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WATERSHED-BASED PLAN

Lower Artichoke Reservoir

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Prepared For:

MassDEP
Commonwealth of Massachusetts
Department of Environmental Protection

MASSACHUSETTS watershed·based plans

Contents

Executive Summary

Introduction: The purpose of a Massachusetts Watershed-Based Plan (WBP) is to organize information about Massachusetts' watersheds and present it in a format that will enhance the development and implementation of projects that will restore water quality and beneficial uses in the Commonwealth. The Massachusetts WBP follows USEPA's recommended format for "nine-element" watershed plans. This WBP was developed by the City of Newburyport, with support from Merrimack Valley Planning Commission and consultants Woodard & Curran with funding, input, and collaboration with the Massachusetts Department of Environmental Protection (MassDEP).

This WBP was prepared for the Lower Artichoke Reservoir, which is an impoundment along the Artichoke River in the City of Newburyport and Town of West Newbury, Massachusetts. The Lower Artichoke Reservoir is the last impoundment along the Artichoke River, located downstream from the Indian Hill and Upper Artichoke Reservoirs. While the Lower Artichoke Reservoir is only 24 acres in size, the Lower Artichoke Reservoir Watershed spans 3,824.2 acres, encompassing both the Indian Hill and Upper Artichoke Reservoirs. The WBP references both the Lower Artichoke Reservoir (34-acre water body), and the Lower Artichoke Reservoir Watershed (384.2-acre watershed area) to discuss current conditions and future management strategies. The Lower Artichoke Reservoir Watershed includes the Towns of West Newbury and Newbury, and the City of Newburyport. These municipalities all rely on the Lower Artichoke Reservoir as a drinking water source, making it a critical resource for these communities.

Impairments and Pollution Sources: The targeted pollutant for this effort is phosphorous. Phosphorous enrichment is a key contributor to repetitive cyanobacteria caused Harmful Algal Blooms, (HABs) within the Reservoir, rendering it unsafe for recreation and requiring additional processing during drinking water treatment. The effort to reduce phosphorous from key watershed sources (i.e. agricultural, residential, and other developed lands) will in turn reduce HABs within the system. Additional pollutant sources from suburban runoff into the Artichoke River and its reservoirs have been identified from two municipal stormwater drainage outfalls which discharge into the Lower Artichoke Reservoir.

Goals, Management measures, and funding: The primary goals of this project are to reduce phosphorous loading from agricultural and suburban runoff into the Artichoke River and its reservoirs. In addition, project partners and stakeholders look to educate and empower local landowners to minimize nutrient runoff on their own properties and build relationships and local knowledge to enable future BMP implementation projects. The Best Management Practices (BMP) implementation projects identified in **Element C** will help accomplish these goals by reducing runoff, filtering and storing pollutants, and encourage a more proactive stewardship of the Lower Artichoke Reservoir Watershed.

Public Education and Outreach: Goals of public education and outreach are to provide information about proposed stormwater improvements and their anticipated benefits and to promote watershed stewardship. Outreach to local landowners, municipal staff, and recreators will educate and inspire future local action to ensure the preservation of the region's drinking water resource. A two-pronged approach has been identified for public outreach and education (detailed in **Element E: Public Information and Education)** consisting of a public education program to engage local landowners and communities, as well as a focused educational initiative for fertilizer and pesticide use.

- **General public education:** Public education and outreach are focused on raising awareness of non-point source pollution in the watershed through identifying key stakeholders and strategically engaging the public through a variety of effective media campaigns and events. Additionally, regular meetings of neighboring communities and stakeholders will provide a forum to discuss larger land-use practices and ensure broader stewardship approaches for the Reservoir.
- **Fertilizer and Pesticide Use/Management Education:** A specific education and outreach focus will be given to addressing fertilizer and pesticide use. To reduce agricultural nutrient runoff in the Lower Artichoke Reservoir Watershed, private landowners must feel empowered and excited about opportunities to implement BMPs. Outreach will target private landowners, especially hobby farm[1] owners to provide education and engagement on implementing BMPs through hosting casual conversations and opportunities to observe local projects. The City of Newburyport will work to build off the Artichoke's Water Supply Watershed Program Framework (Woodard & Curran, 2023) which outlines strategies for outreach and partnering with key stakeholders in the region to organize and administer outreach.

Implementation Schedule and Evaluation Criteria: Project activities will be implemented based on the information outlined in the following elements for monitoring, implementation of structural BMPs, public education and outreach activities, and periodic updates to the WBP. It is expected that continuous water quality monitoring and HAB monitoring will be used to evaluate improvements from BMPs over time, as well as establish concrete long-term load reduction goals.

The Watershed Based Plan will be re-evaluated and adjusted as needed once every five years or as conditions warrant additional evaluation.

[1] The term "hobby farm" refers to an IRS farming classification for small farms maintained without expectation of being a primary income source.

Introduction

What is a Watershed-Based Plan?

Purpose & Need

The purpose of a Massachusetts Watershed-Based Plan (WBP) is to organize information about Massachusetts' watersheds and present the information in a format that will enhance the development and implementation of projects that will restore water quality and beneficial uses in the Commonwealth. The Massachusetts WBP follows the United States Environmental Protection Agency's (EPA's) recommended format for "nine-element" watershed plans, as described below.

All states are required to develop WBPs, but not all states have taken the same approach. Most states develop WBPs only for selected watersheds. Massachusetts Department of Environmental Protection's (MassDEP's) approach has been to develop a tool to support statewide development of WBPs so that good projects in all areas of the state may **be eligible for federal watershed implementation grant funds** under Section 319 of the Clean Water Act.

EPA guidelines promote the use of Section 319 funding for developing and implementing WBPs. WBPs are required for all projects implemented with Section 319 funds and are recommended for all watershed projects, whether they are designed to protect unimpaired waters, restore impaired waters, or both.

Watershed-Based Plan Outline

This WBP includes nine elements (a through i) in accordance with EPA Guidelines:

a) An **identification of the causes and sources** or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this WBP and to achieve any other watershed goals identified in the WBP, as discussed in item (b) immediately below.

b) An **estimate of the load reductions** expected for the management measures described under paragraph (c) below, recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time.

c) A **description of the nonpoint source (NPS) management measures** needed to achieve the load reductions estimated under paragraph (b) above as well as to achieve other watershed goals identified in this WBP and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.

d) An **estimate of the amounts of technical and financial assistance needed**, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan. As sources of funding, States should consider the use of their Section 319 programs, State Revolving Funds, United States Department of Agriculture's (USDA's) Environmental Quality Incentives Program and Conservation Reserve Program, and other relevant federal, state, local, and private funds that may be available to assist in implementing this plan.

e) An **information/education component** that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the NPS management measures that will be implemented.

f) A **schedule for implementing the NPS management measures** identified in this plan that is reasonably expeditious.

g) A description of **interim, measurable milestones** for determining whether NPS management measures or other control actions are being implemented.

h) A set of **criteria to determine if loading reductions are being achieved** over time and substantial progress is being made toward attaining water quality standards and, if not, the criteria for determining whether this WBP needs to be revised or, if a NPS total maximum daily load (TMDL) has been established, whether the TMDL needs to be revised.

i) A **monitoring component** to evaluate the effectiveness of the implementation efforts over time measured against the criteria established under item (h) immediately above.

Project Partners and Stakeholder Input

This WBP was developed by the City of Newburyport, with support from Merrimack Valley Planning Commission and consultants Woodard & Curran with funding, input, and collaboration with the Massachusetts Department of Environmental Protection (MassDEP). In addition to the formation of the WBP, these key stakeholders will be critical to its successful implementation:

- Municipalities, especially the neighboring communities of West Newbury and Newbury
- Landowners, especially adjacent to the reservoirs and tributaries
- Residents and the public in Newburyport, Newbury, and West Newbury
- State and federal agencies (e.g., MassDEP and NRCS)
- Community based organizations (e.g., Merrimack Valley Planning Commission and Essex County Greenbelt Association)
- Technical experts and consultants (e.g. DK Water Resource Consulting LLC)

A critical initial step to achieving the goals outlined in this Watershed Based Plan will be to engage the stakeholders listed above. To do this, Newburyport plans to facilitate the formation of an inter-municipal stakeholder group that can convene regularly to discuss watershed-based challenges and advance projects to improve water quality for the Lower Artichoke Reservoir Watershed.

Data Sources and Completed Work

This WBP was developed using the framework and data sources provided by MassDEP's WBP Tool. Additional resources and references related to water supply quality and watershed management are listed in the table below.

Table I-1:Existing Resources Related to Watershed Management in the Watershed

Report/Resource Name	Description of Contents
Newburyport Reservoirs Water Quality Model Update (DK Water Resource Consulting, 2023)	Describes an update and results of the Newburyport Lake Loading Response Model which uses environmental data to develop annual water and phosphorus loading budgets for the reservoirs and their tributaries.
Water Supply Watershed Program Framework (Woodard & Curran, 2023)	Outlines a framework aimed at protection and improvement of surface water supply in the Artichoke Reservoir through collaborative watershed management.
Artichoke Watershed Protection Plan (Tighe & Bond, 2021)	Includes a broad list of recommendations to protect the water supply and resilience of the reservoirs in the watershed.
Newburyport Reservoirs Water Quality and Cyanobacteria Monitoring Plan (DK Water Resource Consulting LLC, 2021)	Outlines the reservoir ongoing water quality monitoring program that will assist in tracking progress toward improved water quality.
Technical Memorandum: Water quality summary and discussion of 2020 cyanobacteria blooms (Don Kretchmer CLM and Ken Wagner PhD CLM, October 2020)	Evaluates surface water quality data and algal blooms between Fall 2019 and Fall 2020 in all the reservoirs in the watershed.
Newburyport Reservoir Water Quality Study Report (AECOM, 2016)	Evaluates water quality, sediment sampling, and aquatic vegetation survey and outlined a hydrologic and nutrient budget.
Water Resource Protection District in the Zoning Ordinance of the City of Newburyport (Section XIX)	For the protection of surface water and groundwater supplies, outlines allowed and prohibited activities within zones adjacent to water supply in Newburyport.
MassDEP Source Water Assessment and Protection (SWAP) Report (MassDEP, 2003)	SWAP, established under the federal Safe Drinking Water Act, requires every state to inventory land uses within the recharge areas of all public water supply sources, assess the susceptibility of drinking water sources to contamination from these land uses, and · publicize the results to provide support for improved protection.

Element A: Identify Causes of Impairment & Pollution Sources

Element A: Identify the causes and sources or groups of similar sources that need to be controlled to achieve the necessary pollutant load reductions estimated in the watershed based plan (WBP).

General Watershed Information

The Lower Artichoke Reservoir is a 34-acre impoundment along the Artichoke River in the City of Newburyport and the Town of West Newbury situated within the Merrimack Watershed. The Lower Artichoke Reservoir is connected to the Upper Artichoke Reservoir by the 1.2 mile-long Artichoke River. Both reservoirs are part of a cascading water system starting at the Indian Hill Reservoir. Both the Upper and the Lower Artichoke reservoirs are shallow systems that are highly susceptible to changing climate conditions, which increases the likelihood of algal blooms and could compromise the water supply. A drought in the summer of 2020 contributed to an algal bloom in the Upper and Lower Artichoke reservoirs. The Indian Hill Reservoir is a deeper reservoir with lower nutrient loading, however high nutrient levels are still of a concern, as was demonstrated in 2020 when a smaller algal bloom occurred at this site. All three reservoirs are impacted by land uses in their watershed that contribute to nutrient loading and other threats that impact water quality.

The Lower Artichoke Reservoir lies within a largely undeveloped, rural area at the border of West Newbury and Newburyport. Its surrounding landscape includes upland forests and protected wetlands. The developed land surrounding the waterbody includes a residential neighborhood and small agricultural hobby farms. These natural and protected spaces offer residents a range of recreational opportunities. Roads such as Turkey Hill Road wind along portions of the reservoir, serving as scenic routes that can be enjoyed for walking, cycling, bird watching, and other outdoor activities. The land surrounding the Reservoir is relatively flat, with modest hills to the south-southeast leading into the waterbody. The land along the western banks of the waterbody is West Newbury owned conservation land called the "Withers Conservation Area." This 24-acre parcel offers hiking trails as well as a scenic shoreline view of the Upper Artichoke Reservoir. Also within the watershed is Newburyport owned land called "City Forest." This 47-acre plot not only serves as land conservation and recreation opportunities, but also acts as a buffer zone between the reservoir and surrounding agricultural land.

Both the Lower and Upper Artichoke Reservoirs serve as a source of drinking water for three communities: Newburyport, Newbury, and West Newbury, and are therefore considered critical resources in the region. Water from the Lower Artichoke Reservoir is treated and sold by the City of Newburyport. The Lower Artichoke Reservoir Watershed is approximately 3,824 acres and extends into the jurisdictions of Newburyport, Newbury, West Newbury. In addition to primary usage as a water supply, the Reservoir provides important recreational and ecological services for people and wildlife.

The Newburyport Reservoir Water Quality Study Report (AECOM, 2016), Watershed Protection Plan (Tighe & Bond, 2021), Newburyport Reservoirs Watershed and Water Quality Protection for the Future (DK Water Resource Consulting LLC, 2022), Water Supply Watershed Program Framework (Woodard & Curran, 2023), and the Newburyport Reservoirs Watershed Model Update (DK Water Resource Consulting LLC, 2023) highlight a significant nutrient loading concern in the reservoirs, with a particular concern for Total Phosphorous (TP).

Total Phosphorus (TP) has been identified as a leading pollutant in the Merrimack River watershed and is currently reporting higher levels of TP than the suggested EPA concentration of 25 ug/L within any lake or reservoir at the point where it enters any lake or reservoir (US EPA, 1986). The Reservoir has experienced several bouts of cyanobacteria-caused harmful algal blooms (HABs), which have required additional processing of drinking water supplies on multiple occasions, making this a chronic issue. Currently, in 2024, the City of Newburyport is on its 3rd treatment of Copper Sulfate (algaecide). Non-point pollution sources for TP in the Merrimack River have been attributed to the River's tributaries, including the Artichoke River. High levels of TP continue to be an issue for the Merrimack River watershed.

