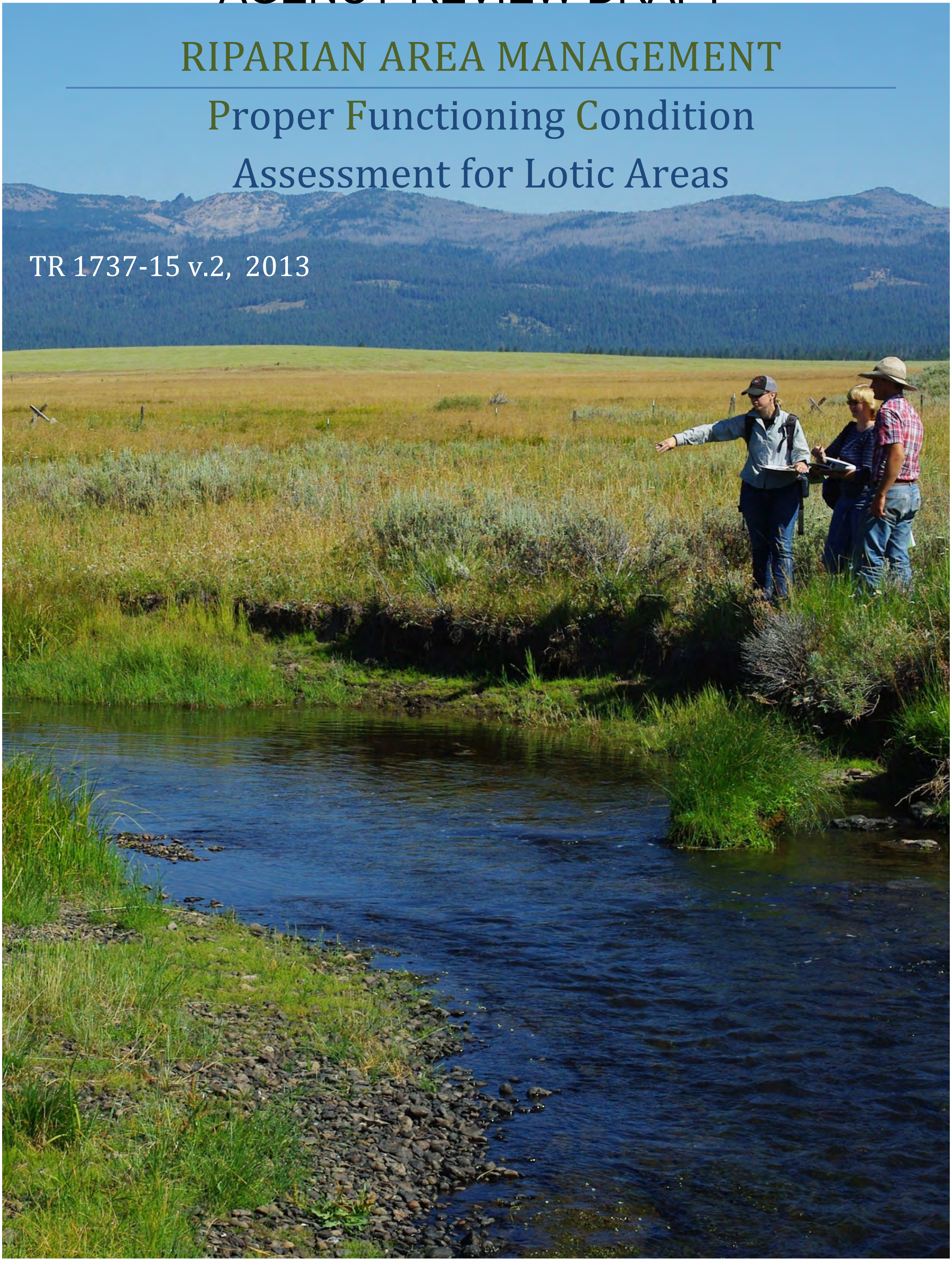
AGENCY REVIEW DRAFT

RIPARIAN AREA MANAGEMENT

Proper Functioning Condition Assessment for Lotic Areas

TR 1737-15 v.2, 2013



Riparian Area Management

Proper Functioning Condition Assessment for Lotic Areas

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Abbreviation list

BLM - Bureau of Land Management

DMA – Designated Monitoring Area

FAC – Facultative species

FACU – Facultative Upland species

FACW – Facultative Wetland species

FAR – Functional-at-risk

FWS – Fish and Wildlife Service

ID – Interdisciplinary

GIS – Geographic Information System

MIM – Multiple Indicator Monitoring

NF - Nonfunctional

NRCS – National Resources Conservation Service

OBL – Obligate Wetland species

PFC – Proper Functioning Condition, either the method or the rating determination

TR – Technical Reference

UPL – Obligate Upland species

USFS – United States Forest Service

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1. Introduction

Riparian areas are transitional areas regularly influenced by fresh water, normally extending from the edges of water bodies to the edges of upland communities (Naiman et al. 2005) (Figure 1). They reflect interactions between aquatic and terrestrial components of a landscape, and are where hydrology, vegetation, and soils come together on a stream to influence physical function. These areas exhibit vegetation or physical characteristics reflective of permanent surface or subsurface water influence. Ephemeral streams or washes that do not exhibit the presence of vegetation dependent upon free water in the soil are not included.

This technical reference addresses the physical functioning of perennial or intermittent lotic (flowing water) riparian systems, such as rivers or streams. Lentic (still or very slow water) riparian systems, such as wetlands, ponds, or marshes, are addressed in TR 1737-16. This technical reference provides instructions for the application of the PFC protocol. It is not intended to serve as a textbook addressing every aspect of stream and riparian function and ecology.

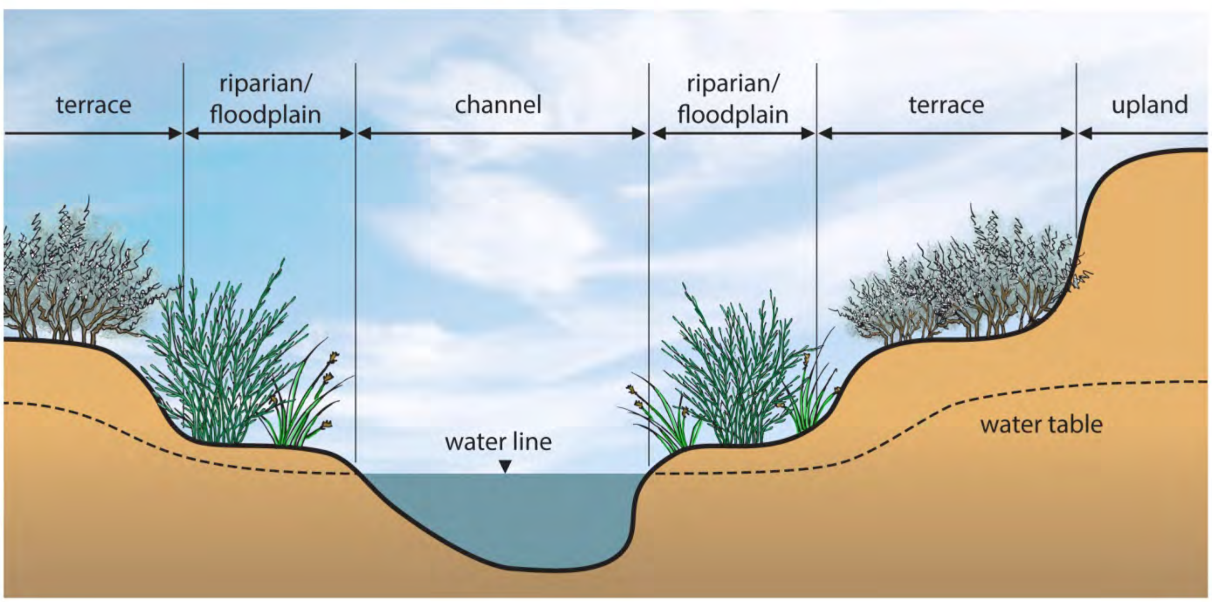


Figure 1. Schematic drawing of a riparian area.

Riparian areas are complex, dynamic ecosystems incorporating biological, physical, and chemical processes. The Proper Functioning Condition (PFC) assessment method was created to qualitatively evaluate the foundation of these process—specifically the functionality of the physical processes occurring on a stream. These physical processes include the interactions of hydrology, stabilizing vegetation, and geomorphology. Professionals with background in these subjects assess the stream together as an interdisciplinary team (ID team). Because the PFC assessment compares each stream to its own potential, it is universally applicable to all but the most highly modified perennial and intermittent streams.

The term PFC is used to describe both the assessment process, and a defined, on-the-ground condition of a riparian area. The on-the-ground condition termed PFC refers to how well physical processes are functioning. A system in PFC displays a resilience that will allow the riparian area to remain reasonably intact during high-flow events (such as the 5-, 10- or 25-year flow), and recover quickly, with a high degree of reliability.

The PFC assessment refers to a consistent approach for considering hydrologic, vegetation, and geomorphic attributes and processes to assess the condition of riparian areas at a point in time. An assessment form (Appendix A), synthesizes information that is foundational to determining the physical functioning of a riparian system. Following completion of the assessment form, the stream reach is placed in one of three rating categories:

Proper Functioning Condition (PFC): A lotic riparian area is considered to be in PFC, or "functioning properly" when adequate vegetation, landform, or large woody material is present to:

- Dissipate stream energy associated with high waterflow, thereby reducing erosion and improving water quality.
- Filter sediment, capture bedload, and aid floodplain development.
- Improve flood-water retention and ground-water recharge.
- Develop root masses that stabilize streambanks against erosion.
- Maintain channel characteristics.

Functional—At Risk (FAR): Riparian areas that are in functional condition, but an existing landform, water, or vegetation attribute makes them susceptible to impairment.

Nonfunctional (NF): Riparian areas that clearly are not providing adequate vegetation, landform, or large woody material to dissipate stream energy associated with high flows, and thus are not reducing erosion, improving water quality, etc.

The physical functionality of a riparian area is the foundation of stream processes (Figure 2). Physical attributes and processes of the stream exist in a hierarchical relationship with chemical processes and biological processes. The dotted lines around each stratum indicate that each level of the pyramid interacts with the adjoining levels. The arrows indicate the direction of influence. Although biological and chemical processes act upon physical function, the majority of the cause-and-effect relationships flow upward through the pyramid. Stream processes are underlain by geology and climate.

If the riparian area is functioning properly, then it is capable of producing good water quality and suitable habitat. If, on the other hand, the riparian area is not functioning properly, it is likely that chemical processes, such as the production of good water quality, and biological processes, such as the creation of suitable habitat will also be impaired (Harman et al. 2012, Shields et al. 2010). However, PFC does not guarantee that chemical and biological processes are functioning well. For example, sediment, thermal, or nutrient regimes could remain impaired because of upstream impacts that are transmitted downstream. If a parameter representing a biological or chemical process, such as habitat complexity, is of interest, the ID team should use a protocol specifically intended to assess that parameter, in conjunction with the PFC assessment.

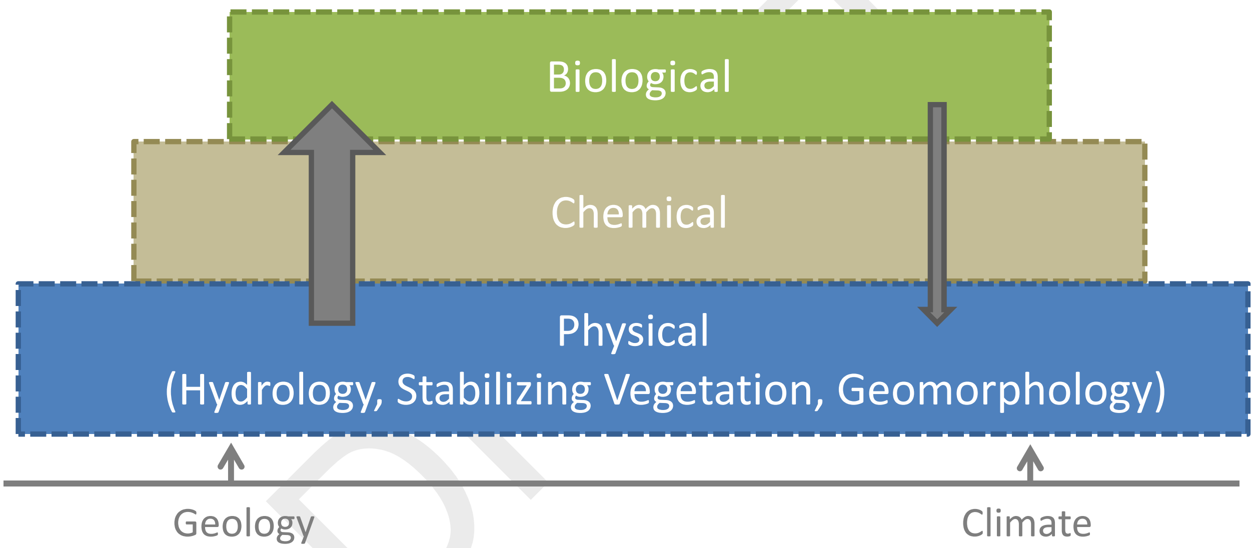


Figure 2. Stream Functions Pyramid, adapted from Harman et al. 2012.

An interdisciplinary team must possess an understanding of stream dynamics and potential to accurately complete the assessment, and discussion among experts using their professional experience and judgment is key to producing a quality product. So, although PFC relies on basic concepts of stream function, it cannot be completed by a non-professional after a half-day training. PFC involves both the art and the science of "reading the stream," and a working understanding of each takes time to develop.

PFC and additional quantitative techniques

PFC is a qualitative assessment based on quantitative science. For example, item 17 on the PFC assessment form asks whether the stream is in balance with the water and sediment being supplied by the watershed. An out-of-balance system would lead to excessive deposition or erosion. For example, excess sedimentation forming mid-channel bars where they would not be expected, or bank erosion at areas other than outside meander bends of the stream would provide visual evidence without needing detailed measurements to judge whether this is happening. If the channel shape needs to be quantified, or tracked over time, other tools provide the rigorous methods to do so. The same kind of scenario can be produced for each item on the assessment.

Quantitative techniques are encouraged in conjunction with the PFC assessment for individual or ID team calibration, or where opinions differ among specialists. PFC is also an appropriate starting point for determining and prioritizing the type and location of quantitative inventory or monitoring needed. It can also provide context for quantitative data. Appendix E provides a list of possible quantitative techniques for stream assessment.

Changes in this revision of the document

This revised TR 1737-15 does not change the overall approach from the 1998 document. The majority of the changes address the need to include new science, provide better examples, clarify the wording of some of the assessment items and sections, and provide additional detail where needed. Because a number of new quantitative procedures have been developed since 1998, and the Ecological Site Index methods in TR 1737-7 are not widely used, the quantitative procedures used to validate PFC assessments have been updated.

In addition, the process for applying potential and capability to the PFC assessment has been refined to improve the consistent use of these concepts. Potential has been described in detail, and the specific term "*capability*," used in the 1998 version to describe limiting factors as a result of human changes,) has been eliminated. The need to address altered stream reaches in a unique way still applies and a set of guidelines has been developed to assess how human alterations affect potential.

Finally, the order of Items 6 and 7 has been reversed, as it made for a more logical flow to the assessment process. This will need to be considered in database management.

Use of Rosgen stream classification system

Many different classification systems are available and each one brings valuable information to a discussion of stream condition. For the purposes of this document, stream types will be described using the Rosgen stream classification system (Rosgen 1996). This system is widely used and provides a good “common language” to communicate information about channel morphology. See Appendix B for a key to the Rosgen Stream Classification of Natural Rivers.

2. Intended Applications

The Proper Functioning Condition (PFC) assessment has been a useful tool for land management agencies for several years. It is important, however, that the protocol is used only for its intended purposes.

The PFC Assessment Protocol described in this technical reference IS designed to:

Assess the function of perennial and intermittent streams and their associated riparian areas. The attributes and processes developed for the PFC assessment are specific to perennial and intermittent streams. Ephemeral streams generally do not support riparian vegetation; the assumptions built into the assessment items are based on streams that can support riparian vegetation. Other protocols should be used to assess ephemeral systems (e.g. Pellant et al. 2005).

Be used only by an experienced interdisciplinary team of resource specialists. Because PFC is a qualitative assessment of indicators of stream and riparian function, the resource specialists completing the PFC assessment should have a strong technical background and experience collecting, analyzing, and interpreting quantitative data related to the assessment items specific to their discipline. Also, most ID team members should have local experience in the watershed(s) being assessed.

Provide a consistent approach for assessing the physical functioning of riparian areas through consideration of hydrologic, vegetation, and geomorphological attributes relative to the potential of the stream being assessed. The PFC assessment synthesizes information that is foundational to determining the overall health of a riparian area.

Help establish and prioritize management, monitoring, and restoration activities. The PFC assessment can provide an early warning of problems and opportunities by helping to identify key management issues, focus monitoring activities (to maximize the efficiency of monitoring efforts), and prioritize restoration actions on the “at-risk” systems (This is based on the premise that if a riparian area becomes nonfunctional, often more effort, time, and cost is required for recovery).

Provide a focused and effective foundation for determining resource goals and identified resource values by identifying attributes and processes that are out of balance for the landscape setting.

Communicate fundamental riparian concepts to a wide variety of audiences. This process forms a "common vocabulary" for discussing stream and riparian functions and for developing long-term desired conditions.

The PFC Assessment Protocol IS NOT designed to:

Assess the function of ephemeral streams. As described above.

Be used by inexperienced personnel. Because PFC is an observational assessment, personnel must have enough experience to recognize visual indicators of function.

Be completed *without* an interdisciplinary team. While individuals may learn about riparian areas by incorporating the PFC thought process, the assessment must be completed by an ID team.

Monitor resource conditions and trends. PFC is an assessment and is not intended to be a monitoring tool because it generally lacks the sensitivity to detect incremental changes in riparian condition.

Assess specific riparian values or be the sole method for assessing the health of the aquatic or terrestrial components of a riparian area. The PFC assessment is not a replacement for inventory, assessment or monitoring protocols designed to yield information on the "biology" of the plants and animals, or other habitat parameters. The condition of PFC is generally a prerequisite for achieving and maintaining habitat quality and other values.

Assess the function of streams where human alterations have created artificial channel conditions for a substantial part of the reach. Instructions for how to consider altered stream reaches are in Chapter 4.

3. Instructions for Completing the PFC Assessment—Step 1: Identify Assessment Area and Assemble Interdisciplinary Team

The following instructions provide ID teams with stepwise guidance for completing the PFC assessment. Figure 3 illustrates the steps in the process of completing a PFC assessment. A failure to do a thorough job of completing each of these steps will jeopardize the quality of the PFC assessment.

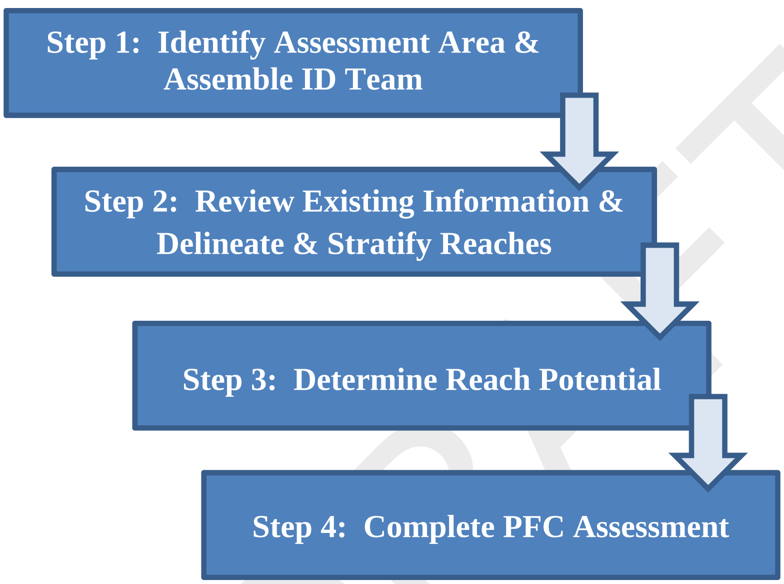


Figure 3. Steps for Completing the PFC Assessment

A. Identify Assessment Area

The PFC assessment can be completed at various scales depending on information needs. It can be done at the landscape or watershed scale by either assessing all streams or a random sample of streams in the area, or at the project level (allotment, grouping of allotments, 5th order hydrologic unit code (HUC), etc.). Complete a PFC assessment to obtain information for a particular purpose. The manager and ID team should determine what the assessment is to be used for and select the assessment area that matches the appropriate information needs.

B. Assemble ID Team – Skills and Training Requirements

PFC assessment involves the art and science of understanding streams and their associated riparian areas with a watershed perspective. The assessment is intended to be performed by an ID team with knowledge of the attributes and processes occurring in the riparian areas being assessed. Team members should have strong observational skills, experience collecting and evaluating quantitative monitoring data related to the attributes and processes addressed in PFC, and experience working with other specialists. They must be able to interpret the appearance of physical attributes visually to assess the functionality of each system correctly. The ID team requirement is important because different disciplines must work together to interpret existing information about the dynamic nature of riparian areas, and how riparian attributes and processes change over time in response to management, climatic patterns and watershed condition. The ID team needs to have an understanding of riparian function attained from education, trainings, reading, time in the field with experienced personnel, interpretation of the available information, etc. The BLM TR 1737 series provides several references that are helpful for developing an understanding of riparian concepts.

At a minimum, ID team members should attend PFC assessment training prior to completing a PFC assessment. If untrained personnel serve on the ID team, they should be mentored by trained and experienced team members. A broad set of skills are necessary (collectively within the team) to conduct PFC assessment, and are summarized below.

- Knowledge of the types of quantitative sampling methods that support the PFC assessment.
- Ability to gather information pertinent to the assessment: GIS layers, remote sensing products, maps, monitoring data, etc.
- Knowledge of the watershed's geology, size, landforms, climate and weather patterns, hydrologic and fluvial processes, sediment dynamics, and how each affects streams in the region.
- Knowledge of reference conditions for the assessment reaches, whether based on data or professional judgment.
- Ability to identify riparian plant species/communities of the region, including common riparian trees, shrubs, grass-likes, grasses, and forbs. This includes the ability to use taxonomic plant keys.
- Knowledge of riparian ecology, riparian vegetation's reproductive strategies, rooting characteristics, disturbance response (e.g., fire sprouters), ecological amplitude, soil water/moisture tolerance and dependence on ground water. depths, as well as expected distribution, structure, and abundance in different stream types, fluvial surfaces, and flooding regimes.

- Ability to determine soil texture by feel, interpret soil features, particularly redoximorphic features, and relate soil texture and soil-water states to expected potential vegetation.
- Knowledge of geomorphic processes including sediment sources and storage/transport dynamics, influence of roughness element, alluvial/colluvial channel distinction, etc.
- Knowledge of stream attributes and bankfull indicators of the region. Ability to use stream gauges and appropriate publications to determine timing, frequency and duration of flooding (local relationship between stream depth and time spent at depth over a prescribed period), and flood frequency (how often a flood of a certain discharge or stage is likely to occur).
- General knowledge of surface water-ground-water interactions within river corridors including water tables and hyporheic zones.
- Ability to document assessment results in a report, make recommendations, and use PFC assessment results to inform collaborative management and monitoring.

4. Step 2: Review Existing Information and Delineate and Stratify Reaches

A. Gather and Review Existing Information

Considerable information can be obtained by gathering, assembling, and reviewing past work, where available. PFC is a qualitative assessment, but quantitative data, photographs, and information from many different sources help the ID team prepare to recognize key attributes and interpret field observations correctly. Knowledge of historical conditions, interpretation of current information, *combined with* field observation of visual indicators (i.e. "reading the land"), leads the ID team towards a determination of potential, appropriate responses on assessment items, a trend determination, and an understanding of any current deterioration and expected recovery for the stream being assessed.

Each member of the ID team should review files and other known sources of information about the areas under investigation and share that information with the entire ID team. This provides the information needed to finalize reach delineations and initiate a discussion of the potential of the reach. A pre-work file, which includes summaries of the pertinent pre-work information, is then developed for each assessment reach, or a set of reaches, within a project area.

The following sources may provide valuable information as the ID team prepares to complete a PFC assessment.

- A time series of aerial photographs (or other remote sensing products).
- Photo points, historic photos, any pertinent photos of past conditions.
- GIS layers and other information that will help with reach delineation (ecoregions, geology maps, watershed mapping, stream order, valley segments, stream types, general patterns of soil and riparian vegetation, management unit boundaries such as allotments and pastures).
- Topographic maps.
- Soil surveys and ecological site descriptions.
- Valley-bottom or stream-type classification measurements and mapping
- Data from nearby weather stations and stream gages to understand precipitation and runoff patterns.
- Riparian and wetland plant lists.
- Watershed assessment documents.
- National Wetlands Inventory (NWI) maps.
- Ground water reports.

- Species lists (animals and plants) which could be used to determine species habitat needs. This could shed light on riparian conditions that support/-ed those species.
- Land survey notes or other documentation of past/historical conditions;
- Previous assessments, inventory, or monitoring data, including interpretations/results concerning soil, water, vegetation, and wildlife; check other agencies' (e.g., state fish and wildlife) files for data.
- Information on reference areas (exclosures, preserves, slightly disturbed areas, well managed areas with late-seral communities).
- Management records, including allotment management plans, annual operating instructions, actual-use records, range inspections records, or other activity records of the assessed area.

A review of existing information in preparation for delineating and stratifying reaches and establishing potential is critical.

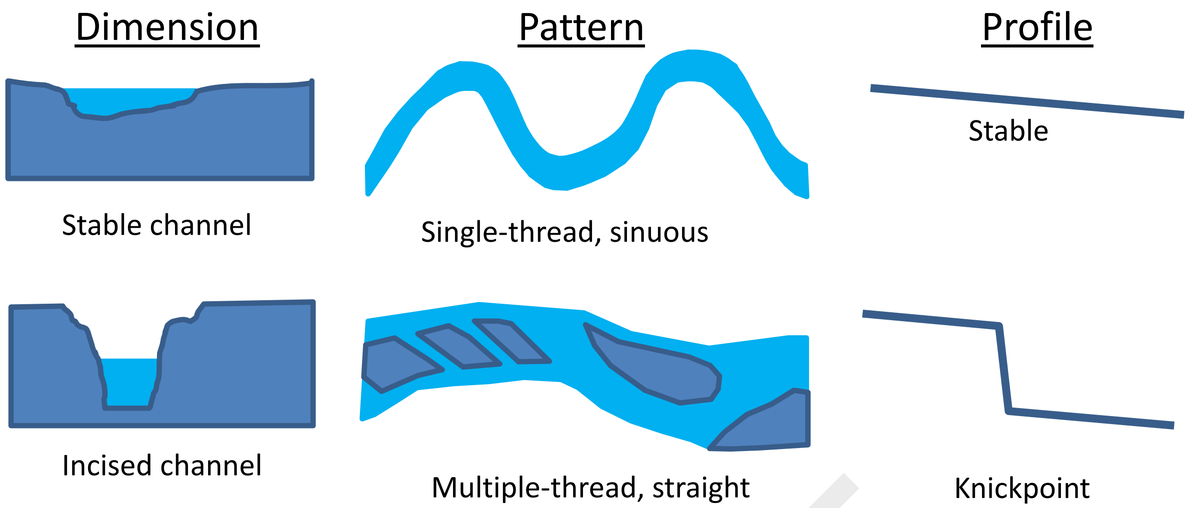
B. Delineation and Stratification

Definitions

Delineation is an exercise performed by the ID team to identify reach breaks (i.e., the starting and ending points of reaches). The stream reach is the fundamental assessment unit. Reaches are delineated on observable differences in geomorphology (geomorphic processes, landscape position, and landform patterns), hydrology, soils, stream gradient, and vegetation (USDA-FS 1992; Maxwell et al. 1995).

In contrast to delineation, **stratification** is a process of finding similarities among reaches, grouping reaches by commonalities, and classifying stream reaches into similar functional groups (stratum, strata (plural)) that share a common set of attributes, processes, and management practices.

A **reach** is defined as a length of stream with similar dimension, pattern, and profile. Specifically, the valley form; the channel dimensions and pattern, hydrologic regime, sediment load, gradient, sinuosity, meander-belt width, and entrenchment ratio; the channel and bank materials; and the soil properties (including texture, chemistry, organic-matter content, and soil-moisture holding capacity) are fairly uniform within a reach.



- Dimension describes channel shape, typically in terms of bankfull width, mean depth, and/or maximum depth.
- Pattern refers to the planimetric (overhead or map) aspects of the channel, particularly whether the channel is single-thread or multi-thread, and the degree of sinuosity.
- Profile refers to the gradient or slope of the channel bed, bankfull stage, water surface, or similar surface along the longitudinal profile of the channel.

A **riparian complex** is a unit of land with a unique set of biotic and abiotic factors (Winward 2000). Formal and comprehensive riparian complex inventories don't necessarily need to be done in order to do PFC, however it is useful to understand how they are identified. Complexes are identified on the basis of their overall geomorphology, substrate characteristics, stream gradient and associated water flow features, and general vegetation patterns (USDA-FS 1992; Winward 2000). Riparian complexes typically follow a formalized naming convention based on dominant (overstory/understory) community type(s)—soil group—landform; for example, coyote willow (*Salix exigua*)/woolly sedge (*Carex pellita*)—Haploboroll—Trough Floodplain Riparian Complex.

Both reaches and riparian complexes are identified by the same set of biotic and abiotic factors. The distinction is that a reach is treated as a linear feature and emphasizes the properties of the stream channel; whereas a riparian complex represents a polygon or the entire width of the riparian area along a reach (Maxwell et al. 1995; Winward 2000). The terms may be used interchangeably with an understanding of the differences in their geometry. The ***assessment reach*** in a PFC assessment may be part of a riparian complex (e.g., when an individual complex is divided by fences or land-ownership boundaries into different management units); may coincide entirely with the extent of a riparian complex; or could be more than one riparian complex depending on management issues and environmental complexity.

Purposes and Objectives of Delineation and Stratification

The ID team needs to work through the delineation and stratification process to create the foundation for the assessment. Much depends on the delineation and stratification process, including: (1) the identification of potential natural condition by reach (see p. 23 for details on determining reach potential); (2) determination of assessment approaches (see p. 32 for details); (3) prioritization of work plan; (4) extrapolation of findings for management purposes; and (5) selection of sites for subsequent monitoring of riparian areas (see p. 40 for details).

Assessment approaches. The ID team evaluates the assessment area and determines the type and degree of inspection a reach receives, dependent on time, budget, and availability of qualified ID team members. Other factors influencing the assessment approach include: level of controversy; values at risk; and history and legacy effects of management practices and natural processes, current practices and expected conditions, and accessibility of reaches (see p. 32 for details).

Prioritization. Stratification is a tool to prioritize not only assessment of reaches, but also subsequent management activities and monitoring efforts. Prioritization parameters could include (but are not limited to): current success of management; applicability of federal and state laws and regulations; values inherent in a stratum; time since last assessment or to next planning effort; and amount of monitoring data and management information for the stratum.

Efficiency and extrapolation. Stratification permits managers to inventory, assess, and monitor a representative fraction of the land base. With proper stratification, land managers can work efficiently. The knowledge gained from inspection of a representative area can be extended and applied to other areas within the same stratum of reaches. Extrapolation and inference among different types of reaches should be done carefully or not at all. One example of extrapolation or inference among reaches from different strata is a practice in which the ID team thoroughly inspects the complex that is most sensitive to the management activity within a pasture, allotment, or other management unit. If the most sensitive reach shows no ill effects from the management activity, then less sensitive reaches from the same pasture, allotment or management unit can be rationally expected to be in as good or better condition. Consequently reaches in less sensitive strata might justifiably receive less attention than reaches in the most sensitive stratum.

Selection of Designated Monitoring Sites (DMAs). Stratification of reaches also serves to target the most sensitive, highest value, or most representative reaches for future monitoring. There is little benefit to monitoring sites that are highly resistant to change or to the management activities. Details on the stratification process for DMA selection are provided in Burton et al. (2011, pp. 5-9; and herein p. 40).

Delineation Process

The stream reach is the fundamental assessment unit. Typically, a reach break is based on:

- Geology (bedrock geology and valley substrate (colluvium, alluvium, bedrock)).
- Geomorphic processes and properties including sinuosity, channel dimensions, drainage density, relief ratios.
- The shape of the valley bottom, valley sides, confinement ratio or stream entrenchment.
- Stream and valley gradients.
- Dominant sediment-transport characteristics: sediment volume and size; source, transport, or response reach (Montgomery and Buffington 1993; Schumm 1977).
- A major confluence, i.e. one where the additional discharge and/or sediment contributed by the tributary are enough to substantially change the dimension, pattern, or profile of the channel it joins.
- Hydrogeologic features that mark a relatively fixed boundary between losing and gaining stream reaches.
- Hydrologic controls (including dams, diversions, etc.) that are big enough to alter the hydrologic regime.
- Riparian complexes.
- Pattern of dominant plant communities.

Generally the delineation of stream reaches is a two-step process. First, the ID team identifies tentative reach breaks using office reference materials (e.g., topographic maps, aerial photography, and any other physiographic and biotic information that delineate reaches). Tentative reach breaks are marked on a base map. Second, the ID team uses field observations to validate or modify starting and ending points of reaches. Reach breaks may be modified if delineations made in the office do not conform to physiographic and ecological observations made in the field.

The ID team should explain the rationale used to delineate reaches so that subsequent teams can properly use existing reach breaks. Reach breaks are semi-permanent and only modified if a major change in management (e.g., elimination or addition of fence lines) or the environment (e.g., construction of a new, major dam or water-diversion structure) creates a need to adjust them.

Additional considerations

Ownership and management boundaries. Boundaries dividing land ownership, allotments and pastures, or other management units can and typically do serve as reach breaks. Even if the management is the same on opposite sides of a pasture fence, it may delineate a reach break for several reasons (e.g. different managers, livestock, off-stream water supplies, etc.).

Repeating complexes. Commonly, two or more riparian complexes repeat or alternate along a valley segment. For example, in narrow mountain valleys, the valley floor typically narrows and the channel becomes confined where it passes a fan from a tributary stream (, complex A). Upstream of the fan, the gradient is typically low, the valley bottom is slightly wider, and the channel is less confined (, complex B). Where an alternating or repeating pattern of riparian complexes is noted, decide whether to complete (1) one assessment form for the entire valley segment, which comprises a repeating pattern of riparian complexes; (2) one assessment form for each reach; or (3) two assessment forms with one specific to all the “A” complexes; and one for all the “B” complexes within the valley segment. If one form is completed, then the relative percent of each complex within the reach should be noted; each complex should be described; and any conditions or trends specific to a complex should be noted. Document the rationale for grouping complexes. The method employed should best capture the riparian conditions and management implications for each complex.

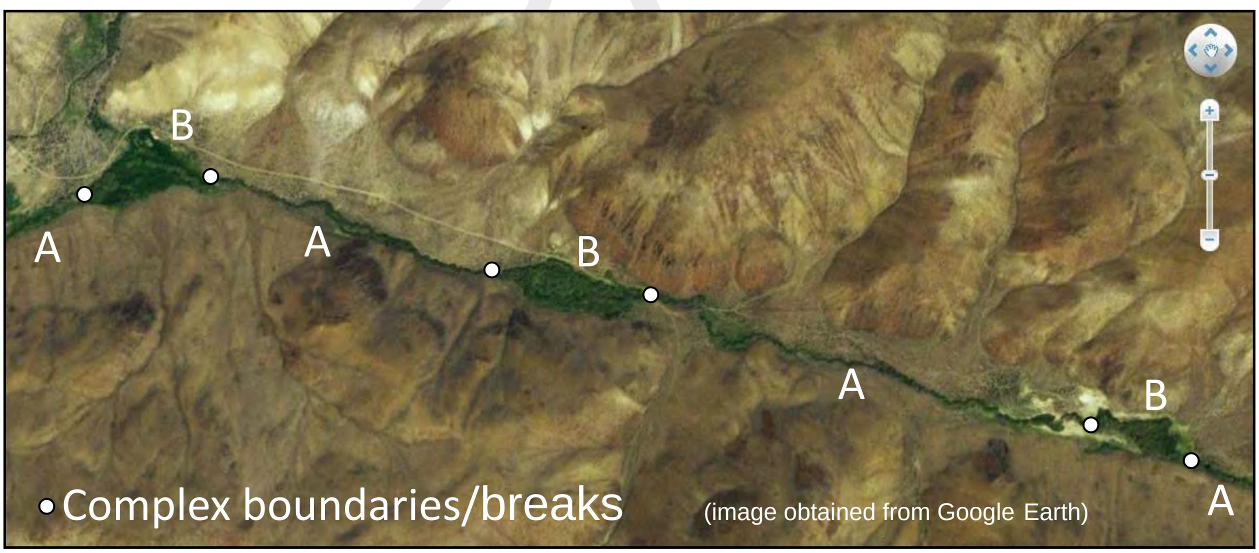


Figure 4. Alternating complexes within a valley segment.

Some assessment reaches include alternating lotic and lentic reaches; for example, where beaver ponds or wet meadows alternate with discrete channels that flow between ponds/meadows (Figure 5). In this example, the ID team may use a lotic and lentic assessment form (see Prichard et al. 2003). Because individual complexes do not exceed ¼ mile length, it is impractical to assess individual reaches. Instead, the ID team could complete one lotic assessment form to describe the condition of all "A" (stream-willow) complexes and one lentic assessment form for all "B" (beaver dam/wet meadow) complexes within a valley segment or management unit.

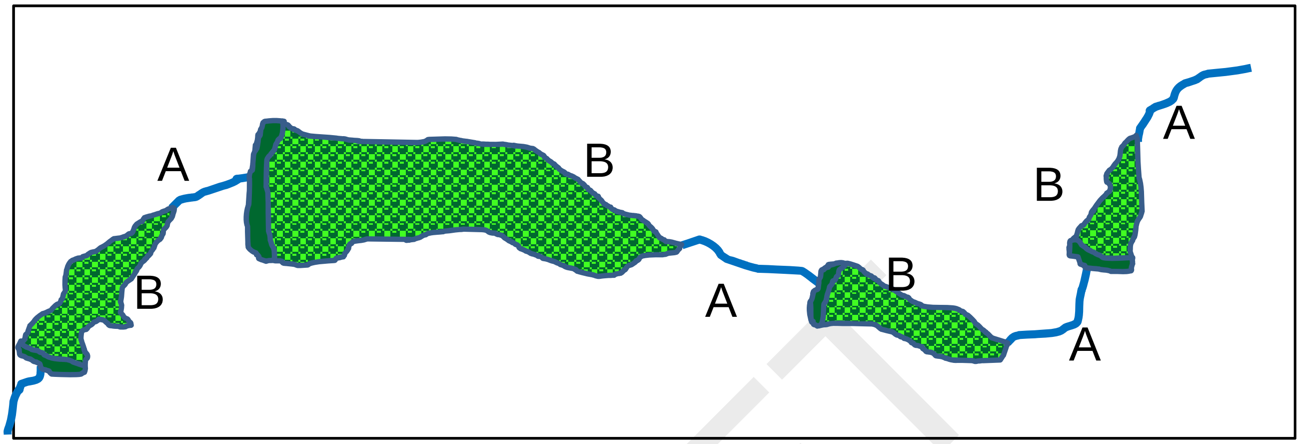


Figure 5. Lotic (complex A) and lentic (complex B) complexes alternate within an assessment reach.

Ecotones and gradational reaches. Transition areas (ecotones) can exist between riparian complexes. An assessment should not focus on conditions within an ecotone to make interpretations for the entire riparian complex. Also, the hydrologic, geomorphic, and biotic attributes and processes might change gradually along the entire length of a reach such that there is no distinct starting and ending point to subdivide the reach. For example, if an alluvial reach is a losing reach, and the streamflow gradually changes from perennial flow to intermittent flow, the point in space and time where intermittent flow begins is not fixed. The ID team might establish a downstream reach break where intermittent flow is obvious and reflected in the composition of the riparian plant community; however, the team would note the gradational nature of diminishing streamflow and the gradual drying along the entire reach. The ID team would also use a gradational concept of potential in this reach.

Management practicality. The defined stream reach should be a manageable unit – as a *general rule*, it is at least ¼ mile in length, as smaller reaches are generally impractical to manage and assess individually. Reach delineation is typically performed once and never repeated. Once reach breaks have been established, it is customary to continue using the same breaks. Changes in land ownership, fencing patterns, or management could necessitate a change in reach breaks, but these would be the exceptions to the general rule.

Stratification Process

To stratify riparian areas into recognizable and repeating groups, the ID team notes similarities and differences among reaches in the project area (see Table 1). For example, reaches can be stratified by slope, with low-gradient reaches segregated from steep reaches. Similarly, reaches can be stratified by substrate (bedrock from fine-textured alluvial reaches) to discriminate low versus high vulnerability to streambank alteration. Also, reaches dominated by communities of riparian shrubs, should be differentiated from reaches that are dominated by herbaceous communities, because livestock, wildlife, and human access to streambanks differs between these types of plant communities.

