Executive Summary

As a part of the 2014 Chesapeake Bay Watershed Agreement, Maryland committed to restoring oyster populations in five tributaries in Maryland's portion of the Chesapeake Bay by 2025 (Chesapeake Executive Council 2014).

In a December 15, 2017 press release, DNR announced the intention to design and develop oyster management plans for other sanctuaries in addition to the five tributaries. Specifically, the press released stated the Manokin, Nanticoke and Severn rivers would have plans developed to determine how the strategic use of state investment and resources could restore oyster populations, using planting seed, shell and spat to spur natural oyster growth and reproduction (MD DNR 2017). In a September 5, 2018 press release, DNR announced the intention to study and survey existing state oyster sanctuaries in Anne Arundel County, including the Severn River Sanctuary and working with the local watershed associations to maximize the restoration potential in the tributaries (MD DNR 2018). The South, Severn and Magothy river systems are referred to as the Anne Arundel Complex (Figure 1).

Restoration in the Anne Arundel Complex is part of an overall plan to invest state resources in sanctuaries other than those selected towards the Chesapeake Bay Agreement. The investment for these other sanctuaries is for small-scale restoration. This document provides a restoration plan for the Anne Arundel Complex sanctuaries; however, this investment may not occur in sequential years. State resources may vary between other sanctuaries from year to year.

As part of the Oyster Management Review 2010-2015, MD DNR classified sanctuaries within Maryland waters of the Chesapeake Bay into tiers (0, 1A, 1, 2 and 3), based on their relative oyster productivity, to help inform management actions (MD DNR 2016). Magothy and Severn River sanctuaries were classified as Tier 1A, areas that contain oyster restoration or research projects conducted by the USACE, while the South River sanctuary was classified as a Tier 2 sanctuary, having had no investment in the maintenance or restoration of oyster populations (2016).

This plan evaluates areas within the Magothy, Severn and South River sanctuaries that are suitable for restoration efforts. The plan includes specific areas targeted for restoration work, an analysis of the seed required, and an estimated cost. A basic monitoring effort of the population and water quality is included.

Bottom habitat is based on the Coastal Marine Ecological Classification Standards (CMECS) bottom characterization from data collected during the 1970-80's Bay Bottom Survey and a 2011 side scan sonar survey conducted by Maryland Geological Survey (MGS) to determine areas that are currently restorable oyster habitat. Areas that are considered currently restorable from bottom substrate data have degraded from the time of the Bay Bottom Survey and may have declined further since the MGS side scan sonar data. Patent tong data was used to verify bottom habitat, when possible. Many areas throughout the Bay that have received restoration efforts in the past did not have adequate patent tong samples taken to fully verify the habitat.

Selecting the type of restoration to apply to a site largely depends on the habitat and the existing oyster population. In the case of large-scale restoration, criteria were developed to determine whether restoration areas are candidates for receiving oyster seed only (areas with 5-50 oysters per m^2), whether they will require possible substrate addition as well as oyster seed (areas with <5 oysters per m^2), or if they already meet the restoration targets (areas with >50 oysters per m^2) (Oyster Metrics Workgroup 2011). These guidelines for seed or substrate and seed restoration can be applied to all reef level restoration.

Using large-scale restoration as a guide, areas within the Anne Arundel Complex that have existing oyster densities greater than 5 per m^2 are considered as potential areas for spat-on-shell only restoration. Areas with hard bottom and less than 5 oyster per m^2 are potential candidates for substrate placement followed by spat-on-shell restoration. However, due to limited resources and funding, the Anne Arundel efforts will be focused

on planting spat-on-shell without the need for additional substrate. The cost of adding additional substrate is prohibitive within this limited budget. Using seed only, restoration can be done more quickly and work can occur under the existing permits.

Given low natural recruitment, a planting density of 5 million spat-on-shell per acre and a minimum of 800 bushels of shell with spat per acre will be used for reefs within the Anne Arundel Complex. The number of spat per one shell varies widely on hatchery produced spat-on-shell. As a result, the amount of shell planted on a given restoration site varies tremendously, even assuming a constant planting density. The minimum bushel of shell with spat per acre aims to help standardize the set rate (number of spat per one shell). This density is similar the density for initial restoration efforts within the St. Mary's sanctuary. The Anne Arundel Complex area is an area with low natural recruitment. In low recruitment areas in the upper Bay, like the Anne Arundel Complex area, it is important to have multiple year classes of oysters on the reef to ensure that as oysters from initial plantings age and progressively contain more females that a younger year class with more males is present to ensure fertilization (Oyster Metrics Workgroup 2011). Restoration efforts within this area would likely benefit from the introduction of additional year classes by re-seeding every few years to help ensure the male to female ratio for potential future recruitment.

Community based oyster restoration groups are active in sanctuaries within Maryland, including the South, Severn and Magothy River sanctuaries. The Marylanders Grow Oysters (MGO) program is a program that is co-managed by MD DNR and Oyster Recovery Partnership in which local waterfront residents and businesses hang cages with spat-on-shell from their docks and maintain them for 9 months. The young oysters are then planted on areas within the local sanctuary, increasing the chance of survival for spat-on-shell. MGO has local tributary organizers, including the Magothy River Association for the Magothy River, the Arundel River Federation for the South River and the Severn River Association for the Severn River. The Chesapeake Bay Foundation organizes community oyster gardening throughout the Chesapeake Bay, including areas within the Severn, South and Magothy River sanctuaries. All of these community based oyster programs can contribute oysters to actions taken under this plan.

The total acreage estimated for potential restoration in the Magothy River sanctuary is 3.1 acres, the South River sanctuary is 6.7 acres and the Severn River sanctuary is 40.4 acres.

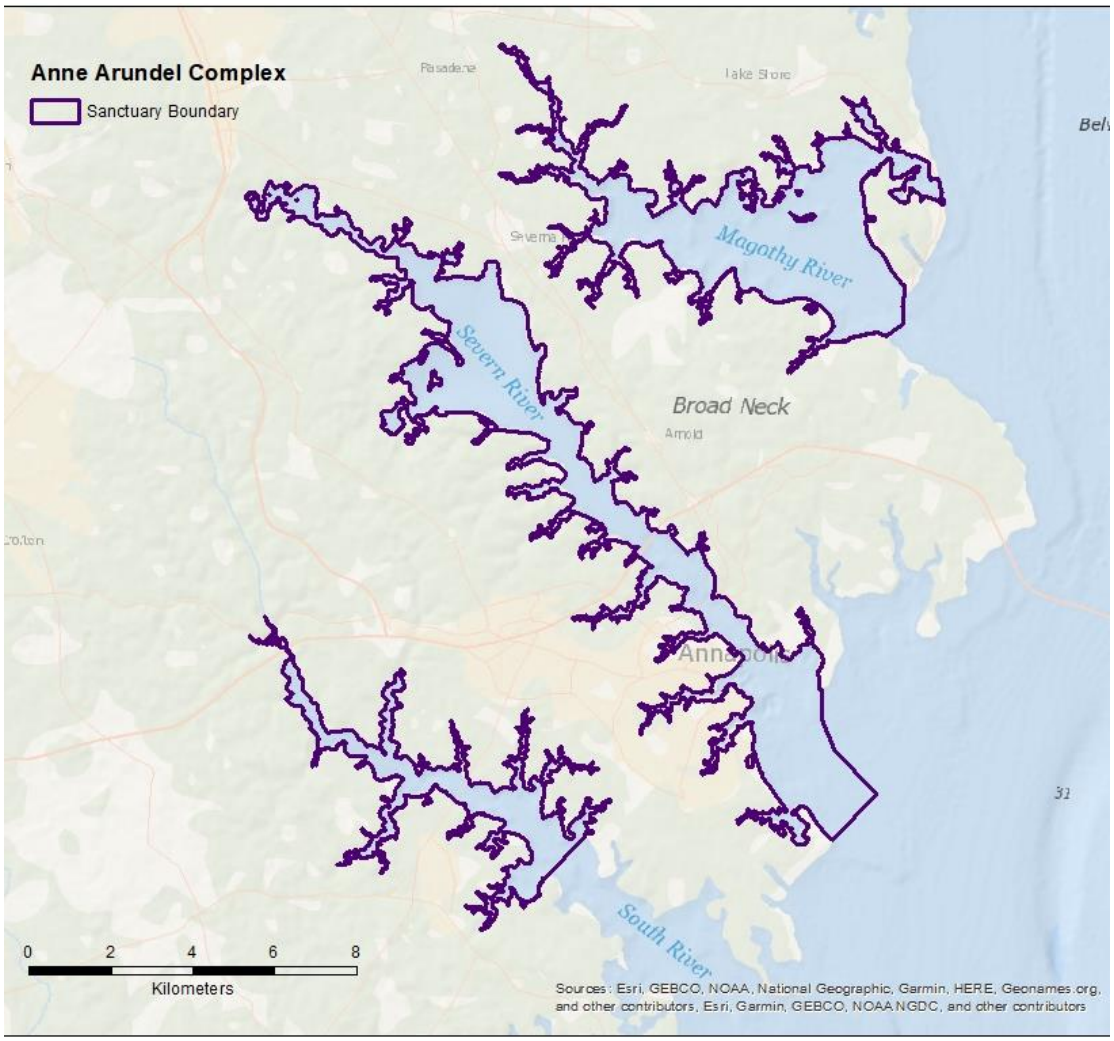

Figure 1. The South, Severn and Magothy river sanctuaries that make up the Anne Arundel Complex.

Magothy River Sanctuary

Environmental Conditions

The Magothy River is a tidal tributary of the Chesapeake Bay with 640 acres of wetlands (USACE 2012). The sanctuary within the Magothy River was established in 2010 and encompasses 5,607 surface acres (Figure 2). A portion of the sanctuary is classified as a restricted area to shellfish harvesting by the Maryland Department of the Environment (2018) due to potential contamination of shellfish by fecal coliform and other bacteria (Figure 2). The Magothy River sanctuary is considered a low salinity region (<12ppt) which may help to suppress oyster disease pressures, but is considered to be low for optimal recruitment relative to higher salinity areas (USACE 2012). The Magothy River is at risk for potential impacts from freshets during years of high rainfall (Figure 3, Table 1). The mean bottom water dissolved oxygen level within the Magothy River is generally above the USACE Native Oyster Restoration Master Plan water quality parameter preferred lower limit of 5 mg/l during the winter, spring and fall, but generally has monthly average minimum values below 5 mg/l in the summer months (Figure 4, Table 2). Dissolved oxygen concentrations of 2 mg/l are considered anoxic. Oysters can survive periods of low DO, but the recommended level for oyster survival is 5 mg/l, below this level, increased stress may influence the oysters' susceptibility to other stresses (USACE 2012). Magothy River has periods of low dissolved oxygen during the summer months. The USACE reported 83 acres of submerged aquatic vegetation (SAV) habitat in the Magothy River sanctuary (2012).

Benthic habitat is important to understanding the suitability of an area for oyster reefs. Areas in which the bottom substrate is mud, even if they historically had oyster reefs, will not be considered as areas suitable for planting seed. Bottom habitat is based on the Coastal Marine Ecological Classification Standards (CMECS) bottom characterization from data collected during the 1970-80's Bay Bottom Survey and a 2011 side scan sonar survey conducted by Maryland Geological Survey (Figure 5). Areas of historic oyster bars that have substrate other than mud, including consolidated sediments, gravel mixes, sand, biogenic oyster, anthropogenic oyster and muddy sand were considered for restoration. From these areas, a 150 ft. buffer around aquaculture leases and any area that intersected with submerged aquatic vegetation were removed. The resulting area is classified as currently restorable oyster habitat (CROH) (Figure 6). When considering the historic oyster habitat (HOH) to the CROH, the potential acreage of oyster bars within the sanctuary decrease from 229 acres to 163 acres (Figure 6).

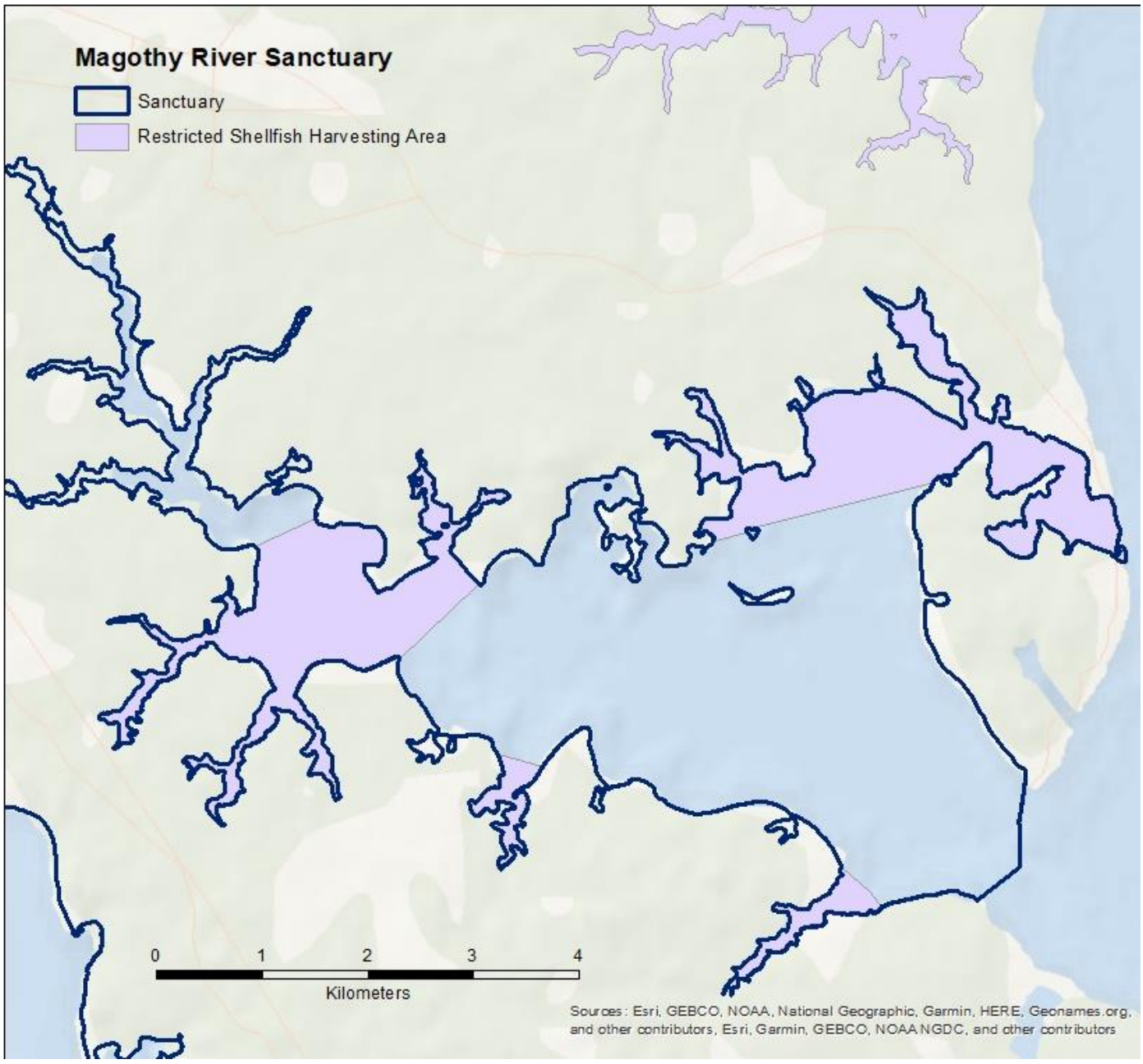

Figure 2. Magothy River Sanctuary and areas restricted by Maryland Department of the Environment for shellfish harvest.

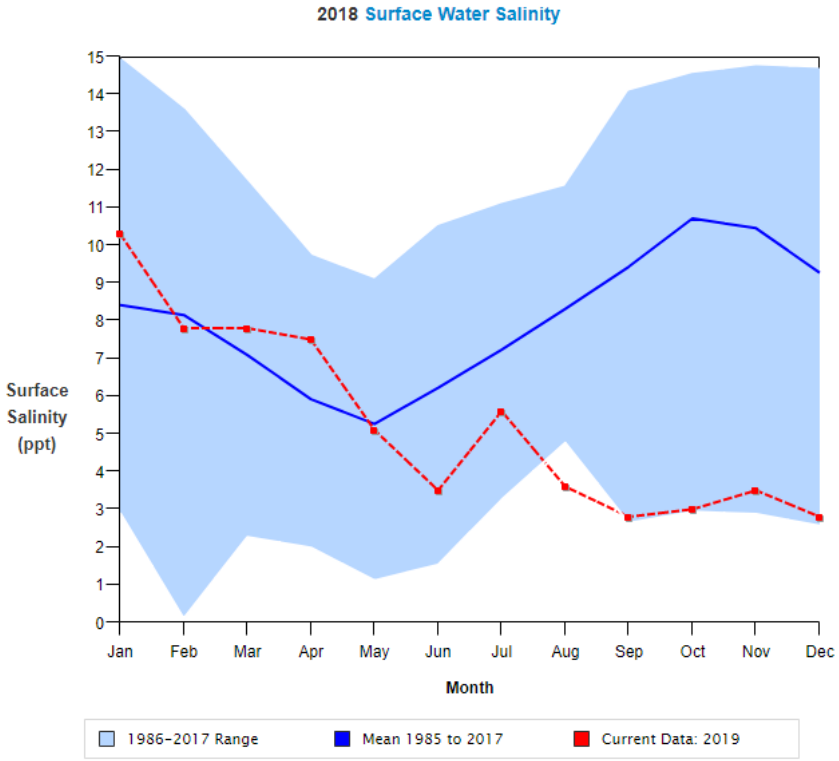

Figure 3. MD DNR Eyes on the Bay station WT6.1 surface water salinity for 2018.

Table 1. Monthly surface water salinity values for 2017 and 2018 from MD DNR Eyes on the Bay station WT6.1.

