

**SAMPLING & ANALYSIS PLAN**  
ANNUAL MONITORING  
REGIONAL MONITORING NETWORK

CN#: 590.0



Massachusetts Department of Environmental Protection  
Division of Watershed Management  
Watershed Planning Program  
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## Project Overview

The establishment and implementation of Reference Monitoring Networks (RMNs) represent a collaborative endeavor led by the United States Environmental Protection Agency (U.S. EPA). The agency is working in synergy with regional branches, state bodies, tribes, river basin commissions, and other stakeholders. The initiative aims to assess and understand the impacts of climate change on pristine freshwater streams that are typically shallow enough to wade through, focusing on augmenting the initiatives under the Clean Water Act (CWA).

RMNs have been integrated into the monitoring strategies of the Massachusetts Department of Environmental Protection (MassDEP), Division of Watershed Management (DWM), Watershed Planning Program (WPP) since 2012, serving as integral components in understanding and maintaining the ecological balance and health of aquatic ecosystems across different regions such as the Northeast, Mid-Atlantic, Midwest, and Southeast. The expansion of RMNs is strategic and continuous, with networks broadening their reach into additional regions, fostering a comprehensive, interconnected understanding of aquatic environments across diverse landscapes (Fig. 1).

MassDEP is contributing to this integrative approach, aiming to generate and harmonize data congruent with other organizations within the Northeast network. The intention is to create versatile, multi-purpose data that can be utilized by biomonitoring programs across both short and long-term timescales. The overarching objectives of RMNs encompass several scientific and operational goals, including:

- ❖ The identification and analysis of trends related to climate change, contributing to broader ecological discourse, and understanding.
- ❖ The enhancement of Clean Water Act (CWA) programs and initiatives by refining ecological criteria under various sections of the CWA, defining natural conditions, quantifying natural variability, and developing biological indicators crucial for protection planning and assessment.
- ❖ Investigation into ecosystem responses and adaptive trajectories post-extreme weather events, to unravel the intricate patterns of resilience and adaptability in aquatic ecosystems.
- ❖ A deepened understanding of the relationships among biological, thermal, and hydrologic data.
- ❖ The monitoring of conditions of minimally and least disturbed streams, to ensure the sustained documentation and preservation of pristine aquatic environments.
- ❖ The exploration of the impacts of regional phenomena such as drought and pollutant/nutrient deposition on aquatic ecosystems and bioassessment programs.

The focus of the RMN is to compile data at six distinctive sites, with the objective of contributing to the need for long-term simultaneous biological and physiochemical data in

least-disturbed freshwater Wadeable streams. The categories of data to be amassed at each site include:

1. Continuous temperature, conductivity, and dissolved oxygen (long-term deployments)
2. Instantaneous temperature, conductivity, and dissolved oxygen (attended probe)
3. Nutrients
4. Benthic macroinvertebrate community
5. Fish community
6. Habitat assessment
7. Digital photo documentation
8. Streamflow monitoring with trail cameras

This aligns with the goals of RMNs and solidifies the commitment to the understanding and preservation of aquatic ecosystems, thus enabling the implementation of informed, data-driven interventions and policy frameworks.

## Project Description

### 1. Continuous Temperature and Conductivity Monitoring

In our endeavor to monitor water quality, continuous loggers for temperature and conductivity will be strategically redeployed with no determined end date, ensuring a long-term and uninterrupted data accumulation. The deployment sites are selected, and each logger is safeguarded inside protective PVC housings, wrapped around a tree, and anchored firmly to permanent structures like large tree roots using cables, with the goal of minimizing loss or damage risks.

During each site visit, as per WPP's continuous data collection SOPs, quality control (QC) readings are captured using a separate attended YSI meter to maintain data accuracy. These readings are invaluable as they undergo QA/QC reviews and validations, ensuring the data's reliability. The continuous data are downloaded quarterly using a HOBO optical shuttle and are carefully offloaded and analyzed in the laboratory, post-field download.

### 2. Continuous Dissolved Oxygen and Additional Temperature Monitoring

Complementing the aforementioned loggers, HOBO-DOTs will be incorporated adjacent to the Conductivity/Temperature loggers on a similar long-term basis. These data are downloaded quarterly as well.

### 3. Water Chemistry (Nutrients)

Monitoring nutrients is useful as it aids in evaluating the chemical state of the stream, which directly impacts aquatic life and overall health of the stream. The presence of excess nutrients can lead to excess algal growth and oxygen depletion in water bodies with adverse effects.

Samples will be collected and submitted to the laboratory for nutrients analysis beginning in 2024. Analytes to be collected are Total Phosphorus (TP), Total Nitrogen (TN), Ammonia (NH<sub>3</sub>), and Total Kjeldahl Nitrogen (TKN).

#### 4. Benthic Macroinvertebrate Community:

Historically, a single annual sampling in mid-October was employed to study the benthic macroinvertebrate community, using the “Vermont Sampling Method” of 5-composite-kicks. However, ongoing discussions and collaborative thought processes with RMN partners have highlighted the potential advantages of using our own WPP methodology. This approach, integrating with Targeted Monitoring Assessment data, is envisioned to provide more holistic and integrated insights.

A three-year (2023 through 2025) comparative study will be conducted, exploring samples from July to October using differing methods—DEP 10-kick Rapid Bioassessment Protocols (RBP) in July and 5-kick (Vermont) in October. Post completion, analysis using statistical metrics and professional judgment will be conducted to conclude the more effective methodology.

Benthic macroinvertebrates, due to their integrative reflection of environmental conditions, serve as significant indicators of aquatic health. Each site, specifically chosen with sufficient high gradient streams and catchments, undergoes sampling within a predetermined 100-meter reach. Samples will be composited into 2L Nalgene jars, preserved with 95% ethanol and transported to the WPP lab for storage. The samples are then sent out for further analysis by outside taxonomists, this year, Mike Cole Ecological Inc., who specializes in macroinvertebrate sample enumeration and taxonomic identifications will be processing our samples.

#### 5. Fish Community

Fish collection at RMN sites, while optional, is strongly encouraged. This is due to their economic and social importance, and their ability to be easily and consistently identified without significant further sample processing, making them cost-effective to analyze. Fish behaviors and physiologic traits also serve as tangible indicators of environmental conditions. There’s a considerable focus on protecting fisheries from various organizations, and ongoing research examines how fish communities are altering in response to climate change.

For fish collection at RMN sites species-level identifications will be conducted by trained fish biologists. [Also, a photographic reference collection of each unique taxon will be maintained for verification or comparison.] Currently, only the Southeast region is consistently collecting fish data; however, if organizations in other regions initiate regular fish sampling, the comparability of fish sampling protocols within and across RMN regions requires reassessment.

Integrative approaches involving diverse biological communities offer more nuanced insights into the stream health and resilience, allowing for adaptive management and conservation initiatives that are both informed and responsive to changing environmental conditions.

Beginning in 2024, fish will be collected within each pre-defined reach according to the WPP Fish Community Standard Operating Procedures document ([Link to all WPP SOPs](#)).