Whereas the delineation process emphasizes division of the stream system into small discreet assessment reaches, the stratification process works in reverse direction by aggregating reaches with similar biotic and abiotic features into a stratum. The stratification process can start the aggregation process within a single valley segment, and then build to progressively larger areas of interest, such as the sub-watershed, the watershed, ecoregion or management area (see Table 1). Managers can then use the stratified information to make apples-to-apples determinations about prioritization of assessments or restoration activities, location of DMAs, etc.

Table 1. Hierarchy of stratification levels and possible data sources

Geomorphic provinces (ecological life zones, or similar) (10^2 to 10^3 mi^2; extent of USFS ranger district or BLM field office; 100,000 to few million acres) • Geologic maps (USGS, state geologic maps). • LRRs or MLRAs (USDA-NRCS 2006; also available from USDA-NRCS: http://soils.usda.gov/survey/geography/mlra/, or Penn State University: http://www.cei.psu.edu/mlra/).Ecoregions (available from USDA-FS: http://www.fs.fed.us/rm/ecoregions/products/map-ecoregions-united-states (Bailey 1976, 1983, 1988, 1995, 1996, 1998); EPA: http://www.epa.gov/ bioiweb1/html/usecoregions.html (Omernik 1987, 1995, 2004); NatureServe: http://www.natureserve.org/publications/usEcologicalsystems.jsp. (Comer et al. 2003).
Watersheds (10^1 to 10^2 mi^2; average 227 mi^2; 40,000 to 250,000 acres) and **sub-watersheds** (10^0 to 10^1 mi^2; average 40 mi^2; 10,000 to 40,000 acres) • Hydrologic unit codes and watershed boundary dataset (WBD) (USDA-NRCS). • Stream order (National Hydrography Dataset (NHD; Simley and Carswell 2009); available from USDA-NRCS: http://datagateway.nrcs.usda.gov/ , the USGS: http://nhd.usgs.gov/, or *The National Map*: http://nationalmap.gov/).
Valley segments (hundreds of yards (meters) to tens of miles (kilometers)) • Geomorphic properties including: drainage density, relief ratios, valley substrate (colluvium, alluvium, bedrock) (topographic maps and geologic maps). • Valley gradient, valley cross-sectional shape, and degree of valley confinement (1:24,000 scale USGS topographic maps; aerial photography). • Sediment-transport characteristics: sediment supply and size; source, transport or response reach (sediment analysis) . • Major tributary confluences with changes in sediment and water discharges (topographic maps and aerial photographs). • Hydrologic properties including: runoff-contributing areas vs. recharge areas; flashy overland systems vs. dominantly baseflow-fed systems; losing from gaining reaches (USGS stream-gaging stations and ground water monitoring wells). • Spatial scales: stream-order hierarchy (topographic maps). • Elevation and climate with particular emphasis on the influence these features have on plant life zones and hydrologic budgets (topographic and ecologic maps, aerial photography).
Stream reaches and land types (1/4 miles (hundreds of meters) to several miles (kilometers)) • Stream type, stream gradient, stream sinuosity, meander-belt width, stream entrenchment (topographic maps; aerial photos). • Channel and bed material (field examinations). • Hydrologic regime (USGS stream-gaging stations, field examinations). • Patterns of soil properties especially soil texture, soil chemistry, soil-organic matter, and soil-moisture holding capacity (soil surveys, field examinations). • General patterns of plant communities (dominant vegetation species; riparian classifications, aerial photographs, field examinations). • Wetland indicator status: obligate wetland, facultative wetland, facultative, facultative upland, upland. • Life form: tree, shrub, graminoid. • Land ownership or management unit boundaries.

5. Step 3: Determine Reach Potential

A. Determine key attributes and processes

Before determining reach potential, the ID team must identify the attributes and processes important to the riparian area being assessed. If they do not spend the time developing an understanding of the processes affecting an area, their judgment about PFC will be incomplete and may be incorrect.

Table 2 provides a partial list of attributes and processes which may occur in any given riparian area.

Table 2. Attributes/processes list.

Hydrogeomorphic	**Vegetation**	**Soils**
Ground water discharge	Community types	Soil type
Accessible Floodplain	Community type distribution	Distribution of aerobic/anaerobic soils
Ground water recharge	Surface density	Capillarity
Floodplain storage and release	Canopy	Annual pattern of soil water states
Flood modification	Community dynamics and succession	
Bankfull width	Recruitment/reproduction	**Water quality**
Width/depth ration	Root density	Temperature
Sinuosity	Survival	Salinity
Gradient		Nutrients
Stream power	**Geomorphology**	Dissolved Oxygen
Hydraulic controls	Bank stability	Sediment
Bed elevation	Bed stability (bedload transport rate)	
	Depositional features	

* This list provides examples of various attributes/ processes that may be present in a riparian area and is by no means complete.

To understand these processes, an example from the Great Basin of an alluvial valley-bottom-type riparian area is provided in Figure 6 (Jensen

1992). State 1 represents a high degree of bank stability, floodplain development, and plant community development, and would be classified as PFC. The important attributes and processes present for State 1 are:

Hydrogeomorphic - Accessible floodplain, storage and gradual release of flood waters from floodplain aquifer, flood modification, bankfull width, width/depth ratio, sinuosity, gradient, stream power, and hydraulic controls.

- Vegetation - Community type, community type distribution, root density, canopy, community dynamics, recruitment/reproduction, and survival.
- Geomorphology - Bank stability.
- Soil - Distribution of anaerobic soil, capillarity, soil saturation and depth to water table.
- Water Quality - No change.

State 2 may be PFC or FAR. It may be classified as PFC if bank stabilizing vegetation is dominant along the reach and other factors such as soil disturbance are not evident. It is important to identify the species of vegetation present since they vary in their ability to stabilize streambanks and filter sediment.

State 2 would be classified as FAR if bank-stabilizing vegetation is not dominant (even though it may be in an improving trend from prior conditions), undesirable species are abundant (e.g., Kentucky bluegrass), excess soil disturbance is evident (e.g., caved banks from livestock or vehicle use, or greater than 25 year flood events), or hydrologic factors such as degraded watershed conditions exist, increasing the probability of extreme flow events that would damage the reach. The following changes in attributes/processes are likely in **State 2**:

- Hydrogeomorphic - Bankfull width (increase), width/depth ratio (increase in width, decrease in depth), floodplain frequency of inundation (decrease).
- Vegetation – Community types changed, community type distribution changed, root density (decrease), canopy, community dynamics, recruitment/reproduction, and survival.
- Geomorphology - Bank stability (decrease).
- Soil – Change in water table depth.
- Water Quality – Possible increase in temperature.

Figure on this page will be redrafted for the final TR.

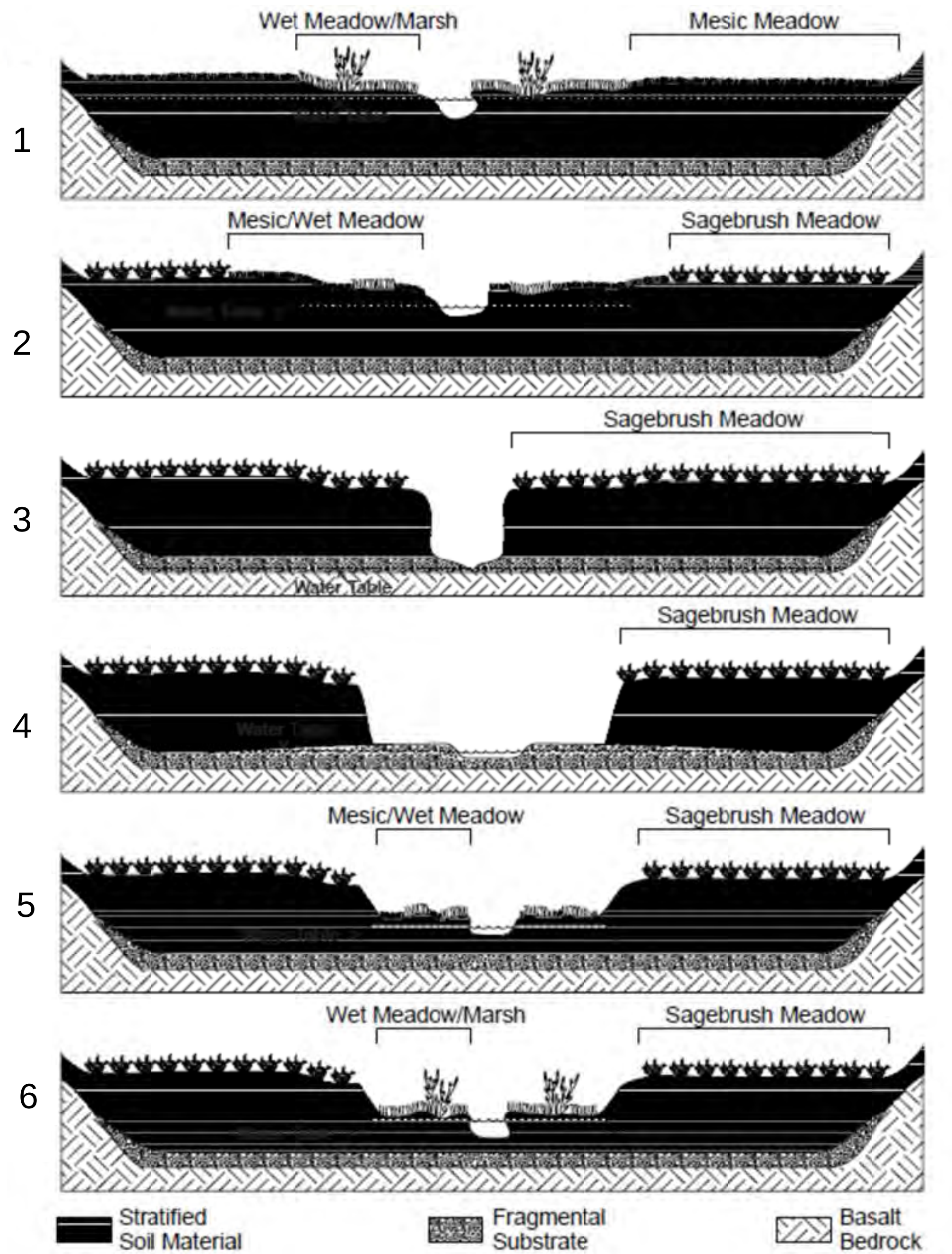


Figure 6. Succession of states for alluvial valley-bottom type.

States 3 and 4 would be classified as nonfunctional. **State 3** represents incision of the stream channel to a new base level. There is little or no bank stabilizing vegetation and no floodplain. Channel widening exhibited in **State 4** must occur to allow floodplain development. Vegetation, if present, is often only temporary due to the large adjustment process occurring. The following changes in attributes/processes are likely in **States 3 and 4**:

- Hydrogeomorphic - Bankfull width (increase), width/depth (increasing), floodplain access frequency (decrease).
- Vegetation - Riparian community types lost, community type distribution changed, root density low but possibly increasing, canopy variable, community dynamics successional, recruitment, reproduction, survival (decrease).
- Geomorphology - Bank stability poor but possibly improving.
- Soil - Well drained, drop in water table.
- Water Quality – Temperature variation (increase), sediment (increase).

State 5 may again be classified as functional-at- risk or PFC depending on vegetation, soil, and hydrologic attributes. Establishment of the floodplain and bank stabilizing vegetation indicate reestablishment of functional conditions. However, stream reaches in this state are usually at-risk for the same reasons described for **State 2**. Attributes and processes would revert back to those that appear in **State 2**.

State 6 is classified as PFC even though the riparian area may not have achieved the greater extent exhibited in **State 1**. Banks are stabilized and exhibit channel geometry similar to **State 1**. The floodplain has widened to the extent that confinement of peak flows is less frequent and aggrading processes are slowed because of the surface area available. The largest difference between **States 1 and 6** occurs in size and extent of hydrologic influence, which regulates size and extent of the riparian area.

This valley-bottom example represents only one of many types found. However, remember that there are other types and to understand that:

> *Riparian areas have fundamental commonalities in how they function, but they also have their own unique attributes and can and do function quite differently. As a result, they need to be evaluated against their potential. Even for similar areas, human influence may have introduced components that have changed the area's potential. Assessments, to be correct, must consider these factors and the uniqueness of each system.*

B. Potential and Altered Potential

Evaluate each stream reach against its potential. As indicated, the basic map unit in riparian areas is the riparian complex. An assessment reach will have one or more complex; therefore, a general description of the potential of the complex(s) within the reach must be completed before the PFC assessment is done.

Potential, as defined here, is the highest ecological status a riparian area (stream reach) can attain in the present climate.   This is sometimes referred to as "potential natural condition" (this is not to be confused with "PNC - potential natural community" which is specific to the plant community. The word "condition" is used to clarify that it encompasses hydrologic, vegetation, and geomorphic attributes – not just plant communities).

Ecological status, as defined here, is the degree of similarity between existing hydrologic, vegetation, and geomorphic conditions and the potential of a reach; the higher the ecological status, the closer the reach is to potential.

> *A determination of the potential of a stream reach can be challenging and often represents an "educated estimate." A concrete, detailed description of every attribute of potential can be very difficult (often impossible) and unnecessary for completing PFC. For the PFC assessment, the ID team must have a reasonable idea of the attributes and processes that are possible within the reach to ensure that the system will be gauged against what it can actually be.*

The identified potential should reflect what is possible within a reasonable time frame in the present climate (generally no more than 50 years). Attempting to gauge current conditions against stream attributes and processes that may occur several decades or centuries in the future (or more) is conjectural and impractical for this assessment. For example, alluvial valley floor aggradation can drastically change riparian area potential but occurs over hundreds of years.

Applying Potential to the Assessment

Potential is applied to the PFC assessment by considering *each item on the assessment form* relative to what it can possibly attain. When there is *no* possibility for a "yes" response for an item, because a "yes" response does not exist within the system's potential, the item is answered "NA." When the possibility does exist for a "yes" response, a determination of whether the item should be answered "yes" or "no" based on current conditions has to be made. However, a reach does *not* have to be *at* potential for an answer to be "yes"; it only has to be evaluated against its potential.

For example, item 6 states, "There is stabilizing riparian vegetation present for recovery/maintenance." If the *potential* of a particular reach is a combination of herbaceous plants and multiple shrub species; and the *existing condition* is a dominance of multiple stabilizing herbaceous riparian plants with only one shrub species, the item should be answered “yes” because even though the reach has the potential for more shrub species than is currently present, the composition of stabilizing plants is adequate for recovery/maintenance of the reach.

Applying Potential to the Assessment for Altered Stream Reaches

The need to assess stream reaches that have experienced human alteration is common. Human-altered stream reaches, for this assessment, are defined as those with *relatively permanent human alterations that directly affect stream function.* Examples include railroads, dams, diversions, channelization, levees, roads, ground water pumping, and related alterations that change the potential of the reach. Management practices such as grazing, farming, recreation, and timber practices are activities that can affect the reach; however, they are not relatively permanent human alterations. Streams that have incised, due at least in part to grazing impacts, are not considered to be human-altered stream reaches in accordance with this definition. This is because not only can grazing practices be changed, but the entrenchment stage of channel evolution can be caused by natural processes as well as management activities.

Establishing potential for altered systems can be complex because alterations range from a highway that cuts off a few meander bends of a stream, to a large dam with significant flow regulation. As a result, the reach must be analyzed in more detail to determine how these alterations affect potential. Carefully consider the extent and magnitude of the alteration to determine if the potential (as described above) has actually changed.

Because there is a tremendous variety of unique stream alteration scenarios, and because PFC is a universal tool, it would be impractical to create detailed instructions applicable to all altered stream reaches. A set of questions are provided below to guide ID teams as they determine the potential of altered stream reaches. Examples are given in Appendix D.

1) Are alterations present creating artificial channel conditions for a substantial part of the reach?

   Determining if the reach is altered so extensively that it is largely artificial will require some professional judgment by the ID team. The intent of this question is to eliminate from consideration reaches that have been altered so significantly that, for the most part, they do not resemble stream conditions that would occur naturally. Such reaches are generally not expected to provide natural functions in any significant way. While one could argue that all flow regulated streams are “artificial,” many of them can still produce attributes and processes allowing them to function properly – they just may function differently than prior to the alteration (dam or diversion).

If the reach is largely artificial and the structures or activities are not expected to be removed, PFC is not an appropriate tool for assessing the reach.

An example would be a channelized reach where stream meanders have been removed and banks have been constructed or stabilized with hardened material (revetment) along most of the reach. If the structure or activity is scheduled for removal, determine what effect the removal will have on the potential of the reach (it may or may not be able to return to its original potential).

2) Are alterations present but the overall potential of the *reach remains unchanged*?

If this is the case, the ID team assesses the reach against its original potential as described above for applying potential to the assessment. The mere presence of a human alteration does not necessarily change the potential of a reach.

An example would be a stream reach where a few meander bends have been cut off due to road construction creating only minor localized effects that have not changed the overall potential of the reach.

3) Are alterations present that *have changed* the overall potential of the reach (but *have not* created artificial channel conditions for a substantial part of the reach)?

If this is the case, the ID team must determine what the new potential is. If the structure or activity is scheduled for removal, as described above, the ID team still should analyze what effect the removal will have on the potential of the reach. Once the new potential is identified, the ID team (a) documents that the original potential of the stream reach has changed as a result of a human alteration, (b) provides a rationale for how the new potential was determined, and (c) assesses the stream reach against this new potential.

The ID team will need to use professional judgment answering these questions and provide rationale for how these guidelines were used to determine if PFC is appropriate and if so, how potential was established for the altered reach.

An example of a reach that has a changed potential (“yes” to question 3 above) will help to illustrate. Consider a stream with channel dimensions consistent with a C stream type (riffle-pool channel with point bars) that is dominated by willow and birch with lesser amounts of herbaceous vegetation. A concrete dam is constructed and flows are highly regulated. Shortly thereafter, due to flow regulation, flood flows are attenuated and depositional events needed for the establishment of woody vegetation are considerably reduced. The downstream reach then slowly changes into an E stream type (narrow, very sinuous channel) with little or no woody vegetation. The determination for this reach is as follows:

1) Are alterations present creating artificial channel conditions for a substantial part of the reach?

No. While the streamflows are highly regulated, the channel can still produce attributes that will allow the stream to meet the definition of PFC.

2) Are alterations present but the overall potential of the reach *remains unchanged*?

No. The potential has changed.

3) Are alterations present that *have changed* the overall potential of the reach? (but have not created artificial channel conditions for a substantial part of the reach)?

Yes, due to the installation of the dam, flow regulation has changed the stream from a C stream type dominated by willow and birch with lesser amounts of herbaceous vegetation to a narrow E stream type, dominated by herbaceous vegetation with few or no woody plants. The stream is still able to function properly, but cannot be expected to produce the same channel and vegetation conditions possible prior to construction of the dam.

If this stream were evaluated against its potential (prior to the dam), among other attributes, it would never achieve the sinuosity, width/depth ratio and gradient that is in balance with the landscape setting (item 3) because it will never return to a C stream type without removal of the dam or significant changes in the flow regime. Nor will it ever return to the woody dominated system that existed prior to the construction of the dam and therefore must rely on herbaceous plant communities to “protect streambanks and dissipate energy” (item 11). Therefore, the new potential of this stream is an E stream type dominated by herbaceous plants and the stream will be evaluated against this new potential. Note: This does not imply that every dam will have this effect.

C. Determine Potential of Stream Reaches

This section describes the kind of detailed information that will be helpful for determining the potential of specific reaches. Much of the information used to delineate reaches will have direct bearing on determining potential.

The ID team should gather geologic, geomorphic, and topographic; climatic and hydrologic; soil; and vegetation and ecological data to determine the potential of each reach. This is a combination of literature review, GIS analysis, and field reconnaissance. Riparian ecological site descriptions with state-and-transition models, where developed, can provide a conceptual model of the processes and attributes that affect the potential of a reach.

Also, the ID team must consider historical land-use practices and recent management activities to determine if current conditions reflect potential conditions or notable departures from potential, which may constitute a new model of altered potential.

Geology, Geomorphology, and Topography

The geology, geomorphology, and topographic characteristics of a drainage basin exert strong influence on the shape and size of valleys and stream channels, which can affect:

- Dominant sediment characteristics.
- Sediment transport pathways to the riparian area.
- Shape and slope of hillslopes; and width and gradient of valley bottoms;
- Thickness of alluvial fill and depth to bedrock.
- The hydrologic controls that divide precipitation into overland flow, base flow, and moisture storage and losses, which in turn affect the hydrologic responsiveness of a drainage basin.
- The temporal and spatial distribution and delivery of energy to the stream channel and the riparian area.

Topography plays a fundamental role in establishing the valley type and in influencing the hydrologic responsiveness of a drainage basin. When considering the topographic controls on potential, thought should be given to the sources of sediment; the processes that transport sediment, water, and energy to and through channels; and the places where sediment, water, and energy can be stored or attenuated.

Climate and Hydrology

Climate and hydrology affect potential natural condition in several ways, by controlling:

- The annual amount and variability of precipitation, which in turn affects the annual amount and variability (peak, mean, and low flows) of streamflow.
- The depth to water table and ground water interactions.
- The relative balance between surface runoff and base flow.
- The annual range in temperature, particularly as temperature affects the freeze-thaw cycle, the physical production of sediment, and the storage and release of precipitation in the forms of snow, channel ice, melt-water, and runoff.
- Local weather patterns, which influence the flashiness or complacency of a system.
- Evapotranspiration rates.
- The overall extreme values in temperature and precipitation, which can constitute stressors or disturbance regimes in some systems.

Climate is itself affected by latitude, elevation, general circulation patterns, distance from ocean influences, mountain effects among other factors. Microclimatic controls can be especially pronounced in mountainous or hilly terrain where insolation (incoming solar radiation) varies significantly between north- and south-facing slopes. Differences in insolation can result in different plant communities, which are adapted to different soil-moisture conditions, evapotranspiration rates, and tolerances of droughty conditions. Understanding climatic processes is vital to understanding which plant communities can occupy and thrive in different riparian areas.

Soil

Soil properties greatly influence plant distribution and potential of riparian plant communities. The distribution of riparian plant communities is tied to various soil properties, including:

- Soil texture.
- Soil chemistry, especially pH, oxidation-reduction potential, salinity/alkalinity, and cation-exchange capacity.
- Soil-moisture regimes (also see hydrology above).
- Soil physics, especially bulk density and its effects on root growth.
- Soil organic-matter content, especially the cation-exchange capacity, and nutrient and moisture-retention properties of soil organic matter.

Vegetation and Ecology

Riparian plant communities are adjusted to soil properties, climate, hydrologic regimes, and disturbance regimes of the sites they occupy. Ecologists have studied riparian plant communities across the western United States and developed site specific riparian vegetation classifications. Many riparian vegetation classification guides are available and should be used to help ascertain potential. Although many classifications are written for specific regional areas, many of them can be extrapolated and used in neighboring areas that are physiographically similar. Riparian plant communities are best understood for perennial systems and for those intermittent systems that are slightly drier than perennial systems. In those intermittent systems that are scarcely wetter than ephemeral systems, riparian plant communities are more highly variable and less well understood.

Determination of the potential riparian plant community of a given reach is an ecological exercise that requires integration of the physical, chemical, and biological properties of a reach. Ideally, the ID team would identify and inspect the riparian complexes of reference areas to establish potential. Some reference areas might be within natural areas, within livestock or wildlife exclosures, or in administrative units, such as guard stations that are undisturbed by grazing. However, never assume that areas protected from grazing, recreation, or other uses are appropriate reference areas. The initial reason for protecting an area might have been to restore a severely deteriorated stream segment. The area may be still in the process of recovering; therefore, select and use reference areas with care. The reference condition for potential can be based on data or professional judgment, though the basis for the latter should be explained.

Historical, Environmental and Managerial Data

An understanding of current condition and establishment of trend is enhanced by knowledge of previous conditions, events, and processes. Historical photographs, General Land Office original land surveys, aerial photography, management records, grazing records, allotment inspections notes, or range condition monitoring data can permit the ID team to reconstruct past conditions and processes.

Many reaches show the legacy of past management or former environmental conditions. Streams might degrade in a few years, but recovery to a stable, properly functioning system might take decades to centuries. Recovery might occur in many ways, at different rates, at different times. Therefore, knowledge of the possible time and rate of channel changes is vital to addressing potential or altered potential within a management timeframe of 10-50 years, which coincides with the life span of many management activities or plans.

Summary of Potential

The PFC assessment is a qualitative, science-based, expert-driven method. The assessment cannot succeed if the ID team fails to gather information to provide a context for interpreting field observations in the riparian area. Reach potential must be documented with the ID team's rationale.

Establishing reach potential is necessary to serve as a benchmark or gauge of possible conditions required for an accurate PFC assessment. The work completed in delineating reaches and addressing potential is no less important than the field observations made in performing a PFC assessment. Therefore, ID teams must do a thorough job of both the pre-work and field work.

6. Step 4: Complete PFC Assessment

A. Plan the Assessment Approach

The PFC assessment, in most cases, requires the ID team to physically inspect the stream reaches in the field or at least sample various sites within a reach. The most effective way to accomplish a PFC assessment is for an ID team to do a complete reconnaissance of the stream by walking or floating the reaches. However, depending on the availability and quality of remote sensing tools (digital photos, aerial photos, GIS data, Very Large Scale Aerial (VLSA) photos, Light Detection and Ranging (LiDAR), etc), some reaches can be at least partially analyzed in the office using one or more of these tools followed by selective inspections of representative sites. One example would be steep, brushy headwater streams or deep, narrow canyons that can be difficult to access and inspect physically (in some cases, physical inspection may be unnecessary). In these instances, remote sensing tools can be effectively used in conjunction with selective inspections of representative sites as needed to complete the assessment. Other factors that may influence the assessment approach include the level of controversy, the degree of resource values, sensitivity to management impacts, etc. All of these factors should be considered by the ID team to establish priorities for PFC assessments and to select the most suitable assessment approach.

Regardless of the approach selected, document the tools and approach used to complete the assessment. ID teams using remote imagery must ensure they have the appropriate experience with these tools.

The ID team should plan to complete the assessments from the top of the reach or watershed and work downstream. This allows for a more accurate assessment of the downstream reaches as the ID team observes upstream conditions prior to assessing downstream reaches. This helps assess factors that may be influencing downstream reaches (there may also be downstream impacts affecting upstream reaches). Also, the team should try to view the reach from an elevated area to get an overall picture of the reach.

Timing

The optimal time to complete the PFC assessment is during the growing season when the stream is at low flow and has not been heavily grazed; however, the PFC assessment can be effectively completed at any time of year provided the riparian area is not covered with snow. It is, however, more challenging to complete the assessment during the dormant season, when the stream is at high flow, or when the riparian area has received considerable grazing. In these cases, ID teams must be cautious to avoid allowing the appearance of the riparian area to bias the assessment. If necessary, teams may need to postpone assessments until conditions are more favorable.

ID teams should also be cautious about completing PFC immediately following high-magnitude flood events. In most cases, it is best to allow streams to at least start to adjust to these events before completing the assessment if possible.

B. Complete Reach Information and PFC Assessment Forms

The Reach Information Form records key information that must be included with the assessment. The PFC Assessment Form records the assessment. Detailed instructions for completing both forms are in Appendix A.

C. Making the Functional Rating

Following completion of the items on the assessment form, a "functional rating" is determined based on the ID team's discussions. Review the "yes" and "no" responses and rationale on the assessment form and collectively assign a rating of **proper functioning condition, functional-at-risk, or nonfunctional** as defined below.

A lotic riparian area is considered to be in **proper functioning condition (PFC)** when adequate vegetation, landform, or woody material is present to:

- Dissipate stream energy associated with high waterflow, thereby reducing erosion and improving water quality.
- Filter sediment, capture bedload, and aid floodplain development.
- Improve flood-water retention and ground-water recharge.
- Develop root masses that stabilize streambanks against erosion.
- Maintain channel characteristics.

The components of this definition are in order, relative to how processes work on the ground.

If a riparian area is not in PFC, it is placed into one of two other categories:

Functional-at-risk - Riparian areas that are in functional condition, but an existing landform, water, or vegetation attribute makes them susceptible to impairment.

Nonfunctional - Riparian areas that clearly are not providing adequate vegetation, landform, or woody material to dissipate stream energy associated with high flows, and thus are not reducing erosion, improving water quality, etc.

The PFC assessment is designed to assess if the physical elements (abiotic and biotic) are in working order relative to potential. When these physical elements are in working order, channel characteristics develop, which provide habitat for wildlife and other uses. Functionality comes first, and then functions lead to the achievement of desired conditions.

Because of the variability in types of lotic riparian areas (based on differences in climatic setting, geology, landform, and substrate) and variability in the severity of individual factors relative to an area's ability to withstand relatively high-flow events, there is no required number of "no" responses that dictate an area to be at-risk or nonfunctional. If a riparian area possesses the necessary elements, then it has a **high probability to withstand relatively high-flow events.** If all the responses on the assessment form are "yes," the reach is undoubtedly meeting these criteria and would be rated at PFC. If some responses are "no," the reach may still meet the definition of PFC – depending on the nature and severity of the "no" responses.

The definition of PFC includes "adequate vegetation, landform, *or* woody material" because not all streams and riparian areas process the energies of flowing water in the same way or have the same potential plant community. For example, many areas in the Great Basin have a mixed willow, sedge/rush vegetation potential. High energy stream reaches require some combination of both stabilizing woody and herbaceous vegetation (and sometimes rock and woody material) to dissipate energy while lower energy or low gradient reaches are often able to dissipate energy with only the herbaceous components.

An example that many are familiar with, where landform drives stream energy dissipation, is the Yellowstone River below the Lower Falls in Yellowstone National Park. The canyon's geology and bedrock channel are such that they dissipate stream energy associated with high water flows. This reach of the Yellowstone River has no potential to produce vegetation, does not need vegetation to dissipate energy, and is functioning properly.

When determining PFC, high-flow events are frequent events like 5-, 10-, and 25-year events. To sustain a given riparian area over time, the energies associated with high-flow events have to be accommodated. Experience has shown that riparian areas rated PFC generally withstand these events. Extreme events like the 50- 100year or larger, events occur infrequently and have such power that riparian areas in PFC may unravel, at least in places. However, those reaches in PFC prior to these extreme events can generally recover in a more timely manner than FAR or NF reaches.

A **functional-at-risk** riparian area may possess some or even most of the elements in the definition, but at least one of its attributes/processes gives it a **high probability for**

impairment with a relatively high-flow event(s). Most of the time, several “no” responses will be evident because of the correlation among items. If these “no” responses, in the ID team’s opinion, collectively provide a high probability for impairment in relatively high-flow events, then the rating is functional-at-risk. There is one situation where only one “no” response can put a riparian area at-risk. *If a stream reach has a head-cut moving upstream (item 16), then the reach above the head-cut to a point where there is some geologic or structural grade control is functioning at-risk regardless of other factors (Figure 7). Caution must be used when evaluating downstream headcuts as some may only be local grade adjustments where the stream is cutting through a depositional fan or related feature.*

Figure 7. Headcut is moving up through a meadow, making the area above functional-at-risk.

Nonfunctional riparian areas **clearly lack the elements** listed in the PFC definition. Usually nonfunctional riparian areas translate to a preponderance of “no” responses on the assessment, but not necessarily all “no” responses. A laterally unstable stream may still retain a floodplain, the upland watershed conditions may be acceptable, and the stream may be vertically stable, but still clearly nonfunctional.

Although it may appear that the final rating category selected is the primary objective of the PFC assessment, *how* each item is addressed provides specific, critical information useful for subsequent management, restoration, and monitoring efforts and for estimating the recovery trajectory and rate. Thus, managers who focus only on the rating miss important opportunities and a key value of the PFC assessment.

Addressing Trend

Trend toward or away from PFC must be described when a rating of FAR is given. Trend is the direction of change in an attribute(s) over time and can be addressed two ways. *If trend is determined using photos, monitoring data, detailed inventories, and any other measurement or documentation to compare past conditions to present conditions, it is defined as "monitored trend." Monitored trend is described as upward, downward, or static.* If this information is not available, indicators of "apparent trend" may be used to estimate trend during the assessment process. *Apparent trend is defined as "an interpretation of trend based on observation and professional judgment at a single point in time" (Bedell 1998). Apparent trend is described as upward, downward, or not apparent.*

ID teams need to indicate which trend method was used and provide rationale for the selected trend determination on the assessment form.

PFC, Succession and Recovery

Riparian areas can function properly before they achieve their potential. The PFC definition does not mean potential or optimal conditions for a particular species have to be achieved for an area to be considered functioning properly. Figure 8 and Figure 9 provide **a simplified example of the relationship between PFC and channel/vegetation succession for one kind of stream reach; the relationship may be different for other areas because of differences in potential and how specific systems progress/regress.**

In the example in Figure 8, assuming succession continues uninterrupted; the stream will evolve through some predictable changes from bare ground to potential (although not always along the trajectory depicted). The stream will progress through phases of NF, FAR, and PFC along with channel changes and plant succession. **In this example, PFC occurs at the mid-seral state, though this is not always the case.** PFC is not a single point in time; depending on which attributes and processes are required for function, it may occur from early seral to late seral states (although PFC occurs less commonly in streams at an early seral state than those that are in a more advanced state). Figure 9 shows a cross section of a stream with the potential for shrubs/trees for each condition (States 1-5) illustrated in Figure 8.

"States" represent distinct conditions at a defined point in time. A stream reach may remain at one state or condition for an undetermined length of time because of coinciding circumstances of management and climate. Progress toward a higher state or condition may at times be impeded by greater natural stresses associated with high flows. Regression toward a lower condition may be dependent on exceeding a threshold of stability, progressing slowly at first, and then rapidly declining as the threshold is crossed. Often during recovery, the progress will appear like a stock market graph with a series of peaks and valleys with the average over time representing progress toward a higher condition. In any condition, from functioning at-risk to desired condition, an event, either human-induced or natural (fire, volcanic eruption, floods, dewatering, etc.), can cause the area to regress to a lower condition. A much greater disturbance event is necessary to cause the condition to regress in areas that are in proper functioning condition than in those that are functioning at-risk. Not all streams will follow this same progression. Depending on reach specific attributes and processes, impairment can occur quickly and recovery can often be slow. In general, this is why it is desirable to maintain streams in PFC.

As a system progresses towards potential natural condition, a number of physical changes begin to occur. These include reduced erosion, sediment filtering, and improved flood-water retention (when adequate vegetation, landform, or woody material are present to dissipate energy associated with high flows). As the physical aspects of a system begin to function, the process of developing ponding and channel characteristics that provide habitat for fish, waterfowl, and other uses is initiated. The physical aspects have to be in working order to sustain the channel characteristics that provide habitat for these resource values.

At various states within this successional process, the stream can provide resource values for different uses. For the example in Figure 8, optimal conditions for grazing occur when forage is abundant and the area is stable and sustainable (mid-seral). Wildlife goals depend upon the species for which the area is being managed. If the riparian area in Figure 8 is to provide habitat for shrub nesting birds, the optimum conditions would be from mid- to late seral. Trout habitat conditions would be optimum from mid-seral to late seral. Desired plant communities would be determined based on management objectives through an interdisciplinary approach. The threshold for any goal is at least PFC because any rating below this would not be sustainable. Thus, until PFC is attained, there is little decision space available to managers to emphasize one resource value over another because NF and FAR reaches are not sustainable.

As streams recover and attain PFC, they will generally continue to progress towards some advanced condition unless management actions are implemented to modify the process. The “decision space” in Figure 8 does not imply that management has unlimited control over every riparian attribute or process nor does it imply that it is always easy to manipulate riparian attributes to feature one value over another.

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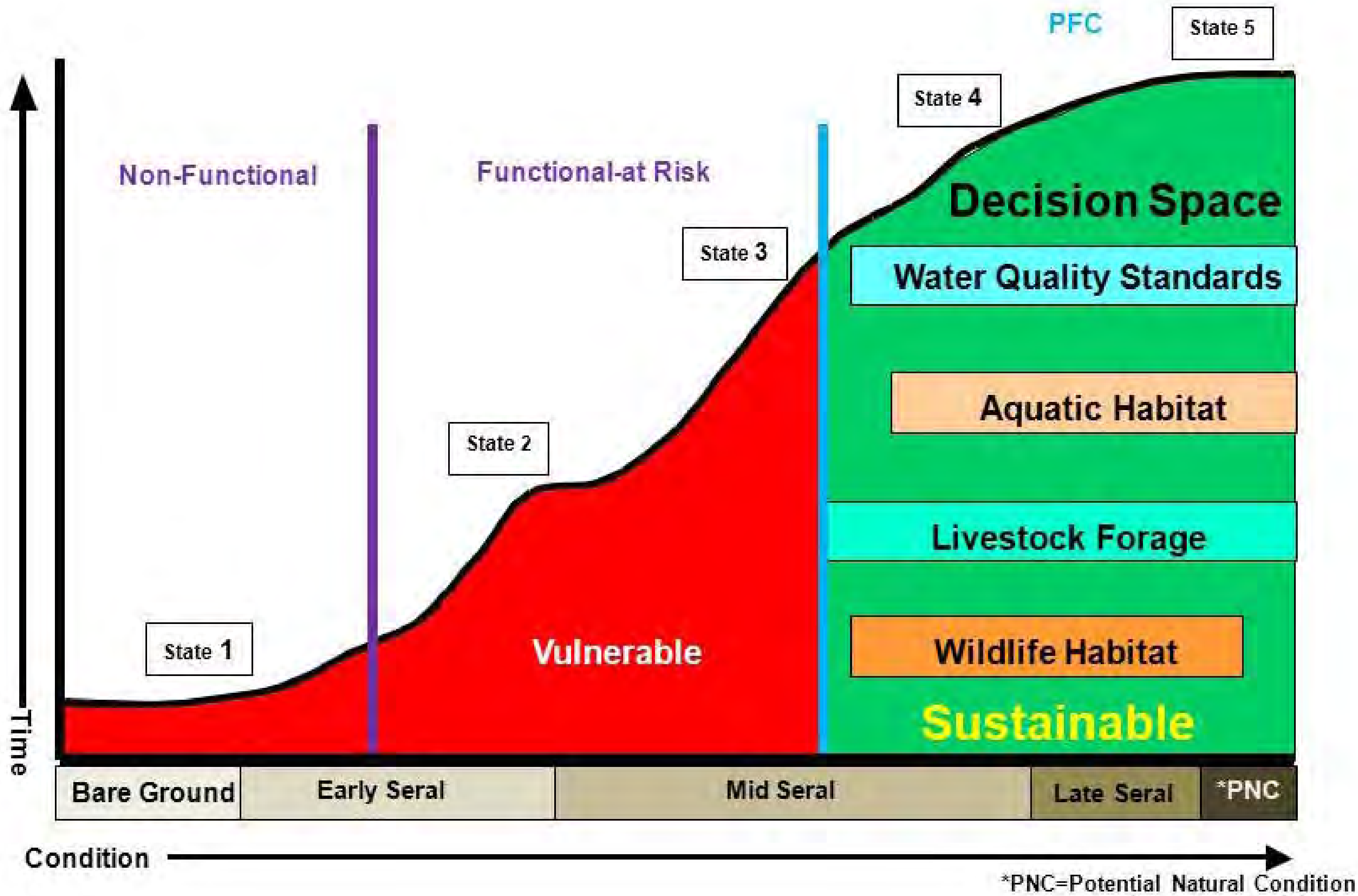

Figure 8. Example of succession as it relates to stream recovery and function.

