

BUILDOUT ANALYSIS

A Study of Nantucket with Climate Change
Considerations

A thesis submitted by

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in partial fulfillment of the requirements for the degree of

Joint Master of Science

in

Urban Environmental Planning & Policy and Civil & Environmental Engineering

Tufts University

May 2022

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ABSTRACT

This study analyzes local zoning rules and regulations to establish a possible maximum buildout for the island of Nantucket, including additional dwelling units and subdividable lots. With those numbers at the forefront, the study takes them a bit further in analyzing their significance and connection to climate change impacts and makes suggestions for how a small island community can plan for them.

ACKNOWLEDGMENTS

I want to thank my thesis advisor for her continual support, guidance, and review of this thesis. I also want to thank my thesis reader for providing feedback and guidance in the process as well. Of course, this thesis would not have been possible without the partnered assistance from Weston & Sampson and the Nantucket town officials. I appreciate all the support and guidance that has resulted in a finished product and hopeful contribution to the planning and engineering professions.

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GLOSSARY OF TERMS

Attribute - Nonspatial information about a geographic feature in a GIS, usually stored in a table and linked to the feature by a unique identifier.

Comprehensive/Master Plan - a document designed to guide the future actions of a community. It presents a vision for the future, with long-range goals and objectives for all activities that affect the local government.

Coupled Model Intercomparison Project (CMIP) - The objective of the project is to better understand past, present, and future climate changes arising from natural, unforced variability or in response to changes in radiative forcing in a multi-model context.

Dwelling Unit - A room or enclosed floor space used, or to be used, as a habitable unit for one family or household, with facilities for sleeping, cooking and sanitation.

Erosion - is a natural process that occurs through the actions of wind, waves, currents and drainage. It results in the loss of coastal sediment in some places and accretion elsewhere.

Green Infrastructure - the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspire stormwater and reduce flows to sewer systems or to surface waters.

Ground Cover Ratio - The ground cover upon a lot divided by the area of the lot, expressed as a percentage.

Parcel/Lot - A tract of land in common ownership, including land under water, not divided by a street, which may include multiple parcels of adjacent land in common ownership to the extent necessary to eliminate or minimize zoning nonconformities.

EXECUTIVE SUMMARY

Below is a bulleted list of the recommendations made in the discussion of this thesis. Its purpose is to provide an overall summary in a succinct format. The important overarching takeaways from this thesis is to plan ahead far in advance, update rules and regulations to accommodate changing trends, access available state and federal funding, and to conduct aquifer/groundwater studies that are specific to Nantucket and incorporate all environmental factors.

- Continue using the Conservation Committee as a mechanism to reduce future development.
- Based on the potential additional dwelling unit numbers reported in the maximum buildout, clearly define an allowable dwelling unit count for a lot specific to each district based on the minimum lot size.
- Continue to develop affordable housing options to offset the restrictions on ADUs.
- Restrict development in high-risk coastal areas and require resilient development strategies for properties near a high-risk coastal area in the zoning code.
- Identify and alert properties in the high-risk coastal areas of relocation opportunities and/or take measures as a Town to protect or adapt areas where there is a large cluster of high-risk development, like the downtown area.
- Require all new development to install I/As and access funding to assist existing residents to switch to I/As from conventional while the Town continues to expand its sewer network.
- Update sewer master plan to reflect buildout analysis potential additional dwelling units within the sewer service areas.
- Restrict development in areas where future high groundwater tables occur and where septic systems exist or could be built.
- Hire a consultant or have conversations with the EPA or MassDEP to conduct a study on the ability of the aquifer to provide for the island as a whole, not just from a single public well site.

1.0 INTRODUCTION

This report is a buildout analysis for the island of Nantucket. Nantucket is located off the coast of Massachusetts southeast of the arm of the Cape (see Figure 1.0.1).

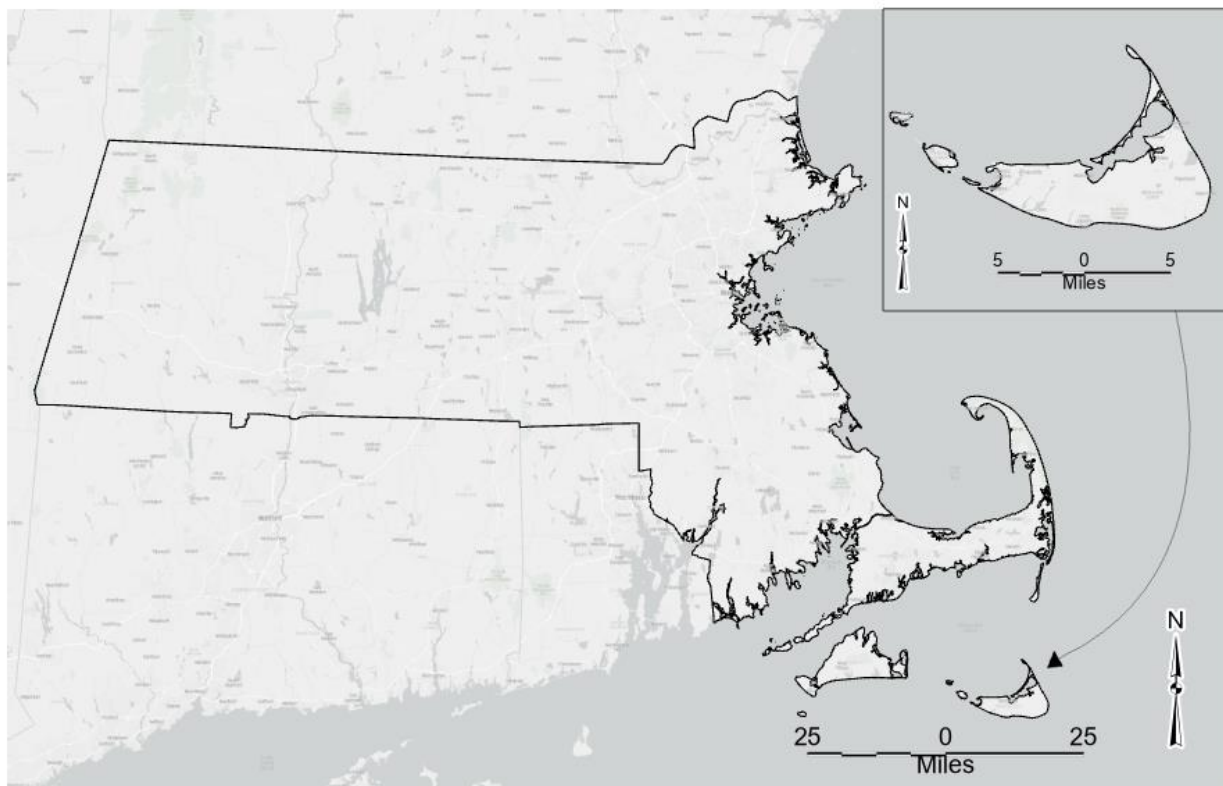


Figure 1.0.1 – Map of Study Area

It is home to about 14,255 year-round residents and a fluctuating 65,000 seasonal tourists and residents (“FAQs • Nantucket, MA • CivicEngage” 2020). Since 2010, the population has grown by 40%. Nantucket is a tourist driven Town where more and more people are interested in building homes to rent out as vacation rentals or for families to come and visit. A buildout analysis is a process in which the town zoning rules and regulations are deployed in addition to environmental constraints to establish how much more a town could be developed. The Town of Nantucket Planning Department is looking for a maximum buildout for both residential and commercial properties. The Town has observed a trend where property owners seeking

supplementary incomes subdivide their lots or add second (or third) dwellings on their existing lots for their family, short-term rentals, or vacation homes. The Town is concerned about increased density and community character, the ability of the Town to provide facilities and services, and the sustainability implications that this growth will have on the island in the future (Barr et al. 2018).

This analysis will include considerations in regard to water resources, sewer/septic, sea level rise, and erosion. To understand the lots available for buildout, the following tasks will be completed:

1. Analyze the parcels in ArcGIS and remove the lots that are currently protected from development by state and local regulations. This analysis will provide a maximum buildout number per minimum lot size and other zoning regulations.
2. Analyze potential impacts of sea level rise due to climate change and erosion. This will include a review of historical erosion data and potential impacts of erosion from projected climate change impacts.
3. Compute how many new parcels will be in need of septic systems and how many dwelling units can be built on each lot in accordance with existing regulations. Some parcels will be excluded from this analysis, as they are serviced or will be serviced by proposed sewer lines.
4. Perform a water resources analysis to determine how much water is required for the current population, how much can be pumped from the aquifer according to existing state withdrawal permits, and how these numbers may be impacted by climate change qualitatively under the IPCC's most aggressive climate predictions for 2100.

Therefore, my research questions are:

1. What is the maximum buildout scenario?
2. What are the associated water and wastewater requirements?
3. How may climate change and SLR impact questions 1 and 2?

I will complete the buildout analysis with a combination of spatial analyses in GIS and Excel spreadsheet work. GIS data layers will be obtained from MassGIS, National Oceanic and Atmospheric Administration (NOAA), and the Town of Nantucket's GIS department. I will also have meetings with Nantucket's Director of Planning to scope out the project and ensure that they are receiving a product that is useful to them. The town plans to use this analysis to inform future planning policies that may or may not restrict growth on the island. This is an appropriate application of a buildout analysis; as Balsas points out, "When conducted early, buildouts can facilitate political leaders to champion changes in land-use regulations and help to save land for its use value instead of only for its exchange value" (Balsas 2021, p. 17). This study could have the potential to inform future planning and policy changes that could change the way in which Nantucket develops.

This buildout study can further be used to inform a comprehensive plan for the Town which may influence a prioritization of infrastructure development as the Town continues to grow with sustainability and climate change in mind. Although the buildout analysis regarding their current zoning rules and regulations in GIS will be pertinent to their specific town, the climate change considerations can be applied to other islands and towns impacted by the same phenomena. In order to conduct the buildout analysis, the following outline will inform the comprehensive research and report.

This thesis starts by exploring other buildout analyses and climate change considerations and analyses through a literature review. It then dives into the buildout analysis for the island of Nantucket by first establishing the parcels that are not further developable. It then takes the remaining parcels and calculates the potential additional parcels and estimates when approximately Nantucket will reach this buildout. With these numbers, the following chapters explain how different considerations should be taken into account for the island regarding climate change. These include sea level rise, septic and sewer, and water resources considerations. The chapters explore how the buildout analysis should inform future decisions in these areas and why it is important to plan for climate change regarding these considerations. The thesis wraps up with a recommendations chapter on how the island of Nantucket should move forward in planning with this information. The purpose of this report is to provide relevant technical data and information on developmental growth and climate change that will strategically inform the planning decisions made by the stakeholders of Nantucket to ensure sustainable development.

2.0 LITERATURE REVIEW

A literature review is an analysis of a subset of literature to inform background knowledge of the topics to be discussed and analyzed in this thesis. This literature review will include analyzing examples of other buildout analyses and their methods in approaching the analysis. The search also included the different components of the buildout analysis' climate change impact considerations. The major climate change impacts that may affect the island include the coupled effects of coastal erosion and sea level rise. To further inform my background research and methodology, the literature review explores sources that give a little background on how these impacts may affect water use and the septic and sewer systems on the island. Reputable sources such as practitioner reports, peer-reviewed articles, government documents, and scholarly articles were extracted from the search results to inform this literature review. This segmented search yielded more comprehensive resources to inform the research and methodology for the Buildout Analysis of Nantucket.

2.1 Buildout Analysis

A buildout analysis generally looks at a town and determines from its zoning rules and regulations, how much more it can be developed both commercially and residentially. Developmental problems in urban planning have become very complex, making a “buildout analysis a critical land-use and environmental planning methodology” (Balsas 2021, p. 2). Balsas (2021) further states that GIS is a sophisticated tool that if used accurately by the correct expertise can provide statistically relevant findings. He argues that oftentimes, professionals with a background in geographical sciences will know how to use GIS properly for a buildout analysis, but stresses how important it is for planners to understand how to employ the technology as well. The paper then goes on to discuss the analytical approach to a buildout analysis using GIS. Critical

considerations in a more sustainable land-use planning initiative include preserving the natural resources including agricultural land, wetlands, marshes, and landscapes while holding true to ecological and cultural values. Son provides some insight on specific GIS tools that can be used to incorporate environmental considerations (Son 2009).

In short, Balsas describes a buildout analysis to include “mapping the location of all developable land in a jurisdiction using GIS and calculating the number of housing units, commercial and industrial acreage, and the demographic changes that could result if all buildable land was developed”. He goes on to explain three different methodologies in which to approach this buildout analysis, and those include the parcel buildout, the land-use buildout, and the site design-level buildout. The parcel buildout estimates how many units can fit on each parcel individually. The land-use buildout is resorted to when parcel data is not readily available and consists of displaying the distribution of different types of densities in large zoning districts. The site design level buildout is to draw out potential site designs for every vacant parcel and then add up the units. In this analysis, “the buildable land minus the percentage taken out for roads is then divided by the minimum lot size in order to estimate the number of units”. Through examining some example buildout analyses from Amherst and Georgetown, MA, Balsas realizes that even though a buildout analysis is relatively straightforward there are some assumptions that need to be made in regard to wetlands, residential, commercial and industrial water-use consumption, and solid waste generation, among others that will alter the outcome of the analysis.

These example efforts also presented two different analyses for each, one was conducted by the state for both towns and the other was conducted by a private consultant for Amherst and five graduate students from UMass Amherst for Georgetown. In both cases, the developable land found by the private consultant and the UMass Amherst students was less than the developable

land found by the state agency. Balsas attributes this to the private consultants and students taking time to confer with the Town's stakeholders through group meetings and presentations. These examples demonstrate how important it is to engage with community stakeholders to confirm data findings and fill in the gaps where the data is lacking. The need to engage with stakeholders early and often in planning processes is a generally considered best practice (e.g. Stocker et al. 2020). Balsas further acknowledges and concludes that a future challenge and concern of buildout analyses is accounting for climate change.

Undergraduate students at UMass Amherst recently conducted a buildout study of Nantucket in 2018 following the methods of the parcel buildout as described by Balsas (Barr et al. 2018). They obtained parcel and district data in a GIS format. They divided the residential dwellings into their respective districts and identified parcels that had one or more dwellings in the residential zones. They then identified parcels under three criteria: undeveloped, large enough to be subdividable, or had one dwelling but a second dwelling was eligible. However, their GIS analysis did not incorporate wetlands or conservation restrictions. Instead, they went through with the Town GIS and assessor, on a parcel by parcel basis to determine if a parcel could be developed or not under environmental protection considerations. This leaves a lot of room for error as it is unlikely they were able to cover every parcel in their meetings. Some parcels may have also been written off when part of it could have been developable if the wetland only partially covered it. The assumptions of what constituted a buildable parcel under these environmental protection considerations are unclear.

From these steps, the maximum buildout of residential units was determined. They also took the analysis a step further and projected likely high and low growth scenarios based on building permit data and population growth trends after conferring with Town officials to make

the most accurate assumptions specific to Nantucket. The report briefly explains how the buildout analysis may be applied to point to areas of development that sewer services may be needed. However, they do not consider how climate change may impact their buildout analysis and how an influx of development may strain the systems on the island.

Frenchman Bay Conservancy (FBE) conducted a buildout study for Ellsworth, Maine in 2020 and their methods followed much of the same for the UMass Amherst Nantucket study. FBE did incorporate a 250 ft setback on Rated Wetlands, Floodplains, Steep Slopes, Hydric Soils, Erodible Areas, Significant Natural Areas and a 75 ft setback on watercourses as defined by the Town's City Development Ordinances. In addition to this, their analysis also included a numeric and spatial buildout where they estimated the number of possible buildings by mapping them out while considering the size of projected buildings, geometry of lots, and setbacks to various spatial features. They assumed a minimum building footprint of 35'x35' and also accounted for minimum lot sizes according to the zoning district. The study also conducted a 'Time Scope Analysis' which is much like the study done by UMass Amherst for Nantucket. It provides an analysis of the potential development based on population projections. In order for FBE to complete both the spatial buildout and time scope analysis, they utilized a GIS based software called CommunityViz. For these analyses, assumptions were made that may alter the outcome of the models if others were able to justify different assumptions. It is also important to note that the time scope analysis does not account for future zoning or design changes.

Rozum, Arnold, and Wilson also offers three different methods to a buildout analysis in their report, *About Buildouts* written in 2007. The first method is a simple mathematical method based on using Excel. The first step is to figure out how many dwelling units are possible under current zoning regulations. This is done by taking the area in each district of the town, multiplying

it by the density (or dividing by the minimum lot sizes), multiplying by the allowable dwelling units, and then by an efficiency factor that accounts for land constraints, infrastructure such as roads, and lot layout inefficiencies. This is the maximum number of dwellings, to find the new dwellings possible, you just subtract the existing dwellings from this number. This is a very simplistic way of thinking about a buildout analysis that does not account for any environmental constraints. The second method utilizes GIS and first identifies the land that is developable in which it does not include lands already developed, permanently committed open space, and lands that have environmental constraints. The zoning layer is then overlaid on the developable land to determine their buildout densities according to their residential districts. Then a calculation as described in the first method is performed to calculate the number of dwelling units. This method is a more efficient way of calculating a buildout as it allows for recognition of environmental constraints and some spatial recognition of their distribution among the properties.

In the report, Applied Geographics, by Herr in 2002, they used much of the same steps as the second method written by Rozum et al. They followed the GIS steps to establish developable land but then performed a “random dot placement routine” to identify the potential dwellings. They found that once they did this, they got a different response from the town’s people from showing them the buildable lot parcels to the dots identifying the dwellings. The town’s people pushed back once they realized how close these other dwellings could be to their house. Although this method makes the buildout more realistic and presentable to the town, it is not very helpful. The model did not account for some realities including the existing landscape in addition to some structures like pools.

The third method written by Rozum et al. 2009 is the most detailed and follows along the same steps as the methods used by FBE, where it utilized GIS and CommunityViz to perform the

buildout. This method identifies if subdividing the parcels is spatially possible following zoning setbacks. It spatially designs the buildout as opposed to computing numbers without a layout context. This third method is the most detailed and efficient method if one has the correct training and access to the tools to do so. Access to CommunityViz and working knowledge of how to use it made these more detailed studies possible. With the time and fiscal constraints of this study, obtaining access to CommunityViz and learning how to employ it, is not realistic even though it would be ideal in providing a more in-depth analysis. Given the opportunity, learning how to employ CommunityViz may be a useful tool in performing future buildout analyses.

On the contrary to these traditional methods of basing a buildout analysis on existing zoning rules and regulations for vacant land, the Metropolitan Area Planning Council (MAPC) made a series of its own assumptions that included redeveloping existing properties to their full potential in Waltham, MA (McCarthy 2006). This study was conducted in 2006 and was an addition to their study in 2000. The first study followed the traditional methods as stated by Balsas, FBE, and UMass Amherst. The 2000 study initially focused on identifying opportunities for new development on vacant lands, while the 2006 study focused on identifying future development on already developed or underdeveloped land. However, much like the previously mentioned studies (i.e. Balsas, FBE and UMass Amherst), they did conduct this study at the parcel level. Some of the assumptions made in this analysis included converting existing residential and commercial properties into mixed use where zoning allowed, residential properties were converted to commercial where more than 5,000 square feet of commercial space was allowed, and many more that involved converting or changing existing development completely. Even though these assumptions and changes were allowed by zoning, most of them were unlikely to happen due to human factors and resistance. It is not realistic to envision tearing down huge swaths of existing

structures to replace them with new, more densely developed ones. This complete rezoning method may not be an ideal method for all towns. Instead, one should select parcels that are underdeveloped and review them with Town officials to determine if they can be further developed under current zoning regulations. As the report from Balsas 2021 demonstrated, communication with the town is the most important asset to drive realistic decision making that may actually be reflected in actions taken by the town.

Sea Level Rise & Coastal Erosion Considerations

Sea level rise is an impending issue resulting from climate change and different sources report different projections on how much they anticipate sea levels to rise. A study conducted by Milone & MacBroom Inc found that sea levels are projected to rise up to ten feet by the year 2100 as found by the Northeast Climate Adaptation Science Center of the University of Massachusetts, Amherst in their most aggressive climate change scenario (Milone & MacBroom Inc 2020). Another report published on NOAA's website reported a sea level rise of 8.2 feet by the year 2100 (Lindsey 2020). These reports got their information from the Intergovernmental Panel on Climate Change (IPCC) who based their projections off of a model developed by the World Climate Research Programme (WCRP) (World Climate Research Programme 2021). The model is in constant development and repairs as new climate change data becomes available that can better inform the projections. The previously stated projections are based off of an old model, the 5th phase. The newest model is phase 6 (CMIP6) and predicts a sea level rise of 1.3 meters or about 4 feet and 3 inches in the most aggressive climate change scenario for the year 2100. Any further considerations should be based on this newer model and its subsequent data to inform future recommendations. This timescale is generally outside the scope of municipal planning, but the effects need to be considered when it comes to long term infrastructure investments, resilience

planning, and climate change adaptation and mitigation measures. These implications will further be discussed in chapter 4.3.

As a result of sea level rise, Milone & MacBroom Inc also found the average long term erosion rate for Nantucket's south shore to be about 2.1 ± 0.5 meters per year. The Massachusetts agency of Coastal Zone Management (CZM) accomplished this analysis by intersecting up to eight historical shorelines from orthophotographs and Lidar. These calculated rates are available through interactive maps and downloadable files for use in GIS. Snoussi et al. 2011 did something similar in their report outlining how to use GIS to assess shoreline evolution. They also introduce a rate of shoreline recession equation to estimate future shoreline recession due to sea level rise. This model has been widely accepted and used by others (Snoussi et al. 2011).

Snoussi et al. 2011 also describes how to account for the land at risk of coastal flooding from sea level rise. They used a formula to calculate the design water level utilizing sea level rise, the mean high-water line, wave height, and the sea level rise due to a lowering of the barometric pressure. They then used digital elevation models (DEMs) in combination with this determined height to evaluate the land area that would be inundated. FEMA utilizes base flood elevations (BFEs) to depict what land will be inundated by the 1 percent annual chance flood. For coastal areas, BFEs also account for wave height. Figure 2.1.1 shows how BFEs and FEMA flood zones work. To account for sea level rise, one could use the FEMA flood maps for the BFE and add a projected sea level rise to it following the model used by Snoussi et al. 2011. This would use an established system that is highly regarded but also account for future uncertainties in regard to sea level rise.

