The Horseshoe Pond Sediment Project and
The Mystery of Sediment Accumulation Rate in Kezar Lake

The Kezar Lake Watershed Association (KLWA) Climate Change Observatory (CCO) has been taking sediment cores from Kezar Lake and Horseshoe Pond over the last 5 years. Our purpose is to better understand observed watershed trends by determining environmental conditions in the watershed over the past 200 to 1000 years. When sediment cores were taken in Kezar Lake in 2015, a key finding was an unexpected exponential rise in sediment accumulation rate since 1980. In an attempt to solve this mystery, the CCO decided to take cores in Horseshoe Pond for comparison. Horseshoe Pond is a small and tranquil pond in the same watershed This article focuses on the coring and added Ground Penetrating Radar (GPR) activities conducted in Horseshoe Pond in February 2020.

Introduction

A key observation of the Kezar Lake cores was the exponential rise in sediment accumulation rate (cm per year) since 1980 as shown in Figure 1. The cause of this dramatic rise in the sediment rate is a mystery. In comparison with the sedimentation rate from 1890 to 2000, we concluded that the usual sources from atmospheric fallout, erosion from land disturbances and internal processes in the water body have not been a factor since 2000. Consequently, our team of researchers and volunteers hypothesized that in the absence of huge amounts of sediment from the usual sources, the rise in the rate might be due to increased boat wakes in the lake eroding the shoreline and stirring up bottom sediment in shallow water. Since Horseshoe Pond has virtually no boat wakes, we expect comparing its rate to Kezar's could help determine why we're seeing the dramatic rise in the rate of sediment accumulation in Kezar. A full report on the results of the Kezar Lake coring can be found in the 2016 CCO Annual Report (available on the KLWA website). The Horseshoe Pond coring is still being dated and analyzed and the results, along with added ground penetrating radar data, should be available in late 2020.

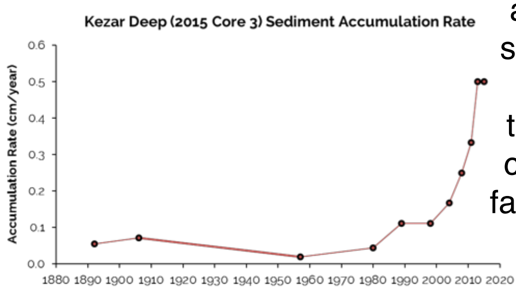

Fig. 1. Sediment Accumulation Rate, Kezar Lake 2015, Core3

So, a project was planned to measure the sediment rate in Horseshoe Pond. Two cores were taken in July 2019 but turned out to be not long enough, so two additional cores were taken in February 2020.

A fortuitous opportunity arose as we were planning the winter coring. Dr. Steve Arcone, an Adjunct Professor at Dartmouth College and the University of Maine Climate Change Institute, offered to do a ground penetrating radar (GPR) profile of the Pond while the coring was being done.

The technical leader for the coring was Dr. Lisa Doner from Plymouth State University and the GPR work was led by Dr. Steve Arcone, mentioned above. KLWA volunteers included Heinrich Wurm, Michael Stastny and Tom Hughes. A snowmobile was graciously supplied by Brian Fox

The GPR is pulled over the ice to create a profile of the sedimentary architecture of the pond sub-bottom. The radar data and the core data have a synergistic relationship and will be analyzed together when core interpretations are completed later this year.

There are many physical, chemical, ecological and biological reasons for studying lakes and the sediments beneath them. Coring provides point historical records of sedimentation rates, identifies sediment types, identifies cm-scale architecture of various types of deposits, and provides a chemical record of toxic chemicals, mineral biologic nutrients and even temperature. Our Kezar Lake coring project provided a sediment record dating back 1,000 years.

GPR profiles provide the sub-bottom geological architecture and, therefore, how those core sediments may be distributed in the lake and what deposition processes have been present. The sub-bottom geologic structure beneath lakes is determined using sub-bottom radar techniques. Where lake waters have very low electrical conductivity, radar signal penetration and return can exceed 20 m of water and 6 m or more of the sub-bottom. Ground penetrating radar systems emit short pulses of radio waves and profile the resulting reflection horizons as the antenna is moved along the water or ice surface. The reflections are caused by interfaces between sediments with various water contents, hence GPR is virtually a qualitative profiler of density changes. A core is then required to determine the density and water content of the sediments, from which signal velocity is calculated, so that echo time of return can be converted to depth.

Listed below are some important scientific questions that the cores and profiles might help answer. Some of these questions pertain to Dr Arcones geophysical work and some are relevant to understanding our mystery.

- How and when was the pond formed? Was it a kettle pond formed by a buildup of sand and gravel around a remnant ice block, a natural bedrock depression, or a glacial gouge into bedrock?
- What timeline does the core tell us? When was glacial till deposited and when did the ice sheet recede from this core site? What processes occurred during the 2000–3000 years after ice recession but before vegetation began? What was the sequence of vegetative species that took hold and how fast did they grow and spread?
- What generally caused sediment deposition? Was it day-to-day aerial and stream input, frequent runoff from week to week storms, intense pulses of spring runoff, severe storms like hurricanes, or earthquakes that liquefied surrounding sediments and started them flowing down to the pond? Is there a climatic signature within the cores; i.e., a noticeable repetition of events?

