Vermont Stream Geomorphic Assessment
Phase 2 Handbook

RAPID
STREAM ASSESSMENT

FIELD PROTOCOLS

Vermont Agency of Natural Resources
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The Phase 2 Handbook may be downloaded from the River Corridor Management, Geomorphic Assessment internet web page at: **www.vtwaterquality.org/rivers.htm**

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* The Vermont ANR Stream Geomorphic Assessment Handbooks, Phase 1 through 3, have a shared set of appendices. Not all appendices are included with the Phase 2 Handbook.

PHASE 2 INTRODUCTION

This Handbook is a guide to the Phase 2 Rapid Stream Assessment, the second of 3 phases of the Vermont Stream Geomorphic Assessment Protocols. The Phase 2 Rapid Stream Assessment is a detailed protocol for gathering scientifically sound information about the stream channel and riparian corridor that can be used in watershed planning and detailed evaluations of aquatic habitat and erosion hazards. References used to develop the Phase 2 protocols are listed after the field data collection and analysis sections (Steps 1-7). The Phase 2 Assessment is composed of field observations and measurements that help verify Phase 1 stream geomorphic data and provide more specific information about stream reaches of interest. Phase 2 assessments can be used to compare stream reaches within the same watershed to each other and/or to regional reference conditions.

Where to complete a Phase 2 Rapid Stream Assessment

Prior to starting an assessment, it is important to answer the questions; *"Why are you collecting this information? And, how will you use it?"* For example, you may want to identify and protect areas with the highest quality habitat in your watershed and focus on conserving specific habitats or natural communities. You may focus on protecting a river corridor through fluvial erosion hazard mapping and land use planning. Whether you have just completed a Watershed Assessment or are responding to a specific concern, your assessment team needs to select a set of reaches on which to conduct Rapid Stream Assessments. Watershed planning and project-related reach selection processes are described below.

Watershed Planning

This process ensures a broad focus to watershed management and includes the assessment of many interests, resources, and issues, such as stream bank erosion, flood hazard and aquatic habitat. As part of a Watershed Assessment (Phase 1) priorities are established for reaches in the watershed based on impact ratings, which are determined through the assessment of land cover and hydrology changes, channel modifications, and floodplain modifications. When selecting a sample of reaches on which to conduct Rapid Stream Assessments it is important to focus on both impacted and undisturbed areas, while making sure to represent all the stream types in the watershed. Undisturbed areas may serve as "reference reaches" for the degraded reaches of the same stream type, and may become priorities for corridor protection projects. Use the Phase 1, Step 10 Like Reach Evaluation to help in the selection of Phase 2 reaches. For those using Phase 2 assessment data to direct watershed improvement projects, it is useful to select reaches that will provide information about **conservation, incising, high recovery,** and **degraded sites**. These types of sites, described below, outline a prioritization process that a watershed group or planner may use to direct watershed improvement efforts. The River Management Program has produced a more in-depth discussion of this process, which can be obtained through the RMP web page. In general, reaches with low Watershed Assessment impact scores are potential conservation sites, and those with high impact scores are potential degraded sites. Incising and high recovery sites are more related to specific adjustment processes and may not be easily identified from Phase 1 Watershed Assessment data.

Conservation – Minimally disturbed sites with river form and fluvial processes intact.

***Incising* –** Actively downcutting sites, where continued bed erosion may trigger off-site responses. A typical example would be a stream located in an urbanizing watershed, where increased hydrologic inputs may trigger channel incision that could migrate upstream if left unmanaged.

***High Recovery* -** Sites that may recover on their own or with low cost/low risk management. Channel form and process are nearing reference condition. Minimal bank treatments, riparian revegetation, and/or changes in land use practices may speed channel recovery.

***Degraded* -** Sites that may be actively and rapidly adjusting to past and/or current impacts and that may require intensive, high-risk, and/or expensive protection, management and restoration practices.

Project Planning and Design
This approach is designed to evaluate specific reaches with specific interests and resources in mind. When assessing a specific reach, you will often find you need to broaden your assessment to other parts of the watershed in order to understand the target reach more fully. For example, you may need to evaluate upstream and downstream reaches around the target reach to determine sources of channel adjustment, or evaluate reference reaches within the watershed to understand the relative condition of physical habitat and geomorphic condition in the target reach. Use the Phase 1 Watershed Assessment to familiarize yourself with the watershed in which your project is located prior to conducting Rapid Stream Assessments. Important information can be gained through an examination of topographic maps, aerial photos, existing data, and a "windshield survey" of your watershed.

For projects designed to solve specific erosion, flood-related, or habitat problems you need to determine what type of channel adjustment process is underway at your site, as well as whether the condition is the result of impacts initiated upstream and/or downstream. Rapid Stream Assessments should be conducted on upstream reaches and watershed areas that may be the source of flow and sediment load changes, and downstream reaches that may be the source of streambed degradation. Good project planning, alternatives analysis, and design also involve the assessment of reference reaches, which can be compared to the project site so as to more fully understand the type and degree of channel instability present at the project site.

What are reference reaches, and why use them? It is important to identify and assess undisturbed reaches, where stream geomorphic form and process are in equilibrium, and use these reaches as references when evaluating degraded reaches. A comparison of reference reaches, degraded and adjusting reaches of the same stream type will help you understand the extent to which the degraded reach has departed from reference condition. Use Phase 1 data to help you identify potential reference reaches. Look for areas that have primarily forested watersheds, wide forested riparian buffers, few historical or current floodplain encroachments, few channel modifications, and other characteristics that result in low impact ratings in the Phase 1 assessment.

Even if you do not have long reaches in your watershed that exhibit reference conditions, it is often possible to find a discrete reference segment within a reach undergoing minor adjustments that can serve as a guide to what the stream may look like if it were in equilibrium. Even a single meander or cross-section could provide useful reference information. To identify reference reaches, also consider what stage of the evolution process a channel is undergoing (see Appendix C). Sometimes reference channel dimensions can be measured in channels that are entering stages 4 and 5 of the channel evolution process, during which the channel is regaining equilibrium with its watershed inputs.

Final Products of the Phase 2 Rapid Stream Assessment

Products of a Rapid Stream Assessment include:

1. An **Existing Stream Type** determination for each reach assessed. Stream typing is a classification of stream reaches based on physical parameters such as valley landform, floodplain, channel dimensions, streambed forms, and channel slopes. The stream type describes general physical characteristics of the channel and the fluvial processes ongoing in the assessed reach. Stream typing in the field provides an opportunity to verify the provisional reference stream type made during the Phase 1 Watershed Assessment and to identify where the existing stream type has departed from the reference stream type.

2. A **Geomorphic Condition Evaluation** for each reach assessed that includes:

   - **reach condition** based on land use and channel and floodplain modifications and the current degree of departure from the reference condition for parameters such as channel dimensions, pattern, sediment regime, and vegetation;
   - **channel adjustment process** or change in channel form and fluvial process that may be underway due to natural causes or human activity that results in a change to the valley, floodplain, and/or channel condition (e.g., vertical, lateral, or channel planform adjustment processes); and
   - **reach sensitivity** of the valley, floodplain, and/or channel to change due to natural causes and/or human activity.

   The Stream Geomorphic Assessment can be used to problem solve and set priorities for river corridor conservation at a watershed scale because it allows you to ascertain how one reach may be affecting the condition of another. In the Rapid Field Assessment you use direct observations to evaluate stream geomorphic condition and different channel adjustment processes in each reach. In the Rapid Stream Assessment, the geomorphic stream condition is largely a function of the type and degree to which the stream has departed from its reference condition and the type and magnitude of channel adjustments that are happening in response to the channel and floodplain modifications you have documented at assessed reaches in the watershed.

3. A **Stream Habitat Assessment** for physical habitat parameters at each reach assessed that includes a stream habitat condition rating. Habitat condition ratings can be used to identify high quality habitat and to "red-flag" areas of degraded habitat for more detailed evaluation. It is also useful to examine habitat condition ratings at a watershed scale and compare these ratings with Phase 1 impact rating data to determine potential reasons for habitat degradation, and to understand habitat quality and availability throughout the watershed, which is important in particular when evaluating habitat for species that move and/or migrate within a stream system to meet different life needs.

4. **Field Maps and Photographs** detailing the reach planform, typical condition, and numerous assessed features.

Basic Methods and Skills

Data Sources

The information collected in a Rapid Stream Assessment comes from field observations and measurements. The completion of a Phase 2 assessment, including data entry and reporting, can take 1 or 2 days for a mile long reach. While an entire day may not seem "rapid," a survey-level assessment (Phase 3) can take 3 to 4 days for a site that is less than half that length. Usually attempts to reduce the assessment time per reach result in poorer data consistency, accuracy, and completeness (see Phase 2 Quality Assurance Program).

Data Management System

Vermont ANR has developed a geomorphic data management system (DMS) for entering Phase 2 information from field data sheets. The DMS is a web-based application, and provides for data entry, data retrieval functions, and a suite of standard data report. Contact DEC River Management Program, River Scientists for training and access to the data management system. Appendix B shows examples of the forms and data queries in the database used to complete Phase 2 products.

Field Assessment Skills

The protocols are divided into two basic parts. In Steps 1 through 5, the Rapid Assessment Field Notes, you describe, measure, and photograph stream components. Steps 6 and 7 are the Rapid Habitat Assessment and Rapid Geomorphic Assessment, respectively, where you qualitatively assess and score physical habitat and geomorphic stream features to determine overall reach conditions for aquatic habitat and channel geomorphology.

The skills needed to complete a Rapid Stream Assessment are:

- Reading topographic maps
- Measuring distances in and around streams
- Calculating basic mathematical equations (examples are provided in the text)
- Estimating lengths and areas
- Interpreting field data and making determinations of fluvial geomorphic processes
- Data entry and database management

These skills may be learned through training. Individual site assessments should be conduced in teams of two, at a minimum. It is important to have someone who has experience evaluating fluvial geomorphology and stream habitat to either lead or be a part of the assessment team(s). The involvement and technical assistance of specialists in the fields of geology, aquatic ecology, and fisheries is also highly recommended. Contact the DEC River Management Program, the Vermont Department of Fish and Wildlife, or the Vermont Geological Survey about the availability of professionals in these fields and/or to learn about opportunities and requirements for technical training to complete Phase 2 Assessments. A glossary of technical terms is contained in Appendix Q.

Materials Needed

To conduct the Rapid Stream Assessments you will need the following materials and equipment:

- Phase 1 data reports and the Phase 1 corridor drawn for reference during the completion of Step 1.6
- Measuring tape (100 ft. or longer – preferably incremented in tenths of feet, **not** inches)
- Range Finder and Hand Level (optional)
- Line level
- Topographic map and ortho-photographs for each reach being assessed (1:3600 or 1:5400)
- Pencils and Clipboard
- Camera digital or film (200 speed film is recommended as it works well at various light levels)
- Measuring rod (A length of 1” to 1 ½” diameter PVC pipe or wooden staff, marked in 1/2 foot increments with a permanent marker, works well. Be sure to plug the ends of PVC pipe with silicon caulking or PVC caps so the rod will not sink or break at the ends.)
- Two long screw drivers or heavy-duty tent stakes to secure the tape measure into the banks when measuring bankfull width.
- Metric ruler or gravelometer
- Waders and/or wading shoes (Old sneakers work well, felt-bottomed boots provide extra traction on slippery rocks; sandals are **not recommended**, in order to prevent foot injuries.)
- High-speed internet access for entering data into the DMS (see Appendix B)
- GPS unit to record field locations

Getting Started

Read the Handbook

Every member of an assessment team should read the Phase 2 Handbook before getting started. Understanding the entire protocol and the rationale behind it before beginning the field work will allow for more efficient, accurate, and consistent data collection.

Contact the ANR

It is *highly recommended* that you set up a project-scoping meeting with the DEC River Management Program before beginning an assessment. This offers several advantages: finding out whether there have been updates of the protocols or database; receiving information on Phase 2 assessment training opportunities; receiving data quality assurance (QA) assistance; and learning about other assessments that may have occurred or are currently underway in your study area. The River Management Program will also update your assessment team about the most current applications of Phase 2 data, including the QA requirements of different programs.

Protocol Steps

The Phase 2 Rapid Stream Assessment handbook is organized by parameter number. The numbers on the Field Notes form correspond to the section numbers in the Phase 2 handbook. For example, if you need more information pertaining to the parameter labeled on the Field Notes form as "2.1: Bankfull Width," then turn to Step 2, Section 2.1, of the Phase 2 handbook.

Data Forms

Paper data forms (Appendix A) and computer data entry forms (Appendix B) are organized by step and parameter number and have a heading to record the following information:

- ***Stream Name:*** As printed on the USGS topographic map. It is also helpful to note the name of the receiving water in parentheses.
- ***Segment:*** This is a unique identifier label for segments. It is composed of the reach number in which the segment is located (ex: M07) and a capital letter (ex: A, B, C…) that indicates the segment's location, from downstream to upstream, within the reach. For example, the most downstream segment within the mainstem reach M07, would be labeled as M07A. The next segment upstream would be labeled M07B, and so on. If you decide that the reach should not be segmented, do not use the capital letter convention and write "entire reach" in this space.
- ***Location:*** The segment location description should help someone unfamiliar with the area to locate the site. Provide detail in your description. Mark all upstream and downstream boundaries of reaches and segments on a topographic map and label each reach and segment with the appropriate identifiers.

  Example: Off Rt. 100, 2 miles up from Rt.100 / Bridge St. intersection in Granville. Segment begins NE approximately 1/2 mile off Rt.100 just above tributary entering on the east bank.
- ***Date:*** Date or dates during which you conduct the Rapid Stream Assessment for the segment.
- ***Town:*** Town(s) in which segment is located.
- ***Elevation:*** Record the elevation of the *upstream* end of the segment from the topographic map.
- ***Observers:*** Name of observer(s).
- ***Organization/Agency:*** Several-letter acronym(s) of the organizations, groups, and agencies represented in the assessment crew.
- ***Latitude and Longitude:*** If you are using a GPS fill this section out. Make sure to note the datum used, which should be the NAD 83 State Plane Coordinates (in meters).
- ***U.S.G.S. Map Name:*** USGS map name(s) on which the watershed is located. Map names are usually located in the bottom right hand corner of the maps.
- ***Drainage Area:*** If the drainage area has not already been determined from a Phase 1 survey, or from a published source, calculate drainage area as described in the Phase 1 Watershed Assessment, Step 1. Record the drainage area in square miles.
- ***Segment (or reach) Length:*** If the segment is < 500 ft. long, measure the length of the segment with a measuring tape (100 ft. tape or greater). Record the segment length in feet. Have one person hold the tape at one end of the segment and have the second person stretch the tape out as they walk to the other end of the segment. Follow the thalweg (deepest part of the channel) as much as possible when walking with the tape. If the segment is longer than your tape, leapfrog each other along the channel until you have measured the total distance of the segment. If the segment is > 500 ft. long, or is very difficult or unsafe to walk in the channel, measure the length of the segment off the orthophotos. Draw on the photo any areas where the channel has moved from the location shown on the photo, and make sure to adjust your segment length measurement to capture these channel changes. Circle on the Field Notes form whether your segment measurement is a ground or an orthophoto measurement.
- ***Weather:*** Air temperature and precipitation conditions. (Examples: Temperature is approx. 70^0 F with overcast sky // Temperature is approx. 75^0, sunny, no clouds)
- ***Rain Storm within past 7 days****:* Answer "yes" or "no" based on whether the river has carried flows from a large rainstorm on any of the seven days prior to your field assessment.
- ***Flood history:*** Indicate (yes or no) whether you are familiar with the last occurrence(s) of major flood(s) in your assessment reach (recurrence interval ≥ 10 yrs). Appendix L contains long-term flood history graphs for 33 U.S.G.S. Gage Stations around Vermont. Refer to the station data nearest to the reach you are assessing and/or use additional local sources and recent knowledge where possible. This may be important

Paper Records
You are encouraged to use and keep both the hard paper copy data forms, sketches, and computer report forms to catalogue and store assessment data. Ideally, data forms are accompanied with paper maps. These base maps will likely be USGS topographic maps, but if you are using GIS you may create your own base maps that contain topography and other useful data layers you may have available. Be sure to include basic information on the map, such as the beginnings and ends of each stream segments and reaches. Appendix A includes a list of map notation used in the field.

Computer Tools & Outputs
Use the ANR Geomorphic DMS described earlier to store and manage your assessment data. Appendix B shows examples of the data entry forms and describes the data outputs which may be used to complete Phase 2 reports.

Entry of data (into the DMS) provides several benefits:

- ensures that data is maintained over time, as protocols are updated, the DMS will be updated as well;
- builds a statewide database that will result in a more powerful problem solving tool; and
- provide opportunities to receive assistance from other geomorphic assessment professionals in data interpretation.

The Feature Indexing Tool (FIT) is part of the Stream Geomorphic Assessment Tool (SGAT) GIS extension used in Phase 2 assessments to document on-the-ground locations of features such as bank armoring, berms, or channelized segments. Documentation using the FIT will be extremely helpful to the river manager or future assessor attempting to interpret your data. A more in-depth description of the FIT is provided in Appendix P.

Safety
Phase 2 assessments should be conducted in teams. Be safe, do not cross high waters, and do not enter cold water (unless you are suited up with thermals, dry suit, life jacket, etc). Shallow riffle areas are often the safest place to cross a channel. ***Face upstream when crossing a river***. When in doubt, be safe, and do not cross. For both safety and data consistency reasons, it is best to collect Phase 2 data during the late summer months when streams levels are naturally low.

Landowner Permission
Make sure you have landowner permission to conduct assessments on private property. If you are carrying out this analysis under the auspices of your town or other entity, distributing a "generic letter" explaining the purpose of the study is also recommended.

Quick Refer Menus
Parameter menus and related diagrams have been organized on "Quick Refer Menu" pages that can be taken into the field for easy reference when conducting Phase 2 assessments (Appendix A).

Phase 2 Quality Assurance Program

The Phase 2 assessment is primarily field work, and thus requires the establishment of field teams to complete the assessment. Each field team should consist of a minimum of 2 people. There may be several field teams within a watershed. These teams need to be trained in the protocols and field assessments techniques. To make the teams as flexible as possible, there may be different levels of training and time commitment for different members of a team.

Team Structure

The following team structure is recommended for completing Phase 2 assessments:

Field Team Leader: One person should be designated to oversee the entire field assessment and to work with all field teams to ensure consistency in data collection. Groups should seek to hire a person who has more extensive training to fulfill this role. The field team leader must be able to go out with each team to check their data collection practices for consistency. This is especially important early on in the assessment when field teams are just starting. A field team leader may also serve as a "trained field team member" and/or QA Team Leader as described below.

Trained Field Team Member: At least one person on a field team must commit to a complete training in the protocols and field assessment techniques and be willing to commit enough time to complete the assessments on the selected reaches. This person is responsible for the completeness and accuracy of the data collected for the reaches they assess and for communicating any questions or concerns about data collection back to the field team leader. If there is only one field team working on the assessment, this person may be the same person as the field team leader described above.

Support Field Team Member: Other members of the team may have less extensive training and/or ability to commit enough time to do all the reaches selected, but would be able to assist in the assessment at some level. These people benefit from being involved in that they learn more about their watershed and its rivers and support the data collection and field measurements done in the assessment. They do not have to be as responsible for the completeness and accuracy of the data as the more trained team member(s). It is often beneficial to involve people who are landowners in the watershed, active in the watershed government(s), or avid and interested watershed residents, as these people are effective in using the assessment data to undertake watershed conservation.

Establishing the roles of different team members at the start of the field season will insure that teams work efficiently and collect meaningful data. Once teams are established and the roles of each team member determined, the group is ready to start their field season. Each teams should be provided with the materials and data pertinent to the reaches they are to assess, including: Phase 1 data, a topographic map, an orthophotograph, Phase 2 data forms and sketch sheets, a copy of the protocols to take in the field, and landowner information. Teams will also need to have complete sets of equipment with which to conduct the assessments, as listed above under "Materials Needed."

To insure consistent data collection between teams and within teams, some general guidelines need to be followed.

- Teams need to walk the entire reach before conducting their assessment. This is the only way to determine if the reach needs to be segmented or broken into sub-reaches before completing an assessment. If a team is unable to walk the entire reach due to time constraints then the team needs to document on their map and field sheets the portion of reach that was walked and assessed, so that the rest of the reach can be evaluated at a later date. Teams should be aware that it may take more than one day to complete their assessment on a reach. If teams are not able to go back to a reach in consecutive days, they should return during conditions similar to that of their first field visit to the reach, if possible. Have teams mark on the Field Notes form in the comments section any changes in conditions between days.
- Most parameters should be co-evaluated by team members to ensure overall consistency and accuracy in the assessment data; however teams may choose to assign the evaluation of some parameters to specific team members who will be responsible for evaluating that parameter at every site. This is particularly useful with those parameters that require tallies, such as pieces of LWD (large woody debris), grade controls, number of bridges/culverts. **Do not** split up parameters in the RHA (Step 6) and the RGA (Step 7) **or** have one team member complete all the Field Notes (Steps 1-5) and another team member complete the RHA and RGA. These assessments are interrelated and must be conducted by the same person or persons.

Quality Assurance Team: At the start of the field season establish a Quality Assurance (QA) team. This team will be responsible for reviewing the data collected and for doing field checks on segments and reaches that have been assessed by other teams. The QA team should include a QA Team Leader who is well versed in the protocols and has had training in the assessments and conducting QA reviews. Other members of the team should also be familiar with the protocols and assessments, but may have less training and might assist primarily with field measurements and basic data review. Training and QA team assistance can be obtained from the DEC River Management Program (RMP).

Data Collection Review

To help determine the accuracy of field data collected, the QA team should do field checks of several segments and reaches that were assessed by the field teams. The field teams doing the assessments need to mark on their field maps the locations of any segments that were broken out in the reach and where they chose to do their Step 2 channel measurements so that the QA team can determine where to complete QA assessments. Cross-section data and bankfull indicators should also be recorded on the Cross-section Worksheet and then passed on to the QA team. By checking data collected in the field, the QA team can determine if there are problems with the data that need to be corrected and/or if there are areas within the training program that can be improved.

Data Entry Review

Once all Phase 2 data has been entered into the DMS, the standard reports and tables should be generated and reviewed by the QA team. The team can determine if there is information that is missing, inconsistent with the protocols, or needs further evaluation. Data that raises concerns or problems can then be assessed and the method of correcting or completing the information can be established. If data is found in Phase 2 that would change data collected in Phase 1, the QA team needs to identify those parameters for which the data needs to be updated in the Phase 1 database. Completing a QA check list and including the date that data is updated in the database is important for tracking data completion, adjustments, and accuracy.

Data Storage

The QA team should establish a filing system for keeping track of paper copies of the data sheets, photos, and maps for each year's data. The paper copies are very important to keep for future reference. Notes and location data on the maps are important to refer back to if future work is to be done on the reach or segment. Assessment teams should use the Feature Indexing Tool to make digital maps of the different data that is shown on the field maps to aid in further data analysis and/or data presentation. A digital map can be updated each year and is useful for displaying information in a watershed, reach and segment context.

Everyone who attempts to use your Phase 2 data will appreciate the efforts you make to document its quality, including its deficiencies. If you encounter problems with incomplete data for certain parameters, make hard copy and DMS notes that can be found and considered later. It is amazing what just a few months (let alone years) can do to the collective memories of your assessment team.

QA Documentation

After the Phase 2 assessment steps are completed, the QA sheet and data entry form in the database (Appendices A and B) should be completed. The QA sheet is a set of questions that should be completed by those who collected the Phase 2 data. These questions evaluate: which steps were completed and when; what assessment tools and data sources were used; the level of training received by members of your team; and confidence level of the assessors of the data collected at each assessment step. These QA sheets should be reviewed and finalized by the QA team. When data is updated or changed, the same process of data review will need to be completed. The QA sheet can then be updated to indicate the change in data.

QA functions have also been incorporated into the Phase 2 DMS. Data is checked for internal consistency between Phase 2 parameters and between Phase 1 and Phase 2 data where appropriate. Reports from these DMS functions may be invaluable to the QA team for finding transcription errors, catching issues with interpretation, or documenting those reaches which may be outliers to stressor-response expectations.

Starting the Phase 2 Assessment – Defining Segments and Making Sketches

To start the Phase 2 assessment you must first do the following:

1. Create sub-reaches and reach segments where appropriate to define stream units within the Phase 1 reaches which have different reference and existing conditions.
2. Complete field sketches of the segments and reaches for which Phase 2 assessments will be completed.

1. Creating Sub-reaches and Reach Segments

In a Rapid Stream Assessment you are field verifying the reaches delineated and typed in Phase 1. In doing so, if you determine that valley setting and reference stream type conditions change within a reach such that there is more than one reference stream type within the reach, you may decide to subdivide the reach into two or more reaches, which are termed "**sub-reaches.**" In addition, to capture the variation in the observed physical channel and habitat conditions within a given reach, it may be necessary to break the reach into **segments** that correspond with substantial changes in the channel condition. The distinctions between the uses of reach, sub-reach, and segment designations are explained below.

> ***Reach:*** A section of stream having relatively uniform physical attributes, such as confinement, valley slope, sinuosity, dominant bed material, sediment regime and bed form. Reach determinations do not take into account human disturbances, but rather are based on variables related to valley setting, stream morphology, and their inherent fluvial processes. Provisional reference stream types for each reach are ascribed in a Phase 1 Assessment. The reference stream type is confirmed or refined during the Phase 2 assessment. Any change or refinement of the reference stream type should be recorded in the Phase 1 DMS.
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> ***Segment:*** A segment is a relatively homogenous section of stream contained within a reach (illustrated in Figure I.1) that has the same reference stream type but is distinct from other segments in the reach in one or more of the following parameters: degree of floodplain encroachment, presence/absence of grade controls, bankfull channel dimensions (W/D ratio, entrenchment), channel sinuosity and slope, riparian buffer and corridor conditions, abundance of springs/seeps/adjacent wetlands/stormwater inputs, degree of flow regulation and withdrawals, and degree of channel alterations. The stream type ascribed in a Phase 2 Assessment is the existing stream type of the segment, as compared to the reference type ascribed to the entire reach in Phase 1. The existing stream type reflects a stream's morphological form and process attributes as influenced by human or natural disturbance. Where only minor channel adjustments are occurring (especially where little or no vertical adjustment is observed), the existing and reference stream types may be the same or nearly the same. Segments are labeled with capital letters (A, B, C….) suffixed to the reach number and assigned sequentially from downstream to upstream. Where no segments are deemed necessary, the assessment should be conducted for the entire reach.
>
> ***Sub-Reach:*** Upon field observation, you may find that part of a reach has a different reference stream type that was overlooked or was not discernable in the Phase 1 assessment. In this case, make a sub-reach within the original reach to differentiate the part(s) of the reach that has a different reference stream type. Use the checkbox provided next to the Segment ID line in the Field Note header to remind you in the field and during data entry that the data is associated with a sub-reach. Sub-reaches follow the same stream typing and labeling convention as segments (A, B, C… suffixes) but are designated as sub-reaches by entering a reference sub-reach stream type into the spaces provided in the Phase 2 DMS at the bottom of Step 2.14. For example if you deter-

mined during a Phase 2 assessment that reach T5.03S1.02 contained three parts and the downstream-most part was actually a sub-reach because it has a different reference stream type than the other two parts (segments), you would create a sub-reach labeled T5.03S1.02A and two segments labeled T5.03S1.02B and T5.03S1.02C. For the sub-reach, in the field, use the stream type box in Step 2.14 to record the existing stream type and record the reference stream type under the box. Then during data entry record both the existing and reference stream type information into the slots provided in Step 2.14 of the Phase 2 DMS. Do not use the "reference type" check box on the Field Notes form when assessing a segment as this is used solely for indicating that a reach has a different reference stream type than designated during the Phase 1 assessment.

If the two segments of the original reach (segments B and C) also happen to have a different reference stream type than what was selected during the Phase 1 assessment, record the changes on the field form, use the "reference type" checkbox, and finally go back and update the DMS recording a new reference stream type for the segments in Phase 1 Step 7.1 (remembering to change the metadata to reflect the Phase 2 determination). Do not record updated reference stream type information for segments in the Phase 2 sub-reach reference data slots.

Remember that in Phase 1 you only used remote sensing techniques and windshield surveys to delineate reaches and stream types based on changes in the morphological and geologic characteristics of the valley. Now, in Phase 2, you will be able to further fine-tune your assessment of the watershed by segmenting out sections of stream within given reaches based on their different responses to land use impacts and other channel conditions that were not measurable in Phase 1. The following guidance is offered to help in breaking out segments consistently; however these are not hard and fast rules. Use your own experience and knowledge of the watershed to further assist you with determining segments. Keep in mind how you will be using this information, whether it's watershed planning or project assessment, and be sure not too break out so many segments that the data becomes meaningless or too cumbersome. A segment is not meant to be broken out for every small area of change, but rather to identify those areas of a reach that differ substantially from one another in geomorphic and/or habitat conditions. If the reach is similar throughout its entirety you may choose not to break out any segments, and the Phase 2 assessment you conduct will be for the overall reach. **Use the following protocols when segmenting a reach:**

Review of Topographic Maps and Orthophotographs: Once you have decided which reaches you would like to assess, prepare for the field by reviewing the topographic maps and orthophotographs for those reaches. This will familiarize you with the reaches and provide you the opportunity to make some preliminary segment breaks within the reach (Figure S.1). Although a reach has overall similarity in valley setting and reference stream type (as determined in Phase 1) there may be different stream corridor conditions, such as buffer width (Phase 2, Step 3) or sinuosity (Phase 2, Step 2), along the reach that were not considered for delineating separate reaches in the Phase 1 assessment. Where these stream characteristics change, note these locations on the map and orthophoto as possible segment breaks.

Confirm Segment Breaks in the Field: Walk the **entire** length of the reach to confirm your preliminary segment breaks and adjust as necessary. Additional attributes you should look for, which may not have been easily observable on the maps and orthophotos, are:

a. grade controls (Step 1) usually require a segment break, but not always (see Section 1.6 for more information on grade controls and segment breaks);
b. substantial changes in channel dimensions, such as bankfull widths and depths, W/D ratio, and entrenchment and incision ratios (Step 2);
c. persistent changes in dominant substrate size, channel slope, sinuosity, natural entrenchment (i.e., bedrock gorges) and bed form (Step 2); and
d. signs of planform changes, aggradation, and degradation (Step 5).

