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Technical Memorandum

Prepared for: City of Worcester, MA

Project Title: Coes Reservoir Watershed Study

Project No.: 147291

Subject: Watershed Delineation and Bathymetric Survey

Date: August 31, 2015

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1.1 Introduction

This Technical Memorandum (TM) was developed by Brown and Caldwell for the City of Worcester, MA (City) as part of the Coes Reservoir Watershed Study (Study).

The Study had two primary goals:

- Delineate the watershed tributary to Coes Reservoir
- Perform a bathymetric survey of Coes Reservoir

This TM documents the results of the Study.

1.2 Physical Description

Coes Reservoir (Reservoir) is located in the City of Worcester, MA as shown in Figure 1. The Reservoir is fed by Tatnuck Brook through Williams Mill Pond at its northern end. Flows discharge from the Reservoir over a dam and enter Beaver Brook at its southern end.

The physical characteristics of the Reservoir are provided in Table 1. The maximum length/width, shoreline length, and surface area were developed using a GIS layer of the Reservoir provided by the City. The volume, average depth to sediment, average sediment depth and watershed area were developed as part of this Study and will be discussed in the Sections that follow.

Table 1. Coes Reservoir Data

Data	Value
Maximum length	4,000 ft[1]
Maximum width	1,400 ft[1]
Shoreline length	2.8 miles[1]
Surface area	91 acres[1]
Water volume	695 acre feet[2]
Average depth to sediment	8 feet[2]
Average sediment depth	1.5 ft[2]
Watershed area	3,618 acres[2, 3]

Notes:

1. *Source: GIS layer of Coes Reservoir provided by the City of Worcester*
2. *Source: Developed as part of this Study. Refer to Section 1.3 and1.4 for more information.*
3. *Watershed area upstream of the Holden Reservoir Number 2 outlet is not included. The watershed delineation performed as part of this Study did not extend further upstream.*

