# CHAPTER 9. CHANNEL CHARACTERISTICS

## STREAM ENERGY

General features of stream and river systems reflect the long-term constraints of geology, landform, climate and resultant vegetation patterns. During landscape evolution, stream characteristics such as drainage density, stream order, and the longitudinal channel profile develop from the interaction of runoff and stream sediment transport processes.

Channels undergo many subtle and not easily detected changes from season to season, year to year. A riffle may scour during the high flow and immediately backfill as flow decreases. To the casual observer, no change has occurred. Channel changes are a part of the natural equilibrium in stream dynamics. Recognizing that channels are constantly changing with scour and fill, to aggrade and degrade, with bankcuts and deposits, both the immediate and long-term effects need to be considered. Knowledge of stream dynamics and energy dissipation is fundamental for understanding how channels change.

Precipitation that falls on a catchment is forced by gravity along a downward path toward the ocean with a certain amount of potential energy that will be dissipated in transit. The water's initial elevation above sea level determines the total amount of potential energy available to do work. Once the water heads downstream, the potential energy is converted to kinetic energy. Some kinetic energy is utilized for sediment transport, bed scour, and bank erosion, but more than 95 percent is ultimately consumed as heat loss during turbulent mixing within the main flow as well as along channel margins (Morisawa 1968).

At a given location along a stream, the availability of energy to do work depends upon the time-rate loss of potential energy (Bagnold 1966) or total stream power. Unit stream power can be defined as the time-rate loss of potential energy per unit mass of water. In this equation the energy slope of flowing water is often assumed to be approximated by channel gradient. The unit stream power concept is important because it provides a basis for understanding the erosive capability of flowing water in open channel systems. Channels that are steep, straight, with hydraulically "smooth" banks and beds, uniform in cross-section, and of large hydraulic radius will be associated with relatively high unit stream powers. But, the unit stream power of the channel sections can be reduced in several ways.

A stream channel that changes from being relatively deep and narrow to being shallower and wider (i.e., increase in width/depth ratio) may experience a concurrent loss of pools which often provide important instream habitat for fish. Because bed shear stress would be increased in a wide, shallow cross-section, such channels would have relatively high potential for bedload transport and bank erosion, and would generally be characterized as unstable.

Channels with these types of cross-sections occur naturally but can also be the result of increased sediment loads, increased peak flows, decreased riparian vegetation (particularly woody species), mechanical damage to streambanks (by heavy equipment, livestock trampling, or ice flows), or some combination of these factors. More detailed discussions of stream hydraulics and sediment transport can be found in Leopold et al. 1964, Bagnold 1966, Morisawa 1968, Dunne and Leopold 1978, and Richards 1982.

# CHANNEL MORPHOLOGY

Methods to characterize small stream channel morphology generally use some expression of width and depth. However, channels are not uniform in their cross-sectional shape and any width-to-depth measurement is only a relative index to the actual channel shape (Park 1977). Channel morphology is related to a large number of interacting variables so the expected width or depth of a particular stream reach cannot easily be predicted. In general, width usually increases faster than depth downstream. Some have considered using width/depth ration as a dimensionless index of channel morphology and useful to compare upstream and downstream reaches. Due the complex nature of the interactions in the stream channel comparisons of width/depth should only be made for streams of equal order or drainage area.

Any attempt to characterize stream channel morphology must recognize its three-dimensional aspects. Even though average widths and depths can generally index the amount and quality of instream habitat (Beschta and Platts 1986), longitudinal variability in width and depth is also important. One stream may express a uniform depth and width and have insignificant amounts of fish-rearing habitat. Yet, in another segment of the same stream with essentially the same average width and depth, but formed so that there are shallow riffle sections that are interspersed with deep pools and overhanging banks, may have relatively abundant rearing habitat. The patterns of variations in width, depth, and channel morphology are not entirely random, but are often grouped so as to provide a hierarchical structure to a stream system (Frissel, et al. 1985). Even though alluvial channels do not have fixed spacing of pools and riffles, nearly 90 percent of the pool-riffle sequences may consist of channel reaches 3 to 9 widths in length. Where bed and bank characteristics are controlled by large roughness elements the expected size and spacing of morphological features may be more variable.