As you walk the reach, occasionally measure attributes such as bankfull widths and depths to keep track of whether or not these parameters are changing substantially along the reach. Usually changes that substantiate a segment break are easily noticeable and occur for more than one parameter at a time. For example, if you observe the channel has widened from a 40' bankfull width to a 90' bankfull width, most likely the dominant channel substrate has also decreased in size, say from cobble-sized substrates to sands and gravels.

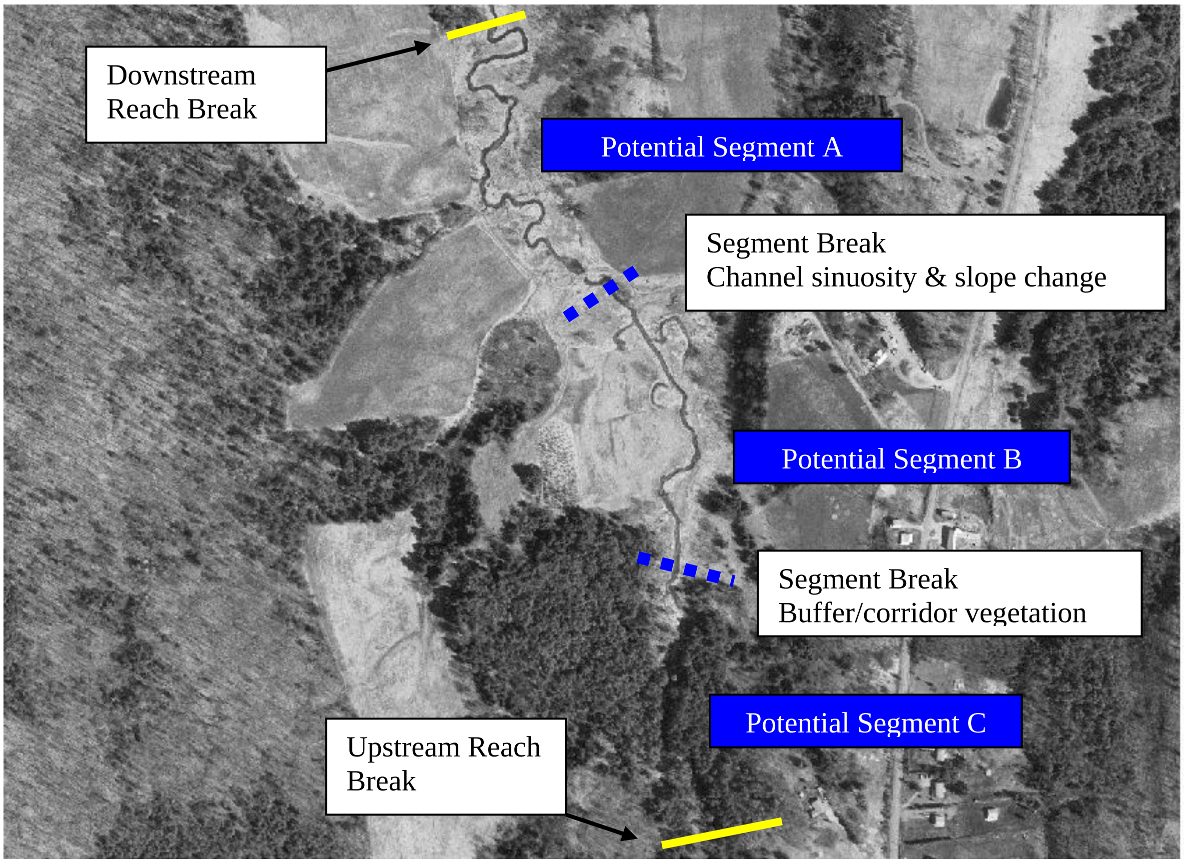


Figure S.1. Preliminary segment breaks in a reach (determined in Phase 1 to have the same valley setting and reference conditions) made using orthophoto analysis to determine changes in reach conditions.

2. Completing Segment Sketches

Making a sketch of your segment (or reach) is an essential part of conducting in stream assessments. Use the Segment/Reach Sketch Form (Appendix A) to draw a planform (bird's eye) view of the stream and surrounding corridor. Using the topographic map(s) to help get oriented, draw a North arrow on the sketch. A complete set of Sketch and Map codes are provided in Appendix A to help you label features on the sketch and topographic maps.

The plan form sketch provides an opportunity to see both the vertical and lateral constraints on the stream system. These constraints may modify channel adjustments (i.e., natural grade control provide vertical stability) or they may substantially increase the stream's erosion hazard potential. Take special note of planform alignments on the sketch (e.g., the stream entering a culvert or bridge at an acute or right angle, or a house located on the outside and downstream end of a meander bend). You may find it helpful to use the topographic map, a copy of the orthophoto, or an outline of the channel traced from the orthophoto to begin your sketch. Make sure to include a scale on your sketch (e.g., 1 inch = 500 ft).

The same sketch codes can be used to note the location of features, developments, and infrastructure on topographic maps and orthophotos. Map coding can be especially useful in examining the location of features within the length of your reach and within the watershed as a whole. For instance, marking grade controls on the topographic map may help you evaluate the distance over which a bed degradation process will migrate upstream or the amount of stream habitat affected by grade controls that are fish migration barriers.

All Phase 2 parameters are evaluated as you walk the entire segment (or reach); however, you will be choosing a representative section within the segment (or reach) to do more detailed measurements of cross-sections, sediment, and streambank and riparian condition and to complete the Rapid Assessment forms.

The Segment/Reach Sketch Form includes a work area on the lower right corner to make tallies of large woody debris, debris jams, stormwater inputs, and channel constrictions (i.e. bridges and culverts). The form also has columns on the reverse side for recording **lengths** and **heights** of eroding banks and lengths of bank revetments, floodplain developments and beaver influenced segments. Keep tally of these various parameters on the Sketch Form and field maps as you walk the reach to help you recall details about these parameters when you complete the Field Notes form at the representative section you have selected.

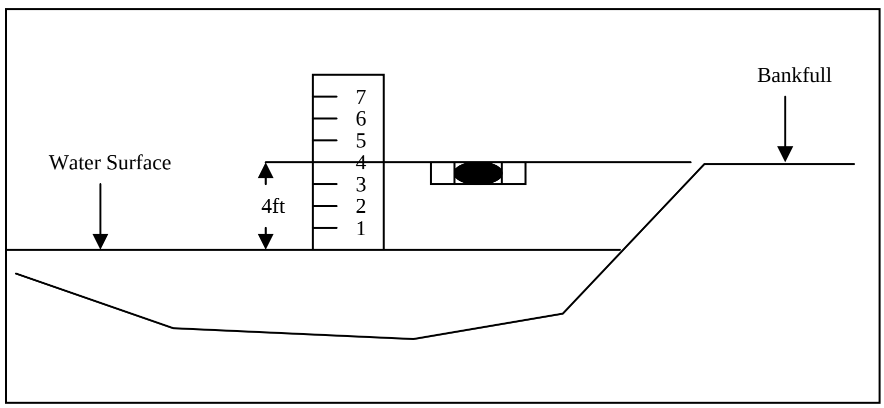


Figure S.2 Measuring height of bankfull above current water surface using a tape, line level and survey rod.

Bankfull Indicators: At each bankfull indicator you identify during your initial walk along the segment (or reach), record the height of the bankfull feature above the current water surface on the Segment/Reach Sketch Form. Calculate the height using a measuring rod against a tape stretched level out from the bankfull indicator across the channel (see Figure S.2). Once you have completed this exercise at each indicator, make a decision as to which subset of indicators best represent the bankfull stage. Bankfull features should be approximately the same height above water surface (± 0.5 ft.) throughout the segment (or reach). If the bankfull features are not the same height above water surface throughout, you may be looking at different features, some of which may be recent flood elevations or past bankfull elevations which the channel has since abandoned. Place the selected bankfull height above current water surface in the box on the Segment/Reach Sketch Form. This value can be used to determine and verify bankfull stage at your cross-sections.

Why Bankfull? Consistent measurement of channel dimensions that are comparable between sites and over time requires a method for consistently delineating stream channel limits. Because stream flow levels may change, the stream cannot be defined as the wetted area at the time of assessment. If this method were used, the size of the stream would change from day to day. Instead, the size of the stream is based upon the channel shape. The channel limits can be defined by the **bankfull stage**: or the point at which the flow just begins to enter the active floodplain (Leopold, 1994). Use of the bankfull stage as a benchmark for comparison between sites is beneficial because it has hydrologic and morphologic significance and it is identifiable in the field.

It can be difficult to determine the correct elevation for the bankfull stage, especially in streams that are in adjustment or that have recently flooded. Look for physical features, called bankfull indicators, which include tops of bars, the base of woody vegetation on stable banks (with the exception of red-osier dogwood and willow species), and breaks in bank slopes to determine the elevation of the bankfull flow. In disturbed channels the tops of bars may not always be the best indicators. Indicators may be found on either bank and should be at approximately the same level above the water surface. Do not use areas of the bank that have obstructions that can cause high flows to backwater across the entire channel (such as debris jams or bridge abutments). Areas with undercut banks are poor choices for bankfull determination since bank slumping will give a false reading of bankfull elevation. Actively eroding banks are also unreliable sites for measuring bankfull, as are areas where the channel has split flow around permanently vegetated, established islands. Confirm that the indicators you are using are consistent throughout the segment, or reach, and are not just an anomaly at the site you are evaluating. For more detailed information on identifying bankfull indicators, see Appendix K.

Taking Pictures*:* Use the Standard Photo Log form (Appendix A) to document the pictures you have taken in the field. The Photo Log is designed to allow you to record on one sheet photos taken at several segments. For every photo you take, record the site number, frame number, photo location and a brief description of what is in the picture (example: Sandy sitting by eroded right bank with shovel in left hand) to help you match up the photos with the photo log descriptions after you download them or get them back from being developed. When you remove your film from the camera, be sure to label it with the appropriate roll number with a permanent marker. Then, write this number on the envelope in which you submit the film for processing so that when you receive the pictures back you will know which roll it is.

For each segment assessed take at least 4 photos; **upstream view**, **downstream view**, **right bank** and **left bank**, in order to fully represent the conditions of the segment. Include some measurement of scale in your photos; for example, have a person stand next to the banks when taking the left and right bank photos. A measuring tape or depth rod can also be used to achieve scale in photographs. Take the upstream and downstream picture while you are measuring bankfull elevation and have the measuring tape stretched across the channel. Stand upstream of the tape to take the downstream picture, and vice a versa, so the tape will show where you measured the bankfull elevation. Also take pictures of any distinct features, especially those noted on the sketch plan (i.e. animal ford, headcut, grade controls, culverts, large debris jams, etc…). It is helpful for future reference to indicate on your field map where you took photos by writing the photo number on the map at the appropriate location. After you have the photos developed (or downloaded) you should label the photos with the segment number, roll and photo number (if applicable), date(s) of survey, photo view or feature, and brief photo description.

Using a GPS: You may choose to use a handheld GPS (Global Positioning System) unit to document feature locations that can later be imported into GIS software as a data layer. Depending on how you plan to use the data, you may or may not need the greater level of accuracy that GPS can provide. Using a GPS unit for the Phase 2 assessment should be considered when project goals demand a high level of accuracy for location data. GPS data can be used in tandem with the Reach Indexing Tool (RIT) for creating and storing location data as GIS point and line themes, as well as updating the Phase 1 DMS which accepts RIT downloads for calculating the extent and impact of certain Phase 1 parameters (Appendix P). See http://www.dnr.state.wi.us/maps/gis/documents/gps_tools.pdf for information on how to use GPS.

Field Form: Rapid Stream Assessment Field Notes

A rapid stream assessment should begin with a walk through the entire reach in order to familiarize yourself with the stream channel and corridor (See Introduction: Starting the Phase 2 Assessment). Many parameters on the Field Notes form require measuring or estimating stream features along the entire segment (or reach). If you are unsure how to evaluate a parameter or unable to measure a parameter due to unsafe conditions, choose **"unknown"** or **"not evaluated,"** respectively, from the parameter menus (where available) and record this on the Field Notes form.

Step 1: Valley and River Corridor

Step 1 parameters evaluate the natural features and human structures that define the extent to which a stream can move laterally and vertically within its valley and floodplain. Valley walls and geologic features that naturally confine a stream dictate the type of hydraulic and sediment transport processes that occur in the channel. Human structures that impose limits on the stream's ability to utilize its floodplain or adjust its width, depth, and slope may lead to channel adjustment.

1.1 SEGMENTATION

Background

The Phase 2 Protocol Introduction contains a lengthy discussion on how to segment a geomorphic reach. If, after walking and sketching the reach, you have decided the reach should be segmented, recording the basis of this decision may be important during future applications of the data.

Evaluation

Use the menu below and circle each two-letter abbreviation of the one or more reasons for segmenting the reach. Each of the reasons will be further documented in this and other sections of the Phase 2 assessment, but it is here that you are indicating that the feature was the pre-dominant reason(s) for segmentation.

If a segment is not able to be assessed, there is a check box in Step 0 to indicate "not assessed" and a menu to indicate the reason why the segment / reach could not be assessed. **The assessor should still look at steps 1, 3, 4, and 5 for segments that may not be able to be assessed in their entirety.** Portions of these steps may be able to be completed from limited field access. For parameters that indicated as FIT, the assessor should review the segment from remote sensing data (orthos/topos) to determine if there are any parameters in these steps that could be captured remotely if the segment can not be accessed along the river.

Menu (circle all that apply)

GC	**Grade Controls**	The presence of any single or multiple channel spanning grade controls where the channel is otherwise dominated by alluvium.
CD	**Channel Dimensions**	Substantial change in channel dimensions, such as bankfull width and depth, W/D ratio, and entrenchment and incision ratios.
SS	**Substrate Size**	Persistent changes in dominant substrate size category (e.g., cobble to gravel).
PS	**Planform and Slope**	Substantial change in channel planform or slope, either by natural or human alteration.

DF	**Depositional Features**	Persistent change in bed forms (e.g. riffle-pool to plan bed) and/or bars, flood chutes, steep riffles, etc.
CE	**Corridor Encroachment**	Substantial change in human investments within and along the Phase 1 river corridor which would conflict with the channel adjustment processes.
BB	**Banks and Buffers**	Substantial change in the stability and erosion of the stream banks and the presence/absence of a woody vegetated buffer.
FS	**Flow Status**	Substantial change in the stream flows either for natural reasons (springs, tributary confluence, subsurface flow, etc.) or due to human alteration (e.g., stormwater inputs).
PA	**Property Access**	Property access was limited to a portion of the reach and therefore the reach was segmented where access permission was not granted.
SR	**Sub-reach**	Segment was created to capture a sub-reach
VW	**Valley width**	Valley width changed from overall condition of the reach
OT	**Other Reason**	Describe the reason for segmenting.
None	**None**	The reach is not being segmented.

Segment Not Assessed Menu

W	**Wetland**	**Segment was dominated by wetland features and river characteristics were not able to be assessed**
I	**Impounded**	**Segment was dominated by influence from impoundment**
N	**No Property Access**	**Property Access was not granted**
G	**Bed rock gorge**	**Segment was dominated by bedrock gorge and**
B	**Beaver Dams**	**Multiple beaver dams have caused the segment to be impounded and river characteristics were not able to be assessed**
O	**Other**	**Describe reason for not assessing the segment in the comments**

1.2 ALLUVIAL FANS (FIT)

Background

An alluvial fan is a thick deposit of sediments located at an area where the slope of the stream becomes gentler and stream flow velocity decreases, thereby reducing the stream's ability to carry sediment. The sediment load drops out of the water and is deposited across the channel bed, and sometimes the adjacent floodplain, in the shape of a fan (Figure 1.2). Alluvial fans may be very unstable, and multiple channels are commonly found within them. Alluvial fans can be large, such as those that occur at the base of mountains, or small, occurring in multiple locations throughout a watershed

Figure 1.1 A small alluvial fan deposited from a steep tributary due to a change in slope.

where dramatic changes in channel slope occur. Bed type often changes from a plane bed to a riffle-pool or braided bed feature as the dominant stream process abruptly changes from sediment transport to sediment deposition. The sediments in an alluvial fan are typically loose unconsolidated sediments transported by the stream, or by a debris or mud flow.

Evaluation
When an alluvial fan is located at or near a tributary confluence, the presence of an alluvial fan is noted for the reach in the tributary stream that created the fan, not for the receiving stream reach. Use a topographic map of your reach and field observations of: sediment deposits in the channel and floodplain; the presence of channel braiding; and, the presence of significantly steeper reaches upstream to evaluate whether the assessment reach is on an alluvial fan.

Menu

Yes	Maps and/or field visit suggest an alluvial fan exists in the segment and/or reach.
No	Maps and/or field visit suggest no alluvial fan exists in the segment and/or reach.
Unknown	Unknown whether the segment is located on an alluvial fan

Use the Feature Indexing Tool (FIT) in SGAT to document the location of alluvial fans. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where an alluvial fan is noted. Data must be manually entered into the DMS for reaches where either “No” or “Unknown” is selected.

1.3 RIVER CORRIDOR ENCROACHMENTS (FIT)

Background
Structures that encroach into the river corridor are not only threatened by the river, but the armoring and berming of the river banks often deemed necessary to protect these investments may pose a threat to downstream areas, by limiting slope adjustments and increasing flood velocities and stream power of the confined stream. Floodplain & belt width encroachments typically concentrate flow in the channel during floods, increasing the stress of flood flows on the channel bed and banks. They can also effectively turn a response or depositional stream into a transfer stream, which may lead to an increase in sediment loading and aggradation, as well as bank erosion, in downstream reaches.

For the Phase 2 assessment use the same corridor created in SGAT for Phase 1 assessment. Basically, the corridor delineation seeks to provide for an unconstrained lateral dimension (measured perpendicular to the meander centerline) equal to 8 times the channel width. Ideally, the belt width can be provided by 4 channel widths either side of the meander centerline. Oftentimes, however, the valley topography or other constraints prohibit channel plan form adjustment such that the full 8 channel widths can only be achieved by providing more width on one side of the stream than the other.

Figure 1.2 Berms built with river-dredged material.

Evaluation
Map the individual locations and heights of **berms, roads, railroads, improved paths, and development** running parallel or nearly parallel to the stream, within the river corridor. When these encroachments are

indexed they will be for one side and both sides (at the same time) of the river corridor. Indicate the absence of an encroachment type with a zero in the length columns. Figure 1.4 shows an example of encroachments within the river corridor.

If you have encroachments on both sides record the height of the lower encroachment in the FIT. Measure the height from the thalweg.

Berms – Mounds of sediment built parallel to the stream banks designed to keep flood flows from entering the adjacent floodplain (Figure 1.3).

***Roads* –** Transportation infrastructure includes private, town, and state roads, made of dirt, gravel, or pavement.

Railroads – Used or unused railroad beds and tracks.

Improved paths – Maintained paths, typically surfaced with gravel, macadam, or pavement.

Development – Buildings, parking lots, and fill.

Mark the locations and record the height of river corridor encroachments on your field map as you walk the segment (or reach). The GIS indexing of encroachments (FIT Tool, see Appendix P) is a part of the Phase 1 assessment protocol. Phase 2 encroachment data, if mapped properly in the field, can facilitate additions or revisions to data indexed to the surface water during Phase 1. If the user is familiar with GPS units, it is beneficial to spatially locate these features. Spatial information can be used for indexing and helping to insure features are noted for future projects. See http://www.dnr.state.wi.us/maps/gis/documents/gps_tools.pdf for information on how to use GPS.

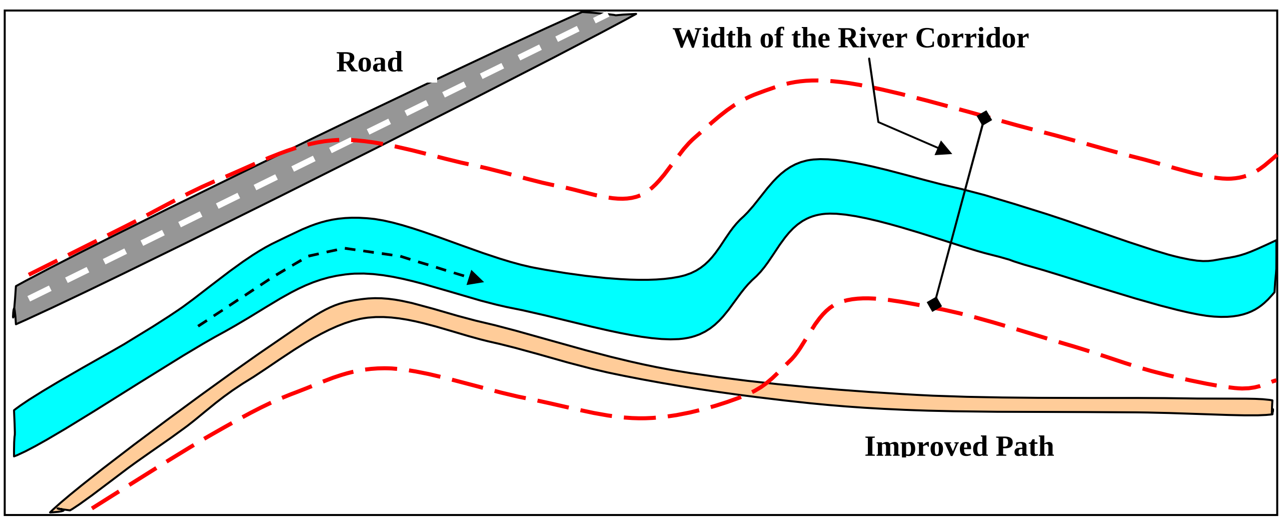


Figure 1.3 Example of road and improved path in the river belt width corridor at a distance of 6 X the reference channel width from the meander center line. In this example, you would record the length of the road within the left side of the corridor and the length of the improved path along the right side of the corridor.

Use the Feature Indexing Tool (FIT) in SGAT to document the location and heights of berms, improved paths, railroads, roads and development on either one side or both sides of the stream. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where an area is noted having a berm of improved path, railroads, roads and development for one side or both sides.

1.4 ADJACENT TERRACE OR HILLSIDE

Background

Terraces are depositional features that when newly formed are flat with abrupt sloped faces caused by erosional processes. They may be old lake beds formed during the last glacial period or floodplains more recently abandoned. With time they become weathered and more rounded features but are still distinct from the existing channel and active floodplain (at lower elevations) and from the hill and mountain sides (at higher elevations).

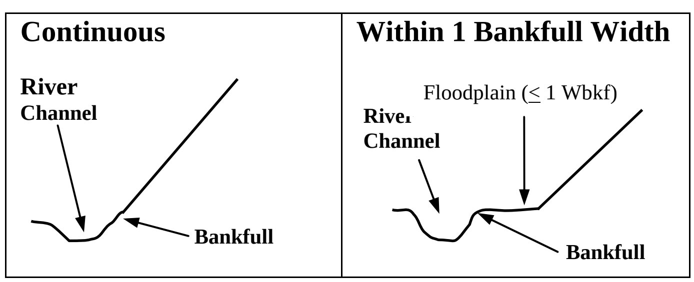
Adjacent terraces and hillsides, especially continuous slopes and those within 1 bankfull width, are potential sources of sediment to the stream system. Knowing what type of sediment makes up the lower part of the slope allows you to evaluate the erodibility of the soils and the potential for sediment contribution to the stream.

Evaluation

This parameter evaluates the gradient and texture of the terrace or hillside **most** adjacent to the channel. This is not an evaluation of the gradient and texture of the stream bank, which is a part of the active channel measured in Step 3. To identify the adjacent terrace or hillside, visually locate the nearest sloped feature above the channel. This slope may be continuous with the stream bank, or may be several hundred feet away across a wide floodplain. Circle the choice on the data sheet that describes the gradient of the most adjacent terrace or hillside, for both left and right sides of the channel (see menu below). Also make a check next to the appropriate lines on the data sheet if the adjacent side slope is continuous with the bank or within a distance of one bankfull width to the channel, as estimated from top of the bank (see lower tier of menu below). Circle whether either of these relationships occurs always (A), sometimes (S), or never (N) along the segment (or reach).

Menu:

Classification	Percent Slope
Flat	0-3%
Hilly	4-8%
Steep	9-15%
Very Steep	16-25%
Extremely Steep	>25%



An example of a continuous adjacent hillside may be found in narrow, V-shaped valleys where the hillside may join the stream bank with little noticeable change in slope gradient between the two features. It is important to indicate when an adjacent terrace or hillside is within a distance of 1 bankfull width to the channel, as the river has the potential to migrate across the valley floor and rapidly run up against the bottom of the terrace or hillside, which could cause instability of the side slope.

While you are looking at the slope of adjacent terrace or hillside, evaluate the **dominant** texture of exposed materials in the **lower** half of the slope for both the right bank and left bank.

Menu

Bedrock	Boulder	Cobble	Gravel	Sand
Silt /Clay	Mixed Texture		Other	Not Evaluated (NE)

1.5 CONFINEMENT

Background

This parameter is a measurement of the **actual** confinement, compared to the natural confinement measured in Phase 1. The purpose of evaluating confinement is to understand whether flood flows are concentrated and are thereby more powerful and effective at transporting sediment, as well as to what degree the valley walls limit the lateral extent of stream meander bends and channel slope adjustment. In valleys containing active railroads, highways, integral infrastructure, or any publicly owned class 3 road, **permanent** high embankments are designed and maintained to elevate the road above the flood prone elevation (Step 2.4). Due to their size and durability, these embankments serve as artificial valley walls, and should be considered as such when measuring Phase 2 valley width. In urban settings, it may be difficult to determine if all encroachments, such as houses, are a reason for changing the valley width. Remember, this parameters is trying to capture features that will change both the flood flows, and possible lateral migration of the channel. If the structures are not built up off the floodplain, and can be flooded; they should not be counted as "valley walls". The influence of these structures for lateral constraint will be captured in Step 1.3.

Evaluation

Use a tape measure or range finder to measure the width of the valley and record this on the Field Notes form. If it is impractical to measure the valley width, use a topographic map to help you make a visual estimate. Record this value for valley width with the letters "est" after it. If the stream is in good or reference condition and not over widened than you should use the bankfull width you measure in step 2 for the confinement calculation. Otherwise, use the Phase 1 reference channel width to divide this value into valley width to determine the confinement ratio. Circle the appropriate choice of confinement on the Field Notes form. A check box has been provided to indicate when the measured valley width is narrower than the natural valley width due to a "human caused change in valley width," for instance, when road or railroad embankments are located in the valley. If the stream is in reference or good condition make sure to update the Phase 1 reference channel and valley width.

A helpful way to evaluate this parameter is to visualize the number of reference channels or bankfull widths that could fit side-by-side across the valley bottom. For example, in a narrow confining valley you would only be able to put 1 to 1.5 channels (at the channel's current bankfull width) side by side within the valley, whereas in a very broad valley you could put 10 or more channels side by side across the valley floor. You should also indicate whether the reach you are assessing is flowing in a gorge, defined as a narrowly or semi-confined valley with continuous rock walls at least ten feet high on both sides of the stream.

Menu

Confinement	Valley Width / Channel Width Ratio
Narrowly Confined	≥1 and < 2
Semi Confined	≥2 and <4
Narrow	≥4 and <6
Broad	≥6 and <10
Very Broad	≥10, may have abandoned terraces on one or both sides

1.6 GRADE CONTROLS (FIT)

Figure 1.4: Example of a waterfall grade control

Background

Grade controls are critically important features in maintaining bed elevation and overall channel stability, and in determining upstream migration of many aquatic organisms, primarily fish. By definition, grade controls must extend across the entire bankfull channel from bank to bank in order to function as true controls. Natural and man-made features which may serve as grade controls include:

Waterfall - Bedrock that extends across the channel and forms a vertical, or near vertical, drop in the channel bed
Ledge - Bedrock that extends across the channel and forms no noticeable drop in the channel bed, or only a gradual drop in the channel bed
Dam - High cross-channel structures
Weir - At-grade or low cross-channel structures

With the exception of adult trout and salmon, most fish cannot swim (jump) over vertical obstructions greater than .5 foot above the water's surface, if these obstructions span the width of the channel. Most of the trout species (and other salmonids) found in Vermont can clear vertical obstructions up to 1 foot high as adults, depending on local conditions. It is amazing what obstacles most fish can pass. Large piles of woody debris, boulders, and similar materials blocking the channel rarely obstruct fish movement and migration. Many fish can even swim up bedrock falls that are angled back or have abundant "steps" (i.e. Steelhead migrating up the Willoughby Falls). Truly vertical waterfalls, however, are often natural migration barriers, and dams are almost always upstream fish migration barriers (Figure 1.6), unless they are fitted with functioning fish passage structures (i.e. fish ladders).

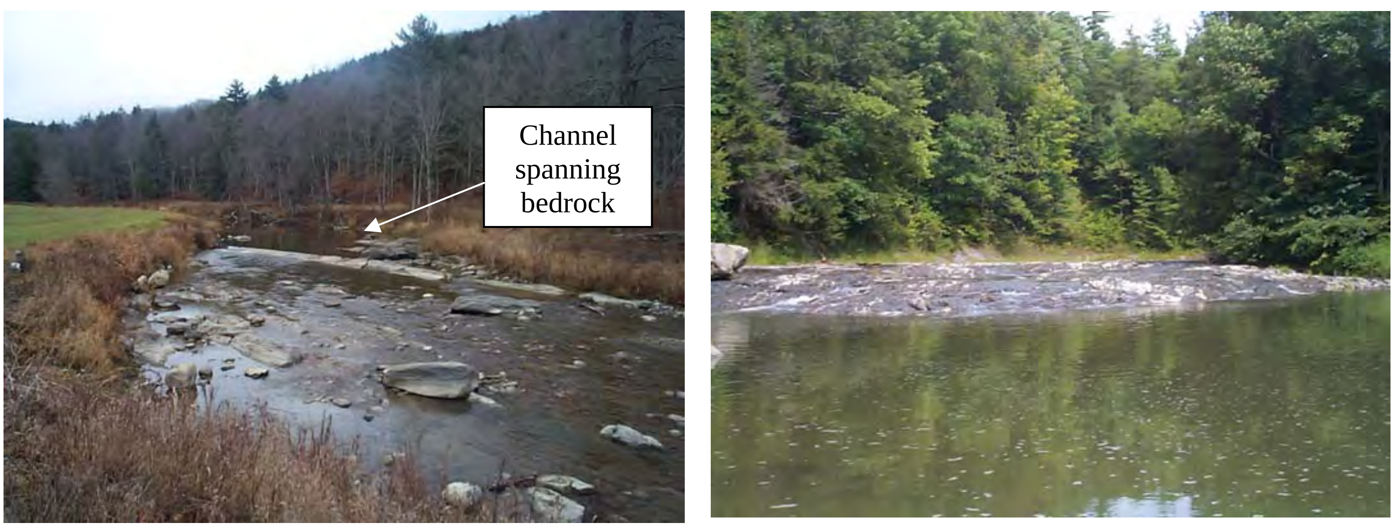


Figure 1.5 Examples of bedrock ledge grade controls spanning channel.