## 6. Habitat Assessments

RBP III habitat assessments will be completed at all sites. See link to Habitat Assessment SOP ([Link to all WPP SOPs](#)).

## 7. Digital Photography Documentation:

When visiting RMN sites for biological sampling, digital photographs to document any alterations at the monitoring locations, illustrate near-stream habitats, and provide qualitative evidence of geomorphic changes will be captured. These photographs are crucial for noting variations in lateral and vertical channel stability and for locating sensors in subsequent visits.

Each visit requires consistent photo locations, with GPS coordinates (latitude and longitude) recorded in decimal degrees, using the NAD83 datum. Field personnel will ensure precise connection before recording and later verify coordinate accuracy using ArcGIS Pro.

Photographs will be directed to upstream, downstream, left bank, and right bank views from a mid-reach location, including identifiable objects like large trees, boulders, and woody debris. Additionally, it is encouraged to capture images of the riffles where macroinvertebrates are collected and locations where discharge measurements are taken. These photographs will be archived and readily accessible to serve as references for observing changes in habitat quality over time and to ensure consistent sampling locations.

## 8. Streamflow Monitoring with Trail Cameras:

For enhanced streamflow monitoring, trail cameras (RECONYX HyperFire 2) are strategically deployed at selected stream sections, focusing on the center of the stream channel. These cameras capture periodic, high-quality images, assisting in accurate data collection for computer vision machine learning. Setup involves secure installation, proper orientation, and regular maintenance to ensure consistency in photo quality. The captured images are submitted to be integrated into the USGS Flow Photo Explorer, contributing valuable insights into streamflow and environmental conditions for conservation efforts.

Camera chips are switched out every quarter and downloaded upon return to the office. [Link to RMN Photos](#).

## Dissemination of Data to Our Collaborators

WPP staff will ensure the sharing of both discrete and continuous monitoring data with our partners while adhering to data quality standards and formatting guidelines. Continuous data such as temperature and conductivity, alongside discrete temperatures and conductivity data, nutrient analysis and macroinvertebrate studies, will undergo quality assurance processes. Data will be electronically submitted to our partners.

## Sampling Process Design

One aim of the RMN is to target minimally or least disturbed sites (per Stoddard et al., 2006). The use of high-quality waters allows for a better separation of natural variation and human-induced changes and minimally disturbed waters serve as a standard against which other bioassessment sites can be compared.

Reference site decisions were based on best professional judgment and involved a thorough assessment of both land use and percent impervious cover. The significance of land use relates to its potential to affect water quality, especially with urban and agricultural developments, which are common in much of Massachusetts. Increased impervious cover, such as paved areas, can lead to more runoff and potentially more pollutants entering the water bodies. Therefore, these factors were crucial in the site evaluation. To ensure that the sites aligned with the RMN's criteria, on-ground reconnaissance was employed, providing a verification of the suitability of each site. (See Figs. 2, 3, 4a-f, 5).

As a long-term study, RMN both aims for a current assessment of water bodies but more so seeks to monitor changes over time, more specifically concerning the impacts of long-term weather pattern changes on freshwater ecosystems. Overall, the RMN's objective is to provide a comprehensive understanding of water quality, aquatic life, and the broader implications of changing weather patterns on these ecosystems.

## Figures and Tables



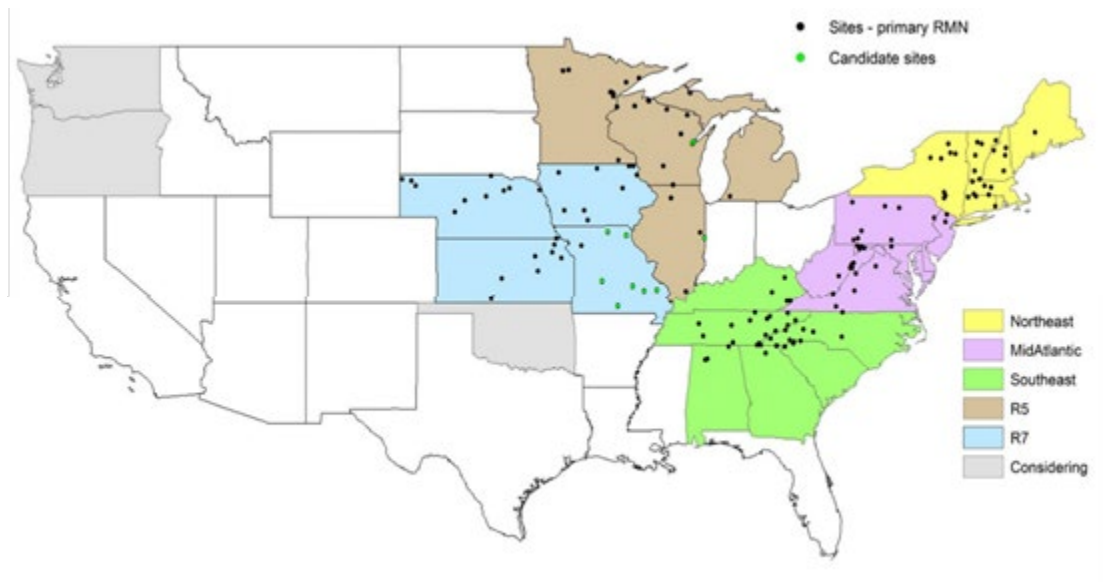


Figure 1. Current Regional Monitoring Network (RMN) sites by region. (Before the recent addition of Avery Brook).