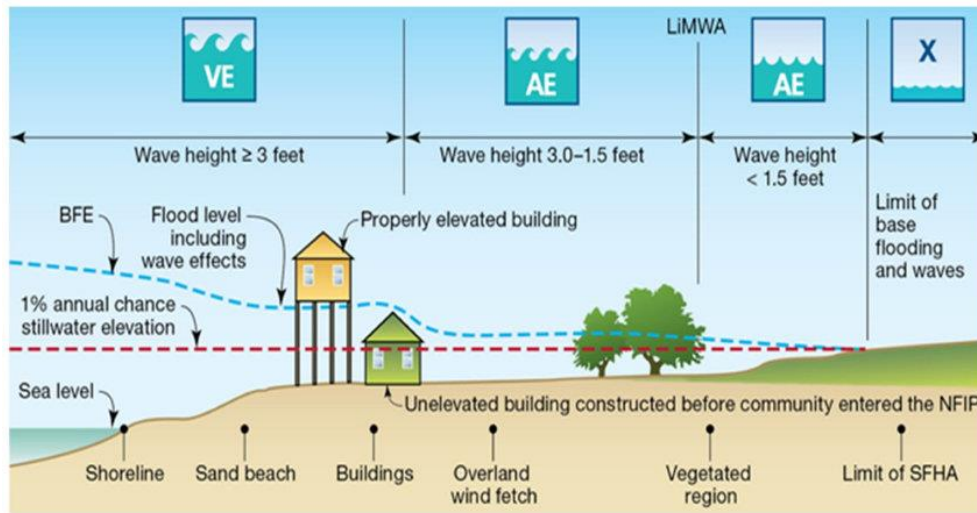


Figure 2.1.1 - BFEs and FEMA Flood Elevation Depiction (Spaulding et al., 2020)

As sea levels rise, water tables will rise with it. If water tables rise, it reduces the depth of soil that septic systems can leach into before reaching the water table (Hozid 2017). This will further reduce the amount of time allowed for filtration, allowing more bacteria and diseases from the wastewater to seep into the drinking water supply. Installing municipal wastewater treatment facilities and infrastructure can also reduce nitrogen loading as it treats effluent in a facility before releasing it back into the environment (Walton 2020). Although, installing municipal wastewater systems can take a lot of time and the I/A systems can be installed faster and fill in for the municipal wastewater systems in the meantime. These considerations will be further discussed in a comparison of septic systems versus town sewer specific to Nantucket.

Septic & Sewer Considerations

There is not room for any interpretation or variability in a septic analysis as the state of Massachusetts has prescribed regulations that have to be met when installing septic systems (State of Massachusetts 2016). There are procedures that determine the design of a septic system and include siting tests like a soil profile, percolation test, observation hole test, and analyzing the hydrogeologic properties of the soil. These tests will help determine what kind of system is most

appropriate for the area. There are many different types of septic systems that are based on different factors including household size, soil type, site slope, lot size, proximity to sensitive water bodies, weather conditions, or even local regulations (US EPA 2018).

For Nantucket, the proximity to sensitive water bodies is going to govern the design and choice between a septic and sewer system as coastal communities must consider their nitrogen loading in their septic systems. Excess nitrogen in water bodies causes nutrient enrichment that encourages algae growths. These algae growths can absorb important nutrients and block sunlight from the organisms below, inhibiting their ability to thrive. This nitrogen can even reach and contaminate the drinking water supply. Typical Title V systems do not efficiently treat nitrogen removal and thus, an alternative has been developed. New technologies called I/A septic systems are more efficient at treating and removing nitrogen from the effluent and releasing it back into the atmosphere instead of into the groundwater through the leach field (Walton 2020). More on the benefits and challenges of I/A systems and sewer systems will be discussed in chapter 4.4.

Many residents of Nantucket have already installed the I/A systems (Weston & Sampson 2020). Weston & Sampson has also worked with the Town to develop a comprehensive Sewer Master Plan to establish where the Town should be focusing their efforts. As a part of this plan, they identified service areas and calculated how much flow the system could accommodate from each property. The study calculated average daily flows at two thirds of the Title V maximum daily flow rate. They also calculated the flows based on a per capita water use basis. They found the per capita water use basis to govern the study as it determined higher future flows. Weston & Sampson found that their flow results were higher than a previous study done in 2014. This is due to the fact that they accounted for the future potential of properties being further built out or additional properties being added to parcels through subdivision. The study resulted in a plan to

meet the current and future needs of sewer processing in identified areas on the island through a proposed sewer design. The study did not analyze the entire island, it instead focused on areas that the Town identified as needs areas identified in the 2014 CWMP, planned development and redevelopment within the existing Town Sewer District, areas of interest outside of the existing Town Sewer District, and allowance for additional building construction based on current zoning regulations (Weston & Sampson 2020). Weston & Sampson was conservative in the areas that they did analyze in utilizing the higher flows resulting from a per capita water use analysis. This per capita water use analysis in the sewer buildout will be used to further inform the water use considerations section. It is important to be conservative for Nantucket as their systems are more susceptible to climate change impacts (Nurse et al. 2014). Islands are extremely susceptible to climate change impacts, especially sea level rise, because of their low-lying elevations and largely coastal characteristics.

Water Use Considerations

Another system that is susceptible to climate change impacts is the aquifer that feeds the island's water use. It will be important to analyze the current water use and predict if this will be sufficient to supply water to the increase in residents from the projected buildout without overdrawing the aquifer. A study conducted in Barneget Bay, New Jersey provides some insight on how they accounted for water use after their buildout was complete (Conway and Lathrop 2004). They estimated the amount of people living in the potential buildout and multiplied it by the average per capita water use. They then compared this to the available supply as determined by the New Jersey Statewide water supply plan. This plan assesses future water needs and makes a few conservative assumptions including: each person uses 125 gallons of water per day (based on current day (2015) uses); no changes to water supply infrastructure or additional permitted

allocations (new or expanded sources of supply); all projected population growth is served by a public water system (i.e. private potable wells were not considered for future growth); and, since a deficit/surplus analysis was not conducted for many small water systems, a surplus of zero was assumed for these system (Christie and Guadagno 2017). Tighe & Bond uses a more in-depth analysis approach as their data access requires the issued water bills. They go on to analyze annual long-term consumption trends, seasonal variation, usage by customer class, residential use by subclass, how single-family customers use water, the relative impact on peak demand caused by top users, and the relative contribution of the top users on seasonal revenue.

The analysis done by New Jersey gave them an idea of how much more water they would need to serve the future population. This plan then discusses how some areas of New Jersey will be underserved by their current regulated withdrawal rates and some will be overserved. It allows them to reassess how their public water should be distributed. The report recognizes that climate change will bring more frequent extreme weather events including droughts and those need to be prepared for through municipal action. These actions include monitoring for drought and then issuing emergency orders to reduce water consumption. A report of this detail is not available for Nantucket. Strategies that can be used to get around the missing data, or what can be recommended to make sure that people's lives or properties are not endangered in the event of insufficient water will be discussed further in chapter 4.5.

In addition to restricting water use, Moore et al. 2016 offers that Green Infrastructure and underground water storage can help mitigate the impacts of extreme weather events and provide protection against flooding. Cisneros et al. 2014 further states that an adaptive integrative water resource management plan can help plan for the future uncertainties of climate change on the water supply. The report provides an extensive list of mitigation strategies to assist with the water supply

uncertainties that the future holds. Some of these strategies include rainwater harvesting, conservation tillage, maintaining vegetation cover, planting trees in steeply sloping fields, mini terracing for soil and moisture conservation, improved pasture management, water reuse, desalination, and more efficient soil and irrigation water management. These are all strategies that involve preserving the natural landscape and reducing impervious surfaces to allow water to percolate into the water table. This thesis will suggest mitigation and adaptation strategies to reduce water consumption and support aquifer recharge to encourage a healthy and sustainable water cycle under climate change stressors.

2.2 Conclusions

It is important to draw from the recommendations and methods of others to utilize the best knowledge of how to conduct this buildout analysis and the subsequent analyses to follow. The buildout analysis will closely follow the examples described in the second method of Rozum et al. 2007 and Balsas 2021. The other methods are either too simplistic or they utilize a proprietary software, CommunityViz. It is useful to utilize non-proprietary software for this analysis because many municipalities will not have access to these specific tools, or the technical training on how to properly implement them. Following the other examples, this project will remain in contact with the Town to confirm properties and data presented in the GIS data layers. It will be important to identify which properties are or are going to be served by public sewer as those without a connection to the public sewer systems will be more susceptible to climate change impacts and endangering the water quality. It will also be important to utilize a simplistic method of estimating the water use increase with this projected buildout to provide an idea of how close to current withdrawal limits the Town will be so that they may prepare for future conservation efforts. Sea level rise and coastal erosion only exacerbates and further threatens the water and sewer

infrastructure. It will be important to model which areas will be inundated by a projected sea level rise to see which areas should require attention in these future conservation efforts first. Paying attention to the processes that are most at risk from the effects of climate change will help Nantucket prioritize and plan for mitigation strategies.

3.0 METHODOLOGY

3.1 Nantucket Buildout Research

Step 0. Literature Review and Research

Steps 2 and 3 below required a literature review of Nantucket’s zoning bylaws as well as their rules and regulations. These documents are readily available on their Town website¹. This review also included reviewing other buildout analyses to gain an understanding of how they are typically done.

Step 4 below required a literature review of how erosion due to sea level rise, septic/sewer considerations, and water resource use may impact a buildout analysis due to climate change. Climate change projections were taken from the International Panel on Climate Change (IPCC), who employs and synthesizes climate data developed by a model created by the World Climate Research Programme (WCRP) (World Climate Research Programme 2021). This model is ever evolving; currently in its 6th phase, the model is still and may never be comprehensive. Meanwhile, climate change projections are notoriously unpredictable and change as more research is conducted throughout the years. This can be seen in the drastic change of sea level rise predictions from the 5th phase of the model to the 6th phase (Iturbide et al. 2021). This will require me to research how others have dealt with data uncertainties in regard to climate change projections for buildout analyses.

¹ <https://www.nantucket-ma.gov/445/Town-of-Nantucket-Bylaws>

Step 1. Meetings

Any unanswered questions from the literature review for steps 2 and 3 were supplemented by meetings with the Nantucket Director of Planning. These meetings occurred during and after each of the three steps in the buildout study outlined below. They were used to review the completed progress and provide guidance on the next steps and clarify the rules and regulations of the Town. Because of the meetings with the Town, this study was required to obtain a Non Human Subjects Research Determination from the Tufts University Internal Review Board (IRB). That request was approved on November 2, 2021. The following meetings with the Director of Planning subsequently occurred:

- November 10, 2021 - Discussed the results from step 2 and confirmed the buildable lots in the Town-owned land and the non-buildable lots as protected by various conservation entities.
- January 19, 2022 - Discussed the additional results from step 2 and confirmed additional unbuildable lots. Defined allowable dwelling units per district for step 3 and reviewed potential further developable parcels.

3.2 Nantucket Buildout Study

Step 2. Identify Buildable Lot Areas

Determined buildable areas using parcel data and information about development constraints. Non-buildable areas were removed from each parcel in GIS so that only the buildable lot areas remained. Then, calculated buildable area on each parcel and summarized the total amount of buildable lots for each parcel. The following considerations will be made when determining if a lot is “buildable” or not. Non-buildable areas include:

- Permanently conserved land parcels (source: MassGIS and Town of Nantucket)
 - Include Nantucket-owned land as developable land and review undevelopable properties with the Director of Planning.
- Open Space layer
 - Review all open space and recreation parcels with the Director of Planning to confirm buildability.
- Development constraints, including streams, coastal buffers, hydric soils (although these may be developable), wetlands, and associated buffers. Buffers will be set according to these parameters:
 - Under the Massachusetts Wetlands Protection Act, no one may “remove, fill, dredge, or alter” any wetland, floodplain, bank, land under a water body, land within 100 feet of a wetland, or land within 200 feet of a perennial stream or river (25 feet of a few urban rivers), without a permit (known as an Order of Conditions) from the local conservation commission that protects the wetland “interests” identified in the Act (Massachusetts Association of Conservation Commissions n.d.).
 - Annual chance of flooding -
 - Under Nantucket Zoning Regulations 100 foot buffer around the 1% flood line and Coastal Storm Flow (Town of Nantucket 2021b).

A map by zoning district was produced to illustrate the spatial distribution of non-buildable and buildable areas. GIS data will also be exported into Excel spreadsheets for analyzing potential development numerically in Step 3.

GIS Steps

1. Compiled all the layers necessary for the analysis and clipped out just Nantucket data and exported the data to new layers made just for Nantucket to ensure faster processing in GIS.
2. Took the MassGIS Open Space layer and selected by attribute the parcels that were protected in perpetuity. Then, overlaid this with the Land Bank Town Land and Nantucket Owned Land layers to find parcels that are not currently protected under Nantucket's layers but are protected by Mass law. This analysis resulted in the "OPENSOURCE_NotProtected1" layer. Exported the table that resulted from this analysis as an excel.
3. Removed the ocean from the wetlands layer, put a 100 ft buffer around the WETLANDSDEP_POLY layer and chose 'Dissolve all output features into a single feature'.
4. Selected by attribute, the A and AE flood zones from FEMA_NFHL_POLY_Nantucket to create a layer for the 1% flood zones (FEMA_NFHL_POLY_Nantucket_1percent) and selected by attribute the VE flood zones to create a layer for the coastal flood zones (FEMA_NFHL_POLY_Nantucket_CoastalStor).
 - a. Put a 25 ft buffer around the 1% flood zones, a 100 ft buffer around the coastal flood zones and chose 'Dissolve all output features into a single feature' for both.

5. Selected, by attribute, the perennial and intermittent streams from the HYDRO25K_ARC_Nantucket to create a layer for just the rivers governed by the Wetlands Protection Act (Massachusetts Association of Conservation Commissions, n.d.).
 - a. Put a 200 ft buffer around this layer and chose ‘Dissolve all output features into a single feature’.

Step 3. Analyze Maximum Buildout

The following steps were completed to determine how many additional buildings and subdivisions are possible on each lot given its buildable area, minimum lot size, and zoning:

- Lots that are unlikely to add dwellings based on the constraints analysis in Step 2 will be confirmed with the Director of Planning and will not be counted in the assessment of buildable area.
- Comparison of existing lots vs potential lots (i.e. subdivision potential)
 - Base zoning districts will be identified and categorized based on their potential for subdivisions under current standards for minimum lot size and building setbacks. The minimum allowable lot size for each zoning district will be counted as a potential “future lot.” The evaluation will factor in rights-of-way by assuming that each lot will need an additional 15% of its minimum lot size for utility easements.
 - Based on the previous step and buildable area, determine if the lot can be subdivided further.
- Comparison of existing dwellings vs. potential dwellings on buildable parcel area (i.e., development and infill potential)

- Buildable areas without existing buildings will be evaluated against zoning categories for each parcel, to determine if additional buildings can be added to each site.
- Parcels with existing buildings will be reviewed with the Director of Planning to determine if they are underutilized and represent development potential. The analysis will result in a maximum buildout potential.
- Secondary dwellings and secondary lots will also be accounted for in this analysis.
- Other zoning overlay districts and their specific zoning regulations will be considered in the analysis and on a lot-by-lot basis.

Maps of potential buildout will be created where lots are identified as further developable or not.

Numerical buildout – By comparing buildable area to the minimum lot size requirements specified in the Zoning Bylaws, we will determine the total possible buildout for each parcel. This information will be summarized for each zoning district and at the town level in a GIS map and summary table.

Based on this, projected maximum buildout was estimated, after confirmation from the Director of Planning that the model parameters in Step 3 were acceptable in the January 19th meeting.

Step 4. Analyze Climate Change Impacts on Buildout

Some data and information were utilized from the Sewer Master Plan developed by Weston & Sampson to ensure that background information is consistent for the considerations and recommendations. The following steps were completed to determine, incorporate, and consider climate change impacts on sewer/septic, water resources, and sea level rise and erosion.

Coastal Erosion & Sea Level Rise Considerations

- Under the most aggressive climate change scenario as found by the IPCC in the 6th Assessment in regard to the greatest temperature changes and worst impacts, a sea level rise of 4ft was assumed for the analysis.
 - Chapter 2.0 sets the context for why this sea level rise scenario was chosen for analysis and how it relates to previous studies.
 - Four feet in elevation was added to the average BFE that FEMA currently shows in their coastal flooding layer.
 - Lots located within or partially within a 100 ft buffer around the 4-ft sea level rise areas were removed from the buildout.
 - A new map and buildout summary were produced following this change.
- These considerations also explore how detrimental erosion and sea level rise can be to coastal communities and how climate change may exacerbate this.
- Historical rates of erosion and historical coastline maps show qualitatively how much land Nantucket has lost over the years.
- Chapter 4.3 also includes a review of what Nantucket is currently doing to mitigate the impacts of coastal erosion and climate change.

Septic & Sewer Considerations

- Chapter 4.4 includes an overview of Title V and Wastewater Treatment Plant rules and regulations.

- A map was produced showing the properties that are currently served by Town sewer or are planned to be served by Town sewer in the near future as proposed by Weston & Sampson and approved by the Town. This map also highlights where potential additional parcels are that will need to be sewerred or a septic installed.
 - Those that can be easily connected to Town sewer will be on newly subdivided properties that were previously served by Town sewer before the buildout analysis.
- Chapter 4.4 also includes a qualitative comparison of septic systems versus Town sewer.
- These considerations also include qualitatively exploring how detrimental septic systems can be to coastal communities and how climate change may exacerbate this.

Water Resources Considerations

- Chapter 4.5 includes a short section on local and state policies for water use and resources.
- A map in this chapter provides a visual representation of which parcels are serviced by Town water, while showing the potential additional lots found in step 3 that could be connected to Town water or will need a private well installed.
 - Those that can be easily connected to Town water were on newly subdivided properties that were previously served by Town water before the buildout analysis.
- This includes considerations for the current per capita consumption of water during the peak tourist season. Peak season and off-season population and water use rates were utilized and pulled from the Weston & Sampson Sewer Master Plan. This was then compared to the projected population from the maximum buildout and the water rate needed to sustain it.

- State water permits for public wells provide a baseline for the current per capita consumption rate and permitted withdrawals.
- Qualitatively discuss the connections of saltwater intrusion and sea level rise on water supply.

Step 5. Recommendations

This section includes conclusions from the buildout analysis and further recommendations on how to approach planning uncertainties due to the climate change considerations. It required an additional literature review on what others have done in regard to the three considerations listed in step 4.

4.0 BUILDOUT ANALYSIS

4.1 Protected vs. Available Land

Nantucket Island is located off the coast of Massachusetts, see Figure 1.0.1, with an approximate land area of 45 square miles (U.S. Census Bureau 2021). In a buildout analysis, the first step is to determine which lands could be developable. This chapter first identifies the parcels of land that are not protected by development constraints associated with the environment, conservation and open space, and land owned by the Town. Each of these constraints are either communicated in Town or State rules and regulations or by Nantucket's Town Director of Planning. These parcels may have existing development on them, but those are explored in the following chapter to determine if they are further developable or not. At the basis of each analysis is the GIS Tax Parcel layer provided by the Town of Nantucket with updated parcel information as of 2021.

Environmental Constraints

The typical environmental development constraints include streams, coastal buffers, hydric soils (although these may be developable), wetlands, and associated buffers. The layers used in this part of the analysis can be seen in Table 4.1.1.

Table 4.1.1 - Environmental Constraint Layers

GIS Layer	Source	Year Developed/Updated	Buffer
Wetlands	MassGIS	2008	100 ft
Ponds or Lakes	MassGIS	2008	100 ft
FEMA 1% Flood	MassGIS	2017	100 ft
FEMA Coastal Storm	MassGIS	2017	100 ft
Perennial and Intermittent Stream	MassGIS	2008	200 ft

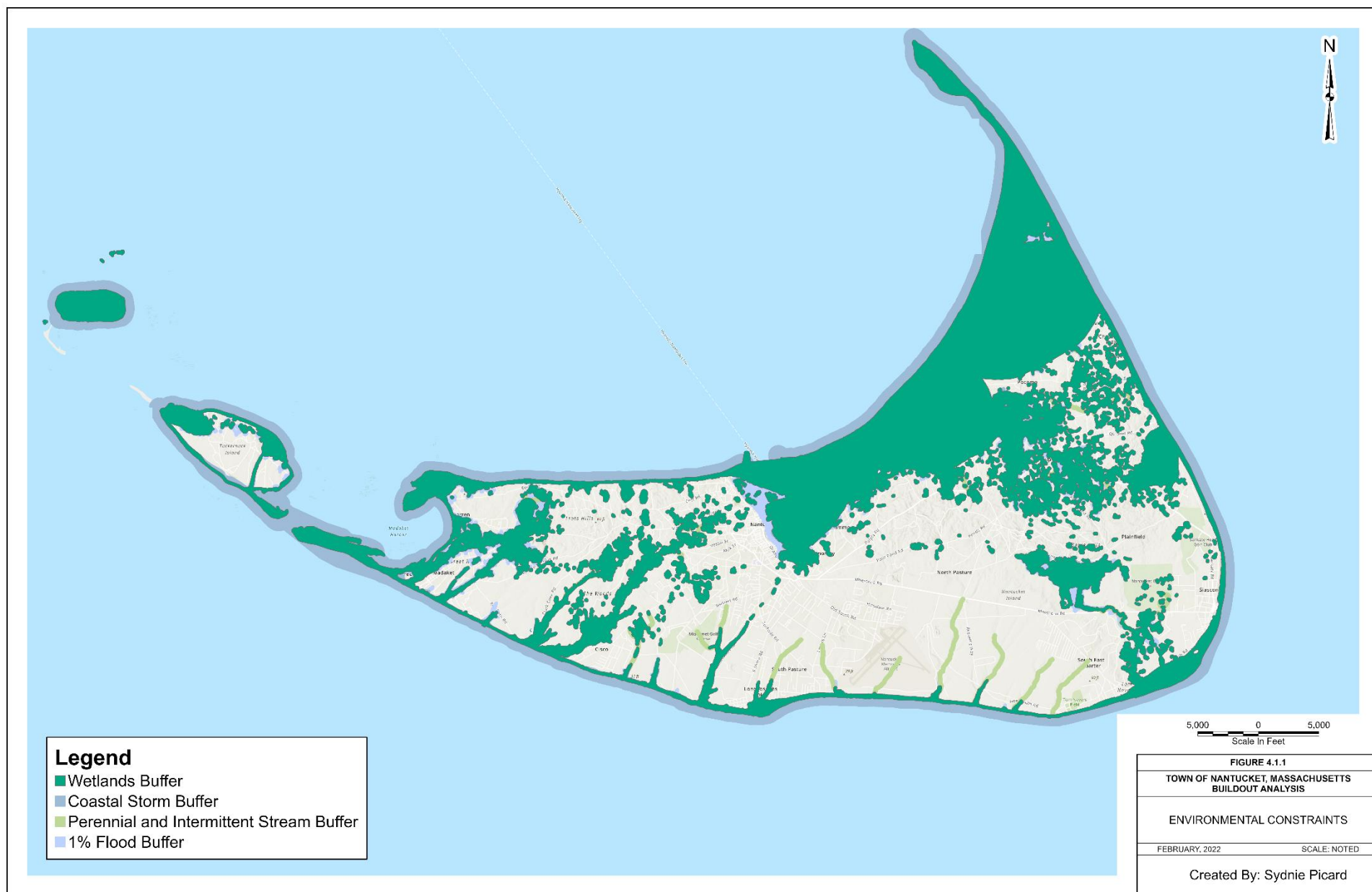
Each environmental constraint carried a buffer with it according to state and local regulations. State and local zoning regulations were sifted through to determine which regulations were more conservative. For example, if State regulations imposed a larger buffer around wetlands than local regulations, then the State regulations governed. These buffers can also be seen in Table 1. The hydric soils consideration was removed from the analysis because it was observed in GIS that their locations aligned with the wetlands. Therefore, the wetlands covered the hydric soils and removed the necessary areas in the analysis. After creating buffers for each of the environmental constraints and removing them from the Tax Parcel layer, it was found that 18.5 sq miles of the island is restricted by current regulated environmental constraints. A map of the environmental constraints can be seen on the following page in Figure 4.1.1.

