FINAL

South Bethany Canals Sediment Evaluation

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Prepared for:
South Bethany Canal Water Quality Committee
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1.0 INTRODUCTION

Woods Hole Group, Inc. (WHG) was contracted by the Town of South Bethany, Delaware (the South Bethany Canals Water Quality Committee) to assist in the efforts to improve water quality in their canal system through the assessment of bottom sediments. The purpose of this report is to summarize the work completed to date, describe methodologies, present data collected and results, and suggest recommendations for future actions.

1.1 SITE HISTORY

The town of South Bethany is a densely-populated, primarily residential town located on the coast of south Delaware, between the Atlantic Ocean, Little Assawoman Bay (LAB) and the Assawoman Canal. The town consists of approximately 1,387 lots, the main feature being a 5-mile network of canals with a surface area of 35 acres constructed through the filling of marshland and following excavation in the 1950's. The canal system is part of the Little Assawoman Bay watershed, connected to LAB and Little Bay to the south by Jefferson Creek; and Indian River Bay and Rehoboth Bay to the north. The canals are used primarily for recreation, including boating, fishing, swimming and crabbing.

1.2 SUMMARY OF PROBLEM

Observations over the last several decades have indicated a decline in water quality in the South Bethany canals. The canal system and resulting infrastructure were developed prior to federal Clean Water Act as well as water quality and storm water management regulations instituted by the State in the 1990's. The area of impervious surfaces (roads, roofs) and direct runoff pathways into the canals, has contributed to the issue.

1.3 PURPOSE OF STUDY

The ultimate goal of the South Bethany Water Quality Committee is to return the canals to a 'fishable and swimmable' condition. Based on the background information provided by the South Bethany Canals Water Quality Committee, WHG developed this study to delineate the extent of nutrient rich organic bottom sediments in the canals, which have been documented to contribute to the decline of water quality, and to inform remediation strategies, such as dredging. The specific objective for this project was to map and identify sediment characteristics in the canals. These data will be used in two ways: 1) to help the Town determine the best course of action to mitigate eutrophic conditions in the canals, and 2) to provide the information that is required as part of a permit application to State and Federal regulators.

To this end, the project scoped included three tasks:

1) Assessment of bathymetry and sediment bed composition through a bathymetric and subbottom acoustic survey
2) Characterization of sediments that likely 'fuel' eutrophication processes through extensive sediment sampling
3) Selection of best remediation approach

Upon review of data from Tasks 1 and 2, it became clear that minor change in project approach was needed, and more data were collected to facilitate a targeted removal of sediments by dredging. This resulted in two field data collection events, which can be described as Phase 1 and Phase 2. Phase 2 field data were collected to maximize the collection of relevant information to support a Town permit application to dredge a targeted area. This report summarizes the work completed on Tasks 1 and 2, in Phase 1 and Phase 2.

2.0 PHASE 1: BATHYMETRY SURVEY AND SEDIMENT CHARACTERIZATION

This section summarizes the methods and results from Task 1: an acoustic survey of sediment bed elevation and subsurface composition in the South Bethany canals.

2.1 METHODS

2.1.1 Bathymetric survey

A bathymetric survey was required to calculate potential volume of material to be dredged to reach the canal's controlling depth of -4 feet mean lower low water (MLLW). The bathymetric survey was performed on September 20, 2018 using an Odom Hydrotrac 200-kHz single beam echosounder interfaced with a Trimble R8 Real-time Kinematic (RTK) GPS for navigation using the HYPACK 2017 survey software. The survey vessel was a 20-ft pontoon boat donated for use by South Bethany resident, Mr. George Junkin.

The RTK-GPS provided horizontal and vertical accuracy to within 3 cm for the survey, with all vertical data referenced to the North American Vertical Datum (NAVD88). Water level data from a USGS monitoring station (#01484696) in Jefferson Creek, South Bethany, were used as a secondary check on the RTK tide correction. The USGS station water level data are referenced to vertical datum NAVD88.

2.1.2 Sub-bottom acoustic survey

In addition to the bathymetric survey, an acoustic sub-bottom profiling system was used to quantify bed and sub-surface characteristics. An Edgetech 3100P CHIRP sonar system and SB-424 towfish were used to complete the sub-bottom survey on September 19, 2018. The towfish was deployed off the bow of the survey vessel (20-foot pontoon boat). The 3100 sub-bottom system is suited for use in a small boat and provides excellent image quality. The SB-424 operates at 4-24 kHz and will provide slightly higher resolution but less penetration than a lower frequency system – ideal for the canal system. The subbottom system is able to characterize the difference in acoustic properties that exists between the organic rich sediment (low density) and underlying, more consolidated sediments (higher density) of the canal. The results are profile images of subsurface sediment layering.

2.1.3 Sediment coring

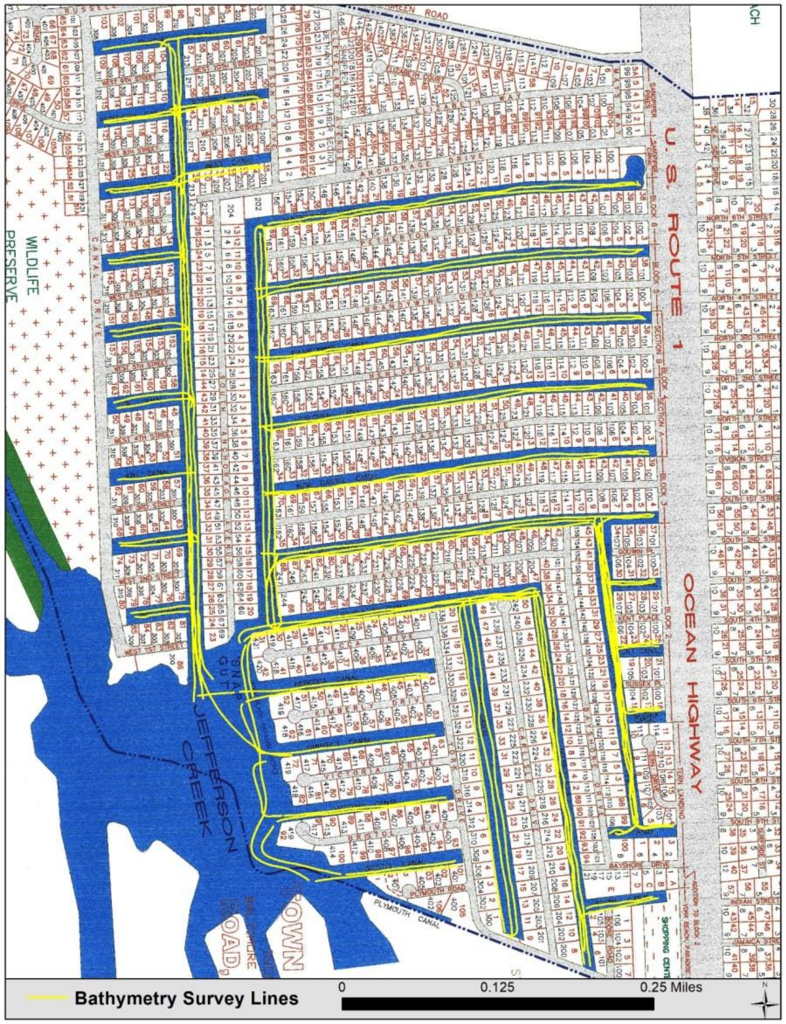
A total of 8 sediment cores were collected on September 20, 2018 in the canal network to ground truth the acoustic sub-bottom survey results and characterize the physical properties of the sediment. Cores were collected in lengths of up to 3.3 feet (or refusal) via a push core assembly equipped with a slide hammer and piston, which was designed to minimize compaction and maximize recovery by providing suction at the sediment-water interface. Cores were collected in clear polycarbonate "lexan" tubes with a diameter of 2.625". The clear core tubes facilitate a quick visual characterization of the recovered sediment. The cores were photographed and described then subsampled based on lithology. The samples were submitted for laboratory analysis for the parameters: 1) grain size, 2) organic content, 3) moisture content, 4) total Carbon, Nitrogen and Phosphorus, 5) inorganic and organic Phosphorus, and 6) pore water ammonium and exchangeable ammonium.

