Permit Application for Artificial Reef Development – Harwich MA

Submitted by:
Town of Harwich
c/o Tom Leach, Harbormaster
732 Main Street
Harwich, Massachusetts 02645
Tom Leach – Harbormaster

Massachusetts Division of Marine Fisheries
c/o Mark Rousseau, Environmental Analyst
251 Causeway Street, Suite 400
Boston MA 02114
Mark Rousseau – Artificial Reef Program Coordinator

Proposal for Harwich Artificial Reef Permit Application

Table of Contents

List of Attachments for ENF

1. Copy of Environmental Notification Form Application
2. Copy of Project narrative including Figures and Appendices

List of Agencies and persons receiving the ENF

1. MEPA Office (2 copies)
   Secretary Richard K. Sullivan, Jr.
   Executive Office of Energy and Environmental Affairs (EEA)
   Attn: MEPA Office
   100 Cambridge Street, Suite 900
   Boston, MA 02114

2. Department of Environmental Protection Boston Office
   Commissioner's Office
   One Winter Street
   Boston, MA 02108

3. DEP Southeastern Regional Office
   Attn: MEPA Coordinator
   20 Riverside Drive
   Lakeville, MA 02347

4. DEP Southeast Region Cape Cod Office
   3195 Main St.
   Barnstable, MA 02630

5. Applicable Massachusetts DOT District Office District #5
   Attn: MEPA Coordinator
   Box 111
   1000 County Street
   Taunton, MA 02780

6. Massachusetts Historical Commission
   The MA Archives Building
   220 Morrissey Boulevard
   Boston, MA 02125

7. Massachusetts Department of Transportation
   Public/Private Development Unit
   10 Park Plaza
   Boston, MA 02116

8. Cape Cod Commission
   3225 Main Street
   Barnstable, MA 02630

9. DCR
   Attn: MEPA Coordinator
   251 Causeway St. Suite 600
   Boston MA 02114

10. Coastal Zone Management
    Attn: Project Review Coordinator
    251 Causeway Street, Suite 800
    Boston, MA 0211

11. Conservation Commission
    Town of Yarmouth
    1146 Route 28
    South Yarmouth, Massachusetts 02664-4492

12. Division of Marine Fisheries (South Shore)
    Attn: Environmental Reviewer
    1213 Purchase Street - 3rd Floor
    New Bedford, MA 02740-6694

13. Natural Heritage and Endangered Species Program
    Commonwealth of Massachusetts
    Route 135
    Westborough MA 01581

List of Municipal and Federal Permits required

Local
Notice of intent (filed)

State
WPA NOI (filed)
Chapter 91 license
401 Water Quality Certification

Federal
Army Corps of Engineers

Harwich Artificial Reef Project Proposal

Introduction

The creation of artificial reef habitat has been employed by many coastal states as an effective method of increasing fisheries productivity, augmenting fisheries habitat, and enhancing local recreational fisheries (Ditton et al. 2002; Figley 2004). The Division of Marine Fisheries (DMF) has an established artificial reef program designed to provide an operational framework for responsible long-term management of artificial habitats that provide benefits to fisheries resources. Nantucket Sound is an area of limited hard bottom habitat relative to other coastal regions of Massachusetts. Bugley and Carr (1994) reviewed the status of artificial structures in Nantucket Sound and found many of the once plentiful shipwrecks were deteriorating, resulting in an overall loss of relief and habitat value. Public interest in developing artificial reefs in the region has grown over concerns that the amount of available structured fish habitat along southern Cape Cod is diminishing.

This proposal describes the methods for selection and placement of materials at a location in Harwich, identified in Notice of Intent (NOI) file # SE 32-2103 issued by the Department of Environmental Protection (DEP) on 3/15/12. The deployments of reef materials proposed at this location are for creating an artificial reef to provide benefits to marine resources by providing shelter for cryptic marine vertebrate and invertebrate species in a location that is otherwise limited in hard bottom structural complexity. This project will also provide near-shore fishing for anglers in Nantucket Sound. This document addresses seven specific issues: 1) Assessment of current on-site conditions 2) proposed project size 3) dispersion of materials on-site 4) volume of new materials 5) construction impacts 6) monitoring and 7) alternatives analysis.

1. Site Assessment

DMF conducted a site assessment to examine the potential for artificial reef development in state waters off the coast of Harwich in Nantucket Sound. Sidescan sonar and diver transect data were collected in 2009 and 2010 from an area identified using a modification of an exclusion mapping protocol established by Barber et al (2009) for selecting an artificial reef site in Boston MA. Substrate and benthic infaunal data were also collected from an existing artificial reef in state waters off the coast of Yarmouth for comparative purposes (Figure 1).

Exclusion mapping

Prior to collecting field data, DMF employed an exclusion mapping method (see Barber et al., 2009) to identify and eliminate areas unsuitable for reef development. Seven general criteria were used to determine an optimal location to assess for potential artificial reef development (Table 1). Existing information, including NOAA charts and GIS data were reviewed for this analysis.

Table 1. Criteria for selecting a site for artificial reef deployment

Criterion	Description
accessibility	Area is suitable for safe small boat operation and recreational use and does not interfere with commercial vessel traffic.
depth and wave action	Water is deep enough to protect the reef from wave action. Targeted depth range was between 26 and 40 feet.
established habitats	Avoid existing established habitats.
substrate	Substrate consists of firm sediment types that provide a stable platform for approved materials.
slope	Sites with slopes less than 5º are needed for reef stability.
water quality	Low turbidity, low siltation rate, and adequate light penetration.
user conflicts	Avoid potential conflicts with other user groups, including ferry routes, weir fisheries, and other commercial and recreational fishing activities.

Accessibility

Site accessibility was determined based on the distances recreational boaters would be required to travel from local ports. Charter boats originating from Saquatucket Harbor were witnessed on the Yarmouth reef site, over seven miles from port, on several occasions. Based on these observations, all areas within the 3-mile Harwich jurisdictional limits were determined to meet this criterion.

Depth and wave action

Depth data were analyzed using NOAA chart #13237 and available bathymetry data from MassGIS. Depth data was collected during diver transect surveys and calibrated for actual mean low water (MLW) using local tide data available from NOAA. Charted depths between 26 and 40 feet (MLW) were considered for site evaluation.

Established habitats

A substantial amount of area within Harwich coastal waters is designated as habitat suitable for shellfish, specifically *Mercenaria mercenaria* (quahog) and *Spisula solidissima* (surf clam), according to data published by DMF and MassGIS (see Figure 7). This information includes sites where shellfish have been observed since the mid-1970's, but may not currently support any shellfish. Therefore, these designations represent potential rather than actual shellfish habitat areas. Site-specific surveys are necessary to ascertain current distribution and abundance of shellfish species. As such, additional information was required in order to make a site-specific assessment on established habitats. This factor was addressed by collecting information on the presence of shellfish species during diver transect survey.

Substrate

Initial substrate data analysis consisted of a review of navigational hazards, rock outcrops, and other relevant information depicted on NOAA chart #13237 and data available from Mass GIS. There is limited published information available in finer scale resolutions on the surficial

substrate composition of the seafloor in the Harwich region of Nantucket Sound. Further, substrate composition is one of the most critical components when selecting a suitable location to deploy an artificial reef. Therefore, sidescan sonar and diver transect survey data are the primary sources of information used in this assessment.

Slope
Slope data reviewed from soundings measurements listed on NOAA chart #13237 and bathymetry data from MassGIS were used to select an assessment area with a slope of <5°. Slope was verified by collecting depth data at 10m intervals along each diver transect and calculating slope from observed depth changes over the total length of each 100m transect.

User conflicts
Within the jurisdictional limits of the Town of Harwich, uses that could present potential conflicts for siting an artificial reef were avoided. Available GIS data including mapped navigational ferry routes, weir fisheries and identified commercial and recreational fishing uses were considered when sizing and selecting an appropriate location for further assessment.

Using these criteria, a 1.15 square mile area (735 acres) located south of Saquatucket Harbor (Figure 1) was identified for further assessment using sidescan sonar and diver transect surveys.

Sidescan Sonar survey
In August 2009, DMF contracted American Underwater Search and Survey (AUSS) to perform a sidescan sonar survey of the area identified through exclusion mapping. The tire reef site off the coast of the Town of Yarmouth was also assessed to compare the characteristics of a potential site in Harwich to an existing artificial reef. From the sidescan survey, a mosaic image (Figure 2) was generated to depict characteristic differences in surficial substrate. Visual analysis of image data generated from the sidescan sonar survey was used to identify locations for diver surveys.

Diver surveys
Diver surveys were conducted to verify the composition of surficial substrate at locations selected from mosaic imagery analysis and to collect data on finfish, motile invertebrates, and visibly quantifiable sessile invertebrates. Twenty-eight transect locations were selected from a visual analysis of sidescan mosaic imagery. Twenty-four out of twenty-eight transect locations were surveyed in October 2009 and October 2010 (Figure 2). (Note: transect #'s 11,19,22,29 listed in Figure 2 were not surveyed).

Transect Survey Results
Depth verification
Depth data (Table 3) was collected *in situ* on all diver transect surveys at 10m intervals and averaged for each transect. Depth data was standardized to a mean low water (MLW) value by synchronizing the time of depth measurement to local tide data available from NOAA. Once adjusted to MLW values, seven transect locations (16, 17, 20, 21, 23, 25, 26) were determined to be unsuitable based on the weighting and ranking analysis criteria.

Slope and wave action

Slope was calculated from the change in depth along 100m diver transect surveys. Barber et al (2009) used a 5°change in slope to eliminate potential sites because of concerns with reef stability. Slope calculations did not exceed 1° at any location within the surveyed area. There were no sand wave / ripple areas witnessed on any of the 24 diver transects sampled.

Substrate weighting and ranking analysis

A weighting and ranking analysis modified from Barber et al (2009) was utilized to assess field data for selecting a potential site location. Criteria included primary substrate percentage, depth, and proximity to other locations with suitable primary substrate composition. For each potential site, a numerical score was assigned to each category (Table 2).

Table 2. Reclassification values for substrate and depth

Primary surficial substrate			Rank value
silt	unsuitable	not capable of supporting reef weight	0
bolder / cobble	unsuitable	existing hard bottom habitat	0
sand/silt	potential	sediment reworking	1
sand / granule / pebble	prime		2
Depth			
<30 ft	unsuitable	navigational concerns, wave action	0
30 ft - 35 ft	prime		2
>35 ft	potential	reduced time for recreational divers	1

Substrate composition

Divers quantified substrate types along both sides of a 100m central transect line out to a distance of 2 meters. Larger substrate types were visually classified according to categories defined by Wentworth (1922 – Wentworth scale) and verified using rulers. Finer substrates were categorized as sand, mud, or silt. Primary (area contained >50% of sediment type) and secondary (area contained 10-50% of sediment type) sediment types were recorded at 10m intervals. The results of the surficial substrate composition (Figure 3) includes transects 1 through 7 collected at the Yarmouth tire reef site for comparative purposes. Transects where >50% of primary substrate was identified as silt were eliminated as potential sites because of their inability to support the weight of reef materials. This eliminated all transects within the deeper section of the survey area (8, 9, 10, 12, 13, 14, 24), three of the nine sites within the middle survey region (15, 26, 30) and four sites within the shallower region (17, 18, 20, 31). Site # 35 was eliminated as a potential reef site as it was outside the survey area. Transect sites were then ranked by adding depth and primary substrate ranking scores (Table 3).

Table 3. Reclassification rankings (see table 2) for each transect.