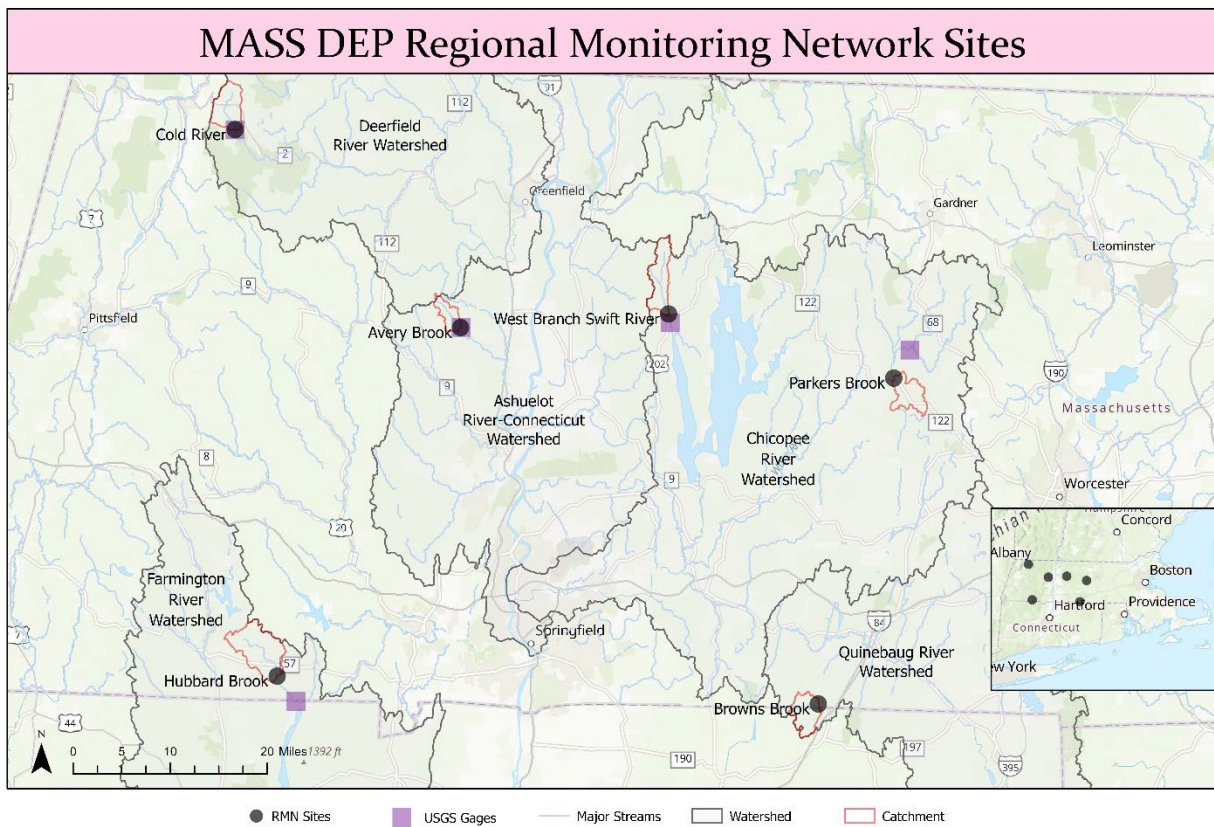


Figure 2. Reference Monitoring Network (RMN) sites in Massachusetts. Showing USGS gages, catchments, and HUC8 watersheds.

Table 1. Characteristics of Reference Monitoring Network (RMN) sites in Massachusetts.

Site ID	Unique ID (WQ)	Unique ID (Benthic)	Basin	Site Name	Description	Latitude	Longitude
CR01ACC	W2467	B0824	Deerfield	Cold River	[approximately 70 meters upstream/north of South County Road, Florida.]	42.6669	-73.0302
HRCC	W2468	B0825	Farmington	Hubbard Brook	[approximately 245 meters upstream/northwest of West Hartland Road, Granville.]	42.0654	-72.9675
BB01CC	W2220	B0737	Quinebaug	Browns Brook	[approximately 645 meters upstream from May Brook Road, Holland]	42.0348	-72.1616
WSR01CC	W2218	B0736	Chicopee	W Br Swift River	[approximately 195 meters upstream from Cooleyville Road Extension, Shutesbury]	42.4647	-72.3845
PBCC	W0678	B0823	Chicopee	Unnamed and/or Undefined SARIS	[unnamed tributary (known as Parkers Brook on USGS 1988 Barre quad) approximately 160 meters west (downstream) of Coldbrook Road, Oakham (due south of Route 122)]	42.3943	-72.0492
AVB01	W3258	B1223	Connecticut	Avery Brook	[west of Conway Road, Whately approximately 825 feet upstream of mouth at inlet of Northampton Reservoir, Whately]	42.4498	-72.6944

Table 2. Project roles and responsibilities related to monitoring and data use.

<b>Project Personnel</b>	<b>Responsibility</b>
<u>Project Coordinators</u> - Peter Mitchell (Lead) - Steven Bittner (co-lead)	Responsible for defining logistics for efficient monitoring and generation of usable data at assigned sites in accordance with WPP SOPs.
<u>Continuous Dissolved Oxygen (D.O.), Conductivity and Additional Temperature Monitoring</u> - Peter Mitchell (Lead) - Steven Bittner (co-lead) - WPP Staff	Responsible for download of loggers in accordance with WPP SOPs.
<u>Nutrients Sampling</u> - Peter Mitchell (Lead) - Steven Bittner (co-lead) - WPP Staff	Responsible for collection and delivery of nutrient samples.
<u>Benthic macroinvertebrate surveys</u> - Steven Bittner (Lead) - Peter Mitchell (co-lead) - WPP Staff	Responsible for benthic macroinvertebrate survey data collection in accordance with WPP SOPs.
<u>Fish Community</u> - Peter Mitchell (Lead) - Steven Bittner (co-lead) - WPP Staff	Responsible for fish survey data collection in accordance with WPP SOPs.

<u>Habitat Assessments</u> - Peter Mitchell (Lead) - Steven Bittner (co-lead) - WPP Staff	Responsible for conducting habitat assessments in accordance with WPP SOPs.
<u>Digital Photography Documentation</u> - Peter Mitchell (Lead) - Steven Bittner (co-lead) - WPP Staff	Responsible for collection and download of images captured via iPhone.
<u>Streamflow Monitoring with Trail Cameras</u> - Peter Mitchell (Lead) - Steven Bittner (co-lead) - WPP Staff	Responsible for quarterly download of camera data according to SOP.

Table 3. Approximate Project Schedule for Regional Monitoring Network. This schedule outlines the recurring annual activities and their corresponding deliverables. Each year follows a similar cycle.

Activity	Approx. Date of Initiation	Approx. Date of Completion	Deliverable
Draft sampling plan review and approval	March 2023	April 2023	Internal WPP concurrence on sampling plan
2020-2024 WPP monitoring QAPP	March 2023	TBD	2020-2024 WPP monitoring QAPP
2022 taxonomic data received from contractor and input into mabenthos	June 2023	December 2023	mabenthos up to date with 2022 data
Quarterly temperature and conductivity data download	April 2023	April 2023	Field data
Quarterly temperature and conductivity data download	July 2023	July 2023	Field data
Annual Benthic/Habitat sampling survey	July 2023	July 2023	Field data
Quarterly temperature, D.O. and conductivity data download	October 2023	October 2023	Field data
Annual Benthic/Habitat sampling survey	October 2023	October 2023	Field data; benthic samples to contractor
Quarterly temperature, D.O. and conductivity data download	January 2024	January 2024	Field data
Data QA/QC review and validation	January 2024	June 2024	2023 data validation report

## Non-Direct Measurements

Table 3 is a brief list of relevant external data sources that may be used in coordinating monitoring efforts or the interpretation of monitoring data. For example, stage and flow data from the USGS may be used to determine if water levels are appropriate for certain types of sampling or rain data from The Weather Underground could be used to determine if a sampling event occurred during wet or dry weather.

Table 4. External data sources used for RMN monitoring.

Organization	Data
United States Geological Survey (USGS) <a href="https://dashboard.waterdata.usgs.gov/">https://dashboard.waterdata.usgs.gov/</a>	Continuous stream stage and discharge measurements at gaging stations within the project extent.
The Weather Underground <a href="http://www.wunderground.com/">http://www.wunderground.com/</a>	Daily precipitation and temperature data weather stations within the project extent.
AccuWeather <a href="https://www.accuweather.com/en/us/national/weather-radar">https://www.accuweather.com/en/us/national/weather-radar</a>	Daily precipitation and temperature data weather stations within the project extent.
CoCoRaHS <a href="https://maps.cocorahs.org/">https://maps.cocorahs.org/</a>	Community Collaborative Rain, Hail, & Snow Network

Table 5. USGS gage locations in proximity to RMN sites.