Surface Water Salinity (ppt) Lower Western Shore / Magothy River (WT6.1)					
Month	**Minimum**	**Mean**	**Maximum**	**2017**	**2018**
January	2.90	8.41	14.93	10.40	10.30
February	0.10	8.15	13.59	10.90	7.80
March	2.26	7.09	11.67	8.90	7.80
April	1.98	5.92	9.72	6.00	7.50
May	1.11	5.26	9.08	5.30	5.10
June	1.53	6.22	10.50	5.40	3.50
July	3.25	7.23	11.08	6.20	5.60
August	4.76	8.31	11.54	5.80	3.60
September	2.63	9.43	14.06	10.00	2.80
October	2.93	10.71	14.53	13.20	3.00
November	2.87	10.45	14.73	10.60	3.50
December	2.56	9.27	14.66	11.70	2.80

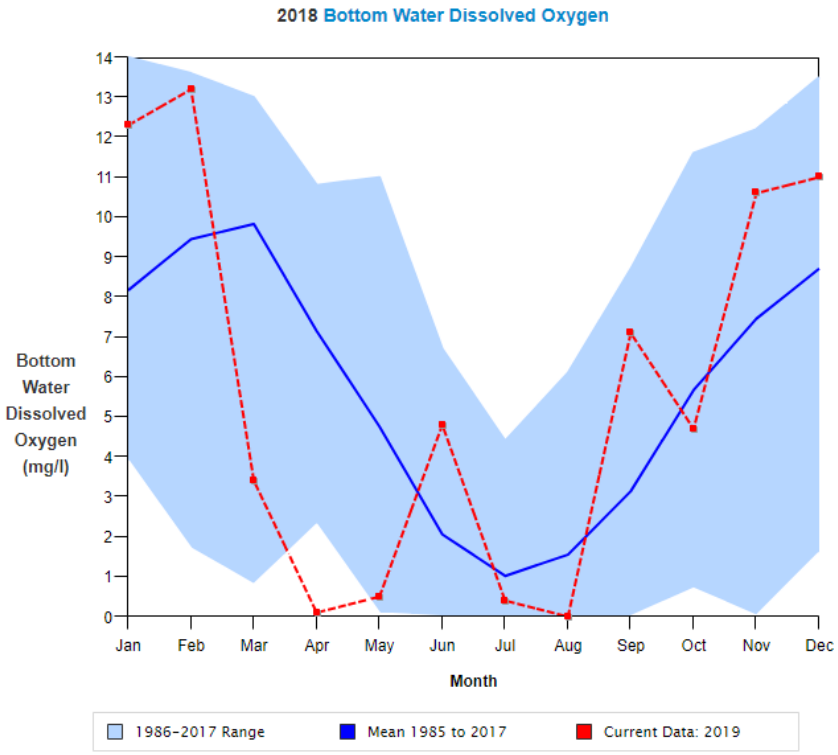

Figure 4. MD DNR Eyes on the Bay station WT6.1 bottom dissolved oxygen for 2018.

Table 2. Monthly bottom dissolved oxygen values for 2017 and 2018 from MD DNR Eyes on the Bay station WT6.1.

Bottom Water Dissolved Oxygen (mg/l) Lower Western Shore / Magothy River (WT6.1)					
Month	**Minimum**	**Mean**	**Maximum**	**2017**	**2018**
January	3.90	8.17	14.00	4.90	12.30
February	1.70	9.45	13.60	12.30	13.20
March	0.80	9.83	13.00	7.60	3.40
April	2.30	7.15	10.80	8.60	0.10
May	0.08	4.76	11.00	8.30	0.50
June	0.00	2.06	6.70	0.00	4.80
July	0.00	1.02	4.40	4.70	0.40
August	0.00	1.55	6.10	3.60	0.00
September	0.00	3.14	8.70	0.00	7.10
October	0.70	5.67	11.60	5.90	4.70
November	0.02	7.46	12.20	7.40	10.60
December	1.60	8.71	13.50	5.70	11.00

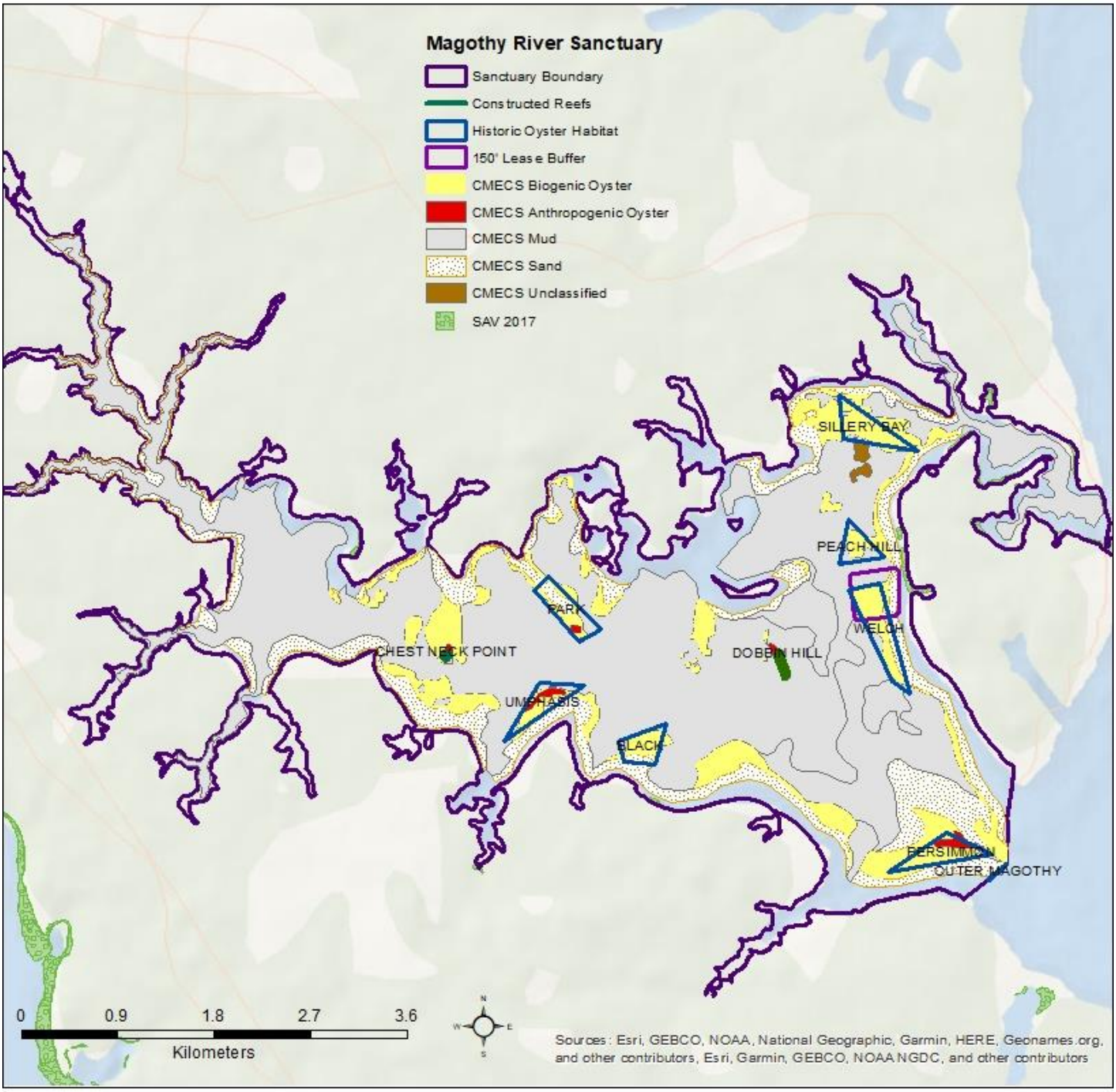

Figure 5. Historic oyster bars and the Coastal Marine Ecological Classification Standards (CMECS) bottom characterization from data collected during the 1970-80's Bay Bottom Survey and a 2011 side scan sonar survey conducted by Maryland Geological Survey within the Magothy River Sanctuary.

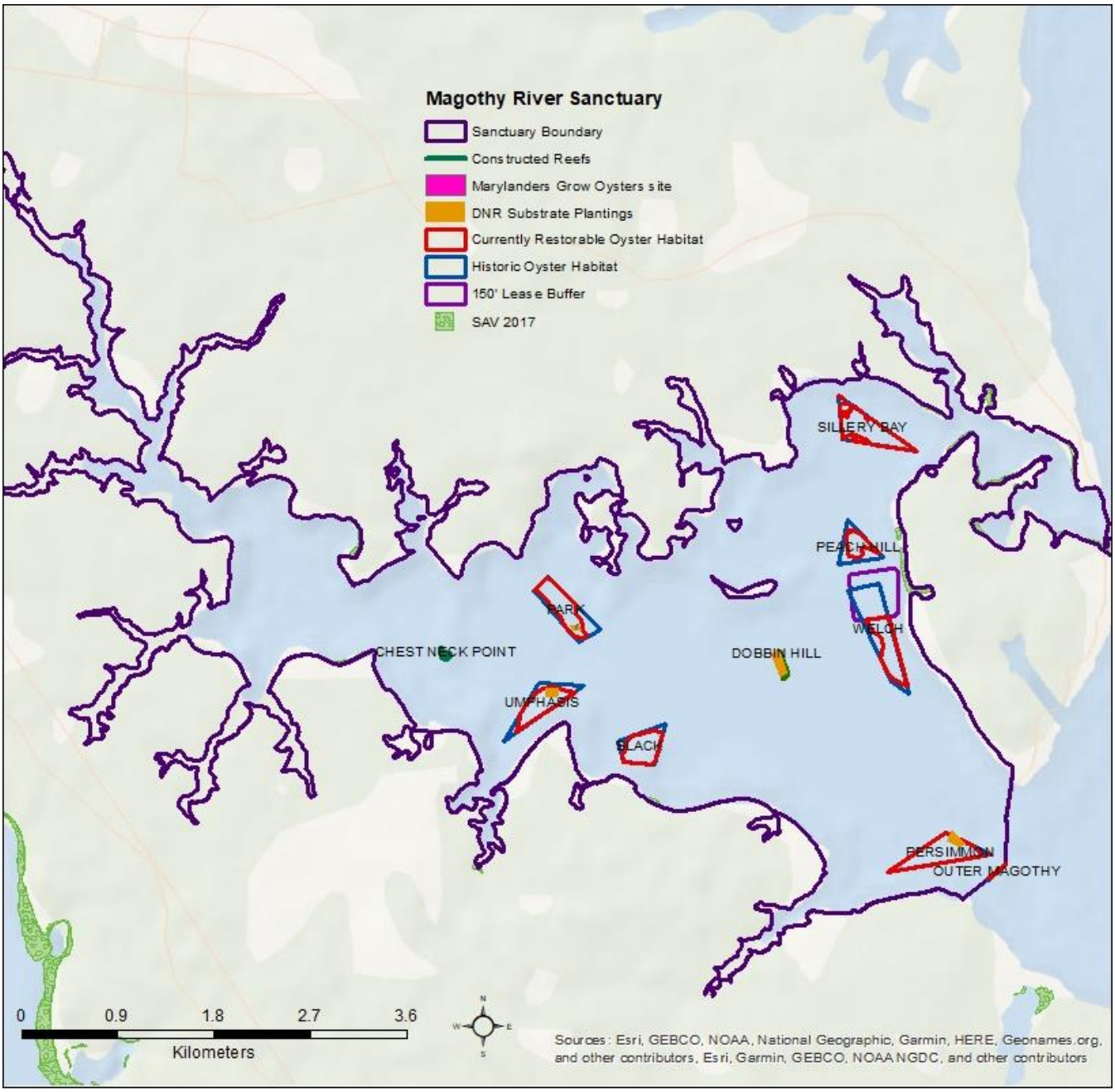

Figure 6. Currently restorable oyster habitat (CROH), oyster bars and DNR substrate planting areas in the Magothy River Sanctuary. Of the 163 acres of CROH, most are not feasible for spat-on-shell only restoration, with Chest Neck and Umphasis having 3.1 acres available to plant spat-on-shell.

Current Oyster Population Characteristics

There are 230 acres of historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments) consisting of eight historic oyster bars, seven fully within the sanctuary and one just over reaching the boundary (MD DNR 2016). There are no MD DNR Fall Oyster Survey sites that fall within the Magothy River Sanctuary since 1990. A patent tong survey was conducted in 2018 by MD DNR and found no spat, an average density of 0.04 ±0.32 small oysters and an average of 0.26 ±2.27market size oysters. The average total volume of shell was 2.85 liters ±5.46 with an average of 0.52 ±1.6 liters of surface shell and an average 2.27 ±4.34 liters of gray shell. There were 55 samples taken on historic oyster bars and 40 supplemental samples taken. Of those, 57 out of 90 samples (30 on historic oyster bars and 27 supplemental) had no live oysters and no volume of shell, indicating poor habitat in those areas. The Magothy River Association hatchery spat-on-shell planting sites that were sampled (8 samples total on the 5 sites) exhibited higher densities than non-planted reefs (Table 3, Figure 7). Areas of Chest Neck, Park and Dobbin Hill were not able to be monitored during the patent tong survey due to the presence of reef balls and stone substrate. The Magothy River Association has a volunteer diver program to monitor the reefs that they plant. The results of their 2018 monitoring showed the highest densities at Chest Neck (Table 4).

Table 3. Average density and shell volume of oysters found on Magothy River Association restoration reefs in the 2018 MD DNR patent tong survey.

Reef	**Average Live Oysters (number per m^2)**				**Average Volume (L)**			
	Spat	**Small**	**Market**	**Total**	**Oysters**	**Surface Shell**	**Gray Shell**	**Total Shell**
Park	0	1.5	15.5	17	3.25	2.25	4	9.5
Persimmon	0	0	1	1	trace	8.95	11.5	20.5
Chest Neck Pt	123	0	0	123	1	9.5	8	18.5
Dobbins	0	0	3	3	0.5	3	14	17.5
Umphasis	0	0	10	10	3	N/A	N/A	18

Table 4. Magothy River Association planting sites diver monitoring results 2018.

Reef	**Oysters per m^2**
Chest Neck	32
Umphasis	6
Park	24
Dobbin Hill	6

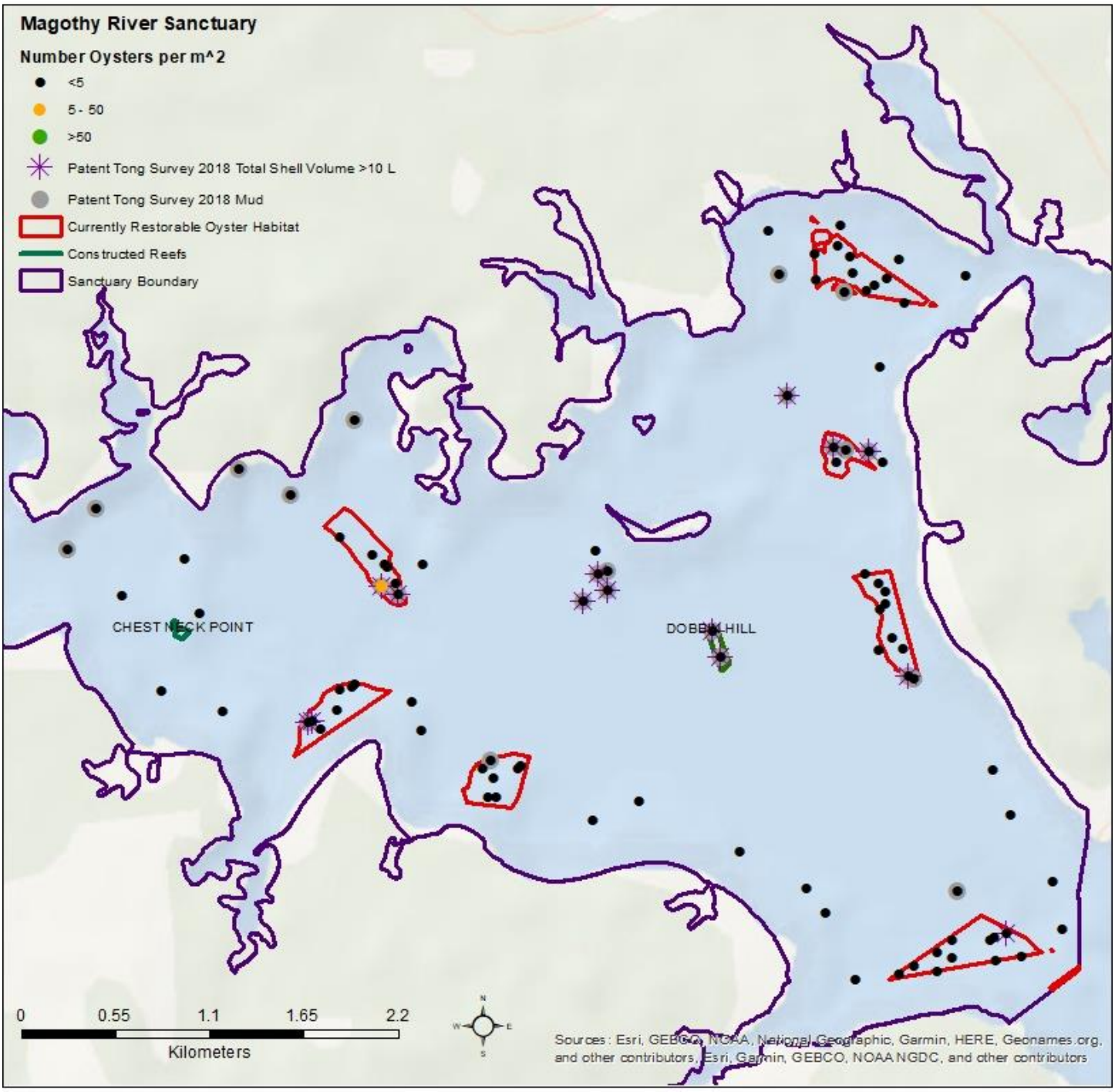

Figure 7. Currently restorable oyster habitat (CROH) and MD DNR 2018 patent tong survey results.