Table A-1: General Watershed Information

Watershed Name (Assessment Unit ID):	Lower Artichoke Reservoir
Major Basin:	Merrimack
Watershed Area (within MA):	3824.2 (ac)
Water Body Size:	34 (ac)

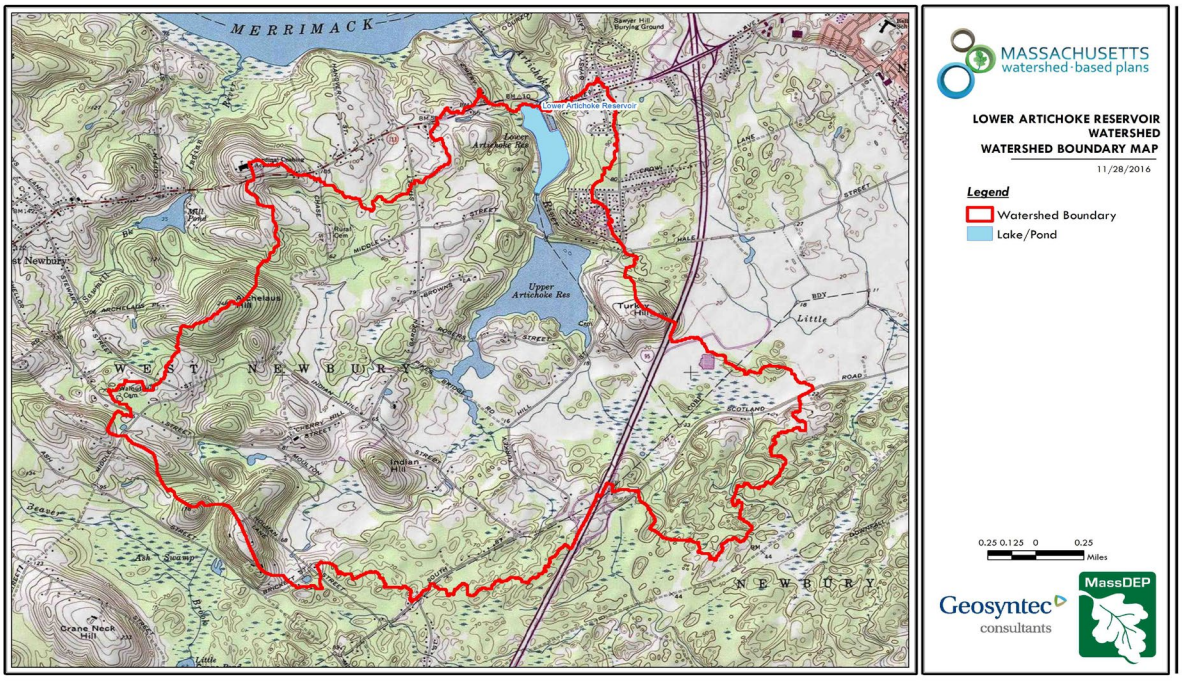


Figure A-1: Watershed Boundary Map (MassGIS, 1999; MassGIS, 2001; USGS, 2016)

Ctrl + Click on the map to view a full-sized image in your web browser

MassDEP Water Quality Assessment Report and TMDL Review

The Artichoke River and its reservoirs have not been assessed by MassDEP. The following reports are available:

- No Associated Report Summaries Are Available for the Artichoke
- The Following Reports are Available for the Merrimack Watershed of which the Artichoke River and reservoirs are a part of
    - Draft Pathogen TMDL for the Merrimack River Watershed
    - Merrimack River Watershed 2004 Water Quality Assessment Report

The section below summarizes the findings of any available Water Quality Assessment Report and/or TMDL that relate to water quality and water quality impairments. Select excerpts from these documents relating to the water quality in the watershed are included below (note: relevant information is included directly from these documents for informational purposes and has not been modified).

Additional Assessments and Reports

Newburyport Reservoir Water Quality Study Report (AECOM, 2016)

The City of Newburyport retained the services of AECOM in 2016 to conduct a water quality study of their water supply reservoirs including the Artichoke Reservoir System (Indian Hill Reservoir, Upper Artichoke Reservoir, and the Lower Artichoke Reservoir) and Bartlett Pond. The goal of the study was to provide data to restore and protect water quality in the reservoirs. This effort included a water quality and sediment sampling program as well as an aquatic vegetation survey and the construction of a hydrologic and nutrient budget. This report found that "Current TP watershed loading to the reservoirs from tributaries and direct overland flow has the potential to create algal blooms and encourage the growth of aquatic vegetation in all four Newburyport reservoirs." Further "A watershed-based plan should be developed for 319 funding eligibility. This plan can include the results and recommendations included in this report." The document also recommends BMP installations and continual water quality monitoring for the watershed and its reservoirs.

Newburyport Reservoirs Water Quality and Cyanobacteria Monitoring Plan (DK Water Resource Consulting LLC, 2021)

The City of Newburyport with assistance of Don Kretchmer, Certified Lake Manager (CLM), produced a Technical Memorandum to assess water quality and analysis of 2020 cyanobacteria blooms. The memorandum focused on water quality data and algal blooms between Fall 2019 and Fall 2020 in all reservoirs in the watershed. The report found that the Upper and Lower Artichoke reservoirs were susceptible to Harmful Algal Blooms due to Total Phosphorus and nutrient loading. Future monitoring recommendations include a monitoring plan "for the foreseeable future."

Newburyport Reservoirs Water Quality Model Update (DK Water Resource Consulting LCC, 2023)

This Technical Memorandum provides an update of the Lake Loading Response Model developed for the Newburyport Reservoirs by AECOM in 2016. This model summarizes the water quality model calibration since 2016 and can be used to identify current and future pollution sources, estimate pollution limits and water quality goals, and guide watershed protection and improvement projects.

Water Quality Impairments

Known water quality impairments, as documented in the Massachusetts Department of Environmental Protection (MassDEP) 2018/2020 Massachusetts Integrated List of Waters (MassDEP, 2021), are listed below. Impairment categories from the Integrated List are as follows:

Table A-2: 2018/2020 MA Integrated List of Waters Categories

Integrated List Category	Description
1	Unimpaired and not threatened for all designated uses.
2	Unimpaired for some uses and not assessed for others.
3	Insufficient information to make assessments for any uses.
4	Impaired or threatened for one or more uses, but not requiring calculation of a Total Maximum Daily Load (TMDL), including: 4a: TMDL is completed 4b: Impairment controlled by alternative pollution control requirements 4c: Impairment not caused by a pollutant - TMDL not required
5	Impaired or threatened for one or more uses and requiring preparation of a TMDL.

Table A-3: Water Quality Impairments (MassDEP 2021)

The Artichoke River and its reservoirs have not been assessed by MassDEP. No Impairments Found.

While no impairments have been documented by MassDEP, sample collection, analysis, and modeling from multiple studies indicate concerning levels of Total Phosphorus in the Lower Artichoke Reservoir and other upstream systems. Specifically, the Newburyport Reservoir Water Quality Study Report (AECOM, 2016) and the Newburyport Reservoirs Watershed Model Update (DK Water Resource Consulting LLC, 2023), provide an overview of Total Phosphorus sources and loading into the Lower Artichoke Reservoir.

Loading from the watershed was found to be the largest source of phosphorus to each reservoir in the system (Indian Hill, Upper Artichoke, Lower Artichoke) (AEOC, 2016; DK Water Resource Consulting LLC, 2023). Atmospheric deposition was identified as a small source in the Lower Artichoke Reservoir, at 8.6 lbs/year (DK Water Resource Consulting, 2023). Point sources such as residential septic systems were found to be negligible as there are no residences within 250 feet of any reservoirs and therefore no additional load associated with septic system export (AEOC, 2016). Similarly, waterfowl contributions were estimated to be low at 4.4 lbs/year in the Lower

Artichoke Reservoir (DK Water Resource Consulting, 2023). Sediment sampling in 2015 indicated a moderate risk for internal loading of phosphorus (1,500 mg/kg) in the Lower Artichoke Reservoir (AECOM, 2016), however it was identified that TP in sediment is almost always a direct result of watershed loading.

As the watershed load has been found to contribute the largest sources of TP loading to the Lower Artichoke Reservoir, land cover information can provide greater insights to local sources contributing to TP in the system. Under natural background conditions (i.e. forest and wetlands), defined as background TP loading from non-anthropogenic sources, models indicate a Total Phosphorus load of 361.6 lbs/year (DK Water Resource Consulting LLC, 2023). Because forests have a lower pollutant load export rate (PLER) than other land use types (e.g. agriculture, cropland, developed), we can infer that the additional Phosphorus in the system (beyond 361.6 lbs/year) resulting from watershed loading originates from other, higher PLER land use types.

Water Quality Goals

Water quality goals may be established for a variety of purposes, including the following:

a.) For **water bodies with known impairments**, a Total Maximum Daily Load (TMDL) is established by MassDEP and the United States Environmental Protection Agency (USEPA) as the maximum amount of the target pollutant that the waterbody can receive and still safely meet water quality standards. If the waterbody has a TMDL for total phosphorus (TP) or total nitrogen (TN), or total suspended solids (TSS), that information is provided below and included as a water quality goal.

b.) For **water bodies without a TMDL for total phosphorus** (TP), a default water quality goal for TP is based on target concentrations established in the Quality Criteria for Water (USEPA, 1986) (also known as the "Gold Book"). The Gold Book states that TP should not exceed 50 ug/L in any stream at the point where it enters any lake or reservoir, nor 25 ug/L within a lake or reservoir. For the purposes of developing WBPs, MassDEP has adopted 50 ug/L as the TP target for all streams at their downstream discharge point, regardless of which type of water body the stream discharges to.

c.) Massachusetts Surface Water Quality Standards (MassDEP 2022) prescribe the minimum water quality criteria required to sustain a waterbody's designated uses. Lower Artichoke Reservoir is a Class 'A' waterbody. The water quality goal for fecal coliform bacteria is based on the Massachusetts Surface Water Quality Standards.

d.) **Other water quality goals set by the community** (e.g., protection of high quality waters, in-lake phosphorus concentration goal to reduce recurrence of cyanobacteria blooms, etc.).

Table A-4: Surface Water Quality Classification by Assessment Unit

Assessment Unit ID	Waterbody	Class
	Lower Artichoke Reservoir	A

Table A-5: Water Quality Goals

Pollutant	Goal	Source
Total Phosphorus (TP)	Total phosphorus should not exceed: --50 ug/L in any stream --25 ug/L within any lake or reservoir	Quality Criteria for Water (USEPA, 1986)
Bacteria	**Class A Standards** • At water supply intakes in unfiltered public water supplies: either fecal coliform shall not exceed 20 fecal coliform organisms per 100 mL in all samples taken in any six-month period, or total coliform shall not exceed 100 organisms per 100 mL in 90% of the samples taken in any six-month period. If both fecal coliform and total coliform are measured, then only the fecal coliform criterion must be met. More stringent regulations may apply under 310 CMR 22.00: Drinking Water (see 314 CMR 4.06(1)(d)1.) •Primary contact recreation: For E. coli, geometric mean of samples collected within any 90-day or smaller period shall not exceed 126 cfu/100 mL, and no more than 10% of all such samples shall exceed 410 cfu/100 mL. For enterococci, geometric mean of all samples collected within any 90-day or smaller period shall not exceed 35 cfu/100 mL, and no more than 10% of all such samples shall exceed 130 cfu/100 mL.	Massachusetts Surface Water Quality Standards (MassDEP, 2022)

Note: *There may be more than one water quality goal for bacteria due to different Massachusetts Surface Water Quality Standards Classes for different Assessment Units within the watershed.*

Land Use and Impervious Cover Information

Land use information and impervious cover is presented in the tables and figures below. Land use source data is from 2005 and was obtained from MassGIS (2009b). The data set was developed based on aerial photography interpreted by the University of Massachusetts Department of Forest Resources. The data are organized into several use categories: Agriculture, Commercial, Forest, High Density Residential, Highway, Industrial, Low Density Residential, Medium Density Residential, Open Land, and Water. *Land use code definitions can be found here: MassGIS Data: Land Use (2005) | Mass.gov.*

Watershed Land Uses

Table A-6: Lower Artichoke Reservoir Watershed Land Uses

Land Use	Area (acres)	% of Watershed
Agriculture	365.75	9.6
Commercial	4.38	0.1
Forest	2509.16	65.6
High Density Residential	37.87	1
Highway	58.32	1.5
Industrial	0	0
Low Density Residential	395.24	10.3
Medium Density Residential	58.92	1.5
Open Land	99.83	2.6
Water	294.75	7.7
Artichoke Watershed Total	3,824.22	100

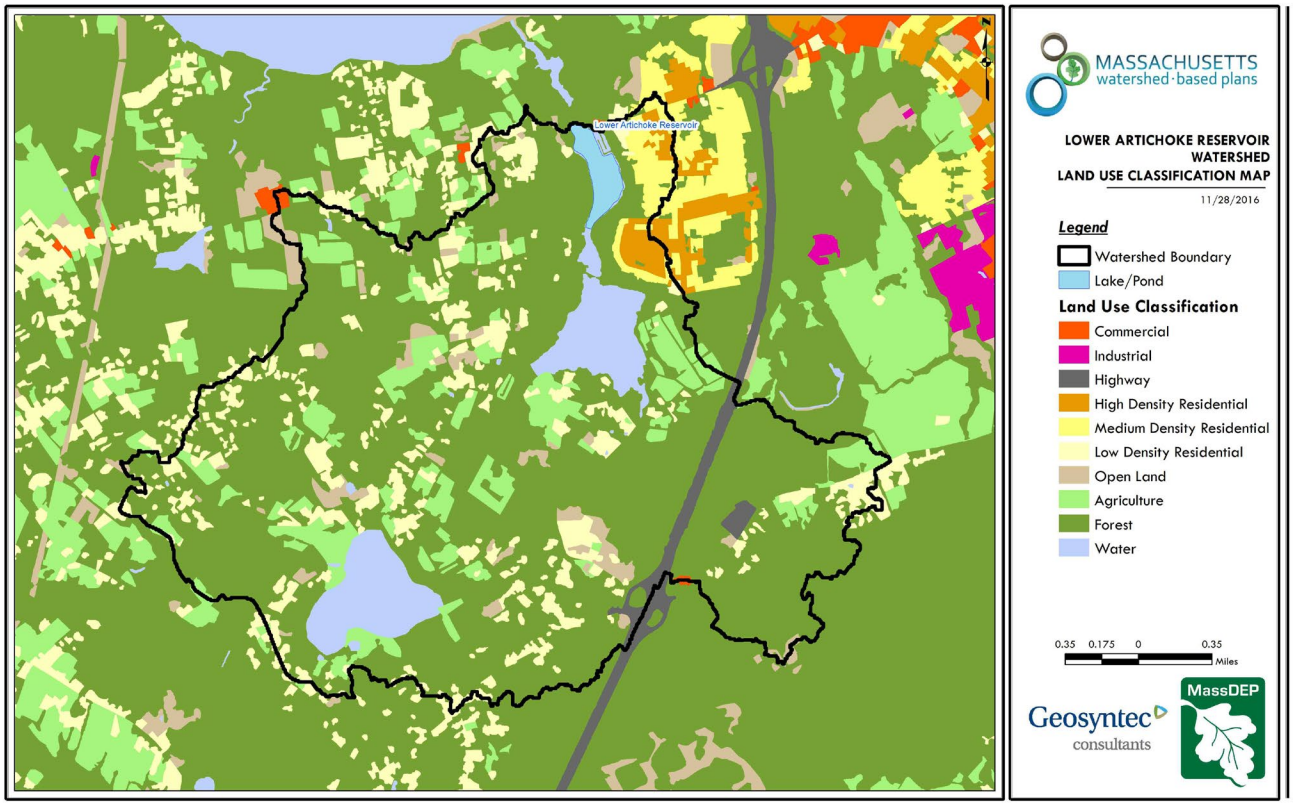


Figure A-2: Watershed Land Use Map (MassGIS, 2009b; MassGIS, 1999; MassGIS, 2001; USGS, 2016)

Ctrl + Click on the map to view a full sized image in your web browser.

Land use information

While the Lower Artichoke Reservoir Watershed is not substantially developed, (over 50% remaining as forested land) 10% is denoted as agricultural use, with an additional ~13% designated as low, medium, or high-density residential development. The majority of these developed uses directly abut the tributary. Agricultural uses consist primarily of privately owned hobby farms with livestock. Based on their land area and associated pollutant contribution levels, cropland and pasture have been identified as local sources of phosphorus loading in the Artichoke Reservoir system and watershed (i.e. fertilizer, manure, etc.). Water Operators in Newburyport have been working with individual land owners in the watershed to address potential agricultural sources through implementing solutions such as fencing to restrict livestock access to the reservoirs. Additionally, run off from suburban development is believed to be another common source, enabling nutrients from fertilizer, pet waste, lawn clippings, and other activities, to enter the system. Impervious surfaces that are directly connected to receiving waters produce higher runoff volumes and transport stormwater pollutants with greater efficiency than disconnected impervious cover areas which are surrounded by vegetated, pervious land.