- What processes shaped the sub-bottom architecture? Did earthquakes cause slumps and if so, how can a slump differentiate from a local glacial moraine dump, or a kame (a steep-sided mound of sand and gravel deposited by a melting ice sheet)?
- Were there dynamic turbidity currents launched by storms, or debris flows?

Note: The answers to some of these questions can come from cores and profiles obtained from other New England lakes with similar geological profiles allowing us to extrapolate results and infer similar conclusions for Horseshoe Pond. Our preliminary conclusion here is that the sedimentary architecture of Horseshoe Pond has not resulted from any unusual and constant processes such as landslides that might bias the Horseshoe Pond-Kezar Lake comparison.

Taking the Cores and Running the GPR Sled

The operational processes for this project began on Saturday February 8th when Heinrich and Tom met Steve Arcone, at Horseshoe Pond. The GPR equipment was deployed on the ice and the process or walking the first of 4 cross-pond transects began, pulling the ground radar antenna/sled across the ice. See photo of this process in Figure 2.

Fig. 2 Ground Penetrating Radar in Action

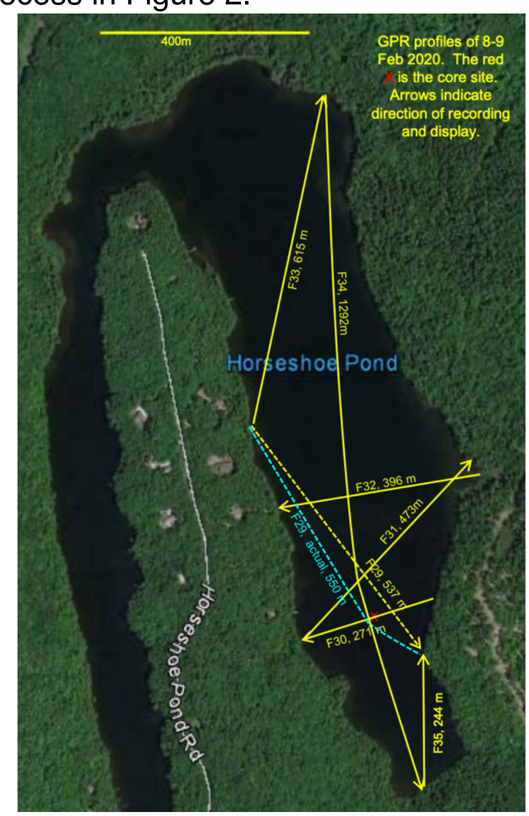

Fig 3: Map of transects obtained for GPR

There was a nice crust on top of the snow and the sled was easily pulled. The outstanding weather was sunny and bright all day, with little if any wind.

The first transect passed through the location of the 40' deep hole in Horseshoe Pond. After completing the first transect, three additional cross pond transects were imaged in different locations. GPS coordinates were marked at all transects termination points. Heinrich and Tom alternated pulling the sled for about 2 miles for the 4 transects. A map of Horseshoe Pond showing these transects (and the ones done on 9 February) is shown in Figure 3.

On Sunday February 9th Heinrich, Mike and Tom met the PSU contingent, Dr. Lisa Doner and her assistants, Melissa and Sydney at about 10:15 A.M. at Horseshoe Pond. Dr. Arcone returned for some additional transect runs.

The core sampling gear was loaded into three sleds and everyone pitched in to pull the sleds across the ice to the same site as the mid-summer 2019 core sample.

Fig. 4 Dr. Lisa Doner and crew, Mike Stastny and Leigh Hayes visiting

Two holes were bored through the ice and depth readings taken. The PSU team laid out the coring gear (Figure 4) at each of the two locations and the coring process for the first and largest core sample got underway. The process went without a hitch and an 88 cm core sample was retrieved and secured. (Figure 5) The largest core sample retrieved last summer was 28 cm, so this sample was a big improvement.

Fig. 5. Feb. 2020: 88 cm Core from Horseshoe Pond

While the core sampling was underway, Heinrich and Tom along with Dr. Arcone used a snowmobile to make several additional transits with the GPR. The total number of transects for both days are shown on the map in Figure 3.

Fig 6. Core 2: Pushing the pipe assembly into the sediment.

With the first core sample secured, the team moved to the site for the second sample. The second sample process used a different approach in that a sediment container was attached to a connected series of pipes that were lowered to the bottom. When the container reached the bottom, the team pushed the container into the sediment. (Figure 6). That work went well, and the smaller core sample was retrieved.

The process for securing and preserving the cores was completed and a little after 2:00 PM, the core samples were placed in a sled along with all of the remaining gear for the ride back to the parking area. Again, the weather was bright and sunny with only some light wind which greatly facilitated the whole operation.

