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Students: *LUCY ANDREWS*, Macalester College, *AMY DELBECQ*, Beloit College, *SAMANTHA DOW*, Univ. Connecticut, *CATHERINE DUNN*, Oberlin College, *WESLEY JOHNSON*, Univ. Massachusetts, *RACHEL JOHNSON,* Carleton College, *SCOTT KUGEL*, The College of Wooster, *AIDA OROZCO*, Amherst College, *JULIA SEIDENSTEIN,* Lafayette College

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Research Advisor: Dru Germanoski

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A CASE STUDY OF STORM DEPOSITION IN LITTLEVILLE LAKE, HUNTINGTON, MA

CATHERINE DUNN, Oberlin College
Research Advisor: Amanda Schmidt

INTRODUCTION

It is important to understand the nature of past extreme events in order to prepare for future storms and anticipate their effects on fluvial, sedimentological and geomorphological processes. Tropical Storm Irene is a perfect example of how extreme precipitation can change the landscape through flooding, sediment transport and depositional patterns. On August 28 and 29, 2011, Tropical Storm Irene dumped 18-25 cm of precipitation in the Connecticut River Valley in a 24 hour period. The resulting flooding from Irene was more severe due to 18 mm of rain the month before, which is almost double the monthly average (Woodruff et al., 2013a). This wet August lead to high runoff and extreme flooding during the storm.

Flood control dams in the Connecticut River Valley provide an ideal site for studying sediment deposition because reservoir impoundment provides a time stamp for sediment trapping. Tropical Storm Irene deposited an anomalously grey, fine grained and organic poor layer of sediment (Woodruff et al., 2013a). This Irene layer and the lake bottom provide important time markers in sediment cores. The sediment cores also allow us to quantify differences between sediment deposited regularly and sediment deposited in extreme events. The importance of the flood control feature in trapping sediment can also be analyzed from the sediment cores.

Using sediment cores collected from Litteville Lake, I am comparing the extremity and sediment deposition of Tropical Storm Irene. This is important in preparing for future climate change. In the event that our climate experiences intense warming, storms such as Irene will possibly become the norm. It is important to know how the storm behaved and what we can expect in the future so that preparation and damage prevention plans can be made.

GEOLOGIC SETTING

Littleville Lake is a flood control reservoir on the middle branch of the Westfield River, a tributary to the Connecticut River. The lake lies in the Berkshire Hills in Huntington, MA and is a backup water reservoir to Springfield, Massachusetts. At Littleville Lake and along the Westfield, the bedrock is Lower Devonian Goshen Formation, which is composed of mostly fine to medium-grained quartz, micas, garnet, staurolite schist and fine-grained gray quartzite (Hatch, 1967; Zen et al., 1983).

The dam on Littleville Lake was built in 1962 and completed in 1965. It stands at 50 m tall with a storage capacity of 7.49 billion gallons of water. The watershed is roughly 132 km^2 with a 158 m target pool stage. The Army Corps of Engineers states that the reservoir is never drawn down more than 30 cm every few years, except for 1.5 to 2 m for an annual springtime canoes race (Tow Wisnauckas, personal communication, March 6, 2014). The dam cost $6.8 million to build but is estimated to have saved $148.5 million in flood damages as of September 2011 (U.S. Army Corps of Engineers).

FIELD METHODS

The four long push cores, L1D1, L2D1, L3D1 and LL12, were collected using a piston push corer. Once a location on the reservoir was selected, the water depth was recorded using a Speedtech depth sounder, and the piston corer was lowered into the water. The remaining six cores were collected using a Uwitec Gravity Corer. Gravity cores LLSC1 and LLSC2 were extruded in the field at 0.5 cm depth increments and bagged for transport. Cores LLSC3, LTt1 and LTt2 were brought to shore and subsampled with a piece of 5cm diameter polycarbonate tubing. The final successful core, LVS16D2, was capped and taped with the core catcher still inside the barrel because the proper extruding materials were not brought along. In some unsuccessful areas of the reservoir the core barrels came back up cracked or with pieces completely broken off. In other unsuccessful locations, the gravity corer would hit the sediment water interface and bubbles would rise up to the surface and the core barrel would bring up organics and cloudy water.

LAB/ANALYTIC METHODS

All samples were brought back to the Quaternary Lab at the University of Massachusetts, Amherst for analysis. The long push cores and LVS16D2 were run through the Geotek-MSCL-S for bulk density, before being sliced open on a Geotek Core Splitter. Cores were then subsampled every centimeter and placed in ceramic crucibles or open-faced aluminum tins. All samples were weighed and dried in a 105°C oven for a few hours. The samples were then reweighed to determine porosity, and placed in a 550°C oven for at least three hours to combust the organics and determine the loss on ignition (LOI). X-ray fluorescence (XRF) was run on some of the cores to detect elemental abundances in potassium (K) and zirconium (Zr) following procedures similar to those in Woodruff et al., (2009). The XRF produces an X-ray image of the core, which gives good representation of density. Along with the X-ray image are elemental signatures for K and Zr. K is a strong indicator of unweathered clays usually found in tills. Conversely, Zr is usually present in weathered Zr bearing sands (Woodruff et al. 2013a).