Table A-7: Total Impervious Area (TIA) and Directly Connected Impervious Areas (DCIA) Values for the Watershed

	Estimated TIA (%)	Estimated DCIA (%)
Lower Artichoke Reservoir	5.6	3.6

The relationship between Total Impervious Area (TIA) and water quality can generally be categorized as shown in **Table A-8** (Schueler et al. 2009):

Table A-8: Relationship between Total Impervious Area (TIA) and water quality (Schueler et al. 2009)

% Watershed Impervious Cover	Stream Water Quality
0-10%	Typically high quality, and typified by stable channels, excellent habitat structure, good to excellent water quality, and diverse communities of both fish and aquatic insects.
11-25%	These streams show clear signs of degradation. Elevated storm flows begin to alter stream geometry, with evident erosion and channel widening. Streams banks become unstable, and physical stream habitat is degraded. Stream water quality shifts into the fair/good category during both storms and dry weather periods. Stream biodiversity declines to fair levels, with most sensitive fish and aquatic insects disappearing from the stream.
26-60%	These streams typically no longer support a diverse stream community. The stream channel becomes highly unstable, and many stream reaches experience severe widening, downcutting, and streambank erosion. Pool and riffle structure needed to sustain fish is diminished or eliminated and the substrate can no longer provide habitat for aquatic insects, or spawning areas for fish. Biological quality is typically poor, dominated by pollution tolerant insects and fish. Water quality is consistently rated as fair to poor, and water recreation is often no longer possible due to the presence of high bacteria levels.
>60%	These streams are typical of “urban drainage”, with most ecological functions greatly impaired or absent, and the stream channel primarily functioning as a conveyance for stormwater flows.

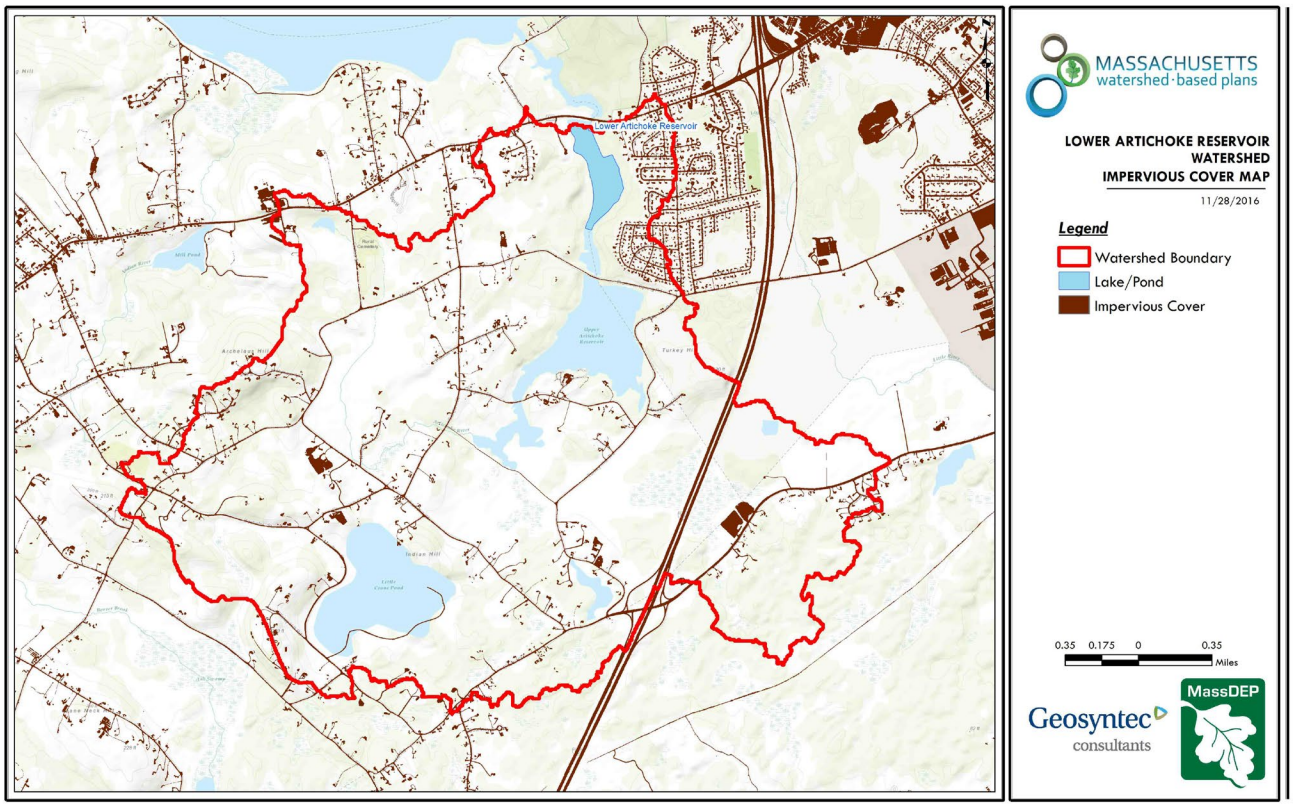


Figure A-3: Watershed Impervious Surface Map (MassGIS, 2009b; MassGIS, 1999; MassGIS, 2001; USGS, 2016)

Ctrl + Click on the map to view a full sized image in your web browser.

Watershed Impervious Cover

There is a strong link between impervious land cover and stream water quality. Impervious cover includes land surfaces that prevent the infiltration of water into the ground, such as paved roads and parking lots, roofs, basketball courts, etc.

Impervious areas that are directly connected (DCIA) to receiving waters (via storm sewers, gutters, or other impervious drainage pathways) produce higher runoff volumes and transport stormwater pollutants with greater efficiency than disconnected impervious cover areas which are surrounded by vegetated, pervious land. Runoff volumes from disconnected impervious cover areas are reduced as stormwater infiltrates when it flows across adjacent pervious surfaces.

An estimate of DCIA for the watershed was calculated based on the Sutherland equations[2]. USEPA provides guidance (USEPA, 2010) on the use of the Sutherland equations to predict relative levels of connection and disconnection based on the type of stormwater infrastructure within the **total impervious area (TIA)** of a

[2] The Sutherland equations are a set of empirical equations used to calculate the percentage of directly connected impervious areas (DCIA) in urban watersheds. The equations were developed by R.C. Sutherland in 1995 and are based on USGS data. The EPA uses the equations to estimate DCIA based on land use types.

watershed. Within each subwatershed, the total area of each land use was summed and used to calculate the percent TIA.

Total impervious area in the Lower Artichoke Reservoir watershed falls below 10%. At this level, TIA is not an immediate issue for this WBP, however, areas of more condensed development or properties with significant impervious surface still enable opportunities for runoff into the Lower Artichoke Reservoir. For example, the Turkey Hill neighborhood in Newburyport is a medium-density residential area with a high amount of impervious surfaces and a high potential for runoff. Residential activities that may contribute to pollutant runoff into the Artichoke include lawn fertilizer/herbicide application and pet waste. Increasing the amount of land protected from development would reduce the potential for future runoff and TP entry into the watershed. To meet this goal, the Artichoke Watershed Protection Plan prioritized and recommended parcels that could be purchased for water supply protection (Weston and Sampson, 2005). Since the plan was developed, parcels have been purchased and protected within the watershed including the Roger's Property which was jointly acquired by West Newbury and Essex County Greenbelt Association, and a parcel on Indian Hill Street acquired by the City of Newburyport. Maintaining undeveloped land within the watershed is a priority for improving water quality in the Reservoir, and has been identified as a topic of interest for future BMPs detailed in Element C.

While the Lower Artichoke Reservoir Watershed falls within the 0-10% impervious cover range, the system experiences degraded water quality, highlighting the role that other land-use types beyond solely impervious surface, can have in contributing to nutrient loading and reduced water quality in the Reservoir. To further assess the different factors contributing to water quality conditions, impervious cover, as well as other land-uses within the watershed were reviewed.

Pollutant Loading

A Geographic Information Systems (GIS) was used for the pollutant loading analysis. The land use data (shown in Figure A-2) was intersected with impervious cover data (shown in Figure A-3) and United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) soils data (USDA NRCS and MassGIS, 2012) to create a combined land use/land cover grid. The grid was used to sum the total area of each unique land use/land cover type.

The amount of DCIA was estimated using the Sutherland equations as described above and any reduction in impervious area due to disconnection (i.e., the area difference between TIA and DCIA) was assigned to the pervious D soil category for that land use to simulate that some infiltration will likely occur after runoff from disconnected impervious surfaces passes over pervious surfaces.

Pollutant loading for key nonpoint source pollutants in the watershed was estimated by multiplying each land use/cover type area by its pollutant load export rate (PLER) as follows: $L_n = A_n * P_n$

Where L_n = Loading of land use/cover type n (lb/yr); A_n = area of land use/cover type n (acres);
P_n = pollutant load export rate of land use/cover type n (lb/acre/yr)

The PLERs are an estimate of the annual total pollutant load exported via stormwater from a given unit area of a particular land cover type. The PLER values for TN, TP and TSS were obtained from USEPA (USEPA, 2020; UNHSC,

2018, Tetra Tech, 2015) (see values provided in Appendix A). **Table A-9** presents the estimated land-use based TN, TP and TSS pollutant loading in the watershed.

Table A-9: Estimated Pollutant Loading for Key Nonpoint Source Pollutants

Land Use Type	Pollutant Loading[1]		
	Total Phosphorus (TP) (lbs/yr)	Total Nitrogen (TN) (lbs/yr)	Total Suspended Solids (TSS) (tons/yr)
Agriculture	175	1,047	12.90
Commercial	4	31	0.39
Forest	363	1,896	96.83
High Density Residential	27	199	2.85
Highway	43	358	19.50
Industrial	0	0	0.00
Low Density Residential	114	1,126	15.31
Medium Density Residential	25	223	3.04
Open Land	26	242	4.05
TOTAL	776	5,121	154.86

[1]These estimates do not consider loads from point sources or septic systems.

Pollutant loading information

Using the pollutant loading calculation detailed above, the Watershed Based Planning tool calculated the following pollutant loading per land use type (**Table A-9**). Based off of these calculations, forested land contributes the greatest phosphorus load, followed by agricultural land, and low density residential. While forest land contributes a small amount of Phosphorus to surface waters on a per area basis, this land use type covers a large area of the watershed. **Table A-6** shows that 65% of the watershed is forested and Table A-9 shows that forest land contributes 47% of the TP load (363 lbs/year). Because forest phosphorus inputs are low on a per area basis and cannot be appreciably reduced through management, focusing on the areas where reductions can be realized (agricultural land and residential/commercial areas) is recommended for best management.

While the Watershed Based Planning Tool provides a comprehensive estimate of pollutant loading, local data can help to further inform conditions and future management. The Newburyport Reservoirs Water Quality Model Update (DK Water Resource Consulting LLC, 2023) estimated the pollutant loads for the Lower Artichoke Reservoir and its upstream sources using water quality sampling and analysis to generate localized models for the reservoirs. The model also incorporates data about watershed and sub-basin boundaries, land cover, point sources (if applicable), septic systems, waterfowl, rainfall, lake volume and surface area, and internal phosphorus loading. These data were combined with coefficients, attenuation factors, and equations from scientific literature on lakes, rivers, and nutrient cycles to produce an annual water and phosphorous loading budget for the Indian Hill, Upper and Lower Artichoke reservoirs.

Using this model, the Indian Hill Reservoir had the highest water quality in the system with Total Phosphorus at 65.7 kg/year (49.0 kg/year watershed load). This is due in large part to the small size of the watershed in comparison to the lake area.

The Upper Artichoke Reservoir reported an estimated 456.7 kg/year (369.8 kg/year watershed load). The Upper Artichoke receives phosphorus from a much larger watershed area that includes the Indian Hill Watershed. Much of the land cover in both the Indian Hill and Upper Artichoke watersheds is residential or agricultural. These land covers typically export much more phosphorus per area than natural forested land covers.

The Lower Artichoke Reservoir reported an estimated 313.4 kg/year (307.5 kg/year watershed load). The Lower Artichoke Reservoir receives water and phosphorus from both the Upper Artichoke and Indian Hill (via the Upper Artichoke). The direct watershed of the Lower Artichoke Reservoir is quite small and much of it remains in a natural state which typically would export little phosphorus. However, because of the magnitude of the loads originating in the upstream reservoirs, phosphorus concentrations in the Lower Artichoke Reservoir were also found to be quite high (DK Water Resource Consulting LLC, 2023). Increases in phosphorus means there is a higher probability that algal concentrations will also be high.

The Newburyport Reservoirs Water Quality Model Update (DK Water Resource Consulting LLC, 2023) identifies Total Phosphorus loading by source in the Lower Artichoke Reservoir under current conditions (**Table A-10**). Through this modeling approach, the watershed load, which includes phosphorus from the Upper Artichoke release, is identified as the largest source. The load to the Lower Artichoke Reservoir is nearly all watershed-based, much of which comes from Upper Artichoke Reservoir and its watershed (DK Water Resource Consulting LLC, 2023).

Table A-10: Estimated Pollutant Loading Summary by Source

Direct Load to Reservoir	P (kg/year)
Atmospheric	3.9 (8.6 lbs/year)
Internal (drawdown zone erosion)	0.0
Internal (anoxic release)	0.0
Waterfowl	2.0 (4.4 lbs/year)
Septic System	0.0
Watershed Load	307.5 (678 lbs/year)
Total Load to Reservoir (watershed + direct loads)	313.4 (691 lbs/year)

The Existing Estimated Total Load for TP in the Lower Artichoke Reservoir calculated in the 2023 Newburyport Reservoirs Water Quality Model update (691 lbs/year) is similar to the 776 lbs/year estimate generated using the Watershed Based Tool. Because the watershed load estimated in the 2023 Newburyport Reservoirs Water Quality Model was based on direct water quality sampling and analysis, and are more representative of local conditions, these values have been reported throughout the document and used for management and planning purposes.

Element B: Determine Pollutant Load Reductions Needed to Achieve Water Quality Goals

Element B of your WBP should:

Determine the pollutant load reductions needed to achieve the water quality goals established in Element A. The water quality goals should incorporate Total Maximum Daily Load (TMDL) goals, when applicable. For impaired water bodies, a TMDL establishes pollutant loading limits as needed to attain water quality standards.

Estimated Pollutant Loads

Table B-1 lists estimated pollutant loads for the following primary nonpoint source (NPS) pollutants: total phosphorus (TP), total nitrogen (TN), total suspended solids (TSS). These estimated loads are based on the pollutant loading analysis presented in Element A.

Water Quality Goals

Water quality goals for primary NPS pollutants are listed in **Table B-1** based on the following:

- TMDL water quality goals (if a TMDL exists for the water body);
- For all water bodies, including impaired waters that have a pathogen TMDL, the water quality goal for bacteria is based on the Massachusetts Surface Water Quality Criteria for Bacteria (CN 563.0, 2021) that apply to the Water Class of the selected water body.
- If the water body does not have a TMDL for TP, a default target TP concentrations is provided which is based on guidance provided by the USEPA in Quality Criteria for Water (1986), also known as the "Gold Book". Because there are no similar default water quality goals for TN and TSS, goals for these pollutants are provided in **Table B-1** only if a TMDL exists or alternate goal(s) have been optionally established by the WBP author.
- According to the USEPA Gold Book, total phosphorus should not exceed 50 ug/L in any stream and 25 ug/L for any lake or reservoir.

