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# Lynnhaven River Oyster Restoration Plan: A Blueprint for Restoring Oyster Populations per the Chesapeake Bay Watershed Agreement

*October 2018*


Drafted by the Hampton Roads Oyster Restoration Workgroup under the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team

The Hampton Roads Oyster Restoration Workgroup includes representatives from: National Oceanic Atmospheric Administration (NOAA, cochair), Lynnhaven River Now, Chesapeake Bay Foundation, Christopher Newport University, City of Virginia Beach, U.S. Army Corps of Engineers' Norfolk District (USACE, cochair), Virginia Institute of Marine Science, Virginia Marine Resources Commission, and Ludford Brothers Oyster Company.

Photo: Lynnhaven River Now

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## Executive Summary

The 2014 Chesapeake Bay Watershed Agreement[1] is the guiding directive for the work of the federal-state Chesapeake Bay Program. The Agreement established a goal to "restore native oyster habitat and populations in 10 Bay tributaries by 2025, and ensure their protection." Responsibility for achieving this goal rests with the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (GIT). For Virginia, the Sustainable Fisheries GIT convened tributary-specific workgroups to plan, implement, and track progress toward this goal. The Hampton Roads Oyster Restoration Workgroup developed this document to (1) describe how the river's restoration goal was established and to (2) clarify the plans to achieve it.

Consistent with the Chesapeake Bay Oyster Metrics success criteria, the Workgroup developed a restoration goal of 152 acres for the river. Approximately 54.6 acres of oyster reefs already have been successfully restored in the river, through the combined efforts of the U.S. Army Corps of Engineers, the Virginia Marine Resources Commission, and Lynnhaven River Now. In addition, the Workgroup determined that there are 36 acres of intertidal oyster reefs functioning at a restored level. The total amount of existing oyster reefs that have either been restored or are functioning at a restored level is 90.6 acres. Therefore, partners need to restore an additional 61.4 acres of oyster habitat to achieve the goal set by the Workgroup under the Chesapeake Bay Watershed Agreement oyster outcome.

The cost estimate for completing the remaining acreage ranges from $60,000 to $250,000 per acre, based on a range of different construction techniques, location, materials, and other factors. Funding is in place to construct approximately 18 of the remaining acres in 2019. In addition, there are plans to construct approximately 5 additional acres in 2019, subject to the receipt of funding from pending grant applications.

## Section I: Policy Drivers, Chesapeake Bay Oyster Metrics, and Hampton Roads Oyster Restoration Workgroup Organizational Framework

### 1.1 Policy Drivers

Executive Order 13508 on Chesapeake Bay Protection and Restoration directs federal agencies to protect and restore oysters in the Bay. The 2014 Chesapeake Bay Watershed Agreement calls for state

[1] Chesapeake Executive Council, 2014. The Chesapeake Bay Watershed Agreement. http://www.chesapeakebay.net/documents/FINAL_Ches_Bay_Watershed_Agreement. withsignatures-HIres.pdf.

and federal partners to "restore native oyster habitat and populations in 10 Bay tributaries by 2025, and ensure their protection." Responsibility for achieving this goal rests with the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (GIT). For Virginia, the Sustainable Fisheries GIT convened tributary-specific workgroups to plan, implement, and track progress toward this goal. Members of the Workgroup include federal, state, and local agencies, universities, private business, and nonprofit organizations.

**1.2 Chesapeake Bay Oyster Metrics**

The Sustainable Fisheries GIT convened an Oyster Metrics panel to develop a science-based, common definition of a successfully restored tributary for the purpose of tracking progress toward the "10 tributaries by 2025" goal. The panel was composed of representatives from the state and federal agencies involved in Chesapeake Bay oyster restoration, as well as oyster scientists from academic institutions. The panel produced "Restoration Goals, Quantitative Metrics and Assessment Protocols for Evaluating Success on Restored Oyster Reef Sanctuaries,"[2] a report detailing these recommended success metrics (hereafter referred to as the Oyster Metrics report).
The following criteria were among those set forth in the metrics report:
1) A successfully restored reef should have:

- a 'minimum threshold' of 15 oysters and 15 grams dry weight/square meter ($m^2$) covering at least 30% of the target restoration area at 6 years post restoration;
- Ideally, a higher, 'target' of 50 oysters and 50 grams dry weight/square meter ($m^2$) covering at least 30% of the target restoration area at 6 years post restoration; and,
- Two or more oyster year classes present.

2) A successfully restored tributary is one where:

- 50-100% of the "currently restorable oyster habitat" has oyster reefs that meet the reef-level metrics above.
- 8-16% of its historic oyster bottom has oyster reefs that meet the reef-level metrics above.

These Oyster Metrics success criteria are being applied to tributary-scale oyster restoration work planned and implemented under the 2014 Chesapeake Bay Watershed Agreement.

**1.3 Selection of the Lynnhaven River as Target Tributary under the Chesapeake Bay Agreement Oyster Outcome**

Several factors led to the designation of the Lynnhaven River as a target tributary for large-scale oyster restoration under the Chesapeake Bay Watershed Agreement.

- In 2005, the U.S. Army Corps of Engineers (USACE) identified the Lynnhaven as suitable for large-scale restoration. USACE completed a feasibility study to assess the river and then constructed nearly 50 acres of oyster reefs in 2007 and 2008, mainly in Broad and Linkhorn bays.

[2] Oyster Metrics Panel, 2011. "Restoration Goals, Quantitative Metrics and Assessment Protocols for Evaluating Success on Restored Oyster Reef Sanctuaries." Report to the Sustainable Fisheries Goal Implementation Team of the Chesapeake Bay Program.
http://www.chesapeakebay.net/channel_files/17932/oyster_restoration_success_metrics_final.pdf

USACE had identified both bays as critical areas to enhance spatset throughout the river and as locations where restoration projects were most likely to succeed.