Site ID	Depth (MLW)	Depth rank	Primary substrate	Primary Substrate rank	Total (depth rank +primary substrate rank)	Rank Total*
8	33.4	2	Soft sand / silt	0	2	2
9	33.8	2	Soft sand / silt	0	2	2
10	33.8	2	Soft sand / silt	0	2	2
12	34.0	2	Soft sand / silt	0	2	2
13	34.0	2	Soft sand / silt	0	2	2
14	32.3	2	Soft sand / silt	0	2	2
15	31.0	2	Soft sand / silt	0	2	2
16	26.0	0	Sand	2	2	2
17	29.3	0	Soft sand / silt	0	0	4
18	31.5	2	Soft sand / silt	0	2	2
20	28.4	0	Shell debris/shack	1	1	3
21	25.3	0	Sand	2	2	2
23	27.4	0	Sand	2	2	2
24	33.7	2	Soft sand / silt	0	2	2
25	29.9	0	Sand	2	2	2
26	29.1	0	Soft sand / silt	0	0	4
27	30.0	2	Sand	2	4	1
28	31.3	2	Sand	2	4	1
30	35.1	1	Soft sand / silt	0	1	3
31	36.9	1	Soft sand / silt	0	1	3
32	31.2	2	Sand	2	4	1
33	30.8	2	Sand	2	4	1
34	30.8	2	Sand	2	4	1
35	32.0	2	Soft sand / silt	0	2	2
*Sites ranking >1 were eliminated as potential sites						

Surficial substrate composition is relatively uniform among the five highest ranking transects (27, 28, 32, 33, 34), consisting primarily of sand and resembling the primary substrate at the Yarmouth artificial reef site (Figure 3, transects 1-7). These locations exhibited depth values of potential or prime based on weighting and ranking analysis criteria.

To select the most optimal location for reef development, a “nearest neighbor” analysis was conducted by dividing the survey site into 200m^2 block grid and selecting blocks within the grid where transect surveys were conducted (Figure 4A). Blocks within the grid where no transect data was collected and grid blocks containing transects eliminated during the weighting and ranking analysis were eliminated from consideration for site selection (Figure 4B). Two sites (site 27 and 34) were located adjacent to other sites that also scored high in the ranking analysis (Figure 4C). Site 27 was selected as the target area for permitting.

Table 4. Top 5 ranking transects.

Site ID	Rank	# of adjacent ranked sites	Rank
27*	1	2	1
28	1	1	2
32	1	1	2
33	1	1	2
34	1	2	1
* selected location (Figure 8).			

Species presence and relative abundance

Divers quantified all fish species, motile invertebrates, and sessile macroinvertebrates along both sides of a 100m transect. Collected data was totaled from both divers for each site.

Survey totals for observed fish species from the five top ranking transect sites are depicted in Table 5 and Figure 5. Fish presence were recorded in only 2 instances and included only 2 fish species, black sea bass and cunner. There were six different fish species recorded among all transects within the Harwich survey area, compared to eleven fish species recorded at the Yarmouth transects (Table 7). Black sea bass and cunner were the only two species found along all five of the highest ranking transects, and only seven fish species were recorded over all 24 transects. Black sea bass and cunner were the only two fish species averaging greater than one occurrence per transect.

Table 5. Fish data

	Transect					
Fish (count)	T27	T28	T32	T33	T34	Totals
Centropristis Striata (Black sea bass)	2	0	0	0	0	2
Tautogolabrus adspersus (Cunner)	0	0	0	2	0	2
Totals	2	0	0	2	0	4

For invertebrates, ten species were recorded among the top five ranked transect sites, and 23 invertebrate species were recorded from all transects. Survey totals for observed invertebrate species for the five top ranking transects are depicted in Table 6 and Figure 6. Two species, hermit crabs and spider crabs were observed on all five transects. Two invertebrate species (lobster, lady crab) were observed on only one occasion during transect sampling. A notable observation from site 27 included a large, patch of adult sized sea scallops along the sample transect. Several hundred individuals

Table 6. Invertebrate data

	Transect					
Invertebrates (count)	T27	T28	T32	T33	T34	Totals
Hermit crabs	29	19	3	20	24	95
Libinia emarginata (spider crab)	16	7	7	14	29	73
Cancer sp. (Rock and Jonah)	6	0	3	10	14	33
Busycon and Buccinum (whelks)	1	0	7	5	1	14
Neopanope sp (mud crab)	0	0	0	1	1	2
Limulus polyphemus (Horseshoe crab)	3	1	1	0	5	10
Ovalipes ocellatus (Lady Crab)	0	0	0	1	0	1
Metridium sp. (anemonies)	2	14	0	10	2	28
Homarus americanus (lobster)	0	0	1	0	0	1
Placopecten magellanicus (Sea scallop)	356	0	0	0	0	356
Totals	413	41	22	61	76	613

were found in dense concentrations along a section 20 – 30m in length and approximately 10m in width. No other scallops could be located outside of this patch in any direction. Sea scallop densities of this magnitude are not known to occur in this location, and the presence of sea scallops, individual occurrences or large densities, were not noted at any of the 23 other transects sampled. A review of more than 30 years of DMF's Nantucket Sound trawl survey data did not reveal a single tow containing high densities of sea scallops anywhere near the survey area. It was determined that their occurrence in this location must be incidental.

Slipper shells (*Crepidula sp*) were also recorded in dense, patchy areas in four of the five ranked sites. Live animals along with shell "shack" comprised between 10 and 20% of the surficial substrate in these areas, however classification of live animal vs. shell only was not assessed. *Crepidula sp.* require a hard object for attachment to the bottom during their larval settling stage, indicating surficial substrates where they are found are comprised of sediments where grain sizes are equal to or greater than sand.

Land Containing Shellfish

This site lies within an area designated as habitat suitable for shellfish, specifically *Mercenaria mercenaria* (hard clam), according to data published by DMF and MassGIS (Figure 7). The GIS data includes areas where shellfish have been observed since the mid-1970's, but may not currently support any shellfish. Therefore, these designations represent potential rather than actual shellfish habitat areas. This factor was addressed by collecting information during transect surveys on the actual presence of all shellfish species. Two shellfish species, hard clam (N=1) and *Mytilus edulis* (blue mussel) (N=2) were observed over all seven transects. Although this site has been identified as suitable shellfish habitat, low numbers of shellfish were observed during transect surveys. The deployment of new materials on site as proposed is not expected to have a significant impact on shellfish habitat or abundance.

Table 7. Total species counts from all transect sample locations.

SPECIES COUNTS						
	Yarmouth (N=7)		Harwich (N=24)		All (N=31)	
	Total	Average per transect	Total	Average per transect	Total	Average per transect
FISH						
Centropristis Striata (Black sea bass)	487	69.6	395	16.5	882	28.5
Stenotomus chrysops (Scup)	401	57.3	10	0.4	411	13.3
Tautogolabrus adspersus (Cunner)	47	6.7	119	5.0	166	5.4
Pseudopleuronectes americanus (Winter flounder)	3	0.4	4	0.2	7	0.2
Paralichthys dentatus (Summer flounder)	3	0.4	4	0.2	7	0.2
Tautoga onitis (Tautog)	21	3.0	18	0.8	39	1.3
*Caranx crysos (*Blue Runner)	179	25.6	0	0.0	179	5.8
*Seriola fasciata (*Lesser amber jacks (juv.))	25	3.6	0	0.0	25	0.8
*Peprilus triacanthus (*butter fish)	3	0.4	0	0.0	3	0.1
*Chaetodon ocellatus (*Spotfin butterfly)	5	0.7	0	0.0	5	0.2
*Prionotus carolinus (*Northern sea robin)	1	0.1	0	0.0	1	0.0
*Urophycis chuss (*Red Hake)	0	0.0	1	0.0	1	0.0
Totals	**1175**	**167.9**	**551**	**23.0**	**1726**	**55.7**
INVERTEBRATES						
Crepidula sp	0	0.0	3917	163.2	3917	126.4
Barnacles	0	0.0	1404	58.5	1404	45.3
Hermit crabs	588	84.0	211	8.8	799	25.8
Libinia emarginata (Spider crab)	1	0.1	187	7.8	188	6.1
Cancer sp. (Rock and Jonah)	0	0.0	149	6.2	149	4.8
Busycon and Buccinum (Whelks)	4	0.6	41	1.7	45	1.5
Neopanope sp. (Mud crabs)	0	0.0	37	1.5	37	1.2
Argopecten irradians (Bay scallop)	0	0.0	20	0.8	20	0.6
Limulus polyphemus (Horseshoe crab)	0	0.0	17	0.7	17	0.5
Ovalipes ocellatus (Lady Crab)	0	0.0	15	0.6	15	0.5
Metridium sp. (Anemonies)	1	0.1	7	0.3	8	0.3
Cerianthis sp. (holes)	0	0.0	5	0.2	5	0.2
Botryloides sp.	0	0.0	4	0.2	4	0.1
Mercenaria mercenaria (Quahog)	1	0.1	3	0.1	4	0.1
Cliona celata (yellow sponge)	68	9.7	9	0.4	77	2.5
Hemigrapsus sanguineus (Asian shore crab)	0	0.0	2	0.1	2	0.1
White tunicate	0	0.0	1	0.0	1	0.0
Tufted bryozoan	9	1.3	0	0.0	9	0.3
Mytilus edulis (Blue mussel)	2	0.3	0	0.0	2	0.1
Homarus americanus (lobster)	1	0.1	0	0.0	1	0.0
Astrangia sp. (Northern Sea Coral)	0	0.0	2	0.1	2	0.1
Placopecten magellanicus (Sea scallop)	0	0.0	358	14.9	358	11.5
Totals	**675**	**96.4**	**6389**	**266.2**	**7064**	**227.9**

2. Proposed Project Size

This proposed project will place a cap on the amount of new materials that may be deployed to 1.11 acres (48,352 ft^2) of area, or 11% of the total surface of the proposed site. Deploying new material within these limits will provide additional environmental benefits to structure-oriented marine resources in an area of limited structured habitat, maintain a substantial amount of undisturbed area on-site, and afford additional opportunities for near-shore anglers. Materials deployed at the proposed location will be distributed to create multiple patch habitat arrays across the 9.88-acre site. The proposed site is divided into four equal quadrants containing one-hundred 10m x 10m blocks each for tracking material deployments (Table 8).

Table 8. Calculations for material coverage

Quadrant	Acres	# of 10m x 10m Blocks	# of Developable Blocks within quadrant (1:2 ratio of total area)	Blocks containing structures	Blocks no structures	Blocks Available for new materials	Acreage for development (Blocks Available * acreage)	Total Acreage material coverage using targeted 1:2 ratio of material to space (33%)
NE	2.47	100.00	33.00	0.00	100.00	33.00	0.82	0.28
NW	2.47	100.00	33.00	0.00	100.00	33.00	0.82	0.28
SE	2.47	100.00	33.00	0.00	100.00	33.00	0.82	0.28
SW	2.47	100.00	33.00	0.00	100.00	33.00	0.82	0.28
Total	9.88	400.00	132.00	0.00	400.00	132.00	3.26	1.11

3. Dispersion of Materials

A literature review was undertaken to define optimal densities for patch reef development and to determine appropriate options for dispersing new materials on site. Peer reviewed information on optimal densities for patch reef development is limited and varies substantially depending upon location. In general, artificial reefs of smaller sizes are utilized by more fish because of a higher perimeter to area ratio (Ambrose and Swarbrick, 1989). Interstitial spaces are important for maintaining trophic relationships between reef inhabitants and the surrounding fauna. Hueckel et al. (1989) found that bottom development consisting of a ratio of one part reef material for every two parts of undisturbed bottom was optimal when mitigating for habitat loss using artificial reefs. Based on this information, this project proposes an arrangement of materials utilizing a 1:2 ratio (33% coverage) of new material to natural bottom.