Undevelopable Parcels

Aside from environmental constraints that do not have a prescribed shape and can stretch across multiple parcels, there are also specific parcels that cannot be developed for various reasons. This includes protected Open Space parcels, parcels set aside by the Town, and Town Conservation Commission parcels. Parcels set aside by the Town can include municipal offices and services or parcels they deem as developed and permits would not be issued for further development. The layers used for the undevelopable parcels can be seen in Table 4.1.2 below.

Table 4.1.2 - Undevelopable Parcel Layers

GIS Layer	Source	Year Developed/Updated
Open Space	MassGIS	2005
Land Bank Owned Land	Town of Nantucket	2020
Nantucket Owned Land	Town of Nantucket	2020



This analysis removed just the “Protected in Perpetuity” Open Space parcels as those are defined as legally protected and recorded as such in a deed or other official document. This may include lands that are “owned by the town’s conservation commission, by the water department; if a town has a conservation restriction on the property in perpetuity; if it is owned by one of the state’s conservation agencies (thereby covered by Article 97²); if it is owned by a non-profit land trust; or if the town received federal or state assistance for the purchase or improvement of the property” (MassGIS (Bureau of Geographic Information) 2021). Other parcels with the attributes “Limited” or “Temporary” are only restricted for a certain amount of time or for some specific purpose. These parcels can change over time and become unprotected, rendering them developable. These parcels were reviewed with the Town to determine if any of them should be left out of the maximum density buildout.

After reviewing the Open Space layer with the Town, some areas were ignored because the Open Space polygons did not match up with the parcel data polygons (see Figure 4.1.2). Since the Open Space layer is older than the parcel data, the parcel data and Town Director of Planning’s knowledge of the properties were favored over the Open Space data. In reviewing the Town owned parcels and Conservation Commission parcels, a list of parcels that were believed to be undevelopable (and their respective owners) was created prior to the meeting with the Town Director of Planning on November 10th, 2021 (Appendix 1-A). In addition to this list of owners, the meeting resulted in a marked-up map identifying additional properties that should be



Figure 4.1.2 – Open Space Parcel Inconsistencies

² <https://www.mass.gov/files/dcsarticle97.pdf>

removed from the analysis and deemed undevelopable (Appendix 1-B). For example, the light blue parcels lined up in the middle of Nantucket of Figure 4.1.2 are for the boys and girl scout camps. The Town intends to maintain these and not alter them or develop them further. This analysis resulted in 2,668 parcels deemed as undevelopable by the Town covering 30.8 square miles of the island (Table 4.1.3). Of those parcels, about 80% of the undevelopable parcels are due to conservation and land trust associations. The Town is already protecting about half of the land on the island through conservation and land trusts.

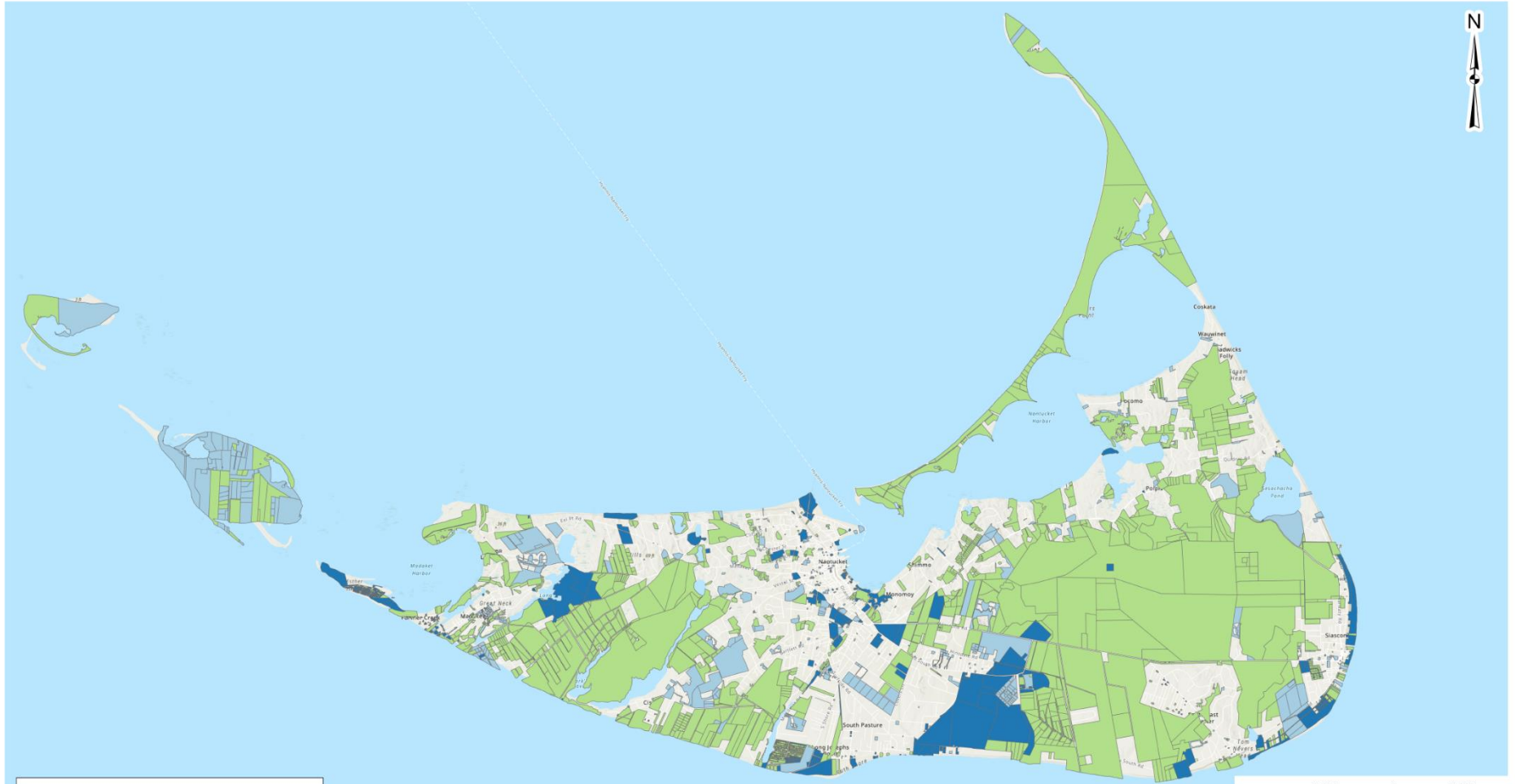
Table 4.1.3 - Undevelopable Parcel Count

Reason Protected	Parcels	Area (sq. mi.)	% of Island
Conservation & Land Trust	1,430	23.9	53.1%
Town Owned	662	3.03	6.7%
Various Restrictions	576	3.84	8.5%
Totals	2,688	30.8	68.4%

Some parcels are owned by the Town, in which they are not intended to be built upon further. These are not formally protected lands, but they are used for the municipal offices and services. Other parcels in light blue have various reasons for why they were excluded as undevelopable. Some have land trusts associated with them, a few of the parcels are owned by the U.S. Coast Guard, and others are restricted from further development, because they were deemed Open Space as required by Nantucket’s flex development zoning regulations, Article III § 139-8 A.

Under the environmental buffer regulations defined by Nantucket, only a permit is required for development within the buffer area, but it’s best not to develop in these environmentally sensitive areas either way. The purpose of a buffer around environmentally sensitive areas is to reduce the direct impact of human disturbance. Undisturbed vegetative buffers

provide habitat for wildlife and filter out contaminants within surface water runoff from the built parcel that would adversely impact the environment.



Legend

Reason Protected

- Conservation & Land Trust
- Town Owned
- Various Restrictions



FIGURE 4.1.3	
TOWN OF NANTUCKET, MASSACHUSETTS BUILDOUT ANALYSIS	
UNDEVELOPABLE PARCELS	
FEBRUARY, 2022	SCALE: NOTED
Created by: Sydnie Picard	

For future planning purposes and to maintain the sensitive natural resources of the island in the name of sustainability, these buffers were considered undevelopable. This action was accepted and approved by the Town Director of Planning. The same regulation, Wetlands chapter 136-3, requires a permit if any land is to be altered in a “habitat for rare/significant wildlife”. This land was excluded from the strictly undevelopable as these should be reviewed on a case-by-case basis by the planning board. The reasoning for this decision followed a GIS analysis using the Core Habitat layer from the Biomap 2 data set from MassGIS (Figure 4.1.4). It showed that an additional 4 square miles would be removed from the buildable area, rendering the Town with only 6 square miles to further develop. The Core Habitat layer defines areas that are “necessary to promote the long-term



Figure 4.1.4 – MassGIS Biomap 2

persistence of rare species, other Species of Conservation Concern, exemplary natural communities, and intact ecosystems” (Patrick et al. 2010). Furthermore, given the nature of animals, defined map boundaries for species are subjective, it is unlikely that a species is going to remain in one spot and not move about. After observing this map, it is important to note that most of the additional development will impact species of critical concern and their core habitat areas. This should be considered when issuing building permits and allowing future development. With both the environmental restrictions and undevelopable land as defined by conservation organizations and the Town, the total undevelopable land that will be removed from further analysis is approximately 35 square miles. This leaves about 10 square miles for additional development and the maximum density buildout in chapter 4.2.

4.2 Maximum Density Buildout

This analysis presents the maximum density buildout in additional subdividable lots and additional dwelling units as allowed by the current Town zoning rules and regulations.³ Before analyzing and calculating any additional lots or dwelling units, the existing lots and units had to be established through data management. This analysis was left with about 10 square miles available for further development once the environmental, conservation, and municipal properties were removed. However, this developable land included parcels that are currently built on. The total developed land area based on the required lot size for existing properties calculated using their building area and ground cover is about 19.3 square miles and the additional buildable area is about 3.05 square miles. This means that the land buildout of the island is currently at 86.3%. There are currently 13,502 lots on the island and the total additional lots amounted to 947. This places the island's current parcel buildout at about 93.4%. The current dwelling units on the island amount to 11,672 and the additional allowable dwelling units was found to be 14,561. This results in the current dwelling unit buildout of the island to be about 44.5%. This averages to about 1.8 dwelling units per lot on Nantucket. Below is a table that shows the maximum density buildout for this analysis (Table 4.2.1).

Table 4.2.1 - Maximum Density Buildout Summary

Analysis	Existing	Additional	Total	Current % of Total Buildout
Lots	13,502	947	14,449	93.4%
Dwelling Units	11,672	14,561	26,233	44.5%
Buildings	13,072	-	-	-

³ <https://ecode360.com/NA0948?needHash=true>

Existing Buildings & Dwelling Units

Establishing a baseline of the existing buildings and dwelling units on the island took a bit of work. There is a building layer accessible through GIS. However, upon closer inspection, this layer was found to be not so accurate, as there were buildings missing and others that were the wrong shape. This information is obtained through utilizing LiDAR technology (MassGIS, 2021).

Unfortunately, this technology will also pick up other structures that do not include buildings such as pools. Please see Figure 4.2.1 for an example of missing building data. The light blue polygons are the structures picked up by the LiDAR technology and the darker gray polygons are structures in the



Figure 4.2.1 – Inconsistent Building Data

basemap that currently exist but were not picked up by the LiDAR technology.

Instead of using readily available data, I worked with the Town Assessor to obtain a set of Excel spreadsheets that had data on the buildings on the island. When cross-referencing the data on the different spreadsheets, there were some overlaps that required some data cleaning. This data included a different row for each building even if it shared a parcel with another entry. This allowed for the creation of a column for buildings that resulted in an entry of 1 for each row/entry. Each data entry included the GIS_ID, property address, use code, and other pertinent information. A column was also created for dwelling units. The information entered for the dwelling units was obtained by looking up the property card for each entry on the Town's GIS website.⁴ Some assumptions had to be made, as some of the property cards were confusing and incomplete. For

⁴ <https://nantucketma.mapgeo.io/datasets/properties?abuttersDistance=100&latlng=41.315932%2C-70.134825>

example, elderly living facilities and dormitories each equal 1 dwelling unit, because they often do not have separate kitchens and bathrooms for each occupant or set of occupants. Hotels, Inns, and Motels were counted as 0 for dwelling units because they do not house full-time residents. There were some buildings that reported kitchens on their property cards but then reported 0 bedrooms and 0 bathrooms; these were not counted as dwelling units. Some properties did not report a kitchen count, but they did report a style of the kitchen - those were assumed to have a kitchen. Guest units and accessory units were counted as 1 dwelling unit as long as they had a kitchen and bathroom. Any properties with a vacant land style description received a 0 for both their buildings and dwelling units. Some properties did not have property cards, in which case the excel spreadsheet info and use code were taken at face value.

Once the data was transferred over to the overall spreadsheet including all of the properties on the island without any being removed from the environmental and protection constraints, there were some data points that did not fill in or have a match from the set of spreadsheets from the assessor. Most of these were given zeros for their building and dwelling units as they were right of ways or water. Some additional property card research was required to fill in the rest. This analysis resulted in the existing dwelling units and building count for the island.

Additional Lots

Moving forward with the analysis, the area of land left after the environmental constraints and undevelopable parcels were removed resulted in about 10 square miles of developable land. Many of the existing properties lie within some of these environmental constraints, more prominently the wetlands, because they were built before the Wetlands Protection Act (310 CMR 10.00) was put in place. See Figure 4.2.2 for an example of



Figure 4.2.2 - Existing Buildings in Wetlands

this. To be conservative in this case, the area required for the existing lot was subtracted from the resulting land area after the environmental constraints were removed. The area required for the existing lot included the building area or building footprint divided by the ground cover percentage to obtain the total area needed for that lot (Eq. 1). The leftover area for the parcel was then divided by the minimum lot size times 1.15 to establish potential lots (Eq. 2). The commercial lots' minimum lot sizes were adjusted to the numbers in Table 4.2.2, all others followed minimum lot sizes as defined by the zoning rules and regulations in the intensity regulations.

$$\text{leftover_AREA} = \text{AREA} - (\text{BLD_AREA}/\text{Ground_Cover}) \quad \text{Eq. 1}$$

$$\text{AD_LOT} = \text{leftover_AREA}/(\text{Min_Lot_Size} \times 1.15) \quad \text{Eq. 2}$$

The 1.15 accounts for an estimated need of 15% additional land for right of ways (Zirkle 2003). A caveat to this calculation is that the BLD_AREA column in excel only counts the primary dwelling unit's area. This dials back the conservative nature of removing the existing property area from the leftover buildable area, because it should in fact be including more land area than the calculation accounts for. Parcels where the additional lots exceeded 4 were checked to assign a more realistic lot subdivision. Some of these were not subdividable as they had more buildings on them than the BLD_AREA accounted for and others were configured in oblong shapes so that they could obtain frontage and land for their driveways. An example can be seen in Figure 4.2.3. The automatic calculation for this lot resulted in a subdivision of an additional 6 lots, because the calculation only takes into account the land area and not the configuration or layout of the lot. A polygon tool was used to



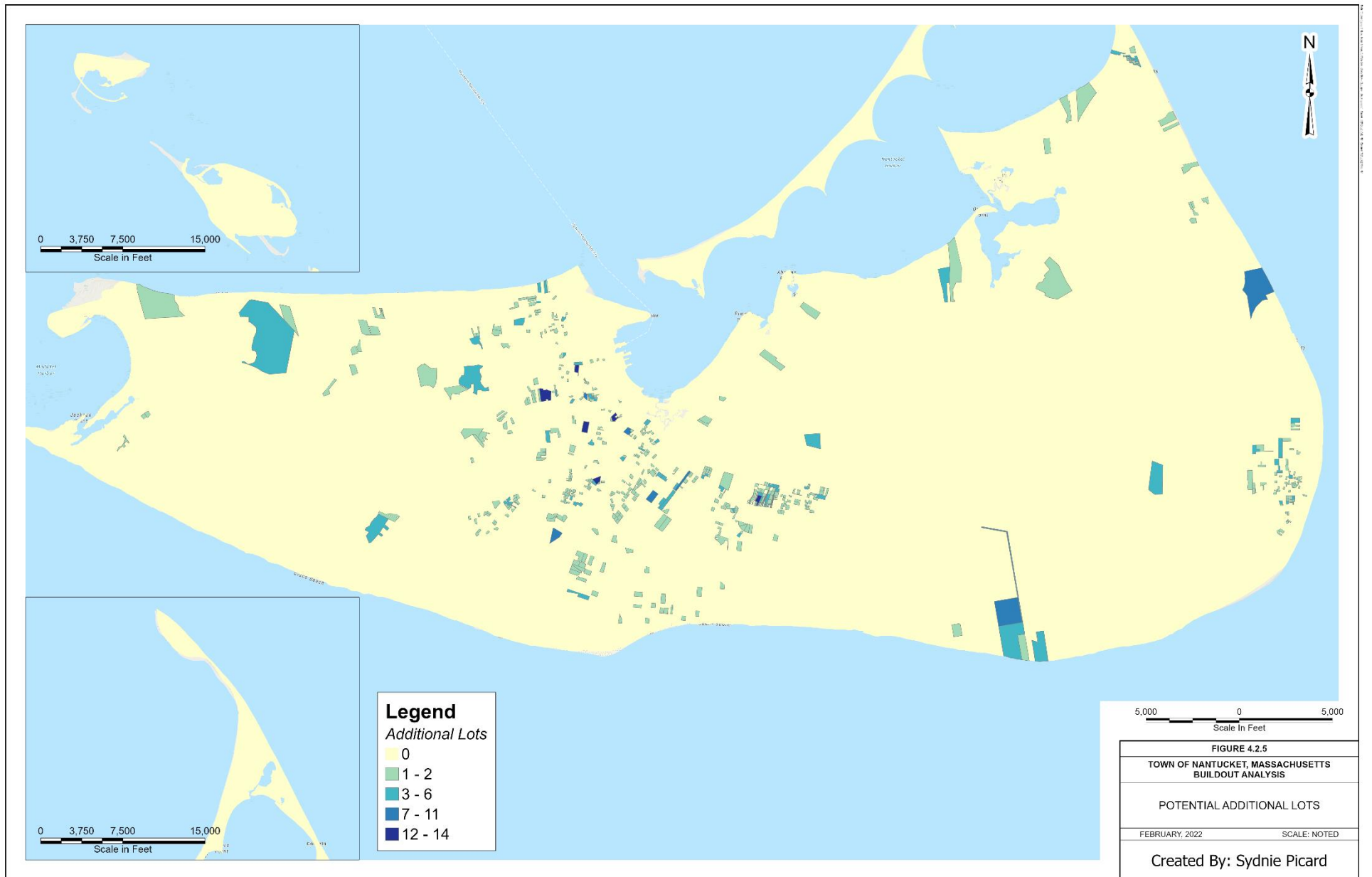
Figure 4.2.3 – Elongated Land for ROW Access

measure the approximate area where additional lots could be added as long as they had frontage (Figure 4.2.4). For example, this lot could realistically have approximately two additional lots.



Figure 4.2.4 - Additional Potential Lots

Again, part of some of the existing properties lie within the boundaries of the imposed environmental constraints so not all of their area would have to be removed from the land area outside of the environmental constraints. This would require a more in-depth analysis that would result in looking at each parcel one at a time and computing how much land of each parcel is within the environmental constraints and whether that can be used towards the existing property's lot area. This calculation would require a lot by lot review with the Town, which is out of scope for this project. This conservative calculation is also backed by the fact that current properties can be spread out and the minimum lot size may not cover all of their structures. It may be likely that the owner is willing to move some of their smaller structures and condense their property to subdivide and sell more of their land, but this would also require a more in-depth analysis of which owners are willing to do that and how much land they will need for their lot following the ground cover regulations. This would require a Town-wide survey or contacting all property owners with large enough lots, which are both outside the scope of this project. Of the 10 square miles of land left for development, about 3 square miles resulted after removing the existing buildings and their required ground cover ratios from the parcels. The excel spreadsheet used for these calculations and the following ones can be found in Appendix 2-A. Some columns were hidden as they were not pertinent to the analyses. The numerical results from this analysis can be found in Appendix 2-B. A map depicting the spatial density of additional lots can be found on the following page in Figure 4.2.5.



Additional Dwelling Units

The existing dwelling unit information can be used to gain an understanding of what exists on the island and then determine how close the island is to its dwelling unit maximum buildout. The additional dwelling units analysis also demands a baseline of what exists so that it can be compared to how many dwelling units are possible according to the particular district's zoning regulations. This analysis assumes that the dwelling units will be designed to the specifications necessary to meet the ground cover and lot configuration requirements in the Town's zoning rules and regulations. It only presents a number of how many more dwelling units can be added to a property and how many are allowed on newly subdivided properties as determined by the additional lots analysis. The Use Chart provided by the Town of Nantucket in their zoning rules and regulations can be found in Appendix 2-C. This was used to determine the approximate total amount of dwelling units and buildings allowed on a parcel in each district. Table 4.2.2 displays the assumptions that were made and confirmed by the Town Director of Planning.

