Vermont Agency of Natural Resources
Stream Geomorphic Assessment

Protocol Handbooks

Remote Sensing and Field Surveys Techniques for conducting Watershed and Reach Level Assessments

Vermont Agency of Natural Resources
April, 2004

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Funding for assessment protocol development has been provided by the:

U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service – Conservation and Reinvestment Act Funding
Federal Emergency Management Agency
Lake Champlain Basin Program
U.S. Forest Service – Green Mountain National Forest
Vermont Agency of Transportation Research Grant
Vermont Geological Survey State Map Grant

Acknowledgements: Many Agency of Natural Resources staff worked to make the Stream Geomorphic Assessment Handbooks possible by reviewing drafts, participating in pilot projects, suggesting references, administering grants, and assisting with the development of databases. Numerous pilot projects were conducted in cooperation with other state and federal agencies, regional planning commissions, watershed organizations, and consulting scientists, without which these protocols would not have been possible. Special thanks to the Lake Champlain Basin Program, Technical Advisory Committee for submitting the Phase 1, Phase 2, and Phase 3 Handbooks to a national peer review panel. The peer reviewer comments have strengthened both the technical aspects and readability of the handbooks. *"The reviewers felt that the protocols were technically sound and should result in scientifically defensible geomorphic assessments in Vermont. The information collected will have utility for more intelligent river basin planning and stream management"* (Lake Champlain Basin Program, December, 2002).

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The Stream Geomorphic Assessment handbooks and database may be downloaded from the River Corridor Management, Geomorphic Assessment internet web page at: **www.vtwaterquality.org/rivers.htm**

VERMONT AGENCY OF NATURAL RESOURCES
STREAM GEOMORPHIC ASSESSMENT

PROGRAM INTRODUCTION

Stream and River Corridor Conservation

A goal of Vermont's stream and river corridor conservation programs is to resolve or avoid conflicts between human investments and river systems in a manner that is technically sound and both economically and ecologically sustainable. The purpose of the stream geomorphic assessment protocols is to provide a method for gathering scientifically sound information that can be used for watershed planning and detailed characterization of riparian and instream habitat, stream-related erosion, and flood hazards.

The Vermont Agency of Natural Resources has prepared a series of Stream Geomorphic Assessment Protocol Handbooks. The Handbooks are a collaborative effort by the Department of Environmental Conservation, River Management Program; the Department of Fish and Wildlife, Fisheries Division; and the Vermont Geological Survey. The Handbooks have been developed to help meet the Agency's watershed and river conservation and assessment goals.

The stream geomorphic assessment protocols, while providing essential information to river protection and restoration projects, are not intended to provide a complete methodology for project design. Geomorphic-based river restoration projects in particular may involve hydraulic and hydrologic modeling and sediment transport analysis to confirm channel and floodplain design criteria. While the data generated through application of the geomorphic assessment protocols will be very useful in setting up and running design models, they should not be used in place of them.

Stream Geomorphic Assessment

There are many reasons to do a stream geomorphic assessment, ranging from learning about the natural environment and the effects humans have had on the landscape over time, to identifying high quality aquatic habitats, to characterizing erosion and flood hazards. Data collected during stream geomorphic assessments will not only foster a better understanding of the physical processes and features shaping a watershed but will also help in making strategic decisions about how to best protect, manage, and restore watershed resources.

The Vermont Agency of Natural Resources stream geomorphic assessment program objectives are:

1) To create a data collection protocol for the physical assessment of streams and rivers that is scientifically sound and produces repeatable results, so that data can be compared not only within a watershed, but also between watersheds and regions.
2) To create a state Geographic Information System (GIS) and database system of fluvial geomorphic data that is accessible to users inside and outside the Agency of Natural Resources.
3) To create a method for predicting stream channel and floodplain evolution in Vermont that will technically support the resolution of river/land use conflicts and allow for sound land use practices and planning at the watershed scale.
4) To create a river assessment methodology that will help lay people understand how human activities over time within a watershed can be conducted in a manner that is both ecologically and economically sustainable.

Overall, stream geomorphic assessment will show that stream sites should not be viewed in isolation, but rather within their watershed landscapes and history of land and water use changes. For instance, channel modifications upstream or downstream of a site, conducted decades ago, may be the source of the problems observed at that site today. Maps, aerial photos, and historic information will be invaluable when combined with field observations in piecing together the story of a stream's response to the natural and human disturbances that have occurred over time.