Station and Location	Station Number	Latitude	Longitude
Cold River at Florida, MA	01168250	42.666694	-73.030167
Hubbard River near West Hartland, CT	01187300	42.037500	-72.939328
West Branch Swift River near Shutesbury, MA	01174565	42.455000	-72.382222
Ware River near Barre, MA	01172500	42.425000	-72.025000
Avery Brook near Whately, MA	01171000	42.44990946	-72.6935489

## Literature Cited

Stoddard, J.L., Larsen, D.P., Hawkins C.P., Johnson, R.K., and R.H. Norris. 2006. Setting expectations for the ecological condition of streams: The concept of reference condition. *Ecological Applications* 16(4):1267-1276.

Table 6. Comprehensive overview of selected sites, highlighting both ecoregional classifications and hierarchical watershed delineations. The table enumerates unique water quality (WQ) and benthic identifiers, specific waterbody names, and spans four levels of ecoregional details and watershed categories (from HUC6 to HUC12).

<b>Site ID</b>	<b>CR01ACC</b>	<b>HRCC</b>	<b>BB01CC</b>	<b>WSR01CC</b>	<b>PBCC</b>	<b>AVB01</b>
Unique ID (WQ)	W2467	W2468	W2220	W2218	W0678	W3258
Unique ID (Benthic)	B0824	B0825	B0737	B0736	B0823	B1223
Waterbody	Cold River	Hubbard Brook	Browns Brook	W Br Swift River	Parkers Brook	Avery Brook
HUC6	Lower Connecticut	Lower Connecticut	Connecticut Coastal	Lower Connecticut	Lower Connecticut	Lower Connecticut
HUC8/Watershed	Deerfield River	Farmington River	Quinebaug River	Chicopee River	Chicopee River	Ashuelot River-Connecticut River
HUC10	Middle Deerfield River	East Branch Farmington River	Upper Quinebaug River	Swift River	Ware River	Manhan River-Connecticut River
HUC12	Cold River	Hubbard River	Hamilton Reservoir	Quabbin Reservoir-Swift River	Winimusset Brook-Ware River	West Brook-Mill River
Ecoregion 1	Northern forests	Northern forests	Eastern temperate forests	Northern forests	Eastern temperate forests	Northern forests
Ecoregion 2	Atlantic highlands	Atlantic highlands	Mixed wood plains	Atlantic highlands	Mixed wood plains	Atlantic highlands
Ecoregion 3	Northeastern Highlands	Northeastern Highlands	Northeastern Coastal Zone	Northeastern Highlands	Northeastern Coastal Zone	Northeastern Highlands



Ecoregion 4	Green Mtns. / Berkshire Highlands	Lower Berkshire Hills	Lower Worcester Plateau / Eastern CT Upland	Worcester / Monadnock Plateau	Lower Worcester Plateau / Eastern CT Upland	Berkshire Transition
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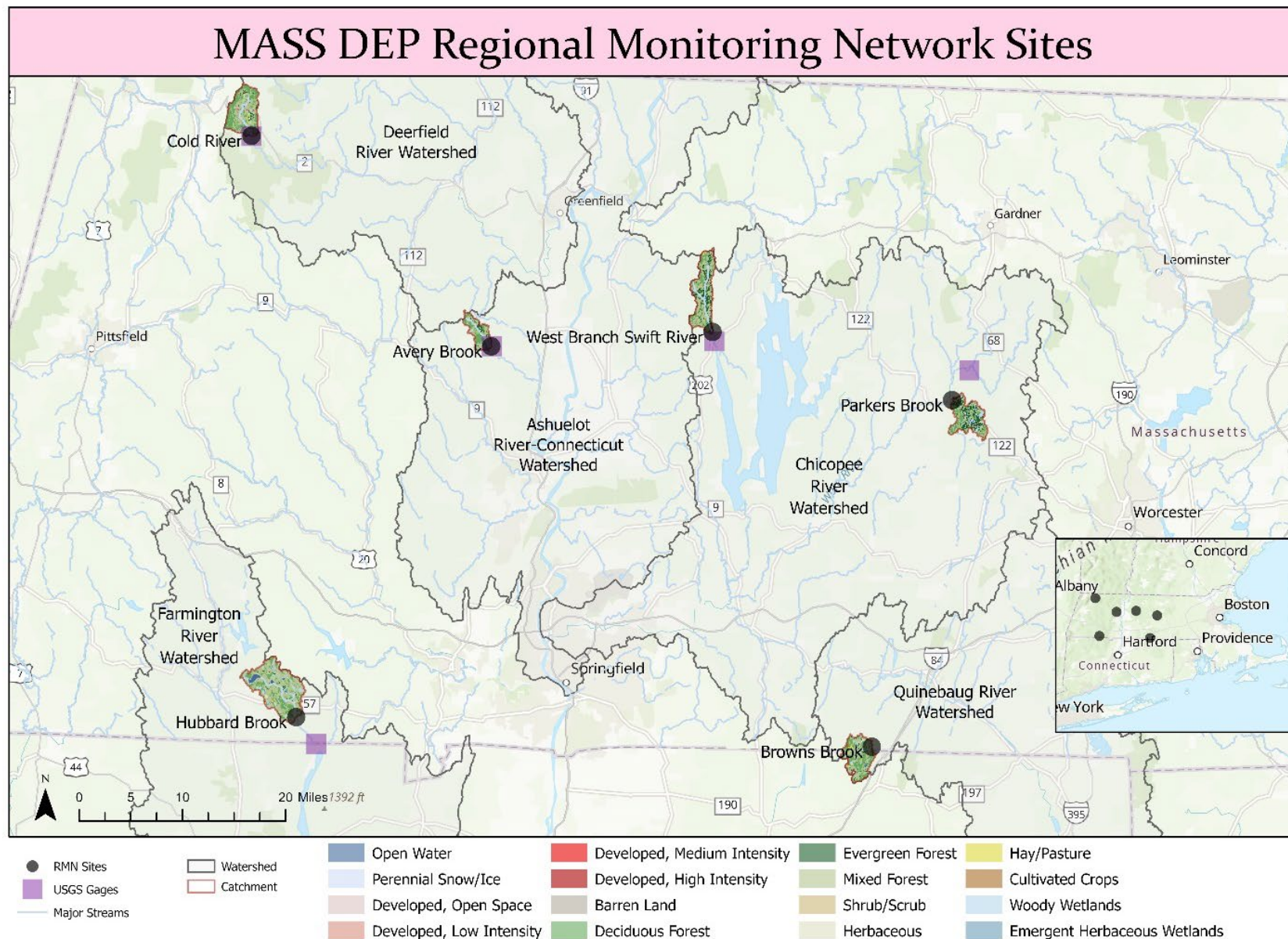


Figure 3. Regional Monitoring Network (RMN) sites in Massachusetts. Showing USGS gages, catchments, and HUC8 watersheds

