Stream Visual Assessment Protocol for the Commonwealth of the Northern Mariana Islands

VERSION 2 – UPDATED 2020

The Stream Visual Assessment Protocol was originally prepared in 2018 for the Division of Coastal Resources Management with financial assistance provided by the Coastal Zone Management Act of 1972, as amended, administered by the Office for Coastal Management, National Oceanic and Atmospheric Administration (NOAA).

The statements, findings, conclusions, and recommendations are those of the authors and do not necessarily reflect the views of OCRM, NOAA.

This guidance was prepared by the BECQ-DCRM Permitting, Planning, and Water Quality sections to further multiple resource management goals. The resulting SVAP is an adaptation of existing guidance documents from other jurisdictions which has been locally scaled and enhanced by the input and expertise of the following contributors: Erin M. Derrington, Emily Northrop, Kathy Yuknavage, Rodney Camacho, Malcolm Johnson, Larry Maurin, and Katie Graziano.

Version 2 of the SVAP has been developed in 2020 by the Division of Environmental Quality – Water Quality Surveillance Nonpoint Source Branch to reflect the changes made while training staff on the use of the protocol in 2019. This update was supported by the US Environmental Protection Agency (US EPA) with financial assistance under the federal Clean Water Act. Some updates were made to the protocol to better reflect conditions of CNMI streams and capture indicators of stream health that are important for local resource conservation. Special thanks goes to the personnel who have spent time training on the use of the CNMI-SVAP and have provided input to make Version 2 of the CNMI-SVAP more useful and representative of actual conditions encountered in CNMI streams. These personnel include Olivia Tenorio, John San Nicolas, Carlos Ketebengang, Shawn Masga, Joe Ito, Ian Iriarte, Kathy Yuknavage, and Zachary Williams.

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Preface

In 2013, the Commonwealth of the Norther Mariana Islands' (CNMI) Division of Environmental Quality (DEQ) completed a Surface Water Quality Monitoring Plan (2013 Plan) for six priority CNMI watersheds to support enhanced monitoring and data assessments for the U.S. Environmental Protection Agency's Integrated 305(b) and 303(d) water quality assessment reporting. The 2013 Plan was intended to guide collection of water quality data to enable improved upland management to address impaired water quality. Recognizing the importance of describing the ecological conditions of the streams of CNMI, the 2013 Plan included a "Stream Reconnaissance" assessment form, which describes stream conditions in relation to twenty physical and biological indicators as well as an optional macroinvertebrate survey. However, although watershed monitoring, including sampling protocols articulated in the 2013 Plan have been ongoing, the stream assessment protocol has not been routinely applied.

In 2014, the Division of Environmental Quality (DEQ) merged with the Division of Coastal Resources Management (DCRM) under the Bureau of Environmental and Coastal Quality (BECQ). With a mission to balance resource use with development, today BECQ is leveraging the management expertise of a diverse team of technical staff to support land and water resource management objectives. Watershed monitoring remains an important focus of the agency's mission, and the Water Quality Surveillance/Nonpoint Source Branch continues to implement water quality testing according to the 2013 protocols. Recent efforts to valuate wetland areas resulted in the development of the 2015 Rapid Assessment Methodology (2015 RAM). While the 2015 RAM was intended to quickly enable ecological assessment and valuation of wetland systems, it became apparent that the RAM was not well calibrated to describe streams or seeps, which are included under DCRM's regulatory definition of wetlands. In 2016, BECQ staff researched improved assessment techniques for streams that would be (i) easy to apply in the field and (ii) provide meaningful, quantifiable descriptions of stream systems in CNMI that could be used to indicate ecological quality and change in these systems over time. What follows is a brief description of other methodologies assessed and the selection process of a rapid assessment methodology suitable for CNMI streams.

Rapid assessment approaches are gaining popularity in the resource management sector in order to streamline classification and quantitative measurement of factors that influence resource quality. For streams, assessed elements typically include consideration of major biotic and abiotic factors. Qualitative habitat and multidisciplinary assessments include the US EPA Rapid Bio-assessment Protocol (RBP) (Plafkin et al., 1989), the Ohio EPA Qualitative Habitat Evaluation Index (QHEI) (Rankin, 1989), and the Natural Resource Conservation Service

(NRCS) Stream Visual Assessment Protocol (SVAP) (NRCS, 1998) and the updated SVAP2 (NRCS, 2009). Conversely, quantitative stream assessments involve taking physical measurements of various parameters (e.g., channel cross-section surveys, collection and analysis of bed sediment samples, flow measurements, vegetation surveys, biological species collection). Quantitative assessment can take several hours to days to complete at a site and they require high levels of training (Frothingham et al., 2012). Rapid assessment techniques are designed to provide simple reconnaissance-level assessment of ecological conditions.

For example, the 1989 Rapid Bio-assessment Protocols from the U.S. Environmental Protection Agency's Plafkin et al. was designed to provide basic aquatic life data for water quality management purposes such as problem screening, site ranking, and trend monitoring. This methodology included elements of biomonitoring, including fish, benthic macroinvertebrate, and periphyton sampling, as well as habitat assessment, and physicochemical parameters, based on fixed counts of 100 organism samples. Protocols from this guide have been revised several times since the 1989 publication, and are still widely used today. However, the rapid bio-assessment protocols (RBPs) approach is heavily reliant on presence of diverse taxa, with particular attention paid to macroinvertebrate populations, which are not well studied in the CNMI or the Pacific region. Thus, the RBPs approach has not been selected as a viable methodology to support rapid assessment of stream characteristics in CNMI at this time.

In 1998 a user-friendly Stream Visual Assessment Protocol (SVAP) was developed in a joint effort by the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture and the University of Georgia to serve as introductory screening–level stream assessment methodology (NRCS, 1998a). SVAP was designed as a versatile, adaptable, and relatively simple technique for use by NRCS field staff who work with agricultural landowners to support conservation practices in the more than 2000 field offices throughout the U.S. In 2001, NRCS supported the development and publication of the Hawaii Stream Visual Assessment Protocol (HI-SVAP). In 2009, NRCS published an updated SVAP Version 2, adding background information, state modifications, and an additional assessment element.

A number of studies have found significant correlations between RBP and SVAP assessments, as well as agreement between qualitative SVAP and indexes based on qualitative stream assessments (Frothingham et al., 2012, citing de Jesús-Crespo and Ramirez, 2011; Hughes et al., 2010; McQuaid and Norfleet, 1999). Results of the analysis assessing usefulness of SVAP as a monitoring protocol of stream corridor conditions concluded that comparing SVAP scores over time can be "an appropriate tool to monitor on-going and post-project stream corridor conditions" (Frothingham et al., 2012). Frothingham et al. go on to discuss that one "notable benefit of the SVAP is the ability to modify the protocol to better suit a particular geographic location and/or a specific watershed management plan (citing de Jesús-Crespo and Ramirez, 2011; Bjorkland et al., 2001; NRCS, 2001b; NRCS, 1998). However, the authors observe that, "[b]ased on the problems associated with reach length encountered during this study, changing the definition of reach length is recommended for monitoring stream corridor conditions over time." A standard reach length could be selected based on what other researchers have done (de Jesús-Crespo and Ramirez, 2011; Hughes et al., 2010; Ward et al., 2003; McQuaid and Norfleet,

1999) or GPS coordinates could be recorded, which would give future field crews the ability to accurately locate each reach. With these recommendations in mind, the CNMI Division of Coastal Resources Management has modified the NRCS SVAP2 and HI SVAP protocols as follows for application of SVAP in CNMI for the purpose of rapid, tier-one stream valuation.

SVAP Version 1 measures a maximum of fifteen (15) elements and is based on visual inspection of the physical and biological characteristics of instream and riparian environments, while the SVAP Version 2 (SVAP2) update measures sixteen (16). In each of the SVAPs, each element is assigned a numerical score relative to reference conditions and an overall score for the stream reach is calculated. A qualitative description of the stream reach, a length of stream with relatively consistent gradient and channel form, is made based on overall numerical score. The CNMI SVAP (CNMI-SVAP) selects 10 of these elements, detailed below.

While SVAP is not intended to replace more robust stream assessment protocols, it provides reliable information that is useful for agencies and landowners alike. The tool assesses visually-apparent physical, chemical, and biological features within a specified reach of a stream corridor.[1] Because of its qualitative nature, the protocol may not detect all causes of resource impacts, especially if such causes are a result of land use actions in other parts of the watershed. However, this tool does provide a means to quickly assess site conditions in the context of the larger watershed. It is also an educational tool through which landowners can learn about conservation of aquatic resources. As such, SVAP2 and HI-SVAP methodology has been adapted in the following guidance to support rapid assessment of stream conditions for the purposes of riparian buffer establishment in the Commonwealth of the Northern Mariana Islands.

[1] In 2002, the University of Hawaii Stream Assessment Protocol Version 3 was published with the addition of Biological Integrity metrics for native macrofauna. In order to support truly rapid stream assessments, macrofauna assessment is not proposed in the CNMI methodology at this time, however, further development of more in-depth analysis with inclusion of the macrofauna considerations are encouraged moving forward.

CNMI-SVAP

This protocol is intended for use in the field for rapid resource assessment of the chemical, physical, and biological integrity of the streams in the CNMI. The CNMI-SVAP contains both quantitative and qualitative elements.

Stream Assessment Elements

The ten stream elements considered in the Hawai'i SVAP Protocol and adopted for the CNMI-SVAP are as follows:

1. YSI Multiprobe Measurements – Turbidity, Salinity/Conductivity, Temperature, pH, Dissolved Oxygen
2. Visible Nutrient Enrichment (Aquatic Plant Growth)
3. Channel Condition
4. Channel Flow Alteration
5. Bank Stability
6. Substrate Embeddedness
7. Canopy Cover / Shade
8. Riparian Width/Condition
9. Habitat Availability (Wood Cover)
10. Litter/Trash/Waste (Contamination) Presence

Additional elements that were included in the NRCS SVAP2 and are also included in the CNMI-SVAP are water appearance, salinity, pool presence, and invertebrate/fish presence. As part of the CNMI-SVAP, DEQ staff identify flora and fauna encountered in the stream, down to species level if possible. BECQ hopes to partner with the Department of Lands and Natural Resources, Division of Fish and Wildlife in the future to further develop assessment criteria for invertebrate parameters. Details supporting these assessment elements are provided in the "Guidance Documentation" section below. Additional classification information is included in the Appendices of this publication.

Methodology and Guidance for Completing CNMI-SVAP

The following guidance was originally modified from the NRCS Hawaii Stream Visual Assessment Protocol (HI-SVAP) and NRCS' current Steam Visual Assessment Protocol (SVAP2). As stated above, the CNMI-SVAP has been further modified following training and field experience to better reflect the stream conditions in the CNMI.

Before leaving the office to assess a stream, a preliminary assessment of watershed features should be conducted using GIS or maps and findings should be recorded in the office. In many cases when access points to the stream cannot be determined from maps, or when landowner permission is needed for access, these efforts should be made ahead of time and this information should be recorded for future use. Creating reliable access points to streams from roadways and knowing the area landmarks well can save a significant amount of time and effort in conducting the SVAP. Additionally, if a long distance will be covered in one day or the terrain is difficult, it may save time and effort to use multiple vehicles for shuttling personnel at the end of the day.

Preliminary Watershed Assessment

Before conducting a site visit, the following watershed-level assessment steps are recommended:

- *Become familiar with watershed conditions before visiting the assessment site.* Stream conditions are influenced by the entire watershed including uplands that surround the assessment site. Changes in upland conditions can change the discharge, timing, and duration of streamflow events that affect stream conditions. Aerial images, topographic maps, stream gauges, and any other source of available data can be used to obtain information about watershed conditions before conducting the SVAP on a stream.

- *Gather land use information about the watershed to provide context for the stream and site conditions.* For example, road crossings and water control structures may prevent movement of aquatic species, while agriculture or urbanization can influence water quality and quantity as well as stream corridor conditions. Understanding the impacts of upland land uses can support analysis within the SVAP.

- *Review available water resource information for the watershed and stream reach.* For example, water control structures and/or activities outside of the assessment reach may be affecting streamflow. Understanding upstream influences can support analysis within the SVAP.

- *Become familiar with flora and fauna expected in the area to be assessed.* Understanding the local biota will support further analysis within the SVAP.

Field Preparation

Before entering the field to conduct a site-specific stream visual assessment, review the following checklist to ensure you are field ready.

