Changes in the Depth of the Lower Charles River Basin

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Abstract

The Lower Charles River is a 14.5 km long body of freshwater that is heavily used for recreation. In response to concerns about sediment deposition and shoaling incidents, The Charles River Alliance of Boaters (CRAB) and MIT Sea Grant College Program created the first detailed bathymetric chart of the river since 1902, using consumer-grade fish-finder sonar and GPS electronics, inexpensive water level loggers, and off-the-shelf charting software. The methodology to measure the water depth and create the chart is briefly discussed. The resulting chart presents an objective model of the river bed, revealing shallows, bars, and trenches of importance to boaters, and serves as a baseline for further study of sedimentation. Comparison of this new chart to the available historical record illustrates how the riverbed has changed since the original Charles River Dam was built.

Introduction

The Charles River in eastern Massachusetts flows along a meandering 80 mile path from Echo Lake near Hopkinton to Boston Harbor. Below the Watertown Dam, the Charles River Basin has become one of the busiest recreational rivers in the country, if not the world, with more than 20 facilities dedicated to rowing, sailing, paddling, and power boating. On a typical day from April to October, more than 6000 rowers and several hundred sailors are on the water. The lower end of the Basin is home to the MIT Sailing Pavilion, the birthplace of collegiate sailing and the most active college sailing venue in the nation, to Community Boating, the oldest and one of the largest public sailing programs in the country, and to Union Boat Club, the third oldest rowing pavilion in America. At the upper end of the Basin is Community Rowing, one of the largest rowing programs in the country. The Basin is also the venue for weekly collegiate and scholastic rowing regattas as well as the Head of the Charles, the largest two-day rowing event in the world, attracting over 11,000 athletes and thousands of spectators.

As is common with rivers that have been dammed, deposition of sediments has become a problem over time. In recent years, sediment deposits have contributed damage to watercraft and personal injuries, while also threatening the viability of several facilities. Despite the river's importance to the region, it lacked a current and comprehensive depth chart, complicating efforts in long-term planning. To address this issue, the Charles River Alliance of Boaters (CRAB) and MIT Sea Grant College formed a partnership in 2015 to chart the river depth between the Charles River Dam and the Watertown Dam, a distance of 9 miles.

Methods

The water depth was measured using a Lowrance HDS-7 chartplotter/fishfinder with Point-1 GPS and HST-WSBL 200 KHz broadband sonar transducer[1] at a rate of 10 Hz, with sonar range and sensitivity in "Auto" mode, along the driven track lines. To obtain the depth relative to the design height of the watersheet, a correction was applied to the measured sonar data corresponding to the difference in the measured height of the watersheet and the design height of 107.5 ft. MA MDC base. The height of the watersheet was measured using Onset HOBO Model #U20L-04 Water Level Data Loggers installed at three locations 2.5 (Riverside Boat Club), 4.8 (Herter Park), and 6.4 (Community Rowing) miles upriver from the USGS First St. gauge station in 2016. Data from an additional logger above the water line was used to correct water level data for variations in atmospheric pressure. In 2017, a fourth logger was installed at First St. Charts were developed using ReefMaster and ArcGIS/ArcMap software.

Results

The measured depth chart [Figure 1] is available to the public in various formats including a GIS map, a Google map, a KMZ file suitable for Google Earth and some navigation instruments, a chart booklet similar to that published by NOAA, and a wall chart.[2]

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[1] "Determining Bathymetry of the Charles River Basin Using Cost-Effective Tools", by Michael J. Sacarny, Carl Zimba, Madonna Yoder, Ben Bray, and Chryssostomos Chryssostomidis, https://eos.ucs.uri.edu/seagrant_Linked_Documents/mit/Cost-effective_Bathymetry.pdf, 2018.

[2] GIS map: https://mit.sea-grant.net/maps/charleschart/
Google map: https://drive.google.com/open?id=1ARLFwNKFNv1Y9KO12lbVoKjRJB8&usp=sharing

Discussion

Since the founding of Boston and Cambridge in 1630, the Charles River has undergone many changes transforming it from a vast tidal estuary to the enclosed fresh water lake of today. While the river above the present-day BU Bridge follows the same path, it is now spanned by almost a dozen bridges and the shorelines have become tamer and more sculpted. Between the BU Bridge and Boston Harbor, the river has undergone vast changes with much of the former estuary filled to create land in both Boston and Cambridge.