River Corridor Management Using Fluvial Geomorphic Science

The Vermont ANR stream geomorphic assessment protocol brings the best accepted practices of the emerging science of fluvial geomorphology into the practical realm of river management in Vermont. Applying these protocols with the sciences of engineering, hydrology, and river ecology together will place Vermont in a better position to achieve long-term ecological and economic sustainability of Vermont's river and watershed resources.

Fluvial geomorphic science explains the physical river processes and forms that occur in different landforms and geologic and climatic settings. In applying fluvial geomorphic science, it is assumed that:

1) Although rivers are dynamic, with a form or geometry that is ever changing through erosion and depositional processes, there is a central tendency of form and process that has a predictable relationship with surrounding and watershed land forms and which may undergo significant change naturally with climate changes over time;
2) Human-related physical change to river channels, floodplains, and watersheds often mimic and/or change the rate of natural physical processes;
3) A scientifically sound river corridor management program can be based in part on regional channel evolution models that help predict how an altered river channel may return to a former channel form (or type) when significant disturbances end, or how the channel may adjust to develop a new form (or type) if the disturbances continue; and
4) The distribution and condition of stream types, especially those indicative of reach and watershed scale adjustments, influence erosion and flood hazard risk levels and aquatic habitat quantity and quality.

In the Vermont Stream Geomorphic Assessment Protocols the term "in adjustment" is used to describe a river that is undergoing change in its channel form and/or fluvial processes outside the range of natural variability. The fluvial processes typically affected in river reaches that are "in adjustment" are those associated with reach hydrology and sediment transport.

Channel adjustment typically involves erosion, but the terms are not synonymous. The processes of erosion and sediment deposition are ongoing and often result in changes in channel form and fluvial processes that are well within the range of natural variability. Fluvial geomorphic assessments help us understand whether the observed channel changes (such as eroding banks) are indicative of a river adjustment process, and if so, to what extent and over what period of time the adjustment will occur. Fluvial geomorphic assessments can also help us evaluate how the adjustment will likely play out under various management scenarios. With this knowledge river managers can weigh the long-term costs and risks associated with different human activities, including channel and floodplain encroachments or land use conversions at the watershed scale.

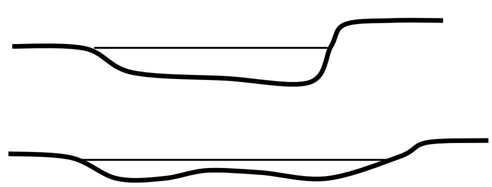
Introduction to Physical River Processes

Until recently, river management has largely depended on the science of hydrology to explain the behavior of rivers. This science focuses on the pattern and volume of runoff, the ability of structures to withstand the forces created by runoff, and the damages associated with inundation. Now, across the nation and in Vermont, natural resource scientists and managers are using fluvial geomorphology to improve planning for and management of river corridors. Because fluvial geomorphology explains the physical processes that shape river channels while considering the different landforms and geologic and climatic settings in which river systems exist, the use of this science has led to an understanding that structures and land uses placed near rivers must not only withstand the forces of running water, but must also avoid changing the fluvial processes of a river system, including the **movement of sediment**, in order for such structures and land uses to remain secure.

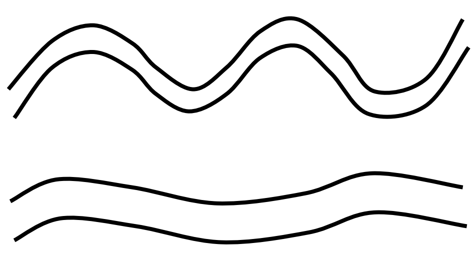
The physical attributes of a stream or river channel are composed of watershed inputs, which are water, sediment and organic debris (i.e., fallen trees, leaf matter, etc…). The arrangement of these materials into a river channel is influenced by the characteristics of the valley within which the river is located, including valley slope and width, bedrock and surficial geology, soils, and vegetation. Watershed inputs and valley characteristics together determine a river channel's dimension (channel width and depth), pattern (or plan form), and profile (or slope), which are developed and maintained over time by the channel forming flow and the sediment produced by the watershed. The channel forming flow, also called the bankfull flow, is approximately the average annual high water event, which, by virtue of its frequency, does the greatest amount of "work" on the channel and floodplain and transports the greatest volume of sediment over time.