Past Planting Activities

The Magothy River sanctuary has seven Yates bars within its boundaries, Sillery Bay, Peach Hill, Welch, Persimmon, Back, Umphasis and Park. Of these, three have received substrate material, Park, Umphasis, and Persimmon. Two other reefs are not historic oyster bars, but were created by the planting of substrate, Dobbin Hill and Chest Neck (Table 5). Chest Neck Reef was built as a memorial to Marshall Duer, while MD DNR placed substrate to create Dobbin Hill. The five reefs that have received substrate are the only areas that will support spat-on-shell restoration without the addition of substrate. The areas that received substrate in the past had very few samples taken within the substrate placement area during the patent tong survey. Umphasis had one sample taken within the area of substrate addition, which had no live oysters, and a total shell volume of 6 liters. Park had one sample within the substrate addition area. This sample had 25 live oysters and a total shell volume of 16 liters. The MGO site is located within Park reef, but the MGO planting area was not sampled as part of the patent tong survey. Dobbin Hill had two samples taken during the patent tong survey in the area that had received substrate. One had a one live oyster and a total shell volume of 17.1 liters and another, which had no live oysters and a total shell volume of 15 liters. Persimmon had one patent tong sample within the substrate planting area. It had two live oysters and a total shell volume of 28 liters. Chest Neck was sampled in two locations and found no oysters in one location with 19 liters of total shell volume and 246 spat in the other sample with 18 liters of total shell volume.

Table 5. Oyster bars in the Magothy River sanctuary and the restoration treatments received.

Oyster Bar	Size (acres)	Year substrate planted	Base substrate material planted	Hatchery Spat-on-Shell Plantings
Sillery Bay	35	N/A	N/A	N/A
Peach Hill	20	N/A	N/A	N/A
Welch	50	N/A	N/A	N/A
Persimmon	32	1998, 1999	3 acres of dredged shell	Planted in 1998, Boys Scouts of America planted 200 bags of spat-on-shell in 2000
Dobbin Hill	4	1999	4 acres of dredged shell, ~60 reef balls	Planted in 1999
Black	25	N/A	N/A	Planted in 1995, High school project in 2004
Umphasis	30	1999	2 acres of dredged shell planted	Planted in 1999 and 2006, MRA planted 200 bags of SOS
Park	34	2003	1.1 acres of stone (4-8” diameter) , 55 reef balls	Planted in 2003, MGO oysters planted there yearly
Chest Neck Point	1.1	2003	dredged shell planted, 22 reef balls	Planted in 2001, 2003, and 2006

Restoration Plan

Even though the total area of CROH was estimated at 163 acres based on bottom habitat, results from the 2018 patent tong survey exhibited only one area with a density of oysters > 5 per m^2. Bottom types throughout the sanctuary from the patent tong survey were sand, mud and a combination of both sand and mud. As a general guide for restoration, areas that have existing oyster densities greater than 5 per m^2 are considered as potential areas for spat-on-shell only restoration. Areas with hard bottom and less than 5 oyster per m^2 are

potential candidates for substrate placement and then spat-on-shell restoration. Since this restoration effort is limited in scope to only spat-on-shell restoration, much of the 163 acres of CROH is not feasible for spat-on-shell only restoration.

Park Reef will remain as the Marylanders Grow Oysters planting site and will receive yearly plantings of young oysters through the program. Based on the recommendation from the Magothy River Association, Chest Neck Point Reef and Umphasis Reefs will be the areas to receive spat-on-shell plantings of oysters under this effort. Chest Neck has a good shell base with an average total shell volume of 18.5 liters. Umphasis has had substrate planted and multiple spat-on-shell plantings. Magothy River Association divers report good bottom, even though the patent tong survey samples were limited on the site of restoration. Dobbin Hill has many reef balls within the area and had mud as the primary bottom type in the patent tong survey, with a low volume of surface shell and will not be considered for current restoration. Persimmon had sand as the primary bottom type in the patent tong survey and had an overall low surface shell volume. Persimmon had oysters planted on it by the Boys Scouts and was monitored by the Magothy River Association. The reef is sloped and upon monitoring, it was noticed that the oysters were mostly at the bottom of the slope. Persimmon Reef and Dobbin Hill will not be the focus of planting spat-on-shell at this time due to the degraded bottom habitat since the time that substrate was planted.

Chest Neck has an area of 1.1 acres with substrate available to plant with spat-on-shell, while Umphasis has an area of approximately 2 acres with substrate available. Planting at a density of 5 million spat-on-shell per acre on the estimated 3.1 acres yields total of 15.5 million spat-on-shell for initial restoration. The approximate cost for this restoration is $55,800.

Population monitoring of the planted reefs will be done yearly by the Magothy River Association volunteer diver program. Water quality is monitored regularly throughout the Magothy River by the Magothy River Association. Population monitoring data will help to inform if the reef is at a density that would be considered self-sustaining and whether multiple year classes are present. This will determine whether a second planting is necessary after a few years and at what density.

Severn River Sanctuary

Environmental Conditions

The Severn River is a tidal tributary of the Chesapeake Bay with 2,048 acres of wetlands (USACE 2012). In 1998, 6,719 acres were designated by Maryland Department of the Environment (MDE) as restricted from harvest due to potential contamination of shellfish by fecal coliform and other bacteria. This restricted area constituted most of the river and essentially made the area a sanctuary since no harvest was allowed. In 2010, the entire river (7,804 acres) was officially designated as a sanctuary (Figure 8). The Severn River sanctuary is considered a low salinity region (<12ppt) which may help to suppress oyster disease pressures, but is considered to be low for optimal recruitment relative to higher salinity areas (USACE 2012). The Severn River is at risk for potential impacts from freshets during years of high rainfall (Figure 9, Table 6). The mean bottom water dissolved oxygen level within the Severn River is generally above the USACE Native Oyster Restoration Master Plan water quality parameter preferred lower limit of 5 mg/l during the winter, spring and fall, but generally has monthly average minimum values below 5 mg/l in the summer months (Figure 10, Table 7). Dissolved oxygen concentrations of 2 mg/l are considered anoxic. Oysters can survive periods of low DO, but the recommended level for oyster survival is 5 mg/l, below this level, increased stress may influence the oysters' susceptibility to other stresses (USACE 2012). The USACE reported 326 acres of submerged aquatic vegetation (SAV) habitat in the Severn River sanctuary (2012).

Benthic habitat is important to understanding the suitability of an area for oyster reefs. Areas in which the bottom substrate is mud, even if they historically had oyster reefs, will not be considered as areas suitable for planting seed. Bottom habitat is based on the Coastal Marine Ecological Classification Standards (CMECS) bottom characterization from data collected during the 1970-80's Bay Bottom Survey and a 2011 side scan sonar survey conducted by Maryland Geological Survey (Figure 11). Areas of historic oyster bars that have substrate other than mud, including consolidated sediments, gravel mixes, sand, biogenic oyster, anthropogenic oyster and muddy sand were considered for restoration. From these areas, a 150 ft. buffer around aquaculture leases and any area that intersected with submerged aquatic vegetation were removed. The resulting area is classified as currently restorable oyster habitat (CROH) (Figure 12a & 12b). When considering the historic oyster habitat (HOH) to the CROH, the potential acreage of oyster bars within the sanctuary decrease from 1,383 acres to 1,020 acres. This area does not include reefs created from substrate addition on areas not within historic oyster bars. A lot of the area of CROH was not sampled during the patent tong survey and therefore the bottom habitat was not verified as acceptable for spat-on-shell restoration.

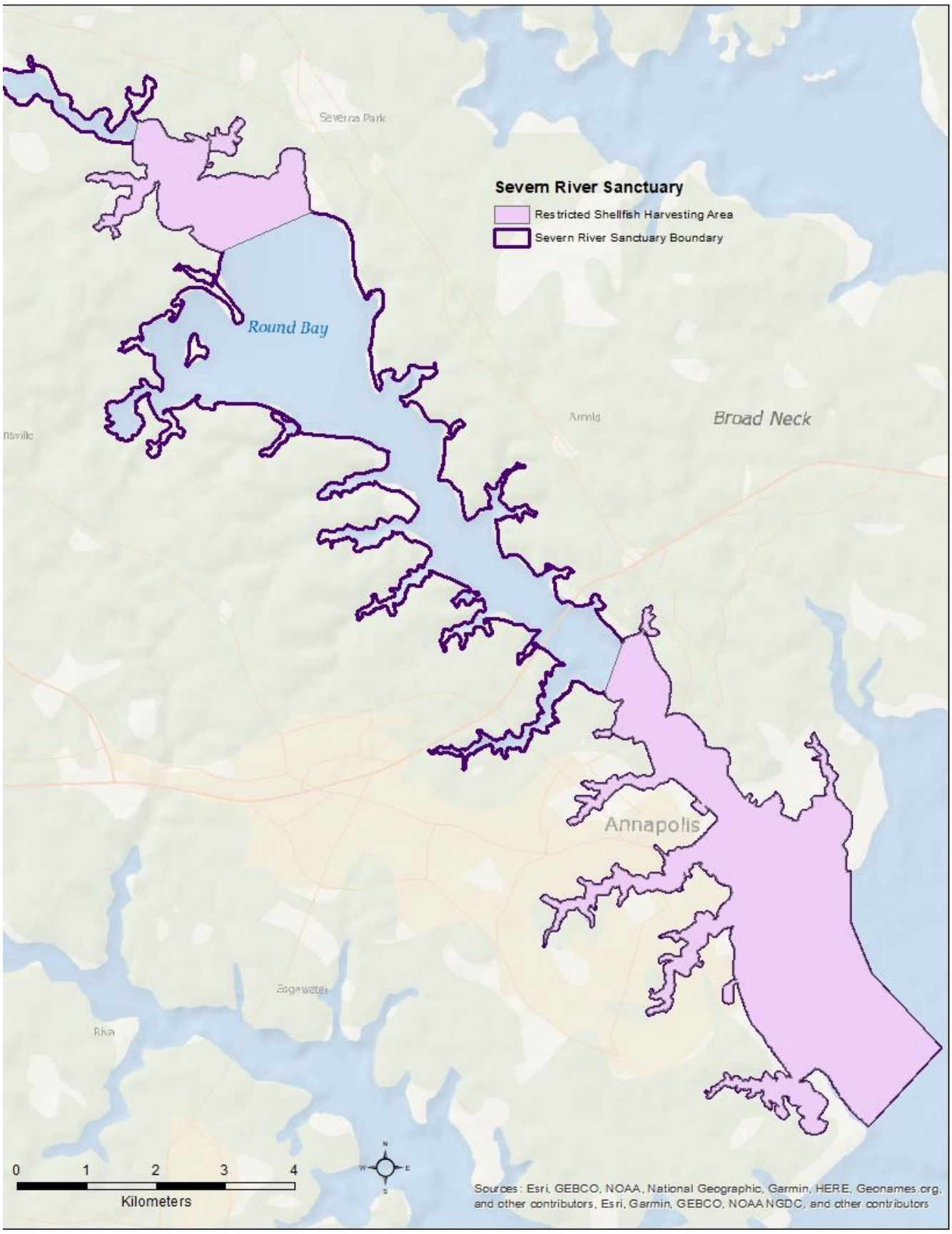

Figure 8. Severn River Sanctuary and areas restricted by Maryland Department of the Environment for shellfish harvest.

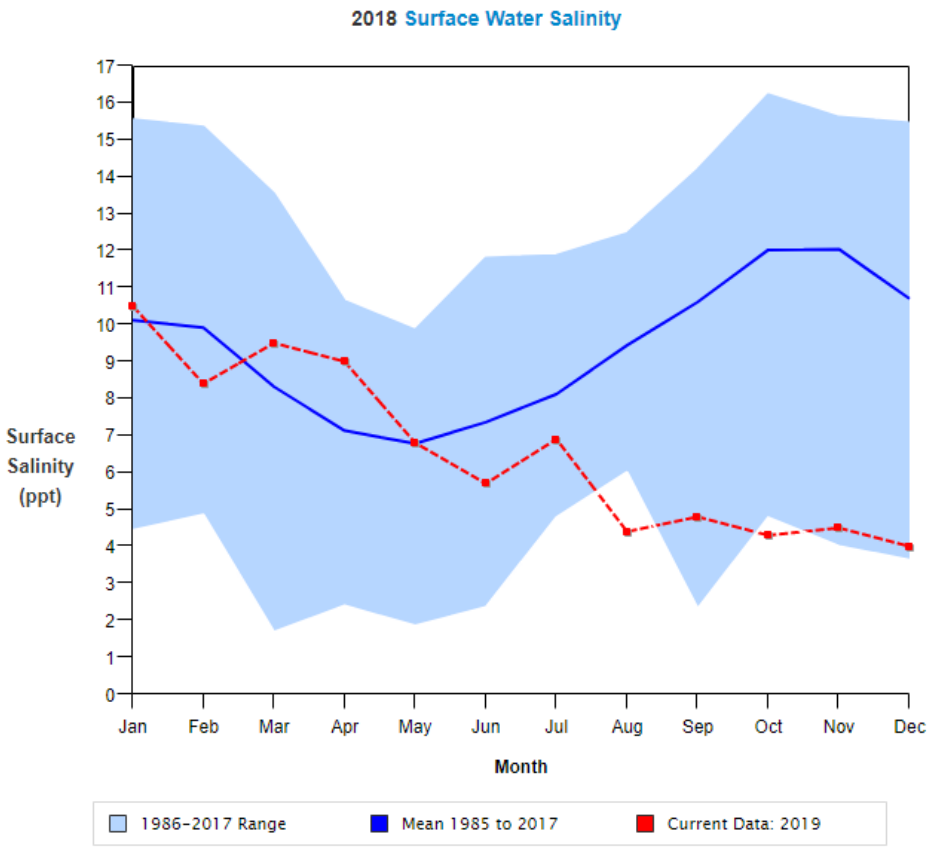

Figure 9. MD DNR Eyes on the Bay station WT7.1 surface water salinity for 2018.

Table 6. Monthly surface water salinity values for 2017 and 2018 from MD DNR Eyes on the Bay station WT7.1.

Surface Water Salinity (ppt) Lower Western Shore / Severn River (WT7.1)					
Month	**Minimum**	**Mean**	**Maximum**	**2017**	**2018**
January	4.43	10.12	15.54	11.30	10.50
February	4.85	9.92	15.34	12.60	8.40
March	1.68	8.32	13.53	10.50	9.50
April	2.39	7.13	10.63	6.20	9.00
May	1.85	6.78	9.85	6.50	6.80
June	2.35	7.36	11.80	7.00	5.70
July	4.78	8.12	11.87	7.50	6.90
August	6.00	9.44	12.46	7.50	4.40
September	2.31	10.61	14.19	11.20	4.80
October	4.78	12.02	16.22	13.90	4.30
November	4.00	12.04	15.61	12.80	4.50
December	3.63	10.70	15.45	13.30	4.00

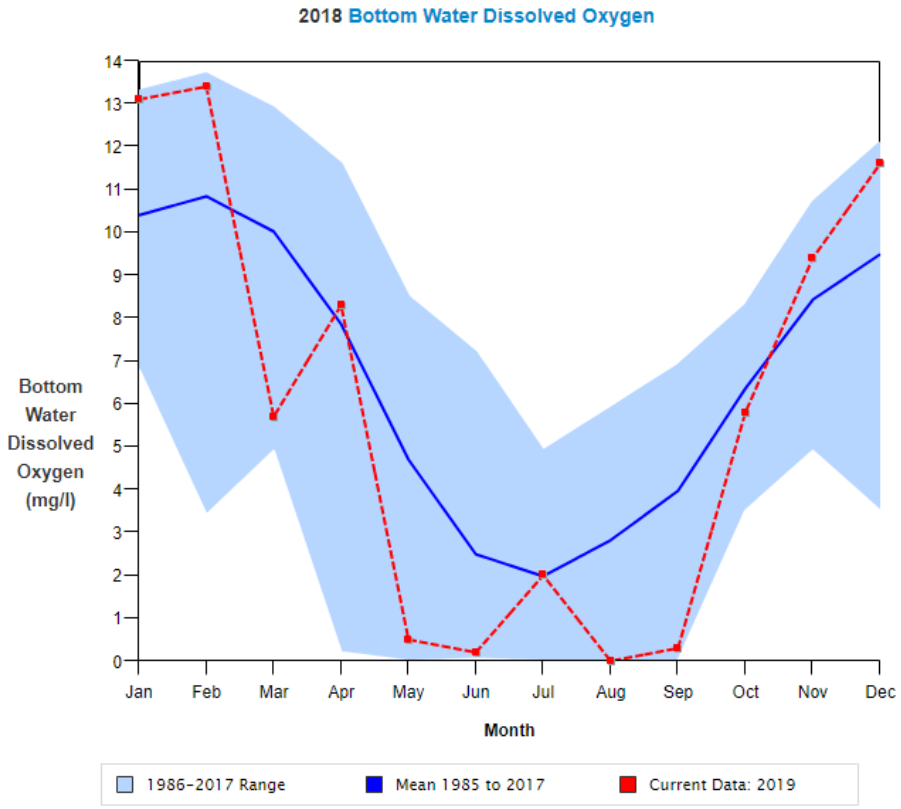

Figure 10. MD DNR Eyes on the Bay station WT7.1 bottom dissolved oxygen for 2018.

Table 7. Monthly bottom dissolved oxygen values for 2017 and 2018 from MD DNR Eyes on the Bay station WT7.1.