In this lower portion of the river below the BU Bridge, there have been several periods of damming and land creation:[3,4,5] 1640's: Mill Pond Dam across the Mill Cove, 1808 to 1811: creation of the Bulfinch Triangle by filling the North Cove, 1818-21: creation of the Great Mill Dam and the Cross Dam in the Back Bay, 1850-1880 filling of the Back Bay, 1865-1870: creation of the Cambridge Embankment, 1881 to 1884: filling of the area between Back St., Deerfield St., and the Cross Dam, 1905 to 1910: creation of the original Charles River Dam, and the Boston Embankment, 1931 to 1934: widening of the Boston Esplanade, Charlesbank, and land west of the Harvard Bridge, 1951 to 1952: a second expansion of the Boston Esplanade to compensate for the construction of Storrow Drive, 1970: creation of the present-day Charles River Dam. Except for the Mill Cove and filling the Back Bay, each of these land-making efforts involved dredging material from the river bottom to use as fill.

At present, there are four areas of the Lower Basin (between the New Charles River Dam and the Watertown Dam) that are a concern for sedimentation: Muddy River and Stony Brook Outlet, Magazine Beach, Faneuil Brook Outlet, and Sunset Bay. In addition, dredging to form part of the Boston Esplanade has left canyons of deeper water in the Sailing Basin between the Harvard and Longfellow Bridge.

Muddy River and Stony Brook Outlet

This is a broad and shallow delta-like feature approximately 150 feet north of the outflow culverts for the Muddy River and Stony Brook [Figure 2]. The shallowest area is 1-2 feet below the water surface and is firm enough to walk on. Sample dredging indicates that the material is fine stone and sand. While shallow enough to be a hazard to navigation, it is in an area of the river that is not used by the typical user and does not pose a hazard to the informed user. It was initially discovered by the Boston University sailors when they went aground on it more than 15 years ago. The current state is quite similar to what existed in 1946,[6] prior to the dredging[7] of a trench 700 feet long, 50-75 feet wide, and 11 feet deep, perpendicular to the shore from near the Fens Gate House.

KMZ file: http://www.charlesriverallianceofboaters.org/chart/charles.kmz
Chart booklet: http://www.charlesriverallianceofboaters.org/chart/isobaths.pdf
Wall Chart: http://www.charlesriverallianceofboaters.org/chart/wall.pdf

[3] Gaining Ground: A History of Landmaking in Boston, by Nancy Seasholes, MIT Press, 2018.
[4] Inventing the Charles River, by Karl Haglund, MIT Press, 2002.
[5] Mapping Boston, by Alex Krieger, MIT Press, 2001.
[6] Dredging Near Charlesgate East and at Culverts from Ashby St. to Berkeley St., http://www.CharlesRiverAllianceofBoaters.org/chart_archive/DCR/1946_27344_2_Dredging_near_Charlesgate_East_dcr.tif. Accessed 27 Sep. 2019.
[7] Metropolitan District Commission Minutes, Sept. 12, 1946, Item #5, https://archive.org/details/metropolitandist16mass/page/n333. Accessed 27 Sep. 2019.

Magazine Beach

There is a shallow region spanning the entire width of the river in the area of Magazine Beach [Figure 3], near the proposed realignment of I-90 and Soldiers Field Road in Allston. Compared to an engineering survey done in 1920[8,9] for a potential bridge connecting Magazine Street in Cambridge to St. Paul Street in Boston, it appears that the area is 4-6 feet shallower now than in 1920. While the current water depth in this area has not hampered use of the water sheet, the depth is likely continuing to decrease. Future monitoring of the water depth in this area is warranted.