Equipment List

Hiking boots / sturdy water-resistant footwear
Machete for clearing access to the stream
Backpack for carrying field supplies
Protective, field-appropriate clothing
GPS unit
Paper maps of stream(s) to determine and mark access and assessment location(s) in the field
Tablet or clipboard for recording assessment data
Brightly-colored flagging to mark access points or landmarks in the field
Measuring tape (100m water resistant recommended) – ensure same measurement units used consistently
Meter / yard stick (for depth measurements)
YSI Multiprobe for water quality measurements
Turbidimeter
Sunscreen / mosquito repellant as needed
Plenty of drinking water
See Water Quality Sampling Protocol and Checklist if water quality measurements or samples will be taken

It is recommended that the CNMI-SVAP be conducted with a team of three people. One person should be responsible for recording all field data on the tablet or data sheet. The other two people should be responsible for making measurements and relaying the information to the recorder to enter on the tablet or data sheet. As with all field work, basic safety protocols, including conducting site visit with a partner and informing office staff of the site being assessed and expected duration of site visit are recommended. The SVAP field work ideally should be completed during base flows or low-flow conditions when habitat feature limitations are likely to be most visible. It is also recommended that area landowners be informed ahead of time that the SVAP will be conducted in the area, and access permission be granted when necessary. For more remote locations, adding a basic first aid kit to your equipment list is also advisable, especially because cell phone signal is not available in all locations. Even if cell phone signal is available nearby, it can be a weak signal when in narrow valley terrain as is common when conducting the SVAP.

Choosing where to begin the CNMI-SVAP

The CNMI-SVAP can be used to assess entire lengths of streams from the ocean to the upper watershed, or can be used to assess shorter segments of stream as necessary for case-by-case investigations. When using the CNMI-SVAP to assess the entire stream length (as part of a watershed assessment for examples, the survey should begin where the stream channel form becomes apparent at the stream outlet to the ocean. This is typically seen where the stream channel meets the average high tide line. Typically, there will be a very apparent delineation between the beach that derives its form from marine wave action and the stream that derives its form from streamflow. Some streams are brackish and tidally influenced, and these streams should be included in the CNMI-SVAP. The CNMI-SVAP can also be used to assess tributaries or sub-watersheds, in which case the survey would begin where a tributary meets another stream channel to form a larger stream.

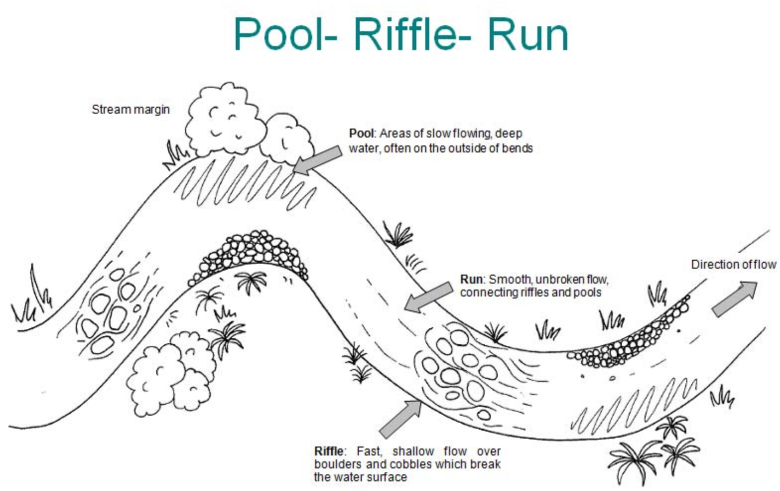
Delineate Assessment Reach

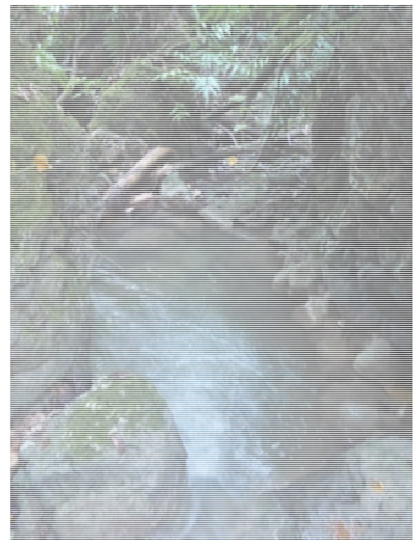
The CNMI-SVAP should be conducted while facing upstream and each successive reach surveyed should be upstream of the previous reach. Reaches are delineated from each other using a number of factors, the most important factor being the morphology of the reach (reach type). Determination of reach types based on channel morphology is discussed in more detail below. Reaches can also be delineated using other factors such as dominant substrate, gradient, riparian condition or channel condition, for example. Professional judgement should be used to determine the appropriate place to delineate one reach from the next so that the variability between each reach is appropriately captured. A general rule of thumb is that reaches should be at least as long as the bankfull width, but reaches may be many times longer than bankfull width if, based on professional judgement, other factors considered in the CNMI-SVAP are relatively uniform along the entire reach length.

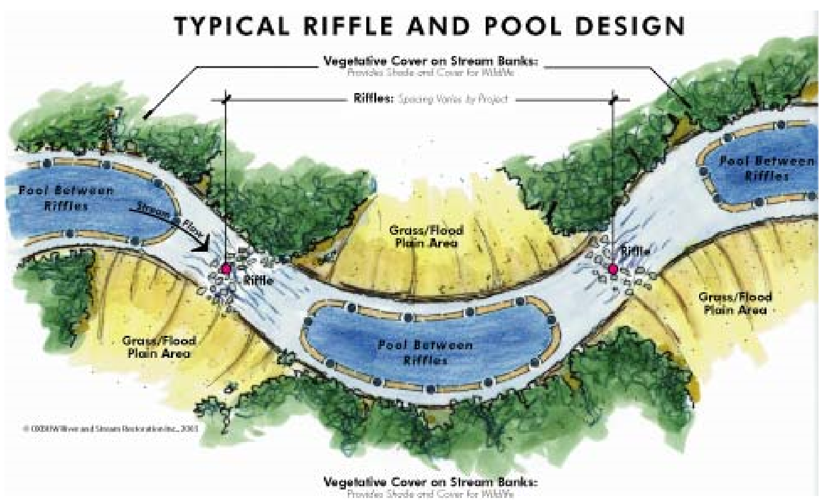
Use your GPS to mark the starting point of each assessed reach for mapping and georeferencing purposes and record this latitude and longitude on the data sheet. Use of brightly-colored biodegradable flagging tape may be appropriate to mark sections if periodic assessments are planned.

A *stream reach* is a length of stream with relatively uniform gradient, channel form, dominant substrate, riparian condition and channel condition.

Three general reach types are used in the CNMI-SVAP and must be understood when conducting the CNMI-SVAP. These three general reach types; pool, rifle, run, should be readily identifiable in the field, even if no water is present in the stream, by observing the shape, or morphology, of the stream and understanding how flowing water shapes the stream channel.




Example of a pool reach on Rota, CNMI



Pool: Pools are short, deep reaches that usually provide good habitat for aquatic organisms when water is present. Pools can vary greatly in depth and are often created when fast-moving water scours substrate out to create a deep pocket of slower moving water during high flow events. Pools often form downstream or adjacent to hard structures such as culverts, large boulders, tree stumps, logjams, or bedrock. Silt, clay, or sand can usually be seen at the bottom of pools due to the lower velocity of water allowing these substrates to settle out of suspension in the water column. Pools are often wide and bowl shaped, but can be narrow, especially in areas of highly incised bedrock in upper watersheds.

Run: Runs are relatively uncommon reach types that often occur in the lower watershed, but are quite rare in the upper watershed. Runs usually U-spaded or canal-shaped channel cross-section and have a flat bottom with a flat surface to flowing water when water is present. The dominant substrate for runs varies from clay, silt, sand, or gravel, but is almost never cobble or bedrock.

Riffle: Riffles are by far the most common reach type and vary greatly in length, slope, and dominant substrate. Rifles are often wide and steep gradient with relatively fast flowing water. Dominant substrate varies from gravel to bedrock, and the average substrate size usually increases with the stream gradient. Waterfalls and cascades are also sub-types of riffles that occur in the upper portions of watersheds. Generally, riffles will comprise a greater percentage of reach types in the upper portions of a watershed.

One the reach type has been determined and the start and end points have been determined, use the measuring tape to determine the reach length and record this value on the data sheet. The measuring tape should follow the deepest part of the stream channel (also known as a thalweg), which may be curved, rather than following the straight-line distance between the start and end point.

Collection of Data Parameters

Elevation

If the elevation above sea level at the start of each reach can be determined accurately in the field, indicate the elevation on the data sheet. If the GPS or Trimble unit used in the field is not accurate in determining elevation above sea level, leave the Elevation blank on the data sheet. In this case, elevation can be accurately determined in the office by overlaying the coordinates on a digital elevation model (DEM) using GIS.

Bankfull Channel Width

A bankfull *channel width* is the stream width at the bankfull discharge, or flow rate that forms and controls the shape and size of the active channel.

Bankfull discharge or *bankfull flow* is the flow rate at which the stream begins to move onto its active flood plain, if one is present. On average, the bankfull discharge occurs every 1.5 to 2 years, depending on local stream channel and weather conditions. Figure 1 illustrates the relationship between baseflow (low flow), bankfull flow, and the flood plain.

Bankfull width is determined by locating the first flat depositional surface occurring above the bed of the stream. The lowest elevation at which the bankfull surface could occur is at the top of the point bars (an alluvial deposit that forms by accretion on the inner side of an expanding loop of a river) or other sediment deposits in the channel bed. These generally occur on the inside of the meanders (white part of the figure 1, below).

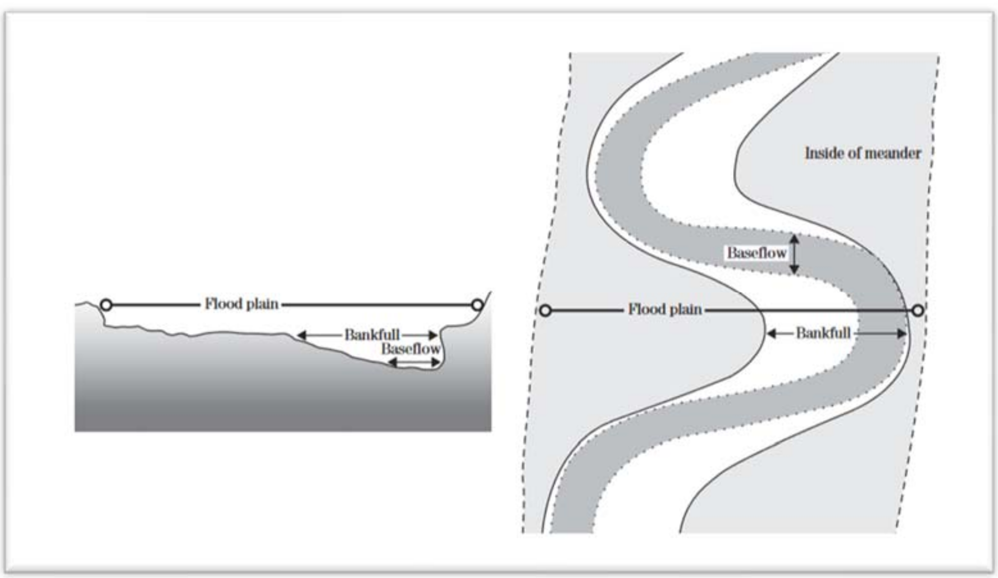


Figure 1 - Baseflow, bankfull, and flood plain locations (Rosgen 1996), from NRCS SVAP2, Dec. 2009

Other indicators of bankfull elevation include a break in slope on the bank, vegetation changes or exposed roots, a change in the particle size of bank material, lines on boulders or bedrock indicating high water levels, and wood or small debris left from high waters. Vegetation can grow into depositional bars below some bankfull indicators. Therefore, look for signs of well-established vegetation at the elevation level with the top of point bars to help identify bankfull stage.[2] If the bankfull height cannot be determined at the cross-section where are standing, you can look upstream or downstream to see if there is a clear bankfull line from which you can extrapolate. Sometimes, the bankfull level may not be easily identified on one bank and may be clearer on the opposite side of the stream. Most often, no one factor will tell you the bankfull height and you will need to use multiple factors to determine the bankfull height in a given reach. See Appendix F for more in-depth discussion of determining the bankfull channel height and width.

To determine the average Bankfull Width, take a measurement with the measuring tape at 3 representative cross-sections within the reach. The average of these 3 measurements is the average bankfull width that will be recorded on the data sheet.

Wetted Width

If water is present within the reach, measure the wetted width based on the average of 3 representative cross-section measurements within the reach. The average of these 3 wetted width measurements is the average wetted width that will be recorded on the data sheet. If no water is present, indicate 'No Water' in the wetted width row.

Average Water Depth

If water is present in the reach, average water depth can be determined using a meter stick. This is best accomplished by taking three depth measurements across each channel cross section where the wetted width is determined. The average of these depth measurements can be averaged with the average depth at other cross-sections within the reach to determine the Average Water Depth for the reach. Write the Average Water Depth for the reach on the data sheet.