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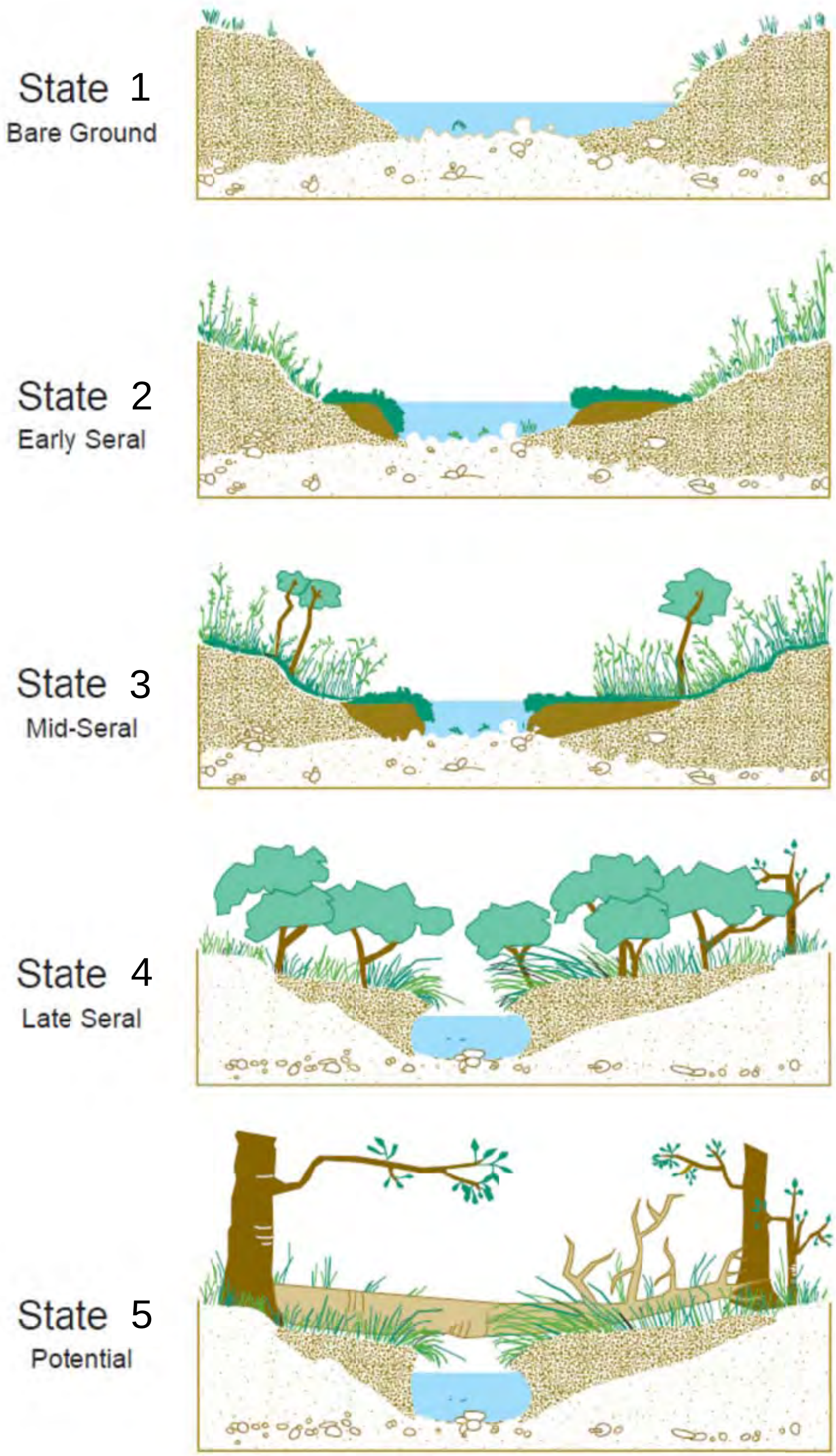

Figure 9. Stream cross sections depicting the states displayed in Figure 8. (Not all streams will follow this successional progression).

D. Using Quantitative Data to Validate Assessment Items

If ID teams have difficulty resolving some “yes” and “no” responses, the assessment item(s) should be quantified to help resolve the issue(s). In some cases, the team may simply want to validate an item by collecting quantitative data. Appendix E describes quantitative techniques that are effective in quantifying the assessment items.

Monitoring should take place at randomly selected designated monitoring areas or “DMAs.” DMAs are permanently marked segments of streams used for monitoring; Burton et al. (2011) described a process and criteria for establishing DMAs. Elzinga et al. (1998) also provided detailed information for sampling design and quantitative monitoring. Following validation of PFC, these DMAs will then serve as the locations where monitoring data are collected for developing and tracking the achievement of riparian objectives. Often DMAs are selected to represent FAR reaches where the PFC assessment identifies a need for a management change or a monitoring focus.

Burton et al. (2011) stated that “It is important that DMAs are established by an ID team of highly experienced personnel with knowledge of the management area.” Because an experienced ID team has been assembled to do the PFC assessment and reaches/complexes have been delineated/stratified, this is an appropriate time to locate new representative DMAs or validate the location of existing DMAs (Figure 10). If establishing new DMAs, it is best to locate them during the stratification process and then validate locations during PFC assessments.

Figure 10. Conducting monitoring at a DMA.

E. Finalize the PFC Assessment

Once a PFC assessment is completed, the ID team should have completed the following *for each reach*:

- Reach Information Form (including a riparian plant list form, Appendix A).
- PFC Assessment Form.
- Photographs supporting the PFC assessment (with documentation).
- Assessment results entered into the appropriate agency database (as needed).

In addition, it is strongly recommended that *the ID team summarize the findings of the assessment in the form of a comprehensive report if multiple reaches are completed.* A suggested outline is included in the box below. At the conclusion of the PFC assessment, a report is essential to provide readily available information for future projects and analyses.

Example PFC Assessment Report Outline

I. Introduction

II. PFC Assessment Results
  - A. Description of assessment area
  - B. Reach delineation/stratification
  - C. Description of potential(s)
  - D. Reach narratives (summary of PFC assessment results in narrative form)
  - E. Observations/findings
  - F. Issue identification and management recommendations

III. References (soils surveys, stream classification, etc.)

IV. Appendices
  - Appendix 1: PFC assessment and plant list forms
  - Appendix 2: Photos and captions
  - Appendix 3: Maps with reach breaks and photo waypoints
  - Appendix 4: Waypoint log

(Depending on complexity, a table of comments, executive summary, methods summary, and details of stream classification may also be included.)

8. Assessment Items

The following section outlines the 17 assessment items used to determine the functional rating category for each stream. Each item describes:

- The purpose of the assessment item.
- Observational indicators and examples useful for addressing the item.
- The supporting science used to derive the item.
- How each item correlates to other items on the list.

The assessment items are designed to address the common attributes and processes that have to be in working order for a riparian area to function properly. Each item on the list answered with a “yes,” indicates that the attribute or process is working; a “no,” response indicates that it is not working, and an “NA,” means that the item is not applicable to that particular area.

Many of the assessment items are closely related. This provides a system of checks and balances and requires users to closely consider related responses to ensure that they are consistent. For example, if item 14 (point bars are revegetating) is answered “yes” for a recovering system, item 4 should be answered “yes” because the riparian area is expanding. It is also important to note the items are numbered for the purpose of cataloging comments and that the numbers do not declare importance. The importance of any one item will vary relative to a riparian area’s attributes and processes.

Account for the effects of high-magnitude, low-frequency events. Although PFC is a barometer of how well a stream will endure a high-flow event, even the best functioning systems may unravel or experience major channel adjustments as a consequence of large, rare floods (i.e., those with a return interval greater than 25 years). Knowledge of historical streamflow is critical in distinguishing channel responses to rare events from changes resulting from poor riparian conditions and poor land management.

The supporting science for some of the items is the same or overlapping. Explanations are provided in the most appropriate items, but some cross-referencing may be required.

The ID team should do a thorough job of completing each item and not dismiss the importance of an individual item just because it may not significantly influence the final rating. *How an individual item is addressed* often has a significant effect on future management, restoration, and monitoring actions – regardless of the functional rating.

This section does not include quantitative techniques to measure a particular assessment item. Appendix E provides a detailed list of techniques and references that can be used to quantify each item on the assessment form.

A. Hydrology

Items 1-5 address hydrological attributes and processes that must be present for a riparian area to function properly. Hydrology is a fundamental aspect of stream function, relating to erosion and sediment transport, channel morphology, flood flow energy dissipation, and the ability of a riparian area to sustain appropriate vegetation.

Item 1 addresses whether the stream has access to the floodplain and can spread out during high flow events to dissipate energy.

Item 2 determines whether beaver dams are present, and if so, are they being maintained. Stable beaver dams increase aquatic habitat heterogeneity, assist in floodplain development, and can buffer the impacts of low magnitude floods to downstream riparian areas. Unstable beaver dams may fail during high flows, contributing to the magnitude of the flow and increasing both downstream erosion and sediment deposition.

Item 3 is specific to stream channel dimension, pattern, and profile. Is the stream channel sinuosity, width/depth ratio, and gradient in balance with the landscape setting and potential for the site?

Item 4 focuses on the lateral extent of the riparian area. Degraded streams often have a narrowed riparian area as a result of lost contact with ground water; whereas riparian area expansion indicates recovery.

Item 5 addresses whether impairment upstream or within the drainage area upland may be contributing to riparian impairment. It does not pertain to upland conditions.

The ID team needs to collect background information and understand key concepts prior to assessing the hydrology section of the checklist. Pre-work must be done prior to fieldwork and should include (but is not limited to):

- Calculating the drainage area size from topographic maps, GIS, or other appropriate means.
- Finding and using applicable hydraulic geometry or regional curves or both.
- Determining the presence or absence of dams or diversions. The ID team can find information on the streamflow characteristics for their stream from USGS stream gage sites in the area.

There are three USGS websites that provide flow information or regional regression equations to predict streamflow:

- Streamstats – http://water.usgs.gov/osw/streamstats/.
- USGS PeakFQ Flood Frequency Analysis based upon USGS Bulletin 17B – http://water.usgs.gov/software/PeakFQ/.

- USGS National Streamflow Statistics Program that lists publication with regional regression equation by state and downloadable software – http://water.usgs.gov/osw/programs/nss/pubs.html.

The stream gage itself may not be on the stream they are assessing, but if close enough and under the same geologic and hydrologic regime, they can extrapolate information. Important information that can be obtained from stream gage data available on the USGS webpage may include:

- Information whether the assessment reaches are perennial, intermittent, or have interrupted segments. Streamflow hydrographs can show surface flow duration and periods when it is non-existent.
- Streamflow hydrographs can indicate flood event timing (spring snow melt, summer thunderstorms, or if floods occur throughout the year).
- Hydrograph shapes can identify streams that have peak flows that are high but of short duration (tall and narrow curve from thunderstorm driven system) or more moderate with a longer duration (wide as in the case of snowmelt that occurs over a long period of time).
- The difference between summer baseflows and the relatively frequent flood flow event that fills the active channel, as well as the difference between the 1.5 year and 100 year return interval floods. These differences influence the potential channel form and riparian vegetation composition.
- Drainage area size at the gage.
- Flood flow frequency information to identify 1.5, 2, 5, 10, and 25 year return interval flood flows; Peak flow data can also inform the ID team when the last large flood occurred in their area. If a large flood recently occurred it needs to be determined whether the observed conditions can be attributed to land management or from the large flood event.

Someone on the ID team should be familiar with the concepts of Manning's equation and the continuity equation. These equations demonstrate some of the relationships between flow discharges or velocity and channel characteristics. Solving the equations using known variables that can be measured or estimated should result in estimates of velocity or cross-sectional area that are reasonable for the reach in question. This can help the ID team in separating the true floodplain from terrace and understand some aspects of channel behavior.

Manning's equation calculates the mean velocity of flowing water in feet per second:

$$\text{Mean velocity} = 1.49\,\frac{S^{0.5}R^{0.66}}{n}$$

Where

- *S* = water surface slope (ft/ft).
- *R* = hydraulic radius (stream cross sectional area divided by the wetted perimeter) (in all but very narrow natural channels the mean depth can be used to approximate the hydraulic radius).
- *n* = roughness coefficient. *O*ften referred to as Manning's "*n*", it describes the roughness of the channel bed or feature that flow is being measured across. A higher number indicates greater channel roughness.

The continuity equation calculates flow discharge in cubic feet per second:
Discharge or $Q = A(V)$ *or* $Q = W(D)(V)$
Where *A* = cross-sectional area of the channel.
V = mean velocity.
W = channel width.
D = channel mean depth.

The larger the channel and faster the flow, the more water goes past a point in a given time. For more information regarding a stream or river's form and its relationship with its watershed, see Leopold (1994), Knighton (1998), or Harman et al. (2012).

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Item 1: Floodplain is inundated in "relatively frequent" events.

Purpose

Item 1 determines whether frequent flood flows are capable of spreading out on a low-lying area adjacent to the stream to dissipate energy, deposit sediment, recharge floodplain aquifers, and inundate riparian vegetation. The presence of adequate vegetation or landform (floodplain, canyon walls, etc.) to "dissipate stream energy associated with high water flow, thereby reducing erosion and improving water quality" is one requirement for a riparian area to be in "proper functioning condition."

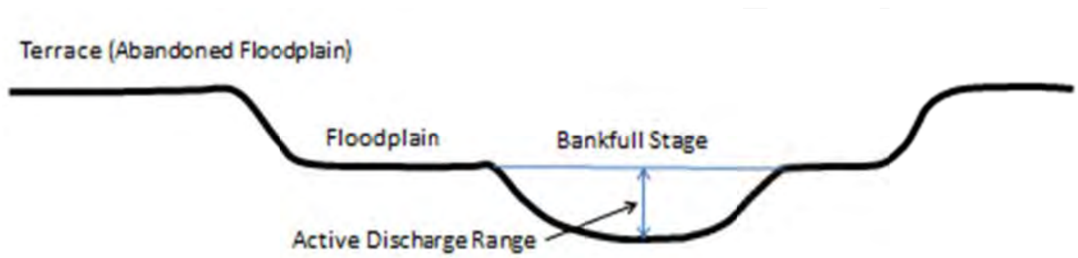

Figure 11. Stream channel cross-section with important flow features identified.

Stream channels that are not landform controlled, and with a low gradient (generally less than 2 percent) need a floodplain to in which flood flows can spread out and energy be dissipated. The floodplain is the level depositional area adjacent to the river channel, constructed by the river in the present climate, and overflowed during moderate flow events (Figure 11) (Wolman and Leopold 1957, Leopold 1994). The flow that fills the active channel to the edge of the floodplain is referred to as the bankfull discharge. This floodplain edge is referred to as the incipient point of flooding. When streamflow begins to spread over the floodplain, it is referred to as a flood. Water surface elevations below the incipient point of flooding are collectively referred to as the active channel discharge; they are located within the active channel.

Observational Indicators and Examples

Item 1 would be answered "yes" if relatively frequent flood flows can spread out on an adjacent floodplain. If the true floodplain is present at a representative site on the reach, it must be present through the entire assessed reach. Visual evidence of frequent inundation of the active floodplain may include but is not limited to:

- Fresh deposits of fine sediment.
- Floodplain vegetation matted down or lying flat of floodplain from by overbank flow or by deposition of overbank sediment.
- Debris piled on the upstream side of tree trucks.
- High water marks seen on rocks, trees, or other stationary objects; and ice-rafted deposits on the floodplain.

Be careful when using flood debris deposited in streambank vegetation as evidence that a floodplain is present or that relative frequent inundation has occurred. Less frequent, larger floods may deposit debris and litter in vegetation on an adjacent terrace, especially in incised channels. Study the flood deposits carefully to distinguish recent from relict and frequent from rare deposits. Older vegetation loses color and begins decomposing. Eventually floodplain vegetation will grow up through old flood deposits.

Item 1 would be answered "no" if a floodplain is not inundated by relatively frequent events. Visual evidence of infrequent inundation may include but is not limited to:

- The presence of a dam or diversion within or upstream of the assessed reach prevents relatively frequent flood events from occurring.
- Downcut channels to depths that do not allow relatively frequent flood events to reach the top of the channel and spread out.
- Stream banks are vertical (or steeply angled) and populated with upland vegetation rather than the expected riparian vegetation.
- Stream channel has an estimated cross-sectional area much larger than dimensions predicted by local regional curves.
- Stream channel is much larger than what would be predicted needed to convey discharges calculated using the continuity equation.

Item 1 would be answered "NA" if a floodplain is not required for the riparian area to function. Flood-flow energy is instead dissipated by channel roughness (boulders, cobbles, woody material) and landforms (friction from canyon walls) rather than spreading out on an active floodplain. This would include channels:

- That are naturally confined (located within narrow valleys or canyons) where there is insufficient width for a floodplain to develop, or
- Located in steep valleys or canyons with high water surface gradients (greater than 2%) that do not permit suspended sediment to settle out and develop floodplains.

Floodplain location should not be arbitrarily selected by the ID team. It must be properly identified using information collected during the pre-work preparation because:

- To answer item 1 correctly, the floodplain must be correctly identified in order to determine if relative frequent floods are able to spread out and dissipate energy.
- Future monitoring depends upon an accurate and detailed description of the active floodplain. Future ID teams must be able to identify what the original ID team identified as the floodplain. If two separate deposition features are monitored through time, interpretations would be inconsistent due to observer error rather than from a change in channel structure or riparian condition.

Drainage area is needed to determine the bankfull discharge and bankfull channel dimensions to properly identify the floodplain in the assessed stream reach. Bankfull discharge can be determined by flood frequency analysis from available stream gages. If assessments are to be done on streams that do not have gages, bankfull discharge must be estimated by other means.

The ID team, during pre-work, should determine if regional curves are available for their region, or if those developed elsewhere with similar characteristics would be applicable. Regional curves are developed from regression analyses of the relation between drainage area size and bankfull channel cross-sectional area, mean depth, width, and discharge. These relationships are derived from data collected at stream gages within a similar hydrologic province. Emmitt (1975) provided the first calculated regional curves for bankfull discharge and channel dimensions for different drainage areas in Idaho. Dunne and Leopold (1978) used Emmitt (1975) and other relationship data to provide regional curves for different regions in the United States. The bankfull channel dimensions observed in the field may not exactly match those calculated from regional curves, but should be used as a general approximation to what to expect.

Supporting Science

Montgomery and Buffington (1997) recognized three primary channel reach substrates:

- Alluvial channels consist of materials that are readily transported by water and when flow energy is diminished can be deposited in the channel or on the adjacent floodplain. Alluvial channels consist of materials ranging in size from boulders to sand, depending upon the streams ability to move them during flood flows. Unconfined and low gradient alluvial channels are expected to have a floodplain.
- Colluvial channels consist of materials that have been transported into the channel by gravity from the adjacent hill slopes. Colluvium is only moved by infrequent high flows. Colluvial channels generally do not have floodplains due to their locations in canyon bottoms.

- Bedrock reaches have little sediment deposition in the channel and represent high sediment transport capabilities (Rosgen 1996, Montgomery and Buffington 1997). Bedrock channels may or may not have a floodplain, depending whether they are located in steep and narrow canyons, or in broad flat valleys.

Wolman and Miller (1960) describe bankfull discharge as that in which channel maintenance is the most effective, thus bankfull discharge is also referred to as the effective discharge. This discharge erodes and deposits materials which provide for lateral movement of stream channel and maintains the consistent morphologic characteristics and shape of the channel.

Bankfull discharge, which is exceeded by the maximum annual peak discharge in two out of three years, is considered a relatively frequent event (Wolman and Miller 1960). Recurrence intervals can vary from one stream to another within the same hydrologic region. The 1.5 year value provides guidance for areas where there is limited flood flow information. There are regional differences in bankfull discharge recurrence intervals. Bankfull discharge has a recurrence interval on average of 1.2 years in western Oregon (Castro and Jackson 2001). Moody et al. (2003) found that bankfull discharge has recurrence intervals that varied between 1.0 and 1.8 years in Arizona.

Correlation with other assessment items

Item 1 relates to item 13, (floodplain and channel adequate to dissipate energy). Item1 can be answered “yes” if a developing floodplain is inundated frequently, but item 13 may be answered either “yes” or “no” depending on width.

Item 1 also relates to item 16 (stream system not incising) because if Item1 is answered “yes” due to a consistent floodplain found through the assessed reach, the channel is not incising. In this case, item 16 would also be answered “yes”. However, if the channel has recently or is actively incising and has abandoned the floodplain, both Items 1 and 16 would be answered “no”.

Item 2: Beaver dams are stable.

Purpose

Beavers may be key agents of riparian succession because the dams they build act as hydrologic modifiers. Item 2 documents whether beaver dams are present and if so are they being maintained. Stable beaver dams benefit aquatic systems by:

- Trapping and storing large amounts of water and sediment.
- Reducing stream velocities during floods and maintaining uniform base flows by slowly releasing water through drier seasons.
- Aiding floodplain development and raising floodplain water table elevations.
- Increasing riparian vegetation structure, diversity, and productivity.
- Decreasing downstream water temperatures as water seeps from below the dam.

If beaver dams are not stable or grown over by vegetation, over time, they can breach and release flood flow energies that may result in downstream impairment. Beaver dams are stable when they are actively maintained or riparian vegetation establishes on the dam that help hold it in place. Aerial photographs or past photo points can show changes to beaver dams over time.

Observational Indicators and Examples

If the active are present and are being maintained item 2 would be answered “yes”. Field indicators of maintained or stable beaver dams may include:

- Fresh wood cuttings (leaves present or wood appears freshly cut) found on the dam;
- Both ends of the dam are actively constructed, water is not pouring over either end causing streambank erosion.
- Riparian vegetation has established and appears to be solidly supporting the dam (Figure 14 and 15), note that new dams may not yet have riparian vegetation growing on them.

Beaver dams that are broken and not maintained would be considered unstable and item 2 would be answered “no.” Field indicators of maintained or stable beaver dams may include:

- Broken and excessively leaking dams (beaver dams are not impermeable).
- End of the beaver dams are not anchored into both streambanks. Increased flow through either end can quickly erode and cause the dam to fail.

If beavers dams are not present, item 2 would be answered “NA.”

Examine the dam size and the amounts of water and sediment backed up behind it.   Beaver dams often breach or fail during flood events. Does the dam block enough water that would contribute additional flow to the flood to increase damage that would not occur as a result of only the flood to the downstream riparian resources? Would the trapped sediment result in excessive deposition in the channel forming bars or adversely affecting fish habitat? A small, unstable dam may have a “no” answer, but the comments should reflect that this would have little impact on the overall functionality of the stream.

Also consider the size of the beaver pond and associated wetlands to determine if the lentic assessment or a combination of the lotic and lentic assessment items should be used to address important attributes and processes of that portion of the assessed reach.

Stable beaver dams in woody riparian systems will often be stabilized by vegetation that grows on or at the base of the dam (Figure 12). Eventually the dam may be totally overgrown with vegetation (Figure 13).

Figure 12. Very stable beaver dam covered with a thick growth of herbaceous and woody vegetation.

Figure 13. Beaver dam totally overgrown with woody riparian vegetation.

While many beaver dams are constructed from woody material, others are built with only herbaceous materials such as cattail and bulrush (Figure 14). These dams are typically low in stature and back up relatively small amounts of water. These dams are commonly washed out during summer storm or snow melt events. The ID Team may still answer this item “no” for the above mentioned reasons but clarify in the notes that it is not anticipated that dam failure in that case would result in riparian damage up or down stream.

Figure 14. Low stature beaver dam constructed with cattail and bulrush stems, (photo courtesy P. Shafroth, USGS Fort Collins).

Supporting Science

Beavers are a natural component of riparian ecosystems. Prior to European colonization, it is estimated that there were millions of beavers and beaver dams in North America (Naiman et al. 1988, Butler and Malanson 2005, Westbrook et al. 2010). Beavers had a much larger influence on many lotic systems in the past than what they have today (Pollock et al. 2003). Beavers can convert riparian systems from lotic to lentic (Naiman and Melillo 1984, Andersen and Shafroth 2010).

Beaver dams can widen incised channels to allow floodplain formation to occur. The dams back up water and reduce the stream gradient. This increases the stream's ability to meander or move laterally. The meandering causes lateral erosion and widening in the incised channel. The increased channel width reduces flow energy which allows suspended sediment deposition for floodplain formation.

Water immediately upstream of a dam is at a higher elevation that water downstream. This raises the water table in incised channels allowing riparian vegetation to establish and spread upstream of the dam.

Assessment of this item requires professional judgment. Active dams are usually considered stable, but over time, vegetation needs to establish and provide stability to the dam (Butler and Malanson 2005). However, if dams become unstable and fail, they can result in stream impairment and stream adjustments that include channel widening, lowering, and lateral migration (Butler and Malanson 2005) and impact aquatic species (Stock and Schlosser 1991). This is not to imply that stable beaver dams are resistant to flood events. Active beaver dams can and are often breached or destroyed by flood events (Butler and Malanson 2005; Anderson and Shafroth 2010). Beaver dam failures typically occur after intensive and or extensive rainfall or in association with high spring runoff from snowmelt (Stock and Schlosser 1991, Butler and Malanson 2005).

Correlation with other assessment items

Item 4 (riparian area is expanding) is related to item 2 because elevated water tables and lower flow velocities upstream of the dams can promote and riparian vegetation establishment and maintenance. Item 2 also relates to item 6 (beaver dams are stable) because the area upstream of a beaver dam may support different vegetation communities than downstream because of differences in soil texture and chemistry.

Item 3: Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region).

Purpose

Item 3 identifies if the stream channel is at or near the shape and size expected for its landscape setting and potential. Sinuosity, width/depth ratio, and gradient must be in balance for this item to be answered "yes"; if one is not in balance, this item is answered "no". Sinuosity, width/depth ratio, and gradient play important roles in how well a stream conveys water and sediment and dissipates energy. Channel classification tools like Montgomery and Buffington (1997) or Rosgen (1994 and 1996) describe a range of characteristics for landscape settings.

These three attributes play a more important role in lower gradient alluvial streams (C, E, F, and some B stream types). Steeper gradient streams (A stream types) or streams of more moderate gradient which are confined laterally by their valley walls (some B stream types) tend to have channels largely composed of erosion resistant colluvial material or bedrock. In these streams, channel form is maintained by energy dissipation over and around woody material, bedrock, or large rocks (Montgomery and Buffington 1997) often arrayed in predictable step-pool sequences (Chin 1999 and 2002).

Sinuosity describes level of the stream meandering observed through a valley. Sinuosity is the valley length divided by stream length (Figure 15).

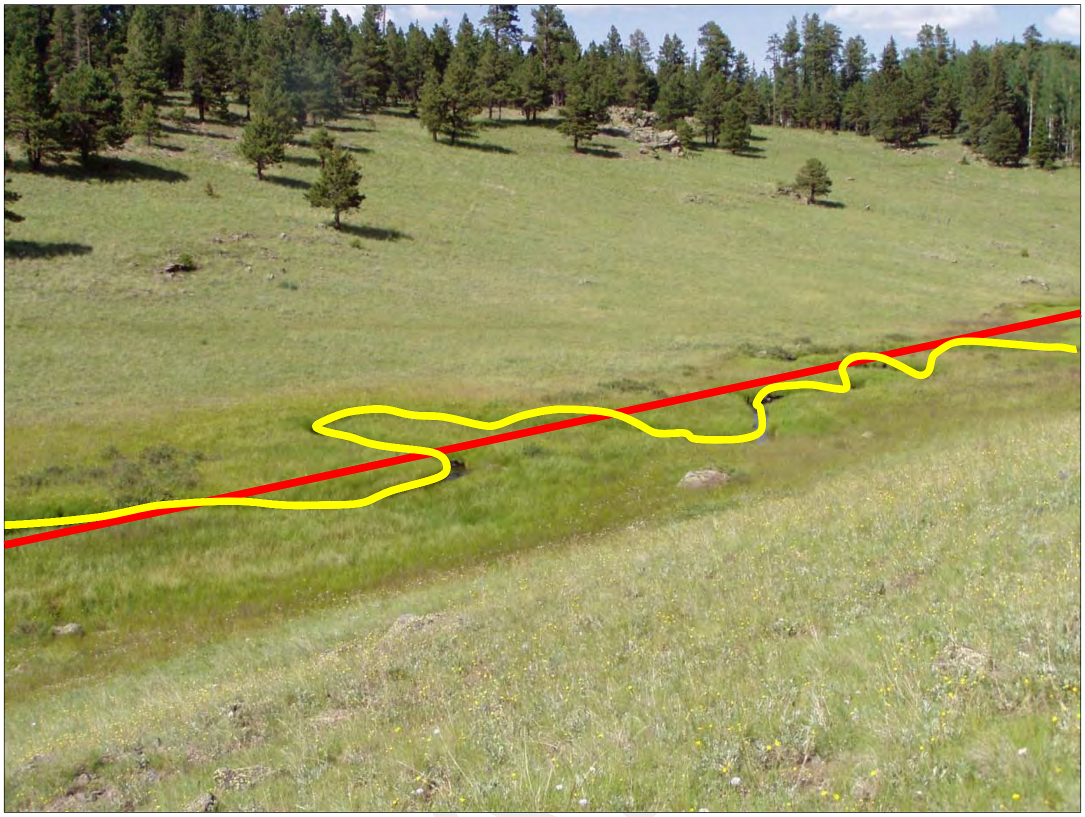

Figure 15. Stream length (yellow line) and valley length (red line) used to calculate stream sinuosity.

Stream gradient, or water surface slope, is the steepness of the flow measured by dividing the water surface elevation differences between the upstream end and the downstream end of the reach by the length of the reach, or “rise over run” of the stream length.

The width/depth ratio is the bankfull width divided by the mean bankfull depth. This value can be directly measured in the field or careful estimated (Figure 19).

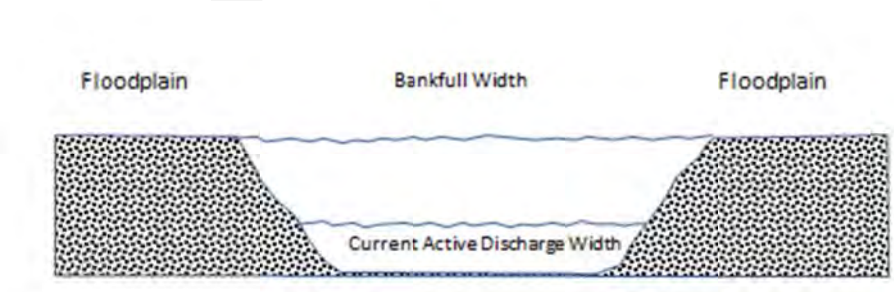

Figure 16. Stream channel cross-section showing bankfull width and current active discharge width.

Observational Indicators and Examples

Sinuosity is identified as that which would occur during a bankfull discharge flow event. It can be evaluated from recent aerial photographs or in the field from a vantage point that allows the ID team to observe the entire reach. Be careful not to overestimate sinuosity if the active channel or thalweg are more sinuous than the bankfull channel.

Unless the stream is located within woody vegetation and not visible, sinuosity can easily be estimated or measured from a recent topographic maps, aerial photograph, or, calculated in GIS from many of the numerous programs on the internet (Google Earth, Acme Mapper, National Hydrography Database, etc.). Precise measurements on very small streams may be difficult unless large scale imagery is available. This should be done as part of the pre-assessment tasks and then validated from visual observations in the field.

Another aspect of sinuosity to be aware of is when the stream channel is located in a narrow canyon or valley that in itself exhibits sinuosity. The stream and valley lengths could be very similar, with a sinuosity close to 1.0. Stream systems in deep narrow canyon can present this situation (Figure 17). If the valley sinuosity is at its potential and not resulting from a human influence, the stream sinuosity is in balance.   Sinuosity's role in energy dissipation is being met by the resistance of flood flows against the canyon walls and channel bottom roughness.

Figure 17. The Colorado River in Dead Horse Point State Park, Utah, has a sinuosity close to 1.0

If a frequently inundated floodplain is identified in Item 1, the ID team uses that location to determine the bankfull channel width/depth ratio:

- If the channel is very wide and shallow; the width/depth ratio is high. Higher width/depth ratios can be found in streams that have sand or gravel or both as the primary stream bed and bank substrate.
- If the channel is narrower and deeper; the width/depth ratio low. Lower width depth ratios would be expected in streams where the bed and banks are primarily clay and some silts.

The ID team should document the observed bankfull width/depth ratio throughout the reach. The observed channel width and depth will vary depending upon streamflow. The bankfull width/depth ratio remains the same regardless of current water level because it is measured or estimated from the expected bankfull channel dimensions (Figure 19).

The bankfull width/depth ratio can be measured or estimated in the field when bankfull indicators are properly identified.   Bankfull width/depth ratios should be estimated or measured:

- In a riffle rather than a pool in C, E, and F stream types (Lowham 1976, Rosgen 1996).
- In the middle of a rapid in a B stream type.
- At the narrowest point between the base of a step and the upstream end of the downstream pool in stream types that exhibit step-pool features (A and G) (Rosgen 1996, figure 5.5).

Stream gradient can be determined to be in balance with the landscape setting by observing the stream sinuosity. If the sinuosity is too low, the gradient will likely be too high. Visual indicators of this imbalance can be:

- Active downcutting or headcut formation from increased flow energy from the steeper gradient.
- Larger than expected or previous observed channel substrate resulting from increased energies moving the smaller material.
- Observed a difference in the bank height above the current water surface from one end of the assessed reach to another where it would be expected to be consistent; or
- The stream channel losing access to its floodplain (relates to Item 1).

If the ID team observes excessive widening and/or mid-channel sediment deposition the gradient may be too low (see Item 17). The previously stable single-thread channel may be widening and changing to an unstable braided channel (D stream type).

If the riparian area is located within a wide, low gradient alluvial valley (potential C or E stream types) and it exhibits moderate to high sinuosity, expected width/depth ratios and stream gradient (potential C or E stream types) the answer to Item 3 would be “yes”.

Item 3 would also be answered “yes” in streams located in laterally-confined valleys where large rock, bedrock, step-pool sequences, or boulder exert a dominant influence on channel form and energy dissipation.

If the riparian area is located in a wide, low gradient alluvial valley and it exhibits low sinuosity, high width/depth ratio, and higher than expected gradient; Item 3 would be answered “no”. These streams may also exhibit a lower sinuosity, higher gradient and a lower width/depth ratio than expected, as a result of active downcutting. Item 3 would also be answered “no” under this setting.

Item 3 will never be answered “NA”; it will always have a “yes” or “no” answer. ***All three elements have to be in balance with the landscape setting and potential for this item to be answered “yes.”***

Supporting Science

Stream stability is defined as the stream’s ability in the present climate to transport the streamflow and sediment of its drainage area over time in such a manner that the channel maintains its dimension, pattern and profile without aggrading or degrading. If the width/depth ratio, gradient, and sinuosity are not in balance with the landscape setting, the assessed stream is not likely to be stable and functioning properly.

The bankfull channel’s width and depth dimensions have important roles in moving water and sediment. Shear stress describes a stream’s ability to move sediment and bed material. The shear stress equation, measured as pounds per square foot, is as follows:

$\tau = gRs$ (lbs./sq.ft.),

Where:

τ is the shear stress.
g is the specific gravity or density of water (62.4 lbs./sq.ft).
R is the hydraulic radius.
s is the slope of the channel.

The hydraulic radius (channel cross sectional area divided by the wetted perimeter) can sometimes be approximated using the mean depth in natural channels with high width/depth ratios. This would be less accurate in stream channels that have low width/depth ratios (less than 12) such as A, E, and G-stream types. Therefore, when using the above equation, the greater the hydraulic radius (or mean depth where applicable), the greater the shear stress and the ability for a stream to move sediment. When both hydraulic radius and slope decrease, stream shear stress decreases. Often, impaired streams with high width/depth ratios will also have high bedload deposition in the channel (item 17). This is one observation the ID team can note to determine whether or not the width/depth ratio of a low gradient stream is in balance or too high. Is the stream channel able to carry its sediment load?

When a stream begins to incise as a result of excessive energy, the shear stress becomes too high; the hydraulic radius is increasing and in many cases the slope or gradient of the channel is also increasing (item16). Also be aware of width/depth ratio and sinuosity values that are too low for the landscape setting. Lower than expected width/depth ratios may also be a sign of instability. A degrading stream that is downcutting or incising will have a decreased width/depth ratio.

By contrast, in steep, high-energy streams and in streams of moderate gradient confined by non-alluvial valley walls, channel form represents a balance between hydraulic erosive force and the resistance to erosion of the colluvial material and/or bedrock forming the channel boundaries (Church 2006; Wilcock 2004). These streams are constrained laterally from developing sinuous channels, and have beds and banks dominated by large colluvium from adjacent hillsides, bedrock, and in some cases woody material. This large substrate is immobile during all but infrequent, large-magnitude flood events (Montgomery and Buffington 1997). The relatively frequent events that are important in channel formation and maintenance in lower gradient alluvial streams cannot move the larger colluvial material found in steep or confined streams. The role of energy dissipation from increased sinuosity and decreased gradient in alluvial streams is accomplished by the channel roughness provided by the large substrate and resistant valley walls.

Step pool sequences, also found in these colluvial channels, dissipate energy by having a sinuous water path in the vertical dimension as water passes over steps (Montgomery and Buffington 1997). This is analogous to the energy dissipation achieved by alternately turning the water flow left and right in a horizontally sinuous channel (Chin 2002).

Correlation with other assessment items

If Item 3 is answered "yes" because the expected width/depth ratio is found through the assessed reach; the stream system is not incising (item 16). However, if the channel has recently or is actively incising and has abandoned the floodplain; both items 1 (floodplain frequently inundated) and 16 would be answered "no". Also, if Item 3 is answered "no" and there is evidence of excessive sediment in the channel, item 17 (stream in balance with water and sediment supplied) would also be answered "no".

Item 4: Riparian area is expanding or has achieved potential extent.

Purpose

Impaired riparian areas recover and expand by capturing sediment, which aids floodplain development and improves flood-water retention. This recovery is generally first expressed by an increase in riparian vegetation. Item 4 documents whether a riparian area is recovering or has recovered. At some point in time, all riparian areas achieve potential extent.

Item 4 has two parts. Part one asks if a riparian area is expanding, and part two asks if a riparian area has achieved potential extent. The reason for this separation is so a “yes” answer is always applied for a positive attribute or process.

Observational Indicators and Examples

There are two mechanisms by which riparian expansion can occur during recovery:

As the water table rises, the riparian area can expand outward toward the valley walls by establishing in or expanding into bare areas or areas occupied by non-riparian plants parallel to the channel (Figure 18). Or, streambanks are rebuilt by vegetation growth and sediment deposition, which narrows the stream channel width and expands the riparian area inward (Figure 19).

Or, streambanks are rebuilt by vegetation growth and sediment deposition, which narrows the stream channel width and expands the riparian area inward (Figure 19).

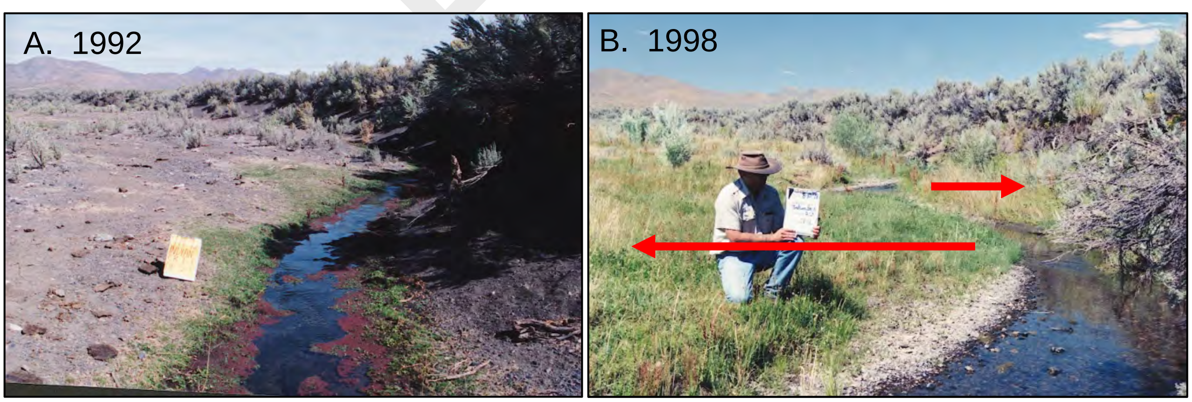

Figure 18. Example of riparian area expansion 1992, 1998.

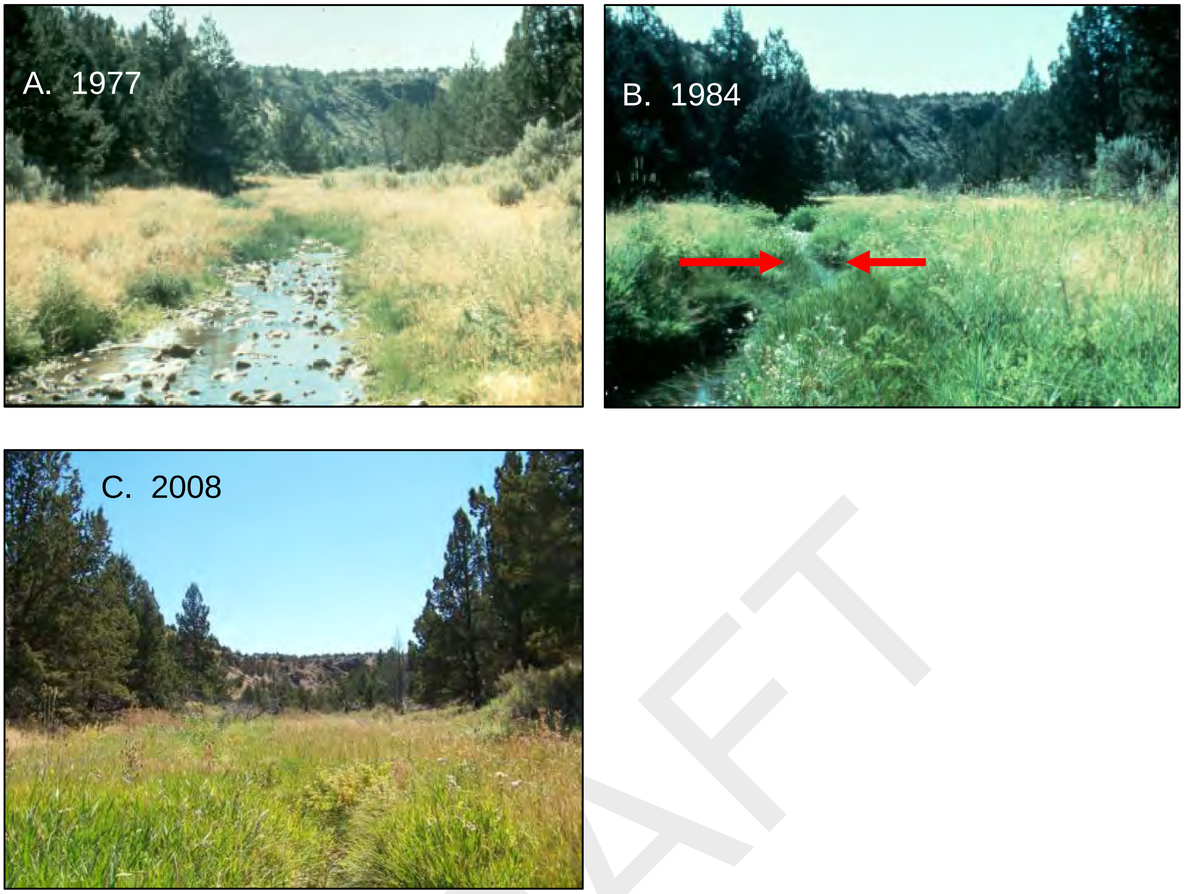

Figure 19. Channel narrowing due to riparian area expansion, 1977, 1984, 2008. By 2008 the riparian area had achieved potential extent.