Faneuil Brook Outlet

Faneuil Brook empties in the Charles River on the south bank between the Arsenal St and North Beacon St bridges. Over the last few decades, a significant bar formed that reduced in half the width of the river. While much of the bar was just below the water surface, presenting a significant hazard to the typical boater, the bar could also become exposed when water levels were low water [Figure 4]. Due to the narrowness of the river, this sandbar was the cause of several collisions and groundings involving damage to boats and injury to people. Fortunately, two years ago, this bar was dredged, restoring the river depth and eliminating the safety dangers that the sandbar was causing. This outfall was dredged previously in 1921[10] and 1936[11]. Dredging was contemplated but not done in 1954[12], 1965[13], and 1976[14]. This area was dredged to restore the depth to the surrounding river bottom in 2016[15]. There seems to have been some refilling of this dredged area four years later. This outfall will need to be periodically dredged in the future, as it has over the past 100 years.

Sunset Bay

The most threatened area for sedimentation is Sunset Bay [Figure 5], the area west of the North Beacon St. Bridge where Community Rowing, Watertown Yacht Club, and Newton Yacht Club are. Today, much of the area in 2 feet deep or less, with a narrow channel of 3-4 feet depth. A vast portion of the area between Newton Yacht Club, Watertown Yacht Club, and Community Rowing is too shallow for motorized vessels to pass safely. Both Watertown and Newton yacht clubs have already lost dock space due to the sedimentation and some boaters are unable to move their boats is the water level of the water sheet is lower than average. There has also been quite a bit of sedimentation under the docks of Community

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[8] Plan of Charles River, MDC 277. EN4.04/series 622. Metropolitan District Commission, Division of Parks Engineering. Massachusetts Archives. Boston, Massachusetts.
[9] Metropolitan District Commission Engineering Department Field Notebook No. 297, pp. 1-22, Massachusetts Department of Conservation and Recreation Archive, 1921.
[10] Metropolitan District Commission Minutes, Sept. 15, 1921, Item #4, https://archive.org/details/metropolitandist02mass/page/38. Accessed 27 Sep. 2019.
[11] Metropolitan District Commission Minutes, Sept. 3, 1936, Item #2, https://archive.org/details/metropolitandist12mass/page/44. Accessed 27 Sep. 2019.
[12] Metropolitan District Commission Minutes, Dec. 6, 1956, Item #6, https://archive.org/details/metropolitandist25mass/page/156. Accessed 27 Sep. 2019.
[13] Plan for Dredging Charles River, Faneuil Valley Brook Outlet, 1965, http://www.charlesriverallianceofboaters.org/chart_archive/DCR/1965_C-1936_22706_Dredging_Charles_River_Fanueil_Valley_Brook_Outlet_dcr.pdf
[14] Engineering survey of Charles River near the Faneuil Brook Outlet, May 1976, http://www.charlesriverallianceofboaters.org/chart_archive/DCR/1976_Charles_River_Fanueil_Brook_Plan_dcr.pdf
[15] Charles River Dredging - a 24 hour operation, 3/18/16, https://charter.us/2016/03/18/charles-river-dredging-a-24-hour-operation/

Rowing, especially at the western end near the boat ramp. Docks at Community Rowing that used to be in 2 feet of water when built in 2008 are now resting on mud.

In the past, the Sunset Bay area, between Watertown and Newton Yacht Clubs, was used as an anchorage since there was 8-10 feet of water. This is clearly evident in a USGS aerial photograph taken in 1952[16] and 1963[17]. According to MDC records, this area was subject to periodic dredging in 1914[18], 1932[19,20,21,22,23], 1948[24], and 1956[25]. In general, the dredged depths were at least 6 feet, allowing both the Watertown Yacht Club and Newton Yacht club to develop mooring fields and marinas in the 1960's. As late as 1970, depths of 8 feet or more were reported to be present upstream of the Nonantum boat ramp.[26] In 1998, Cortell and Associates found much of the area to have depths of 1-3 feet.[27]

> "A bottom profile of the lower basin between the new Charles River Dam and the Watertown dam is shown in Figure 3-14. The profile was prepared by Camp Dresser & McKee as part of its work on the destratification project in the basin [Camp Dresser & McKee Inc. "An Evaluation of The Removal of Salt Water from the Charles River Basin, August 1976]. Although the profile is updated in the Camp Dresser & McKee report, Jonathan French (CDM's Project Manager) reported that the soundings were apparently made sometime between 1967 and 1976. In the river reaches upstream of the MDC Nonantum Road public boat ramp, water depths of eight feet