Water Quality Parameters

If you are using a YSI meter, gather and record basic water quality parameters including turbidity (NTU), conductivity (μs/m), salinity (ppt), pH, dissolved oxygen (%), and temperature (°C) measurements and write the results on the data sheet. Be sure to use the correct units that are indicated on the data sheet. If using a YSI meter without a turbidity probe, you may use a separate HACH turbidimeter to evaluate the turbidity of a sample vial. Even without a turbidimeter, clarity of the water is an obvious and easy feature to assess. The deeper an object in the water can be seen, the lower the amount of turbidity. Use the depth (this may be assessed with a meter stick) that objects are visible only if the stream is deep enough to evaluate turbidity using this approach. For example, if the water is clear, but only 20 cms deep, do not rate it as if an object became obscured at a depth of 20 cms. This measure should be taken after a stream has had the opportunity to "settle" following a storm event. This element cannot be measured after recent heavy rains (come back to the site another day). Recognize that organic acids can create tea-colored water; this is not turbidity and should not be counted as turbid. Identify the condition and note the score on the datasheet.

Surface Velocity

Surface Velocity can be evaluated by how quickly a floating object floats downstream. Surface velocity may vary greatly throughout the year and will generally be highest following storm events. Using best

[2] Note, NRCS recommends numerous videos and publications to assist in identification of bankfull discharge indicators, available at https://www.fs.fed.us/biology/nsaec/products-videoswebinars.html. See e.g. Harrelson, C., L. Rawlins, and J.P. Potyondy (1994). Stream Channel Reference Sites: An Illustrated Guide to Field Technique. USDA General Technical Report (RM–245): 61.

professional judgement, choose from the following options and record the surface velocity on the data sheet:

Dry
No surface water is present in the reach

Standing
Surface water is present in the reach but not flowing

Slow
Surface water is present and flowing, but a floating object takes considerable time to travel downstream through the reach. This is also known as "baseflow" conditions when there has been considerable time since the last significant rainfall event

Medium
Surface water is flowing with considerable velocity to carry a small floating object such as a stick through the reach.

Fast
Surface water is flowing with significant velocity to carry away even large floating objects such as branches. This condition is usually only seen following significant rainfall events.

Water Appearance/Color

Under Water Appearance/Color note on the data sheet the color of the water in the reach. Options are "clear", "oily sheen", "brown", "orange", and "green."

-"Clear" should be used when there are no visible signs of the water color being altered from natural conditions and the bottom can be seen easily.
-"Oily sheen" should be used if there is any visible rainbow sheen seen on the water surface.
-"Brown" should be used if the water is turbid due to suspended sediment, or if the water is stained brown (but not turbid) due to dissolved organic nutrients.
-"Orange" should be used if the water appears orange due to growth of anaerobic algae or bacteria in the water.
-"Green" should be used if there is a visible green tinge in the water due to algal/phytoplankton growth.

Water Odor

Note on the data sheet whether there is any odor emanating from the water in the reach. Options for odor are "none", "sewage". "fishy", "sulphur", or "foul odor". Sulphur odors usually originate from hydrogen sulfide gas originating from anaerobic bacteria in stagnant areas. "Foul odor" can emanate from feces or rotting animals.

Streambed Material

Indicate on the data sheet the dominant streambed material. The dominant streambed material is the material that covers the most area in the reach below the bankfull level. Options are "manmade", "bedrock", "boulder", "cobble", "gravel", "sand", and "silt".

-"Manmade" should be used when the bottom of the reach is an artificial surface such as concrete or metal.
-"Bedrock" should be used when the streambed is composed of a natural bedrock layer.
-"Boulder" should be used when the stream bed is dominated by boulders (roughly 1 foot or greater in diameter).

-"Cobble" should be used when the streambed is dominated by cobbles (roughly 2 inches to 1-foot diameter).
-"Gravel" should be used when the streambed is dominated by gravel (less than 2 inches diameter but coarser than 2 millimeters).
-"Sand should be used when the streambed is dominated by sand.
-"Silt" should be used when the streambed is dominated by fine silt or clay. Silt is usually only found in depositional areas such as at the bottom of pools.

Embeddedness

Embeddedness is the extent to which particles larger than sand (gravel, cobble, and boulders) are surrounded by, covered, or sunken into the silt, sand, or clay of the stream bottom. Generally, as particles become embedded, fewer living spaces are available to macroinvertebrates and fish for shelter, spawning and egg incubation. To measure average percent embeddedness in a reach, choose at random a sample of approximately 10 particles of gravel, cobble, or boulders and note the extent to which they are buried in the surrounding sand, silt, or clay. You can usually tell the extent by picking up the particle and noting where the line of change in coloration occurs. The percent of the particle below this line is the percent embeddedness. The average of these is the average percent embeddedness in the reach and this value should be recorded on the data sheet.

For example, loose gravel that is not buried in silt, sand or clay is 0% embedded. Gravel that is completely buried in sediment and only the surface is exposed is 100% embedded. A reach with pure bedrock or hardbottom culvert is 0% embedded. Although extremely rare, a reach with pure homogenous silt, sand or clay is 100% embedded.

In rare instances, you may encounter a reach that has partial bedrock or hardbottom culvert, but the hardbottom is partially covered in settled particles. In this case, evaluate the embeddedness of any gravel, cobble, and boulders in the reach. If there are only silt, sand, or clay particles settled on top of the partially visible hardbottom and no gravel, cobble, and boulders present in the reach, the embeddedness for the reach is 0%.

Flora

Dominant flora species should be documented on the data sheet, with approximately 5 species recorded. The idea is to capture only the most dominant species present in the riparian and canopy area that have the most influence on aquatic and riparian habitat. Too few species recorded will not capture variation between reaches. If too many species are recorded, the dominant species will not be captured in the data. Usually, there is an obvious delineation between the dominant vegetation species and all other vegetation species. This usually amounts to approximately 5 species, but may range from 3-7 species depending on the reach.

English, local, or Latin names can be used as long as the same names are being used consistently during the survey of a particular stream.

Fauna

Similarly to flora, fauna species should be documented with an emphasis on aquatic fauna species if water is present. These include fauna that have only part of their life cycles being aquatic such as toads, mosquitoes, and dragonflies. Terrestrial fauna may be documented if they are actively using riparian habitat, especially birds, mammals, and reptiles. Approximately 5 dominant species should be captured, although less may be present in the reach, especially if there is no water present in the reach. Species present outside the immediate riparian area need not be recorded.

English, local, or Latin names can be used as long as the same names are being used consistently during the survey of a particular stream.

At the completion of the quantitative portion of the CNMI-SVAP (Page 1 of the data sheet), any notes about the reach including presence of tributaries, discharge, anything requiring further investigation such as a withdrawal line, or the presence of any unique species should be taken on the data sheet.

Scoring Elements of the Stream Visual Assessment Protocol

The following section discusses Part 2 of the CNMI-SVAP scoring sheet which is a more qualitative assessment of stream health using up to nine factors. Each assessment element is scored with a value of one to four on the data sheet, with four having the highest quality. Background information is provided for each assessment element, as well as a description of what to look for. Using Part 2 of the Stream Visual Assessment Protocol Summary Sheet (CNMI-SVAP Form Part 2), record the score that best fits the observations made in the assessment reach. Base observations on the descriptions in the scoring key or "cheat sheet" provided for each element assessed. Assign a score that applies to the conditions observed in the assessment reach. Again, evaluate conditions on both sides of the stream and along the entire length of the reach. Reach conditions can also be sketched in the "Site Assessment Diagram" portion of the form (CNMI-SVAP Form Part 3). Space is provided for a description of the reach, which may be useful to locate the reach or illustrate problem areas. You may indicate tributaries, presence of drainage ditches, and irrigation ditches; note springs and ponds that drain to the stream; include road crossings, and note whether they are fords, culverts, or bridges, and note any other noticeable features in and around the site.

Section 2 is used to record the scores for up to 9 assessment elements. Score an element by comparing the observations to the descriptions provided. If matching descriptions is difficult, try to compare what is being observed to the conditions at reference sites for the area. Again, some of the elements may not be applicable to the site if the reach is dry and, therefore, should not be included in the assessment. The overall assessment score is determined by adding the values for each element and dividing by the number of elements assessed (denominator). For example, if the scores add up to 26 and 9 assessment elements were used, the overall assessment value would be 2.89, which is classified as FAIR. This value provides a numerical score of the environmental condition of the stream reach. This value can be used as a general statement about the state of the environment of the stream or (over time) as an indicator of trends in condition. The following section provides additional narratives to guide quantification of assessment components.

1. Aquatic Invertebrate/Fish Presence

This indicator is used if surface water is present in the reach and characterizes the aquatic fauna diversity found in a given reach. If no surface water is present in the reach, indicate "Dry" on the data sheet. Aquatic species should be seen in or on the water during the survey and rely on water for at least part of their life cycle. Some insects (dragonflies, mosquitoes) as well as amphibians (toads), for example, rely on water for their juvenile life stages even if they are not aquatic as adults. Below is a summary of the four scoring levels for this indicator:

1 – Surface water is present in the reach, but no aquatic species are present
2 – Surface water is present and at least one aquatic species is present
3 – Surface water is present and crustaceans, or two or more other aquatic species are present

4 – Surface water is present and there is significant diversity of aquatic species (four or more species) including fish, crustaceans, insects, or amphibians

2. Aquatic Plant Growth

This indicator is used if surface water is present in the reach and characterizes the aquatic plant or algae growth in a given reach. If no surface water is present in the reach, indicate "Dry" on the data sheet. Water that has slight nutrient enrichment may support communities of algae, which provide a greenish color to the water. Streams with heavy loads of nutrients have thick coatings of algae attached to the rocks and other submerged objects. Floating algal mats, surface scum, or microbial sheen (fern hydrite) are indicators of a eutrophic stream. If surface water is present in the reach note the level of plant/algal growth in the water on the datasheet using one of the following four scoring levels:

1 – Water is green or pea green or the channel is choked with grasses
2 – Large clumps or mats of macroalgae are present, or distinctive green/brown scums are visible on the bottom or sides of the stream
3 – Submerged stones, twigs or other material are slimy but algae growth is not obvious
4 – Water is clear with no significant algal scum or microalgae present

3. Channel Condition

This indicator is used to determine the extent of human alteration of the channel structure. As mentioned above, it often makes sense to use changes in channel condition to delineate boundaries between reaches. Changes in the channel may affect the way a stream naturally does its work, such as the transport of sediment and water, and the development and maintenance of habitat for fish, aquatic insects, and aquatic plants. Some modifications to the stream channels have more impact on stream health than others. And some stream types are more sensitive to management stress than others. For example, riprap along the sides and bottom of the reach can affect a stream more than channelization. Active downcutting and excessive lateral cutting are serious impairments to stream function. Both conditions are indicative of an unstable stream channel. Usually, this instability must be addressed before committing time and money toward improving other stream problems. Extensive bank-armoring of channels to stop lateral cutting usually leads to more problems (especially downstream). To score this element, pick the condition from the following that best characterizes the reach and document the score on the data sheet:

1 – The walls and bottom of the channel have been hardened by humans. This may occur in culverts or constructed canals.
2 – The walls of the channel have been hardened by humans, but the channel bottom is made up of natural materials. In some cases, the channel bottom may have been hardened, but sediment or other natural material have settled out over the hardened bottom.
3 – The channel structure has been altered by humans from its natural state, however the channel walls and bottom are still made up of natural material
4 – The channel structure is natural and has not been modified by humans

4. Channel Flow Alteration

This indicator is used to characterize any manmade changes to the streamflow, whether discharge into the reach or withdrawals from the reach. Water withdrawals from the stream have potential to affect habitat conditions and change the biological and geomorphological conditions of the stream. Temporary diversions are those that are not meant to last (e g small rock diversions for taro that would blow out during a normal storm event). Intermittent withdrawals are those that are occasional or periodic. Any flow alterations outside of the reach should not be counted in this element; instead, note distant diversions/inputs in the "Overview" sheet. If temporary or intermittent, the score should reflect also the amount of water being taken, scoring higher within the range if minimal water is being diverted. Also note if there are inputs, such as stormwater outfalls or culverts in the reach. Record score on the data sheet using the following scoring levels:

1 – Withdrawals from or inputs to the stream equal or exceed the streamflow in the channel reach.
2 – Withdrawals or inputs are occurring constantly in the reach but are less than the stream flow
3 – Intermittent withdrawals or inputs are occurring within the reach. You may use this scoring if an irrigation pipe, drainage pipe, or stormwater pipe is entering the reach but no withdrawals or inputs are actively occurring during the assessment.
4 – There are no constant or intermittent withdrawals or inputs occurring within the assessment reach

5. Bank Stability

This element is the potential for soil erosion from the upper and lower stream banks into the stream. The bank consists of the sides of the channel, between which the flow is confined.
Some bank erosion is normal in a healthy stream. Excessive bank erosion occurs where riparian zones are degraded or where the stream is unstable because of changes in hydrology, sediment load, or isolation from the flood plain. High and steep banks are more susceptible to erosion or collapse. A healthy riparian corridor with a vegetated flood plain contributes to bank stability.