- In 2012, USACE drafted the Native Oyster Restoration Master Plan[3], which evaluated 63 tributaries of the Chesapeake Bay watershed. The document prioritized rivers based on historical, physical, and biological attributes to support self-sustaining oyster populations in large-scale oyster restoration efforts. In this document, the Lynnhaven River was designated as a Tier One tributary, indicating it was an appropriate location for restoration.
- The river has historically exhibited very strong oyster recruitment (natural spat set).[4]
- Oyster restoration efforts have been under way in the river since the 1990s. These were implemented by USACE, the Virginia Marine Resources Commission (VMRC), and Lynnhaven River Now (LRNow). Existing projects demonstrated multiple generations of healthy oysters. These collective efforts won a Coastal America Partnership Award in 2010.
- Interest from local watershed groups was strong.
- The National Oceanic and Atmospheric Administration (NOAA), USACE, and VMRC held conversations at length to determine which tributaries in Virginia would be suitable and tenable for large-scale oyster restoration. The Lynnhaven River consistently was among the top candidates.

By consensus among NOAA, USACE, VMRC, and local partners, and with agreement from the Sustainable Fisheries GIT, the Lynnhaven River was designated as a target tributary for large-scale oyster restoration in Virginia under the 2014 Chesapeake Bay Watershed Agreement.

### 1.4 Organizational Framework

Responsibility for achieving the Chesapeake Bay Watershed Agreement oyster restoration goal rests with the Sustainable Fisheries GIT. To plan and coordinate large-scale oyster restoration, the Sustainable Fisheries GIT convened workgroups in Maryland and Virginia. Virginia's groups are the Western Shore Workgroup (working in the Piankatank, Great Wicomico and Lower York rivers), and the Hampton Roads Workgroup (working in the Lafayette and Lynnhaven rivers). The Hampton Roads Workgroup (hereafter, "Workgroup") developed this plan. Like all Goal Implementation Teams under the Chesapeake Bay Program, the Sustainable Fisheries GIT crafted "management strategies" that describe the steps necessary to achieve each goal in the Chesapeake Bay Agreement. The strategies provide broad, overarching direction and are further supported by two-year work plans summarizing the specific commitments, short-term actions and resources required for success. The Oyster Restoration Outcome Management Strategy[5] calls for the Virginia workgroups to develop tributary-specific plans to restore oysters in each tributary, consistent with the Oyster Metrics success criteria.

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[3] U.S. Army Corps of Engineers, Baltimore and Norfolk Districts, 2012. "Chesapeake Bay Oyster Recovery: Native Oyster Restoration Master Plan, Maryland and Virginia."

[4] Ibid.

[5] Chesapeake Bay Program, 2015. Oyster Restoration Outcome Management Strategy. http://www.chesapeakebay.net/documents/22030/1b_oyster_ms_6-24-15_ff_formatted.pdf.

The Hampton Roads Workgroup (originally convened in late 2015 as the Lynnhaven Workgroup) comprises representatives from NOAA (cochair), LRNow, Chesapeake Bay Foundation, Christopher Newport University, City of Virginia Beach, USACE (cochair), Virginia Institute of Marine Science, VMRC, and Ludford Brothers Oyster Company.

This "Lynnhaven River Oyster Restoration Plan: A Blueprint for Restoring Oyster Populations per the Chesapeake Bay Watershed Agreement" document, completed by the Hampton Roads Oyster Workgroup, is the definitive plan for the Lynnhaven River. The Hampton Roads Oyster Workgroup recognizes that its members may also have organization-specific oyster restoration plans and goals (e.g., USACE's Native Oyster Restoration Master Plan[6], the USACE Lynnhaven River Basin Ecosystem Restoration Project Final Feasibility Report and Integrated Environmental Assessment[7], and the USACE Lynnhaven River Oyster Restoration Decision Document. This document is not meant to replace the existing plans; rather, it is meant to be inclusive of those plans and provide the overarching strategy to achieve restoration of oyster populations of the Lynnhaven River. These documents are in alignment with the Workgroup's efforts and often provide technical knowledge to support decision-making.

