**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, offering nuanced insights into the multifaceted dynamics of ecosystems.
* The monitoring of conditions of minimally and least disturbed streams, ensuring 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.

In 2023, 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 meticulously, and each logger is safeguarded inside protective PVC housings, wrapped around a large boulder, and anchored firmly to permanent structures like large tree roots using cables, 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 meter to maintain data accuracy and integrity. These readings are invaluable as they undergo rigorous 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 (NH3), 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 meticulous 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 Mike Cole Ecological Inc., who specializes in macroinvertebrate sample enumeration and taxonomic identifications.

## 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](https://www.mass.gov/doc/quality-assurance-program-plan-2020-2024-appendix-e-wpp-standard-operating-procedures-sops/download)).

## 6. Habitat Assessments

RBP III habitat assessments will be completed at all sites. See link to Habitat Assessment SOP ([Link to all WPP SOPs](https://www.mass.gov/doc/quality-assurance-program-plan-2020-2024-appendix-e-wpp-standard-operating-procedures-sops/download)).

## 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 encompass upstream and downstream views from a mid-reach location, including identifiable objects like large trees, boulders, and woody debris. Additionally, capturing images of the riffles where macroinvertebrates are collected and locations where discharge measurements are taken is encouraged. These photographs will be archived and readily accessible, serving as valuable references for observing changes in physical habitats over time.

## 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](https://massgov-my.sharepoint.com/:f:/r/personal/steven_m_bittner_mass_gov/Documents/SBittner/RMNet%20Streams/Photos?csf=1&web=1&e=xWDTUw) .

# Dissemination of Data to the EPA

WPP staff will ensure the efficient sharing of both discrete and continuous environmental monitoring data with the EPA, adhering to data quality standards and formatting guidelines. Continuous data such as temperature and conductivity levels, alongside discrete temperatures and conductivity data, nutrient analysis and macroinvertebrate studies, will undergo thorough quality assurance processes. Data will be electronically submitted to the EPA, complemented by metadata detailing methodologies and site information. This streamlined data-sharing protocol facilitates the integration of RMN findings into national databases, supporting environmental policy and management decisions. ([Flow Camera Submissions](https://www.usgs.gov/apps/ecosheds/fpe/%23/))).

# Sampling Process Design

The RMN emphasizes sites that are minimally disturbed or undisturbed, following the guidelines set out by Stoddard et al., 2006. The goal is to differentiate natural ecological variations from those that might be induced by human activities. Using high-quality waters as reference points, these selected sites serve as a comprehensive baseline, facilitating more accurate comparisons with other bioassessment locations.

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. Increased impervious cover, such as paved areas, can lead to more runoff and potentially more pollutants entering the water bodies. Hence, 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 an accurate verification of each site's suitability. (See Figs. 2, 3, 4a-f, 5).

Being a long-term study, the RMN not only aims for a precise current assessment of water bodies but mainly seeks to monitor changes over time, more specifically concerning the impacts of climate change on aquatic ecosystems. By maintaining consistent data collection and following established evaluation methodologies, the RMN's objective is to provide a comprehensive understanding of water quality, aquatic life, and the broader implications of climate change on these parameters.

# Figures and Tables

A map of the united states

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

Map

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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.

|  |  |
| --- | --- |
| **Project Personnel** | **Responsibility** |
| Project Coordinators  -Steven Bittner (Lead)  -Peter Mitchell (co-lead) | Responsible for defining logistics for efficient monitoring and generation of usable data at assigned sites in accordance with WPP SOPs. |
| Continuous Dissolved Oxygen (D.O.), Conductivity and Additional Temperature Monitoring  -Steven Bittner (Lead)  - Peter Mitchell (co-lead)  -WPP Staff | Responsible for download of loggers in accordance with WPP SOPs. |
| Nutrients Sampling  -Steven Bittner (Lead)  -Peter Mitchell (co-lead)  -WPP Staff | Responsible for collection and delivery of nutrient samples. |
| Benthic macroinvertebrate surveys  -Steven Bittner (Lead)  -Peter Mitchell (co-lead)  -WPP Staff | Responsible for benthic macroinvertebrate survey data collection in accordance with WPP SOPs. |
| Fish Community  -Steven Bittner (Lead)  -Peter Mitchell (co-lead)  -WPP Staff | Responsible for fish survey data collection in accordance with WPP SOPs. |
| Habitat Assessments  -Steven Bittner (Lead)  -Peter Mitchell (co-lead)  -WPP Staff | Responsible for conducting habitat assessments in accordance with WPP SOPs. |
| Digital Photography Documentation  -Steven Bittner (Lead)  -Peter Mitchel (co-lead)  -WPP Staff | Responsible for collection and download of images captured via iPhone. |
| Streamflow Monitoring with Trail Cameras  -Steven Bittner (Lead)  -Peter Mitchell (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)  [https://dashboard.waterdata.usgs.gov/](https://dashboard.waterdata.usgs.gov/app/nwd/en/?region=lower48&aoi=default) | Continuous stream stage and discharge measurements at gaging stations within the project extent. |
| The Weather Underground  <http://www.wunderground.com/> | Daily precipitation and temperature data weather stations within the project extent. |
| AccuWeather  <https://www.accuweather.com/en/us/national/weather-radar> | Daily precipitation and temperature data weather stations within the project extent. |
| CoCoRaHS  <https://maps.cocorahs.org/> | 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).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Site ID** | **CR01ACC** | **HRCC** | **BB01CC** | **WSR01CC** | **PBCC** | **AVB01** |
| 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 |

A map of a network

Description automatically generatedFigure 3. Regional Monitoring Network (RMN) sites in Massachusetts. Showing USGS gages, catchments, and HUC8 watersheds Map

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|  |  |
| --- | --- |
| **Landcover Class** | **Proportion** |
| Open Water | 0.71 |
| Dev, Open Space | 1.75 |
| Dev, Low Intensity | 0.13 |
| Dev, Medium Intensity | 0.04 |
| Barren Land | 0.14 |
| Deciduous Forest | 39.49 |
| Evergreen Forest | 4.96 |
| Mixed Forest | 39.57 |
| Shrub/Scrub | 0.35 |
| Herbaceous | 1.27 |
| Hay/Pasture | 1.84 |
| Cultivated Crops | 1.28 |
| Woody Wetlands | 7.73 |
| Emergent Herbaceous Wetlands | 0.74 |

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

A map of a forest

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|  |  |
| --- | --- |
| **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.

A map of a large area

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|  |  |
| --- | --- |
| **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.

A map of a large area

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|  |  |
| --- | --- |
| **Landcover Class** | **Proportion** |
| Open Water | 0.06 |
| Dev, Open Space | 3.41 |
| Dev, Low Intensity | 0.36 |
| Dev, Medium Intensity | 0.08 |
| Dev, High Intensity | 0.01 |
| Barren Land | 0.01 |
| Deciduous Forest | 15.27 |
| Evergreen Forest | 25.12 |
| Mixed Forest | 50.82 |
| Shrub/Scrub | 0.26 |
| Herbaceous | 0.12 |
| Hay/Pasture | 0.48 |
| Woody Wetlands | 3.53 |
| Emergent Herbaceous Wetlands | 0.47 |

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

A map of a large area

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|  |  |
| --- | --- |
| **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.

A map of a large green area

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|  |  |
| --- | --- |
| **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 |
| Hay/Pasture | 1.07 |
| Woody Wetlands | 3.49 |

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

A map of different colors

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