The type of vegetation along the banks is important. For example, most trees, shrubs, sedges, and rushes have the type of root masses capable of withstanding high streamflow events, while pioneer species (such as guinea grass) do not. Mulch can also act as a stabilizer (e.g. ironwood twigs). Hardened banks (e g riprap) are also stable. Soil type at the surface and below the surface also influences bank stability. Look for signs of erosion, unvegetated stretches, exposed tree roots, or scalloped edges. Evidence of construction, vehicular, or animal paths near banks or grazing area leading directly to the water's edge suggest conditions that may lead to the collapse of banks Take into account the six key factors that influence stability:

1. Bank Height
2. Bank Angle
3. Bank Composition
4. Root Depth
5. Root Density
6. Surface Protection

Estimate the size or area of the bank on both sides of the stream that is bare and unstable, relative to the total bank area. Total bank area includes the slope and area immediately adjacent that if unstable would erode into the stream. This element will be difficult to score during high water. Calculate the ratio of eroded-disturbed bank /total area, yielding a percent stable bank value.

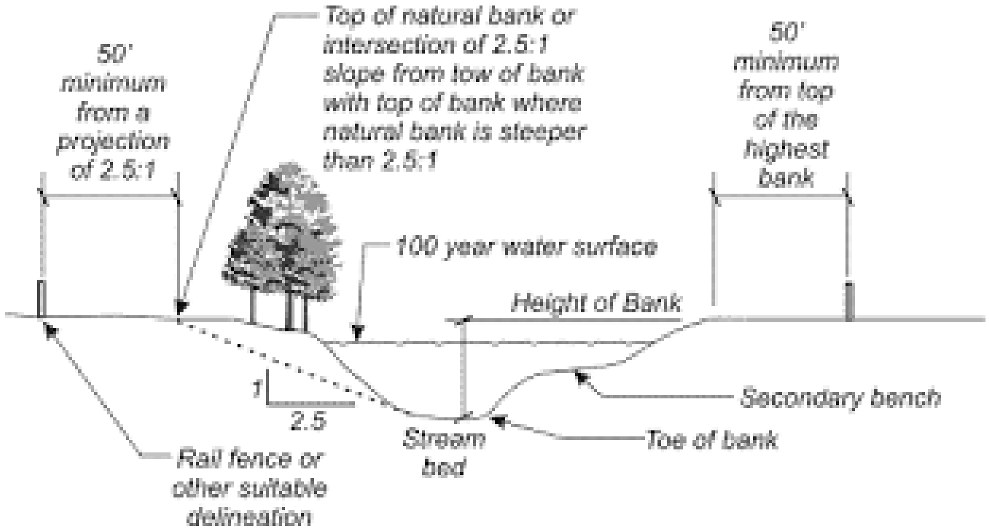


Figure 2 – Measurement of banks and buffers, courtesy of [Santa Clara City Code 20-30.040, CA]

Record the percent bank stability on the data sheet according to the following scoring levels:

1 – <25% stable (not bare or erodible)
2 – 25-50% stable (not bare or erodible)
3 – 50-75% stable (not bare or erodible)
4 – >75% stable (not bare or erodible)

6. Canopy / Shade

This element is the measurement of shade across the active channel. Shading of the stream is important because it keeps water cool and limits the growth of less preferred types of algal. Cool water has a greater oxygen holding capacity than does warm water. When streamside trees are removed, the stream is exposed to the warming effects of the sun, which can change plant and animal species composition and abundance. For instance, alien fish such as tilapia are more adaptable to high water temperatures than some native species. To assess canopy cover, an instrument known as a densiometer is normally used. A densiometer is a tool used in forestry and is a small convex mirror with a grid etched into it. When the densiometer is held out facing up to the canopy, the number of squares occupied mostly by tree canopy cover can be divided by the number of total squares to derive a percent canopy cover. The squares occupied mostly by sky are considered to be mostly covered by trees. In the absence of a densiometer, this measurement can be replicated by standing in the middle of the stream channel and facing straight up. The arms can be extended at an angle that reaches the edge of the observers peripheral vision. The percent canopy cover can be estimated within the circle created within the observer's peripheral vision. Canopy cover measurements should be taken at three representative points along the length of the reach and averaged to derive the percent canopy cover for the reach.

Record the canopy cover on the data sheet according to the following scoring levels:

1 – <20% canopy cover
2 – 20-50% canopy cover
3 – 50-80% canopy cover
4 – >80% canopy cover

7. Wood Cover Presence

Woody debris presence in a reach below the bankfull height level is an excellent indicator of habitat availability for aquatic and terrestrial organisms in a reach. These organisms use woody debris cover as refugia from predators, from extreme heat, and from rushing water during high streamflow events. Without these complex microhabitats, few aquatic organisms can survive disturbance events that occur during heavy rainfall or extreme heat or drought. Wood cover can include live or dead logs, logjams, roots, trees, fallen branches, or sticks. The total percent of the area of the reach below the bankfull height should be aggregated to obtain the total percent wood cover in the reach.

Record the wood cover on the data sheet according to the following scoring levels:

1 – <5% wood cover below bankfull
2 – 5-25% wood cover below bankfull
3 – 25-50% wood cover below bankfull
4 – >50% wood cover below bankfull

8. Riparian Width/Condition

"Riparian area" is the width of the natural vegetation zone from the edge of the active channel (or normal water line) out onto the flood plain. For this element, the word natural vegetation means plants native to the site or introduced species that function like them.

In most cases, this zone:

- Reduces the amount of pollutants that reach the stream in surface runoff.
- Helps control erosion
- Provides a microclimate that keeps the water cool for stream biota
- Provides fish habitat in the form of undercut banks with the "ceiling" held together by roots of woody vegetation
- Provides organic material for stream biota that, among other functions, is the base of the food chain in lower order streams
- Provides habitat for terrestrial insects, and habitat and travel corridors for terrestrial animals
- Dissipates energy during flood events
- Often provides the only refuge areas for fish during out-of-bank flows (behind trees, stumps, and logs).

In CNMI, much like in Hawai'i, we often find highly incised stream channels with steep-sloped riparian areas in their "natural" condition. This means that the stream is in the evolutionary stage of head-cutting. It will typically have a gradient greater than 3%, and should not be scored lower because it is not yet in the stage of having floodplains or terraces. The type, timing, intensity, and extent of activity in riparian zones are critical in determining the impact on these areas.

Narrow riparian zones and/or riparian zones that have roads, agricultural activities residential or commercial structures, or significant areas of bare soils reduce stream functions. The filtering function of riparian zones can be compromised by concentrated flows. Look for evidence of concentrated flows through the riparian zone.

Compare the width of the riparian zone to the active bankfull channel width. In this case, observe how much of the flood plain is covered by riparian vegetation. The vegetation must be natural, take particular note of pioneer, invasive species. These do not provide good cover or stability to the banks and can wash away after storm events. Vegetation should consist of all of the structural components (aquatic plants, sedges or rushes, grasses, forbs, shrubs, understory trees, and overstory trees) appropriate for the area.

Examine both sides of the stream and note on the "Channel cross section" diagram which side of the stream has problems. Check for evidence of concentrated flows through the riparian zone that are not adequately buffered before entering the riparian zone. Pick the condition from the following scoring levels that best characterizes the reach and document the score on the data sheet.

1 – The riparian area adjacent to the stream is severely degraded and is less than one bankfull channel width wide. Little to no vegetation exists on either side of the stream.
2 – The riparian area is the same width as the bankfull channel width and vegetation is non-diverse or mostly non-native vegetation.
3 – The riparian area is at least than two bankfull channel widths and vegetation is diverse (native or non-native).
4 – The riparian area covers the entire floodplain or slope above the stream and consists of diverse, mostly native vegetation.

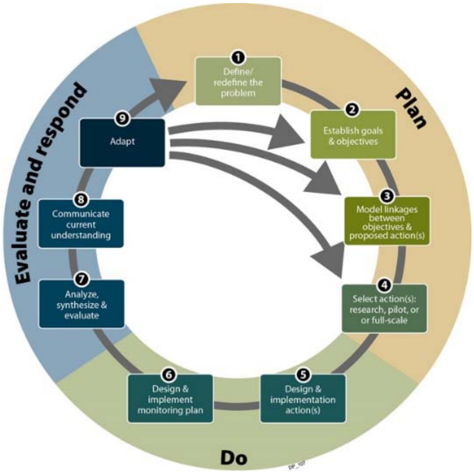
9. Contamination (Litter/Trash/Waste) Presence

The presence of litter, trash and fish or animal carcasses are obvious signs of stream degradation. Assess the presence in both the wetted area and riparian zone. Outflow pipes, encroaching piggeries, and the presence of other waste should be noted and geolocated if possible. Select from the following scoring levels and note the condition and score on the datasheet.

1 – Unsanitary waste or environmental toxins are present, for example animal carcasses, excessive litter, excrement, diapers, bleach bottles, chemicals.
2 – Contamination such as litter is prominent in the reach and can be detected obviously.
3 – A small amount of contamination is evident in the reach (eg. Litter such as plastic bottles or metal) but not obvious or prominent
4 – No sources of contamination are present in the reach

Restoration Recommendations Evaluation

After conducting a SVAP, enhancement opportunities or management recommendations may be identified. The following ideas are a few examples for improving the various stream elements. It is important to have interdisciplinary input from experts in geomorphology, engineering, plant ecology and fish and wildlife biology. Applying adaptive management principles to achieve identified restoration objectives is recommended. See *Salafsky et al., Adaptive Management: A Tool for Conservation Practitioners*, and *U.S. Forest Service NSAEC Guidance for Stream Restoration, 2018* for additional information.



Adaptive management cycle.

1. Turbidity — Improve water quality by reducing sediment loads into the stream, by revegetating banks, reducing inputs from fields, or other means.

2. Plant growth — Improve water quality by reducing nutrient loading in the stream (e.g. nitrates and phosphates). Improve canopy cover to encourage compatible species of algal growth.

3. Channel Condition — Evaluate ways to reconnect or enhance the connectivity of the stream channel to its floodplain, where applicable.

4. Channel Flow Alteration — Evaluate ways to restore altered sites, producing changes in hydrology (e.g. bioengineering, removing diversions).

5. Percent Embeddedness — Reduce fine sediment input from the upper watershed and/or eroding streambanks.

6. Bank Stability — Improve bank stability with a wide riparian buffer, better channel conditions and bioengineering methods. Note that if there is major, contiguous erosion occurring around a bend, it may be a system-wide problem that needs to be addressed, compared with small eroding spots that may be treated on site.

7. Canopy/Shade — Enhance canopy over the stream to keep water temperature cool with plantings and management.

8. Riparian Condition — Improve conditions with plantings and management for a wide riparian buffer.

9. Habitat Available for Native Species — Evaluate ways to improve habitat conditions for native flora and fauna (e.g. flow, water depth, roughness of the channel)

10. Litter/trash/human or animal waste — Identify source(s) and clean up litter/trash in the stream and stream riparian areas and set up regular trash pickup.

Recommended Next Steps

Stream Classification and Reference Sites

NRCS guidance notes that healthy streams will look and function differently depending on its location or ecological setting. Thus, accurately classifying the type of stream in an area of interest is important to assessing the current condition, or health, of that particular stream and whether it meets the designated uses defined in the CNMI Water Quality Standards. Stream classification is a way to account for the effects of natural variation in streams and helps avoid comparing the conditions of streams of different classes. A stream's classification provides a point of reference for subsequent assessments that may occur at the site. Ideally, a separate SVAP modification should be developed for each stream class, but realistically, this is not possible. Therefore, NRCS recommends that States identify only as many stream classes as are necessary to account for natural variation in streams caused by the prevailing environmental influences of their region. Some important factors to consider are major land resource areas (MLRA) or ecoregion, drainage area, and gradient. Ecoregions are geographic areas in which ecosystems are expected to be similar. Drainage area is the size of the area of a watershed (catchment or basin).

SVAP2 Guidance recommends that enough up-front work should be done by State Offices in tailoring the protocol to permit field offices to use it without further modification. This includes refining and evaluating the protocol, modifying the element criteria and scoring to reflect local conditions, and delineating the geographic boundaries for its intended use. To reach this objective, it is important to identify and assess reference sites to represent the range of conditions that potential exist for a particular class of stream. Least impaired reference sites represent the best conditions attainable, and most impaired reference sites the worst. Accessible, least impaired reference sites are important not only because they define a benchmark for attainable conditions, but they also serve as demonstration areas for field staff to observe the characteristics of the region's best streams that would result in the highest possible SVAP2 scores. NRCS instructs that reference sites should represent an entire stream class and thus may be located in another county or State. Therefore, it helps if they can be identified at a State or higher level and with the help of State agencies that may have already established reference sites that represent a full range of human perturbations for a given class of stream.

