RIVER STYLES® REPORT FOR THE MIDDLE FORK JOHN DAY WATERSHED, OREGON

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EXECUTIVE SUMMARY

- The Middle Fork John Day River (MFJDR) in eastern Oregon is an Intensively Monitored Watershed and is part of habitat status and trend monitoring through the Columbia Habitat and Monitoring Program (CHaMP). The Middle Fork John Day Watershed (MFJDW) supports Chinook salmon and steelhead, and numerous river restoration projects have been undertaken in the watershed to improve channel and riparian habitat.
- The MFJDW was the focus of a complete geomorphic assessment using the River Styles framework®. The River Styles framework employs a hierarchical scheme of river assessment that is "nested" on the scale of regional, watershed, river reach, geomorphic unit, and habitat or hydraulic unit features. This approach also encompasses the ecological setting at every scale of analysis. The River Styles framework includes four stages that build one upon the next, and and culminate in what can be used as a template for a strategic river management plan.
- The geomorphology of river channels and their associated floodplains and valleys are key to deciphering form and process by which habitat suitable for salmonid species is created and maintained. At the heart of restoration efforts for degraded streams is a focus on the river channel and its current geomorphic condition relative to a reference, or natural state for the river in question.
- Building upon a strong characterization of the regional and watershed setting, we documented in detail the physical and flux controls on river character (i.e., "form") and behavior ("function"). Measured metrics include valley and channel width, channel slope and stream power, upstream drainage area, and sediment process zone.
- We identified fourteen distinct river styles throughout the MFJDW. Six reside in confined valley settings, four in partly confined valleys, and four occupy laterally unconfined valley settings. Valley setting is a strong indicator of *capacity for adjustment*, a gauge of the relative sensitivity of a stream to natural and human disturbance. In the MFJDW, streams of that laterally unconfined valley setting have the highest capacity for adjustment and sensitivity to disturbance. They are also the most accessible; consequently, they have incurred disproportionate land use pressure and direct, visible impact.
- River Styles in most watersheds tend to form downstream patterns based on characteristics of lithology, channel slope, elevation and vegetation cover. Tributary streams typically occupy confined valley settings high in the watershed and grade to partly confined or laterally unconfined valley settings nearer their base levels. The upper MFJDW follows a similar pattern, characterized by widespread laterally unconfined valleys. The lower watershed, however, is strongly bedrock-controlled and flows entirely within a confined valley setting. Thus, most of the land use—and visible impacts to streams and floodplains—is focused in the upper watershed.
- Rivers and tributaries of the MFJDW showed a range of geomorphic conditions, based on historic and current land use. The geomorphic condition of each river style is based upon the "adjustment potential" and possession of physical attributes that are ecogeomophically linked to the boundary conditions in which it functions (i.e., geoindicators). An assessment of geomorphic condition inevitably identifies "variants" within each river style, when compared to a "reference" or best condition available in the watershed. Most

of the variability is keyed to reach position in the watershed and land use pressures and impacts. We recognized and described at least two, and as many as five, variants within each non-ephemeral River Style.

- Geomorphic condition of MFJDW streams form the basis for assessing their trajectory of future change, and for judging the recovery potential of each reach of every River Style. Our watershed map of geomorphic recovery potential suggests that, with a few exceptions, most streams have a high probability of recovering from land use pressures without intervention. Streams of the southeast MFJDW have incurred disproportionate impacts in a relatively delicate landscape (basic soils, sparse forests, accessible terrain for multiple land uses), and have only moderate recovery potential. Isolated reaches of the mainstem and a few tributaries have poor recovery potential—their geomorphic condition and function will not improve without intervention.
- To complete Stage Four of the River Styles framework, we developed a watershed-framed physical vision where realistic goals for river recovery and restoration are set within a timeframe of 50-100 years. . This vision is not a huge departure from the key management drivers that are currently operating in the MFJD. Management objectives for reaches of every river style encourage preservation of unique or remaining natural areas, followed by restoration efforts that support and influence the overall health of good condition reaches with high recovery potential.
- Results of the prioritized management reaches from this study suggest that most of the highland and upland areas of the watershed are in good geomorphic condition, have high recovery potential, and should recover without intervention. *Strategic Reaches* on moderate and poor condition reaches of the mainstem MFJDR are targets for mitigation to improve habitat quality and refugia for anadromous reaches throughout the upper MFJDW. *Connected reaches* in good condition should be managed with the conservation and intact reaches they are integrated with. Finally, *isolated, good condition* reaches are critical to help improve strategic reaches and enhance the viability of habitat along the mainstem.
- Overall, the positioning of good versus moderate or poor condition reaches is favorable in the MFJDW. That is, intact and good condition streams lie upstream of moderate and poor condition reaches within the upper watershed. One exception is the moderate and poor condition of headwater streams of the southeast watershed—a concern because they lie upstream of mainstem reaches with high adjustment potential and greater sensitivity to disturbance. The other exception is the poor condition reaches downstream of Camp Creek. It is a potential trouble spot for transit of fish and healthy refugia, but of lesser concern to the lower watershed as a whole because the downstream mainstem exhibits very low adjustment potential, and has higher resistance to intrinsic disturbances.
- Results of this study corroborate previous documentation that the MFJDW has incurred significant impact through ranching operations, road building and clear-cut logging, channel re-routing, floodplain/wetland drainage and grazing, and channel bed mining throughout the last century. Fortunately, the most damaging of these practices have since been curtailed and the recovery potential for the watershed is very favorable.
- Although this report culminates in a potential strategic management plan, the MFJD plan Is NOT intended as *the* actual management plan as it was not developed in direct consultation with MFJD stakeholders and managers. Moreover, although River Styles is biophysically framed, the framework focuses heavily on the geomorphic template, which although extremely important for understanding physical habitat for fish, does not consider other important factors like temperature and food availability. In systems where the primary limiting factors are physical habitat degradation (excluding temperature and food), River Styles can be used

to get 90% to 95% of the way towards useful summaries of habitat condition, and physical recovery potential.

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1 INTRODUCTION

1.1 BACKGROUND

The Middle Fork John Day Watershed (hereafter, MFJDW) is a 2050 km^2 subwatershed of the Columbia River Basin (CRB) located in east-central Oregon (Figure 1). A natural home to native salmonid species, the John Day basin supports a wild population of Chinook salmon and summer steelhead but that is significantly reduced relative to historic levels (e.g., Wilson et al., 2004-2005). Rivers of the CRB have been modified by human development since settlement in the early 19th Century. Impacts to anadromous salmonid populations have been most directly measured through physical barriers to upstream migration in the form of hydroelectric dams, and through degradation of local habitat by economic and subsistence activities within individual watersheds. These primarily include logging, grazing and ranching across alluvial floodplains and adjacent landscapes, and mining of river channels, floodplains and contributing watersheds (NOAA, 2013).

As a response to listing of Chinook salmon as threatened under the Endangered Species Act, biological opinions of the National Marine Fisheries Service directed that reduced historic populations of salmonid in the CRB be offset by improvement in habitat. The Bonneville Power Administration (BPA) was responsible for building dams across the CRB through the Federal Columbia River Power System (FCRPS) that have adversely impacted salmon and steelhead populations. BPA partnered with National Oceanic and Atmospheric Administration (NOAA) and U S Forest Service (USFS) to implement new habitat assessment protocols for salmon species across the CRB. One such program is the Integrated Status and Effectiveness Monitoring Program (ISEMP), which designs and tests sampling and data management protocols. ISEMP designated the Middle Fork John Day an Intensively Monitored Watershed (IMW), a status that seeks to implement stream restoration efforts in an experimental framework to determine the effectiveness of restoration on increasing salmon productivity (Bouwes et al., 2011) (ISEMP, 2012).

Since that time myriad restoration efforts (e.g., Holburn et al., 2009) and geomorphic reach assessments (Reclamation, 2008, 2010) have been launched in partnership with federal agencies, local Tribal entities, and residents of Grant County, Oregon. ISEMP tests sampling and analytical designs under authority of NOAA and BPA, and in 2006 launched the Columbia Habitat and Monitoring Program (CHaMP). The purpose of CHaMP is to design and implement a suite of fish habitat monitoring methods. CHaMP maintains dozens of monitoring sites in the MFJDW under a scientific protocol intended to identify factors limiting fish production, design restoration actions to address them, and to implement restoration actions as large-scale experiments to monitor the success of those efforts (CHaMP, 2012). The protocol is structured to collect and evaluate the geomorphology of sites (including channel classification) at a range of spatial scales. The protocol is “fish-centric”, recognizing that specific habitat elements are strongly tied to life-cycle requirements of fish. The geomorphology of stream beds, their adjacent floodplains, and their enclosing valleys are powerful indicators of habitat health, because fish respond to the condition of geomorphic units as well as reaches and of the watershed as a whole (Beechie and Sibley, 1997; Montgomery, 2004).

