Vermont's Functioning Floodplains Initiative
Scope of Work for Phases 1 and 2

The Vermont Department of Environmental Conservation has now secured the services of a consulting team of professional practitioners and researchers to carry out a Functioning Floodplain Initiative that will usher in a new era of applied river and floodplain science in Vermont. The goal of the Initiative is to provide practitioners, program managers, and policymakers with the maps and data they need to protect and restore highly valued streams, wetlands, riparian areas, and floodplains in the Lake Champlain Basin of Vermont.

Executive Summary

The Initiative will consist of tools to create maps and data explaining: a) hydrologic connectivity upstream to downstream and across the riverscape; b) departures in natural erosion, deposition, and storage-related processes due to the loss of connectivity; c) existing and potential stream, wetland, and floodplain functions related to water quality, flood resiliency and ecological integrity; and d) value of protecting or restoring connectivity and natural processes at the reach and watershed scales.

Connectivity mapping will include features and data that explain:

- *vertical and lateral floodplain connectivity* (i.e., groundwater – surface water stage at different flows and the freedom of the stream to move across the river corridor).

- *longitudinal and temporal stream connectivity* (i.e., upstream to downstream flowage of sediment and debris and natural flow characteristics over time).

River, wetland, and floodplain connectivity mapping will then be augmented with estimates of fluvial processes and what beneficial functions, as derived from connected forms and these dynamic processes, might be restored and/or protected. Natural functioning floodplains, as green infrastructure, will be assessed a water quality value and compared to the cost and function of gray infrastructure. The benefits of natural functions will also be valued by examining the avoided costs of inundation and erosion damages during major floods.

To achieve the TMDL for unstable streams in the Lake Champlain Basin, five-year estimated load reduction allocations for will be developed for sub-watersheds at the HUC 12 scale, based on natural functions, ecosystem services, and project feasibility. This system will include methods for calculating credits for common restoration and protection practices, based on the data used for conducting the departure analyses. In addition, the Initiative will produce a web-based system to track implementation, effectiveness, and value of river and floodplain/wetland restoration and conservation projects.

These important mapping, assessment, and tracking tools will be essential to the function and ongoing support of state basin water quality and hazard mitigation planning. The Initiative will also be geared as an accessible planning tool at the local level. Outreach materials, training modules and a user manual for the web-based tracking tools will be created with local watershed associations and conservation districts as intended audiences. The objective is to not only enhance engagement of local groups in TMDL implementation at the basin scale, but also support the accrual of benefits from their work to reconnect rivers and floodplains at their local sub-watershed scale.

Phase 1 (2019-2020)

Vermont DEC has contracted to develop methods and maps that quantify and display stream and floodplain connectivity and those optimal locations where restoration and protection practices would increase connectivity, stream equilibrium, and natural process conditions.

Specifically, Phase 1 of Vermont's Functioning Floodplains Initiative will include:

1. Stream reach and watershed departure and attainment scoring for floodplain connectivity. Methods will be developed using existing data to answer the following questions for floodplain connectivity:
   - Which rivers/streams and what percentage of stream lengths are (dis)connected in a given watershed due to existing stressors, including existing encroachments and valley features that confine or constrain meander and channel slope adjustments commensurate with least erosive conditions?
   - What is the opportunity to readily achieve connectivity in each reach and the watershed? How should lateral connectivity be scored to support a strategic restoration and protection plan for preserving river corridor meander space from further encroachment and the restoring woody riparian buffers and floodplains?
   - When a project is completed to restore or protect vertical/lateral connectivity, how is that project scored and credited to the existing lateral connectivity scores for tracking progress at the reach and watershed scales?
   - When a project is completed to restore or protect connectivity, how is that project scored and credited to the existing connectivity scores for tracking progress at the reach and watershed scales?
   - What are the highest priority floodplain reconnection projects? Including:
     - River corridor easements
     - Floodplain restoration (berm removals, floodplain cuts/benching, feature reconnections)
     - Equilibrium channel restoration
     - Riparian buffer planting