Schumm's (1977) complex response concept identifies several expected changes in channel morphology by stream systems undergoing changes in flow or sediment availability. Increased high flows tend to increase channel width and depth. Increased sediment availability and transport tend to increase width, steepen gradient by decreasing sinuosity, and decrease depth. If a channel is undergoing widening, it may be responding to increases in flow, increases in sediment availability, some other factor (such as loss of streamside vegetation), or a combination of all of these.

# Pools

Pools are a major stream habitat for most fish. Salmonids often require backwater or dammed pools with water moving at low velocities to survive harsh winter conditions. Elser (1968) and Lewis (1969) demonstrated that deep, slow velocity pools with large amounts of overhanging cover support the highest and most stable fish populations. Platts (1974) found that high-quality pools also supported the highest fish biomass. In the South fork Salmon River drainage of Idaho, pool quality was an important factor accounting for explained variation in total fish numbers. High-quality pools alone, however, do not make the fishery. Pools of all shapes, sizes and quality are needed. Young-of-the-year need shallow, low-quality pools that other fish will not use. Increased growth allows them to eventually compete, without undue predation, in the higher quality pools, which have better food supplies and winter rearing habitat.

Pools generally result from localized scour during moderate to highflows. The fact that a pool has formed indicates that the location is one of intense turbulence and energy dissipation during high flows. In many instances, subtle changes in channel dimensions or roughness may be sufficient to initiate pool formation and maintain pools over time (Keller and Melhorn 1973). The narrowing of channel banks can cause a converging of flow lines and acceleration of water; the gain is kinetic energy ultimately dissipated as turbulence along the bottom of a downstream pool. Although pools may form in this manner along straight reaches of a stream, they are more commonly formed at bends where flows are deflected by channel banks, turbulence is intense, and the bed is erodible. They can also be formed by large roughness elements; for instance, water flowing over a log partially or wholly buried in the bed, boulders or bedrock outcrop may create a pool immediately downstream. The size, frequency, distribution and quality of pools in a stream depend upon the mechanisms of formation and other characteristics such as size of channel substrates, erodibility of banks, size of obstruction, and depth of flow.

# Riffles

Riffles, seen during periods of low flow, when substantial portions of the channel bed may become exposed or have relatively shallow water flowing over it, are remnant channel features formed at higher flows and are major storage locations of bed material. In a meandering stream, riffles are ideally located between successive pools at the inflection point of the thalweg. Their form represents a balance between the frequency and magnitude of flows, sediment transport, and other channel characteristics such as obstructions, bank erosion, or deposition. Keller and Melhorn's (1973) description of diverging flows may be an important mechanism of formation, though other mechanisms undoubtedly exist. As water moves out of a highly turbulent pool during high flow, it encounters a lower effective slope, hence reduced stream power, and may deposit coarse bedload sediment in transport. As the water continues to pass over the riffle, it accelerates until again expending most of its kinetic energy, as turbulence, at the next pool

# THEORY AND FIELD METHODS

The ability of scientists and resource managers to provide for the most efficient channel form should be based on specific conditions of the fluvial system. There are few generalizations drawn from scientific studies of channel form that can be useful in practical problems of river restoration or maintenance. Width is the morphologic parameter most easily altered by the river. If the river is deprived of some of its natural discharge, it will narrow its channel. Bank erosion usually will follow unusual or unnatural alteration in sediment supply or a change in water-sediment relation. An alteration in channel gradient (slope) is the most disruptive to the natural equilibrium. The increase in gradient is the main reason channel straightening or channelization is so destructive to river systems. Also, river curves provide an essential source of hydraulic resistance necessary for equilibrium.
To develop maintenance and restoration objectives, a procedure might in principle, include the following steps. Inspect the channel upstream and downstream of the reach exhibiting problems. Inspect nearby or similar valleys that appear more natural. Choose a reach of a natural river, which appears to represent the condition of the problem channel before it was disturbed or disrupted.