Table 4.2.2 - Allotted Potential Dwelling Units

District ⁵	Adj. Min. Lot Size (sf)	Potential Dwelling Units per Parcel
All Town Residential	-	2
CDT	4,000	4
CMI	7,500	6
CN	15,000	6
CTEC	16,000	6

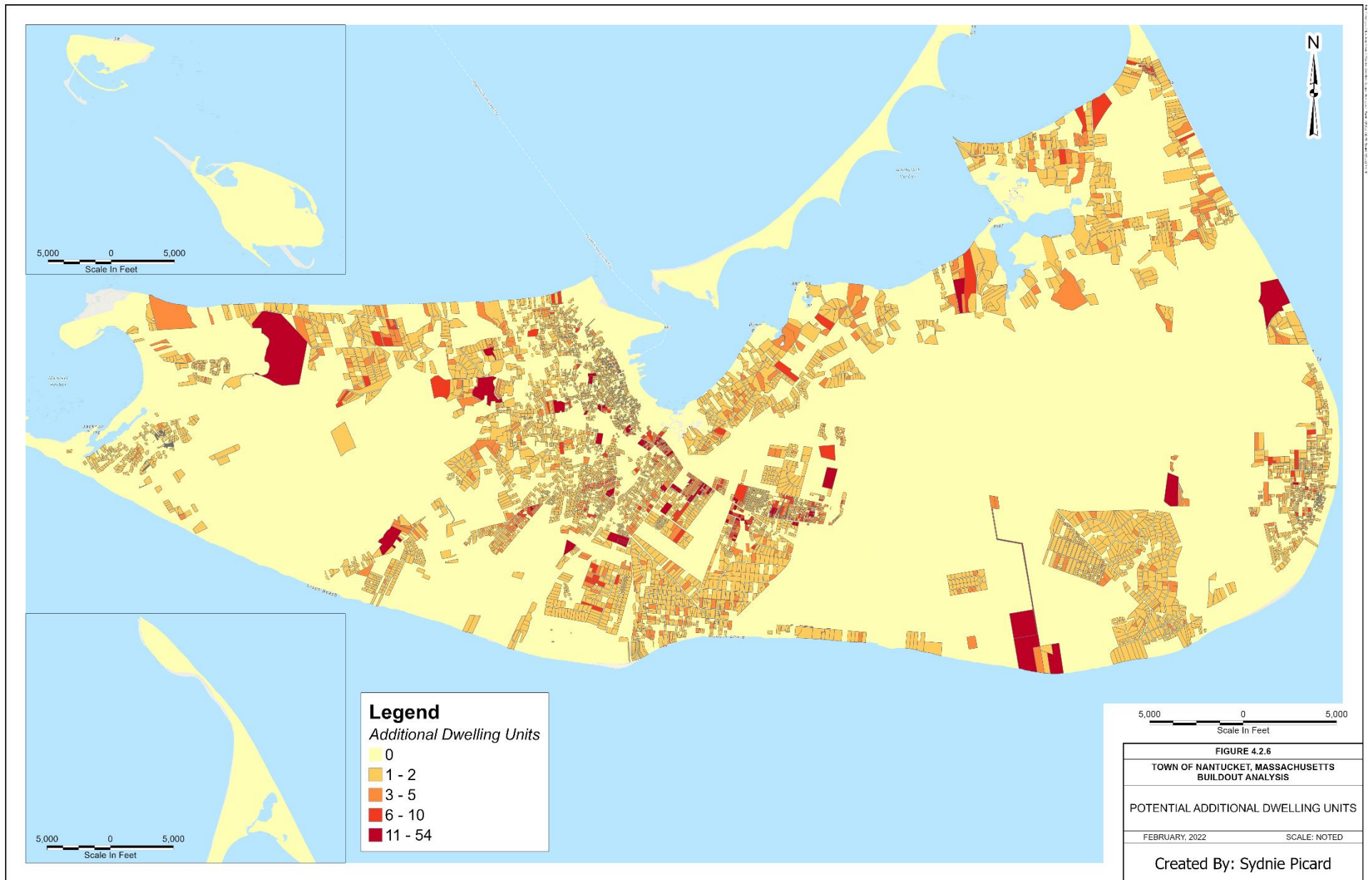
⁵ <https://ecode360.com/11471590?highlight=district,districts&searchId=4309102863829449#11471590>

RC/RC-2	-	2
VR/MMD/VTEC	-	2
LUG-1/2/3	-	3
VN	15,000	6
CI/OIH/ALC	-	0

The adjusted minimum lot size for the commercial lots was changed to reflect the necessary lot size needed for the maximum amount of dwelling units. In addition to the districts CI, OIH, and ALC, there were also some use codes that could not have additional dwelling units added to them and those include; Charitable Museums (9560 & 9561), Educational (9430 & 9461), Interval M01 (1080), Landbank (9920 & 9921), Dormitories (123C), and Charitable Hospitals (9550 & 9551). The additional dwelling units were determined by subtracting the existing from the allotted and adding the allotted units per additional lot. Equation 3 shows the excel equation for the additional dwelling units column.

$$AD_DWL_UNIT = (P_DWL_UNIT - DWL_UNIT) + (P_DWL_UNIT * AD_LOT) \quad \text{Eq. 3}$$

Some data entries for the additional dwelling units and additional lots were overridden, because of current development plans that are in the works. These entries were adjusted to reflect the units and lots that are currently designed for the parcels. The numerical results from the dwelling unit buildout analysis can be found in Appendix 2-D. The map depicting the spatial density buildout for potential dwelling units can be found on the following pages in Figure 4.2.6. Again, this analysis does not cover lot configuration and building design. It is assumed that the additional buildings will be designed according to the established zoning rules and regulations regarding ground cover and setbacks.



Projected Population and Dwelling Growth

We can tie the projected population growth to dwelling unit growth by using an average household size. This will help us determine how fast the maximum buildout will be reached. This is important to note so that the Town can have an idea of the timeline they have to implement policies to restrict development. Based on the 2020 census reported population of 14,255 and an average household of 2.52, the necessary existing dwelling units for the current population would be 5,656. Given that the population in Nantucket grew by 40% between 2010 and 2020, I wanted to use a more conservative growth estimate based on state trends. With an estimated 5% annual compounded increase in the population by the year 2050, the town would increase by 20,248 residents (UMass Amherst 2021). Nantucket would need an additional 8,034 units to sustain this population growth. Based on numbers reported in this buildout analysis, the average household size would be 1.76. This 1.76 is based on all the primary existing dwelling units on the island, regardless if there are people living in the unit year-round. Accessory dwelling units were ignored and only one dwelling unit was counted for each property with an existing dwelling unit on it. With the increase of 20,248 residents by 2050, an additional 11,505 dwelling units would be required at this household size. The buildout analysis resulted in a potential additional 14,561 so there is room for the population to grow based on these projections. However, if the populations projections could not fit the available additional dwelling units, then the maximum dwelling units will be achieved before the year 2050.

The difference in household size can differ by how the term “household” is defined. An independent study, Estimating Nantucket’s Effective Population by Peter A. Morrison, et al., found this discrepancy amongst the Census reported household size and the town street list (TSL/MSL) reported household size in 2010. The census reported a household size of 2.39 people and the TSL

reported 1.82 people per household. This report chose to adopt the MSL due to its accuracy in reporting annual population numbers specific to Nantucket as opposed to the standardized estimation methods of the decennial census. The census bases its numbers off of population surveys, but not everyone fills out these surveys. They then use algorithms to estimate population and other statistics by comparing previous years and trends. They account for a margin of error in their statistics which tells us how confident they are in the numbers (U.S. Census Bureau). The town continuously updates the MSL through residents' daily in-person transactions with the Town Clerk's office, statewide-reported vital events by place of residence, and an official annual Town Census, which serves to re-confirm and update the names of all known household members currently shown on the street list (Morrison et al. 2020). For the purposes of this report, it would be more effective to adopt the household size of 1.76 to estimate future population growth and housing needs in Nantucket.

If we base the household size off all the dwelling units on the island regardless of people living there year-round or not, the average household size would be 1.22 and the required additional dwelling units would be 16,597 with the projected population size. This emphasizes that if the Town allows people to continue developing their homes and properties as they are now with secondary and even tertiary dwelling units, they will reach their maximum buildout potential in dwelling units before 2050. At this household size, the island would reach its maximum buildout potential according to their current zoning rules and regulations in the year 2038. Because Nantucket has a large seasonal population as opposed to its year-round residents, there may be sometimes in the summer where every one of these units are full due to vacationers and people visiting their families.

It should also be noted that these maximum buildout numbers are potential based on current regulations and not necessarily predictive of what will happen. The Community Preservation Committee has authority to acquire land for preservation and protection as it sees fit with the Town's approval. The Town also has the authority to restrict and deny building permits at its discretion. Properties are also constantly being rezoned. These actions could reduce the number of future lots and dwelling units that are allowed to develop on the island. If Nantucket is allowed to reach its maximum buildout potential as estimated in this report, then the next question the Town has to ask is whether or not their facilities and the island's natural resources can support this growth.

4.3 Sea Level Rise & Erosion Considerations

Sea level rise (SLR) is one of the most concerning results of human-induced climate change. SLR can be exacerbated by the intensifying and increasing occurrences of severe weather events that are also associated with climate change. Globally, the IPCC reports in chapter 3 of its Special Report: Global Warming of 1.5 °C that the sea level will rise on average by 0.1 meters with medium level confidence by 2100. Sea level rise causes further issues aside from inundating the coastlines. It amplifies the impacts of storms and coastal erosion, especially for small islands like Nantucket and low level lying coastal communities. The increase in the number of storms and their intensity increases the risk that natural and human systems may be overwhelmed, inhibiting them from recovering quickly as the occurrences increase. Strong wind and waves damage coastal infrastructure and ecosystems such as seagrass beds that support a healthy coastline (Bindi et al. 2018, sec. 3.4.4.3). Sea level rise and severe storms also exacerbate the effects of coastal erosion. Erosion can affect properties along the southern shore of Nantucket, inundate the historic downtown area, erode key infrastructure, including two wastewater treatment plants, roads, and the airport, and result in the loss of tidal wetlands when combined with sea level rise. Nantucket



Figure 4.3.1 – A Home in Nantucket Left to Fall into the Ocean (Brace 2015)

has been battling the natural effects of coastal erosion for years, where coastal homes and buildings have been falling into the ocean (Figure 4.3.1).

A map showing the potential erosion predicted from 2030 to 2100 is based on the high sea level rise scenario from IPCC (1.2m or about 4ft). It is hard to make out the differences between these colors, but you can see that the islands located to the left of the island have altered in shape and size. You can also observe that the shape of the main island will change overall as you follow the coastline in Figure 4.3.2.

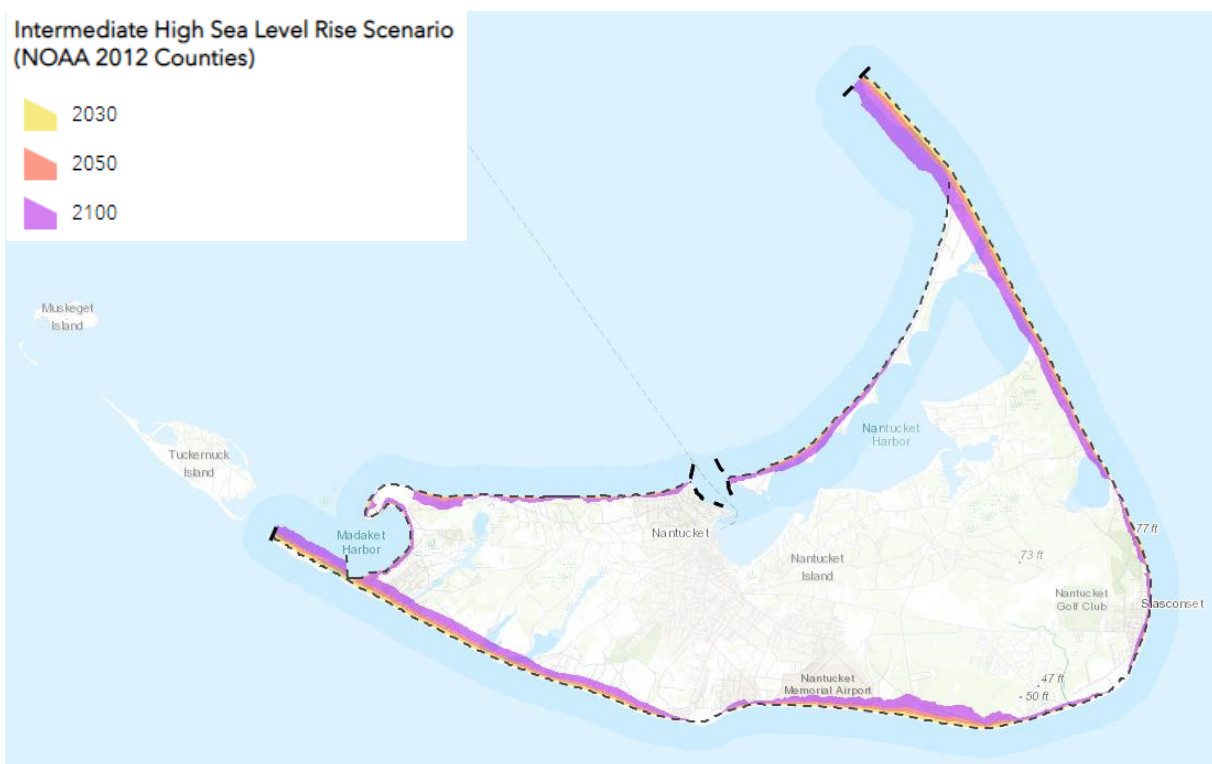


Figure 4.3.2 – Coastal Erosion Predictions for Nantucket (FEMA 2012)

In the report published by Milone and Macbroom from chapter 2, Nantucket is reported to be losing an average of 2.1 meters of coast per year along its south shore and Tuckernuck Island. We can see in the picture above that the width of the island appears to be dwindling from the north shore to the south shore of the island. Coastal erosion is already an important factor when it comes to planning development on Nantucket as it is a naturally occurring phenomenon. However,

erosion on Nantucket is exacerbated by the effects of human induced climate change as previously found in reports by the IPCC. Strategic planning will help deal with both kinds of erosion in a proactive way, but the pace and intensity is due to increase as a result of climate change, and therefore a more proactive approach to planning is needed.

The Town has historically supported efforts to mitigate erosion through sand nourishment, the management of drainage, vegetation for bluff stabilization, sand-filled jute-fiber bags, geotextile tubes (geotubes) along high-risk portions of bluffs, and the relocation of structures more inland (Arcadis 2021). The relocation of structures more inland is for extreme circumstances in order to protect significant historical structures or homes of those who can afford it. Otherwise, the structures are left to fall in the ocean such as the one in Figure 4.3.1. A more notable relocation of a structure was the historical Sankaty Lighthouse, built in 1849, where the 'Sconset Trust Association moved the 405-ton lighthouse 267 feet away from the bluff in 2007 ('Sconset Trust 2022). This feat, among others and the implementation of the above listed mitigation strategies have thus far been protecting Nantucket's existing infrastructure. As global temperatures continue to rise and the effects of climate change are becoming more prevalent, it is imperative that coastal communities, like Nantucket, plan for climate change impacts. The typical year that people are planning for in regard to climate change is the year 2050. Town comprehensive and master plans also plan for about 10-20 years out. Given the time difference from when the Sankaty lighthouse was built and when it needed to be moved due to coastal erosion, it would be appropriate to plan past the typical 20-year forecast. It would be appropriate to start planning how Nantucket should look and operate 50 to 100 years from now. Planning and implementing retreat and mitigation responses have long lead times and the benefits are greatest if it occurs sooner (Nicholls 2011).

Aside from responding to the causes of climate change, it is critical for coastal communities to plan ahead so that they may avoid causing more harm to their coastal communities or having to react and adapt to the impacts. With the loss of shoreline and increasing coastal erosion, infrastructure is not the only thing that Nantucket should be aiming to protect. Ecosystems are at risk just as much as the coastal infrastructure. These ecosystems contribute to biodiversity and the overall natural health of the island's environment. "While some ecosystems (e.g., mangroves) may be able to shift shoreward as sea levels increase, coastal development (e.g., buildings, seawalls and agriculture) often interrupts shoreward shifts, as well as reducing sediment supplies down some rivers (e.g., dams) due to coastal development" (Bindi et al. 2018). Not only is coastal development detrimental to the coastal ecosystems that are fighting to be resilient towards climate change, but it is also risky for infrastructure to be exposed to erosion and increased flooding from severe storms and sea level rise.

People are investing in coastal infrastructure, but then that infrastructure is at higher risk of being destroyed due to climate change and the high rates of coastal erosion in Nantucket. Money would have to be invested to protect or even repair the coastal infrastructure. It requires more money to retroactively plan than to proactively plan to protect our coastlines by restricting development and implementing planning strategies to support a robust coastline. Proactive protection against sea level rise has been favored as optimal in a cost-benefit analysis but it can be costly (Nicholls 2011). Multiple sources, including the IPCC, have estimated that multi-billions of dollars would have to be invested annually on a global scale to protect against 1 meter of sea level rise (Nicholls 2011). Small islands are relatively more vulnerable to climate change impacts and as such should act as leaders in paving the way for coastal resilience.

Sea Level Rise Analysis

Due to the risks associated with coastal development and climate change, a sea level rise analysis will remove additional areas of land that may be inundated with flooding as the sea level rises. As stated in chapter 2, the newest climate change predictions model is in phase 6 (CMIP6) and predicts a sea level rise of 1.3 meters or about 4 feet and 3 inches in the most aggressive climate change scenario for the year 2100 for the eastern seaboard of North America. For the purposes of this analysis in GIS, a rounded 4 feet of sea level rise was assumed. As explained in the literature review in chapter 2, NOAA utilizes base flood elevations (BFEs) to approximate coastal flooding and severe storm inundation areas. Through a quick statistical analysis in GIS, the mean BFE for the existing coastal flooding layer was found to be 9.8 feet and the median was 10 feet. For the purpose of this analysis, a uniform BFE of 10 feet was utilized. The topographic line features or the digital elevation model (DEM) obtained from the Town of Nantucket was converted to a raster and then the integer values were reclassified to reflect the 4-foot sea level rise. The

bounds were anything ≤ 0 ft (ocean/water), $0 < x \leq 10$ ft (BFE), $10 < x \leq 14$ ft (4 ft sea level rise), $14 < x \leq 107$ ft (every other elevation).

The final step was converting it back to polygons so that it could be used to clip out areas from the buildable



Figure 4.3.3 – Coastal Storm Flooding with 4ft SLR

land. Figure 4.3.3 shows the area that would be inundated by flooding during coastal storms if the sea level were to rise 4 ft by 2100.

Once removed from the buildable land, the same analysis in step 3 was run on this newly developed data. With the same constraints as before, the maximum buildout analysis was reduced to the following in Table 4.3.1. A map of the additional lots and dwelling units can be seen in the appendices of 3-A and 3-B. The numerical breakdown of the buildout by district can also be found in these appendices.

Table 4.3.1 – SLR Maximum Density Buildout Summary

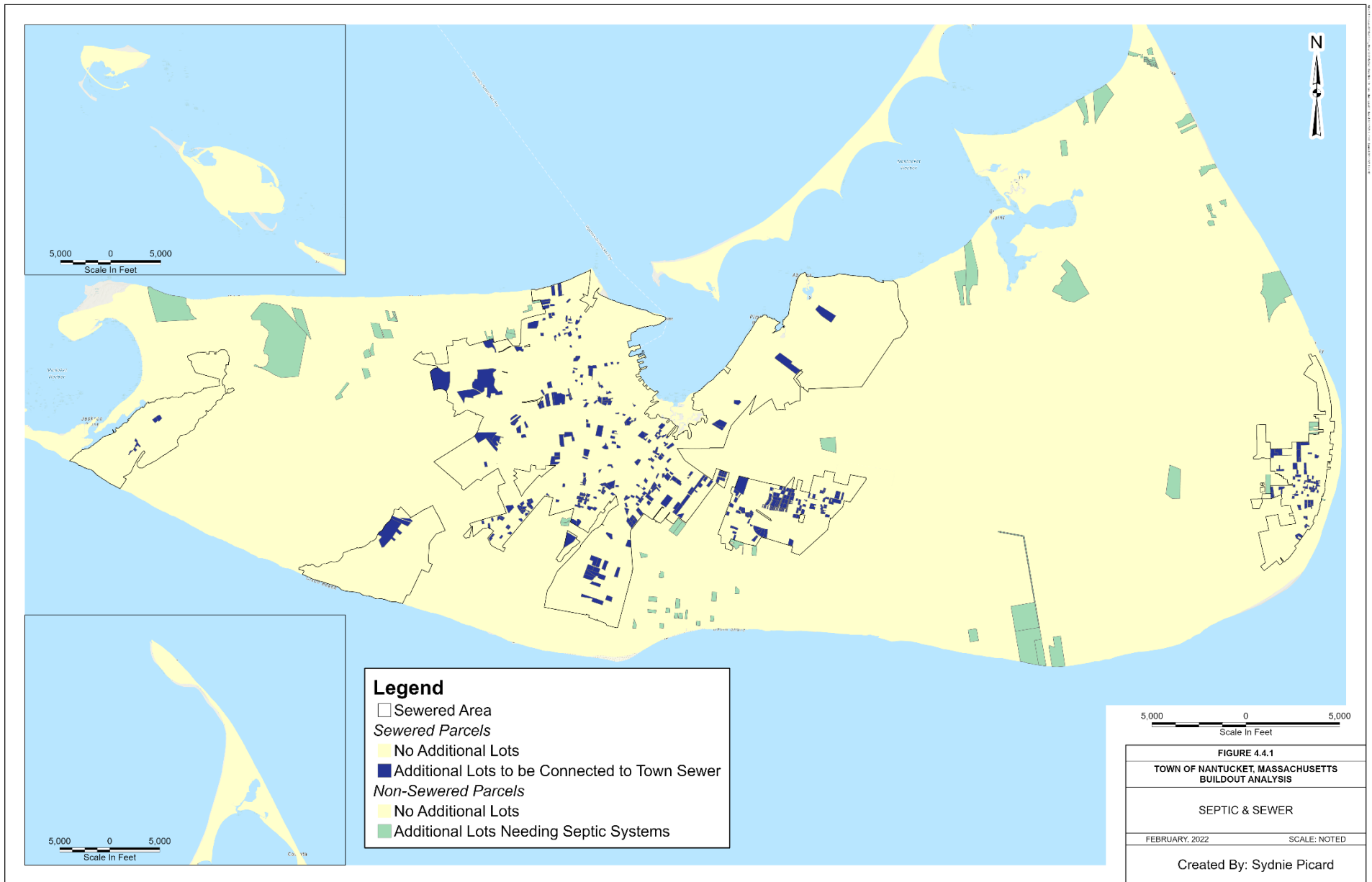
Analysis	Existing	Additional	Total	Current % of Total Buildout
Lots	13,502	909	14,411	94.0%
Dwelling Units	11,672	13,863	25,535	45.7%
Buildings	13,072	-	-	-

A lot of the area that would have been removed from further development due to the SLR scenario mostly overlaps with the environmental constraints discussed in chapter 4.1. A total of 0.8 additional square miles were removed due to the flooding inundation area resulting from sea level rise. The SLR analysis also does not remove much more potential for additional dwelling units and lots than the original analysis in chapter 4.2. The potential additional dwelling units were reduced by 698 and the additional lots were reduced by 38. It should not be too difficult for the Town to restrict development in the areas highlighted by the SLR flooding in Figure 4.3.3 above. As stated before, it would reduce retroactive planning and the need to protect or rehabilitate new infrastructure. It would also help to maintain a healthy natural barrier between the sea and land including reducing development impact on mangroves, dune grass, and wetlands. These natural communities help support a robust coastline and reduce the need for human intervention.

4.4 Septic & Sewer Considerations

In addition to sea level rise and erosion, the Town of Nantucket should also consider how the maximum projected buildout will impact their sewer and septic systems on the island. Title V regulations in Massachusetts set standards for the siting, design, construction, repair, replacement of on-site sewage disposal systems, and inspection and maintenance of these systems. The regulations also have an outline for the responsibilities of municipalities in regard to wastewater treatment plants while referencing other regulations that are applicable to these standards. Most of Nantucket is currently running on Town sewer as opposed to septic systems. Around 8,000 existing lots of the 13,502 lots on the island are served by sewer and an additional 929 existing are proposed in the Sewer Master Plan to be served by Town sewer in the near future by Weston & Sampson (2020). The Sewer Master Plan accounts for additional flows from potential future dwelling units within their proposed sewer expansion areas. Future dwelling units and subdivided parcels outside these areas should also be served by Town sewer as septic systems are detrimental to coastal communities with high water tables, such as those found on Nantucket.

Figure 4.4.1 on the following page identifies the additional future buildout parcels outside of the proposed sewer areas. According to the buildout analysis, 819 subdivided parcels and 11,045 new dwelling units will fall within the areas that are planned to be sewered within the next 10-12 years. However, these new dwelling units will increase the load on existing septic systems and 128 newly subdivided parcels outside the sewered areas will require new septic systems whether that be conventional or I/A. An updated sewer analysis on the flow loading would be necessary to accurately depict the impacts of this buildout analysis.