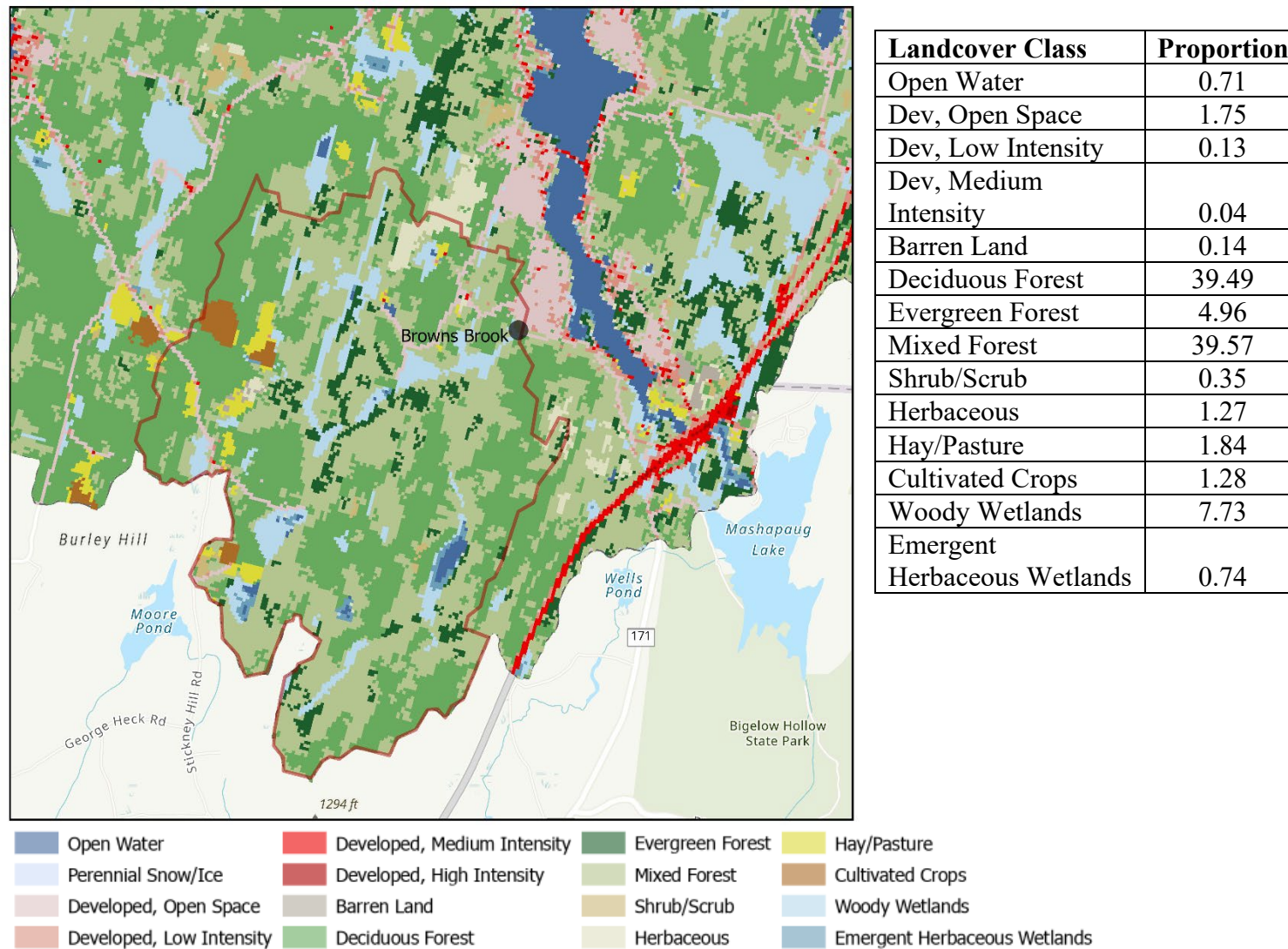
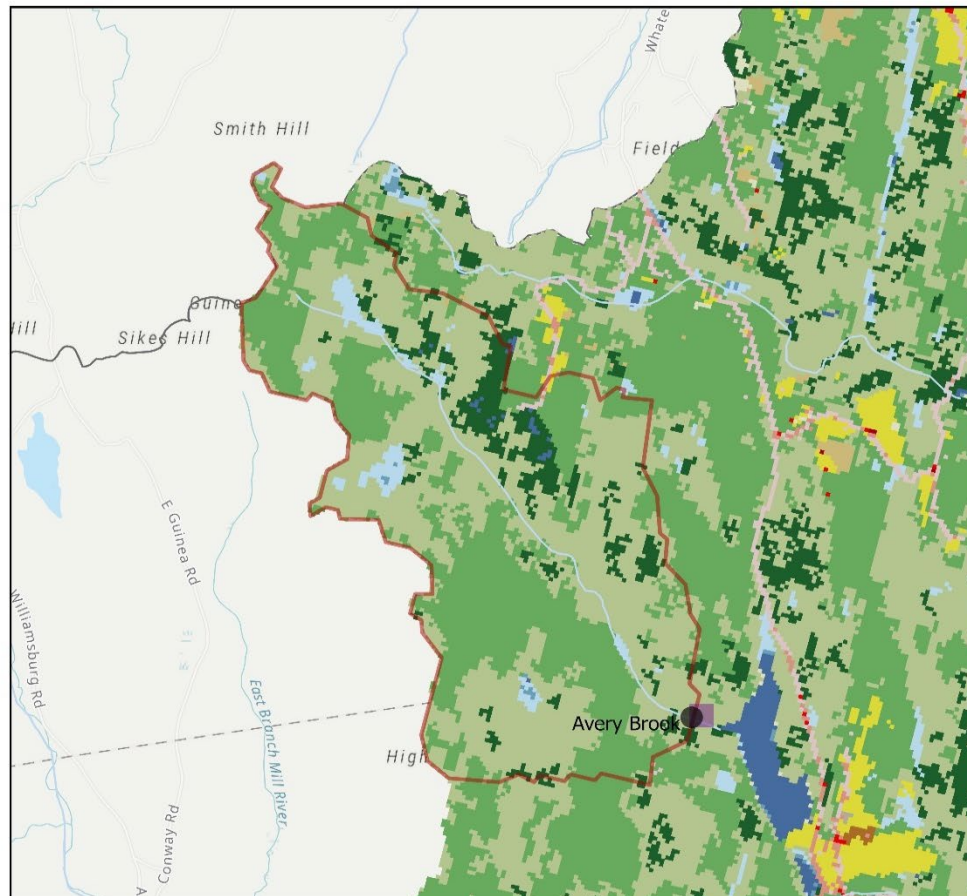


Figure 4-A. Land cover classification and proportionality within the Brown's Brook catchment and watershed.