CHANNEL DEPTH and SLOPE & FLOODPLAIN WIDTH ARE CRITICAL FACTORS IN:

DIMENSION



PATTERN & PROFILE



SEDIMENT CONTINUITY

- **Stable streams are in dynamic equilibrium**
- **Dynamic equilibrium is achieved over time through sediment continuity**
- **Sediment continuity is achieved when the stream has the power to move the size and quantity of sediment delivered from upstream**
- **Stream power is a function of channel slope and discharge**
- **Stream discharge is a function of climate, geology, and land cover**
- **Channel slope is a function of valley slope, floodplain width and meander pattern**
- **Flow velocity and channel area are functions of discharge and are determined by channel and floodplain dimensions (width and depth)**

Figure 1.1 illustrates how water volume, sediment volume and particle size, and slope (or energy grade) of a river channel are naturally balanced (Lane, 1955). If the balance is tipped the channel responds by either aggrading (building up sediment on the channel bed) or degrading (scouring down the channel bed). A change in any one of these parameters will cause adjustments of the other variables until the river system is brought back into balance. For example, in some cases rapid urbanization of a watershed has shown to increase peak runoff such that a river channel receives a greater volume of water more frequently. Using the diagram below it can be seen that this increase in the river's water volume would tip the scale downward on the right. The river will respond by degrading until either the volume and/or size of sediment increases enough to bring the scale (river channel) back into balance.

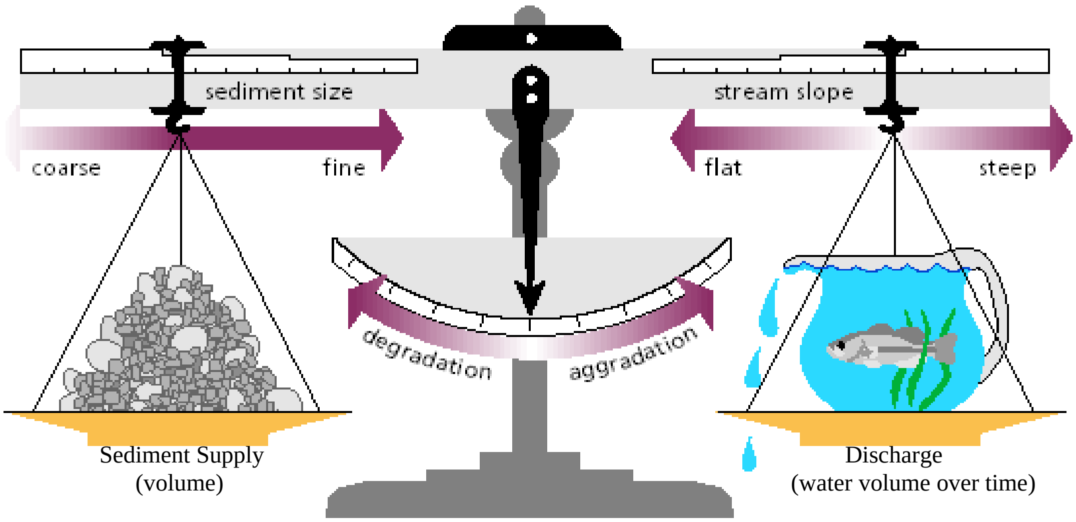


Figure 1.1 Lane's Balance of: Sediment Supply & Sediment Size **with** Slope (energy grade) & Discharge (Lane, E.W. 1955. "The Importance of Fluvial Morphology in Hydraulic Engineering." In Proceedings of the American Society of Civil Engineers 81(745): 1-17.) Reproduced by permission of the American Society of Civil Engineers.

When a stream is undergoing physical adjustments we say that it is seeking equilibrium, or trying to get in balance with its watershed inputs. Using the fundamental equation offered by Lane, the assessor can begin to understand how different land uses or management activities "tip the balance." Land use patterns, especially those within or adjacent to riparian corridors, that significantly alter the runoff patterns of water **and/or** sediment will elicit a channel adjustment process. When these processes change the relationship of the river with its floodplain (by aggrading or degrading the channel bed) it becomes increasingly difficult to plan for, as well as expensive to maintain, those land uses.

Streams are naturally in **dynamic equilibrium** when they have achieved a "balance" with the water, sediment and organic debris delivered from their watersheds. Streams in equilibrium may still erode their banks, migrate over time across their valleys, and periodically experience small-scale lateral and/or vertical adjustments. Even with these changes, a stream will maintain dynamic equilibrium as long as its channel **form** (dimension, pattern, and profile) allows it to carry out the **functions** of discharging its water, sediment, and organic debris.