SLR will cause groundwater tables to rise, reducing the vertical distance that a septic system's leach field has to naturally filter out contaminants like nitrogen and more dangerous contaminants such as e coli. Figure 4.4.2 shows a depiction of how a typical septic system is laid out. "The USGS conducted research on Cape Cod, Massachusetts to simulate the response of water table height to sea-level rise. The data showed that, for that

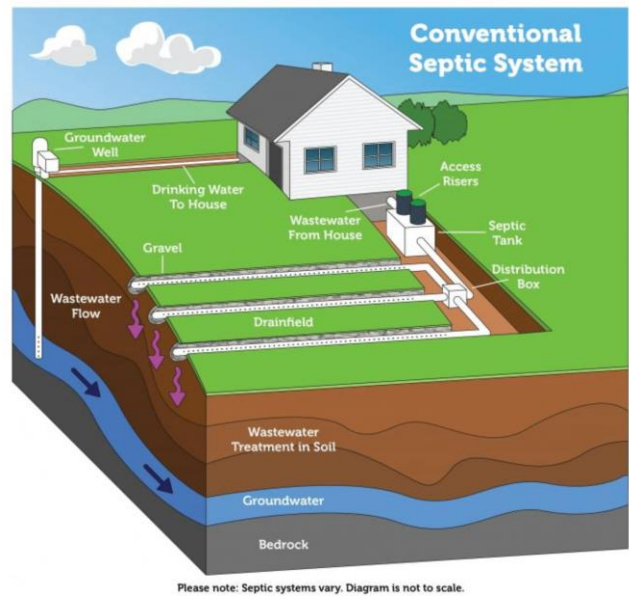


Figure 4.4.2 – Conventional Septic System Diagram
(Martin Septic Service 2019)

geographic area, the groundwater table would rise at about 31 to 35 percent of the rate of sea level rise" (Mihaly 2018). For example, if sea-level rises 4 feet, as predicted in chapter 4.3, the groundwater table would rise somewhere between 1.24 and 1.4 feet. Lots that have septic systems and private wells are especially susceptible to contamination and an increased likelihood of contamination with climate change. This would further endanger the quality of the groundwater supply and drinking water. Increased occurrences and inundation of coastal flooding can also exacerbate unfavorable conditions for septic systems as it can over saturate the soil and not allow the effluent to percolate and filter properly through the leach field. Septic systems located on coastal properties and those with high water tables are therefore particularly concerning due to climate change scenarios.

Homes on Nantucket should be served by the Town sewer as much as possible, as the nitrogen loading from septic systems in the ground can be detrimental to the natural systems on the island as discussed in chapter 2. There are restrictions in Title V associated with nitrogen

loading in order to protect the environment. Title V requires design flow rates for systems to be based on 110 gpd per bedroom. However, if these residential units are in Zone II of the public water supply wells, new residential construction served by both private wells and on-site systems, or other areas formally designated as nitrogen sensitive, the flows are restricted to 440 gpd per acre. These areas include the Nantucket Harbor Watershed, Madaket Harbor Watershed, Hummock Pond Watershed, Miacomet Pond, Sesachacha Pond, and the Wellhead Protection district (Zone II). There are currently 8,203 lots affected by this restriction and potentially 825 new lots that will be restricted due to nitrogen loading and other contaminants. Of these new lots in the nitrogen sensitive areas, 44 of these lots will need septic systems as they are outside the sewer service areas. These lots will be subject to the restricted flows and thus reduce the potential for additional dwelling units.

There are new technologies that are innovative and alternative (I/A) to the conventional septic system that allow property owners in nitrogen sensitive areas to increase their flow rate allowance to 550 or 660 gpd per acre (MassDEP 2022a). Massachusetts has approved 18 I/A technologies for nitrogen removal credits that allow for a higher flow design. Nitrogen outflows are significantly reduced with I/A systems, boasting a target of 19 mg/L with the best performing systems in a range of 5-11 mg/L, while conventional septic systems regulated under Title V range from 26 to 42 mg/L outflows (Walton 2020). The best approach for restricting nitrogen outflow from sewer systems is to be on Town sewer services. According to Nantucket's groundwater discharge permits issued by MassDEP, the wastewater treatment plants' effluent contains around 10 mg/L of nitrogen. However, the better performing I/A systems are around the same efficiency for removal. In addition to considering the nitrogen removal, the bigger picture includes considerations for total cost.

Sewer & Septic Systems Comparison

Table 4.4.1 - Wastewater Management Cost Summary

	Initial Investment	Maintenance and Operation	Total Cost (Over 20 yrs)
Conventional Septic	\$12,000	\$1,500 - \$2,700	\$13,500 - \$14,700
I/A Septic	\$20,000 - \$30,000	\$22,000 - \$23,000	\$42,000 - \$53,000
Town Sewer	\$12,000	\$18,000 - \$27,000	\$30,000 - \$39,000

A study done for the Cape Cod area for a house that had 2-3 bedrooms, found that conventional septic systems cost around \$12,000 with a \$75-\$135 a year every 2-3 years to be pumped out or serviced (Walton 2020). This study also found that for a 20-year I/A system, the cost would be between \$42,000 and \$53,000. The direct cost to the homeowner for a hookup to the sewer system would cost around \$30,000 to \$39,000 for the 20-year design life. This includes the initial hook-up charge, system development fee, and an annual sewer bill estimation. In regard to cost, the conventional septic system is the cheapest, but it does not reduce nitrogen loading on the soils and groundwater table. With the goal of reducing nitrogen loading and direct cost to the consumer, the best option would be to sewer all new and existing parcels. However, Town sewer systems require a lot more capital investment upfront and time to install. The average cost burden to a Town in the Cape Cod area for a sewer system is about \$108,000 per home. Also, the timeline for the proposed sewer upgrades in the Nantucket Sewer Master Plan is projected to start in 2023 and occur over the next 10-12 years. In this case, I/A systems are a faster alternative for allowing new construction opportunities to be habitable. I/A systems are more efficient and sustainable than conventional septic systems, their only drawback is the cost associated with their installation and maintenance.

4.5 Water Resources Considerations

Water resources are a basic human need that are threatened by the intensifying effects of climate change. Nantucket has an opportunity to plan their future development with concerns for their natural water supply in mind. The island of Nantucket is unique, because the Town has access to and draws from its own aquifer. There are six public water wells, four of which belong to the Wannacomet Water Company and two belong to the Sconset Water Company. Of the 9,688 properties with buildings reported on them, these wells currently service approximately 3,900 parcels, which leaves 5,788 parcels that presumably obtain their water supply from private wells. The Wannacomet Water Company services most of the people on the island that are on public water supply while the Sconset Water Company serves just the Siasconset community on the eastern side of the island.

The Massachusetts Department of Environmental Protection (MassDEP) is responsible for issuing public water supply permits and withdrawal limits under the Water Management Act. The Wannacomet Water Company is restricted to 1.68 mgd while the Sconset Water Company is restricted to 0.11 mgd. In 2019, the estimated per capita water use in Sconset was 65 gpd and Wannacomet was 91 gpd. In 2020, these numbers increased to 75 gpd and 103 gpd respectively with the same permitted withdrawal limits.

Both water companies were pushed over their permitted withdrawals in 2020. This over withdrawal can somewhat be connected to the influx in population during the summer months due to tourists and vacationers. Water use can also increase

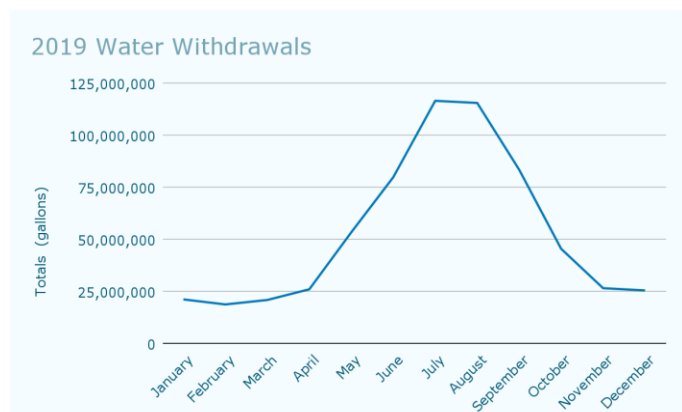


Figure 4.5.1 – 2019 Monthly Total Public Water Withdrawal in Nantucket

during the summer months for lawn care. Figure 4.5.1 shows the spike in total water withdrawal over the summer months in 2019. As previously discussed, identifying a year-round population is difficult due to the tourist economy on the island. There could have been an influx in vacationers in 2020 that caused larger amounts of water to be withdrawn and the per capita consumption to increase as they would not have been accounted for in the Town's population numbers reported in their water supply permit.

Private wells supply water to the rest of the island that is not serviced by the public water supply. Private wells are dependent on a permit issued by Nantucket's Board of Health. To obtain a permit, the applicant has to demonstrate in documentation that the well is located far enough away from other potential contaminants (Town of Nantucket 2022). There are also minimum requirements for distances between a well and a septic leach field. In addition, Nantucket's regulations require five feet of separation between the bottom of a leaching facility to the groundwater table and six feet in nitrogen sensitive areas. However, there are no regulations that limit water withdrawals or limit the number of wells on the island. Any property owner can apply for a permit and install a private well given the appropriate buffers and location. Therefore, private wells do not allow for withdrawals from the groundwater to be easily monitored. Nantucket does require the landowner to sample their own wells for contaminants every odd year (Town of Nantucket 2022). It is at the owner's own discretion to monitor their wells, so they do not overdraw or 'run their well dry'. There are USGS monitoring wells on the island that monitor overall instantaneous drawdowns in the water table. Drawdowns are usually localized and not an accurate indicator of the overall pumping capacity of the aquifer. The monitoring wells are useful in providing information on the localized pumping capacity of the wells.

MassDEP determines water withdrawal limits after the Town applies for a water withdrawal permit under the Water Management Act protocols and submits the required information. The information includes groundwater sources of supply, for each groundwater withdrawal, future water needs, evaluation of potential effects of the withdrawal(s), alternatives to the proposed withdrawal(s), groundwater hydraulic analyses (GHA) is fulfilled for new public water supply wells by completing the MassDEP Drinking Water Program Groundwater Supply Development and the Source Approval Process (MassDEP 2022b). This information was researched and collected by an independent contractor hired by the Town. The report and granting of a withdrawal permit is based on a localized study conducted on the proposed well location and its surrounding influences. The report does touch on the recharge rate of the island and discusses its connection with the withdrawal rate. The report points out that the cumulation of pumping from the two largest wells on the island only accounted for about 2.2% of the annual recharge in 2005 (Hayley and Ward, Inc. 2011). However, the report does not discuss how climate change may impact the aquifer's ability to continue providing a water supply at this pumping rate. Aside from aquifer recharge, there are other considerations to be made when evaluating an aquifer's long-term capability to provide a safe yield to wells established now and in the future. Sea level rise, saltwater intrusion, and septic systems all impact the quality and quantity of water drawn from an aquifer and its groundwater table.

Groundwater & Sea Level Rise

As sea level rises, less surface area will be able to receive groundwater recharge as the onshore land is reduced. Not only is the reduced surface area for groundwater recharge a concern resulting from sea level rise, but so is saltwater intrusion. Seawater could be drawn into the wells from excessive pumping. Future climate change scenarios regarding sea level rise for the U.S. had

a greater impact on saltwater intrusion than future land use / land cover change (Bindi et al. 2018). The Town is currently monitoring for saltwater intrusion at their monitoring wells on the island and it has not currently been an issue. However, it is imperative that this phenomenon be taken into consideration when determining whether to install more public water wells, increase pumping from public water wells, or even issue permits for private water wells. The Town should proactively plan so that it does not ever become a problem and overburden the freshwater supply on the island.

Groundwater Recharge & Saltwater Interface

As previously stated, the IPCC recognizes small islands as particularly vulnerable to the effects of climate change. Changes in precipitation, sea level rise, and coastal storm flooding combined with anthropogenic influences that increase development of impervious surfaces all will negatively affect the freshwater recharge of Nantucket's sole source aquifer. As such, a hypothetical study was conducted by Yazicigil et al. (2011), to analyze the impact that freshwater recharge reduction has on the saltwater interface and pumping capacity of small islands. A circular island with a uniform groundwater table was modeled. With a decrease in recharge of 15%, the study found that the pumping capacity of a well located in the center of the island decreased by 30% due to a rise in the saltwater interface. This study is generic, and the shape, size, and configuration of Nantucket and its aquifer would yield different results. However, it is an indication that the reduction in groundwater recharge through various climate induced and anthropogenic causes can have a significant impact on the saltwater intrusion and subsequent pumping capacity of the wells on the island. A study specific to the subsurface and aquifer characteristics on Nantucket could provide more direct data on how changes in groundwater recharge may affect Nantucket's freshwater supply.

Groundwater & Septic Systems

Nantucket's aquifer of glacial origin is composed of highly permeable soil characteristics which makes it more susceptible to contamination (US EPA 1984). As stated in the previous chapter, as sea level rises, so does the groundwater table. This reduces the soil buffer between septic systems and the groundwater table that the Town relies on for their freshwater supply. Figure 4.5.2 is a map of the nitrogen sensitive areas on the island and the Zone II protection district for the public wells on the island.

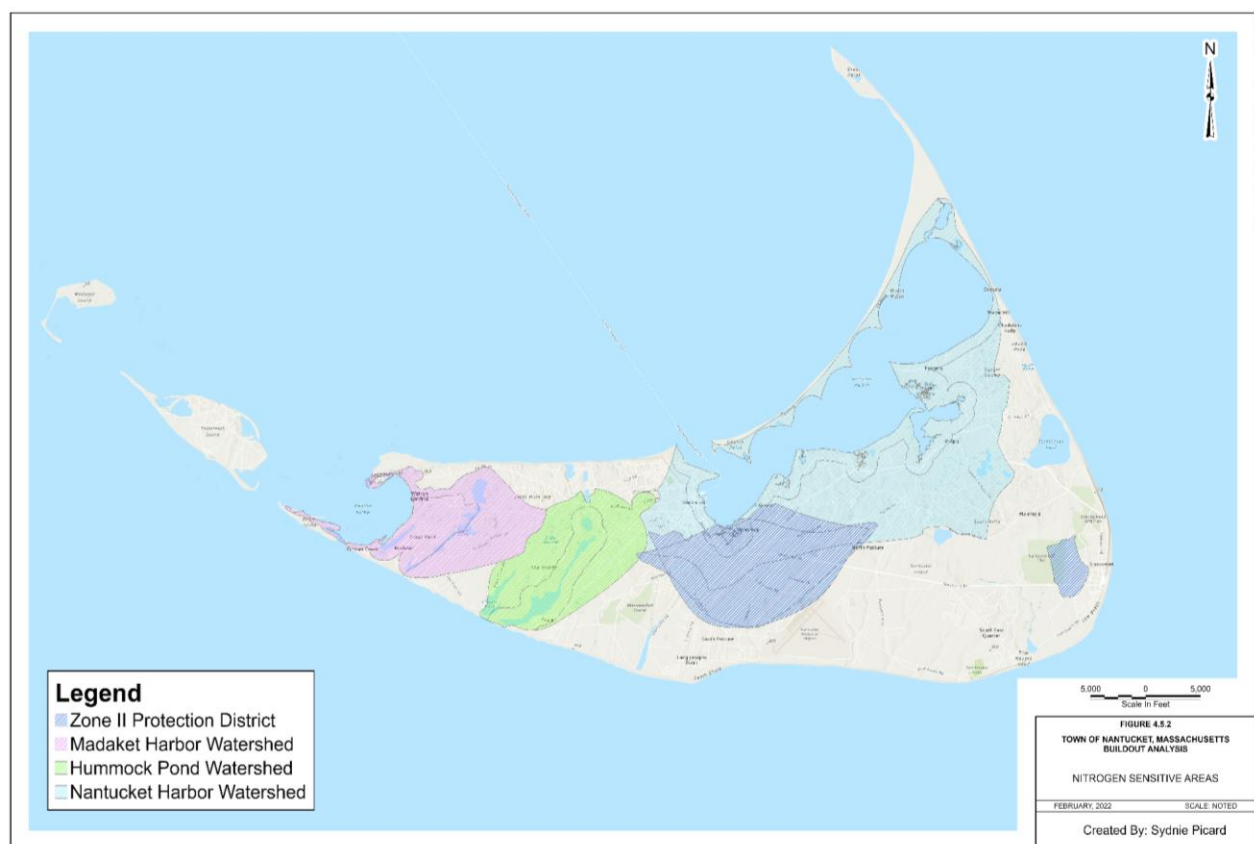
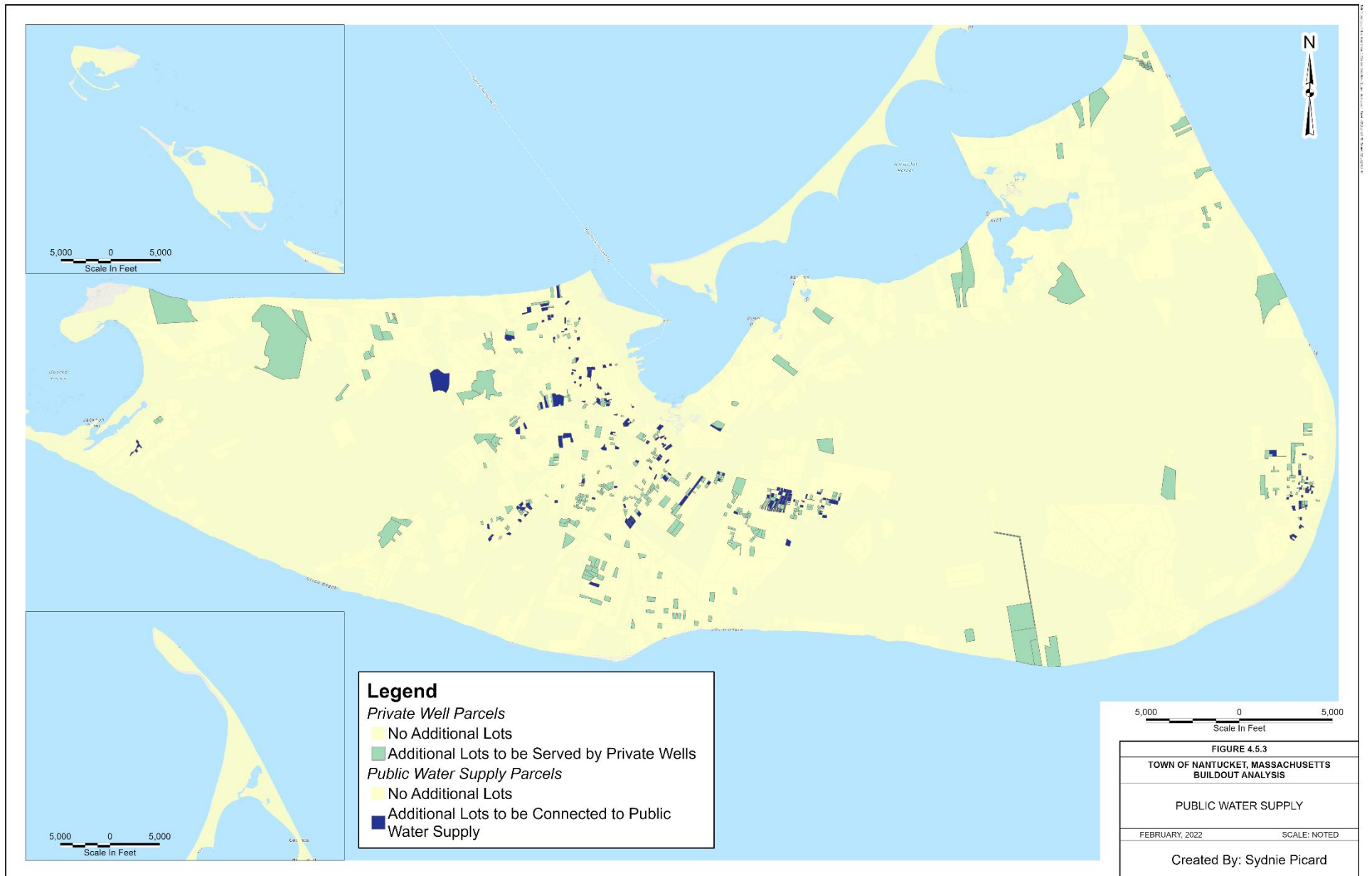


Figure 4.5.2 – Water Resource Protection Districts

Approximately 9,879 potential additional dwelling units could be built within these sensitive areas, increasing the demand of the water supply on the island, and creating a strain between water resources and wastewater disposal. This increase in dwelling units would cause the demand on the public water supply to more than double in just these sensitive areas.



Maximum Buildout Implications

Figure 4.5.3 on the previous page shows approximately the area that is served by the public water supply. With the previously stated per capita water consumption projections of 2020, at maximum buildout with 20,248 additional people, the increased overall water demand would be an additional 2.03 mgpd to the current public totals, increasing the demand by 213%. The additional water demand was based proportionally on the new units in the Siasconset area that could be serviced by the public water supply versus the new units that could be served by the public water on the rest of the island to obtain a better representation of the two different reported per capita water uses. More public wells and connections will need to be made or more private wells will need to be constructed to accommodate the increase in demand since the Town is already at their pumping capacity with their established wells. Either scenario increases the draw on the water table and aquifer and would require increases to permit limits.

It should be noted that the observed water withdrawal totals in the beginning of the chapter do not account for private wells. The estimated annual water use percent of the total recharge as previously stated also does not account for private well usage or all of the public wells. This means that percent is even higher than reported and does not accurately depict the water usage to recharge ratio on the island. In a fairly thorough search, I have not found evidence of a quantitative analysis that accounts for the cumulative pumping capabilities of the Nantucket aquifer and the impacts of all wells, private or public, on the island. An extensive analysis quantifying the effects of climate change on the fresh water supply and the long-term cumulative pumping capacity of the aquifer serving the island would provide a better understanding of how the future population growth and island development should be impacted by municipal planning.

5.0 DISCUSSION & RECOMMENDATIONS

5.1 Protected vs. Available Land

Nantucket is already protecting much of the land on the island using conservation restrictions and restricting development through acquiring parcels for the Town of Nantucket to use for municipal services or to simply protect and maintain it as it is. These various restrictions on parcels account for about 68% of the island's land area. With the ability of the Conservation Committee to acquire more land, Nantucket has the opportunity to drastically restrict future human development on the island. The rare and significant wildlife on the island occupy about 87% of the land area and the environmental constraints cover about 40% of the island's land area. Much of these areas overlap with each other and since the significant wildlife was not accounted for in the analysis, about 4 square miles of their habitat overlaps with areas allowed to be further developable. Given the unique and fragile environment of Nantucket, the Town could continue to use the Conservation Committee as a mechanism to reduce future development in sensitive and biologically diverse areas. This would allow the island to maintain its current balance between human development and available natural resources.

Land conservation has been an ongoing practice where other islands that are tourist hubs are also taking this approach to protecting island communities such as Hawaii (Pukui 2021). A little closer to home, the Peconic Land Trust on Long Island in NY also recognizes the importance of protecting natural lands to increase the adaptability of the land in regard to climate change (Peconic Land Trust n.d.). They acknowledge that protecting lands means ensuring clean recharge to their sole source aquifer, increasing carbon sequestration by protecting trees and vegetation, and implementing easements that will protect shorelines to support coastal storm

protection. Supporting and protecting the natural environment can be the best asset in climate resiliency.

5.2 Maximum Density Buildout

In this analysis lots were subdivided, and additional dwelling units were calculated for each existing and additional lot. After seeing the maximum buildout numbers in chapter 4.2, the Town may want to consider and rethink how their regulations are set up regarding dwelling units. These additional dwelling units were calculated using allowances stated in Table 4.2.2, that were determined in a meeting with the Town. There are currently no regulations that clearly define the maximum allowable dwelling units on a lot according to its zoning code. However, as stated in chapter 4.2, there is a municipal document that states what kinds of dwellings and development is allowed in each district, but it does not clearly define limits. This document can be found in Appendix 2-C. There are density restrictions in the Town's Zoning code that state dwelling unit restrictions for apartments and apartment buildings, but not for every zoning district and it is based on square footage of the lot as opposed to a hard standard cap based on the minimum lot size.