Table B-1: Pollutant Load Reductions Needed

Pollutant	Existing Estimated Total Load	Water Quality Goal	Required Load Reduction
Total Phosphorus	691 lbs/yr (reported from DK Water Resource Consulting, 2023)	403 lbs/yr (15.6 ug/L target)	288 lbs/yr
Total Nitrogen	5121 lbs/yr		
Total Suspended Solids	155 ton/yr		
Bacteria	*MSWQS for bacteria are concentration standards (e.g., colonies of fecal coliform bacteria per 100 ml), which are difficult to predict based on estimated annual loading.*	**Class A Standards** • At water supply intakes in unfiltered public water supplies: either fecal coliform shall not exceed 20 fecal coliform organisms per 100 mL in all samples taken in any six-month period, or total coliform shall not exceed 100 organisms per 100 mL in 90% of the samples taken in any six-month period. If both fecal coliform and total coliform are measured, then only the fecal coliform criterion must be met. More stringent regulations may apply under 310 CMR 22.00: Drinking Water (see 314 CMR 4.06(1)(d)1.) • Primary contact recreation: For E. coli, geometric mean of samples collected within any 90-day or smaller period shall not exceed 126 cfu/100 mL, and no more than 10% of all such samples shall exceed 410 cfu/100 mL. For enterococci, geometric mean of all samples collected within any 90-day or smaller period shall not exceed 35 cfu/100 mL, and no more than 10% of all such samples shall exceed 130 cfu/100 mL.	

TMDL Pollutant Load Criteria

No TMDL Pollutant Load Criteria Data Found

Pollutant load reduction information:

No TMDL Pollutant Load Criteria data exists for the Lower Artichoke Reservoir. Using DEP's Watershed Based Planning Tool, an existing estimated total load of 776 lbs/year was determined. This estimated total load was calculated by multiplying the target maximum phosphorus concentration by the estimated annual watershed discharge for the selected water body. To estimate the annual watershed discharge, the mean flow was used, which was estimated based on United States Geological Survey (USGS) "Runoff Depth" estimates for Massachusetts (Cohen and Randall, 1998). Cohen and Randall (1998) provide statewide estimates of annual Precipitation (P), Evapotranspiration (ET), and Runoff (R) depths for the northeastern U.S. According to their method, Runoff Depth (R) is defined as all water reaching a discharge point (including surface and groundwater), and is calculated by: $P - ET = R$. A mean Runoff Depth R was determined for the watershed by calculating the

average value of R within the watershed boundary. This method averages the TP load across the entire watershed, and only accounts for phosphorus due to stormwater runoff.

Due to these limitations, and the availability of local TP modeling data, the decision was made to use the estimated Total Phosphorus load of 691 lbs/year identified through the Newburyport Reservoirs Water Quality Model Update (DK Water Resource Consulting LLC, 2023), as the Existing Estimated Total Load reported in **Table B-1**.

Using the USEPA Gold Book standards for water quality targets in streams and lakes (25 ug/l) would yield a water quality goal of 520 lbs/year and a load reduction of 170 lbs/year. A more stringent water quality target of 15.6 ug/l was chosen to set the TP load reduction goal for the Lower Artichoke Reservoir. This decision was made based on biological response parameters for the system. The largest risk to the system has been identified to be potentially-toxic cyanobacteria blooms threatening drinking water supply for public consumption. Based on local modeling reporting in the Newburyport Reservoirs Water Quality Model Update, a water quality goal of 25 ug/L for TP would still allow for a 40-90% bloom risk for the Lower Artichoke Reservoir (DK Water Resource Consulting LLC, 2023). Using the modeling from the Newburyport Reservoirs Water Quality Model Update, a regression analysis for the Lower Artichoke Reservoir was created to relate the following critical parameters: TP load, TP concentration, Chlorophyll a concentration, and bloom probability to help determine the best load reduction goal for the system of 15.6 ug/l.

The MassDEP CALM considers a waterbody impaired if it exceeds 20 bloom days/yr, which is 5.5% of the year. Currently, the Lower Artichoke Reservoir exceeds 20 bloom days/year. For the Lower Artichoke Reservoir to meet the <5.5% threshold , load reduction would need to be reverted back to natural background conditions (i.e. an undeveloped and completely forested watershed), which is not possible for the system. Setting a more achievable target for blooms occurring 15% of the year (55 bloom days/year) would yield a target Chlorophyll a value of 7.0 ppb, and a target TP load of 15.6 ug/l or 403 lbs/year. The associated required load reduction for the system would be 288 lbs/year. These values are reflected in **Table B-1**. By setting a more stringent, yet achievable water quality goal, the Watershed Based Plan aims to reduce Phosphorous loading into the Artichoke River and its reservoirs, ultimately reducing algal blooms and improving the quality of this vital resource.

The frequency of algal blooms has been increasing in recent years, with blooms occurring in all three reservoirs (Indian Hill, Upper Artichoke, and Lower Artichoke) in 2019 and 2020. Increased bloom events are likely the result of a number of factors, including climatic changes such as increased temperatures and more intensive precipitation events, as well as high nutrient loading from the watershed. Treatments for algal blooms were administered in 2020, 2021, 2022, 2023 & 2024 with copper sulfate treatments, and algal blooms were greatly reduced during that time period. The constant need for treatment over the last five years has identified this as a chronic problem for the City. The Best Management Practices described in Element C aim to reduce TP and other pollutants persistent in the waterbody.

No TMDL exists for Total Nitrogen and Total Suspended Solid in the reservoir. Additionally, no local consistent data on levels and impacts is currently available for the Lower Artichoke Reservoir. Due to the lack of information and regulatory guidance available, neither pollutant are directly addressed in this plan. Future research to better understand, measure, and if needed address, these pollutants should be further explored.

Element C: Describe management measures that will be implemented to achieve water quality goals

Element C: A description of the nonpoint source management measures needed to achieve the pollutant load reductions presented in Element B, and a description of the critical areas where those measures will be needed to implement this plan.

BMP Hotspot Map:

Using DEP's Watershed-Based Planning Tool, the following GIS-based analysis was performed within the watershed to identify high priority parcels for best management practice (BMP; or "management measure") implementation:

- Each parcel within the watershed was evaluated based on ten different criteria accounting for the parcel ownership, social value, and implementation feasibility (See **Table C-1** for more detail below);
- Each criterion was then given a score from 0 to 5 to represent the priority for BMP implementation based on a metric corresponding to the criterion (e.g., a score of 0 would represent the lowest priority for BMP implementation whereas a score of 5 would represent the highest priority for BMP implementation);
- A multiplier curated by the WBP Tool was also assigned to each criterion to reflect the weighted importance of the criterion (e.g., a criterion with a multiplier of 3 had greater weight on the overall prioritization of the parcel than a criterion with a multiplier of 1);
- The weighted scores for all the criteria were then summed for each parcel to calculate a total BMP priority score. The highest score possible to receive was 100.

Table C-1 presents the criteria, indicator type, metrics, scores, and multipliers that were used for this analysis. Parcels with total scores above 60 indicate high potential for BMP implementation suitability and are recommended for further investigation. **Figure C-1** presents the resulting BMP Suitability Index Map for the watershed. The following link, generated by the DEP WBP Tool, includes a Microsoft Excel file with information for all parcels that received a score of more than 60: **BMP Suitability Index Spreadsheet.**

This analysis solely evaluated individual parcels for BMP implementation suitability and likelihood for the measures to perform effectively within the parcel's features. The analysis did not quantify the pollutant loading to these parcels from the parcel's upstream catchment. Therefore, this initial step served as a starting point to identify potential locations, and further evaluate BMP implementation suitability, cost-effectiveness, and nutrient reduction of BMP implementation.

GIS data used for the BMP Hotspot Map analysis included:

- Fire Stations (MassGIS, 2015a)

- Police Stations (MassGIS, 2015b)
- Town and City Halls (MassGIS, 2017a)
- Libraries (MassGIS, 2017b)
- Massachusetts Schools (MassGIS, 2020)
- Property Type Classification Codes (MA Depart. of Revenue Division of Local Services, 2016)
- Elevation (MassGIS, 2005)
- U.S. Soil Hydrologic Groups (ArcGIS, 2020)
- 2005 Land Use (MassGIS,2009b)
- 2010 U.S. Census Environmental Justice Populations (MassGIS, 2012)
- U.S. Soil Water Table Depth (ArcGIS, 2020b)

Table C-1: Example of Scoring Matrix used for BMP Hotspot Map GIS-based Analysis

Criteria	Indicator Type	METRICS																											Multiplier	Maximum Potential Score
		Yes or No?		Hydrologic Soil Group				Land Use Type									Water Table Depth				Parcel Area			Parcel Average Slope						
		Yes	No	A or A/D	B or B/D	C or C/D	D	Low and Medium Density Residential	High Density Residential	Commercial	Industrial	Highway	Agriculture	Forest	Open Land	Water	101-200 cm	62-100 cm	31-61 cm	0-30 cm	Greater than 2 acres	Between 1-2 acres	Less than 1 acre	Less than 2%	Between 2% and 15%	Greater than 15%	Less than 50%	Between 51% and 100%		
Is the parcel a school, fire station, police station, town hall or library?	Ownership	5	0																										2	10
Is the parcel's use code in the 900 series (i.e. public property or university)?	Ownership	5	0																										2	10
Is parcel fully or partially in an Environmental Justice Area?	Social	5	0																										2	10
Most favorable Hydrologic Soil Group within Parcel	Implementation Feasibility			5	3	0	0																						2	10
Most favorable Land Use in Parcel	Implementation Feasibility							1	2	4	2	4	5	1	4	X[1]													3	15
Most favorable Water Table Depth (deepest in Parcel)	Implementation Feasibility																5	4	3	0									2	10
Parcel Area	Implementation Feasibility																				5	4	1						3	15
Parcel Average Slope	Implementation Feasibility																							3	5	1			1	5
Percent Impervious Area in Parcel	Implementation Feasibility																										5	2.5	1	5
Within 100 ft buffer of receiving water (stream or lake/pond)?	Implementation Feasibility	5	2																										2	10

Note 1: **X** denotes that parcel is excluded

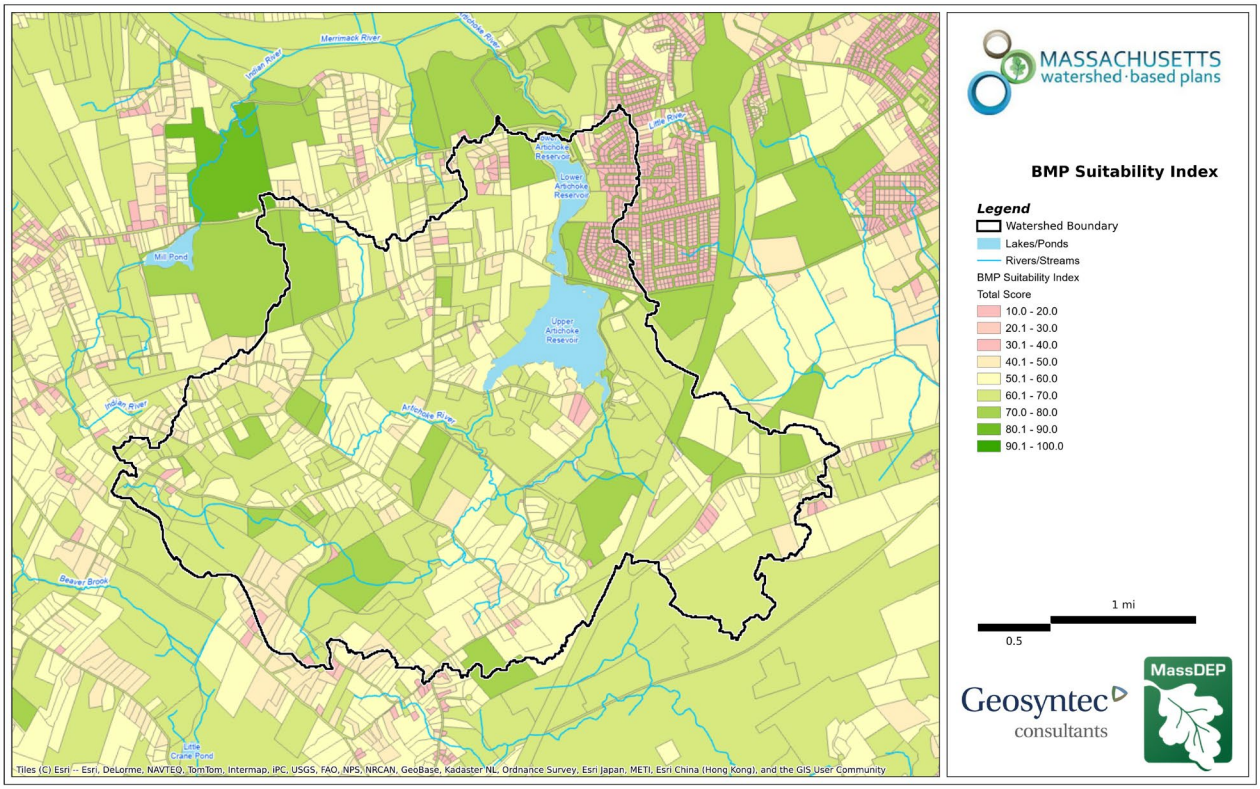


Figure C-1: BMP Suitability Index Map (MassGIS (2015a), MassGIS (2015b), MassGIS (2017a), MassGIS (2017b), MassGIS (2020), MA Department of Revenue Division of Local Services (2016), MassGIS (2005), ArcGIS (2020), MassGIS (2019), MassGIS (2012), ArcGIS (2020b))

Ctrl + Click on the map to view a full sized image in your web browser.

Through this assessment, the most optimal sites for future BMPs were identified. Sites denoted by green in **Figure C-1**, scoring between 60-100, indicate the most suitable locations to focus future implementation efforts. Developed areas, including the Turkey Hill neighborhood abutting the Artichoke, received a low favorability for potential BMP locations.

While the DEP Watershed Based Planning tool identifies recommended locations for further investigation of BMP implementation, many of the sites were identified as unsuitable locations based on local knowledge of the site. Through integrating past planning efforts such as the Water Supply Watershed Program Framework (Woodard & Curan, 2023), and the Watershed Protection Plan (Tighe & Bond, 2021) along with assessing local parcels and activities within the watershed, potential BMPs were further assessed and identified for the Plan.

Proposed Management Measures:

A holistic approach to TP reduction in the reservoir is outlined in the City's Water Supply Watershed Program Framework (Woodard & Curran, 2023). Suggested reduction measures included land acquisition for conservation, water supply protection bylaws, inter-municipal partnerships to promote landowner and recreator education, as well as Best Management Practices (BMPs). As such, a dual education and implementation program has been identified as the best approach for the Artichoke Reservoir to address agricultural and suburban TP loading across different stakeholder groups to protect this essential drinking water and recreational resource.