To assess the viability of utilizing the proposed 1:2 ratio of materials to open space for further site development, a map of the site was divided into quadrants (NE, NW, SE, and SW) containing 10m x 10m grid blocks (Figure 9). The grid system provides a mechanism to plan and monitor material deployment in order to maintain the proposed 1:2 or greater ratio throughout the entire reef site. Examples of potential organized and random configurations within a 10m x 10m grid for different material types are depicted in Figures 13 – 16.

4. Volume of Reef Materials

The type of and source for materials for this site have not been determined. This project is designed to take advantage of low or no cost clean materials approved under the "Guidelines for Marine Artificial Reef Materials, Second Edition" (ASMFC 2004), the National Artificial Reef Plan (NOAA 2007), and the Massachusetts Artificial Reef plan (Rousseau 2008). Two primary categories of materials have been used in the development of artificial reefs in U.S. coastal waters – 1) materials of opportunity and 2) designed/constructed reef units (*Guidelines for Marine Artificial Reef Materials, Second Edition*, ASMFC 2004). To maximize opportunities to acquire materials for deployment this proposal examines both materials of opportunity and engineered structures. Examples of clean materials include concrete culverts, concrete sewage dry well (honeycomb), natural rock, or manufactured units such as "Reef Balls" or other similar structures. Tire units are no longer considered approved materials.

Deployments of designed reef structures

There is a considerable amount of variation in shape and size among various types of designed reef structures (See Figure 11). To estimate the approximate area and volume of an array of different designs, the footprint of an individual unit was calculated by squaring the longest base length. Base dimensions for specific designs vary, but the base dimension of a unit generally increases as vertical dimension increases to maintain structural stability. To maintain a minimum 24' depth clearance over the reef site, new materials are limited to a maximum height of six feet. Table 9 lists the estimated area and volume for a range of designed structures with up to six feet of vertical relief. Using this method, we were able to determine the number of units of various sizes needed to cover the proposed 1.11-acre (413,820 ft^2) area.

New deployments of consolidated materials

Consolidated materials consist of clean debris, quarried stone or other approved materials of opportunity. (see Appendix B for examples). To estimate the approximate quantity of materials ranging from 3' to 6' of vertical relief, a 1:2 ratio of material to natural bottom was used to calculate the available area within a single 10m x 10m block. This value is multiplied by the number of blocks available in each quadrant (see table in Figure 10). Base dimensions for specific designs and material types vary, but in general

Table 9. Estimated area and volume for a range of designed reef structures

Structure size (l x w)	Footprint (ft^2)	Volume (ft^3)	# units / acre	Total # units / 1.11 acres
3ft x 3ft	9	27	4,840	5,372
4ft x 4ft	16	64	2,722	3,021
5ft x 5ft	25	125	1,742	1,934
6ft x 6ft	36	216	1,210	1,343

the base dimension of a unit increases as vertical dimension increases. To maintain a minimum 24' clearance over the reef site, new materials are limited to a maximum height of 6'. Table 10 estimates area and volume for a vertical range of consolidated designs. Using these

calculations, a volume of material needed to cover 1.11 acres within the permitted area can be determined.

Table 10. Maximum area and volume for consolidated and prefabricated materials.

			NW = 33		NE = 33		SW = 33		SE = 33		Total = 132	
Max Vertical relief (ft)	1:2 Max area (ft^2) per block (l x w)*.33	Volume per block (ft^3)	(ft^2) per quadrant NW	(ft^3) per quadrant NW	(ft^2) per quadrant NE	(ft^3)per quadrant NE	(ft^2) per quadrant SW	(ft^3) per quadrant SW	(ft^2) per quadrant SE	(ft^3)per quadrant SE	Total area (ft^2)	Total volume (ft^3)
3	359	1,077	11,847	35,541	11,847	35,541	11,847	35,541	35,541	393,105	47,388	142,164
4	359	1,436	11,847	47,388	11,847	47,388	11,847	47,388	47,388	524,140	47,388	189,552
5	359	1,795	11,847	59,235	11,847	59,235	11,847	59,235	59,235	655,175	47,388	236,940
6	359	2,154	11,847	71082	11,847	71082	11,847	71082	71082	786,210	47,388	284,328

5. Construction impacts

Clean materials will be deployed during daylight hours via floating barge. DMF recommends time of year (TOY) work windows for coastal alteration projects impacting important marine species and habitats. The time of year with the least amount of disruptive impacts to marine species in Nantucket Sound can vary by species. The preferred construction window for minimizing impacts is expected to be from October through January.

Settlement of materials can be expected to occur over time, and must be considered when selecting new materials for deployment on site. The addition of new reef material to the site shall be in accordance with the "Guidelines for Marine Artificial Reef Materials, Second Edition" (ASMFC 2004), the National Artificial Reef Plan (NOAA 2007), the Massachusetts Artificial Reef plan (Rousseau 2008), and follow the materials and design criteria outlined in Appendix A.

6. Monitoring

Representatives from DMF and the Town of Harwich will verify that materials to be deployed meet the criteria for approved artificial reef materials as outlined in the MA Artificial Reef Plan, The National Artificial Reef Plan, and the Guidelines for Marine Artificial reefs (ASMFC 2004) and any other conditions specified through permitting. This document provides options that address configurations, volumes, and dispersal of both consolidated materials and designed reef structures. Although several material types have been discussed in this proposal, scenarios employing varying types of materials on-site may occur. In order to track the progress of site development, a log of the amount and type of materials being deployed and coordinates identifying the location of the deployed material will be recorded for every trip. Representatives from DMF and the Town of Harwich will verify that materials deployed on-site follow the deployment specifications outlined herein and confirm that materials and deployments conform to all permit conditions. DMF will conduct annual inspections of the reef to verify that the reef materials have remained structurally stable, in place, pose no threat to navigation, and shall immediately report any problems found during the inspections.

DMF is also interested in exploring other monitoring opportunities to address specific fisheries management decisions for important commercial and recreational species that utilize this site during on or more stage of their life history.

7. Alternatives Analysis

Alternatives to the site location, material types and the distribution of materials on site were considered for this project. The option of developing other locations in state waters within the Harwich town boundaries were evaluated during the site selection analysis for this proposal.

Although materials for this proposal have yet to be defined, a range of materials was identified in an attempt to replicate the structured habitats created by materials previously deployed on other reef sites in Massachusetts. This range is based on the experience of the DMF in developing artificial reef sites and mitigation projects designed to enhance hard bottom habitats. The options outlined herein considered materials of opportunity, potential hazards to navigation, and the options available for obtaining and deploying materials.

Several alternatives for distributing materials on site were examined during the development of this proposal. For deployment purposes, aggregating large quantities of materials in a single location is an easy and economically efficient method. However, the alternative method proposed here is designed to create an array of patch habitats similar to those created during the deployment of tire structures on the Yarmouth reef site. The deployment methods utilized in Yarmouth relied on a broadcast distribution method from a moving barge, whereas the alternative method proposed here will rely more extensively on GIS and GPS to direct materials to specific areas. This approach will minimize impacts of construction activities to larger areas while creating a dispersed array of additional patch habitats.

References

ASMFC, GSMFC. 2004. Guidelines for Marine Artificial Reef Materials. A joint publication of the Gulf and Atlantic States Marine Fisheries Commissions. www.gsmfc.org.

Ambrose, R. F. and S. L. Swarbrick. 1989. Comparison of fish assemblages on artificial and natural reefs off the coast of southern California. Bull. Mar. Sci. 44: 718-733.

Barber, J. S., D. M. Chosid, R. P. Glenn, and K. A. Whitmore. 2009. A systematic model for artificial reef site selection. New Zealand J. Mar. Freshw. Res. 43:283-297.http://www.mass.gov/dfwele/dmf/publications/26_barberhi.pdf?

Barber, J. S., K. A. Whitmore, M. Rousseau, D. M. Chosid, and R. P. Glenn. 2009. Boston Harbor artificial reef site selection and monitoring program. Massachusetts Division of Marine Fisheries technical report TR-35. http://www.mass.gov/dfwele/dmf/publications/tr35_artificial_reef.pdf

Bugley, K.E. and A.H. Carr. 1994. Massachusetts coastal waters. The status and potential for artificial reefs. Bulletin of Marine Science. 55(2-3).

Carr, H.A., and E.H. Amaral. 1981. Review of the potential for artificial reefs along coastal Massachusetts. Proceedings of MTS Oceans '81 conference.

Ditton, R.B., H.R. Osburn, T.L. Baker and C.E. Thailing. 2002. Demographics, attitudes, and reef management preferences of sport divers in offshore Texas waters. ICES Journal of Marine Science. 59: S186-S191.

Figley, B. 2004. Artificial reef management plan for New Jersey. Department of Environmental Protection. Fish and Wildlife Division. 116pp.

Hueckel, G. J., R. M. Buckley, and B. L. Benson. 1989. Mitigating rocky habitat loss using artificial reefs. Bull. of Mar. Sci. 44: 913-922.

NOAA. 2007. National Artificial Reef Plan (as Amended): Guidelines for Siting, Construction, Development, and Assessment of Artificial Reefs. United States Department of Commerce. National Oceanic and Atmospheric Administration. http://www.gpo.gov/fdsys/pkg/USCODE-2008-title33/pdf/USCODE-2008-title33-chap35-sec2103.pdf

Rousseau, M. 2008. Massachusetts Marine Artificial Reef Plan. Massachusetts Division of Marine Fisheries. http://www.mass.gov/dfwele/dmf/programsandprojects/artificial_reef_policy.pdf

Yarmouth Artificial Reef Permit
List of Figures

Figure 1. Harwich survey area.

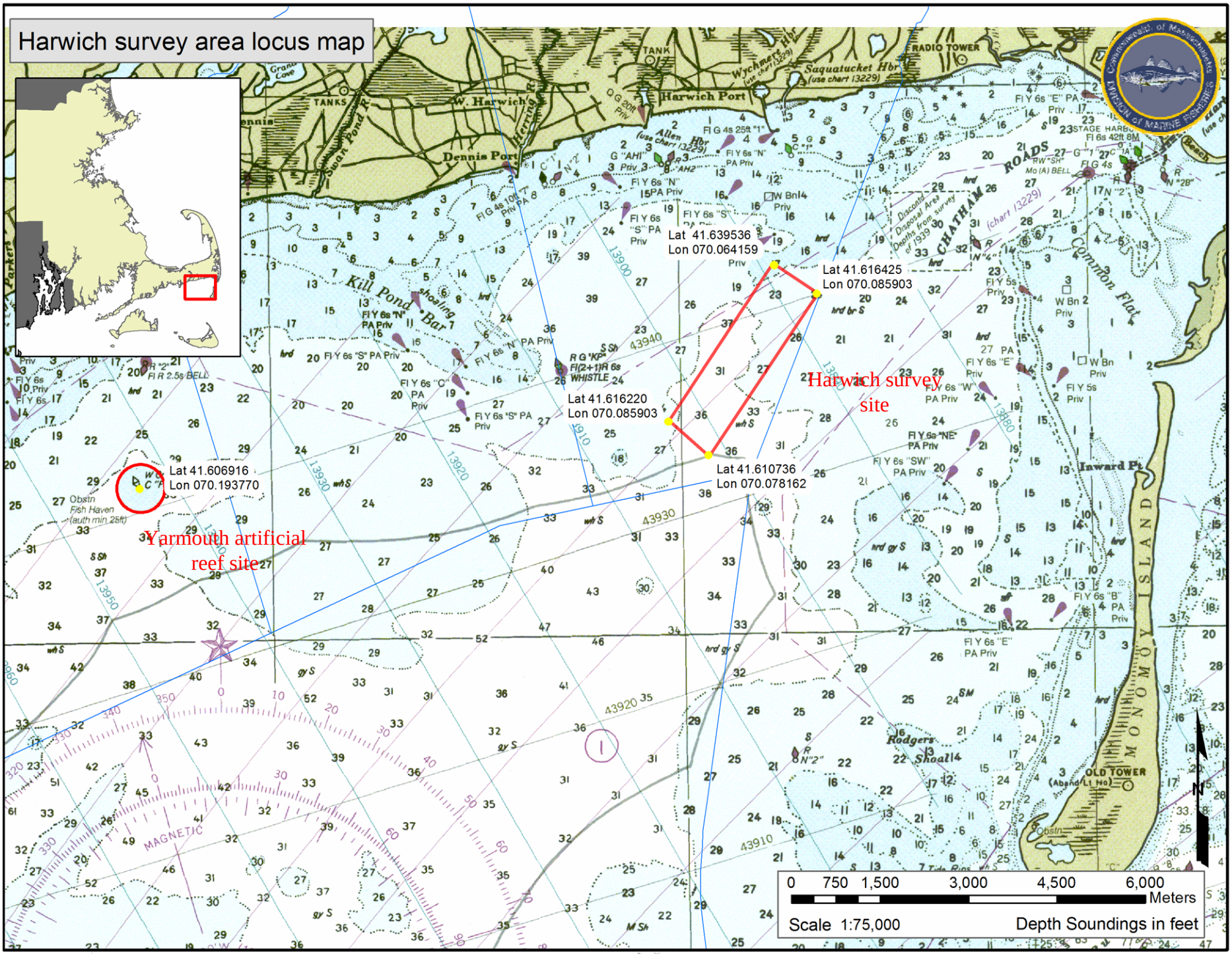


Figure 2. Sidescan sonar mosaic image and locations of diver transects.