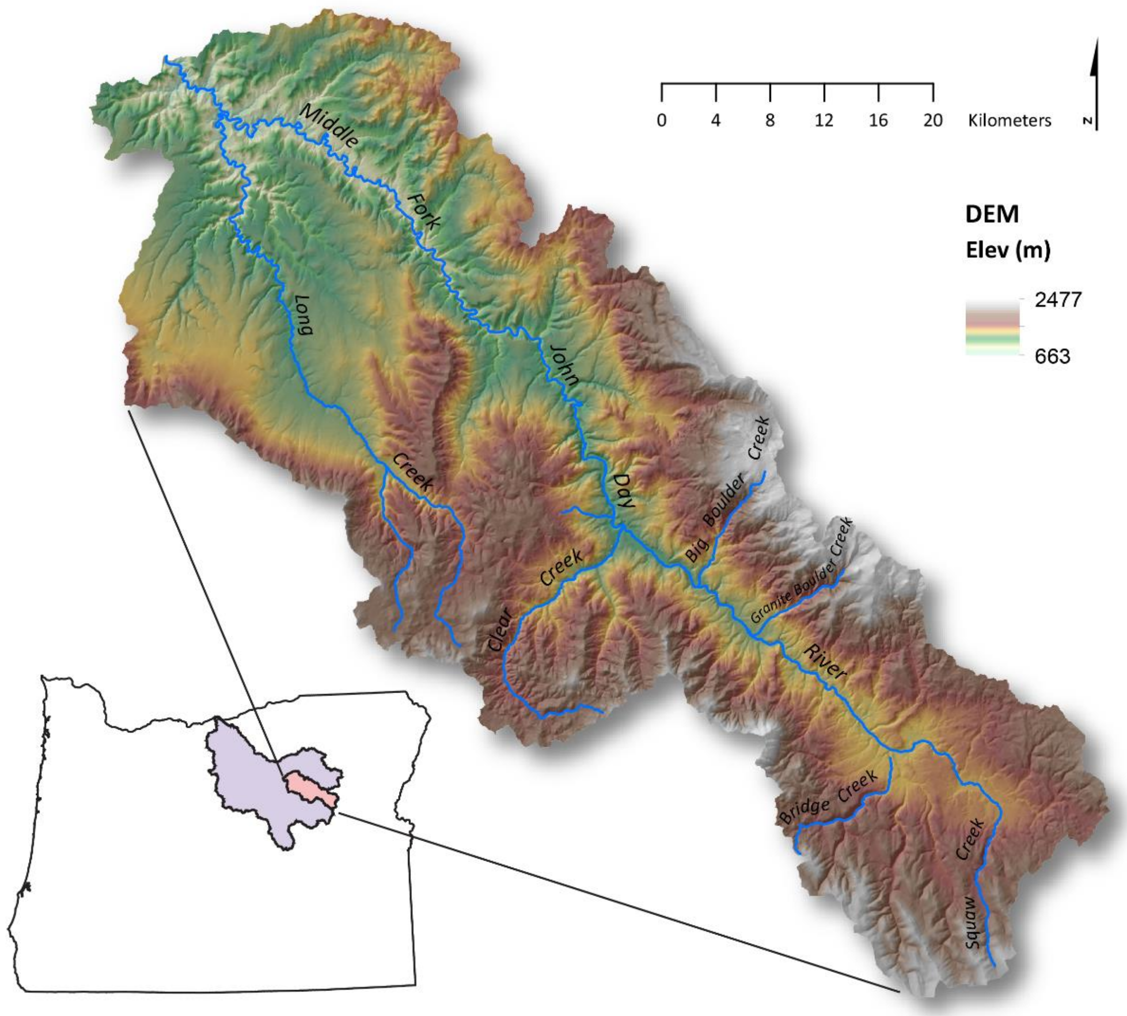


Figure 1. Shaded relief map of the MFJDW showing key tributary streams. The John Day basin is shown in purple of the inset map; the Middle Fork John Day Watershed is colored pink.

1.2 PURPOSE OF THE STUDY

The purpose of this report is to present an example of the River Styles framework implemented in a CRB Context. We used the MFJDW as an example watershed, due to its overlap with previous assessments. The key objectives of the study are to map and define the different river styles in the basin, assess their geomorphic condition, assess their geomorphic recovery potential, and show an example of how this information can be synthesized into a watershed management plan. **We present this report as a proof-of-concept for a standardized geomorphic assessment of a study watershed using the River Styles framework and using some assumptions about management priorities.** Although the reach typing (river styles), condition assessment and recovery potential are complete from a geomorphic perspective, we do not intend the Stage Four strategic plan to be an actual river management plan as it was not developed in conjunction with key stakeholders, land managers and decision makers. Moreover, as one of the primary drivers of watershed management and tributary habitat in the CRB is managing for salmon populations, an actual management plan would also need to include more fish-centric inputs. Specifically, the geomorphic condition assessment would be best extended to a fish habitat condition assessment, which in addition to geomorphic condition would consider other life-stage specific factors like temperature and food availability. To consider fish habitat recovery potential, one would not only consider the geomorphic recovery potential, but also the potential to improve temperature and overall habitat.

Fluvial geomorphology presents a physical template of landscape forms and processes that "..underpin the ecological integrity and biodiversity of river systems" (Brierley and Fryirs, 2005). Because enhancing or maintaining these values in the context of conservation or enhancement goals forms the basis for river management efforts to a large degree, interpretation of the form and function of river characteristics and behaviors is key to proactive river management (Beechie and Sibley, 1997; Kondolf, 2000). Given the importance of fluvial geomorphology in the determination of relative ecosystem health and river condition, the primary purpose of this report is to (a) apply the River Styles framework to the entire MFJDW and present data on the geomorphic condition and recovery potential of streams in the watershed; and (b) to develop a river management vision and set of recommendations based on those findings.

1.3 THE RIVER STYLES FRAMEWORK

The River Styles framework is a methodology for understanding why rivers appear and behave the way they do under current sediment and flow regimes, and how they are likely to appear and behave in the future. At the core of the River Styles framework is the recognition that rivers operate and adjust under the strong influence of a nested hierarchy of landscapes, landforms, deposits and habitats (Figure 2). Brierley and Fryirs (2005) state that the River Styles framework provides "..a coherent set of guidelines… with which to document the structure and function of rivers, and appraise patterns of river types and their biophysical linkages in catchment context". It does this by characterizing rivers within their unique watersheds, a trait uncommon to most existing river classification schemes (cf. Montgomery and Buffington, 1997; Rosgen, 1994). Within this method is a focus on the observation and interpretation of geomorphic forms and processes with which to assess river character and river behavior. Using these observations, a rigorous process for predicting future river condition is based on contemporary conditions, evidence of past conditions, and the recovery potential of any given reach with individual streams (e.g., Frissell et al., 1986; Kellerhals et al., 1976). Yet a river styles analysis is not finished with completion of the baseline survey of River Character and Behavior. In fact, the Stage One analysis sets the stage for geomorphic condition (Stage Two) and recovery potential (Stage Three) assessments that inform priorities for strategic management plans (Stage Four).

The River Styles framework stresses the importance of connectivity between all parts of a watershed at multiple spatial scales (Figure 2). Despite a tremendous level of detailed and thorough site-based monitoring employed through programs like CHaMP, point or site-specific sampling can fail to capture the full range of natural variability implicit in river systems, especially those occurring at tributary junctions and at reach boundaries. Use of a geomorphic classification system that is based on ecological and landscape principals and perspectives can work effectively with the principals and practices of habitat and effectiveness monitoring in the MFJDW.

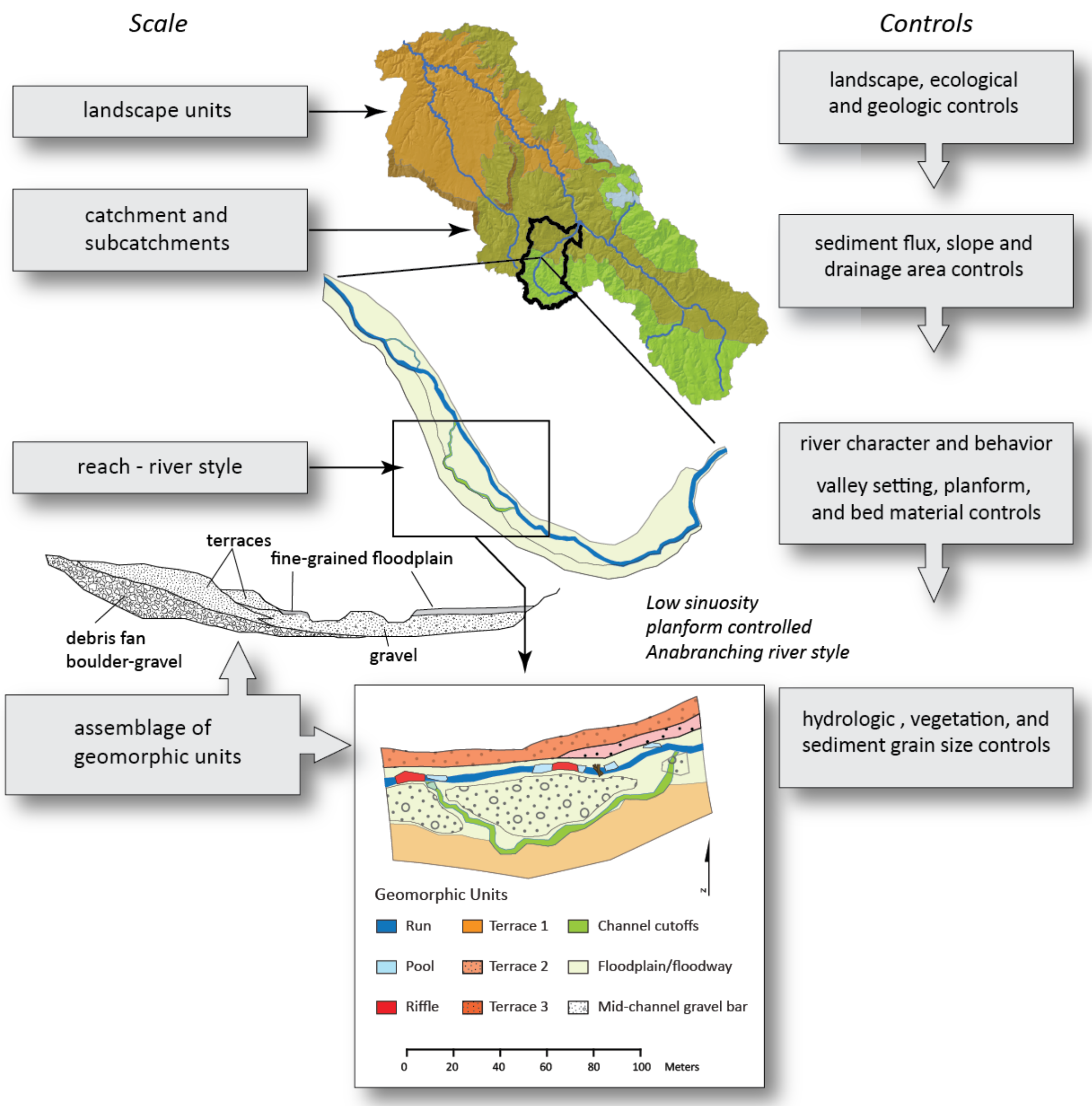


Figure 2. The river styles nested hierarchy depicting the *Low sinuosity planform-controlled anabranching river style* in Camp Creek, MFJDW (after Brierley and Fryirs, 2005).

The basis for geomorphic river classification is the systematic categorization of physical attributes of a river flowing in its channel, the valley through which it flows, and the geomorphic features that comprise its floodplain and channel (Buffington and Montgomery, 2013). Through a spectrum of bedrock and alluvial variants, these characteristics reflect a balance of sediment supply and channel transport capacity. A river's *character* is its unique river morphology, including valley, floodplain and instream geomorphic features; whereas river *behavior* is the tendency and capacity for adjustment within its valley setting and floodplain, tied to boundary conditions set by flow and sediment fluxes typical for that stream. River behavior drives the assembly of geomorphic units present within its channel—by form and process associations.