Bottom Water Dissolved Oxygen (mg/l) Lower Western Shore / Severn River (WT7.1)					
Month	**Minimum**	**Mean**	**Maximum**	**2017**	**2018**
January	6.80	10.40	13.30	12.50	13.10
February	3.40	10.84	13.70	11.90	13.40
March	4.90	10.02	12.90	12.80	5.70
April	0.20	7.86	11.60	10.60	8.30
May	0.00	4.70	8.50	8.20	0.50
June	0.05	2.49	7.20	0.00	0.20
July	0.00	1.98	4.90	2.00	2.00
August	0.00	2.82	5.90	4.70	0.00
September	0.00	3.97	6.90	1.30	0.30
October	3.50	6.36	8.30	5.60	5.80
November	4.90	8.43	10.70	7.00	9.40
December	3.50	9.49	12.10	10.10	11.60

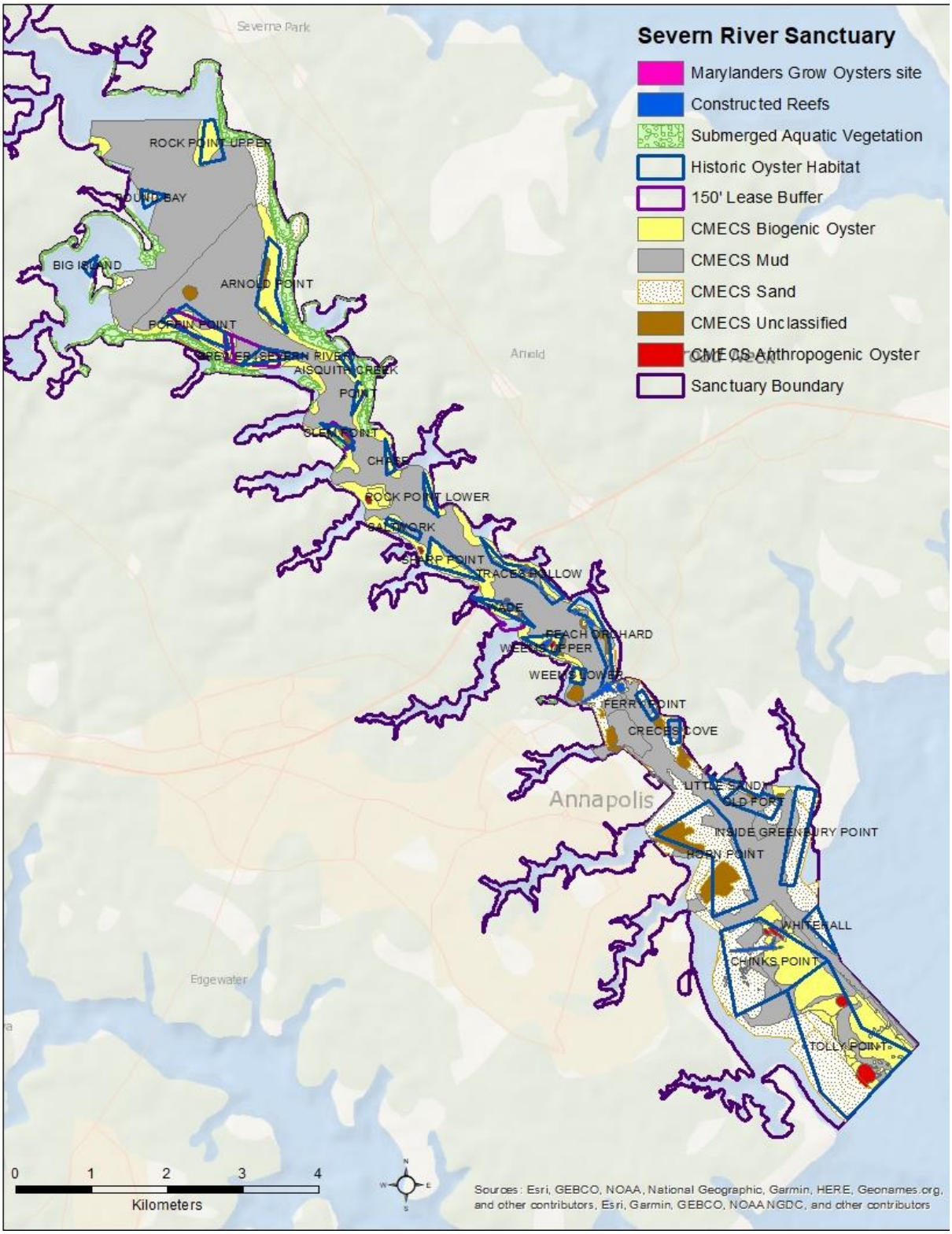

Figure 11. Historic oyster bars and the Coastal Marine Ecological Classification Standards (CMECS) bottom characterization from data collected during the 1970-80's Bay Bottom Survey and a 2011 side scan sonar survey conducted by Maryland Geological Survey within the Severn River Sanctuary.

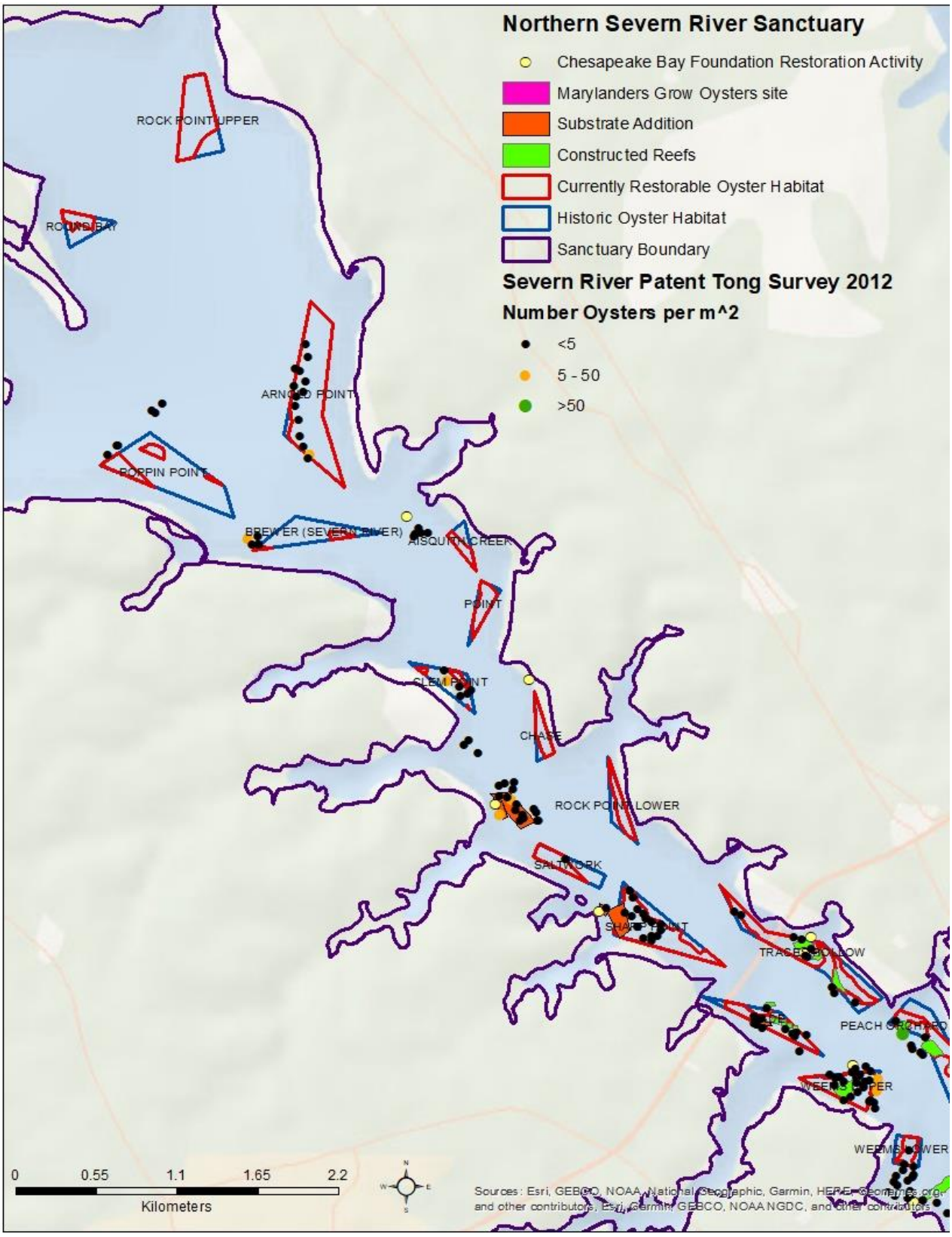

Figure 12a. Currently restorable oyster habitat (CROH), oyster bars and MD DNR 2012 patent tong survey results. There are six reefs that are within historic oyster bars and have bottom habitat that would support spat-on-shell plantings, Traces Hollow, Wade, Weems Upper, Peach Orchard, Chink Point and Tolly Point, totaling 40.4 acres available for spat-on-shell restoration.

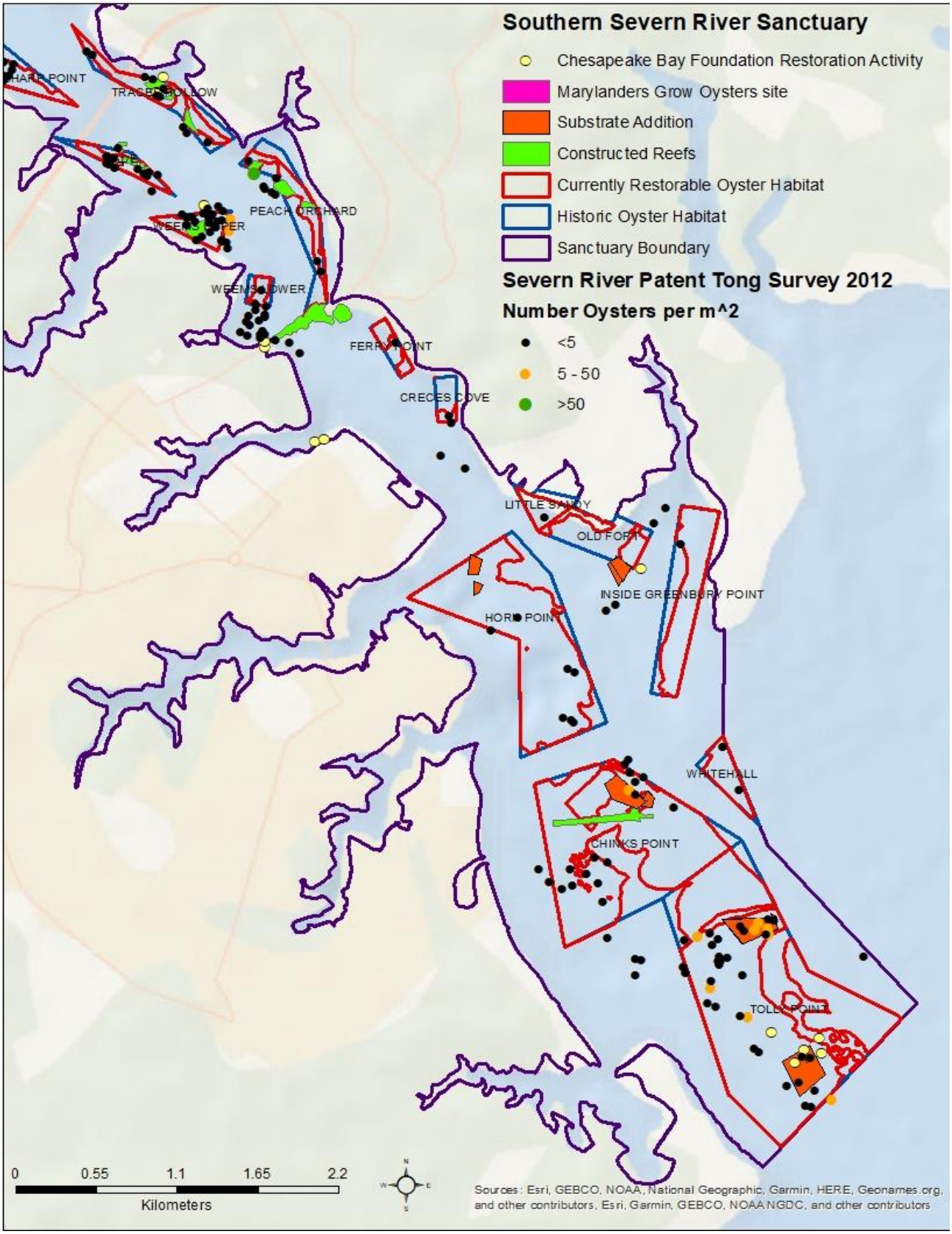

Figure 12b. Currently restorable oyster habitat (CROH), oyster bars and MD DNR 2012 patent tong survey results. There are six reefs that are within historic oyster bars and have bottom habitat that would support spat-on-shell plantings, Traces Hollow, Wade, Weems Upper, Peach Orchard, Chink Point and Tolly Point, totaling 40.4 acres available for spat-on-shell restoration.

Current Oyster Population Characteristics

There are 1,383 acres of historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments) consisting of twenty seven historic oyster bars, twenty five fully within the sanctuary and two extending over the boundary. There are several reef areas that have been constructed that are not on historic oyster bars (Table 8). There is one MD DNR Fall Oyster Survey site, on Chinks Point, which falls within the Severn River Sanctuary. From 1998-2015 the number of live oysters from the Fall Oyster Survey per bushel was 88 ±18, with 34 ±17 smalls and 51±8 market-sized oysters (MD DNR 2016). A patent tong survey was conducted in 2012 by MD DNR and found no spat, and average density of 1.6 ±14.3 small oysters and an average of 0.5 ±2.4 market size oysters (Figures 12a & 12b). The average total surface shell volume was 1.3 ±3.5 liters. There were 236 samples taken, of which 105 had zero oysters and zero total shell volume. Of the reefs that received oyster shell for substrate plantings, six had no patent tong samples taken on the restored area (Wade, Round Bay, Martins Pond, College Point, Old Fort and Horn Point). Sharp Point and Traces Hollow reefs had only one patent tong sample collected within the restoration areas, so would not be a good indication of the restoration area. Chinks Point had two samples taken within the restoration area, which both exhibited a total shell volume >10 liters. Saltwork Creek had multiple samples taken and exhibited some shell remaining, but most samples (eight out of nine) had less than 10 liters of total shell. Tolly Point had many samples within the restoration areas. The southern area of Tolly Point that received oyster shell as substrate had almost no shell volume exhibited in the patent tong survey. The northern area of Tolly Point which received oyster shell as substrate had many samples and exhibited many with > 10 liter of total shell (Figure 13). Areas that have alternate substrate including concrete, stone, slag, and rip rap, were unable to be sampled as part of the patent tong survey. These areas have received spat-on-shell plantings in the past and are considered to be areas that would still support spat-on-shell restoration. In figures 12a and 12 b, CMECS unspecified reef areas are those that have received alternate substrate materials.

Table 8. Oyster bars within the Severn River Sanctuary and the restoration that they have received. MGO oysters are Marylanders Grow Oysters planting sites. Oyster gardeners are other community oyster gardening participants through the Chesapeake Bay Foundation.

Oyster Bar	Size (acres)	Year Substrate planted	Base substrate material planted	Hatchery Spat-on-Shell Plantings
Rock Point Upper	31	N/A	N/A	N/A
Round Bay	11	N/A	N/A	N/A
Big Island	6	N/A	N/A	N/A
Arnold Point	58	N/A	N/A	N/A
Poppin Point	50	N/A	N/A	N/A
Brewer	21	N/A	N/A	N/A
Unknown Bar (area off of Aisquith, constructed reef)	5	2008	Crushed concrete	2009, 2017, Oyster Gardening oysters
Aisquith Creek	6	N/A	N/A	N/A
Point	8	N/A	N/A	N/A
Clem Point	13	N/A	N/A	N/A
Round Bay (constructed reef)	?	2004	Oyster shell	N/A
Chase	7	N/A	N/A	N/A
Rock Point Lower	9	N/A	N/A	N/A
Saltwork Creek (constructed reef)	7	1962, 2005	Oyster shell	2005, Oyster Gardening oysters
Saltwork	12	N/A	N/A	N/A
Martins Pond (constructed reef)	0.8	2005	Oyster shell	2005, Oyster Gardening oysters
Sharp Point	36	1963	Oyster shell	N/A
Traces Hollow	36	2005, 2010, ?	Granite, Oyster shell	2005, 2010, MGO oysters
Wade	16	2010, 2001	Concrete, slag, granite, Oyster shell	2010, 2012
Weems Upper	19	?	granite	2001, 2010, 2013, 2018
Peach Orchard	43	2010, 2009	Granite, slag	2010, 2013, 2015, 2018 MGO oysters
Weems Lower	8	N/A	N/A	N/A
USNA Bridge (constructed reef)	0.2	1998	Rip rap	2005
Ferry Point	11	N/A	N/A	1992
College Creek (constructed reef)	?	2001	Oyster shell	2001
Creces Cove	10	N/A	N/A	N/A
Little Sandy	16	N/A	N/A	N/A
Old Fort	45	1998	Oyster shell	
Horn Point	194	1996	Oyster shell	1998
Inside Greenbury Point	70	N/A	N/A	N/A
Chinks Point	252	?, 1998, 1999	Construction rubble, Oyster shell	1999, 2007, 2008
Tolly Point	897 / 381 within the sanctuary	1999, 2009	Oyster shell	1999, 2000, 2001, 2006, 2008, 2009
Whitehall	550 / 19.7 within the sanctuary	N/A	N/A	N/A

Even though the total area of CROH was estimated at 1,020 acres based on bottom habitat, results from the 2012 patent tong survey exhibited few areas with a density of oysters > 5 per m^2. Bottom types throughout the sanctuary from the patent tong survey were sand, mud, shell, rock, alternate materials and combinations of sand, mud, grit and shell. As a general guide for restoration, areas that have existing oyster densities greater than 5 per m^2 are considered as potential areas for spat-on-shell only restoration. Areas with hard bottom and less than 5 oyster per m^2 are potential candidates for substrate placement and then spat-on-shell restoration. Since this restoration effort is limited in scope to only spat-on-shell restoration, much of the 1,020 acres of CROH is not feasible for spat-on-shell only restoration.

Based on the volume of surface shell volume from the 2012 patent tong survey, and areas that have alternate substrate planted in the past, there are six reefs that are within historic oyster bars and have bottom habitat that would support spat-on-shell plantings: Traces Hollow, Wade, Weems Upper, Peach Orchard, Chink Point and Tolly Point (Table 9, Figure 13). Traces Hollow is a Marylanders Grow Oysters (MGO) planting site and will continue to receive yearly plantings of young oysters through the MGO program. Traces Hollow also has three reef areas that had granite used to construct a reef base, totaling 4.1 acres. It also has a 0.78 acre area that had dredged shell added. The patent tong survey only had one sample within the dredged shell addition area, which was not enough data to support spat-on-shell plantings.