Carefully consider the principle morphological features of the river channel that must be retained or restored. First, the slope or gradient of the channel must be the same as it is in the natural or undisturbed reach of the river. The deviation from this natural slope, as with drop structures or grade control, is the clearest reason that the channel may be making additional adjustments.

The second imperative is channel width. The width must represent the bankfull dimension such that when the normal bankfull discharge is exceeded, the water will overflow onto a flood plain of much greater width. This means that both width and depth at bankfull must be considered and an overflow area provided for greater discharges.

If a river curves or meanders present in the undisturbed reaches have been eliminated or importantly changed in the disturbed area, they must be reinstalled by physically constructing them. The layout of curves is the principle way the desired gradient is maintained or restored. No natural channel is straight, so the restoration of curves of appropriate size and shape is a main element in river restoration. The bed elevation should vary, in that pools occur in the curved reach and shallower zones in the crossovers.

The dimension of width, depth, meander length, radius of curvature, slope, and other features have been published for many regions in the United States. These dimensions can be used as a rough check on those measured in undisturbed reaches of the river in question.

By observing a river it should be obvious that a grade control structure flattens the channel gradient upstream for only a short distance and intrudes an unnatural-anomaly into the fluvial system. Such an anomaly will be attacked by the flow and, given time, will be eliminated. It will ultimately be destroyed by undercutting, by lateral erosion of the abutments, by scour hole erosion at the toe, or by some combination of these.

If a reach of channel is suffering unusual bank erosion, downcutting of the bed, aggradation, change of channel pattern, or other evidence of disequilibrium, a realistic approach to amelioration of these problems should be based on restoring the natural combination of dimension and form characteristics of similar channels in quasi-equilibrium. These characteristics include appropriate values of width, gradient, pool and riffle sequence, length, radius, amplitude of curves and meanders, and hydraulic roughness.

# CHANNEL CLASSIFICATION

Stream channel characteristics such as width, depth, or number of pools in a section of stream are determined by many factors, including topography, geology, hydrology, and climate. Additionally, vegetation conditions and the history of disturbance, such as floods, fires, landslides, road-construction, channel modification, or livestock and timber management practices may influence stream channel conditions. High in the watershed, slopes are steep, and the rapid streamflows readily erode sediment, gravel and rocks from the banks and bed. Lower in the watershed, streams often meander across the valley bottom and may divide into multiple channels. These features may provide stream channel characteristics that respond predictably to natural and human-caused modifications and may be classified into channel habitat types (CHTs). Classifying current CHTs in the watershed helps to (1) evaluate basin-wide stream channel conditions, (2) understand how land use activities may have affected the channel form, and (3) predict how different channels may respond to particular restoration efforts (WPN 1999). Ultimately, changes in watershed processes will affect channel form and produce changes in habitat for fish and other organisms.

Channel responses to changes in ecosystem processes are strongly influenced by channel confinement and gradient (Naiman and Bilby 1998). Classifying stream channels in the watershed may help identify which stream segments are most affected by disturbances, and which segments are most likely to respond favorably to restoration activities. As an example, more confined, higher gradient streams may provide little response to restoration efforts.

In-channel structures and activities associated with human activities such as ditching and streambank stabilization (for example with riprap) and flood control can adversely affect aquatic organisms and their associated habitats by changing the physical character of the stream channel. These changes can ultimately alter community composition of in-stream aquatic biota.

Identification of channel modification activities can help in the determination of the likely effects of human-caused channel disturbances on channel morphology, aquatic habitat, and hydrologic functioning.

Unfortunately, not much data exist regarding the specific locations of channel modifications and historical channel disturbances. We present information in this section based on existing relevant data, but many sources of channel modification are undocumented.

The key questions we will address in this chapter include:

1. What are the channel habitat types?
2. What are the changes in watershed conditions?
3. What are the major modifications to channel morphology?