1.4 STAGES OF THE RIVER STYLES FRAMEWORK

The River Styles framework comprises four steps or stages. The first involves characterizing the watershed in terms of its regional setting and landscape components, and delineating the drainage network into river styles based on stream characteristics and behavioral attributes governed by landscape and lithologic controls (i.e., bedrock hardness and erodibility). In this stage, the emerging network of river styles breaks into common downstream patterns that help to characterize forcing mechanisms for river attributes in the watershed. Given the assessment of river character and behavior accomplished in Stage One, the geomorphic condition of each river style is assessed in Stage Two, on the basis of their evolution, or the natural capacity for the system to adjust within its boundary conditions (i.e., valley setting, sediment supply and flow regime, catchment characteristics). These results allow an appraisal of the pathway of likely future adjustment and the recovery potential for each River Style in reaches where they occur (Stage Three). A knowledge of potential future trajectories for rivers of specific catchments and patterns of river styles sets up Stage Four, the process of conceptualizing, designing, and implementing management initiatives such as river restoration plans.

1.5 PERSONNEL AND INSTITUTIONAL AFFILIATION

This River Styles report originated from the Fluvial Habitat Center, Watershed Sciences Department, Utah State University (USU), Logan, in association with Eco Logical Research, Inc. The lead scientists who conducted the work are Fluvial Geomorphologists Gary O'Brien and Joe Wheaton. Earlier drafts of Stage One assessments were conducted by Alan Kasprak (USU). We did not create this report with typical stakeholders; this project was funded by Eco Logical Research through the Bonneville Power Administration and the National Oceanic and Atmospheric Administration (NOAA).

2 METHODS

Methods described in this chapter reflect office-based tasks required to procure information and process data, and field methods undertaken during fieldwork. Stage One of the River Styles framework (Section 4) focuses on the regional and watershed setting, and determines controls over river character (i.e., "form") and behavior ("function"). These data underpin the identification of river styles. We designate river styles and their downstream patterns and present a watershed map at the end of chapter 4.

2.1 STAGE ONE: RIVER CHARACTER AND BEHAVIOR

2.1.1 REGIONAL AND WATERSHED SETTING

The core of Section 3, the *Regional and Watershed Setting* is background on the Geologic setting, derivation and significance of landscape units, climate and basin hydrology, vegetation, and land use history. Much of this background was accomplished by a literature search and available online resources that included government databases and data sources (digital datasets such as stream networks, digital elevation models and LiDAR coverage), regional resource maps and GIS databases (i.e., ecoregions, geology, soils, vegetation), and flood history records and gauge station data taken from United States Geological Survey (USGS) Stream flow records. Numerous sources are available for reporting the geology of northeast Oregon. Reports and GIS layers are available through the Oregon Department of Geology and Mineral Industries (DOGAMI), and USGS maps (e.g., Walker and MacLeod, 1991)
URL: http://mrdata.usgs.gov/sgmc/or.html. Particularly helpful was the DOGAMI Publication IMS-28, "Oregon: a Geologic History" http://www.oregongeology.org/sub/publications/IMS/ims-028/index.htm.

The delineation and analysis of landscape units is central to understanding controls on river character and behavior. Using combined attributes of various data sources, we determined boundaries between landscape units using similar physiographic characteristics, landscape position, geology, and relief. Landscape units were field checked during field work in July 2013, and through air overflights in 2012.

1. *Maps of Level IV Ecoregions*: These maps form the basis for understanding the spatial framework of the similarities of ecosystems. They are compilations of information based on geology, physiography, vegetation, climate, soils, land use, wildlife distributions, and hydrology.
2. *Geologic Maps of Oregon*: (Madin, 2009) Relative differences in bedrock hardness and composition strongly influence channel channel characteristics, i.e., slope, channel width, sediment production and storage.
3. *Vegetation maps*: Distributed by LANDFIRE, the Landscape Resource Management Planning Program. http://www.landfire.gov/index.php. LANDFIRE maps are distributed at 30m resolution.
4. *Digital Elevation Models (DEM)*: Slope rasters were used to determine the distribution and character of relief throughout the watershed. We used 10 m DEMs for this analysis.

2.1.2 INTERPRETATION AND DESIGNATION OF RIVER STYLES

Compilation of background information and designation of landscape units precedes the task of designating river styles for streams throughout the watershed. We accomplished this through aerial reconnaissance using Google Earth™ imagery (high-resolution satellite [SPOT image]) and aerial photography (Digital Globe; 2014 Google). This involved mapping river styles onto a drainage network using the core criteria for identification of river types as put forth by Brierley and Fryirs (2005): recognizing the geomorphic attributes of valley setting or channel confinement, channel planform (the channel outline in map view), geomorphic units, and bed material texture. Fundamental change in any one of these physical attributes marks a *reach break* between one river style and the next along a stream length. In this report, reach breaks were determined using criteria outlined in Figure 3 and intensive, systematic observation of aerial photography. We corroborated representative reaches of each river style determined remotely, during fieldwork at proforma validation sites (see below).

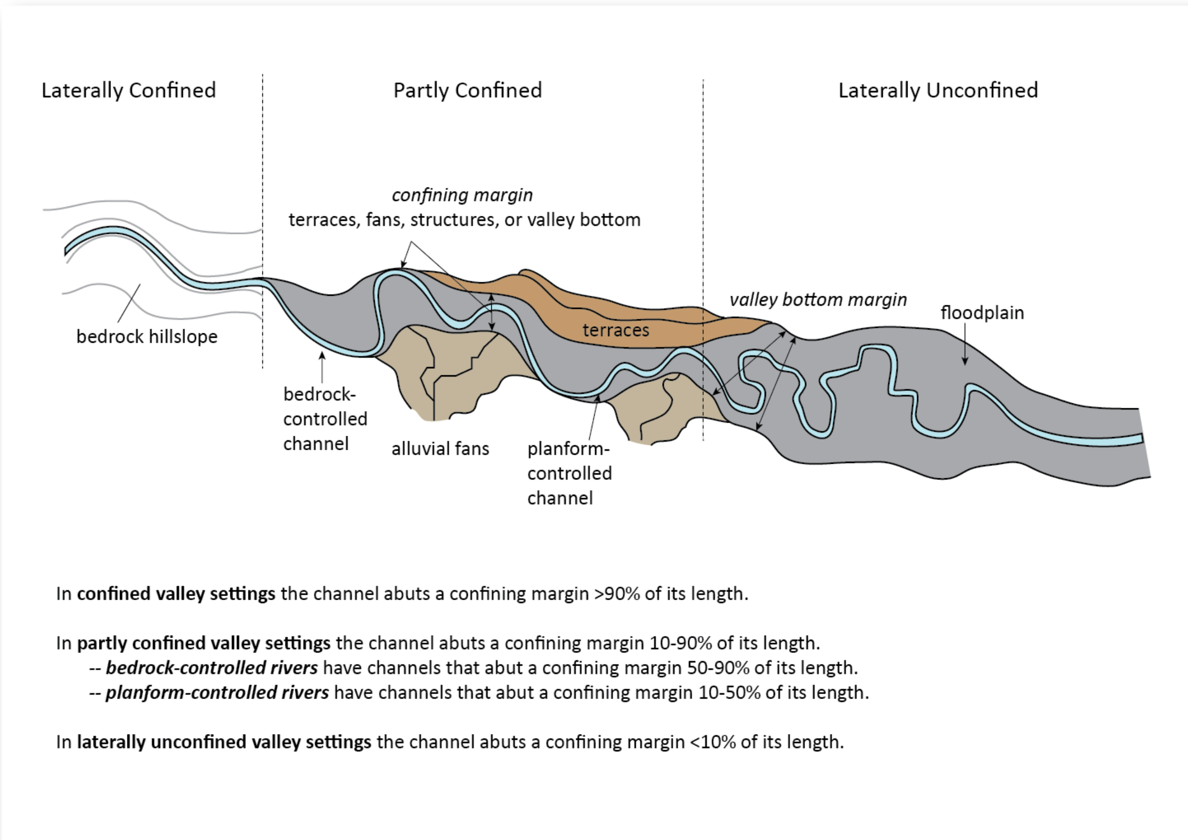


Figure 3. Conceptual schematic of valley setting along three distinct reaches. Gray background indicates floodplain. In confined valley settings the channel is between narrow valley walls and contains little or no floodplain (see text for details). Modified from Wheaton et al. (in press).

NHD stands for National Hydrography Dataset (NHD) and is the surface water component of the USGS's National Map (USGS, 2007). The 24k NHD was chosen for mapping the types, boundaries and spatial distribution of river styles because it is a cartographically derived, digital vector dataset that realistically follows actual river courses. With the use of photo-draped, high-resolution imagery available in Google Earth, most of these features were easily viewed "in 3D" and river styles interpreted from the remote desktop setting. This allowed a strong "first cut" of river styles to be recognized throughout the watershed.

Once defined in terms of river character and behavior, we keyed each river style to a series of *river styles trees* (Section 4.1) that display the criteria appropriate for individual settings. The "road map" for each river style tree is the *river styles procedural tree* shown in Figure 4. This is an important document because core criteria are unique to each set of landscape controls within subcatchments that drive valley and channel characteristics. The differences are most apparent in the sense of top-down controls, starting with the valley setting configuration. For example, floodplain and planform characteristics are important in laterally unconfined and partly confined valley settings but are not important in confined valleys. Conversely, bedrock channels are not generally a factor in laterally unconfined valleys.

The entry-level criteria for determining a river style is *valley setting*, or degree of channel confinement. The degree of confinement is critical to understanding river behavior (the ability of a river to adjust laterally and to some extent, vertically, within its channel) because valley setting tends to dictate whether a river is storing sediment and maneuvering within its floodplain, or whether it is conveying sediment downstream over a steeper gradient with little room to adjust. It is an expression of the rate of bedrock incision relative to valley widening.

The *valley setting* describes the valley through which the river flows along with any other deposits or structures that impose a barrier to lateral adjustment of the river within its channel. Valley setting is determined through the interaction of the channel with confining margins imposed by (a) the *valley bottom margin,* which is the trace of the alluvial floodplain, defined by the valley walls or other deposits; and (b) deposits such as alluvial or debris fans, coarse-grained abandoned floodplains (terraces) or bedrock outcrops (Figure 3). Together, the valley bottom margin and surficial deposits define the *confining margin*.

If a channel flows within a *confined valley* setting, there generally is no floodplain or only short, discontinuous floodplain pockets. The channel abuts a confining margin >90% of its length in confined valley settings. In *partly confined valley* settings, the channel is restricted against the valley wall 10-90% of its course within that reach, and discontinuous floodplain segments may be observed as the river sweeps or scrolls between one valley wall and the next (Fryirs and Brierley, 2013). A river flowing across a *laterally unconfined valley* is free to adjust laterally and downstream within its floodplain. It is in contact with confining margins 10% of its length or less. In the MFJDW, laterally unconfined valley settings are typically fine-grained, vertically aggraded floodplains where the channel has assumed a meandering, planform-controlled profile. By convention, the percent of channel contact is calculated by:

$$\frac{RL + RR}{2L}$$

where the sum of channel contact on river left (RL) and river right (RR) per unit length is divided by twice the overall reach length (L). In this study, the approach to determining valley setting was subjective, based on visual estimates of channel contact, floodplain extent, and valley wall characteristics between reach breaks.