Implementation, Training, and Outreach

- Training is needed to reduce SVAP variability. Occasional training refreshers are needed to ensure that consistency is maintained *(See Hannaford et al., 1997).*

- Develop CNMI bio-assessment protocols to support further water quality assessment and valuation. The CNMI-SVAP provides a basic level of stream health evaluation, known as a "first level" protocol in a four-part assessment hierarchy; Tier 2 is the NRCS Water Quality Indicators Guide, Tier 3 is the NRCS Stream Ecological Assessment Field Handbook, and Tier 4 is the intensive bio-assessment protocol used by State water quality agencies. Because CNMI does not have established bio-assessment protocols, future development of localized assessment hierarchy protocols is recommended to support assessment, valuation, and management efforts. Consideration of Hawaii's 2002 Stream Bioassessment Protocol, Version 3, is recommended.
- Build capacity in natural resource management staff to support implementation of stream valuation to support protection and restoration objections.

CNMI-SVAP Form

Part 1 – Stream Visual Assessment Data Sheet

CNMI SVAP SCORING DATA SHEET - PART I

Date:		**Season** (wet, dry)		**Team:**		
Stream Name:		**Weather** (sunny, partly cloudy, overcast, rain)		**Recorder:**		
Stream Reach ID						
GPS Reach Start: Latitude						
Longitude						
Reach Type: pool, riffle, run						
Reach Length (m)						
Elevation (m)						
Average Width (m) Bankfull						
Wetted (if water present)						
Average Depth (m) = in x 0.0254						
Turbidity (NTU)						
Temperature (Celsius)						
Dissolved Oxygen(%)						
Salinity (ppt)						
Conductivity (uS/m)						
Surface Velocity no water, standing, slow, medium, fast						
Water Appearance/Color clear, oily sheen, brown, orange, green						
Water Odor None, sewage, fishy, sulphur, foul odor						
Streambed Material manmade, bedrock, boulder, cobble, gravel, sand, silt						
Embeddedness Average Percent Embeddedness (%)						
Flora eg. Identify ~5 most dominant riparian species						
Fauna eg. identify ~5 most dominant species (especially aquatic and riparian)						
Notes: (tributaries, anything requiring investigation, unique species etc.)						

If No Water Present enter "No Water"

Updated 10/5/2020

Part 2 – Stream Visual Assessment Scoring Sheets

CNMI SVAP SCORING DATA SHEET - PART II

Stream Reach ID					
	Score Each Applicable Element from Good to Bad (4-1)			If dry write "dry" in Element 1 and 2	
1. Aquatic Invert/Fish present (Diverse=**4**, crustaceans or ≥2=3, ≥1=2, 0=1)					
2. Aquatic Plant Growth (clear-4, slime-3, macroalgae-2, pea green-1)					
3. Channel Condition (natural-4, altered/soft-3, hard walls-2, hard walls/bottom-1)					
4. Channel Flow Alteration (natural-4, Withdrawal/Discharge input-3, many W/D-2, W > flow-1)					
5. Bank Stability (Stable >75%-4, 50-75%-3, 25-50%-2, <25%-1)					
6. Canopy/Shade (>80%-4, 50-80%-3, 20-50%-2, <20%-1)					
7. Wood Cover/Habitat below Bankfull (>50%-4, 25-50%-3, 5-25%-2, <5%-1)					
8. Riparian Condition (Rip=Fldplain&diverse-**4**, Rip=2 channel&diverse-3, Rip=Bnkfull-2, Rip<1 channel-1)					
9. Contamination (None-**4**, Small amount-3, Prominent-2, Unsanitary-1)					
Circle all applicable sources:	-Trash/Litter -Rd./Surface Runoff -UXO -Marine Debris -Human Waste/TP -Farm Runoff -Illicit Discharge/Pipe -Other (see notes)	-Trash/Litter -Rd./Surface Runoff -UXO -Marine Debris -Human Waste/TP -Farm Runoff -Illicit Discharge/Pipe -Other (see notes)	-Trash/Litter -Rd./Surface Runoff -UXO -Marine Debris -Human Waste/TP -Farm Runoff -Illicit Discharge/Pipe -Other (see notes)	-Trash/Litter -Rd./Surface Runoff -UXO -Marine Debris -Human Waste/TP -Farm Runoff -Illicit Discharge/Pipe -Other (see notes)	-Trash/Litter -Rd./Surface Runoff -UXO -Marine Debris -Human Waste/TP -Farm Runoff -Illicit Discharge/Pipe -Other (see notes)
Total Score					
Denominator (# of elements)					
Average Score					
Rating					
> than 3.5 = Very High					
3.1 - 3.5 = High					
2-3 = Fair					
< 2 = Low					
Notes: ("Other", restoration opportunities, artifacts, overall stream summary, drawings)					

Updated 10/5/2020

Part 3 – Stream Visual Assessment Site Diagram

Site Diagram: Indicate approximate scale, major features, resource concerns, etc. Provide notes related to each element scored on back of site diagram, as needed.

Site Assessment Diagram ***Sketch Stream Cross Section(s)***
Stream Reach ID:

SVAP Scoring Key

CNMI SVAP SCORING KEY

1. Aquatic Invert/Fish present	
Condition	Score
Diverse - fish, crustaceans, insects, tadpoles	4
crustaceans, or two or more other species	3
one or more aquatic species (striders, etc.)	2
water present, but no aquatic species	1

2. Aquatic Plant Growth (indicator of eutrophication)	
Condition	Score
Water clear with no significant algal scum or microalgae	4
Submerged stones, twigs or other material are slimy but algae is not obvious	3
Large clumps or mats of macroalgae present; or distinctive green/brown scums visible on bottom or sides of stream	2
Water green or pea green; or channel choked with grasses	1

3. Channel Condition (indicator of artificial bank modifications)	
Condition	Score
Natural Channel	4
Channelized by humans but natural walls and bottom	3
Walls Hardened (eg. concrete, rip-rap)	2
Walls and Bottom Hardened	1

4. Channel Flow Alteration	
Condition	Score
No withdrawals, diversions, or stormwater/ag water discharge entering segment	4
Intermittent withdrawals or inputs not actively occuring during assessment (eg. Pipe or hose present)	3
Constant withdrawals/inputs occuring within segment, but less than streamflow	2
Withdrawals/inputs equal or exceed stream flow	1

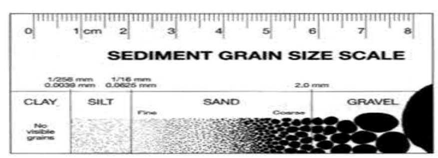
5. Bank Stability (up to bankfull, both sides)	
Condition	Score
>75 % Stable (not bare or erodible)	4
50-75 % Stable (not bare or erodible)	3
25-50 % Stable (not bare or erodible)	2
<25 % Stable (not bare or erodible)	1

6. Canopy/Shade	
Condition	Score
>80 % cover	4
50-80 % cover	3
20-50 % cover	2
<20 % cover	1

7. Wood Cover Presence in Stream below Bankfull	
Condition	Score
>50 % cover	4
25-50 % cover	3
5-25 % cover	2
<5 % cover	1

8. Riparian Condition (indicator of buffer capacity)	
Condition	Score
Riparian area covers entire floodplain, undisturbed, diverse mostly native vegetation.	4
Riparian area more than two channel widths (bankfull) wide, diverse vegetation.	3
Riparian area same width as channel (bankfull), non-diverse or mostly non-native vegetation.	2
Severely degraded riparian area, less than one channel width (bankfull) wide. Little or no vegetation.	1

9. Contamination	
Condition	Score
No sources of contamination are present	4
A small amount of contamination is evident but not prominent	3
Contamination is prominent	2
Unsanitary waste or environmental toxins are present (eg. animal carcass or excrement, diapers, bleach bottles)	1



Updated 10/1/2020

Appendices

The appendices below contain additional techniques that can be used for stream classification and may be added to the standard CNMI-SVAP if appropriate. Classification techniques discussed in the SVAP and described in more detail in the appendices included herein do not come without flaws. One of the reasons why there are so many classification techniques and not one universal technique is because none of them are applicable to every stream. Most of the classification techniques listed were developed for a certain region and can only accurately classify a stream located in a similar climate amongst similar vegetation and at a similar elevation. For example, Montgomery and Buffington's method, which is not included in the appended information, focuses on larger mountain systems with steep gradients. Leopold and Wolman's method also leaves a very broad description of the system. Describing a river as braided, meandering, or straight has its advantages but it does not give any other information. Also, river systems typically only continue with one of these descriptions for a brief time and therefore can only be classified for short reaches. Many rivers exhibit all three of these characteristics at some point. Many of these methods also require costly and sometimes inaccurate data measurement from field technicians. Using GIS data can solve this problem. Unfortunately, there are still a number of biological variables that cannot be determined with GIS.

Similarly, although Rosgen's method is currently the most widely used, it doesn't go without criticism. *Simon et al.* takes a critical look at the Rosgen method of classification and addresses what could be considered a number of critical flaws, particularly as it relates to Rosgen's analysis of bankfull dimensions (Simorn, 2007). When considering sediments for classification, Rosgen suggests that particle counts should be considered from one bankfull level to the opposite bankfull level. Simon et al. suggests that this mixes two different alluvial materials requiring different forces and processes while depositing at different times. Classification related to this issue can be seen when trying to describe two channels classified as C. One channel can have gravel bed and silt-clay banks, while the other containing a sand bed and sandbanks. These two channels could have the same median diameters of particle size. Thus, the following information is intended to be informative and assist with terminology in applying the CNMI-SVAP and should not be considered required elements of SVAP narratives.

The appendices that follow start with a glossary of key terms and then provide summaries of classification techniques and relevant ecological indicators to support application of the CNMI-SVAP.

Appendix A – Glossary

Active floodplain: The land between the active channel at the bankfull elevation and the terraces that are flooded by stream water on a periodic basis. This is not synonymous with the FEMA flood zone designation.

Aggradation: The rising of a streambed due to sediment deposition.

Alluvial and/or Alluvium: Clay, silt, sand, gravel, or similar detrital material deposited by running water.

Back water pools: A pool type formed by an eddy along channel margins downstream from obstructions such as bars, rootwads, or boulders, or resulting from backflooding upstream from an obstructional blockage. Backwater pools are sometimes separated from the channel by sand or gravel bars.

Bankfull: The water level, or stage, at which a stream, river or lake is at the top of its banks and any further rise would result in water moving into the flood plain. It may be identified by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas.

Bankfull Bench: A flat or shallowly sloped area above bankfull that slows high velocity flows during flows above bankfull.

Bankfull Depth: The average depth measured at Bankfull Discharge.

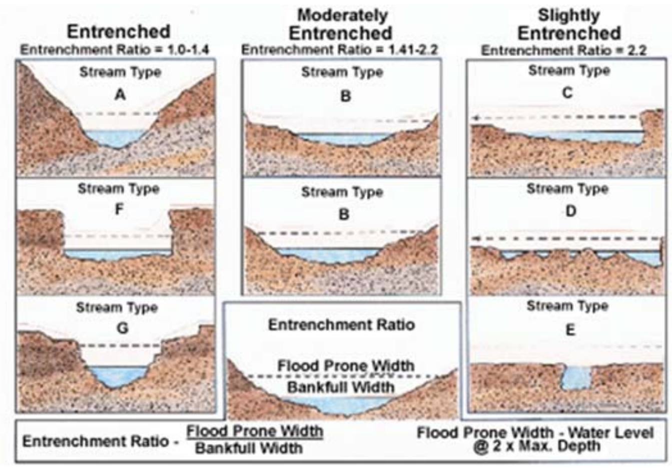
Bankfull Discharge: The dominant channel forming flow with a recurrence interval seldom outside the 1 to 2-year range.

Bankfull Width: Channel width at Bankfull Discharge.

Baseflow: Also called drought flow, groundwater recession flow, low flow, low-water flow, low-water discharge and sustained or fair-weather runoff) is the portion of streamflow that comes from "the sum of deep subsurface flow and delayed shallow subsurface flow".

Drainage Area: The horizontal projection of the area upstream from a specific location that has a common outlet at the site for its surface runoff from precipitation that normally drains by gravity into a stream.

Embeddedness: The extent to which rocks (gravel, cobble, and boulders) are surrounded by, covered, or sunken into the silt, sand, or mud of the stream bottom. Generally, as rocks become embedded, fewer living spaces are available to macroinvertebrates and fish for shelter, spawning and egg incubation.



Entrenchment ratio. The vertical containment of the river described as the ratio of the flood-prone width to the bankfull width (Rosgen, 1996).

Flood-prone width: The width across the flood plain, measured at a section perpendicular to the streamflow, at a water-surface elevation corresponding to twice the maximum depth of the bankfull channel (Rosgen, 1996).

Manning's roughness coefficient (n): A dimensionless measure of the frictional resistance to flow, or roughness, of a stream channel.