Peach Orchard has granite substrate reefs and has areas that are deep. It received spat-on-shell restoration in 2018 funded by MDOT grant funds through MD DNR, which were enhanced with additional efforts through the Build-a-Reef campaign by the Severn River Association. Due to historic rainfall in 2018, there was concern as to whether the spat-on-shell survived the low salinity conditions. Oyster Recovery Partnership sampled some areas in April 2019 that received spat-on-shell plantings in 2018 and found that spat survived the low salinity with an approximate spat mortality range of 5-20% and measured an average size of 18 mm. Oyster Recovery Partnership also found many large, market sized oysters. Since Peach Orchard received spat-on-shell restoration in every two to three years since 2010 and multiple age classes are present, it will not be considered for this restoration effort, but might be considered in future efforts.

Severn River Association suggested that restoration work should be focused on Wade and Weems Upper. Weems Upper also received spat-on-shell restoration in 2018 funded by MDOT grant funds through MD DNR, which were enhanced with additional efforts through the Build-a-Reef campaign by the Severn River Association. It has received spat-on-shell restoration every three to five years since 2010. Oyster Recovery Partnership found spat and large oysters on the reef in the April 2019 monitoring. Weems Upper is a reef that was recommended by the Severn River Association to receive spat-on-shell planting as part of this effort. Since it has received continued restoration efforts, it may not be considered as the primary area for restoration under this effort, but might be considered in future efforts.

Wade, Chinks Point, and northern portion of Tolly's Point are all good candidates for spat-on-shell restoration. Wade has six areas of alternate substrate reefs, five constructed from concrete, slag or granite and one from dredged shell. It has received spat-on-shell planting in 2010 and 2012. Chinks Point and Tolly Point are both close to the border of the sanctuary. Both have demonstrated areas >5 oysters per m^2 in the patent tong survey as well as areas> 10 liters of surface shell. Chinks Point has an area of reef constructed with construction rubble and an area of reef constructed from dredged shell. It has not been planted with spat-on-shell in the last 10 years. Tolly Point has two areas that were constructed with dredged shell. The northern reef area had oysters >5 per m^2 and >10 liters of surface shell, while the southern reef area had no oysters and little shell present.

Table 10 shows the projected spat-on-shell per acre and cost of restoration per reef with 5 million spat-on-shell are planted per acre. Actual acreage restored and which reefs receive restoration will be chosen from these six reefs.

Population monitoring of the planted reef areas is undetermined at this time. Since the plantings will occur on areas with alternate substrate, divers will be needed to monitor the planted area. MD DNR does not have a diver monitoring program and cannot fund monitoring with capital funds. The Severn River Association does not have a diver monitoring program and does not have the capacity to monitor the plantings. Water quality is monitored regularly throughout the Severn River by the Severn River Association.

Table 9. Reefs with >10 liters of surface shell volume or alternate substrate that would support spat-on-shell plantings.

Oyster Bar	**Substrate Characteristics**	**Alternate Substrate Restoration Area (acres)**
Traces Hollow	Granite	4.1
Wade	Concrete, slag and granite	2.0
Weems Upper	Granite	2.6
Peach Orchard	Granite, areas >10 L surface shell	4.4
Chinks Point	Construction rubble, areas >10 L surface shell	7.8, 9.4, total 17.1
Tolly Point	Dredged shell addition areas >10 L surface shell	10.2

Table 10. Restoration areas, amount of spat-on-shell and cost estimates for reefs in the Severn River sanctuary.

Oyster Bar	**Restoration Area (acres)**	**Restoration**	**Amount SOS (millions)**	**Cost**
Traces Hollow	0.12	MGO oysters	0	0
Traces Hollow	4.1	SOS	20.5	$73,800
Wade	2.0	SOS	10	$36,000
Weems Upper	2.6	SOS	13	$46,800
Peach Orchard	4.4	SOS	22	$79,200
Chinks Point	17.1	SOS	85.5	$307,800
Tolly Point	10.2	SOS	51	$183,600

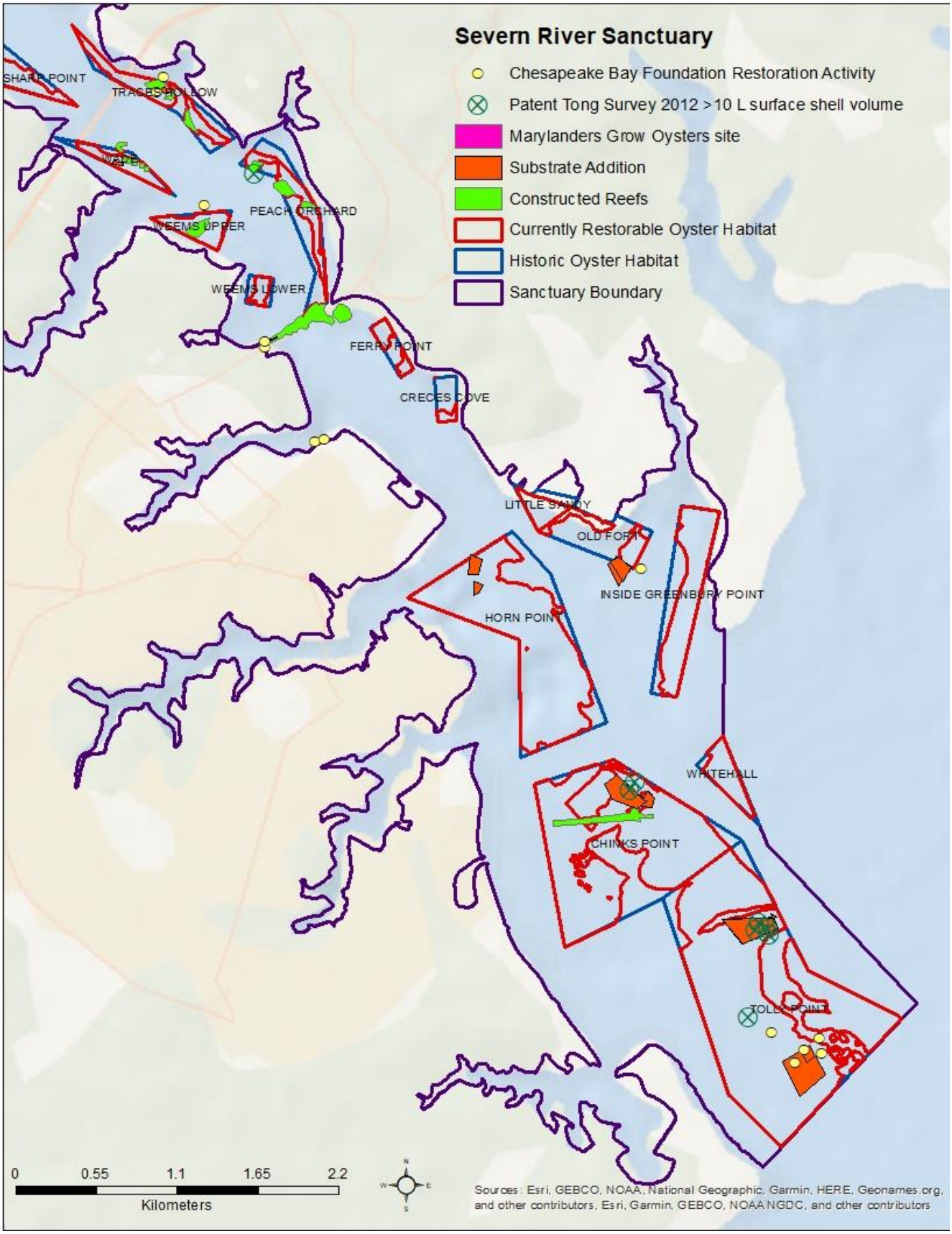

Figure 13. Areas in the Severn River Sanctuary that had surface shell volume >10L per meter squared, constructed reef areas and areas that have received alternate substrate.

South River Sanctuary

Environmental Conditions

The South River is a tidal tributary of the Chesapeake Bay with 1,792 acres of wetlands (USACE 2012). The sanctuary within the South River was established in 2000 and encompasses 2,327 surface acres (Figure 14). The South River sanctuary is considered a low salinity region (<12ppt) which may help to suppress oyster disease pressures, but is considered to be low for optimal recruitment relative to higher salinity areas (USACE 2012). The South River is at risk for potential impacts from freshets during years of high rainfall (Figure 15, Table 11). The mean bottom water dissolved oxygen level within the South River is generally above the USACE Native Oyster Restoration Master Plan water quality parameter preferred lower limit of 5 mg/l during the winter, spring and fall, but generally has monthly average minimum values below 5 mg/l in the summer months (Figure 16, Table 12). Dissolved oxygen concentrations of 2 mg/l are considered anoxic. Oysters can survive periods of low DO, but the recommended level for oyster survival is 5 mg/l, below this level, increased stress may influence the oysters' susceptibility to other stresses (USACE 2012). The USACE reported 8 acres of submerged aquatic vegetation (SAV) habitat in the South River sanctuary (2012).

Benthic habitat is important to understanding the suitability of an area for oyster reefs. Areas in which the bottom substrate is mud, even if they historically had oyster reefs, will not be considered as areas suitable for planting seed. Bottom habitat is based on the Coastal Marine Ecological Classification Standards (CMECS) bottom characterization from data collected during the 1970-80's Bay Bottom Survey and a 2011 side scan sonar survey conducted by Maryland Geological Survey (Figure 17). Areas of historic oyster bars that have substrate other than mud, including consolidated sediments, gravel mixes, sand, biogenic oyster, anthropogenic oyster and muddy sand was classified as currently restorable oyster habitat (CROH) (Figure 18). When considering the historic oyster habitat (HOH) to the CROH, the potential acreage of oyster bars within the sanctuary decrease from 141 acres to 66 acres. A portion of the sanctuary is classified as a restricted area to shellfish harvesting by the Maryland Department of the Environment (2018) due to potential contamination of shellfish by fecal coliform and other bacteria (Figure 14).

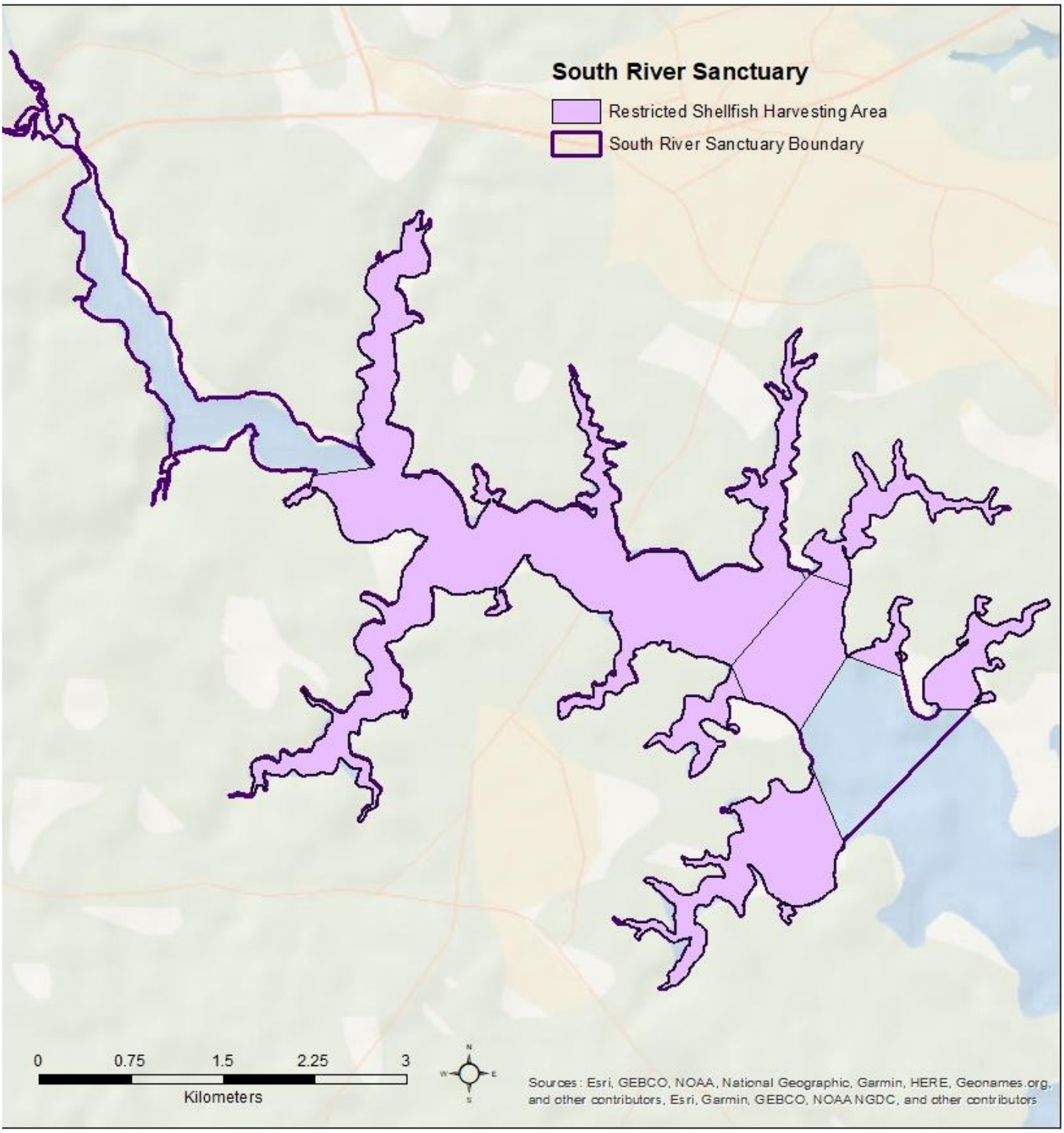

Figure 14. South River Sanctuary and areas restricted by Maryland Department of the Environment for shellfish harvest.

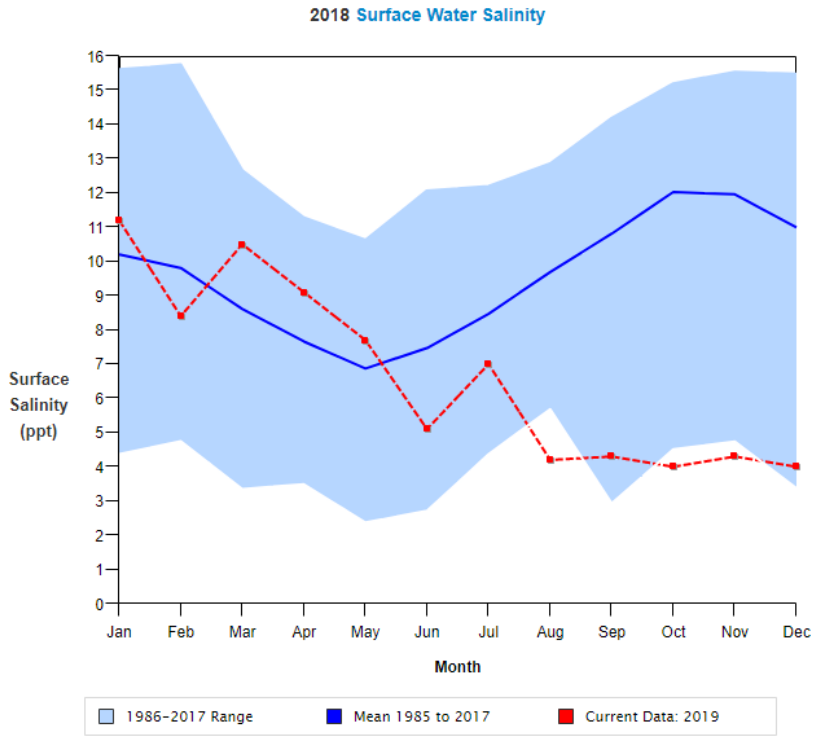

Figure 15. MD DNR Eyes on the Bay station WT8.1 surface water salinity for 2018.

Table 11. Monthly surface water salinity values for 2017 and 2018 from MD DNR Eyes on the Bay station WT8.1.

Surface Water Salinity (ppt) Lower Western Shore / South River (WT8.1)					
Month	**Minimum**	**Mean**	**Maximum**	**2017**	**2018**
January	4.37	10.20	15.61	13.60	11.20
February	4.75	9.81	15.75	12.50	8.40
March	3.35	8.61	12.66	9.90	10.50
April	3.49	7.66	11.28	7.60	9.10
May	2.37	6.87	10.63	6.40	7.70
June	2.71	7.47	12.07	7.10	5.10
July	4.37	8.47	12.20	7.90	7.00
August	5.68	9.69	12.86	7.30	4.20
September	2.93	10.81	14.19	11.70	4.30
October	4.51	12.03	15.20	14.10	4.00
November	4.74	11.96	15.54	13.80	4.30
December	3.37	10.99	15.48	13.00	4.00

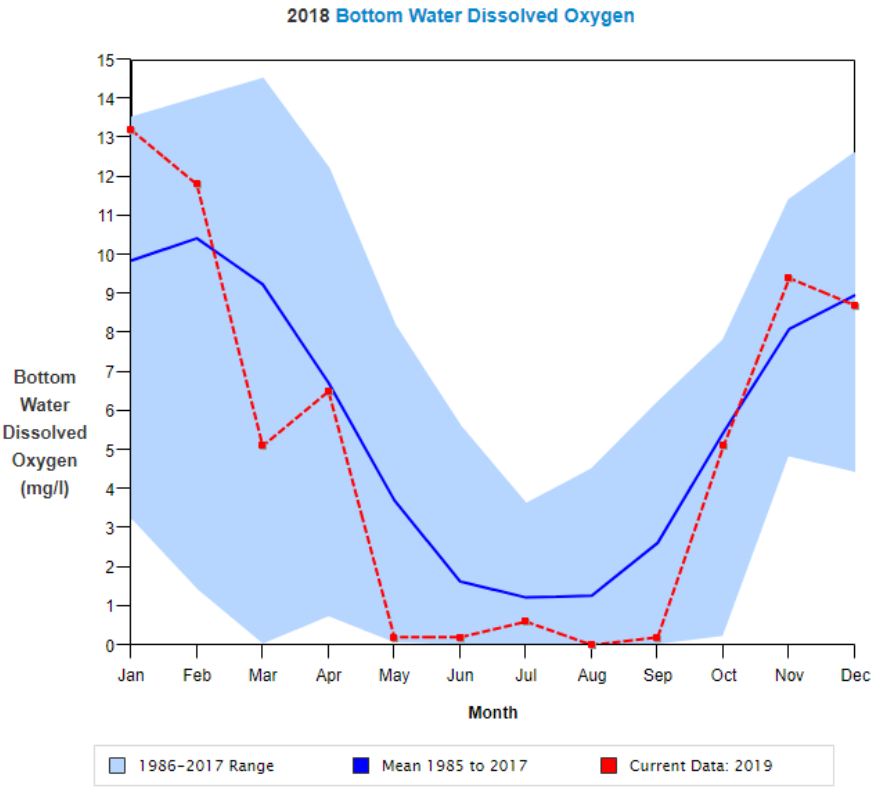

Figure 16. MD DNR Eyes on the Bay station WT8.1 bottom dissolved oxygen for 2018.

