.316	18.805

D₅₀ 6.605

Sample ID: OMP-C5 25cm

Initial wt. (g) 19.209

End wt. (g) 16.472

% Error 14.249

phi Φ	Beaker (g)	Beaker and Sediment (g)	Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)	*50 (not 4 phi)	Cumulative % Coarser Than	Individual Wt %	S, M, C (%)
4	85.711	86.713	1.002	1.002	1.002	5.216	5.216	5.216
5	86.424	86.825	0.401	0.309	15.470	15.033	9.816	
6	85.332	85.657	0.325	0.233	11.670	35.904	20.871	
7	84.970	85.225	0.255	0.163	8.170	55.127	19.223	
8	85.899	86.110	0.211	0.119	5.970	67.210	12.083	61.994
9	84.570	84.760	0.190	0.098	4.920	72.977	5.767	32.790

D₅₀ 6.733

Sample ID: OMP-G9

Initial wt. (g) 11.656

End wt. (g) 11.156

% Error 4.290

phi Φ	Beaker (g)	Beaker and Sediment (g)	Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)	*50 (not 4 phi)	Cumulative % Coarser Than	Individual Wt %	S, M, C (%)
4	86.832	88.118	1.286	1.286	1.286	11.033	11.033	11.033
5	83.164	83.453	0.289	0.197	9.870	4.822	-	
6	87.649	87.912	0.263	0.171	8.570	17.358	12.536	
7	85.912	86.132	0.220	0.128	6.420	38.091	20.733	
8	85.919	86.108	0.189	0.097	4.870	53.038	14.947	48.216
9	85.091	85.259	0.168	0.076	3.820	63.163	10.125	40.751

D₅₀ 7.797

Sample ID: OMP-C5 10cm

Initial wt. (g) 13.582

End wt. (g) 11.966

% Error 11.898

phi Φ	Beaker (g)	Beaker and Sediment (g)	Dry Sediment Only (g)	0.0916g Less Dispersant (g) (not 4 phi)	*50 (not 4 phi)	Cumulative % Coarser Than	Individual Wt %	S, M, C (%)
4	87.484	89.480	1.996	1.996	1.996	14.696	14.696	14.696
5	84.079	84.370	0.291	0.199	9.970	13.948	-	
6	85.115	85.361	0.246	0.154	7.720	33.368	19.420	
7	85.725	85.926	0.201	0.109	5.470	52.788	19.420	
8	84.067	84.242	0.175	0.083	4.170	64.008	11.220	50.060
9	86.653	86.816	0.163	0.071	3.570	69.187	5.179	35.244

D₅₀ 6.856

Sample ID: OMP-G7
Initial wt. (g) 40.451
% Error 0.710

m_{Φ}	ϕ	Individual weight (g)	Individual weight (%)	G, S, M (%)	Cummulative Weight (%)	$f m_{\Phi}$	$m_{\Phi-X}$	$(m_{\Phi-X})^2$	$f(m_{\Phi-X})^2$	$(m_{\Phi-X})^3$	$f(m_{\Phi-X})^3$
-4.25	-4.00	3.773	9.394		9.394	-39.924	-3.408	11.615	109.112	-39.586	-371.866
-3.68	-3.35	2.590	6.449	47.055	15.843	-23.698	-2.833	8.026	51.759	-22.740	-146.639
-3.18	-3.00	0.898	2.236		18.078	-7.099	-2.333	5.443	12.170	-12.700	-28.3948
-2.80	-2.60	3.310	8.241		26.320	-23.075	-1.958	3.834	31.598	-7.508	-61.8721
-2.30	-2.00	2.604	6.483		32.803	-14.912	-1.458	2.126	13.784	-3.100	-20.0986
-1.75	-1.50	3.110	7.743		40.546	-13.551	-0.908	0.825	6.385	-0.749	-5.7986
-1.25	-1.00	2.614	6.508		47.055	-8.135	-0.408	0.167	1.084	-0.068	-0.44235
-0.75	-0.50	2.489	6.197		53.252	-4.648	0.092	0.008	0.052	0.001	0.00481
-0.25	0.00	2.347	5.844		59.095	-1.461	0.592	0.350	2.047	0.207	1.21178
0.25	0.50	2.660	6.623		65.718	1.656	1.092	1.192	7.896	1.302	8.62172
0.75	1.00	3.474	8.650		74.368	6.487	1.592	2.534	21.919	4.034	34.8932
1.25	1.50	4.403	10.963		85.330	13.703	2.092	4.376	47.973	9.154	100.354
1.75	2.00	3.747	9.329	52.447	94.659	16.326	2.592	6.718	62.673	17.412	162.443
2.25	2.50	1.397	3.478		98.138	7.826	3.092	9.560	33.251	29.558	102.81
2.75	3.00	0.304	0.757		98.895	2.081	3.592	12.902	9.765	46.342	35.076
3.25	3.50	0.129	0.321		99.216	1.044	4.092	16.744	5.378	68.513	22.0053
3.75	4.00	0.115	0.286		99.502	1.074	4.592	21.086	6.037	96.823	27.7229
4.25	>4	0.200	0.498	0.498	100.000	2.116	5.092	25.927	12.911	132.020	65.7405
TOTAL		40.164				-84.190			435.797		-74.2274