2.2 RESULTS

2.2.1 Bathymetry

A total of 13.8 miles of survey lines were collected over the course of the bathymetric survey (Figure 1). A minimum of two along-channel lines were collected in each canal, with a third line along either the center of the canal or zig-zagging across the previously collected channel lines to optimize the coverage of the survey. Soundings were recorded in feet relative to NAVD88, resulting from the real-time RTK tide processing. Following the survey, data were post-processed to remove erroneous soundings (for example, when turbulence from the boat wake prevented the transducer from sensing the bed), smooth the 1-Hz data through averaging and interpolating a full-channel bathymetry map (Figure 2).

The survey revealed depths in the canal system ranging from -10 feet NAVD88 to 2 feet NAVD88. The eastern canals (Anchorage to Layton, and Goodwin to May) were typically shallower, on average -4 to -6 feet NAVD88. The western dead-end canals (1^{st} through 6^{th}) as well as the southern canals (Kimberley to Bristol) were deep, ranging -10 to -7 feet NAVD88.



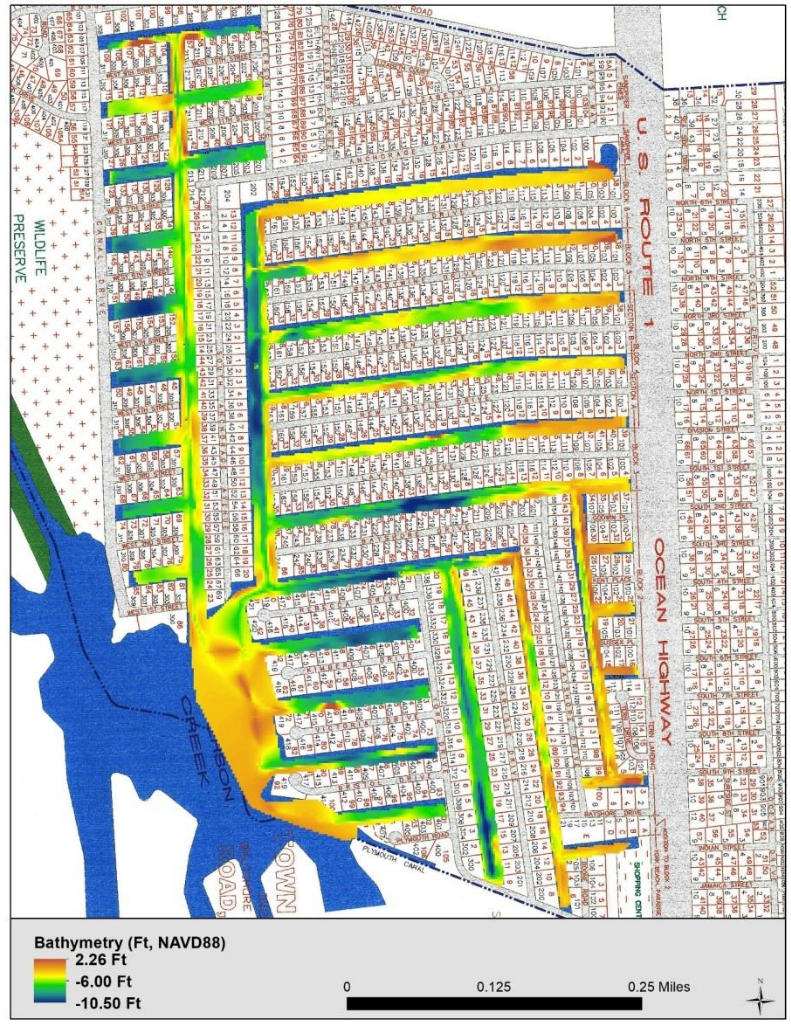


Figure 1. **Bathymetry survey tracklines collected September 20, 2018.**

Figure 2. **Bathymetric surface in feet relative to NAVD 88.**

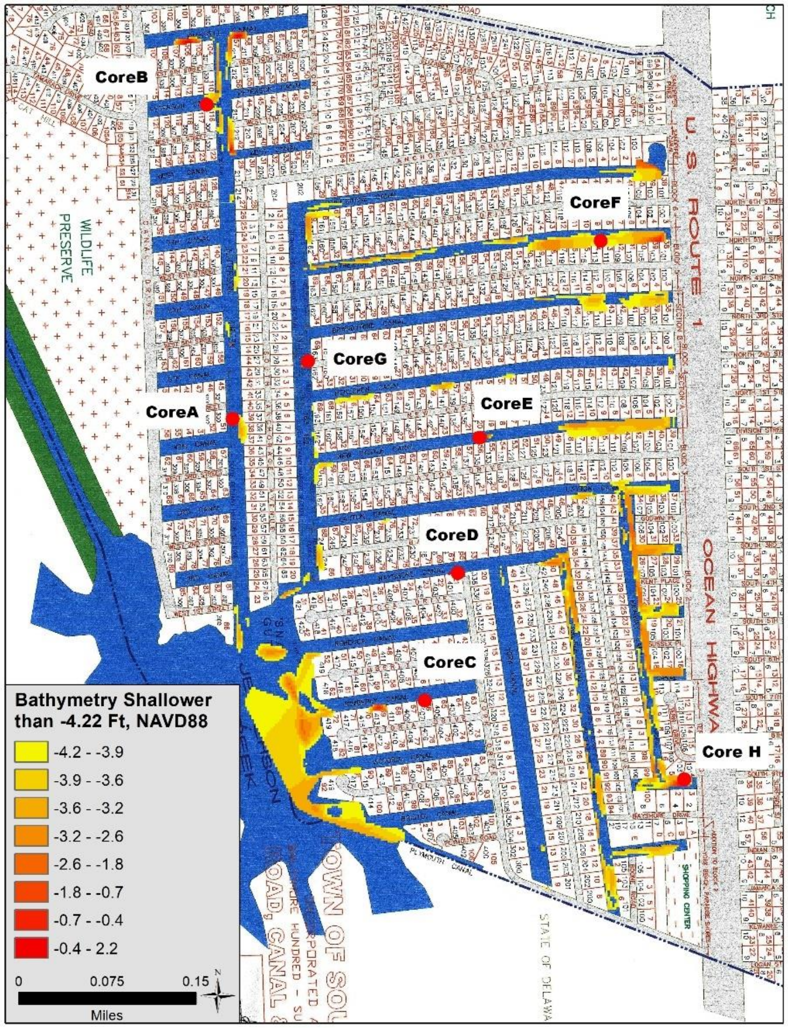


Figure 3. **Bathymetric regions with elevation of -4.22 feet NAVD 88 or higher, collected September 20, 2018.**

Figure 4. **Bathymetric regions with elevation of -7.0 feet NAVD 88 or lower, collected September 20, 2018.**

2.2.1.1 Bathymetry in relation to MLLW

While the data presented in this report is in elevation relative to NAVD88, it may be useful to have bathymetry data relative to Mean Lower Low Water (MLLW), to compare with past dredging events or engineering plans. The elevations of tidal benchmarks were calculated using a month of tide data from the USGS Jefferson Creek (September 1-30 2018, coinciding with the survey). As a minimum of 19 years of tide data are required to determine official tidal datums over the last tidal epoch, the elevations of mean tide levels during the month of the survey are still helpful references. Tide elevations are presented in Table 1 relative to NAVD88; to covert data from NAVD88 to MLLW simply add the two values together.