Watershed and River Corridor Management Activities
Land Use / Land Cover – changes in storm water and sediment runoff
Channel Modifications – changes in bankfull channel geometry & sediments
Floodplain Modifications – changes in bankfull and flood channel geometry

Leading to changes ↓ in the balance between:

Sediment Supply, Sediment Size and % Slope, Discharge

That when unbalanced ↕ typically result in:

Channel Adjustment and Channel Evolution – site and setting specific combinations of Degradation, Aggradation, Widening, and Planform adjustment processes as the channel evolves from balanced to unbalanced and back to balanced geomorphology.

That can be observed ↕ through changes in:

Channel **Dimension, Pattern, Profile, Sediment Transport and Size Distribution** evaluated using comparisons between reference and existing stream conditions.

The periodic disturbance that occurs in natural stream and river systems is actually beneficial to an aquatic ecosystem and has been shown to increase biotic diversity, as long as the degree and frequency of disturbance remain within the adaptive capabilities of the aquatic organisms present in the system (Allan, 1995). Aquatic habitat and the communities of organisms it supports are more complex and diverse as a result of periodic bed and bank erosion, substrate deposition, and debris accumulation in the active channel and floodplain. The difficult question that many scientists are trying to answer is what magnitude and frequency of disturbance in a given stream system is healthy and at what scale of channel adjustment do the populations of certain aquatic organisms begin to be negatively affected.

Floodplain Access and Channel Evolution

Of the many surface water management deficiencies of the 20th century, the failure to understand, protect and preserve the access of rivers to their floodplains has directly resulted in some of the most intractable conflicts between human investments and river system dynamics being experienced today. Over the last century, many miles of Vermont's rivers have been subjected to channel management practices such as armoring, dredging, gravel mining and channelization, for the purpose of containing high flows in the channel and to protect human investments built in the historic floodplains that are incompatible with periodic inundation. In addition, floodplains have been and continue to be filled to elevate land above "design" flood stages.

Containing greater flows in the stream channel results in an increase in the stream's power that must be resisted by the channel boundary materials; i.e., the rocks, soil, vegetation or man-made structures that make up the bed and banks of the river. Depending on the type of channel boundary materials that exist, the effects of disconnecting a channel from its floodplain can be varied. Channel evolution models (CEMs) published by Schumm (1969 and 1984) and Thorne, Hey, and Newson (1997) help to explain a stream channel's response to losing its floodplain (models are illustrated in Appendix C). The models show the response at the channel cross section, as well as the profound physical adjustments that occur upstream and downstream from the site of alteration as bed degradation (head cuts) migrate upstream through the system and bed aggradation, in the form of sedimentation, occurs downstream.

It is important to recognize the temporal aspect of channel response to change. Fluvial systems are energized by episodic events. Channel adjustment in response to land use practices or floodplain encroachments may begin immediately and persist for decades, depending on the sensitivity and morphology of the affected stream, the magnitude of alteration, and the frequency of high flow events. The channel evolution stages related to channel incision (bed degradation) and widening might occur within a few months to a few years; but stages associated with plan form adjustment and flood plain redevelopment might not reach completion for decades.

Fluvial Geomorphic Assessment Tools

The Agency of Natural Resources has designed these protocols to bring together what have traditionally been distinct river and watershed assessment and resource management programs, including those associated with property protection and flood remediation and those focused on aquatic habitat protection and restoration.

Conflicts arise when the management practices associated with the protection and maintenance of public and private property are imposed upon a naturally dynamic river system. The challenge to landowners, river managers and the general public is to learn why a stream or river is eroding or moving and take actions that are consistent with its stream type (form **and** process), recognizing the inherent sensitivity of the stream, the implications of current adjustments, and the likely stage of channel evolution. To do otherwise may result in continued erosion and channel adjustments, perpetuating widespread and long-term conflicts and potential habitat impacts associated with large-scale channel aggradation and degradation. Conflict resolution and avoidance are facilitated by use of the following geomorphic assessment tools so that the dual long-term goals of ecological and economic sustainability are achieved.

Stream Geomorphic Classification as an Assessment Tool

River managers increasingly use stream geomorphic classification systems in communicating stream adjustment processes, channel evolution models and river corridor management goals. Vermont ANR has adopted a system that combines several nationally recognized stream geomorphic classification systems (Schumm, 1977; Rosgen, 1996; Montgomery and Buffington, 1997). In so doing, the Agency recognizes the importance of emphasizing what a classification system communicates and what it does not.