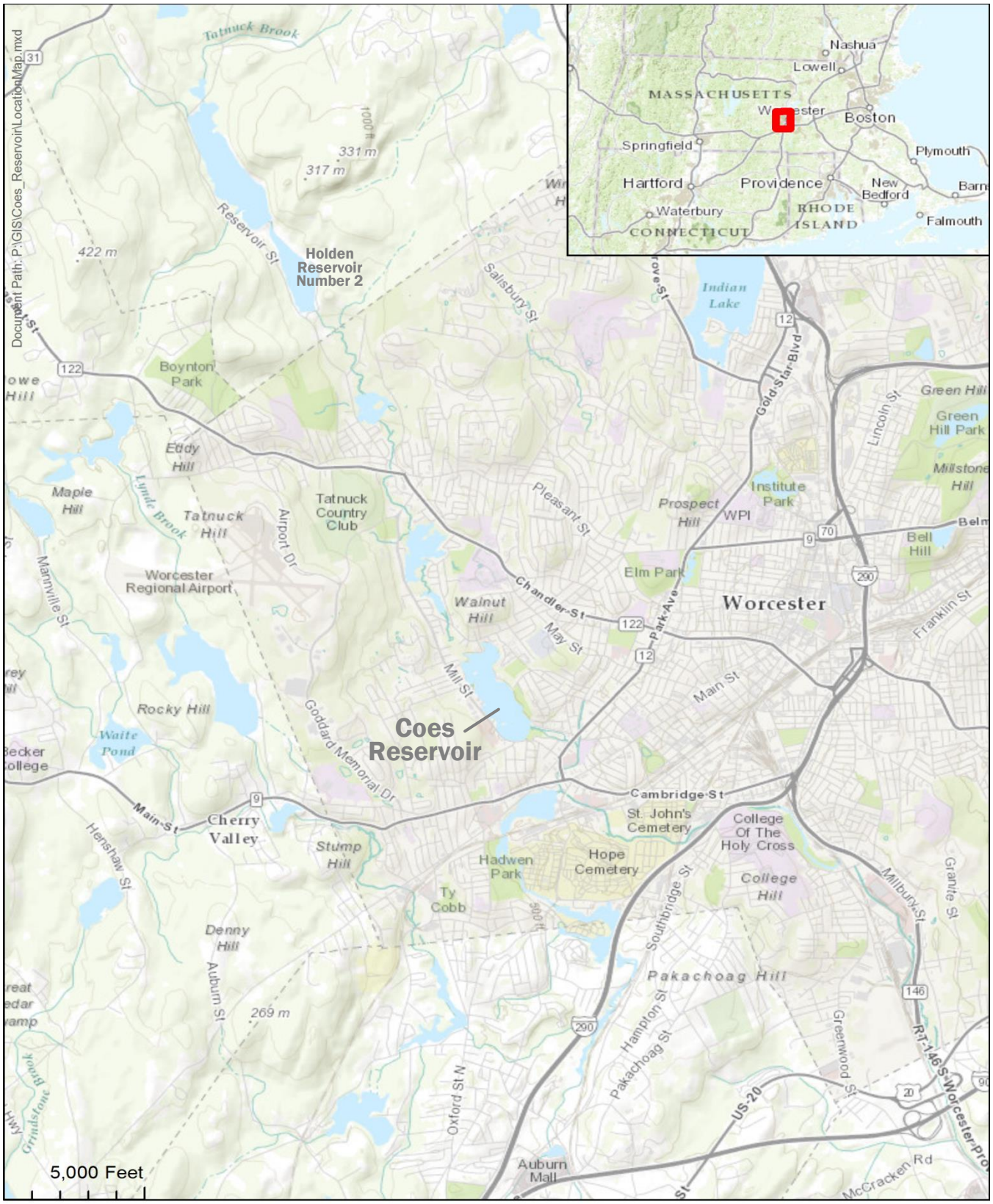

Figure 1. Coes Reservoir Location

1.3 Watershed Delineation

The Coes Reservoir watershed was delineated, and the watershed area was subdivided into catchments. One large subcatchment was delineated for the area upstream of the Reservoir, while smaller catchments were delineated for areas that drain directly to the Reservoir through storm drain outfalls and overland flow.

Approach

The watershed/subcatchment delineation was performed using the following GIS data provided by the City and MassGIS:

- Storm drain pipes (City)
- Storm drain catchments (City)
- Storm drain outfalls (City)
- Coes Reservoir shoreline (City)
- Contours (City)
- Digital elevation models (MassGIS)
- Mass DEP Hydrography (MassGIS)
- USGS Color Ortho Imagery (2013/2014) (MassGIS)

The watershed delineation proceeded in three steps:

- Step1 - The digital elevation models were used to create a surface drainage pattern GIS layer. An initial watershed boundary (inclusive of all of the subcatchments) was created by using the GIS to trace all of the land surfaces that drain to the outlet of the Reservoir. The trace was halted when it reached the outlet of Holden Reservoir Number 2.
- Step 2- The watershed boundary was modified by hand to adjust the drainage patterns due to the City's storm drain system. The City's storm drain pipes, catchments and outfalls were displayed on a map with the watershed boundary and the watershed boundaries were adjusted based on the subsurface drainage. The City provided clarification at a number of locations where the storm drain system characteristics could not be completely ascertained from the GIS data.
- Step 3 - The watershed boundary was manually adjusted using the orthoimagery. This helped to ensure that the boundary appropriately followed surface features such as roads, buildings, parking lots and other impervious surfaces.

After the watershed was delineated, the subcatchments that drain directly to the Reservoir were delineated. First, the subcatchments that drain to the Reservoir's outfalls were delineated. Then the subcatchments that drain to the lake by overland flow were delineated. The subcatchments were delineated using the same process as the watershed: the surface runoff patterns, storm drain system and orthoimagery were used to define the boundaries. The subcatchment upstream of the Reservoir was delineated by subtracting the watershed boundary from the boundaries of subcatchments that drain directly to the Reservoir.