Maximum bankfull depth: The maximum depth of the bankfull channel measured at a section perpendicular to streamflow.

Mean annual precipitation: The basin average value for annual precipitation.

Mean bankfull depth: The mean depth of the bankfull channel measured at a section perpendicular to streamflow.

Percent of basin covered by forest: That portion of the drainage area of a stream shown in green on a 7.5-minute U.S. Geological Survey topographic map, divided by the total drainage area, and multiplied by 100.

Reach: A reach is a length of stream with relatively consistent gradient and channel form.

Recurrence interval: The average interval, in years, between exceedances of a particular annual peak discharge.

Rosgen classification: A system of describing river channels based on channel geometry, stream plan-view patterns, and streambed material (Rosgen, 1996). See Appendix D.

Stream bank / river bank: Terrain alongside the bed of a river, creek, or stream consisting of the sides of the channel, between which flow is confined.

Stream classification: The process of assigning a numeric order to links in a stream network based on the number of tributaries.

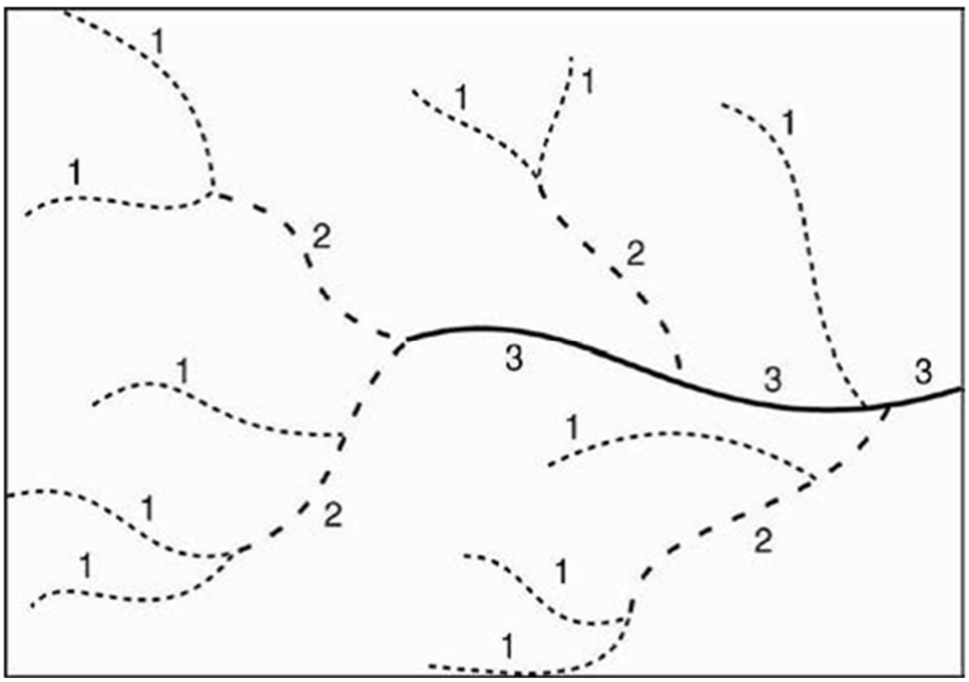
Sinuosity: The ratio of the measured channel distance divided by the straight-line distance of the valley from the beginning of the channel reach to the end of the channel reach.

Thalweg: The lowest point in a stream channel.

Width/depth ratio: The ratio of bankfull width to mean bankfull depth measured at a section perpendicular to streamflow.

Appendix B - Stream Classification Tools – Strahler's Stream Order Classification

One of the first methods developed for stream classification was developed by Strahler in 1952. This method simply describes the order of streams. This method starts with the smallest tributaries are considered 1st order. When two of these tributaries meet, the resulting tributary is considered 2nd order. When two 2nd order streams meet, the result is a 3rd order and so on (Strahler, 1952). Although this type of classification is fairly vague, it is an important indicator of stream size and drainage (Ward et al., 2008). Long 1st and 2nd order streams are often characteristic of manmade or severely altered natural channels. As CNMI has not adopted stream order assignments, applying this methodology can support initial classification of stream orders for the purposes of CNMI-SVAP application.

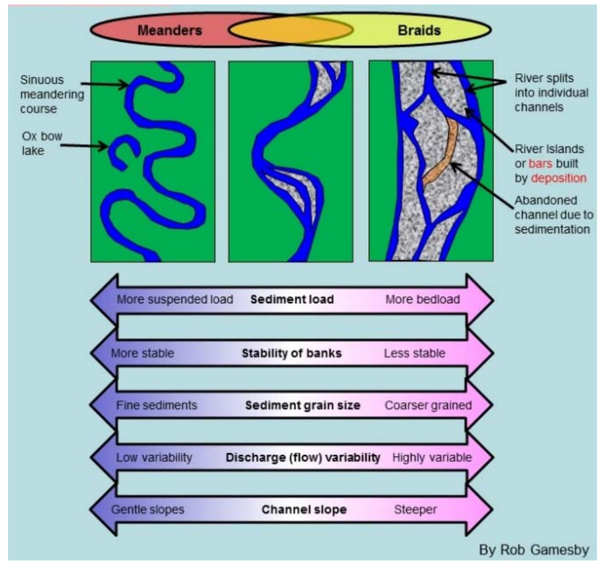


Stahler Stream Order Classification Diagram

Appendix C - Stream Classification Tools – Channel Evolution Model

Leopold and Wolman's "Channel Evolution Model" method, developed in 1952, describes streams as braided, meandering, or straight. The method looks at specific reaches of the system as opposed to the whole system due to the river system often changing from straight, to meandering, to braided, etc. This early method was developed in order to attempt to "understand the mechanisms by which these laws operate in a river" (Leopold et al., 1952).

Leopold and Wolman describe braided rivers as channels that flow around alluvial islands developed in the system. This can include two or more channels. Braided channels are typically seen as wider, shallower and steeper than undivided channels of similar flow (Leopold et al, 1952). Velocity, cross sectional area, and roughness can all be factors resulting in the development of a braided channel. Leopold and Wolman performed a study in the lab by developing a braided channel by depositing a central bar consisting of coarse particles that could not be transported under current conditions. The coarse material acted as a catalyst for a subsequent island that developed and was maintained naturally by the system, thus creating a braided channel.



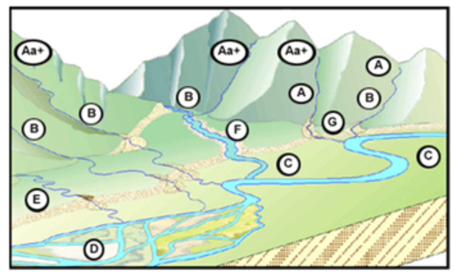
Meandering channels are different than braided channels in that they typically exhibit a single channel that is characterized by multiple turns or curves through the floodplain as it flows downstream. Sediment is deposited on the outside banks of the floodplain often leading to erosion. Meandering reaches are the most common classification of the three discussed by Leopold and Wolman.

Straight channels are classified in the Leopold Wolman method but are often rare in a natural setting. Straight natural reaches are most often shorter than ten times the width of the channel. Straight reaches longer than this is often altered by man. Studies by Leopold and Wolman indicate that straight reaches also exhibit pools and riffles as do meandering channels. Further studies by Leopold and Wolman also indicate that although the banks of "straight channels" may be linear, the flow within the banks often exhibit a sort of meandering quality.

Appendix D - Stream Classification Tools – Rosgen Stream Classification System

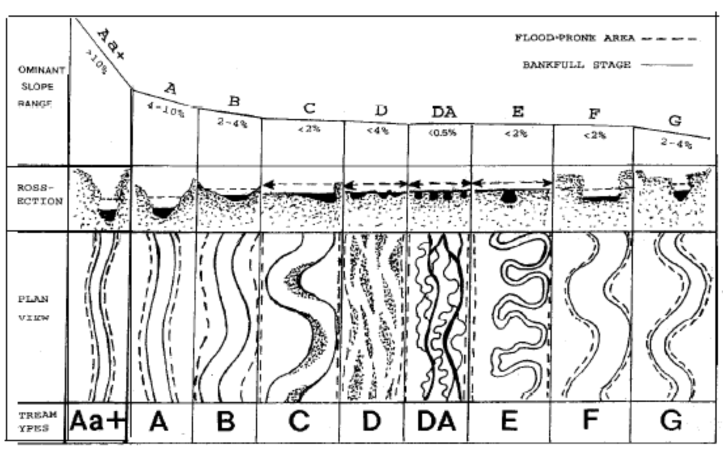
For the purpose of easily classifying rivers, Rosgen has broken the process into four levels. A river starts by being classified using Level I. The river is then further classified in Level II, by describing the river in the next sub-genre of classification. The river is then further classified in Levels III and IV. Each level deals with a different topic of characterization. Level I begins with geomorphic characterization. Level II deals with morphological descriptions. Level III characterizes the streams state. Finally, Level IV addresses validation of process characteristics (Rosgen, 1994). For the purpose of clarity, Rosgen primarily describes Level I and II in detail, and only briefly describes Level III and IV. For the purposes of assessing “stream types” for the CNMI-SVAP, the focus here is mainly on Level I and II. These descriptions are included to support initial channel assessment and inclusion of relevant terminology. Rosgen classification is not intended to be applied in full during the SVAP assessment or analysis.

Level I provides a broad geomorphic characterization to start the classification process. Landform and fluvial characteristics are described and combine channel relief, shape, and dimension profiles (Rosgen, 1994). There are 8 categories that a stream can be classified as in Rosgen’s method. Streams are broadly classified as A, B, C, D, DA, E, F, or G. These categories are used to describe a variety of characteristics.



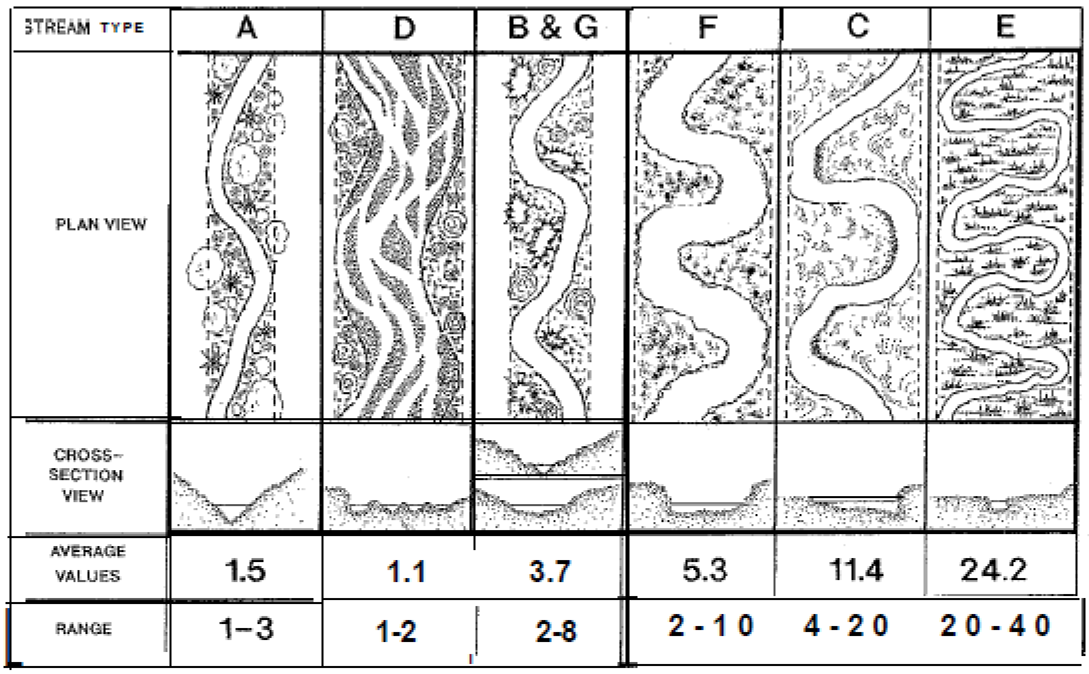
Different “Level I” stream types tend to occur in different landscape settings.

The first distinguishable characteristics in Level I are the longitudinal profiles used to represent slope. The slopes start with Aa+ being very steep at >10% gradually decreasing to DA at <0.5% and then increasing in slope to 4% at G. Slope can be related to bed features and can be described as pools, riffles, rapids, cascades, and steps (Rosgen, 1994). Riffle/pool streams are represented with CE, and F streams. Rapids are found in B and G streams, while steps and cascades are found in A and Aa+ streams. See figure below for details.



Cross section morphology is also described in Level I of Rosgen’s method. The cross sections differ greatly in the 9 categories ranging from deep and narrow to wide and shallow. The cross section morphology also describes the flood plain ranging from well-developed flood plains to virtually no flood plain.