Establishing a maximum dwelling unit count according to the minimum lot size would restrict development, but also may provide additional space in a lot larger than the minimum lot size where development may not occur because the maximum number of dwelling units has already been met. It would also address their concerns of Town residents building additional dwelling units (ADU) to accommodate family and even summer vacation rentals, as this influx in tourists during the summer months puts a strain on the natural resources on the island. The potential additional development also threatens the cultural and quaint identity of the Town.

Oppositions on restricting ADUs claim that it is in turn restricting access to affordable housing. ADUs have been an affordable option to increase the housing stock as they are an

expansion and conversion of a space like garage apartments, in-law suites, and ‘granny flats’ (Willis 2021). Although, because of the housing market over the past few years, there has been a dramatic increase in the ADU market, turning low density development into higher density development and causing an influx of population. Setting a maximum dwelling unit limit on lots per zoning district would restrict access to these more affordable housing options and create push-back. However, increasing affordable housing on the island could be a solution to this push-back. Nantucket is already taking steps to support and establish more affordable housing through their Affordable Housing Trust (Town of Nantucket 2021a).

Nantucket should continue to work with residents and prospective residents to make housing more affordable and support their goal of restricting the spread of high-density development throughout the island. A strategy that the Affordable Housing Trust is planning to implement as of their 2021 plans, is to create a Community Land Trust (Town of Nantucket 2021a). This will allow families to purchase homes on land that is owned by the Land Trust for only the price of the home while leasing the land. This significantly decreases the purchase price, making housing more affordable and reducing high density developments by making existing properties affordable to single families. This may reduce the need for developers to create multi-unit affordable housing projects and thus reduce high density development.

5.3 Sea Level Rise & Erosion Considerations

Even though the sea level rise is based on a time scale of about 80 years from now (2100), it is still important that the Town of Nantucket plan for it. The IPCC reports from multiple sources that on these long-time scales, because of the uncertainty of the climate change analysis, a 50-meter sea level rise is possible. Furthermore, it is “virtually certain” that the sea will continue to rise past the year 2100. The amount of rise is dependent on future emissions profiles and what

humans have done to curb their emissions (Bindi et al. 2018). Regardless of sea level rise, we can see from past experiences that erosion has been an on-going issue for Nantucket and sea level rise is only expected to further intensify the effects of erosion. The Sankaty lighthouse was constructed in 1849, and yet 158 years later, the Town had to move it away from the disappearing coastline. There are many other structures, including homes, that were built over 100 years ago on the island that also needed to be relocated or were left to fall into the ocean. The timescale of these climate change effects may seem to be out of scope for municipal planning, but it seems that the trend is to retroactively plan as problems and their consequences become more real and serious. The time to plan for the island's future with climate change considerations is now. As discussed in chapter 4.3, coastal development also damages the healthy balance of ecosystems that support a robust coastline.

The Town of Nantucket hired consultants that published a Coastal Resiliency Plan (CRP) in November of 2021 (Arcadis et al. 2021). This plan discusses resilient strategies for a more robust coastal community on Nantucket given the impending impacts of climate change and coastal erosion. Their analysis of Nantucket's coastal resiliency has drawn attention to and addressed what this buildout analysis also seeks to point out. They identify essentially three different approaches to building a more robust coastline in Nantucket; protect, adapt, and relocate. Protecting Nantucket, which involves constructing floodwalls, deployable barriers, berms and levees, and bulkheads. Another way they identify is to adapt with the changing coastline by raising critical systems out of the basement to avoid flood damage, expanding culverts and increasing bridge heights, creating tidal parks, and beach nourishment. These two approaches are a little more retroactive than proactive, as they are a direct response to the impacts of climate change and coastal erosion. A more proactive approach is to analyze what the trends of climate change have been and

how they might advance in the future. The report groups together relocating, which is retroactive planning, with regulating growth, which is more proactive and what this thesis aims to draw attention to. Parts of the CRP recognize the importance of and support this thesis in its call for action against climate change through policy and proactive planning. For more information and details on the coastal resiliency plan, please visit the Town website⁶.

Along with regulating growth, the report points out that this can also include acquiring more land for preservation and implementing buyouts of buildings that are in coastal areas of high risk. This thesis identified the high-risk coastal flooding areas in the GIS analysis and removed them from further analysis in chapter 4.3. There was a reduction of 698 potential dwelling units from the original additional 14,561 in chapter 4.2. The additional dwelling units are more than the existing units on the island, which should not make it hard to limit coastal development when there is room for more development inland. Although, the coastal resiliency plan team points out that current development practices and norms conflict with resilient planning and may create pushback amongst developers. At the same time, they also agree that policy and regulatory strategies will be critical in protecting Nantucket's coastal community. Restricting coastal development and imposing coastal conservation setbacks will help support robust coastlines and contribute to coastal storm protection.

5.4 Septic & Sewer Considerations

The Town of Nantucket is mostly served by sewer and has plans to expand their sewer services. However, there are still properties that are served by private septic systems in high-risk

⁶ <https://www.nantucket-ma.gov/2030/Coastal-Resilience-Plan>

coastal areas and areas that can be detrimental to the water table and private wells. This report has identified the subdividable lots where additional homes may be added and can be readily connected to the Town sewer services. An updated sewer master plan analysis would be necessary to accurately depict the increase in wastewater flow within the Town sewer service areas. It has also identified the additional septic systems that will be necessary if subdivision occurs under the current zoning rules and regulations. It is best to reduce the nitrogen, excess nutrients, and contaminants that are released from septic systems to ensure a sustainable and healthy environment on Nantucket.

Even though wastewater treatment facilities are the most efficient at reducing nitrogen and excess nutrients, they are costly and a quick connection to a sewer main may not be physically feasible. An alternative, but more pricey option to the conventional septic system is an I/A system. These systems are more efficient at reducing excess nutrients before releasing the effluent into the ground. One recommendation that would support I/A systems over conventional would be to require I/As for all new construction and allow the owner to operate on the I/A for the manufacturer's life of the system before requiring the lot to connect to Town sewer. The Town could also offer a rebate if the lot is required to connect to Town sewer before the design life of the I/A is complete. Suffolk County in New York approved legislation in October of 2020 that went into effect July 1st of 2021, which required all new septic systems in new family residential construction, projects considered “major reconstruction”, new multi-family or non-residential projects, and all new commercial projects to have I/A systems installed (Town of Southampton, NY 2021). Suffolk county enacted this legislation in hopes of offsetting their lack of sewer infrastructure, reducing environmental nitrogen levels, and improving the overall quality of their water sources. They also implemented a Septic Improvement Program back in 2017 that provides

financial resources in assisting residents make the upgrade to I/A systems. This could attract some opposition from developers and landowners, but regulatory steps are necessary to adequately protect Nantucket's unique culture and environment from the negative side effects of excessive development pressures.

The EPA is currently working in partnership with Barnstable, MA to implement a neighborhood scale study of I/A systems (US EPA 2020). They plan to replace conventional septic systems with I/A systems in 40 homes starting back in early 2021. Through this study, they hope to provide more information about the performance measures and cost effectiveness of the deployed IA septic systems, an impact evaluation of the systems on groundwater nitrogen levels, and lessons learned that local, state, regional and federal partners can use in watersheds similarly compromised by traditional septic systems. Staying up to date with this study and the efforts of Suffolk County can provide Nantucket with the tools to implement policies in support of I/A systems to improve and protect the water quality on the island.

The previous suggestion only addresses the new septic systems that will be needed for new development, but there are existing septic systems that are detrimental to the health of the island as well. The ones that are located too close to the coast or the ones in sensitive areas that can flood often may need to be relocated. Although relocating a septic is not easy, as there are regulations that most likely caused it to be put where it is now. For example, if there is an onsite private well, then the septic system has to be located downhill of the well so the effluent does not directly flow into the drinking water supply. Other regulations restrict how close it can be to natural resources like wetlands and open water. Relocating a septic on a small lot can also contribute to the challenge. Encouraging residents to reduce their flow into septic systems on days of flooding or heavy rains can also reduce effluent flow into already saturated soils that will not be able to

effectively filter out excess nutrients as the soil could on dryer days. Some residents are already taking the initiative to install I/A systems on their properties and supporting the switch from conventional to I/A could also be another approach for the Town. Nantucket should seek funding to assist the current residents that are not near any sewer mains to switch to I/A systems in the short term while the Town develops more sewer mains and wastewater treatment plants.

5.5 Water Resources Considerations

Just as septic and sewer services, water demand will also increase with an increase in development and residents. As residents expand or build new homes this will also allow for a higher influx in summer vacationers and tourists. Since the public water companies on the island are already at their pumping capacities or exceeding, more public wells or private wells will need to be drilled to meet the growing demand. This will increase the stress on the aquifer as pressures from climate change also increase stress on the aquifer. However, because Nantucket draws from a sole source aquifer, they have the ability to study its yield and ensure that their withdrawal is sustainable. The Town should hire a consultant to analyze the yield of the aquifer and compare it to the current and future water demands of the Town. These demands should not be exclusive to the public water supply. It is important that the analysis capture the entire picture of water withdrawal, including the private wells on the island. With a full picture of the aquifer yield, development should be restricted so that the demand does not exceed a safe percentage of this yield, allowing for aquifer regeneration and preventing saltwater intrusion.

With SLR, erosion, and high-water demand, saltwater intrusion is a concern for water quality and availability. SLR may also damage the water quality inadvertently through the release of effluent from septic systems. As sea level rises, so does the water table. The CRP for Nantucket shows a map of the depth to groundwater in 2050. However, the plan does not discuss which SLR

scenario or the rate of groundwater rise that has occurred to result in this map. With a clarified data analysis, the Town should analyze in which areas the water table is above four feet (Title V requirement for septic systems), and in those areas whether there is an existing septic system or there may be a future septic system as predicted in this potential buildout analysis. Regulations and zoning changes should restrict development in these areas to protect the groundwater quality of the island. Regulations should also be pushing these areas as high priority to be connected to the public sewer services or upgrade to an I/A septic system.

There are water resource mitigation and adaptation strategies that can be used to preserve the water quality and quantity on the island outside of focusing on septic systems. The CRP for Nantucket calls out some best practices to combat coastal erosion that can also assist with water resource management. These best practices include redirecting stormwater runoff away from coastal areas, removing or reducing impervious areas, and retaining stormwater. Redirecting the stormwater away from coastal areas by constructing a vegetated berm, constructing drainage pipes, and re-grading a site can reduce runoff and retain water by directing it to areas that are less saturated and contain more permeable soils. Removing or reducing impervious areas also works to allow for more stormwater infiltration that recharges the groundwater table. Residents can reduce driveway pavement or use pavers that allow for some infiltration around the stone, install rain gardens and vegetative swales. Residential, commercial, and municipal buildings can install rain barrels that capture roof runoff, which can then be used for watering or other purposes. Aside from direct investment into stormwater infrastructure, the above stated private solutions to water resource mitigation are a viable alternative to offload some municipal investment responsibility onto property owners.

To support implementation of water resource management and climate change adaptation, Miller and Belton (2014) describe an innovative methodological framework for planning development that was developed by the United Nations Environment Program. The first suggestion is to optimize spending on green infrastructure and implement a metric that compares capital investment to improved performance, whatever that may be, ie. increased freshwater yield or area protected. To reduce municipal spending and shift the responsibility more directly to property owners as stated above, the Town could implement policies that reward private investments either through tax breaks or rights to recharged water. The report also suggests complying with the required timing of policy interventions by creating a modular approach that allows for flexibility as more information regarding the local hydrological conditions and climate impacts become available. As stated in the literature review in chapter 2, climate change models are evolving as more data and information becomes available. It is imperative that Nantucket conservatively plan for the future impacts of climate change with flexibility in mind.

6.0 LIMITATIONS

With any analysis and research, there are limitations to the work that may include time constraints, individual capabilities, data uncertainties, and software access. It is important to make note of these limitations as to indicate how future research and planning could improve. It is also important to acknowledge where this report has limitations so that others who reference it can recognize and pass judgment on how heavily they want to rely on the data. A study without limitations, does not acknowledge its own faults and is therefore narrowly written.

As with any map layer acquired from another source, the data is only as accurate as the creator makes it to be. All map layers were obtained from either the Town of Nantucket or the MassGIS database. Even though the most up to date maps were obtained for the analysis, this meant that some layers were not updated since 2006. What is reported in this report is only as accurate as the data provides. Additionally, this study was not able to obtain a list of residents served by the Town water to obtain a precise map for chapter 4.5. Instead, the water main layout was provided in a GIS layer. All properties that fell within 20 ft of the water main and contained a building value in the assessor's data table were considered to be on Town water.

Some data management was needed to obtain the existing dwelling units and buildings on the island. This data was not readily available in an easy format to utilize. Even by going through each property card, there were some discrepancies and assumptions that had to be made in order to move forward. For example, one data source reported a property in one zoning district while the property card reported a different district. When reviewed further, some properties sat in between the districts and may have changed recently but was not reflected in all documentation. Changes in zoning, construction of new buildings and developments happen all the time. At some point, updates to the data had to stop for the analysis to move forward.

This study was not able to obtain maps which depicted the height of the groundwater table throughout the island. This would have been used to identify areas where the water table would be too high for septic systems due to SLR, and the subsequent groundwater table rise. Instead, the predetermined nitrogen sensitive areas as depicted in the water protection districts were used to identify the potential future development that could cause damage to existing areas of concern. The CRP depicts a groundwater table map for the year 2050. Though the layers used in this analysis by the CRP are not readily available online, which means that they may have been produced by the consultant. Further analysis would include obtaining those layers and conducting the analysis stated above.

Specific site design requirements such as the septic and sewer restrictions under Title V were not built into the buildout analysis. Setbacks, building footprint, and other site orientation and design was also not worked into the analysis. This would require more time and analysis and it is outside the scope of this project to design each and every lot on the island. As discussed in the literature review, there are applications that make this process a bit easier, but the study did not have access to such or the basic knowledge on how to utilize them.

One of the main focuses of this Thesis was to maintain contact and feedback from the Town of Nantucket. Unfortunately, because of unforeseen circumstances this study did not get to meet with the Town as much as was intended. The Town provided sufficient feedback for buildout analysis through meetings, but because of the extremely busy nature of the Town planning office at the time, the other climate change considerations were not able to be discussed with the Town, thus limiting the amount of meetings with the Town to only two. For future buildout analyses, it would be important to establish set dates for meetings and hold to those deadlines, as

Town offices can be overwhelmed with other work that would cause impromptu meetings to be pushed aside.

Despite these limitations, this thesis makes an important contribution to the planning realm for municipalities regarding future growth and climate change. It synthesizes the growth capabilities of a small island community with the existing and potential impacts of climate change. It includes considerations for the major services necessary to sustain the way we operate and live. It also includes considerations for how these services may be impacted by climate change. It then closes by recommending how a small island community can plan for a sustainable future in the face of climate change challenges and developmental pressures.

REFERENCES

- Arcadis. 2021. “Baxter Road Long Term Planning FINAL MEMO 10_20.” Arcadis, 84.
- Arcadis, Stoss, ONE Architecture, and The Craig Group. 2021. “Coastal Resilience Plan | Nantucket, MA - Official Website.” Coastal Resilience Plan. 2021. <https://www.nantucket-ma.gov/2030/Coastal-Resilience-Plan>.
- Balsas, Carlos J. L. 2021. “GIS Buildout Analysis and Urban Planning.” *Chinese Journal of Urban and Environmental Studies* 09 (01): 17. <https://doi.org/10.1142/S2345748121500068>.
- Barr, Jonathan, Peter Durkin, James Heineman, and David Simpson. 2018. “Nantucket Buildout Analysis.” 2018. <https://digital.wpi.edu/pdfviewer/7m01bm16z>.
- Bindi, Marco, Sally Brown, Ines Camilloni, Arona Diedhiou, Riyanti Djalante, Kristie Ebi, Francois Engelbrecht, et al. 2018. “Chapter 3 — Global Warming of 1.5 °C.” In *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*. <https://www.ipcc.ch/sr15/chapter/chapter-3/>.
- Brace, Peter. 2015. “Coastal Erosion Is Everyone’s Problem.” Nantucket Chronicle. 2015. <https://www.nantucketchronicle.com/outdoors/2015/coastal-erosion-everyones-problem>.
- Christie, Governor Chris, and Lt Governor Kim Guadagno. 2017. “New Jersey Water Supply Plan 2017-2022,” 102.
- Cisneros, Jimenez, Taikan Oki, N.W. Arnell, Gerardo Benito, J.Graham Cogley, Petra Doll, Tong Jiang, and Shadrack Mwakalila. 2014. “3 — Freshwater Resources.” *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 229–69.
- Conway, Tenley, and Richard Lathrop. 2004. “Alternative Land Use Regulations and Environmental Impacts: Assessing Future Land Use in an Urbanizing Watershed - ScienceDirect.” *Landscape and Urban Planning* 71 (1): 1–15.
- “FAQs • Nantucket, MA • CivicEngage.” 2020. 2020. <https://www.nantucket-ma.gov/Faq.aspx?QID=289>.
- FEMA. 2012. “FEMA Region I Coastal Erosion Hazard Map.” 2012. <https://fema.maps.arcgis.com/apps/webappviewer/index.html?id=a4aa86031a3a40be9d453d781ff210b3>.
- Frenchman Bay Conservancy. 2020. “Build-Out Analysis, City of Ellsworth.”
- Hayley and Ward, Inc. 2011. “Source Final Report: North Pasture Well, Nantucket MA.” Board of Water Commissioners of the Wannacomet Water Co.
- Hozid, Zachary. 2017. “The Hidden Risk to Clean Water in the Age of Climate Change: Septic Systems.” Conservation Law Foundation. February 24, 2017. <https://www.clf.org/blog/climate-change-risks-septic-systems/>.
- Iturbide, M, J Fernandez, J.M. Guiterrez, J Bedia, E Cimadevilla, J Diez-Sierra, R Manzananas, et al. 2021. “Repository Supporting the Implementation of FAIR Principles in the IPCC-WG1 Atlas.” 2021. <https://interactive-atlas.ipcc.ch/atlas>.
- Lindsey, Rebecca. 2020. “Climate Change: Atmospheric Carbon Dioxide.” *Nature*, August. <https://doi.org/10.1038/nature06949>.

- Massachusetts Association of Conservation Commissions. n.d. “Wetlands Protection Act FAQ’s - Massachusetts Association of Conservation Commissions.” MACC. Accessed November 22, 2021. <https://www.maccweb.org/page/ResWPAFAQS>.
- MassDEP. 2022a. “Innovative Technology and Title 5 Systems | Mass.Gov.” 2022. <https://www.mass.gov/guides/innovative-technology-and-title-5-systems>.
- . 2022b. “WM03: Water Management Withdrawal Permits | Mass.Gov.” 2022. <https://www.mass.gov/how-to/wm03-water-management-withdrawal-permits>.
- MassGIS (Bureau of Geographic Information). 2021. “MassGIS Data: Protected and Recreational OpenSpace | Mass.Gov.” Mass.Gov. July 2021. <https://www.mass.gov/info-details/massgis-data-protected-and-recreational-openspace>.
- McCarthy, Jeannette A. 2006. “Waltham, Massachusetts - Buildout Analysis, 2006,” 45.
- Mihaly, Elena. 2018. “Avoiding Septic Shock: How Climate Change Can Cause Septic System Failure and Whether New England States Are Prepared.” *Ocean and Coastal Law Journal* 23 (1): 1.
- Miller, Kathleen A., and Valerie Belton. 2014. “Water Resource Management and Climate Change Adaptation: A Holistic and Multiple Criteria Perspective.” *Mitigation and Adaptation Strategies for Global Change* 19 (3): 289–308. <https://doi.org/10.1007/s11027-013-9537-0>.
- Milone & MacBroom Inc. 2020. “Town of Nantucket Coastal Risk Assessment and Resiliency Strategies.”
- Moore, Trisha L., John S. Gulliver, Latham Stack, and Michael H. Simpson. 2016. “Stormwater Management and Climate Change: Vulnerability and Capacity for Adaptation in Urban and Suburban Contexts.” *Climatic Change* 138 (3): 491–504. <https://doi.org/10.1007/s10584-016-1766-2>.
- Morrison, Peter, Brad Edmondson, Kristie Ferrantella, David Lockhart, Samantha Reis, and Anna Tapp. 2020. “Estimating Nantucket’s Effective Population.” *Population Research and Policy Review* 39 (June). <https://doi.org/10.1007/s11113-019-09565-8>.
- Nicholls, Robert. 2011. “Planning for the Impacts of Sea Level Rise.” *Oceanography* 24 (2): 144–57. <https://doi.org/10.5670/oceanog.2011.34>.
- Nurse, L.A., R.F. McLean, J. Agard, L.P. Briguglio, V. Duvat-Magnan, N. Pelesikoti, E. Tompkins, and A. Webb. 2014. “29 - Small Islands.” *Climate Change 2014: Impacts, Adaptation, and Vulnerability Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 1613–54.
- Patrick, Deval L, Timothy P Murray, Ian A Bowles, Mary B Griffin, WAYNE F MacCALLUM, Henry Woolsey, Andrew Finton, and JAMES DeNORMANDIE. 2010. “BioMap2: Conserving the Biodiversity of Massachusetts in a Changing World,” 64.
- Peconic Land Trust. n.d. “Climate, Conservation and Stewardship.” Peconic. Accessed March 7, 2022. <https://peconiclandtrust.org/our-work/climate-conservation-and-stewardship>.
- Pukui, Mary Kawena. 2021. “Community Guide to Hawai’i Land Conservation.”
- Rozum, John S., Chester L. Arnold, and Emily H. Wilson. 2007. “About Buildouts.” CT Nemo.
- ’Sconset Trust. 2022. “Sankaty Head Lighthouse - ’Sconset Trust.” 2022. <https://www.sconsettrust.org/preservation/sankaty-head/>.
- Snoussi, Maria, Saïda Niazi, Abdou Khouakhi, and Otmene Raji. 2011. “Climate Change and Sea-Level Rise: A GIS Based Vulnerability and Impact Assessment, the Case of the Moroccan Coast.” In *Geomatic Solutions for Coastal Environments*, 275–310.