Table 12. Monthly bottom dissolved oxygen values for 2017 and 2018 from MD DNR Eyes on the Bay station W8.1.

Bottom Water Dissolved Oxygen (mg/l) Lower Western Shore / South River (WT8.1)					
Month	**Minimum**	**Mean**	**Maximum**	**2017**	**2018**
January	3.20	9.85	13.50	13.20	13.20
February	1.40	10.42	14.00	11.90	11.80
March	0.00	9.24	14.50	12.30	5.10
April	0.70	6.72	12.20	6.60	6.50
May	0.04	3.71	8.20	6.70	0.20
June	0.00	1.63	5.60	0.00	0.20
July	0.00	1.22	3.60	2.60	0.60
August	0.00	1.27	4.50	0.80	0.00
September	0.00	2.62	6.20	0.00	0.20
October	0.20	5.45	7.80	2.60	5.10
November	4.80	8.10	11.40	9.30	9.40
December	4.40	8.97	12.60	10.70	8.70

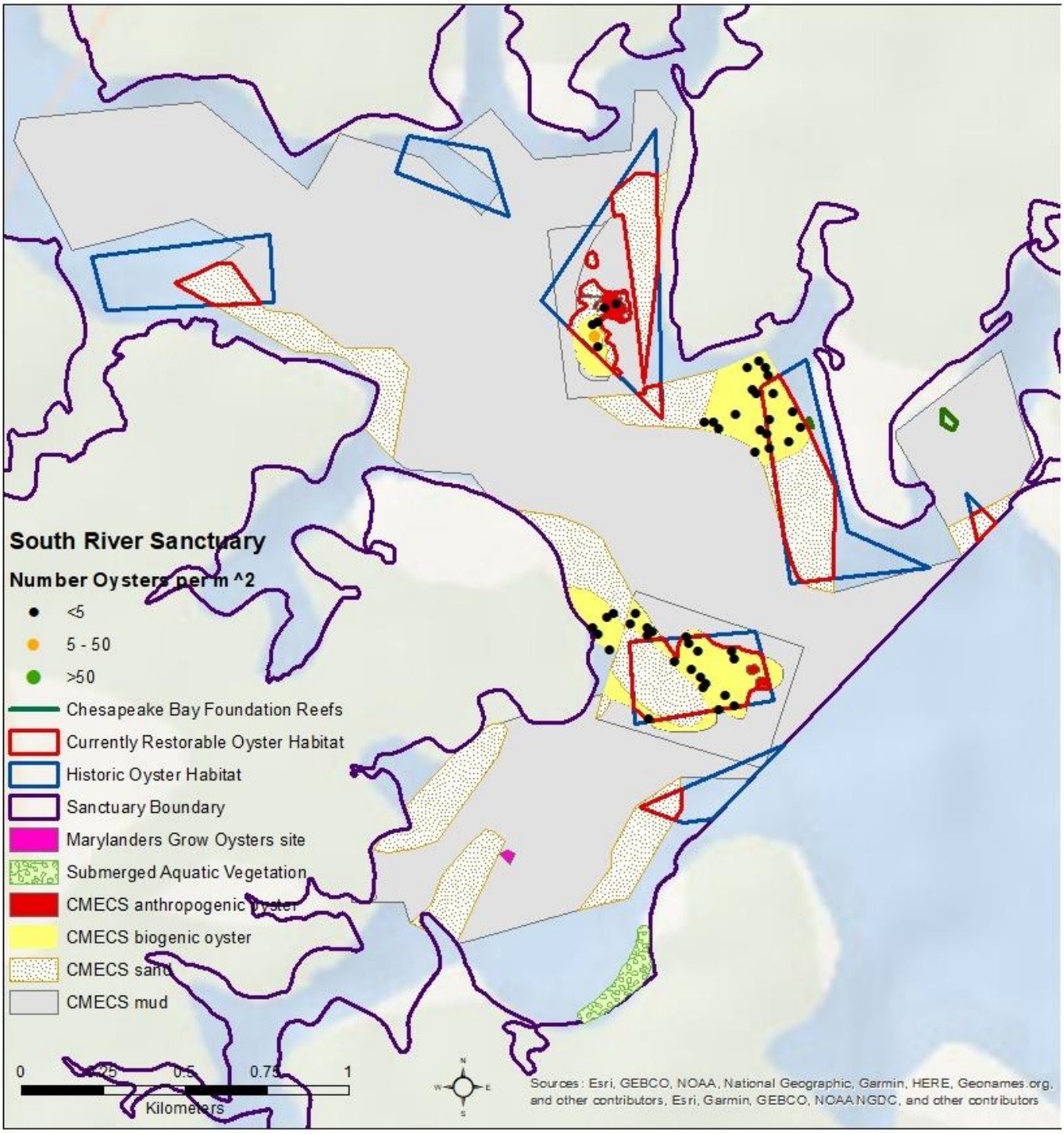

Figure 17. Historic oyster bars and the Coastal Marine Ecological Classification Standards (CMECS) bottom characterization from data collected during the 1970-80's Bay Bottom Survey and a 2011 side scan sonar survey conducted by Maryland Geological Survey within the South River Sanctuary and 2014 MD DNR patent tong survey data.

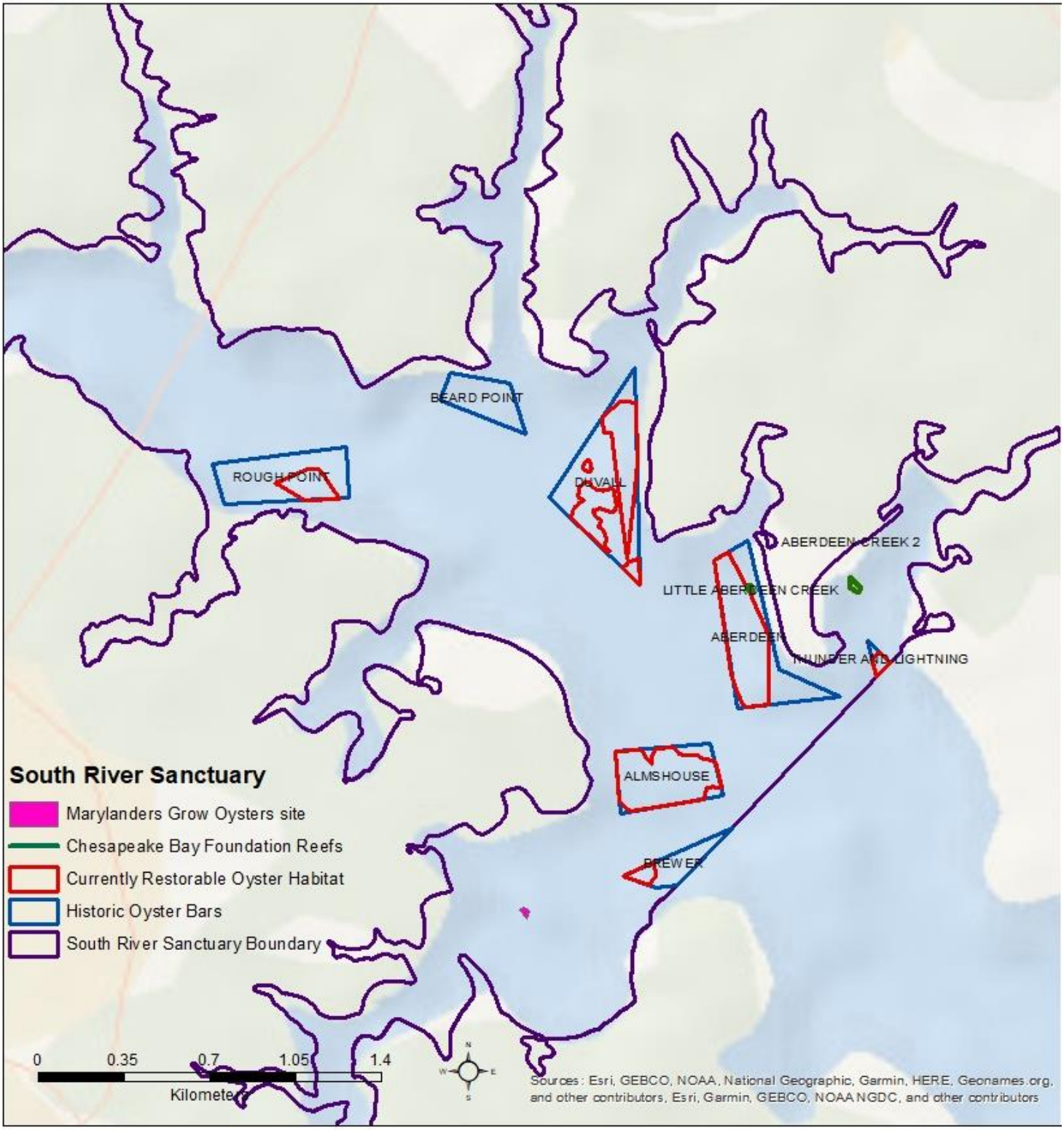

Figure 18. Currently restorable oyster habitat (CROH) and oyster bars within the South River sanctuary. Much of the 66 acres of CROH is not feasible for spat-on-shell only restoration, with only 6.7 acres within Duval Reef with adequate benthic substrate for spat-on shell restoration.

Current Oyster Population Characteristics

There are 141 acres of historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments) consisting of seven historic oyster bars, five fully within the sanctuary and two extending over the boundary (MD DNR 2016). There are no MD DNR Fall Oyster Survey sites consistently sampled annually, within the South River Sanctuary. A patent tong survey was conducted in 2014 by MD DNR. Forty-nine samples were taken within the sanctuary. The average volume of shell was 1.93 liters and the average volume of surface shell was 1.31 liters. There were 18 sites with the bottom type as mud, 16 with mud as the primary bottom type and sand as the secondary bottom type, there were 2 sites with sand as the bottom type and 10 site with sand as the primary bottom type and mud as the secondary bottom type. Live oysters were only found within an area on Duvall. The average density of oysters was 0.57 ±3.06 oysters per meter squared, with an average density of 0.14 ±0.71 for smalls and 0.43 ±2.6 for market size oysters (Figure 17). The average total shell volume was 1.93 ±4.2 liters and the average surface shell volume was 1.31 ±2.85 liters. Eighteen out of 49 samples had mud as the only bottom type and no live oysters.

There are seven historic oyster bars that lie within the South River Sanctuary, five of which lie completely within the boundary (Rough Point, Beard Point, Duvall, Aberdeen and Almshouse) and two which are partially within the sanctuary (Brewer and Thunder and Lightning). There are three reef areas within the sanctuary that were constructed by the Chesapeake Bay Foundation, Little Aberdeen Creek (within Aberdeen Reef), Aberdeen Creek 2 and Edgewater Beach. The area referred to as Glebe Bay has received seed plantings and is the area where Marylanders Grow Oysters (MGO) plant their yearly plantings of young oysters (Table 13).

Table 13. Oyster bars within the South River Sanctuary and the restoration that they have received.

Oyster Bar	Size (acres)	Year substrate planted	Base substrate material planted	Hatchery Spat-on-Shell Plantings
Rough Point	24	N/A	N/A	N/A
Beard Point	11	N/A	N/A	N/A
Duvall	40	2006, 1997	Concrete, oyster shell	Planted in 1997, 1998, 2006, 2007
Aberdeen/ Little Aberdeen	32 / 0.07	2002	Oyster shell	
Aberdeen Creek 2		2003	Oyster shell	2003, 2007 Spat-on-marl
Almshouse	24	1997	1.7 acres oyster shell	N/A
Brewer	44 / 8 within sanctuary	N/A	N/A	N/A
Thunder and Lightning	48 / 1.2 within sanctuary	1969	Oyster shell	N/A
Edgewater Beach		N/A	N/A	2007 Spat-on-marl
Glebe Bay	0.25	2000, 2001, 2005	Oyster shell	Planted in 2000, 2001, 2006, 2017, MGO oysters, Oyster Gardening oysters

Restoration Plan

Even though the total area of CROH was estimated at 66 acres based on bottom habitat, results from the 2014 patent tong survey exhibited only one area with a density of oysters > 5 per m^2. Bottom types throughout the

sanctuary from the patent tong survey were sand, mud and combinations of sand, mud, grit and clay. As a general guide for restoration, areas that have existing oyster densities greater than 5 per m^2 are considered as potential areas for spat-on-shell only restoration. Areas with hard bottom and less than 5 oyster per m^2 are potential candidates for substrate placement and then spat-on-shell restoration. Since this restoration effort is limited in scope to only spat-on-shell restoration, much of the 66 acres of CROH is not feasible for spat-on-shell only restoration.

Based on the patent tong survey conducted by MD DNR in 2014, the only historic oyster bar that has sufficient surface shell volume to support a spat-on-shell planting without adding substrate is Duvall (Figure 19). Therefore, spat-on-shell restoration efforts will be focused on Duvall. The area within Duval Reef that has adequate benthic substrate is approximately 6.7 acres. Planting at a density of 5 million spat-on-shell per acre on the estimated 6.7 acres yields a total of 33.5 million spat. The estimated cost for this restoration is $120,600.

Population monitoring of the planted reef will be done by the Arundel Rivers Federation, which is working on setting up a diver monitoring program. Water quality is monitored regularly throughout the South River by the Arundel Rivers Federation and the South Riverkeeper. Monitoring data will help to inform if the reef is at a density that would be considered self-sustaining and whether multiple year classes are present. This will determine whether a second planting is necessary after a few years and at what density.

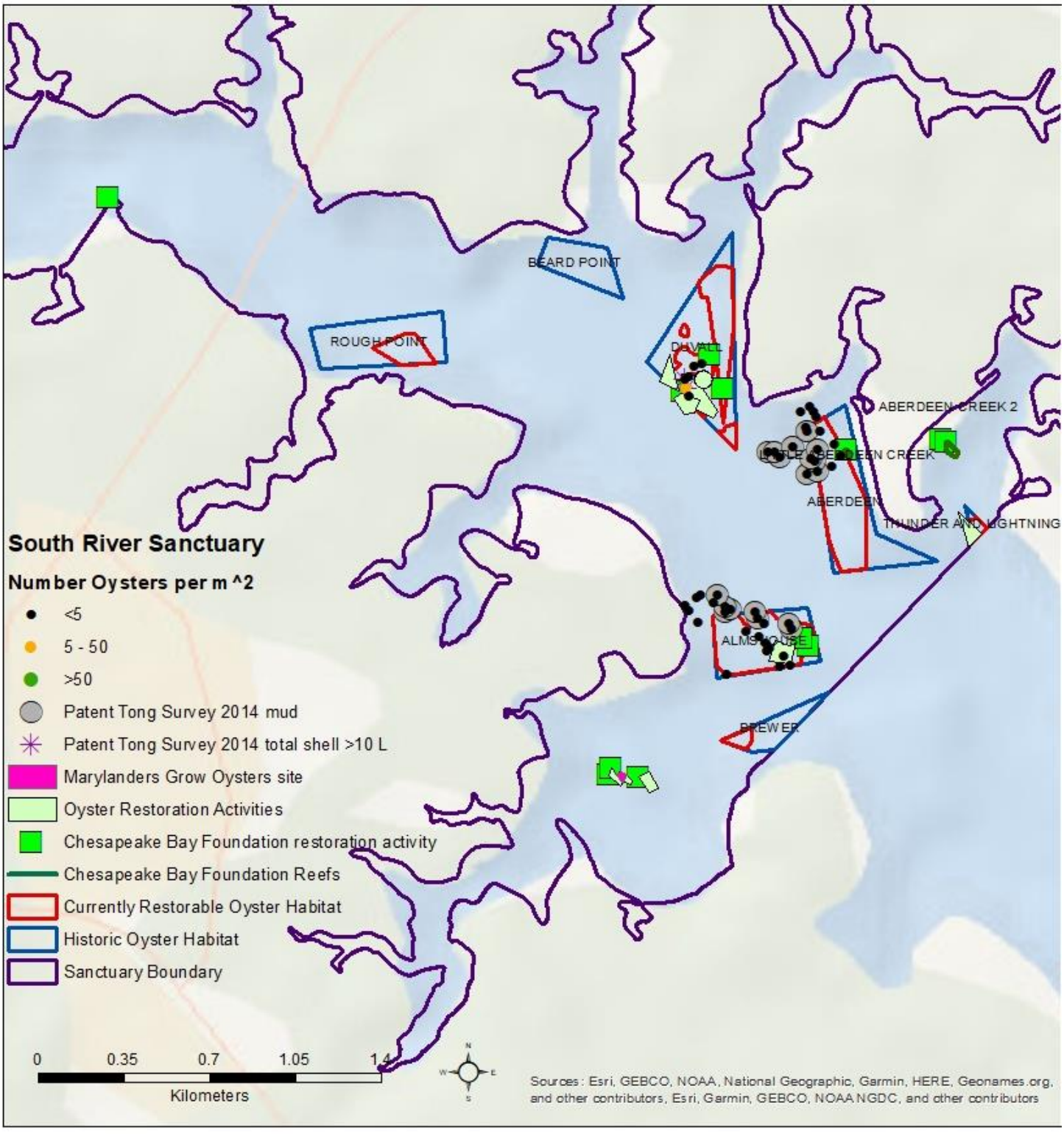

Figure 19. Sites with shell volume >10 liters per meter squared and sites with mud only from the 2014 MD DNR patent tong survey.