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[16] Aerial View, Watertown Arsenal, ~1942-59, https://www.digitalcommonwealth.org/search/commonwealth:2n49vd897

[17] Aerial View, Watertown Arsenal, ~1963-67, https://www.digitalcommonwealth.org/search/commonwealth:2n49vq19d

[18] Metropolitan Park Commission Minutes, Sept. 10, 1913, Item #8, https://archive.org/details/metropolitanpark13mass/page/84, Accessed 1 October 2019.

[19] Proposed Dredging in Charles River near Watertown, Mass., and Newton, Mass., http://www.charlesriverallianceofboaters.org/chart_archive/DCR/1-A_20955_1_CRR_Charles_River_Dredging_North_Beacon_to_Galen_1932_dcr.pdf, Accessed 1 October 2019.

[20] Plan of Site A, Proposed Dredging in Charles River near Watertown, Mass., and Newton, Mass., http://www.charlesriverallianceofboaters.org/chart_archive/DCR/1-A_21259_2_CRR_Charles_River_Filling_Nonantum_1933_dcr.pdf, Accessed 1 October 2019.

[21] Plan of Site B, Proposed Dredging in Charles River near Watertown, Mass., and Newton, Mass., http://www.charlesriverallianceofboaters.org/chart_archive/DCR/1-A_20957_3_CRR_Charles_River_Dredging_Site_B_at_Maple_Nonantum_1932_dcr.pdf, Accessed 1 October 2019.

[22] Proposed Filling of Charles River in Newton, Mass., http://www.CharlesRiverAllianceofBoaters.org/chart_archive/DCR/1-A_21258_1_CRR_Charles_River_Filling_Nonantum_1933_dcr.pdf, Accessed 1 October 2019.

[23] Cross Section of Fill, Proposed Filling of Charles River in Newton, Mass., http://www.charlesriverallianceofboaters.org/chart_archive/DCR/1-A_21259_2_CRR_Charles_River_Filling_Nonantum_1933_dcr.pdf, Accessed 1 October 2019.

[24] Proposed Dredging and Shore Improvement, http://www.CharlesRiverAllianceofBoaters.org/chart_archive/DCR/1948_28010_2_Watertown_Dredging_Shore_Improvement_dcr.tif, Accessed 1 October 2019.

[25] Metropolitan District Commission Minutes, Dec. 6,1956, Item #6, https://archive.org/details/metropolitandist25mass/page/156, Accessed 1 October 2019.

[26] "An Evaluation of the Removal of Salt Water from the Charles River Basin", Metropolitan District Commission, Camp Dresser McKee, August 1976.

[27] MDC, Charles River Master Plan, Technical Memorandum, Users of the Water Sheet, Bathymetry and Aquatic Vegetation in the Charles River Basin, by Cortell Associates, December 1977, pages 3-1 and 3-2, http://www.charlesriverallianceofboaters.org/chart_archive/Other/Cortell_Findings_1997.pdf. Accessed 27 Sep. 2019.

or more were reported in the profile. In addition, the profile does not show any suggestion of the presence of the sandbar at BWSC Outfall 032 [Faneuil Brook]"

"While conducting this Master plan, interviews and site visits were held with the Newton Yacht Club and the Watertown Yacht Club. Both clubs reported that the shallow water depths and extremely dense aquatic vegetation have become so limiting that the ability for the yacht clubs to utilize their facilities is severely threatened. The shallow water situation is particularly severe at the Newton Yacht Club where it was reported that between 1985 and the present [12/30/1997], approximately three feet of water depth has been lost. Even at normal river stage of 108 ft, the water is barely deep enough to avoid propellers churning the bottom. Boats at the Newton Yacht Club often hit bottom in their berths. Water depths at the Watertown Yacht Club are slightly deeper, yet also threatening its operations."