Surfaces for riparian area expansion can be created by flood-induced erosion/deposition processes, channel avulsions, or channel evolution of an incised channel (Figure 4). An ID team may assess a riparian area early in its recovery with little riparian vegetation and determine that the revegetation process is working. An ID team may also assess a riparian area that is very healthy, has not experienced a large flood for some time, and is at potential extent. Both would merit a "yes" answer. Documentation of the rationale should include which visual indicators or data demonstrate expanding, contracting, or potential extent.

Visual evidence that a riparian area is expanding may include:

- An increase in cover of riparian species (e.g., obligate wetland and facultative wetland species).
- Establishment of riparian vegetation in soils deposited along a streambank.
- Increasing amounts of stabilizing riparian vegetation replacing upland species on sites where there is the possibility for expansion. The riparian vegetation would be vigorous and regenerating while the upland species would be dying or showing declining vigor.

Be aware that some riparian trees and shrubs will have widespread germination of seeds, but few of the seedlings survive. To document riparian expansion, look for establishment of the woody species as sprouts and young.

Evidence that a riparian area is contracting includes:

- Redoximorphic features in the soil, but riparian species have been replaced by more drought-tolerant and/or upland species.
- Bare ground on geomorphic surfaces that should be revegetating with riparian vegetation.

Evidence that a riparian area is at potential extent:

- Riparian vegetation is covering all surfaces that have the potential to grow riparian vegetation.

If available, existing monitoring data such as vegetation transects, greenline-to-greenline widths (a measurement of the nonvegetated distance between the greenlines on each side of the stream), channel cross-section surveys, or repeat photography are brought into the assessment and interpreted as to whether or not riparian area expansion has occurred.

In some stream channels, riparian vegetation is not a factor in holding streambanks in place and contributing to the adjustment of channel dimensions, shape, and gradient; channel form is predominantly controlled by the size and strength of the bed material (e.g., bedrock or boulders). In these cases, this item would be answered “NA.”

Supporting Science

Riparian areas expand as a result of aggradation, along with other natural stream adjustments such as lateral migration, channel narrowing, and floodplain development. Potential riparian extent is largely determined by the valley bottom topography, soil variables, and water availability (height of surfaces above the wetted channel and depth to ground water) (Dwire et al. 2006, Law et al. 2000, Stromberg et al. 1996). Where there is a well-defined change in elevation, such as a terrace, the community type changes can be distinct (Naiman et al. 2005).

Riparian recovery is usually first expressed by establishment of riparian vegetation. The vegetation slows water velocity of overbank flows and runoff from adjacent landforms, resulting in sediment deposition, creation of sites for water storage (Elmore et al. 1994), and increased streambank and channel stability (Hayashi and Rosenberry 2002, Tabacchi et al. 2000), which in turn keeps the channel connected to the floodplain. Riparian vegetation increases infiltration

(Weixelman et al. 1996 and 1999, Bharati et al. 2002) and soil-moisture retention capacity by adding organic matter and creating macropores via root channels. Effective infiltration then leads to saturated ground water flow, raises the water table near the streambank (Ponce 1989), and slows the release of subsurface waters to surface waters (Barber 1988). Over time, all these processes lead to further expansion of riparian vegetation until potential extent is achieved.

Some riparian species such as hardstem bulrush, aquatic sedge, and creeping spike rush expand by rhizomes rooting into the streambed and thrive in standing water. They capture sediments to rebuild streambanks and narrow a channel.

Repeat photography, qualitative surveys, and quantitative surveys have been used to document riparian area expansion or riparian area contraction (Borman et al. 1999, Groeneveld and Griepentrog 1985, Kozlowski et al. 2010, Newman and Swanson 2008, Sipple and Swanson 1996, Smith et al. 1991, Stromberg et al. 1996, Webb and Leake 2006).

Correlation with other assessment items:

The answer to item 4 is related to item 3 (sinuosity, width/depth ratio and gradient in balance) because for low-gradient alluvial streams, expansion of the riparian area may coincide with channel narrowing as documented by a decrease in the width/depth ratio. If the riparian area expands, recent colonization or revegetation of bare areas will have younger age-classes growing on them (item 7—recruitment of stabilizing vegetation). Riparian expansion also indicates maintenance of soil moisture characteristics (item 8).

Item 4 also relates to item 13 (floodplain and channel adequate to dissipate energy) because often it is the dissipation of energy that allows for riparian area expansion and item 14 (point bars revegetating) because for stream types with point bars, the tops of point bars are a critical location for the establishment and expansion of stabilizing vegetation for maintenance of channel characteristics.

Item 5: The watershed is not contributing to riparian impairment.

Purpose

Item 5 addresses whether there has been a change in the water or sediment being supplied to a riparian area from its watershed, and whether that change is resulting in impairment. The watershed of a stream reach includes its entire contributing upstream basin (upland areas adjacent to the riparian area, as well as upstream reaches and their uplands). This item pertains to whether the watershed is contributing to the impairment of a riparian area; it does not pertain to the condition of the watershed. It provides the opportunity to differentiate, if possible, between any impacts from the watershed versus direct impacts to the riparian area being assessed.

Note that this item is worded differently ("is not contributing") than the other items on the assessment and therefore should be answered carefully. The reason for this wording is to make this item consistent with the others so that a "yes" answer provides a positive indicator of functionality.

Observational Indicators and Examples

Use a step-wise evaluation process:

Is there evidence of riparian impairment? If not, then item 5 is a "Yes." It is possible to have disturbances in the uplands without causing major changes in discharge, timing, or duration of streamflows or impairment to a riparian area.

1. If there is evidence of impairment, then determine the source.
2. Local (in situ) source, item 5 may still be "Yes".
3. Upstream/upland source, then item 5 is "No".
4. Identify potential upland contributors.
5. Identify cause-effect relations between upland conditions and channel/riparian area impairment.

The visual indicators for item 5 are not subtle. If the watershed is contributing to riparian impairment, the channel form is altered by excessive deposition or channel incision. There can be natural events in the watershed such as wildfire and subsequent sediment delivery to channels that cause changes to channel form that would merit a "no" answer with an explanation of the severity of that "no".

If the greenline is dominated by healthy riparian vegetation, yet there is braiding of what should be a single-thread channel, overloading of point bars, or fan deposits from excessive upland erosion that alters sinuosity, this could be evidence that the excessive sediment is from the uplands or upstream reaches, and not associated with direct impact to the assessment reach's streambanks. If these characteristics are present, the answer to item 5 could be "no." Figure 20 shows an example of where an ID team determined this item should be answered "no." The reach had many mid-channel bars and overloaded point bars (note the steepness of the point bar slope) due to receiving excessive sediment. The mid-channel bar fomations are indicators of deterioration for this stream type. In this example, the ID team determined excessive erosion is occurring from both the streambanks of the reach being assessed <u>and</u> from mine tailings that are being delivered to an upstream reach, leading to an answer of "no" for item 5, since an impact in the watershed is contributing to riparian impairment. Either during step 2 (review existing information) or after the field portion of the assessment, sediment sources in the watershed can be investigated through analysis of aerial photography.

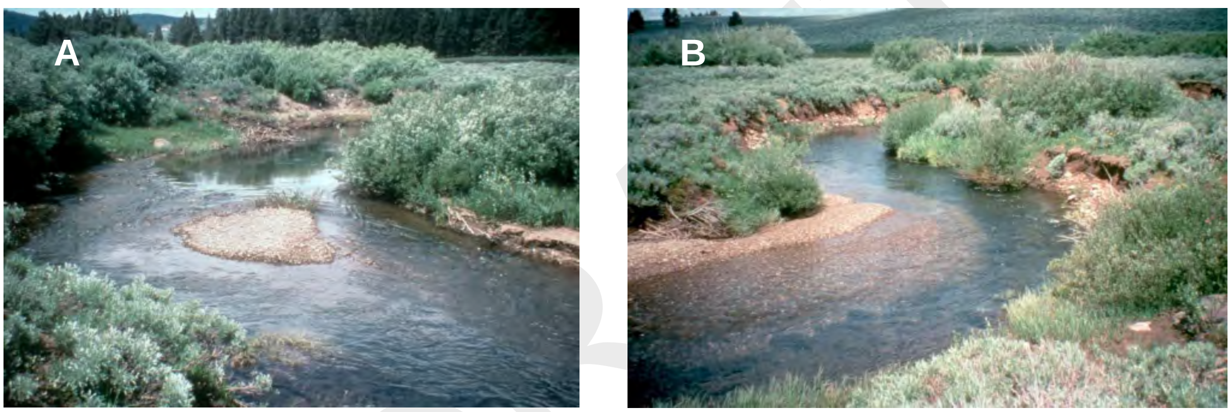

Figure 20. Example of (A) a mid-channel bar and (B) an overloaded point bar.

Item 5 will never be answered "NA"; it will always have a "yes" or "no" answer.

Supporting Science

The ID team determines if impairment is present, and whether it is related to some *in situ* channel/riparian disturbance or to some impairment elsewhere in the watershed that is being transmitted to the assessment reach. Stream channels are the primary conduit of water, sediment, and other materials derived from the watershed, as well as possible sediment sources from eroding streambanks. A channel system is said to be at dynamic equilibrium when, through a period of years, the shear stress is sufficient to transport the sediment delivered to the channel, and neither excessive deposition nor excessive erosion takes place. This leads to a dynamic form of stability in the cross section and longitudinal profile. Dynamic equilibrium does not imply absolute equilibrium conditions, but rather the stream and riparian area are resilient and able to recover from many natural disturbances. Dynamic equilibrium also implies naturally formed channels may experience little net change in channel form at reach and larger scales, despite numerous local changes. Changes in shear stress, sediment supply, and resistance of bed and bank materials to cutting can upset the equilibrium of the channel system and cause excessive erosion or deposition in the channel, which can lead to impairment of the associated riparian area. Hence, the condition of the watershed can greatly affect the condition of a stream reach and its associated riparian area (Naiman 1992, Satterlund and Adams 1992). See the explanation of the Lane/Borland balance (Section C. Geomorphology, page 91), which is a conceptual model that portrays processes of aggradation and channel incision in terms of changes in sediment supply, sediment size, discharge, and gradient.

Interpreting the dynamic equilibrium concept requires an understanding of watershed history, including both natural events and land use practices, and the adjustment processes active in channel evolution. Channel adjustments seen today may be in response to something that happened in the watershed 50-200 years ago, and is still being transmitted up and/or down the stream system.

Correlation with other assessment items:

Item 5 is related to item 3 (sinuosity, width/depth ratio, and gradient in balance), because impairment from the watershed involves excessive erosion or deposition which affects channel form. It is also related the sediment supply and transport ability of a reach looked at in item 17 (stream in balance with water and sediment supplied). Item 5 provides the opportunity to differentiate, if possible, between *in situ* channel/riparian disturbance or to some impairment elsewhere in the watershed that is being transmitted to the assessment reach.

B. Vegetation

Items 6-12 address vegetation attributes and processes that need to be in working order for a riparian area to function properly. Although most streams that are affected by management activities require vegetation to function, some landform controlled reaches (e.g. steep, boulder dominated streams) may not require vegetation to function; thus many of the vegetation items would be answered “NA”.

Factors such as the kind, proportion, and amount (cover or density) of vegetation in the riparian community contribute to stream and riparian function. The linear distribution of stabilizing vegetation along the stream margins is the primary factor affecting the erosion of streambanks and stream bars. The lateral distribution of vegetation across the riparian area determines the site’s ability to accommodate periods of floods (overbank flows) and drought.

A progression exists in plant density and plant community development, from the complete absence of stabilizing vegetation species to the development of “stabilizing” plant communities throughout a riparian area approximating ecological potential. Thus, all of the vegetation items are closely correlated to one another because they represent different stages in this progression.

- Items 6-8 are asking about the kind of plants in the riparian area and if there is recruitment of young plants and maintenance of others. These 3 items seek to determine if the right plants are present by asking “are they there?” and “are they reproducing?” These items do not address the amount or “how much,” just whether they are there because the presence of key riparian plants is the first step in the recovery process.

- Item 9 is asking if the riparian plants identified in items 6-8 have progressed to the point that stabilizing species are forming recognizable and distinct communities ***on the streambank*** **(note that item 9 is specific to the streambank whereas items 6-8 address the entire riparian area).** This is the next logical developmental phase after vegetation establishment and is key to determining if recovery is imminent or not. Item 9 also does not address if the amount is adequate, just the presence of stabilizing plant communities.

- Item 10 is asking if the plants present (addressed by the previous items) are vigorous because healthy plants with good vigor are attributes for plant community establishment, expansion, and persistence necessary for recovery and maintenance of a riparian area.

- Item 11 is a key synthesis item for the vegetation items in that it seeks to determine if there is an adequate *amount* of vegetation as expressed by the distribution of stabilizing riparian plant communities present ***on the streambank*** to protect banks and dissipate energy during high flows. Note that the "amount" item is last in this sequence of recovery – vegetation has to first become established, reproduce, and form communities before there is enough cover to protect streambanks.

- Finally, item 12 is asking if there is an adequate source of live trees for large or coarse wood availability to the stream (for streams that depend on woody material for function).

Completing the riparian plant list form in Appendix A is an important preparatory step. It is particularly important to record dominant vegetation, colonizing and stabilizing species, and diagnostic species for ecological site descriptions or other classifications that help indicate or refine potential. It is also important to record the wetland indicator status (Lichvar and Kartesz 2009) and the greenline stability rating or rooting strength for each plant. While important, simply recording plants and their attributes is not sufficient to accurately address the vegetation items on the PFC assessment form. The plant specialist(s) on the ID team must *understand* the growth, distribution, and reproductive habits of those plants; and how each functional vegetation group influences stream function.

As riparian areas are a transition between areas with surface and ground water influence and upland areas, riparian vegetation varies from obligate wetland vegetation to facultative vegetation (Lichvar and Kartesz 2009). Facultative upland and upland vegetation may naturally occur with obligate and facultative wetland species in some situations including the outer margin of almost all riparian wetland areas, intermittent streams, "problem wetlands" (Prichard et al. 2003), and "flashy " systems (systems that exhibit sudden, sometime extreme flows associated with localized convective storms) where obligate and facultative wetland species often establish on regeneration sites at the channel edge or even within active channels. Some forest species such as Douglas fir in the Pacific Northwest and many hardwoods of more mesic climate regimes may occur on both upland and riparian environments but often have a higher growth rate in riparian environments and may also have different associated species.

Riparian vegetation may also include invasive species or noxious weeds. Because PFC focuses on the physical function of the stream, the presence of invasive or noxious weeds does not necessarily preclude the achievement of PFC – some invasive species possess good bank stabilizing properties but obviously are not desirable for providing native plant resource values. Invasive species and noxious weeds should however be noted in the appropriate detail on the assessment form.

Vegetation items are designed to be both diagnostic of the functional rating and useful for interpreting recovery potential. For example, if item 9 is answered "yes" (plant communities/community types that have root masses capable of withstanding high streamflow events present along the streambank) and item 11 is answered no (adequate stabilizing riparian vegetative cover is present to protect banks), it is clear that management is allowing the right plants to form communities, but that there is just not enough cover yet to protect banks – this is particularly positive if the trend is up. In this example, improvement is likely imminent by either continuing current management or by making some modifications; it can also be a "red flag" if the trend is down. This is in contrast to a stream reach where items 9 and 11 are both answered no. In this case, recovery is not imminent, the problem is likely severe, and a different management approach may be necessary. Although both of these streams would likely result in a functional-at-risk rating, the management approach may be very different for each reach.

Colonizers and Stabilizers

To better understand and communicate the role of vegetation in stream function, the functional groups "colonizers" and "stabilizers," modified from Winward (2000) are useful for completing the PFC assessment.

Colonizers – Plant species that become established in open, barren areas are among the first plants to occupy open sites. In riparian areas they colonize edges of bars or areas where streambanks have freshly eroded. They are rhizomatous/stoloniferous in growth form, but the roots are shallow and the stems are relatively weak. They are short lived, but have a capacity to grow very rapidly. Examples include brookgrass and watercress. Some colonizers have more established root systems and can persist for long periods of time; these plants are considered "intermediate colonizers." Examples include common spikerush and coyote willow.

Stabilizers – Plant species that become established along edges of streams, rivers, ponds, and lakes. Although they generally require hydric settings for establishment, some may persist in drier conditions once they have become firmly established. They commonly have strong, cord-like rhizomes as well as deep fibrous root masses. They are able to buffer streambanks against the erosive forces of moving water. Examples include Nebraska sedge and Geyer's willow.

Item 6: There is stabilizing riparian vegetation for recovery/maintenance.

Purpose

Most lotic riparian areas require the presence of plant communities that contain stabilizing riparian vegetation to recover or maintain themselves. This item is not asking whether all the stabilizing plants that an area can support are present. Item 6 documents whether a sufficient number of species is present. For most riparian areas, this means having two or more stabilizing riparian species present as defined by Winward (2000) or Burton et al. (2011) depending on reach potential.

The presence of only one stabilizing species often makes a site vulnerable to disease or extreme changes in climate, which may result in impairment of an area. Many riparian plant communities are dominated by a single stabilizing species but at the reach scale a complex of plant communities is most often expected. There are some areas with only one major community type dominated by a single stabilizing species even at potential; however, these are generally not common (at the reach scale) and are usually limited as a result of a unique soil property, vegetative characteristic, or water regime.

Observational Indicators and Examples

Riparian areas that are slightly entrenched, meandering, and sand dominated with well-developed floodplains (C5 stream type) require the appropriate vegetation to be present if they are to function properly. If a reach with a C5 stream type is found to have peach leaf willow and coyote willow, the answer to item 6 would be "yes," as this is sufficient composition to recover or maintain this reach. If this same reach contained only coyote willow, the answer to item 6 would be "no."

Many streams can function properly with herbaceous vegetation and do not require woody riparian vegetation. Many (although not all) streams with less than 0.5% gradient, where the floodplain is saturated to the surface through most of the growing season, tend to be dominated by herbaceous vegetation at potential.

In other cases woody vegetation may be the desired condition but is not necessary for the reach to function properly. Streams greater than 0.5% gradient with cohesive substrates or bank materials may have the potential to produce both herbaceous and woody stabilizing vegetation but may only require herbaceous stabilizers to function properly. For example, if a reach contained Nebraska sedge and beaked sedge, the answer to item 6 would be “yes.” If the same reach contained only Nebraska sedge, the answer to item 6 would be “no.”

Some reaches may require both herbaceous and woody riparian vegetation to dissipate energy. These are often unconsolidated, coarse substrate or bank material reaches subject to high energy flow events. Item 6 can be answered both “yes” and “no” ” if both herbaceous and woody vegetation are required but one is present and the other is not (e.g. Nebraska sedge and Baltic rush are present but low elevation willows needed for function are absent).

Caution must be used when assessing reaches that lack a diversity of stabilizing species near the water’s edge. This is because it is not uncommon for only one stabilizing species to occur on streamside surfaces where the water table is shallow and stable, and why it is important to understand the growth habits of the riparian plants on the reach. In general, zones where stable water tables occur near the surface result in limited species diversity. Mesic zones (moderately moist areas) that are further away from the stream, where the water table is somewhat deeper, tend to produce greater species diversity.

“NA” would apply for those stream types that do not require vegetation to function properly.

Supporting Science

Riparian sites are usually extremely heterogeneous as evidenced by the many riparian classification documents in existence today. In general, ecosystem stability is characterized by an increase in species diversity, structural complexity, and organic matter (Kormondy 1969). Fluvial landform dynamics associated with natural systems appear to be inextricable from associated riparian plant species characteristics (Corenblit et al. 2009). Different land forms at the reach scale generally exhibit differences in available water for associated plant needs (Cooper and Merritt 2012).   It appears unlikely that monocultures can maintain fluvial landforms associated with natural stream dynamics in most cases. Monocultures are also susceptible to disease, herbivory, insect infestations, and extreme temperature fluctuations. Riparian communities must be able to adapt to extremes in water availability and stresses associated with reduction/oxidation occurring in the rooting zone. In the northwestern U.S., 20 to 30 years out of the last 100 have had at least moderate drought (Leonard and Karl 1995). Distribution about the mean precipitation is approximately normal, with a nearly equal number of “wet” years. However, the period between successive drought (or wet) years is completely unpredictable and variable. Streamflow and attendant water tables may vary considerably over time in conjunction with precipitation and runoff. Therefore, stabilizing plant diversity (as opposed to traditional indices of diversity) of vegetation within the riparian area must be enough to accommodate substantial shifts in the water table or zone of saturation or be able to sustain itself under varying conditions.

Although thresholds for diversity of stabilizing plants are not established, it seems unreasonable in most cases that stability would be expected without at least two stabilizing species present in a streamside community complex and gradient of riparian plants away from the water's edge.

Correlation with other assessment items

This item specifically addresses the presence of stabilizing species while item 9 (stabilizing root masses present) and 11 (adequate stabilizing vegetation) determine if recognizable and distinct stabilizing plant communities have started to develop and if there is an adequate amount of stabilizing riparian vegetation. Although the focus of item 6 (stabilizing vegetation for recovery/maintenance) is on the stabilizing species needed to achieve a "yes" answer, the presence of colonizing species, the wetland indicator status of other species, and presence of invasive species or noxious weeds can also help interpret potential maintenance or recovery of the reach.

Item 7: There is recruitment of stabilizing riparian vegetation for recovery/maintenance.

Purpose

For a riparian area to recover or maintain itself, it has to have vegetative recruitment that results in an increase of stabilizing species necessary for recovery or replacement. This item is not asking whether all possible age classes are present; it is asking whether the age classes that provide recruitment to maintain an area or to allow an area to recover are present.

Most woody riparian plant communities will recover or maintain themselves with two age classes, as long as one of the age classes is young (recruitment) and the other is middle-aged (replacement). Note that presence of current year seedlings (germination) does not necessarily indicate recruitment (establishment of young plants) as there are many streams where germination is common and widespread but the plants have difficulty advancing into older age classes due to site specific stream dynamics. Older age classes (mature) usually persist, as they are well-attached to existing water tables. Older age classes can persist even with degraded conditions. Recruitment of herbaceous stabilizers is indicated by maintenance of dense sod where it exists, presence of young shoots around established plants in sparse communities and/or apparent expansion of shoots into colonizing riparian vegetation.

Observational Indicators and Examples

For riparian areas that require woody vegetation to achieve functionality, a “yes” answer would be given if there are established sapling trees or young shrubs present on the reach being assessed. A “no” answer would be given if either recruitment or replacement age classes are absent.

Many herbaceous stabilizers expand or colonize a site by stem and root extension (e.g., Nebraska sedge). If there is a dense matting of these plants, the answer to item 7 would be “yes.” If there are individual plants of Nebraska sedge scattered along the reach being assessed, the answer to item 7 would be “no.”

Many riparian areas have potential for both woody and herbaceous vegetation. If a combination of woody and herbaceous plants, either young and/or middle aged, is present, the answer to item 7 would be “yes.”

Item 7 can also be answered both “yes” and “no” if one class of vegetation (i.e. herbaceous stabilizers) appears to be reproducing well but the other (i.e. woody vegetation) appears to have limited or no recruitment. The rationale for both answers should be documented in the comments.

Because different vegetation functional groups and species are adapted to specific elevation surfaces across the riparian area (top of bank, floodplain, lower terrace, etc.), the recruitment of new plants of a particular group or species is tied to the moisture gradient and disturbance zones. This is important to understand so that appropriate expectations are set for *where t*o look for recruitment within the riparian area.

Some judgment should be used in plant communities that establish as even-aged stands as a result of episodic events as this is common. Many woody species will establish in dense even-aged stands where past disturbance has depleted or eliminated their presence and a change in management and climatic circumstances coincide for reestablishment. These stands may persist at an even age until disturbances open parts of the stand for additional recruitment. Episodic recruitment scenarios (such as post-flood or -fire) or communities at potential natural condition may not have a diversity of age classes. Reaches that are in an advanced ecological status have limited opportunity for recruitment but small patches of disturbance usually exist. These kinds of reaches would be given a “yes” response.

An “NA” answer would apply for channels that are entrenched and confined in bedrock (e.g., A1 stream type).

Supporting Science

Cooper and Merritt (2012) summarize methods to determine water needs of riparian vegetation including plant recruitment, growth and maintenance that can affect age class distribution. Recruitment is further affected by physiological and mechanical stresses such as defoliation, mechanical damage, and fire. The interrelationships of age structure can be quite complex, but general characterizations can be made of expanding, stable, and diminishing populations (Kormondy 1969). Expanding populations generally have a pyramid shape of age distribution, with many young forming a wide base, fewer middle-aged, and very few old at the top (Figure 21). Stable populations are more “bullet” shaped, with rather equal young and middle-aged groups forming the base and middle, and then gradually diminishing to the oldest ages. Diminishing populations are more “urn” shaped distributions with a narrow base of young, widening toward the older age classes, then sharply narrowing with the oldest individuals. Of particular concern are indicators of diminishing populations of bank-forming species/communities. These indicators are generally low proportions or missing classes of young and/or middle-aged individuals where apparently suitable niches for recruitment are vacant.

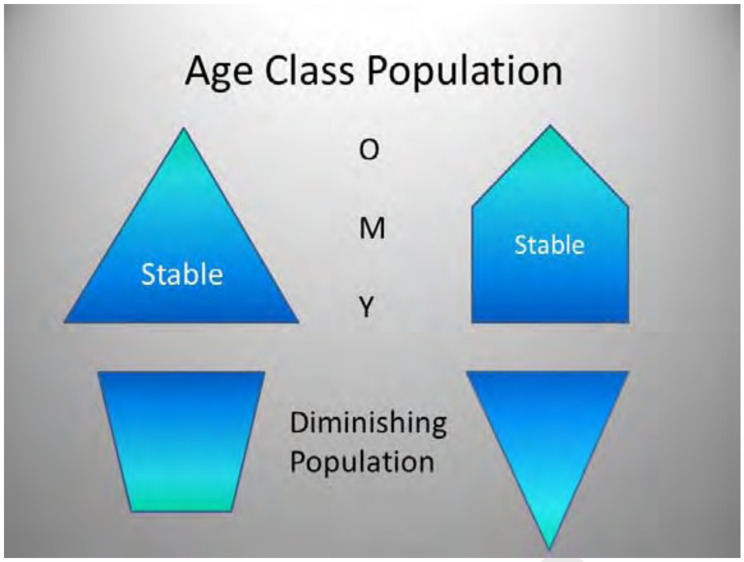

Figure 21. Age class population distribution forms.

For herbaceous species, the term age-class distribution is somewhat misleading, but the intent of identifying indicators of expanding, stable, or diminishing populations through recruitment/reproduction is the same. Dahl and Hyder (1977) discuss developmental morphology attributes that have implications pertinent to plant recruitment and maintenance. Indicators include ratio of vegetative to reproductive culms (for plants reproducing by seed), amount and degree of lateral shoot development and/or tillering, and types of vegetative shoots.

Correlation with other assessment items

Item 7 is relevant to item 12 if woody material is required for streambank stability. Diverse age class of a wood source is required for sustainability.

Item 8: Species present indicate maintenance of riparian soil-moisture characteristics.

Purpose

Item 8 looks for evidence that level of the water table is being maintained or is moving towards its potential extent as indicated by the presence of riparian vegetation. Maintenance or recovery of an existing water table is vital to the maintenance or recovery of a riparian area.

Riparian areas by definition are a transition between the aquatic and upland components of a watershed so care should be taken to evaluate the wet and dry vegetation components relative to appropriate positions on the landscape. An abandoned floodplain that is now a terrace cannot be expected to maintain the same wetland indicators it possessed as a floodplain.

Observational Indicators and Examples

A "yes" answer would be given for item 8 when OBL or FACW plants are present on appropriate streambank and floodplain positions of a perennial reach as determined by expected wetland soil characteristics including depth and duration of saturation. Knowledge of individual species' soil-moisture requirements and tolerance is also required. A "no" answer would be given if FACU or UPL plants occupy positions expected to be occupied by hydrophytes indicating a potential change in flow related variables.

Some intermittent and some common perennial systems, depending on flow related characteristics, could be somewhat different, as their potential may be primarily FAC plants If this is the case and they are dominated by FAC plants, the answer to item 8 would be "yes." An intermittent riparian area or perennial riparian area with FAC potential vegetation dominated by FACU and/or UPL plants would be given a "no" answer.

Note that mature OBL and FACW plants by themselves may not always indicate that soil-moisture characteristics are being maintained. Mature plants that established contact with the water table long ago are often able to maintain contact with a declining water table due to deep roots. However, in the "flashy" systems of the southwest, OBL and FACW plant recruitment is often in the active channel and the floodplain potential actually is a combination of young and/or mid-aged and mature FACW woody species interspersed with shallow rooted FAC, FACU or even UPL species depending on soils and drainage. In other instances, OBL and FACW plants may occur well above the riparian area, in non-hydric soils because they are connected by roots or rhizomes to the riparian area (e.g. Baltic rush).

"NA" would be used for riparian areas that have no potential to produce vegetation.

Supporting Science

Plants are divided into categories relative to the likelihood of their occurrence in wetlands or non-wetlands (Table 3) (Reed 1988). Plants that occur in wetlands are hydrophytes, and they have to be in contact with the water table, which is why they can be used as indicators of soil-moisture characteristics. The term “hydrophytes” is generally restricted to obligate wetland and facultative wetland plants.

Although the focus of other vegetation items is on stabilizing vegetation species or communities, item 8 focuses solely on assessing the vegetation present (regardless of its other ecological/functional properties) to determine if soil moisture is being maintained.

Table 3. Indicator categories

Indicator Code	**Wetland Type**	**Comment**
OBL	Obligate Wetland	Occurs almost always (estimated probability 99%) under natural conditions in wetlands.
FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
FAC	Facultative	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
FACU	Facultative Upland	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).
UPL	Obligate Upland	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.
NA	No agreement	The regional panel was not able to reach a unanimous decision on this species.
NI	No indicator	Insufficient information was available to determine an indicator status.
NO	No occurrence	The species does not occur in that region.

USDA, NRCS. 2012.

Myers (1989) and most of the classification literature mentioned in item 9 cite an increase in upland plants as indicators of declining water table.

Measurements of composition must be analyzed relative to soil, site, channel, and flow related characteristics for quantitative analysis (Cooper and Merritt 2012). Special care should be used in evaluating recovering systems. Depositional events may initiate a temporary shift toward upland plants during the lag time required for a rising water table to “catch up.” This should be noted so that the rating is not down-graded.

Correlation with other assessment items

Item 8 correlates with item 4 (riparian area is expanding). The expansion of OBL/FACW plants may be an indication of a rising water table or reconnecting with the floodplain.

Item 9: Plant communities that have root masses capable of withstanding high streamflow events are present along the streambank.

Purpose

Item 9 determines whether **streambanks** have stabilizing plant communities present along the reach to support recovery and maintenance. Streambanks with vegetation lacking extensive root masses are undercut during high-flow events and collapse. Excessive collapse of streambanks results in an increase of the active channel's width/depth ratio, which reduces a riparian area's ability to dissipate energy. Gradient and sinuosity may also be adversely affected further increasing stream energy.

Whereas item 6 is designed to determine if stabilizing species are simply present in the entire riparian area, this item is asking if those plants have formed *recognizable and distinct communities on the streambanks.* However, item 9 does not address adequacy and is not intended to determine if *enough* vegetation or *enough* communities are present.

Most stabilizing riparian plant communities are dominated by specific OBL and FACW plants that have deep, strong root masses capable of withstanding high-flow events. In some geographic areas some FAC plants may also function as stabilizers. Most plant communities dominated by FACU and UPL species do not have stabilizing root characteristics. The presence of stabilizing plant communities, even if they do not dominate the streambanks along the reach, has additional interpretational value for recovery or maintenance potential of a reach over presence of stabilizing species alone.

Observational Indicators and Examples

Riparian species, such as willow, alder, aspen, birch, and cottonwood, and/or deep-rooted herbaceous species, such as sedges, rushes, bulrush, and some riparian grasses, have root masses capable of withstanding high-flow events (Figure 22). If these plants have formed recognizable communities along a streambank or developing banks (such as point bars) of a degraded stream, the answer to item 9 would be "yes." Intermittent systems would be an exception. For many intermittent systems (and some perennial systems as noted above), the presence of recognizable communities of FAC plants is all that is required for a "yes" answer, as this is all these systems can produce.

Figure 22. Baltic rush exhibiting highly stabilizing root masses.

A "yes" response is possible on item 9 if there are patches along the streambank that contain deep-rooted plant communities. In such conditions, it is likely that reproduction of the characterizing deep-rooted (or potential) vegetation could occur and eventually fill in the gaps along the streambank. If deep-rooted riparian plants only occur as scattered individual plants along a reach, item 9 would be "no."

Plant communities such as Kentucky bluegrass, redtop, blue grama, and sagebrush do not have the root masses capable of withstanding high-flow events. If these communities exist *in lieu of* communities of stabilizing riparian plants on the streambanks, the answer to item 9 would be "no."

There are exceptions, such as high gradient, bedrock, or boulder/cobble stream types, where the vegetation community contributes little, if any, to bank stability. For these, the answer would be "NA."

Supporting Science

Stability ratings have been developed for plant communities and individual plants species and other bank features (barren, rock, woody material) that help characterize how well the streambanks may resist erosion (Winward 2000, Burton et al. 2011, Crowe and Clausnitzer 1997). Many OBL and FACW and some FAC species have high erosion control potential.

Erosion control potential can also be determined from rooting habits of individual species (Lewis 1958; Manning et al. 1989, Kleinfelder et al. 1992), or preferably from ratings or discussions of both species and plant communities, such as in Weixelman et al. (1996), Hansen et al. (1995), Manning and Padgett (1995), USDA Forest Service (1992), and

Kovalchik (1987). Even though these publications are geographically specific, the species and similar plant communities occur broadly across various geographic regions.

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Correlation with other assessment items

This item is correlated to item 11 (adequate stabilizing vegetation) and is particularly useful for cases where item 11 is a “no.” In those instances, a “yes” on item 9 indicates that there is an adequate reservoir of the right kinds of plant communities to support recovery and progress towards an adequate amount if provided an opportunity to do so.

Item 10: Riparian plants exhibit high vigor.

Purpose

Item 10 determines whether riparian plants are healthy and robust or are weakened and stressed. Plants that are in an unhealthy state have a diminished ability to grow (expand), reproduce, or contribute to function and can be at risk of mortality. The loss of key riparian plants can subject the riparian area to impairment. The aboveground expression is a reflection of belowground condition and ability for riparian species to stabilize an area.

Observational Indicators and Examples

Reduced height, leaf width, or leaf area (production) and signs of stress, such as chlorosis, have traditionally been used as indicators of reduced vigor on herbaceous species. Growth form (morphology), leader length, and the amount of dead or dying limbs (Cole 1958, Keigley et al. 1998) are also long-standing indicators of vigor for shrubs.

Chlorosis occurs when leaves produce insufficient chlorophyll. If willow leaves are turning yellow during the growing season, often water is being removed or added to a system, which stresses the plants. However, change in color can also indicate a disease, nutrient problem, or climatic factors.

It is useful to separate woody plants and herbaceous plants when assessing vigor. For most riparian areas, plant size, shape, and leaf color during the growing season can be used to discern vigor. For example, if willows in a given reach are well-rounded and robust, the answer to item 10 would be “yes.” If these same plants have altered growth forms and/or suppressed leader growth, the answer to item 10 would be “no” (Figure 23).

Abundance of herbaceous plants can be used to assess vigor. If Nebraska sedge is comprised of a dense mat on the reach being assessed, the answer to item 10 would be “yes.” If Nebraska sedge occurs as isolated plants or broken clumps that are not forming communities (interspaces between sedge plants are occupied by upland species or bare ground), the answer to item 10 would be “no.” In some instances, the plants may be healthy, but young and in the process of expanding. In general there will be other indicators of vigor such as leaf width or height that correspond.

This item can also be answered both “yes” and “no” if herbaceous species appear healthy and vigorous, for example, and woody species appear diseased or stressed.

“NA” would be used for riparian areas that have no potential to produce vegetation.

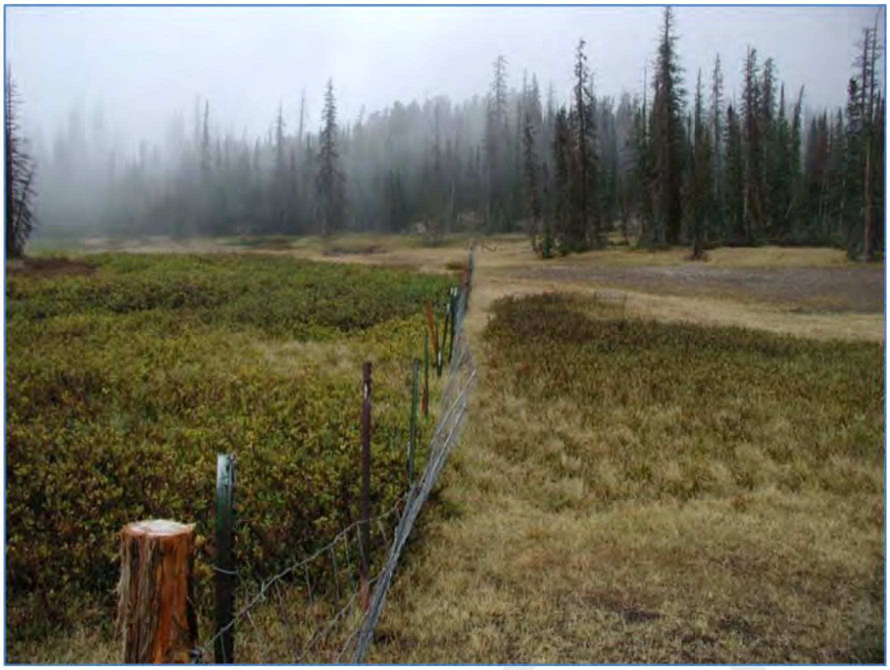

Figure 23. The shrubs to the left of the fence line show high vigor while those to the right of the fence line do not.

Supporting Science

The relative health of plants within a community can be expressed in many morphological and physiological forms. The reproductive indicators for herbaceous species discussed in item 7 (unhealthy plants don't reproduce as well), as well as plant size, leaf area and size, and root growth are all associated with relative plant health or vigor.

Some stabilizing riparian plant communities have up to a 3:1 ratio of belowground to aboveground growth, whereas upland plant communities are closer to a 1:1.5 ratio.

Weixelman et al. (1996) have established procedures for documenting mean rooting depth and expected ranges of rooting depth associated with various ecological conditions of specific herbaceous riparian plant communities. Shallower rooting depths associated with declining status can, in part, be a quantitative measure of the vigor of the community.

Correlation with other assessment items

There is a correlation between item 10 and 7 (recruitment of stabilizing vegetation). If there is a 'no' response on item 7, a "no" response is likely on item 10, depending upon the reason for lack of age classes.

Item 11: Adequate stabilizing riparian vegetative cover is present to protect banks and dissipate energy during high flows.

Purpose

Item 11 determines whether there is an adequate *amount* of vegetation as expressed by the lineal distribution of stabilizing riparian plant communities present along the streambank to dissipate and withstand stream energies from moderately high-flow events like 5-, 10-, and 25-year events.

This item is important for areas where vegetation is required for proper functioning condition. For a riparian area to recover, composition of the right plant communities, vigor, and recruitment are necessary, but until an adequate amount is present, the riparian area is vulnerable.

Item 11 addresses an *amount*, while items 6-10 address species, recruitment, wetland indicator status, the presence and location of communities, and vigor – not amount.

Observational Indicators and Examples

Streambanks with adequate stabilizing riparian vegetative cover are more stable than those dominated by shallow rooted plants. Thus, the excessive occurrence of streambank failures/slump blocks, eroding banks, and excessively high width/depth ratios throughout the reach *combined* with a limited amount of stabilizing riparian vegetation observed on streambanks are clear indications of inadequate cover. However, the absence of instability features is not necessarily an indication of adequate cover. It may be that the timing and magnitude of high flows sufficient to degrade the channel have just not occurred recently; and when high flows do occur, there is a high likelihood for stream impairment if adequate cover is not present.

Bank instability features must be carefully assessed as it is common for many channels to exhibit some bank instability/erosion on outside meander bends but still maintain the channel dimension, pattern and profile. Bank instability along straight reaches (not on a meander), however, is often another indication that the stream is not adequately dissipating energy; which could be at least partially attributable to a lack of enough stabilizing streambank vegetation.