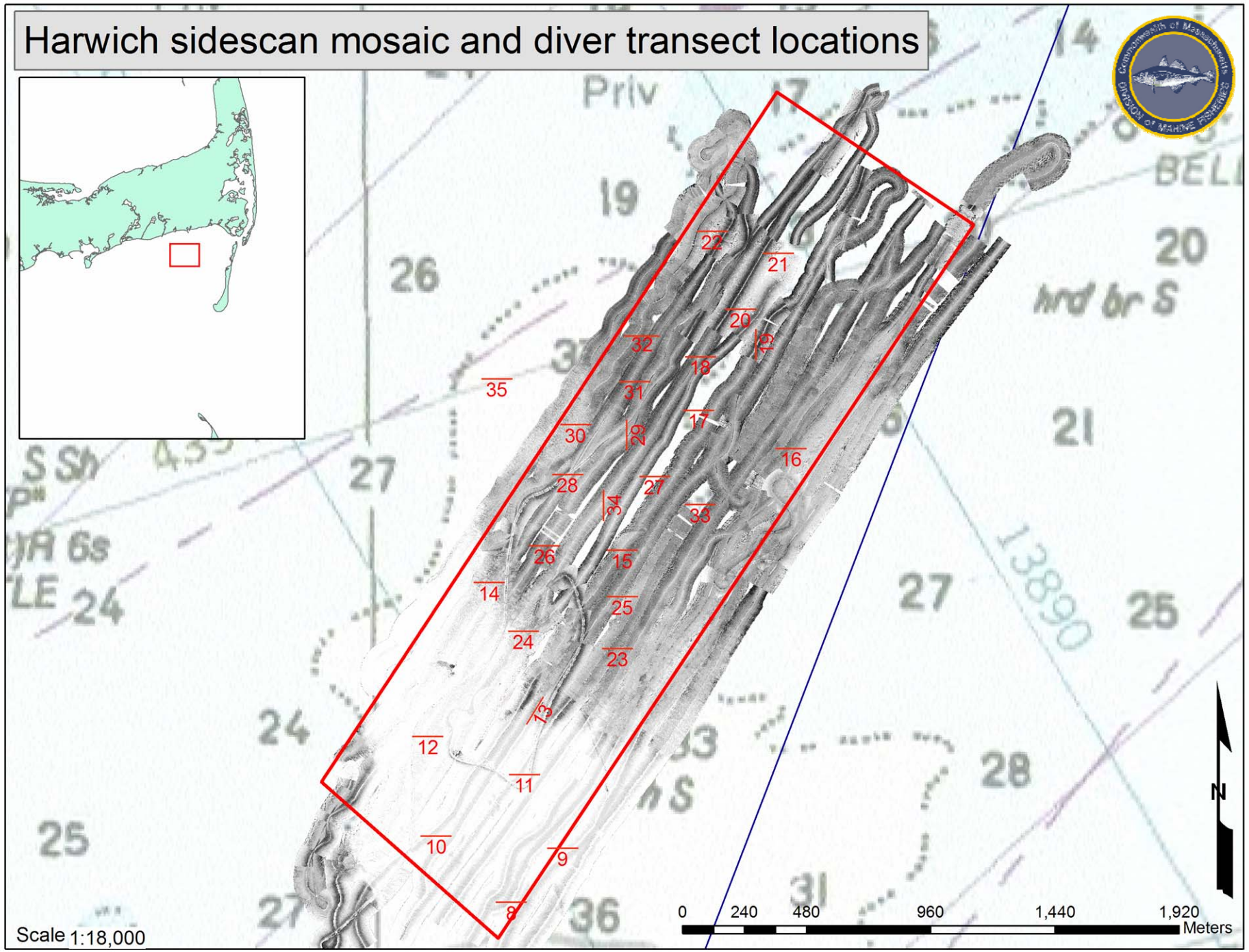


Figure 3. Surficial substrate composition (Transects 1-7 contain information collected from the Yarmouth artificial reef site for comparative purposes).

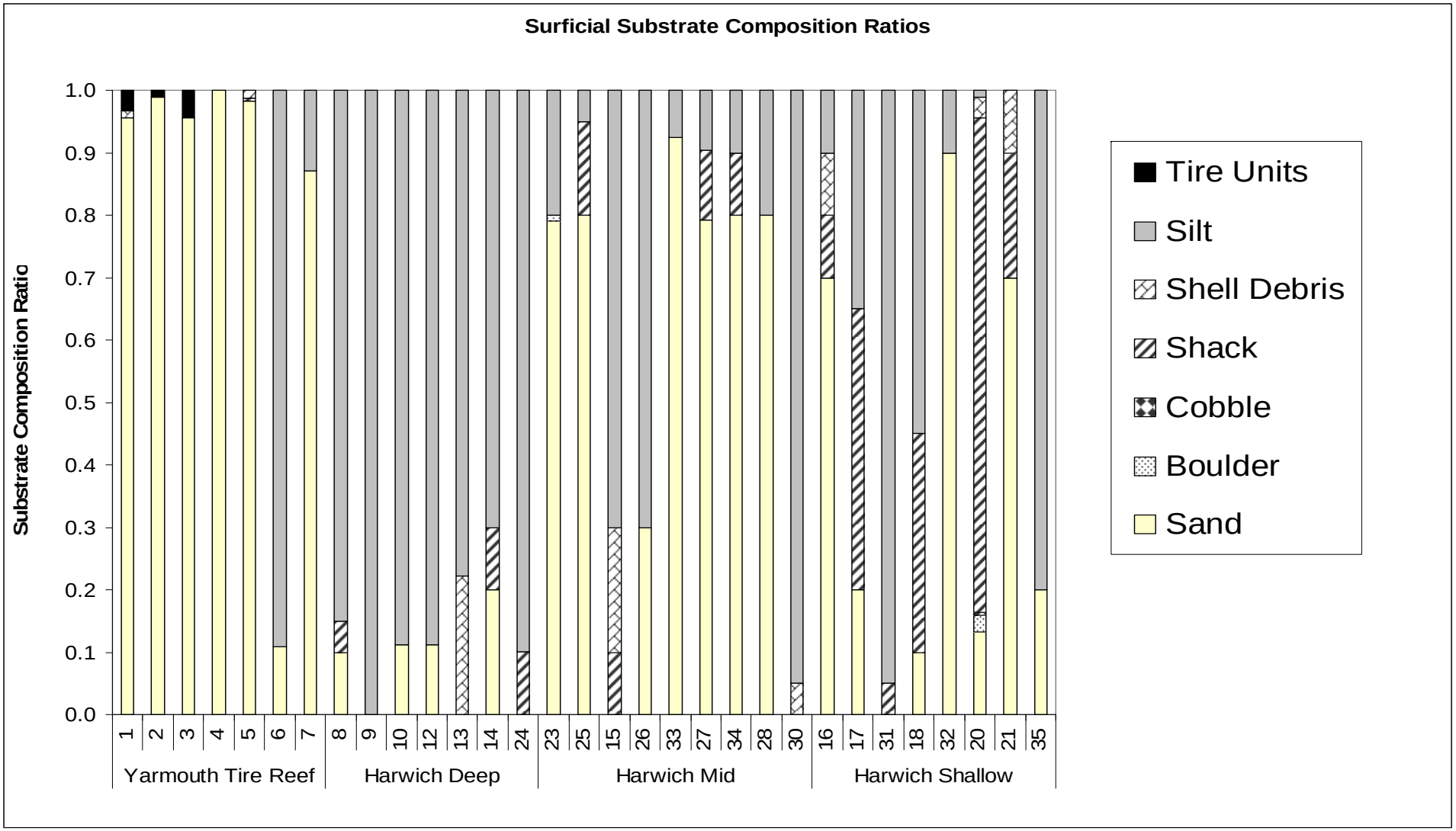


Figure 4. Schematic for selecting the most optimal location for reef site based on primary surficial substrate analysis.

A.	B.	C.
200m x 200m grid developed within the survey area and transect locations (numbered red lines), orientated north – south.. Grid block containing >50% of the transect length were selected as the representative areas for each transect.	200m x 200m grids depicted in green are blocks where survey data was collected, Grid blocks depicted with red cross hatches are blocks where no data was collected.	200m x 200m grid blocks outlined in red are the locations where >50% of the primary substrate was characterized as prime. In addition, grids containing transects 16, 17, 20, 21, 23, 25, 26 were eliminated for not mmeting the defined depth criteria. Yellow block (transect 27) is the area selected for permitting.