"By comparing the profile data and the present soundings, it was found that an extremely high rate of sedimentation has resulted in the filling of approximately five or more feet of water over the past 20-30 years. The source(s) of the sedimentation is not known."

"In terms of the impacts to future navigation, sedimentation in the upper reaches of the basin has already reached the point of being a detriment to navigation by power boats. Such conditions were found at BWSC Outfall 032 [Faneuil Brook] and in upstream areas leading to the Newton and Watertown yacht clubs. The shallow water depths which in mid-river have been found to be approximately one foot, do not at present represent an impediment to rowers and canoeists. Dense vegetation growth, however, has an adverse effect on all users of the water sheet."

"While depth have changed dramatically, they may be in, or approaching. A steady state condition. This is due to the effect of decreasing water depth combined with recurring flow volume results in increased water velocity. As water over a given cross section becomes shallower, water flow velocity must increase thereby increasing the erosive velocity on sediments. In the future, suspended solids contributed to the river will merely accumulate over a larger area and extend further downstream."

The sedimentation cited in the Cortell and Associates report has continued over the ensuing years, 1997 to 2018, as measured in our depth studies. The areas near Newton and Watertown Yacht Clubs have continued to lose depth and the areas of usable depth have shrunk. The dense plant growth has continued and spread as the shallower areas have grown. The up-river docks at Community Rowing that were in 18-24 inches of water when the new boathouse was opened in 2008 are now resting on mud and silt. Sedimentation in this area is a threat to the future of both yacht clubs and Community Rowing.

Of these four areas where sedimentation is a concern, two are outflows of tributaries that carry material into the Charles. The other two areas of sedimentation involve changes from a narrow width to a significantly wider width. Between the Watertown Dam and Sunset Bay, the river has a width of 80 to 130 feet. At Newton Yacht Club, Watertown Yacht Club, and Community Rowing, the widths are 400, 800, and 350 feet, respectively. While the Lower Basin is essentially a lake with very little current under dry conditions, the increased discharge due to rainfall and runoff create increased stream velocities along the length of the river. In places, such as Sunset Bay, where the river transitions from narrow to significantly wider, the stream velocities decrease markedly due to the increase in cross-sectional area. As the stream velocity decreases, the suspended solids drop out of the water column, depositing on the river bottom. The area near Magazine Beach has a less dramatic widening from 330 feet in the linear Power

Stretch between the River Street and Western Avenue bridges to 625 feet at the widest, before becoming 500 feet wide further down river and 300 feet wide at the BU Bridge.

Sailing Basin

In the Sailing Basin between the Harvard (Massachusetts Avenue) Bridge and the Longfellow Bridge, there are four trenches with depths between 20 and 30 feet [Figure 6]. These trenches were not present in the detailed survey of 1902[28] and were created through dredging during the expansion of the Boston Esplanade in the 1930's and 1950's. It has been well-documented that some salt water travels from Boston Harbor into the river through the locks of the dam and that this denser salt water tends to sink to the lowests depths of the river basin and not mix with the overlying fresh water layer.[29] In addition, the salt water layer becomes oxygen depleted and does not allow the natural decomposition of plant matter on the river bottom to occur, resulting in a sulfurous-smelling muck on the river bottom. While the New Charles River Dam was designed to minimize the influx of sea-water, salt water still is introduced to the river with much of it becoming trapped in the deep water trenches. The influx of the sea water is seasonal, high in the summer season when recreational boats passing through the lock is highest and quite low in the winter when the lock is seldom used. High flows of fresh water from precipitation and runoff during and following storms cause the salt water to flush out of the river basin.[29] An open question is the influence of the deep trenches on the flushing of the salt water. Would the salt water be flushed out more effectively if the trenches were filled? Or would the salt water remain and merely be spread out over a larger area of the river bottom?