Although there are exceptions, most perennial stream channels require at least 70% total lineal cover of stabilizing cover on the streambanks to buffer the erosive force of water. Depending on the size and composition of soil materials on the banks, 80% total lineal cover or more may be required for some channels and many low gradient, sinuous streams require as much as

90% or more total lineal cover to maintain function. The use of local references and validation monitoring, if available, should be used to determine cover thresholds. It should also be recognized that embedded rock and anchored woody material constitute significant portions of the streambanks on some reaches; if this is the case, the combined cover of stabilizing vegetation, embedded rock and anchored woody material should be considered in the estimate of adequate cover (Winward 2000).

If a streambank for the reach being assessed is primarily upland plant communities, the answer to item 11 would be “no.” If this same streambank is 50 percent stabilizing riparian plant communities and 50 percent upland plant communities, the answer to item 11 would still be “no.”

Intermittent and some perennial systems may not have the potential for OBL and FACW stabilizing plant communities and have FAC plant communities that stabilize streambanks.

Item 11 would be answered “NA” for riparian areas that do not need vegetation to achieve PFC.

Supporting Science

As indicated, stability ratings have been developed for plant communities and individual plants species and other bank features (barren, rock, woody material) that help characterize how well the streambanks may resist erosion (Winward 2000, Burton et al. 2011, Crowe and Clausnitzer 1997). In general, because stream channels are dynamic systems subject to constant energy and disturbance, the maximum amount of cover most streams can achieve at potential is approximately 98% total lineal cover of stabilizing vegetation, anchored rocks, and anchored woody material on the streambank (Winward 2000). Adequate stabilizing vegetation combined with anchored rocks/logs is usually, if not always, less than the maximum achievable.

Winward (2000) and Burton et al. (2011) both provide total vegetation cover and vegetation stability class metrics derived from greenline vegetation data. Stability class values 7 and above (on a scale of 1, lowest, to 10, highest) are considered high to excellent by Winward while values greater than 6 are considered high (the highest class in a three tier scale of low, medium and high) by Burton et al. High stability class values calculated by either method are generally considered adequate for PFC. From a practical assessment standpoint, greater than 70% estimated stabilizing cover will usually yield a high stability rating. Practitioners may use a higher value for particularly sensitive stream types or lower value for resistant stream types if rationale is provided. Although there is no detailed research to validate how much cover different stream~~s~~ types need to maintain function, voluminous anecdotal evidence encompassing thousands of stream miles assessed by PFC developers and practitioners over the past 20+ years suggests that 70% is a reasonable stabilizing cover necessary for function absent site-specific information.

Bank erosion occurs when the eroding force (shear stress) of water moving along the bank exceeds those forces in the bank that are resisting the shear force. Shear force on the bank is directly proportional to the velocity gradient in the water; i.e., the rate at which velocity increases when moving away from the bank. Thus, if velocity increases very rapidly in the near-bank region, the velocity gradient is steep and shear stress is high. Conversely, if velocity increases slowly or not at all in the near-bank region, shear stress on the bank will be minimal or negligible.

Forces resisting bank erosion result from physical properties of the streambank and protection from erosive shear by overhanging vegetation. Physical properties of the bank are primarily related to cohesive strength of bank materials and other factors increasing bank tensile strength. Cohesive strength of bank materials is largely a function of soil texture (especially particle size), soil chemistry, and soil structure. Vegetation root mass is a key factor in increasing tensile strength of the bank.

Vegetation has the potential to influence the balance of energy during high flows in at least two ways. First, living or dead vegetation (or any other cover, for that matter) that extends into the flow has the potential to reduce near-bank velocities, thus reducing erosive shear forces acting upon the bank. In an ideal situation, vegetation along the bank is sufficient to produce a zone of near-zero velocities near the bank, effectively moving the velocity profile away from the bank so that shear stress is dissipated in turbulent eddies in the flow. A similar process occurs in the overbank region when density of vegetation is sufficient to produce near-zero velocities at ground level in overbank flow during flood events.

Vegetation also influences the balance of energy during high flows by increasing resisting forces in the streambank. Particularly in non-cohesive soils and sediments, the presence of stabilizing vegetation may greatly increase binding forces in bank materials. Tensile strength provided by root masses of riparian vegetation may be the primary source of resistance in the alluvial sediments of many streams. Tensile strength will be dependent upon both the kind of vegetation present and the extent and density of root masses in the sediments. Determination of root-mass adequacy will be site-specific, as less cohesive sediments will require greater root mass to achieve the same level of stability as more cohesive sediments elsewhere.

Correlation with other assessment items

The cause of streambank instability is also closely related to the channel geometry described in items 1 (floodplain frequently inundated), item 3 (sinuosity, width/depth ratio, and gradient in balance), and item 15 (stream banks laterally stable). Channels that do not exhibit the appropriate channel geometry (lack of floodplain access and channel dimensions and pattern not conducive to energy dissipation) *combined* with a lack of stabilizing riparian plants on the streambanks contribute to bank instability.

Note that items 6-9 can all have “yes” responses as appropriate with item 11 being a “no” if there is simply not enough stabilizing cover on the streambanks. Conversely, if all of items 6-9 are “no,” it is not possible for 11 to be a “yes.” In addition, item 15 (stream banks laterally stable) is also related to item 11 as inadequate streambank cover and bank instability can also contribute to excessive lateral channel movement. Also, item 4 (riparian area expanding) and 14 (point bars revegetating) are determined by evaluating the presence of adequate riparian vegetation on the streambanks.

Item 12: Plant communities are an adequate source of woody material for maintenance/recovery.

Purpose

Item 12 determines whether enough standing dead and live trees are present to become a source of downed woody material for stream maintenance and or recovery. *Before answering item 12, it must be determined if woody material is necessary for a given reach to function properly and if the woody material is large enough to stay for a period of time to function as a hydrologic modifier*. Material size will vary by stream size, flow regime, and ecological setting, therefore each site should be evaluated to determine what is appropriate and where woody material is required. Many rangeland and meadow riparian areas do not require woody material to maintain channel stability.

Some stream systems cannot maintain their dimension, pattern, and profile and function properly without woody material, including small limbs and root wads. These streams require a supply of woody material on the banks and floodplains, over time, which is of the appropriate size to capture bed load, aid floodplain development, provide organic matter, and dissipate energy.

The size of downed wood provided by species like aspen or water birch may provide adequate hydrologic control on some streams while mature cottonwoods, Douglas fir, or similar trees may be required for others.

Observational Indicators and Examples

If woody material is necessary and trees are present, next determine if they are sufficient in number, age, and size. If a reach contains an adequate number of mature trees and they are large enough to serve as hydrologic modifiers, the answer to item 12 would be “yes.”

If a stream reach requires woody material and there are young trees but no living mature trees present that will access the stream in the future, then the answer to item 12 would be “no” but with a comment describing the current situation. If there are only few, scattered, or isolated trees, the answer to item 12 would also be “no.”

This item will be answered “NA” for many riparian areas such as sedge/rush/grass meadow systems because woody species are not needed for stability.

Supporting Science

A large amount of literature has been produced in recent years that documents observations and measurements of forest riparian areas describing the relative value of woody material needed to maintain stream geomorphology and function (Gregory et al. 2003; Naiman et al. 2002). Some forested riparian areas depend on trees to maintain or achieve desired condition and achieve potential (Latterell, JJ and R.J. Naiman 2007). The way each part of the stream system functions changes as streams merge and increase in size. This results in an enormous variety in stream slope, geology, hydrologies, and vegetation types which increases the difficulty in determining how the entire system functions (Chin et al. 2008).

Woody material in a stream:

- Dead, down, and living trees are essential to development and maintenance of some forested riparian stream ecosystems from their headwaters to the downstream end of the forest stream continuum.

- The riparian/stream continuum is in a state of dynamic stability when it is functioning properly and the movement of woody material down the stream system is normal and necessary. The function of woody material in the stream and on the floodplain changes from the headwaters to the wider downstream valleys.

- Floods, fires, wind-throw, torrents, landslides, and normal tree mortality are essential delivery mechanisms needed to maintain and restore the riparian stream system's functionality.

- The temporal processes of the forest riparian/stream system should be measured in decades and centuries.

- The spatial location of woody material is continually shifting during annual and episodic events. This spatial movement replenishes materials that are broken down or flushed out of the system.

Correlation with other assessment items

The woody material addressed in item 12 closely relates to item 13 (floodplain and channel characteristics adequate to dissipate energy) because item 12 address the adequacy of the *source* of woody material important for energy dissipation on the floodplain and in the channel.

C. Geomorphology

Items 13-17 deal with erosional and depositional attributes and processes that have to be in working order for a stream channel and riparian area to function properly. The intent of items 13-17 is to include observations of fluvial geomorphology, sediment load, discharge, and stream energy and to evaluate their effects on stream processes and riparian conditions. Key concepts in one or more of these items include:

- The balance between driving and resisting forces.
- The balance between sediment supply and transport capacity.
- The mechanism by which energy is dissipated within a channel or across a floodplain.
- The relations between watershed runoff and stream discharge.
- The distinctions between rates and magnitudes of natural processes in comparison to those that result from human management of riparian areas, in specific, and of watersheds as a whole.
- Intrinsic and extrinsic factors that can push unstable systems across a geomorphic threshold, leading to rapid and substantial changes in channel dimension, pattern, and profile.

An objective of the PFC assessment method is to determine if stream channels and connected riparian areas are stable. Stability is the capacity of the stream channel to maintain dimension, pattern, and profile during moderately high discharge events (i.e., stream discharges of 2-, 5-, 10-, to approximately 25-year recurrence interval). Rare, high-magnitude, low-frequency events (such as floods with a recurrence interval greater than approximately 25 years) can destabilize channels and reconfigure valley bottoms, even when the pre-flood conditions were at PFC.

Also, stability does not imply a rigid or static condition. Instead stability is meant to describe a resilient, flexible condition synonymous with the concept of a graded stream. Mackin (1948) described the **graded stream** as:

> "…one in which, over a period of years, slope is delicately adjusted to provide, with available discharge and the prevailing channel characteristics, just the velocity required for transportation of the load supplied from the drainage basin."

The graded stream is one where adjustments occur, over time, in channel slope, but only to a minor extent or not at all by concurrent changes in channel dimensions.

The stability of a channel can also be assessed by the Lane equation:

$$Q_sD_{50} \; \alpha \; QS,$$

which states that the sum of the sediment load (Q_s) and bed-sediment size (D_{50}, mean-particle size) is proportional to the sum of stream discharge (Q) and stream slope (S). The Lane/Borland balance (Lane 1955; and Borland 1960 *in* Pemberton and Strand 2005) is a conceptual graphic model of the Lane equation (Figure 24). It portrays processes of aggradation (deposition and elevation of channel bed) and degradation (channel incision) in terms of sediment supply (sediment load and size) and transport capacity, discharge, and gradient (stream slope). The concepts inherent in the Lane equation and Lane/Borland balance can facilitate discussion of stream function, but other stream and riparian attributes, such as bed and bank roughness, channel dimensions, floodplain accessibility, and stabilizing riparian vegetation, which are indicative of broader riparian functionality relations, are not explicitly portrayed or accounted for by this model.

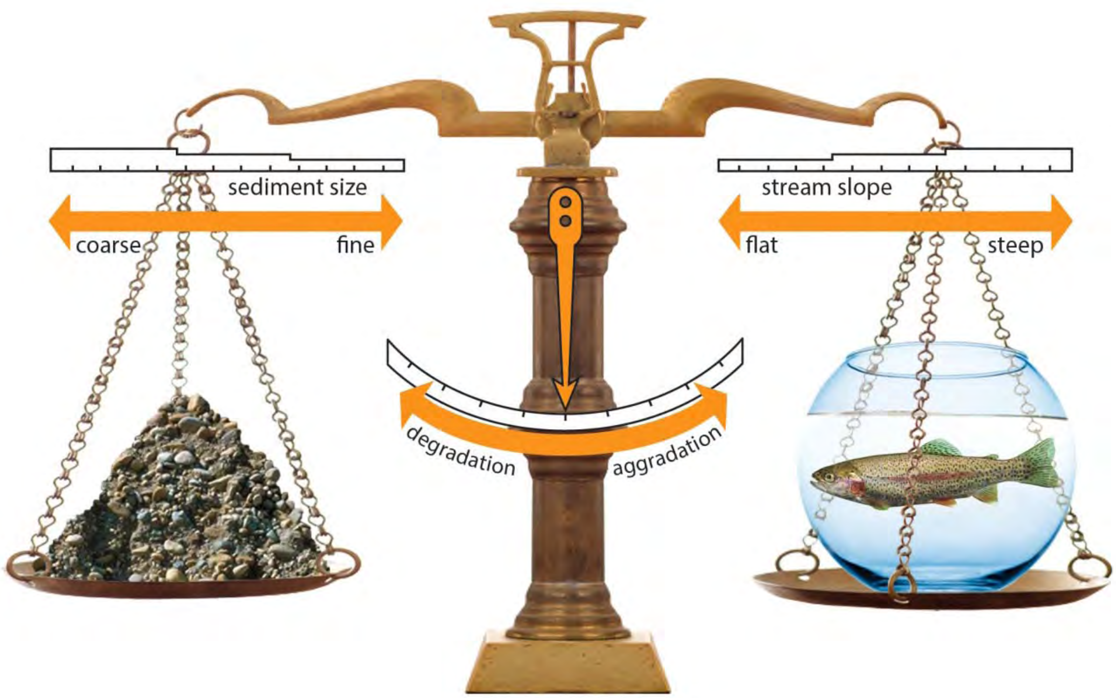

Figure 24. Lane/Borland balance.

Item 13 deals with the dissipation of energy within the channel and on the floodplain. Energy dissipation is vital to maintaining riparian resilience and channel stability. In the presence of excessive unchecked energy, driving forces exceed resisting forces; and the fluvial system may become unstable, cross a geomorphic threshold, and the channel may incise or widen. When resisting forces exceed driving forces, transport capacity diminishes and the stream channel form will adjust to compensate for an inability to transport its sediment load.

Item 14 focuses attention on the condition of point bars. Point bars form within the active channel on the inside bend of a meander where stream hydraulics deposit bedload sediment. When the fluvial/riparian system is operating properly, riparian vegetation on the top of the point bars will retard stream velocity, induce deposition, and create a hydraulic connection between the top of the point bar and the floodplain. Poor riparian management may prevent riparian vegetation from colonizing and stabilizing the top of the point bar and maintaining hydraulic connectivity with the floodplain. Poor watershed or channel conditions could introduce excess sediment and excessive deposition on the point bar, which either hinders development of riparian vegetation or isolates the floodplain from the point bar. Alternately, poor watershed or channel conditions could create excessive stream energy, which removes stabilizing riparian vegetation from the top of the point bar, erodes the point bar, alters channel dimensions, and prevents high flows from accessing the floodplain.

Items 15 and 16 are directed at the lateral and vertical stability, respectively, of the channels. Alluvial channels are not static; they naturally migrate across their valley floors. However, the highest rates of channel migration should occur at meanders, where cut-bank erosion acts on the outside bend of a meander. Rapid thalweg relocation, unusual channel avulsion, excessive sidewall erosion, or cut-bank erosion in excess of point bar deposition, all suggest excessive energy and erosion in the system. Likewise, channels that incise or widen so that floodplains are no longer accessible by high-flow events are unstable and cease to function properly.

Item 17 integrates the observations across a drainage basin to determine if the sediment supply and transport capacity are in balance.

Stream systems are dynamic environments where incremental changes occur over time with virtually every change in discharge. However, the properly functioning stream system will maintain a stable, resilient form (i.e., combination of channel dimensions, pattern, and profile) throughout the incremental changes in discharge. A poorly functioning stream/riparian system may cross a geomorphic threshold and undergo rapid and substantive changes that can only heal or be restored through great expenditure of resources, or through great time intervals as such transformed streams undergo a cycle of channel evolution (Figure 6), which occurs over decades to hundreds of years.

Item 13: Floodplain and channel characteristics (i.e., rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy.

Purpose

For riparian areas to function properly and preserve dynamic equilibrium, energy has to be dissipated during high-flow events. Item 13 focuses on whatever is appropriate in a landform setting and for the potential of a reach **from the listed characteristics** to provide roughness and dissipate energy. On some stream types, energy is dissipated when an adequately sized floodplain is accessed and high flows can spread out, through channel characteristics that create forces resistant to downstream movement of channel and bank materials, or when obstructions to flow such as large rocks, woody material, or vegetation slow water velocity. If these energy dissipating elements are removed from a stream reach, water velocity during floods would increase, which could cause excessive erosion. In most cases, both channel characteristics and adequate floodplain will be needed to effectively dissipate energy.

Observational Indicators and Examples

The ID team identifies whether the specified floodplain and channel characteristics are a part of the stream type being assessed; and if so, observe if they are in place and adequately dissipating energy. Determining what the 5-, 10-, and 25-year flow events are for the reach being assessed helps the ID team with interpretation of this item. In many cases, if energy is being dissipated, while erosional areas may be present, floodplain and channel characteristics are sufficiently resistant to allow only short, discontinuous erosional segments.

Rocks: Rocks can influence the channel cross-section and stream type. Anchored rocks that seldom move with high flow provide stability. Large rocks that are exposed during high-flow events also provide resistance and slow water velocity. The ID team will note if rocks are necessary or playing a role in energy dissipation based on the geology and potential of the reach being assessed.

Woody material: Riparian areas that require down logs, down branches, or jams to function are forested, high energy or large bedload environments where the large woody material is required to capture sediment and bedload for streambank repair and floodplain development to occur. Woody material can vary from a few pieces of wood with associated organic material to several dozen large logs tangled together spanning across a stream channel. For areas that require woody material to dissipate energy, the answer would be "yes" if woody material is in place and some of it is large enough to remain in place during high-flow events, but the answer would be “no” if the area lacks woody material to act as hydrologic modifiers.

Vegetation: Live vegetation that is an obstruction to flow also provides roughness. Note that vegetation does not always grow in a channel because it can be repeatedly scoured out by high flows. The ID team will note if vegetation is necessary or playing a role in energy dissipation based on the potential of the reach being assessed.

Adequate floodplain size: Channels that are progressing through a channel evolution sequence similar to the example in Figure 6 are, in most cases, able to adequately dissipate energy only after the floodplain has developed the appropriate width. Indicators that this has occurred include:

- A vegetated angle of repose developing at the base of the terrace walls or sometimes very cohesive soils will be straight up and down but no longer eroding,.
- Stable channel dimensions after moderate floods.
- Appropriate meander-width ratios (belt width divided by bankfull width). Rosgen (1996) presents average values and ranges for meander-width ratios by Rosgen stream type. Notice the ranges are large, so other indicators come into play for interpretation, like sediment processing and whether riparian vegetation can establish, thrive, and recover.

Overflow channels: Some single-thread stream reaches have backwater areas, oxbows (abandoned meanders), or overflow channels that are accessed during floods and contribute to energy dissipation. Note that this is different from naturally braided or anastomosing channels. Abandoned meanders and overflow channels are usually only connected to the active channel during flood flow events. The presence and condition of riparian vegetation or large woody material in or near overflow channels influences energy dissipation as well (Figure 25). The overflow channel shown in photo A is adjacent to the stream shown in photo B. The high flow channel is providing for energy dissipation from both its position on the floodplain and the roughness contributed from the adjacent riparian vegetation.

The presence of stable overflow channels would contribute towards a “yes” answer for this item. If overflow channels have been artificially disconnected from the main channel, and the main channel shows signs of excessive erosion, the answer would be “no.”

Figure 25. Overflow channel (A) adjacent to a stream (B).

Item 13 will never be answered “NA”; it will always have either a “yes” or “no” answer.

Supporting Science

One of the three governing laws of fluid mechanics is that total energy (i.e., potential energy due to height above some datum, kinetic energy due to velocity of flow, and pressure energy due to depth of flow) should be conserved as water moves downstream through a channel. However, even in the case of uniform flow, where both velocity and depth are unchanged in the downstream direction, potential energy is lost as water moves from a higher position to a lower one. This energy loss is a result of forces acting at the channel boundary to resist the downstream movement of water. Various hydraulic equations have been developed to quantify this energy loss and to predict the stable depth of flow for a specified discharge in a channel.

Although item 13 focuses on a subset of what provides roughness and energy dissipation, the supporting science comes from Manning’s equation which provides the basis for computing differences in flow velocities due to differences in hydraulic roughness (Arcement and Schneider 1989). Manning’s equation is presented in the hydrology items introduction (page 43). Manning’s equation is also used to calculate energy losses by using the equation calculations from several cross-sections in a reach. Computer models, such as HEC-2, perform these calculations (Federal Interagency Stream Restoration Working Group 1998). Manning’s roughness coefficient “*n*” may be thought of as an index of the features of channel roughness that contribute to the dissipation of stream energy. It varies with changes in stage (water level), channel irregularities, obstructions, vegetation, sinuosity, bed material, and bedforms. Cowan (1956) developed a formula for estimating “*n*” values based on observed channel characteristics. Chow (1959) published suggested values for *“n”* for natural streams tabulated according to factors that affect roughness, ranging from 0.20 to 0.200. Barnes (1967) catalogued verified *“n”* values for 50 stream channels having roughness coefficients ranging from 0.024 to 0.075. Channel data, plan sketches, cross sections, and photographs are presented so experience could be gained by examining and becoming acquainted with the appearance of typical channels whose roughness coefficients are known.

In forested areas, woody material contributes to energy dissipation that supports riparian function by adding to flow resistance, increasing sediment storage, reducing sediment transport, and influencing channel form. The characteristics and function of woody material change in relation to stream size (Bilby and Ward 1989, Gurnell et al. 2002, Naiman et al. 2002). Braudrick and Grant 2000 found large diameter pieces with orientation parallel to flow and rootwads increased the stability of large woody material.

Correlation with other assessment items

Item 13 is related to item 1 (floodplain frequently inundated). For some stream types, floodplain access is very important for energy dissipation. A floodplain may be developing, but is not yet an adequate size; item 1 would be answered "yes", but item 13 would be answered "no," with the appropriate remarks describing the situation. If item 1 is answered "no," and no new floodplain has developed, then item 13 would also be answered "no."

Item 13 is also related to item 12, as item 12 is about the trees that will fall over and become woody material. Item 17 (stream in balance with water and sediment supplied) is related because if the floodplain and channel characteristics are adequate to dissipate energy, this will have a positive influence on the sediment/water balance.

Item 14: Point bars are revegetating with stabilizing riparian plants.

Purpose

Item 14 determines whether stabilizing riparian vegetation is establishing on the top of point bars to capture sediment and aid in floodplain development and to maintain a balance between bank erosion on the cut-bank and bank formation on the point bar.

Formation and extension of point bars is a natural depositional process for some stream types. Riparian vegetation must colonize the point bar to: (1) stabilize and prevent excessive point-bar erosion; (2) trap sediment during high-flow events; (3) aid in floodplain development; and (4) improve water quality by filtering sediment from stream water. When vegetation fails to establish on tops of point bars, the energy associated with high-flow events can cause erosion that affects sinuosity, gradient, channel dimensions and floodplain accessibility, which results in impairment of riparian function. For example, in Figure 26, the point bar located on the right side of the channel has largely been removed by a recent flow event. Erosion of point bars may result from excess velocity, related in part to channel incision or lack of channel roughness from lack of vegetation on banks and point bars. Erosion of point bars can lead to over-widening of the channel, decrease in floodplain accessibility, decrease in sinuosity, and corresponding increase in channel gradient.

Figure 26. Eroded point bar with vertical bank.

Observational Indicators and Examples

A geomorphically stable point bar is commonly recognized by:

- Cross-sectional shape, with a gently inclined to moderately convex profile across the point-bar deposits from the floodplain toward the thalweg.
- Topographic continuity (and hydrologic accessibility) between the top of the point bar and the floodplain.
- A fining-upward sequence of sedimentary textures. The deposits at the base of the point bar are generally the coarsest with progressively finer sediment toward the top of the point bar.
- Preservation of channel cross-sectional area, indicating that the volume of sediment deposited on the point bar (as suggested by growth of the point bar from time 1 (t_1) through time 4 (t_4) is approximately equal to the volume of sediment eroded from the corresponding cut-bank (suggested by retreat of the cut-bank from t_1 to t_4) on the opposite side of the channel.
- Establishment of stabilizing riparian vegetation near the top of the point bar, commonly with colonizing riparian vegetation lower on the point-bar surface.

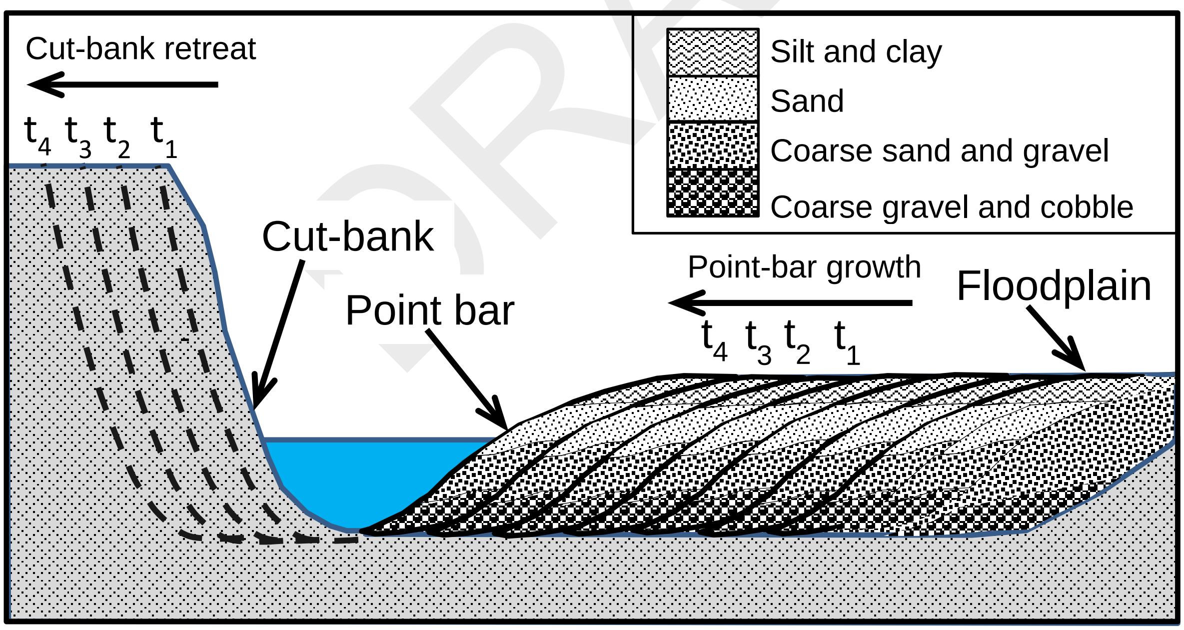

Figure 27. Idealized cross-section through a point bar.

Figure 27 show a hypothetical meandering channel, illustrating: (1) gently sloping to convex upward form of the point bar surface; (2) topographic continuity between the top of the point bar and the floodplain; (3) fining-upward sequence of sedimentary textures within the point bar; and a constancy of channel cross-sectional area, indicating that the volume of erosion on the cut-bank is approximately equal to the corresponding volume of sediment accumulated on the point bar over time (as suggested by channel position from time 1 (t_1) through time 4 (t_4).

Point bars are an important characteristic of most meandering streams, especially C and some B stream types. Also, point bars can occur in some F stream types, particularly where these entrenched stream types have begun to widen and form inset floodplain features as part of a channel evolutionary path toward more stable stream types. Observations concerning the presence of point bars and establishment of riparian vegetation on point bars in F stream types provide important information on restoration potential and stage of channel recovery.

The abundance of stabilizing riparian vegetation along E stream types typically results in very low meander rates, and point bars are not typically associated with this stream form. The situations where point bars are observed in E stream types should be carefully noted and studied. These occurrences might represent transitory situations where E stream types are degrading into C stream types; or vice versa.

Point bars are not expected in landform-controlled streams with high-gradients and narrow valley bottoms. Such streams (A stream types) dissipate energy primarily through bed-roughness elements, cascades, and step-pools. The answer to item 14 in steep, straight landform-controlled channels is “NA.”

If point bars are expected for the stream type, but are not developed due to low sinuosity, gradient higher than expected, or in-channel erosion that has removed point bars (Figure 27), then the answer to item 14 would be “no”. This situation occurs when C stream types are destabilized and are converted to D streams by excess sediment load, or into F or G stream types by excess energy that widens or incises the channel.

If the top of the point bar is vegetated with upland or facultative upland plants, the answer to item 14 could be “yes” if the reach is part of an intermittent system with a limited potential for hydric riparian plants; or the answer could be “no” if the reach is perennial and the potential vegetation should be dominated by obligate wetland and facultative wetland plants.

If point bars are vegetated by riparian plants like willows and sedges with strong or moderately strong root masses, the answer to item 14 would be “yes” (Figure 28). Note that point bars are dynamic features within a channel. Consequently, this item is focused on the presence or absence of stabilizing riparian species at the top of the point bar (near the floodplain), and is not intended to determine if there is enough of this type of vegetation, which is the intent of item 11.

Figure 28. Point bars colonized with riparian vegetation.

The establishment of stabilizing vegetation on point bars reflects the interplay among stream energy, sediment load, hydrologic regime, and riparian vegetation. For example, in a high energy system, stabilizing riparian plants will likely be located high on the point bar; lower parts of the point bar are part of an active channel and could be below a distinct scour line. Also, where the hydrologic regime has a high range between peak and base flows, stabilizing riparian vegetation would be expected near the top of the point bar; whereas annual plants or colonizing riparian vegetation might establish near the base of the point bar near the low- or base-flow waterline. However, the colonizing plants are well within the active channel and may be removed during the next high-flow event. Parts of the point bar may be unvegetated between the stabilizing vegetation near the top of the point bar and the colonizing vegetation at the base of the point bar. Finally, recognize that the upstream end of a point bar generally experiences higher energy than the downstream end. Consequently, finer sediments with high soil-moisture holding capacity are deposited on the downstream end of the point bar. The downstream end of the point bar can better support stabilizing vegetation given the lower overall energy and better soil properties than the upstream end of the point bar. Figure 29 shows that stabilizing riparian vegetation will generally establish near the top of the point bar and can establish at lower parts of the point bar on the downstream end of the point bar where the stream energy from high-flow events is lower.

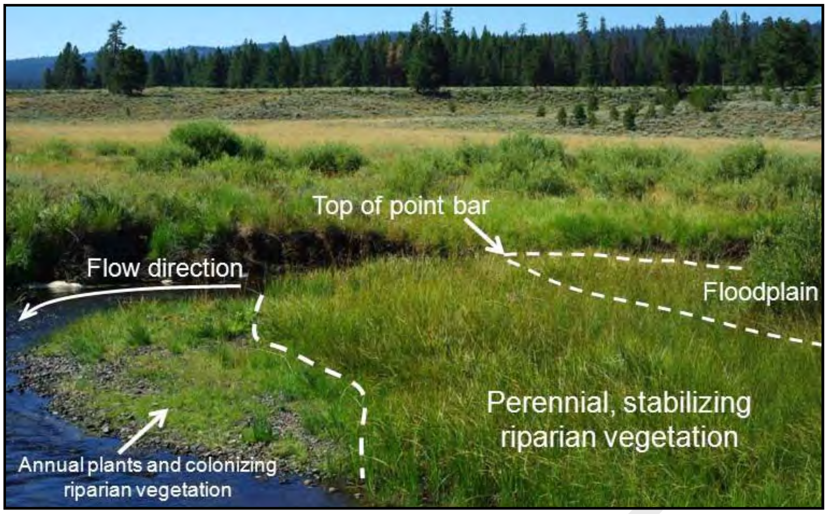

Figure 29. Point bar and establishment of vegetation.

Figure 30 shows a schematic, planimetric view of idealized point bar features. The top of the point bar coincides with the bankfull stage and the edge of the floodplain. Item 14 assesses the development of stabilizing riparian vegetation along the top of the point bar. This vegetation traps sediment, which aides in the construction and expansion of the floodplain. Lower parts of the point bar, especially on the upstream end of the point bar, are well within the active channel and may not be vegetated. The base of the point bar in contact with the base flow may contain annual plants and/or colonizing riparian vegetation; but such vegetation is vulnerable to scour during bankfull or flood events.

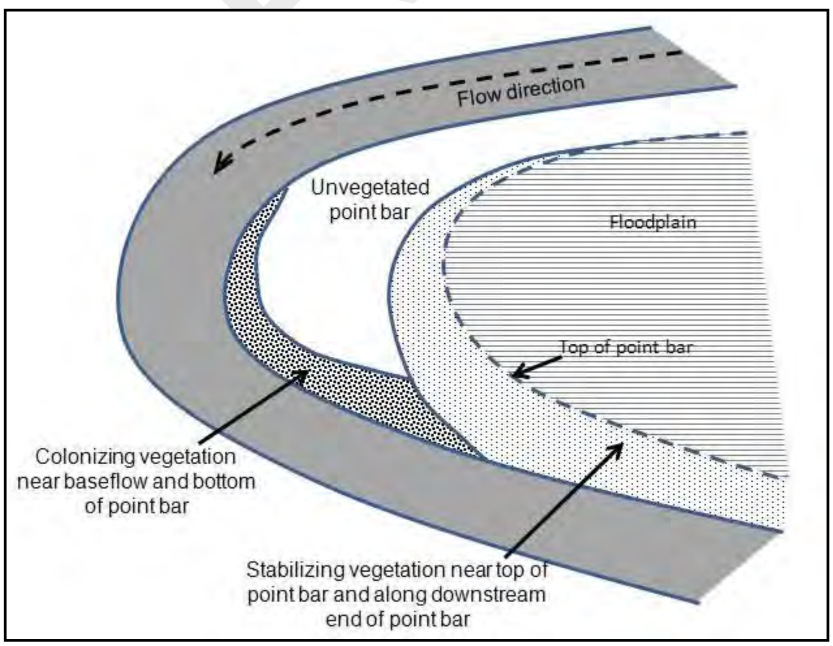

Figure 30. Schematic, planimetric view of idealized point bar features.

When assessments are conducted soon after a high-discharge event, it is possible for the point-bar surface to be devoid of vegetation and covered by recent deposition. Therefore, the soil specialist/geomorphologist should dig exploratory pits to determine if riparian plants exist beneath the recent point-bar deposits. Well-vegetated point bars can trap sediment; and riparian vegetation can grow through the sediments in little time if it was vigorous before burial. Point-bar deposition may indicate that the point-bar vegetation was healthy and adequate to trap sediment, filter flood waters, and protect the banks from erosion.

Supporting Science

This item assesses whether appropriate vegetation is colonizing and stabilizing a point bar, so the same methods used in items 7, 9, and 11 can be used here. Plant lists published by the U.S. Fish and Wildlife Service (e.g., Reed 1988, 1997; Lichvar 2012; http://rsgisias.crrel.usace.army.mil/NWPL/) provide information on riparian plants.

Correlation with other assessment items

The answer to item 14 is related item 7 (recruitment of stabilizing vegetation), item 9 (stabilizing root masses present), and item 11 (adequate stabilizing vegetation) at the top of the point bar. Because riparian vegetation on point bars is a form of channel roughness, item 14 is also related to item 13, (floodplain and channel characteristics adequate to dissipate energy).

Item 15: Stream banks are laterally stable.

Purpose

Streams located within landforms that are not confining meander back and forth across an alluvial valley bottom over time. Stream meandering is a natural process. Item 15 documents if the rate and type of lateral movements are within a range necessary to maintain stable channel dimensions, pattern, and profile. Bank stability serves as a proxy indicator of the amount and location of lateral movement. Item 15 draws attention to the location of bank instability and lateral stream movements. Bank erosion and deposition in a stable system occurs primarily at meander bends (cut-banks and point bars, respectively; Figure 27) rather than the intervening straight segments of a stream channel.

Observational Indicators and Examples

Lateral bank instability may be an indication of poor land-management activities or could result from natural environmental conditions, such as high-magnitude floods. Use stream-gage data and historical records to discriminate management-induced changes from potentially natural channel adjustments. If bank stability is adequate to maintain a stable channel or to permit recovery of an impaired channel, while lateral movement of an active channel is progressing across its valley floor, the answer to item 15 would be “yes.” Indicators of lateral bank stability include:

- Maintenance of a single-thread channel, provided this is the potential channel pattern;
- Formation and retention of bankfull indicators, which tend to become obscured or ill-defined in unstable conditions.
- Development of a nearly continuous greenline along the scour line over much of the reach.
- Stable streambanks, especially on straight segments between meanders (Figure 31);
- Smooth channel margins (Figure 31).
- Natural rates of deposition with little to no change in bed elevation.
- Orderly progression of plant-community seral stages on the inside of a meander bend.
- Movement of the active channel, primarily at meander bends, with little to no net change in dimension (channel cross-sectional area and shape; width/depth ratio), pattern (sinuosity; single vs. multithread channel), or profile (gradient), as deposition on the inside equals the erosion on the outside of a meander (Figure 27). However, in a recovering system, expansion of a riparian area due to floodplain formation and a decrease in the width/depth ratio would be interpreted as a “yes” because the changes noted should be leading to a more stable and better functioning system.

In contrast, indicators of lateral bank instability, which would result in a “no” response, include:

- Evidence that the thalweg or the entire active channel relocates itself with high-flow events (Figure 33).
- High degree of bank erosion along straight channel segments. Bank erosion might include slump, slough, or fracturing (Figure 33 and Figure 34).
- Overly wide channel width corresponding to a lack of bankfull indicators and to a lack of evidence of recent overbank deposition.
- Evidence of numerous hoof prints and hoof shears from large ungulates (wildlife or livestock with annual carry over effects along much of the reach; Figure 34).

The field indicators of bank stability and instability must be interpreted with respect to location and stream potential. Erosion at meander cut-banks is generally natural if the rate of deposition on the point bar is roughly equal (see item 14). Bank erosion along straight channel reaches may require additional evaluation. For example, banks composed of non-cohesive material, such as sandy soils, might naturally have many broken banks. In comparison, cohesive materials, such as clay- and silt-rich soils, tend to have few broken banks at potential (e.g., Figure 31). The typical stable streambank is well vegetated with strongly rooted riparian plants. The banks should be devoid of slumps, sloughs, fractures, and slides to the degree appropriate for the stream type and bank materials.

Figure 31. The typical stable streambank.

Stable banks are recognized by well-developed indicators of bankfull stage, smooth and roughly parallel banks, and an erosion/deposition pattern that occurs primarily at meander bends (Figure 33). In contrast, unstable banks that have eroded due to excessive hoof shears, bank failures, etc., develop an irregular margin, which in turn can generate highly turbulent flow, which itself causes accelerated bank erosion (Figure 32). Bank failures commonly lead to channel widening.

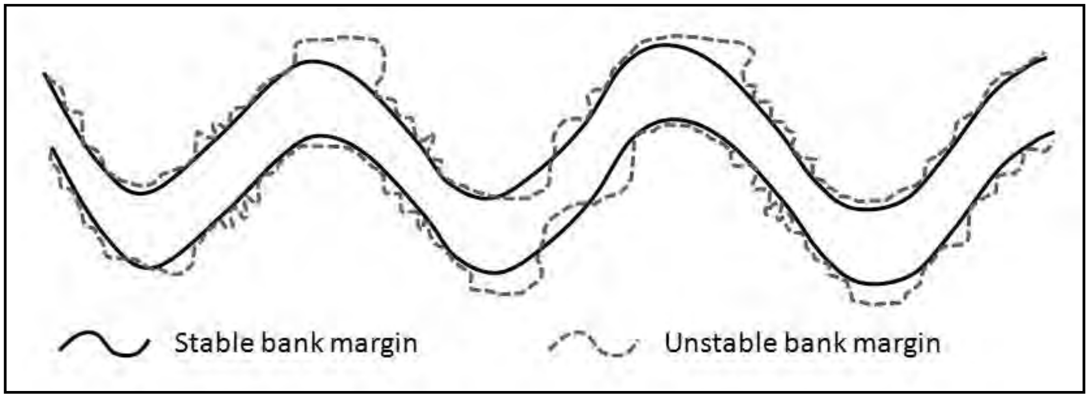

Figure 32. Planimetric view illustrates the contrast between idealized stable and unstable bank margins.

Evidence of bank erosion in an unstable channel could include slump, slough, fracture, or slides. In Figure 33, the banks have eroded along long (several hundred meter), continuous spans.

In Figure 33, long, continuous stretches of banks (left side) have eroded along the greenline, the channel width is very high to accommodate high sediment loads, sediment has accumulated into channel bars, and the bankfull indicators are ambiguous (both banks) due to the unstable nature of banks and rapid rates of erosion and sedimentation. Unstable banks can occur from hoof shear, turbulence, poorly vegetated banks, and other factors that mechanically weaken banks. The condition of the banks is addressed relative to the potential vegetation, stream type, and bank and bed materials. Isolated bank failures, if not excessive, may be normal and not necessarily indicative of overall instability.

Figure 33. Bank erosion in an unstable channel.

Figure 34. Irregular bank margins (white dotted line).

Generally, when the channel experiences either lateral or vertical instability (or undergoes relatively rapid adjustments), the characteristics of the channel and banks change to reflect the instability of the system. For example, vegetation composition may shift to early seral communities; and erosion and sedimentation rates increase. Also, channel morphology is poorly developed along unstable channels and results in difficulties in determining bankfull elevation (Figure 33 and Figure 34).