- Son, Jihoon. 2009. "Residential Build-Out Analysis Based on Zoning." 2009. <https://www.esri.com/news/arcuser/0109/buildout.html>.
- Spaulding, Malcolm, Annette Grilli, Chris Damon, Reza Hashemi, Soroush Kouhi, and Grover Fugate. 2020. "Stormtools Design Elevation (SDE) Maps: Including Impact of Sea Level Rise." *Journal of Marine Science and Engineering* 8 (April): 292. <https://doi.org/10.3390/jmse8040292>.
- State of Massachusetts. 2016. *310 CMR 15: State Environmental Code, Title 5: Standard Requirements for the Siting, Construction, Inspection, Upgrade and Expansion of on-Site Sewage Treatment and Disposal Systems and for the Transport and Disposal of Septage* | Mass.Gov. <https://www.mass.gov/regulations/310-CMR-15-state-environmental-code-title-5-standard-requirements-for-the-siting>.
- Stocker, Fabricio, Michelle P. de Arruda, Keysa M. C. de Mascena, and João M. G. Boaventura. 2020. "Stakeholder Engagement in Sustainability Reporting: A Classification Model." *Corporate Social Responsibility and Environmental Management* 27 (5): 2071–80. <https://doi.org/10.1002/csr.1947>.
- Town of Nantucket. 2021a. "Affordable Housing Trust | Nantucket, MA - Official Website." 2021. <https://www.nantucket-ma.gov/184/Affordable-Housing-Trust>.
- . 2021b. "Town of Nantucket, MA: Zoning." Town of Nantucket, MA Code. 2021. <https://ecode360.com/11471474>.
- . 2022. "Town of Nantucket Board of Health Regulations." <https://www.nantucket-ma.gov/229/Regulations>.
- Town of Southampton, NY. 2021. "Suffolk County Introduces New I/A OWTS Requirements Effective July 1." *Bridgewater Environmental Services* (blog). July 1, 2021. <https://www.bridgewaterenviro.com/suffolk-county-introduces-new-i-a-owts-requirements-effective-july-1/>.
- UMass Amherst. 2021. "Massachusetts Keeps Pace with U.S. Growth; Island Counties Show Big Gains and Cape Cod Reverses Population Drain: UMass Amherst." August 2021. <https://www.umass.edu/news/article/massachusetts-keeps-pace-us-growth-island-counties-show-big-gains-and-cape-cod>.
- U.S. Census Bureau. 2021. "U.S. Census Bureau QuickFacts: Nantucket Town, Nantucket County, Massachusetts." 2021. <https://www.census.gov/quickfacts/nantuckettownnantucketcountymassachusetts>.
- . n.d. "Households and Persons Per Household." Accessed March 11, 2022. <https://www.census.gov/quickfacts/fact/note/US/HSD410219>.
- US EPA. 1984. "Nantucket 49 FR 2952." Overviews & Factsheets. 1984. <https://www3.epa.gov/region1/eco/drinkwater/solenan.html>.
- . 2018. "Types of Septic Systems." Overviews and Factsheets. November 15, 2018. <https://www.epa.gov/septic/types-septic-systems>.
- . 2020. "Innovative/Alternative Septic Systems." Overviews and Factsheets. April 6, 2020. <https://www.epa.gov/water-research/innovativealternative-septic-systems>.
- Walton, Bruce. 2020. "Distributed Nitrogen Removing I/A Septic Systems: A 2020 Primer for Cape Cod." *NEWEA - New England Water Environment Association* (blog). October 9, 2020. <http://www.newea.org/2020/10/09/distributed-nitrogen-removing-i-a-septic-systems-a-2020-primer-for-cape-cod/>.
- Weston & Sampson. 2020. "Sewer Master Plan." Weston & Sampson. <https://www.nantucket-ma.gov/DocumentCenter/View/36750/Nantucket-Sewer-Master-Plan-Report-FINAL>.

- Willis, Haisten. 2021. “Accessory Dwellings Offer One Solution to the Affordable Housing Problem.” *Washington Post*, 2021. https://www.washingtonpost.com/realestate/accessory-dwellings-offer-one-solution-to-the-affordable-housing-problem/2021/01/07/b7e48918-0417-11eb-897d-3a6201d6643f_story.html.
- World Climate Research Programme. 2021. “WCRP Coupled Model Intercomparison Project (CMIP).” World Climate Research Programme. 2021. <https://www.wcrp-climate.org/wgcm-cmip>.
- Yazicigil, Hasan, Koray K. Yilmaz, Burcu Unsal Erdemli, and Ozlem Yagbasan. 2011. “Impacts of Decreasing Recharge Rates on Sustainable Groundwater Management.” In *Climate Change and Its Effects on Water Resources*, edited by Alper Baba, Gökmen Tayfur, Orhan Gündüz, Ken W.F. Howard, Michael J. Friedel, and Antonio Chambel, 43–50. NATO Science for Peace and Security Series C: Environmental Security. Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-007-1143-3_6.
- Zirkle, Mary A. 2003. “Build-Out Analysis as a Planning Tool With a Demonstration for Roanoke County, Virginia,” April. <https://vtechworks.lib.vt.edu/handle/10919/37087>.

APPENDIX 1-A

List of Undevelopable Parcel Owners & Meeting Notes

Andrew
Leslie
Dan + Sydney



Town of Nantucket, MA

Build-Out Study

Progress Meeting
Wednesday, October 20, 2021

Building permits →
Agenda replacement units

1. Overview of work to date

- Data compiled
- Methodology Summary
 - Are there any additional constraints that we did not address?
 - Thesis

2. Data/map review and questions

- Review Nantucket owned parcels for potential development
- Review/confirm conserved land parcels (see listing on following page)
- Discuss bedroom lot restrictions – the rules and regs state SF per bedroom for apartment building and residential lots. See next question, also the SF conflicts between two different regs.
- Discuss septic sizing and restrictions –
 - In your minimum lot sizes, were septic systems considered?
- Review possible rezoning for any parcels in the town
 - Could any parcels be rezoned?
- Sea Level Rise was analyzed and it is covered by coastal storm and other water buffers.
- Is Sconset residential treated differently than the rest of the residential in regard to minimum lot size and bedroom allowance? Sconset has its own zoning code, but that zoning code is not referenced anywhere in the rules and regs.

see
definitions

IA - Dan?

Rezoned?
No major
in works.

3. Data Needed from Town

- GIS layers for each District below:
 - All overlay districts
- GIS layer for water service areas
- Public well permits and permitted withdrawal rates
- Documentation of private wells

- will send
updated zoning
layer

- 40,000 +

• Tom Nevers -
not build w/
septic
BC you
are in

4. Next steps

- Existing efforts and where should we partner
- Analysis
 - Maximum build-out and projected build-out
- Public meetings
- Next meeting with the Town - schedule

Carrying
Capacity

overfield

see Mr

Sconset - all tertiary
allowed - check
use chart

won't force
rental
talking
about
extending
to Sconset
district.
Bonus lot
but not
da

Pond St.

Seal Watch
area conservation
rdn

Russell's Way
remove as industrial

Listing of conserved properties to be confirmed.

Conserved

- Golf Clubs - Miacomet, Sconset, Nantucket Golf, Sankaty Head
- Tuckernuck Island - conserved
- US Coast Guard - Sconset. Parcel has Coast Guard housing.
- Sconset Trust Inc - Land Bank (conserved)
- Mass Audubon Society - unbuildable
- Commonwealth of Mass - DEM. Fairgrounds - house south will be developed
- Nantucket Land Bank - conserved
- Nantucket Conservation Foundation - conserved
- Nantucket Land Council - conserved
- Nantucket Historical Association - windmill + park for personnel
- Fishers Landing Assoc. Inc - Warrens Landing Rd Park @ same density
- EK Associates LLC - Finback Lane nd
- Ogren Peter J Trst - Nanahumacke Lane nd
- Tetawkimmo Commons Assoc. Trust - Tetawkimmo Dr nd
- Bluefin Partners LLC - Ellen's Way nd
- Madaket Conservation Land Trust nd
- Madaket Land Trust nd
- Nantucket Airport Commission nd
- Phillips Run Road Homeowners Assoc. Phillips Run in Sconset nd
- Bartlett Farm LLC - conserved
- BOVF LLC - 33 Bartlett Farm Rd conserved
- Hummock Pond of NHA Inc - conserved
- Prospect Hill Cemetery nd
- Catholic Cemetery nd
- Seal Watch LLC Area will go as well zoned
- FOLGER TRUST & NILB (include in layer) - nc
- Folger Square Trust - 10 Folger Lane (Greenbelt land use code) nd
- CONGDON MARION L TR - 71 N Pasture Lane open space
- Robert Greenhill Trust - Hoicks Hollow Road - (Multi WF land use code)
- Nathan Allen Trust - Gay St, Quince St, Coatue nd
- Trustees of Reservations - Great Point
- 6 Nobadeer Ave - shown as Town property and private property
- 8 Nobadeer Ave - shown on tax parcel layer as 16 Folger Ave
- 80 Millbrook - parcel 78 - now Nantucket Conservation Foundation?
- William Graves Trust - Chase Links Circle - sections of parcels are shown as restricted open space (cluster)
- 345 Madaket Road - shown as town owned and private? Madaket Milk LLC (not buildable) @ end of road.
- 56 Madequecham Vallet - part town owned? Land use code - Multi WF land use code - (Road = town. Rest is private)
- 17 Clarendon - shown as both town owned and private
- 4 Kendrick - shown as both town owned and private - will already be built
- Multiple properties with Land Use Code - RES ACLNDV M00
- (5 Weeweeder 54 & 58 Miacomet Rd, 5 Burnt Swamp 11 Chase Links) (w/ 4 nobadeer Buildable unbuildable restricted)

Burnt Pt
not develop.

Gwin Uge

Housing
Authority
@ Tom Nevers
Rd.
not developable

not
level.

Subdividing

Hydrangea
Rd - developed
Sconset
Hydrangea
conserved
as open space

Bright Island
Tom Nevers

error
in parcel

no hsg

Airport Comm = buffer
no housing @ airport no housing

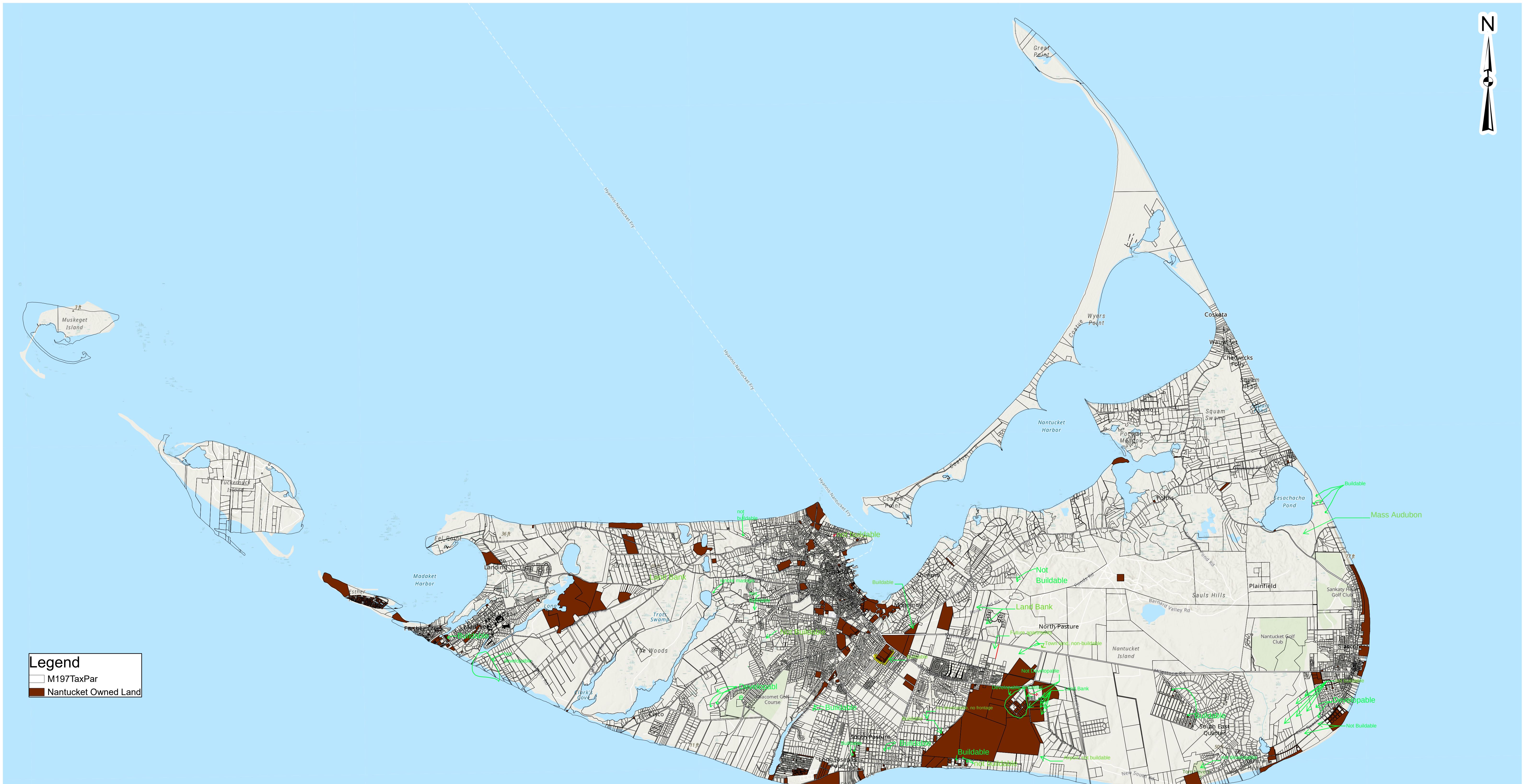
homes on
Cantebury
now develop.

to CN zoning
marijuana
+ LUGZ
develop

Leslie
will
send
Buildings
lower
in fees
5000-
80 000
SP

APPENDIX 1-B

Marked-Up Map of Undevelopable Parcels



Legend

- M197TaxPar
- Nantucket Owned Land

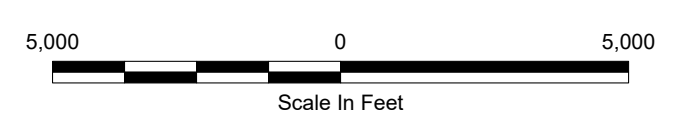


FIGURE X	
TOWN OF NANTUCKET, MASSACHUSETTS	
BUILD-OUT ANALYSIS	
DEVELOPMENT CONSTRAINTS	
AUGUST, 2021	SCALE: NOTED

APPENDIX 2-A

Maximum Buildout Analysis Excel Sheet

OBJECTID	TARGET_FID	MAP_PAR_ID	LOC_ID	POLY_TYPE	BLDG_VAL	FY	LOT_SIZE	USE_CODE	SITE_ADDR	District	SHAPE_Length	SHAPE_Area	AREA (SF)	leftover_AREA	COM_MIN_LC	AD_LOT	BLDG	DWL_UNIT	P_DWL_UNIT	AD_DWL_UNIT
1	13478	11 28	F_1067636	FEE	3759900	2021	6.2148	1093	84 WAUWINET RD	LUG-3	358.2793881	6521.654928	70173	0			0	3	3	3
2	13469	14 18	F_1066869	FEE	0	2021	25.1948	1303	78 WAUWINET RD	LUG-3	1356.291531	26561.40334	285801	285801			2	0	0	3
3	13496	11 25	F_1068534	FEE	1497700	2021	3.3048	1093	98 WAUWINET RD	LUG-3	437.5513026	6978.198369	75085	0			0	2	2	3
4	13499	11 24.1	F_1068767	FEE	0	2021	2.0783	1303	100 WAUWINET RD	LUG-3	445.191986	3828.363715	41193	41193			0	0	0	3
5	13505	11 24.3	F_1068506	FEE	3391500	2021	3.0783	1013	100R WAUWINET RD	LUG-1	342.4951831	3685.711882	39658	0			0	1	1	3
6	13509	11 24.2	F_1068804	FEE	800600	2021	2.3883	1093	102 WAUWINET RD	LUG-1	475.8933369	5671.258254	61023	9708.714286			0	2	2	3
8	13477	11 27.3	F_1068336	FEE	3938100	2021	2.7848	1090	88 WAUWINET RD	LUG-3	436.6890447	11258.34302	121140	0			0	2	2	3
9	13481	11 27.4	F_1067963	FEE	1561700	2021	5.0348	1013	86 WAUWINET RD	LUG-3	607.8191149	17808.51088	191620	0			0	1	1	3
10	13491	11 26	F_1068345	FEE	1655300	2021	12.9048	1013	94 WAUWINET RD	LUG-3	1029.317355	24159.44065	259956	32189.33333			0	1	1	3
11	13383	14 21	F_1066888	FEE	484200	2021	3.1048	1010	59 WAUWINET RD	LUG-3	319.3727332	6142.061138	66089	0			0	1	1	3
12	13396	14 20	F_1066863	FEE	1308300	2021	3.5	1010	61 WAUWINET RD	LUG-3	357.3398746	7439.321369	80047	0			0	1	1	3
13	13366	14 65	F_1066388	FEE	428000	2021	1.2	1010	58 WAUWINET RD	LUG-3	279.6768497	4783.375128	51469	0			0	1	1	3
14	13504	12 58	F_1069472	FEE	2853100	2021	0.9248	1010	5 PLOVER LN	R-1	539.1014	3626.723383	39024	8944			1	1	1	2
16	13500	12 60	F_1069714	FEE	3160900	2021	0.9248	109R	107 SQUAM RD	R-1	695.0505792	4052.057552	43600	20960			3	2	2	6
18	13498	12 40.1	F_1069211	FEE	0	2021	0.2	1310	95 WAUWINET RD	R-1	124.3134007	842.7346409	9068	9068			1	0	0	2
19	13503	12 59	F_1069307	FEE	3218100	2021	0.9348	109R	4 PLOVER LN	R-1	553.1596542	3330.445177	35836	13169.33333			2	2	2	4
20	13387	14 11.2	F_1064639	FEE	1223200	2021	2.76	1090	19 POCOMO RD	LUG-3	339.6605473	6185.908356	66560	0			0	2	2	3
21	13392	14 90	F_1064430	FEE	2287100	2021	2.7548	109R	21 POCOMO RD	LUG-3	272.8229891	2345.026342	25232	0			0	2	2	3
22	13418	14 53	F_1064420	FEE	677000	2021	2.9948	1010	7 LAURETTA LN	LUG-3	124.4522204	711.550233	7656	0			0	2	2	3
23	13400	14 50	F_1063942	FEE	210500	2021	0.41	1013	29 POCOMO RD	LUG-3	23.01133231	14.74734347	159	0			0	1	1	3
24	13402	14 51	F_1064114	FEE	0	0	0			LUG-3	194.2666064	1081.195988	11634	11634			0	1	1	2
25	13398	14 48	F_1063736	FEE	0	2021	1.1	1300	31 POCOMO RD	LUG-3	115.8479289	420.2898053	4522	4522			0	0	0	3
26	13399	14 49	F_1063853	FEE	175700	2021	0.55	1013	31 POCOMO RD	LUG-3	129.1138329	708.9057682	7628	0			0	1	1	3
27	13441	14 56.2	F_1064768	FEE	2332900	2021	3.34	1093	11 LAURETTA LN	LUG-3	199.2536238	2324.965307	25017	0			0	2	2	3
28	13407	14 14.2	F_1065625	FEE	0	2021	3.3248	1300	2 COSKATA COURSE WY	LUG-3	621.9080553	9433.002081	101499	101499			0	0	0	3
29	13385	14 64	F_1066369	FEE	479800	2021	1.2	1010	60 WAUWINET RD	LUG-3	286.5496052	5012.352093	53933	0			0	1	1	3
30	13386	14 14.3	F_1065874	FEE	0	2021	3.6248	1300	1 COSKATA COURSE WY	LUG-3	511.9197649	14997.54201	161374	161374			1	0	0	3
31	13410	14 14.6	F_1066105	FEE	0	2021	3.7448	1300	3 COSKATA COURSE WY	LUG-3	613.8399015	15297.55239	164602	164602			1	0	0	3
32	13412	14 63	F_1066347	FEE	417700	2021	2.34	1010	62 WAUWINET RD	LUG-3	387.9650163	9306.620047	100139	21205.66667			0	1	1	2
33	13454	14 14	F_1065590	FEE	27393800	2021	12.6448	1093	4 COSKATA COURSE WY	LUG-3	975.0564169	44160.12045	475163	0			0	4	4	3
34	13460	14 14.1	F_1065919	FEE	0	2021	9.6248	1303	5 COSKATA COURSE WY	LUG-3	985.613848	31553.29367	339513	339513			0	2	0	3
35	13425	14 62	F_1066314	FEE	753100	2021	2.5	1090	4 FARGO WY	LUG-3	399.0997749	9834.065082	105815	9581.666667			0	2	2	3
36	13440	14 61.1	F_1066278	FEE	1767600	2021	2.98	1010	6 FARGO WY	LUG-3	465.7748085	13187.47341	141897	0			0	1	1	3
37	13457	14 61	F_1066259	FEE	10624200	2021	3.0248	1093	8 FARGO WY	LUG-3	426.7385046	10794.1536	116145	0			0	2	2	3
39	13464	14 17	F_1066287	FEE	952100	2021	1.62	1093	14 FARGO WY	LUG-3	200.0342041	2123.486911	22849	0			0	2	2	3
40	13375	15 19	F_1062297	FEE	4787500	2021	3.0748	1093	47 POCOMO RD	LUG-3	303.5063314	5640.339826	60690	0			0	3	3	3
41	13393	15 20	F_1062733	FEE	4697200	2021	4.6048	1093	43 POCOMO RD	LUG-3	428.1324045	4830.979595	51981	0			0	2	2	3
42	13374	14 80	F_1063539	FEE	3436000	2021	3.6	1090	33 POCOMO RD	LUG-3	468.4672593	9291.035712	99972	0			0	3	3	3
43	13376	14 38	F_1063221	FEE	0	2021	2.7	1300	37 POCOMO RD	LUG-3	465.2910471	11623.91706	125073	125073			0	0	0	3
44	13378	14 39	F_1063109	FEE	483600	2021	0.18	1010	10 VILLAGE WY	LUG-3	112.0960072	784.7384305	8444	0			0	1	1	3
45	13379	14 41	F_1063196	FEE	182300	2021	0.1998	1010	8 VILLAGE WY	LUG-3	109.8140871	752.2593849	8094	0			0	1	1	3
46	13381	14 42	F_1063270	FEE	114600	2021	0.12	1010	6 VILLAGE WY	LUG-3	96.04795775	555.0420954	5972	0			0	1	1	3
47	13388	14 43	F_1063378	FEE	219600	2021	0.31	1010	9 VILLAGE WY	LUG-3	153.7723398	1311.250876	14109	0			0	1	1	3
48	13389	14 44	F_1063456	FEE	1127900	2021	0.2961	1010	7 VILLAGE WY	LUG-3	115.9259949	231.1836091	2488	0			0	1	1	3
49	13401	15 20.1	F_1062975	FEE	528000	2021	3.8548	1013	41 POCOMO RD	LUG-3	537.1012303	11876.03907	127786	0			0	1	1	3
50	13405	14 45	F_1063360	FEE	899700	2021	0.35	1010	13 VILLAGE WY	LUG-3	106.3079751	722.4626035	7774	0			0	1	1	3
51	13408	14 46	F_1063434	FEE	208800	2021	0.3655	1010	11 VILLAGE WY	LUG-3	54.80683252	73.74172553	793	0			0	1	1	3
52	13409	14 1	F_1063167	FEE	253400	2021	1.48	1013	12 VILLAGE WY	LUG-3	198.4990455	1630.011411	17539	0			0	1	1	3
53	13361	15 16	F_1061590	FEE	3673200	2021	3.9648	1093	57 POCOMO RD	LUG-3	423.1059699	11011.03554	118479	0			0	2	2	3
54	13362	15 18	F_1061870	FEE	4220200	2021	2.7748	1093	55 POCOMO RD	LUG-3	392.6134852	7702.969156	82884	0			0	3	3	3
55	13368	15 17	F_1062088	FEE	401700	2021	2.8148	1013	53 POCOMO RD	LUG-3	346.8307881	6535.724744	70324	15524			0	1	1	3
56	13351	15 12	F_1061147	FEE	411900	2021	0.89	1013	63 POCOMO RD	LUG-3	291.6826287	2031.591211	21860	0			0	2	2	3
57	13352	15 15	F_1061274	FEE	474300	2021	1.5	1013	61 POCOMO RD	LUG-3	215.459187	2911.133649	31324	0			0	1	1	3
58	13394	15 3	F_1059688	FEE	1567300	2021	4.9348	1093	81 POCOMO RD	LUG-3	443.4659008	8478.577978	91229	0			0	2	2	3
59	13258	20 7	F_1066676	FEE	650400	2021	4.2	1090	41 WAUWINET RD	LUG-3	589.6941992	13365.48898	143813	42213			0	2	2	3
60	13259	20 53	F_1066997	FEE	1448100	2021	2.8	1090	4 OLD QUIDNET MILK RT	LUG-3	489.4186673	6113.67626	65783	0			0	2	2	3
62	13271	14 30	F_1065930	FEE	0	2021	2.32	1300	8 POCOMO RD	LUG-3	360.9222355	6695.614295	72045	72045			0	0	0	3
63	13363	14 22	F_1066914	FEE	1897400	2021	3.2148	109R	57 WAUWINET RD	LUG-3	289.1716747	4603.023789	49529	0			0	2	2	3
65	13263	20 8.7	F_1067243	FEE	929600	2021	3.2	1090	6 OLD QUIDNET MILK RT	LUG-3	271.1538601	1413.676221	15211	0			0	2	2	3
66	13274	14 27	F_1066734	FEE	712200	2021	1.6	1090	45 WAUWINET RD	LUG-3	327.5050717	6079.228865	65413	0			0	2	2	3
67	13275	20 8.6	F_1067344	FEE	398300	2021	3.4	1010	8 OLD QUIDNET MILK RT	LUG-3	177.7345795	675.1632935	7265	0			0	1	1	3
68	13285	14 26	F_1066772	FEE	601600	2021	1.5	1090	49 WAUWINET RD	LUG-3	293.3222717	4984.288693	53631	0			0	2	2	3
69	13298	14 68.2	F_1066382	FEE	636400	2021	3.0048	1010	50 WAUWINET RD	LUG-3	220.3386556	901.4452459	9700	0			0	1	1	3
70	13314	14 70	F_1065548	FEE	2166000	2021	4.6	1010	12 POCOMO RD	LUG-3	558.1424072	18418.33587	198181	0			0	1	1	3
71	13316	14 69	F_1065897	FEE																

APPENDIX 2-B

Numerical Results for Maximum Additional Potential Lots by District

District	Existing Lots	Additional Potential Lots	Total Lots	Current % of Total Buildout
R-1 SR-1	945	124	1,069	88.4%
ROH SOH	1,680	117	1,797	93.5%
R-5 R-5L	633	138	771	82.1%
R-10 R-10L SR-10	991	102	1,093	90.7%
R-20 SR-20	1,427	138	1,565	91.2%
R-40	510	10	520	98.1%
CDT	177	1	178	99.4%
CMI	141	28	169	83.4%
CN	345	30	375	92.0%
CTEC	116	10	126	92.1%
CI	114	9	123	92.7%
RC	53	4	57	93.0%
RC-2	121	114	235	51.5%
V-R	636	12	648	98.1%
LUG-1	638	32	670	95.2%
LUG-2	1,021	20	1041	98.1%
LUG-3	3,740	56	3796	98.5%
MMD	188	-	188	100%
VN	4	-	4	100%
VTEC	12	5	17	70.6%

District	Existing Lots	Additional Potential Lots	Total Lots	Current % of Total Buildout
OIH	4	-	4	100%
ALC	6	-	6	100%

APPENDIX 2-C

Nantucket Land Use Chart

ZONING

139 Attachment 2

Town of Nantucket
Use Chart
(See § 139-7A.)