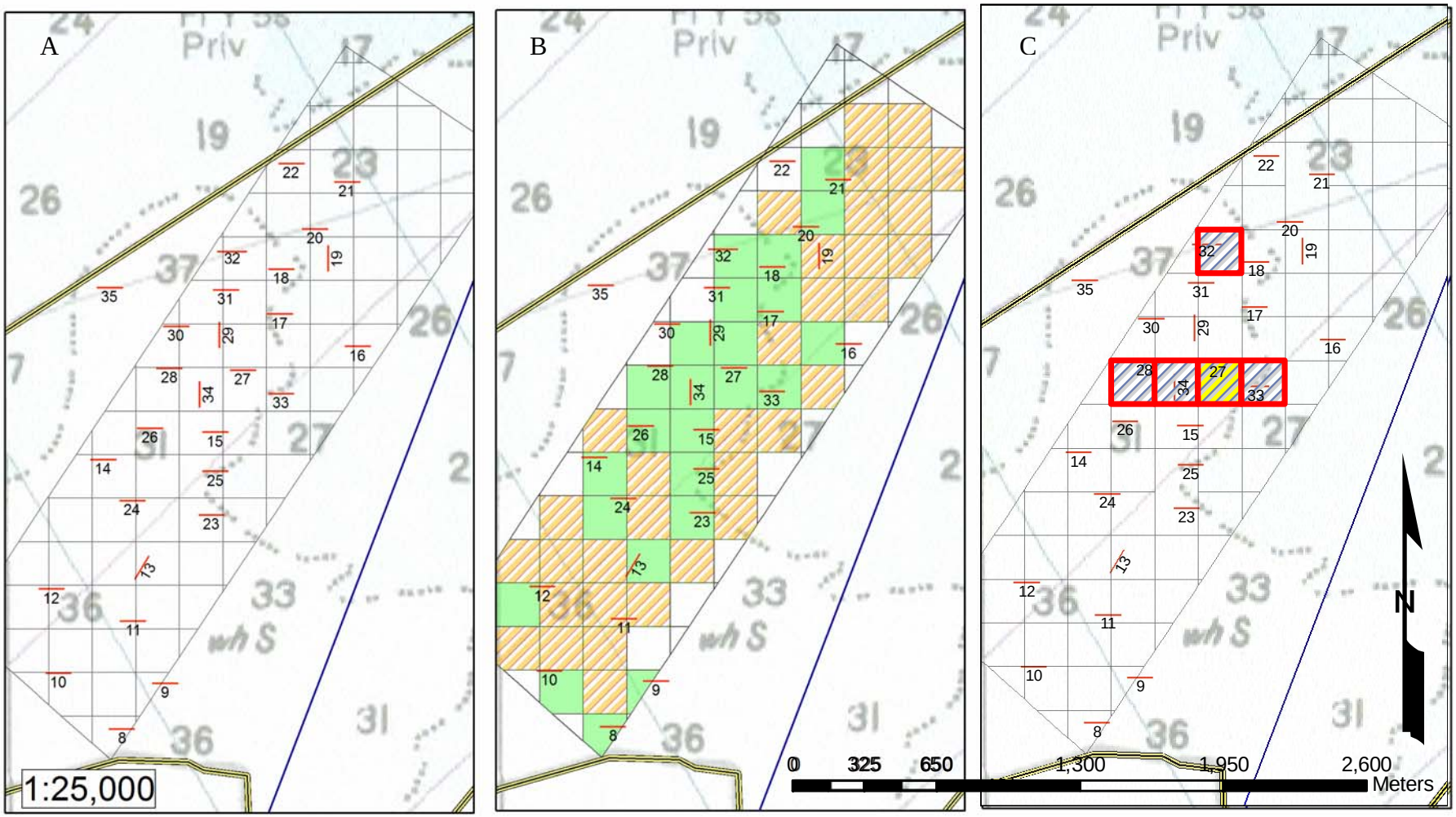


Figure 5. Fish counts by transect for top five ranked sites.

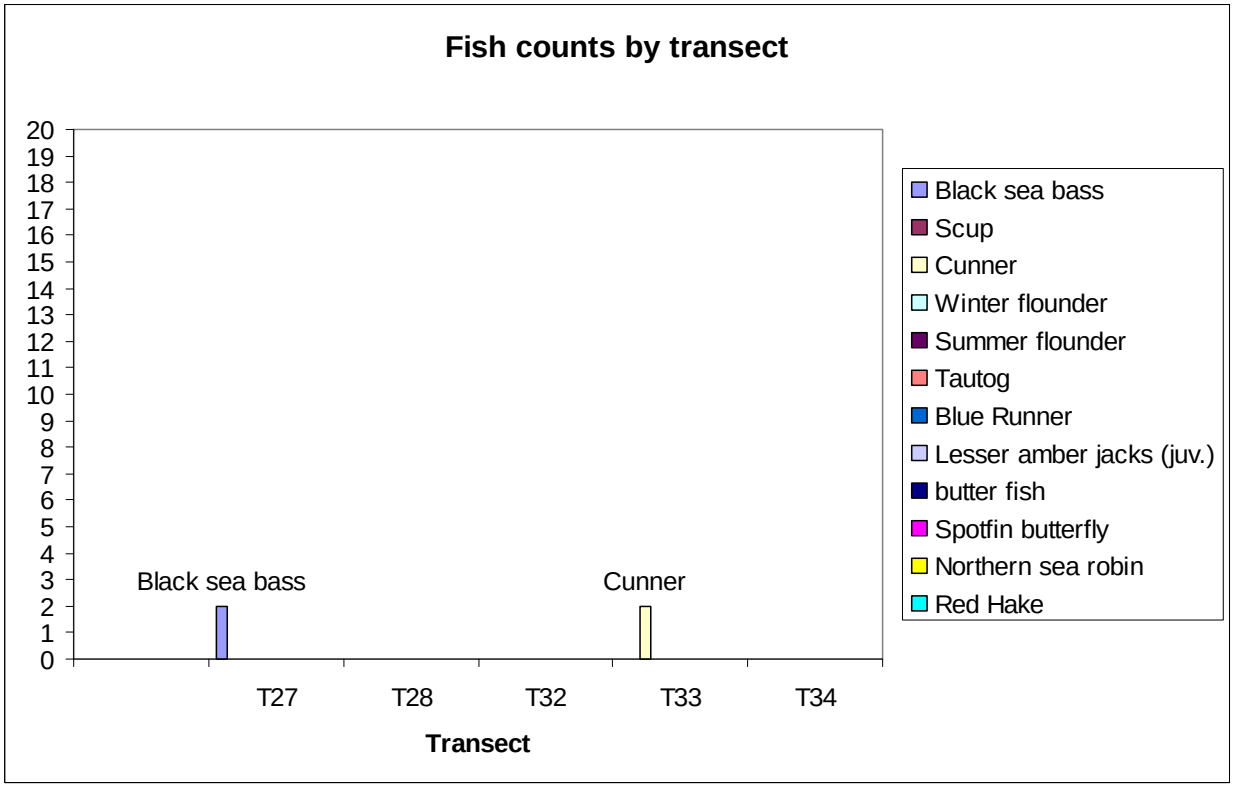


Figure 6. Invertebrate counts by transect for top five ranked sites.

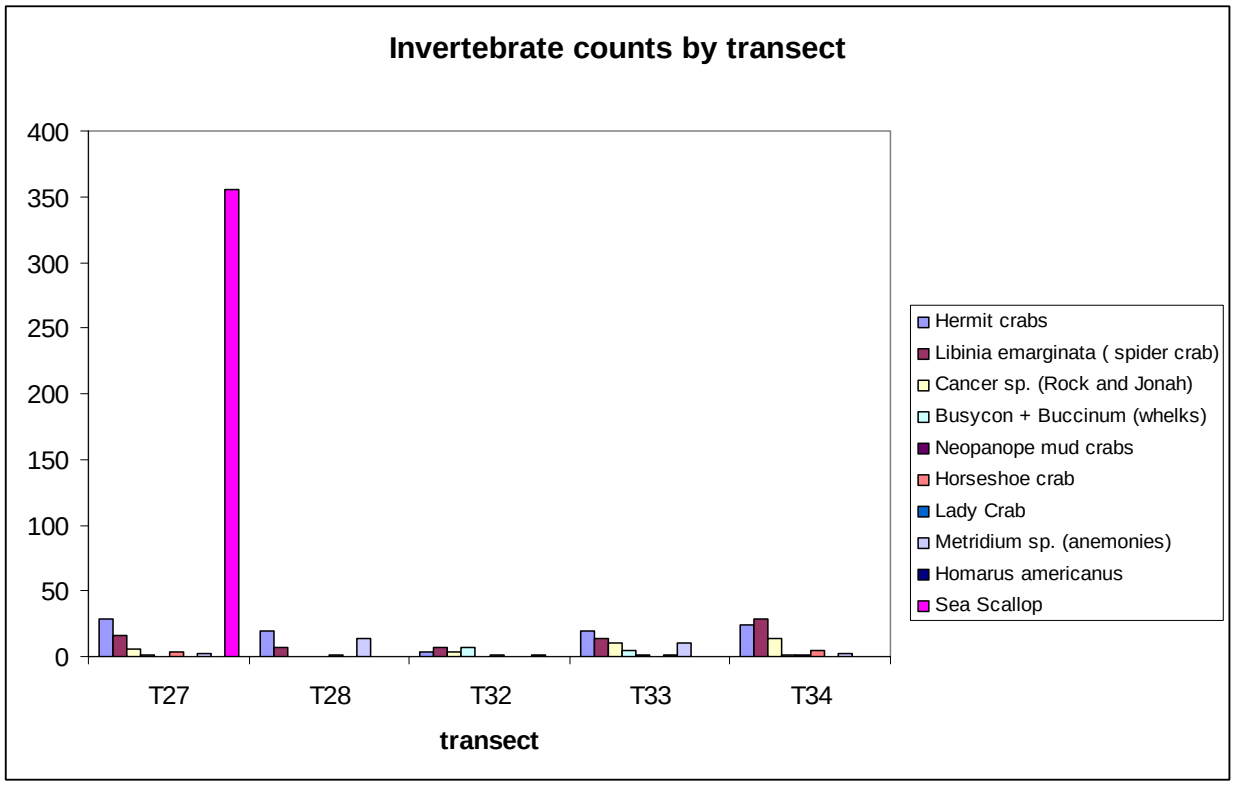


Figure 7. Land Containing Shellfish (from MASSGIS shellfish suitability data layer).

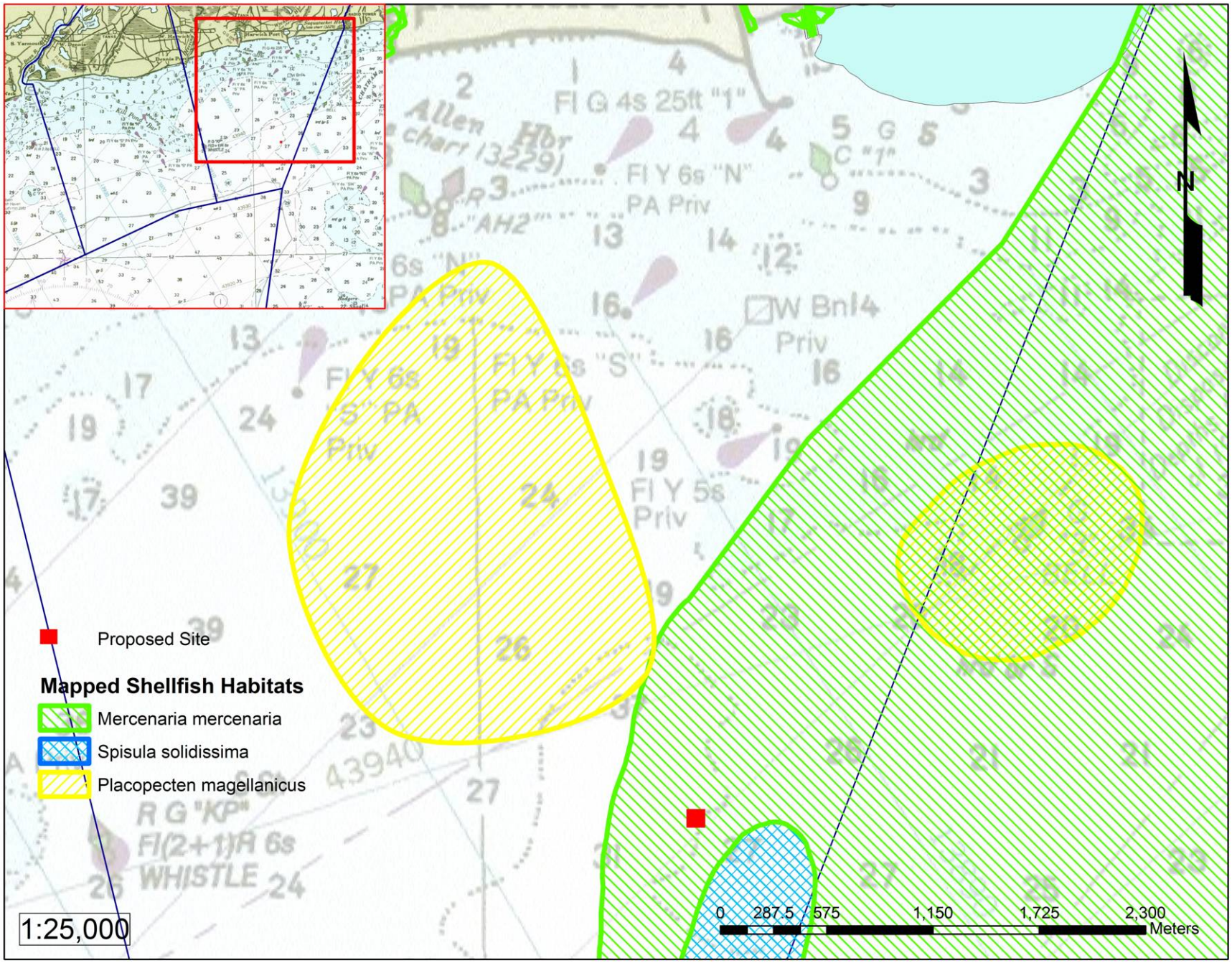


Figure 8. Location of proposed reef site.