Results

Figure 2 provides a map of the subcatchments that drain directly to the Reservoir while Figure 3 shows all of the subcatchments, including the one upstream of the Reservoir. At the outset of the Study, it was recognized that the watershed upstream of the Reservoir could be extensive. As a result, it was decided that the watershed delineation for Coes would not extend beyond the outlet of Holden Reservoir Number 2 (see Figure 1). This is close to the political boundary between the City of Worcester and the Town of Holden.

The outlet of the watershed is the Coes Reservoir dam. The area at the southeastern corner of the Reservoir is not included in the watershed because it drains to Beaver Brook which is downstream of the dam.

In total, 30 subcatchments were delineated, including the Reservoir's four islands. The total area of the water shed is 3,618 acres. 8% of the land area is attributable to subcatchments that drain directly to the Reservoir while 92% comes from the upstream subcatchment (Coes-US). Table 2 provides a summary of the subcatchments.

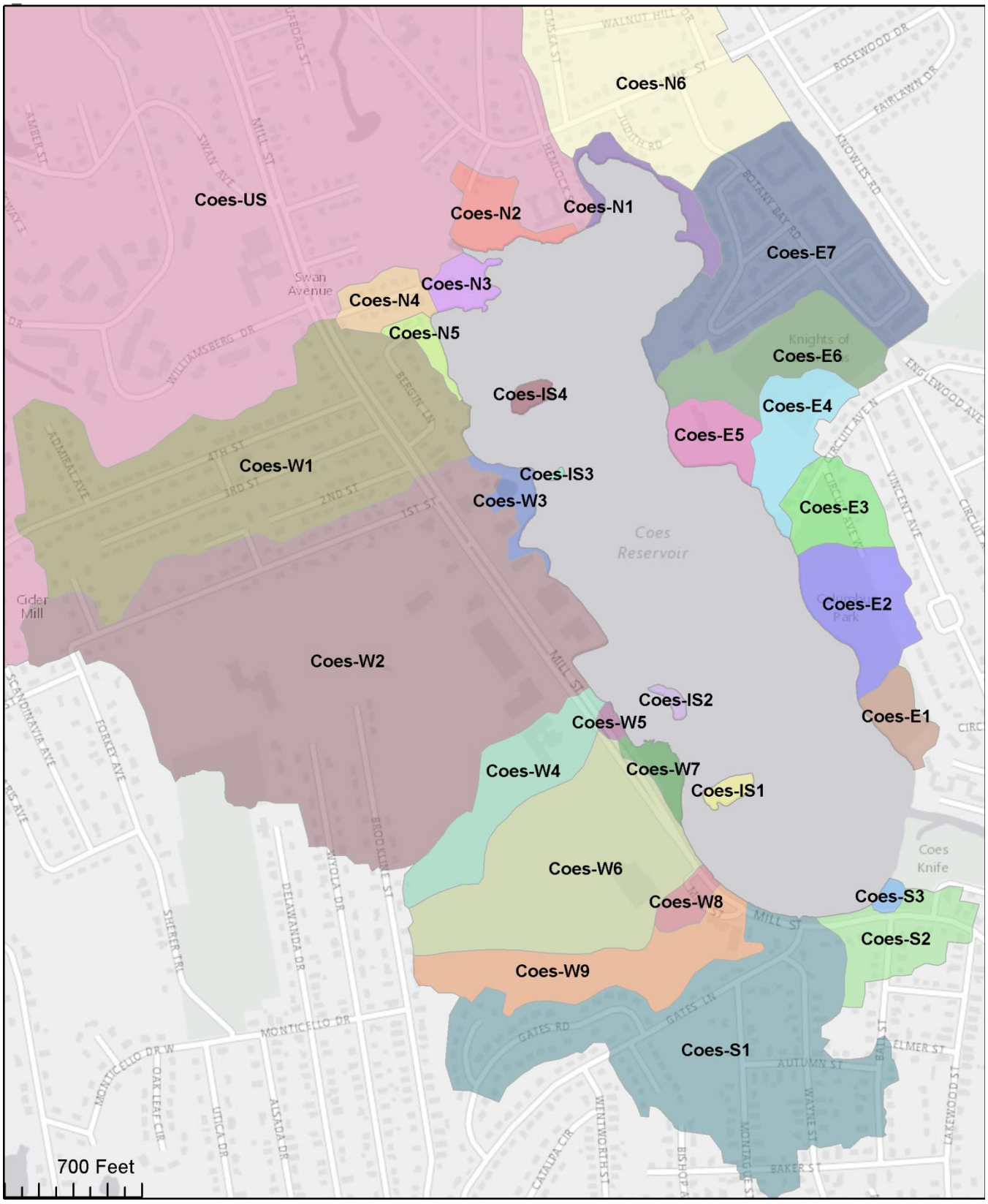