Landcover Class	Proportion
Open Water	0.30
Dev, Open Space	0.14
Dev, Low Intensity	0.02
Deciduous Forest	36.64
Evergreen Forest	8.29
Mixed Forest	51.74
Shrub/Scrub	0.05

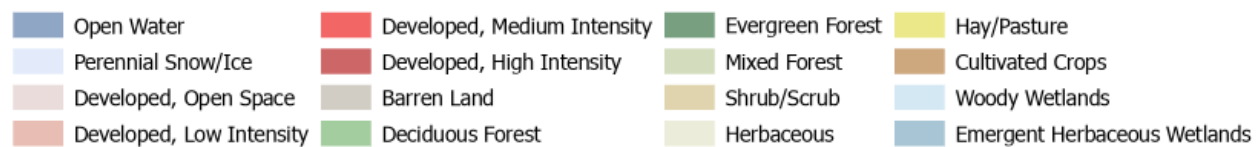
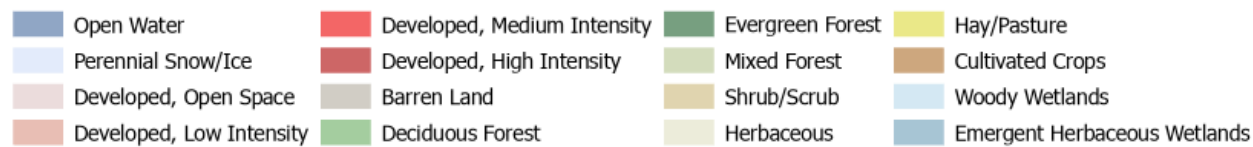
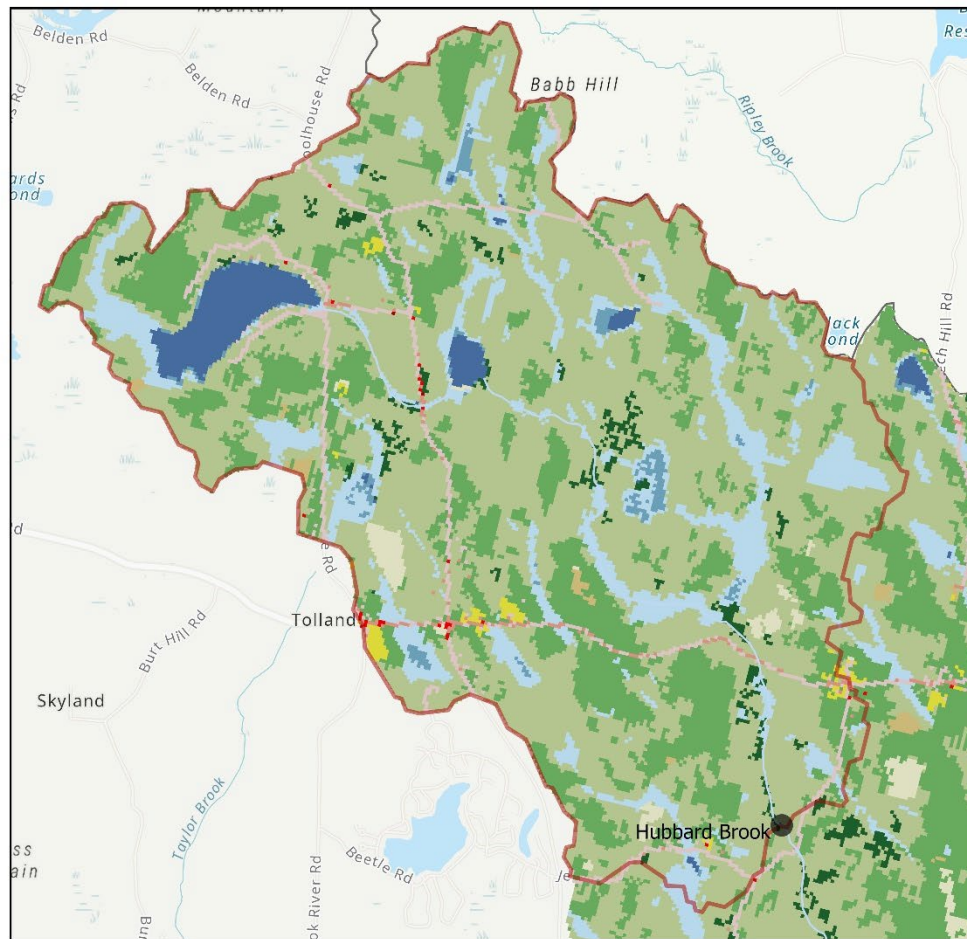


Figure 4-B Land cover classification and proportionality within the Avery Brook catchment and watershed.



Landcover Class	Proportion
Open Water	2.81
Dev, Open Space	2.63
Dev, Low Intensity	0.42
Dev, Medium Intensity	0.08
Dev, High Intensity	0.01
Deciduous Forest	21.09
Evergreen Forest	1.55
Mixed Forest	57.01
Shrub/Scrub	0.27
Herbaceous	0.93
Hay/Pasture	0.50
Woody Wetlands	11.71
Emergent Herbaceous Wetlands	1.01

Figure 4-C. Land cover classification and proportionality within the Hubbard Brook catchment and watershed.