Table 1. Tidal datums for South Bethany Canals, based on a month of data from the USGS Jefferson Creek Gage

Datum	Elevation (feet, NAVD 88)
MHHW	1.282
MHW	1.174
MTL	0.852
MLW	0.530
MLLW	0.435

2.2.2 Sub-bottom characteristics

A total of 12.3 miles of survey lines were collected during the sub-bottom survey (Figure 5). Initial tests lines were conducted to optimize the internal gain settings and sonar ping intensity, to optimize the imagery collected by the Edgetech 3100 CHIRIP system. The sonar system displayed imagery in real-time, enabling adjustments to refine the data as changes in the bed conditions occurred throughout the survey. Two along-channel lines were collected in each canal. In specific areas of interest (e.g., where unique features occurred), lines were resurveyed. Post-processing of the data included trimming of bad data from the record, and digitizing certain sub-surface layers.

The subbottom survey yielded subsurface imagery and depth along each line, typically up to 30 feet below the canal bed. For this project, the features in the top 5 feet are of greatest interest. Sub-bottom sonar imagery has been used extensively to map subsurface features in aquatic environments. Typically, a darker image layer is correlated with a stronger acoustic reflection to the sonar, which indicates a change in sediment properties.

Figure 5. Sub-bottom survey tracklines collected September 19, 2018.

Distinct layering was observed in many canals throughout the system. The sonar imagery best resolved features on the order of half a foot. A summary of the subbottom sonar imagery follows:

- The southern-most four canals (Rebecca, Kimberley, Victoria and Bristol) are deep (8-9 feet of water at the time of survey), with a distinctive subbottom profile consisting of a soft 1-2 ft return on top of a stronger return, yet with no distinctive layering or firm surface, suggesting soft bed material with no sand.
- The central, east-west oriented canals (Anchorage to New Castle) are mid-depth (4-6 feet of water above imagery) and predominantly sandy with inconsistent features and some layering in the top 3 ft of the subsurface. The eastern, shallower ends had a stronger acoustic return. Imagery from New Castle Canal is presented in Figure 6.

- Layton and Bayshore contained alternating hard and soft returns, layering and then noise. Bayshore had a soft, messy return similar to the southern canals mid-line. Shallowing and distinct return adjacent to openings of southern offshoot canals (thin 0.5 ft, hard return).
- South Anchorage is heterogenous, with surface layering, soft and hard returns. The long transects are some of the best examples of the subbottom data collection. The southern third of the lines appear softer, with a return similar to that of the southern (Kimberly) canals. The eastern bank is shallower. South Anchorage Canal sub-bottom imagery is presented in Figure 7.
- Carlisle has sand at either end, with some soft spots and layering mid-line.
- York is a deep, wide canal with layering in the top 4 ft. Likely layering of sand and fines, with sand at the surface.
- Jefferson Creek Canal has two high-resolution sonar lines, the best imagery of the survey. The southern end has a soft return similar to the southern four canals, likely a soft, mucky bottom. The northern end has detailed layering in the top 3 ft.
- Short, E-W oriented canals off Jefferson are typically deep with layering in the top 3 ft of the surface.

In summary, the bed characteristics of the South Bethany canal system are heterogeneous. Several canals have soft, unconsolidated sediments clearly identified in the subbottom imagery. There is frequent layering in the surface indicative of layered textures, likely coarse (sand) and fine (mud and organics). A distinct 'hump' feature was frequently observed at the intersection of canals and along the outflows from properties (pipes discharging into canals), potentially indicating trapping of unconsolidated organic material in these locations of convergence.

The sub-bottom imagery was used to inform sediment coring and generally define bed characteristics throughout the canal system. Additional canal-specific imagery can be provided upon request.

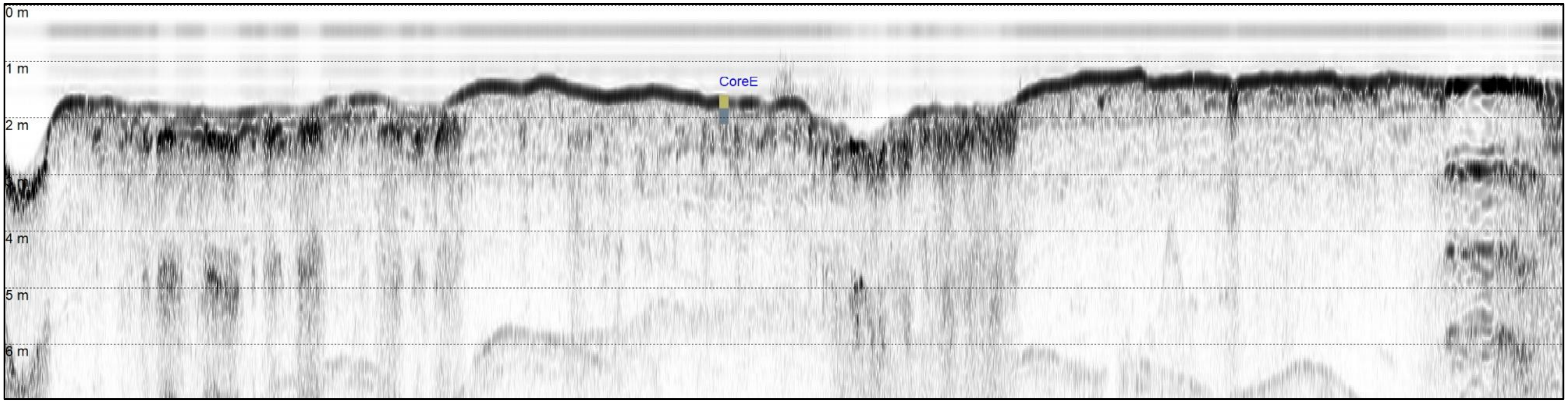


Figure 6. New Castle Canal (line number 09), oriented west to east (left to right). The line is 494.3 m long.