Figure 2. Watershed Subcatchments that Drain Directly to Coes Reservoir

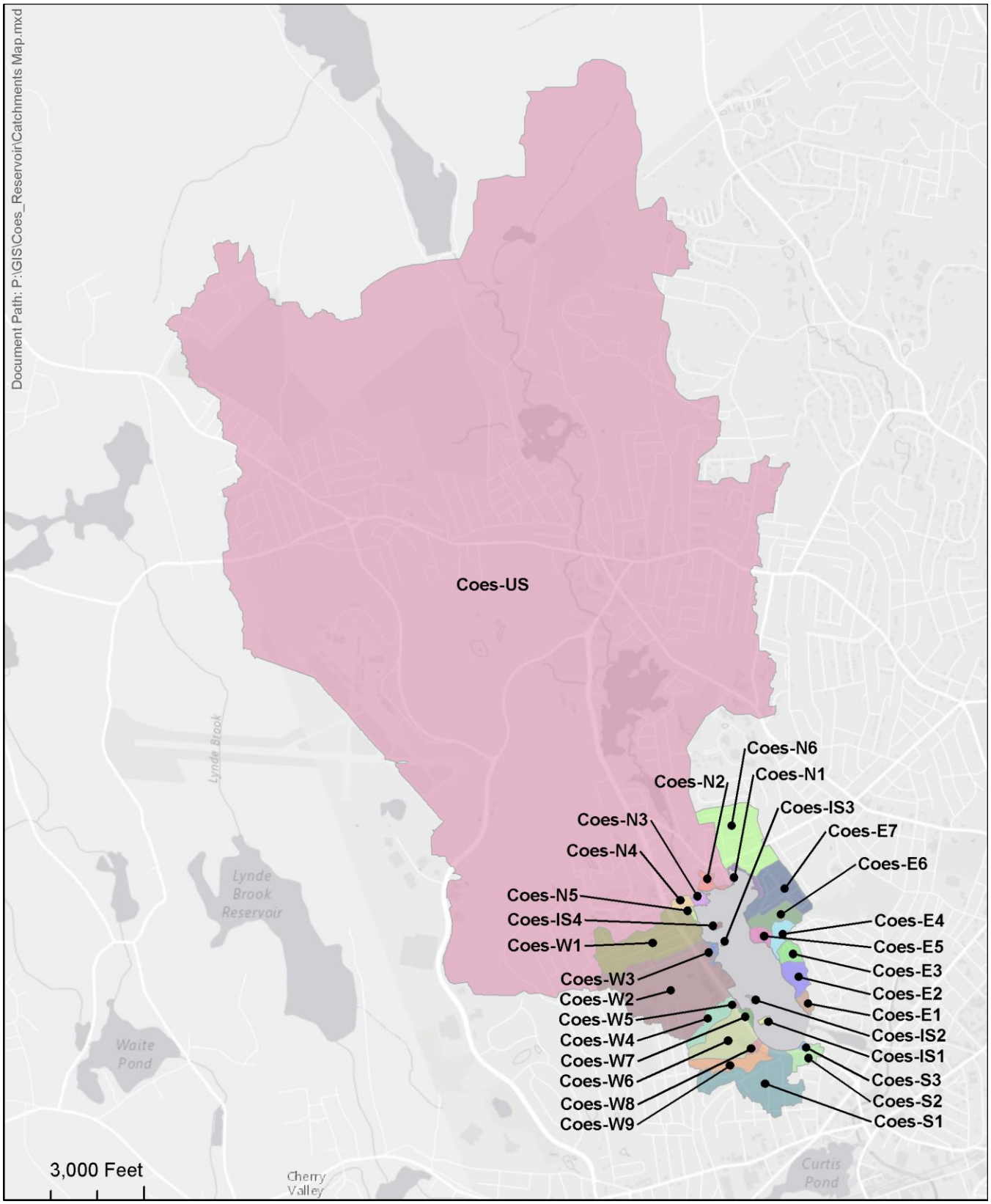

Figure 3. Coes Reservoir – All Watershed Subcatchments

Table 2. Coes Reservoir Watershed Subcatchments		
Subcatchment	Area (acres)[1]	Outfall ID[2]
Coes - E1	2.4	
Coes - E2	6.9	
Coes - E3	4.5	227
Coes - E4	5.1	
Coes - E5	3.3	
Coes - E6	8.3	
Coes - E7	20.6	Unknown
Coes - IS1	0.7	
Coes - IS2	0.3	
Coes - IS3	0.1	
Coes - IS4	0.6	
Coes - N1	2.4	
Coes - N2	3.2	
Coes - N3	1.8	
Coes - N4	2.7	102
Coes - N5	1.1	
Coes – N6	35.1	[private]
Coes - S1	35.2	287
Coes - S2	5.8	288
Coes - S3	0.4	
Coes - US	3,316.7[3]	
Coes - W1	39.7	192
Coes - W2	75.8	283
Coes - W3	1.7	
Coes - W4	8.2	308
Coes - W5	0.4	
Coes - W6	21.9	284
Coes - W7	1.5	
Coes - W8	1.4	285
Coes - W9	10.3	286
Total	3,618.0	

Notes:

1. *All values rounded to the nearest tenth of an acre.*
2. *City designation.*
3. *Does not include area upstream of the Holden Reservoir Number 2 outlet.*

1.4 Bathymetric Survey

A bathymetric survey of the Reservoir was performed on May 6, 2015. The primary purpose of the survey was to determine the spatial distribution of the water depth in the Reservoir. The survey also had a secondary purpose of measuring the sediment depth at numerous locations.

Approach

The bathymetric survey was performed from a canoe outfitted with a data acquisition system. The data acquisition system consisted of the following:

- Ultrasonic depth transducer - Measures the distance from the water surface to the surface of the sediments
- GPS receiver – Measures position (northing and easting)
- Data logger – Reads measurements from the transducer and GPS and logs the data to an SD card every six seconds.

The canoe traversed the Reservoir as shown in Figure 4, and recorded over 2,700 measurements. In addition, 24 manual measurements were taken during the survey. The manual measurements were used to calibrate and verify the data collected by the data acquisition system. An extendable pole with depth markings was used to measure the distance to the bottom. The pole was fitted with a flat grate at its end to keep it from penetrating into the sediments. The measurements from the data acquisition agreed well with the manual measurements.