Environmental Impact

The shallower water resulting from sedimentation has likely had several impacts on the environment of the river. Foremost is an increase in the average temperature of the water. Increases in water temperature have been correlated to increases in the growth of cyanobacteria,[30,31] and may be partially responsible for the increase in cyanobacteria blooms in the Charles River Basin in recent years. It has been reported that cyanobacteria may become the dominant phytoplankton at temperatures above 25C.[32]

As observed in the Sunset Bay area, dense plant growth can become dominant when the water depth becomes shallow enough and sunlight can penetrate the water column. At these shallow depths, the plants prosper and grow to within several inches of the water surface, making it difficult for even rowers

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[28] Charles River Basin Contour Map of Lower Basin, River Street to the Craigie Bridge, *Report of the Committee on Charles River Dam*, 1903, http://www.charlesriverallianceofboaters.org/chart_archive/DCR/CR-Lower-Basin-Contour-Map-1902-Map3.pdf, Accessed 1 October 2019.

[29] Spatial distribution, temporal variability, and chemistry of the salt wedge in the lower Charles River, Massachusetts, June 1998 to July 1999, Water-Resources Investigations Report 2000-4124 by R.F. Breault, L.K. Barlow, K.D. Reisig, and G.W. Parker, 2000.

[30] Effect of Temperature on Blue-Green Algae (Cyanobacteria) in Lake Mendota, Appl. Environ. Microbiol. 1978 Oct; 36(4): 572–576.

[31] Nutrients and water temperature are significant predictors of cyanobacterial biomass in a 1147 lakes data set, Limnol. Oceanogr., 58(5), 2013, 1736–1746.

[32] Berg M and Sutula M. 2015. Factors affecting the growth of cyanobacteria with special emphasis on the Sacramento-San Joaquin Delta. Southern California Coastal Water Research Project Technical Report 869 August 2015.

and paddlers to use the water sheet. Increased plant growth in this area has likely led to further reduction in water flow, leading to more sedimentation.

Conclusion

It is clear that the Lower Basin of the Charles River is becoming shallower over time due to sedimentation from both the main stream and its tributaries. We have been able to demonstrate the changes in the water depth through new field measurements and a detailed comparison to historical data. If left unchecked and unremediated, the shallower water will result in

Acknowledgements

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References

List out references from the footnotes….

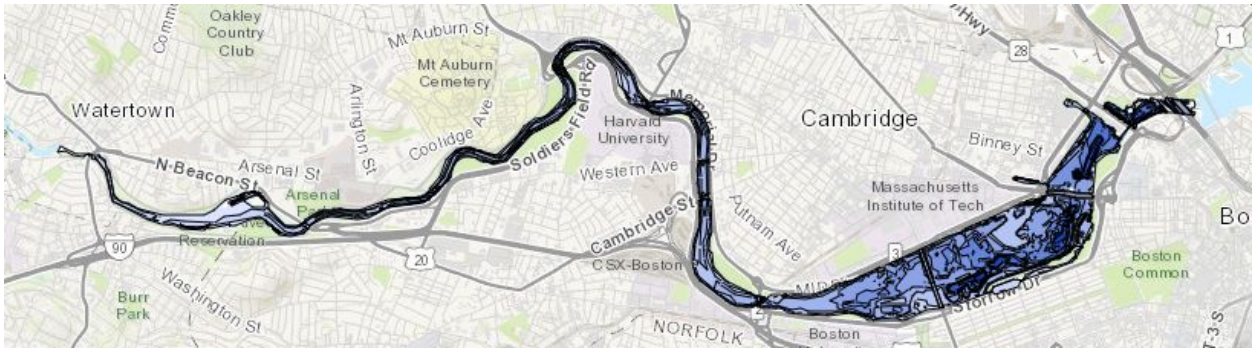

Figure 1. Depth Chart of the Lower Basin of the Charles River. This can be viewed in detail at https://mit.sea-grant.net/maps/charleschart/.