## Section II: Current Status of Lynnhaven River Oyster Restoration Efforts

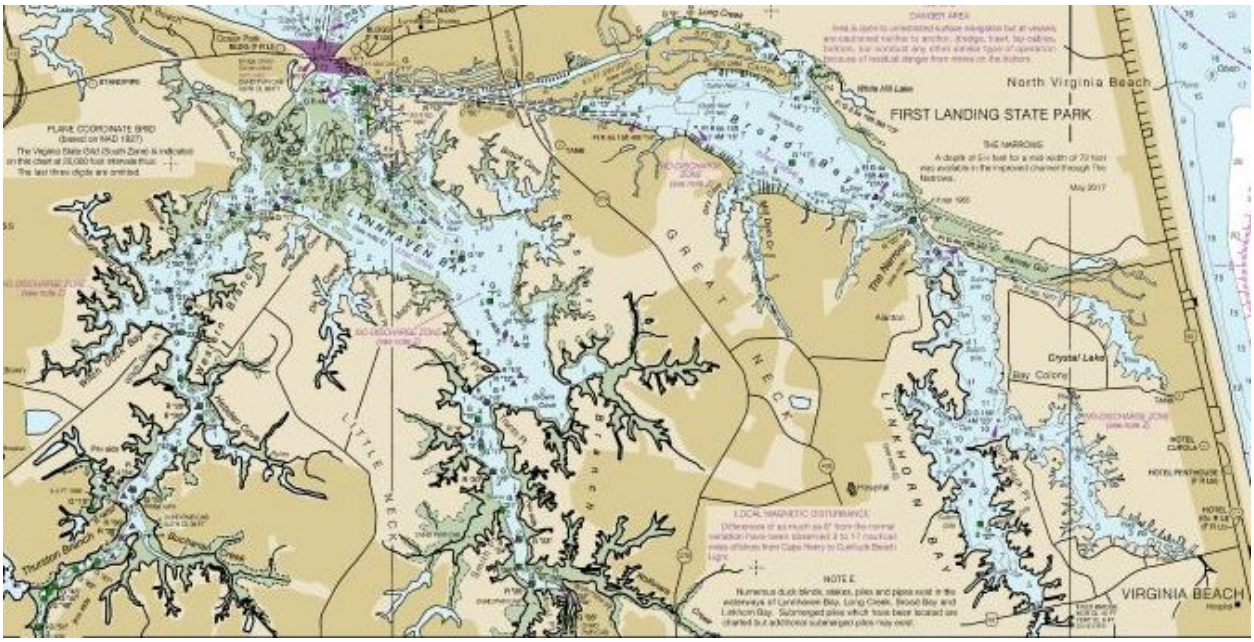


Fig. 1 – Map of Lynnhaven River depicting its tributaries, including (from left to right) the Western Branch, Lynnhaven Bay, the Eastern Branch, Long Creek, Broad Bay, and Linkhorn Bay.

[6] U.S. Army Corps of Engineers, Baltimore and Norfolk Districts, 2012. "Chesapeake Bay Oyster Recovery: Native Oyster Restoration Master Plan, Maryland and Virginia."

[7] U.S. Army Corps of Engineers, 2014. "Lynnhaven River Basin Ecosystem Restoration Project Final Feasibility Report and Integrated Environmental Assessment." https://www.gpo.gov/fdsys/pkg/CDOC-113hdoc176/pdf/CDOC-113hdoc176.pdf.

The Lynnhaven River Basin is a tidal estuary and the southernmost tributary of the Chesapeake Bay, covering 64 square miles within the city limits of Virginia Beach, Virginia. The river includes 150 miles of shoreline and hundreds of acres of marsh, mudflats, and shallow-water habitats.[8] The river is subdivided into two major segments. One is Broad Bay, connected via Long Creek and a constructed channel to Lynnhaven Bay. The other segment is Lynnhaven Bay, which is the confluence of the two branches (eastern and western) of the Lynnhaven River.[9]

The Lynnhaven River is a high-recruitment area for juvenile oysters due favorable salinity and to the narrow inlet that limits water exchange with the Chesapeake Bay and therefore promotes larval retention.[10]

Historical records indicate that the Lynnhaven River had abundant and high-quality oyster reefs, primarily in Broad Bay and Linkhorn Bay.[11] However, these oyster reefs were eventually eliminated due to overfishing, destructive fishing practices, and pollution.[12] In addition, the public grounds in the Lynnhaven were not maintained, and most were made available as private leased bottom.

Restoration and water quality improvements have resulted in large sections of the Lynnhaven River reopening to shellfish harvesting by the Virginia Department of Health. Approximately 42% is currently open for shellfish harvesting.

Beginning in 2007 and continuing through 2008, USACE, in partnership with nonfederal sponsors VMRC and the City of Virginia Beach, constructed approximately 46.8 acres of oyster reefs using fossil oyster shell in the Broad Bay, Linkhorn Bay, and Lynnhaven Bay portions of the river. Surveys conducted in 2012 determined that due to storms, current, and wave action in the eight years since those reefs were constructed, approximately 2.2 acres of USACE constructed reefs were lost, likely due to Hurricane Sandy, which affected the reefs by covering them with sand as well as disturbing the reef structure, displacing some of the shells.

VMRC and LRNow have directly constructed approximately 10 acres of oyster reefs, the most recent project (a two-acre shell reef) was completed by LRNow in the summer of 2017 using grant funds from the National Fish and Wildlife Foundation and 19,000 bushels of shell donated by the City of Virginia Beach.

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[8] Lipcius et al., "Overcoming restoration paradigms: value of the historical record and metapopulation dynamics in native oyster restoration," *Frontiers of Marine Science*, 2015, 2. http://www.vims.edu/people/seitz_rd/pubs/Lipcius%20et%20al_15.pdf.

[9] Ibid.

[10] Sisson et al., "Development of Hydrodynamic & Water Quality Models for the Lynnhaven River System." Final Report to the U.S. Army Corps of Engineers, Norfolk Office, and the City of Virginia Beach, 2010.

[11] Lipcius et al., 7. http://www.vims.edu/people/seitz_rd/pubs/Lipcius%20et%20al_15.pdf.

[12] Ibid.

The Workgroup relied on population surveys conducted by scientists from VIMS, USACE, VMRC, and LRNow and acoustic bottom surveys conducted by NOAA. The population surveys determined that the surviving 54.6 acres had oyster populations that are considered 'restored' per the Oyster Metrics success criteria. In addition, the Workgroup determined that there are 36 acres of naturally occurring intertidal oyster reefs functioning at a restored level.[13]

The information on these reefs as well as leased areas and other features is housed in the Lynnhaven River oyster restoration GIS geodatabase, www.habitat.noaa.gov/chesapeakebay/gis/Oyster_Restoration_Geodatabases/, which is maintained by NOAA using information provided by the Workgroup.

## Section III: Oyster Restoration Goal Setting

Oyster Metrics success criteria have a two-pronged test to determine if a river is successfully restored (see Figure 2). The Oyster Metrics report states that "an operational goal of restoring 50-100% of a river's currently restorable oyster habitat represents a reasonable target for tributary level restoration."[14] Currently Restorable Oyster Habitat (CROH) is defined as *evidence-based oyster habitat* within the restoration constraints determined by the Workgroup. Evidence-based oyster habitat is the seabed or river bottom observed by either remote sensing (i.e. sonar surveys) and ground truth data informed by historical information regarding bottom that contained productive oyster bottom or currently does.