Grainsize was run at either the University of Massachusetts, Amherst or Mercyhurst University on a laser particle analyzer (Table 1). Post LOI sediment was added to a beaker of distilled water and sonicated for around five minutes. The solution was then added to a test tube and placed on a Fisher Vortex before being poured into the Coulter LS 200. Controls were run at Mercyhurst, as well as three reruns from the core LLSC3 to test for consistency between the two machines. The controls showed accurate analysis and the reruns showed almost identical mode values between the two cores. Grain size analysis data was computed and reported in Faunhofer 780d, using the D_{90} calculation in microns, which is the grain size that 90% of the grains in the sample are smaller than.

Mercury analysis was run on one centimeter, organic-rich subsamples from cores (Table 1). Scott Kugel ran the samples on Amherst College's Teledyne Leeman Lab's Hydra-C following procedures described in Woodruff et al. (2013b). Because mercury is sorbed to organics, the mercury values were normalized by dividing the mercury concentration by the LOI. These analyses were used to find an average sediment deposition rate in the reservoir.

In an attempt to create an accurate age model in the cores, fallout short-lived radioisotope analysis (^{137}Cs and ^{210}Pb) was run on dried organic rich sediment from the L1D1 core following methods similar to Woodruff et al., (2001). The samples were packed in one-centimeter increments and sealed for three weeks before being run on a Canberra BeGE Germanium Detector for 72 hours. The samples were run for ^{137}Cs to determine the 1954 onset and the 1963 peak, and ^{210}Pb for dating using its 22.3 year half-life. No unsupported ^{210}Pb was detected in the run sample. Levels of ^{137}Cs were low and had such high percentages of error, that to get an accurate reading would require a 13-day run per sample. Thus, this method was not used for analysis.

River discharge data from the west branch of the Westfield River was downloaded from the United States Army Corps of Engineers. The west branch was used because it does not have a dam, therefore giving a more accurate volume of water going through the area.

Name	Date	Type	Lat/Long	Depth (m)	Porosity	LOI	Density	Grainsize	Mercury	XRF
LTt1*	4/27/13	Short Gravity	42.28411N 72.88932W	14.1	X	X	X			X
LTt2*	4/27/14	Short Gravity	42.28736N 72.89228W	6.6	X	X	X			X
LLSC1	7/2/13	Short Gravity	42.28522N 72.89116W	6.2	X	X			X#	
LLSC2	7/2/13	Short Gravity	42.28399N 72.89046W	12	X	X				
LLSC3	7/2/13	Short Gravity	42.28529N 72.89030W	11.5	X	X		X		
L1D1	7/9/13	Long Push	42.17028N 72.53230W	9.2	X	X	X		X#	X
L2D1	7/9/13	Long Push	42.17000N 72.53200W	11.7	X	X	X	X^	X#	
L3D1	7/9/13	Long Push	42.17023N 72.53208W	12.3	X	X	X			
LVS16D2	7/17/13	Short Gravity	42.28374N 72.89124W	4.5	X	X	X	X^		
LL12*	10/26/13	Long Push	42.27511N 72.88431W	17	X	X	X			X

* Collected by Brian Yellen
^ Run at Mercyhurst University
+ Run at Amherst College

Table 1. Details on the coring attempts in Littleville Lake with latitude and longitude accurate within +/- 3m. The lab methods were run at the University of Massachusetts, Amherst unless otherwise noted.