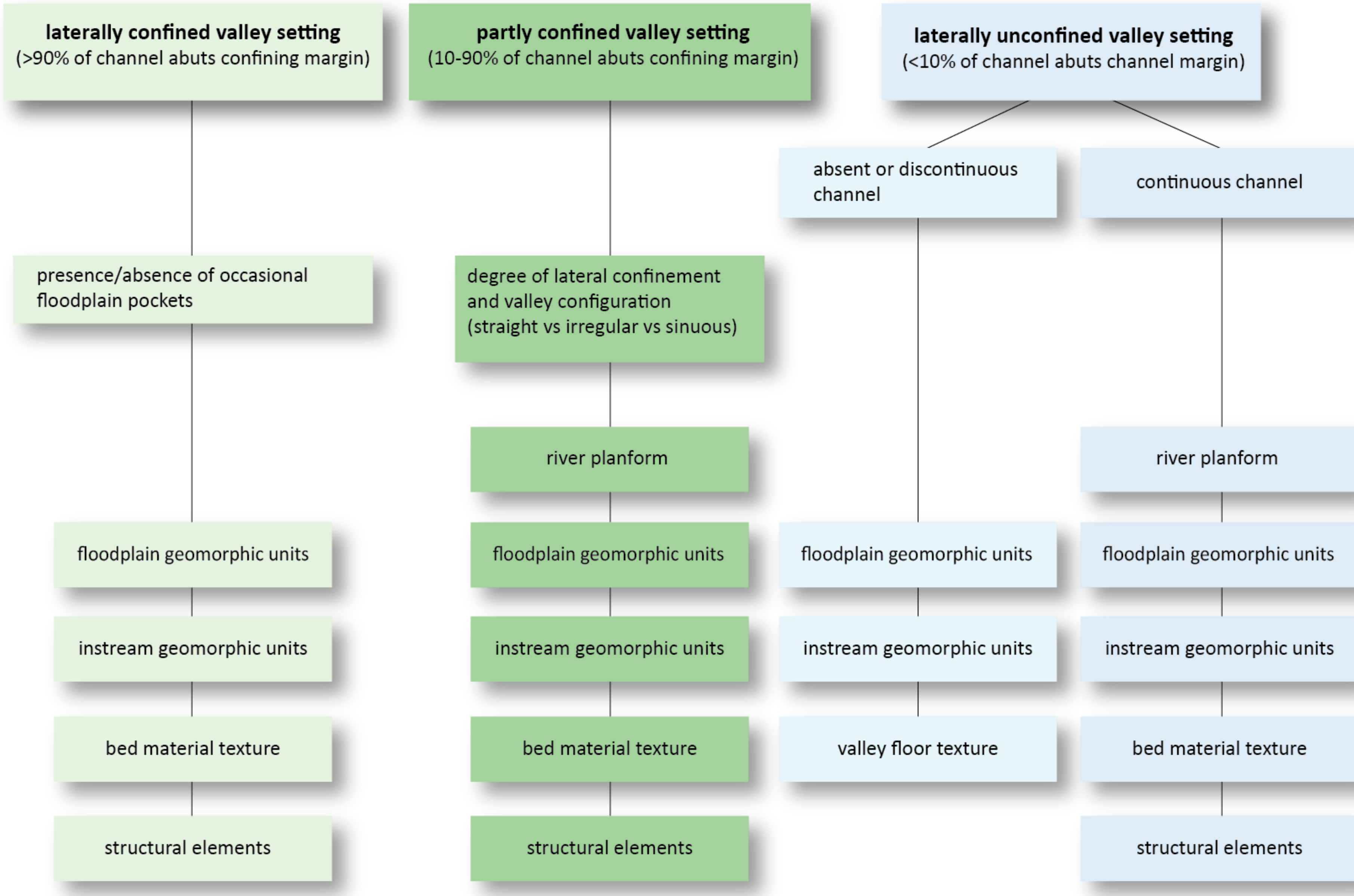


Figure 4. The river style procedural tree modified from Brierley and Fryiers (2005), for the MFJDW. Structural elements include any of the following: natural woody debris, large boulders, installed restoration structures, and engineered additions to the channel (roads, bridges, culverts, etc).

The next consideration is channel planform. The degree of channel sinuosity (channel length divided by downstream distance) and the number of channels present is noted, and whether the channel is bedrock-controlled, or planform-controlled (able to laterally adjust or shift within its floodplain). Valley confinement and planform characteristics strongly influence the presence and character of floodplain and instream geomorphic units (Figure 2). These m-to km-scale features are the key indicators of flux boundary conditions (i.e., flow regime, flood history, and sediment flux through, or being stored within the reach). Bed material texture (sediment caliber or grain size) and sorting are strong indicators of system energy and proximity to source, transfer or accumulation process zones. In addition to the above criteria, we have added observations of *structural elements* given their importance in creating and maintaining fishery habitat (Wheaton et al., 2010). Instream structural elements occur as naturally accumulated woody debris that are capable of forcing modification of bar forms (Wheaton et al., 2012), and as restoration structures that are installed to enhance channel form heterogeneity and habitat diversity (Figure 5 and Figure 6).

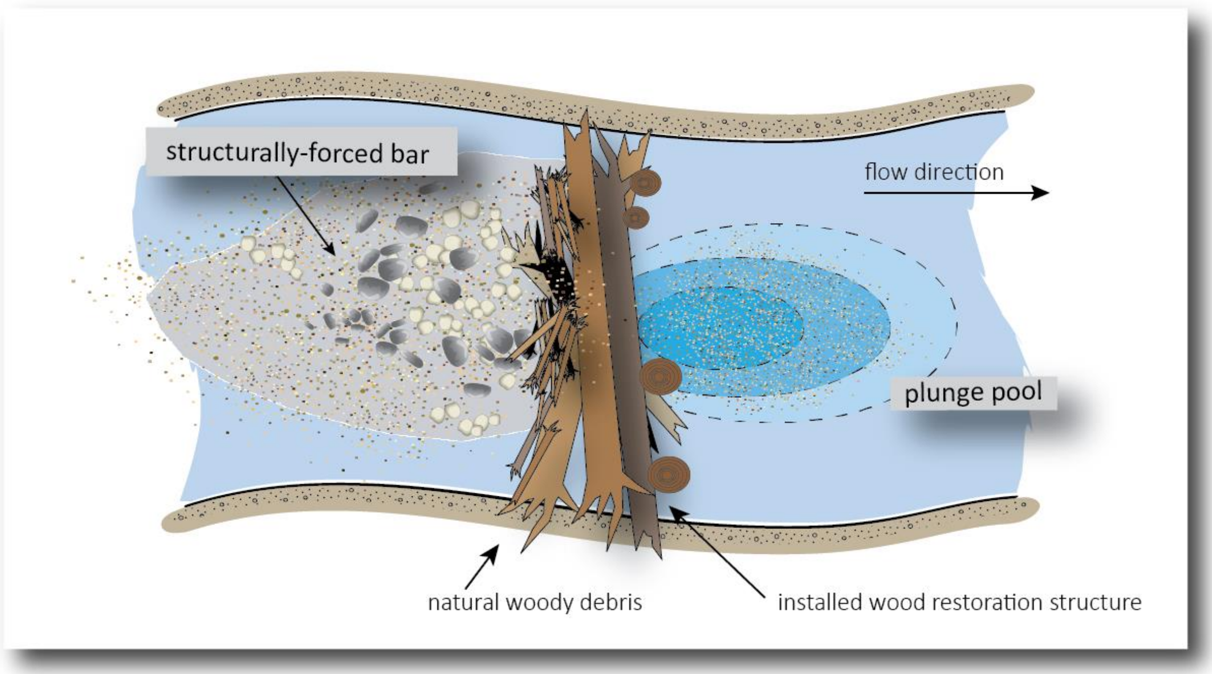
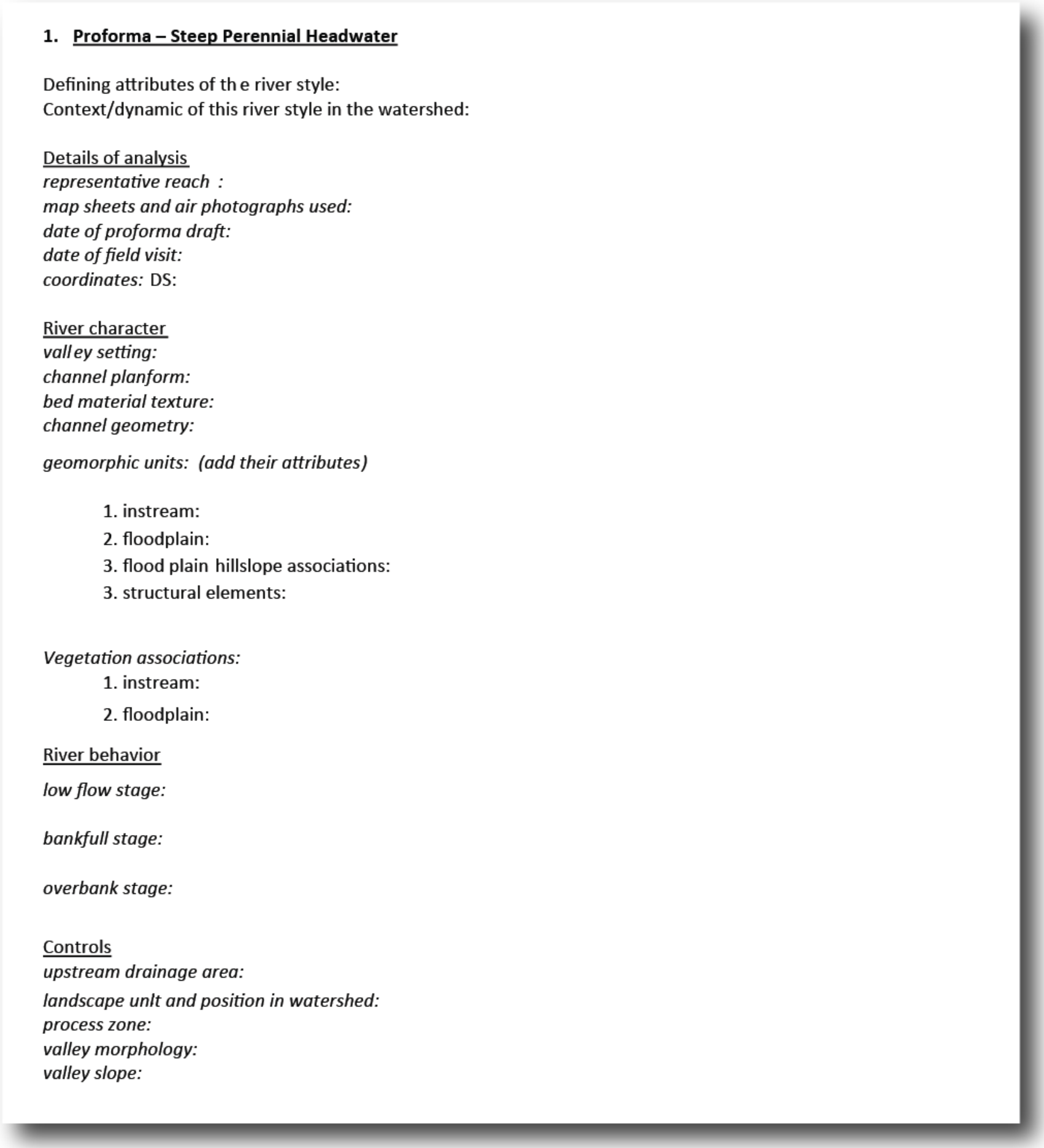


Figure 5. Conceptual map view of an instream, channel-spanning woody restoration structure. Features such as plunge/scour pools and structurally forced mid-channel bars result from hydraulic modification of the channel bed material.