For the purposes of setting the restoration goal, the Lynnhaven River was defined as all waters upstream of the Lesner Bridge (not to include the upper extremity of the branches) at the mouth of the river.

For goal-setting purposes, CROH in the Lynnhaven excludes sediments without evidence (acoustic, sampling, or historical) of oyster shell. With respect to acoustic survey data findings, the following types were considered CROH: anthropogenic shell rubble; biogenic shell rubble and shell rubble with sand or mud; constructed three-dimensional shell reefs; other reefs (reef castles); and unclassified bottom with evidence of oyster rubble. In the Lynnhaven, CROH includes all areas shallower than 12 feet. The group set no upper limit so as to include historical oyster habitat in intertidal or shallow subtidal areas. (The Workgroup decided to include intertidal areas of the Lynnhaven because this tributary more closely resembled the Atlantic seaside tributaries of Virginia than any other tributary in Chesapeake Bay, because a significant portion of its oyster habitat areas lies within the intertidal zone and the mortality rate for these intertidal oysters is low compared to other Bay tributaries that experience colder temperatures.) Areas of historic submerged aquatic vegetation (SAV) beds were also excluded from consideration as CROH.

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[13] Sources used in this assessment include: Luckenbach, M., and P.G. Ross, "Recruitment, substrate quality and standing stock monitoring in support of NOAA-ACOE oyster restoration projects in Great Wicomico, Rappahannock, Piankatank and Lynnhaven River Basins (2004-2006)."

[14] Oyster Metrics Panel, 2011.

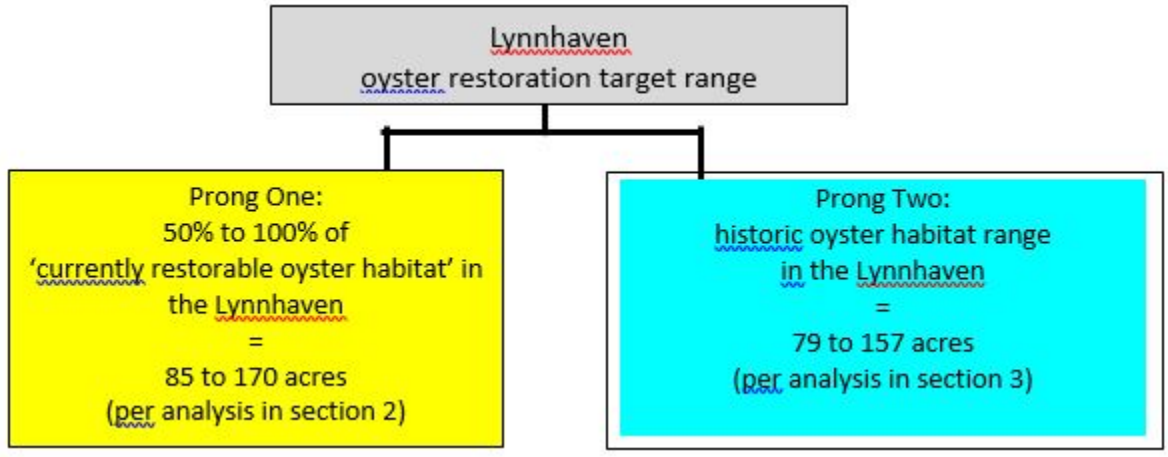
An analysis of acoustic survey data and historical records as well as an assessment of intertidal oyster acres determined that there are an estimated 170 acres of CROH in the Lynnhaven. Therefore, 50-100% (Figure 1) of CROH would be in the 85- to 170-acre range.

**Summary of 170 acres of CROH**

| Identified by subtidal surveys | Identified by intertidal extent assessment | Sum of CROH acreage identified by subtidal surveys & intertidal assessment |
|---|---|---|
| 108 acres | 62 acres | 170 acres |

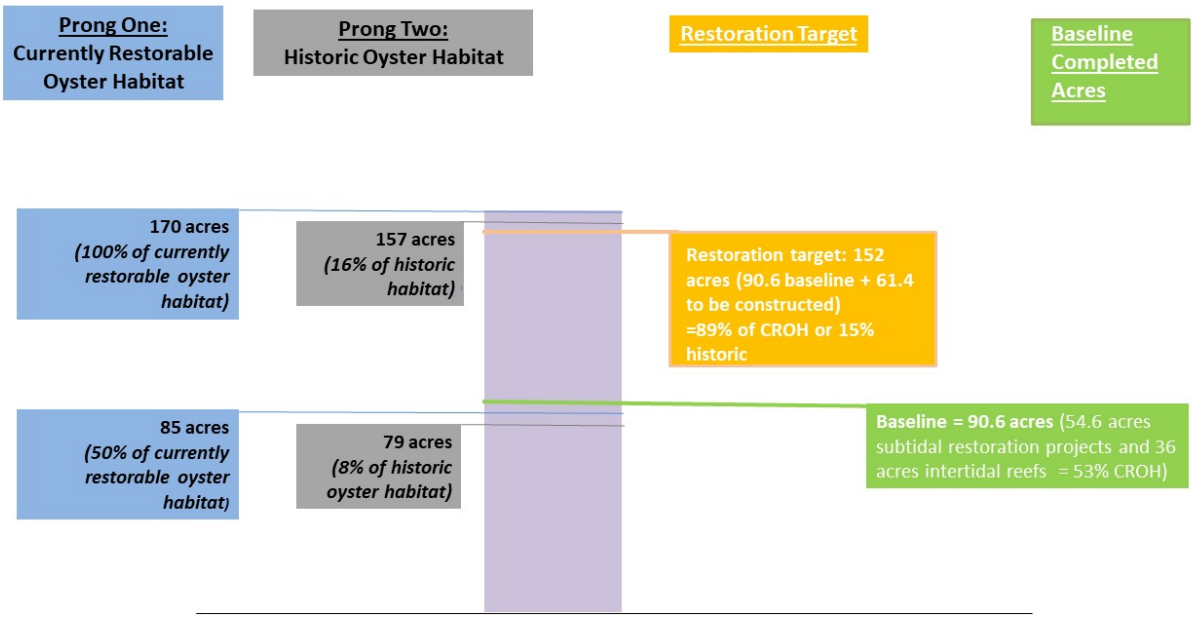
The second prong of the Oyster Metrics success criteria calls for at least 8-16% (Figure 1) of the historic acreage of oyster reefs in the river to be restored. In the Lynnhaven River, per the USACE Native Oyster Restoration Master Plan, 8% of historic reef acreage is estimated at approximately 79 acres. Thus, meeting the first prong (85 acres or 50% of CROH) will also meet the second prong (79 acres).