Tom, Lisa, Melissa, Sydney and Steve drove the short distance to the Hughes Camp to relax and recap the day's events over hot soup and sausage bread and great conversation. The project was deemed a complete success. KLWA is very appreciative of the work of all the participants and the Edmonds for use of their property to launch the sleds.

The results of the GPR analysis

A summary of Dr Arcone's analysis of the profiles generated by the GPR are presented below. The complete report by Dr. Arcone is available here.

Preliminary analysis shows that the GPR penetrated the ice, the water and several layers of bottom materials up to about 20 feet deep. It appears that Horseshoe Pond was formed by glacial gouging some 22,000 years ago. The pond looks like an ancient Fjord gouged out of bedrock and the GPR suggests an even narrower channel. As the glacier retreated to the area of Horseshoe Pond about 14,600 years ago, it deposited boulders, rocks and other debris called till that is estimated to be about 5 meters thick. On top if this till, various erosion processes driven by storms and hurricanes as well as atmospheric depositions and earthquakes have layered about 7 meters of sediment on the bottom called gyttja. So, with 12 meters of water, 7 meters of organic sediment (gyttja) and 5 meters of till, the bed rock in Horseshoe Pond is estimated to be at least 24 meters deep or about 80 feet, nearly twice the current depth of the water.

This sediment contains an exquisite environmental history throughout the last 12,000 years. While we only need a few hundred years of the environmental history to try to resolve our sediment rate mystery, an understanding of the larger picture can be helpful.

There are many forces and processes at work in forming the structure of the bottom of the pond that Dr Arcone discusses in his report. His report contains several GPR profiles with annotations as to the key features. He has also provided considerable insight into what the interpretations of the GPR profiles are revealing. Figure 7 below is a view of one of the profiles to give a feel of what a GPR image looks like. This profile is transect number F30 running East to West right by the deep hole where the core was taken. Dr Arcone was pleased with the GPR results because of the excellent radar signal sub-bottom penetration due to the extremely low conductivity of the water, and by implication, that of the sub-bottom sediments.

Dr. Arcone's main interest in Dr. Doner's core is its profile of water content and density, in order to calibrate sub-bottom radar signal velocity, the occurrence of sandy layers and how they are stratified to verify his interpretation of turbidites, and of course, dates. Although Dr. Doner's core is only 88 cm long it should be sufficient to have recorded any severe storms over the last few hundred years. Dating the organics around these layers will show when such storms occurred. The synergy of the analysis of the core data along with the GPR data provides an enhanced understanding of the environmental history of Horseshoe Pond.

The report also contains a map of the glacial recession progress in New England. Please read the report for the full explanation of this and the other profiles.

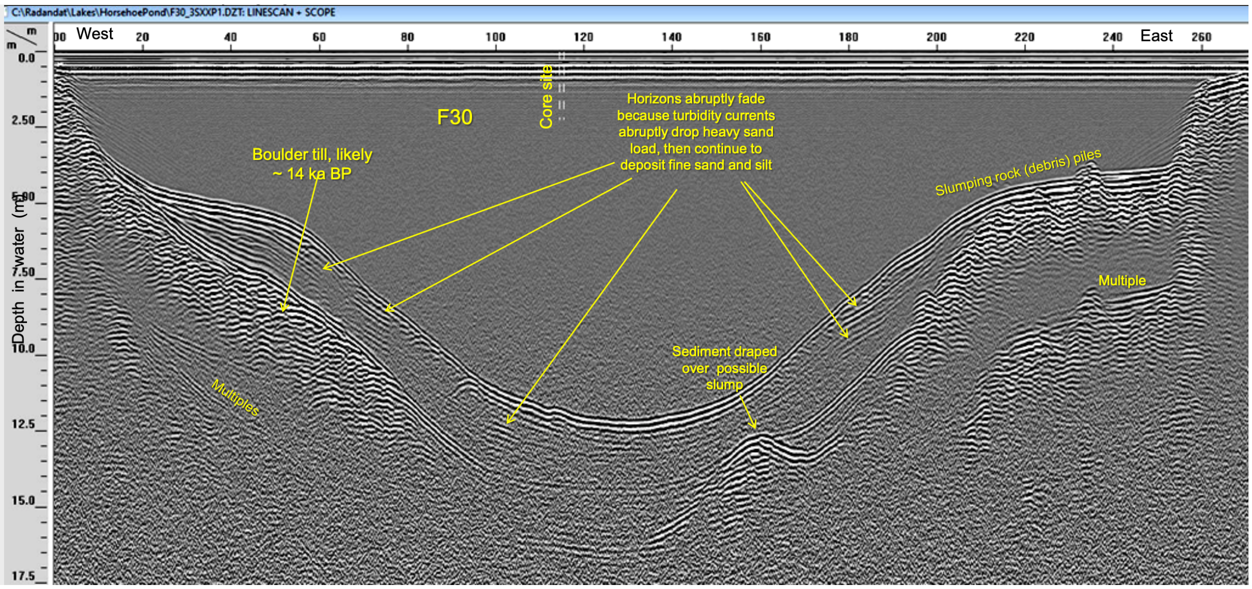

Fig 7. GPR Profile for Transect F30.