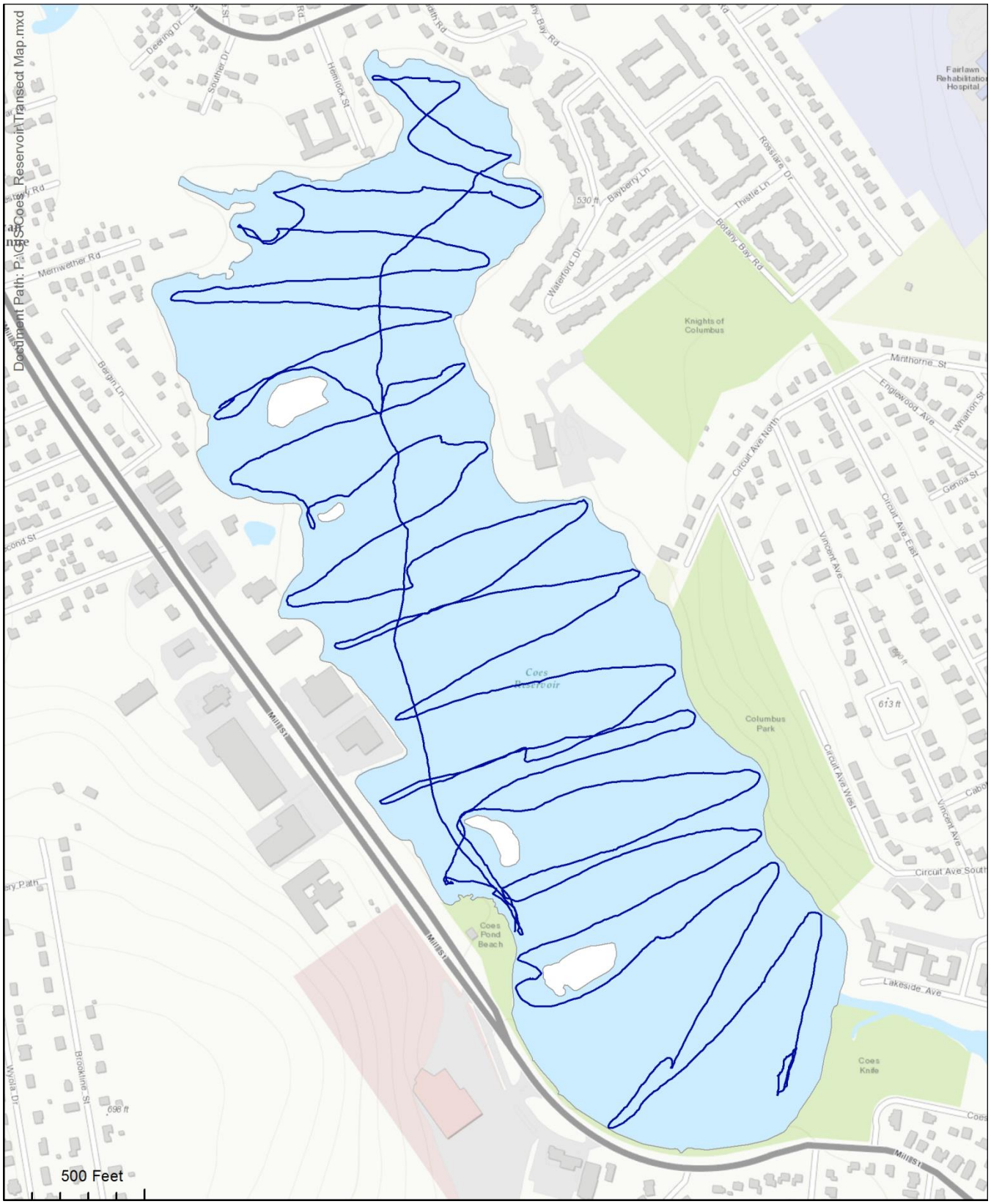

Figure 4. Path of Canoe during Bathymetric Survey

The depth data measured by the data acquisition system were filtered for consistency and then used to build a triangulated irregular network (TIN), to represent a surface model of the bottom of the Reservoir. From this surface model, contours were calculated in GIS. These contours were edited to remove artifacts from the contour interpolation, and then smoothed to more realistically represent natural curves.

The sediment depth was measured manually at 24 locations in the Reservoir. The sediment depth was determined by taking two separate depth measurements while the canoe remained in the same location. The first depth measurement was made using an extendable pole fitted at its end with a narrow tip to penetrate the sediment. The second depth measurement was made using an extendable pole fitted at its end with a grate to prevent penetration of the sediments. The second depth was subtracted from the first to estimate the sediment depth.

Results

The water depth throughout the Reservoir is shown in Figure 5. The depth contours are provided at two foot intervals. The deepest measured point in the lake was 17.2 feet and was measured near the dam. The average depth is 8.0 feet. The water volume of the lake was calculated using GIS to be 695 acre-ft.