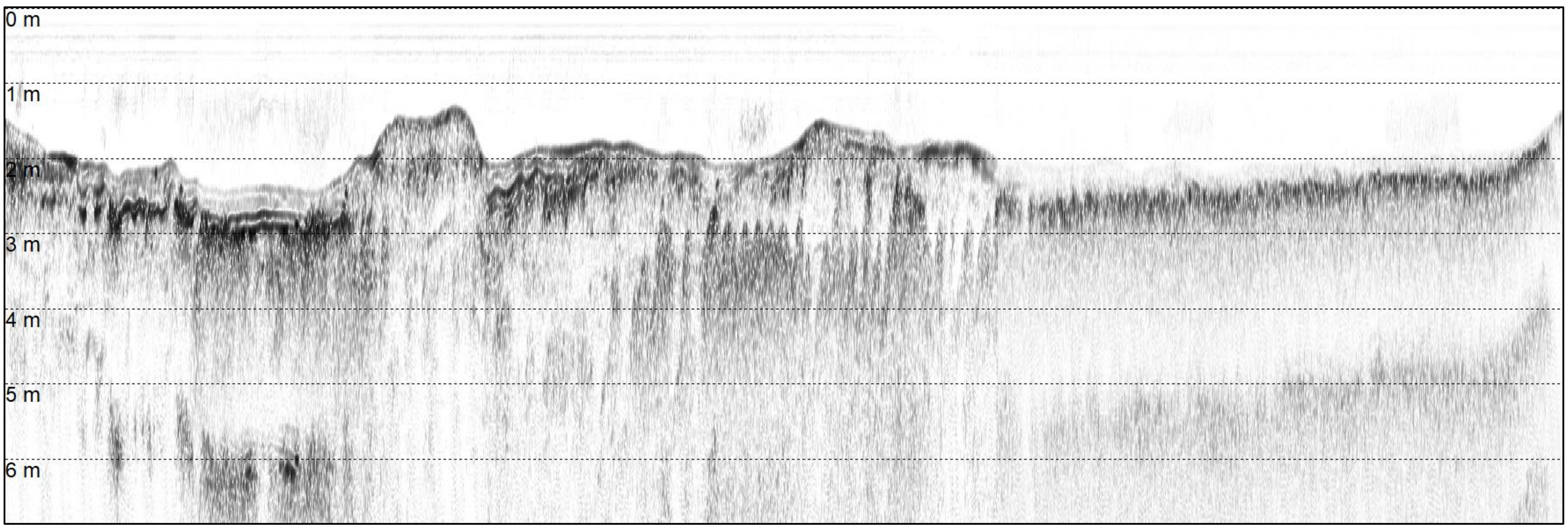


Figure 7. South Anchorage Canal (line number 71), oriented north to south (left to right). The line is 484.5 m long.

2.2.3 Sediment cores

A total of eight sediment cores were collected in the canals (Figure 8). Sample locations were selected following the review of preliminary subbottom imagery to select locations to best validate the sonar data interpretation; for example, locations where distinct layering was observed in the top 6 feet of the subsurface. Additional cores were added where there was suspected soft, fine sediments.

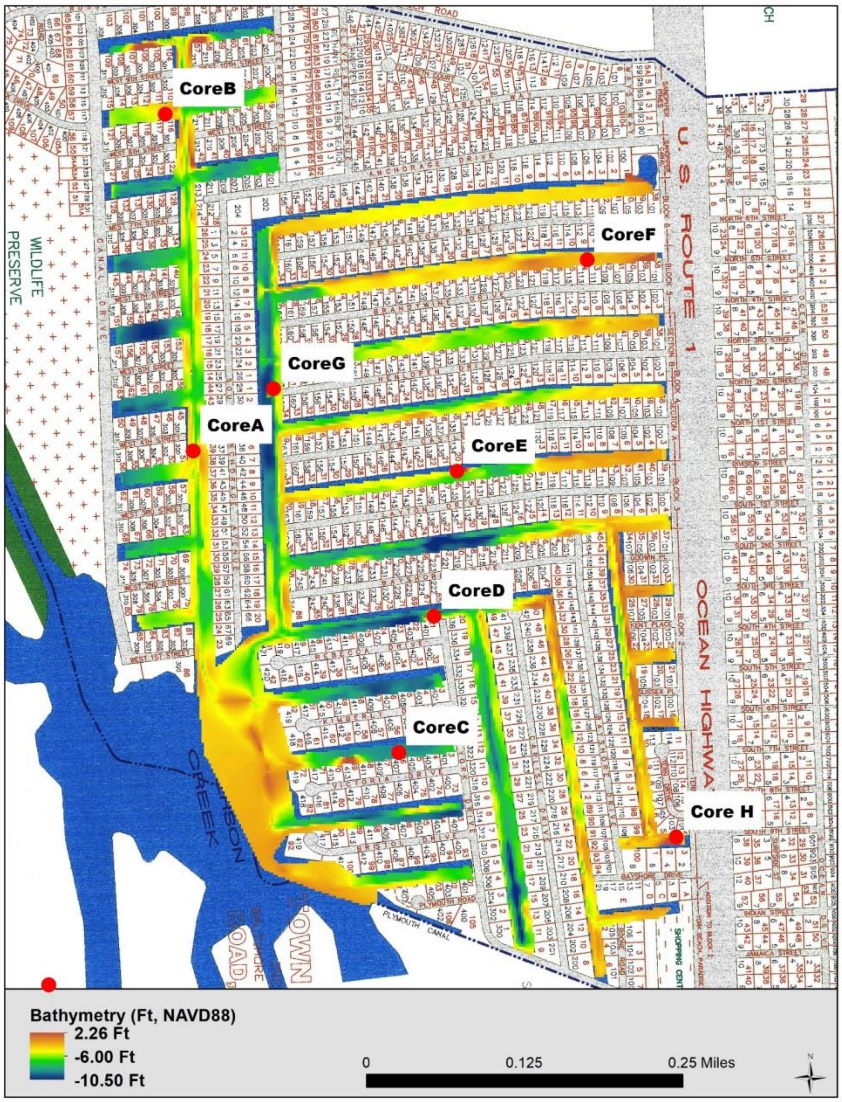


Figure 8. South Bethany canals bathymetry in feet relative to NAVD 88 with locations of sediment cores collected on September 20, 2018.

The sediment core structure correlated well with the sub-bottom acoustic survey results, providing confidence in the interpretation of the acoustic data. For example, in Figure 9, the thickness of the dark acoustic return at the sediment-water interface matches the thickness of medium grained sand layer at top of Core E, which overlays estuarine clay in New Castle Canal.

In Figure 10, the acoustics from Petherton Canal correlate well with sediment Core F – a thin layer (2 inches) of loosely consolidated organic material overlays medium to fine sand.

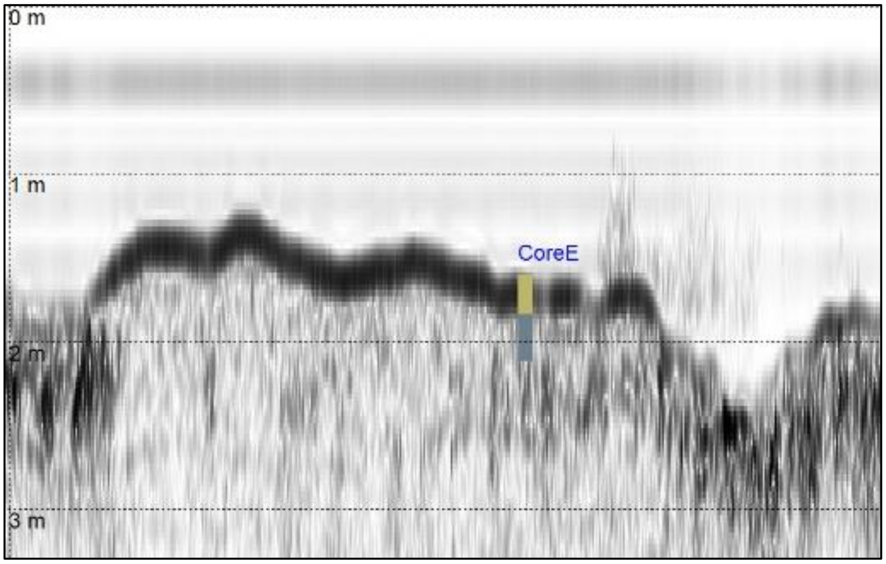


Figure 9. **Correlation between acoustic sub-bottom imagery and sediment core E, collected in New Castle canal.**