Figure 6. Structural elements present in the MFJDW and part of criteria in the river styles procedural tree. (A) Channel-spanning log in Summit Creek, designed to create scour pools and downstream bars; (B) channel-spanning restoration structure log and instream woody debris, Squaw Creek; (C) channel-spanning, instream jam of large woody debris, MFJDR.

With these tools in hand, we selected representative reaches for each river style, and proforma maps prepared from aerial photographs and LiDAR coverage. Their purpose was to provide a tool for site validation of our office-based geomorphic interpretations. Figure 7 shows the site evaluation template. We rendered watershed maps at a scale of 1:350,000, and proforma sites mapped at a scale of 1:5,000 to 1:10,000 depending on detail required to depict detail of each site, such as geomorphic units and cross-section surveys.



1. **<u>Proforma – Steep Perennial Headwater</u>**

Defining attributes of th e river style:
Context/dynamic of this river style in the watershed:

<u>Details of analysis</u>
representative reach :
map sheets and air photographs used:
date of proforma draft:
date of field visit:
coordinates: DS:

<u>River character</u>
vall ey setting:
channel planform:
bed material texture:
channel geometry:

geomorphic units: (add their attributes)

1. instream:
2. floodplain:
3. flood plain hillslope associations:
3. structural elements:

Vegetation associations:
1. instream:
2. floodplain:

<u>River behavior</u>

low flow stage:

bankfull stage:

overbank stage:

<u>Controls</u>
upstream drainage area:
landscape unlt and position in watershed:
process zone:
valley morphology:
valley slope:

Figure 7. Proforma site evaluation form used for field validation of mapped geomorphic attributes

Field validation of proforma sites occurred during July 14-22, 2013, with an additional site visit November 15-17, 2013. Field work consisted of visits to all 14 proforma sites to validate prepared maps, conduct survey cross sections, map geomorphic units, and collect a host of related information (Figure 8; Table 1). Onsite assessments of key criteria included valley setting (channel width, deposits), channel planform and geometry, bed material texture, and mapping of geomorphic/hydraulic units. Data collection also included hundreds of geo-tagged photographs taken with a digital camera, and more than 70 pages of handwritten field notes, maps, diagrams and survey data.

Geomorphic stream units and features, locations of major landforms, and cross sections were digitally mapped on an iPad using the GIS Pro application. Mapping also included 11 x 17" proforma planform images prepared beforehand during the standard GIS desktop preparation exercise. Several sites were accessed by mountain bike and by foot where vehicle access was not possible. We surveyed channel cross sections using a laser level technique: a tripod-mounted rotating laser level was stationed as the backsite, and point heights above datum were recorded manually using an electronic sensor mounted on an extendable survey rod. Intervals between points were read from a 100 m tape fixed at the backsite and stretched along the survey transect. Survey data for proforma sites are in Appendix A.

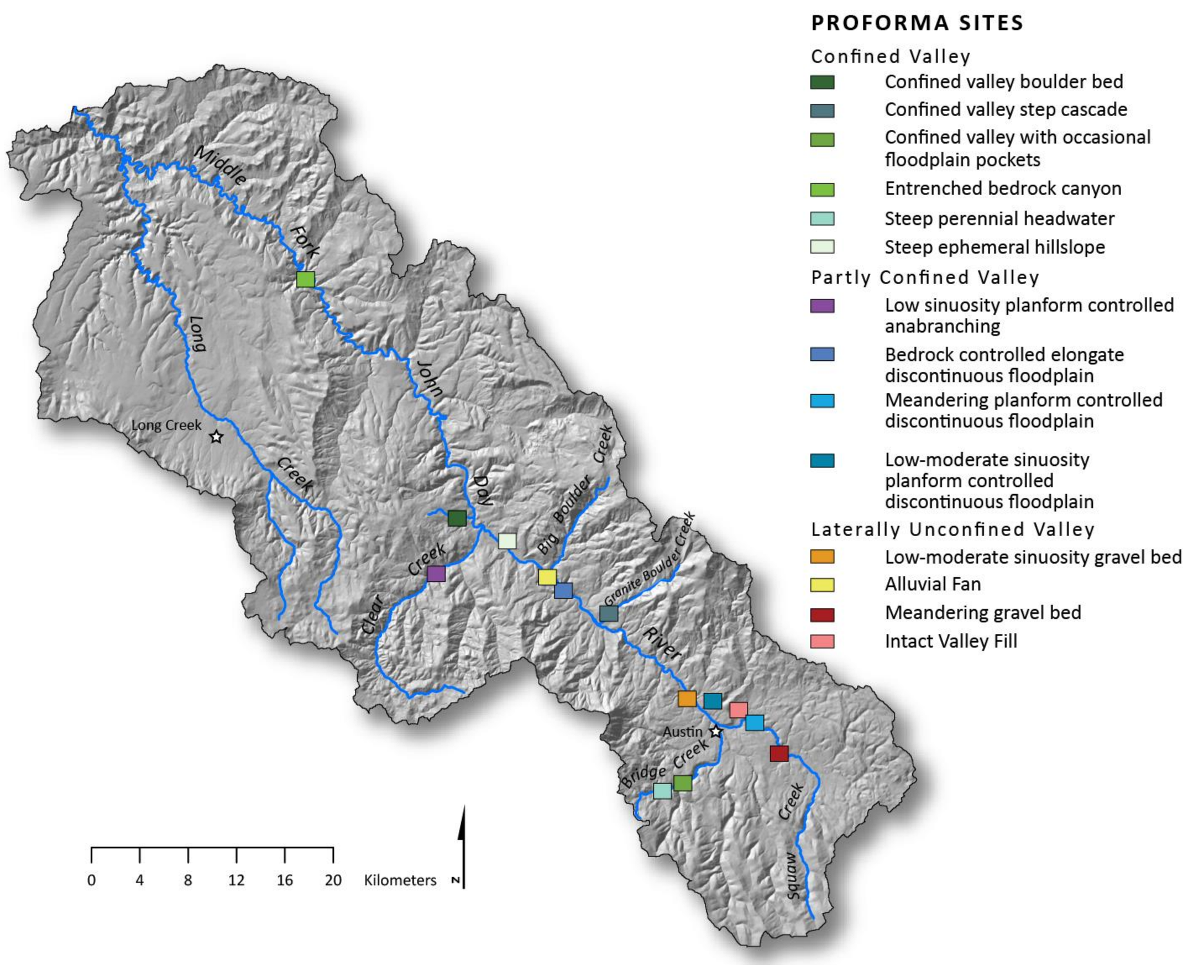


Figure 8. **Locations of proforma field validation sites, and locations of the towns of Long Creek and Austin, Oregon.**

Table 1. Field validated proforma sites in the MFJDW

River style proforma site	Revisit/New Visit[1]	Cross section (Y/N)	Stream
Laterally unconfined valley settings			
Low-moderate sinuosity gravel bed river	new	N	Middle Fork John Day River
Meandering gravel bed[1]	revisit	N	Middle Fork John Day River
Intact valley fill	new	N	Unnamed tributary
Alluvial fan	new	N	Big Boulder Creek
Partly confined Valley settings			
Meandering planform-controlled discontinuous floodplain	new	Y	Middle Fork John Day River
Low sinuosity planform-controlled anabranching	new	Y	Granite Boulder Creek
Low-moderate sinuosity planform-controlled discontinuous floodplain	new	Y	Vinegar Creek
Bedrock-controlled elongate discontinuous floodplain	revisit	Y	Middle Fork John Day River
Confined valley settings			
Confined valley with occasional floodplain pockets[1]	revisit	Y	Bridge Creek
Steep ephemeral hillslope	new	N	Unnamed tributary
Steep perennial headwater[1]	revisit	Y	Unnamed tributary
Confined valley boulder bed	new	Y	Jungle Creek
Confined valley step-cascade	new	N	Granite Boulder Creek
Entrenched bedrock canyon	Revisit	Y	Middle Fork John Day River

[1] Proforma sites established by Kasprak and Wheaton (2012) that were revisited and used in this study.

Thirty-two of thirty-nine CHaMP sites in the upper MFJDW (upstream of and including Camp Creek), were visited along the MFJDR and seven of its tributaries (Clear, Dry Clear, Squaw, Summit, Camp, and Granite Boulder Creeks). Seven sites were not visited because they were proximal to sites that were visited and recorded. Field notes, drawings and photographs were recorded at thirty-two of these. Visits to CHaMP sites provided the opportunity to evaluate the valley and channel characteristics of many more study sites than river style proforma sites alone. This was valuable for understanding variability within various landscape and geologic settings, and for assessing the downstream patterns of river styles in selected study tributary basins.