Finally, Level I discusses plan view morphology. The nine categories describe the sinuosity of the river system in question. River A types represent relatively straight streams, B represents low sinuosity, C represents meandering streams, E represents high meandering, and D/DA represent complex braided systems (Rosgen, 1994). This form of classification often uses the meander width ratio to describe the sinuosity. Plan view morphology is also very important for proper river restoration. Rosgen's method can be used for "describing the most probable state of channel pattern in stream restoration work," (Rosgen, 1994). See figure below for plan view morphology.



Level I Stream Classification

The Level I stream classification serves four primary functions:

1. provide for the initial integration of basin characteristics, valley types, and landforms with stream system morphology.
2. provide a consistent initial framework for organizing river information and communicating the aspects of river morphology. Mapping of physiographic attributes at Level I can quickly determine location and approximate percentage of river types within a watershed and/or valley type.
3. assist in the setting of priorities for conducting more detailed assessments and/or companion inventories.
4. correlate similar general level inventories such as fisheries habitat, river boating categories, and riparian habitat with companion river inventories.

The advantage of a broad, general classification is that it allows for a rapid initial delineation of stream types and illustrates the distribution of these types that would be encountered within a given study area. The Level I classification and delineation process provides a general characterization of valley types (addressed in the second part of this module), and identifies the corresponding major stream types, A through G, discussed here. Illustrations of the Level I stream types are shown in the accompanying figure; clicking on each stream type will also bring up a brief text description of that type in this text window.

The "Aa+" Stream Type

Stream type "Aa+" is very steep (>10%), well entrenched, has a low width/depth ratio, and is totally confined (laterally contained). The bedforms are typically a step/pool morphology with chutes, debris flows, and waterfalls. The "Aa+" stream types often occur in debris avalanche terrain, zones of deep deposition such as glacial tills and outwash terraces, or landforms that are structurally controlled or influenced by faults, joints, or other structural contact zones. Streamflow at the bankfull stage in the "Aa+" stream type is generally observed as a torrent or waterfall. The "Aa+" stream types can be associated with bedrock, and zones of deep deposition and/or be deeply incised in residual soils. The "Aa+" can often be described as high energy/high sediment supply systems due to their inherently steep channel slopes and narrow/deep channel cross-sections. "Aa+" stream types may also be found in alluvial landforms, where a change in the base level of the mainstem channel initiates a headward expansion of the tributary network through a channel rejuvenation process. Examples of rejuvenation may be observed where lower-slope position streams are deeply incised in over-steepened adjacent side-wall slopes, or older holocene terrace features that have cut their way through to the elevation of the existing mainstem river. The "Aa+" stream types are often found in valley types I, III, and VII, discussed in the next part of this module.

The "A" Stream Type

Stream type "A" is similar to the described "Aa+", in terms of associated landforms and channel characteristics. The exception being that channel slopes range from 4 to 10 percent, and streamflows at the bankfull stage are typically described as step/pools, with attendant plunge or scour pools. Normally, "A" stream types are found within valley types that due to their inherent channel steepness, exhibit a high sediment transport potential and a relatively low in-channel sediment storage capacity. Although a large number of "A" stream types occur as low-order streams, located at upper-slope positions, stream order for these stream types can range from 1st order up to 5th order or larger. Stream order referred to is that of Strahler, where the incipient crenulation of a drainage way on the landscape is order 1 and the confluence of the first two drainage ways become order 2 and so on. The influx of large organic debris can play a major role in determining the bedform and overall channel stability of "A" stream types. Landforms associated with deeply incised fanhead troughs are associated with both "Aa+" and "A" stream types. Valley types associated with the "A" stream types are I, III, and VII.

The "B" Stream Type

The "B" stream types exist primarily on moderately steep to gently sloped terrain, with the predominant landform seen as a narrow and moderately sloping basin. Many of the "B" stream types are the result of the integrated influence of structural contact zones, faults, joints, colluvial-alluvial deposits, and structurally controlled valley side-slopes which tend to result in narrow valleys that limit the development of a wide floodplain. "B" stream types are moderately entrenched, have a cross-section width/depth ratio (greater than 12), display a low channel sinuosity, and exhibit a "rapids" dominated bed morphology. Bedform morphology, which may be influenced by debris constrictions and local confinement, typically produces scour pools (pocket water) and characteristic "rapids." Streambank erosion rates are normally low as are the channel aggradation/degradation process rates. Pool-to-pool spacing is generally four to five bankfull widths, decreasing with an increase in slope gradient. Meander width ratios (belt width/bankfull width) are generally low which reflect the low rates of lateral extension. "B" stream types are usually found within valley types II, III, and VI.

The "C" Stream Type

The "C" stream types are located in narrow to wide valleys, constructed from alluvial deposition. The "C" type channels have a well-developed floodplain (slightly entrenched), are relatively sinuous with a channel slope of 2% or less and a bedform morphology indicative of a riffle/pool configuration. The shape and form of the "C" stream types are indicated by cross-sectional width/depth ratios generally greater than 12, and sinuosities exceeding 1.2. The "C" stream type exhibits a sequencing of steeps (riffles) and flats (pools), that are linked to the meander geometry of the river where the riffle/pool sequence or spacing is on the average one-half a meander wavelength or approximately 5-7 bankfull channel widths. The primary morphological features of the "C" stream type are the sinuous, low relief channel, the well-developed floodplains built by the river, and characteristic "point bars" within the active channel. The channel aggradation/degradation and lateral extension processes, notably active in "C" stream types, are inherently dependent on the natural stability of streambanks, the existing upstream watershed conditions and flow and sediment regime. Channels of the "C" stream type can be significantly altered and rapidly de-stabilized when the effects of imposed changes in bank stability, watershed condition, or flow regime are combined to cause an exceedance of a channel stability threshold. "C" stream types may be observed in valley types IV, V, VI, VIII, IX and X. They can also be found on the lower slope positions of the very low gradient valley type III.

The "D" Stream Type

The "D" stream type is uniquely configured as a multiple channel system exhibiting a braided, or bar-braided pattern with a very high channel width/depth ratio, and a channel slope generally the same as the attendant valley slope. "D" type stream channels are found in landforms and related valley types consisting of steep depositional fans, steep glacial trough valleys, glacial outwash valleys, broad alluvial mountain valleys, and deltas. While the very wide and shallow "D" stream types are not deeply incised, they can be laterally contained in narrower or confined valleys. Bank erosion rates are characteristically high and meander width ratios are very low. Sediment supply is generally unlimited and bed features are the result of a convergence/divergence process of local bed scour and sediment deposition. The multiple channel features are displayed as a series of various bar types and unvegetated islands that shift position frequently during runoff events. Adjustments in channel patterns can be initiated with either natural or imposed changes in the conditions of the encompassing landform, contributing watershed area, or the existing channel system. Aggradation and lateral extension are dominant channel adjustment processes occurring within a range of landscapes from desert to glacial outwash plains. Typically, the runoff regime is "flashy," especially in arid landscapes with highly variable extremes of stage occurring on an annual basis which generates a very high sediment supply. Braided channel patterns can be found developing in very coarse materials located in valleys with moderately steep slopes, to very wide, flat, low gradient valleys containing finer materials. The "D" stream type may develop within valley types III, V, VIII, IX, X, and XI.

The "DA" (Anastomosed) Stream Type

The "DA" or anastomosed stream type is a multiple-thread channel system with a very low stream gradient and the bankfull width of each individual channel noted as highly variable. Stream banks are often constructed with fine grained cohesive bank materials, supporting dense-rooted vegetation species, and are extremely stable. Channel slopes are very gentle, commonly found to be at or less than .0001. Lateral migration rates of the individual channels are very low except for infrequent avulsion. Relative to the "D" stream type, the "DA" stream type is considered as a stable system composed of multiple channels. Channel width/depth ratios and sinuosities may vary from very low to very high. The related valley morphology is seen as a series of broad, gently sloping wetland features developed on or within lacustrine deposits, river deltas or splays, and fine-grained alluvial deposits. The "DA" stream types make up a very small number of observed stream types, but are unique both in the process of their creation and maintenance. In certain locations operating at a "control" point within a valley, maintains the valley base level where a vertical balance exists between the rate of deposition and the rate of uplift. The geologic processes responsible for development of the anastomosed river include subsidence of sedimentary basins in tectonically active forelands, valley base level rise at the basin outlet, regional basin tilting derived from glacial-induced differential isostatic rebound, and the uplifting of sea or lake bed levels. The bedform features of the "DA" stream types are riffle/pool, similar to stream types "C" and "E." The streambanks and island surfaces between channels are well vegetated and constructed with either fine grained alluvium, or fine, cohesive depositional materials. The ratio of bedload to total sediment load is very low for these very stable stream types. The "DA" stream type normally occurs in valley types X and XI.

The "E" Stream Type

The "E" type stream channels are conceptually designated as evolutionary in terms of fluvial process and morphology. The "E" stream type represents the developmental "end-point" of channel stability and fluvial process efficiency for certain alluvial streams undergoing a natural dynamic sequence of system evolution. The "E" type system often develops inside of the wide, entrenched and meandering channels of the "F" stream types, following floodplain development on and vegetation recovery of the former "F" channel beds. The "E" stream types are slightly entrenched, exhibit very low channel width/depth ratios, and display very high channel sinuosities which result in the highest meander width ratio values of all the other stream types.

The bedform features of the "E" stream type are predominantly a consistent series of riffle/pool reaches, generating the highest number of pools per unit distance of channel, when compared to other riffle/pool stream types (C, DA, and F). "E" type stream systems generally occur in alluvial valleys that exhibit low elevational relief characteristics and physiographically range from the high elevations of alpine meadows to the low elevations of coastal plains. While the "E" stream types are considered as highly stable systems, provided the floodplain and the low channel width/depth characteristics are maintained, they are very sensitive to disturbance and can be rapidly adjusted and converted to other stream types in relatively short time periods. The "E" stream type typically develops within valley types VIII, X, and XI.

The "F" Stream Type

The "F" stream types are the classic "entrenched, meandering" channels described by early day geomorphologists, and are often observed to be working towards re-establishment of a functional floodplain inside the confines of a channel that is consistently increasing its width within the valley. "F" stream types are deeply incised in valleys of relatively low elevational relief, containing highly weathered rock and/or erodible materials. The "F" stream systems are characterized by very high channel width/depth ratios at the bankfull stage, and bedform features occurring as a moderated riffle/pool sequence. "F" stream channels can develop very high bank erosion rates, lateral extension rates, significant bar deposition and accelerated channel aggradation and/or degradation while providing for very high sediment supply and storage capacities. The "F" stream types occur in low relief valley type III, and in valley types IV, V, VI, VIII, IX, and X

The "G" Stream Type

The "G" or "gully" stream type is an entrenched, narrow, and deep, step/pool channel with a low to moderate sinuosity. Channel slopes are generally steeper than .02, although "G" channels may be associated with gentler slopes where they occur as "down-cut" gullies in meadows. The "G" stream type channels are found in a variety of landtypes to include alluvial fans, debris cones, meadows, or channels within older relic channels. The "fanhead trench" which is a channel feature deeply incised in alluvial fans is typical of "G" type stream channels. With the exception of those channels containing bedrock and boulder materials, the "G" stream types have very high bank erosion rates and a high sediment supply. Exhibiting moderate to steep channel slopes, low channel width/depth ratios and high sediment supply, the "G" stream type generates high bedload and suspended sediment transport rates. Channel degradation and sideslope rejuvenation processes are typical. The valley types supporting the "G" stream types are I, III, V, VI, VII, VIII, and X. The "G" stream type can also be observed in valley types II, VI, VIII and X, under conditions of instability or disequilibrium that are often imposed by watershed changes and/or direct channel impacts.

Level II represents the morphological description of the channel. The next level of classification further describes the stream system in a more specific manner. This level breaks the channel into discreet slope ranges and introduces particle sizes of channel material. The stream types are given numbers to represent particle size diameter of the material with 1 representing bedrock, 2 is boulder, 3 is cobble, 4 is gravel, 5 is sand, and 6 is silt/clay. This generates 42 major stream types. The morphological description can only be applied to a limited length of river channel. This is due to the fact that morphology of stream systems often changes in a relatively short distance. Level II is therefore applied to only individual reaches, as opposed to being averaged over the entire basin (Rosgen, 1994).