In some streams, root wads, woody material, and large boulders deflect streamflow and create local scour on banks. These irregularities in the channel margin are related to natural hydraulic action and not to management activities, which might have destabilized banks or induced lateral channel movement.

The lateral movement of some streams is constrained by existing landforms, valley topography, and/or bedrock; and for these streams, the appropriate answer is “NA” (Figure 35).

Figure 35. Landform-controlled streams have little opportunity to move laterally.

Supporting Science

Lateral movement of stream channels is a natural phenomenon in many environments and should be considered relative to the normal adjustment processes of a stream. Lateral movement of stream channels (bank erosion) is influenced by many factors, especially stream type, hydrologic regime, nature of bank materials, and kinds and amount of stabilizing cover on the streambank. Therefore, “natural” rates of channel migration will vary by stream type and bank material (Schumm 1960, 1963), and should be determined empirically through regional studies linked to these factors or through a review of reference conditions.

Finally, the natural rates of channel adjustments should be interpreted relative to the hydroperiod, climate, and physiographic provinces of the stream reach (Wolman and Gerson, 1978). For example, the stabilizing effect of riparian vegetation along perennial streams should be more extensive than the effect along an intermittent stream, where available water may be a limiting factor on plant growth. Likewise, stabilizing effects of riparian vegetation will likely be greater in humid environments than in semiarid or arid environments (Wolman and Gerson, 1978). Furthermore, reaches that are limited in sediment supply may have fewer resources to rebuild fluvial landforms and to reestablish geomorphic stability than reaches with adequate supply of sediment (Bull, 1991). The ID team should distinguish between transport- and supply-limiting systems, as well as climatic zones and the overall effect of the natural rates of recovery following rare, catastrophic streamflow events.

Correlation with other assessment items

Because bank stability and erosion can alter channel dimension (channel shape and size), item 15 is strongly related to item 3 (sinuosity, width/depth ratio, and gradient in balance). Lateral stream movement usually occurs through bank erosion; thus, item 15 also is strongly correlated to responses to item 11 (adequate stabilizing vegetation).

Item 16: Stream system is not incising.

Purpose

Item 16 documents if the elevation of the channel bed is stable or lowering due to channel incision. Incision could be the result of natural processes (e.g., loss of vegetation related to climatic fluctuations, wildfire, extreme hydrologic events, intrinsic geomorphic thresholds (Schumm, 1973, 1979)), or a consequence of certain land uses or human activities, such as urbanization, logging, road construction, and grazing. Channel incision adversely affects the ability of streams to dissipate energy by reducing the hydrologic accessibility to floodplains, to store water by reducing recharge of alluvial aquifers, and to maintain a diverse and robust riparian plant community due to a drop in water table.

Item 16 is specific to short cycles of sediment storage and removal, where episodes of channel incision are rapid (occurring over a few years to decades) and result in noticeable bed lowering. The time frame of years to decades fits within the realm of a management time scale. Item 16 does not speak to the gradual lowering of landscapes that result over geologic time scales of thousands to millions of years. Also, item 16 does not consider localized channel scour, which can produce irregularities in the elevation of the channel bed but does not indicate systemic channel incision.

Note that this item addresses vertical adjustments occurring today, not those that have occurred in the past. *Also, understand that this item deals only with the lowering of a streambed and not aggradation, which is addressed in item 17.*

Observational Indicators and Examples

If a riparian area has no evidence of vertical incision (e.g., headcuts), the answer to item 16 is "yes."

Field indicators of vertical incision that result in a "no" response might include:

- Presence of one or more knickpoints or knickzones (Figure 37); Greater height from channel bed to the floodplain downstream of a knickpoint or knickzone than upstream of the knickpoint/zone (Figure 37).
- A channel that has lost hydrologic connection to a floodplain (though this may be an inherited condition from a past period of incision).
- Lack of bankfull indicators and an enlarged cross-sectional area that is much larger than the cross-sectional area needed to convey the mean-annual flood (Figure 36).

- Morphology of the channel is gully- or arroyo-like with vertical or nearly vertical walls and little or no sediment at the toe slope.
- The channel is scoured to a resistant layer or bedrock with little or no sediment within the channel bed i.e. recovery is not eminent.
- The alluvial aquifer is dewatered as indicated by seepage on banks and/or suggested by reduced vigor of riparian vegetation when the water table declines.
- Upland vegetation has encroached onto an abandoned floodplain or high streambanks or other riparian locations due to a decline in water table.

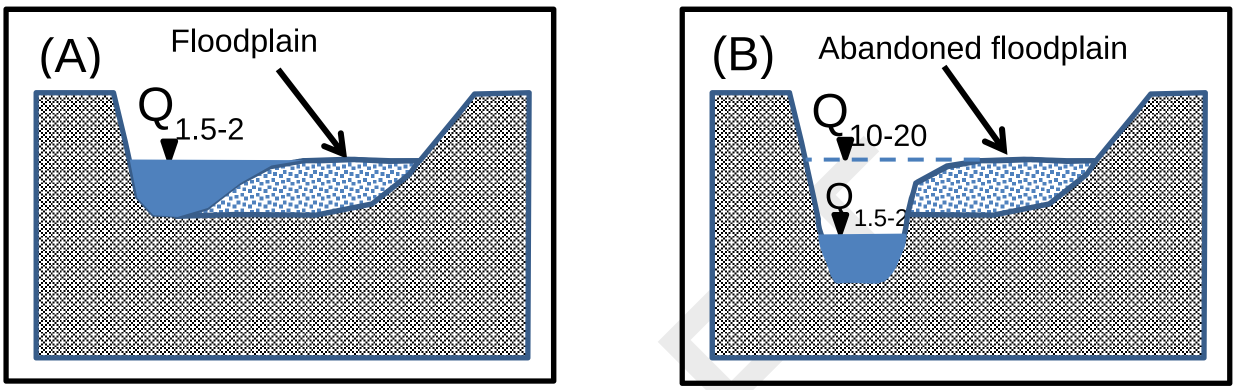

Figure 36. Schematic diagrams illustrating the relations between channel cross-sectional area and discharges of different recurrence interval.

If a stream channel is incised and would have to rise much greater than a 1.5 to 2 year recurrence interval to access the floodplain, the answer to item 16 would be "no". Figure 36 show schematic diagrams illustrating the relations between channel cross-sectional area and discharges of different recurrence interval ($Q_{1.5\text{-}2}$ represents the mean-annual flood discharge with a recurrence interval of 1.5 to 2 years and $Q_{10\text{-}20}$ represents the discharge with a recurrence interval of 10-20 years). Diagram (A) represents an un-incised channel where the mean annual discharge completely fills the channel to the bankfull stage and is able to spill onto the floodplain with any increase in discharge. Diagram (B) illustrates an incised channel with a cross-sectional area that can convey a discharge that is considerably larger than the mean-annual flood and will inundate the adjacent (abandoned) floodplain infrequently, if ever.

If a stream channel has incised but shows development of a new, inset floodplain, the answer to item 16 would be "yes." The formation of an inset floodplain implies channel incision has halted, and the channel has regained vertical stability.

For a reach containing an active headcut resulting in channel incision, the answer to item 16 would be "no." Also, if an active headcut is downstream of the assessed reach, and there is no grade control or impediment to prevent migration of the headcut into the assessed reach, then the answer to item 16 would be "no."

The headcut could either be distinct, like a knickpoint, which is an abrupt, vertical or nearly vertical change in bed elevation along the longitudinal profile, or more subtle, like a knickzone, which is a more gradual change in elevation, occurring in an over-steepened part of the longitudinal profile (Figure 37). Visual clues to a knickzone might include changes in the cross-sectional area of the channel above, through, and below the knickzone; an increase in the height between channel bed and floodplain surface downstream of the knick (Figure 37), or coarser substrate on the channel bed reflecting greater scouring power of the stream through the steeper knickzone.

A visual test to determine whether a knickpoint is an active headcut is to measure the height from channel bed to bankfull or floodplain elevation upstream and downstream from the knickpoint. If the height between these is greater downstream (Z_2) than upstream (Z_1) of the knickpoint, then the knickpoint is likely an active headcut (Figure 37), and the answer to item 16 would be “no.” In contrast, when the channel drops across a step in a step-pool sequence (or across a riffle in a riffle-pool sequence), the floodplain surface drops too, so the heights, Z_1 and Z_2, remain equal.

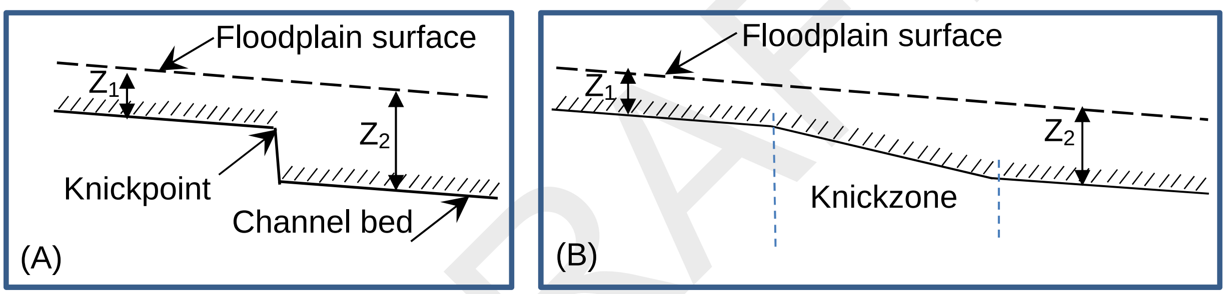

Figure 37. Longitudinal gradient of a stream across (A) a knickpoint, and across (B) a knickzone.

Another result of a downstream headcut is dewatering of the alluvial aquifer and corresponding drop in water table (addressed under items 4 and 8).

Some stream types, such as step-pool or cascading streams, have numerous vertical scarps or short sections with a steep gradient. These steps might have the form and appearance of a headcut, but they typically are stable, armored by coarse, embedded boulders or wood, and not associated with active channel incision. If a stream type naturally contains step-pools or cascades, then the answer to item 16 would be “yes” provided the steps are indeed stable. Likewise, vertical scarps across resistant rock strata are not susceptible to land-management activities and do not constitute headcuts; therefore the channel is likely not incising.

If a channel's stability at potential is controlled by bedrock, item 16 should be answered "NA." In contrast, if the channel is actively incising through alluvium to expose bedrock, item 16 would be answered "no."

If Item 16 is answered "no" because of a head-cut moving upstream, then the reach above the head-cut to a point where there is some geologic or structural grade control is FAR regardless of other factors.

Supporting Science

Vertical instability results in channel incision, loss of connection to a floodplain, and a disconnection from the riparian area. If vertical instability of the stream is suspected, it may be useful to determine if adjustments in bed elevation are the result of local conditions or system-wide instability. Adjustment processes that affect entire fluvial systems often include upstream-progressing incision, downstream aggradation, channel widening or narrowing, and changes in the amount and size of sediment. These processes differ from localized processes, such as scour and fill, which can be limited in magnitude and extent. Scour and fill occur over periods of hours to days and affect local areas in response to high flow events. In contrast, processes of incision and aggradation usually affect all or much of a stream reach or an entire drainage basin and may be most noticeable over a period of several years to several decades. Channel adjustment processes such as incision and aggradation can exacerbate local scour problems, and bed-level adjustments may result in bank instability, channel incision, and/or changes in channel pattern. The consequences of local scour are typically undetectable within a short distance (e.g., a length equal to a few channel-widths) of the scour.

Changes to the hydrologic function or sediment production in uplands will commonly trigger adjustments to channel position and/or channel pattern. Hydrologic changes might include a shorter response time (flashy events) and greater volume of overland runoff. Sediment load could change as a consequence of upland activities, such as logging, wildfire, chronic overgrazing, or other natural or management actions that decrease protective vegetation cover, decrease interception of precipitation, or decrease storage of precipitation.

Other anthropogenic activities that can be related to rapid channel adjustments include urbanization (Wolman, 1967; Dunne and Leopold, 1976); road construction, which can alter natural hydrologic processes by concentrating and diverting water into road ditches and culverts; dam construction, which can alter volume, time (seasonality), frequency, and duration of stream discharge, and sediment (e.g., Williams and Wolman 1984; Friedman et al. 1998; Magilligan et al. 2003); and interbasin water transfers, which could alter the volume of streamflow. This is not an exhaustive list of human impacts to streams, but rather a list of some common practices that have well-documented instances of causing stream incision.

In contrast to systemic aggradation and incision, with predictable changes in channel evolution upstream or downstream of a knickpoint, instability problems related to local conditions can often be attributed to redirection of flow caused by debris or structures (e.g., beaver dams). During moderate and high flows, obstructions often result in vortices and eddies that produce local scour, erosion of bank toes, and ultimately, bank failures. Constrictions in the channel from debris accumulations or structures also can cause a backwater condition upstream, with acceleration of flow and scour through the constriction. Local scour should not be interpreted as channel incision.

Channel incision of a magnitude and rate sufficient to be easily observed and measured is indicative of systemic instability. However, take care when interpreting changes in bed elevations along sand-bed channels. Scour and fill in some sand channels may approach 10 feet or more during the passage of a single flood event with virtually no long-term change in streambed elevation. Although such channels may be considered vertically unstable with respect to bed elevations, they may or may not be functioning properly for their landscape setting.

Correlation with other assessment items

Item 16 addresses vertical adjustments related to channel incision. Item 17 (stream in balance with water and sediment supplied) is broader in scope and addresses vertical adjustments related to either channel incision or channel aggradation. Also item 17 includes changes in channel size and shape with no net change in channel elevation.

Item 16 is also elated to items 1 (floodplain frequently inundated), 3 (sinuosity, width/depth ratio, and gradient in balance), 4 (riparian area expanding), and 8 (maintenance of soil moisture). When a channel incises, it becomes less likely that large flow events will overtop the banks and access the floodplain (item 1). Commonly, channel incision coincides with channel straightening and increased channel gradient (item 3), all factors which reflect increased and concentrated energy in the channel. When channels incise, the alluvial aquifer drains into the lowered channel and the water table declines. If the decline is greater than the effective rooting depth of the riparian plants, the plant community will also reflect drier conditions, which may be reflected in the answers to items 4 and 8.

Item 17: Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition).

Purpose

Streams transport water and sediment. Item 17 looks for any evidence that the sediment supply and transport capacity are out of balance, thus causing channel incision or excessive aggradation.

Observational Indicators and Examples

Item 17 is answered "no" whenever there is an observable imbalance between sediment supply and transport capacity. Field indicators of systems where sediment supply exceeds transport capacity might include:

- Formation of mid-channel bars or development of a braided channel bed in a stream that has the potential for a single-thread channel.
- Rapid floodplain aggradation with burial of riparian vegetation and floodplain soils;
- Burial of fence posts or other modern cultural artifacts.
- Rise in channel-bed elevation related to an accumulation of sediment in the channel.
- Incongruities in the particle-size relations of bedload, streambed surface textures and subsurface textures.

Field indicators of systems where driving forces exceed resisting forces include many of those features described under item 15 (lateral bank stability) and item 16 (vertical incision), particularly:

- Erosion (slump, sloughing, fracturing, slides) of unstable streambanks (Figure 33 and Figure 34).
- Development of knickpoints or knickzones with active upstream migration of headcuts (Figure 37).
- Greater height from channel bed to the floodplain downstream of a knickpoint or knickzone than upstream of the knickpoint/zone (Figure 37).
- A channel that has lost hydrologic connection to a floodplain (though this may be an inherited condition from a past period of incision; Figure 36).
- Channel cross-sectional areas that are enlarged and can convey discharges that are much greater than the mean-annual flood (Figure 36).

Different channel adjustments tend to occur in a given order, reflecting the magnitude of the imbalance and the time required for various adjustments to appear. For example, when sediment supply and transport capacity are imbalanced, a first response may be in the grain size of the stream bed, a subsequent response may be construction or removal of in-channel bars, progressing next to channel incision or bed aggradation, then bank erosion, and ultimately to an adjustment in channel slope (Wilcock et al. 2009).

Natural channels can be classified as either single-thread or multi-thread (braided or anastomosing) channels. Factors that determine channel pattern include sediment supply, sediment size (i.e., suspended versus bed load) and particle cohesion, stream discharge, and stream slope. A glacial outwash stream is an example of a system with a naturally braided channel pattern. Braided streams are characterized by highly variable discharge, high bank erosion, high sediment loads, deposition occurring as both longitudinal and transverse bars, and annual shifts of the bed location. Similar systems can be found where sand is the dominant bed material. Remember that each riparian area is assessed according to its potential.

If a stream has a single-thread channel, shows no evidence of mid-channel bars, and is not aggrading as a result of excess sediment from the watershed the answer to item 17 would be "yes." If the flow in a stream is increased from an interbasin transfer or diversion, and excessive erosion or deposition is taking place as a result of this increased flow, the answer to item 17 would be "no."

If a channel is found to be braided and has high streambank erosion, and these conditions are consistent with the landscape setting (i.e, natural sediment load, gradient and discharge) the answer to item 17 would be "yes." If braiding or bank erosion are the result of poor land management (e.g., clear-cut logging or road construction (Swanson and Dyrness 1975; Beschta 1978); hydraulic mining of placer deposits (James 1991, 1999), excessive erosion from agricultural practices (Knox 1977; Trimble 1983, 1985)); or other anthropogenic actions (e.g., the operation of a dam (Williams and Wolman 1984)), or water withdrawals, the answer to item 17 would be "no."

Particularly in gravel-bed streams, the presence of excess sediment might be detected by a comparison of the bedload with both the streambed's surface texture and the subsurface texture (Figure 24). When the modern bedload is similar to the substrate, then there is reason to believe the sediment supply and transport capacity are relatively well balanced. When the two differ substantially, there is reason to believe sediment supply and transport capacity are out of balance.

Item 17 should never be answered "NA"; it will always have a "yes" or "no" answer.

Supporting Science

Stream channels are constantly adjusting to the volume, seasonality, duration of streamflow and amount and caliber of sediment (Lane 1955; Leopold and Maddock 1953). Lane (1955) developed a conceptual model to describe the types of channel adjustments (aggradation or incision) that can occur in response to changes in sediment supply and transport capacity. Lane's conceptual model was developed into a schematic model by Borland (Figure 24) (1960; *in* Pemberton and Strand, 2005). Additional stream responses to disequilibrium can include a change in channel gradient, stream sinuosity, channel size and shape, and changes in sediment caliber. Interpretation of channel adjustments requires an understanding of changes in streamflow and sediment production throughout the drainage.

The processes of channel adjustment should be evaluated with respect to both temporal and spatial considerations. For example, channel adjustments related to rare, high-magnitude streamflow events (e.g., a 50- or 100-year flood) can change channel and valley bottom conditions immediately after such events; but they may not reflect any problems related to poor stream function. Likewise, headwater streams that produce large quantities of sediment need to be evaluated separately from reaches that transport and store sediment. The relations between sediment load and transport capacity, especially for gravel-bed streams, is discussed by Parker (1990), Bunte and Abt (2001), Pitlick et al. (2009), and Wilcock et al. (2009) among many others.

Correlation with other assessment items

This item is related to items 3 (sinuosity, width/depth ratio, and gradient in balance), 5 (watershed not contributing), 13 (floodplain and channel characteristics adequate to dissipate energy), and 16 (stream system not incising). Changes in sediment load or transport capacity have the effect of altering stream power, which in turn can produce changes in channel gradient, shape, and sinuosity (item 3). This item and item 5 are both dependent on the amount of water and sediment supplied by the drainage basin. However, the intent of item 5 is to determine where the cause of any riparian deterioration is occurring, i.e., is the cause from activities occurring within the immediate riparian area (in situ; which would correspond to a "yes" response in item 5) or from activities in the uplands or in riparian reaches that are upstream of the assessed reach (which would correspond to a "no" response in item 5).

Evidence of rapid aggradation from excess sediment is not only observed as in-channel deposits, but also is commonly found on the floodplain and in overflow channels; therefore, items 13 and 17 can be related. And though item 16 is exclusively about channel incision and active headcut migration, item 17 is broader in scope and includes processes of both channel erosion from downcutting, channel erosion from lateral enlargement, and stream aggradation of the channel and/or floodplain.

9. Instituting the Riparian Management Process

Once the PFC assessment has been completed, it can be used to help address planning and management efforts. Figure 38 illustrates the steps in the PFC assessment process as described in chapter 3.

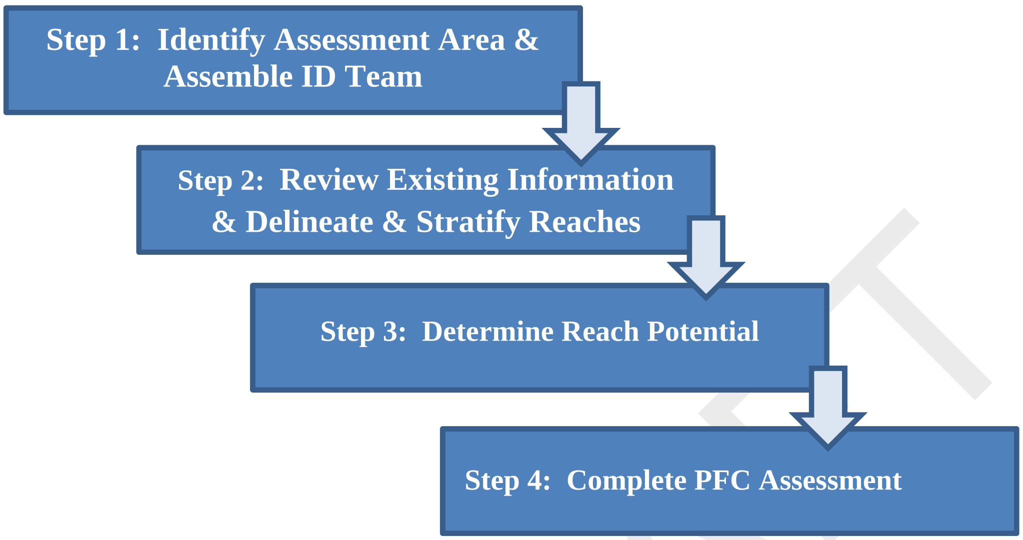

Figure 38. Steps for completing the PFC assessment

A logical sequence of six additional steps for incorporating information from the PFC assessment into a management approach is described below (note that steps 8-10 represent an iterative process (Figure 39). Steps 1-7 are not necessarily iterative and generally do not need to be repeated if done correctly unless dramatic disturbances such as fire or flood have considerably changed a reach.

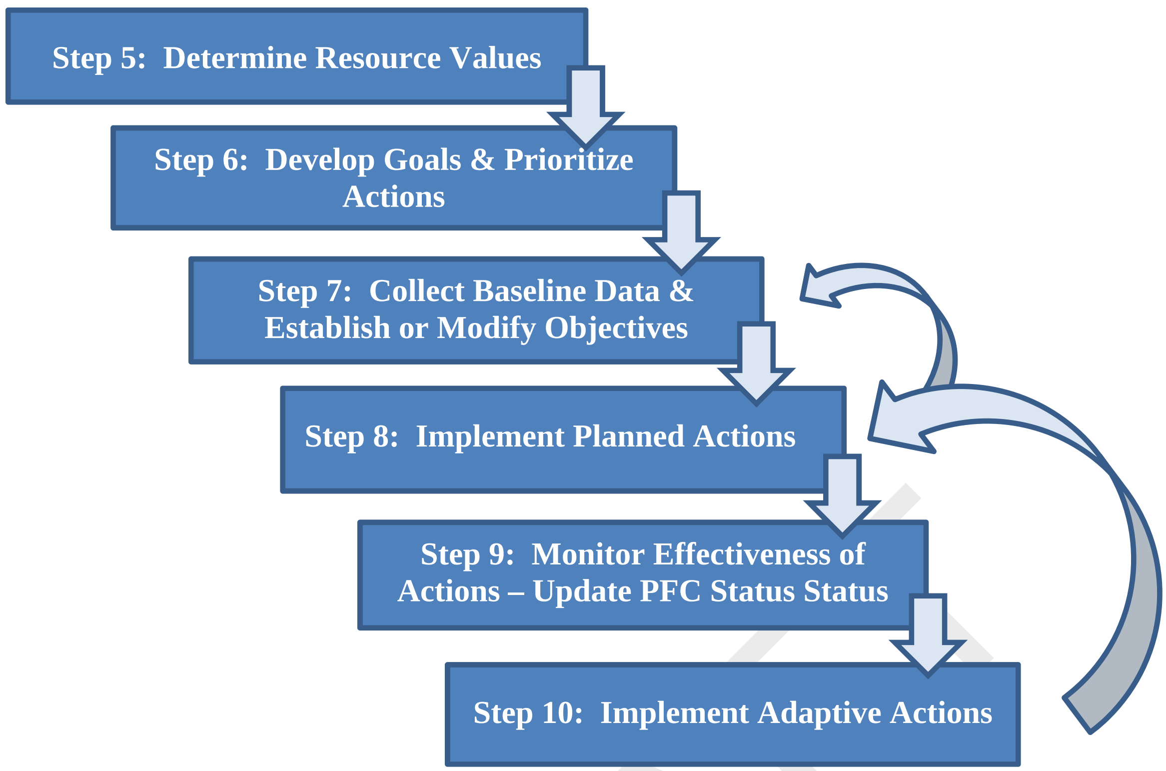

Figure 39. Recommended steps for Incorporating PFC into management

Step 5: Determine Resource Values

Within the assessment area, establish resource values for the various reaches to help establish priorities for management, restoration, and monitoring. Values include fish and wildlife habitat, recreational opportunities, livestock forage, sensitive plants, water quality, Endangered Species Act (ESA) requirements, species of concern, special interest areas, etc. While some level of resource values may be established in the land use plan, it is generally useful to validate and/or refine them at the reach scale following the PFC assessment.

Step 6: Develop Goals and Prioritize Actions

Information from the PFC assessment can be used to develop goals to ensure that management is maintaining reaches at PFC, and improving those identified as functional-at-risk and nonfunctional. Describe goals that are tied to the findings (issues) of the PFC assessment that can be refined later if quantitative data are collected.

Broad-scale prioritization is done during reach delineation and stratification (step 2) to determine which streams and reaches to assess and which assessment approach is to be used. When combined with an identification of resource values, the PFC assessment provides a basis for prioritizing reaches for management, restoration, or monitoring actions.

By concentrating on the sensitive at-risk areas that may be near the threshold of rapidly degrading into nonfunctional condition, timely restoration activities can halt the decline and begin the recovery process before deterioration progresses further and recovery actions are expensive. Often, once an area is nonfunctional, the effort/risk, cost, and time required for recovery is dramatically increased.

Restoration of most nonfunctional systems should be reserved for those situations where the riparian area has reached a point where recovery is possible, when efforts are not at the expense of at-risk systems, or when unique opportunities exist. At the same time, areas that are functioning properly are usually not the highest priorities for restoration because they are more resilient than the at-risk areas. However, it is critical to manage these areas to retain their resilience and further progress towards desired condition.

Because not all at-risk reaches have the same resource values, information from the PFC assessment must be combined with resource values to establish reasonable priorities. Reaches that are FAR with high resource values would be a higher priority than FAR reaches with low resource values.

The PFC assessment can also help determine the appropriate timing and help determine which elements to focus on in riparian restoration projects (including structural and management changes). It can identify situations where instream structures are either entirely inappropriate or premature.

Identifying systems at PFC also allows local managers to assess why these systems have fared well in the past and to possibly use them as models for recovery of similar systems.

The results of the PFC assessment can be used in watershed analysis. Whereas the methodology and data are reach-based, the ratings can be aggregated and analyzed at the watershed scale. The PFC method is most useful when condition is determined based on local information, experience, and knowledge of functions and processes at the watershed scale. Information from the PFC assessment, along with other watershed and habitat condition information, helps provide a good picture of watershed health and the possible causal factors affecting watershed health. The knowledge gained from applying the PFC assessment will help to identify watershed-scale problems and suggest management remedies and priorities. *These management decisions are derived by concentrating on the “no” responses and corresponding comments on the assessment form.*

Step 7: Collect Baseline Data & Establish or Modify Objectives

The ID team should acquire baseline data and establish resource objectives for reaches identified during the PFC assessment where there is a need for some kind of management action. Low priority reaches may only require infrequent qualitative monitoring while others may need formal DMAs, specific objectives, and quantitative monitoring. Regardless, information from the PFC assessment will allow the ID team to focus on key attributes that may need to improve and subsequently be monitored to determine if improvement has occurred.

If quantitative monitoring is planned, identify the key attributes to monitor and acquire baseline data to develop well-written objectives. Good objectives should be based on the potential of the stream and should include components illustrated by the acronym “SMART” (Adamcik et al. 2004):

(1) **S**pecific
(2) **M**easurable
(3) **A**chievable
(4) **R**esults-oriented
(5) **T**ime-fixed

Writing good objectives starts with determining the current state of a component (quantitatively) to establish a plan for how much it may need to change. To do this, quantitative baseline data needs to be obtained. Some baseline data may already have been collected for reaches where validation monitoring was done to support the PFC assessment (step 4). Representative DMAs should be based on priority actions (based on PFC assessment and resource values) for which monitoring will be used in adaptive management.” How much an attribute can be expected to change should be based on a reasonable estimate of the potential of the reach. Measurements at a reference DMA can be an effective way to establish quantitative objectives for the representative DMA.

Burton et al. (2011) provides a protocol for measuring 7 long term stream channel and streambank indicators useful for developing and monitoring the achievement of objectives. Other quantitative techniques can be used as appropriate to collect baseline data as well (see Appendix E). An example of using PFC in this process would be if item 11 “Adequate stabilizing riparian wetland vegetative cover is present to protect banks and dissipate energy during high flows” was given a “no” response and was a key factor in a reach being rated “at-risk.” A general *goal* for that reach would then include the need to improve stabilizing riparian cover on the streambanks. Once quantitative data is obtained on a DMA, one related “SMART” objective could be: Improve streambank stability from 65% to 85% in 5 years on Willow Creek at DMA WC#12.

It is sometimes advantageous to establish intermediate objectives (5-7 years) and long term objectives (> 7 years) for streams that need considerable time to recover. Note that progress towards management objectives is partly a function of management actions and partly controlled by environmental circumstances such as the timing of floods, droughts, fire and other watershed disturbances. Objectives may need to be modified as part of the adaptive management process; as a result, this step is part of the iterative cycle to accommodate the modification of objectives if necessary.

Step 8: Implement Planned Actions

Implement management or restoration actions for selected reaches, sites, or units within the assessment area (e.g. grazing allotment). In order to document actions and to help establish cause and effect relationships when evaluating trend, some level of implementation monitoring should be done periodically for ongoing activities such as grazing by livestock or wildlife. For grazed areas, Burton et al. (2011) provided techniques for short-term (annual) monitoring of stubble height, streambank alteration, and woody species use along the greenline.

Step 9: Monitor Effectiveness of Actions – Update PFC Status

Implement management or restoration actions for selected reaches, sites, or units within the assessment area (e.g. grazing allotment). In order to document actions and to help establish cause and effect relationships when evaluating trend, some level of implementation monitoring should be done periodically for ongoing activities such as grazing by livestock or wildlife. For grazed areas, Burton et al. (2011) provided techniques for short-term (annual) monitoring of stubble height, streambank alteration, and woody species use along the greenline.

Updating PFC Status

The need to update the status of a PFC assessment rating is common for various purposes (e.g. completing a National Environmental Policy Act - NEPA analysis). For example, if a stream reach was rated less than PFC during the initial assessment and a management change was implemented (step 8), the assessment will eventually need to be updated. Because PFC is not a monitoring tool, simply repeating a complete PFC assessment to detect improvement (or deterioration) is usually not particularly useful or necessary. This is because PFC is a coarse assessment tool that is not precise enough to detect small changes in condition. In addition, if the management steps presented in this chapter are used, some level of monitoring (qualitative and/or quantitative) will have been done. Therefore, using monitoring data is an appropriate and efficient way to update the status of a PFC assessment if a DMA has been established on the reach.

Re-assessing a reach for PFC in the same comprehensive manner as was done initially is necessary in some circumstances. Instances where dramatic ecological disturbances such as fire or flood have considerably changed a reach are examples of when re-assessing a reach with the PFC protocol may be necessary (in which case both potential and stratification of assessment reaches may also need to be redone). Also, if considerable time has elapsed since the initial assessment or if the quality of the original PFC assessment is suspect, the ID team may determine that a comprehensive PFC assessment needs to be redone.

The following example from step 7 will illustrate an effective way to update the status of PFC assessments where quantitative monitoring has been done:

1. The reach was rated functional-at-risk primarily due to a lack of adequate stabilizing riparian vegetation on streambanks (item 11).
2. Baseline data collected shortly after the PFC assessment revealed that streambank stability was 65% and the streambank lacked stabilizing riparian plants.
3. Effectiveness monitoring done on Willow Creek DMA WC#12 five years after the PFC assessment and baseline data were obtained revealed that streambank stability had improved from 65% to 85% (assuming 85% is adequate), and vegetation composition on the streambank had experienced a similar increase in stabilizing riparian plants.
4. The ID team would consider the “no” recorded for item 11in the initial PFC assessment to now be a “yes” as improvement is now conclusive for this item.
5. The ID team would then observe the rest of the reach to validate if the other “yes” responses are still valid and if so, the reach can be now be considered to be at PFC.

If DMAs were not established and quantitative baseline monitoring was not completed following the PFC assessment, high quality photo points or other qualitative monitoring information can be used to update the PFC assessment. This generally works best where quantitative baseline data were not collected because the stream reach was a low priority for monitoring (e.g. the reach was located in a complex that is not sensitive to management and was rated at PFC).

Step 10: Implement Adaptive Actions as Necessary

Modify actions if not making acceptable progress towards meeting the established goals or objectives. In some cases, the original objectives may need to be modified to incorporate knowledge acquired from monitoring and adaptive actions.

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Glossary

Active Floodplain - The level surface adjacent to a stream and formed under the present flow regime. The active floodplain is inundated at least once or twice (on average) every 3 years.

Aggradation (vertical)– The geologic process by which a stream bottom or floodplain is raised in elevation by the deposition of material.

Alluvial - Deposited by running water.

Anastomosing – Multiple channels with relatively permanent, stable vegetated islands. Banks are cohesive, and sediment load is primarily suspended load.

Bankfull, Bankfull stage (or elevation) – The elevation of the bank where flooding begins. The bankfull level is associated with the streamflow that just fills the channel to the top of its banks where water begins to overflow onto the floodplain. This streamflow level is often associated with moving sediment, bar formation, and, generally, the work that forms the morphological characteristics of the stream channel (Wolman and Miller 1960).

Community Dynamics (Vegetation) - Response of plant communities to changes in their environment, to their use, and to stresses to which they are subjected. Climatic cycles, fire, insects, grazing, and physical disturbances are some of the many causes of changes in plant communities. Some changes are temporary, whereas others are long lasting.

Community type—a repeating classified and recognizable assemblage or grouping of plant species. Riparian community types represent the existing structure and composition of plant communities with no indication of successional status. They often occur as patches, stringers, or islands, and are distinguished by floristic similarities in both their overstory and understory layers.

Degradation – geologic process that produces lowering of the stream channel due to erosion. Also referred to as downcutting.

Dynamic equilibrium – a system in a steady state in which parts of the system are continually changing, but are moving in opposite directions at equal rates so that the overall system is not changing.

Ecological Site (Riparian) – a kind of land with specific physical characteristics which differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its response to management. An area of land with a specific potential plant community and specific physical site characteristics, differing from other areas of land in its ability to produce vegetation and to respond to management. Ecological site is synonymous with range site.

Ecotone – A transition area of vegetation between two communities, having characteristics of both kinds of neighboring vegetation as well as characteristics of its own. Varies in width depending on site and climatic factors.

Entrenchment – describes the relationship of the stream to its valley and landform features. It is qualitatively defined as the vertical containment of a stream and the degree to which it is incised in the valley floor; channel incision.

Ephemeral – A stream that flows only in direct response to precipitation, and whose channel is above the water table at all times.

Floodplain - A relatively flat landform adjacent to a stream that is composed of primarily unconsolidated depositional material derived from the stream and that is subject to periodic flooding.

Fluvial - Shaped by the movement of water, particularly channelized flow.

Geomorphology – the study of landforms and the processes that shape them.

Graded stream – a stream maintaining an equilibrium between the processes of erosion and deposition, and therefore between *aggradation* and *degradation*. It is also defined as one in which, over a period of years, slope is delicately adjusted to provide, with available discharge and the prevailing channel characteristics, just the velocity required for transportation of the load supplied from the drainage basin.

Greenline – The first perennial vegetation that forms a lineal grouping of community types on or near the water's edge. Most often it occurs at or slightly below the bankfull stage (Winward, 2000). A linear grouping of perennial plants at or near the water's edge along a stream channel (Burton et al. 2011).

Hydraulic Control - Features of landform (bedform and bed material), vegetation, or organic debris that control the relationship between stage (depth) and flow rate (discharge) of a stream.

Hydraulic radius – the ratio of the cross-sectional area to the wetted perimeter.

Hydric -- characterized by, relating to, or requiring an abundance of moisture.

Hydrogeomorphic - Features pertaining to the interaction of water and landform.

Hydroperiod – period of time during which soils, waterbodies, and sites are wet.

Hyporheic zone - a unique hydrochemical and biological region beneath and lateral to a stream bed, where there is mixing of ground water and surface water.

Incised channel – a stream that through erosive lowering of the streambed is cutting its channel into the bed of the valley, and no longer accesses its floodplain in relatively frequent events.

Intermittent – A stream that flows only at certain times of the year when it receives water from springs or from some surface source such as melting snow in mountainous areas.

Interrupted - A stream with discontinuities in space. The interrupted reach only flows as groundwater beneath the bed elevation except perhaps during high flows.

Large Wood - Pieces of wood in a stream that affect channel morphology by splitting flows, dissipating stream energy, and capturing and storing sediment/bedload. Beyond a minimum threshold, size varies with stream size but generally can be described as large enough to have low probability of being moved by the stream (Bilby and Ward 1987). Pieces with a length of one-half the channel width or larger are generally considered as stable (Bisson et al. 1987).

Lentic – of, relating to, or living in still waters (as lakes, ponds, or swamps).

Lotic – of, relating to, or living in actively moving water.

Mean-annual Flood – the average of annual peak flows for a period of record.

Perennial – A stream that flows continuously. Perennial streams are generally associated with a water table in the localities through which they flow.

Potential – is the highest ecological status a riparian area (stream reach) can attain in the present climate.

Redoximorphic features – Soil features formed by the process of reduction, translocation, and/or oxidation of iron and manganese oxides; formerly called mottles and low-chroma colors.

Sinuosity – Degree to which a stream channel curves or meanders laterally across the land surface. The ratio of channel length divided by valley length.

Stabilizer – are plant species that become established along edges of streams, rivers, ponds, and lakes. Although they generally require hydric settings for establishment, some may persist in drier conditions once they have become firmly established. They commonly have strong, cord-like rhizomes as well as deep fibrous root masses. They are able to buffer streambanks against the erosive forces of moving water. Examples include Nebraska sedge and Geyer's willow.

State-and-transition model - a conceptual ecological model describing the relationships and changes between persistent vegetation communities possible at a site.

Stream Energy/Power - A measure of a stream's ability to erode and transport sediment. It is equal to the product of shear stress and velocity.

Thalweg - The line followed by the majority of the streamflow. The line connecting the lowest or deepest points along the streambed.

Watershed – a region or area bounded peripherally by a divide and draining ultimately to a particular watercourse or body of water; drainage basin for a stream; catchment.

Wetted perimeter – the distance along the stream bed and banks at a cross-section where they contact the water.

Woody Material - Pieces of wood in a stream that affect channel morphology by splitting flows, dissipating stream energy, and capturing and storing sediment/bedload. Beyond a minimum threshold, size varies with stream size but generally can be described as large enough to have low probability of being moved by the stream (Bilby and Ward 1987). Pieces with a length of one-half the channel width or larger are generally considered as stable (Bisson et al. 1987).

Appendix A—Instructions and Forms

Reach Information Form – Instructions

Background Information.

1. Provide pertinent background information.
2. List all members of core ID team by name and discipline. Include others not on the core ID team and identify their role as extended team members.
3. Indicate the nature of the assessment method (i.e., complete field reconnaissance, inspection of selected representative areas, or a combination using remote imagery and selective field inspections).
4. Attach an aerial photograph and/or topographic map showing the location of the reach with reach breaks.

Reach Breaks.

5. Record the upper and lower reach breaks in one or more geographic systems (latitude and longitude in degrees, minutes, and seconds, or in decimal degrees; or Universal Transverse Mercator (UTM) coordinate system). If UTM coordinates are used, indicate the UTM zone; for latitude-longitude coordinate systems, provide the datum (or geographic coordinate system; e.g., North American Datum 1927 (NAD27), North American Datum 1983 (NAD83), World Geodetic System 1984 (WGS 84)). Omission of the datum can result in aberrations whenever the geographic data are projected in a different coordinate system than the one used to fix the location originally.
6. Provide a rationale for reach breaks. For example, "Reach begins at transition from confined bedrock reach to unconfined alluvial reach"; or "Reach ends at fence line along private land."