Mean Φ -0.842
 $\sigma \Phi$ 2.088
SK Φ -0.742
 D_{50} -0.762

Sample ID: OMP-G8
Initial wt. (g) 35.15
% Error 1.29

m_{Φ}	ϕ	Individual weight (g)	Individual weight (%)	G, S, M (%)	Cummulative Weight (%)	$f_{m_{\Phi}}$	$m_{\Phi-X}$	$(m_{\Phi-X})^2$	$f(m_{\Phi-X})^2$	$(m_{\Phi-X})^3$	$f(m_{\Phi-X})^3$
-4.25	-4.00	0.000	0.000		0.000	0.000	-4.892	23.932	0.000	-117.080	0.000
-3.68	-3.35	0.000	0.000	12.054	0.000	0.000	-4.317	18.637	0.000	-80.458	0.000
-3.18	-3.00	0.994	2.865		2.865	-9.096	-3.817	14.570	41.743	-55.615	-159.336
-2.80	-2.60	0.366	1.055		3.920	-2.954	-3.442	11.848	12.498	-40.782	-43.021
-2.30	-2.00	0.000	0.000		3.920	0.000	-2.942	8.656	0.000	-25.466	0.000
-1.75	-1.50	1.321	3.807		7.727	-6.663	-2.392	5.722	21.787	-13.688	-52.1151
-1.25	-1.00	1.501	4.326		12.054	-5.408	-1.892	3.580	15.488	-6.774	-29.30441
-0.75	-0.50	2.046	5.897		17.951	-4.423	-1.392	1.938	11.428	-2.698	-15.90861
-0.25	0.00	3.010	8.676		26.626	-2.169	-0.892	0.796	6.904	-0.710	-6.159032
0.25	0.50	4.027	11.607		38.233	2.902	-0.392	0.154	1.784	-0.060	-0.699588
0.75	1.00	5.622	16.204		54.437	12.153	0.108	0.012	0.189	0.001	0.0203666
1.25	1.50	6.778	19.536		73.973	24.420	0.608	0.370	7.220	0.225	4.3890633
1.75	2.00	5.186	14.947	87.125	88.921	26.158	1.108	1.227	18.348	1.360	20.327766
2.25	2.50	2.244	6.468		95.388	14.553	1.608	2.585	16.722	4.157	26.887379
2.75	3.00	0.897	2.585		97.974	7.110	2.108	4.443	11.488	9.366	24.215158
3.25	3.50	0.266	0.767		98.740	2.492	2.608	6.801	5.214	17.737	13.598689
3.75	4.00	0.152	0.438		99.179	1.643	3.108	9.659	4.232	30.020	13.151818
4.25	>4	0.285	0.821	0.821	100.000	3.491	3.608	13.017	10.693	46.965	38.578764
TOTAL		34.695				64.208			185.737		-165.3743

Mean Φ 0.642
 $\sigma \Phi$ 1.363
SK Φ -1.654
 D_{50} 0.863

Sample ID: LB-G14
Initial wt. (g) 40.400
% Error 7.08

m_{Φ}	ϕ	Individual weight (g)	Individual weight (%)	G, S, M (%)	Cummulative Weight (%)	$f m_{\Phi}$	$m_{\Phi-X}$	$(m_{\Phi-X})^2$	$f(m_{\Phi-X})^2$	$(m_{\Phi-X})^3$	$f(m_{\Phi-X})^3$
-4.25	-4.00	0.000	0.000		0.000	0.000	-5.273	27.806	0.000	-146.621	0
-3.68	-3.35	0.000	0.000	3.077	0.000	0.000	-4.698	22.072	0.000	-103.697	0
-3.18	-3.00	0.000	0.000		0.000	0.000	-4.198	17.624	0.000	-73.987	0
-2.80	-2.60	0.000	0.000		0.000	0.000	-3.823	14.616	0.000	-55.879	0
-2.30	-2.00	0.265	0.706		0.706	-1.624	-3.323	11.043	7.795	-36.697	-25.9041
-1.75	-1.50	0.324	0.863		1.569	-1.510	-2.773	7.690	6.637	-21.325	-18.4049
-1.25	-1.00	0.566	1.508		3.077	-1.885	-2.273	5.167	7.790	-11.745	-17.7077
-0.75	-0.50	1.509	4.020		7.096	-3.015	-1.773	3.144	12.637	-5.574	-22.4068
-0.25	0.00	2.635	7.019		14.115	-1.755	-1.273	1.621	11.376	-2.063	-14.4829
0.25	0.50	4.438	11.822		25.937	2.955	-0.773	0.598	7.066	-0.462	-5.46235
0.75	1.00	7.526	20.047		45.984	15.036	-0.273	0.075	1.495	-0.020	-0.40832
1.25	1.50	10.147	27.029		73.014	33.786	0.227	0.051	1.392	0.012	0.31577
1.75	2.00	6.186	16.478	95.227	89.491	28.836	0.727	0.528	8.707	0.384	6.32903
2.25	2.50	1.691	4.504		93.996	10.135	1.227	1.505	6.780	1.847	8.31899
2.75	3.00	0.533	1.420		95.416	3.904	1.727	2.982	4.234	5.150	7.31184
3.25	3.50	0.447	1.191		96.606	3.870	2.227	4.959	5.905	11.043	13.1494
3.75	4.00	0.637	1.697		98.303	6.363	2.727	7.436	12.618	20.277	34.4068
4.25	>4	0.637	1.697	1.697	100.000	7.211	3.227	10.413	17.669	33.601	57.0154
TOTAL		37.541			102.309				112.100		22.070
Mean Φ	1.023										
$\sigma \Phi$	1.059										
SK Φ	0.221										
D_{50}	1.074										