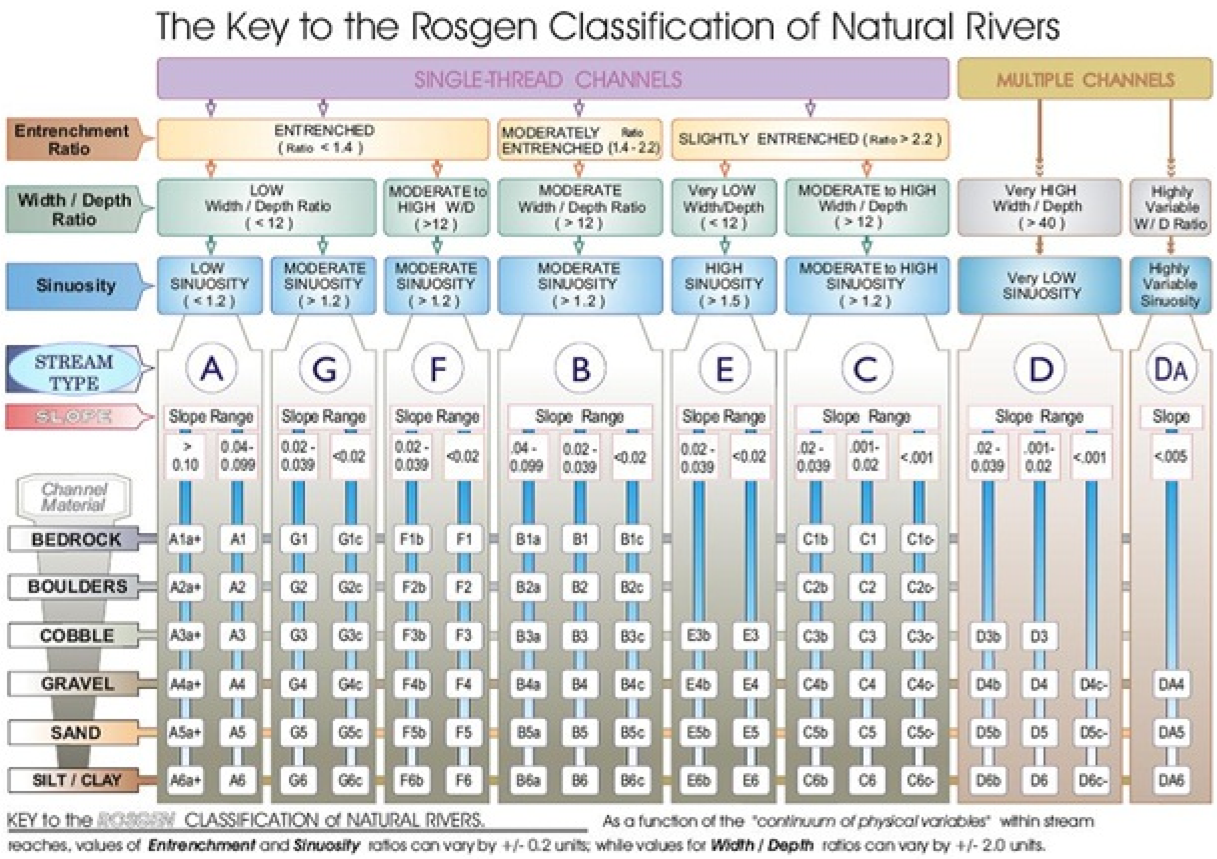
The continuum concept is also applied to Level II. As stated before, stream systems are often changing throughout its length. Some parameters change while others stay the same and therefore only one or two of the variables that define a stream classification will be outside of the presented values. "This level recognizes and describes a continuum of river morphology within and between stream types," (Rosgen, 1994). This application allows stream parameters such as slope to be sorted in sub-categories as opposed to slope. For example, if the majority of variables of a stream fit in the classification of C4 but has a slope of less than 0.001, the stream can be classified as C4c- (Rosgen, 1994).

Other variables considered at this level are entrenchment, width/depth, and sinuosity. For entrenchment, the entrenchment ratio can be defined as "the width of the flood-prone area to the bankfull surface width of the channel," (Rosgen, 1994). The entrenchment ratios are given numbers for classification where 1 to 1.4 are significantly entrenched streams, 1.41 to 2.2 can be described as moderately entrenched, and greater than 2.2 are slightly entrenched. Width/depth ratio can be described as "the ratio of bankfull channel width to mean depth," (Rosgen, 1994). A small ratio can be considered less than 12 while a moderate to high ratio is considered greater than 12. Sinuosity is defined as "the ratio of stream length to valley length," (Rosgen, 1994). Sinuosity is often linked to slope and particle size of the channel and leads into our next topic of consideration.

Level II also addresses channel materials and slope. Channel materials play important roles in sediment transport as well as the development of the form, plan, and profile of the channel (Rosgen, 1994). Channel materials are classified using the pebble count method. Water surface slope plays an important role in channel morphology. Slopes, like other variables, can delineate from the expected values of the channels classification and therefore can be addressed with the continuum concept.

Level III describes the state of streams and helps measure existing conditions in response to channel change. This level acts as a method to propose prediction methodologies and can be used to aid in restoration efforts. Important variables in order to apply Level III include riparian vegetation, depositional patterns, meander patterns, confinement features, fish habitat indices, flow regime, river size category, debris occurrence, channel stability index, and bank erodibility (Rosgen, 1994).

The last level of classification in the Rosgen method is Level IV, which describes verification. This level provides specific information on stream processes used to verify various parameters. This level helps "provide sediment, hydraulic and biological information related to specific stream types," (Rosgen, 1994). Classification at this level requires measurements and observations of sediment transport, bank erosion, channel geometry, biological data, and riparian vegetation data (Rosgen, 1994). See the figure below for the breakdown of Rosgen's classification.

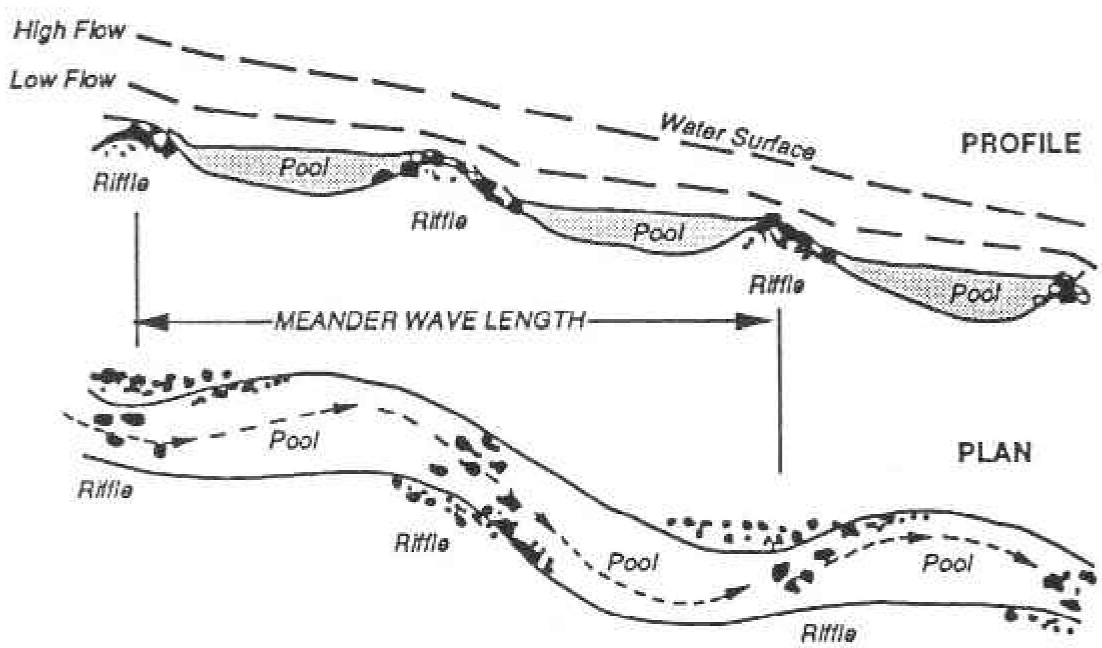


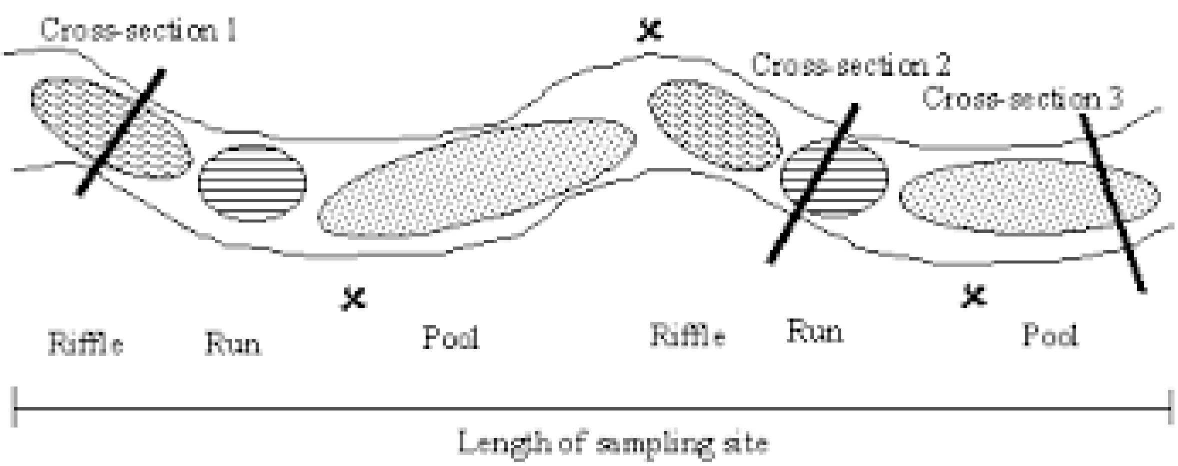
Rosgen's method is currently the most used classification system. Rosgen also discusses applying the system to restoration efforts. Historical data has shown that streams have been changing character due to imposed anthropogenic alterations in order to provide things like flood control, hydro-electric power, and allocation of water rights. These variables used to classify a river are often changed due to these alterations. Therefore, "to restore the "disturbed" river, the natural stable tendencies must be understood to predict the most probable form," (Rosgen, 1994). Stream classification aids in providing the restoration team with knowledge of how a system's variables naturally behave.

Source: USEPA Watershed Academy, [Fundamentals of Rosgen Stream Classification System]

Appendix E - Stream Classification Tools – Sketching Stream Features

The following images are provided to support completion of the “Site Assessment Diagram” portion of the CNMI-SVAP (Part 3). Inclusion of a stream reach profile and cross section are encouraged.





Appendix F - Stream Classification Tools – Bankfull Discharge: Principles and Indicators

"Bankfull discharge" is a frequently occurring peak flow whose stage represents the incipient point of flooding. It is often related to the elevation associated with a shift in the hydraulic geometry of the channel and is often associated with a return period of 1-2 years, with an average of 1.5 years. Bankfull discharge is expressed as the momentary maximum of instantaneous peak flows rather than the mean daily discharge. Bankfull discharge plays a fundamental role in shaping alluvial channels. Because site visits are often not made during a bankfull event, physical indicators (floodplains, depositional features, breaks in slope, changes in vegetation) must often be relied upon. Rosgen outlines four basic principles for bankfull stage indicators, and highlights common bankfull stage indicators to support field assessments as follows.

Bankfull Discharge: Basic Principles

Locating bankfull is a skill that is developed over time by field observations of different stream types in a variety of climates. However, four basic principles apply to reliable indicator selection. These are:

1. Seek indicators in the locations appropriate for specific stream types.
2. Know the recent flood and drought history of an area to avoid being misled by spurious indicators (e.g. flood debris accumulation caught in up-gradient trees following an unusual or extreme flood event).
3. Use multiple indicators whenever possible to reinforce common stage elevation observations.
4. Where possible, calibrate field-determined bankfull stage elevation and corresponding bankfull channel dimensions to known recurrence interval discharges at gage stations. This procedure, called "calibrating bankfull stage" can verify the difference between floodplain of the river and the low terrace. Where no existing gages are installed, gage installation and monitoring may be warranted to ground-truth observations.

Bankfull Discharge: Indicators

The following are common bankfull stage indicators:

1. **Floodplains.** The term bankfull elevation is often associated with the point at which the stream begins to spread out onto the floodplain. This definition can be applied to stream types C, D, DA, and E, which often have well-developed floodplains. However, this approach does not apply to entrenched stream types (A, B, F, and G), which generally do not have floodplains. Do not confuse the low terrace with the floodplain. Terraces are abandoned floodplains that often have perennial vegetation and definite soil structure.
2. **Highest active depositional feature.** The elevation on top of the highest depositional feature (point bar or central bar) within the active channel is often associated with bankfull stage. These depositional features are especially good bankfull indicators for confined channels.
3. **Slope breaks or change in particle size distribution.** Breaks in slope of the banks or a change in the particle size distribution from coarse to fine is often associated with deposition by overland flow.
4. **Evidence of an inundation feature such as small benches.** Benches, or flat / shallowly sloped areas slow high velocity flows during high flow events, and are therefore strong indicators of bankfull width.
5. **Staining of rocks.**
6. **Exposed root hairs below an intact soil layer indicating exposure to erosive flow.**
7. **Lichens and, for some stream types and locales, certain riparian vegetation species.**

Adapted from Wildland Hydrology: River Morphology, Field Day Instructions and Forms, 2011.

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