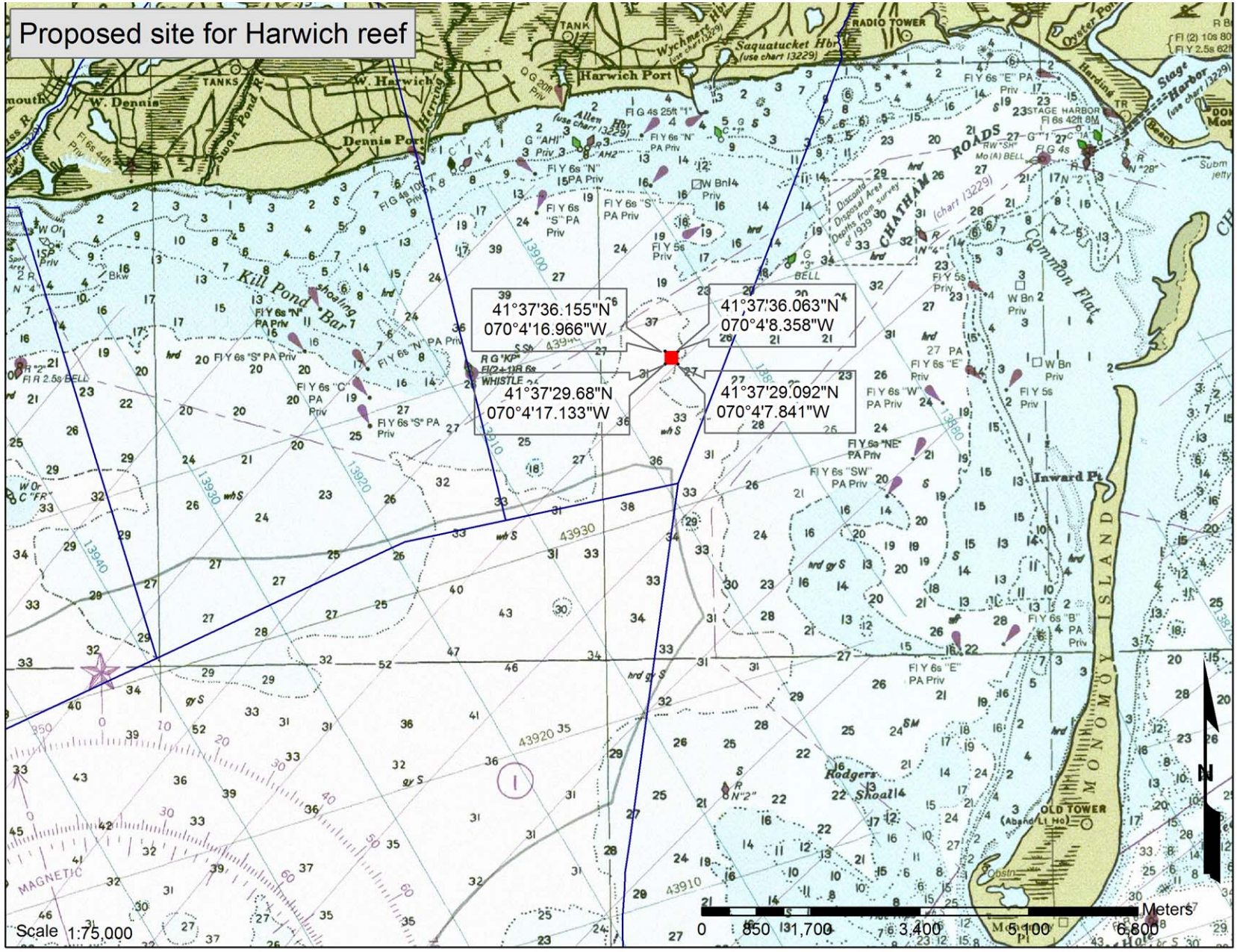


Figure 9. Harwich site divided into quadrants containing 10m x 10m grids.

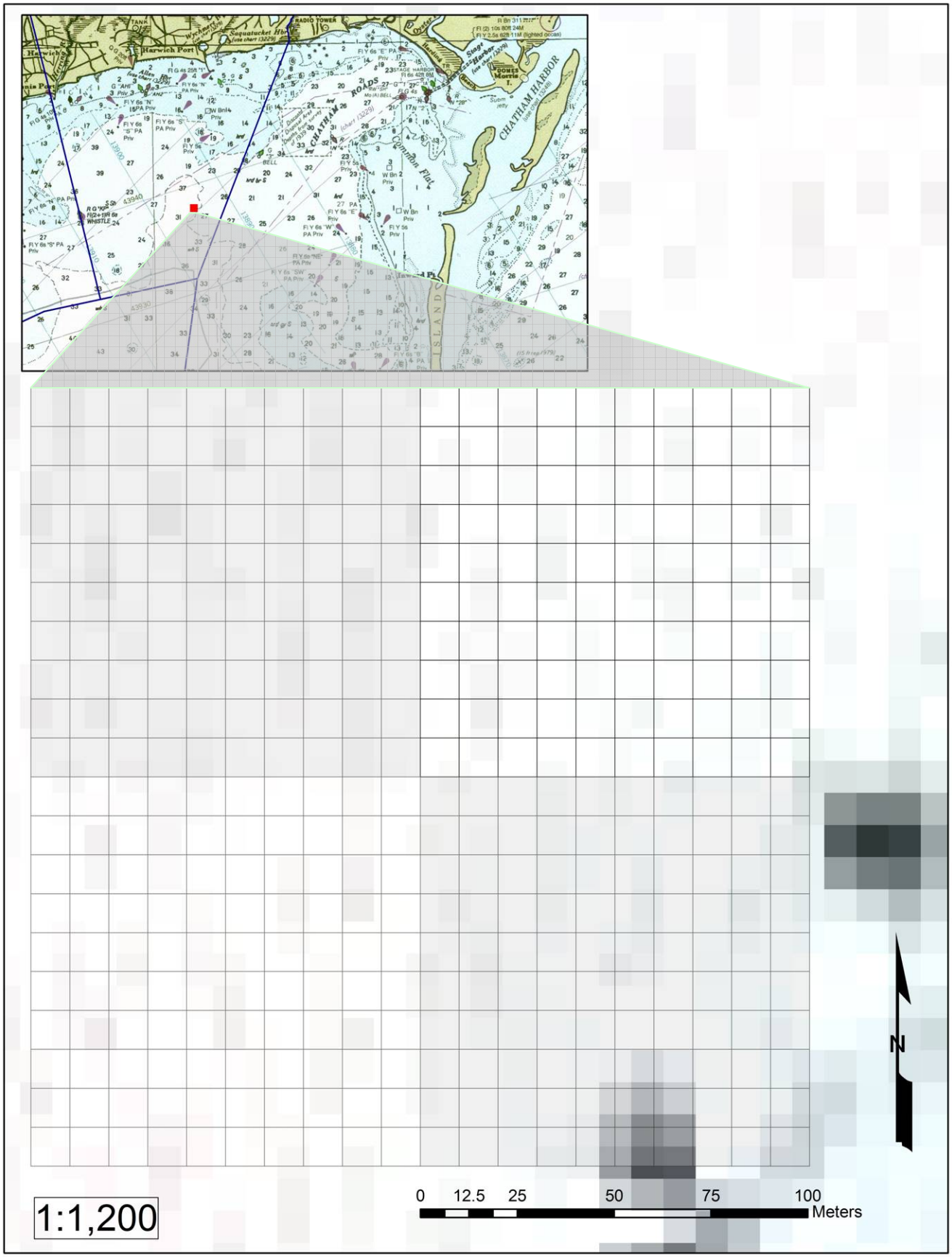
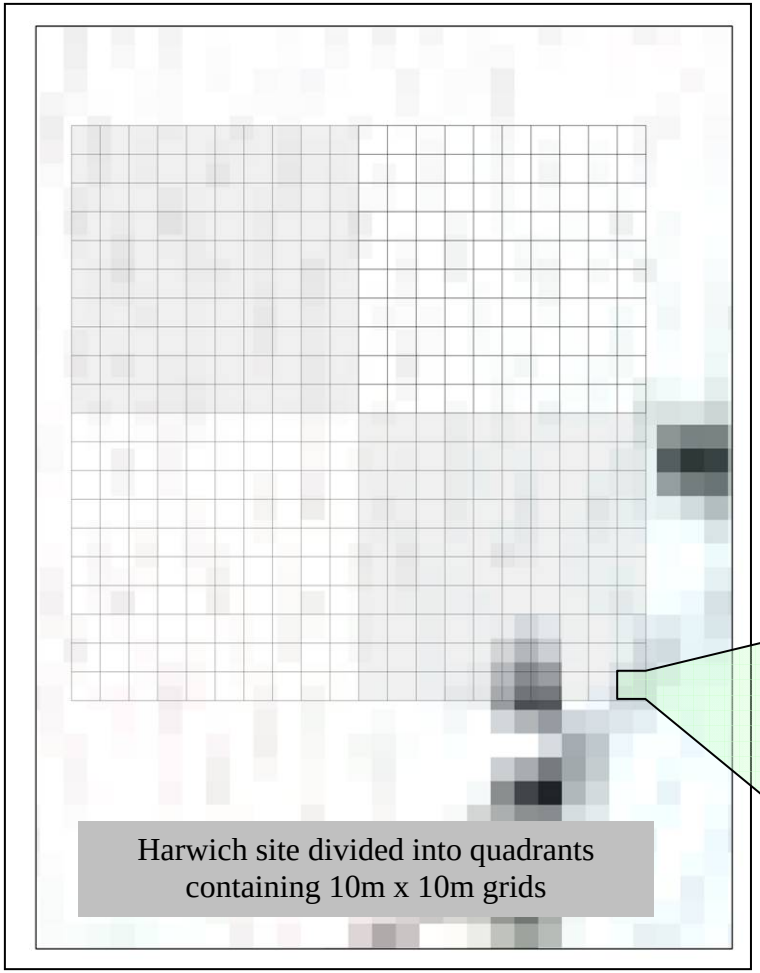


Figure 10. Reef site divided into quadrants containing 10m x 10m block.



Quadrant	Acres	# of 10m x 10m Blocks	# of Developable Blocks within quadrant (1:2 ratio of total area)	Acreage for development (Blocks Available * acreage)	Total Acreage material coverage using targeted 1:2 ratio of material to space (33%)
NE	2.47	100.00	33.00	0.82	0.28
NW	2.47	100.00	33.00	0.82	0.28
SE	2.47	100.00	33.00	0.82	0.28
SW	2.47	100.00	33.00	0.82	0.28
Total	9.88	400.00	132.00	3.26	1.11

One 10m x 10m block = $100m^2$ = 0.0247 acres

1:2 ratio for dispersion of material based on study by *Hueckel et al.* (1989).