By ascribing a stream type or classification to a stream reach, the assessor communicates information about the reach's surrounding landform and geologic characteristics as well as its typical physical state (or central tendency) with respect to channel form and fluvial processes. The stream type classification system used in the Agency's assessment protocols is a set of broad descriptors and ratios that when combined generally characterize: a) the relationship of the stream with its flood plain; b) the respective roles of bed form, relative channel depth, and gradient in sediment transport processes; c) the size and quantity of sediment in transport; d) the boundary resistance of the stream bed and banks; and e) the hydrologic runoff characteristics.

The following points further clarify the meaning and intended purpose of stream classification as used in the Vermont ANR Stream Geomorphic Assessment Protocols:

- Stream typing assigns categories based on the general forms and interactions between channel and floodplain geometry that are narrow enough to distinguish between different fluvial process characteristics but broad enough to allow for the natural variability of channel dimension, plan form geometry, and longitudinal slope that is inherent in fluvial systems of all types.

- Stream types do not imply static conditions and will not serve to specify the channel dimension, pattern, profile, and sediment characteristics as absolute measures. Some streams are very dynamic, undergoing a great deal of adjustment while remaining the same basic stream type.
- Over time the stream type (or set of geomorphic descriptors) used to characterize a stream reach may change given certain stressors such as climate (including major floods), geologic processes, or human activities within the channel, flood plain and/or watershed.
- ANR's stream classification tool can describe stages in a stream's evolutionary process as a stream adjusts through what may be different forms and fluvial processes to reach equilibrium with its watershed inputs.
- Defining stream reaches based on stream type provides a structure for completing watershed analysis with a measurable unit for storing, sorting, and retrieving data.
- Understanding the nature and origin of observed channel adjustments and the outcomes of those adjustments is greatly enhanced by stream classification where the sensitivity of stream types to different imposed changes has been previously documented.

More often than not, a detailed assessment of a stream reach's geomorphology is begun after channel adjustments are underway. In order to determine what stream type is likely to result from these adjustments, and what the upstream and downstream ramifications of the impending adjustments may be, it is extremely useful to understand the stream type that characterized the reach before adjustments began. If there have not been significant changes in watershed hydrology or sediment supply the stream reach in question is likely to evolve back to the stream type from which it started. If, on the other hand, there have been substantial watershed changes resulting in significant changes in watershed inputs, then the stream may evolve to a different stream type. The Vermont assessment protocols are set up to help the assessor identify stream types, from three different perspectives, for any discrete stream reach as follows :

- **Reference Stream Type** – the natural stream type that would exist in the absence of human-related changes to the channel, flood plain, and/or watershed. Given the long history of human-related changes to the Vermont landscape the assignment of reference stream type is often based largely on characteristics of the valley, geology, and climate. Verification and refinement of the reference stream type is made by observing sediment and hydrologic characteristics, as well as channel, floodplain, and terrace land forms.
- **Existing Stream Type –** the current stream type as measured that takes into consideration any human related changes to the channel, flood plain, and/or watershed. In many instances, a stream may be in adjustment and still be the same stream type as the reference. For example, a stream may be undergoing extensive and rapid lateral adjustments (also referred to as planform adjustments) due to removal of riparian vegetation, but still have the same general form and fluvial process as the reference stream type for the reach. In this scenario there may still be ample reason to be concerned and to develop a management plan for this reach. The management plan, however, may look significantly different if the reach was starting a channel evolution process (documented by a change in stream type from the reference) where both vertical and lateral adjustments were occurring.
- **Modified Reference Stream Type –** the stream type that will evolve as a result of existing or emerging stressors, including human imposed changes to the channel, flood plain, and/or watershed. A modified reference stream type assignment recognizes that watershed land use conversion, alone or in combination with channel, valley, and/or flood plain modifications, may prohibit the evolution of the channel back to the natural reference stream type. In this case, management towards an equilibrium state that is different than the natural reference type that existed historically may be more consistent with the State river corridor conservation goal of ecological and economic sustainability in both the short and long term. Typically the assignment of a modified reference stream type is limited to situations were historic watershed and river

corridor development is so predominant that relief of the stressors associated with such development (which in many cases would require removal of substantial amounts of infrastructure) is impractical. The ANR protocol specifies that where a modified stream type has not been assigned, the reference stream type is the most prudent benchmark for achievement of the State river corridor conservation goal.

Assignment of existing and reference stream types provides a way to communicate adjustments and channel evolution processes as well as the stream's sensitivity to natural or human-caused stressors.