Table 2. CHaMP study sites evaluated for river styles data in 2013

	Champ site number	Stream	visited	River style validated[1]
1	232178	Bridge Creek	Y	Y
2	223986	Bridge Creek	Y	Y
3	479218	Bridge Creek	Y	Y
4	086002	Bridge Creek	Y	Y
5	348146	Bridge Creek	Y	Y
6	092914	Bridge Creek	Y	Y
7	109298	Bridge Creek	Y	Y
8	043762	Bridge Creek	Y	Y
9	383986	Camp Creek	Y	Y
10	515058	Camp Creek	Y	N
11	000031	Camp Creek	Y	N
12	030730	Camp Creek	Y	N
13	182770	Camp Creek	Y	N
14	330226	Camp Creek	Y	N
15	232178	Camp Creek	Y	Y
16	477938	Camp Creek	Y	N
17	299658	Clear Creek	Y	N
18	234122	Clear Creek	Y	N
19	051954	Dry Fork Clear Creek	Y	Y
20	438922	Dry Fork Clear Creek	Y	Y
21	189938	Granite Boulder Creek	Y	Y
22	531698	Granite Boulder Creek	Y	Y
23	290034	Middle Fork John Day River	Y	Y
24	497650	Middle Fork John Day River	Y	Y
25	314610	Middle Fork John Day River	Y	Y
26	000534	Middle Fork John Day River	Y	Y
27	449266	Middle Fork John Day River	Y	Y
28	298738	Middle Fork John Day River	Y	Y
29	282354	Middle Fork John Day River	Y	Y
30	358130	Squaw Creek	Y	N
31	325362	Summit Creek	Y	Y
32	429810	Summit Creek	Y	Y

[1]a 'no' response means the existing river styles designation was updated and revised based on re-evaluation of site characteristics.

2.1.3 RESOLUTION OF RIVER STYLES MAPPING – "LUMPING VERSUS SPLITTING"

A motivation for conducting a river styles classification is its utility informing watershed-scale studies of anadromous salmonid populations with a strong focus on geomorphic units as viable habitat (cf. Beechie and Sibley, 1997; Moir and Pasternack, 2008). The relationship of river styles classification to CHaMP monitoring protocols in MFJDW is based on the protocol's multi-scalar, hierarchical approach to channel and watershed classification (Program), 2012). For this reason, river styles were mapped and analyzed in enough detail to complement and inform ongoing studies related to topographic modeling of habitat and geomorphic detection (Bangen et al., 2013), rapid fish habitat surveys and modeling of watershed primary productivity. The lengths of individual river styles within reaches varied according to controls in the watershed (see next section), but generally occurred over an average maximum length of 13 km and a minimum of 1-2 km. Apart from first order tributaries, reaches of a particular river style shorter than one kilometer in length are uncommon in the MFJDW (Table 3).

Table 3. Stream length summary of river styles in the MFJDW

River style	Maximum length (km)	Minimum length (km)	Total length[1] (km)	Number of tributaries where observed
Low-moderate sinuosity gravel bed river	5.6	2.7	24.6	3
Meandering gravel bed	8.8	0.7	101.2	22
Meandering planform-controlled discontinuous floodplain	11.7	1.5	57.4	9
Bedrock-controlled elongate discontinuous floodplain	19.4	2.4	65.2	5
Confined valley with occasional floodplain pockets	10.5	1.5	369.2	>79
Entrenched bedrock canyon	66.7	1.1	119.4	7
Low sinuosity planform-controlled anabranching	9.1	1.4	17.8	3
Low-moderate sinuosity planform-controlled discontinuous floodplain	7.9	~1.0	170.2	37
Confined valley step-cascade	6.3	0.9	37.7	13
Steep perennial headwater	4.5	0.5	337.5	>300
Steep ephemeral hillslope	2.2	0.4	1461.3	>1000
Confined valley boulder bed	5.3	0.6	1230.6	>300
Alluvial fan	3.8	~.05	49	31
Intact valley fill	53	~.03	99.3	53

[1] denotes the total length of the river style in the Watershed.

2.1.4 CONTROLS ON RIVER CHARACTER AND BEHAVIOR – LONGITUDINAL PROFILES

The primary tool for understanding and interpreting the controls governing character and behavior of streams are longitudinal profile plots depicting the imposed boundary conditions under which rivers operate (Sections 3.3.1 and 4.2). Important among these are elevation, upstream catchment area, slope, and stream power. The shape of profiles indicates variability in lithology and rates of channel incision versus lateral expansion in valley widths, as well as different process zones in a watershed where sediments are produced, conveyed and stored. Each set of controls is specific to their subcatchments and the lithologic and flux conditions (sediment and discharge) are unique to each. The various perturbations displayed on a profile are usually coincident with reaches and river styles, valley setting (confinement); process zones of sediment source, transfer and accumulation; and sediment transport regime.

Construction of each plot is based on the National Hydrography Dataset plus Version 2 (NHDPlusV2) drainage network (McKay et al., 2012). NHDPlusV2 is a geospatial, hydrologic digital vector dataset that incorporates features of the National Hydrography Dataset (NHD), the National Elevation Dataset (NED), and the Watershed Boundary Dataset (WBD). Unlike NHD, which is a cartographic-based digital dataset, the NHDPlusV2 dataset derives from a 10 meter DEM, allowing many embedded attributes to be utilized. For this exercise, we used the NHD streamlines and WBD layers. We derived upstream catchment area from an available flow accumulation raster. For extracting longitudinal profiles, we segmented the streamlines in increments of 100 m to ensure high-resolution calculations of upstream catchment area and slope. For this operation, and to derive catchment area from the flow accumulation raster at the same intervals, we used the Geospatial Modeling Environment (GME) tool (Beyer, 2012).

Stream power, a measure of the capability of a river to do work on the bed and banks of the river (Worthy, 2005) was calculated for each 100 m interval, where:

$$\Omega = \rho g Q S$$

ρ is the density of water, g is acceleration due to gravity, Q is a characteristic discharge, S is the channel slope, and Ω is stream power in watts. We used a two-year recurrence interval flow for discharge (Q_2), given the effectiveness of frequent bankfull flows in modifying and maintaining channel form relative to larger magnitude, infrequent floodstage flows (Wolman and Miller, 1960). To estimate Q, a regional regression equation is needed and was obtained from the United States Geological Survey (USGS) National Streamflow Statistics Website (URL: http://water.usgs.gov/osw/programs/nss/pubs.html). Kasprak and Wheaton (2012) used the National Streamflow Statistics Program (Ries, 2006) to compute an area-discharge relationship between Q_2 and drainage area, based on seven gauges in the John Day basin, including the Middle Fork (Figure 9), and regional gauge data from Northeastern Oregon (Harris and Hubbard, 1982): $Q_2 = 2.26237 \times 10^{-8} A_d$

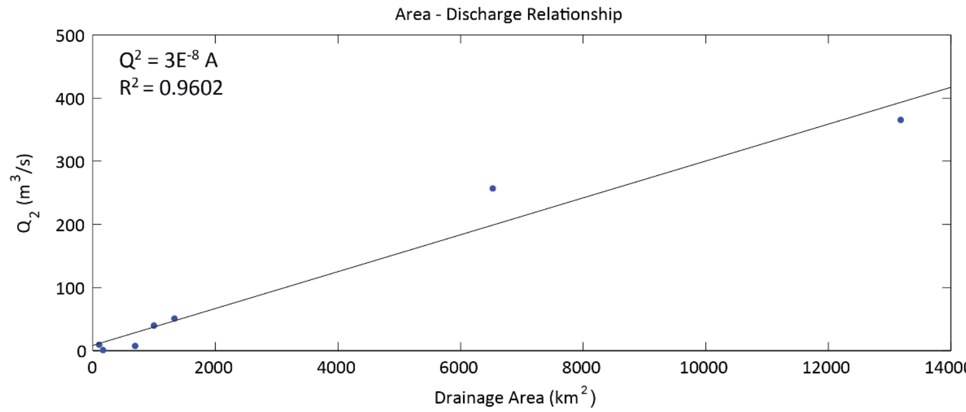


Figure 9. Area-discharge curve developed from seven USGS measuring stations in three subbasins of the John Day basin, for 2-yr recurrence interval. Modified from Kasprak and Wheaton, 2012.

Streamflow data of flood recurrence and flow duration analyses were obtained from the USGS streamflow website for Oregon (URL: http://or.water.usgs.gov/). The Log-Pearson III analysis of peak discharge data was performed using background and methodology outlined by Klingeman et al. (2002) in an instructional website supported by the Oregon State University Civil, Construction, and Environmental Engineering Department (URL:http://water.oregonstate.edu/streamflow/). Background on Oregon peak flow analysis was obtained through the State of Oregon Water Resources Department (Cooper, 2006).

2.1.5 TRIBUTARIES SELECTED FOR ANALYSIS IN MIDDLE FORK JOHN DAY WATERSHED

We selected four tributaries of the MFJDR for analysis of controls on character, behavior and downstream patterns of river styles. We chose these because they have contrasting lithologic and geomorphic characteristics and therefore represent the greatest diversity of channel types and valley characteristics within the MFJDW. With the exception of Long Creek, they are drainages with existing CHaMP survey sites.

Tributaries selected for detailed analysis occupy four of five HUC 10 watersheds of the subbasin, defined by the Hydrologic Unit Code (USGS and NRCS, 2012) (Figure 10). These are Bridge Creek and Camp Creek, which drain the south and central watershed, respectively; and Big Boulder Creek draining the southeast aspect of the watershed. Long Creek in the northwest portion of the watershed was included because of its large area and distinct semiarid dissected tablelands. The MFJDW is 42% privately owned in terms of total area, but the MFJDR corridor is almost entirely under private ownership (Table 4). Much of the land within the corridor is alluvial floodplain that has been farmed and grazed since the early 1860s, and much of it remains in that status today. The remainder is largely federal land, a mix of U.S. Forest Service and minor area owed by the U.S. Bureau of Land Management (BLM). Thus, a major consideration for detailed study was on the ground access to mapping and survey sites. For this study, permission was obtained to access three proforma sites located on privately owned land. We were denied access to one, and permission was not required for nine others located on federal land.