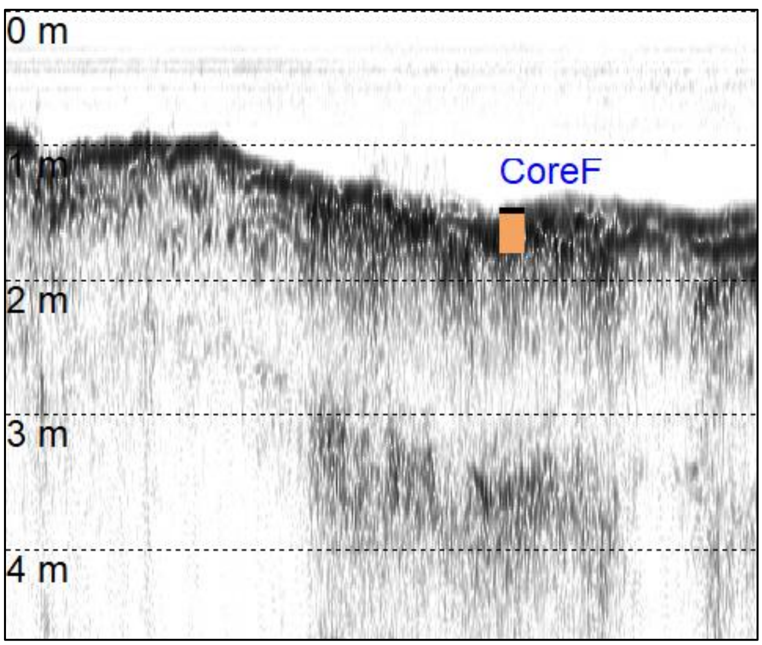


Figure 10. **Correlation between acoustic sub-bottom imagery and sediment core F, collected in Petherton canal.**

Tables 2 and 3 summarize the sediment core physical characteristics and analytical nutrient content. As expected, nutrient concentrations trended with grain size; the highest concentrations of nutrients (carbon, nitrogen, phosphorus and ammonium) were observed in samples with the most fine-grained material, the surface layers of Cores B, C and D.

2.3 CONCLUSIONS FROM SURVEY

The combination of bathymetry, sub-bottom sonar imagery, and sediment coring and analyses indicate that the South Bethany canal system is composed of heterogenous bed characteristics. A mixture of sand, silt, and organics were found in the system, with sand the dominant grain size of the top 1-2 feet. The range in bathymetry was nearly 14 feet in total. The deeper canals tend to have finer sediments, along with higher nutrient concentrations, indicative of the trapping that is enabled in quiescent, deeper settings.

Incidentally, the regions with fine, nutrient-rich sediment that would be the target for removal, appear to be concentrated in the deepest sections of the canals which likely would not be dredged. The deeper than expected bathymetry, combined with the varied bed characteristics and poor water flow in dead end canals, suggests that the potential organic, nutrient-source material is dispersed throughout the shallow canals, likely as a thin, < 0.5 ft surface layer. To confirm this, spatially-intensive surficial sediment sampling was proposed in the place of additional coring.

This shift in field data collection ends Phase 1, and starts Phase 2. The objective of the Phase2 sediment sampling will be to identify where the “hot spots” nutrient rich sediments are located so that area of dredging can be defined; this is based on the hypothesis that removal of the labile nutrients contained in these sediments will curtail eutrophication in the canals.

Table 2. Sediment core data; texture and moisture.

Core ID	Sample ID	Core Section (ft)	Sand %	Silt %	Clay %	H2O %
A	SB-A1	0 -1.1	75.2	13.3	11.5	19.8
B	SB-B1	0 - 0.12	44.8	54.4	0.7	53.0
C	SB-C1	0 - 1.9	15.2	20.9	63.9	66.2
D	SB-D1	0 - 0.1	25.1	34.1	40.9	68.6
E	SB-E1	0 - 0.8	78.2	7.8	14.0	23.1
F	SB-F1	0 - 0.16	73.6	2.9	23.5	47.4
G	SB-G1	0 - 0.66	77.8	8.5	13.7	33.2
H	SB-H1	0 - 0.04	75.1	2.4	22.5	43.6

Table 3. Sediment core data; nutrients.

Core ID	Sample ID	Core Section (ft)	Carbon %	Nitrogen %	Total P, umol g-1	Inorganic P, umol g-1	Organic P, umol g-1	Pore water NH4+, umol L-1	Exchangeable NH4 KCL, umol g-1
A	SB-A1	0 -1.1	0.4	0.0	4.2	5.6	0.0	383.8	1,376.0
B	SB-B1	0 - 0.12	2.3	0.2	11.4	9.8	1.7	437.1	2,236.1
C	SB-C1	0 - 1.9	3.8	0.3	18.4	16.0	2.4	2,713.3	7,989.6
D	SB-D1	0 - 0.1	4.4	0.4	19.0	13.0	6.0	1,371.7	2,822.7
E	SB-E1	0 - 0.8	0.5	0.0	7.0	6.4	0.6	899.8	800.2
F	SB-F1	0 - 0.16	1.6	0.1	9.6	7.4	2.1	628.5	995.8
G	SB-G1	0 - 0.66	0.8	0.1	7.2	6.6	0.6	786.2	912.2
H	SB-H1	0 - 0.04	1.4	0.1	8.8	6.3	2.5	388.4	750.6

3.0 PHASE 2: INTENSIVE SEDIMENT SAMPLING AND CONTAMINANT ANALYSIS

3.1 METHODS

A total of 69 surficial sediment grab samples were collected at predetermined locations, targeting the ends of canals and deep canals with previously observed high nutrient levels (Figure 11). Samples were collected from a small boat using a Petite Ponar grab sampler, which collected approximately 2.4 L of sediment per grab. Samples were photographed, described, subsampled for nutrient analysis, and archived on ice (in the field). Duplicate samples were collected at five locations in the event that spatial heterogeneity was evaluated. Samples were delivered to the University of Maryland Center for Environmental Science laboratory. A total of 69 samples were analyzed for particulate carbon and particulate nitrogen, with the remaining sediment volume from each sample archived at 4°C in the laboratory.

3.2 RESULTS

Table 4 summarizes the results of the total particulate nitrogen (PN), particulate carbon (PC) and resulting carbon to nitrogen (C:N) molar ratios of the surface sediment grab samples collected from the South Bethany canals.

Concentrations of particulate nitrogen range from 0.01 to 0.67% by weight of the sample (Figure 12). These values fall within the typical concentrations observed in estuarine settings (Boynton and Kemp, 1985).