# Designation of Channel Habitat Types

Stream segments were separated into channel habitat type categories using the Rosgen methodology (Rosgen 1996), rather than by the Oregon Watershed Enhancement Board (OWEB) protocols. The Rosgen approach was selected because of the large spatial extent of the assessment area and to maintain consistency with previous assessment efforts in the Klamath Basin. A Level I Rosgen classification was conducted based on aerial photos, digital elevation models, and topographic maps, and verified from US Forest Service data gathered in the field. The Rosgen Level I classification provides a general view of conditions in the subbasin, but is insufficient for site-specific planning. An intensive field-based analysis of channel conditions is beyond the scope of a watershed assessment, but may be desirable at selected locations in the future.

CHT categories were based on stream geomorphic structure, including stream gradient, channel size, and channel pattern. Topography in the Upper Sprague River subbasin is characterized by moderate to steep-gradient uplands that move quickly into low - gradient lowlands. Low gradient streams with extensive floodplains tend to be especially sensitive to the effects of watershed disturbance (see Figure 9-1 and Figure 9-2).

## *Type Aa+ Channels*

Rosgen Type Aa+ channels are confined, very steep gradient streams (greater than 10 percent) found in the headwaters of the stream network. During high flows, the stream may appear as a torrent or waterfall. Type Aa+ channels typically have a step/pool morphology with chutes, debris flows, and waterfalls.

## Type A Channels

Type A channels are similar to Type Aa+, but are found on slightly less steep gradients. These channels have similar landform characteristics, and gradients ranging from 4 percent to 10 percent. Type A channels are often small streams high in the stream network, although sections of Type A may be found along larger streams, as well (see Figure 9-3).

## Type B Channels

The B channel designation includes streams having moderately steep to gently sloped channels, with low rates of aggradation and streambank erosion. Type B channels are moderately entrenched (see Figure 9-4).

## Type C Channels

Type C stream segments have low-gradient channels, with generally less than 2 percent slope. They are frequently found in valleys formed by alluvial deposits. Type C channels characteristically meander across the valley floor, and form point-bars on inner bends (see Figure 9-5).

## Type D Channels

Type D channels are shallow, wide, and braided, with active bank erosion. They are low-gradient and often include multiple channel systems.

## Type DA Channels

Type DA channels are low-gradient, multiple channel systems, which are generally stable and deep relative to channel width.

## Type E

Type E/F stream segments are characterized by a gentle gradient, similar to Type C, but Type E streams are narrower and deeper than Type C streams, and are more stable (see Figure 9-6).

## F Channels

Type F streams are entrenched meandering streams that are not stable, continually eroding, depositing sediment, and gradually re-establishing a functional floodplain. In the absence of severe disturbance to the stream system, Type F streams may transition to Type E as they become stable (see Figure 9-7).

## Ditched Channels

In addition to the Rosgen channel classifications; there were channels that have been redirected through ditches.

**Table 9-1. Rosgen channel type descriptions for the Upper Sprague River subbasin. (Data Source: Rosgen 1996; WPN 1999).**

| Rosgen Channel Type | Comparable OWEB Stream Type(s) | General Description | Entrenchment ratio | W/D ratio | Sinuosity | Slope | Landform/soils/features |
|---|---|---|---|---|---|---|---|
| Aa + | VH<br>SV | Very steep, deeply entrenched, debris transport streams. | < 1.4 | < 12 | 1.0 to 1.1 | >0.10 | Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with/deep scour pools; waterfalls. |
| A | SV<br>BC<br>MV<br>MH | Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel. | < 1.4 | < 12 | 1.0 to 1.2 | 0.04 to 0.10 | High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step-pool bed morphology. |
| B | MH<br>MM | Moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks. | 1.4 to 2.2 | > 12 | > 1.2 | 0.02 to 0.039 | Moderate relief, colluvial deposition and/or residual soils. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate with occasional pools. |
| C | LM<br>FP1<br>FP3 | Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodplains | > 2.2 | > 12 | > 1.4 | < 0.02 | Broad valleys with terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channel. Riffle-pool bed morphology. |
| D | AF<br>FP2 | Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks. | N/A | > 40 | n/a | < 0.04 | Broad valleys with alluvial and colluvial fans. Glacial debris and depositional features. Active lateral adjustment, with abundance of sediment supply. |
| DA | LM<br>LC | Multiple channels that are narrow and deep with expansive well vegetated floodplain and associated wetlands. Very gentle relief with highly variable sinuosities. Stable streambanks. | > 4.0 | < 40 | Variable | < 0.005 | Broad, low-gradient valleys with fine alluvium and/ or lacustrine soils. Multiple channels controlled geologically creating fine deposition with well-vegetated bars that are laterally stable with broad wetland floodplains. |