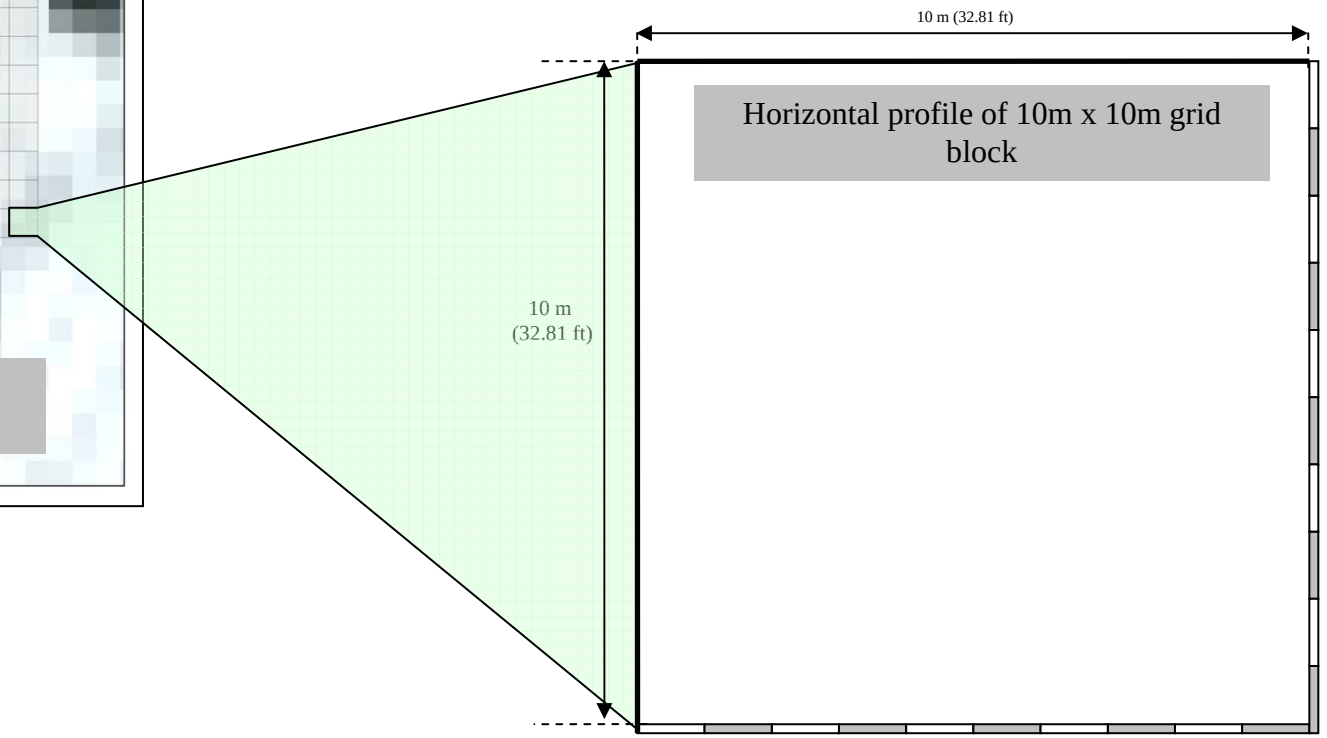
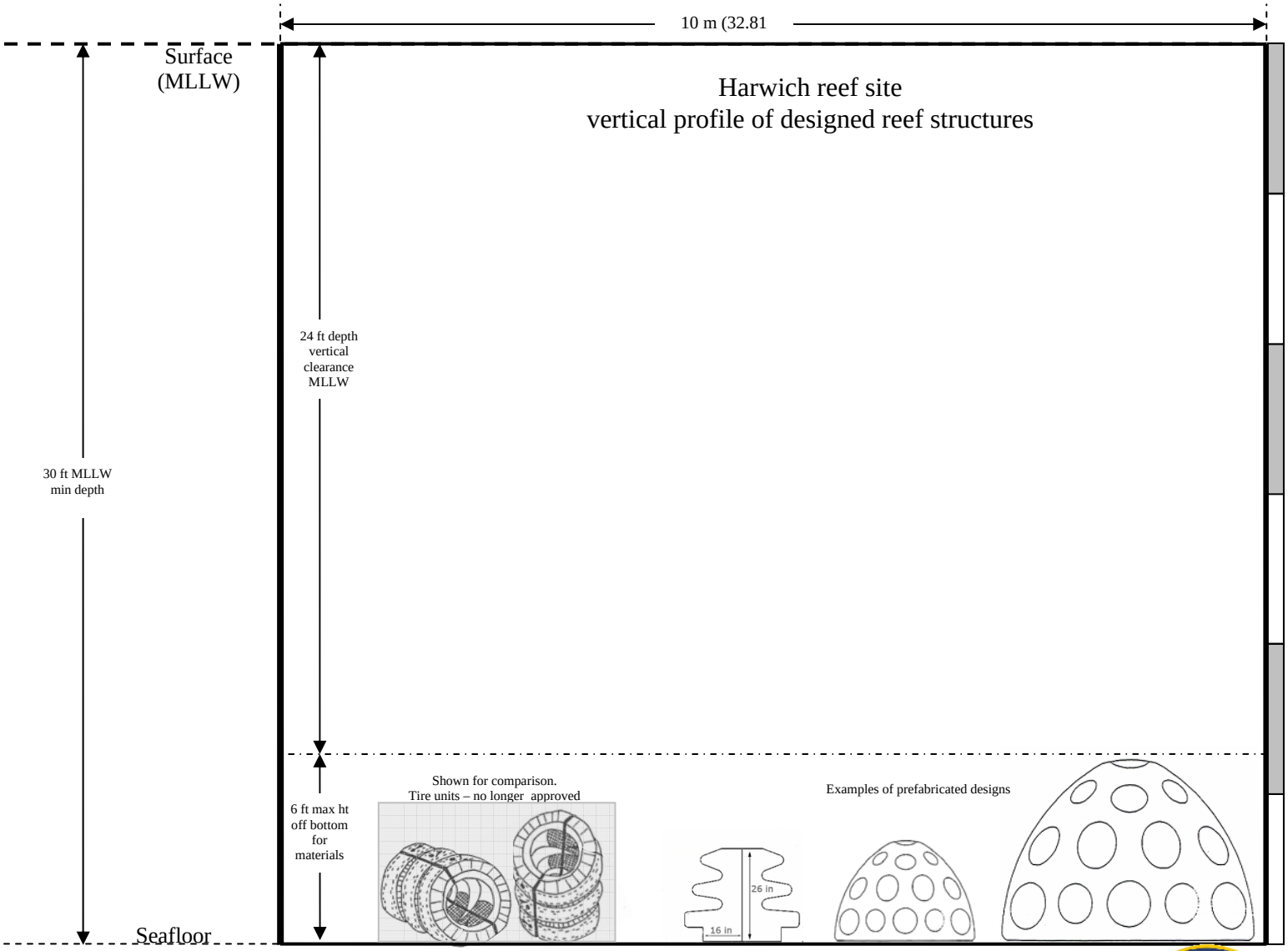
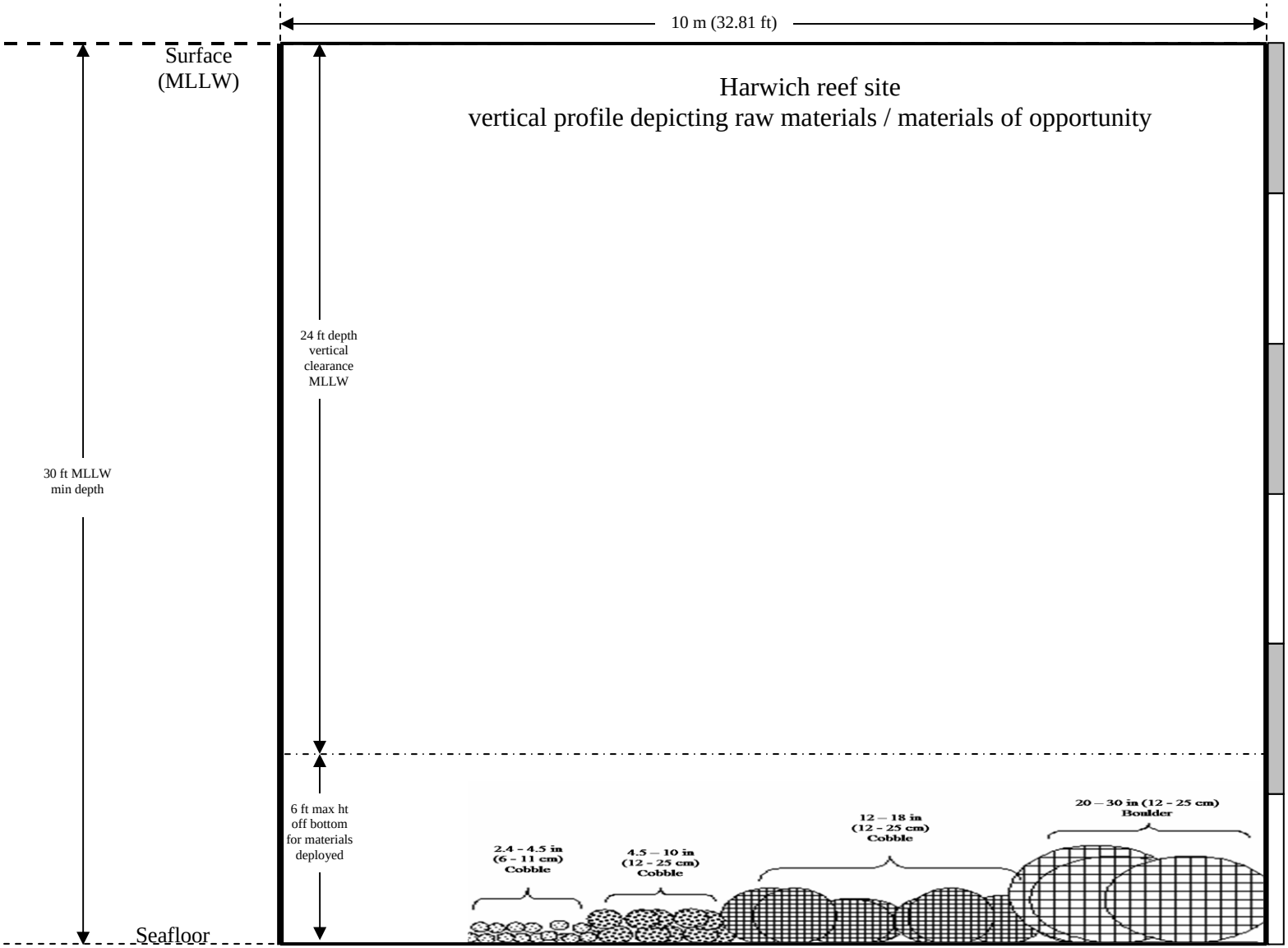


Figure 11. Vertical profile of various designed reef structures



Prefabricated reef units not drawn to scale. Actual prefabricated material sizes can vary. Prefabricated unit images represent examples of different reef material options and are not an endorsement of any particular product or manufacturer.

Figure 12. Vertical profile of various consolidated materials.



Materials not drawn to scale. Actual material sizes will vary. Material images represent examples of different reef material options and are not an endorsement of any particular manufacturer.

Figure 13. Example of organized dispersion of designed reef structures within a 10m x 10m grid using a 1:2 ratio of new materials to existing bottom.