Description of the riparian complex.

7. Record information that describes the geomorphic characteristics of the riparian complex, including the valley bottom type, stream type, stream gradient, entrenchment ratio, sinuosity, width/depth ratio, bank and bed materials, and any other physical features that describe the riparian complex.
8. Record the existing dominant community type(s) before or after assessing the reach.
9. Describe the potential natural condition (or altered potential), which includes both the dominant plant community type(s) and the stream type(s).

Previous assessments and monitoring data.

10. Indicate if the reach has been previously assessed. If it has been assessed, indicate when, the previous functional rating(s), and any trend information.

11. Indicate if a DMA has been established within the reach. Indicate when the DMA was monitored.
12. Include copies of existing data to inform the current assessment effort.

Riparian Plant List Form

A detailed riparian plant list includes: plant codes (column PCODE), common and/or scientific name(s) of plants, their relative abundance (column AB), their wetland indicator category (column WIC), their geomorphic location (column LOC), and their stability class (column SC).

Presence/relative abundance. Document the riparian species observed in the reach to answer item 6. The ID team may choose to indicate the presence of a plant with a checkmark in the AB column or preferably to note the relative abundance of each species observed using a numerical scale, ranging from 1-4. The scale is not based on plant-cover data collected from quadrats but on a crude visual estimation of the abundance of a species in a given reach. In this scale:

1 = Species present, but with only one to a few individuals found in the reach.
2 = Species found intermittently or occasionally throughout reach.
3 = Species generally common and missing in comparatively small parts of the reach.
4 = Species abundant and found along the entire reach.

Location. The location of riparian plants with different wetland indicator status helps address item 8 (Species present indicate maintenance of riparian soil-moisture characteristics) and item 4 (Riparian area is expanding or has achieved potential extent.) The ID team can learn much about the depth to a shallow water table by noting which geomorphic surfaces have hydric plants and which have upland plants. Geomorphic surfaces include: C= active channel; B = streambank; F = floodplain; MC = mid-channel bar; PB = point bar; T = terrace; specify and define others.

Wetland indicator Categores (WIC). The ID team can address item 8 by noting the WIC (U.S. Fish and Wildlife Service 2012, 1988, 1993) of individual species throughout the riparian area. The WICs include: obligate wetland (OBL), facultative wetland (FACW), facultative (FAC), facultative upland (FACU) and obligate upland (UPL). See item 8 (p. 76) and the footnotes at the end of the riparian plant list (p. 137) for details.

The wetland indicator status of plants can change from one region to the next. Note the U.S. Fish and Wildlife region (see http://plants.usda.gov/wetinfo.html) for the assessed reach on the riparian plant list.

Stability class. Item 9 asks if the right plants/plant communities (i.e., those with strong, stabilizing root systems) are present to protect streambanks during high flows. A few studies (e.g., Winward 2000) have attempted to quantify the relative rooting strength of common riparian plants. Winward (2000) used a numerical scale from 1 (weakest) to 10 (strongest) to denote relative rooting strength of various community types. However, when ID teams conduct PFC assessments, they are not making the quantified measurements to justify use of highly detailed numerical scales. Also, the plant list typically lists individual species and not community types. Therefore, a broad three-tier scale of “low,” “medium,” and “high” rooting stability is recommended for PFC assessments. These classes approximate Winward’s (2000) stability classes of 1-3 for “low,” 4-6 for “medium,” and 7-10 for “high.” The MIM data analysis module by Burton et al. (2011) contains stability classes for most riparian plants in the central and western United States.

Photo Log

Photographs to support key observations are an important part of a PFC assessment. Each photograph may have readily apparent meaning to one or more ID team members immediately after the assessment; but time, change in personnel, retirement, and poor memories may quickly obscure the location, meaning, and importance of photographs. A brief description of the key feature should be recorded for each photograph. Preferably, the location of photographs will be determined by a global positioning system (GPS) and marked on an attached aerial photograph or topographic map. Storage of GPS photopoints in a GIS will facilitate electronic storage and retrieval of photographs on a reach-by-reach manner.

Reach Information Form

I. Background information Date:____________________

Name of Riparian Area:______________________________ Reach ID:________________

Management Unit (Allotment/Pasture; other):______________ State:_____ Office:__________

Observers:____

____

Assessment method: Reach length (miles/km):________________

☐ Complete reconnaissance
☐ Selective inspection of representative areas
☐ Remote imagery with selective ground inspection

Location: Attach aerial photo or USGS 7.5-minute topographic map with reach breaks indicated.

II. Reach breaks

Reach starting point (upstream)	**Reach ending point (downstream)**
________N. Lat. or UTM E________m ________W.Long. N________m	________N. Lat. or UTM E________m ________W.Long. N________m

Positions by GPS? ☐ Yes ☐ No Photos taken? ☐ Yes ☐ No UTM Zone____________

Datum: ☐ NAD27 ☐ NAD83 ☐ WGS84 ☐ Other (specify):____________

Rationale for reach breaks:____

____

____

III. Channel Descriptors: Indicate if values are estimated (X) or measured (√).

Valley bottom type:____________ Stream type:________ Stream gradient:_________%

Entrenchment ratio:__________ Sinuosity:___________ Width/Depth ratio:__________

Bed materials:________________________ Bank materials:____________________

Existing dominant community type(s):____

____

☐ Potential or ☐ Altered potential description (dominant community type(s), stream type): _____

____

____

____

____

____

IV. Previous assessments/monitoring

Has the reach been previously assessed? ☐ Yes ☐ No

If yes, provide date(s) and ratings:____

Have designated monitoring area(s) (DMA) been established? ☐ Yes ☐ No

Type of DMA: ☐ MIM ☐ PIBO ☐ Winward paced methods ☐Other (specify)____________________

DMA ID:____

Dates of data collection:____

Riparian Plant List Form

Riparian Area______________________ Reach ID_______________ Date_____________

U.S. Fish and Wildlife Service Region:________________

√	PCODE	Common Name	Scientific Name	AB	LOC	WIC	SC
Trees/Shrubs							
Graminoids/Grasses							
Forbs							

EXPLANATION OF PLANT LIST

√ Check species present.

AB: Abundance (1-4). 1 = species is present but with only 1 to a few individuals in the area; 2 = species is found occasionally throughout the area; 3 = species is common throughout the area; 4 = species is ubiquitous throughout the area.

GS: Geomorphic Surface. C= active channel; B = streambank; F = floodplain; MC = mid-channel bar; PB = point bar; T = terrace; **specify and define others**.

WIC: Wetland Indicator Category. (See "2012 National Wetland Plant List" (Lichvar 2012) or the USDA-NRCS PLANTS Database (http://plants.usda.gov/java/))

Indicator Code	Wetland Type	Comment
OBL	Obligate Wetland	Occurs almost always (estimated probability 99%) under natural conditions in wetlands.
FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
FAC	Facultative	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
FACU	Facultative Upland	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).
UPL	Obligate Upland	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.
NA	No agreement	The regional panel was not able to reach a unanimous decision on this species.
NI	No indicator	Insufficient information was available to determine an indicator status.
NO	No occurrence	The species does not occur in that region.

SC: Stability Class/Rooting Strength. Relative values based on general rooting characteristics assigned by Burton et al. (2011); and numerical values conform to Winward (2000).

Forbs	
Taproot and/or most roots, shallow (<15.2 cm.)	Low (2)
Fibrous roots, usually up to 30.5 cm.	Medium (5)
Rhizomatous roots, little indication of extensive fibrous roots	Medium (5)
Rhizomatous roots, with extensive fibrous roots	High (8.5)
Graminoids	
Annual, biennial, and short-lived perennials	Low (2)
Stoloniferous, cespitose, tufted, or short rhizomatous perennials (<1 m tall)	Low (2)
Slender or thin creeping rhizomes	Medium (5)
Long, stout, well-developed creeping rhizomes	High (8.5)
Woody Species	
Taprooted species	Low (2)
Short shrubs (<1 m tall) with shallow root systems	Low (2)
Shallow to moderate root systems	Medium (5)
Rhizomatous root system, generally shallow (<12 in.)	Medium (5)
Root crown with spreading roots	High (8.5)
Widespread root systems	High (8.5)

PFC Assessment Form – Instructions

1. Prior to completing the form, examine the entire reach using the selected approach (complete reconnaissance or selective inspections). The team should take notes and photographs and discuss key attributes observed along the reach.

2. The form is completed by the ID team after the reach is examined. Examining multiple reaches and then completing several forms at once is not advised. The end of an assessment reach (reach break) where the team completes the form often coincides with an ecotone. Ecotones are generally not representative of average reach conditions, and teams should not use observations from the ecotone to represent reach conditions.

3. Mark one box for each item on the list *unless* the ID team concludes that there is strong evidence that neither a conclusive "yes" nor "no" is appropriate or that both apply; if this is the case, check *both* the "yes" and "no" boxes for that item. This approach should be used sparingly, and the team should work to make a conclusive determination of a "yes" or "no" for each item. The "NA" box is provided for reaches that do not have the potential for that item.

4. Document the response to each item with a short narrative describing their rationale. Because PFC is a qualitative assessment, it is important that rationale be provided for each item. As the assessment form is being completed, the ID team should frequently refer to Chapter 5 for the purpose of each item and useful observational indicators.

5. Following the completion of all 17 items, read the definitions of the three functional categories, discuss how the assessment items were rated, and determine the functional rating category of the reach. A short narrative should be provided describing the rationale used for the selected rating.

6. Address trend for FAR reaches. Trend can be addressed by using "monitored trend" (using supplemental information) or "apparent trend" (based on a one-time observation of indicators). Provide a short narrative describing the rationale used for the trend determination.

7. Based on the condition of the reach, estimate the status of the reach within the PFC and FAR categories on the stylized thermometer scale to the nearest third of the category (Figure A-1). For example, if the reach appears to be FAR but close to PFC, the appropriate blocks in the FAR category should be filled in on the thermometer. The purpose of using this scale on the thermometer is to provide important additional information for decision making. For example, FAR

reaches at the bottom of the scale may be managed differently than those almost at PFC.

8. If the reach is rated FAR or NF, the ID team must determine if there are factors contributing to those conditions that are outside the control of the manager. If the reach is rated PFC, it is also useful to document any factors that may affect the achievement of desired condition for other values. Indicate “yes” or “no” and the factor(s) that are contributing and describe in the remarks section.

9. Complete summary remarks and use additional space if needed. Note that attributes and processes that drive the assessment are documented with written comments and photographs. For example, if item 11 (“Adequate stabilizing riparian vegetation is present to protect banks…”) is no for a reach, it is critical that this is supported with written observations and photographic evidence.

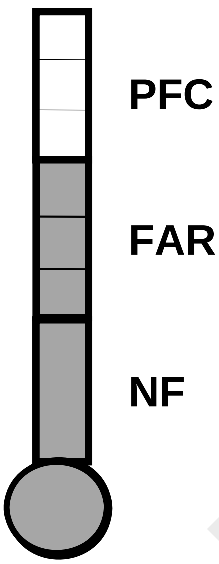


Figure A-1. Stylized “thermometer” scale for recording functionality. Example shows a shaded thermometer in the upper third condition of FAR.

Lotic PFC Assessment Form

Riparian Area____________________Reach ID_____________Date____________

Yes	No	NA	HYDROLOGIC
			1) Floodplain is inundated in “relatively frequent” events.
Rationale:			
			2) Beaver dams are stable.
Rationale:			
			3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region).
Rationale:			
			4) Riparian area is expanding or has achieved potential extent.
Rationale:			
			5) The watershed is not contributing to riparian impairment.
Rationale:			

Yes	No	NA	VEGETATIVE
			6) There is stabilizing riparian vegetation for recovery/maintenance.
Rationale:			
			7) There is recruitment of stabilizing riparian vegetation for recovery/maintenance.
Rationale:			
			8) Species present indicate maintenance of riparian soil-moisture characteristics.
Rationale:			
			9) Plant communities that have root masses capable of withstanding high streamflow events are present along the streambank.
Rationale:			
			10) Riparian plants exhibit high vigor.
Rationale:			
			11) Adequate stabilizing riparian vegetative cover is present to protect banks and dissipate energy during high flows.
Rationale:			
			12) Plant communities are an adequate source of woody material.
Rationale:			

Yes	No	NA	GEOMORPHOLOGY
			13) Floodplain and channel characteristics (i.e., rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy.
Rationale:			
			14) Point bars are revegetating with stabilizing riparian plants.
Rationale:			
			15) Stream banks are laterally stable.
Rationale:			
			16) Stream system is not incising.
Rationale:			
			17) Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition).
Rationale:			

Summary Determination

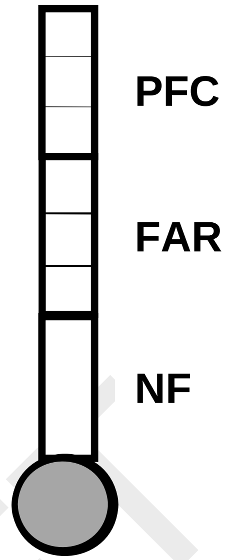
Functional Rating (check one)

___ Proper Functioning Condition

___ Functional-at-risk

___ Nonfunctional

___ Unknown



Trend (check one)

Monitored Trend	Apparent Trend
___ Up	___Up
___ Down	___Down
___ Static	___Not Apparent

Rationale for Rating: ______________________________

Rationale for Trend: ______________________________

Are there factors present preventing the achievement of PFC or affecting progress towards desired condition that are outside the control of the manager?

___Yes ___No

If yes, what are those factors? Check all that apply.

___ Flow regulations
___ Mining activities
___ Upstream channel conditions
___ Channelization
___ Road encroachment
___ Oil field water discharge
___ Augmented flows
___ Other (specify:)____________________

Explain:____

(Revised 2012)

Appendix B—Rosgen Classification System

For the purposes of this document, stream types will be described using the Rosgen stream classification system (Rosgen 1996). This system is widely used and provides a good “common language” to communicate information about channel morphology.

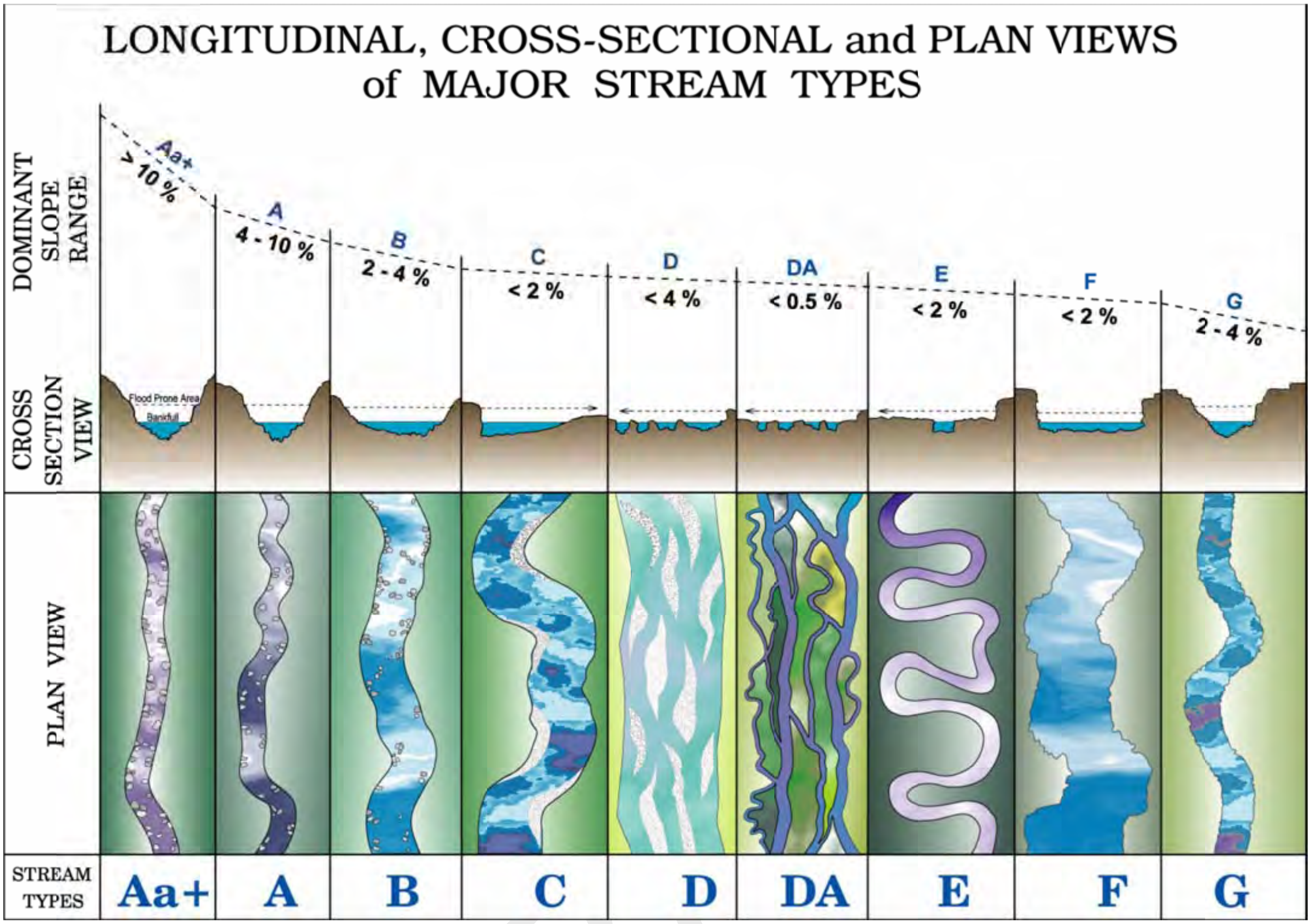
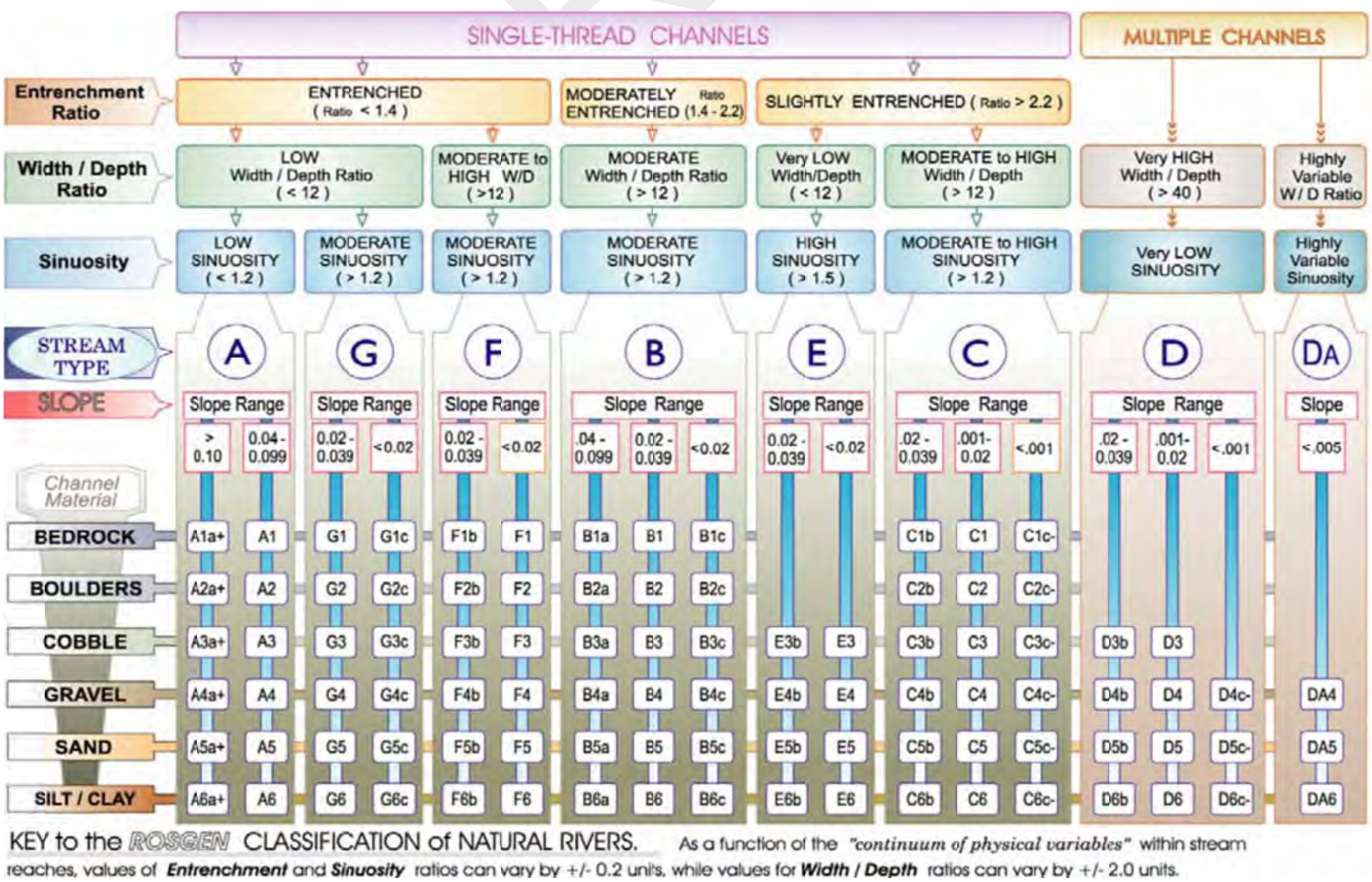


Figure 1. Broad-level stream classification delineation showing longitudinal, cross-sectional and plan views of major stream types (Rosgen, 1994).



Appendix C—Example Assessment

Example Creek was historically summer grazed until 1998. At that time grazing management was changed to allow for riparian and stream recovery. An assessment or inventory was not completed prior to management change.

A PFC assessment was conducted on Reach 3 of Example Creek on August 17, 1998 to determine current condition and short and long-term monitoring needs. The PFC assessment was conducted by an interdisciplinary team (ID team) following the protocols set in TR 1737-15 (Prichard et al. 1998).

Setting: Mid-elevation stream in central Idaho. Current vegetation on the terrace is a dry meadow with ponderosa pine on the hillsides. The channel is deeply incised on one side of the meadow. Hydrologic controls include a culvert through the highway above the upper end of the reach and an old railroad bridge at the lower end.

Soils are the Blackwell clay loam series on 0 to 5 percent slopes. The typical profile is clay loam 0 to 20 inches with stratified gravelly coarse sand to clay loam 20 to 60 inches. It is a poorly drained wet meadow ecological site. A consolidated layer of clay loam occurs about 20 to 30 inches below the surface. Water was seeping into the stream from the top of that layer. Note the dark soil layer in figures 4, 5, and 6.

Livestock typically grazed the area during the summer. The hot season grazing was removed in 1998. The mountains around the meadow have been extensively logged for many years.

An estimated 100 year flood occurred on this stream in January 1998.

Reach Information Form

II. Background information Date: 08/17/1998

Name of Riparian Area: Example Creek Reach ID: 005

Management Unit (Allotment/Pasture; other): Cow pasture State: ID Office: BLM Office

Observers: A. Jones, B. Smith, C. Doe, D. White

Assessment method: Reach length (miles/km): 1.2 miles

☒ Complete reconnaissance
☐ Selective inspection of representative areas
☐ Remote imagery with selective ground inspection

Location: Attach aerial photo or USGS 7.5-minute topographic map with reach breaks indicated.

II. Reach breaks

Reach starting point (upstream)	Reach ending point (downstream)
______N. Lat. or UTM E 39.717223m ______W.Long. N -105.124741m	______N. Lat. or UTM E 39.728049m ______W.Long. N -105.13161m

Positions by GPS? ☒ Yes ☐ No Photos taken? ☒ Yes ☐ No UTM Zone 13

Datum: ☐ NAD27 ☒ NAD83 ☐ WGS84 ☐ Other (specify):________

Rationale for reach breaks: This reach starts at the highway road crossing and continues 1.2 miles downstream. The reach has a moderately wide valley bottom than above and riparian soils are sandier than the upstream meadow soils. End of reach shows a change in gradient after a county gravel road crossing and bridge.

III. Channel Descriptors: Indicate if values are estimated (X) or measured (√).

Valley bottom type: X mod. to wide stream type: X C Stream gradient X 0.05 %

Entrenchment ratio: X >2.2 Sinuosity: X >1.2 Width/Depth ratio: √ >12

Bed materials: Consolidated clay loam layer Bank materials: clay loam to gravelly coarse sand

Existing dominant community type(s): Geyer-booth willow/beaked sedge-water sedge; Gray alder/water sedge-beaked sedge-small fruit bulrush; Coyote willow. Beaked sedge-small fruited bulrush/booth willow communities with scattered Geyer willow and gray alder.

☒ Potential or ☐ Altered potential description (dominant community type(s), stream type):

Based on review of the applicable classifications and other local information, reach potential is estimated to be an E4 stream type dominated by carex aquatilis-carex nebrascensis

IV. Previous assessments/monitoring

Has the reach been previously assessed? ☐ Yes ☒No

If yes, provide date(s) and ratings:____

Have designated monitoring area(s) (DMA) been established? ☒Yes ☐ No

Type of DMA: ☒ MIM☐ PIBO ☐ Winward paced methods ☐ Other (specify)____________

DMA ID:__________DMA0023____

Dates of data collection: established for future monitoring not yet collected

Lotic PFC Assessment Form

Riparian Area Example Creek Reach ID 005 Date 08/17/1998

Yes	No	NA	HYDROLOGIC
X			1) Floodplain inundated in "relatively frequent" events.
Rationale			A floodplain is partially developed, particularly along the left-hand side (looking upstream). All pictures show some floodplain development.
		X	2) Beaver dams are stable.
Rationale			No beaver dams present.
	X		3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region).
Rationale			The sinuosity appears to be appropriate. The width/depth ratio is not appropriate as the channel is excessively wide and shallow. The channel is dish shaped rather than trapezoidal. The gradient is appropriate for the setting. (Photos 3 and 8).
X			4) Riparian area is expanding or has achieved potential extent.
Rationale			The riparian area is in the process of expanding outward from the stream due to the continuing development of the floodplain. Stabilizing vegetation is also expanding along the greenline (at the top of point bars and just getting started at the toe of terraces) which is evidence of channel narrowing. (Photos 3 and 5)
X			5) The watershed is not contributing to riparian impairment.
Rationale			Current impairment is not due to upstream or upland sources of excess water or sediment, but is local in nature. The stream and riparian area are recovering from past incision and recovering after the 1998 change in livestock grazing management.

<table>
<tr><th>Yes</th><th>No</th><th>NA</th><th>VEGETATIVE</th></tr>
<tr><td>X</td><td></td><td></td><td>6) There is stabilizing riparian vegetation for recovery/maintenance</td></tr>
<tr><td colspan="4">Rationale There are at least four herbaceous stabilizers (two sedges, one juncus, and one bulrush), and three woody stabilizer species (willow and alder) present throughout the reach. See plant list. (Photo 1)</td></tr>
<tr><td>X</td><td></td><td></td><td>7) There is recruitment of stabilizing riparian vegetation for recovery/maintenance.</td></tr>
<tr><td colspan="4">Rationale Herbaceous stabilizers listed in #6 are visibly reproducing and expanding on point bars and along the streambanks (as evidenced by visible colonization of new shoots at the perimeter of existing patches). Young and mature woody stabilizers listed in #6 occur throughout the reach on the appropriate geomorphic surfaces (their respective position relative to the water table). (Photo 2).</td></tr>
<tr><td>X</td><td></td><td></td><td>8) Species present indicate maintenance of riparian soil-moisture characteristics</td></tr>
<tr><td colspan="4">Rationale Obligate and facultative wetland species occur along most of the reach on the appropriate geomorphic surfaces where they are expected (see plant list). This is evidence that the water table is being effectively maintained (all photos)</td></tr>
<tr><td>X</td><td></td><td></td><td>9) Plant communities that have root masses capable of withstanding high streamflow events are present along the streambank.</td></tr>
<tr><td colspan="4">Rationale Distinct sedge, bulrush, willow and alder communities are present throughout the reach (Photos 2 and 6). In the upper part of the reach, sedge/rush communities are forming amongst scattered willows. Where the streambank has eroded or sloughed off, upland species and scattered Nebraska sedge plants (low in vigor) occur along the top of the streambanks and on terraces.</td></tr>
<tr><td>X</td><td></td><td></td><td>10) Riparian plants exhibit high vigor</td></tr>
<tr><td colspan="4">Rationale Most of the key stabilizing riparian plants are expanding, producing adequate seed and exhibit substantial robust growth (Photos 2 and 6). There are no indications of plant stress and the growth form of woody plants has not been altered by browsing. Nebraska sedge observed on the terrace is low in vigor but because they are no longer connected to the shallow water table (due to incision), they are diminishing as is expected.</td></tr>
<tr><td></td><td>X</td><td></td><td>11) Adequate stabilizing vegetative cover is present to protect banks and dissipate energy during high flows</td></tr>
<tr><td colspan="4">Rationale Considerable bank instability is present in the form of slough and slump blocks and a large proportion of the streambanks are bare (estimated 40% bare banks). This stream is estimated to require a minimum of about 80% stabilizing vegetative cover for function. Although some regeneration is occurring, the cohesive soils appear to be retarding vegetation reestablishment (Photos 3,5, and 8).</td></tr>
<tr><td></td><td></td><td>X</td><td>12) Plant communities are an adequate source of woody material (for maintenance/recovery)</td></tr>
<tr><td colspan="4">Rationale Although coniferous forest (pine) occurs on adjacent slopes, woody material is not required for function on this reach. After the stream has recovered, woody material may accent function and habitat values in some parts of the reach where trees can fall onto the floodplain or in the channel.</td></tr>
</table>

Yes	No	NA	GEOMORPHOLOGY
	X		13) Floodplain and channel characteristics (i.e., rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy.
Rationale The floodplain is not yet wide enough to adequately dissipate energy as evidenced by only patches of vegetation becoming established at the toe of outside meaner bends (bottom of cut-banks). The floodplain size is close to being adequate as evidenced by the presence of an angle of repose and some lineal establishment of vegetation on the bottom of cut-banks; however, this is not occurring on enough of the reach for a yes response. (Photos 3, 5, and 8).			
X			14) Point bars are revegetating with stabilizing riparian plants
Rationale Point bars are vegetating with sedges, bulrush, willow, and alder. (Photo 7).			
X			15) Stream banks are laterally stable
Rationale There is no evidence of channel avulsions or excessive erosion between meanders.			
X			16) Stream system is not incising.
Rationale No headcuts or energy jumps are evident. Presence of past incision (Photos 5 and 6).			
	X		17) Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition).
Rationale Although improving, excess erosion is present along the streambanks, due to a lack of deep rooted vegetation. The erosion is due to onsite reach conditions.			

Summary Determination

Functional Rating

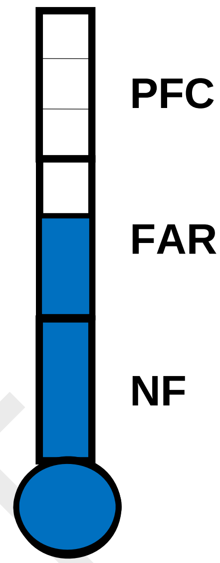
___ Proper Functioning Condition

__ **X** _ Functional-at-risk

___ Nonfunctional

Trend

Monitored Trend	Apparent Trend
___ Up	**X**_ Up
___ Down	___Down
___ Static	___Not Apparent



Rationale for Rating: The lack of an adequate amount of stabilizing riparian vegetation along the streambank and the overwidened channel are the most significant factors attributable to the reach being rated functional-at-risk. All of the “no” responses are associated with the lack of vegetation along portions of the streambank (Items 3,11, 13, and 17) that help maintain streambank stability and dissipate stream energy.

Stabilization of the sloughing and eroding streambanks with deep rooted stabilizing riparian plants is very important for recovery in this reach. . Upland species on the top of the bank lack the root mass necessary to stabilize streambanks.

Rationale for Trend: The apparent trend upward is based on the presence, expansion, and high vigor of key herbaceous riparian vegetation. A winter flood event (this past winter) buried much of the existing vegetation with sediment and there is clear evidence that riparian vegetation is growing through the deposition. The cohesive soils appear to be retarding vegetation reestablishment.

Grazing practices in this reach were changed from summer long grazing in 1998 and are allowing riparian recovery. There is visual evidence of legacy bank trampling from livestock, with large percentages of banks still bare. However, current livestock grazing management appears to be allowing recovery as evidenced by the improvement of vegetation attributes described above.

Are there factors present preventing the achievement of PFC or affecting progress towards desired condition that are outside the control of the manager?

___Yes _X_No

If yes, what are those factors?

___ Flow regulations
___ Mining activities
___ Upstream channel conditions
___ Channelization
___ Road encroachment
___ Oil field water discharge
___ Augmented flows
___ Other (specify)

Explain:____

____

____

____

Other Notes: Resource goals and objectives should include managing for an increase the amount of woody riparian shrubs and herbaceous riparian community types along the streambanks.

Monitoring: Continue grazing management and initiate monitoring on the established DMA .Due to the very high controlling influence of stabilizing riparian vegetation on channel dimension, pattern, and profile, monitoring in this reach should concentrate on measuring riparian vegetation attributes, particularly along the greenline, streambank stability, and channel width/non-vegetated width between greenlines. Short-term monitoring should include measuring annual herbaceous and woody grazing/browsing use and streambank alteration.

Riparian Plant List Form

Riparian Area Example Creek Reach ID   005   Date 08/17/1998

U.S. Fish and Wildlife Service Region: Western Mtns., Valleys, and Coast Region

√	PCODE	Common Name	Scientific Name	AB	LOC	WIS	SC
	Trees/Shrubs						
√	SAEX	Coyote willow	Salix exigua	3	F, B	FACW	med
√	SABO2	Booth Willow	Salix boothii	1	F	FACW	high
√	ALIN2	Gray Alder	Alnus incana	2	F, B	FACW	high
√	SAGE2	Geyer Willow	Salix geyeriana	2	F, T	FACW	high
	Graminoids/Grasses						
√	CAUT	Beaked sedge	Carex utriculata	2	F, B	OBL	high
√	CAAQ	Aquatic sedge	Carex aquatilis	2	F, B	OBL	high
√	SCMI	Small fruit bulrush	Scirpus microcarpus	3	B	OBL	high
√	JUARL	Mountain sedge	Juncus arcticus	2	F, T	FACW	high
√	CANE2	Nebraska Sedge	Carex nebrascensis	1	T, F	OBL	high
	Forbs						

EXPLANATION OF PLANT LIST

√ Check species present.

AB: Abundance (1-4). 1 = species is present but with only 1 to a few individuals in the area; 2 = species is found occasionally throughout the area; 3 = species is common throughout the area; 4 = species is ubiquitous throughout the area.

GS: Geomorphic Surface. C= active channel; B = streambank; F = floodplain; MC = mid-channel bar; PB = point bar; T = terrace; **specify and define others**.

WIC: Wetland Indicator Category. (See “2012 National Wetland Plant List” (Lichvar 2012) or the USDA-NRCS PLANTS Database (http://plants.usda.gov/java/))

Indicator Code	Wetland Type	Comment
OBL	Obligate Wetland	Occurs almost always (estimated probability 99%) under natural conditions in wetlands.
FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
FAC	Facultative	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
FACU	Facultative Upland	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).
UPL	Obligate Upland	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.
NA	No agreement	The regional panel was not able to reach a unanimous decision on this species.
NI	No indicator	Insufficient information was available to determine an indicator status.
NO	No occurrence	The species does not occur in that region.

SC: Stability Class/Rooting Strength. Relative values based on general rooting characteristics assigned by Burton et al. (2011); and numerical values conform to Winward (2000).

Forbs

Taproot and/or most roots, shallow (<15.2 cm.)	Low (2)
Fibrous roots, usually up to 30.5 cm.	Medium (5)
Rhizomatous roots, little indication of extensive fibrous roots	Medium (5)
Rhizomatous roots, with extensive fibrous roots	High (8.5)

Graminoids

Annual, biennial, and short-lived perennials	Low (2)
Stoloniferous, cespitose, tufted, or short rhizomatous perennials (<1 m tall)	Low (2)
Slender or thin creeping rhizomes	Medium (5)
Long, stout, well-developed creeping rhizomes	High (8.5)

Woody Species

Taprooted species	Low (2)
Short shrubs (<1 m tall) with shallow root systems	Low (2)
Shallow to moderate root systems	Medium (5)
Rhizomatous root system, generally shallow (<12 in.)	Medium (5)
Root crown with spreading roots	High (8.5)
Widespread root systems	High (8.5)

Example Creek Reach 3 Photos and Location Map

Photo 1 – View downstream toward the lower end bridge. Note the floodplain development, vegetation, and stream width. Dominant vegetation on the floodplain consists of *Carex utriculata*, *Scirpus microcarpus*, *Carex aquatilis,* and *Alnus incana.*

Photo 2 – View upstream from the same location as photo 1.

Photo 3 – View downstream toward the point bar in photo 2.

Photos 4 – View upstream from the same location as photo 3. The dark band of soil in the middle is very cohesive and restricts downward water movement.

Photo 5 – View downstream toward the photo 4 photograph location. Note the slope of the lower part of the barren terrace wall and streambank.

Photo 6 – View downstream toward the photograph location of photo 5. Vegetation in the foreground is *Scirpus microcarpus.*

Photo 7 – View downstream across a point bar. The gravel on top of the point bar was deposited by the winter flood. Vegetation on the top of the gravel bar is *Salix exigua* growing from existing root crowns that were buried. The vegetation near the water is mostly *Scirpus microcarpus,* and *Carex utriculata.*

Photo 8 – View upstream toward the upper end of the reach (the fence). The dark layers of soil in the terrace wall and streambank consolidated clay loam resulting in the sloping bank.

Appendix D—Applying Potential to Human-altered Stream Reaches

Example 1: Great Basin, channelized intermittent stream with hardened banks

1. **Are alterations present creating artificial channel conditions for a substantial part of the reach?**
   Yes. This reach has been straightened and permanently channelized with hardened banks (revetment material) to protect the road. This channel is not expected to be further modified or rerouted in the near future. PFC will not be completed on this reach at present as it is not expected to function as a natural stream.

2. **Are alterations present but the overall potential of the *reach remains unchanged*?**
   NA

3. **Are alterations present that *have changed* the overall potential of the reach (but *have not* created artificial channel conditions for a substantial part of the reach)?**
   NA

Example 2: Northern Rocky Mountains, dewatered stream with upstream diversion

1. Are alterations present creating artificial channel conditions for a substantial part of the reach?

Yes. An upstream diversion has changed this stream reach from perennial to ephemeral. Black cottonwood and coyote willow are present; however, both are facultative species in this region. This diversion is not expected to be removed in the near future. PFC will not be completed on this reach at present as it is not expected to function as a natural perennial or intermittent stream. Additionally, because the reach is now ephemeral and PFC is designed for perennial and intermittent streams, the PFC assessment is an inappropriate tool.

2. Are alterations present but the overall potential of the *reach remains unchanged*?

NA

3. Are alterations present that *have changed* the overall potential of the reach (but have not created artificial channel conditions for a substantial part of the reach)?

NA

Example 3: Colorado Plateau, perennial stream with earthen dam upstream

1. 1. Are alterations present creating artificial channel conditions for a substantial part of the reach?

No. Although the streamflows are highly regulated, the channel can still produce attributes that will allow the stream to function properly; therefore, a PFC assessment will be completed.

2. Are alterations present but the overall potential of the reach remains unchanged?

No, the potential has been changed.

3. Are alterations present that have changed the overall potential of the reach (but have not created artificial channel conditions for a substantial part of the reach)?

Yes. The new potential will be used as the basis for determining which attributes and processes are now needed for PFC.

An upstream dam has altered the potential of this reach. Prior to installation of an upstream dam in the 1920s for irrigation storage, indications are that this reach was an E4 stream type dominated by a mix of sedge-rush and willow communities with a considerably wider floodplain than currently exists. Flow regulation has reduced the timing and magnitude of flood flows and the channel is nearly dewatered from November to April during many years. As a result, the floodplain area is reduced, the width of the riparian area has decreased, and vegetation communities have changed.

The dam and flow regulation is not expected to change. The potential of this reach is still an E stream type; however, the potential floodplain width and corresponding riparian area is narrower than it was historically. Because overbank flows and depositional events are rare, willow reproduction has been essentially eliminated. The new potential vegetation is exclusively sedge-rush communities along the streambank with mesic graminoid-forb communities away from the channel. Stabilizing wetland vegetation is still needed and the right species may or may not be present, vigorous, reproducing, and adequate.

Appendix E—Quantitative Measures for Assessment Items

The PFC protocol is a qualitative assessment of various attributes and processes. As such, there will be times when items from the assessment need to be quantified. Quantitative techniques are encouraged in conjunction with the PFC assessment for individual calibration where answers are uncertain (to validate a particular assessment item) or where experience is limited. In addition, the use of quantitative techniques is necessary to monitor the change in a particular attribute over time accurately and precisely. Although quantitative techniques can be used to help address most of the assessment items, exclusively observational indicators will be difficult to quantify (e.g. #3 Beaver dams are stable or #10 Riparian plants exhibit high vigor). The following table provides a summary of techniques that can be used to quantify the assessment items. This list represents the most commonly used and accepted procedures and is by no means an exhaustive list of every technique available for quantifying the attributes. It should be noted that Burton et al. 2011 provided a “PFC Validation Table” in the MIM data analysis module that automatically populates data values into the appropriate assessment items where they can be used for interpretation. The most recent version of this module is available at www.xxxxxx.gov.