The sediment depth measurements are presented in Figure 6. The deepest sediment measurement was 3.8 ft. This measurement was taken near the dam. The average sediment depth was 1.5 ft.

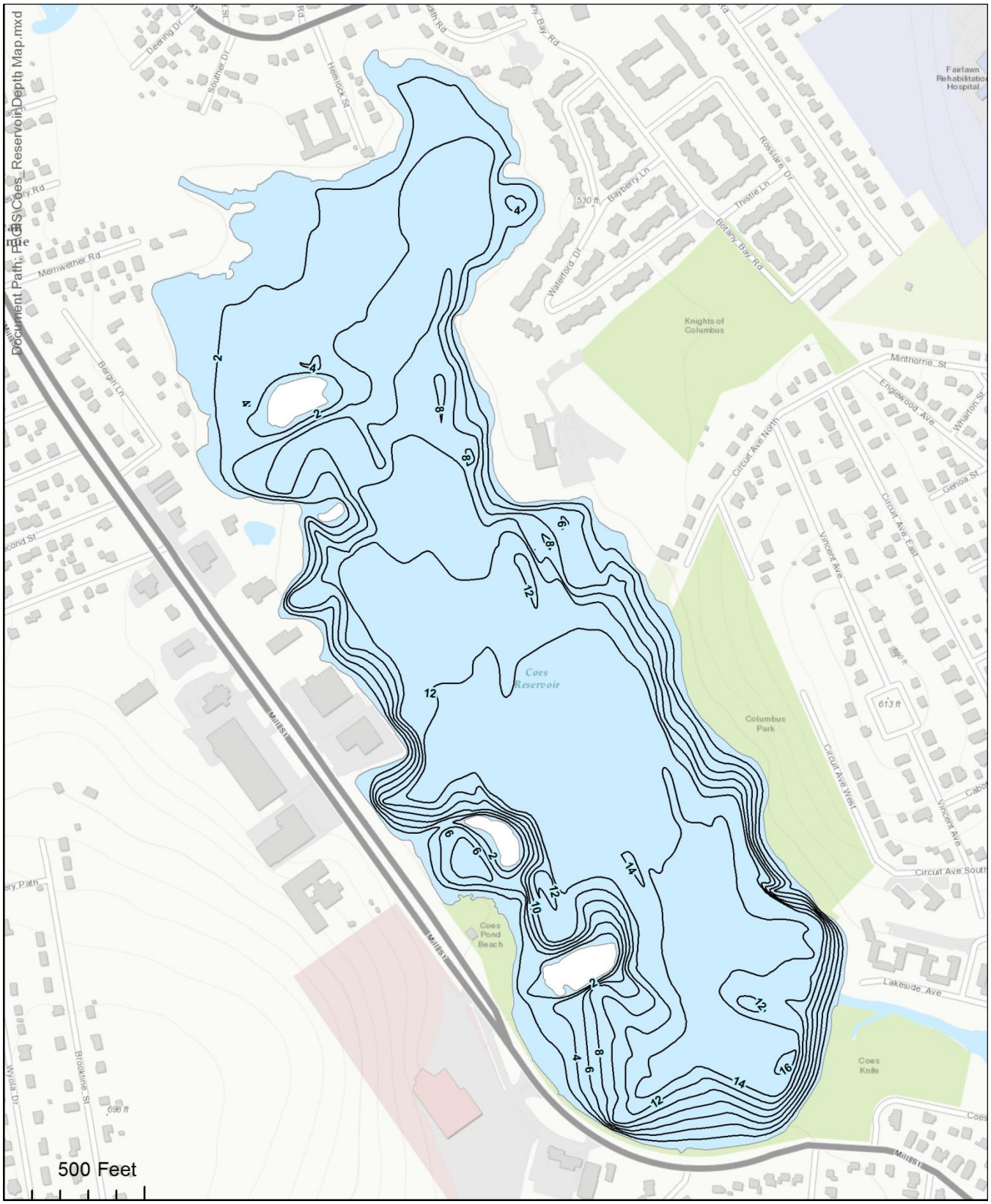

Figure 5. Coes Reservoir Water Depth

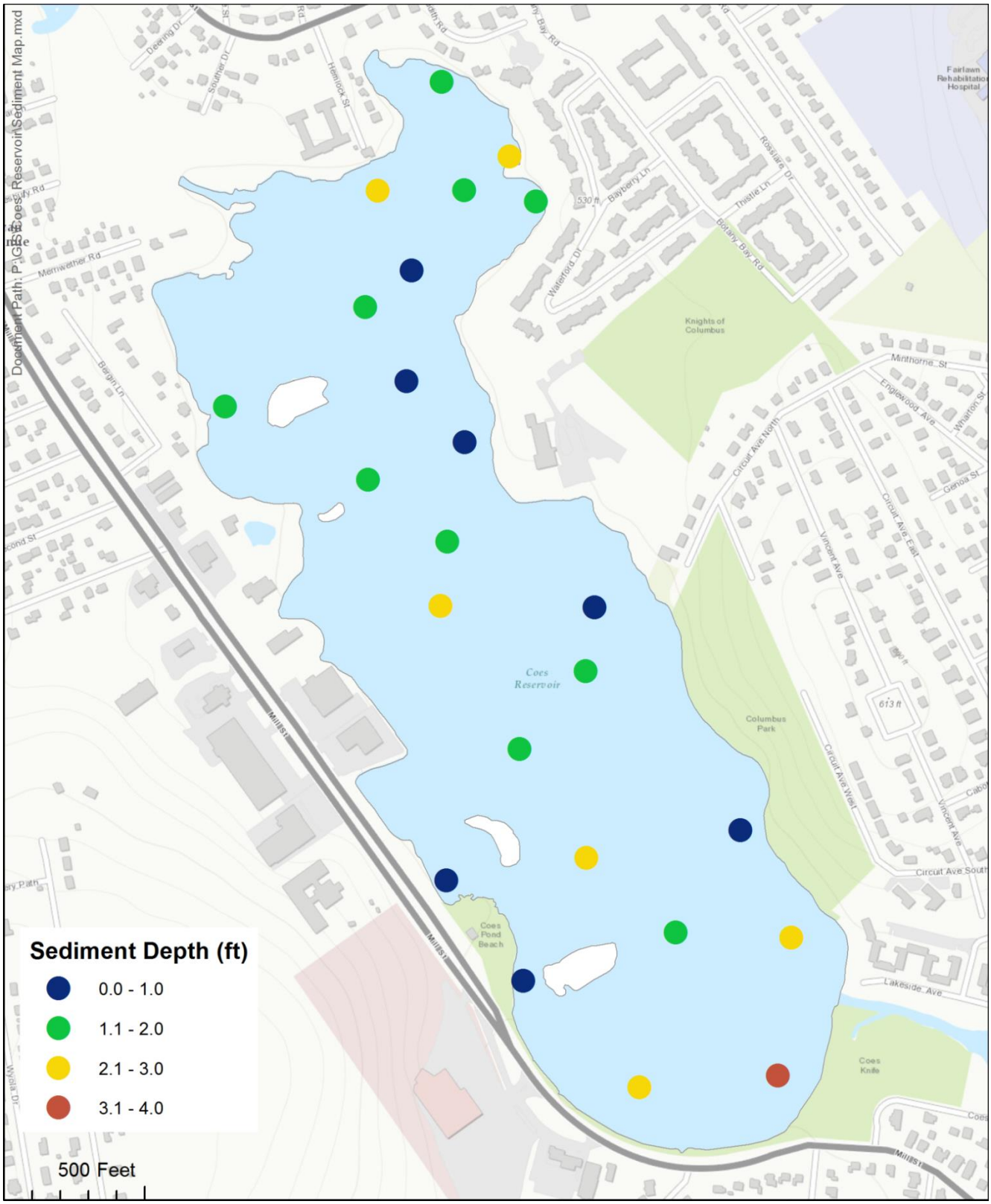

Figure 6. Coes Reservoir Sediment Depth Measurements