Evaluation
In Phase 1, known grade controls were identified within each reach. In Phase 2, these are verified on the ground and additional grade controls that were not detected in the Phase 1 assessment are identified. As you walk the segment (or reach) record each control present by **type**.

Remember that grade controls can determine segment breaks. However, if you observe several grade controls within a short length of channel (< 12 times the bankfull channel width between controls), do not break out multiple small segments, but rather lump all the grade controls together into one segment.

Note the location of all grade controls on the field map with the appropriate symbol. If you have multiple grade controls of different types in one segment you may choose to number the controls on the map and write the numbers on the corresponding data lines on the Field Notes form. By definition, grade controls must extend across the entire bankfull channel from bank to bank in order to function as true controls. For example, if you observe bedrock that does not completely cross the channel, then it is not a grade control (see Figure 1.5). Similarly, do not assume a dam or weir is a true grade control until you have confirmed that is spans the channel and appears sound. Many old dams have breached over time, and may have sections where the dam has fallen away, exposing the original channel bed. If this is the case, it is likely that the dam no longer serves as a grade control.

If the evaluation of fish movement and migration is a major focus of your assessment work, you should seek professional assistance in evaluating fish movement and migration issues around grade controls before undertaking any river corridor management activities related to fish migration. Contact the Vermont Department of Fish and Wildlife fisheries biologists for assistance.

Total Height: Use a depth rod to measure the vertical height of the grade control from the invert of the control down to the channel bed (Figure 1.6). Record to the nearest tenth of a foot (0.0 ft.). Do not attempt this measurement if conditions are unsafe. Also, be careful around dams that are used for power generation, as water levels downstream of the dam can change rapidly when the dams are generating. If measurements are not possible, estimate the total control height and record with an "est" for "estimate."

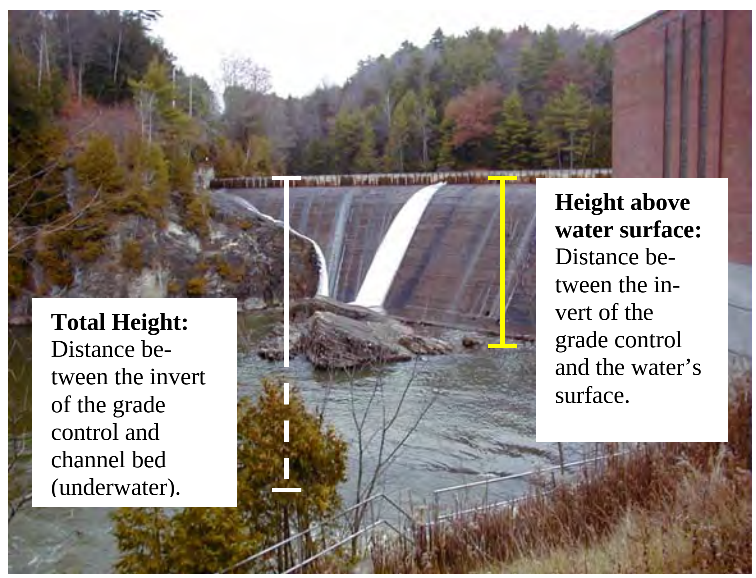


Figure 1.6 Most dams, unless fitted with functioning fish passage structures, are barriers to upstream (and sometimes downstream) fish migration.

Height Above Water Surface: Use a depth rod to measure the vertical height of the grade control from the invert of the control down to the water's surface at the time of survey. Record to the nearest tenth of a foot (0.0 ft.).

Photos: Grade controls are important features that are worth documenting with photographs. Make sure to put a person or a depth rod against the vertical face of the grade control to achieve scale in your photos.

GPS: You may choose to use a handheld GPS (Global Positioning System) unit to document grade control locations. This point data can later be imported into GIS software and indexed as a data layer (using the FIT).

Using a GPS unit is not required for the assessment and should only be considered by those that are proficient with using a GPS unit, as data collection and management can be time consuming.
See http://www.dnr.state.wi.us/maps/gis/documents/gps_tools.pdf for information on how to use GPS.

Use the Feature Indexing Tool (FIT) in SGAT to document the location of grade controls. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where a grade control(s) is noted.

Step 2: Stream Channel

Streams in different physical settings have predictable flow and sediment discharge patterns determined by the climatic, geographic, and geologic characteristics of the valley in which they occur. Different physical settings result in different fluvial processes and different stream types, which are identified by their channel form and sediment transport characteristics. Step 2 involves measuring the dimensions of the channel and its sediments in order to identify the stream type and to determine whether the existing stream type of the present channel is consistent with its setting. For example, a relatively straight channel with little or no access to a floodplain during annual high water is a stream type found in nature, but not typically in an unconfined valley where gravel is the dominant sediment size in the stream bed and banks. This landscape setting would commonly support a meandering, low gradient channel with floodplain access. Finding such an inconsistency at your site may explain observed channel adjustments and reach condition.

Where to Conduct Step 2 Assessments: Measurements of channel dimensions, such as bankfull width, maximum depth and flood prone width (Figure 2.1), are conducted at the channel "cross-over" locations (Figure 2.2). In a meandering stream, a cross-over is the area where the main current or flow in the channel crosses over from one side of the channel to the other. Riffles are usually located at cross-over locations. In steep gradient channels that run relatively straight, the main flow of the channel does not usually move from side to side across the channel, but rather cascades over cobble and boulder steps or runs straight over a uniform channel bottom. In these stream types, channel dimensions should be measured at these cascades, steps, or uniform runs. In a very low gradient stream where distinct riffles may not form, you should still perform channel measurements at cross-over locations, which may resemble shallow runs. **Do not take channel measurements at pools or you will over-estimate the channel width and maximum depth. Be sure to mark on your sketch where you take cross section measurements.**

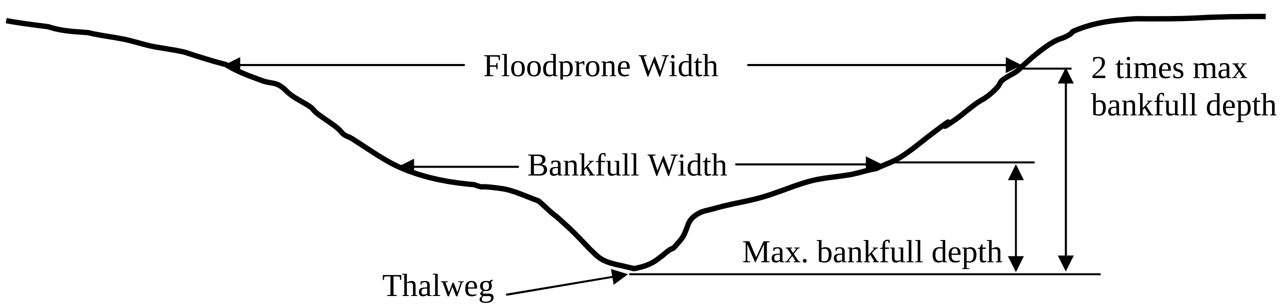


Figure 2.1 Channel dimensions - cross-section view

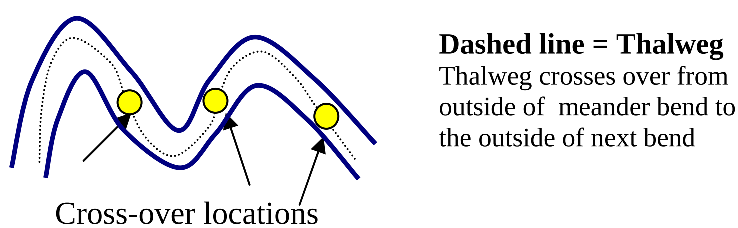


Figure 2.2 Cross-over locations - plan view

Recording Step 2 Data: A separate "Cross-section Worksheet" is provided in Appendix A to record distance and depth measurements for up to three cross-sections along a stream segment. If you complete several cross-sections, do **not** record an average of channel dimensions at these cross-sections on the Field Notes form, but rather the set of values from the cross-section that is most typical of the segment (or reach). You are trying to capture the channel dimensions most prevalent throughout the segment (or reach). Distances and depths recorded at cross-sections may be used to calculate some of the dimension and hydraulic information described in the Phase 3 Handbook. The Worksheet also provides an area for drawing and labeling a typical cross-section and for calculating stream bed particle size percentages at different bed features (Step 2.12). The information from this worksheet will then be transferred to an Excel workbook that is uploaded to the DMS for each reach. The Excel workbook provides a worksheet for entering several cross-sections for a segment. This is a good way of insuring that you have collected the needed information and confirms what you had calculated for channel information.

Evaluation
It is important when doing a cross section to collect enough data to adequately characterize the relationship between the river, its floodplain and the valley. Make sure the cross section goes from one valley wall to the other and captures all important features in between such as abandoned floodplains and historic glacial terraces.

Use the FIT to index the location of cross sections. If you have recorded multiple cross sections within a segment note the number starting downstream and moving up (most downstream would be 1, then 2, etc). Note if the cross section is representative or not.

It is STRONGLY RECOMMENDED that you complete more than one cross section per segment.

2.1 BANKFULL WIDTH

Background
The bankfull width is a measure of how wide the stream is when it is carrying the channel-forming flows. These are the flows that occur on a regular (annual or semi-annual) basis and maintain the channel shape. Bankfull width is a function of flood frequency, sediment regime, and the bed and bank materials of the channel (Rosgen, 1996). Changes in any of these factors may result in a change in width, which in turn changes the hydraulics of the channel and may lead directly to vertical channel adjustments (aggradation or degradation).

Evaluation
To measure bankfull width, stretch a measuring tape taut across the channel, perpendicular to the bankfull flow direction, from the point of bankfull elevation on the left bank across the stream to the bankfull elevation on the right bank (Figure 2.3). Pin the tape at these two points at the bankfull elevation. View the stretched tape from downstream to be sure that it is level. Also check the levelness of your tape with a hand level if you have one, or use your measuring rod along the tape to make sure it is running equal distant from the water surface. Record the width to the nearest foot. Remember that this measurement should be taken over a riffle or similar feature, such as a step, cascade, or run in steep channels. See Appendix M for more information on identifying bed features. It is very important to also capture the adjacent terraces on either side of the channel (Figure 2.3). It is valuable to capture the top of the break in slope and at least one point out beyond that point to help with determining if that feature remains at the same elevation for some distance or changes within a given distance. Be sure to leave space on your cross-section sheet to record these measurements.

Comparing Existing and Reference Bankfull Widths

As part of the Phase 1 Assessment, the reference channel width for unconfined, gentle gradient (C type) streams were calculated by formula using the Vermont Hydraulic Geometry Curves (VTDEC, 2006 – Appendix J). Once you have measured the existing bankfull width, compare it to the bankfull width calculated in the Phase 1 assessment to see if they are similar.

The bankfull widths in Phase 1 are an approximation of the **reference** bankfull width and may not represent what is in the field. If your bankfull width in Phase 2 is significantly different (±10%) from the Phase 1 data, but you are confident with the bankfull indicators you identified in the field, note on the Field Notes form (under Comments) what you used for bankfull indicators and move on. The bankfull channel widths predicted using the Vermont Hydraulic Geometry Curves in Phase 1 will differ significantly from bankfull widths measured in the field for: 1) degraded channels, 2) very sinuous "meadow" channels (E stream type), and 3) some of the small steep channels (A and B stream types).

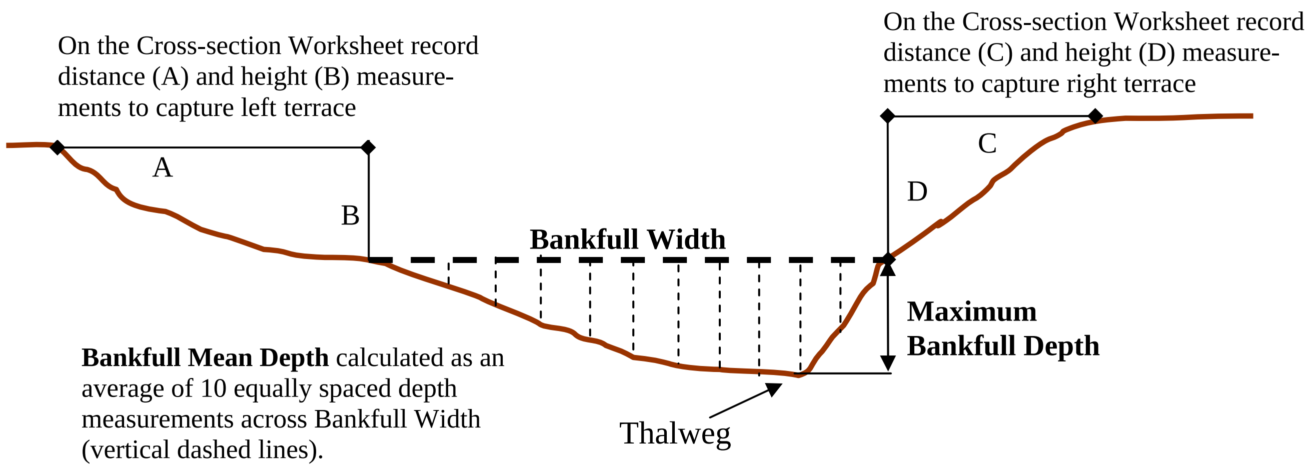


Figure 2.3 Diagram of bankfull width, maximum depth, mean depth and terrace measurements

2.2 BANKFULL MAXIMUM DEPTH

Background

Bankfull maximum depth is a measure of the deepest part of the channel, or thalweg (Figure 2.1 and 2.3). In riffle/pool streams the thalweg typically shifts from the outside of a meander bend to the outside of the next meander bend, crossing over the channel in the middle of the riffle. In a riffle the thalweg may be very subtle or non-existent.

During low-flow periods, such as the late summer and mid-winter periods, many stream-dwelling animals move to the deepest part of a channel, as this area continues to hold water as flows decrease. In channels that have a well-defined, deep thalweg, aquatic biota have a better chance of surviving the low-flow periods in comparison with widened or aggraded streams that are characterized by a shallow bed that rapidly decreases in water depth during low-flow periods.

Evaluation

While the tape is stretched across the riffle section at the bankfull elevation measure the bankfull maximum depth with a depth rod, which is the distance between the tape and the stream bed at the thalweg. Record the measurement to the nearest tenth of a foot. Make sure you are not measuring the water depth.

2.3 BANKFULL MEAN DEPTH

Background

The mean bankfull depth of a channel varies between bed features such as pools and riffles. For this reason, fluvial geomorphologists calculate the mean depth of riffles (depositional zones) to analyze the hydraulics of "transport limited" areas within the stream profile and to compare these characteristics between streams. The forces necessary to perform the work of moving sediment is largely a function of bankfull depth, channel slope, and channel roughness. Changes in the mean bankfull depth of the channel may lead directly to an increase in deposition or scour of sediment and the adjustments associated with channel evolution.

Evaluation

While the tape is still stretched across the channel at bankfull elevation use a depth rod to measure 10 bankfull depths at evenly spaced intervals across the channel (Figure 2.3). The bankfull depth is the distance between the tape and the stream bed. Average the ten measurements to determine a mean bankfull depth. The spacing interval used to measure depths across the channel is determined by dividing the bankfull width by 11. For instance, if the bankfull width is 50 feet, take a depth measurement approximately every 4.5 feet across the channel. At each interval record the distance across the channel (from the left bankfull pin) and the corresponding bankfull depth on the Cross-section Worksheet.

In addition to getting the depths at the given intervals, it will be important to capture the depths at the left and right edge of water.

Important: In addition to the bankfull distances and depths, record the distance and height from the bankfull pins to the top of the first break in slope on nearby terraces or hillside on either side of the active channel and river corridor (see heights B and D and distances A and C in Figure 2.3). Also include at least one other point beyond the top of the break to help capture if the feature ends at that point in the same elevation or changes slope beyond that point. Additional details on the calculation of mean bankfull depth are in the Phase 3 Handbook Step 4.4.

2.4 FLOODPRONE WIDTH

Background

The floodprone width is measured at an elevation that corresponds to twice the maximum depth of the bankfull channel and is the width of the river at flood flows (greater in magnitude than the annual flood), generally including the active floodplain and low terrace (Rosgen, 1996). The floodprone width is used to generate an entrenchment ratio (Step 2.7), which helps to describe the vertical containment of the river.

Evaluation

While you have the rod and tape set up for measuring the bankfull dimensions, also measure the floodprone width. The floodprone width is measured at an elevation that is 2 times the bankfull maximum depth (Figure 2.1). With the depth rod placed in the thalweg, move the measuring tape up the rod to the elevation of 2 times the bankfull maximum depth. For example, if the bankfull maximum depth is 3 ft., you would move the tape up to 6 ft. on the depth rod to reach the floodprone elevation. Then, from the floodprone elevation, stretch the measuring tape out level across the channel and adjacent floodplain until you intersect the next adjacent terrace or hillside at the floodprone elevation on either side of the channel. This total distance across the channel and floodplain area on both sides of the channel, measured at the floodprone elevation, is the floodprone width.

If the floodprone area is so wide that measuring it would take you far across the valley more than 500 feet, estimate the distance by eye or with a range finder, as this distance becomes impractical to measure with a measuring tape. Furthermore, the greater the flood-prone width is in relation to the bankfull width the less precise the flood-prone width measurement needs to be to evaluate entrenchment (Step 2.8).

Make sure to note the floodprone elevation in the cross section workbook.

2.5 RECENTLY ABANDONED FLOODPLAIN (RAF)

Background

The height of the recently (approximately past 200 years) abandoned floodplain, relative to the elevation of the bankfull maximum depth, is an important parameter to measure on streams that have eroded downward but may still have access to this floodplain during larger flood events. When looking for an RAF, key in on floodplain features that the stream had access to within the past 200 years, but due to an incision process the stream has lost access to the feature at the bankfull flow. The stream may still have access to the features at higher flows.

If you have a berm adjacent to the stream you will NOT use the berm height as the RAF elevation. Use the elevation of the floodplain on the other side of the berm. The berm height is captured under Step 1.3.

The RAF height is divided by bankfull maximum depth to determine the incision ratio (IR_{RAF}) for the channel (Step 2.8). The recently abandoned floodplain may be one of the nearby terraces identified and recorded as part of the cross-section measurements (Step 2.3 side box and Figure 2.3). In some cases where the stream has not incised there will not be an abandoned floodplain and the bankfull elevation and the current floodplain elevation will be the same. Be sure to record the current bankfull elevation if the river has access to a floodplain at bankfull flows. In the case of no RAF the incision ratio should be 1.

Evaluation
Stretch a tape taut and level across the channel from the top of the lowest of the two banks to a measuring rod positioned at the bankfull maximum depth, or thalweg (Figure 2.4). Record the height of the recently abandoned floodplain to the nearest tenth of a foot, which is the distance between the measuring tape and the streambed at the thalweg. Record at least one point out beyond the top of bank point to help with determining if the feature continues at the same elevation for some distance or changes slope within a give distance.

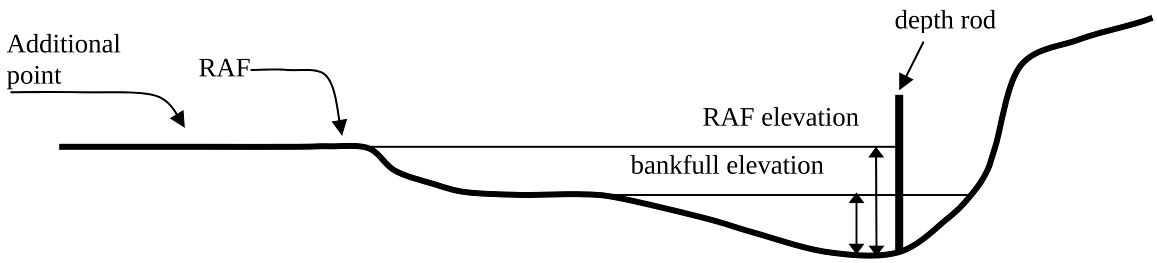


Figure 2.4 Measuring Recently Abandoned Floodplain (RAF)

If the bankfull maximum depth is identical to the height of the RAF then the same number will be recorded for both parameters on the Field Notes form. The height to the adjacent RAF may be greater than the bankfull maximum depth in situations where bed degradation has occurred and what was once an active floodplain during bankfull flows has been abandoned. You are trying to key in on recently abandoned features (that flooded on an annual basis). One way to do this is to only consider terrace **features that are no more than 3 bankfull widths** and typically less than one bankfull width from the left or right bankfull pins. You also what to avoid terraces that were active flood plains before historic times. Do not measure to high abandoned terraces that are more than 3 times the bankfull maximum depth.

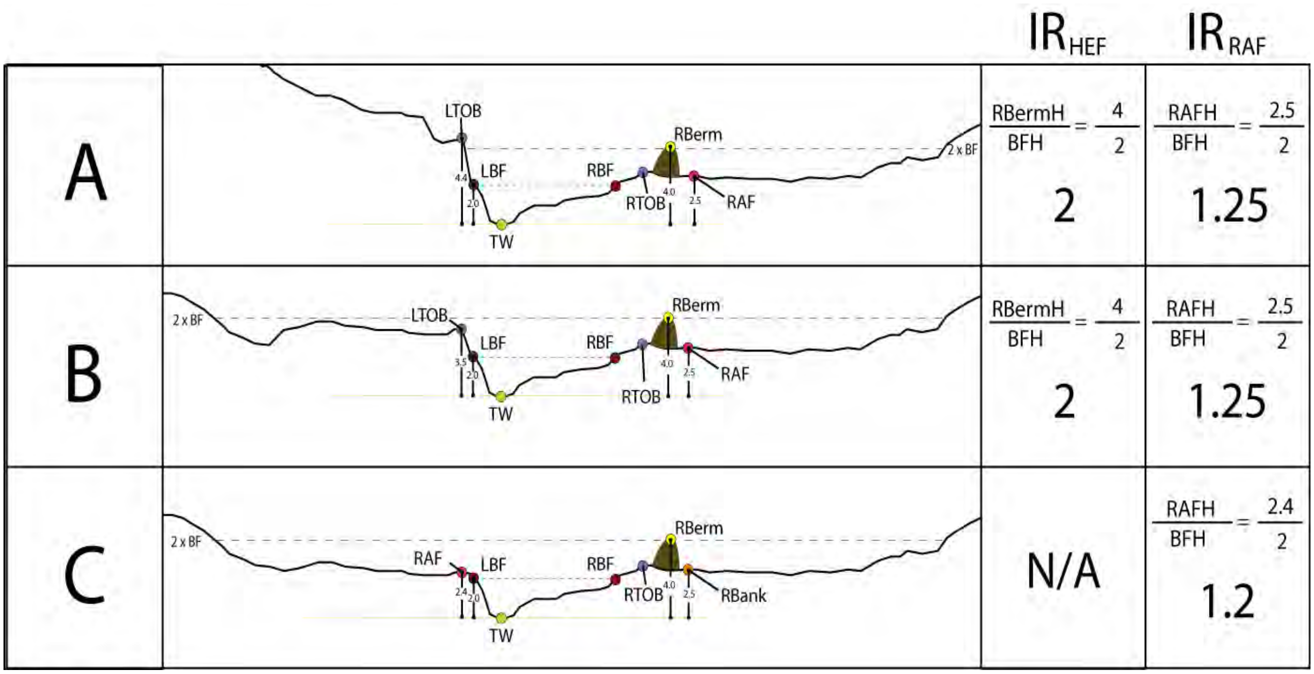
Make sure to note the RAF elevation on in the cross section workbook.

Human Elevated Floodplain (IR_{HEF}) Vs. Abandoned Floodplain (IR_{RAF})

When fill or encroachments such as railroads, roads, berms, levees, and improved paths cause **the incision of the reach to be increased** there is a need to look at the incision ratio caused by the encroachment (IR_{HEF}) for the RGA; as compared to the incision ratio calculated with the floodplain in front of/behind the encroachment (IR_{RAF}).

Human elevated incision ratios should be calculated for <u>all</u> encroachments (berms, roads, railroads, and improved paths) where the encroachment is not considered to be the new valley wall and is blocking access to the floodplain or recently abandoned floodplain (RAF).

Take a moment to look at the encroachment situations below.



Labels are provided for the Left top of bank (LTOB), Left bankfull (LBF), Thalweg (TW), Right bank full (RBF), Right top of bank (RTOB), Right berm (RBerm), and the Right Bank (RBank). The solid green line represents the thalweg height. The red dashed line is equal to bankfull and the gray dashed line is equal to two times bankfull. Numbers represent heights (H) above the thalweg for each of the points.

A. There is no access to the flood plain; due to a natural feature on left side and a berm on the right side. The height of the berm would be used to calculate the incision ratio to be used in the RGA. Human caused incision ratio is calculated using the height of the berm (as measured from the thalweg of the channel) divided by the max depth. The human elevated incision ratio (IR_{HEF}) is 2.0. To determine what the incision ratio would be if the berm were removed; use the "recently abandoned floodplain" (RAF), to calculate the incision ratio. A berm removal project would make the incision ratio equal to 1.25. This incision ratio would be used in project planning.

B. There is access to an abandoned flood plain on the left side of the river, but a more recently abandoned and more accessible feature exists behind the berm on the right side. In this case the height of the berm would be used to calculate the incision ratio (IR_{HEF}) and the IR_{HEF} would be used in the RGA. In this scenario, the human elevated incision ratio is 2.0 and is calculated using the height of the berm (as measured from the thalweg of the channel) divided by the max depth. To determine what the incision ratio would be if the berm were removed; use the "recently abandoned floodplain" (RAF), to calculate the incision ratio (IR_{RAF}). A berm removal project would make the incision ratio equal to 1.25.

C. There is access to the floodplain on the left side of the river opposite the berm. In this case, the top of the berm is not considered the "recently abandoned flooplain" (RAF). The human caused incision ratio (IR_{HEF}) does not need to be calculated for use in the RGA, as there is flood access to a feature on the left side that is at or slightly lower than the abandoned floodplain or terrace on the back side of the berm. The (IR_{RAF}) incision ratio would be used in the RGA, and is calculated using the RAF on the left (as measured from the thalweg of the channel) divided by the max depth for an incision ratio of 1.2. If the berm was removed incision would not change, but the river would have access to flood access to the terrace on both sides.

> ***Note:*** If the encroachment is characteristic of the whole segment (or reach), then the representative cross section would capture this feature, and it would be labeled as the Human Elevated Floodplain (HEF). If there are berms or other encroachments that do not characterize or dominate the whole segment (or reach), then no IR_{HEF} would be needed or used in the RGA.

2.6 WIDTH / DEPTH RATIO

Background

The width/depth ratio (W/d) describes a channel relationship which is independent of stream size. The width depth ratio is key to understanding the distribution of available energy within a channel, and the ability of various discharges occurring within the channel to move sediment (Rosgen, 1996). For aggrading and widening streams this ratio is used to describe the magnitude of adjustment. For example, a riffle-pool stream in reference condition may have a W/d ratio of 18, but a disturbed over-widened reach may have a W/d ratio of 80. This number helps to indicate "departure" from the reference stream type.

Evaluation

Divide the bankfull width (2.1) by the **mean** bankfull depth (2.3). Example: If the stream has a bankfull width of 30 ft. and a mean depth of 2.0 ft., the width/depth ratio is $30 \div 2 = 15$.

2.7 ENTRENCHMENT RATIO

Background

Streams are divided into categories, or typed (Step 2.14), based in part on their degree of entrenchment. Highly entrenched streams (ER<1.4) do not spill out onto a floodplain during high flows, such that flows are contained within the stream channel itself (Figure 2.5A). During floods, moderately entrenched streams (ER = 1.4 - 2.2) spill out into the floodprone area (Figure 2.5B), while streams exhibiting little or no entrenchment (ER>2.2) access their floodplain at bankfull flows (Figure 2.5C). The floodplain provides a pressure release valve for a river system. During floods, the water spills over the banks into the floodplain, flows become shallower and slower, and the potential for scour and erosion-related damage in and adjacent to the channel is reduced.

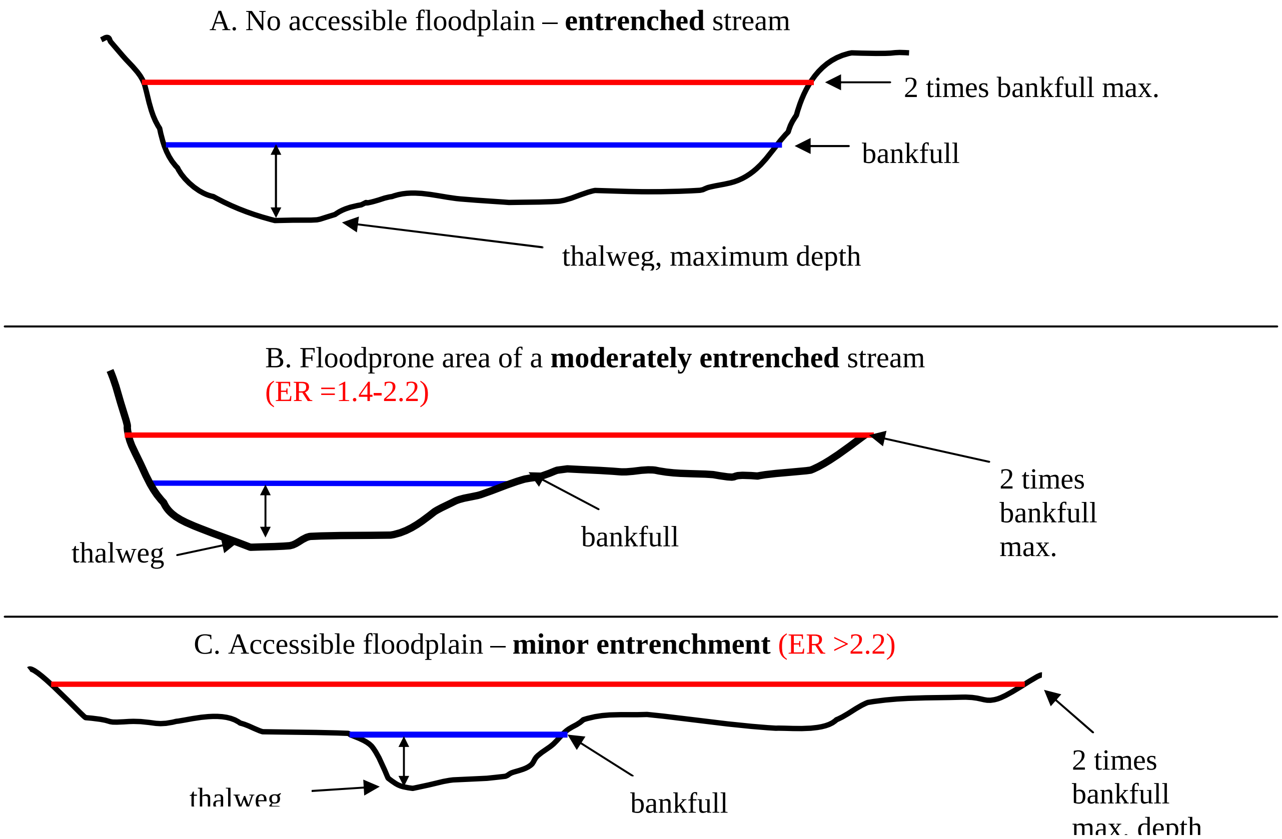


Figure 2.5 Different levels of stream entrenchment.