Table 4. Percent Land Ownership in the Middle Fork John Day Watershed

Land ownership	*%*
Private	42.4
U.S. Forest Service	56.7
Bureau of Land Management	0.8
State, County or City land	0.1

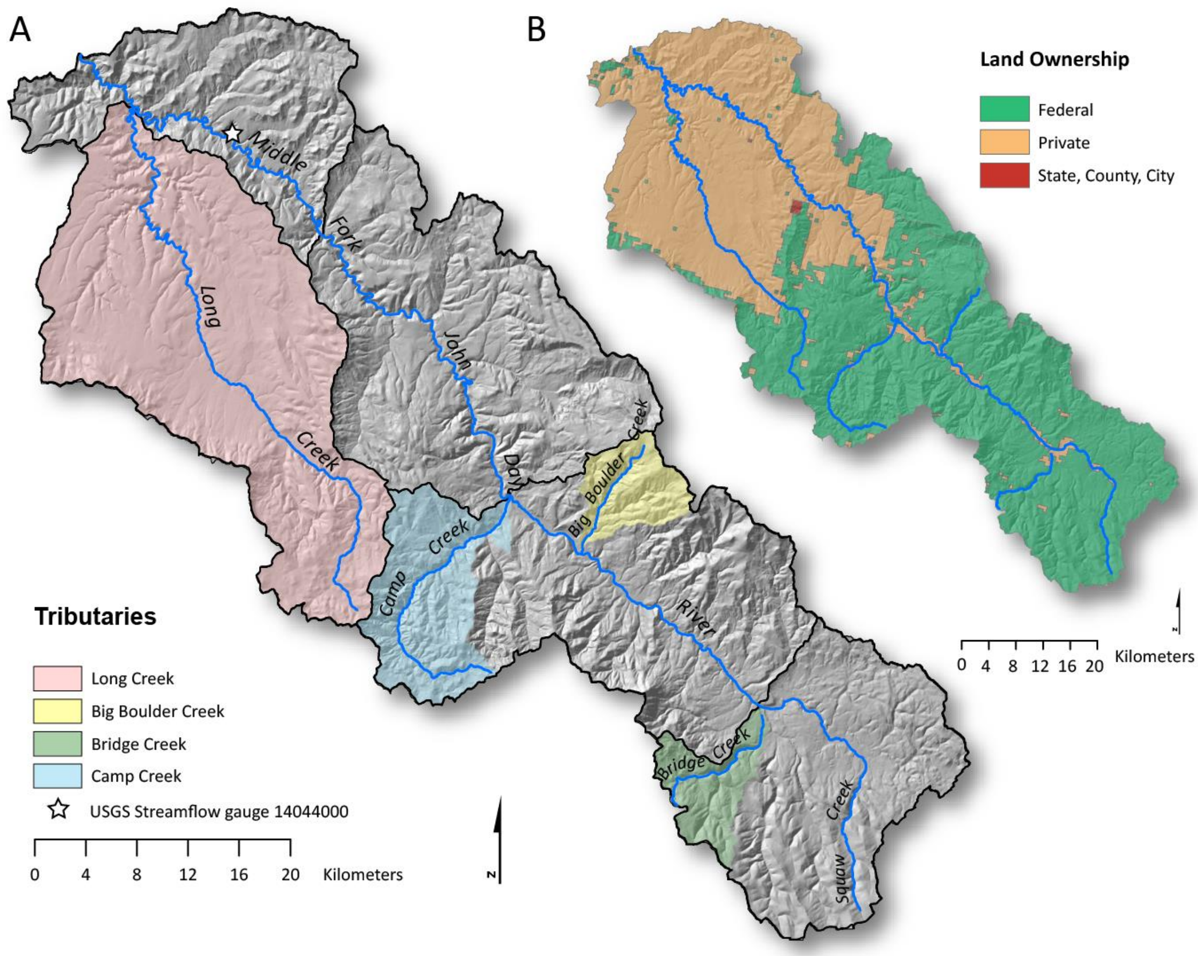


Figure 10. (A) Tributaries representative of watershed-scale diversity selected for study in the Middle Fork John Day Watershed are Long Creek, Big Boulder Creek, Bridge Creek, and Camp Creek; (B) Land ownership in the MFJDW.

2.2 STAGE TWO: ASSESSMENT OF GEOMORPHIC CONDITION

Stage Two of the River Styles framework is an assessment of the geomorphic condition of individual reaches of each river style. The geomorphic condition is the expected form and function of a river flowing in a particular valley setting, subject to boundary conditions of the physical setting and sediment/discharge conditions in the watershed, and constrained by limiting factors and pressures imposed by land use and development. Geomorphic condition is important to measure because it is a gauge of habitat quality, river health, and ties directly to the recovery potential of impacted stream reaches.

The assessment is accomplished by understanding the potential for a reach to modify its channel shape, instream geomorphic units, and floodplain—its "capacity for adjustment". Geomorphic features of the channel and floodplain are identified that have potential to change or respond to disturbances, and thereby provide indicators of the condition of each stream reach (Table 5 and Table 6). Each river style has an explicit pattern of behavior, given its physical setting and boundary conditions. The condition of one reach of a river style relative to another (hereafter "variants") can be understood by comparing each one to a "Reference Reach", the pristine example of that river style found in the watershed that is closest to pristine.

We determined geomorphic condition in three steps: first, the capacity for adjustment of each river style was assessed; next, the geomorphic *evolution* of each river style was investigated to identify irreversible geomorphic change and a "reference condition" (that of the reference reach); finally, the geomorphic condition of each reach was determined and explained (Figure 11). The final product of the geomorphic condition assessment for the MFJDW is a map of geomorphic condition presented in Section 5.3.2.

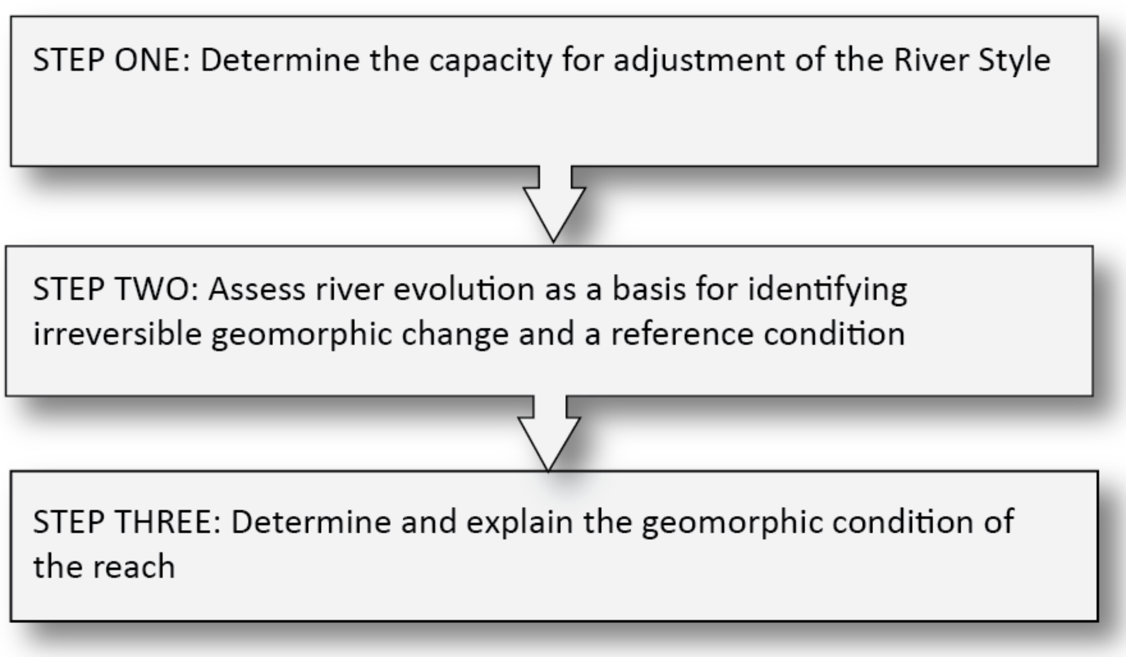


Figure 11. Steps in Stage Two of the River Styles framework. Modified from Figure 10.1 in Brierley and Fryirs (2005)

2.2.1 CAPACITY FOR ADJUSTMENT AND REACH SENSITIVITY TO DISTURBANCE

We define the capacity for adjustment as "morphological adjustments brought about by the changing nature of biophysical fluxes that do not record a wholesale change in river style" ([10]). Specifically, they are modifications of the floodplain, channel, and bed material characteristics controlled by the valley through which the river flows, the bedrock lithology and channel slope, and the sediment-discharge balance in the watershed (the physical and flux boundary conditions that define each river style).

The adjustment potential of a stream is also a gauge of its sensitivity to local and system-wide disturbances in the watershed. For example, river styles possessing low adjustment potential are resistant to natural or anthropogenic disturbances, whereas those with significant adjustment potential are more susceptible to disturbances
The confined valley river style (schematic at left; Figure 12) has very low capacity for adjustment (also see Table 5) and is considered "resistant" or "resilient" to disturbance. The low-moderate sinuosity gravel bed river style (schematic at right) has significant adjustment potential and is sensitive (susceptible) to direct and indirect disturbances. Arrows indicate the vertical and lateral adjustment possible for each valley setting. The confined valley river is able to incise its bed, yet rates of bedrock incision are imperceptibly small compared to aggradation in systems where channel, floodplain and bed characteristics are all controlled by sediment flux. Rivers of confined Valley Settings tend to have low capacity for adjustment because they flow within narrow bedrock walls and possess very limited or absent floodplains. The shape of confined valley channels is restricted by intervening bedrock, leaving only the arrangement of coarse bed material as a mode of adjustment. River styles of laterally unconfined and partly-confined valley settings, on the other hand, have moderate to high adjustment potential because their broad, fine grained floodplains promote dynamically shifting meandering planforms.

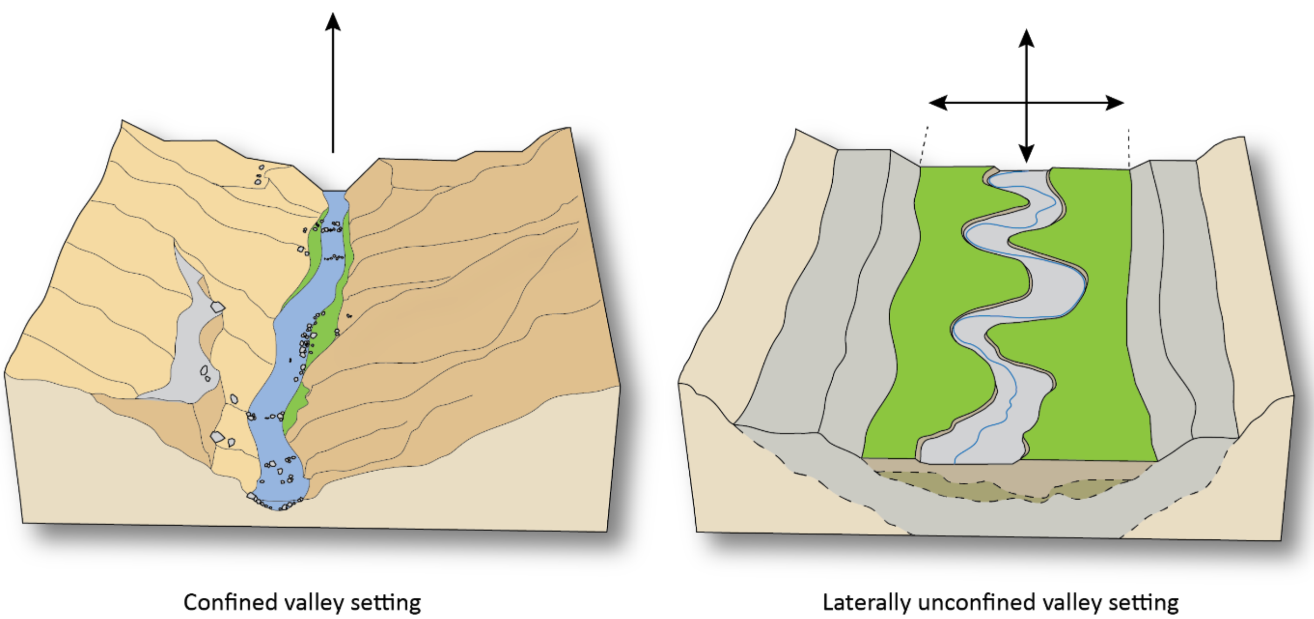


Figure 12. Differences in the natural capacity for adjustment of a river style in a confined valley setting and one within a laterally unconfined valley setting. Floodplain extents are shown in green.