The samples had a large range of total carbon, from (0.16% to 9%) by weight of the sample. The data are spatially variable, and can be mostly be explained by grainsize variation between the sites, with the highest concentrations of carbon typically found with fine-grained material at the ends of canals and in deeper canals with depths greater than -8 ft NAVD88. Samples containing higher than 4% PC are highlighted in Figure 13 with the orange circle. A threshold of 4% PC can be an indicator of high nutrient regeneration. Again, the restricted ends and deep sections of the canals typically fall in this 'hotspot' categorization, over half (34) of the samples contained >4% PC, suggesting the entire system is carbon-rich and has the potential for high nutrient regeneration.

Depositional regions are typically fine grained with high carbon content where sediment and organic matter accumulate. These fine-grained high carbon content sediments can be thought of as "hot spots" of organic matter degradation and nutrient regeneration. In shallow water systems, sediment oxygen demand and nutrient regeneration can have a significant impact on water quality by: 1) providing nutrients to the water column for algal growth and 2) decreasing oxygen in the water column leading to hypoxic or anoxic conditions. Low oxygen conditions tend to enhance both nitrogen and phosphorus release through inhibition of sediment coupled nitrification/denitrification and lowering redox conditions in the sediment.

Figure 11. Basemap of surface sediment grab samples collected December 13, 2018.

Table 4. Results of particulate carbon and particulate nitrogen in surface sediments.

Sample ID	Particulate Nitrogen %	Particulate Carbon %	C/N Molar Ratio
SB01	0.33	4.08	14.31
SB01 Dup	0.29	3.77	15.04
SB02	0.38	4.26	12.97
SB03	0.38	4.23	12.88
SB04	0.17	2.23	15.18
SB05	0.24	2.52	12.15
SB06	0.37	4.02	12.57
SB07	0.28	3.02	12.48
SB08	0.23	2.17	10.92
SB09	0.11	1.18	12.41
SB09 Dup	0.11	1.31	13.78
SB10	0.28	3.19	13.18
SB11	0.42	4.82	13.28
SB12	0.16	1.75	12.65
SB13	0.21	2.15	11.85
SB14	0.25	2.39	11.06
SB15	0.4	4.37	12.64
SB16	0.19	2.08	12.67
SB17	0.39	4.02	11.93
SB18	0.23	2.44	12.27
SB19	0.42	4.7	12.95
SB20	0.43	5.35	14.40
SB21	0.49	5.37	12.68
SB22	0.32	3.49	12.62
SB23	0.45	4.72	12.14
SB24	0.07	0.69	11.40
SB25	0.07	0.78	12.89
SB25 DUP	0.07	0.67	11.07
SB26	0.37	5.27	16.48
SB27	0.49	4.99	11.78
SB28	0.5	5.17	11.96
SB29	0.36	4.44	14.27
SB30	0.14	1.93	15.95
SB31	0.27	2.96	12.68
SB32	0.16	1.6	11.57
SB32 DUP	0.11	1.37	14.41
SB33	0.11	1.29	13.57
SB34	0.59	7.71	15.12

Sample ID	Particulate Nitrogen %	Particulate Carbon %	C/N Molar Ratio
SB35	0.18	2	12.86
SB36	0.53	5.6	12.23
SB37	0.48	5.19	12.51
SB38	0.15	1.69	13.04
SB39	0.43	4.86	13.08
SB40	0.52	5.8	12.91
SB41	0.01	0.16	18.51
SB42	0.05	0.55	12.73
SB43	0.67	8.97	15.49
SB44	0.46	5.28	13.28
SB44 DUP	0.32	3.8	13.74
SB45	0.04	0.38	10.99
SB46	0.49	5.45	12.87
SB47	0.41	5.92	16.71
SB48	0.46	5.14	12.93
SB49	0.45	5.16	13.27
SB50	0.51	5.72	12.98
SB52	0.49	5.29	12.49
SB55	0.34	3.8	12.93
SB56	0.56	5.74	11.86
SB57	0.16	1.66	12.00
SB58	0.57	6.01	12.20
SB59	0.42	4.47	12.31
SB60	0.43	4.82	12.97
SB62	0.39	4.49	13.32
SB63	0.48	5.9	14.22

The ratio of carbon to nitrogen (C: N) in coastal and estuarine sediments provides a reasonable estimate of the organic matter source. The C:N of algae has a nominal C:N ratio of 6.6 while terrestrial plants tend to have a much higher C:N value of >20:1 (Lamb et al., 2006). Figure 14 shows the spatial distribution of C:N. All samples ranged from ratios of 10.9 to 18.5, with an average C:N ratio of 13.1 ±1.4, which indicates a mainly terrestrial source for the sedimentary organic matter. The source material for the organic matter could be derived from grass clippings or wetland plants such as *Spartina alterniflora*. However, the sediment C:N ratio can only suggest a possible carbon source as the sediment carbon is likely degraded and often results from a mixture of carbon sources being deposited to the sediment surface.