Anne Arundel Complex Restoration Summary

The Magothy River sanctuary has two reefs that are available for spat-on-shell planting. Chest Neck has an area of 1.1 acres, while Umphasis has an area of approximately 2 acres available to plant. Planting at a

density of 5 million spat-on-shell per acre on the estimated 3.1 acres would require 15.5 million spat at a cost of $55,800.

The Severn River sanctuary has six reefs that are available for spat-on-shell planting with a total estimated area of 40.4 acres available to plant. Planting at a density of 5 million spat-on-shell per acre over the estimated 40.4 acres would require 202 million spat at a cost of $727,200.

The South River sanctuary has one reef that is available for spat-on-shell planting. The area within the reef that has adequate benthic substrate for spat-on-shell planting is estimated at 6.7 acres. Planting at a density of 5 million spat-on-shell per acre on the estimated 6.7 acres would require 33.5 million spat at a cost of $120,600.

The first year of funding is proposed to support the planting of both reefs within the Magothy River sanctuary (Chest Neck and Umphasis), the reef in the South River sanctuary (Duvall) and the planting of some reefs in the Severn River sanctuary (bar names to be determined). Subsequent years of funding can support second year class plantings in the Severn River sanctuary as well as on Chest Neck, Umphasis and Duvall. Restoration on other reefs that can support spat-on-shell restoration within the Severn River sanctuary will be evaluated as funding is available (Table 10).

Restoration in the Anne Arundel Complex is part of an overall plan to invest state resources in sanctuaries other than those selected towards the Chesapeake Bay Agreement. The investment allocated for restoration in these other sanctuaries is for small-scale restoration. This plan lays out a plan for efforts for restoration within the Anne Arundel Complex sanctuaries; however, this investment may not occur in sequential years. State resources may vary between other sanctuaries from year to year.

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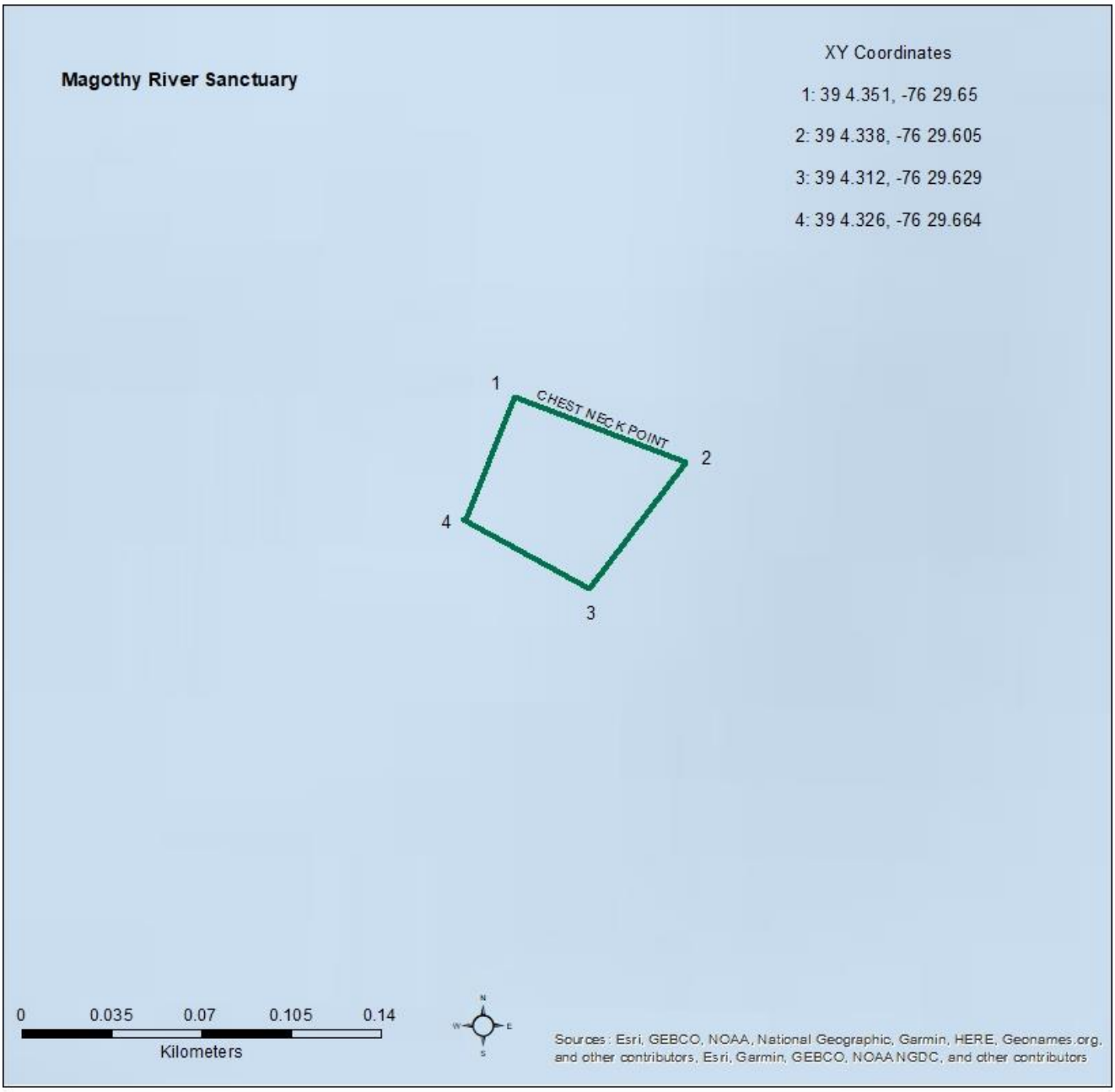
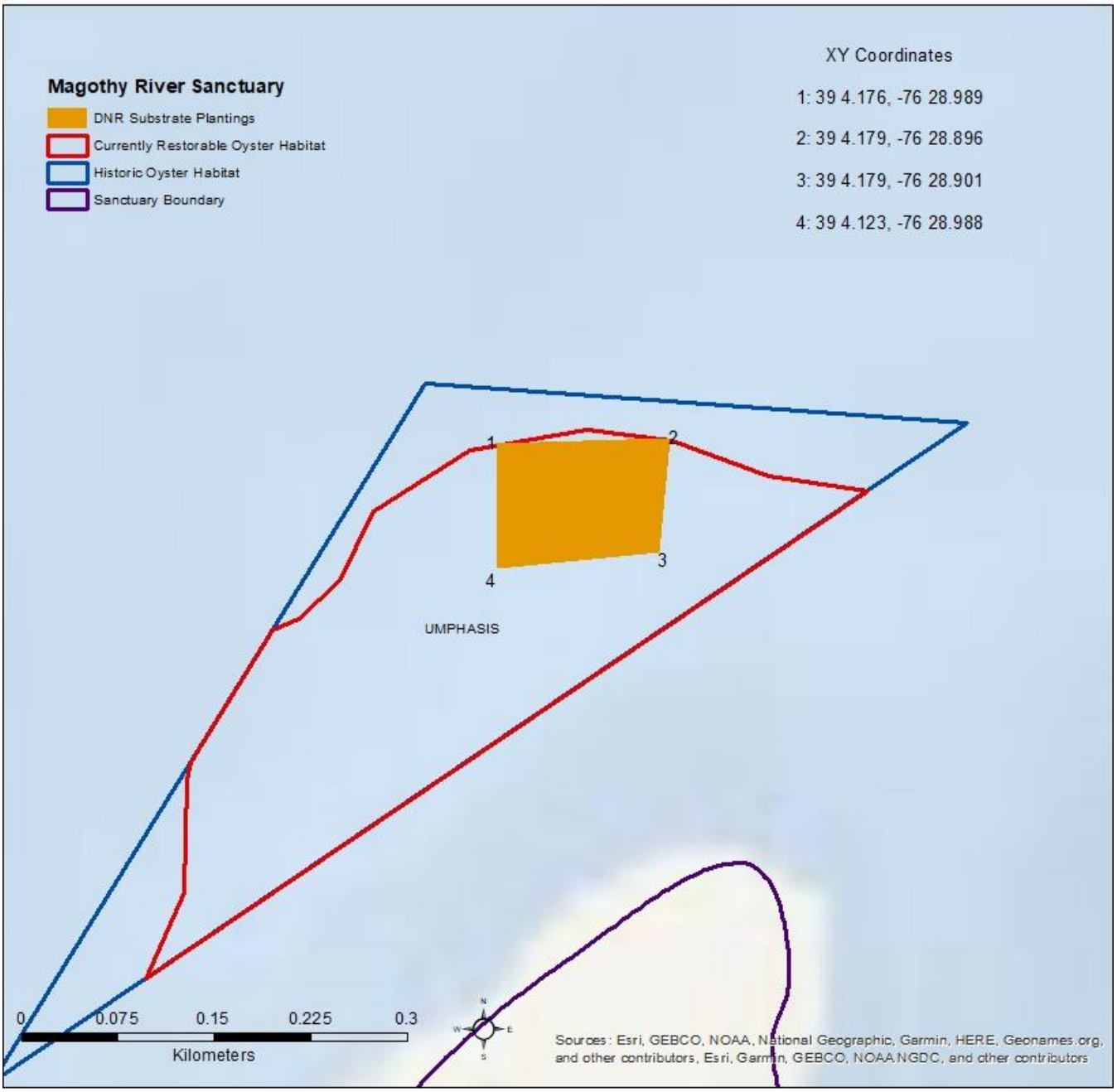
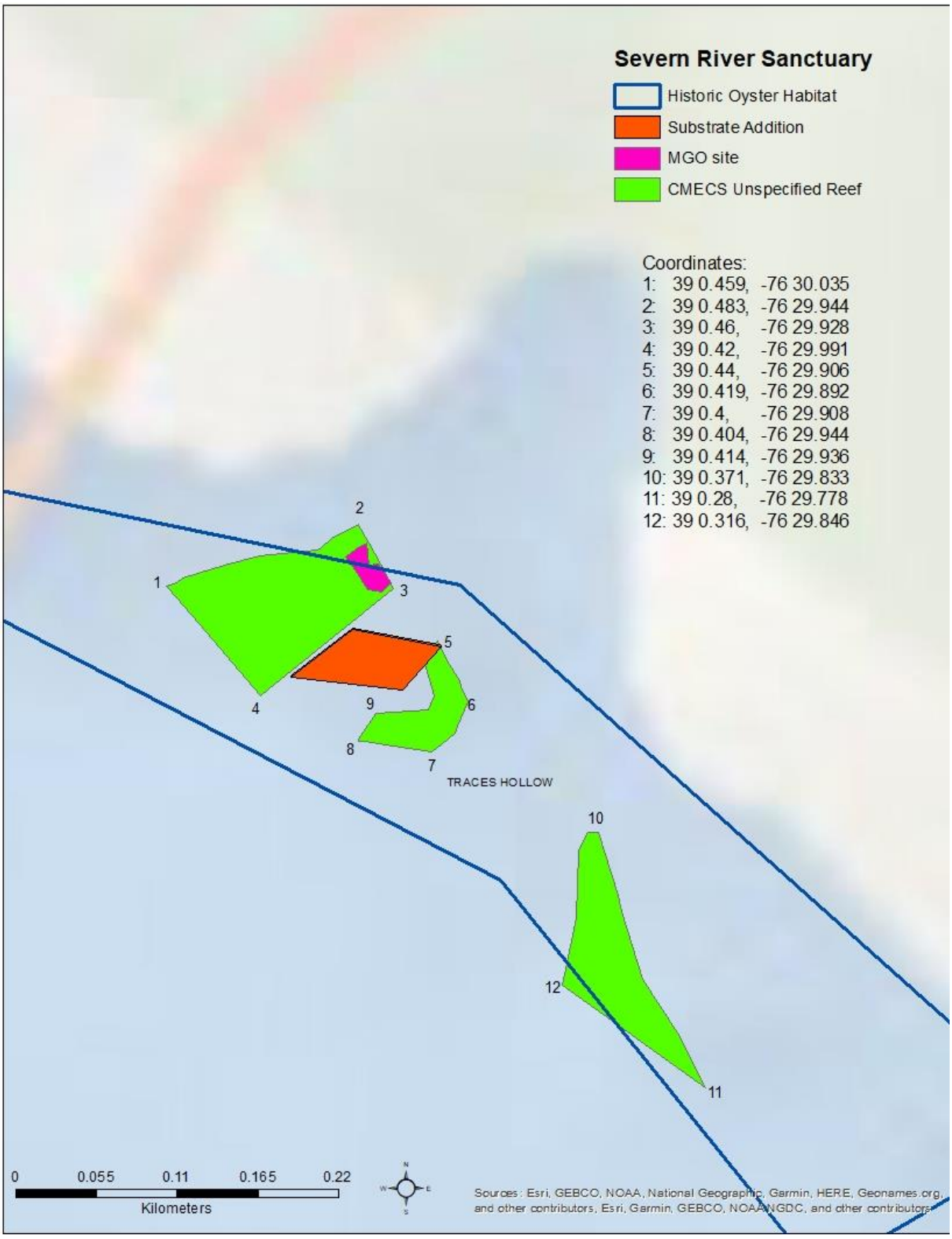