Stream Geomorphic Condition as an Assessment Tool

The Vermont ANR Stream Geomorphic Assessment Protocols help river planners and managers take the first steps in applying channel form, adjustment process, and channel evolution data by providing a method for assigning a **geomorphic and physical habitat condition** to stream reaches. The term "departure from reference" is used synonymously with stream geomorphic condition throughout the protocols. The degree of departure is captured by the following three terms:

In Regime – a stream reach in *reference and good* condition that:

- Is in dynamic equilibrium which involves localized change to its shape or location while maintaining the fluvial processes and functions of its watershed over time and within the range of natural variability; and
- Provides high quality aquatic and riparian habitat with persistent bed features and channel forms that experience periodic disturbance as a result of erosion, deposition, and woody debris.

In Adjustment – a stream reach in *fair* condition that:

- Has experienced changes in channel form and fluvial processes outside the expected range of natural variability; may be poised for additional adjustment with future flooding or changes in watershed inputs that would change the stream type; and
- Provides aquatic and riparian habitat that may lack certain bed features and channel forms due to increases or decreases in the rate of erosion and deposition-related processes.

Active Adjustment and Stream Type Departure – a stream reach in *poor* condition that:

- Is experiencing adjustment outside the expected range of natural variability; is exhibiting a new stream type; is expected to continue to adjust, either evolving back to the historic reference stream type or to a new stream type consistent with watershed inputs; and
- Provides aquatic and riparian habitat that lacks certain bed features and channel forms due to substantial increases or decreases in the rate of erosion and deposition-related processes. Habitat features may be frequently disturbed beyond the range of many species' adaptability.

Geomorphic condition is a useful tool for prioritizing reaches for protection, management and restoration projects at the watershed scale. Data queries of reach conditions upstream and downstream of project locations may be invaluable to solving issues related to watershed hydrology, changes in sediment supply, and large scale channel adjustments.

Stream Sensitivity as an Assessment Tool

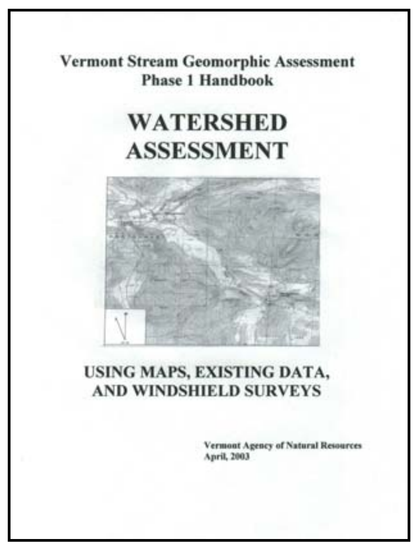
Streams are a metaphor for "change." Every stream changes in time. The exercise of assigning a **sensitivity rating** to a stream is done in the context that some streams, due to their setting and location within the watershed, are more likely to be in an episodic, rapid, and/or measurable state of change or adjustment. A stream's inherent sensitivity may be heightened by human activities. The parameters used in the ANR Stream Geomorphic Assessment Protocols to rate sensitivity include: 1) the erodibility of the channel boundary materials; 2) sediment and flow regimes (volume and runoff characteristics); 3) the confinement and slope of the valley; and 4) the degree of departure from reference conditions observed both in the study reach and in adjacent reaches. Streams that are currently in adjustment, especially degradation or aggradation, may become acutely sensitive.

Defining sensitivity has value in communicating the “rate of change” associated with adjustment and channel evolution processes. For instance, a reach rated as highly sensitive due to relatively large loadings of small-sized sediment would potentially exhibit a more rapid adjustment rate than another reach of the same type but rated as having a low to moderate sensitivity. Understanding the sensitivity of a reach can inform how the stream might react to different river management alternatives.

Three Phases of Stream Geomorphic Assessment

The Vermont ANR Stream Geomorphic Assessment Protocols are broken down into three handbooks that offer separate but interrelated approaches for examining a set of physical parameters and evaluating the geomorphic and habitat condition of a stream reach and its watershed. The handbook series was developed because watershed planners and river managers need to understand river forms and processes and have a clear understanding of the spatial and temporal responses associated with certain human activities. While the protocols require technical training for both professionals and interested lay people, the handbooks provide an accessible method for anyone interested in gaining a limited working knowledge of fluvial geomorphology and the physical components of riparian and instream habitat. They are not intended, however, to provide the full compendium of techniques in the emerging applied sciences of fluvial geomorphology or river ecology.