Evaluation

The width of the floodprone area is divided by the bankfull width to determine the **entrenchment ratio (ER).** The entrenchment ratio is calculated by the equation:

$$\mathbf{ER} = \frac{\mathbf{floodprone\ width}}{\mathbf{bankfull\ width}}$$

2.8 INCISION RATIO

Background

Incision ratios are valuable because they are a more sensitive measurement of bed degradation than the entrenchment ratio, allowing you to identify the occurrence of a degradation process in its early stages. Though the entrenchment ratio is also used to indicate bed degradation, streams in wider floodplain valleys have to incise quite a bit and contain flood flows approaching the 50-year flood before the entrenchment ratio value changes substantially. Incision ratios greater than one (Figure 2.6) may indicate that at some point in the recent (past 200 years) past the stream underwent a downcutting, or bed degradation process.

Evaluation

Divide the recently abandoned floodplain (RAF, Step 2.5) by the bankfull maximum depth (Step 2.2). Values will always be greater than or equal to one. When there are human elevated features that are contributing to incision, you may also calculate the IR_{hef} (noted under Step 2.5), Divide the height of the

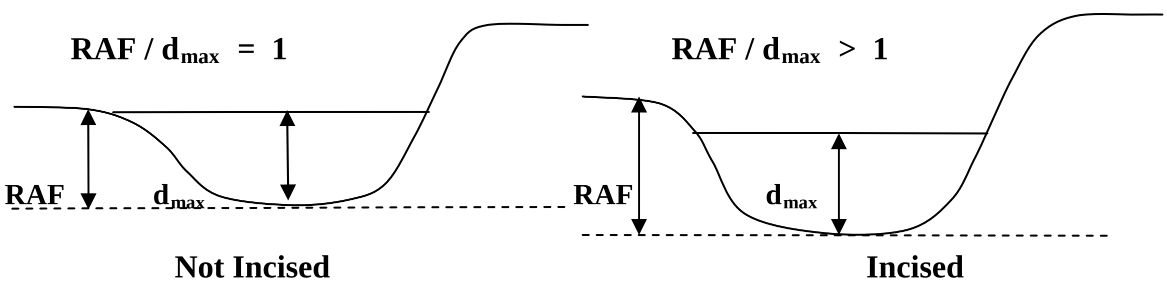


Figure 2.6 Stream cross-sections with different incision ratios: not incised and incised.

encroachment (Step 1.3) by the maximum depth (Step 2.2).

If no incision has occurred the bankfull depth should be entered for the RAF and the IR will be 1.

2.9 SINUOSITY

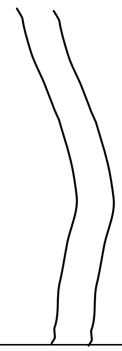
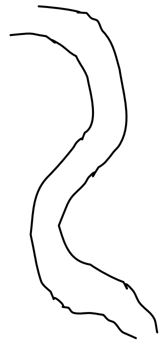
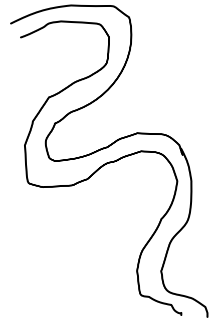
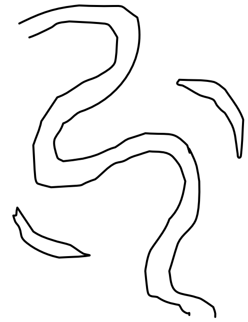
Background

This parameter describes the pattern of the river and when evaluated with bed features indicates sediment transport regime. For example, in relatively straight, high gradient transfer streams (low sinuosity) the bed features are often step-pools. In moderate gradient streams (with a low to moderate sinuosity) a plane bed morphology may develop. Streams with higher sinuosity and moderate gradient channels often have riffle-pool bed features, while those in low gradient systems may have ripple-dune bed features. Oxbows are abandoned channels usually seen in association with high sinuosity response streams.

Evaluation

The 1:5,000 scale stream coverage data layer was used in the Phase 1 Assessment to determine the reach sinuosity. Here, using the following menu, you will make on-the-ground observations and use orthophotos to describe the sinuosity of the bankfull channel. Note that while the observed thalweg of a braided channel may be sinuous, the bankfull channel of a braided system typically has a low sinuosity.

Menu

Low (< 1.2)	Moderate (1.2-1.5)	High (> 1.5)	Oxbows (>1.5)
			

The Phase 2 assessment of sinuosity allows you to confirm the Phase 1 assessment, as well as note significant changes since the orthophotos were taken. Field measurement of sinuosity is completed as part of a Phase 3 assessment.

2.10 RIFFLES / STEPS

Background

The characteristics of riffles and steps may indicate changes in erosion and depositional processes within the channel. For instance, riffles that are well formed (complete) and perpendicular or slightly angled across the channel indicate that the channel is neither degrading nor aggrading.

> ***Riffle*** **-** A section of stream that is characterized by shallow, fast-moving water with the surface broken by the presence of coarse gravels, cobbles, and/or boulders (See Appendix M).
> ***Step*** **-** A near-vertical bed feature composed of large boulders and cobbles or large woody debris stacked across the channel to bankfull elevation. Occur in high gradient streams (>2%).

Meandering streams in unconfined settings with riffles that are either partial or non-existent (runs only) may be “transfer” streams or be in the process of cutting down or degrading their beds. Conversely, streams with continuous and/or diagonal, or sharply angled, riffle lines may be experiencing a build-up, or aggradation, of sediments on the channel bed.

Evaluation

Use the following menu to describe the riffles/steps within your segment (reach). Choose “eroded ” or “sedimented” to describe the riffles/steps in the segment, even if the number of such features are significant but not predominant, so as to capture the adjustment process indicated.

Menu

Complete	All or nearly all riffles or steps completely cross the channel and are perpendicular, or slightly askew, to the channel banks
Eroded	Including partially eroded riffles/steps that do not completely cross the channel (scour process). Predominately runs, riffles/steps washing out or not present, as seen in a sediment limited reach or where bed degradation is occurring.
Sedimented	Including steep diagonal or transverse riffle/step features that cross the channel at a sharp angle in relation to the channel banks (depositional process). Riffles/steps may appear continuous, as seen during an aggradation process, and appearing as a coarse plane bed.
Not Applicable	Riffles and steps do not appear in ripple dune and plane bed (by reference) streambed types.
Not Evaluated	Riffles and steps were not evaluated for completeness – Comment on reason.

2.11 RIFFLE / STEP SPACING

Background

In an equilibrium, riffle-pool stream, riffles are typically spaced every 5-7 bankfull widths (Table 2.1) along the meander centerline (defined in Appendix E) and 8-11 bankfull widths along the thalweg (Williams, 1986). For example, if the bankfull width is 50 ft., then riffles would be expected at a 250-350 ft interval along the mender centerline and at a 400-550 ft interval along the thalweg. Where they are less frequent in this type of stream, it may be a sign of channel adjustment. Step-pool streams generally exhibit a 3-5 bankfull width spacing between steps; however, in steeper streams the step-to-step spacing may become significantly shorter. These steep streams may be dominated by “cascades”, which serve as steps. Plane bed and ripple-dune streams do not have riffles and steps to measure the distance between. If riffles or steps are not present in the reach write “N/A” (not applicable) in the space provided on the Field Notes form and check the “not applicable” box when entering data into the database.

Table 2.1 Typical riffle / step spacing by stream type.

Stream Type		Meander Centerline Spacing	Thalweg Spacing
Cascade / Step-pool	A	1-3 times W_{bkf}	N/A
Step / Riffle-pool	B	3-5 times W_{bkf}	5 - 7 times W_{bkf}
Riffle-pool	C & E	5-7 times W_{bkf}	8 - 11 times W_{bkf}
Plane bed / Ripple-dune	any	Riffles and steps are not present	N/A

Evaluation

With a measuring tape measure the length of the channel generally following the thalweg between consecutive riffles/steps in feet. This is measured from the head or top of a riffle/step to the head of the next riffle/step. Measure the distance between 2 to 3 characteristic pairs of riffles/steps and report an average value on the Field Notes form. On larger rivers this may be very difficult to do with a measuring tape; by capturing the location riffles on your sketch sheet or with a GPS you can measure the distance along the channel between riffles.

2.12 BED SUBSTRATE COMPOSITION

Background

Bed substrate composition is a term used here to capture those materials on the bed of the channel which are significant from a fluvial process and/or aquatic habitat standpoint, including the composition of bed sediments, and the presence of silt/clay, detritus and large woody debris.

Measurements of the bed material are conducted to help characterize the stream’s ability to carry different size sediments. The type of material found in the bed and bars of the stream reflects the depth and slope of the bankfull flow. In the upper reaches of a watershed the bed material tends to be coarser cobbles and boulders. This is because the stream can easily move the smaller materials. As you go further down in the watershed the bed material generally becomes finer, moving towards sands and gravels near the mouth of the rivers. The presence of silt and clay indicate near lake-like flows, which may be ongoing (in the case of silts), but are typically associated with Vermont’s glacial and post-glacial history. Substrate size and abundance are important features of aquatic habitat. Different organisms thrive on different size substrates, and will often use bed sediments for cover (fish, aquatic insects, salamanders) and colonization (algae, aquatic insects).

Detritus is organic material, such as leaves, twigs, branches (too small to qualify as LWD), and other dead plant matter that collects on the stream bed. It may occur in clumps, such as leaf packs at the bottom of a pool or piles of branches and twigs, or as single pieces, such as a fallen tree branch. Though each piece of detritus may be fairly transient in a stream segment (or reach), in that it continually moves downstream over time, the load of detritus in a segment (or reach) should be fairly constant over time if watershed and river corridor characteristics do not change substantially. There are notable seasonal fluctuations in detritus load, however, such as the increase in leaf matter associated with deciduous trees dropping their leaves in the autumn. Large woody debris provides cover for fish and macroinvertebrates and has some influence over sediment deposition and scour in local stream bed and bank environments. The size of large woody debris is factored on those pieces which are not very transient in most size streams.

Evaluation
Bed sediment composition and the presence of silt/clay and detritus are evaluated as the assessor moves along the transect(s) established to perform the pebble count. Large woody debris is counted for the entire segment (reach) during the initial walk through.

Bed Sediment Composition: Using a pebble count methodology, record the percentage of each of the sediment size classes (Table 2.2) in the stream segment (or reach).

Table 2.2 Sediment size classes.

Size Class	Millimeters	Inches	Relative Size
1-Bedrock	> 4096	> 160	Bigger than a Volkswagen Bug
2-Boulder	256 – 4096	10.1 - 160	Basketball to Volkswagen Bug
3-Cobble	64 – 256	2.5 - 10.1	Tennis ball to basketball
4-Coarse Gravel	16 – 64	0.63 – 2.5	Marble to tennis ball
4-Fine Gravel	2-16	0.08 – 0.63	Pepper corn to marble
5-Sand	< 2.00	< 0.08	Smaller than a pepper corn
6-Silt	<.062	<.002	Smaller than sand

How to Perform a Pebble Count: The pebble count methodology used to assess bed sediment composition in the Phase 2 protocol is a modification of the zig-zag method described by Bunte and Abt (2001). A planned, systematic bank-to-bank course is chosen to pick up and measure 100 particles from the stream bed. The method is based on the more rigorous technique developed by Wolman (1954) to describe coarse river bed materials, and modifications of this technique developed by the United States Forest Service developed to describe the channel bed materials within stream reaches (Bevenger and King, 1995 and Harrelson et. al. 1994).

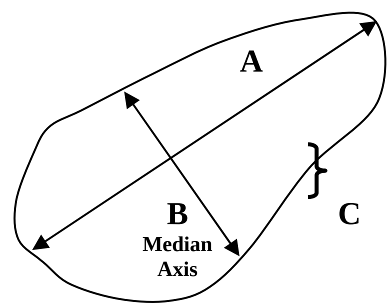


Figure 2.7 Median "B" axis of sediment particle.

1. Exactly 100 particles are to be measured and recorded on the Cross-section Worksheet.

2. Diagonal transects across the stream are paced off until a 100 count is reached (Figure 2.7). A pebble is selected (as described below) at every pace in streams < 50 feet wide, or at every two paces in streams > 50 feet wide. The diagonal transects should extend up the bank to the bankfull elevation on both banks. This method will often take you through the various types of bed features (e.g., riffle, run, pool, glide, and bars) present in the stream.

By assessing the various types of bed features in the stream you will gain a more accurate representation of the types of sediment moved by the stream, than if you assess the sediment size at only one bed feature.

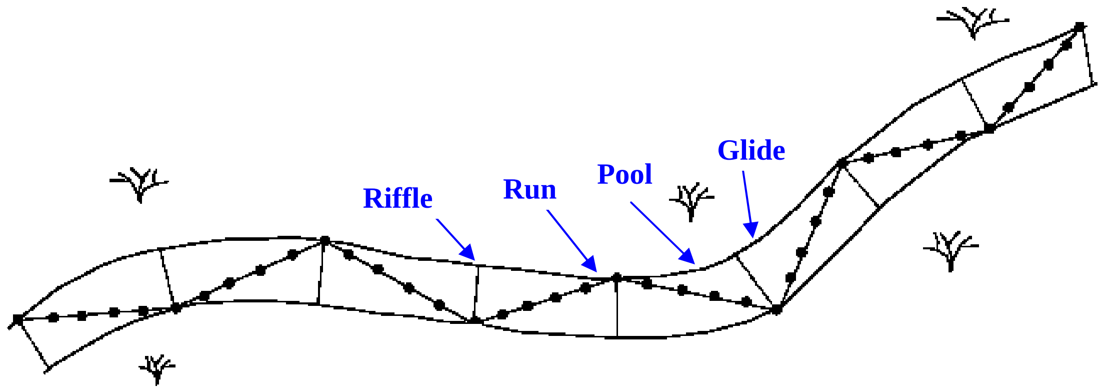


Figure 2.8 Set of diagonal transects used to complete the zig-zag pebble count method.

3. When selecting a particle to measure, avert your eyes and touch the stream bottom with your index finger just off the end of your foot. Measure this randomly selected particle to determine its particle size class. Due to their biological significance, fine and coarse categories are used to differentiate gravel-sized sediments.

4. To determine a particle's size class, use a ruler to measure the median ("B") axis of a particle (see Figure 2.8) or use a gravelometer. When using a gravelometer, the particle must be placed through the smallest cut-out possible such that the median axis is perpendicular to the sides (not diagonally across) of the cut-out. The smallest size category that the pebble falls through is called out to a recorder, who keeps track of the tally until 100 particles is reached.

Make sure that the percentages of size classes 1 through 5 total to 100%. By collecting exactly 100 particles, the tally within each size class will equal the percentage that you will record on the Field Notes form. Be careful not to bias the random selection of particles towards the larger sizes that are easier to encounter as you walk and pick up the first particle you touch with your index finger.

Clay: Note the presence (Y) or absence (N) of clay on the bed along the length of your stream segment.

Detritus: As you conduct the pebble count, your zig-zag course may take you through various bed features (i.e. pool, riffle, run, glide). Estimate the percentage of the streambed area covered by detritus along the portion of the channel in which you do the pebble count. A visual estimate of detritus will be most meaningful to compare between segments (or reaches) or to compare a particular segment over time if field assessments are done at relatively the same time in the calendar year, preferably late summer before leaf drop.

Large Woody Debris: Count the number of pieces of large woody debris (LWD) in the segment (or reach). A box is provided at the bottom of the Sketch Form for tallying LWD pieces as you walk the segment (or reach). When you have completed your tally, record the total number of LWD in the reach on the Field Notes form. To qualify as LWD the wood piece must be at least partially within the bankfull channel area (Figure 2.9), and must meet the dimension criteria listed below. All smaller pieces of wood are considered detritus.

Minimum length: 6 feet
Minimum diameter at wider end: 12 inches
Minimum diameter at 6 feet out from wide end: 6 inches

Figure 2.9 Large woody debris within the bankfull channel.

2.13 AVERAGE LARGEST PARTICLE

Background

Under reference conditions, the largest particles measured on the bed at the head of riffles may indicate the sediment size the stream typically **does not** move at bankfull flow, while the largest particles measured in the bar may indicate the larger bed load sediment size the stream is capable of moving at bankfull flows.

Evaluation

On the bed and on an unvegetated point bar (where they exist) pick out a set of particles that represents the largest size present. Use a ruler to measure the median axis (see Figure 2.8) of 3 to 5 particles of this largest size class and record the average size on the Field Notes form. Be sure to circle the units of measurement (inches or millimeters).

Bed: The average size of the largest particles on the channel bed at a riffle (Figure 2.10).
Bar: The average size of the largest particles on the downstream 1/3 of a point or side bar. Focus your bar particle measurements mid-way up the bar between the bed at the thalweg and the top of the bar.

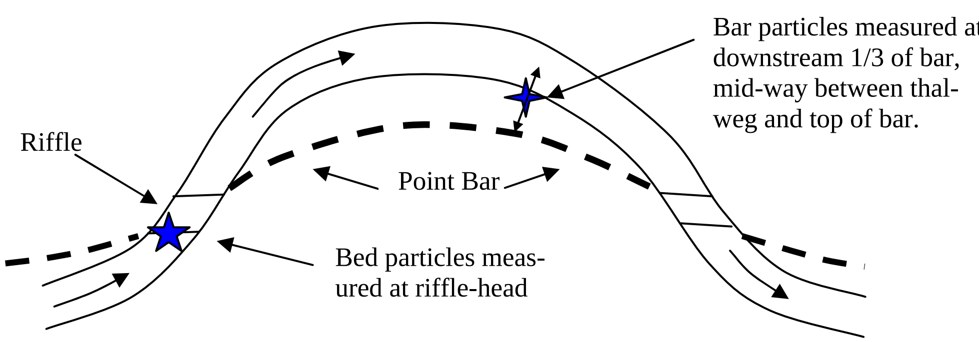


Figure 2.10 Location of bed and bar particle measurements.

2.14 STREAM TYPE

Background

Stream typing involves classifying reaches based on combinations of physical parameters such as valley landform, channel dimensions, slope, sediment supply, and bed forms, which indicate the fluvial processes at work in a river reach. The Vermont ANR uses the Schumm (1977), Rosgen (1994) and the

Montgomery-Buffington (1997) stream classifications systems (Appendix I) to summarize many of the physical parameters thought to be important in typing stream forms and fluvial processes. After defining the reference stream type (Phase 1) and the existing stream type (Phase 2), a departure analysis is completed (Step 7) as part of the geomorphic condition evaluation.

Evaluation
Using the measurements made in Steps 2.1 through 2.12, and referring to Table 3 below, determine the existing stream type for the segment (or reach). Streams are placed into the different stream types based on their entrenchment, width-depth ratio, sinuosity, channel slope, substrate size, and bed features. If the stream type has been based on the use of the +/- factors allowed for entrenchment and width/depth; be sure to include in your comments why those factors were used.

The first stream type descriptor is a capital letter that describes the entrenchment ratio, width-depth ratio, and sinuosity, which are evaluated in the listed order of priority in Table 2.3. The second descriptor is a number that describes the dominant bed substrate category (d50 sediment size described below). The third descriptor is a lower case, subscript letter that describes the channel slope (Table 4) if it falls outside of the range listed for the stream type in Table 3. The fourth descriptor is text that indicates the dominant bed form of the segment (Table 5). Use the tables below and the substrate category table in Section 2.12 to choose the capital letter, number, slope subscript, and bed descriptor that best describe the segment (or reach), and write the stream type descriptors in the box at the bottom right corner of the Field Notes form. For example, a moderately entrenched (<1.4) channel with a width/depth ratio greater than 12, and a moderate sinuosity (>1.2) would be a B type stream. If the dominant bed material for this stream was cobble, it would be labeled a B3 stream. If the elevation drop, as surveyed or measured on the topographic map, indicates a channel slope less than 2 percent, it would be a B3c. And if it had a dominant bed form of riffle-pool, it would be a B3c riffle-pool stream type, which is common in Vermont.

Table 2.3 Stream Type parameters (1-3) are in order of priority for typing (Rosgen 1996).

Stream Type	**(1) Entrenchment Ratio (+/– 0.2 units)**	**(2) Width/depth (+/– 2 units)**	**(3) Sinuosity (+/– 0.2 units)**	**Slope % (See Note)**
A – Single Thread	**<1.4** - Entrenched	**<12** – Low	**<1.2** – Low	**4-10**
G – Single Thread	**<1.4** - Entrenched	**<12** – Low	**>1.2** – Low to Mod.	**2-4**
F – Single Thread	**<1.4** - Entrenched	**>12** – Mod. to High	**>1.2** – Low to Mod.	**<2**
B – Single Thread	**1.4 -2.2** – Moderately Entrenched	**>12** – Moderate	**>1.2** – Low to Mod.	**2-4**
E – Single Thread	**>2.2** – Slightly Entrenched	**<12** – Very Low	**>1.5** – Very High	**<2**
C – Single Thread	**>2.2** – Slightly Entrenched	**>12** – Mod. to High	**>1.2** – Moderate	**<2**
D – Multiple Thread		**>40** – Very high	**<1.2** - Low	**<4**

Note: Channel slope is not a measured value in the Phase 2 protocol. Use an estimate of the channel slope as measured on a topographic map (Phase 1, Step 2.5).

The slope subscripts (Table 2.4) are only used if the channel slope falls outside of the range listed for the stream type in the last column of Table 2.3. In the example above, if the channel slope was measured as 2 percent or greater then the resulting stream type would be a B3 riffle-pool (no subscript is applied). See Appendix I for detailed description of the Rosgen and Montgomery-Buffington Stream classification systems.

Table 2.4 Stream type slope subscripts (Rosgen, 1994)

Slope Subscript	**Slope %**
a	>4
b	2-4
c	<2

Slope: If you have the appropriate equipment to measure slope in the field than you may enter it into the DMS. Please only enter the slope if you feel confident that it is accurate.

Determining d50: The dominant bed sediment type is called the d50 of the channel. The "d" stands for "diameter," meaning the size of the sediment particles, and the "50" represents "50%." The d50 is the sediment size class at which 50 % of the particles present in the bankfull channel are smaller. To estimate the d50 for the segment (or reach) start with the percentage of sand recorded on the Field Notes form (Step 2.12) and add the percentages of gravel (fine and course), then cobble, then boulder, and then bedrock. Note at which sediment size class the sum of the percentages equals or just surpasses 50%, and circle this size class on the Field Notes form. For example, you may have 40% boulder, 30% cobble, 20 % gravel, and 10% sand. By starting at sand and progressively adding the sediment sizes, your d50 would be in the cobble size class (class "3"); even though boulders comprised the largest percentage of particles measured. Remember that the d50 calculated here is associated with the existing stream type and not necessarily the d50 of the reference stream type.

Determining Bed Forms: The Phase 2 determination of bed forms is a visual assessment. Using the descriptions provided in Table 2.5 circle a dominant bed form on the Field Notes form for the segment (or reach). Use the dominant bed form in the Stream Type description box. If the segment exhibits more than one bed form, circle both the dominant and sub-dominant bed forms and write "dom" and "sub-dom" under them on the Field Notes form.

Table 2.5 Stream Type Bed Forms from Montgomery and Buffington (1997) and Rosgen (1996)

Bed Features	Description
Cascade	Generally occur in very steep channels, narrowly confined by valley walls. Characterized by longitudinally and laterally disorganized bed materials, typically bedrock, boulders, and cobbles. Small, partial channel-spanning pools spaced < 1 channel width apart common.
Step-Pool	Often associated with steep channels, low width/depth ratios and confining valleys. Characterized by longitudinal steps formed by large particles (boulder/cobbles) organized into discrete channel-spanning accumulations that separate pools, which contain smaller sized materials. Step-pool systems exhibit pool spacing of 1 to 4 channel widths.
Plane Bed	Occur in low to high gradient and relatively straight channels, have low to high width/depth ratios, and may be either unconfined or confined by valley walls. Composed of sand to small boulder-sized particles, but dominated by gravel and cobble substrates in reference stream condition. Channel lacks discrete bed features (such as pools, riffles, and point bars) and may have long stretches of featureless bed.
Riffle-Pool	Occur in moderate to low gradient and moderately sinuous channels, generally in unconfined valleys, and has well-established floodplain. Channel has undulating bed that defines a sequence of riffles, runs, pools, and bars. Pools spaced every 5 to 7 channel widths in a self-formed (alluvial) riffle-pool channel.
Dune-Ripple	Usually associated with low gradient and highly sinuous channels. Dominated by sand-sized substrates. Channel may exhibit point bars or other bedforms forced by channel geometry. Typically undulating bed does not establish distinct pools and riffles.
Bedrock	Lack a continuous alluvial bed. Some alluvial material may be temporarily stored in scour holes, or behind obstructions. Often confined by valley walls.
Braided	Multiple channel system found on steep depositional fans and deltas. Channel gradient is generally the same as the valley slope. Ongoing deposition leads to high bank erosion rates. Bed features result from the convergence/divergence process of local bed scour and sediment deposition. Unvegetated islands may shift position frequently during runoff events. High bankfull widths and very low meander (belt) widths.

Having a combination of bed forms can be a natural occurrence or the result of a channel adjustment that you will note when completing the Rapid Geomorphic Assessment (RGA) in Step 7. For instance a reference condition channel at the threshold between B and C type streams with a 2 percent slope may predominately exhibit step-pool morphology with riffle features at cross-overs and scour pools on the outside meander bends. In this case, riffle-pool would be circled and labeled as sub-dominant. In another example, a channel with a slope of less than 1 percent may predominately exhibit plane bed morphology, and also exhibit weak riffles and pools. Again riffle-pool would be indicated as a sub-dominant bed form on the Field Note form. In this case, however, the bed form information along with other data may indicate the aggradation and planform adjustments that are occurring due to historic channel straightening that led to the formation of the plane bed morphology.

After you have completed the Phase 2 assessment of existing stream type, look at the provisional reference stream type that was assigned to the reach during the Phase 1 assessment. If the field assessed stream type is different than the provisional stream type, but no channel adjustments are indicated that would change any of the four stream type descriptors (typically RGA "good" to "reference" condition ratings), you should use the reference type check box and refine or change the reference stream type in the Phase 1 database and use the metadata to indicate the change was due to a Phase 2 assessment. If the existing stream type is different than the provisional reference stream type and the difference can be explained by channel adjustments and stressors associated with channel, floodplain, or watershed change, **do not** revise the reference stream type in the Phase 1 database. This departure in stream type may be very significant to your assessment of stream geomorphic condition.

Remember: If you are working on a sub-reach which has a different reference stream type than that which was originally assigned to the entire reach, use the sub-reach checkbox in the Field Note header, and note the new reference stream type **under** the stream type box established for the existing stream type in Step 2.14 of the Field Notes form. There is a similar place-holder for this sub-reach reference stream type information in the Phase 2, Step 2 entry form of the DMS.

Step 3: Stream Banks, Buffers and Corridors

Few landscape features are as important as riparian areas in protecting stream channel forms and functions. Evaluating the condition of the vegetation along a stream's banks and within its riparian corridor provides insight to the overall health of the riparian and stream ecosystems within your watershed. One of the many functions of natural vegetation adjacent to streams is the stabilization of stream banks and the moderation of the rate of lateral channel migration. Vegetation binds the soil, increasing the soil's resistance to erosion, and decreases the rate and volume of overland runoff (i.e. stormwater) and sediment entering the stream from upland sources. This is vitally important to maintaining channel form and function, as increases in the rate and volume of stream flow and sediment load to the stream can lead to substantial channel adjustments, which in turn may affect aquatic habitat.

In addition to riparian vegetation, bank slope and soil texture are also important to evaluate in order to understand the overall condition of riparian areas in your watershed, and their potential benefits to the stream channel and its related habitats.

The streambank, riparian buffer, and river corridor vegetation are important components of aquatic habitats. In addition to the role vegetation plays in maintaining channel form and function, it is also a vital nutrient source and water temperature regulator for stream ecosystems. It is also the source for all the detritus and large woody debris evaluated in Step 2.12. In completing Step 3, the following three riparian areas are evaluated (see Figure 3.1):

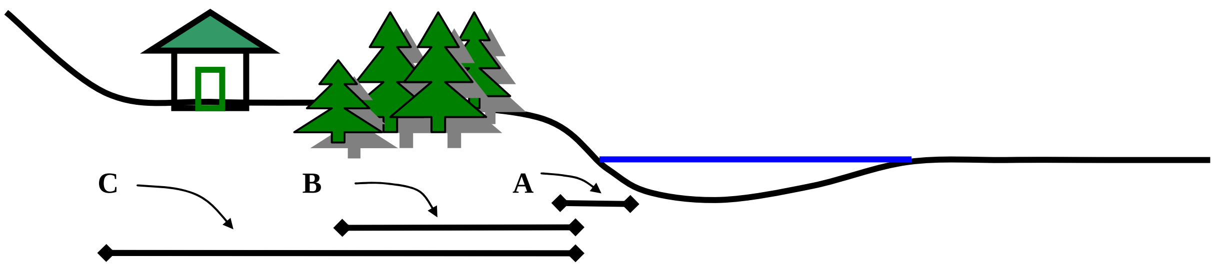


Figure 3.1 Stream bank (A), riparian buffer (B), and river corridor (C) further defined below.

3.1 STREAM BANKS

Background

Stream banks are features that define the channel sides and contain stream flow within the channel, typically extending from the toe of the bank slope to the bankfull elevation. Bank characteristics govern the rate of erosion. Bank erosion is a natural process, but in adjusting channels, bank erosion may be greatly increased in frequency of occurrence and/or volume of sediment eroded.