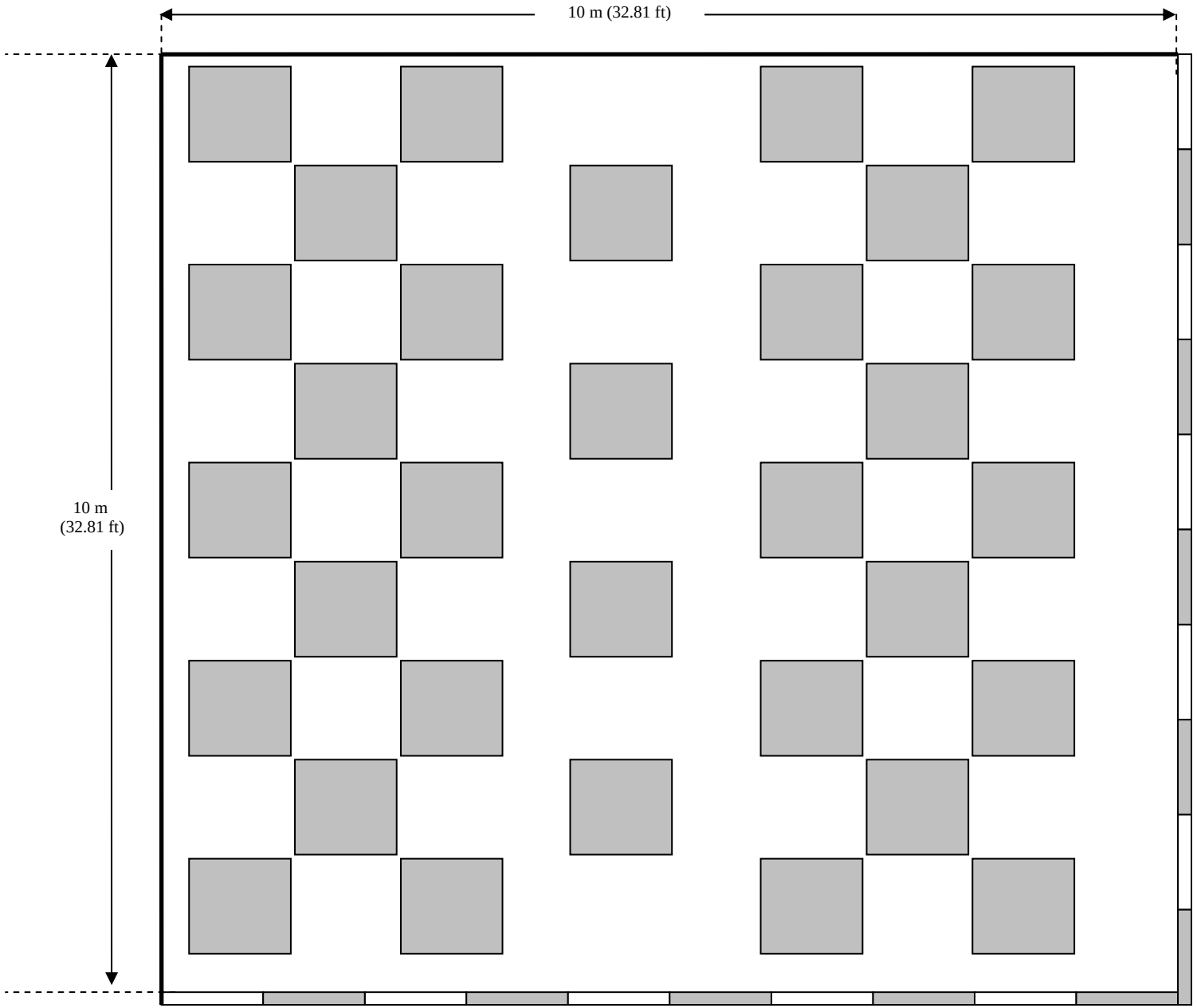


Figure 14. Example of random dispersion of designed reef structures within a 10m x 10m grid using a 1:2 ratio of new materials to existing bottom.

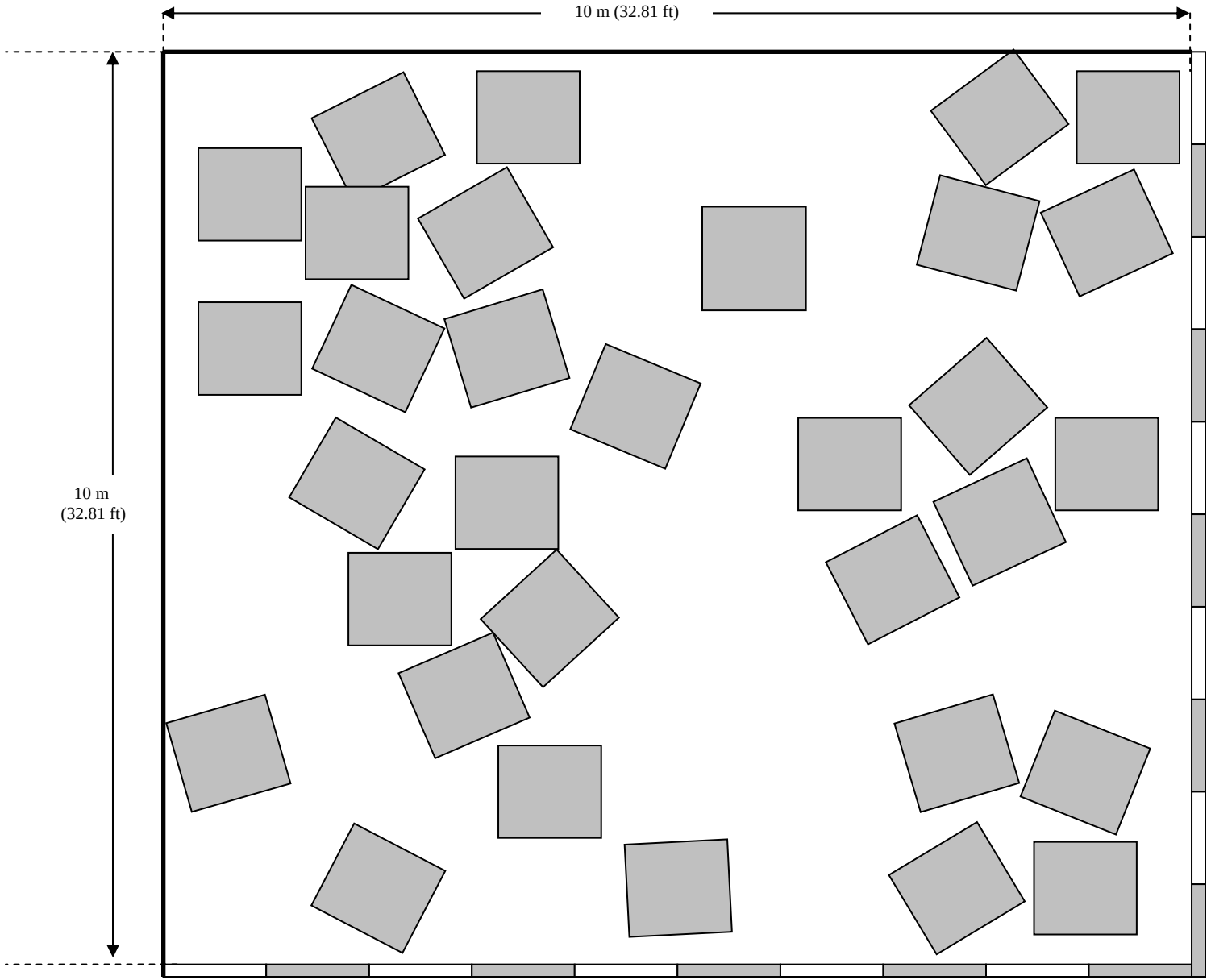


Figure 15. Example of organized dispersion of consolidated materials within a 10m x 10m grid using a 1:2 ratio of new materials to existing bottom.

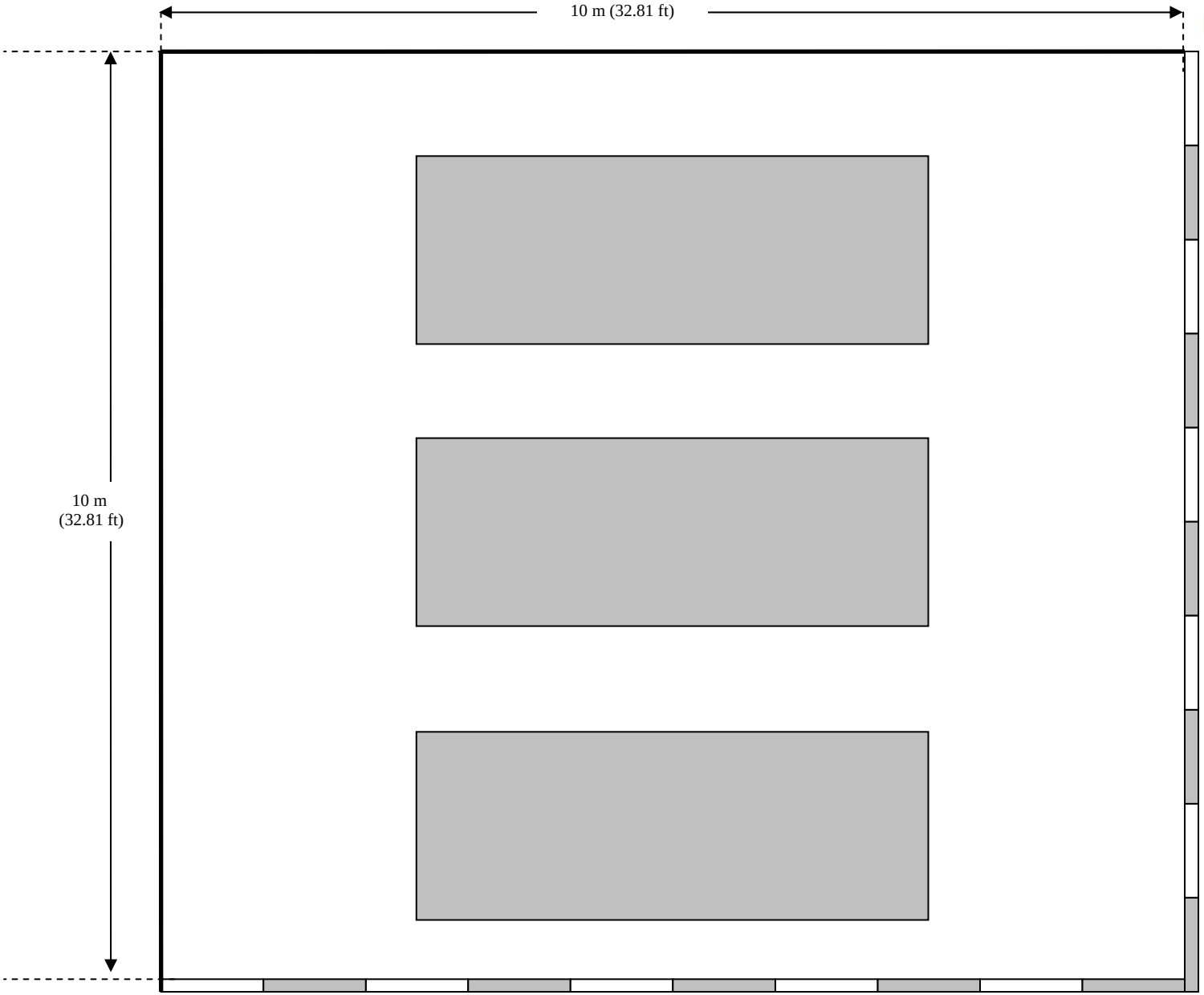


Figure 16. Example of random dispersion of consolidated materials within a 10m x 10m grid using a 1:2 ratio of new materials to existing bottom.