Table C-3 presents the *proposed* management measures as well as the estimated pollutant load reductions and costs. The planning level cost estimates, pollutant load reduction estimates, and estimates of BMP footprint were based off information obtained in the following sources and adjusted to 2016 values using the Consumer Price Index (CPI) (United States Bureau of Labor Statistics, 2016). Planning costs were further ground-truthed and refined based on current conditions and discussion with local municipal staff members:

- Geosyntec Consultants, Inc. (2014);
- Geosyntec Consultants, Inc. (2015);
- King and Hagen (2011);
- Leisenring, et al. (2014);
- MassDEP (2016a);
- MassDEP (2016b);
- University of Massachusetts, Amherst (2004);
- USEPA (2020);
- UNHSC (2018);
- Tetra Tech, Inc. (2015);

A total of 11 possible BMPs were identified through this process and detailed below. These BMPs represent potential opportunities to reduce nutrient runoff into the Lower Artichoke Reservoir. Three structural BMPs were recommended through best fit scenarios for this watershed. All structural BMPs will require coordination, agreement of the property owner(s), and proper permitting and approval to proceed. The combined total reduction of Total Phosphorus for these three proposed BMP's is 49.98 lbs/year. Additional BMPs include initiatives such as vegetated buffer strips, cover crops, as well as non-structural BMP's such as land acquisition and conservation management, and fertilizer and pesticide use management and education. Similarly, these additional BMPs would only be advanced with approval and collaboration with relevant authorities.

Table C-3: Proposed Management Measures, Estimated Pollutant Load Reductions and Costs

STRUCTURAL BMPS	
BMP TYPE	GRASSED CHANNEL/ WATER QUALITY SWALE
BMP SIZE (storm depth; inches)	1.00
DRAINAGE AREA (acres)	24.00
BMP LOCATION	Maple Crest Farm, 102 Moulton Street, West Newbury, MA (R6-18)
LAND USE, COVER TYPE (in drainage area)	**% OF DRAINAGE AREA**
AGRICULTURE, Pervious	90
LOW DENSITY RESIDENTIAL, Pervious	10
ESTIMATED POLLUTANT LOAD REDUCTIONS	
TN (lbs/yr)	7.63
TP (lbs/yr)	2.08
TSS (lbs/yr)	565.29
ESTIMATED FOOTPRINT (sf)	1,350 SF
ESTIMATED COST ($)	$461,385

BMP TYPE	BIORETENTION AND RAIN GARDENS
BMP SIZE (storm depth; inches)	1.00
DRAINAGE AREA (acres)	0.80
BMP LOCATION	0 Middle Street (R20-11A)
LAND USE, COVER TYPE (in drainage area)	**% OF DRAINAGE AREA**
INDUSTRIAL, Impervious	20
OPEN LAND, Pervious	80
ESTIMATED POLLUTANT LOAD REDUCTIONS	
TN (lbs/yr)	2.35
TP (lbs/yr)	0.27
TSS (lbs/yr)	78.43
ESTIMATED FOOTPRINT (sf)	564.7
ESTIMATED COST ($)	$31,394

BMP TYPE	INFILTRATION BASIN W/ SEDIMENT FOREBAY
BMP SIZE (storm depth; inches)	0.25
DRAINAGE AREA (acres)	20.00
BMP LOCATION	70 Longfellow Dr, Newburyport, MA (92-21)
LAND USE, COVER TYPE (in drainage area)	**% OF DRAINAGE AREA**
MEDIUM DENSITY RESIDENTIAL, Impervious	50
MEDIUM DENSITY RESIDENTIAL, Pervious	50
ESTIMATED POLLUTANT LOAD REDUCTIONS	
TN (lbs/yr)	113.93
TP (lbs/yr)	12.63
TSS (lbs/yr)	3879.23
ESTIMATED FOOTPRINT (sf)	5,218
ESTIMATED COST ($)	$300,901

ADDITIONAL BMPS

BMP TYPE	Education and Outreach
BMP LOCATION	Watershed-wide
DESCRIPTION	-Evaluate and assess key stakeholders in watershed and the best communication and outreach format -Establish intermunicipal stakeholder group -Establish key messages to promote watershed health -Identify land owners willing to participate in pilot projects

	-Participate in regular meetings with neighboring communities and key stakeholders -Strategically engage through variety of media (e.g., website, flyers) and at events
ESTIMATED POLLUTANT LOAD REDUCTIONS	
ESTIMATED COST ($)	$50,000

BMP TYPE	Laws and Regulations
BMP LOCATION	Watershed-wide
DESCRIPTION	Create and or bolster local laws and regulations to protect water quality across the watershed. This would include revising the Section XIX Ordinance in the City of Newburyport to reflect appropriate allowed/permitted activities within the Surface Water Overlay and establish adequate and sustainable enforcement and inspection processes. Additionally, working with neighboring communities to establish water supply protection bylaws to identify prohibited activities within a set radius of the reservoirs and reduce pollutant loading. Adoption of, or amendment to, Town Bylaws would require Town Meeting approval.
ESTIMATED POLLUTANT LOAD REDUCTIONS	
ESTIMATED COST ($)	$25,000

BMP TYPE	Land Acquisition and Conservation Management
BMP LOCATION	Watershed-wide
DESCRIPTION	In collaboration with Greenbelt, Essex County's Land Trust, and neighboring municipalities, develop a 10-year land acquisition plan to keep lands minimally developed and control pollutant-generating activities. Several developed and undeveloped parcels have been identified and prioritized by Greenbelt.
ESTIMATED POLLUTANT LOAD REDUCTIONS	
ESTIMATED COST ($)	$35,000

BMP TYPE	Fertilizer and Pesticide Use/Management Education
BMP LOCATION	Zone A and B of watershed
DESCRIPTION	In conjunction with the Education & Outreach plan, develop and distribute educational material about fertilizer/ herbicide selection, application, and storage to residents within Zone A & B.
ESTIMATED POLLUTANT LOAD REDUCTIONS	
ESTIMATED COST ($)	$8,000

BMP TYPE	Inspectional Program

BMP LOCATION	Watershed-wide
DESCRIPTION	Leverage existing inspectional programs to conduct and enhance inspections of construction sites and land development, illicit discharge in sewered portions of the watershed, and Code of Massachusetts Regulations for drinking water (310 CMR 22). This includes establishing inspection protocol and standardized reporting.
ESTIMATED POLLUTANT LOAD REDUCTIONS	
ESTIMATED COST ($)	$24,000

BMP TYPE	Vegetated Buffer Strips
BMP LOCATION	15 Moulton St, West Newbury, Massachusetts (R17-6G)
DESCRIPTION	Establishing vegetated buffer strips along the edges of the crop field can effectively reduce phosphorus runoff. These strips consist of native plants and grasses that act as a natural filter, trapping sediment and nutrients, including phosphorus, before they enter the water. The dense root systems of these plants help stabilize the soil and prevent erosion.
ESTIMATED POLLUTANT LOAD REDUCTIONS	10 lbs TP/year
ESTIMATED COST ($)	5,200

BMP TYPE	Manure Management and Nutrient Storage
BMP LOCATION	Artichoke Dairy, 51 Rogers St, West Newbury, MA 01985
DESCRIPTION	Proper handling and storage of manure is essential to prevent phosphorus and other nutrients from leaching into water bodies. Implementing practices such as constructing manure storage methods, regular removal of manure, and adopting nutrient management plans can help minimize runoff and optimize nutrient application.
ESTIMATED POLLUTANT LOAD REDUCTIONS	20 lbs TP/year
ESTIMATED COST ($)	26,000

BMP TYPE	Cover Crops
BMP LOCATION	100 Turkey Hill Rd Newburyport, Massachusetts
DESCRIPTION	Planting cover crops during the non-growing season, such as winter rye or clover, can significantly reduce phosphorus runoff. These cover crops protect the soil from erosion, absorb excess nutrients, and improve soil health. When the cover crops are later incorporated into the soil, they release the captured nutrients, making them available for the next crop's growth while reducing the risk of phosphorus reaching the reservoir.
ESTIMATED POLLUTANT LOAD REDUCTIONS	5 lbs TP/year
ESTIMATED COST ($)	$1,000

Element D: Identify Technical and Financial Assistance Needed to Implement Plan

Element D: Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.

Table D-1 presents the funding needed to implement the management measures presented in this watershed plan. The table includes costs for structural and non-structural BMPs, operation and maintenance activities, information/education measures, and monitoring/evaluation activities.

Table D-1: Summary of Funding Needed to Implement the Watershed Plan.

Management Measures	Location	Capital Costs[1]	Operation & Maintenance Costs[2]	Relevant Authorities	Technical Assistance Needed	Funding Needed
Structural and Non-Structural BMPs (from Element C)						
Grassed Channel/ Water Quality Swale	Maple Crest Farm	$458,385	$3,000	Town of West Newbury, Private Landowner	USDA Natural Resources Conservation Service (NRCS)	$461,385
Bioretention and Rain Gardens	0 Middle St, West Newbury, MA	$26,394	$5,000	Town of West Newbury	Procured Consultant	$31,394
Infiltration Basin W/ Sediment Forebay	70 Longfellow Dr, Newburyport, MA	$291,401	$9,500	City of Newburyport and Private Landowner	Procured Consultant	$300,901
Laws and Regulations	Watershed-wide	$25,000	-	City of Newburyport, Town of West Newbury	Merrimack Valley Planning Commission or Procured Consultant	$25,000
Land Acquisition and Conservation Management Plan	Watershed-wide	$35,000	-	Greenbelt; City of Newburyport	Greenbelt or Procured Consultant	$35,000
Vegetated Buffer Strips	15 Moulton St, West Newbury, Massachusetts	$5,000	$200	Private Landowner	NRCS	$5,200
Manure Management and Nutrient Storage	Artichoke Dairy, 51 Rogers St, West Newbury, MA 01985	$25,000	$1,000	Private Landowner	NRCS	$26,000

Cover Crops	100 Turkey Hill Rd Newburyport, Massachusetts	$500	$500	Private Landowner	NRCS	$1,000
Information/Education (see Element E)						
Education and Outreach	Watershed-wide	$35,000	$15,000	City of Newburyport	Procured Consultant	$50,000
Fertilizer and Pesticide Use/ Management Education	Zone A and B of watershed	$5,000	$3,000	City of Newburyport; Town of West Newbury	Procured Consultant	$8,000
Monitoring and Evaluation (see Element H/I)						
Inspectional Program	Watershed-wide	-	$24,000	City of Newburyport	DK Water Resource Consulting LLC	$24,000
					Total Funding Needed:	**$506,495**
Funding Sources:						
• City of Newburyport Annual Budget • Massachusetts DEP Section 319 Nonpoint Source Competitive Grants Program						

[1]Capital Costs of BMPs were calculated using the WBP tool. Best professional judgement was also used to assess WBPs in which estimates were not available and to confirm values.

[2]Estimated Operations & Maintenance costs were reported as an annual cost based on professional judgement and past projects. Actual costs may vary widely based on who performs the maintenance.

Element E: Public Information and Education

Element E: Information and Education (I/E) component of the watershed plan used to:

1. Enhance public understanding of the project; and
2. Encourage early and continued public participation in selecting, designing, and implementing the NPS management measures that will be implemented.

Public Education and Outreach for the Lower Artichoke Reservoir is a part of a larger comprehensive program administered by the City of Newburyport. To achieve these goals, the City anticipates engaging key stakeholders including neighboring municipalities, non-profit conservation organizations, community-based organizations, and regional entities. Through expanding communication and partnership on these education and outreach efforts, collective regional improvement can be achieved. A description of each of the outreach elements is provided below.

Step 1: Goals and Objectives

The Lower Artichoke Reservoir is a critical resource for the surrounding communities which rely on the Reservoir as a source of drinking water, recreation, and habitat for key species. Non-point source pollution has been identified as a source of degradation to the water quality in the Reservoir. Therefore, it is necessary to engage with the public and surrounding communities to protect this valuable resource. Outreach will be conducted to build public understanding of the project and help ensure successful outcomes are reached to protect the Reservoir.

Due to the location of the Lower Artichoke Reservoir Watershed, situated between the City of Newburyport, and Towns of Newbury and West Newbury, the need to employ collaborative approaches to reach comprehensive water quality solutions has been identified. As such, Newburyport will look to leverage existing relationships between key stakeholders in the region to protect and improve the communities' surface water supply from contamination using collaborative watershed management. Through the formation of an intermunicipal stakeholder group made up of representatives from Newburyport, Newbury, and West Newbury, solutions outlined in the WBP and beyond may be advanced. Due to the dynamic nature of each municipalities' local government, comprehensive engagement will be conducted to ensure appropriate representation from across each community is achieved. Using a multi-community approach, the stakeholder group will be instrumental in identifying public outreach measures for local landowners and users, disseminating materials to promote watershed health, and connecting with landowners across the watershed who are willing to participate in pilot projects. Public information and education will be conducted as future staffing, resources, and funding opportunities allow.

In addition, the City of Newburyport will share this Watershed Based Plan via their City's website as an opportunity for information sharing. The Merrimack Valley Planning Commission will also share this WBP on their website via their monthly newsletter.

Step 2: Target Audience

A diverse audience will be engaged to realize the goals outlined in the watershed based plan. Surrounding landowners, especially those with property abutting the reservoirs and its tributaries, will be a primary focus for education and outreach. In addition, residents and the public in the surrounding communities of Newbury and West Newbury will be engaged through the intermunicipal stakeholder group. To support outcomes identified in the WBP, state and federal agencies (e.g. MassDEP and NRCS), and local organizations (e.g. Merrimack Valley Planning Commission, Greenbelt, Greenscapes) will also be engaged.

Step 3: Outreach Products and Distribution

Outreach and education activities will be conducted to increase knowledge around current water quality risks in the reservoirs and demonstrate actionable solutions. This could include a media campaign, dissemination of information through water bills, and property and farm tours highlighting agricultural BMPs.

Educational materials will be developed to convey key information about watershed management content, local/regional announcements, important program documents, and how to get involved in watershed protection activities. Products will vary based on stakeholder type and needs. The materials and products may include:

- A website and online content, with an avenue to sign up for electronic updates
- Community events (e.g., tabling at regional events, watershed tours, site visits to BMP locations, meetings with residents)
- Promotion of best management practices (e.g. mailers or handouts to promote fertilizer and pesticide use and management, manure management and storage, benefits of vegetated strips and native vegetation)
- Social media content (e.g. promoting native plant species, water conservation, reducing runoff)
- Presentations at public meetings

Step 4: Evaluate Information/Education Program

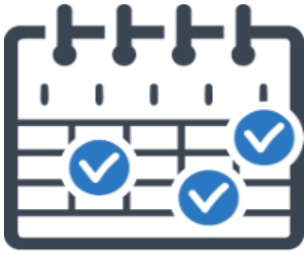
To ensure the efforts to engage the community are effective, the Education and Outreach Plan outlined above will be implemented by the City of Newburyport and other participating stakeholders. Formation of an intermunicipal stakeholder group (meetings held), public participation at events (number of events), dissemination of materials (number circulated), and engagement (visits/engagements) tracked through online analytics will all serve as measures to assess success across the various outreach and education initiatives identified.

Additional education programs and outreach products and events will be determined based on the BMPs installed and completed within the watershed. These will be continuously re-evaluated as needed to ensure that the public has full understanding and to determine the best way to reach residents.

Elements F & G: Implementation Schedule and Measurable Milestones

Element F: Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.

Element G: A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.



Tabel FG-1 Provides a preliminary schedule for implementation of recommendations provided by this WBP. It is expected that the WBP will be re-evaluated and updated as needed, based on monitoring results and other ongoing efforts. New projects will be identified through future data analysis and stakeholder engagement and will be included in updates to the implementation schedule.