**Figure 1:** Analysis of two-prong oyster restoration criteria.




The Workgroup set a target of restoring 152 acres in the Lynnhaven, which is 89% of CROH. Approximately 54.6 acres of oyster reefs have been successfully restored in the river, through the combined efforts of USACE, VMRC, and LRNow. In addition, the Workgroup determined that there are 36 acres of intertidal oyster reefs functioning at a restored level. The total amount of existing oyster reefs that have either been restored or are functioning at a restored level is 90.6 acres (Figure 2). Therefore, a remaining additional 61.4 acres of restoration is needed to achieve the definition of a restored tributary under the Chesapeake Bay Agreement oyster outcome.

**Figure 2:** Lynnhaven River Oyster Restoration Goal-Setting Analysis




**LYNNHAVEN OYSTER RESTORATION GOAL ANALYSIS**

## Section IV: Available and Planned Oyster Restoration Areas in the Lynnhaven

### 4.1 Feasible Restoration Areas

The Hampton Roads Workgroup used the following criteria for determining "feasible" restoration areas (the location where restoration could actually occur).

- Depth interval: Waters between 3 feet and 12 feet are considered to be "feasible" restoration areas. The shallow-water limit was set because sonar surveys are generally unavailable shallower than 3 feet. The deep-water depth limit was set due to concerns about hypoxia. Water from 10-12 feet in depth was identified as a transition zone where restoration efforts should be limited. The group determined that restoration in waters deeper than 12 feet should not be attempted. The Workgroup noted that there are existing thriving oyster restoration projects in the intertidal zone (shallower than 3.3 feet), and these are counted toward the already-restored acreage. Due to the scarcity of "feasible" restoration areas outside of leased bottom areas, future small-scale intertidal projects may be constructed, but they will likely be built outside of areas identified as "feasible" restoration areas.
- No subtidal oyster restoration projects would be constructed
    1) within 200 feet of maintained navigation channel (federal and city)
    2) within 250 feet of navigation aids (federal and city)
- No subtidal oyster restoration projects would be constructed within 250 feet of utility crossings.
- No subtidal oyster restoration projects should be constructed within 100 feet of private docks or boat ramps.
- VIMS High-Priority Recruitment Areas: Areas identified by Virginia Institute of Marine Science and USACE as "High-Priority Recruitment Areas" (depicted in Figure 3) in shallow-water portions (shallower than 3 feet) of the Eastern and Western branches of the river will be included as

feasible restoration areas to the extent that NOAA surveys identified hard bottom in those areas.

- Water quality: Based on Figure IV.3a in "Development of Hydrodynamic and Water Quality Models for the Lynnhaven River System" Mac Sisson et al., a 2010 report for the USACE Norfolk District, dissolved oxygen is generally not an issue or limiting factor for restoration in this tributary. Similarly, salinity is not a limiting factor for restoration in this tributary.
- Submerged Aquatic Vegetation Areas: The areas of Submerged Aquatic Vegetation (SAV) found in aerial surveys from 1978 to the present documented by VIMS (found in the shallow shoreline areas of Broad Bay) will not be considered as restorable bottom.
- Bottom Composition/Prevalence of Hard Bottom: Acreage identified by NOAA and other survey data as "hard bottom" that is either sandy or a mix of sand and mud or a mix of broken shell with mud or sand will be considered as "feasible restoration areas." Mud bottom identified by the survey will not be considered as "feasible restoration areas". EXCEPTION: Areas with very high sand content and sand "waves" (as identified by the NOAA survey or the Mac Sisson paper) are an indication of strong bottom currents and waves and therefore are not suitable areas for oyster restoration. These areas will not be included in "feasible" restoration areas.
- Historic oyster grounds: More than 90% of the original 987 acres of Baylor grounds in the Lynnhaven were released from state management and converted to private leased grounds in the early 1900s. Currently, there are no Baylor grounds left in the river.
- The Workgroup used Fig. 3 and Fig. 4 from "Overcoming restoration paradigms: value of historical record and metapopulation dynamics in native oyster restoration," Lipcius et al., to define the extent of historic grounds in Broad Bay and Linkhorn Bay, which include areas both inside and outside Baylor grounds, as Baylor was not allowed to survey some areas in the Lynnhaven where reefs were located. Areas that were not part of historic oyster grounds in these creeks are not considered "feasible" restoration areas.