Item 1: Floodplain is inundated in “relatively frequent” events.		
<u>Quantitative Item</u>	<u>Measurement (References)</u>	<u>Interpretation, Notes</u>
Bankfull channel dimensions	Harrelson et al. 1994; Rosgen 1996	Quantitative measurement of stream channel to determine cross-sectional area to confirm floodplain identification.
Regional curves	Regional curves have been developed for many regions of the country. ID teams should determine whether they have been developed for their region.	Identifies expected bankfull channel dimensions (channel cross-sectional area, bankfull width, bankfull mean depth, and bankfull discharge) for assessed streams based upon drainage area.
Item 2: Beaver dams are stable.		
Repeat photography, aerial photography, and dendrochronology for age-class determination of shrubs and trees rooted on beaver dams can provide information on the longevity and stability of beaver dams.		
Item 3: Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region).		
Sinuosity	Recent topographic maps, aerial photographs, Rosgen 1996	Measurement of stream channel to determine actual channel sinuosity.

Width/depth ratios	Harrelson et al. 1994; Rosgen 1996	Determine actual width/depth ratio.
Gradient	Harrelson et al. 1994; Rosgen 1996	Determine actual water surface slope gradient.
Reference reach	Leopold and Maddock 1953	The existing channel characteristics of dimension, pattern, and profile are compared to those in a stable channel reach that is the same stream type in similar geology and watershed.
Item 4: Riparian area is expanding or has achieved potential extent.		
Use of remote sensing products (aerial photographs, LIDAR, and satellite imagery)	Clemmer 1994, revised 2001 Imagery products are available from USDA Farm Service Agency Aerial Photography Field Office http://www.fsa.usda.gov/FSA/apfoapp?area=apfohome&subject=landing&topic=landing	Map/measure riparian area and channel width changes over time.
Greenline composition	Burton et al. 2011, Leary and Ebertowski 2010, Winward 2000	Comparison of different year's data of plant composition on the streambanks (on the greenline) determines if riparian vegetation is expanding along the greenline.
Ecological type identification and ecological status determination	Weixelman et al. 1997	Analytical method for classifying ecological types for mountain meadows in central Nevada.
Greenline-to-greenline width	Burton et al. 2011	Nonvegetated distance between greenlines provides an indication of channel narrowing & is correlated with riparian vegetation expanding inward.
Width/depth ratio	Harrelson et al. 1994, Rosgen 1996	The ratio of the bankfull surface width to the mean depth of the bankfull channel. Channel narrowing is correlated with riparian vegetation expanding inward.
Monitoring wells/piezometers	Cooper and Merritt 2012, Sprecher 2000	Methods for installing monitoring wells/piezometers that do not apply to water-sampling studies.
Redox potential	Cooper and Merritt 2012	Redox potential is a measure of the soil oxidation-reduction potential which can be measured with a millivolt meter.
Woody plant age structure	Friedman et al. 1996	Age structure documents channel narrowing through floodplain development and riparian expansion.
Riparian vegetation cross-sections	Leary and Ebertowski 2010, Winward 2000	Plot data (Leary & Ebertowski) and paced transect data (Winward) to quantify plant composition changes across riparian area (to detect riparian area expansion or contraction).

Sampling geomorphic surfaces and riparian vegetation	Scott and Reynolds 2007	Reach scale plot data of geomorphic surfaces & associated riparian vegetation to quantify plant composition changes across riparian area (to detect riparian area expansion or contraction).
The above three protocols establish transects perpendicular to the grade in a riparian complex, sample different geomorphic surfaces with differing soils moisture and depth to ground water, and thus need careful interpretation of results.		
Item 5: The watershed is not contributing to riparian impairment.		
The same quantitative methodologies listed for item 17 about sediment and water balance would apply here to understand whether the watershed is contributing to riparian impairment, along with methods to measure greenline vegetation listed in item 4.		
Item 6: There is stabilizing riparian vegetation for recovery/maintenance.		
Greenline composition	Burton et al. 2011; Leary and Ebertowski 2010	Plot data of plant composition on the streambanks (on the greenline) to determine if stabilizing riparian species are present.
	Winward 2000	Paced transect data of plant composition on the streambanks (on the greenline) to determine if stabilizing riparian species are present.
Cross-section composition (Vegetation)	Winward 2000; Leary and Ebertowski 2010	Paced transect data (Winward) and plot data (Leary & Ebertowski) to determine if stabilizing riparian species are present across the riparian area.
Item 7: There is recruitment of stabilizing riparian vegetation for recovery/maintenance.		
Greenline composition	Burton et al. 2011; Leary and Ebertowski 2010	Plot data of plant composition on the streambanks (on the greenline) to help assess herbaceous plant reproduction status.
	Winward 2000	Paced transect data of plant composition on the streambanks (on the greenline) to help assess herbaceous plant reproduction status.
Riparian vegetation cross-sections	Winward 2000; Leary and Ebertowski 2010	Paced transect data (Winward) and plot data (Leary & Ebertowski) to help assess herbaceous plant reproduction status across the riparian area.
Woody species height class	Burton et al. 2011	Used in conjunction with MIM greenline composition provides metrics to characterize the height of woody plants on/overhanging the greenline.

Woody species age class	Burton et al. 2011	Plot data to quantify woody age classes on the streambanks (on the greenline)
Woody species regeneration	Winward 2000	Paced transect data to quantify woody age classes on the streambanks (on the greenline)
Ecological type identification and ecological status determination	Weixelman et al. 1997	Analytical method for classifying ecological types for mountain meadows in central Nevada.
Item 8: Species present indicate maintenance of riparian soil-moisture characteristics.		
Greenline composition	Burton et al. 2011; Leary and Ebertowski 2010	Plot data of plant composition on the streambanks (on the greenline) to determine wetland status.
	Winward 2000	Paced transect data of plant composition on the streambanks (on the greenline) to help determine wetland status.
Riparian vegetation cross-sections	Winward 2000; Leary and Ebertowski 2010	Paced transect data (Winward) and plot data (Leary & Ebertowski) to help to help determine wetland status across the riparian area.
Ecological type identification and ecological status determination	Weixelman et al. 1997	Analytical method for classifying ecological types for mountain meadows in central Nevada.
Item 9: Plant communities that have root masses capable of withstanding high streamflow events are present along the streambank.		
Greenline composition	Burton et al. 2011; Leary and Ebertowski 2010	Plot data of plant composition on the streambanks (on the greenline) to determine if stabilizing riparian species are present.
	Winward 2000	Paced transect data of plant composition on the streambanks (on the greenline) to determine if stabilizing riparian species are present.
Item 10: Riparian plants exhibit high vigor.		
Vigor is qualitative and must be observed in the field.		
Item 11: Adequate stabilizing riparian vegetative cover is present to protect banks and dissipate energy during high flows.		
Greenline composition	Burton et al. 2011; Leary and Ebertowski 2010	Plot data of plant composition on the streambanks (on the greenline) to determine if enough stabilizing riparian species are present. Burton et al. provides metric for greenline stability rating (vegetation erosion resistance).

	Winward 2000	Paced transect data of plant composition on the streambanks (on the greenline) to determine if enough stabilizing riparian species are present. Provides data for greenline stability rating (vegetation erosion resistance).
Streambank stability & cover	Burton et al. 2011; Leary and Ebertowski 2010	Plot data metrics provide average streambank stability and cover to help determine if present vegetation is providing stability.
Item 12: Plant communities are an adequate source of large woody material for maintenance/recovery.		
Greenline composition	Burton et al. 2011; Leary and Ebertowski 2010	Plot data of plant composition on the streambanks (on the greenline) to quantify woody vegetation.
	Winward 2000	Paced transect data of plant composition on the streambanks (on the greenline) to quantify woody vegetation.
Woody species height class	Burton et al. 2011	Used in conjunction with MIM greenline composition provides metrics to characterize the height of woody plants on/overhanging the greenline.
Woody species age class	Burton et al. 2011	Plot data to quantify woody age classes on the streambanks (on the greenline) .
Woody species regeneration	Winward 2000	Paced transect data to quantify woody age classes on the streambanks (on the greenline).
Riparian vegetation cross-sections	Winward 2000; Leary and Ebertowski 2010	Paced transect data (Winward) and plot data (Leary & Ebertowski) to help to quantify woody vegetation across the riparian area.
Item 13: Floodplain and channel characteristics (i.e. rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy.		
Stream classification	Montgomery and Buffington1997, Montgomery and Buffington 1998, Rosgen 1994, Rosgen 1996	Identify whether the listed floodplain and channel characteristics are a part of the stream type being assessed.
Large woody material counts	Davis et al. 2003, Heitke et al. 2011, Kauffman et al. 1999, U.S. Environmental Protection Agency 2001, Wohl et al. 2010	Quantify the number and size of large woody material.

Range of meander width ratio (belt width/bankfull width) by stream type	Harman et al. 2012, Rosgen 1996 page 4-9 and chapters on Level III and Level IV	Compare measured values against expected values for different stream types.
Manning's *n*, computer models such as HEC-2	Federal Interagency Stream Restoration Working Group 1998, page 7-19	Manning's *n* values are computed for a reach in which multiple cross sections, water surface elevations and at least one discharge have been measured. A series of water surface profiles are then computed with different *n* values, and the computed profile that matches the measured profile is deemed to have an *n* value that most nearly represents the roughness of that stream reach at the specific discharge.
Item 14: Point bars are revegetating with stabilizing riparian plants.		
If quantitative methodologies are required, consult the measurement of vegetation composition, discussed under item 7, and consult the estimation of bank stability, discussed under item 9. Vegetation monitoring methods typically evaluate conditions throughout a DMA and do not make targeted measurements on point bars exclusively.		
Item 15: Stream banks are laterally stable.		
Lateral stream movement	Rosgen 1996	Bank erosion pins. Annual measurements should be related to magnitude and duration of high-flow events.
	Harrelson et al. 1994	Monumented channel cross-section where bank erosion is high (i.e., more than a few feet per year)
	Clemmer 1994; Prichard et al. 1996	Comparison of series of aerial photos covering several years or decades to identify channel adjustments through time
Channel migration rates	Everitt 1968; Nanson and Hicken 1983	Dendrochronology where riparian trees and shrubs establish on point-bar or natural levee deposits
Bank stability	Burton et al. 2011	Bank alteration, bank stability measurements, and greenline-to-greenline width provide clues to channel processes that affect lateral stability.
In some cases, erosion rates may remain low for a period of years until some threshold of flow is exceeded, after which erosion may increase by one or more orders of magnitude. Therefore, obtain a record of the duration and magnitude of high flows sufficient to initiate lateral movement of the channel.		

Item 16: Stream system is not incising.		
Vertical stream movement	Harrelson et al. 1994	Monumented channel cross-section using a stable reference point as a permanent benchmark.
	Clemmer 1994; Prichard et al. 1996	Comparisons of series of aerial photos covering several years or decades to knickpoint migration identify channel adjustments through time.
	Gonzalez 2001a, b	Dendochronology is used to compare the age of the oldest tree (or shrub) on the inset floodplain or channel and the age of the youngest tree (or shrub) on the adjacent terrace (abandoned floodplain or channel) to constrain the date of incision, to determine the rate of headcut propagation upstream, or to determine if channel incision has ceased or is continuing.
Item 17: Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition).		
Stream classification	Rosgen Level IV 1994, 1996 Montgomery and Buffington1997, 1998	Stream classification provides a consistent and semi-quantitative means for describing and comparing geomorphic characteristics of channels (Dorava et al. 2001). The sequence of stream types can reveal system-wide instabilities (FISRWG 1998).
Compare channel surveys (longitudinal and cross section)	Federal Interagency Stream Restoration Working Group 1998 page 7-53; Harrelson et al. 1994	Document changes in channel cross section and longitudinal profile of thalweg, water-surface gradient, bankfull gradient, floodplain, valley, or terrace gradients. Surveys are completed at permanent monitoring sites.
Geomorphic studies and assessments	Thorne 1998; Rosgen 1996	Detailed geomorphic studies require trained geomorphologists with ample field experience; study historical documents, floodplain deposits, and characteristics of abandoned channels. Examines channel, floodplain, and valley characteristics. Requires an understanding of streambank erosion processes and channel forming processes.

Watershed Assessment of River Stability & Sediment Supply (WARSSS), POWERSED, and FLOWSED	Rosgen 2006a, Rosgen 2006b, http://water.epa.gov/scitech/datait/tools/warsss/index.cfm	WARSSS is a three-phase technical framework of methods for assessing suspended and bedload sediment in rivers and streams. It is a watershed approach to sediment assessment that focuses on natural variability in sediment dynamics, geologic versus anthropogenic sediment sources, erosional and depositional processes, prediction of sediment loads, streamflow changes, and stream channel stability and departure from reference condition. POWERSED and FLOWSED models predict changes in incision and/or aggradation processes associated with impaired streams.
Schumm's F versus M relationship F=255M-1.08	Federal Interagency Stream Restoration Working Group 1998 Page 7-38	Channel width/depth ratio (F) at mean annual discharge and the percent of silt and clay in the channel boundary (M) are useful diagnostics for determining systemwide adjustments.
Aerial photograph sequence, evaluation of channel adjustments	Clemmer 1994; Prichard et al. 1996	Review aerial photographs over time.
Scour chains	Harrelson et al. 1994	Scour chains may be used to measure the aggradation or incision of the stream bed.
Pebble counts	Burton et al. 2011; Bunte and Abt 2001; Kerschner et al. 2004; Davis et al. 2003; Bevenger and King 1995	Determine surface substrate size distribution and percent fines.
Residual pool depth	Burton et al.2011; Kaufmann et al. 1999; Keim and Skaugset 2002; Kershner et al. 2004	Pools may fill with sediment associated with a higher sediment load in the channel; and a higher width/depth ratio often is caused by a decrease in the ability of the stream to scour the bed. Maximum (thalweg) depth decrease over time indicates pools filling with sediment.

Relative bed stability	Stoddard et al. 2005; Kaufmann et al. 1999; Robison 1998	Ratio comparing the particle size of observed sediments to the size sediment each stream can move or scour during its flood stage, based on the size, slope and other physical characteristics of the stream channel. Kaufmann et al. 1999 is a measure of stream bed textural “fining” that occurs as a response to increases in the rate of upland erosion, and the increased mobility or instability of the bed substrate that accompanies such inputs of fine textured substrates.
Geomorphic history using stream gaging discharge measurements that include physical measurements of the channel; specific-gage analysis	Smelser and Schmidt 1998, Federal Interagency Stream Restoration Working Group 1998	History of channel adjustment is compared to histories of climate change, flow regulation, and land use to link geomorphic adjustments to particular patterns, events, or activities. A channel is considered to be in equilibrium if the specific gauge record shows no consistent increasing or decreasing trends over time.
Indicators of Hydrologic Alteration software package (Smythe Scientific Software)	Richter et al. 1996	A suite of 33 hydrologic parameters that are ecologically meaningful and serve as sensitive indicators of anthropogenic effects on riverine systems. The software calculates the parameters by using daily streamflow data obtained from USGS.

Appendix F—Ground Water/Surface Water Interactions

An important component of streamflow is the ground water component. That is, the quantity and source of ground water that discharges into the stream. Many streams depend on ground water discharge to maintain flow during periods of low flow. This base flow is determined during winter months when evapotranspiration (ET) is not a factor. For riparian areas dependent on vegetation to function, an important question to resolve is a determination of the ground water component and its importance in maintaining the riparian corridor. Interruption of ground water flow paths such as by ground water withdrawals by wells can have a very detrimental effect on riparian vegetative health. Thus the determination of the existence of water wells in the vicinity of the stream being studied should be made to ensure consideration of ground water withdrawals that might affect streamflow and riparian vegetative health.

Many riparian systems are dependent on ground water discharge to sustain healthy riparian vegetative communities. Geological conditions are an important factor in whether or not ground water can support a healthy riparian system, because geology is the primary control in occurrence and movement of ground water. Ground water discharge to the floodplain alluvium can also contribute to bank storage, thereby providing shallow saturated conditions required for maintaining healthy riparian vegetation. Flood flows are an important component of riparian health, and become part of the ground water component by saturating stream bank alluvial sediments, and this stored ground water then drains back into the stream, increasing streamflow, or maintaining streamflow when dry conditions might occur. Saturation of stream bank sediments during floods also creates a shallow ground water level, promoting healthy riparian vegetative communities.

Ground water flow paths must be understood to be able to accurately assess the full range of factors that determines health of riparian vegetative communities. Geology plays an important role in riparian systems. The presence and extent of permeable, alluvial deposits along the stream can provide extensive areas of favorable geology to maintain saturated conditions suitable for vegetative growth. In this situation, the water level in alluvial floodplain deposits will typically coincide with the water level in the stream, and the shallow water table can extend several hundred feet away from the stream in wide, flat floodplains providing favorable conditions for healthy riparian vegetation growth. The San Pedro River in Arizona is a good example of this situation.

The degree of interaction of the stream with ground water depends on the type of aquifer underlying the stream. Aquifers are geologic units that can store and transmit water at rates that are fast enough to be supply water to a well and are defined as confined or unconfined. The hydrogeology of each type is different, and both types can affect streamflow and riparian area hydrology. For riparian areas, the most common aquifer type is unconfined, also known as a water table aquifer. In this type of aquifer, the upper surface of the saturated zone forms the upper boundary of the aquifer. Confined aquifers are overlain by a confining layer, usually clay or silty clay in basin fill deposits and are found at depth. Unconfined aquifers are normally shallow aquifers and are also referred to as water table aquifers. Unconfined aquifers are usually the type of aquifer that interacts with riparian systems. Both types of aquifers – unconfined and confined -- can simultaneously affect streamflows.

If a confined aquifer has a strong upward vertical gradient that moves water from the confined aquifer through the confining layer into the overlying unconfined aquifer, ground water from the confined aquifer can discharge into the unconfined, or water table aquifer. If the upper aquifer is hydraulically connected to the-stream, this contribution of ground water discharge can help support streamflow.

Gaining and Losing Streams

Unconfined aquifers in riverine valleys typically comprise very permeable unconsolidated alluvium (sand and gravel deposits with possibly some clay layers) that are saturated with a water level ranging from a few inches below ground surface to a few feet or tens of feet below ground surface. In this situation, the shallow ground water is commonly hydraulically connected to the stream, and the ground water level affects streamflow. The ground water level adjacent to the stream may be higher than the stream and results a gaining stream (Figure E- 1) where ground water discharges from the aquifer into the stream, creating increased streamflow throughout the reach where this condition exists. In a losing stream, the ground water level adjacent to the stream is lower than the stream level, and water moves from the stream into the aquifer, resulting in decreased streamflow throughout the reach where this condition occurs (Figure E- 2). The ground water level in the adjacent alluvium can rise and fall depending on recharge from flood flows, so that gaining and losing reaches can occur at different times of the year. Additionally, gaining and losing reaches can be located on the same stream.

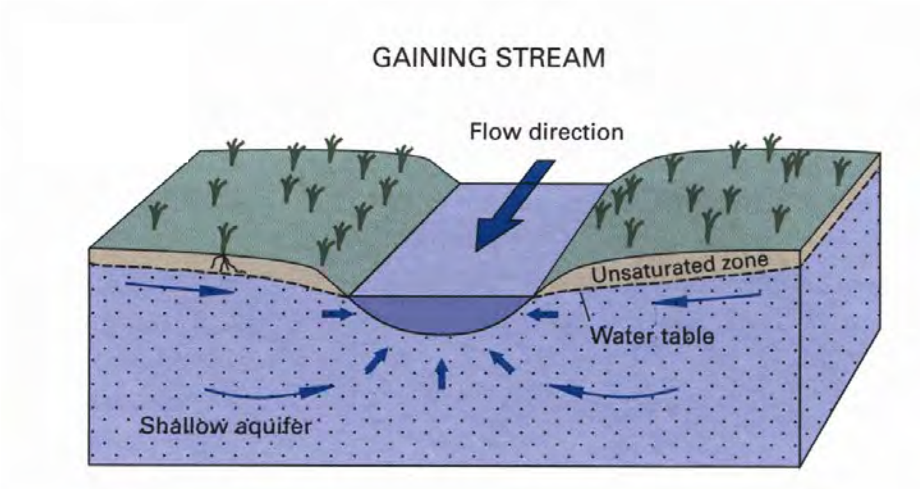


Figure E- 1.Ground water/surface water interactions for a gaining stream.

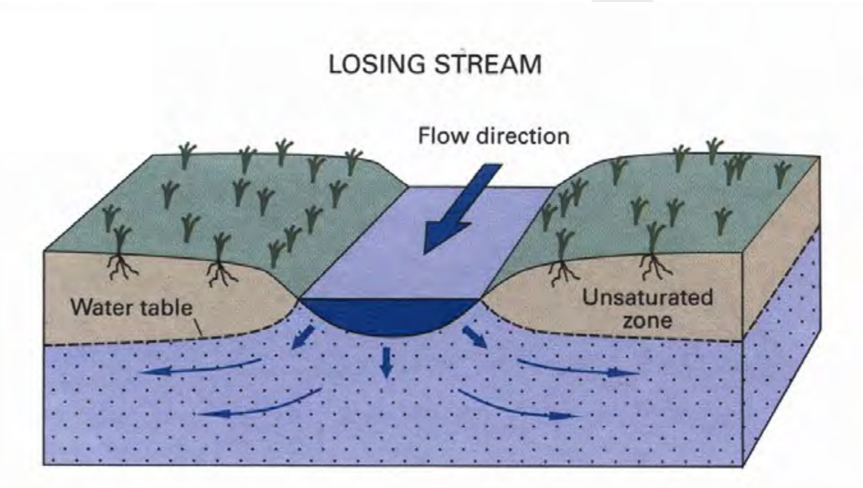


Figure E- 2 Ground water/surface water interactions for a losing stream.

Ground water discharge into riparian areas can also occur from bedrock surrounding an alluvial valley. For example, ground water discharge from fractured bedrock adjacent to the valley floor into the floodplain deposits along a stream can maintain a shallow ground water level in the alluvium, supporting riparian vegetation. Ground water discharging directly into a stream from fractured bedrock could also occur when a stream crosses an exposure of fractured bedrock or an area where the stream bottom sediments are very thin over fractured bedrock. This situation is fairly uncommon, but should be considered during PFC assessments. Outcrops of bedrock along a stream are readily determined during the field reconnaissance of the stream. This type of ground water discharge to streams can most often occur in narrow mountain valleys where alluvium is either very thin or absent (Figure E-3). However, this sometimes occurs only in short reaches where the bedrock is fractured and the unit has a potentiometric surface (hydraulic head) above the surface of the bedrock.

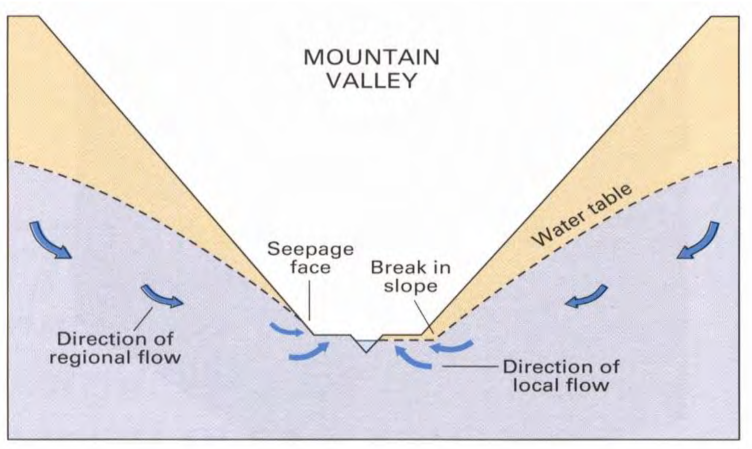


Figure E- 3. Ground water discharge from bedrock into a stream flowing through a narrow mountainous valley

Another mechanism creating ground water discharge to a stream is the situation where a geologic barrier to ground water movement forces ground water to the surface, providing direct discharge into the stream. If streamflow is increased over a very short distance, this geologic situation might be the cause.

Changes in Ground Water Flow Affecting Streams

Declining ground water levels in a shallow aquifer that supports streamflow can have a significant effect on streamflow and on riparian vegetative health when the stream changes from a gaining stream to a losing stream as shown in Figure E-2.

Ground water declines may be brought on by irrigation diversions, pumping near the river, or drought cycles. A stream may undergo changes from a gaining stream to a losing stream and finally to a disconnected stream, where the ground water level is no longer in contact with the river. Figure E-5 shows and example of a disconnected stream. In diagram A, the stream is hydraulically disconnected and is losing water to the underlying water table. If the stream losses are great, a ground water mound could build up underneath the stream. In B, the water table has declined further, and the stream has gone dry. This condition causes the most damage to riparian vegetation and can destroy a wide section of previously healthy riparian vegetative cover.

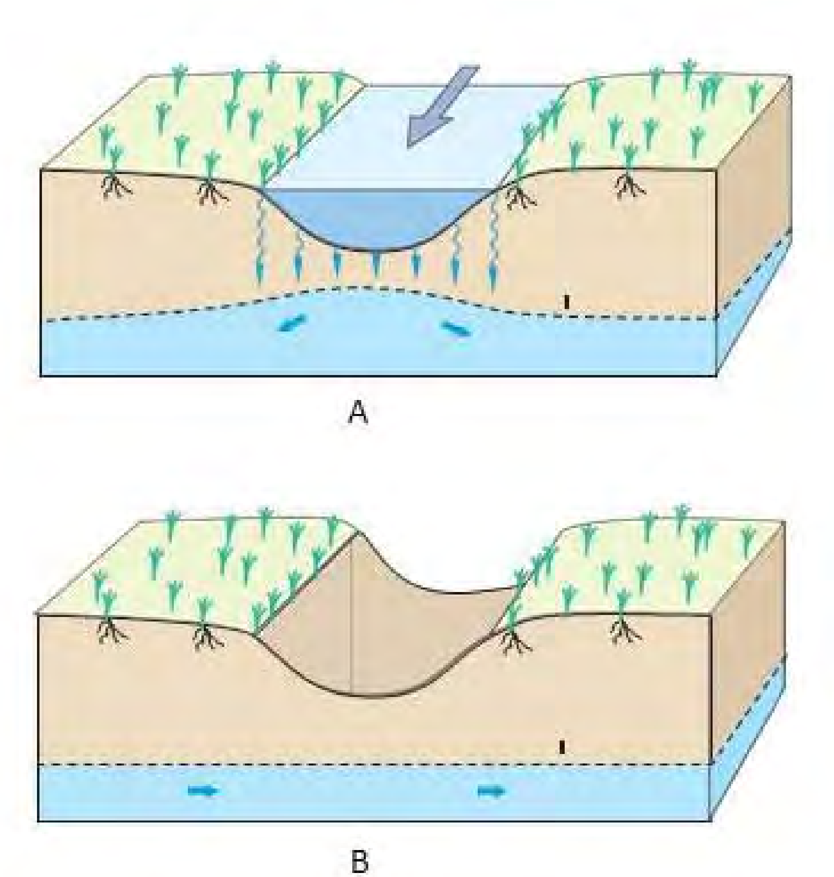


Figure E-5. Disconnected stream reaches

When the disconnected phase occurs, stream losses become greater and the water level in the riparian area is lowered, impacting riparian vegetation if the water level decline is substantial and the duration is long or becomes a permanent condition. As the riparian area ground water level declines further over time, streamflow can eventually cease and the stream becomes dry, or the ground water level in the riparian area may fall to a level too deep for vegetation to survive; creating stressed vegetative conditions in the riparian area or resulting in destruction of riparian vegetation. An example of this situation is shown in Figure E-6. The consequences of a disconnected stream is show in this paired photo of the Santa Cruz River south of Tucson, AZ, taken at the same location in 1942 (top photo) and again in 1989 (bottom photo). The water table has declined more than 100 feet due to ground water pumping, and this pumping appears to be the principal cause for the decrease in vegetation. (Photograph by Robert H. Webb, USGS, in Circular 1186).

Figure E-6. Paired photo points of the consequences of a disconnected stream, 1942 and 1989.

Hyporheic Zone

In either gaining or losing streams, water and dissolved chemicals can move repeatedly over short distances between the stream and the shallow subsurface below the streambed. The resulting subsurface environments, which contain variable proportions of water from ground water inflow and surface water, are referred to as hyporheic zones (Figure E- 7). This mixing of surface water and ground water enhances microbial activity and chemical transformations, creating a unique environment. Hyporheic zones can be longitudinally oriented (parallel to the channel), or laterally extensive, following preferential flow pathways such as relic channels looping out into the floodplain. Hyporheic flow is an active interchange between surface and subsurface water over small time scales (hours to days) that helps cool the stream and filter or metabolize contaminants (the streambed acts as a "chemical reactor" with large surface area from all the grains of sand and gravel). Conditions which impair the hyporheic function include thinning of alluvium due to incision, disconnection from the floodplain, and embedded streambed due to excessive deposition of fine (silt, clay) sediments.

Hyporheic zones can be active sites for aquatic life (Winter et al. 1998). For example, the spawning success of fish may be greater where flow from the stream brings oxygen into contact with eggs that were deposited within the coarse bottom sediment or where stream temperatures are modulated by ground water inflow. Dissolved nutrients in eutrophic stream water moving into the hyporheic zone under riparian vegetation may become available for plant uptake and this improves water quality. The effects of ground water pumping on hyporheic zones and the resulting effects on aquatic life are not well known (Alley et al. 1999).

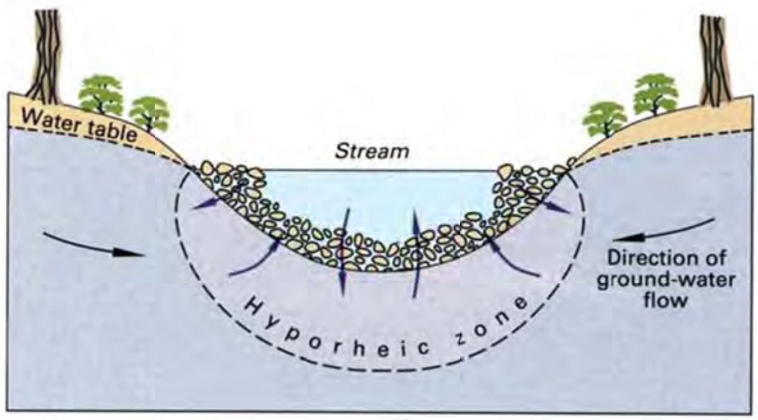


Figure E- 7. Hyporheic zone.

Effects of Pumping Wells Near Streams

Wells that pump within the floodplain of a stream can impact the riparian vegetation by 1) lowering the water table in the vicinity of the well, and 2) by capturing streamflow when the cone of depression extends out to the stream. During “natural conditions”, in a gaining stream, ground water flows from areas of high water table towards the stream. The stream is the ground water discharge point in the flow system. Ground water moves laterally from adjacent landscapes, discharging into the stream (Figure E- 8).

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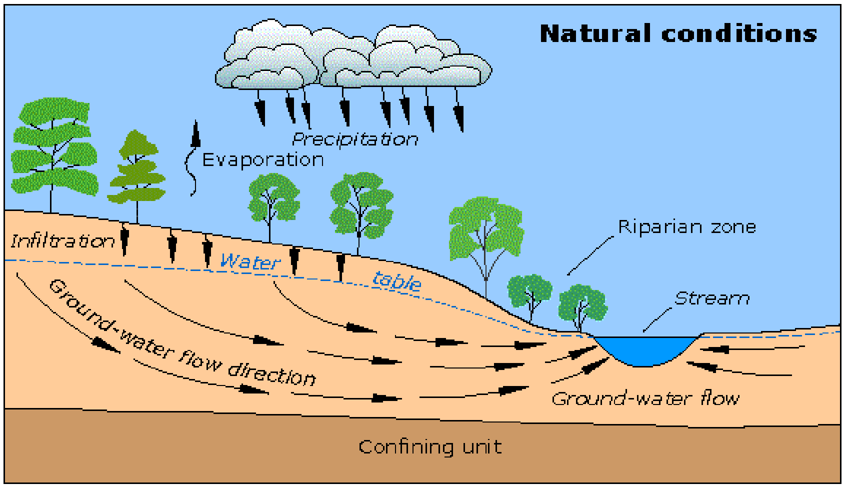

Figure E- 8. Ground water flow system in "natural conditions" for a gaining stream.

When a well is pumped near a stream, ground water that would normally flow to the stream is captured by the cone of depression and the well can also drain water from the stream towards the well (Figure E- 9). Note that the ground water level between the well and the stream is lowered more than the water level on upland side. This is due to induced recharge from the river to the well, resulting in capture of streamflow. In a low flowing stream, the capture of streamflow can cause the stream to go dry in a relatively short time (a few months), depending on the duration and magnitude of the lowered ground water level adjacent to the stream. These effects will not only occur for wells located near a stream, but can occur with a well a mile or more away from the river, if the river and the well are in sediments that are hydraulically connected, such as a floodplain aquifer where the stream is located, with basin fill comprised of unconsolidated sand, gravel deposits.

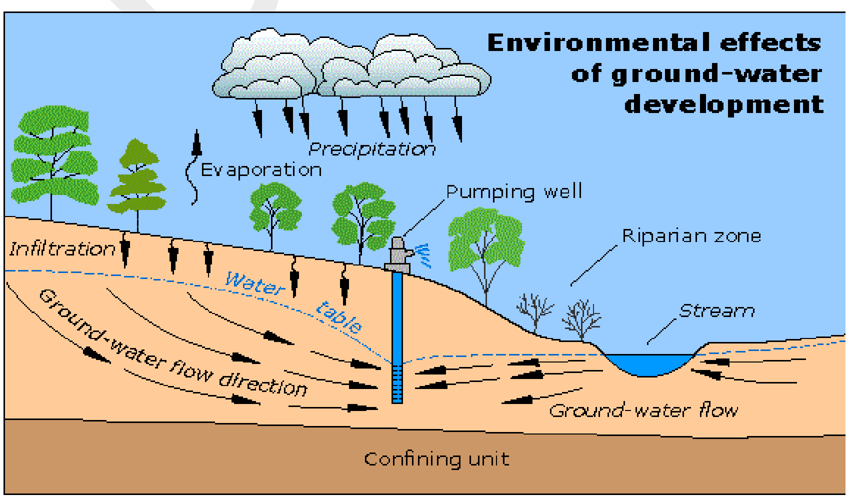

Figure E- 9. Drawdown effects on streamflow and on the riparian area from a pumping well.

Effects to Cone of Depression Due to Pumping

For pumping drawdown to impact the riparian area, two criteria must be met: 1) drawdown of ground water must cause the water level in the riparian area to drop below root zones, and 2) the duration of that drawdown must be of such lengthy duration that riparian vegetation is stressed, or destroyed. Short term declines in ground water levels (3-4 months) won't normally be a stressor on vegetative health, unless some species are extremely sensitive to water level declines.

Drawdown effects from a high capacity pumping well can extend for very long distances if the sediments being pumped and those where the stream is located are hydraulically connected. The duration of pumping and pumping rate are factors in the extent of the cone of depression (drawdown), but effects can sometimes be observed within a short time (several days) if aquifer conditions are favorable and the pumping rate is high (several hundred gallons per minute).

An example of hydraulic connection of the aquifer being pumped and BLM water source can be observed at Needle Point Spring in Utah where pumping of an irrigation well located in alluvial deposits 1 ¼ miles away from the spring in the same geologic unit has caused the spring to go dry due to the cone of depression lowering the water level at the spring, and causing the spring to stop flowing (Figure E- 10). The ground water level at the spring is monitored at a monitoring well located next to the spring expressly for the purpose of monitoring water level changes due to the irrigation well. Note that the water level declines and rises are closely correlated with the pumping cycle of the irrigation season (i.e. pump on in April, pump off in late October). In this case, water level changes occur within a few days of when the pump is turned on because the spring and the well are hydraulically connected.

Although this example is for a spring, if a low flowing stream was located at the same distance away from the well as the spring, the stream would eventually go dry, when the water level beneath the stream drops below the stream causing a disconnected stream to occur.

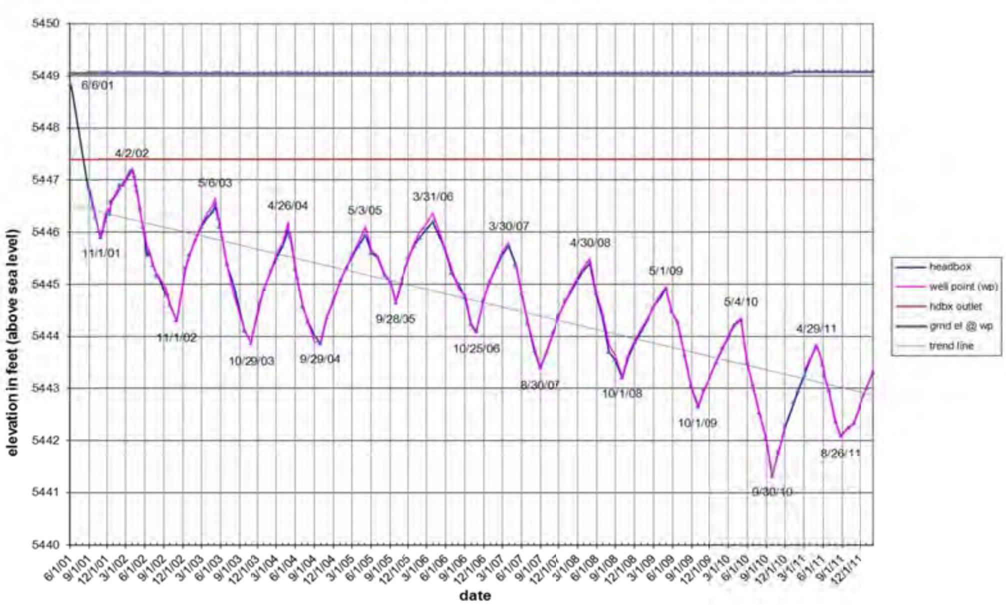

Figure E- 10. Hydrograph of monitoring well at Needle Point Spring, UT, showing cyclic drawdown effects of a high capacity irrigation well located 1 ¼ miles away from the spring in basin fill deposits.

Stressed vegetation alone is not a reliable early warning indicator of declining water levels in riparian areas. The most reliable indicator for changes in shallow ground water conditions supporting riparian vegetation is by combining monitoring well water level measurements in the riparian area with a detailed assessment of vegetative health. For a greater understanding of the ground water/surface water interactions, streamflow measurements can be made and correlated with fluctuations in ground water levels in monitoring wells, with water level measurements taken at the wells at least seasonally, more often if possible. In Figure E-11, streamflow was diverted for irrigation season purposes in early June with the diversion ending in early October. Note that when streamflow drops below about 2 cubic feet per second (cfs), the monitor well is dry. The ground water level response to streamflow changes is within days.

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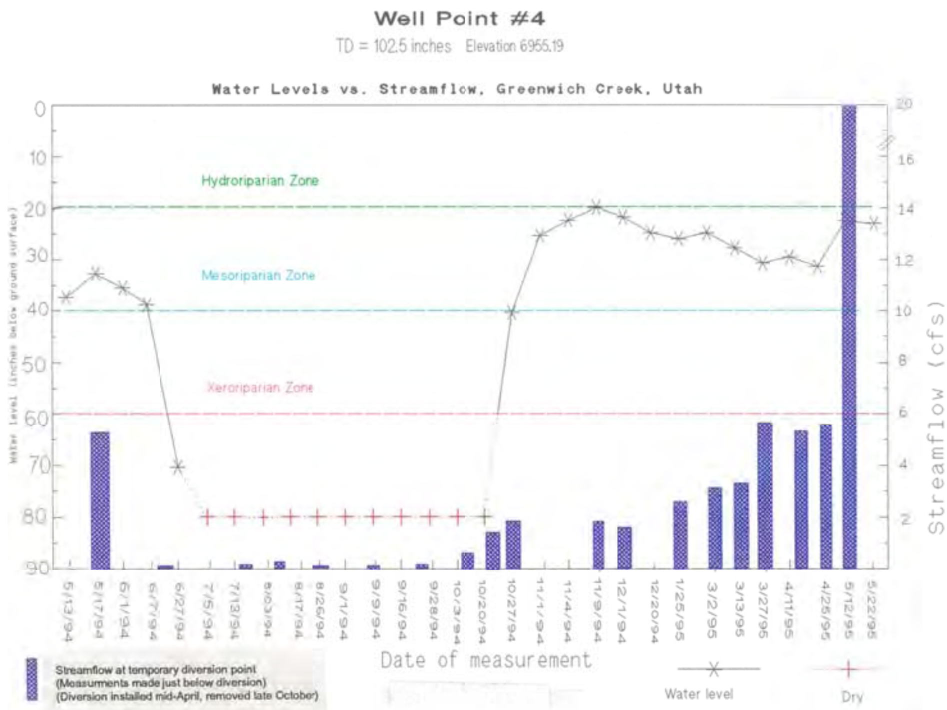

Figure E-11. Shows correlation of streamflow vs. water level in a monitoring well located in a riparian area.