[Amended 4-6-2009 ATM by Art. 27, AG approval 8-10-2009; 4-4-2011 ATM by Arts. 58 and 61, AG approval 9-15-2011; 3-31-2012 ATM by Art. 47, AG approval 7-12-2012;
4-2-2013 ATM by Art. 30, AG approval 7-26-2013; 4-5-2014 ATM by Art. 67, AG approval 5-7-2014; 4-6-2015 ATM by Arts. 44, 47, 61, 62, 64, AG approval 8-5-2015;
11-9-2015 STM by Art. 2, AG approval 12-29-2015; 4-2-2016 ATM by Art. 36, 52, AG approval 7-12-2016; 4-1-2017 ATM by Art. 69, AG approval 5-31-2017; 11-6-2017 STM by Arts. 2, 19, 21, AG approval 2-26-2018; 10-10-
2018 STM by Art. 2, AG approval 5-8-2019; 4-1-2019 ATM by Art. 49, AG approval 8-6-2019; 6-5-2021 ATM by Art. 48, AG approval 10-7-2021]

- A = Accessory Use as defined in § 139-15
- FBED = Formula Business Exclusion District
- N = No
- SP = Special Permit issued by Zoning Board of Appeals, unless the Planning Board is designated as the special permit granting authority pursuant to another section of this chapter.
- Y = Yes

	Use	Town Residential Districts						Town Commercial Districts							Country Residential Districts					Country Commercial Districts	
		R-1 SR-1	ROH SOH	R-5 R-5L	R-10 R-10L SR-10	R-20 SR-20	R-40	CDT	CMI	CN	CTEC	CI	RC	RC-2	V-R	LUG-1	LUG-2	LUG-3	MMD	VN	VTEC
Residential	Primary dwelling	Y	Y	Y	Y	Y	Y	A	A	A	Y	N	Y	Y	Y	Y	Y	Y	Y	A	A
	Secondary dwelling	Y	Y	Y SP R-5L	Y SP R-10L	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N
	Accessory dwelling	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Tertiary dwelling	N	N	Y R-5 N R-5L	Y R-10 N R-10L N SR-10	Y R-20 N SR-20	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N
	Apartment	N	N	N	N	N	N	Y	Y	Y	Y	SP	N	N	N	N	N	N	N	N	N
	Apartment building	N	N	N	N	N	N	N	SP	SP	N	N	N	N	N	N	N	N	N	SP	N
	Tiny house unit	N	N	Y R-5 N R-5L	Y R-10 N R-10L N SR-10	Y R-20 N SR-20	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N
	Garage apartment	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Duplex	Y R-1 N SR-1	N	Y R-5 N R-5L	Y R-10 N R-10L N SR-10	N	N	Y	Y	A	Y	N	Y	Y	N	N	N	N	N	N	N
	Workforce rental community	N	N	N	N	N	N	N	SP	SP	N	N	N	N	N	N	N	N	N	N	N
	Elder housing facilities	SP	SP	SP	SP	SP	SP	N	SP	SP	N	N	SP	SP	SP	SP	SP	SP	N	N	N
	Studio	A	A	A	A	A	A	Y	Y	Y	Y	Y	Y	Y	A	A	A	A	A	Y	Y
	Garage – residential	A/SP	A/SP	A/SP	A/SP	A/SP	A/SP	N	N	A	A	N	A	A	A/SP	A	A	A/SP	A	A	A
	Shed	A	A	A	A	A	A	N	N	A	A	A	A	A	A	A	A	A/SP	A	A	A
	Outbuildings – other	A	A	Y	Y	A	A	N	N	A	A	A	A	A	A	A	A	A/SP	A	A	A
	Swimming pool - residential	A²	N	A²	A	A	A	A	A	A	A	N	A	A	SP	A	A	A	SP	A	A
	Home occupations	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

NANTUCKET CODE

	Use	Town Residential Districts						Town Commercial Districts						Country Residential Districts					Country Commercial Districts		
		R-1 SR-1	ROH SOH	R-5 R-5L	R-10 R-10L SR-10	R-20 SR-20	R-40	CDT	CMI	CN	CTEC	CI	RC	RC-2	V-R	LUG-1	LUG-2	LUG-3	MMD	VN	VTEC
	Keeping of pets for personal use	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Business Commercial	Retail sales	N	N	N	N	N	N	Y	Y	Y	A	A	Y	Y	N	N	N	N	N	Y	A
	Convenience store	N	N	N	N	N	N	Y	Y	Y	N	N	Y	Y	N	N	N	N	N	SP	A
	Alcohol sales	N	N	N	N	N	N	Y	Y	SP/A	N	N	Y	Y	N	N	N	N	N	A	A
	Bakery	N	N	N	N	N	N	Y	Y	Y	Y	SP	SP/A	SP/A	N	N	N	N	N	Y	A/SP
	Open-air market	N	N	N	N	N	N	Y	Y	Y	N	N	Y	Y	N	N	N	N	N	Y	Y
	Pharmacy	N	N	N	N	N	N	Y	Y	Y	N	N	Y	Y	N	N	N	N	N	N	N
	Supermarket	N	N	N	N	N	N	Y	Y	SP	N	N	Y	Y	N	N	N	N	N	N	N
	Restaurants																				
	Small (up to 70 seats)	N	N	N	N	N	N	Y	Y	SP	N	N	Y	Y	N	N	N	N	N	SP	N
	Large (71-200 seats)	N	N	N	N	N	N	SP	SP	N	N	N	Y	Y	N	N	N	N	N	N	N
	Take-out food establishment	N	N	N	N	N	N	Y	Y	SP/A	N	N	SP	SP	N	N	N	N	N	A	N
	Drive-through take-out food	N	N	N	N	N	N	N	N	SP	N	N	SP	SP	N	N	N	N	N	N	N
	Tavern/Bar	N	N	N	N	N	N	Y	Y	SP/A	N	N	SP	SP	N	N	N	N	N	A	A
	Formula businesses																				
	Retail (includes: bakery, convenience store and pharmacy)	N	N	N	N	N	N	N	Y	Y	N	SP	SP/N in FBED	SP	N	N	N	N	N	N	N
	Supermarket	N	N	N	N	N	N	Y	Y	Y	N	N	Y	Y	N	N	N	N	N	N	N
	Restaurant																				
	Small (up to 70 seats)	N	N	N	N	N	N	N	SP	SP	N	N	SP/N in FBED	N	N	N	N	N	N	N	N
	Large (71-200 seats)	N	N	N	N	N	N	N	SP	N	N	N	SP/N in FBED	N	N	N	N	N	N	N	N
	Take-out food establishment	N	N	N	N	N	N	N	SP	SP	N	N	Y/N in FBED	N	N	N	N	N	N	N	N
	Tavern/Bar	N	N	N	N	N	N	N	SP	SP	N	N	Y/N in FBED	N	N	N	N	N	N	N	N
	Offices	N	N	N	N	N	N	Y	Y	Y	A	Y	Y	Y	N	N	N	N	N	Y	A
	Theatres, auditoriums, or other places of public assembly	N	N	N	N	N	N	Y	SP	SP	N	N	Y	Y	N	N	N	N	N	A	A/SP
	Personal services	SP	SP	SP N R-5L	SP N R-10L	SP	SP	Y	Y	Y	A	N	Y	Y	N	N	N	N	N	Y	SP
	Print shop	N	N	N	N	N	N	Y	Y	Y	Y	Y	SP	SP	N	N	N	N	N	N	N
	Laundromat or dry-cleaning establishment	N	N	N	N	N	N	SP	SP	SP	SP	SP	SP	SP	N	N	N	N	N	SP	N
	Bank	N	N	N	N	N	N	Y	Y	Y	N	N	Y	Y	N	N	N	N	N	N	N
	Automated teller machine	N	N	N	N	N	N	Y/A	Y/A	Y/A	N	N	Y	Y	N	N	N	N	N	A	A
	Arcade	N	N	N	N	N	N	N	SP/A	SP/A	N	N	A	A	N	N	N	N	N	N	N
	Art gallery	N	N	N	N	N	N	Y	Y	Y	N	N	SP	SP	N	N	N	N	N	Y	Y
	Museum	N	N	N	N	N	N	Y	N	SP	N	N	Y	Y	N	N	N	SP	N	SP	N
	Catering	N	N	N	N	N	N	N	Y	Y	Y	SP	SP/A	SP/A	N	N	N	N	N	A	A
	Crematorium	N	N	N	N	N	N	N	N	N	N	Y	A	A	N	N	N	SP	N	N	N
	Funeral home	SP	SP	SP N R-5L	SP N R-10L	N	N	Y	Y	Y	N	Y	Y	Y	N	N	N	N	N	N	N
	Health spa	N	N	N	N	N	N	Y	Y	Y	N	N	Y	Y	N	N	N	N	N	N	N
	Medical clinic	N	N	N	N	N	N	N	SP	SP	N	N	Y	Y	N	N	N	N	N	N	N
Adult on-site marijuana social consumption operator	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	
Marijuana membership club	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	
Marijuana establishment, recreational and marijuana treatment center, medical	N	N	N	N	N	N	N	N	SP	N	SP	N	N	N	N	N	N	N	N	N	

ZONING

	Use	Town Residential Districts						Town Commercial Districts						Country Residential Districts					Country Commercial Districts		
		R-1 SR-1	ROH SOH	R-5 R-5L	R-10 R-10L SR-10	R-20 SR-20	R-40	CDT	CMI	CN	CTEC	CI	RC	RC-2	V-R	LUG-1	LUG-2	LUG-3	MMD	VN	VTEC
	Hospital	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N
	Transient residential facilities																				
	Hotel or inn	N	N	N	N	N	N	SP	SP	SP	N	N	Y	N	N	N	N	N	N	N	N
	Rooming, lodging, or guest house	N	SP¹	N	N	N	N	Y	Y	Y	N	N	Y	N	N	N	N	N	N	SP	N
	Time-sharing/Interval dwelling units	N	N	N	N	N	N	Y	Y	Y	N	N	Y	N	N	N	N	N	N	Y	N
Commercial Industrial	Contractor shop	N	N	N	N	N	N	N	SP	SP	Y	Y	SP	SP	N	N	N	N	N	N	A
	Lumberyard	N	N	N	N	N	N	N	N	SP	SP	Y	N	N	N	N	N	N	N	N	SP
	Bulk merchandise retail	N	N	N	N	N	N	Y	Y	Y	SP	Y	N	N	N	N	N	N	SP	SP	
	Landscape contractor	N	N	N	N	N	N	N	N	SP	Y	Y	SP	SP	N	N	N	N	N	N	SP
	Light manufacturing	N	N	N	N	N	N	N	N	A	SP/A	Y	SP	SP	N	N	N	N	N	SP/A	SP/A
	Food processing	N	N	N	N	N	N	N	N	SP	SP	Y	SP	SP	N	N	N	N	N	N	SP
	Shed - commercial	N	N	N	N	N	N	A	A	A	A	A	N	N	N	N	N	N	N	A	A
	Storage container	N	N	N	N	N	N	N	N	SP	SP	SP	N	N	N	N	N	N	N	N	N
	Interior or exterior storage or warehousing	N	N	N	N	N	N	N	N	A	SP/A	Y	SP	SP	N	N	N	N	N	A	SP/A
	Motor vehicle sales	N	N	N	N	N	N	N	SP	SP	N	SP	SP	SP	N	N	N	N	N	N	N
	Motor vehicle rental	N	N	N	N	N	N	Y	N	SP	N	SP	SP	SP	N	N	N	N	N	N	N
	Motor vehicle repair or painting	N	N	N	N	N	N	N	SP	SP	SP	Y	SP	SP	N	N	N	N	N	N	N
	Motor vehicle service station	N	N	N	N	N	N	N	SP	SP	SP	SP	SP	SP	N	N	N	N	N	N	N
	Motor vehicle parking lots or structures	N	N	N	N	N	N	Y	Y	Y	SP	SP	Y	Y	N	N	N	N	N	N	N
	Car wash	N	N	N	N	N	N	N	SP	N	N	SP	SP	SP	N	N	N	N	N	N	N
	Taxicab business	N	N	N	N	N	N	N	Y	Y	Y	N	SP	SP	N	N	N	N	N	N	N
	Bicycle rental or sale	N	N	N	N	N	N	Y	N	SP	SP	N	SP	SP	N	N	N	N	N	SP	A
	Maritime service station	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	SP
	Yacht/Sailing clubs and marinas	N	N	N	N	N	N	Y	N	N	N	SP	Y	Y	N	N	N	N	N	N	SP
Industrial	Adult uses	N	N	N	N	N	N	N	N	N	N	SP	N	SP	N	N	N	N	N	N	N
	Asphalt/Batching plant	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N
	Licensed junkyard	N	N	N	N	N	N	N	N	N	N	SP	N	N	N	N	N	N	N	N	N
	Transfer station	N	N	N	N	N	N	N	N	N	N	SP	N	N	N	N	N	N	N	N	N
	Petroleum product storage or distribution facility (i.e. tank farm)	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N
	Utility production/distribution (does not include WECS)	N	N	N	N	N	N	SP	SP	SP	SP	Y	N	N	N	N	N	N	N	N	N
	Mining	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N
	Truck/Bus terminal	N	N	N	N	N	N	N	N	N	SP	Y	N	N	N	N	N	N	N	N	N
	Boat-related storage	N	N	N	N	N	N	N	N	SP	Y	Y	Y	Y	N	N	N	N	N	N	SP

NANTUCKET CODE

	Use	Town Residential Districts						Town Commercial Districts						Country Residential Districts						Country Commercial Districts	
		R-1 SR-1	ROH SOH	R-5 R-5L	R-10 R-10L SR-10	R-20 SR-20	R-40	CDT	CMI	CN	CTEC	CI	RC	RC-2	V-R	LUG-1	LUG-2	LUG-3	MMD	VN	VTEC
Other	Preservation of a lot in its natural condition	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Care and propagation of fish and shellfish	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	All agricultural uses allowed by Ch. 590 of the Acts of 1989, effective 3-8-1990 (including keeping of farm animals, greenhouses, truck gardens, farms, orchards and nurseries)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Cemeteries	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Municipal uses (any)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Tents	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Day-care center	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Kennel	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP
	Public stable	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP
	Employer dormitory	N	N	N	N	N	N	N	N	N	N	N	N	N	SP	SP	SP	SP	N	SP	SP
	Neighborhood employee housing	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	N	N	N	N	N	N	N
	Swimming pool - commercial	N	N	N	N	N	N	N	SP/A	SP/A	A	N	SP/A	SP/A	A	A	A	A	N	A	A
	Recreational facilities	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP
	Club	N	N	N	SP	SP	SP	Y	Y	Y	Y	N	Y	Y	N	SP	SP	SP	N	SP	SP

NOTES:
¹See the definition of "transient residential facility" in § 139-2A.
²With lots greater than or equal to 7,500 square feet.

APPENDIX 2-D

Numerical Results for Maximum Additional Potential Dwelling Units by District

District	Existing Dwelling Units	Additional Potential Dwelling Units	Total Dwelling Units	Current % of Total Buildout
R-1 SR-1	1,030	751	1,781	57.8%
ROH SOH	1,761	1,271	3,032	58.1%
R-5 R-5L	712	779	1,491	47.8%
R-10 R-10L SR-10	1,153	1,017	2,170	53.1%
R-20 SR-20	1,458	1,328	2,786	52.3%
R-40	442	303	745	59.3%
CDT	85	89	174	48.9%
CMI	147	655	802	18.3%
CN	395	1,417	1,812	21.8%
CTEC	106	628	734	14.4%
CI	21	-	21	100.0%
RC	36	-	36	100.0%
RC-2	115	322	437	26.3%
V-R	482	191	673	71.6%
LUG-1	692	921	1,613	42.9%
LUG-2	973	1,249	2,222	43.8%
LUG-3	1,946	2,891	4,837	40.2%
MMD	43	27	70	61.4%
VN	4	21	25	16.0%
VTEC	6	3	9	66.7%

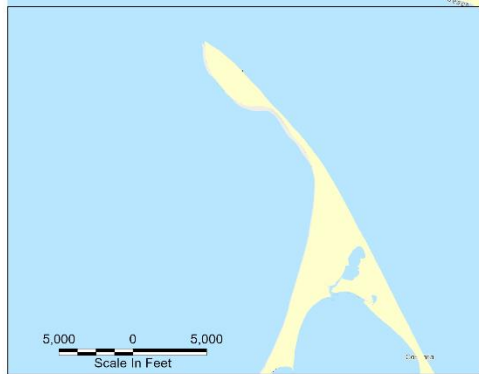
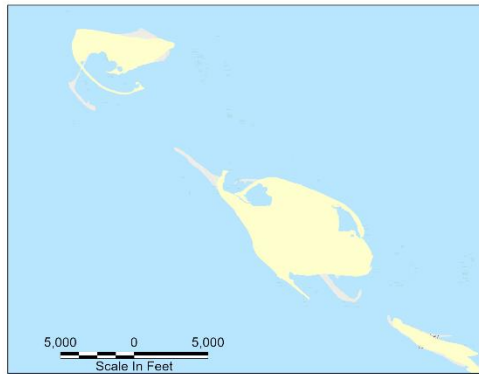
District	Existing Dwelling Units	Additional Potential Dwelling Units	Total Dwelling Units	Current % of Total Buildout
OIH	4	-	4	100.0%
ALC	26	-	26	100.0%

APPENDIX 3-A

Numerical & Map Results for Maximum Additional Potential Lots with SLR by District

District	Existing Lots	Additional Potential Lots	Total Lots	Current % of Total Buildout
R-1 SR-1	945	112	1,057	89.4%
ROH SOH	1,680	116	1,796	93.5%
R-5 R-5L	633	136	769	82.3%
R-10 R-10L SR-10	991	102	1,093	90.7%
R-20 SR-20	1,427	133	1,560	91.5%
R-40	510	10	520	98.1%
CDT	177	-	177	100.0%
CMI	141	28	169	83.4%
CN	345	41	386	89.4%
CTEC	116	12	128	90.6%
CI	114	9	123	92.7%
RC	53	-	53	100.0%
RC-2	121	114	235	51.5%
V-R	636	3	639	99.5%
LUG-1	638	32	670	95.2%
LUG-2	1,021	14	1,035	98.6%
LUG-3	3,740	46	3,786	98.8%
MMD	188	-	188	100.0%
VN	4	-	4	100.0%
VTEC	12	1	13	92.3%

District	Existing Lots	Additional Potential Lots	Total Lots	Current % of Total Buildout
OIH	4	-	4	100.0%
ALC	6	-	6	100.0%



Appendix 3-A	
TOWN OF NANTUCKET, MASSACHUSETTS BUILDOUT ANALYSIS	
ADDITIONAL POTENTIAL LOTS AFTER SLR	
FEBRUARY, 2022	SCALE: NOTED
Created By: Sydnie Picard	

APPENDIX 3-B

Numerical & Map Results for Maximum Additional Potential Dwelling Units with SLR by
District

District	Existing Dwelling Units	Additional Potential Dwelling Units	Total Dwelling Units	Current % of Total Buildout
R-1 SR-1	1,030	805	1,835	56.1%
ROH SOH	1,761	1,319	3,080	57.2%
R-5 R-5L	712	845	1,557	45.7%
R-10 R-10L SR-10	1,153	1,073	2,226	51.8%
R-20 SR-20	1,458	1,468	2,926	49.8%
R-40	442	313	755	58.7%
CDT	85	89	174	48.8%
CMI	147	679	826	17.8%
CN	395	1,417	1,812	21.8%
CTEC	106	628	734	14.4%
CI	21	-	21	100%
RC	36	-	36	100%
RC-2	115	354	469	24.5%
V-R	482	196	678	71.1%
LUG-1	692	975	1,667	41.5%
LUG-2	973	1,291	2,264	43.0%
LUG-3	1,946	2,981	4,927	39.5%
MMD	43	27	70	61.4%
VN	4	21	25	16.0%
VTEC	6	3	9	66.6%

District	Existing Dwelling Units	Additional Potential Dwelling Units	Total Dwelling Units	Current % of Total Buildout
OIH	4	-	4	100%
ALC	26	-	26	100%