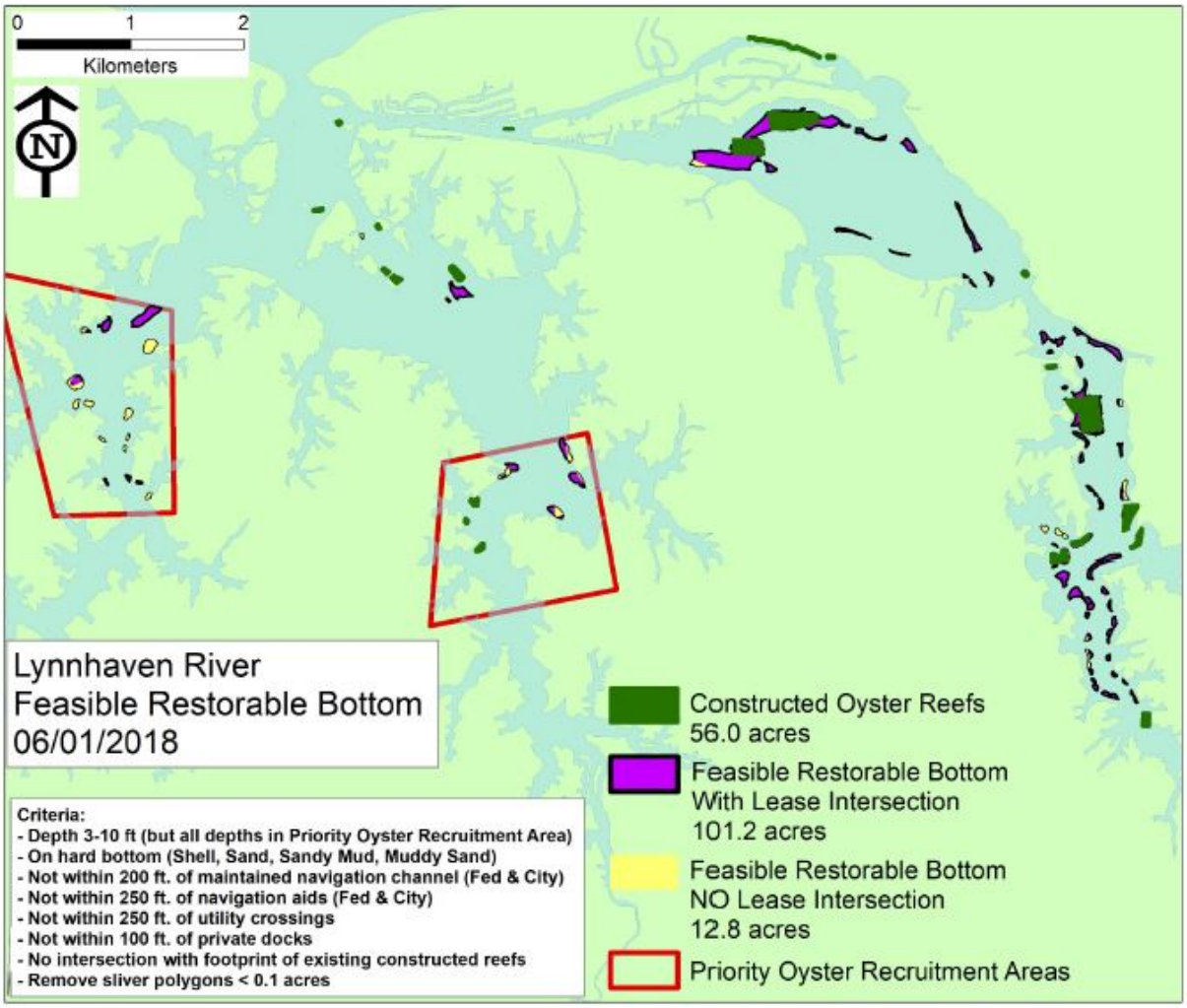
Using the above parameters defined by the Workgroup, NOAA staff developed an estimate of 101 acres of "feasible" restoration areas in the river. Note that these acres do not include already-existing reefs that have been constructed by the restoration partners.

The "feasible" restoration areas are a data-based recommendation of the best places to restore oysters in the river, but future restoration efforts may be sited elsewhere. Most of the acreage identified as "feasible" restoration areas are located within existing leased areas, and restoration may not be possible there if restoration partners cannot acquire the leases. Intertidal and subtidal reefs constructed outside of recommended "feasible" restoration areas will still be counted towards the restoration acreage goal.

**4.2 Areas Targeted for Oyster Restoration & Plans for Implementation**

For reefs constructed in subtidal areas, the Workgroup identified feasible restoration areas for oyster restoration projects (Figure 3). These criteria included evidence of favorable larval transport and avoiding close proximity to navigation channels, aids to navigation, bridges, pipelines, piers, and cable crossings. These criteria will be used as a general guide to reduce user conflicts with planned restoration projects.

**Figure 3:** Map of the Lynnhaven River, showing restored reefs and feasible restoration areas.




The City of Virginia Beach, the nonfederal sponsor cost share partner for the Lynnhaven River Basin Ecosystem Restoration Project, is the lease holder for approximately 135 acres of bottom in the river. These leases were obtained to implement reef habitat and submerged aquatic vegetation restoration projects in the Lynnhaven. USACE, in partnership with the City of Virginia Beach, plans to restore 31 acres of reef habitat on those leased areas, as funding becomes available. USACE, as part of its adaptive management program for the Chesapeake Bay Native Oyster Recovery 704(b) Program, plans to rehabilitate an additional 2.2 acres of previous reefs that were lost.

NOAA has determined, through GIS analysis, that there are approximately 101 acres of feasible restoration area in the river. Approximately 13 of the 101 feasible acres are located on bottom that are not currently leased. The Workgroup recommends restoration partners prioritize construction on those acres when possible.