Upon completing a stream geomorphic assessment, the assessor should be able to “tell the story” of the physical nature of a stream, how a sequence of human activities may have combined to initiate a set of responses (or channel adjustments), and the degree to which the end result of those responses can be predicted. The ability to understand large-scale channel evolution within a watershed is invaluable to the river manager or planner trying to evaluate management alternatives. Each handbook guides the development of a unique data set to inform the “story,” and the completion of each successive phase of assessment (Phase 1 through Phase 3) is intended to increase the certainty of stream type classification and channel evolution prediction. The following descriptions explain the different data types, resources, skills, time frames, and typical applications for each phase of the protocols:

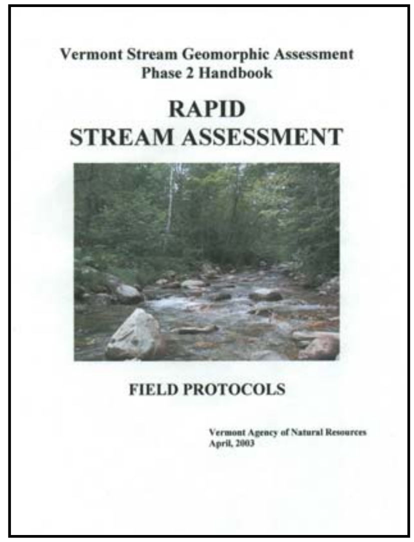

Vermont Stream Geomorphic Assessment
Phase 1 Handbook

WATERSHED
ASSESSMENT

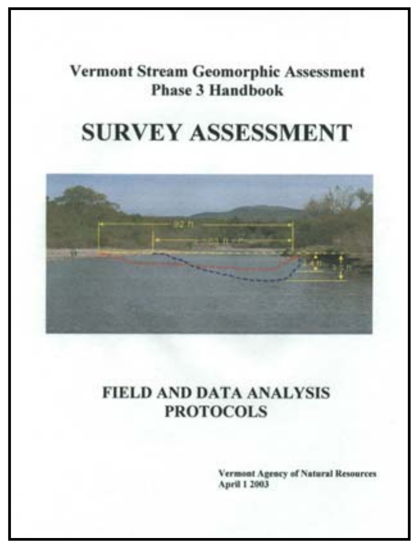
USING MAPS, EXISTING DATA,
AND WINDSHIELD SURVEYS

Vermont Agency of Natural Resources
April, 2003

Phase 1, the remote sensing phase, involves the collection of data from topographic maps and aerial photographs, from existing studies, and from very limited field studies, called “windshield surveys.” Geomorphic reaches and provisional reference stream types are established based on valley land forms and their geology. Predictions of channel condition (departure from reference), adjustment process, and reach sensitivity are based on evaluations of watershed and river corridor land use and channel and floodplain modifications. While stream types and adjustment process predictions are provisional, the Phase 1 remote sensing techniques allow for large watersheds (100-150 square miles) to be assessed within a few months time. GIS and database tools have been developed to automate many Phase 1 measurements and to aid in data evaluation. Computer and river assessment skills are necessary but there are plenty of tasks that can be completed by someone with limited training. Because the Phase 1 database is developed and may be continually refined for an entire watershed, it can be referred to over-and-over again when issues arise at the reach scale for which river form and processes need to be understood at the watershed scale. The Phase 1 assessment is ideal for flagging reaches and completing field studies that will address the goals and issues defined by the assessment group. If a watershed is small (less than 5 square miles), and extensive field surveys are planned throughout, the assessment team may decide to go directly to the field (Phase 2 and/or Phase 3) and return to the Phase 1 assessment to record reference conditions and complete impact ratings.



Phase 2, the rapid field assessment phase, involves the collection of field data from measurements and observations at the reach or sub-reach (segment) scale. Existing stream types are established based on channel and floodplain cross-section and stream substrate measurements. Stream geomorphic condition, physical habitat condition, adjustment processes, reach sensitivity, and stage of channel evolution are based on a qualitative field evaluation of erosion and depositional processes, changes in channel and floodplain geometry, and riparian land use/land cover. Phase 2 assessments are described as rapid but can take 1 to 2 days in the field to complete for a one mile reach, depending on how many different conditions or sub-reaches are encountered. Database tools have been developed to facilitate Phase 2 data reduction and reporting. Stream geomorphic and habitat assessment skills are necessary, but here to, there are plenty of tasks that can be completed or assisted by someone with limited training. Over one or two field seasons, enough Phase 2 work can be completed in the field to enhance the watershed assessment of the Phase 1 database. The Phase 2 assessment is ideal for flagging reaches for protection and restoration projects and the completion of Phase 3 assessments.