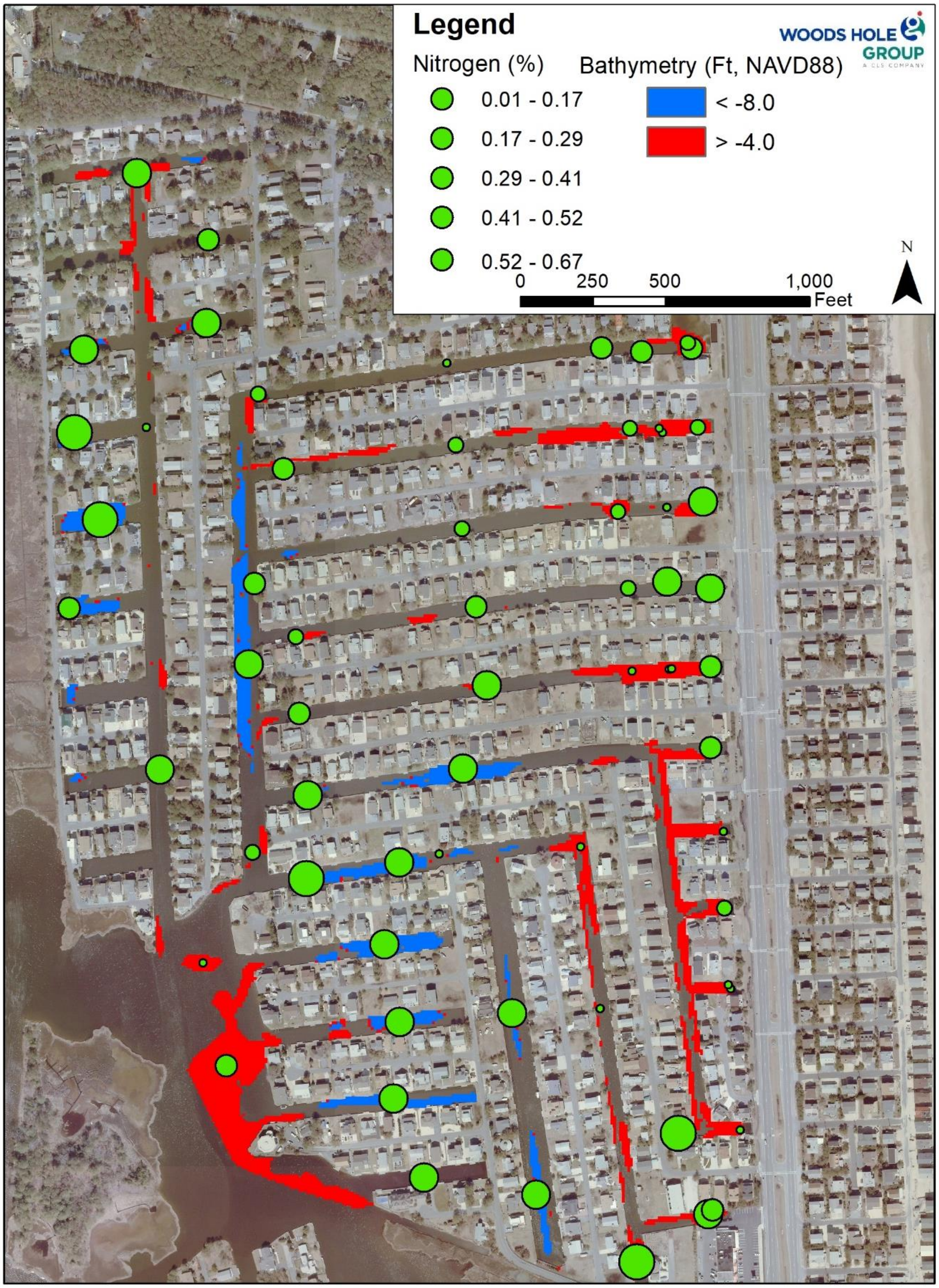


Figure 12. Total nitrogen in surficial grab sediments.

Figure 13. Total carbon in surficial grab sediments. Samples containing greater than 4% carbon (orange circles) are considered 'hot spots' of nutrient regeneration.

Figure 14. Carbon to Nitrogen (C:N) ratio in surficial sediment grab samples. All samples have ratios higher than 6.6, a typical marine value.

3.3 CONTAMINANT ANALYSIS

Since nutrient analyses indicated that sediments at the ends of the canals were likely supporting nutrient regeneration and eutrophication processes, it was decided that removal via dredging was beneficial for the long term water quality of the canals. In order to determine the feasibility of dredging, sediments were submitted for a screening of potential contaminants via a bulk chemistry suite of analytes. Although, the canals have been dredged before, the results should help the Town and regulators determine the most appropriate sediment disposal option.

The remaining surface sediment grab samples were combined and homogenized into three composite samples based on location. Table 5 lists the individual samples that were combined to create each spatial composite sample. Composite samples were submitted to Alpha Analytical Laboratory in Mansfield, MA for bulk chemistry analysis of metals, polycyclic aromatic hydrocarbons (PAHs), PCB congeners, and organochlorine pesticides. Each composite sample was analyzed for grain size, solids, and moisture. The complete laboratory results report is attached as Appendix A. Only composite samples SB-COMP-1 and SB-COMP-2 were analyzed. It is important to note that since these samples were not originally collected for chemical analysis, some constituents were analyzed beyond the recommended hold times (PAHs, PCBs, mercury). However, all samples were archived at 4°C and the general intent of the analyses was to provide data for screening purposes.

Table 5. Sediment composite scheme

Composite ID	Sample IDs	Status
SB-COMP-1	SB01, SB02, SB03, SB08, SB09, SB10, SB11, SB12, SB13, SB18, SB19, SB20, SB25, SB26	Analyzed
SB-COMP-2	SB29, SB30, SB31, SB32, SB34, SB41, SB42, SB43, SB44	Analyzed
SB-COMP-3	SB59, SB60, SB61, SB62, SB63	Archived

The laboratory results are summarized in Tables 6 through 9. Three screening standards are included on the right side of each table to provide context for the data:

- Delaware Department of Natural Resources and Environmental Control HSCA Screening Levels for Marine Sediment (DNREC, 2018)
- NOAA Screening Level for Marine Sediment– Effects Range Low (ERL) (SQuiRT, 2008)
- NOAA Screening Level for Marine Sediment– Effects Range Median (ERM) (SQuiRT, 2008)

In each table, values are highlighted orange if the analytical result exceeds the DNREC standard, and highlighted red if the analytical results exceed the NOAA ERL. No analytes exceed the NOAA ERM concentration. Analytes that were not detected at the laboratory method detection limit are shaded grey.

In general there are not any particularly high concentrations of contaminants in the sediment composites. The samples contained several metals just above the NOAA ERL and DNREC screening levels: arsenic, copper and zinc. These results were consistent (although slightly higher) with a sediment sample from elsewhere in the canals, collected on September 7, 2017. Three pesticides (4,4'-DDE, 2,4'-DDD, and 4,4'-DDD) exceeded DNREC levels (and NOAA ERLs). Multiple PAHs also exceeded the DNREC screening levels. The analysis for PCBs was performed using method 8270D-SIM/680(M) for PCB congeners, reporting the NOAA-22 congeners, rather than PCB aroclors. Therefore, the Total PCBs value is presented in Table 7 as the sum of the NOAA-22 congeners; this is an estimate since it is not a true measurement of total PCBs, but is appropriate for screening purposes. Concentrations of PCBs are well below all screening levels. For context, a sediment sample from the South Bethany Canals, collected September 07, 2017, was analyzed for PCB Aroclors and resulted in non-detection at a reporting limit of 23 µg/kg.

In general, the analyte concentrations in SB-COMP-1 are consistently higher than SB-COMP-2, which may be caused by the different catchment area of road runoff.

3.4 CONCLUSIONS FROM INTENSIVE SAMPLING AND ANALYSIS

While multiple analytes are flagged above the DNREC-SIRS HSCA Screening Levels for Marine Sediment, none of the concentrations exceed the NOAA Effects Range Median level (NOAA ERM). These initial results suggest that the material dredged from the South Bethany Canals could be deposited upland or reused at landfills at a minimum. Coordination with DNREC Wetlands and Subaqueous Lands Section regarding specific disposal options is recommended before the dredging project is scoped and permit applications are prepared and submitted.

Table 6. Analytical results for metals in sediment composites.

Chemical Constituents – Metals (ppm)	South Bethany Samples (All concentrations in ppm) SB-COMP-1		SB-COMP-2		Screening Thresholds NOAA ERL	NOAA ERM	DNREC-SIRS HSCA Screening Levels- Marine Sediment
Arsenic (As)	20.80		11.00		8.2	70.0	7.24
Cadmium (Cd)	0.25	J	0.12	J	1.2	9.6	0.68
Chromium (Cr)	34.40		19.40		81.0	370.0	52.30
Copper (Cu)	99.10		59.10		34.0	270.0	18.70
Lead (Pb)	22.70		10.50		46.7	218.0	30.20
Mercury (Hg)	0.06		0.03		0.2	0.7	0.13
Nickel (Ni)	11.60		4.88		20.9	51.6	15.90
Zinc (Zn)	151.00		74.20		150.0	410.0	124.00

Lab Qualifiers:

ND = Analyte not detected at the method detection limit.

J = Estimated value. Target analyte concentration is below the quantitation limit but above the method detection limit.

P = The relative percent difference between sample runs exceeds the method-specific criteria.

I = The lower value of the two runs is reported due to obvious interference.

Table 7. Analytical results for PCBs in sediment composites.

Chemical Constituents- PCBs (ppm)	South Bethany Samples (All concentrations in ppm) SB-COMP-1		SB-COMP-2		Screening Thresholds NOAA ERL Value	NOAA ERM Value	DNREC-SIRS HSCA Screening Levels- Marine Sediment
Total PCBs (sum of NOAA-22 congeners)	0.0011		0.0004		23	180	0.04

Lab Qualifiers:

ND = Analyte not detected at the method detection limit.