Table FG-1: Implementation Schedule and Interim Measurable Milestones[1]

Category	Goal	Action	Year(s)
Structural BMP	Grassed Channel/ Water Quality Swale *Maple Crest Farm*	Initiate discussion with landowners, develop concept for BMP, seek funding to implement BMP	2024-2029
	Bioretention And Rain Gardens *0 Middle St, West Newbury*	Initiate discussion with landowners, develop concept for BMP, seek funding to implement BMP	2024-2029
	Infiltration Basin W/ Sediment Forebay *70 Longfellow Dr, Newburyport*	Seek funding, design and permit, construct BMP, develop O&M	2024-2025
Non-Structural BMP	Laws and Regulations *Watershed-wide*	Assess current bylaws and regulations, review and develop new regulations, conduct local review, distribute educational materials, complete local adoption	2024-2029
	Land Acquisition and Conservation Management Planning *Watershed-wide*	Convene key stakeholders, develop 10-year acquisition plan, seek funding, acquire parcels as funding allows	2024-2029
	Vegetated Buffer Strips *15 Moulton St, West Newbury*	Initiate discussion with landowners, develop concept for BMP, seek funding to implement BMP	2024-2029
	Manure Management and Nutrient Storage *Artichoke Dairy, 51 Rogers St, West Newbury*	Initiate discussion with landowners, develop concept for BMP, seek funding to implement BMP	2024-2029
	Cover Crops *100 Turkey Hill Rd Newburyport*	Initiate discussion with landowners, develop concept for BMP, seek funding to implement BMP	2024-2026

Public Education & Outreach	Inter-municipal Stakeholder group *Watershed-wide*	Establish inter-municipal stakeholder group, continue to meet quarterly to advance goals outline in the WBP	2025- Ongoing
	Watershed Health Education & Outreach *Watershed-wide*	Develop key messages and branding, prepare materials, share content, continue to develop and disseminate new content	2025-Ongoing
	Fertilizer and Pesticide Use/Management Education *Zone A and B of watershed*	Develop key messages and branding, prepare materials, share content	2024-2026
Monitoring	Water Quality and Cyanobacteria Monitoring Plan	Implement Plan (as prescribed in ice-free season)	2025
	Inspectional Program *Watershed-wide*	Continue illicit discharge inspection twice annually, outline enhanced land development site plan review, outline 310 CMR 22 inspection strategy, continue implementation of inspections	2024-onward
Adaptive Management Planning	Re-evaluate Watershed-Based Plan *Watershed-wide*	Conduct WBP update at least once every five (5) years and adjust, as needed, based on ongoing efforts (e.g., based on monitoring results, 319 funding, etc.). – Next update 2029. Continue to advance long-term goals to improve water quality in the Reservoir	2029

[1]The goals and milestones of this WBP are intended to be adaptable and flexible. Goals and milestones are not intended to be tied to Municipal Separate Storm Sewer (MS4e) permit requirements. Stakeholders will perform tasks contingent on available resources and funding.

Scheduling and milestone information

The Newburyport Reservoirs Water Quality and Cyanobacteria Monitoring Plan (DK Water Resource Consulting LLC, 2021) includes future monitoring recommendations for the water quality and cyanobacteria monitoring plan. The report states as follows:

"Monitoring of the Newburyport reservoirs and watershed should be continued for the foreseeable future. However, the intensity of the monitoring effort is dependent on the findings. The minimal plan, consistent with other water utilities with surface water supplies, should include a combination of parameters designed to assist with treatability of the raw water and parameters to measure trophic state or the relative fertility of the reservoirs. Increases in the concentrations of parameters related to trophic state may lead to more serious long-term ramifications for the water supply including increases or changes in treatment, the presence of harmful algal blooms (cyanobacteria), depression of oxygen at depth in the reservoirs and a more favorable environment for invasive aquatic species, particularly plants."

"Given the recent history of blooms in the reservoirs, it is advised that several years of the baseline monitoring be undertaken prior to a re-evaluation and modification of sampling frequency or parameters. This will give the city a much better picture of the seasonal dynamics of the reservoirs and the interplay between water chemistry and blooms."

In their report, DK Water Resource Consulting LLC identifies that routine monitoring is conducted by City employees with oversight and assistance from contractors as needed.

Elements H & I: Progress Evaluation Criteria and Monitoring

Element H: A set of criteria used to determine (1) if loading reductions are being achieved over time and (2) if progress is being made toward attaining water quality goals. Element H asks "**how will you know if you are making progress towards water quality goals?**" The criteria established to track progress can be direct measurements (e.g., E. coli bacteria concentrations) or indirect indicators of load reduction (e.g., number of beach closings related to bacteria).

Element I: A monitoring component to evaluate the effectiveness of implementation efforts over time, as measured against the Element H criteria. Element I asks "**how, when, and where will you conduct monitoring?**"

The water quality target concentration(s) is presented under Element A of this plan. To achieve this target concentration, the annual loading must be reduced to the amount described in Element B. Element C of this plan describes the various management measures that will be implemented to help achieve this targeted load reduction. The evaluation criteria and monitoring program described below will be used to measure the effectiveness of the proposed management measures (described in Element C) in improving the water quality of the Lower Artichoke Reservoir.

Indirect Indicators of Load Reduction

Non-Structural BMPs

The frequency, location, and extent of algal blooms will be monitored twice weekly during the ice-free season, as prescribed in the monitoring plan. Additionally, direct field measurements conducted by the City of Newburyport will continue to be collected, as detailed below. A reduction in the frequency of algal blooms and improvement of water quality will also indicate an improvement in nutrient loading in the reservoirs.

Potential load reductions from non-structural BMPs, such as enhancing inspections of construction sites and land development, street sweeping, catch basin cleaning, conserving riparian vegetation zones, revegetating native species, and decentralizing discharges, can be estimated from indirect indicators. In Element C of this plan, it is recommended that existing inspectoral programs be leveraged to conduct and enhance inspections of land development sites and illicit discharge in sewered portions of the watershed. While these BMPs do not reduce nutrient loading in an easily calculated way, they are nonetheless essential to the overall load reduction and general upkeep of the watershed.

Project-Specific Indicators

Number of BMPs installed and Pollution Reduction Estimates

As discussed in Element C, there are three recommended structural BMPs, three additional nature-based solutions, and five non-structural BMPs identified in this WBP. The anticipated pollutant load reduction has been documented for each proposed BMP where applicable. The number of BMPs installed will be tracked and quantified as part of this monitoring program. For example, if all recommended BMPs are installed, the anticipated TP load reduction is estimated to be 49.98 pounds per year. Anticipated pollutant load reductions from future BMPs will be tracked as BMPs are installed.

TMDL Criteria

Not applicable - no TMDL for Lower Artichoke Reservoir Watershed.

Direct Measurements

Reservoir water quality monitoring

Direct field measurements are expected to be performed as described below.

Reservoir Sampling: The City of Newburyport will sample the reservoirs at four (4) monitoring locations: Lower Artichoke Reservoir deep spot (S-1), Upper Artichoke Reservoir deep spot (S-2), Indian Hill Reservoir deep spot (S-3), Bartlett Reservoir deep spot (S-4). The following laboratory parameters will be collected: Chlorophyll a, dissolved color, total phosphorus as P, Iron, Manganese, Ammonia as N, Nitrite plus nitrate as N, Total Kjehldahl Nitrogen as N, organic nitrogen, total nitrogen as N, total organic carbon, CyanoScope, CyanoMonitoring. The following field parameters will be collected: temperature, dissolved oxygen, pH, Secchi transparency, specific conductance, turbidity, BloomWatch observations, Phycochyanin. Reservoir sampling will occur within two (2) weeks of ice out, monthly between May and mid-October, and once in late fall.

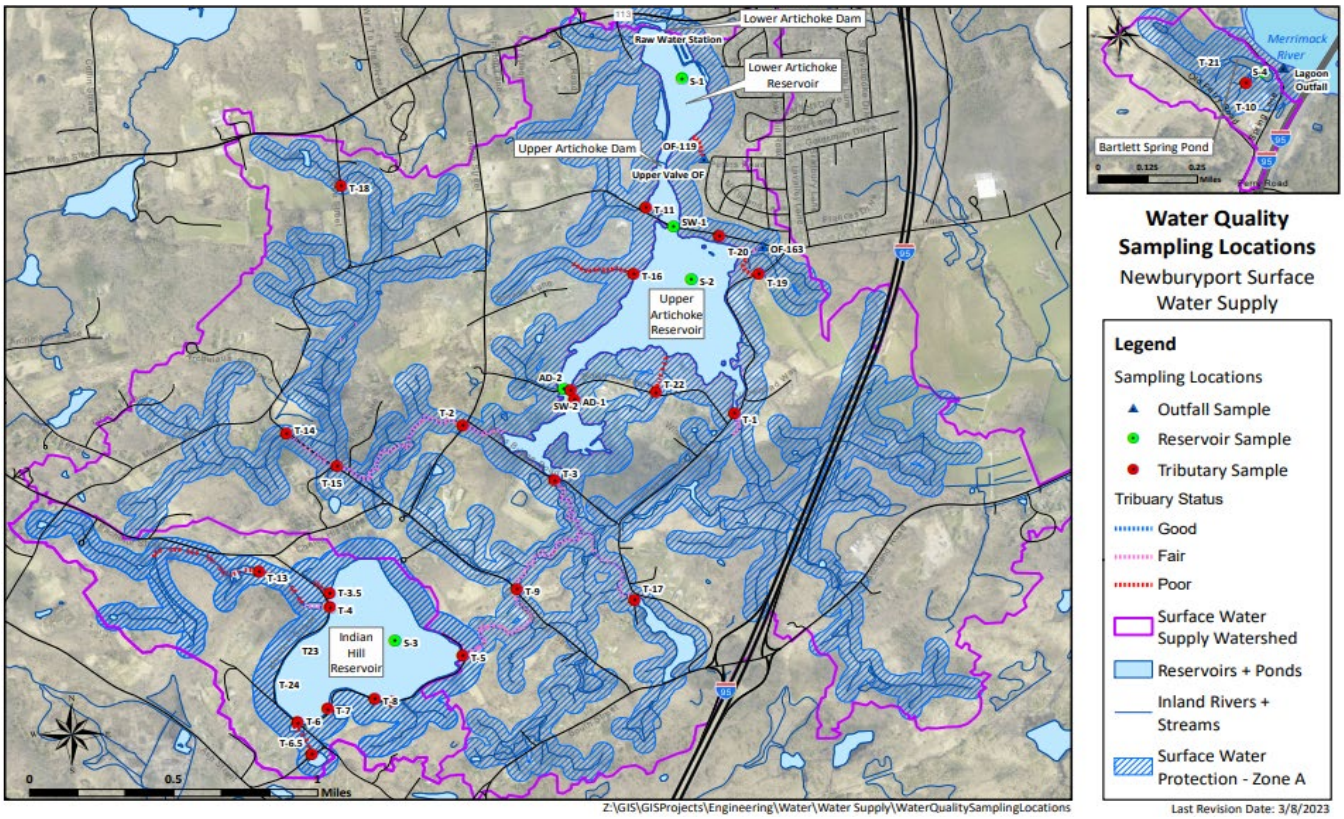


Figure HI-1. Newburyport Reservoir Sampling Locations

(Figure Source: Newburyport Reservoir Water Quality and Cyanobacteria Monitoring Plan)

Regular monitoring of phosphorus levels at the proposed monitoring locations is recommended to provide data on phosphorus concentrations trends in response to implementation of the measures described in Element C.

Tributary water quality sampling: The City of Newburyport will sample the tributaries at nine (9) established locations on Indian Hill Reservoir, eight (8) at Upper Artichoke Reservoir (plus 6 additional contingency locations), one (1) at Lower Artichoke Reservoir, and one (1) at Bartlett Pond tributary. The following laboratory parameters will be collected: Chlorophyll a, dissolved color, total phosphorus as P, Iron, Manganese, Ammonia as N, Nitrite plus nitrate as N, Total Kjehldahl Nitrogen as N, organic nitrogen, total nitrogen as N, total organic carbon, CyanoScope, CyanoMonitoring. Tributary sampling will occur once in the spring (pre leaf-out spring runoff), once in the summer after a rain event, and once in the fall after a runoff event.

This is a dynamic sampling plan. Modifications may be made to the sampling plan outlined above based on changes in seasonal and/or annual conditions.

To achieve the water quality goals identified in this Plan, TP reduction of 288 lbs/year is needed. The structural BMPs identified in section estimate a reduction of ~50 lbs/year, with the potential for greater reduction through the additional 5 non-structural BMPs. However, to achieve the 288 lbs/year of TP reduction, it is clear that additional management techniques will be needed. Through this initial planning process, we look to identify and prioritize best management practices to support progress in achieving nutrient reduction goals.

Adaptive Management

The City of Newburyport recognizes the importance of taking a collaborative approach to improve water quality conditions in the system. Through broader regional engagement, Newburyport plans to establish an inter-municipal stakeholder group made up of water resource professionals, officials from the Department of Public Services, partner consultants, and key stakeholders from neighboring communities. Together, this group aims to more comprehensively understand and consider local water quality concerns for the Lower Artichoke Reservoir and help achieve the objectives of the watershed based plan. By formalizing this group, a structured approach to cross-jurisdictional collaboration can be facilitated and implementation projects can be pursued. Quarterly meetings are recommended at minimum, with a yearly progress report to ensure deadlines are met. A priority for the stakeholder group could be initiating the development of the Education and Outreach Plan as detailed in **Element E: Public Information and Education**.

If after two years of management measure implementation, interim targets are not met and the direct measurements and indirect indicators do not show improvement in the total phosphorus concentrations measured within Indian Hill, Lower Artichoke, and Upper Artichoke reservoirs, the management measures and loading reduction analysis (**Elements A through D**) will be revisited and modified accordingly.

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Water Quality Assessment Reports

No Water Quality Assessment Reports Found

TMDL

No TMDL Found

APPENDICES

- **Appendix A:** Pollutant Load Export Rates (PLERs) for each Hydrological Soil Group (HSG). HSGs are identified and determined by the USDS NRCS, while PLERs are identified and determined by the USEPA (USEPA, 2020; UNHSC, 2018, Tetra Tech, 2015).
- **Appendix B:** Storage Volume and Schematic Profile for Indian Hill and Artichoke Reservoirs from the City of Newburyport Department of Public Services.
- **Appendix C:** Map of the Lower Merrimack Reservoir Watershed provided by Woodard & Curran, 2023.
- **Appendix D:** Newburyport Watershed Protection Plan Executive Summary (Tighe & Bond, 2021).