**Table 9-1. Continued.**

| Rosgen Channel Type | Comparable OWEB Stream Type(s) | General Description | Entrenchment ratio | W/D ratio | Sinuosity | Slope | Landform/soils/features |
|---|---|---|---|---|---|---|---|
| E | FP1 | Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander width ratio. | > 2.2 | < 12 | > 1.5 | < 0.02 | Broad valley/meadows. Alluvial materials with floodplain. Highly sinuous with stable, well-vegetated banks. Riffle/pool morphology with very low width/depth ratio. |
| F | LC | Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio. | < 1.4 | > 12 | > 1.4 | < 0.02 | Entrenched in highly weathered material. Gentle gradients, with a high W/D ratio. Meandering, laterally unstable with high bank-erosion rates. Riffle-pool morphology. |
| G | MC<br>MM | Entrenched "gulley" step/pool and low width/depth ratio on moderate gradients. | < 1.4 | < 12 | > 1.2 | 0.02 to 0.039 | Gulley, step-pool morphology with moderate slopes and low W/D ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials, i.e. fans or deltas. Unstable, with grade control problems and high bank erosion rates. |

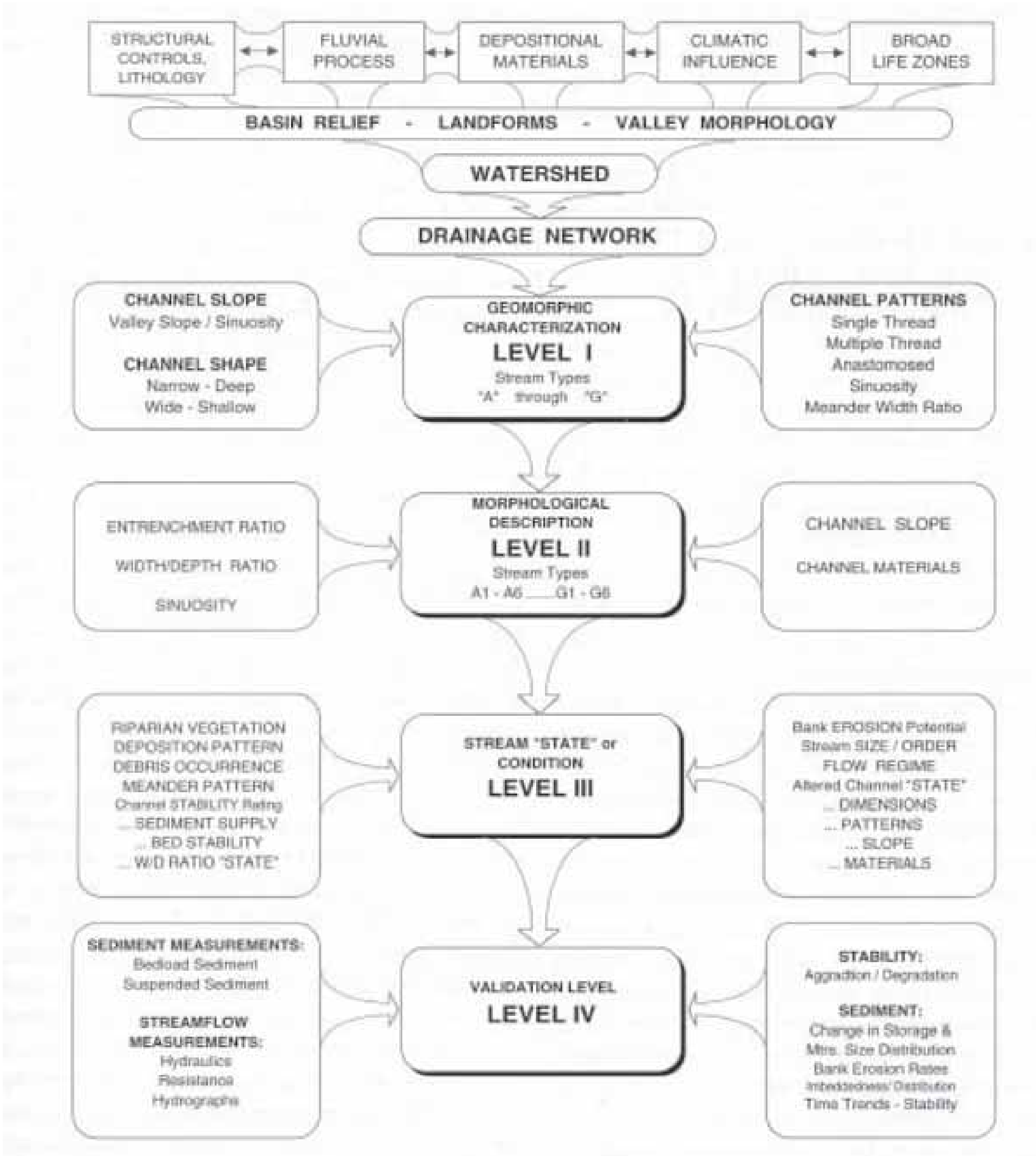



**Figure 9-1. Rosgen Assessment Methodology. (Source: Rosgen 1996.)**

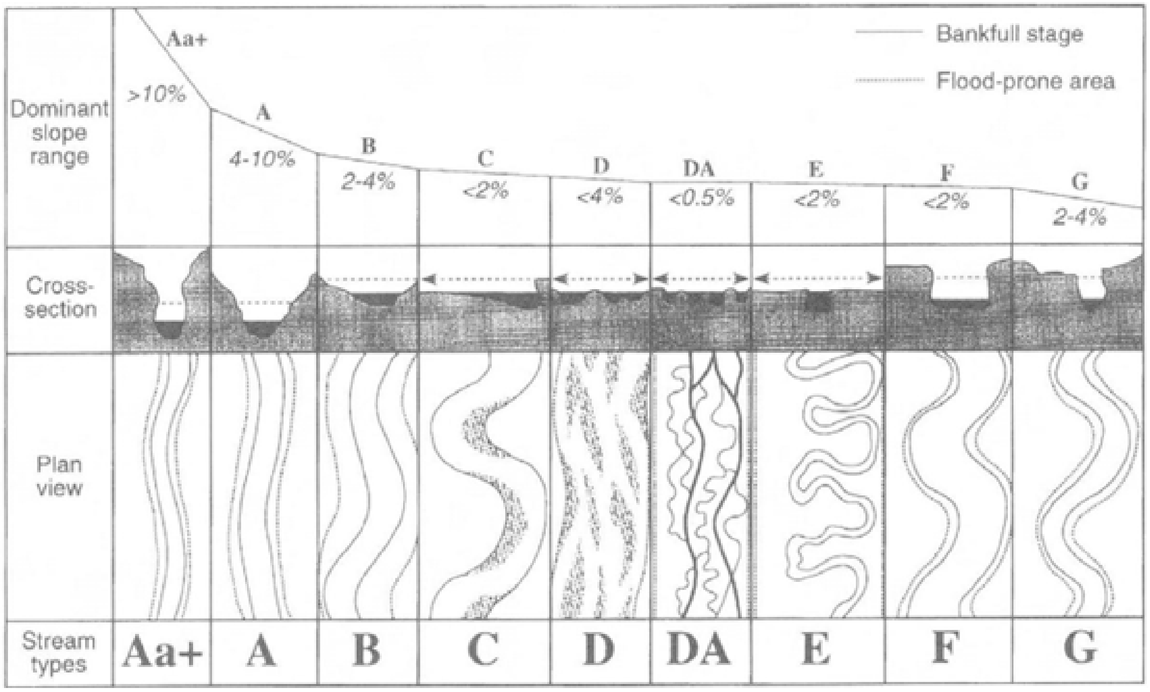



**Figure 9-2. Rosgen Channel Classes. (Data Source: Rosgen 1996.)**

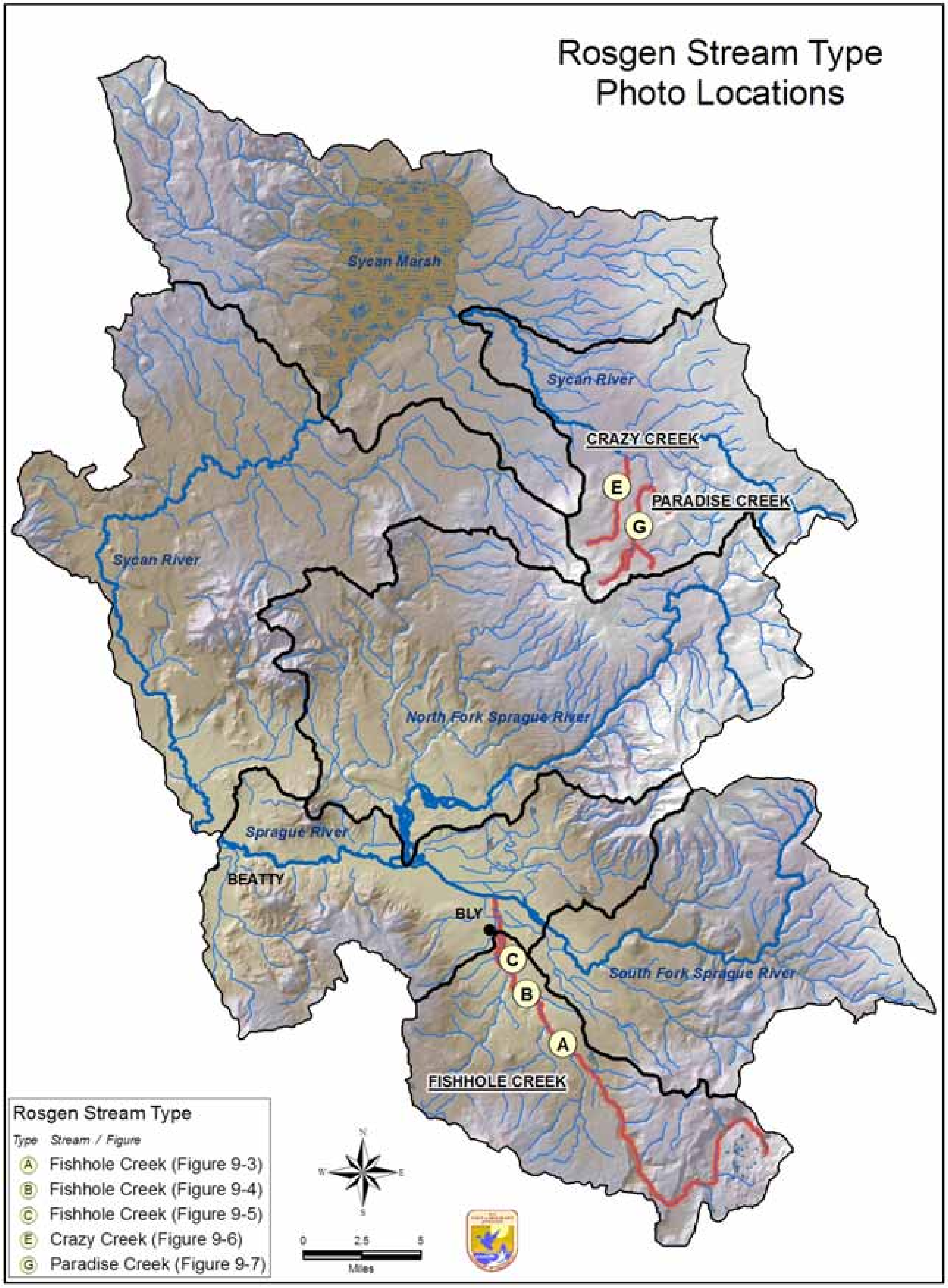
**Figure 9-3. Example of Rosgen channel type A along Fishhole Creek. (Source: S. Mattenberger, USFWS.)**