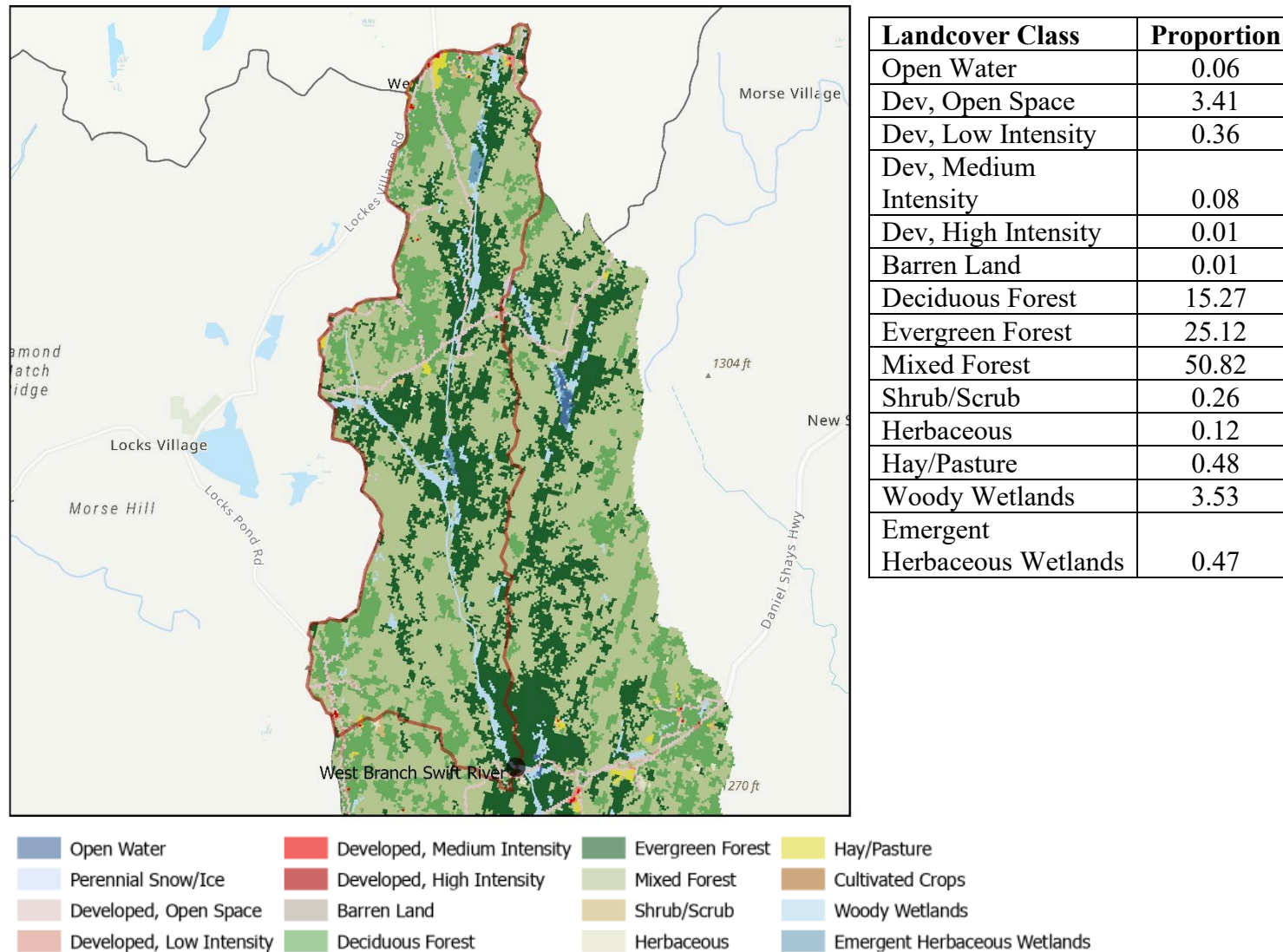
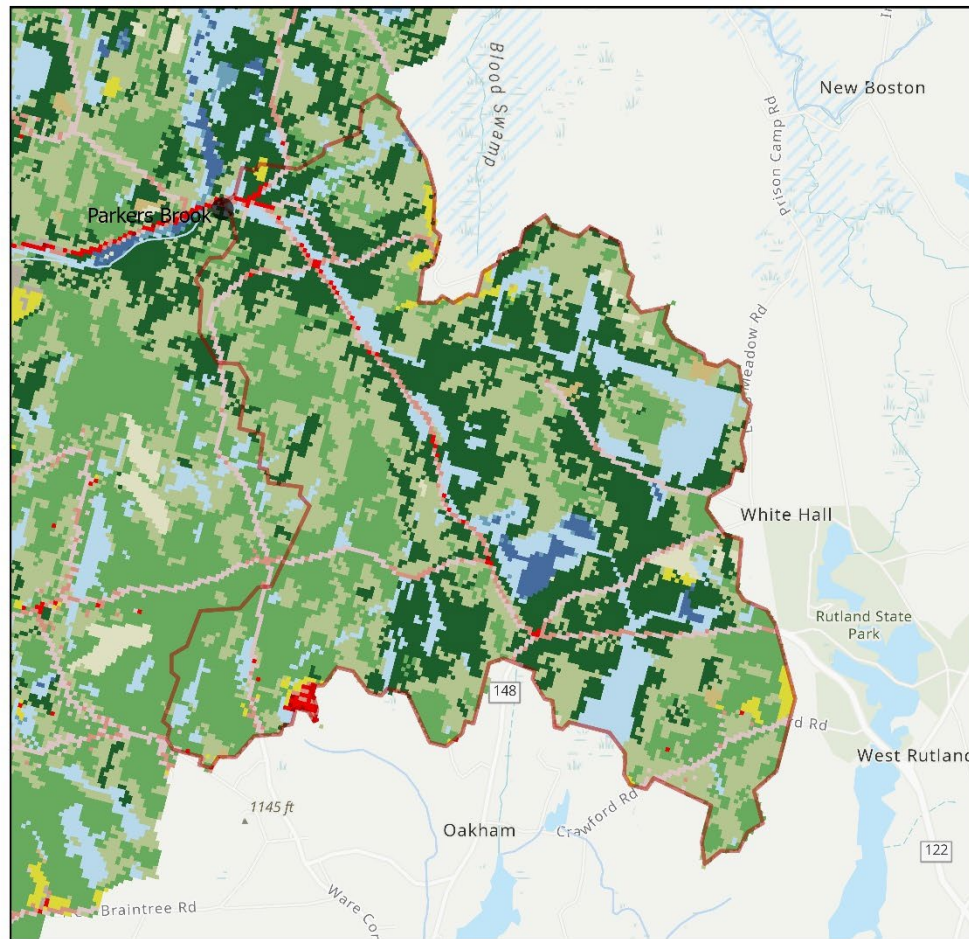


Figure 4-D. Land cover classification and proportionality within the West Branch Swift River catchment and watershed.





Landcover Class	Proportion
Open Water	1.04
Dev, Open Space	3.22
Dev, Low Intensity	1.49
Dev, Medium Intensity	0.52
Dev, High Intensity	0.03
Barren Land	0.01
Deciduous Forest	21.63
Evergreen Forest	27.46
Mixed Forest	30.01
Shrub/Scrub	0.41
Herbaceous	0.72
Hay/Pasture	1.17
Woody Wetlands	12.11
Emergent Herbaceous Wetlands	0.18