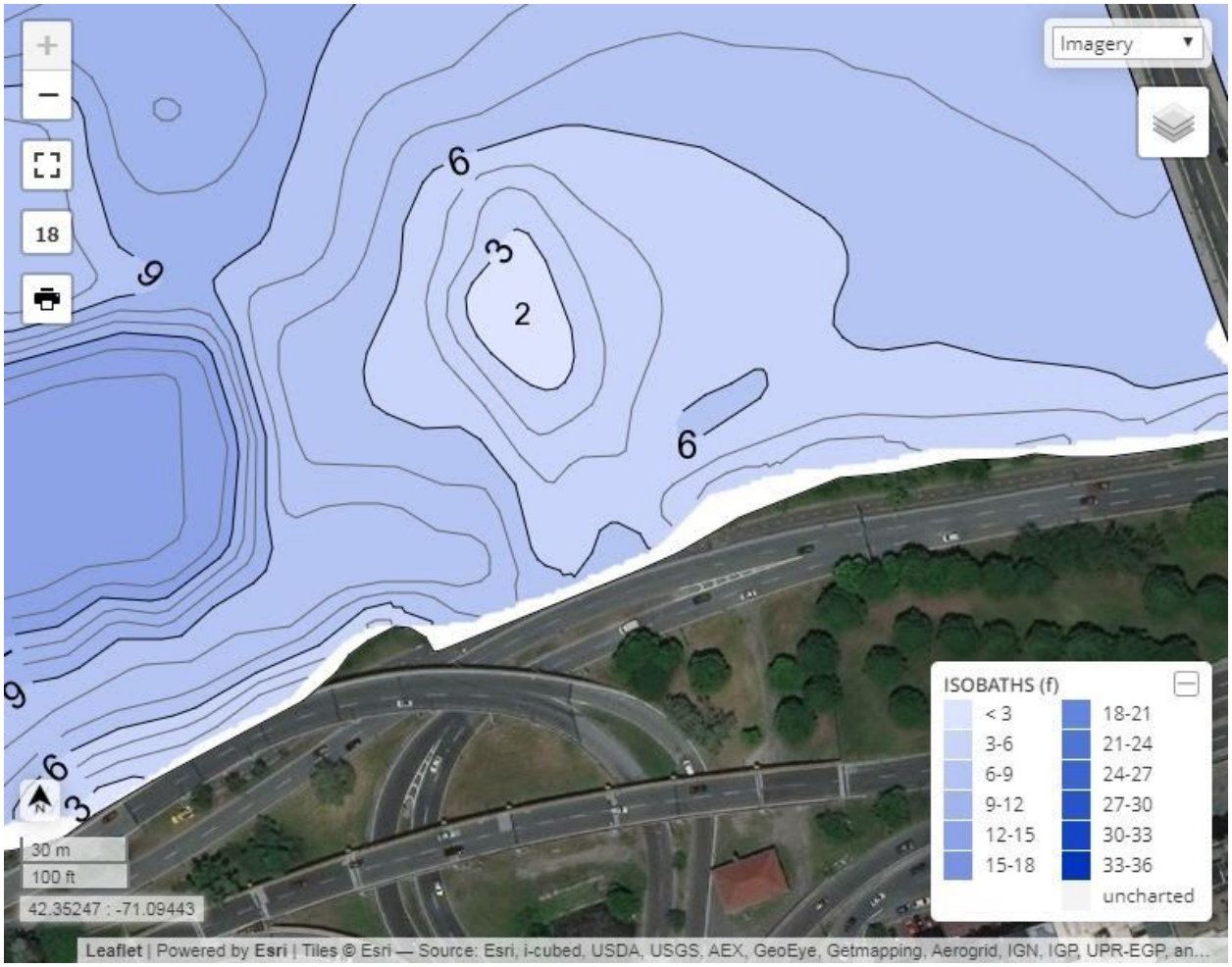

Figure 2. Depth Chart of Charles River near the outflow of Muddy River and Stony Brook.

Figure 3. Depth Chart of Charles River near Magazine Beach.

Figure 4. Faneuil Brook sandbar. [I'm looking for a better picture. This one may be copyrighted by the Globe.]

Figure 5. Depth Chart of Charles River near Sunset Bay. Watertown Yacht Club is the north side of the river, between the island and the main shore. Newton Yacht Club is on the south side of the river on the left (west) half of this image. Community Rowing is on the south side of the river, on the right (east) side of this image. North Beacon Street Bridge is located on the far right.