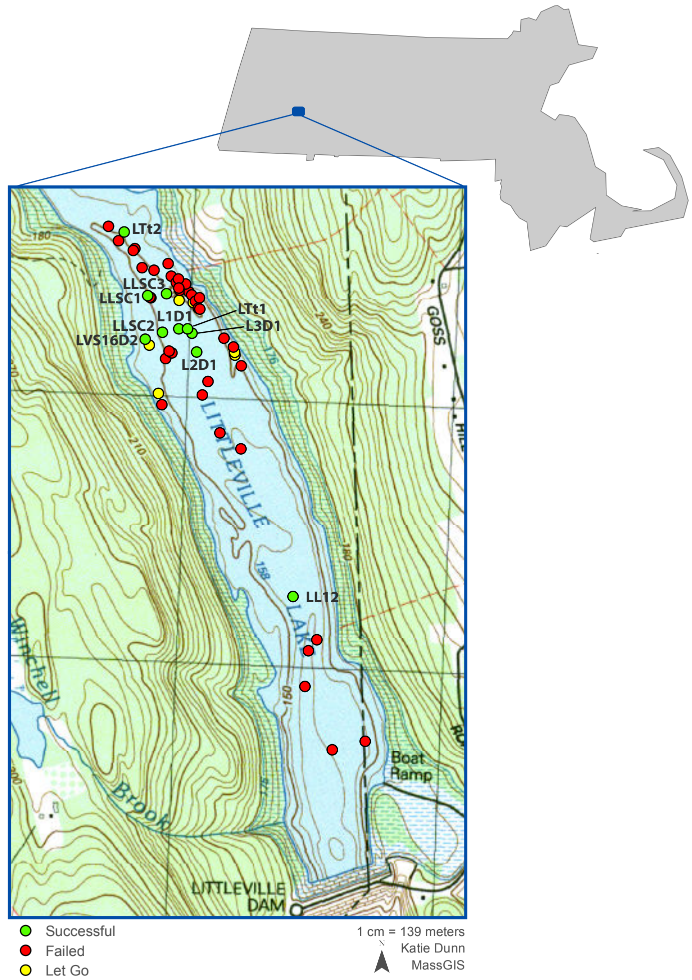

Figure 1. Coring locations shown on a topographic map of Littleville Lake

ARCGIS METHODS

Data such as precipitation and sediment yield were interpreted and presented using ArcGIS. I created a map showing coring locations that includes the location of the successful, let go and unsuccessful coring attempts (Fig. 1). Using ArcGIS I delineated the watershed.

Using the Irene thickness found in my cores, I interpolated the data over the entire reservoir and calculated sediment yield. I was able to interpolate using the thickness of the Irene sediment and the location in which it was cored. I calculated the volume of each pixel, and added them together to find the volume of all the pixels. Then I calculated the total volume of sediment trapped behind the dam using the porosity of the Irene layer in the cores. This allowed for the total mass of sediment to be found. By dividing the total mass of the sediment by the area of the watershed, I found the specific sediment yield.

RESULTS/DISCUSSION

Discharge data shows that 2011 had a high springtime flow, but an incredibly heavy discharge rate in late August and early September (Unites States Army Corps of Engineers). The maximum discharge on the west branch of the Westfield River during Irene was 1,023 m^3/second.

The sediment cores show a few general trends. Both L1D1 and L2D1 show sharp spikes in Hg concentration about halfway up the core, most likely representing the dam closure in 1965. The Irene layer in both of the cores shows a strong dip in Hg concentration. These two points were used to calculate a 0.43 cm/year sediment deposition rate in L1D1 and 0.8 cm/year rate in L2D1. The amount of deposited Irene sediment was small, but not insignificant. Considering that the time scale from the cores suggests that the rate of sediment deposition in Littleville is between 0.4 and 0.8 cm/year, a 3 cm Irene layer is substantial. This means that Irene deposited more sediment in a few days than is usually deposited all year. Grainsize data shows that much of L2D1 was medium silt to fine sand.

A thin layer of grey sediment was seen towards the top of four of the sediment cores. LOI results show these thin grey layers to have a slightly lower organic percentage in cores L1D1, L3D1 and LTt1. Grainsize data in L2D1 also shows that this grey layer had finer grains than the sediment surrounding it (Fig. 2). These results are consistent for the Irene layer found in Woodruff et al, (2013a).

Compositional differences in the sediment also act as tools for differentiating Irene from the rest of the sediment. Potassium and zirconium signatures are compared to the resulting X-ray images from the XRF (Fig. 2). The K peak and Zr dip at the identified Irene layer are consistent with the finding in Woodruff et al. (2013a). This XRF data suggests that the sediment deposited by Irene was K rich and Zr deficient, which signifies that it came from unweathered glacial tills. This X-ray acts as a density image showing the Irene layer as a dark band, signifying high density.

Using the thickness of the Irene layer and the calculated porosity from my samples, I was able to calculate an estimated specific sediment yield for Tropical Storm Irene of 282 kg/km^2. This is relatively low compared to the 1,000 mg/L of sediment eventually deposited at the mouth of the Connecticut River (Kratz, 2012). It is hard to determine sediment yield from Littleville Lake during Tropical Storm Irene because there is no suspended load data from nearby United States Geological Survey or United States Army Corps of Engineers stream gauges. Interpolating Irene sediment deposition in the reservoir is not accurate because the data are coming from four cores that are close to one another. I attempted coring at many locations around the reservoir, but numerous core barrels came back empty or shattered from potentially hitting bedrock. Some of the coring attempts were successful in capturing sediment, but not in capturing Irene. ArcGIS took this cluster of successful Irene cores to mean that there is only one small pocket of Irene sediment in the reservoir and that everything else is bedrock or sediment that does not contain Irene. This could be the case, but it resulted in the low specific sediment yield of 282 kg/km^2. More data would likely result in a more reasonable Irene thicknesses throughout the reservoir.