2. Stream reach and watershed departure and attainment scoring for stream connectivity. Methods will be developed using existing data to answer the following questions for stream connectivity:
   - Which rivers/streams and what percentage of stream lengths are longitudinally or temporally (dis)connected in a given watershed due to existing upstream-downstream barriers that disrupt flow, sediment, and woody debris regimes and the passage of aquatic organisms?
   - What is the opportunity to readily achieve longitudinal and/or temporal connectivity in each reach and the watershed? How should longitudinal connectivity be scored to support a strategic restoration and protection plan for preserving river flowages and the passage of aquatic life?
   - When a project is completed to restore or protect longitudinal or temporal connectivity, how is that project scored and credited to the existing longitudinal connectivity scores for tracking progress at the reach and watershed scales?
   - What are the highest priority stream reconnection projects?
     - Removal of Derelict Dams
     - Culvert Replacements
     - Grade Control Installations
     - Flow Restoration at Impoundments, Diversions, and Withdrawals

3. Separate stream and floodplain connectivity maps for the Lake Champlain Basin in Vermont. Using the scoring systems developed to answer the questions above, create mapping tools and maps for the Lake Champlain Basin in Vermont that depict stream and floodplain connectivity within the Vermont river

corridor in different valley settings. The mapping program should enable the user to turn on different layers for different restoration and protection practices showing high, medium and low priority projects. (Notes: (A) This project does not include the actual mapping of groundwater and groundwater stage to explain vertical connectivity. While this may be pursued in later project phases, it will only be inferred from other data at this time. Vertical connectivity will be focused here on the stage of the surface water during flood flows relative to the top of stream banks. (B) Several Program partners and consultants in Vermont have worked to successfully map longitudinal stream connectivity, as affected by dams and stream crossings. It is anticipated that this project will build upon these efforts.)

4. The reconnection of Vermont rivers. Maps will reside on the State servers, and partners will be able to use them as "best available information" for prioritizing restoration/connectivity projects. The State will use connectivity maps and scoring, developed by this project, as public outreach tools in its "Reconnect Vermont Rivers" campaign. Maps, mapping functions, and summary reports will be tailored to help watershed associations to work with the State, other agencies, and Non-Government Organizations (NGO) in identifying projects to restore their local streams and rivers. Outreach product testing will be conducted at a Watersheds United of Vermont meeting.

Phase 2 (2020-2022)

Vermont DEC has now contracted to develop methods and maps that quantify and display the natural erosion and depositional processes, as well as floodplain functions and values that could be achieved with stream and floodplain connectivity. The resulting products are expected to help identify and track priority protection and restoration projects and be made available through outreach and training of watershed organizations and other natural resources restoration partners.

The set of Phase 2 products will explain and track existing and potential river form and process, as well as the effectiveness of interventions to improve river and floodplain connectivity and function, integrate stakeholder programs involved in restoring stream and floodplain connectivity, and engage the public to support these interventions. Specifically, Phase 2 of the Functioning Floodplains Initiative will include the following tasks:

1. Maps of river, wetland, and floodplain forms with estimates of dynamic processes (flow storage, sediment erosion/deposition, nutrient and carbon retention) that indicate a weighted prioritization of wetland/floodplain and river reconnection projects in a river network context.

This will be accomplished by integrating fluvial process and function data into connectivity maps created in Phase 1 by drawing on on-going research on floodplain mapping, sediment regime mapping, and floodplain/riparian wetland nutrient flux. This task will involve development of a methodology to include factors such as channel evolution stage, sediment regime, and erosion/deposition processes. A piece of this methodology will rely on development of a map layer that describes floodplain and riparian wetland functioning in terms of phosphorous (P) retention. A risk indicator for soluble reactive P release will be developed which will be used with inundation maps, upstream watershed characteristics, and P deposition estimates to develop an indicator of net P retention potential.

Restoration and conservation projects will be prioritized based on an overlay of:

- departure maps developed in Phase 1 of the project,
- mapping of sediment regime and channel evolution,

- floodwater and fine sediment storage extents and riparian wetland nutrient flux
- potentially other factors yet to be determined

Methods will be tested at the scale of a pilot watershed before extending application of the mapping methodology to the entire Lake Champlain Basin.

Deliverables for this task include:
- Expanded floodplain connectivity mapping methods that consider both form and process, and an enhanced project prioritization approach;
- Draft and final expanded floodplain connectivity and project prioritization maps for the pilot watershed; and
- Draft and final expanded floodplain connectivity and project prioritization maps for the Lake Champlain Basin.

2. A valuation of floodplain functions will be created to inform weighted priorities for restoration and conservation projects. These include natural values and functions as well as those ecosystem services related to water quality, habitat, and flood resiliency. Valuation of ecosystem services will include an analysis of tradeoffs in implementing green vs. gray infrastructure projects.