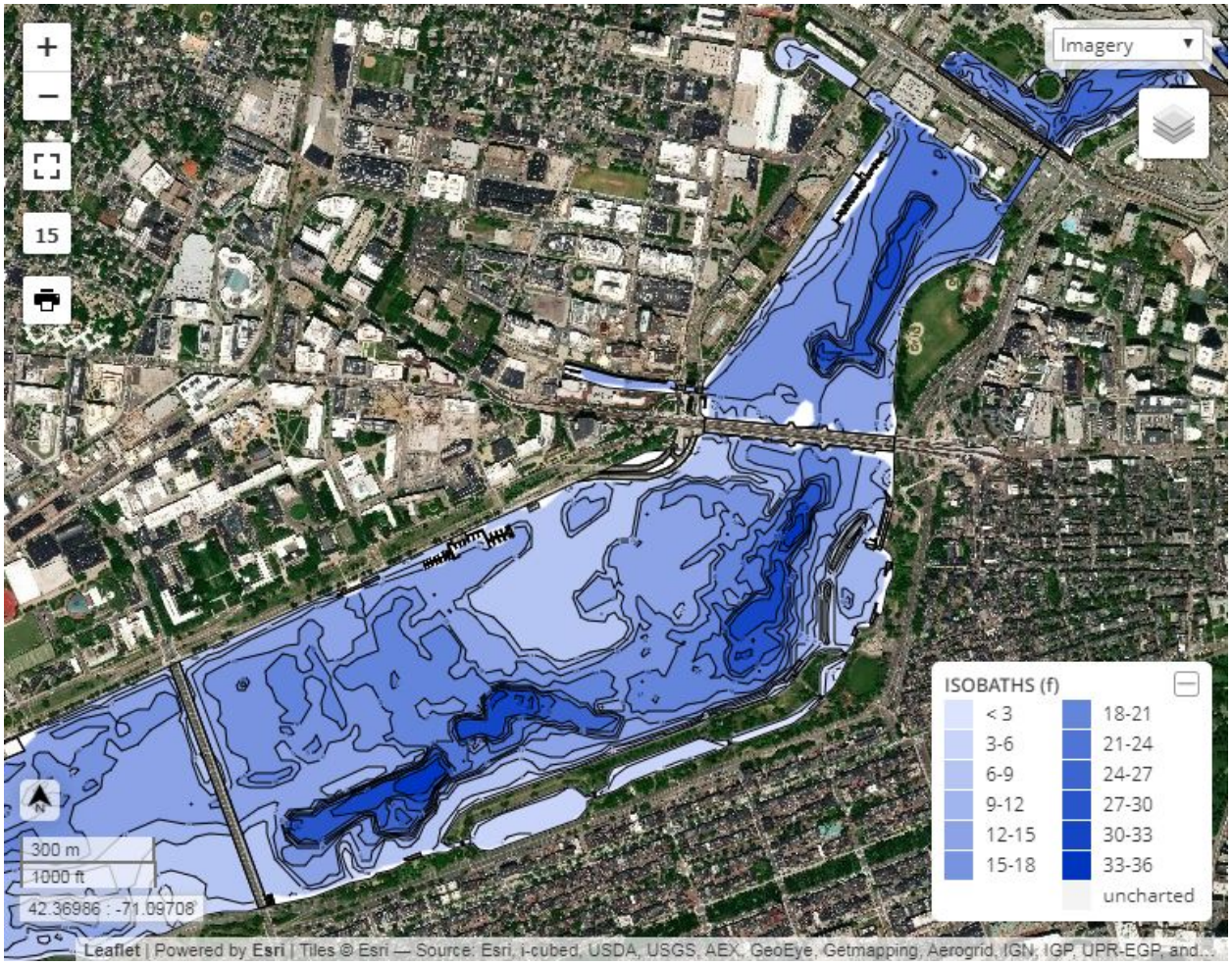

Figure 6. Man-made trenches in Charles River between the Harvard Bridge and the Charles River Dam.

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Original Reports of research results follow the structure of Title and Author Information,
Abstract,
Introduction (highlighting research questions and hypotheses),
Methods,
Results,
Discussion,
Acknowledgements, and
References.
Tables and figure legends follow the main text.