Phase 3, the survey-level field assessment phase, involves the collection of detailed field measurements at the sub-reach or site scale. Existing stream types and adjustment processes are further detailed and confirmed based on quantitative measurements of channel dimension, pattern, profile, and sediments. Phase 3 assessments are completed with field survey and other accurate measuring devices and can take 3 to four days to survey a stream length of two meander wavelengths. Spreadsheet and database tools have been developed to facilitate Phase 3 data reduction and reporting. Professional level stream survey and geomorphic assessment skills are necessary. Phase 3 assessments are typically pursued to augment data requirements for the design and implementation of river corridor protection or restoration projects. The ANR also uses Phase 3 assessment protocols to develop reference tools (such as regional hydraulic geometry curves) to complement Phase 1 and Phase 2 assessments.

Appendices have been developed to support all three levels of assessment and include: data sheets, field forms, database instructions, technical information, detailed techniques, and a glossary of terms. Printed copies of the handbooks are distributed with only those appendices that are referenced in a particular phase of assessment.

The entire handbook series, appendices, and associated database, spreadsheet, and GIS tools are available for download from the DEC River Management Program's Geomorphic Assessment web page at www.vtwaterquality.org. The web page also includes an Assessment Protocol Updates section where new database queries and reports, as well as errata sheets, will be posted as they are developed.

Data Management and Quality Assurance

In order to ensure the collection of accurate and consistent data, users of the Vermont ANR Stream Geomorphic Assessment protocols should establish a quality assurance program for each phase of the assessment. The protocols outline three key components of a good quality assurance (QA) program: training, data review, and use of a data management system. To help with implementing the QA program a "quality assurance team" should be established at the start of an assessment. This team can be made up of a variety of people with different skills and training; it is important though to have at least one person who has had a higher level of training and experience in the assessment process.

1) Training: Training is the first step in starting an assessment. Learning how to use the protocols and evaluate the different parameters is necessary for completing an accurate and consistent assessment. Carefully following the protocols is one way of ensuring that repeatable and consistent sets of data are collected. The level of training may vary for different members of an assessment team, allowing people with different skills and time commitment to be a part of the process without compromising accuracy and consistency. It is important to keep track of the level of training that participants have in order to evaluate and use the data that is collected. Completing the QA sheet at the end of each phase of assessment is part of the tracking process. Before finalizing the assessment team, be sure the people who get trained have the desire and commitment to finish the assessment. This will help to assure consistency by having the same team of assessors throughout the project. Trainings set up by or affiliated with the ANR will be a requirement for the lead assessors of groups that wish to have their data used in state river planning and management activities.

2) Data Review: The second component of a good QA program is ensuring accuracy through data review and documentation. The QA team will be responsible for reviewing data collected and evaluating field assessments. By reviewing the data collected before it is finalized and stored, the team can determine if information is missing, inconsistent with the protocols, or raises questions, and whether there is a need for reevaluation. For groups doing field assessments it is necessary to have one or two people trained as QA field reviewers. This person(s) does several checks in the field to see if they get similar results as the original assessors. This way, errors in field evaluations can be recognized and future training needs identified. A QA sheet should be filled out after the review of data and field evaluations is complete to document the completeness, accuracy and reliability of the data.

3) Data Management System: Finally, using the data management system developed for Vermont Stream Geomorphic Assessments is a critical part of the quality assurance program. Microsoft Access® databases have been developed to support the collection and storing of data collected at each phase of assessment. A Microsoft Excel® workbook has been developed for Phase 3 assessments. Data should be reviewed for completeness and accuracy when it is entered into the workbook and then again when transferred into the Access database. To assist in reviewing data for accuracy and consistency, the databases generate standard reports and tables for data at the watershed, reach, segment, and site level. These reports and tables will also help with determining where additional information should be collected and where further phases of assessments may be needed. Completing the QA sheet at the end of the data entry process will be important in keeping track of the data's level of accuracy and reliability. When groups send their data to the DEC River Management Program, a DEC/ANR reviewer will do a QA check before the data is brought into the State database.

Conducting a QA program at all levels of assessment will ensure that data is accurate and complete. Establishing a QA team to support and complete QA requirements further enables groups to do assessments that, over time, are as reliable and consistent as possible. Quality Assurance details for each phase of assessment are described in each handbook.

Program Introduction References

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