The banks are distinct from the streambed, which is normally wetted and provides a substrate that supports aquatic organisms. The top of bank is the point where an abrupt change in slope is usually evident, and where the stream is generally able to overflow the banks (sometimes only on the low bank side) and enter the adjacent floodplain during

Bank Erosion: All stream banks erode to some degree. Because erosion is a natural ongoing process, it is unrealistic to believe that bank erosion can be or should be totally eliminated. Major floods can always make significant changes in bank lines despite steps taken to prevent it. Thus, it is important to understand that the concern is not that erosion occurs, but rather the location and rate at which it occurs. While bank erosion is occurring naturally over time, it is a process that may be accelerated or decelerated by human activities. Henderson and Shields (1984) define natural erosion as the processes that occur without significant human activities in the drainage basin or catastrophic natural events such as volcanic eruptions or forest fires. They define accelerated erosion as erosion that is atypically high in magnitude and is different in nature than the erosion experienced at the site or reach in question in the recent past. Both natural events (e.g., high flows) and human activities (e.g., changes in land use) can cause accelerated erosion. (Johnson and Stypula eds., 1993).

flows at or exceeding the average annual high water (or bankfull stage). When evaluating streambank vegetation in this assessment, the stream bank also includes the "near bank" area, which is the first 5 feet back from the top of the bank.

Evaluation
The following section includes field protocols for evaluating stream bank characteristics including: bank slope and texture; extent of erosion; type and length of revetments; dominant vegetation; and extent of tree canopy. Erosion and the type and length of revetments are evaluated along the entire segment (reach) during the initial walk through. All other stream bank parameters are assessed at the locations used to complete the cross-sections for the segment.

Typical Bank Slope: Record the slope of the stream bank (Figure 3.2) *immediately adjacent* to the bed of the channel. The area that is evaluated is from the toe of the bank to the bankfull elevation. In the menu the slopes are presented as: percent slopes = rise/run x 100. For example, a slope that is twice as long (the run) as it is high (the rise) would be recorded as a moderate slope (50%).

Menu

Shallow	bank slope (<30%)
Moderate	bank slope (30-50 %)
Steep	bank slope (>50%)
Undercut	upper bank overhanging the streambed

In channels that are sinuous, such that the thalweg moves back and forth across the channel from river bend to river bend, focus on the **higher** of the two banks when evaluating bank slope. The bank against which the thalweg runs is higher, steeper, and is usually associated with a pool scoured at the toe of the bank. If the stream is not sinuous and the thalweg does not shift back and forth across the channel (such as in a straight, steep mountainous stream), consider both banks together when determining the typical bank slope.

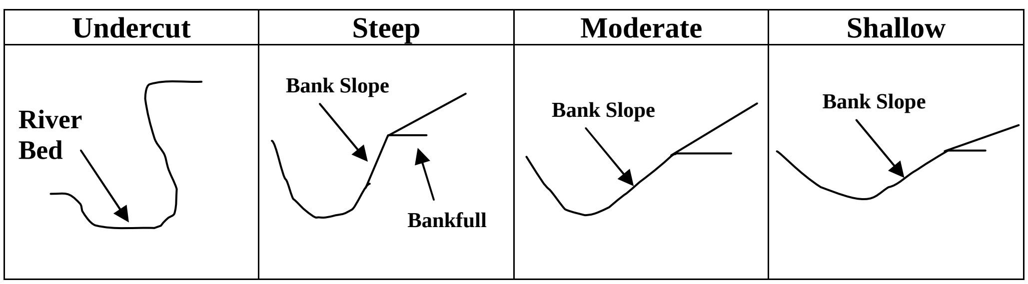


Figure 3.2 Bank slope diagram showing the 4 bank slopes

Lower and Upper Bank Texture: For this parameter "bank" is defined as the area between the toe of the bank slope and the bankfull elevation. To evaluate bank texture, the bank is broken into two parts, the <u>lower</u> 1/3 portion, which experiences the most stress during flood flows, and the <u>upper</u> 2/3 portion (Figure 3.4). For example, if the bank was 6 feet high (between the toe and bankfull), then the lower 1/3 portion would be the first 2 feet from the toe of the bank slope up, and the upper 2/3 portion would be the remaining 4 feet. Describe bank texture by circling the dominant type of materials of which the bank is composed of on both the right and left bank.

Menu

Bedrock	Very resistant to erosion
Boulder/Cobble	(boulders >10" / cobbles 2.5 to 10") Moderately resistant to erosion
Gravel	(0.1 to 2.5 inches) Moderate to high bank erodibility when present as dominant component or as part of the bank materials
Sand	High bank erodibility when present as part of the bank materials
Silt/Clay	Non-cohesive silt has very high / extreme bank erodibility; while cohesive clays are relatively resistant to erosion
Mix	Variety of particle sizes present from very small to very large. Glacial till may be an example of mixed bank materials (Figure 3.3)

Also indicate the material's consistency by circling whether it is **cohesive** or **non-cohesive**. Non-cohesive materials are soft and loose, while cohesive materials feel hard and dense. Bank texture and consistency are important in determining the inherent sensitivity and potential of a bank to erode. For example, if the materials in the bank are very resistant and/or cohesive (e.g., large boulders or clay), there will be less erosion than if the bank materials are highly erodible sands, silts or gravels. See Appendix F for a more detailed description of surficial geologic materials, and see Step 3 of the Phase 3 Handbook for a more detailed protocol for field assessment of bank materials.

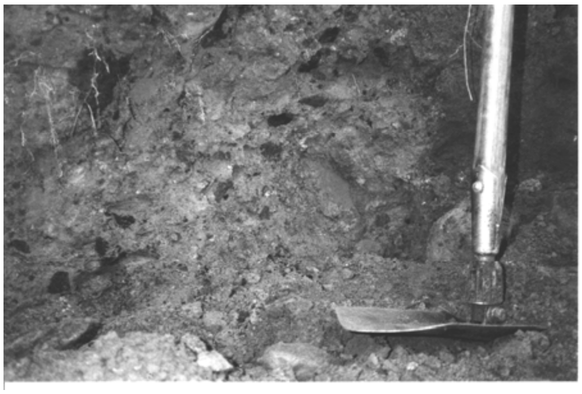


Figure 3.3 Highly compacted basal till.

Figure 3.4 Lower gravel bank texture and upper sandy bank texture.

Bank Erosion (FIT): Note the length and average height of the actively eroding banks on both right and left banks. Measure the height of erosion from the toe of the slope (the streambed) to the top of the bank. There is space on the back of the Sketch Form to tally bank erosion as you walk the segment (or reach).

Figure 3.5 Slumped eroding bank.

Bank erosion is an area of raw and barren soil where the vegetation does not have the ability to hold the soil and/or the soil has slumped or fallen into the channel (Figure 3.5). Phase 2 bank erosion assessment should attempt to quantify active and accelerated erosion, and not the background erosion that occurs at a more natural (slower) rate. For example, you may assess a channel where both banks show exposed soil throughout the reach, which may indicate minor erosion typical of natural stream processes. This minor bank erosion should not be considered in your assessment, especially if the following are true:

- vegetative roots are exposed but the vegetation is holding the bank;
- there are no apparent human-related changes to bank erodibility and/or hydraulic forces (i.e. changes in velocity and direction of flow); and large geo-technical "slump" failures are not observed. Slumps are areas where changes in the moisture content of the bank soils increase the potential for material to slide down (Fischenich, 2000).

Use the Feature Indexing Tool (FIT) in SGAT to document the location of erosion on the right bank or the left bank as well as the height of the erosion. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where erosion is noted.

Gullies and Mass Failures (FIT): Gullies are formed by concentrated storm flows through highly erodible materials and appear as steep-sided ravines. Mass failures sometimes occur when a perennial stream erodes into or undercuts a high erodible landform, such as a glacial lacustrine terrace. If you are familiar with evaluating gullies (Figure 3.5.1) and mass failures, use the boxes located on the Tally Sheet to record the number, the height, and the total length of each feature within the river corridor. Record the location of the mass failure along the stream channel as well as the location of either right bank or left bank.

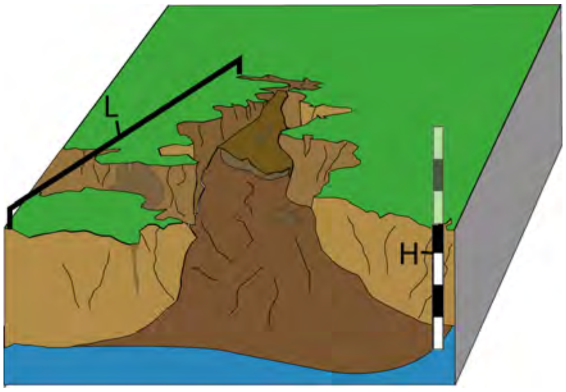


Figure 3.5.1. Example of technique use in the evaluation of gullies.

Use the Feature Indexing Tool (FIT) in SGAT to document the location of gullies and location of mass failures. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where gullies and mass failures are noted.

Bank Revetments (FIT): Bank revetments are structures installed in an attempt to stop stream bank erosion. Revetments may be "hard", such as gabions and riprap, or "soft", such as conifer tree-tops (Figure 3.6). Note the type of revetment and the length of each bank in the segment (or reach) that is artificially stabilized. Typically in Vermont hard bank treatments are used to armor the bank against scour and undercutting; but, in streams that are going through adjustment, rip-rap may become undermined by the stream and contribute to the instability of the channel.

Menu

Rip-rap	Blanket of rock covering the bank, usually large angular boulders
Hard Bank	Walls of large rocks, concrete blocks or rectangular gabion wire baskets (filled with stone) lining banks
Other	Tree revetments or vanes, for example, intended to stop or slow the lateral erosion of the stream channel
None	No bank revetments observed

Use the Feature Indexing Tool (FIT) in SGAT to document the location of revetments on the right bank and left bank. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where revetments are noted.

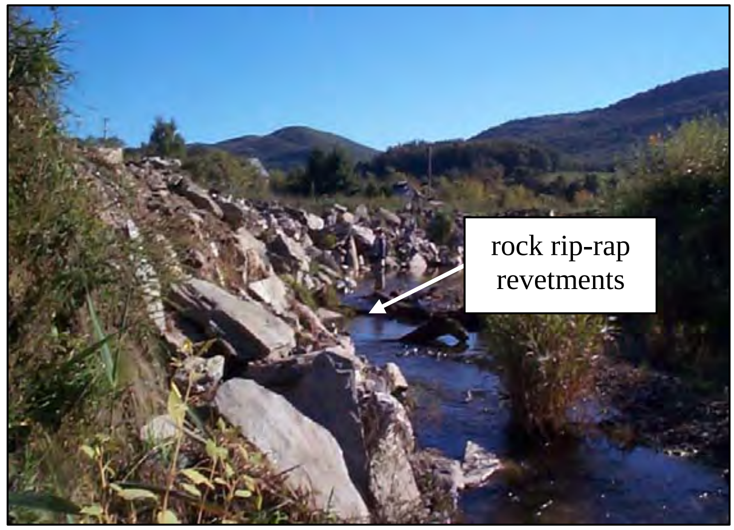


Figure 3.6 "Soft" tree revetments on the left, and "hard" riprap revetments on the right, installed to attempt to stabilize eroding stream banks.

Bank Vegetation Type: Choose the category that best describes the dominant and sub-dominant vegetation types (covering the most surface area) on the bank and in the "near-bank" area for both the left and right stream banks (determined facing downstream). *Evaluate only the area from bankfull to the top of bank plus 5 feet back from the top of the bank.* Circle and indicate dominant ("dom") and sub-dominant ("sub-dom") categories on the Field Notes form.

Menu

Coniferous	Trees that keep their leaves year round i.e. pine, cedar, hemlock
Deciduous	Trees that lose their leaves seasonally i.e. elm, butternut, maple, oak
Shrubs-sapling	Small trees, saplings, and brush species, such as alder, willows, sumac, and dogwoods
Herbaceous	Native grasses, rushes, sedges, forbes and other non-woody plants
Lawn	Mowed lawn
Pasture	Land managed for grazing livestock
Bare	Bare soil, no or very sparse vegetation. This does not pertain to unvegetated features such as point-bars
Invasives	Non-native invasive plant species: Phragmites, Japanese knotweed, Purple loosestrife, Honeysuckle (note there are native honeysuckles too)

The purpose of considering vegetation immediately beyond the bankfull elevation in the near-bank area is to document the presence and type of plant roots that are binding the soil and providing resistance to bank erosion within the channel boundaries. Bank vegetation is also important in shading the channel edge and providing overhanging vegetation which can be used as cover by aquatic animals and is a source of organic matter for the stream. If you are familiar with any species of invasive plants present in the near-bank area, write the names in the comments section of the Field Notes form.

Bank Canopy: For both right and left banks estimate the average percent canopy over the margin of the channel, upstream to downstream along the near-bank area. To do this stand in the channel facing the bank and look straight up into the tree and shrub canopy. From this viewpoint, estimate the percent of the sky within your field of vision that is blocked by foliage and branches. This is the percent canopy. If there is no vegetation above your head when you view the sky then the percent canopy is zero. Do this at the locations within the

Menu:

76 – 100%
51 – 75%
26 – 50%
1 – 25%
0 %

segment where cross-sections were completed (at least 3 locations) and record the average percent canopy along each bank. You are striving for an estimate that is the typical condition along the majority of the segment (or reach).

***Across Channel Canopy*:** Stand in the middle of the channel and evaluate whether the trees that are over the channel have an open or closed canopy (Figures 3.7A and 3.7B). Trees that meet over the channel create a closed canopy. Areas where streamside trees on opposite banks do not meet, or touch, over the channel are considered to have an open canopy. This parameter evaluates complete channel shading and is important in distinguishing canopy cover of small streams from large streams, the latter of which may not form a closed canopy due to the channel width being too great. Record the condition that best represents the majority of the segment (or reach).

Figure 3.7A Open channel canopy

View from middle of channel looking up to sky.

Figure 3.7B Closed channel canopy

3.2 RIPARIAN BUFFER

Background

Riparian buffer is the width of naturally vegetated land adjacent to the stream between the top of the bank (or top of slope, depending on site characteristics) and the edge of other land uses. A buffer is largely undisturbed and consists of the trees, shrubs, groundcover plants, duff layer, and naturally uneven ground surface. Buffer serves numerous functions from protecting water quality and providing for fish and wildlife habitat, to increasing the overall resistance to the channel to erosion during floods (see the ANR Buffer Procedure listed on the WEB page: www.vtwaterquality.org).

Evaluation

The dominant width and vegetation type of the riparian buffer are evaluated for the length of the segment or reach (ideally as the segment sketch is completed during the initial walk through). The areas of stream that have a buffer width less than 25 feet must be noted on the field map and indexed using the SGAT FIT.

Buffer Width: Record the dominant and sub-dominant buffer width categories in the segment (or reach) for both the left and right sides of the channel. This parameter does **not** determine an average buffer width, but rather the most dominant buffer condition of the segment. Remember that the buffer is a portion of the river corridor, adjacent to the channel, that is naturally vegetated and largely undisturbed. Do not count areas that are being pastured, or are recently fallow as buffer. Fallow fields should only be counted as buffer if there is evidence of shrubs/saplings beginning to propagate in the fields. Circle the dominant and

Menu

0 – 25 ft.
26 – 50 ft.
51 – 100 ft
> 100 ft

sub-dominant categories on the Field Notes form, and indicate dominant with "dom" and subdominant with "sub-dom."

Using the FIT in SGAT index the sections of the stream that have a buffer width less than 25 feet in width. This will help in the identification of potential buffer enhancement projects.

Buffer Vegetation Type: Record the dominant and subdominant vegetation types of the riparian buffer for both the left and right sides of the channel. Choose the vegetation type that best represents the majority of the segment (or reach). Circle and indicate dominant ("dom") and sub-dominant ("sub-dom") vegetation coverage types on the Field Notes form. Do not count stems, coverage is defined by the area covered by the over-story vegetation community. If there is no buffer vegetation, choose "none" on the data sheet.

Menu

Coniferous	Trees that keep their leaves year round. i.e. pine, cedar, hemlock
Deciduous	Trees that lose their leaves seasonally. i.e. elm, butternut, maple, oak
Mixed Trees	A fairly even mix of conifers and deciduous trees.
Shrub-sapling	Small trees, saplings, and brush species, such as alder, willows, sumac; fallow field, and dogwoods
Herbaceous	Native grasses, rushes, sedges, forbs and other non-woody plants
Invasives	Non-native invasive plant species: Phragmites, Japanese knotweed, Purple loosestrife, Honeysuckle (note there are native honeysuckles too)
None	No buffer present, bare ground up to the top of the bank

Changes in buffer conditions may warrant segment breaks. If the there is wide variability in the buffer vegetation type and width within a reach, you may consider establishing segments based on these buffer condition differences. These differences should be pronounced and extensive. For example, you would not break out a segment of brush-dominated buffer for a 200 ft. length of channel that is largely conifer tree dominated. On the other hand, you might consider breaking out a 2000 ft. long section of the reach that has no buffer as its own segment, if the majority of the one mile reach has a 50 ft. wide forested buffer.

3.3 RIVER CORRIDOR LAND USE

Background

River corridor includes lands defined by the lateral extent of a stream's meanders necessary to maintain the dimension, pattern, profile, and sediment regime of the stream in equilibrium. For instance, in riffle-pool streams, riparian corridors may be as wide as 6-8 times the channel's bankfull width (see Appendix E). In addition, the riparian corridor typically corresponds to the land area surrounding and including the stream that supports (or could support if unimpacted) a distinct ecosystem, generally with abundant and diverse plant and animal communities (as compared to upland communities).

An evaluation of river corridor land use supports the assessment of human developments or constraints that may diminish riparian ecosystems and inhibit the equilibrium condition and/or the adjustments necessary to achieve the slope and channel length required by the equilibrium condition.

Evaluation

Circle and indicate dominant ("dom") and sub-dominant ("sub-dom") land uses within the left and right corridors of the segment (or reach). Where a wide riparian buffer of natural vegetation separates the stream from adjacent agricultural or development land uses, the buffer may occupy the entire width of the river corridor. In these cases characterize the corridor as "forest" or "shrub-sapling" land use, whichever is appropriate. The river corridor delineated as part of the Phase 1 assessment (see Appendix E) represents the area that should be used to evaluate corridor land use. For confined reaches where an SGAT drawn corridor may be difficult to interpret in the field, remember that the river corridor includes the area from the top of bank extending out perpendicular from the stream channel for a distance of 2 times the channel width or 100 feet, whichever is greater. For example, if the bankfull width is 30 feet, evaluate the area within 100 ft. to either side of the channel (100’ is greater than 2 times the channel width).

Menu

Forest	Woodlands of deciduous or coniferous trees
Shrub-sapling	Fallow field or wetland
Crop **Pasture** **Hay**	Agricultural lands planted in row crops, mowed as a hay field, or pastured with livestock. Circle the appropriate type of agriculture.
Commercial **Industrial**	Retail, industrial or service-type businesses with land developed for buildings, roads, and parking areas
Residential	Land developed with houses, lawns, and driveways
Bare	Bare soil, no or very sparse vegetation. Pertains to gravel pits, construction sites, and similar bare ground

Step 4: Flow Modifiers

Step 4 evaluates the natural processes and human impacts that affect the amount of water in the channel. River systems are affected by *decreases* in flow, such as water withdrawals, or *increases* in flow, such as stormwater runoff, as well as natural features in the system that affect the flow, such as wetlands, springs and seeps. *This section does not evaluate the typical seasonal fluctuations of stream flow.*

4.1 SPRINGS, SEEPS AND SMALL TRIBUTARIES

Background
The prevalence of springs, seeps, and small tributaries may indicate the water storage characteristics of the watershed. Streams with greater surface and sub-surface water storage tend to be less flashy. The extended duration of runoff events in high storage watersheds, may result in streams with relatively smaller dimensions which are less sensitive to the adjustment processes brought on by storm events.

Ground water influence in streams and rivers is especially important during periods of drought or low-flow. The water that enters a stream from springs, seeps or small tributaries is often cooler in the summer than surface water temperatures. Fish seek out these cooler areas during the summer. Similarly, in the winter these areas contain relatively warm water, due to the groundwater origin, compared to the near freezing temperatures of surface water exposed to the cold winter air, and again are beneficial to fish and other aquatic biota.

Evaluation
Note the relative abundance of springs, seeps or small tributaries entering the channel. Natural features such as springs and seeps or tributaries *contribute groundwater* to the channel.

Menu

Abundant	Numerous small tributaries, springs and/or seeps entering the stream site.
Minimal	Infrequent small tributaries, springs and/or seeps do not enter the stream site
None	No small tributaries, springs and/or seeps observed entering the segment (reach)

4.2 ADJACENT WETLANDS

Background
Similar to the watershed characteristics evaluated as part of Step 4.1, wetlands serve both water storage and habitat functions.

Evaluation
Note the relative abundance of wetlands adjacent to the channel. For the purposes of this assessment, wetlands can be identified by the presence of vegetation that usually requires wetted soils, such as cattails, sedges and rushes, willows and alders. Wetland information can be obtained from the ANR Division of Water Quality, which houses the National Wetlands Inventory (NWI) maps and the Vermont Significant Wetland Inventory (VSWI) maps, as well as from the NRCS Soil Surveys.

Menu

Abundant	Extensive wetlands present along stream segment (reach)
Minimal	Wetlands present but to small extent along stream segment (reach)
None	No wetlands observed along stream segment (reach)

4.3 FLOW STATUS

Background

This parameter evaluates the degree to which the channel is filled with water. It includes evaluation of whether a system is being affected by 1) water withdrawals and/or 2) stream adjustments in response to changes in land use, but can also consider naturally occurring low flow conditions due to a channel's underlying geology. The flow status will change as the channel enlarges (e.g., aggrading stream beds with actively widening channels) or as flow decreases as a result of dams and other obstructions, diversions for irrigation, or drought. When water does not cover much of the streambed the amount of suitable substrate for aquatic organisms is limited. In high-gradient streams, cobble and gravel substrates in riffles are exposed; in low-gradient streams, the decrease in water level exposes logs and snags, thereby reducing available habitat.

Evaluation

Indicate whether the amount of flow in the channel at the time of the assessment is **Low** due to drought conditions, **Moderate** (typical summer flows), or **High** as a result of recent storms or flooding. It is highly recommended that you avoid surveying during high flow periods. Not only can stream conditions be dangerous, but stream features may be obscured and difficult to accurately assess due to turbid water.

4.4 DEBRIS JAMS (FIT)

Background

Debris jams are an important part of channel stability and aquatic habitat. Debris jams can also be a problem for infrastructure located adjacent to the channel in the floodplain, as jams may result in channel avulsions, which could jeopardize nearby infrastructure (Figure 4.1).

Figure 4.1 Examples of debris jams.

Evaluation
Note the **number** of debris jams observed in the segment (or reach). Debris jams consist of numerous pieces of large woody debris (more than one log) as defined in Step 2.12, and are channel spanning or nearly so. Hazards from debris jams may primarily apply to infrastructure, such as bridges that are too narrow. Piles of woody debris on the upstream side of the bridges and culverts are an indication of a channel constriction by the infrastructure. Evidence of past debris jam history could be large depositional features upstream of jam sites that create backwaters or evidence of avulsions around jams.

Use the Feature Indexing Tool (FIT) in SGAT to document the location of debris jams within the reach. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where debris jams are noted.

4.5 FLOW REGULATION and WATER WITHDRAWALS (FIT)

Background
Diversions decrease the flow of water to downstream reaches reducing stream power and increasing the likelihood of sediment aggradation within the channel. When flows are decreased the ability to support healthy fish and aquatic insect populations is decreased. Water withdrawals, especially during low-flow periods, which are already stressful for many stream dwelling organisms, can reduce the productivity of a river. Flows are **decreased** if water is withdrawn or impounded behind a dam (which also may be a fish migration barrier) for:

- hydropower
- irrigation
- public water supplies
- snowmaking
- flood control
- recreation

Not all withdrawals have impoundments. Often snowmaking and agricultural irrigation are just pipes in the river, usually with a pump nearby on the bank, that do not significantly affect stream flows.

With some storm or runoff events, flow regulation at impoundments may also result in longer periods of very high flows downstream. Higher duration releases become necessary to provide storage in the impoundment. The duration of very high flows may result in more erosion than what would have occurred had the storm flows peaked and moved out of the watershed more quickly.

Evaluation

In reach flow regulations and water withdrawals:
Indicate any known flow regulations or water withdrawal in the reach (or segment). Use Phase 1 data and existing data from the Water Quality and Water Supply Divisions of the ANR to support your field observations. Use the FIT in SGAT to indicate the locations of the impoundments within the reach.

Menu

Type

Withdrawal	A withdrawal of water from the stream
Bypass	The water is diverted away from the channel and re-enters down stream.
Run of River	Upstream or in reach flows are impounded. Flow quantity spilling or released below the dam is the same as flow quantity entering the impoundment at all times.
Store and Release	Water is impounded and stored and released only during certain times.
None	No known flow regulation or water withdrawals. Select "none" if you have completed the appropriate research and have found no evidence of flow regulations.
No Data	No data sources are available to determine if a flow regulation or water withdrawal exists.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Size

Small	Impoundments not much wider than river itself or withdrawals not affecting the channel forming flow.
Large	Impoundments much wider than river itself (creating a reservoir) or withdrawals significantly affecting the channel forming flow.

Use

Drinking
Irrigation
Flood Control
Hydro-electric
Recreation
Other

4.6 Upstream/Downstream FLOW REGULATION and WATER WITHDRAWALS

Note the presence of water withdrawals and flow regulations outside of the reach (or segment) being assessed that are affecting the reach (or segment). Use the same menus as in Step 4.5 above. DO NOT index these features where you have not completed an assessment. Data must be manually entered to indicate an upstream impoundment affecting the reach (or segment).

Menu

Upstream	Flow regulation or water withdrawal upstream affecting the reach.
Downstream	Flow regulation or water withdrawal downstream affecting the reach.
Both	Flow regulation or water withdrawal both upstream and downstream affecting the reach.
None	No known flow regulation or water withdrawals in the reach watershed affecting the reach.

4.7 STORMWATER INPUTS (FIT)

Background

Stormwater flows can cause severe erosion where flow is concentrated. Activities that change the runoff characteristics of the watershed include urbanization and loss of forest, which *increase* the ability of water to run off the land, and *decrease* the ability of water to infiltrate into the ground. When flows are increased through stormwater discharges, the channel responds to this increased flow by degrading and/or widening; riverbanks collapse and the channel becomes wider and shallower. Stormwater discharges can also be responsible for headcutting of channels, bank mass failures, undermined culverts, and culvert outfall scour.

Figure 4.2 Roadway ditch stormwater culvert.

Evaluation

Note the number of ditches, culverts or pipes collecting and conveying stormwater to the segment (or reach). Structures that merely convey normal intermittent or perennial runoff should not be considered. Any structures, including roadside ditches that concentrate runoff should be counted at the points where the concentrated flow enters the stream (Figure 4.2). The following categories should be indexed and entered into the FIT:

Menu

Tile Drain	Outlet of the pipe drainage typically put in fields to assist with removing surface and sub-surface water from the fields.
Road Ditch	A ditch along roadsides that remove water from the road surface.
Urban Stormwater Pipe	Point at which flows from stormwater collection is outlet to the stream.
Field Ditch	A ditch in agricultural fields used to help drain the fields.
Overland Flow	A point at which concentrated flow is seen to flow across the surface of the ground.

Use the Feature Indexing Tool (FIT) in SGAT to document the location of stormwater inputs. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where stormwater inputs are noted.

4.8 CHANNEL CONSTRICTIONS

Background

Channel constrictions include any natural or human structure which significantly narrows or “pinches” the width of the bankfull channel or floodprone area. Streams with different physical characteristics (i.e. channel slopes and entrenchment ratios) will respond differently to channel constriction. For example:

- Streams that are *not entrenched* (ER > 2.2) require access to the floodplain in order to maintain stability. If bridges or other constrictions are narrower than the bankfull width (worst case), or narrower than the flood prone width, then the channel constriction poses potential hazards.

- In *entrenched (ER < 1.4) or moderately entrenched (ER 1.4 – 2.2)* channels, bridges or other constrictions may be a problem when they are narrower than the bankfull width (especially in the absence of other bedrock controls), but may not pose as great a hazard if they are narrower than the floodprone width. Narrow bridges and culverts can constrict channels and cause debris jams and channel avulsions.

If a structure or feature is too narrow to pass bankfull or flood flows, water dams up behind it and may deposit sediment and/or scour the channel bed upstream or downstream of the structure or feature.

Deposition upstream: Backwater conditions may result if the constriction(s) are:
Undersized: Many bridges and culverts are undersized, causing water to back up above of the structure during high water events. This slowing down of flows leads to the deposition of sediment and debris upstream of the structure.
Associated with substantial filling of channel and/or floodplain: Large amounts of fill supporting a bridge or culvert can act as a poorly constructed dam, which can fail catastrophically if the bridge or culvert gets blocked by debris or sediment. Filling of the channel and floodplain can also raise the stream's water surface level and inhibit sediment transport, resulting in hazardous conditions.

Deposition downstream: When stream flows emerge from a constricted area, they may split (diverge), leaving a low velocity area in the channel that results in mid-channel deposition downstream of the structure.

Scour upstream: Upstream deposition may concentrate flows toward one or both banks or against the structure itself. These concentrated flows may result in scour upstream of the structure.

Scour downstream: A large drop at the downstream end of a structure, for instance between the lower lip of a culvert and the streambed, indicates that the water flowing through the culvert has scoured away the bed sediment. This is a sign of discontinuity in sediment transport due to culvert undersizing. Such "perched" culverts may also be fish migration barriers.

Alignment: Infrastructure that is located at the downstream end of a meander bend, where the water needs to turn a sharp angle to pass through the structure, is more susceptible to damage. Bridges and culverts that try to force water to make sharp bends are at risk of failing. If a structure is causing sediment deposition upstream, the channel may, over time, adjust its planform such that the structure becomes poorly aligned with the channel.

Evaluation
The Field Notes form has a table for entering up to 5 constrictions located along the segment (or reach). **Please record all features, then evaluate whether or not it is a constriction.** Record the type of structure or feature; the diameter /span of structure/feature (in feet or inches); and indicate whether the structure or feature is constricting the bankfull and/or floodprone width of the segment (or reach). Also indicate whether the structure or feature has deposition, scour, and alignment problems associated with the structures. Use the "none" checkbox if no constrictions were encountered along the segment (or reach).