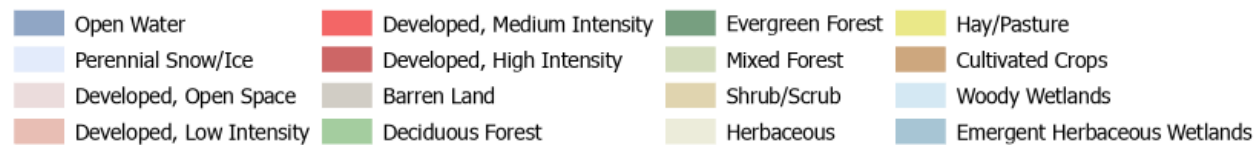
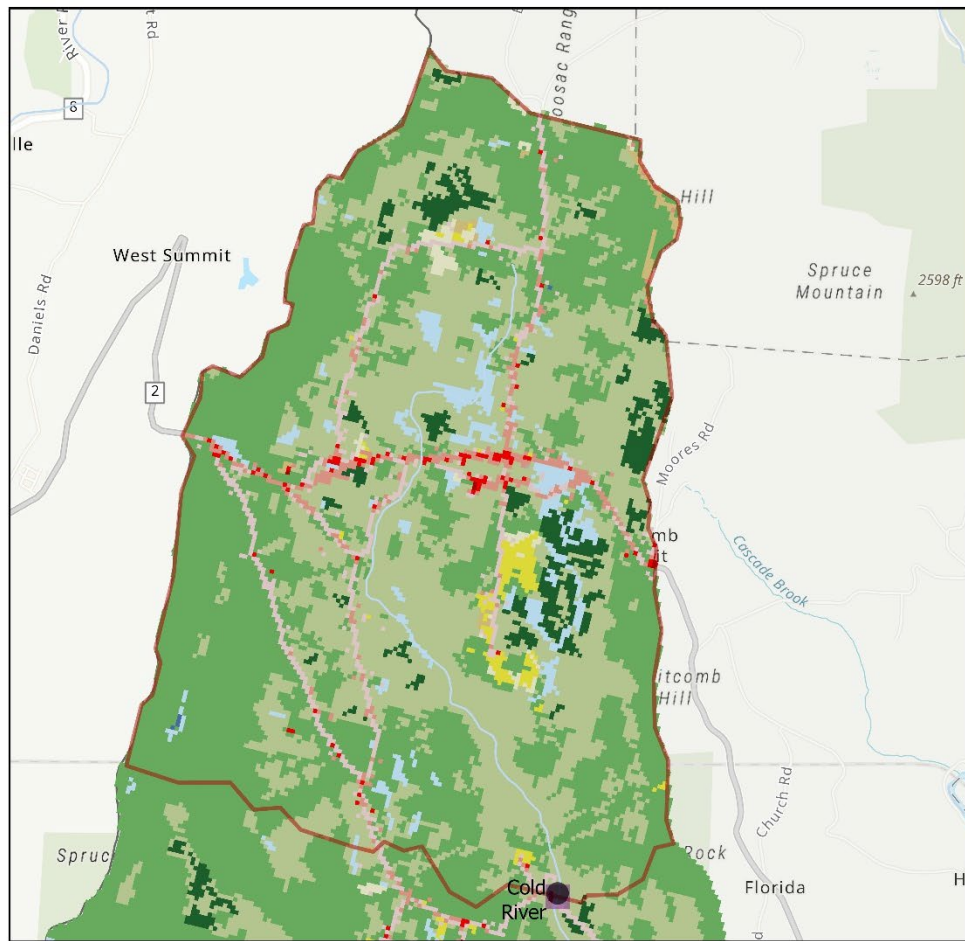


Figure 4-E. Land cover classification and proportionality within the Parker's Brook catchment and watershed.



Landcover Class	Proportion
Open Water	0.03
Dev, Open Space	3.34
Dev, Low Intensity	1.87
Dev, Medium Intensity	0.53
Dev, High Intensity	0.03
Barren Land	0.02
Deciduous Forest	44.98
Evergreen Forest	4.13
Mixed Forest	39.37
Shrub/Scrub	0.49
Herbaceous	0.66

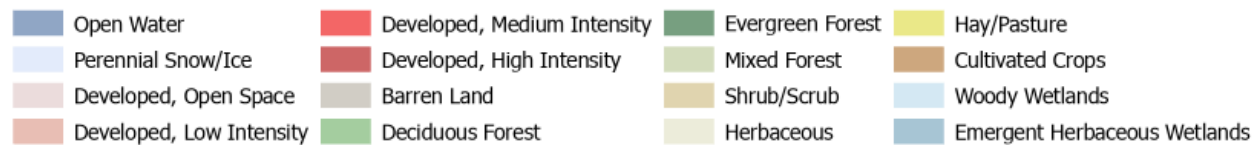


Figure 4-F. Land cover classification and proportionality within the Cold River catchment and watershed.



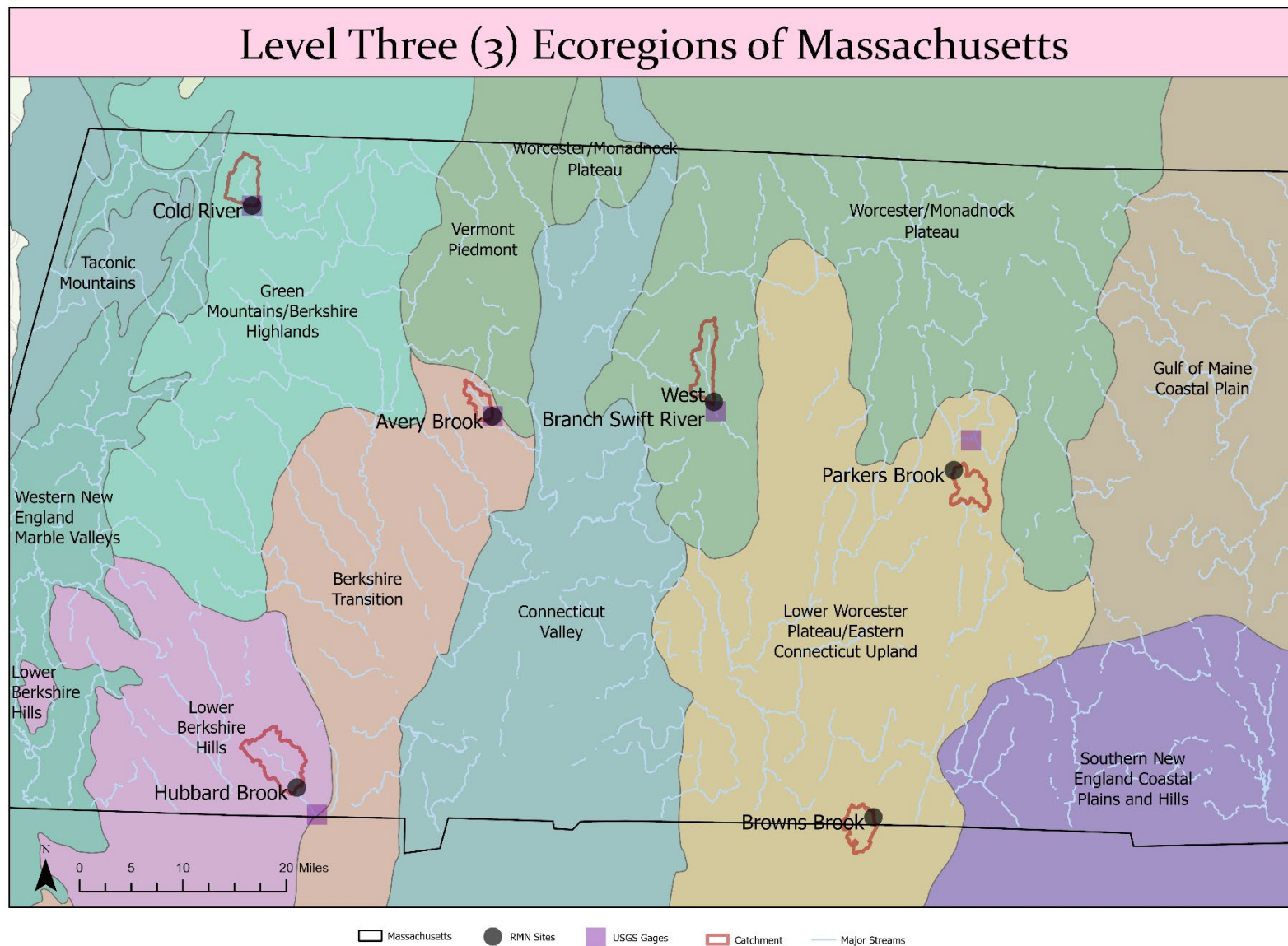


Figure 5. Map of MA RMN Sites with Level 4 Ecoregions displayed on the map.