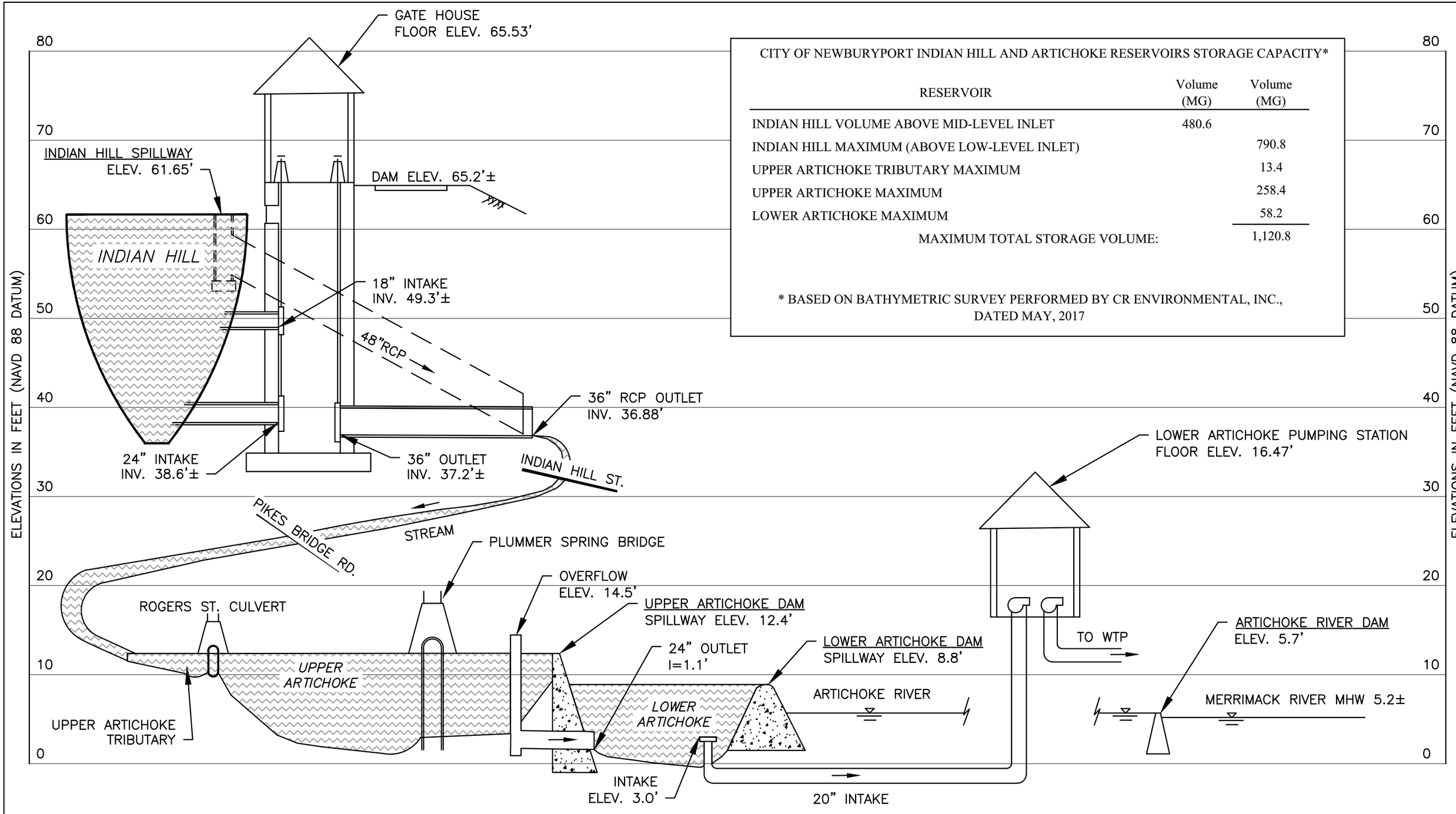
Appendices

Appendix A – Pollutant Load Export Rates (PLERs)

Land Use & Cover[1]	PLERs (lb/acre/year)		
	(TP)	(TSS)	(TN)
AGRICULTURE, HSG A	0.45	7.14	2.6
AGRICULTURE, HSG B	0.45	29.4	2.6
AGRICULTURE, HSG C	0.45	59.8	2.6
AGRICULTURE, HSG D	0.45	91	2.6
AGRICULTURE, IMPERVIOUS	1.52	650	11.3
COMMERCIAL, HSG A	0.03	7.14	0.3
COMMERCIAL, HSG B	0.12	29.4	1.2
COMMERCIAL, HSG C	0.21	59.8	2.4
COMMERCIAL, HSG D	0.37	91	3.7
COMMERCIAL, IMPERVIOUS	1.78	377	15.1
FOREST, HSG A	0.12	7.14	0.5
FOREST, HSG B	0.12	29.4	0.5
FOREST, HSG C	0.12	59.8	0.5
FOREST, HSG D	0.12	91	0.5
FOREST, HSG IMPERVIOUS	1.52	650	11.3
HIGH DENSITY RESIDENTIAL, HSG A	0.03	7.14	0.3
HIGH DENSITY RESIDENTIAL, HSG B	0.12	29.4	1.2
HIGH DENSITY RESIDENTIAL, HSG C	0.21	59.8	2.4
HIGH DENSITY RESIDENTIAL, HSG D	0.37	91	3.7
HIGH DENSITY RESIDENTIAL, IMPERVIOUS	2.32	439	14.1
HIGHWAY, HSG A	0.03	7.14	0.3
HIGHWAY, HSG B	0.12	29.4	1.2
HIGHWAY, HSG C	0.21	59.8	2.4
HIGHWAY, HSG D	0.37	91	3.7
HIGHWAY, IMPERVIOUS	1.34	1,480	10.5
INDUSTRIAL, HSG A	0.03	7.14	0.3
INDUSTRIAL, HSG B	0.12	29.4	1.2

INDUSTRIAL, HSG C	0.21	59.8	2.4
INDUSTRIAL, HSG D	0.37	91	3.7
INDUSTRIAL, IMPERVIOUS	1.78	377	15.1
LOW DENSITY RESIDENTIAL, HSG A	0.03	7.14	0.3
LOW DENSITY RESIDENTIAL, HSG B	0.12	29.4	1.2
LOW DENSITY RESIDENTIAL, HSG C	0.21	59.8	2.4
LOW DENSITY RESIDENTIAL, HSG D	0.37	91	3.7
LOW DENSITY RESIDENTIAL, IMPERVIOUS	1.52	439	14.1
MEDIUM DENSITY RESIDENTIAL, HSG A	0.03	7.14	0.3
MEDIUM DENSITY RESIDENTIAL, HSG B	0.12	29.4	1.2
MEDIUM DENSITY RESIDENTIAL, HSG C	0.21	59.8	2.4
MEDIUM DENSITY RESIDENTIAL, HSG D	0.37	91	3.7
MEDIUM DENSITY RESIDENTIAL, IMPERVIOUS	1.96	439	14.1
OPEN LAND, HSG A	0.03	7.14	0.3
OPEN LAND, HSG B	0.12	29.4	1.2
OPEN LAND, HSG C	0.21	59.8	2.4
OPEN LAND, HSG D	0.37	91	3.7
OPEN LAND, IMPERVIOUS	1.52	650	11.3

[1]HSG = Hydrologic Soil Group, as defined by USDS NRCS (Web Soil Survey (usda.gov)). Soils are classified into four HSG's (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting.



CITY OF NEWBURYPORT INDIAN HILL AND ARTICHOKE RESERVOIRS STORAGE CAPACITY*

RESERVOIR	Volume (MG)	Volume (MG)
INDIAN HILL VOLUME ABOVE MID-LEVEL INLET	480.6	
INDIAN HILL MAXIMUM (ABOVE LOW-LEVEL INLET)		790.8
UPPER ARTICHOKE TRIBUTARY MAXIMUM		13.4
UPPER ARTICHOKE MAXIMUM		258.4
LOWER ARTICHOKE MAXIMUM		58.2
MAXIMUM TOTAL STORAGE VOLUME:		1,120.8

* BASED ON BATHYMETRIC SURVEY PERFORMED BY CR ENVIRONMENTAL, INC., DATED MAY, 2017

CITY OF NEWBURYPORT
DEPARTMENT OF PUBLIC SERVICES
16A PERRY WAY
NEWBURYPORT, MA 01950

Rev No	Date	Drawn	Chkd	Description
				Revisions

Designed By: J-E WHITE
Checked By:
Date: DECEMBER 11, 2020

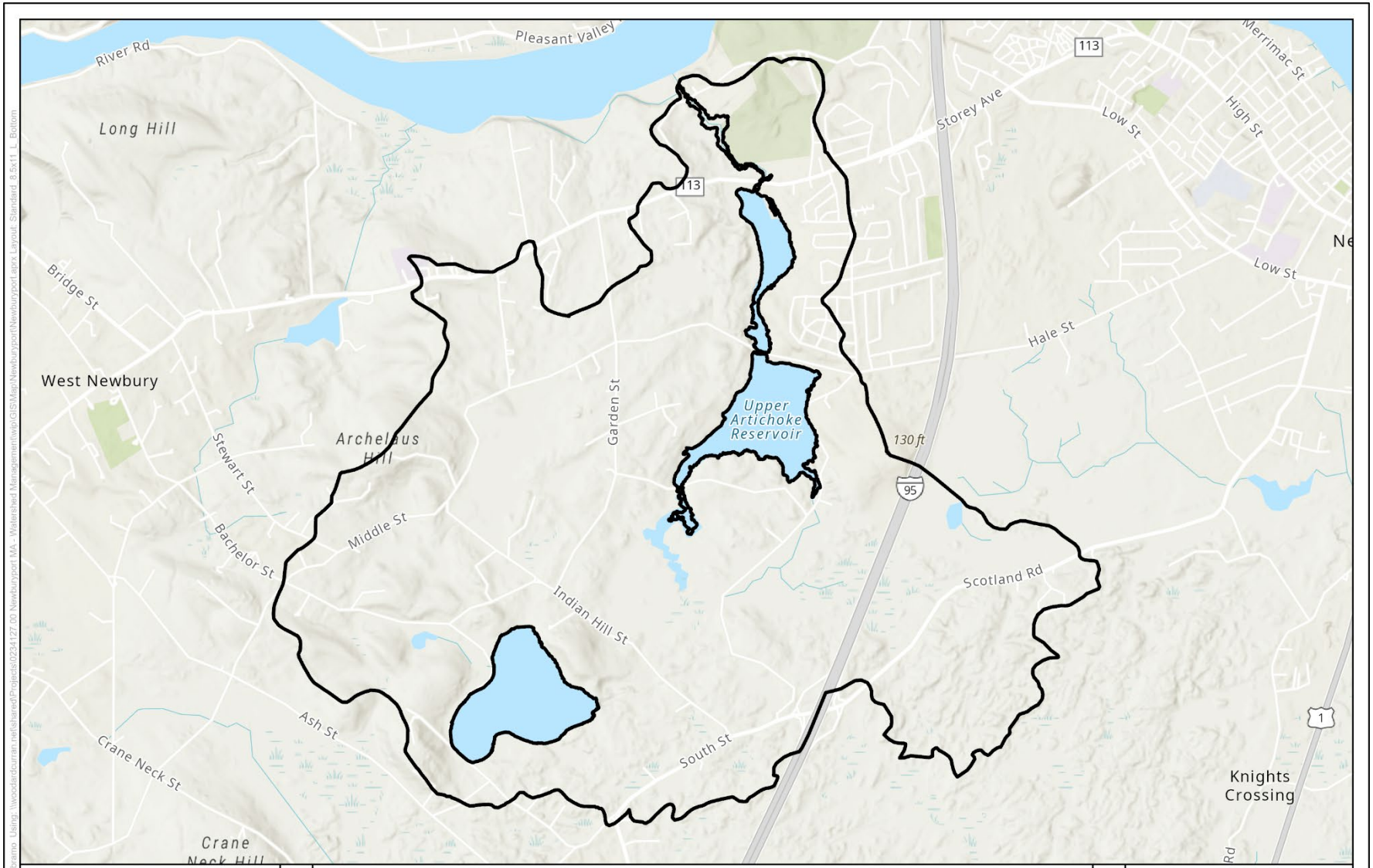
SCALE: 1"=10' VERTICAL ONLY

CITY OF NEWBURYPORT
INDIAN HILL AND ARTICHOKE RESERVOIRS

SCHEMATIC PROFILE & STORAGE VOLUMES

Sheet No. C-1

Appendix C: Map of the Lower Merrimack Reservoir Watershed



Executive Summary

The City of Newburyport receives its water from three interconnected surface reservoirs, one isolated surface pond, and two groundwater supply wells, with the majority of the water coming from the three interconnected surface reservoirs: Indian Hill, Upper Artichoke, and Lower Artichoke. The Indian Hill Reservoir spills over its dam and flows downstream via a natural stream channel to the Upper Artichoke Reservoir, which is held back by a dam that discharges directly into the Lower Artichoke Reservoir. The Lower Artichoke Dam is controlled by a concrete spillway and earthen dam that spills into the Artichoke River. A pumping station adjacent to the Lower Artichoke Reservoir pumps water from the reservoirs to the Water Treatment Plant (WTP) on Spring Lane. Following the treatment process, water flows to a clearwell, and then pumped into the distribution system. Well #1 pumps into the clearwell while Well #2 pumps directly into the distribution system in Ferry Road. Bartlett Spring Pond is a spring fed pond located north of the Water Treatment Plant.

This Watershed Protection Plan focuses on the three reservoirs that provide approximately 80% of Newburyport's water supply: Indian Hill, Upper Artichoke and Lower Artichoke Reservoirs.

According to FEMA's recent revisions to the Flood Insurance Rate Maps, the concrete spillway elevation at the Lower Artichoke Reservoir Dam is 3 feet below the Flood Zone AE Elevation (100-year floodplain), which highlights the vulnerability of the water supply. Storms slightly greater than the 10-year storm have the potential to cause the Merrimack River to back up into the reservoir and contaminate it with brackish saltwater from the incoming tide and potentially other contaminants from the river itself.

There are a variety of issues confronting the City: the need for improved watershed protection, improved resiliency against sea level rise and climate change impacts, and strengthening of the Lower Artichoke Dam. This watershed protection plan incorporates watershed management, by-law development, dam improvements, and options for infrastructure redundancy to provide holistic options for addressing the issues facing the City's water supply system. A summary of the recommendation in the report, organized by topic, is provided below.

Interconnections

- Coordinate with West Newbury regarding the potential groundwater source off Dole Place.
- Continue working with the City of Amesbury for an emergency interconnection.
- Consider a potential interconnect with Salisbury to provide added flexibility under an emergency situation.

Demand Management

- Complete a buildout of the service area in Newbury to determine the anticipated need. As the service area is limited to Old Town and Plum Island, water usage for Newbury may not increase as much as projected.

- Reassess the agreement for sale of water with West Newbury. The projections are currently based on the existing agreement language that states that Newburyport can sell up to 175,000 gpd to Newbury. Typically, the overall volume of water sold to West Newbury is less than this amount over the course of the year. Also, Newburyport should work into the agreement a requirement for West Newbury to establish water supply protection regulations for the surface water supply.

Regulatory Revisions

- Review the current Water Use Restriction Ordinance and update it to be in conformance with updated model language from MassDEP.
    - Providing a definition of Non-essential Outdoor Water Use that includes examples and exceptions.
    - Including a designee of the Board of Water Commissioners who can declare a State of Water Supply Conservation or State of Water Supply Emergency. This avoids any delay in imposing restrictions until the next scheduled board meeting.
    - Prohibiting outdoor watering at a minimum, between 9AM and 5PM. This is consistent with good irrigation practices which seek to avoid irrigation during periods of high evapotranspiration.
    - Removing "odd/even day watering" and replacing it with a limitation on the allowed number of days per week of watering. No more than two days per week is recommended, with the actual number of days and particular hours (outside the 9 am to 5 pm window) to be determined by the Board of Water Commissioners or its designee.
    - Adding an option that would require private well users to abide by restrictions imposed by the community or water district.
    - Adding a definition of a State of Drought and an option to institute additional restrictions during a declared drought.
    - The addition of an optional section at the end of the bylaw that regulates the use of in-ground lawn and garden sprinkler systems.
- The City of Newburyport has adopted a regulation prohibiting the use of pesticides containing glyphosate on City-owned properties, but not for private properties. As part of its coordination efforts with West Newbury and Newbury, the City should encourage these communities to adopt a similar regulation.
- The City should continue to incorporate regulatory changes required through the EPA Municipal Separate Storm Sewer System (MS4) general permit, including encouraging infiltration, Low Impact Development practices, and BMPs that are designed to remove nutrients.