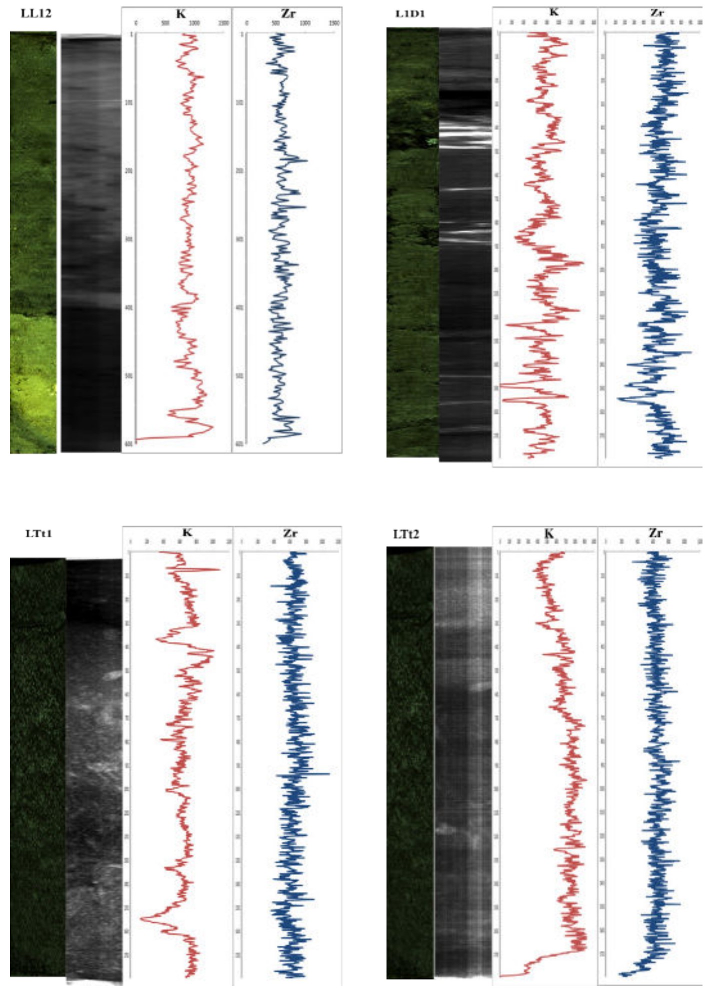

Figure 2. Optical images of cores LL12, L1D1, LTt1, LTt2 compared next to the XRF produced images and the K and Zr signatures. The lighter layers in the X-ray represent denser material.

A possible explanation for the missing sediment in the reservoir is drawdown. Drawdown would explain why many of the cores did not contain the recent Irene sediment, or any sediment at all. However, if drawdown were forcing the sediment to erode and be carried through the dam, then the most erosion would be seen on the delta side of the lake. Yet, we see that the only pocket of sediment in the entire lake is on the delta side (Fig. 3). And according to the data provided by the Army Corps of Engineers, the amount of drawdown occurring in Littleville Lake is almost negligible. This suggests that drawdown is not the explanation for the missing sediment.

Figure 3. Irene sediment deposition in Littleville Lake shows that there is a pocket of sediment on the northern side of the reservoir.

A more likely scenario is that Irene sediment deposition only occurred on the delta side of the lake. This is likely due to the discharge dynamic and sediment carried by the storm. When Irene hit the Littleville watershed, roughly 50% of its precipitation instantly became runoff (Woodruff et al., 2013a). This resulted in large volumes of water flowing down the Westfield River. By the time this water reached Littleville Lake it was probably moving at a relatively high velocity. At these high speeds it would have been hard to deposit any sediment. As a result, the Irene sediment flowed straight through the dam without depositing. After a day or two, the storm passed and the rain let up, causing the water velocity to slow down and the Irene sediment to settle out and deposit on the delta side of the reservoir. The slightly coarser than Woodruff et al. (2013a) Littleville Irene sediment also suggests that this sediment was deposited in slowing waters. Silt is unlikely to deposit in a river with a discharge of around 1,000 m^3/second.

Tropical Storm Irene was an extreme weather event in the northeastern United States. The grey, fine grained, K rich, organic and mercury poor sediment deposited suggests unweathered glacial tills to be the source material. Because of heavy rains in the previous month, the runoff from Irene traveled over saturated soil, picking up sediment and weathering as it went. This storm shows a preview of what extreme weather events could look like in the northeastern United States in the face of climate change. Tropical Storm Irene shows a future with decreased snow cover and increased soil exposure. Results could include less dangerous flooding if occurring in dry months, but devastating floods and deep erosion in the wet months.

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