Menu

Instream culverts	Structures under a transportation route through which the stream flows
Bridges	Structures under a transportation route under which the stream flows
Old abutments	Bridge abutments that no longer have a travel deck between them.
Bedrock outcrops	Bedrock outcrops on both the right and left banks between which the stream flows
Other	Other structures that constrict the channel, for instance rock rip-rap or gabions on both banks that constrict flood flows

To determine if the structure or feature is a constriction, measure its diameter or span to see if it is narrower than the bankfull width (Step 2.1) and floodprone width (Step 2.4).

Bridge and culvert assessment and survey protocols have been developed to help identify structures that are potentially impacting the geomorphic and habitat conditions of a stream (Appendix G). On the Field Notes form indicate whether bridge and culvert (B/C) assessments have been completed for structures in the segment (or reach).

If you find new structures during the Phase 2 Assessment than the Phase 1 FIT data must be updated. Also update the structure type in the DMS if applicable.

4.9 BEAVER DAMS (FIT)

Background

Intact, channel-spanning beaver dams may have a profound effect on channel geometry and the hydrology, ecology, and sediment storage characteristics of the stream. Most beaver dams are ephemeral, often "blowing out" with large runoff events. Unless beavers leave or have been removed from a reach, they rebuild. This dynamic regime of storage and release may increase the natural or inherent sensitivity of a stream.

Evaluation

Record the number of beaver dams in the segment (or reach), counting both intact and partially intact dams. Also note the total length of the segment where channel flows are influenced by the dams and their associated impoundments.

Figure 4.3 Beaver dam.

Sections of stream with two of more beaver dams in close proximity that are impounding water and are heavily influencing channel form and process should be broken out as a separate segment of the reach. **For these segments that are composed of a series of beaver dams and impoundments you should take photos, complete steps 1, 3, and 4 of the Field Notes form, and skip steps 2, 5, 6 (RHA) and 7 (RGA).** Use the Feature Indexing Tool (FIT) in SGAT to document the location of beaver dams. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where beaver dams are noted.

Step 5: Channel Bed and Planform Changes

When disturbed, streams go through a series of adjustments to regain equilibrium with the flow and sediment supply of their watersheds. These adjustments often involve a change in planform (or meander geometry) to achieve a change in channel slope (or steepness). Some planform changes, such as channel avulsions and flood chutes, are easy to spot in the field, while others are more easily observed through an analysis of an air photo time series. Several Step 5 parameters involve looking for signs that the stream bed sediments are building up (aggradation) or being eroded away (degradation). These two adjustment processes occur when changes in channel dimension or slope are imposed on the channel or in response to changes in stream flow or sediment load.

5.1 BED SEDIMENT STORAGE AND BAR TYPES

Background

Sediment deposition and storage in stream channels is a part of the equilibrium condition of many stream types. The sorting and distribution of sediment into the bars of the equilibrium channel, concentrates flow, enhances sediment transport, and results in a diversity of habitat types. When a stream is out of balance, sediment accumulation may raise the elevation of the stream bed and result in the formation of point bars, mid-channel bars, or islands that accentuate vertical and lateral channel adjustments.

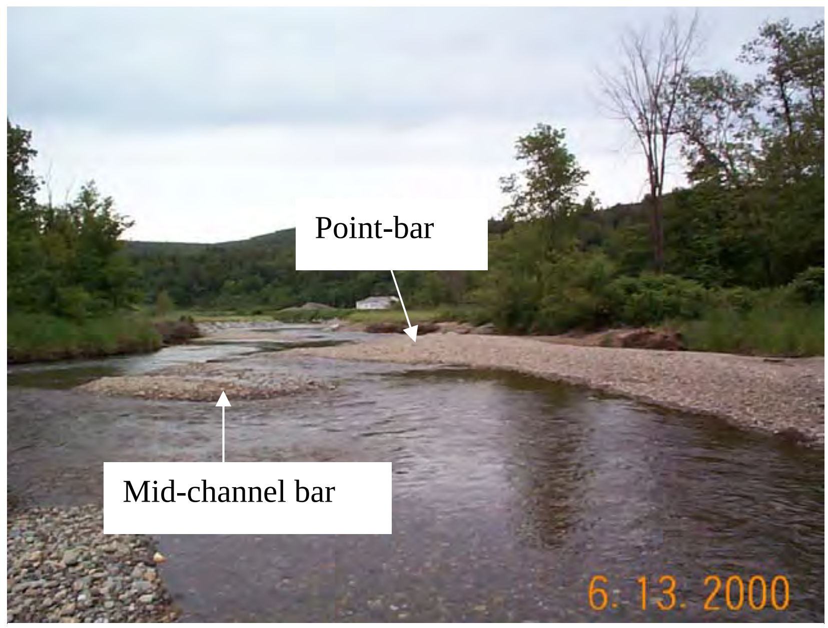


Figure 5.1 Mid-channel and point bars

Mid-channel bars are not attached to the banks and are generally found in straight reaches (Figure 5.1). They form as a result of the flow divergence that occurs around obstructions such as large boulders or rock outcrops or due to an over-widening of the channel. Unvegetated mid-channel bars indicate the bar has recently been formed and may be enlarging. The sediment source for these bars may be from bank failures, downcutting of the channel bed, or from upland sources, such as construction sites or road washouts.

Note there is one situation where the occurrence of a mid-channel bar(s) may not indicate problematic sediment deposition. Often a mid-channel bar will develop just downstream from where a tributary enters the channel as a result of sediments being delivered to the channel from the tributary. This is usually a localized deposition and may not indicate large-scale sediment deposition problems. If this is the only mid-channel bar or similar depositional feature you observe in the segment (or reach), then the segment is not likely being negatively affected by sediment deposition (see *Delta Bars* below).

Point bars are attached to a bank and are usually located on the inside curve of a channel bendway. Point bars are either devoid of vegetation or have only sparse non-woody vegetation usually covering less than 25 % of the bar surface area. Equal size, alternating point bars in a pool-riffle system may be a sign of equilibrium, while unequal size alternating bars and steep-faced bars may indicate channel adjustment.

Side (Lateral) bars are attached to a bank and are usually located on straighter segments of meandering streams or on stream types with very little sinuosity. Side bars are either devoid of vegetation or have only sparse non-woody vegetation usually covering less than 25 % of the bar surface area.

Diagonal (Transverse) bars are usually observed immediately upstream of meander bends that have been armored and/or truncated. The current running off the steep face of a diagonal bar flows towards the bank at an angle that is almost perpendicular to the bank, often causing excessive bank erosion.

Delta bars form where a tributary enters a mainstem river and deposits a load of sediment (Figure 5.2). Very large delta bars are indicators of the size, stability, and/or sediment load (natural or unnatural) of the tributary entering the mainstem. Large delta bars are not necessarily a sign of instability in the tributary, and may not necessarily cause channel adjustment in the receiving water. High gradient tributaries are usually important sources of coarse sediment for receiving waters.

Figure 5.2 Delta bar formed at the confluence of the First Branch of the White River and a small tributary.

Islands form as mid-channel features that remain stable at an elevation above normal high water such that they become vegetated. Islands are mid-channel features that have flow on either side during all but the very lowest flow conditions. They should not be confused with the vegetated lands that have the channel on one side and a flood chute on the other, the latter of which only carries flow during flood conditions. Islands may form and persist for different reason, including:

- They form as part of the deposition-erosion process associated with a braiding. "D" channels consist of many vegetated islands;
- They form as chute cut-offs, deepen, and persist in river systems that went through a dramatic shift in sediment supply. Many watersheds in Vermont have islands that formed as flood chutes when the rivers were clogged with sediment during severe deforestation at the end of the 19th century. In some systems, especially those where large dams were built, the sediment source was reduced dramatically over a short period of time leaving the islands in place

when stream power (and erosion) and sediment deposition were reduced. In other systems, the islands disappeared as deposition and erosion continued.

Evaluation

Indicate the number of each category of depositional feature types are present in the segment (or reach) based on the descriptions below. Very small and localized depositional features, such as a collection of fine gravels downstream of a large boulder, *should not* be considered in evaluating this parameter.

Menu

Mid-Channel	Sediment deposits in middle of channel with split flow
Point	Unvegetated sediment deposits located on inside of channel meander bend
Side (Lateral)	Unvegetated sediment deposits located along the margins of the channel in locations other than the inside of channel meander bends
Diagonal	Bars that cross the channel at sharp oblique angles, associated with transverse riffles
Delta	Sediment deposits where tributary enters mainstem channel, often fan-shaped
Islands	Well-vegetated mid-channel deposits of sediment
None	No deposits of sediment evident

5.2 FLOOD CHUTES, NECK CUT-OFFS, CHANNEL AVULSIONS, MIGRATION AND BRAIDING (FIT)

Background

Flood chutes, cut-offs, channel avulsions, major lateral migration and braiding (or bifurcation) are deposition-related features that strongly indicate the fluvial processes typical of response type stream reaches. Depending on the location and sediment regime of the reach within the watershed, these planform adjustments may be part of the equilibrium condition or associated with vertical adjustments and channel instability.

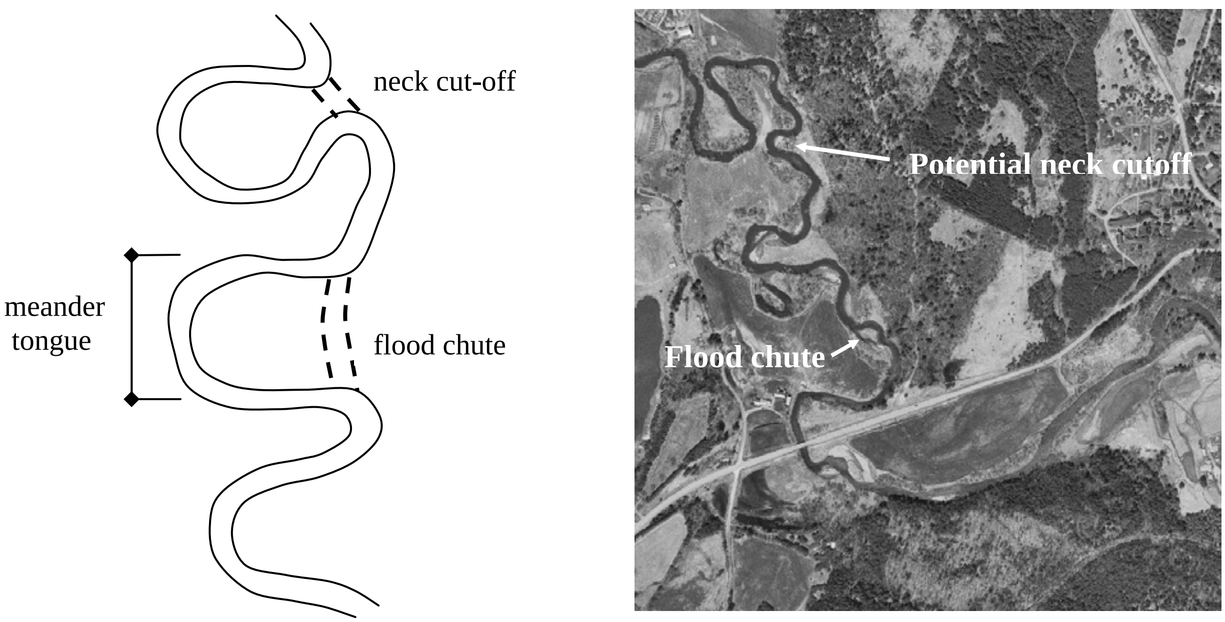


Figure 5.3 Aerial view of neck cut-offs and flood chutes that have or are about to result in channel avulsion.

A neck cutoff forms as two meanders migrate towards one-another and the neck of land between them is *about* to be cut off (Figure 5.3). Flood chutes occur when high flows form a channel across the base of the meander tongue (Pielou, 1998). An avulsion occurs when flood chutes and neck cutoffs become the main channel, completely abandoning the old channel. Sometimes a channel will avulse suddenly, without a neck cutoff or flood chute precursor. These sudden changes in stream channel locations are called channel avulsions. The old channels abandoned after the avulsion takes place look like dry rivers, or long, narrow wetlands, called oxbows.

Braided or bifurcated channels occur where the sediment supply is far in excess of the stream's ability to transport it. Braided channels may occur naturally where a stream transitions rapidly from a high to low gradient channel or where a channel has an extremely high sediment load due to natural erosion processes. They may also occur where human-induced erosion introduces a sediment load to a downstream location where the stream lacks the power to keep the sediment moving downstream. A high degree of sediment deposition may lead to multiple channels persisting even during low flow periods.

Evaluation

Indicate the number of flood chutes, neck cutoffs, channel avulsions, areas of major lateral migration or braiding / bifurcation within the segment (or reach).

Use the Feature Indexing Tool (FIT) in SGAT to document the downstream location of flood chutes, neck cut-offs, channel avulsions and braiding. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where flood chutes, neck cut-offs, channel avulsions and braining are noted.

5.3 STEEP RIFFLES OR HEAD CUTS (FIT)

Background

Steep riffles, as defined in these protocols, are typically associated with aggradation processes where a wedge of sediment drops out at some point along the channel (often at the head of bendways) and forms a steep face of sediment on the downstream side.

Head cuts are a sign of incision, or bed degradation, a lowering of the channel bed elevation through scour of bed material (Figure 5.4). As the water flows over a nick point in the channel bed, the water speeds up. The water that is falling down this steep slope has extra energy, and thus it digs away at the bed like a backhoe scooping its way upstream. The upstream movement of a headcut is stopped when it meets a grade control (i.e. bedrock, dam), or when the channel has re-established a gentler slope. Incision can

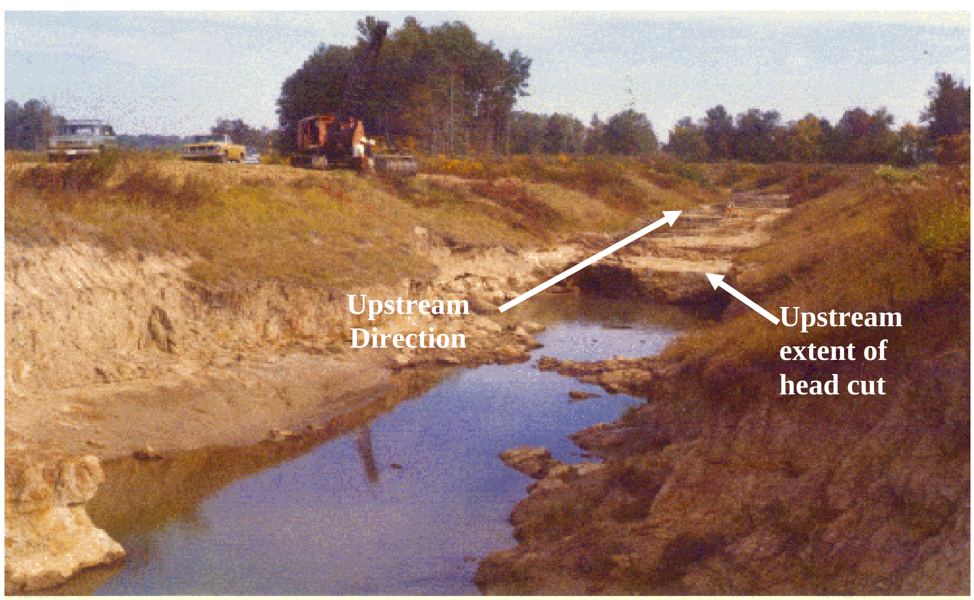


Figure 5.4 A head cut is a steep area in the streambed.

result in catastrophic (mass) bank failures and undermining of infrastructure near the channel, as streambeds have been known to lower tens of vertical feet along a mile length of stream. When a stream is incising in its valley, tributaries will also be affected. As the bed of the mainstem is lowered, headcuts will begin at the mouth of the tributary stream and move upstream "rejuvenating" the tributary stream and the valley through which it flows.

Evaluation
Record the number of head cuts and/or steep riffles, those features that are uncharacteristically steep (2-3 times greater slope than the average riffle within the segment or reach). Indicate "yes" or "no" as to whether headcuts are observed at the mouth of tributary streams that are likely to initiate tributary rejuvenation.

Use the Feature Indexing Tool (FIT) in SGAT to document the location of head cuts and steep riffles. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where head cuts and steep riffles are noted.

5.4 STREAM FORD OR ANIMAL CROSSING (FIT)

Background
Vehicle or animal crossings (Figure 5.5) at the wrong location in the meander geometry of the stream may increase the chance that a stream will avulse, or cut a new channel during a storm event.

Evaluation
Note whether a ford is present in the segment (or reach), and *mark its location on the field map.*

Menu

Yes	A vehicle or animal crossing is evident at the stream site.
No	A vehicle or animal crossing is not evident at the stream site.

Figure 5.5 Cows crossing the river at a stream ford.

Use the Feature Indexing Tool (FIT) in SGAT to document the location of stream fords or animal crossings. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where stream fords or animal crossings are noted.

5.5 CHANNEL ALTERATIONS (FIT)

Background

Activities defined as channel alteration include dredging, straightening, and bar scalping / gravel mining.

Dredging is the removal of sediments and other material from the channel. Though often done with the intention of releasing a "blocked" channel or containing floodwaters in the channel rather than the floodplain, dredging actually mobilizes more sediment in the long run. Channels are shaped over time to carry their water *and* sediment. When sediment is removed the channel slope increases, the stream power increases, and "hungry water" results. This hungry water removes sediment from the channel bed and banks. The resulting degradation and downstream aggradation may result in compromised stream habitat and/or erosion hazards.

Straightening is the process of changing the natural path of the river. It is the removal of meander bends, often done in village centers and along roadways, railroads, and agricultural fields. Straightening increases both the downstream and upstream hazard potential. When the stream is straightened the channel slope increases and there is a corresponding increase in flow velocity and stream power. Increased stream power often results in the erosion of the channel bed and banks, mobilizing sediment that was previously stable. In the eroded area the mobilization of these sediments may result in direct mortality of fish, amphibians, and reptiles, especially incubating eggs and young. Fish, amphibians, and aquatic insects are typically carried downstream, and population recovery may be slow if bed sediments remain highly mobile. The stream often loses access to the floodplain, and bed armor is disturbed. This extra force causes the river to degrade in the upstream direction, initiating head-cuts. Often the channel downstream of a straightened stretch aggrades as the sediment that used to be in the bottom of the river is re-deposited.

Bar Scalping / Gravel Mining: Evidence of gravel mining can be obtained from: a) historical information; b) the landowner; c) heavy equipment tracks on a gravel bar; and d) gravel berms pushed up on side of channel (Figure 5.6).

Both the "re-arranging" and/or removal of gravel can impact the morphology of the river. For example, where gravel is bermed up and bars removed to improve channel capacity, major damage may result from the changed morphology of the river. Damages may include widening and bank erosion, headcuts, and significant changes in the meander geometry and slope of the stream.

Figure 5.6 Gravel mining

Evaluation

A review of aerial photos is helpful in identifying where channels have been straightened, as former (now abandoned) channels are often evident on aerial photos. If in doubt as to whether or not the stream has been straightened, look for evidence, either on the ground or in an aerial photo, of the former course of the channel. In some cases, evidence of straightening can be found on soil maps as well. On the ground, look for oxbow wetlands or similar depressions in the river corridor that may indicate where the old channel meanders used to be.

Dredging Menu

Dredging	Evidence of removal of sediments and other material from the channel
gravel mining	Bar scalping: gravel has been removed from the top of bars Gravel mining: gravel has been removed from bars or bed of river
Commercial Mining	Historic (pre-1988) large-scale commercial extraction of gravel from channel.
None	No evidence of channel alterations

Use the Feature Indexing Tool (FIT) in SGAT to document the location of dredging, gravel mining and commercial mining. Dredging, gravlel mining and commercial mining are indexed as a point in the FIT. Please note whether the point is the exact location or the general location of the dredging. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where channel alterations are noted.

Straightening Menu

Straightening	Evidence that there has been the removal of meander bends and re-alignment of channel. Historically done in village centers and along roadways, railroads, and agricultural fields.
With Windrowing	Pushing gravel up from the stream bed onto the top of either bank as a part of the straightening of the river.

Straightening is indexed as a line in the FIT. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where straightening is noted. Record the length of straightening seen along the segment / reach on the Field Form to assist with confirming values calculated with the FIT.

COMMENTS

This space provides an opportunity to note observations about the site that have not been captured by the other parameters. It is critically important to provide a narrative description of the indicators you used to decide upon the bankfull elevation. See Appendix K for a list of indicators. You may also want to qualify any of the decisions that you made in choosing from the menus offered under each parameter. Finally, if any protocol described in the handbook is unclear given the conditions at your site, make note of this to inform the ANR River management Program on how this protocol can serve you better.

Step 6: Rapid Habitat Assessment (RHA)

Background

Physical processes, combined with chemical constituents and biological interactions, are what determine biological productivity and diversity; and, in essence, drive any given ecosystem. "Habitat", in the truest sense, is composed of all three of these components: physical, chemical, and biological. When evaluating the condition of an aquatic system, assessing the biota will give a good measure of how a system is doing; but once the status of the biota is determined, it is also important to understand why the system is supporting biota well, or why it is not, in order to make good management decisions. Looking closely at the physical processes and the resulting physical conditions that determine aquatic habitat, and thus the biota that inhabit it, and by comparing healthy systems to unhealthy systems, we can understand how fluvial processes impact aquatic habitat and biota.

Simply put, by assessing aquatic biota we can tell whether the system has a problem, and we may even be able to tell what type of problem we have (i.e. there is too much sediment or the water is too hot); but what we cannot answer by assessing biota alone is WHY do we have this problem. What happened in the stream system or watershed that resulted in too much sediment or water that is too warm? That is where understanding the physical processes that drive the stream or river system become necessary.

The U.S. Environmental Protection Agency (EPA) has developed and published Rapid Bioassessment Protocols (RBPs) which contain Rapid Habitat Assessment (RHA) protocols used to:

- Determine if a stream is supporting or not supporting aquatic life
- Characterize the existence and severity of habitat degradation
- Help to identify sources and causes of habitat degradation
- Evaluate the effectiveness of control actions and restoration activities

Evaluation

The parameters listed in the RHA evaluate the physical components of a stream (the channel bed, banks, and riparian vegetation) and how the physical condition of the stream affects aquatic life. The results can be used to compare physical habitat condition between sites, streams, or watersheds, and also serve as a management tool in watershed planning or similar land-use planning. Each parameter is scored on a scale of 0 (poor) to 20 (excellent). Parameter scores are totaled, and the total score is compared to a reference condition score. The reference condition is most useful if it is specific to the stream type being evaluated. References can be identified locally within the watershed or area of study, or regional references can be used.

It is important to learn these protocols well and practice them in the field before collecting data. This will improve your ability to gather data consistently.

Each of the parameters is described in detail in the following sections.

Field Form: Rapid Habitat Assessment

Defining High and Low Gradient Streams: There are two different RHA field forms; one to use for high gradient streams and one to use for low gradient streams. Before starting the RHAs determine whether you are surveying a high or low gradient stream**.**

> ***High gradient streams*** typically appear as steep cascading streams, step/pool streams, or streams that exhibit riffle/pool sequences (usually stream types A, B, and C). *Most of the streams in Vermont are high gradient streams.*

Low gradient streams typically appear slow moving and sinuous, and have less clearly defined riffles and pools and may even exhibit ripple-dune bed features (usually stream types E and sometimes C). These streams are often found in the large valley bottoms of the Champlain Valley and occasionally in high elevation meadows. The lower reaches of the Otter Creek, Lewis Creek, and Poultney River are all examples of areas you are likely to find low gradient streams. In choosing whether to use the high gradient or low gradient RHA field form, consider the following:

When to use high gradient RHA field form	When to use low gradient RHA field form
- reference stream type is A or B - reference stream type is C characterized by riffle/pool bed features and a dominant substrate size of gravel or larger	- reference stream type is E - reference stream type is C with ripple/dune or riffle/pool bed features and dominant substrate size is fine gravel, sand or smaller

Be sure to use the RHA field form that is appropriate for the **reference** stream type of the segment (or reach), as determined in Phase 1 and verified in Phase 2 Step 2.

In the RHAs you will evaluate 10 parameters. Three of these parameters have two versions, an (a) and a (b), which correspond to the two gradient categories, high and low, respectively. If you are surveying a high gradient stream always use option (a), and use option (b) when surveying low gradient streams.

Scoring Guidance: Begin by determining which condition category (reference to poor) matches the conditions you are observing in the stream segment (or reach). For every habitat parameter there are values, ranges, and descriptive text for each condition category that will help you determine the appropriate condition category (i.e. 0-25% embedded). Be sure to read each category completely before determining the condition category.

Once you have chosen the appropriate category, consider the text within the category box more closely to determine which of the 5 score values in the category best matches the condition you are observing in the field. The range of scores within each condition category gives you flexibility in “describing” what you observe in the field. For example, when there is a range of percentages or values presented in the category description, i.e. 0-25% embedded, and your observations indicate that the parameter condition is more towards the optimal end of that range, i.e. 0% embedded, you should choose the highest score within that category to indicate that the habitat parameter was in the highest potential condition for that category. Similarly, if the condition category lists several components that should be present, but you observe that some of these components are missing or scarce, you should score at the low end of the score values within that condition category. Some of the habitat parameters have scoring guidance written into each condition category box, which you should use to determine parameter scores.

Please do not skip parameters, as this will skew the score totals. If you are unsure about how to score a parameter use your best judgment and make a note in the Comments section on the Field Notes form of any questions, concerns, or reasons you had trouble evaluating a parameter.

6.1 EPIFAUNAL SUBSTRATE / AVAILABLE COVER

	Reference	Good	Fair	Poor
Epifaunal Substrate/ Available Cover	Greater than 70% (50% for low gradient streams) of stream bed and lower banks covered with **mix** of substrates favorable for epifaunal colonization and fish cover; substrates include snags, submerged logs, undercut banks, and unembedded cobbles and boulders (for high gradient)	40-70% (30-50% for low gradient streams) of stream bed and lower banks covered with a **mix** of substrates favorable for epifaunal colonization and fish cover	20-40% (10-30% for low gradient streams) of stream bed and lower banks covered with substrates favorable for epifaunal colonization and fish cover; few substrate types present	Less than 20% (10% for low gradient streams) of stream bed and lower banks covered with substrates favorable for epifaunal colonization and fish cover; few substrate types present

Definitions:

Epifaunal – "epi" means surface, and "fauna" means animals. Thus, "epifaunal substrate" is structures on the streambed that provide surfaces on which animals can live. In this case, the animals are aquatic invertebrates (such as aquatic insects and other "bugs"). These bugs live on or under cobbles, boulders, logs, and snags, and the many cracks and crevices found within these structures. In general, older decaying logs are better suited for bugs to live on/in than newly fallen "green" logs and trees.

Cover – "cover" is the general term used to describe any structure that provides refugia for fish, reptiles or amphibians. These animals seek cover to hide from predators, to avoid warm water temperatures, and to rest, by avoiding high velocity water. These animals come in all sizes, so even cobbles on the stream bottom that are not embedded with fine sands and silt can serve as cover for small fish and salamanders. Larger fish and reptiles often use large boulders, undercut banks, submerged logs, and snags for cover.

Figure 6.1A Reference epifaunal substrate and cover.

Evaluation:

When evaluating epifaunal substrate and available cover look at the relative **quantity** and **variety** of natural structures **in the stream**. In general, consider the entire bankfull area of the channel, but give greater weight to the area of the channel that remains wetted during lower flow conditions (such as those during late summer). A wide variety and/or abundance of submerged structures in the stream provide bugs and fish with a large number of niches, thus increasing habitat diversity. As variety and abundance of cover decreases, habitat structure becomes monotonous, diversity decreases, and the potential for fish and bug populations to recover following disturbance decreases. **The greater the abundance and variety of structures serving as epifaunal substrate and cover, the higher the score.**

Figure 6.1B Poor epifaunal substrate and cover.

In ***high gradient*** streams look to see that there are riffles and runs with a wide variety of particle sizes (gravels to boulders). Riffles and runs are critical for maintaining a variety and abundance of invertebrates in most high gradient streams, and they serve as spawning and feeding habitat for many fish. The extent and quality of the riffle is an important factor in the support of a healthy biological condition in high gradient streams. Riffles and runs offer a diversity of habitat through variety of particle sizes, and, in many small high gradient streams, will provide the most stable habitat. In ***low gradient*** streams, snags and submerged logs are among the most productive habitat structures for bug colonization and fish cover. Low gradient streams typically do not have the larger rock substrates found in high gradient streams, but often contain more and larger woody material such as whole fallen trees and log jams.

6.2a EMBEDDEDNESS (high gradient)

	Reference	Good	Fair	Poor
Embeddedness (high gradient)	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment. Little open space between particles.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment. Almost no open space between particles.

Definition:
Embeddedness: is a measure of the amount of surface area of cobbles, boulders, snags and other stream bottom structures that is covered with sand and silt. An embedded streambed may be packed hard with sand and silt such that rocks in the stream bottom are difficult or impossible to pick up. The spaces between the rocks are filled with fine sediments, leaving little room for fish, amphibians, and bugs to use the structures for cover, resting, spawning, and feeding. A streambed that is **not** embedded has loose rocks that are easily removed from the stream bottom, and may even "roll" on one another when you walk on them.

Evaluation:
Embeddedness is a result of large-scale sediment movement and deposition, and is a parameter evaluated in the riffles and runs of high-gradient streams. The rating of this parameter may be variable depending on where the observations are taken. To avoid confusion with sediment deposition (another habitat parameter), make observations of embeddedness in the upstream and central portions of riffles in an area containing cobble substrates. Pick up several rocks of at least softball size, up to volleyball size. As you lift the rock from the stream bottom look down through the water to see if a plume of fine sediment is released from around the rock as you dislodge it from the stream bottom. If so, the rock is embedded. In fast flowing water it may be difficult to see through the water to observe the sediment plume. If the rock is difficult to extract from the stream bottom, it is likely embedded.

To estimate the **percent embeddedness**, observe the surface of the rocks you dislodge from the streambed. If a rock is embedded the surface of the rock that was in contact with the streambed will be "clean", compared to the upper surface of the rock that was exposed to the water. This upper surface will be slimy and often dark in color, due to a covering of algae. If this clean surface extends over the bottom of the rock and up the sides, then the rock was embedded. The algae cannot colonize the surface area of the rock that is covered with silt and sand. Estimate the percent of the total surface area of the rock that is "clean" (embedded). Do this for several rocks and take the average percent embeddedness. Determine into which quartile your average percent embeddedness value falls (0-25%, 25-50%, 50-75%, or 75-100%). Score embeddedness values at the lower end of a quartile with a higher score within the range of scores available for that quartile. The lower the percent embeddedness the higher the rating.