This task will involve further developing the floodplain function valuation methodology established in Phase 1of the project to more explicitly account for the range in natural values and functions of floodplains as well as ecosystem services. A literature search on floodplain valuation will be conducted that will include identifying a range of nutrient and P retention estimates that may be applied to small streams (drainage area less than 2 square miles).

To inform sediment and P retention coefficients, current ongoing monitoring at wetland and floodplain sites will be expanded to support the building of a statistical model to predict the relationship between hydrologic, topographic, and land cover variables to better understand the capacity of floodplains to capture and retain sediment and nutrients. Additionally, ongoing monitoring at wetland sites will be expanded to inform understanding of how wetland characteristics influence attenuation and release of P. These additional data will support creation of a Soluble Reactive Phosphorus (SRP) release risk indicator that will be combined with a sediment P capture indicator to provide an overall ranking of net P retention in riparian wetlands.

This task will also entail development of a tool to show estimated economic benefit of investment in natural resources projects (e.g., comparing wetland or floodplain restoration with gray infrastructure approaches). The tool will show the economic value of a natural resource project with the goal of communicating the economic value of natural resource projects and increasing the awareness of the cost-effectiveness of these “green infrastructure” practices. Specifically, this task will entail:

- Developing green versus gray infrastructure valuation relationships and charts to illustrate the financial comparison between approaches to improve water quality, specifically to store sediment and reduce P. This task will indicate service proxies between green and gray infrastructure such as the number of gallons of stormwater treatment avoided.

- Estimating the cost of improved property in danger in the river corridor and floodplain relying on constraint mapping developed in Phase 1 and estimated values for infrastructure costs. This estimate is the avoided loss or benefit, and will be used to evaluate the financial savings due to reduction in flood inundation and erosion.

• Developing benefit and cost values associated with flood inundation reduction due to a natural resource project. The floodplain modeling, utilizing the Height Above Nearest Drainage (HAND) method, will be used to estimate flood depth reductions and existing FEMA depth-damage curves will be used to value the benefits.

• Apply a characteristic stream-power signature for reaches of various floodplain connectivity conditions relying on work products of an ongoing Sea Grant project, existing SGA data, and connectivity mapping developed in Phase 1. The benefit of reduced erosion potential will be the estimate avoided infrastructure damages.

Deliverables for this task include:

• Annotated bibliography of valuation of floodplain functions;
• A set of empirical relationships estimating unit values of sediment and P retained on connected floodplains relative to a set of environmental variables that influence retention rates. To the extent that existing data permit, this valuation may also extend to flood water storage and habitat provision;
• Green versus gray infrastructure valuation relationships;
• Cost estimate of improved property in danger in the river corridor and floodplain;
• Benefit and cost values associated with flood inundation reduction;
• Benefit and cost values associated with erosion reduction; and
• Floodplain mapping with color ramps showing valuation and green vs. gray value comparisons.

3. Five-year estimated allocations for natural resource load reductions will be developed for Lake Champlain sub-watersheds at the HUC 12 scale, based on natural functions, ecosystem services, and project feasibility. This system will include methods for calculated credits for common restoration and protection practices, based on the data used for conducting the departure analyses.

This task will include estimating load reduction achievable through a set of restoration and conservation projects. Estimates will be aggregated to the HUC12 sub-watershed scale and a 5-year time interval. The nutrient focus will be phosphorous. Relationships for potential P capture will be developed based on project feasibility data developed in Phase 1, natural values and functions developed in task 2, research on sediment deposition and P levels on connected floodplains, and a literature review. An important task of this project will be determining a portion of the overall natural resource-related nutrient load that should be assigned for that portion of the HUC 12 watershed that is not in and along streams and rivers with a drainage area greater than 2 square miles, i.e., a small stream allocation for each sub-watershed. The system for calculating restoration or protection practice "credits" will include simple methods for estimating the load reduction credit a practice would receive in and along a small stream (DA < 2 sq. mls.), i.e., small stream credits would be not be site specific.