**Figure 9-4. Example of Rosgen channel type B along Fishhole Creek. (Source: S. Mattenberger, USFWS.)**

**Figure 9-5. Example of Rosgen channel type C along Fishhole Creek. (Source: S. Mattenberger, USFWS.)**

**Figure 9-6. Example of Rosgen channel type E along Crazy Creek. (Source: S. Mattenberger, USFWS.)**

**Figure 9-7. Example of Rosgen channel type F along Paradise Creek. (Source: S. Mattenberger, USFWS.)**




**Map 9-1. Rosgen stream type photo locations. (Source: B.J. Brush, USFWS.)**

# Modifications to Stream Channel Conditions

## Reservoirs

Modifications to the stream channel in the form of dams and reservoirs can affect not only the impoundment area, but also downstream channel morphology, water quality, and fish habitat and passage. Several reservoirs exist in the headwater reaches of the Upper Sprague River and are present in the Fishhole Creek, North Fork Sprague, South Fork Sprague, and Sprague River above Beatty Watersheds (Table 9-2).

All of the reservoirs in the Fishhole Creek Watershed are located in the headwaters of the drainage area along Fishhole Creek itself or its tributaries. They are all of moderate size, ranging from about 22 to 62 acres.

O'Connors Puddle Reservoir is the only reservoir located at the headwaters of Reservoir Creek in the North Fork Sprague Watershed. Since this reservoir is located at the origination of the creek, it does not pose any threats to fish passage.

The Sprague River above Beatty Watershed contains four reservoirs. Campbell reservoir, located on a tributary to Deming Creek, is the largest in the subbasin (206.6 acres). Hyde and Obenchain Reservoirs are two moderately sized reservoirs located within the Fritz Creek subwatershed. Whitmore Reservoir is relatively small (10.6 acres) and located on a tributary stream to the South Fork Sprague River to the west of Bly.

## Splash Dams & Stream Cleaning

Splash dams have been used throughout the watershed. The history of stream cleaning is somewhat unclear. It is certain that this practice has been used on both public and private lands in the Upper Sprague River subbasin. Logs were never transported by any of the streams due to low levels of streamflow (M. Lugus, General Manager, Timber Resources Services, pers. comm., 2006).

## Stream Widening and Encisement

There are stream channels throughout the Upper Sprague River subbasin that have experienced substantial channel modification associated with erosional activities related to gullying, stream incisement, and channel widening. Such changes to the channel morphology have been caused or exacerbated by a variety of human activities in past decades to centuries. These have included over-grazing, beaver trapping, removal of riparian vegetation, land clearing, wildfires, and loss of wetlands. Data are not available, however, with which to specify the locations or severity of such changes. Nevertheless, the impacts on stream structure and function are important. In particular, such changes to the channel morphology are often associated with increased sedimentation of spawning gravels, increased water temperature, and diminished riparian function.

**Table 9-2. Reservoir distribution in the Upper Sprague River subbasin.**

| Watershed | Reservoir Name | Area (acres) |
|---|---|---|
| Sprague River Above Beatty | Campbell Reservoir | 206.6 |
| | Obenchain Reservoir | 71.2 |
| | Hyde Reservoir | 29.4 |
| | Whitmore Reservoir | 10.6 |
| | Unamed Reservoir1 | 3.0 |
| | Unamed Reservoir2 | 3.5 |
| | Unamed Reservoir3 | 1.7 |
| North Fork Sprague | O'Connors Puddle Reservoir | 33.9 |
| South Fork Sprague | Little Reservoir Number One | 0.2 |
| | Little Reservoir Number Three | 1.7 |
| | Little Reservoir Number Five | 3.0 |
| | Little Reservoir Number Six | 1.2 |
| Fishhole Creek | Holbrook Reservoir | 61.8 |
| | Big Swamp Reservoir | 36.8 |
| | Lofton Reservoir | 41.5 |
| | Lapham Reservoir | 21.7 |
| Total | | 527.8 |

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