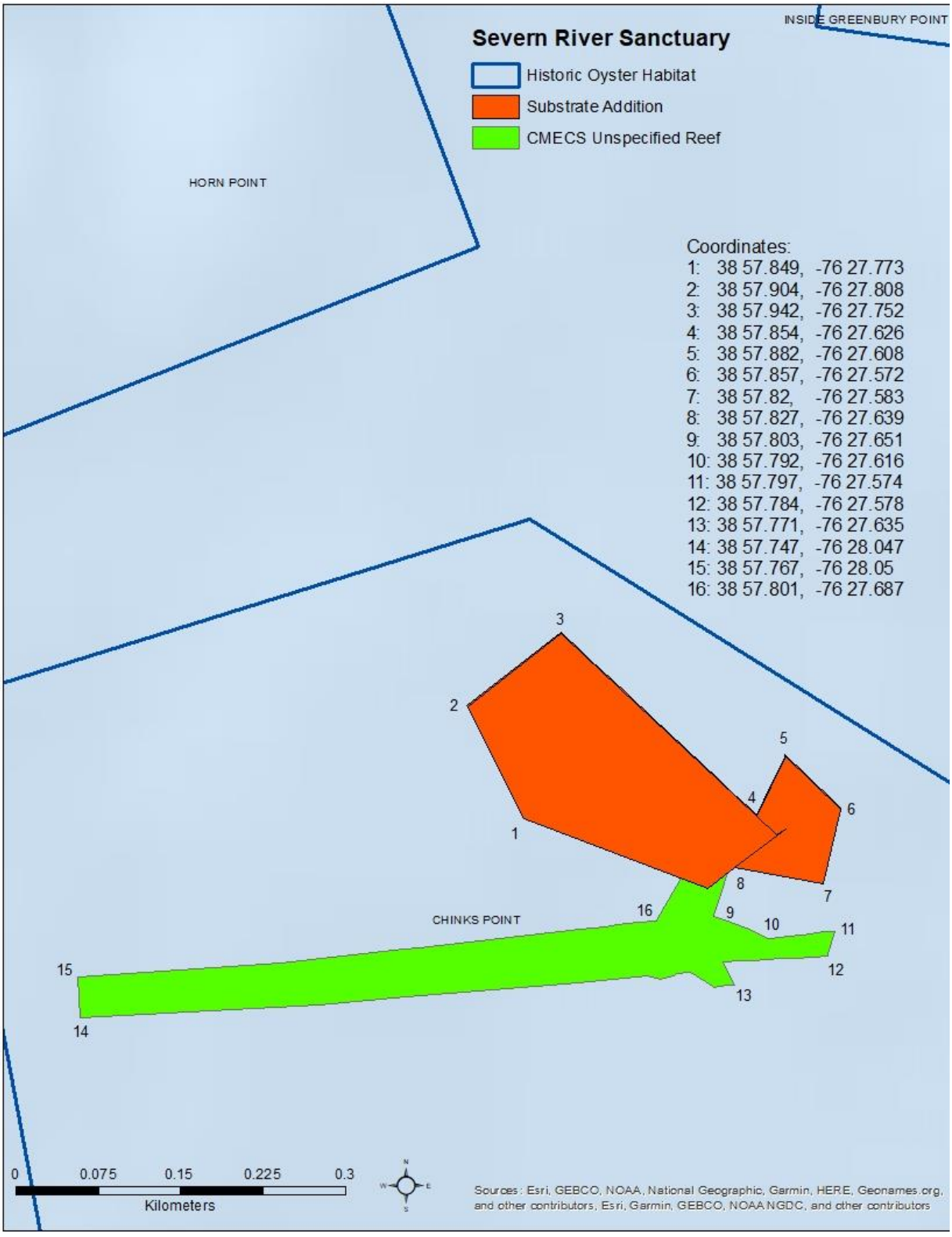
Acreage: 1.1 acres, SOS: 5.5 million



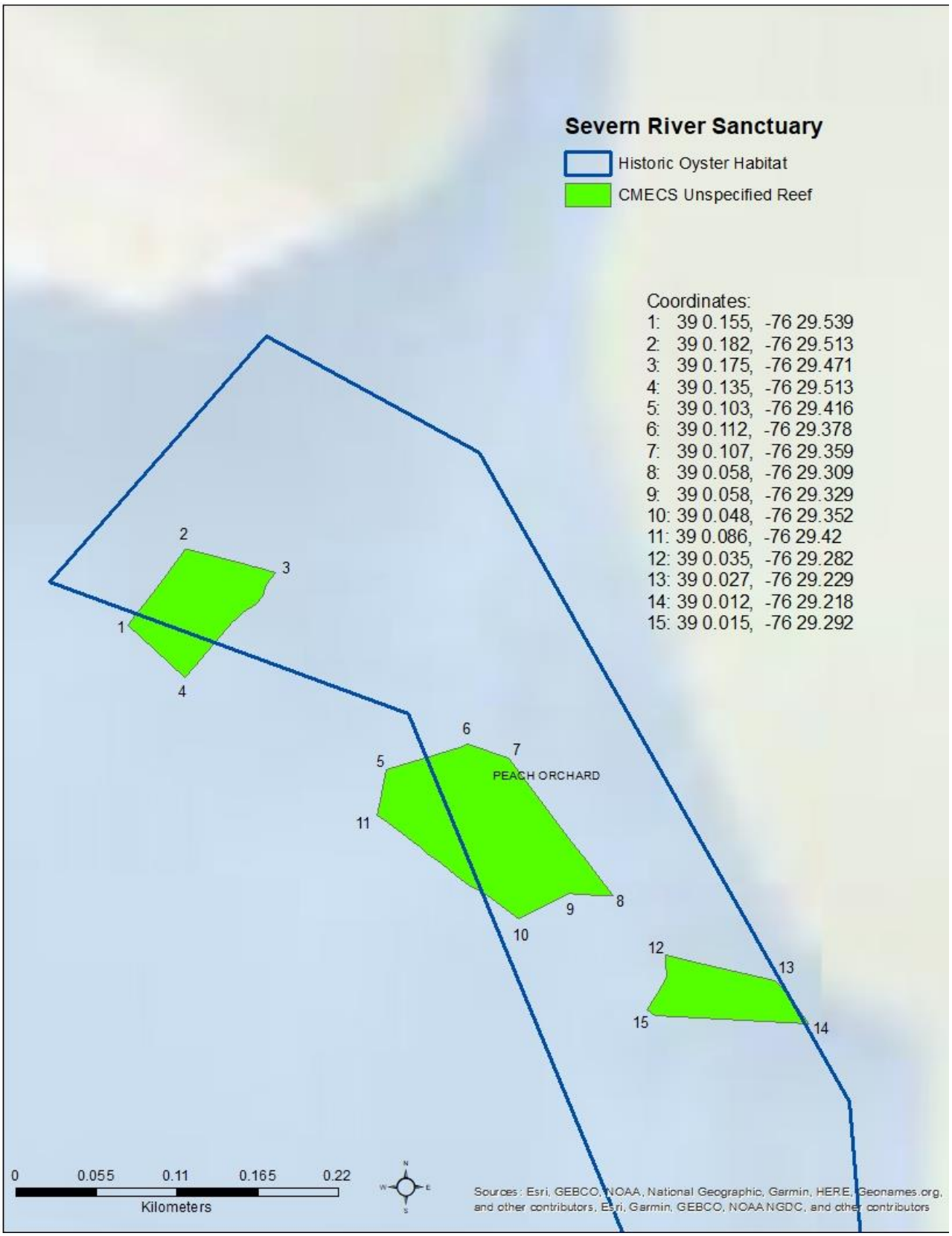
Acreage: 2 acres, SOS: 10 million



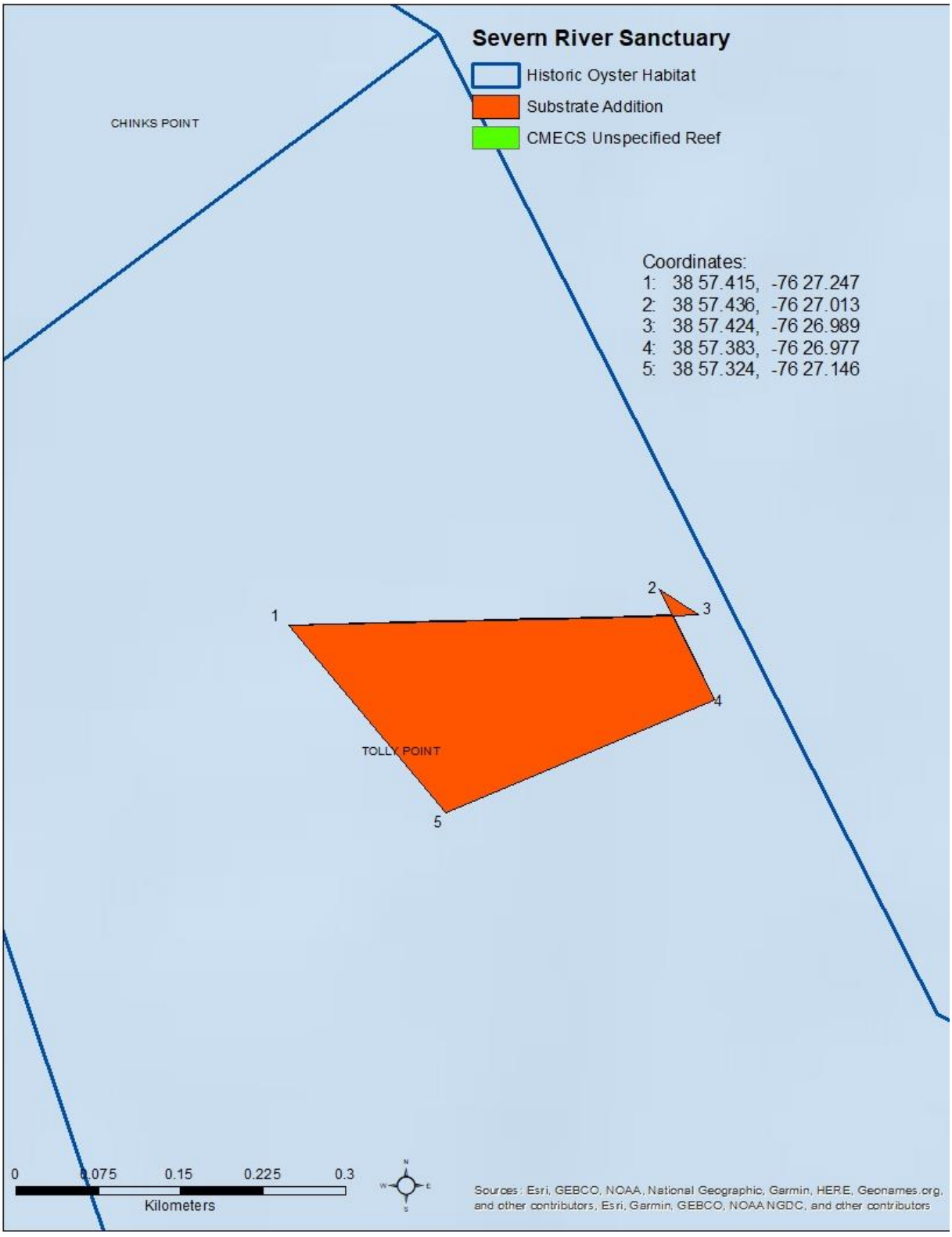
Acreage: 4.1 acres, SOS: 20.5 million



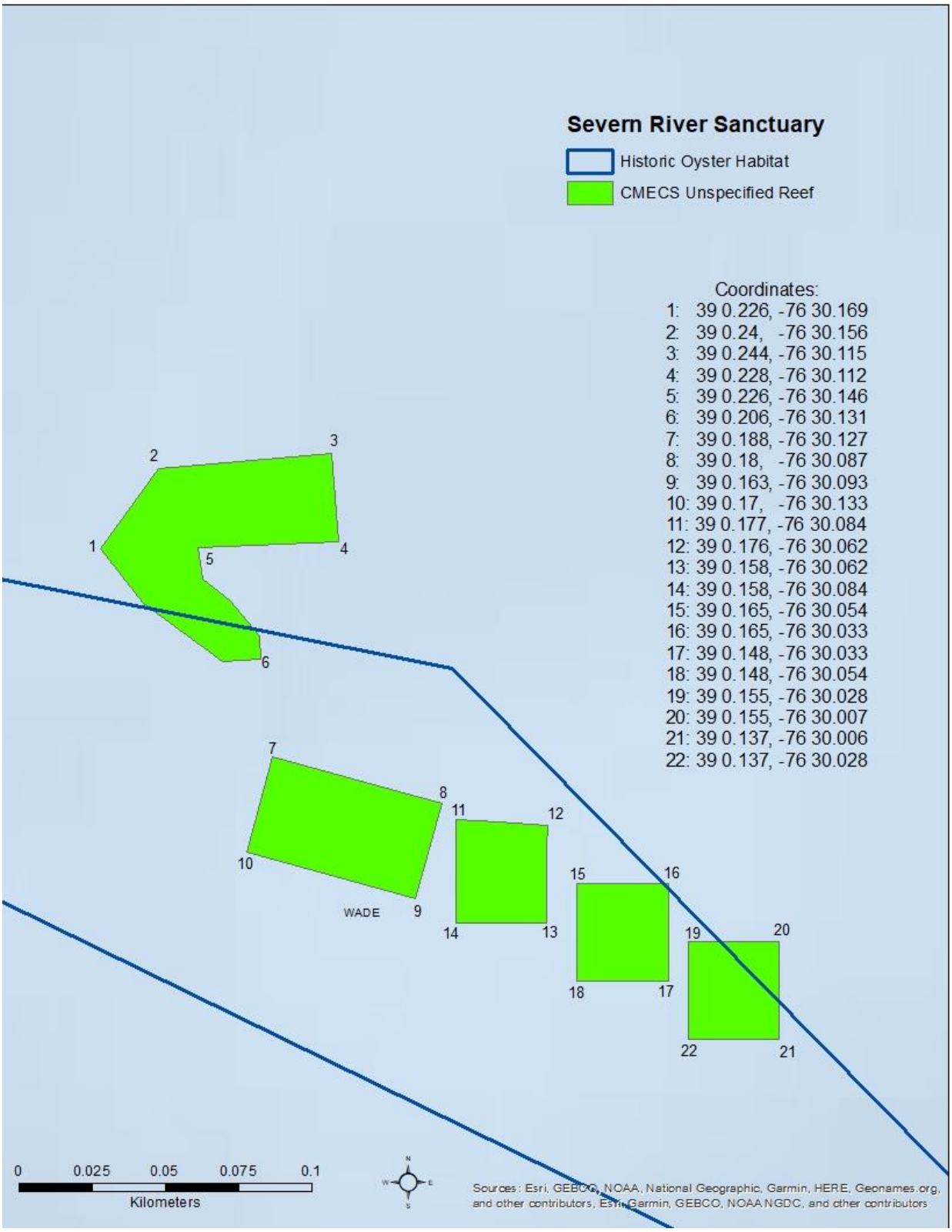
Acreage: 17.1 acres, SOS: 85.5 million



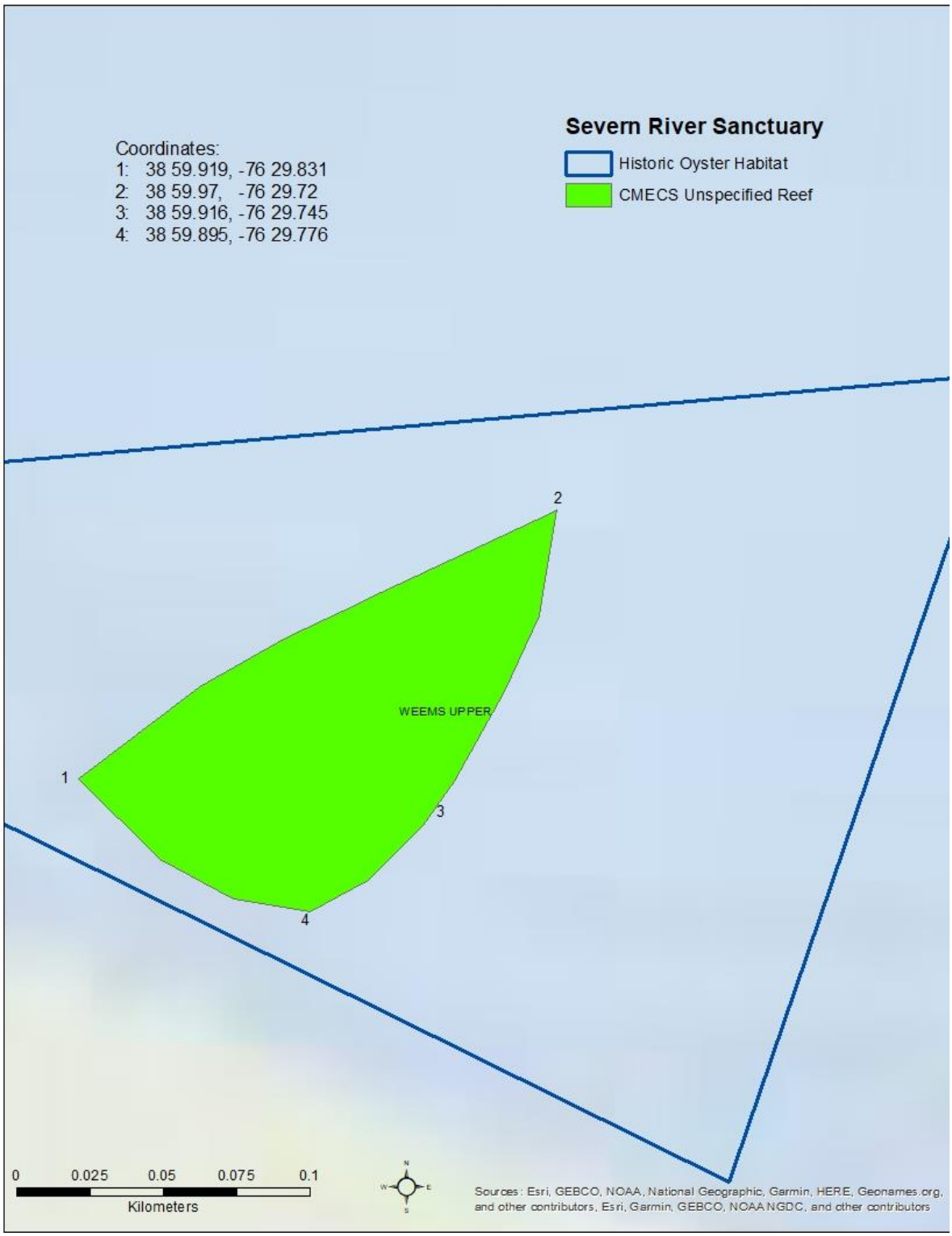
Acreage: 4.4 acres, SOS: 22 million



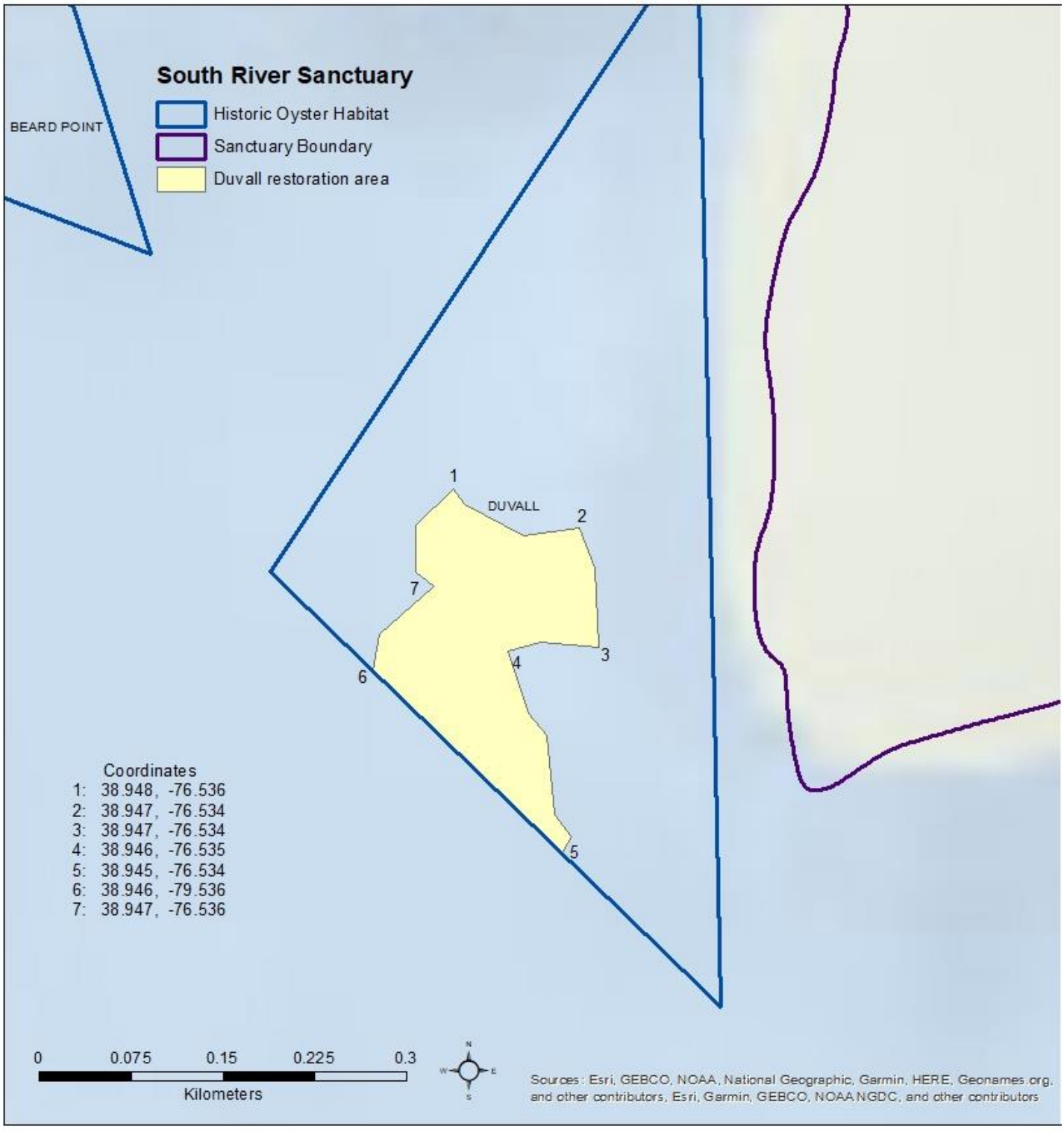
Acreage: 10.2 acres, SOS: 51 million



Acreage: 2.0 acres, SOS: 10 million



Acreage: 2.6 acres, SOS: 13 million



Acreage: 6.7 acres, SOS: 33.5 million