Figure 6.2A Reference embeddedness

Figure 6.2B Poor embeddedness

6.2b POOL SUBSTRATE CHARACTERIZATION (low gradient)

	Reference	Good	Fair	Poor
Pool Substrate Characterization (low gradient)	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.

Since low gradient streams are naturally depositional areas, i.e. they accumulate fine sediments, it is not appropriate to evaluate embeddedness in these streams. The bed of a low gradient stream is usually composed largely of gravel, sand and silt. These sediment types often favor the establishment of aquatic vegetation, which provides surface area for aquatic invertebrates and cover for fish.

Evaluate the **type** and **variety** of bottom substrates found in pools. Firmer sediment types (i.e. gravel, sand) and rooted aquatic plants support a wider variety of organisms than a pool substrate dominated by mud or bedrock and no plants. In addition, a stream that has a uniform substrate in its pools will support fewer types of organisms that a stream that has a variety of substrate types.

Figure 6.3B Poor pool substrate condition

Figure 6.3A Reference pool substrate condition

6.3a VELOCITY/DEPTH PATTERNS (high gradient)

	Reference	Good	Fair	Poor
Velocity/Depth Patterns (high gradient)	All 4 velocity/depth patterns present: slow-deep, slow-shallow, fast-deep, fast-shallow. Slow is < 1 ft/s. (0.3 m/s), deep is > 1.5 ft (0.5 m).	Only 3 of the 4 patterns present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 patterns present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth pattern (usually slow-deep).

Definitions:
Patterns of water velocity and depth are important features of habitat diversity in high gradient streams. Fish, amphibians, and aquatic invertebrates use different velocities and depths at different life stages, for different daily activities, or may specialize in using a particular velocity/depth pattern all their lives. The four patterns are: (1) slow-deep, (2) slow-shallow, (3) fast-deep, and (4) fast-shallow. "Deep" is considered to be 1.5ft (0.5 m) or greater. "Fast" is defined as 1 ft/s (0.3 m/s) or greater. The occurrence of these 4 patterns relates to the stream's ability to provide and maintain a stable aquatic environment. It is closely tied to the distribution of bed features and the overall geomorphic condition of the stream. Bed

features are defined and relate to velocity/depth patterns as follows:

<u>Step</u>**:** A step is a **fast-shallow** bed feature common in high gradient streams (> 2%). Steps are composed of large boulders and cobbles lined up across the stream that result in a near-vertical drop in the streambed. Steps are important for providing grade-control, and for dissipating energy. As water flows over a step it takes various flow paths, thus dissipating stream energy through turbulence and vertical drop.

<u>Riffle</u>**:** A riffle is a **fast-shallow** bed feature common in moderate gradient streams (< 2%). A riffle has relatively shallow depths, coarser bed material and a steeper gradient when compared to the rest of the channel. Riffles are usually found between pools and in straight reaches. The **fast-shallow** water flowing over the coarse bed material introduces a lot of oxygen into the water. These are the critical areas where the bugs (benthic macro-invertebrates) live.

<u>Run</u>: Runs are **fast-deep** bed features common in high and moderate gradient streams (>1 %). Runs are often located just downstream of riffles, leading into pools in stable pool-riffle streams. They are also found along straight sections of channel and gentle meanders. Runs may be the dominant bed feature in disturbed stream channels.

<u>Pool</u>: Pools are **slow-deep** bed features, generally found at the outside of meander bends in riffle-pool streams, and between steps in step-pool streams. Pools are also commonly associated with large woody debris, large boulders and bedrock, and similar channel obstructions that result in scour of the channel bed. Typically pool bed material is finer than the material found in riffles.

<u>Glide</u>: Glides are **slow-shallow** water that form where the bed of the channel rises from the deep scour of the pool to the head of a riffle. A glide is often called a “pool tail”.

Evaluation:

The best habitat will have all 4 velocity/depth patterns present. You may find one of these patterns represented in an entire riffle, step, or pool, or, more commonly, you may find several of these patterns within one riffle or pool. For example, a pool usually has **slow-deep** water at its center or focused to one side of the pool, with **slow-shallow** water in the surrounding pool edges. In high gradient streams characterized by cascades and abundant boulders you are likely to find different velocity/depth patterns within several feet of each other, as water pushes between boulders, eddies back behind them, and tumbles over them.

Figure 6.4A Reference velocity/depth patterns. Arrows indicate different patterns.

Figure 6.4B Poor velocity/depth. Only slow-shallow pattern present.

6.3b POOL VARIABILITY (low gradient)

	Reference	Good	Fair	Poor
Pool Variability (low gradient)	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.

Definition:
This parameter rates the overall mixture of pool types found in streams, according to **size** and **depth**. The 4 pool types are: (1) large-shallow, (2) large- deep, (3) small-shallow, (4) small-deep. Large pools are wider and longer than ½ the average bankfull channel width. Deep pools are >3' deep.

Evaluation:
A stream with many pool types will support a wide variety of aquatic species. Rivers with low sinuosity (few bends) and monotonous pool characteristics do not have sufficient quantities and variety of habitat to support a diverse aquatic community. **An even mix of all pool types is most desirable.** In the absence of some pool types, it is better to have deep pools over shallow pools. All small-shallow pools or lack of pools entirely are the least desirable conditions.

Figure 6.5A Reference pool variability

Figure 6.5B Poor pool variability

6.4 SEDIMENT DEPOSITION

	Reference	Good	Fair	Poor
Sediment Deposition	Little or no enlargement of mid-channel bars or point bars and < 5% (20% in low gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% in low gradient streams) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% in low gradient streams) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; > 50% (80% in low gradient streams) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.

Definitions:
Sediment deposition is the accumulation of sediments on the streambed that raises the bed elevation. Sediment deposition may result in the formation of point bars, mid-channel bars, or islands.

<u>Point Bars</u> **-** unvegetated deposits of sediment located on the inside of a channel bendway, adjacent to the stream bank, typically higher than the average water level.

Mid-channel Bars: unvegetated deposits of sediment located in the middle of the channel away from the banks that split the channel flow, except under very low flow conditions; typically higher than the average water level; generally found in areas where the channel runs straight.

Islands – mid-channel bars that are above the average water level and often above the bankfull elevation; vegetated with well-established woody vegetation.

Evaluation:
This parameter evaluates the amount of sediment deposition that has accumulated in pools and the changes that have occurred to the streambed as a result of the deposition. Deposition occurs from large-scale movement of sediment. It results in the formation of bars and islands and the filling-in of runs and pools. Usually deposition is evident in areas that are obstructed by natural or manmade debris and areas where the stream flow velocity decreases, such as on the inside of bends.

High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many aquatic organisms. While point bars are typical of a healthy stream system, if they are not excessively large or steep, mid-channel bars are indicative of channel instability, and usually occur when the channel is over-widened and thus does not have enough stream power to move the sediment through the channel. The channel may appear braided. While this is a natural condition in parts of the country (i.e. in glacial-fed rivers), it is not naturally common in Vermont.

Look for the presence of unvegetated mid-channel bars, filling-in of pools with fine sediments, and overly steep and large point bars (compared to other point bars in the system) as signs of sediment deposition. Refer to section 5.1 on the Field Notes form. Note there is one situation where the occurrence of a mid-channel bar(s) may not indicate problematic sediment deposition. Often a mid-channel bar will develop just downstream from where a tributary enters the channel as a result of sediments being delivered to the channel from the tributary. This is usually a localized deposition and does not indicate large-scale sediment deposition problems. If this is the only mid-channel bar or similar depositional feature you observe in the segment (or reach), then the segment is not likely being negatively affected by sediment deposition.

Figure 6.6A Reference sediment deposition

Figure 6.6B Poor sediment deposition

6.5 CHANNEL FLOW STATUS

	Reference	Good	Fair	Poor
Channel Flow Status	Water reaches base of both lower banks, and <10% of channel bed substrate is exposed.	Water fills >75% of the available channel; or <25% of channel bed substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.

This parameter evaluates the degree to which the channel is filled with water. It includes evaluation of whether a system is being affected by 1) water withdrawals and/or 2) stream adjustments in response to changes in land use, but can also consider naturally occurring low flow conditions due to a channel's underlying geology. The flow status will change as the channel enlarges (e.g., aggrading stream beds with actively widening channels) or as flow decreases as a result of dams and other obstructions, diversions for irrigation, or drought. When water does not cover much of the streambed the amount of suitable substrate for aquatic organisms is limited. In high-gradient streams, cobble and gravel substrates in riffles are exposed; in low-gradient streams, the decrease in water level exposes logs and snags, thereby reducing available habitat.

When measuring this parameter you should consider the area from the toe of streambank to the opposite streambank. Whether due to natural runoff patterns or human-induced impacts, streams have different flow characteristics ranging from intermittent, to variable, to uniform. A stream that is naturally variable or intermittent is more likely to exhibit poorer channel flow status condition than a uniform stage stream. Be sure to evaluate only what you observe on the day of survey; however, if you have knowledge that the stream flow is high due to a recent storm or goes dry on a regular basis, or similar knowledge due to your familiarity with the stream, be sure to include these as a comment on the bottom of the field form.

Flows are decreased if large quantities of water are withdrawn or impounded for:

$ hydropower
$ irrigation
$ public water supplies
$ snowmaking
$ recreation and flood control reservoirs

Figure 6.7B Poor channel flow status

Figure 6.7A Reference channel flow status

6.6 CHANNEL ALTERATION

	Reference	Good	Fair	Poor
Channel Alteration	Channelization in the form of dredging, straightening, berms or streambank armoring absent; stream with natural pattern.	Some channel alterations present along 10-20% of segment, usually in areas of bridge abutments; evidence of past channelization, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization along 20-80% of stream segment ; riprap or armoring present on both banks.	Over 80% of the stream segment channelized and disrupted. Instream habitat greatly altered or removed entirely.

Definitions:
Activities defined as channel alteration include: berms (Section 1.3), dredging (5.4), straightening (5.4), and streambank armoring (3.1, bank revetments).

Evaluation:
This parameter is a measure of large-scale changes in the shape of the stream channel. Many streams in urban and agricultural areas have been straightened, deepened, or diverted into concrete channels, often for flood control, irrigation, or other property protection purposes. Such streams have far fewer natural habitats for fish, aquatic invertebrates, and plants than do naturally meandering streams. Channel alteration is present when armoring or berms are present; when the stream is straight for long distances, or when dredging has occurred. Evidence of past dredging may be difficult to determine in the field; look for excavation scars or spoil piles. Local knowledge of nearby residents or town/state officials may also help. (You may have acquired information in Phase 1 and Section 5.4 of Phase 2 that will help you assess channel alterations.) In general, channel alteration that occurred several decades ago from which the stream is in the process of recovering rates higher than **recent** channelization of similar magnitude.

Figure 6.8A Reference condition: channel alteration absent.

Figure 6.8B Poor condition: excessive channel straightening.

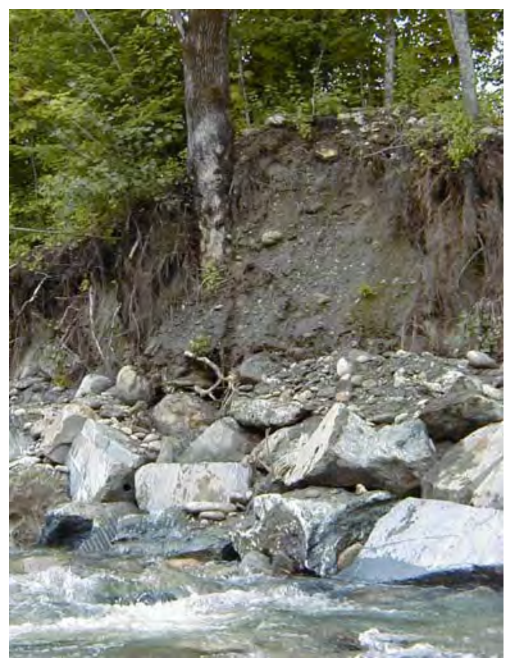


Figure 6.8C Example of berm and streambank armoring with stone wall. Dirt on top of stone wall is an old berm; note large tree growing in berm that was present before berm was constructed. Saplings on top of berm have grown up since berm was built several decades ago. Berm height above average water level is approximately 10 feet.

6.7a FREQUENCY OF RIFFLES / STEPS (MORPHOLOGICAL DIVERSITY) (high gradient)

	Reference	Good	Fair	Poor
Frequency of Riffles/Steps **(high gradient)**	Occurrence of riffles/steps relatively frequent; ratio of distance between riffles is 5-7 times (steps 3-5 times) stream width; variety of habitat is key. In streams where riffles/steps are continuous, presence of boulders or other large, natural obstruction is important.	Occurrence of riffles/steps infrequent; distance between riffles is 7-15 times (steps 5-15 times) stream width.	Occasional riffle/step or bend; bottom contours provide some habitat; distance between riffles/steps is 15 to 25 stream widths.	Generally all flat water or shallow riffles/steps; poor habitat; distance between riffles/steps is >25 stream widths. Mostly runs.

Definition:
Frequency of Riffles/Steps is the ratio of the distance between riffles or steps to the stream width. For high gradient streams and/or streams that are confined by their valleys, where distinct riffles are uncommon, step frequency can be used as a measure of meandering, or sinuosity (see Section 6.7b). Typically these streams have low sinuosity, but may exhibit good step frequency due to the presence of boulder "steps" and cascades that serve to absorb the stream energy much like meanders do in a sinuous, low gradient, unconfined river. This is particularly true in headwater streams.

Evaluation:
This parameter measures the spacing of riffles, and thus the heterogeneity of habitat, or "morphological diversity", in a stream. Riffles and steps are usually separated by pools and/or runs. Frequent riffles means there will also be frequent pool and runs, ensuring a diversity of channel morphologies and thus a diversity of habitat. Refer to the data you recorded in section 2.11 and Table 1 below to determine the riffle/step spacing for the segment you are evaluating.

In unconfined streams that are able to meander back and forth within their valley it is helpful to also consider the sinuosity of the channel when evaluating riffle/step spacing. Typically the greater the sinuosity the lower the riffle/step spacing will be in a stable system. A moderate to high degree of sinuosity provides for diverse habitat and fauna, and the stream is better able to absorb surges when the stream flow fluctuates as a result of storms. The absorption of increased stream energy by bends in the stream protects the channel from excessive erosion during flooding and provides refugia for fish and aquatic invertebrates.

Figure 6.9A Reference frequency of riffles

In some streams, you may need to refer to topographic maps and orthophotos in gain an appreciation of the stream's riffle frequency (or sinuosity). You may also need to look at a stretch of stream longer than your sampling site.

Table 6.1: Typical riffle / step spacing by stream type.

Stream Type	Spacing	Feature
A	1-3 times Wbkf	cascade / step
B	3-5 times Wbkf	step / riffle
C & E	5-7 times Wbkf	riffle

Figure 6.9B Poor frequency of riffles / steps

6.7b CHANNEL SINUOSITY (low gradient)

	Reference	Good	Fair	Poor
Channel Sinuosity (low gradient)	The bends in the stream increase the stream length 2.5 to 4 times longer than the straight down-valley length.	The bends in the stream increase the stream length 1.5 to 2.5 times longer than the straight down-valley length.	The bends in the stream increase the stream length 1 to 1.5 times longer than the straight down-valley length.	Channel straight; waterway has been channelized for a long distance.

Definition:
Sinuosity is the ratio of channel length to direct down-valley length. Sinuosity may also be expressed as the ratio of down-valley slope to channel slope (see Section 2.9). It is used to evaluate the "curviness" of the stream. Curves, or meanders, help to absorb and dissipate stream energy. Those streams with a high sinuosity have many meanders, while straighter streams will have a low sinuosity. Sinuosity is in part a reflection of the slope of the channel, and the slope of the valley. Steep streams in steep valleys have low sinuosity, while low gradient streams meandering through broad valleys can be highly sinuous.

Evaluation:
This parameter evaluates the meandering, or sinuosity, of the stream. A high degree of sinuosity provides for diverse habitat and fauna, and the stream is better able to handle surges when the stream fluctuates as a result of storms. The absorption of this energy by meanders protects the stream from excessive erosion and flooding and provides refugia for benthic invertebrates and fish during storm events. To gain an appreciation of this parameter in low gradient streams, a longer segment or reach than that designated for sampling may be incorporated into the evaluation. In some situations, this parameter may be rated from viewing accurate topographical maps or recent aerial or orthophotos. Refer to your evaluation of sinuosity in Section 2.9 on the Field Notes form when scoring this parameter.

The "sequencing" pattern of the stream morphology is important in rating this parameter. In "oxbow" streams meanders are highly exaggerated and transient. Natural conditions in these streams are shifting channels and bends, and alteration is usually in the form of flow regulation and diversion. A stable channel is one that does not exhibit progressive changes in slope, shape, or dimensions, although short-term variations may occur during floods (Gordon et al. 1992).

Figure 6.10A Reference sinuosity

Figure 6.10B Poor sinuosity

6.8 BANK STABILITY

	Reference	Good	Fair	Poor
Bank Stability (score each bank) *Note: determine left or right side by facing downstream.*	Banks stable; evidence of erosion or bank failure absent or minimal; < 5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly re-vegetated. 5-30% of bank in segment (or reach) has areas of erosion.	Moderately unstable; 30-60% of bank in segment (or reach) has areas of erosion; high erosion potential from crumbling, unvegetated banks during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.

This parameter measures whether the stream banks are eroded or have the potential for erosion. Steep banks are more likely to collapse and suffer from erosion than are gently sloping banks, and are therefore considered to be unstable. Signs of erosion include crumbling, unvegetated banks, freshly exposed tree roots, and exposed soil. Refer to Section 3.1 on the Field Notes form.

Eroded banks indicate a problem of sediment movement and deposition, and suggest a scarcity of cover and organic input to streams. Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.

Figure 6.11A Reference bank stability

Figure 6.11B Poor bank stability

6.9 BANK VEGETATIVE PROTECTION

	Reference	Good	Fair	Poor
Bank Vegetative Protection **(score each bank)** *Note: determine left or right side by facing downstream.*	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or herbaceous vegetation; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.

Definitions:
Immediate Riparian Zone**:** This is the area where the root binding capacity of the vegetation serves to stabilize the streambank. This is a function of bank height. Grasses cannot stabilize banks that are over ½ meter high (~1.5 ft.), and shrubs and woody vegetation cannot stabilize banks that are over 1.5 meters (~4.5 ft.). Banks that are higher than 1.5 meters are beyond the root-binding capacity of the vegetation.

Potential plant height**:** the height to which a plant, shrub or tree would grow if undisturbed.

Evaluation:
This parameter measures the amount of vegetative protection afforded to the streambank and the near-stream portion of the riparian zone. Refer to Section 3.1 on the Field Notes form. The root systems of plants growing on stream banks help hold soil in place, thereby reducing the amount of erosion that is likely to occur. This parameter supplies information on the ability of the bank to resist erosion as well as some additional information on the uptake of nutrients by the plants, the control of instream scouring, and stream shading. Banks that have full, natural plant growth are better for fish and aquatic macroinvertebrates than are banks without vegetative protection or those shored up with concrete or riprap. This parameter is made more effective by defining the native vegetation for the region and stream type (i.e., shrubs, trees).

Figure 6.12A Reference riparian

In some regions, the introduction of exotics has virtually replaced all native vegetation. The value of exotic vegetation to the quality of the habitat structure and contribution to the stream ecosystem must be considered in this parameter. In areas of high grazing pressure from livestock or where residential and urban development activities disrupt the riparian zone, the growth of a natural plant community is impeded and can extend to the bank vegetative protection zone. Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.

Figure 6.12B Poor riparian buffer

Riparian buffers provide structure to the banks of a stream. The roots of the vegetation hold the soil in place, and the grass, shrubs or trees provide friction to slow down the floodwaters. Vermont ANR has developed guidance on the width of riparian zones for stream stability, habitat, and removal of nutrients, sediment and bacteria.

6.10 RIPARIAN VEGETATIVE ZONE WIDTH

	Reference	Good	Fair	Poor
Riparian Vegetative Zone Width (score each side of channel)	Width of **naturally vegetated** riparian zone >100 feet; human activities, (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) and grazing have not impacted zone.	Width of riparian zone 50 - 100 ft; human activities and grazing have impacted zone only minimally.	Width of riparian zone 25 - 50 ft.; human activities and grazing have impacted zone a great deal.	Width of riparian zone < 25 feet: little or no riparian vegetation due to human activities.

Evaluation:

This parameter measures the width of natural vegetation from the edge of the stream bank out through the riparian zone. Refer to section 3.2 on your Field Notes form. The vegetative zone serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides habitat and organic input to the stream. A relatively undisturbed riparian zone supports a robust stream system; narrow riparian zones occur when roads, parking lots, fields, lawns, animal pasture, bare soil, rocks, or buildings are near the stream bank. Residential developments, urban centers, golf courses, and animal pasture are the common causes of anthropogenic degradation of the riparian zone. Conversely, the presence of "old field" (i.e., a previously developed field not currently in use and in the process of growing up to shrubs and trees), paths, and walkways in an otherwise undisturbed riparian zone may be judged to be inconsequential to altering the riparian zone and may be given relatively high scores. Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.

6.11 RAPID HABITAT ASSESSMENT SCORE

Add up the scores circled for the ten habitat parameters (remembering that parameters 8, 9, and 10 have left and right bank scores to add) and divide by 200, which is the total possible score for the RHA.

Use the following table to evaluate the habitat condition of the stream site.

Table 6.2: Phase II Assessment Score Ranges

0.85 – 1.00	Reference Condition
0.65 – 0.84	Good Condition
0.35 – 0.64	Fair Condition
0.00 – 0.34	Poor Condition

Step 7: Rapid Geomorphic Assessment (RGA)

Background

The Rapid Geomorphic Assessment evaluates degradation, aggradation, widening, and planform adjustment processes on the RGA field form (Steps 7.1 to 7.4). The RGA provides a method to document the current adjustment processes occurring in a segment (or reach) and to determine the stage of channel evolution that best describes the set of current and historic adjustment processes observed (Step 7.5). Finally, in Step 7.6 and 7.7, you can use the RGA scores and existing stream type to develop an overall condition score and sensitivity rating for your reach.

A channel adjustment process occurs due to natural causes or human activity that has or will result in a change to the floodplain and/or channel condition and, in some cases, even the valley characteristics. An analysis of channel adjustment involves determining the departure of the stream's existing conditions from those of a reference stream of the same type, and understanding the physical processes at work in the stream as it comes into balance with the flow and sediment regimes of its watershed. Channel evolution models developed and verified by researchers studying channel adjustment in North America and Europe have been found to be useful in Vermont in understanding why and how streams are responding to various watershed, floodplain, and channel modifications (Appendix C).

In a Phase 2 assessment, stream condition is based on the magnitude of adjustment processes underway and the degree to which the stream has departed from the reference, or equilibrium condition. If a stream changes such that it becomes ineffective, or conversely, too effective, at transporting the flow, sediment, and debris produced in its watershed, adjustments occur in the dimension (width and depth), pattern (meandering), and profile (slope) of the channel as the energy grade of the stream (affected by parameters such as channel slope, depth, and velocity) comes back into balance with the current watershed inputs.

Evaluation

Three separate RGA forms have been prepared for streams in different settings; one for streams in narrowly confined and semi-confined valley types (confinement ratio < 4), a second for streams in narrow, broad, or very broad valley types (confinement ratio ≥ 4, typically riffle-pool or ripple-dune stream types), and a third for plane bed stream types in semi-confined to narrow valley types (confinement ratio ≥ 3 and ≤ 5). The descriptions of adjustment processes differ between these forms and attempt to capture the different erosion and depositional processes that occur in these different confinement and slope settings. The greater channel depths and slopes that are present in confined channels under flood conditions, as compared to unconfined stream systems, affect the type of bed forms and depositional features formed, as well as the erosion processes that occur. Be sure to use the appropriate RGA field form based on the **reference** stream type and confinement, and not necessarily the existing confinement type circled in Step 1.5 of the Field Notes form. If the stream is plane bed **by reference**, then use the plane bed RGA form.

Selecting a Reference Stream Type: Start the RGA by assigning the **reference** stream type that would exist in the geographic, geologic, and climatic setting you are working in, and compare the characteristics of this stream type to those of the **existing** stream type you observe in the field. Use the reference stream type assigned in the Phase 1 assessment and confirmed in the Phase 2 assessment. Reference stream type is evaluated on the basis of watershed zone, confinement, and valley slope in Phase 1, in addition to entrenchment, width/depth ratio, sinuosity, channel slope, substrate d50, and bed form determined in Phase 2. Any change in the existing stream type characteristics from those of the reference stream type may explain the adjustment process and condition you observe in the segment (or reach). For example, a stream assessed in Phase 2 as an "F Plane Bed" stream type that exists in a physical setting determined in Phase 1 to be more consistent with a "C Riffle-Pool" stream type may have become more entrenched in its valley. In this scenario the channel would likely exhibit characteristics of a channel that has gone through the degradation process, which you would confirm in completing Step 7.1 of the RGA field form. In this case, the major adjustment that took place describes a plausible evolution of the channel from the selected reference condition to the existing stream condition observed in the field.

Understanding the reference condition is important in understanding past channel adjustments, predicting future adjustments, and most importantly, deciding what management alternatives should be pursued.   Both natural and human-caused changes to a stream channel may complicate the selection of the appropriate reference stream type.

***Assigning a Modified Reference Stream Type**:* Watershed land use conversion, alone or in combination with channel, valley, floodplain and/or flow 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 stream type that historically existed may be more consistent with the river corridor conservation goals 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.   If you decide to assign a modified reference stream type to a segment (or reach), check the "Modified" box in the header on the RGA field form. In these cases, evaluate the stream adjustment and stream type departure, channel evolution stage, stream condition, and stream sensitivity on the comparison of existing conditions to those equilibrium conditions that are typical of the modified stream type. Typical situations for which one might choose a modified reference stream type include:

> ***Streams with dams*** that create various types of impoundments. For large impoundments, where the reservoir is significantly wider than the channel bankfull width, do not complete an RGA. For riverine impoundments, where the impoundment is not significantly wider than the river itself, there may be segments for which completing an RGA makes sense. For instance, a segment located at the upstream end of an impoundment may be aggrading and widening, and thus evaluated as "in adjustment." If you have checked the modified reference box in the RGA heading, write "(impounded)" next to the stream type, and then do not identify the adjustments you see as "stream type departures" under steps 7.1 (degradation) and step 7.2 (aggradation). In impounded segments you may elect to forego the completion of Steps 7.1 through 7.6 and use the reference stream type of the segment as the basis of a sensitivity rating.
>
> ***Streams in urban areas*** may have little or no chance to adjust back to reference conditions. For instance, some Vermont villages were built on alluvial fans. The braided "D" channels that existed there historically were channelized, encroached upon, and hydrologically modified to such a degree as to preclude the adjustment of the stream back to the pre-settlement condition. In this example, you might choose to assign a "B type" channel as a modified reference stream type, due to the greater entrenchment and slope of the channelized stream, which is a stream type that could likely be maintained in equilibrium in the village setting.

Departure From Reference: The Rapid Geomorphic Assessment determines stream geomorphic condition based on the degree of departure of the channel from its reference stream type, which is evaluated by the magnitude and combination of adjustments that are underway in the stream channel. The degree of departure from reference is assessed as *not significant, minor, major, or extreme* and correlated with *reference, good, fair, or poor condition*. With respect to stream equilibrium and natural variability, 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 may involve localized, *insignificant to minimal 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.

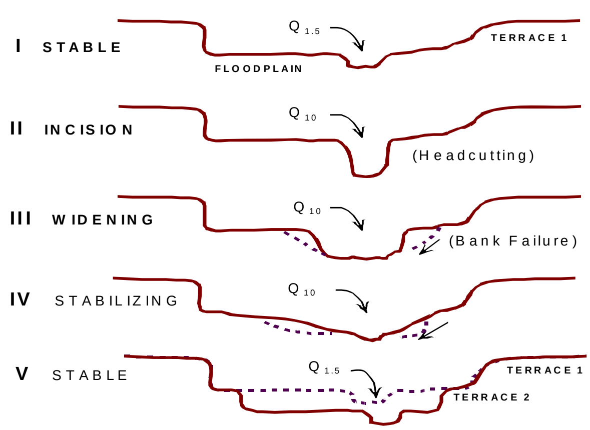
In Adjustment: A stream reach in *fair* condition that has experienced *major change* in channel form and fluvial processes outside the expected range of natural variability; and may be poised for additional adjustment with future flooding or changes in watershed inputs that could change the stream type.

Active Adjustment and Stream Type Departure: A stream reach in *poor* condition that is experiencing extreme adjustment outside the expected range of natural variability for the reference stream type; likely exhibiting a new stream type; and 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 boundary conditions.

Natural Exceptions: Some stream types do not respond or adjust to the stressors identified in the assessment protocols, while others are in a state of ongoing adjustment where management of watershed, channel, and floodplain stressors may have little consequence. Three scenarios where this may occur are described below.

> ***Streams in bedrock controlled gorges*** are changing and adjusting at a geologic time scale and are very unlikely to exhibit the adjustment processes described in the RGA. If your segment is confined within a bedrock gorge, you should forego the completion of Steps 7.1 through 7.6 and assess the segment or reach as having a "Low" sensitivity.
>
> ***Streams impounded by beaver dams*** may be going through aggradation, widening and planform adjustments, but may not be good candidates for evaluation. Streams that have considerable beaver influence over a long period of time may function more as wetlands than fluvial systems. These areas usually have extensive, intact dams impounding large ponds within the stream valley. It is recommended to create separate segments out of these areas and not conduct Phase 2 assessments on them. In other situations streams may have temporary or minimal beaver influence that induces localized channel adjustments but does not trigger long-term or extensive overall channel adjustments in the segment. These areas usually have small dams, or a series of small dams, that wash out regularly and through which the stream still flows in a largely riverine state. In these situations it is recommended that you include the beaver-influenced area within the larger segment, but disregard the localized beaver influence when evaluating stream condition and rather focus on the overall condition of the segment
>
> ***Alluvial fans, extreme deposition zones, and braided "D type" streams,*** typically found at major breaks in valley slope (from steep to gentle), are extremely high deposition zones, where the sediment load exceeds the stream's capacity to move it. While you should complete all the evaluations under the four adjustment processes (because many human-caused alterations may have occurred in these zones), take into consideration that these streams may be wide, full of depositional features, braided, and in an ongoing state of planform adjustment due to the natural setting in which they occur. You should not rate naturally braided streams (or those located on alluvial fans) as in fair or poor condition, based solely on those adjustments that would be expected to occur (i.e., no human-caused stressor involved), unless there has been a management decision to establish a "modified" reference stream type for the segment or reach (see discussion below).