**Figure 4**: Map of Lynnhaven River - Areas Targeted for Restoration

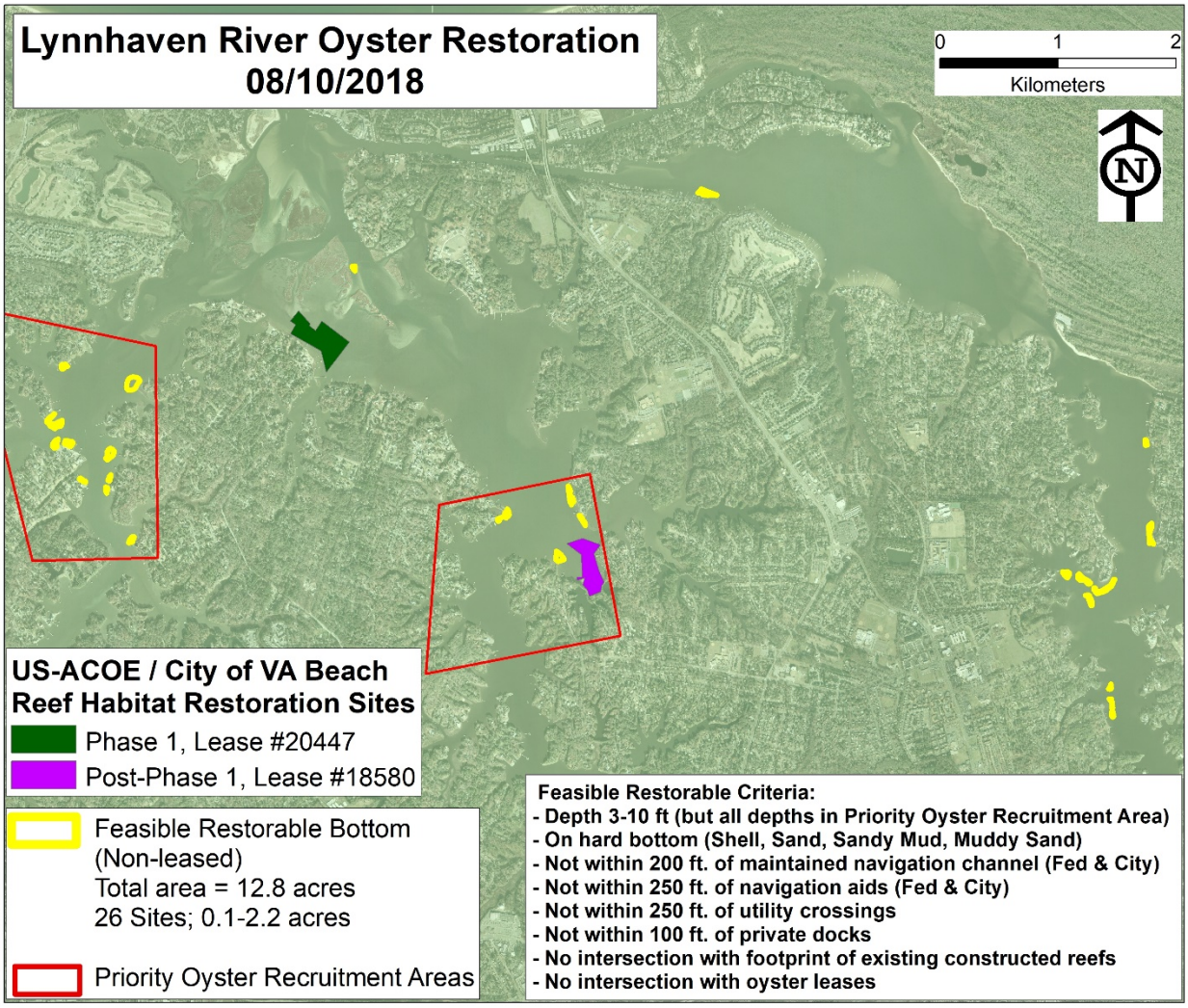



**Table 1:** Summary Table of Acreage Needed and Likely Location of Future Reef Construction Projects

| **Location of Proposed Oyster Reef Construction Projects Needed to Reach the Target Goal** | **# of Acres** |
|---|---|
| A portion of the leased bottom held by City of Virginia Beach (site of USACE Lynnhaven Ecosystem Restoration construction plans) | 31 acres |
| Exact location To Be Determined - Replacement of reef acres constructed by USACE in 2007 but subsequently destroyed by storms and currents. | 2.2 acres |
| Non-leased “feasible” restorable bottom acres prioritized for construction (location: various) | 12.8 acres |

| | |
|---|---|
| Exact location TBD (most likely city-owned leases)--Workgroup needs to identify suitable restoration sites | 14 acres |
| Sum of restoration target goal | 61.4 acres |

Restoration partners will need to construct 61.4 acres to reach the target goal (see Table 1). Even after the river is considered "restored" per the Oyster Metrics criteria, the Workgroup recognizes that there is ecological and social value in doing additional oyster restoration work in the Lynnhaven. Continued future efforts in the tributary are encouraged by the Workgroup.

## Section V: Cost Estimate

The Workgroup recognizes that restoration partners plan to use a variety of reef construction techniques while pursuing the 61-acre goal. The Workgroup anticipates that this will cause the cost estimate to vary depending on a number of factors including:

- quantity and quality of artificial substrate materials used
- habitat restoration focus (fish reefs vs. solely oyster-habitat focused)
- hydrodynamics of the construction site
- environmental compliance and permitting costs
- bottom composition (mud, muddy sand, sand, etc.) at the construction site
- mobilization and demobilization of construction costs
- inclusion of oyster shell
- physical design, spacing, and height of the constructed reefs.