West Newbury Coordination

- Coordinate with West Newbury to establish surface water protection bylaws Newburyport should be designated as a concurrent reviewer by West Newbury and Newbury of any project proposed within Zone A of the watershed.

- Work with West Newbury to implement a manure management bylaw to provide some oversight for horse owners. An example bylaw from the Town of Easton, MA is provided in Appendix K. Additional resources on horse stable and manure management can be found here: https://extension.psu.edu/horse-stable-manure-management.

Recreation Uses and Public Outreach

- Newburyport should continue to coordinate with Essex Greenbelt to ensure proper use of the trail systems to minimize impacts to the watershed.
- Horseback riding along the Indian Hill Reservoir service road should be strongly discouraged, as the waste is difficult to manage and is a direct source of pollutant loading to the reservoir.
- Pet waste eliminator stations should be installed (which should include pet waste clean-up signage) at the unpaved boat launch area at the Upper Artichoke Reservoir in Newburyport and the gated entrance to the access road to Indian Hill Reservoir in West Newbury. Trash pickup/bag refilling should be routinely conducted at these locations.
- Signage should be posted at the gated entrance to the service road and at the boat ramp regarding horseback riding and pet waste clean-up.
- Prepare a recreational management plan to control public access to the reservoirs that would include inspections, enforcement, and public education.

Roadway improvements

- Future design considerations for the roads adjacent to the reservoirs (specifically, Moulton Street along Indian Hill Reservoir and Turkey Hill Road and Rogers Street along the Upper Artichoke Reservoir) should include options to pull the roadway edge away from the reservoir embankment, superelevate or bank the roads away from the reservoirs, install swales, guardrails, and riprap to help address roadway erosion issues and install structural best management practices to pretreat stormwater.
- Deicing practices should also be assessed, as chlorides can negatively impact the drinking water quality and sand can cause sedimentation and carry other pollutants into the reservoirs. A low or no salt zone should be considered for the roadways that directly abut the reservoirs and their tributaries.
- Other roadways within the watershed should be monitored for similar erosion and pollution issues and BMPs implemented where necessary.

Land Acquisition

- Newburyport should continue to work with landowners for right of first refusal, gift, or purchase for priority lands within the watershed. Newburyport should continue to work with local boards and private land trusts, such as the Essex County Greenbelt Association, to pursue land acquisition. In order to fund acquisitions when properties become available, Newburyport should consider establishing an

annual budget line item for purchasing land and development rights for watershed protection purposes.

The City can also seek grant opportunities for land acquisition through:

- the Massachusetts Division of Conservation Services (DCS)
- the Drinking Water Supply Protection Grant Program
- Massachusetts Land and Water Conservation Fund Grant Program
- Local Acquisitions for Natural Diversity (LAND) Grant Program
- Community Preservation Act

- Establish an advisory Watershed Protection Committee that includes representative from Newburyport, West Newbury and Newbury. The committee could provide support to the Newburyport DPS Water Division with review of proposed developments within the watershed, coordinate on opportunities for land acquisition, and assist with outreach to the public.

- Newburyport could consider assigning water supply protection duties to a current staff person or a new staff person to conduct watershed inspections and water quality testing, conduct public outreach including outreach to schools, watershed groups, and local boards. Much of this effort is similar to the duties performed by the Engineering Department's Stormwater Engineer for the NPDES MS4 Permit compliance work. This staff person could also be responsible for conducting outreach to the watershed property owners, reviewing land management plans (e.g, SWPPPs or CNMPs) and permit applications, pursue grant opportunities, perform watershed inspections, and act as a liaison with West Newbury and Newbury for watershed protection.

Wildlife and Waterfowl

- The City should continue to monitor the watershed for the presence of beaver activity and continue to take the appropriate measures if excessive beaver activity that may pose a threat to the water supply is detected.
- As recommended in the 2016 AECOM Newburyport Reservoir Water Quality Study Report, total phosphorus load from waterfowl, including inputs from resident and migratory birds, was estimated in the model due to lack of site-specific waterfowl usage data. It was assumed that waterfowl usage was relatively low at the four surface water reservoirs. A survey of the actual waterfowl population would help to update the model with site-specific data in order to more accurately represent the contribution of phosphorus loading that can be attributed to the presence of waterfowl. Weekly counts are recommended for a one year period. Signage discouraging duck feeding should be posted in the vicinity of Upper Artichoke and Indian Hill Reservoirs. The City should also discourage waterfowl nesting. If nest removal is necessary, a Federal depredation permit from the U.S. Fish & Wildlife Service is required for migratory bird.

In-Lake Monitoring and Management

- The limnologist provided recommendations for sampling in their January 2021 report (see Appendix E). The sampling recommendations are reiterated here, however, the

January 2021 report should be reviewed for sampling locations and frequency. This data collection and analysis is important in identifying potential sources of pollution, identifying a potential an algal bloom and can be used to track progress on watershed management.

  - In-reservoir monitoring will occur in the deep spot of each reservoir as soon as practicable after ice-out and monthly from mid-May through mid-October. After mid-October, monitoring should continue monthly until the reservoirs freeze. It is estimated that this will result in 8 reservoir monitoring events at four (4) locations over the course of a typical year. These data can be used to assess the variability of water quality in the reservoirs, detect seasonal changes and identify water quality conditions that may support future cyanobacteria blooms. Locations and a schedule are provided in the January 2021 report. Every other reservoir sampling event will include the collection of a duplicate sample at a randomly selected station/depth. In reservoir monitoring will also include observation of the reservoirs for cyanobacteria blooms and contingency phytoplankton identification and toxicity testing.
  - Tributary monitoring will be conducted three times each year at a minimum. Monitoring will target three (3) separate runoff events roughly coinciding with spring, summer and fall depending on precipitation patterns. Since flow in many of the small tributaries is primarily storm related, monitoring will occur as soon as practicable after a rainfall of at least 0.25 inches or a period of snowmelt. One event will occur in spring prior to leaf-out. The second event will occur in the mid-summer and the third event will occur in the mid-fall. Typically, dry weather events would be an additional part of a tributary monitoring program however, observations of the tributaries around the reservoirs suggest most are intermittent and only flow when there is rainfall. Sample analyses will be performed by City of Newburyport, Alpha laboratories or the UNH LLMP lab in Durham, NH. This monitoring is expected to be shore based with grab sample collection. Locations and a schedule are provided in the January 2021 report.

- Aquatic vegetation in the reservoirs should continue to be monitored, and the limnologist should be consulted for in-lake recommendations. Results of the continued surveys should be compared to the results of the 2015 aquatic vegetation survey and vegetation management should be considered if invasive species densities appear to be noticeably increasing.

Public Education and Outreach

The development of a public education program for landowners, especially those that abut the reservoirs, will help to address and mitigate impacts within the watershed. The program could focus on effective agricultural BMPs, fertilizer applications, pesticide management, and septic system maintenance for residential landowners.

Outreach to landowners, residents, farms and users of the public lands within the watershed is recommended. The City's goal is to provide information on the watershed, the water quality concerns and the steps that the public can take to better protect the watershed and the reservoirs. Target audiences include:

- Essex County Greenbelt Association and recreational users

- Recreational users of Newburyport's watershed lands
- West Newbury residents and property owners within the watershed
- Newbury residents and property owners within the watershed
- Newburyport residents and property owners within the watershed

Outreach - BMPs

Work with landowners to install BMPs appropriate to the use of the property. As there are multiple farm parcels adjacent to the reservoirs, there are several resources available to farmers to make water quality improvements at their properties. The NRCS, under the United States Department of Agriculture (USDA) has Best Management Practices (BMPs) for farming and agriculture. See Appendix I for resources. The City should continue to work with agricultural and farming operations within the watershed to further reduce agriculture-related pollution by implementing such measures as:

- Installing fencing to separate livestock from reservoirs and their tributaries. Fencing should be installed a minimum of 100 feet from the banks of rivers, streams, water bodies, and other wetland resource areas.
- Planting buffer zones to the reservoirs and their tributaries
- Installing structural BMPs, such as:
    - water treatment residuals (WTRs) for enhanced phosphorus uptake
    - water quality swales
    - sedimentation basins
    - covering of potential pollutant sources, such as manure piles
- Instituting BMPs for herbicide and pesticide use, including:
    - Selecting optimum herbicides and fertilizers
    - Developing spill response plans for pesticide and fertilizers
    - Developing standard procedures for application (do not spray/apply near waterbodies or waterways or near where runoff enters a waterbody or waterway, do not apply herbicides/fertilizer to saturated or wet soil)
    - Retaining and reusing application equipment rinse water
    - Reading and following application instructions
    - Conducting soil sampling and testing
- Addressing stormwater runoff through farming controls, such as conservation tillage farming, erosion control, or vegetative buffer strips
- Encouraging farmers within the watershed to develop NRCS Comprehensive Nutrient Management Plans may be appropriate for livestock operations in Massachusetts. More information is available at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/ma/technical/ecoscience/nutrient/.

Climate Change/Resiliency Recommendations

Options for keeping the reservoir water cooler include:

- Dredging to increase water depth. Dredging is a useful option for removal of nutrient and other pollutants that have settled on the reservoir floor; however, dredging is not anticipated to have a significant impact on the reservoir temperature as the amount of material required to be removed to achieve a reservoir depth to make a difference in the temperature would not be technically or economically feasible.
- Increasing the height of the reservoirs by increasing the height of the Lower Artichoke Dam. This option would require the City to acquire additional land for the construction of the dam and for the taking of property for reservoir use (accounting for the land proposed to be covered by water with the increased reservoir height). This option would require significant coordination with adjacent landowners and significant environmental and dam-related permitting. Regulators have been reluctant to permit increases in dam heights for storage increases.
- Adding aerators to the reservoirs can increase the movement of the water in the reservoirs and decrease the temperature. Added aeration may also result in increases evaporation.
- Potential innovate options include installation of floating solar panels, which can help shade the reservoir and provide a potential revenue source, or floating wetlands could provide some shading of the reservoir and uptake nutrients to help address algal blooms.

These options would have to be further assessed to determine which are feasible and offer the highest value for the cost.

Dam Maintenance

Implement maintenance recommendations from the 2020 Inspection/Evaluation Report for Lower Artichoke Reservoir Dam, Upper Artichoke Reservoir Dam, and Indian Hill Reservoir Dam & Dikes.

Lower Artichoke Dam Improvements

The Lower Artichoke Reservoir Dam is susceptible to backflow from the Merrimack River, and as the only existing intake for the three surface water reservoirs is within the Lower Artichoke Reservoir, a backflow event could compromise the use of 80% of the City's water supply. Performing dam maintenance and preparing for emergency protection situation are strongly recommended.

- Minimizing the length of the Lower Artichoke Reservoir Dam embankment is recommended, whether or not the embankment height is increased. This would involve extending the embankment in line with the spillway to higher ground to the east and west.
- Use a shorter-term method to protect the Lower Artichoke Reservoir spillway from overtopping during a backwater event, such as large sandbags (Super Sack) or a

water filled dam (AquaDam). This includes construction of access to allow equipment to place these materials when needed.

- While more costly, it is recommended the Lower Artichoke Dam be raised over the Upper Artichoke as major repairs are needed at Lower Artichoke Dam regardless if it is raised and improvements would protect both the Lower and Upper Artichoke Reservoirs and the existing raw water intake. It should be noted that these options only increase the embankment and add a crest gate; they are not proposed to increase the normal reservoir elevation.

Redundant Raw Water Transmission Line

Seven alternatives were evaluated for potential raw water transmission mains that could supply the WTP with water directly from the Indian Hill Reservoir or the Upper Artichoke and Indian Hill Reservoirs. Based on the evaluated criteria, Alternative 6, which follows roadways from Indian Hill Reservoir to the Upper Artichoke Dam, and then crosses the dam and continues adjacent to the east side of the Lower Artichoke Reservoir, is the recommended alternative based on the following:

- Alignment is primarily within existing roadways, which eliminates the need for easements, reduces maintenance costs associated with cross county alignments, and reduces potential wetland impacts.
- A pump station at the Indian Hill Reservoir will be required but this will allow for improved operational flexibility and reliability in the event that the Lower Artichoke Pump Station is unavailable.
- Access to the Upper Artichoke Reservoir would also be possible for flexibility to utilize any one of the three reservoirs. Additional evaluations of pump modifications or pipeline elevations will be required during detailed design to confirm the ability to pump directly from Upper Artichoke Reservoir.

2016 Newburyport Reservoir Water Quality Study Report

Additional recommendations from the Newburyport Reservoir Water Quality Study Report, March 2016, prepared by AECOM, are still valid and are reiterated below.

- **Shoreline Stabilization/Erosion Control at Reservoir Access Points**
  Revegetating reservoir access areas with native vegetation is recommended to improve areas eroded due to foot traffic and high water, as soils entering the pond can include associated phosphorus.

  The Upper Artichoke Reservoir public access area located to the east of the Plummer Spring Road/Middle Street bridge (sampling Site SW-1) is particularly eroded and should be immediately addressed.

  Signage is recommended to help prevent additional erosion:
  - Educational signage regarding the presence of erosion
  - Signage redirecting foot traffic to designated trails only.

- **Coordination with Maple Crest Farm**
  Direct coordination with Maple Crest Farm on Moulton Street in West Newbury is strongly recommended to address their current operations, including leaf compost

bag disposal near the southern shoreline of Indian Hill Reservoir and other land use activities that have the potential to cause phosphorus loading to the reservoirs. Installation of infiltration BMPs in this area is recommended.

- **Conduct a Detailed Watershed Inventory**
  A watershed inventory is recommended to identify specific sites throughout the watersheds that are currently contributing phosphorus to the reservoirs. The effort should include an estimation of the nutrient contribution from each site, the potential solution and a cost estimate. The identified sites would then be prioritized based on phosphorus contribution and technical and financial feasibility.

  The results of the inventory would comprise a critical piece of the watershed-based plan described below.

- **Develop a Watershed-based Plan**
  A watershed-based plan should be prepared in order to be eligible for Section 319 grant funding, as described in Section 5.0. The plan should follow the EPA recommended format, which includes the following nine elements (from MassDEP, 2015):

  Impairment: An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan), as discussed in item (b) immediately below.

  Load Reduction: An estimate of the load reductions expected for the management measures described under paragraph (c) below (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time).

  Management Measures: A description of the non-point source (NPS) management measures that will need to be implemented to achieve the load reductions estimated under paragraph (b) above (as well as to achieve other watershed goals identified in this watershed-based plan), and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.

  Technical and Financial Assistance: An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan. As sources of funding, States should consider the use of their Section 319 programs, State Revolving Funds, USDA's Environmental Quality Incentives Program and Conservation Reserve Program, and other relevant Federal, State, local and private funds that may be available to assist in implementing this plan.

  Public Information and Education: An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the NPS management measures that will be implemented.

  Schedule: A schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious.

  Milestones: A description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented.

Performance: A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether this watershed-based plan needs to be revised or, if a NPS TMDL has been established, whether the NPS TMDL needs to be revised.

Monitoring: A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (h) immediately above.

Most of these elements have been addressed in the 2016 report and this report and could be included in the watershed plan, including the monitoring results, management recommendations, and potential funding sources. An implementation schedule and description of milestones will need to be developed and included in the plan. A plan for conducting a watershed inventory to identify specific sources of phosphorus (as described above) should also be included.

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