J = Estimated value. Target analyte concentration is below the quantitation limit but above the method detection limit.

P = The relative percent difference between sample runs exceeds the method-specific criteria.

Table 8. Analytical results for PAHs in sediment composites.

South Bethany Samples (All concentrations in ppm)					Screening Thresholds		
Chemical Constituents-PAH (ppm)	SB-COMP-1		SB-COMP-2		NOAA ERL Value	NOAA ERM Value	DNREC-SIRS HSCA Screening Levels-Marine Sediment
Napthalene	0.010		0.001		0.16	2.10	0.035
Acenaphthylene	0.078		0.047		0.04	0.64	
Acenaphthene	0.017		0.017		0.02	0.50	0.007
Fluorene	0.016		0.016		0.02	0.54	0.021
Phenanthrene	0.113		0.083		0.24	1.50	0.087
Anthracene	0.094		0.066		0.85	1.10	0.047
Fluoranthene	0.872		1.470		0.60	5.10	0.113
Pyrene	1.120		1.080		0.67	2.60	0.153
Benzo(a)anthracene	0.363		0.312		0.26	1.60	0.075
Chrysene	0.721		0.990		0.38	2.80	0.108
Benzo(b)fluoranthene	0.920		0.612		N/A	N/A	N/A
Benzo(k)fluoranthene	0.601		0.418		N/A	N/A	N/A
Benzo(a)pyrene	0.529		0.337		0.43	0.76	0.089
Indeno(1,2,3-cd)pyrene	0.424		0.273		N/A	N/A	N/A
Dibenzo(a,h)anthracene	0.093		0.049		0.06	0.26	0.006
Benzo(g,h,i)perylene	0.408		0.260		N/A	N/A	N/A

Lab Qualifiers:

ND = Analyte not detected at the method detection limit.

J = Estimated value. Target analyte concentration is below the quantitation limit but above the method detection limit.

P = The relative percent difference between sample runs exceeds the method-specific criteria.

I = The lower value of the two runs is reported due to obvious interference.

Table 9. Analytical results for pesticides in sediment composites.

Chemical Constituents-Pesticide (ppm)	South Bethany Samples (All concentrations in ppm) SB-COMP-1		SB-COMP-2		Disposal Option Thresholds NOAA ERL Value	NOAA ERM Value	DNREC-SIRS HSCA Screening Levels- Marine Sediment
alpha-BHC	ND		ND		N/A	N/A	N/A
Hexachlorobenzene	ND		ND		N/A	N/A	N/A
beta-BHC	ND		ND		N/A	N/A	N/A
gamma-BHC	0.0003	P	ND		N/A	N/A	N/A
delta-BHC	ND		ND		N/A	N/A	N/A
Heptachlor	ND		ND		N/A	N/A	N/A
Aldrin	ND		ND		N/A	N/A	N/A
Heptachlor epoxide (B)	ND		ND		N/A	N/A	0.001
Oxychlordane	0.0007		0.00110		N/A	N/A	N/A
gamma-Chlordane	0.0024		0.00092		N/A	N/A	N/A
2,4'-DDE	0.0003	IP	ND		N/A	N/A	N/A
Endosulfan I	ND		ND		N/A	N/A	0.000107
alpha-Chlordane	0.0018		0.00077		N/A	N/A	N/A
trans-Nonachlor	0.0020		0.00078		N/A	N/A	N/A
4,4'-DDE	0.0072		0.00431		0.002	0.027	0.00207
Dieldrin	ND		ND		0.0002	0.008	0.00072
2,4'-DDD	0.0057		0.00146	P	N/A	N/A	0.00122
Endrin	ND		ND		N/A	N/A	0.00267
Endosulfan II	ND		ND		N/A	N/A	N/A
4,4'-DDD	0.0252		0.00358		0.002	0.020	N/A
2,4'-DDT	ND		ND		N/A	N/A	0.00119
cis-Nonachlor	0.0009		0.00034		N/A	N/A	N/A
Endrin aldehyde	ND		ND		N/A	N/A	N/A
Endosulfan sulfate	ND		ND		N/A	N/A	N/A

South Bethany Samples (All concentrations in ppm)					Disposal Option Thresholds		
Chemical Constituents- Pesticide (ppm)	SB-COMP-1		SB-COMP-2		NOAA ERL Value	NOAA ERM Value	DNREC-SIRS HSCA Screening Levels- Marine Sediment
4,4'-DDT	0.0006	I	0.00035	IP	0.001	0.007	N/A
Endrin ketone	ND		0.00051	P	N/A	N/A	N/A
Methoxychlor	0.0041	P	0.00293	P	N/A	N/A	0.0296
Mirex	ND		ND		N/A	N/A	N/A
Toxaphene	ND		ND		N/A	N/A	0.536
Chlordane	ND		ND		0.0005	0.006	N/A

Lab Qualifiers:

ND = Analyte not detected at the method detection limit.

J = Estimated value. Target analyte concentration is below the quantitation limit but above the method detection limit.

P = The relative percent difference between sample runs exceeds the method-specific criteria.

I = The lower value of the two runs is reported due to obvious interference.

4.0 RECOMMENDATIONS FOR NEXT STEPS

It is recommended that the nutrient rich surface sediments are removed from the South Bethany Canals to alleviate eutrophication processes that drive poor water quality. In anticipation of dredging, preliminary estimates of dredge volumes are provided to assist with initial project planning; estimates are presented in Table 10. Dredge volumes for two regions were calculated in Table 10; the first region is the eastern 300 feet of canals Anchorage, Petherton, Brandywine, Henlopen, New Castle, and Layton. The second region is identified as the "Highway Canal System", which includes all of Highway Canal and smaller adjacent canals: Godwin, Kent, Sussex, and May. In summary, according to these areas, the total estimated amount of dredged material will range from approximately 7,500 cubic to 15,000 cubic yards.

It is important to note that nutrient rich sediments are present in the deeper portions of the canals, which are not suggested for dredging at this time. Due to the depth of these locations, a method for isolating the sediment nutrients from the water column may be to cap the sediment with a layer (e.g., 1 foot) of clean sand. This would remove the nutrients from active sediment-water exchange and will decrease the depth, and potentially trapping, of fine sediments in those locations.

This information, along with the sediment characteristics presented in the previous section, should provide sufficient information to scope out the logistics and costs associated with different dredge methods, and disposal options. A project pre-application meeting with DNREC and other Federal regulators (e.g., USACE-NAP, FWS, NOAA, EPA) is recommended before proceeding with additional engineering analysis. Since these canals were artificially excavated, and permit to dredge was recently (approx. 2008) awarded to the Town, this project should be presented to regulators as maintenance dredging. It is recommended that the methods of dredging and disposal that were used in the 2008 dredging project be reviewed and possibly repeated since the project was previously permitted.

Table 10. Preliminary estimates of sediment volume at incremental depths of removal.

Region	Area (acres)	Material Removed (ft)	Estimated Dredge Volume (cubic yards)
Ends of Canals: Anchorage to Layton (300')	2.5	1.0	3,996
Highway Canal System	2.2	1.0	3,571
Ends of Canals: Anchorage to Layton (300')	2.5	1.5	5,994
Highway Canal System	2.2	1.5	5,356
Ends of Canals: Anchorage to Layton (300')	2.5	2.0	7,992
Highway Canal System	2.2	2.0	7,141

APPENDIX A. LABORATORY RESULTS