For example, USACE, in partnership with the City of Virginia Beach, plans to construct 31 acres of reef described in the Lynnhaven River Basin Ecosystem Restoration Project Final Feasibility Report and Integrated Environmental Assessment (USACE 2013) out of three dimensional reef structures.

Assuming funding is available, the Virginia Marine Resources Commission, Lynnhaven River Now, and the Chesapeake Bay Foundation plan to construct their planned reefs using non-shell materials (crushed concrete, stone, etc.) to create stripes of reef-building substrate across a site, rather than covering the full site with substrate. These projects may incorporate a shell component into their design such as spat-on-shell treatment where larval recruitment is relatively low. However, the restoration partners plan to rely on natural recruitment rather than a spat-on-shell veneer, where appropriate. Therefore, after taking into account the various construction techniques and locations, the cost estimate for completing the 61.4 acre goal is a range of $60,000 to $250,000 per acre, depending on the factors outlined above.

There is funding in place to complete approximately 18 acres of oyster reefs in 2019 through the efforts of USACE and the Virginia Marine Resources Commission (with funding from the NOAA Chesapeake Bay Office). Lynnhaven River Now and the Chesapeake Bay Foundation have applied for grants funds from the National Fish and Wildlife Foundation to construct reefs. If they receive those grant funds, they plan

to construct an additional 5 acres in 2019 using crushed concrete donated by the City of Virginia Beach. Assuming that all of these projects proceed as planned using their various construction techniques, it is estimated that this first phase of 23 acres planned for construction will cost a total of $2,975,000.

## Section VI: Public Outreach

The Hampton Roads Oyster Restoration Workgroup, which drafted this plan, comprises representatives from local watershed groups, scientists, private aquaculturists, and personnel from local, state and federal agencies. The group represents an array of viewpoints and stakeholders, and those were incorporated into this plan. LRNow and the USACE, in particular, have consistently worked with the local community on the siting of specific oyster restoration projects. The Chesapeake Bay Foundation and LRNow have both promoted the oyster shell recycling program locally with funding provided by the City of Virginia Beach. These shells have been used to support LRNow's most recent 2-acre oyster restoration project.

Before this plan will be considered "final," the Workgroup will develop and implement public outreach opportunities on this plan to inform the public about the proposals contained here and to receive their feedback.

## Section VII: Monitoring

### VIII.1 Monitoring against Oyster Metrics Success Criteria

The main objective of monitoring efforts in the Lynnhaven River is to determine whether the restored reefs can be considered successful per the Oyster Metrics standards.[15] There are excellent examples of how to perform these oyster metric monitoring protocols in published scientific papers on this topic.[16] According to the Oyster Metrics report, several biological parameters (oyster density, oyster biomass, and presence of multiple year classes), and structural parameters (reef height, reef areal extent), should be monitored to determine reef-level success. For each parameter, the Oyster Metrics report recommends assessment protocols and monitoring intervals (Table 1). The Workgroup stresses the need for consistent monitoring following all protocols referenced in this document to measure success against the metrics and compare across the 10 tributaries associated with the Bay-wide oyster restoration goal.

**Table 2:** Reef-level success criteria and assessment protocols for oyster restoration projects (adapted from the Oyster Metrics report)

[15] Oyster Metrics Panel. 2011.
[16] Schulte, D. M., Burke, R. P., & Lipcius, R. N., "Unprecedented restoration of a native oyster metapopulation." *Science*, 325(5944) (2009), 1124-1128; and Schulte, D. M., Lipcius, R. N., & Burke, R. P., "Gear and survey efficiency of patent tongs for oyster populations on restoration reefs." *PloS one*, 13(5) (2018), e0196725.

| Goal | Success Metric | Assessment Protocol | Frequency |
|---|---|---|---|
| Significantly enhanced live oyster density and biomass | Target: An oyster population with a minimum mean density of 50 oysters and 50 grams dry wt/m2 covering at least 30% of the target restoration area at 3 years post restoration activity. Evaluation at 6 years and beyond should be used to judge ongoing success and guide adaptive management. Minimum threshold: An oyster population with a mean density of 15 oysters and 15 grams dry wt biomass · m-2 covering at least 30% of the target restoration area at 3 years post restoration activity. Minimum threshold is defined as the lowest levels that indicate some degree of success and justify continued restoration efforts. | Patent tong or diver grabs | Minimum 1, 3 and 6 years post restoration |
| Presence of multiple year classes of live oysters | Minimum of 2 year classes at 6 yrs post restoration. | Patent tong or diver grabs | Minimum 3 and 6 years post restoration |
| Positive shell budget | Neutral or positive shell budget. | Quantitative volume estimates shell (live and dead) per unit area | Minimum 1, 3 and 6 years post restoration |
| Stable or increasing spatial extent and reef height | Neutral or positive change in reef spatial extent and reef height as compared to baseline measurements. | Multi-beam sonar, direct measurement, aerial photography | Within 6 -12 months post-restoration, and 3 and 6 years post restoration |

In keeping with the Oyster Metrics report, and assuming funding can be secured, these parameters (Table 1) will be monitored on the Lynnhaven River restored reefs, likely in partnership with scientists, nongovernmental organizations, private contractors, and government agencies. Results will be used to determine reef success and to implement adaptive management actions as necessary.

**VIII.2 Diagnostic Monitoring**

In addition to monitoring to evaluate restored reefs per the Oyster Metrics criteria, it is wise to include further monitoring that will help determine the causes of the success or failure. These are deemed “diagnostic” monitoring parameters, and include water quality and oyster disease. Understanding these parameters alongside metrics of restoration success will allow practitioners to understand not only whether or not the project succeeded, but why. Water quality will be monitored using existing Virginia Department of Environmental Quality water-quality monitoring stations on the Lynnhaven River. Oyster disease information will be obtained where available from VMRC and various academic and research programs.