***Channel Evolution Sequence*:** Depending on when you complete your survey relative to where in the channel evolution stage a channel is, you may come to different conclusions about the adjustment process occurring in the channel.



In regime, reference to good condition, insignificant to minimal adjustment.

Fair to poor condition, major to extreme channel degradation.

Fair to poor condition, major to extreme widening and aggradation.

Fair to good condition, major reducing to minor aggradation, widening, and planform adjustments

In regime, reference to good condition, insignificant to minimal adjustment.

Figure 7.1 Five Stages of Channel Evolution (Schumm, 1977 and 1984), the channel condition and adjustment processes often observed during each stage

For example, a reach adjusting to a large influx of sediment from erosion sources upstream may display signs of one adjustment process over others depending on which stage of channel evolution the channel is in. Initially, there may be signs of **aggradation** and a localized decrease in slope as sediment builds up in the reach. This may be followed by a channel avulsion that significantly shortens the reach length resulting in what may be a dramatic increase in slope. At this step in the process, an assessment may strongly indicate channel **degradation.** Depending on the severity of the degradation process, the balance may have swung too far, and some decrease in channel slope will occur before equilibrium is achieved. If you survey at this time, you may conclude that the dominant processes are either channel **widening** or **planform adjustment** (Figure 7.1). Typical adjustment, or channel evolution, sequences have been observed and documented that may help to explain why your Rapid Geomorphic Assessment reveals signs of more then one type of adjustment process going on at the same time, as well as those adjustments that are likely to occur before the river regains equilibrium with its watershed inputs (Appendix C).

Field Form: Rapid Geomorphic Assessment

Complete the RGA field form header in the same manner of the Field Notes form header, including the reference stream type for the reach based on Phase 1 and/or Phase 2 data .

Selecting Condition Category: The assessment of degradation, aggradation, widening, and planform adjustment processes is set up as a series of 4 to 6 evaluations. In large part, the evaluations are based on the values determined for parameters assessed in Steps 1 through 5 and recorded on the Field Notes form. For each parameter, a separate description is provided under each of the four geomorphic condition headings (reference, good, fair, and poor). You will work down through each evaluation and put a check in the box next to the condition that best describes your segment or reach. Make sure you check one of the four condition boxes in each row. After you have worked through all 4 to 6 evaluations under an adjustment category, look at the array of checks and decide *which of the four condition categories* best captures the stream condition with respect to that adjustment process.

Selecting a Score: Once you have chosen the appropriate category, consider the array of checks and the text within the evaluation boxes of the category more closely to determine *which of the 5 score values* in the category best matches the condition you are observing in the field. The range of scores within each condition category gives you flexibility in "describing" what you observe in the field. Give greater weight to the actual channel and floodplain geometry changes (evaluated in the top 2-4 rows under each adjustment type) than to the human-related modifications (evaluated in the lower 2-3 rows under each adjustment type). When there is a range of percentages or values presented in the category description (i.e. Width/depth is > 30 ≤ 40) and your observations indicate, for instance, that the parameter condition is more towards the optimal end of that range, i.e. 30 W/d, you should factor this into selecting a higher score within that category.

Some of the evaluations under each adjustment process include descriptions of <u>when</u> a modification or channel change occurred (i.e. using the terms "historic," "recent," or "existing"). Recognizing adjustment processes in both space **and** time is essential to your prediction of channel evolution and selecting an appropriate management response. For instance, a channel may have incised decades ago in response to a dredging operation and is still moderately entrenched. However, aggradation and planform change are assessed as the current adjustment processes. The river manager, in trying to resolve conflicts associated with erosion due to these current adjustments, may be particularly concerned about channel degradation and widening processes that may still be active upstream, generating all the sediments that are aggrading in the reach. In the lower left corner of each adjustment process box, next to the adjustment scores, is a **"Historic"** check box to indicate that while the channel is not actively or currently undergoing the adjustment process, the adjustment did occur in the past.

The evaluation of degradation, aggradation, channel widening, and planform adjustments and the stage of channel evolution are discussed in Steps 7.1 through 7.4. Stream condition, based on a rating derived from the adjustment scores, is assessed in Step 7.6. Stream sensitivity, based on the existing stream type, adjustment processes, and whether the existing stream type represents a stream type departure, is assessed in Step 7.7.

7.1 DEGREE OF CHANNEL DEGRADATION (INCISION)

"Incision", "downcutting", and "degradation" are all words used to describe the process whereby the stream bed lowers in elevation through erosion, or scour, of bed material. Some streams incise so deeply they become entrenched stream types (i.e. when a C type stream incises to an F type stream, Table 2.3). Other streams, in more confined valleys, are naturally entrenched and should not be characterized as degraded unless evidence of the downcutting process is observed. Channel degradation may occur when there has been a significant increase in flows, a significant decrease in sediment supply, or a significant increase in slope due to a loss of channel sinuosity or floodplain. Incision occurs during periods of high runoff. Indicators of degradation or incision (noted in the left hand column on the RGA Form) include:

- Exposed till or fresh substrate in the stream bed and exposed infrastructure (bridge footings);
- New terraces or recently abandoned floodplains or flood prone areas along the banks of the stream;
- Headcuts, or nickpoints, in channel. Headcuts look like riffles that are 2-3 times steeper than a typical riffle;
- Freshly eroded, vertical-faced banks (Figure 7.2);
- Old stream channel deposits that are imbricated (stacked like dominoes) high in the bank, indicating that the channel bed used to be at a higher elevation and has since cut down;
- Tributary rejuvenation, sometimes observed through the presence of nickpoints at or upstream of the mouth of a tributary where the tributary enters a river (when the main channel degrades, the tributaries that flow into it respond by degrading and lowering their channel beds to meet the lower main channel bed); and
- bars with steep faces, which usually occur on the downstream end of a bar.

Refer to your Field Notes for the following signs or conditions that may provide evidence of channel incision:

1.3 = berm, road, and railroad encroachments present
1.5 = human-caused change in valley type
1.6 = no grade controls
2.7 = increased incision ratio
2.8 = decrease in entrenchment ratio
2.10 = incomplete riffles or runs only
2.14 = F or G stream types (B in unconfined valleys)
4.5 = impoundments present
4.6 = stormwater inputs present
4.7 = flow regulated (> flows or < sediments)
4.8 = constrictions with scour problems below
5.2 = flood chutes and avulsions present
5.3 = headcuts and nickpoints present
5.5 = gravel mining, dredging or channelization

Figure 7.2 Degraded Channel

Major Degradation and Stream Type Departures: In the upper right hand corner of the degradation section of the RGA form, evaluations concerning head cuts and entrenchment ratio are set apart with darker border lines. If one **or** both of these parameters are checked in the poor condition category, then rate the segment (or reach) as "poor" in the degradation adjustment process regardless of how the other four evaluations within step 7.1 were made. Checking that the stream has exceeded the stated thresholds for incision ratio and entrenchment means that, depending on the reference or modified reference you are comparing to, a "stream type departure" has occurred. You should use the check boxes in the lower left hand corner of the degradation section to indicate the stream type departure that best describes what you are seeing in the field.

7.2 DEGREE OF CHANNEL AGGRADATION

Aggradation is a term used to describe the raising of the bed elevation through an accumulation of sediment. Channel aggradation may occur when there has been a significant decrease in flows, a significant increase in sediment supply, or a significant decrease in slope due to irregular meander migrations. Depending on upstream processes and the boundary conditions of your reach, channel widening (Step 7.3) may occur in association with channel aggradation. Indicators of aggradation (noted in the left hand column on the RGA Form) include:

- Shallow pool depths;
- Abundant sediment deposition on side bars and unvegetated mid-channel bars and extensive sediment deposition at obstructions, channel constrictions, and at the upstream end of tight meander bends (Figure 7.3);
- Most of the channel bed is exposed during typical low flow periods;
- High frequency of debris jams; and
- Coarse gravels, cobbles, and boulders may be embedded with sand/silt and fine gravel.
- Lateral migration of thalweg (deepest thread of flow).

Refer to your Field Notes for the following signs or conditions that may be evidence of channel aggradation:

1.6 = downstream grade controls present
2.6 = high width/depth ratio (> 30)
2.10 = transverse bars or runs only
2.12 = homogenous gravel/sand substrates
2.14 = plane bed stream type (in unconfined valley)
3.1 = significant bank erosion
4.7 = flow regulated (< flows or > sediments)
4.8-4.9 = constrictions with deposition above or below
5.1 = unvegetated mid-channel or diagonal bars
5.2 = flood chutes, neck cutoffs, channel avulsions, and/or braiding present
5.3 = steep riffles present

Figure 7.3 Aggradation

Major Aggradation and Stream Type Departures: In the upper right hand corner of the aggradation section of the RGA form, evaluations concerning loss of bed features and unvegetated deposition features are set apart with a darker border lines. If both of these parameters are assessed in the poor condition category, then rate the segment (or reach) as "poor" in the aggradation process regardless of how the other four evaluations within Step 7.2 were made. The exception being where the reference condition is characterized as extremely depositional. Checking that the stream has experienced these extreme changes in deposition means that, depending on the reference or modified reference you are comparing to, a "stream type departure" has been observed. You should use the check boxes in the lower left hand corner of the aggradation section to indicate the stream type departure that best describes what you are seeing in the field.

7.3 WIDENING CHANNEL

Channel widening usually follows the channel degradation process (Step 7.1). The containment of higher flows within an incised channel typically leads to erosion of both banks. Alternating stages of widening and aggradation occur as the stream forms a floodplain at a lower elevation. An over-widened channel is also an outcome of the sediment aggradation process described in Step 7.2. When the stream becomes incapable of transporting its sediment load, sediments collect on the stream bed, forming mid-channel bars that concentrate flows into both banks, and lead to a wider channel. Streams that score poorly under channel aggradation (7.2) may also score poorly for the channel widening parameter, but in such cases you want to record aggradation as the dominant adjustment process. Channels also become over-widened due to an increase in flows or to a decrease in sediment supply, which is not necessarily related to bed aggradation but may be seen in association with degradation. In these cases widening is the dominant process. Indicators of widening (noted in the left hand column on the RGA Form) include:

- Active undermining of bank vegetation on both sides of the channel; many unstable bank overhangs that have little vegetation holding soils together;
- Erosion on both right and left banks in riffle sections;
- Recently exposed tree roots;
- Fracture lines at the top of the bank that appear as cracks parallel to the river; evidence of land slides and mass failures;
- Deposition of mid-channel bars and shoals (Figure 7.4); and
- Urbanization and stormwater outfalls leading to higher rate and duration of runoff and channel enlargement typically in smaller watershed with a high percentage (>10%) of impervious surface (urban land use).

Refer to your Field Notes for the following signs or conditions that may be evidence of channel over-widening:

2.6 = high width/depth ratio (> 30) (Figure 7.4)
2.7 = increased incision ratio
2.8 = decrease in entrenchment ratio
2.8 = moderately channel entrenchment (<2.0)
3.1 = significant bank erosion or revetments on both banks, overhanging banks
4.6 = stormwater outfalls present
4.7 = flow regulated (> sediments or > flows)
5.1 = mid-channel, side, or diagonal bars present
5.2 = flood chutes, neck cutoffs, channel avulsions, and/or braiding present
5.3 = steep riffles may be present
5.5 = channel alterations present

Figure 7.4 Widening related to aggradation and the formation of a mid-channel bar.

Major Channel Over-Widening: In the upper right hand corner of the over-widening section of the RGA form, evaluations concerning width to depth ratio (W/d) and the active lateral erosion of both banks are set apart with a darker border lines. If both of these parameters are assessed in the poor condition category, then rate the segment (or reach) as "poor" in the widening process regardless of how the other three evaluations (within Step 7.3) were made. Check boxes have not been provided in the lower left hand corner of the over-widening section to indicate the stream type departure. Over-widening is not evaluated as the cause of a stream type departure as are the vertical adjustments of degradation and aggradation.

7.4 CHANGES IN PLANFORM

The planform is the channel shape as seen from the air. Planform change can be the result of a straightened course imposed on the river through different channel management activities, or a channel response to other adjustment processes such as aggradation and widening. When a river changes planform (Figure 7.5) and cuts a new channel, a change in channel slope usually results, sometimes initiating another channel evolution process. This evolution process will start with degradation if the channel slope is increased, or with aggradation if the slope is decreased. Indicators of planform change (noted in the left hand column on the RGA Form) are:

- Flood chutes, which are longitudinal depressions where the stream has straightened and cut a more direct route usually across the inside of a meander bend;
- Channel avulsions, where the stream has suddenly abandoned a previous channel alignment;
- Change or loss in bed form structure, sometimes resulting in a mix of plane bed and pool-riffle forms;
- Island formation and/or multiple thread channels;
- Additional large deposition and scour features in the channel length typically occupied by a single riffle-pool sequence (may result from the lateral extension of meander bends).
- Thalweg not lined up with planform. In meandering streams the thalweg typically travels from the outside of a meander bend to the outside of the next meander bend. Pools are located on the downstream third of the bends. Riffles are at the cross-over points between two pools on successive bends. During planform adjustments, the thalweg may not line up with this pattern.

This parameter assesses not only the presence of flood chutes and channel avulsions, but also the likelihood that they will occur. Channels sometimes change course as the result of catastrophic channel avulsions due to a debris jam, a road crossing, or loss of riparian buffer and bank instability, or they may change course due to human interference through channel straightening (Figure 7.5).

Figure 7.5 Planform Change: In this example, the thalweg was previously on the right bank under both low flow and bankfull flow conditions. Now the thalweg has shifted to the left bank as seen under low flow conditions.

Refer to your Field Notes for the following signs or conditions that may be evidence of channel planform adjustments:

1.3 = floodplain encroachments present
3.1 = significant bank present
2.9 = sinuosity changes within the segment or reach
2.10 = runs only or riffles that are partial or transverse
2.11 = riffle spacing off (< 5 or > 7 channel widths for C and E stream types)
3.1 = excessive bank erosion on outside bends
4.8-4.9 = flood prone constrictions present
5.1 = mid, side, delta, or islands present
5.2 = flood chute, neck cutoffs or channel avulsions
5.5 = straightening present

Major Planform Adjustment: In the upper right hand corner of the planform section of the RGA form, evaluations concerning the extensive lateral erosion of outside bends and evidence of channel avulsions and mid-channel bars are set apart with a darker border lines. If both of these parameters are assessed in the poor condition category, then rate the segment (or reach) as "poor" in the planform adjustment process regardless of how the other two or three evaluations (within Step 7.4) were made. Check boxes have not been provided in the lower left hand corner of the planform section to indicate the stream type departure. Planform adjustment is not evaluated as the cause of a stream type departure as are the vertical adjustments of degradation and aggradation.

7.5 CHANNEL ADJUSTMENT PROCESS

In this step, the adjustment process scores are reviewed. You will decide which processes are active and ongoing, which occurred historically, and then which stage of channel evolution the segment is in. The scores given to each of the four adjustment processes are transferred to the RGA Form (Table 7.5) and sub-totaled under each of the four condition categories. Calculate the condition rating by dividing the total score by 80 (which is the total possible score for the RGA).

Indicate those adjustments that occurred historically and where adjustments have led to stream type departures (STD) by checking the appropriate boxes in Table 7.5 on the RGA field form (transfer the checks from steps 7.1 - 7.4). Then assess what stage of channel evolution best describes the condition of the segment (or reach) based on the types of adjustments, when they occurred in time, and the models provided in Appendix C. Also indicate which channel evolution model you used (F and D-stage models explained in Appendix C). See the example of a completed Adjustment Scores Table in Figure 7.6.

On the "channel adjustment processes" line below Table 7.5 on the RGA field form, list the active adjustment processes that received scores in the fair to poor range in steps 7.1 through 7.4. In some instances there may be more than one process occurring. List any concurrent processes that received a score of 10 or less.

7.5 Channel Adjustment Scores – Stream Condition – Channel Evolution Stage

Condition Departure	Reference N/S	Good Minor	Fair Major	Poor Extreme	STD*	Historic	Condition Rating: (Total Score / 80)	Channel Evolution Stage:
Degradation				4	√	√	**0.4**	**III** **(F-stage)**
Aggradation		14						
Widening			6				**7.6 Stream Condition:** **Poor**	
Planform			8					
Sub-totals:		14	14	4	**Total Score:** 32			

Channel Adjustment Processes: __**Widening and Planform after historic Degradation**__

Figure 7.6 Example of Channel Adjustment Scores filled in from Steps 7.1 to 7.4 to determine Channel Evolution Stage and Stream Condition.

7.6 STREAM CONDITION

Table 7.1: RGA Score Ranges

0.85 – 1.0	Reference Condition
0.65 – 0.84	Good Condition
0.35 – 0.64	Fair Condition
0.00 – 0.34	Poor Condition

Use the table to the right to assign a stream geomorphic condition for the stream segment (or reach). This step requires some discretion, as you may encounter any number of reasons why the condition as scored does not fit with what your seeing in the field. If you record a condition descriptor that is different from that suggested by the rating table (above) be sure to record your rationale on both the RGA field form and in the Phase 2 database. This method of assessing the stream condition is preferred over going back to the adjustment process assessments and changing scores so that the desired ratio can be achieved. For example, for the stream assessed above (Figure 7.6), the condition rating came out as "0.4", which puts it in the "fair" range shown in the table, but the stream condition was described as "poor." The rationale was the Stream Type Departure from a "C" to an "F" stream type. It is appropriate to rate a stream in poor condition when it is experiencing extreme adjustment outside the expected range of natural variability for the reference or modified stream type. A stream type departure is an indication that channel and/or floodplain geometry may have changed to such a degree that the fluvial processes involving the transport of water, sediment and debris have changed in response to a set of natural and/or human stressors. These changes often lead to further change, either back to the reference condition or to a new equilibrium condition.

Either way, the on-going adjustments may cause erosion-related conflicts and/or aquatic ecosystem impacts.

7.7 STREAM SENSITIVITY

Sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance or stressor. With the help of Table 7.1, use the existing stream type and the stream condition to evaluate the sensitivity of your segment or reach. Remember to use the existing stream type determined in Step 2.14, not the reference stream type assigned at the top of the RGA form. If the existing stream type represents a departure from a reference or modified reference stream type then you will use the far right-hand column of Table 7.1.

Table 7.2 Phase 2 Stream Sensitivity Ratings based on existing stream type, condition and departure.

Stream Type Group	Existing Geomorphic Stream Type[1]	Sensitivity		
		Reference or Good Condition	**Fair-Poor Condition in Major Adjustment**	**Poor Condition, Represents a Stream Type Departure**
1	A1, A2, B1, B2	Very Low	Very Low	Low
2	C1, C2	Very Low	Low	Moderate
3	G1, G2	Low	Moderate	High
4	F1, F2	Low	Moderate	High
5	B3, B4, B5	Moderate	High	High
6	B3c, C3, E3	Moderate	High	High
7	C4, C5, B4c, B5c	High	Very High	Very High
8	A3, A4, A5, G3, F3	High	Very High	Extreme
9	G4, G5, F4, F5	Very High	Very High	Extreme
10	D3, D4, D5	Extreme	Extreme	Extreme
11	C6, E4, E5, E6	High	Extreme	Extreme

Assigning a sensitivity rating to a stream is done with the assumption 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 when human activities alter the setting characteristics that influence a stream's natural adjustment rate including: boundary conditions; sediment and flow regimes; and the degree of confinement within the valley. Streams that are currently in adjustment, especially those undergoing degradation or aggradation, may become acutely sensitive. Step 6.2 of the Phase 3 Handbook provides a more detailed description of the factors involved in assessing stream sensitivity.

VT River Management Program
Phase II QA Protocol

<u>Introduction & Purpose:</u>

The Vermont River Management Program (RMP) has developed this Quality Assurance (QA) protocol to ensure the integrity of its Rapid Geomorphic Assessment (RGA) data. High quality data, which is complete and accurate, will form the basis of meaningful natural resources and river management projects, and is therefore one of the primary goals of any assessment project. Documentation of any assessment deficiencies should not necessarily be viewed as a failure, but rather as the first step in identifying future assessment needs.

1 Geomorphic stream types from the Rosgen (1994) Classification System.

Step 1: Automated QA and Assessor Documentation

After all data collected during the Phase 2 RGA has been entered into the DMS, the first step of the QA process is to run through the automated "QA Check." This step follows data entry Step 7 in the DMS and is meant to increase the efficiency of the QA effort by quickly identifying suspect or inconsistent data.

During this process, the DMS will scan through the data set in an attempt to identify fields that may have been left blank, data entry errors, and other possible discrepancies within the data set. A reach or segment will register as "Provisional" as long as "issues" remain unaddressed. For each potential issue that the DMS finds during this process, you are given two options. Either 1.) make an appropriate adjustment to the relevant data, or 2.) provide a comment explaining why the data is correct as it is entered. This process is meant as a way to highlight potential errors, but also as a way for you to provide further documentation on the characteristics of each segment.

This automated QA process is broken down into five sub-steps. They are as follows:

- **X.1 Conflicting Phase 2 blank fields –** This step searches for those fields that are only partially filled out (i.e. you noted a beaver dam but did not indicate the length of reach affected).
- **X.2 General Phase 2 Blank Fields –** This step searches for those fields that should never be left blank (assuming the reach was assessed).
- **X.3 Fix Conflicting data –** This step searches for potential conflicts within the Phase 2 data set
- **X.4 Reconcile Phase 1 data and Phase 2 data –** This step searches for potential conflicts between Phases 1 and 2.
- **X.5 Check RGA Data (Step 7) –** This step compares Phase 1 and 2 data to how you scored the Rapid Geomorphic Assessment to highlight areas that may be scored differently.

Once all issues have been adjusted or commented on, a reach will register as "Complete", and once all relevant reaches register as complete, the project registers as Complete and you have finished the automated QA process. NOTE: Changes made to a project after it has been registered as Complete may cause the project to fail one or more QA Checks. **Make sure that any changes to the data do not cause a project to revert back to Provisional status**.

The comments you provide during this QA step can be found in the QC Comment Report on the Phase 2 reports page in the DMS. This report will be utilized by the RMP staff when conducting a more detailed QA assessment of the data set.

Step 2: Manual Review of Data

In this step of the QA assessment you will manually review the accuracy of the data. Print out both the Phase 1 and Phase 2 Reach Summary Reports for all relevant reaches and segments. Compare the data between Phases 1 and 2 to confirm that all fields that can be in agreement, are in agreement, as well as to confirm that conclusions made about stream processes and channel evolution have taken the Phase 1 data into consideration. It is important that you utilize maps and orthos to confirm that the data collected seems appropriate.

Please utilize the QA Worksheet (Appendix A) to ensure a complete review of the data set.

Step 3: File Upload

Confirm that all cross-section data has been entered and uploaded to DMS and that all required Phase 2 shape files – including FIT themes and Segmentation Points – have been zipped together and uploaded to the DMS.

Step 4: Address Additional QA Concerns and Provide QA Documentation

After fully reviewing your data and uploading all associated files to the DMS you will need to contact your regional River Scientist to make them aware of the project's status. Someone from RMP will then conduct an additional QA assessment and document any potential discrepancies they find, as well as provide comments on where the data might be improved or clarified. You will then be sent a copy of this QA document and will be required to provide your own documentation that explains how these discrepancies or comments were addressed (i.e. how data was corrected or further clarification was given). These comments can be inserted directly into the QA document provided by RMP staff.

A copy of this QA document containing both RMP comments and how they were addressed should then be provided to your Regional Scientist for final review along with copies of all relevant field forms, worksheets, maps, digital copies of photos and an associated photo log. If RMP Staff deems everything is satisfactory you will insert the final copy of the QA document into your final project report and will have at that time completed all necessary QA steps. This QA document will also become part of any River Corridor Plan that is developed using your data set (please refer to Step 4.2 in the River Corridor Planning Guide for further directions).

QA Protocol Worksheet

Step 1: Automated QA and Assessor Documentation

All five steps of the on-line QA Check have registered as “Complete”?

- □ X.1 Conflicting Phase 2 blank fields
- □ X.2 General Phase 2 Blank Fields
- □ X.3 Fix Conflicting data
- □ X.4 Reconcile Phase 1 data and Phase 2 data
- □ X.5 Check RGA Data (Step 7)

Step 2: Manual Review of Data

Print out both the Phase 1 and Phase 2 Reach Summary Reports for all relevant reaches and segments. It is important that you utilize maps and orthos to confirm that the data collected seems appropriate.

Please utilize the check list below to ensure a complete review of the data set. If any of the below questions cannot be simply answered “yes” or “no,” then it might suggest a comment would be useful.

Field Notes & Phase 1 Update – Comprehensive Review:

- □ Are their fields not captured during the Phase 1 assessment that can be updated with relevant information captured during Phase 2? Potential updates include:
  - □ Valley Width – Can the (estimated) Phase 1 width be updated with a more accurate (measured) Phase 2 width? Only update the valley width if the Phase 2 values represent the reference valley width. If the Phase 2 valley width has been narrowed by a road or berm do not update the Phase 1. In this situation be sure to check the “human caused change in valley width”.
  - □ Stream Type, Bed Material and Bed Form – Where Phase 2 is in reference condition the Phase 1 should be updated.
  - □ Ground Water – Though the two phases differ in their specificity, Phase 2 data for springs/seeps/tribs and wetlands should generally agree with the abundance of ground water noted in Phase 1.
  - □ Channel Bars, Meander Migration and Ice/Debris Jams – Phase 1 should be updated to whatever degree possible.

- □ If there are significant corridor encroachments, is there a human caused change in valley type? Where there is a change in valley confinement from unconfined to confined is there also a stream type departure?

- □ Does the stream type selected match the channel dimensions (cross-section data)? If not explain why.

- □ If the stream is in reference or good condition, does the measured channel width make sense compared to the Phase 1 channel width calculated in SGAT (remember, A and E stream types might be over-estimated in Phase 1)?

Where the reach has been segmented:

- □ Did you enter a reason for segmentation?

- □ Where the stream type of any segment is not the same as the Phase 1 stream type, is it identified as either a sub-reach or stream type departure?

RGA

- □ Was the appropriate form used? Field form should be chosen based on Phase 1 reference confinement type, unless plane bed by reference.

- □ Do the adjustment processes reflect field data? If the data is not immediately reflected in the adjustment process scores, are there sufficient comments that support the process chosen? **Use Table 1-1 below** to help evaluate this question.

- □ Was there a stream type departure? If so, is this adequately represented in the related adjustment process?

- □ Is the Channel Evolution Stage strongly supported by the relative adjustment process scores, data and comments?

RHA – Not Yet Written
Cross-sections:

- □ Where multiple cross-sections have been done, does the one entered into the spreadsheet for the segment or reach best represent the adjustment process? Is there a note to indicate which cross-section was used as representative?

- □ Do all cross-sections suggest the same stream type? Where they do not, were the reaches segmented? If not, has an explanation been provided?

- □ **Do cross-sections extend beyond bank full, from valley wall to valley wall**? The important thing is that the cross-section generally captures the channel within its valley setting (i.e. the relative slopes and heights of banks and terraces, flood prone area, etc.).

- □ **Do cross-sections identify all important features**, specifically the bankful, thalwag, recently abandoned floodplain and other terrace features?

File Uploads

- □ All cross-section data entered and uploaded to DMS?

All required Phase 2 shapefiles – including FIT themes and Segmentation Points – have been uploaded to the DMS?

Degradation	Present ?	Widening	Present?
Entrenchment Ratio < 2.0	☐	Low Degradation Score (< 11)	☐
Incision Ratio > 1.4	☐	W/D Ratio > 30	☐
Degraded Plane Bed (result of degradation)	☐	Incision > 1.4	☐
HCC in Confinement (from unconfined to confined)	☐	Entrenchment Ratio < 2.0	☐
“F” or “G” Stream Type Departure (or “B” in unconfined Valleys	☐	Significant Bank Armoring	☐
Significant Berms/ Roads/ Rail/ Imp. Path / Development within corridor	☐	Bed Sediment Storage (mid/side/diagonal bars)	☐
Upstream Flow Reg (greater flow or decreased sediment supply)	☐	Stormwater Inputs	☐
Avulsions (resulting in channel straightening) or neck cut-offs	☐	Current Channel Width (Ph2) > Reference Width (Ph1)	☐
Head Cuts, Nick Points Or Tributary Rejuvenation	☐	Steep Riffles	☐
Dredging or Straightening	☐	Flood Chutes, Neck Cut-offs, Channel Avulsions or Braiding	☐
Stormwater Inputs	☐	Flow Regulation (greater flows or greter sediment supply)	☐
No Grade Controls	☐	“D” Stream Type Departure	☐
Eroded Riffle Type	☐	“A” or “B” to “F” Stream Type Departure	☐
Aggradation	**Present?**	**Planform**	**Present?**
W?D Ratio > 30	☐	Changing Sinuosity Within Reach	☐
Flood Chutes, Avulsions (resulting in abandoned channel), Braiding	☐	Significant Berms/ Roads/ Rail/ Imp. Path / Development within corridor	☐
Aggraded Plane Bed (result of aggradation)	☐	Bank Erosion > 20%	☐
Homogeneous Substrate	☐	Bed Sediment Storage (mid or side bars)	☐
Impoundment (resulting in decreased flows or increased sediment supply)	☐	Meander Migration	☐
Constriction causing aggradation above or below	☐	Runs Only/ Partial Riffles/ Diagonal Bars	☐
Bed Sediment Storage (mid/side/diagonal bars)	☐	5 > Riffle/ Step Spacing > 7 Channel Widths (for C or E Streams)	☐
Embedded Substrate	☐	Constrictions Smaller Than Floodprone Width	☐
Dredging or Straightening	☐	Flood Chutes/ Neck Cuts/ Avulsions/ Braiding	☐
Downstream Flow Reg (decreased flows or greater sediment supply)	☐	Dredging or Straightening	☐
Steep Riffles	☐	Eroded or Sedimented Riffles	☐
Sedimented Riffles (mostly runs)	☐		

Table 1-1: In this table, each adjustment process is accompanied by those data features indicative of that process. Check off which features were present in this reach. If more than 50% of the features for any adjustment are present, it suggests that process is active, and should likely score Fair or Poor in Step 7 of the Phase 2 assessment.

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