A list of projects will be developed that will receive credit and estimate the implementation cost for project types in the natural resources sector. A range of P reductions will be quantified for each project type. Coefficients of P attenuation will be developed for each identified practice on a per acre or per foot basis. Final credits assigned to each practice will be a function of P retention coefficients and the magnitude, duration and periodicity of reconnection that will be informed by validated load reduction estimates from pilot watersheds. Methods for P load estimate reductions will be tested in a pilot watershed and will build on the departure and opportunity analyses developed in Phase 1of the project to upscale benefits of floodplain reconnection projects at the reach and sub-reach scale. This will include estimates of the number and configuration of floodplain reconnection projects that could be implemented

to meet TMDL targets within a watershed. After testing methods on a pilot watershed and making any necessary edits, the framework will be applied to all HUC 12 watersheds in the Lake Champlain Basin.

Deliverables for this task include:

- A list of floodplain reconnection projects and practices;
- A summary of key outcomes of ongoing and expanded monitoring to support load reduction estimates;
- A set of relationships estimating load reduction over five years that will be used to credit potential implemented projects; and
- Estimated project implementation costs.

4. A web-based system to track implementation, effectiveness, and value of river and floodplain/wetland restoration and conservation projects will be created. This system will allow users to readily access information and visualize maps developed in prior efforts and will be designed to track implementation of projects to understand how progress is being made at different scales towards restoring floodplain functionality and flood resilience. This system will include estimated economic benefits of investment in natural resources projects via comparison between green and gray infrastructure approaches.

User requirements will be gathered and refined for the application early in the project in collaboration a Technical Advisor Committee (TAC). Once the user requirements have been confirmed, a set of prototypes will be developed for review by the TAC. There will be several rounds of review to develop prototypes prior to development of the application. Map layers developed in Task 1 will be embedded, attributed with departure, valuation, and load reduction estimates developed in Tasks 2 and 3 so trade-offs can be observed and benefit-cost analysis for a single project or group of projects can be visualized.

The application will be developed with Esri's ArcGIS Online Web AppBuilder functionality, with customization outside of this Esri "out of the box" functionality to provide the necessary tools within the application. It is expected that once the project is complete, VTDEC will host the production version of the application.

The mapping tool will have both a planning and a tracking interface. The planning interface is envisioned to perform the following functions:

- Illustrate connectivity departure scores and supporting data;
- Allow for planning of connectivity projects through observing and comparing natural functions, estimated load reductions, and estimated project costs;
- Facilitate planning for project implementation through selecting one or more potential reconnection projects and seeing how the projects work towards improving reach-based connectivity and meeting TMDL targets for HUC12 sub-watersheds and the Lake Champlain basin; and
- Visualize project implementation progress.

The tracking interface will be used to permanently update and display implemented projects at the parcel, reach, HUC12 sub-watershed, and basin scales, and provide updated calculations of benefits.

The application will be developed with scalability in mind to facilitate the expansion of the application in future phases for dynamic monitoring, forecasting, and management of restoration and conservation projects, providing up to date values regarding floodplain health and status from the reach to sub-watershed level.

Deliverables for this task include:

- Meet with TAC to define application users and user requirements;
- Application prototype in the form of interactive wireframes; and
- Development application for reviewed by TAC

5. Training modules and a user manual for the web-based tracking tools will be created. This task will involve stakeholder involvement to maximize the extent to which partner agencies and organizations help craft the outputs of this program that are supportive of their mapping, assessment and planning or restoration and conservation work.

Drafts of the training module and User Manual will be provided to the TAC for feedback and edits will be made to finalize the materials. The training module will be a one-day classroom session that consists of a computer slide show to give an overview of method development, a demonstration of the application features, and a hands-on project planning exercise. Stakeholders will be selected by VTDEC to participate in the development of these tracking system tools to increase their utility and attend the training.

Deliverables for this task include:

- Draft and final Training Module; and
- User Manual outline, draft and final.

6. Outreach materials will be developed that can be used to engage a greater range of stakeholders in the initiative and learn about their perceptions of place and river dynamics as they relate to both local and statewide initiatives to reconnect Vermont's rivers. Specifically, five (5) one-page outreach sheets will be developed to engage a wider group of stakeholders such as municipal boards, citizens, landowners and businesses. The documents will be quick reads, contain mostly graphics, and be readily transferrable to web content and social media. Outreach may include but are not limited to the following topics.

A. Visual overview of the Vermont Functioning Floodplain Initiative
B. Visual of what a connected floodplain looks like and the benefits of a connected floodplain.
C. Summary of the planning interface of the web application.
D. A summary of the tracking interface of the web application.
E. To be determined with VTDEC.

Deliverables for this task include:

- Five draft and final outreach sheets; and
- Blog contents for VTDEC website.