In this study, capacity for adjustment was determined by tabulating attribute data from each river style collected at proforma study sites (i.e., Figure 7). Table 5 shows the adjustment potential of channel attributes, channel planform, and bed material characteristics for key river styles of each valley setting.

Table 5. Capacity of adjustment of river styles in each type of valley setting in the Middle Fork John Day Watershed. Modified from Table 10.3 of (Brierley and Fryirs, 2005)

River Style	Channel Attributes	Channel Planform	Bed Character	Capacity for Adjustment
Confined valley settings				
Confined valley step-cascade				Low
Entrenched bedrock canyon				Low
Partly confined valley settings				
Meandering planform-controlled discontinuous floodplain				Moderate
Low-moderate sinuosity planform-controlled discontinuous floodplain				Moderate
Laterally unconfined Valley Settings				
Low-moderate sinuosity gravel bed river				High

	Minimal or no adjustment potential
	Localized adjustment potential
	Significant adjustment potential

2.2.2 ASSESS RIVER EVOLUTION AS A BASIS FOR IDENTIFYING GEOMORPHIC CHANGE AND A REFERENCE CONDITION

Reaches of every river style exist in varying stages of development, equilibrium and degradation in the MFJDW. These geomorphic variants occur through natural channel evolution (strongly controlled by watershed position and hydrology) and by local impacts and disturbances that affect their form and function (i.e., capacity for adjustment and reach sensitivity to disturbances). They are described in "Evolutionary Diagrams", a series of conceptual channel cross sections that depict different reaches and their geomorphic attributes—including the type and timing of human impacts and modifications (Section 5.2). Their purpose is to:

- Inventory the range of variants of every River Style, and account for the differences in geomorphic controls
- Assess river character and behavior prior to human settlement
- Determine the nature of boundary conditions for that river style
- Determine whether human disturbance has induced irreversible geomorphic change
- Identify a reference condition for each river style
- Predict future conditions and potential prioritized management reaches for Stage Three analysis

Evolutionary diagrams are constructed through analysis of aerial photographs, field notes and measurements collected during proforma evaluations (including measured cross sections and inventory of geomorphic attributes), and historical data. They include known changes to vegetation, land use, sediment dynamics, basin hydrology and in instances where available, sampling of key floodplain and hillslope deposits for precise age determination (e.g., radiocarbon and luminescence dating of sediments).

2.2.3 DETERMINE AND EXPLAIN THE GEOMORPHIC CONDITION OF A REACH

The channel, planform and bed of a stream possess measurable components (dubbed “geoindicators”) such as channel shape and size, sinuosity of the planform, and stability and storage characteristics of the bed. We assessed geoindicators that are a functional part of each river style (e.g., Table 6) and assigned each a question designed to give a relevant and reliable signal for the condition of a reach for the river style under study. Responses to questions earn a “tick” if true and a “cross” if untrue (Figure 13). The decision process is based on a solid understanding and interpretation of geomorphic form/process associations and collectively produce an assessment of geomorphic condition for representative variants of each river style (Figure 14).

Table 6. The channel attributes portion of a table of measures used to assess good condition reaches of the low-moderate sinuosity planform-controlled discontinuous floodplain river style.

Degrees of freedom and their relevant geoindicators	Questions to be answered to assess geomorphic condition of each reach of the Low-moderate sinuosity planform controlled discontinuous floodplain river style.	Vinegar Creek	Crawford Creek
Channel attributes (3 out of 4)	3 out of 4 questions must be answered YES For stream to be assessed in GOOD condition		
Size	Is channel size appropriate given the catchment area, the prevailing sediment regime, and the vegetation character? Is the channel functionally connected to floodplain pockets? (i.e., is the channel overwidened, overdeepened, or does it have an appropriate width : depth ratio?)	Yes	Yes
Shape	Is the channel shape consistent with partly confined valley features (typically asymmetrical)?	Yes	No
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes	No
Woody debris loading	Is there woody debris in the channel or potential for recruitment	Yes	No

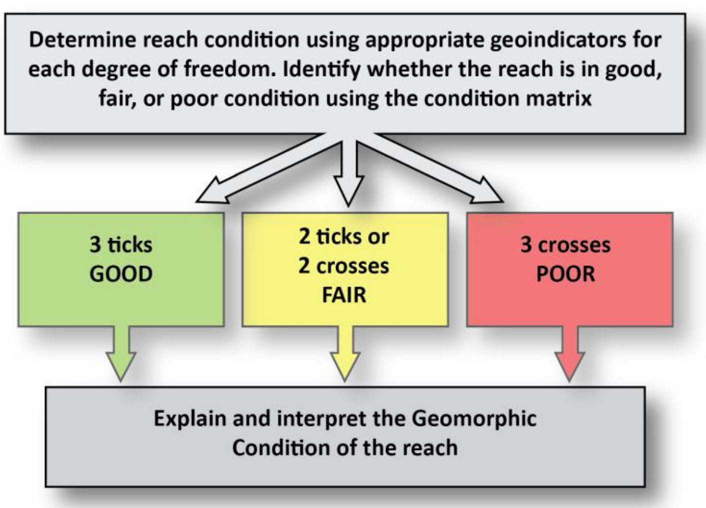


Figure 13. Flow chart showing steps to interpret and explain geomorphic condition of reaches. Modified from Figure 10.9 of Brierley and Fryirs (2005)

Each river style and its geomorphic condition is assessed relative to some benchmark or reference condition that is a gauge of the extent to which human induced change has influenced the long term pattern of river form and function. Reference conditions chosen for river styles of the MFJDW are generally the least-disturbed reaches, because pristine pre-settlement conditions do not exist there. Once chosen, all variants of the river style were compared to these and their conditions explained using plots like Figure 14. The final step in Stage Two is to synthesize all reaches of every river style into a watershed map of geomorphic condition (Section 5.3.2).

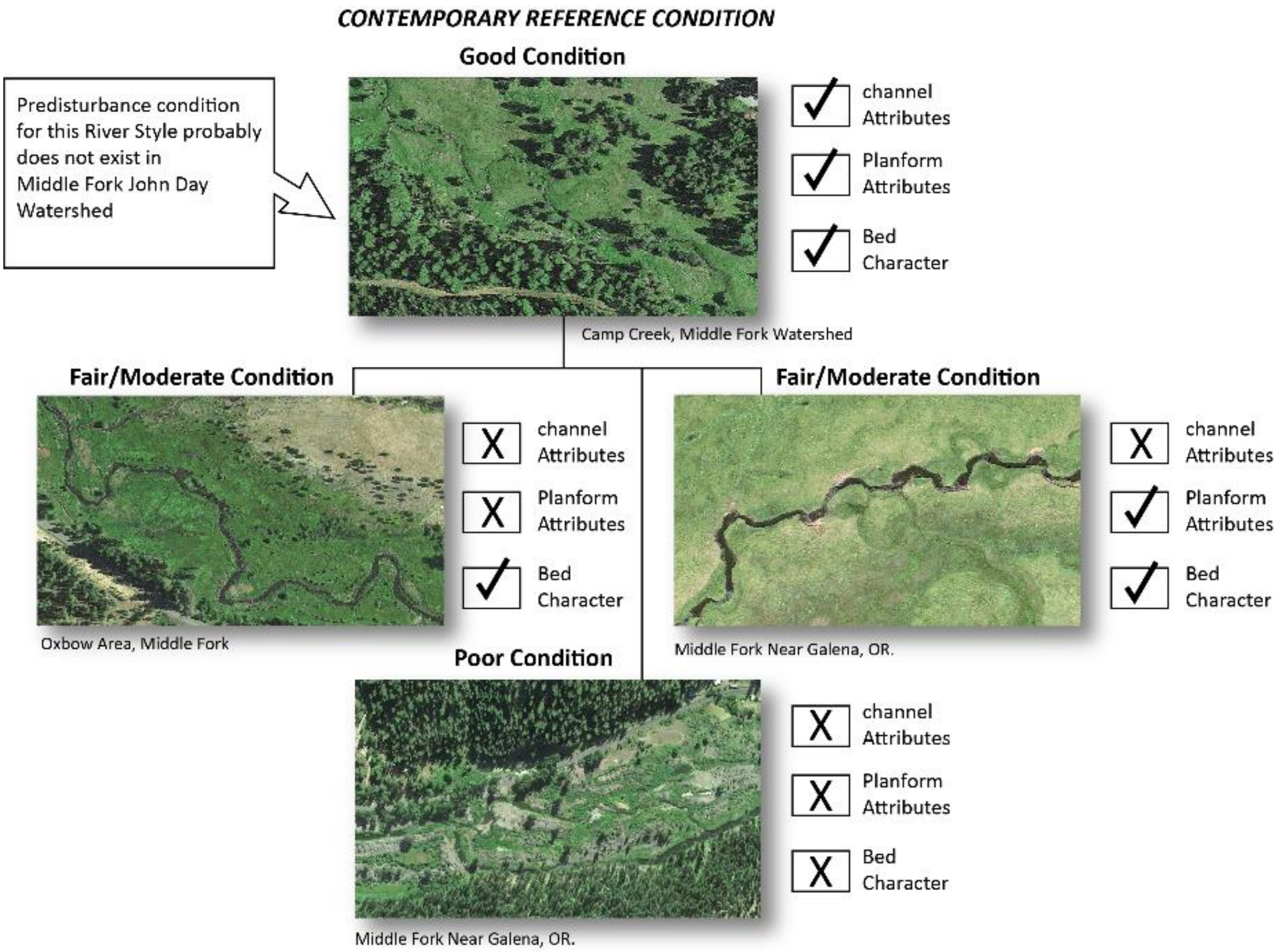


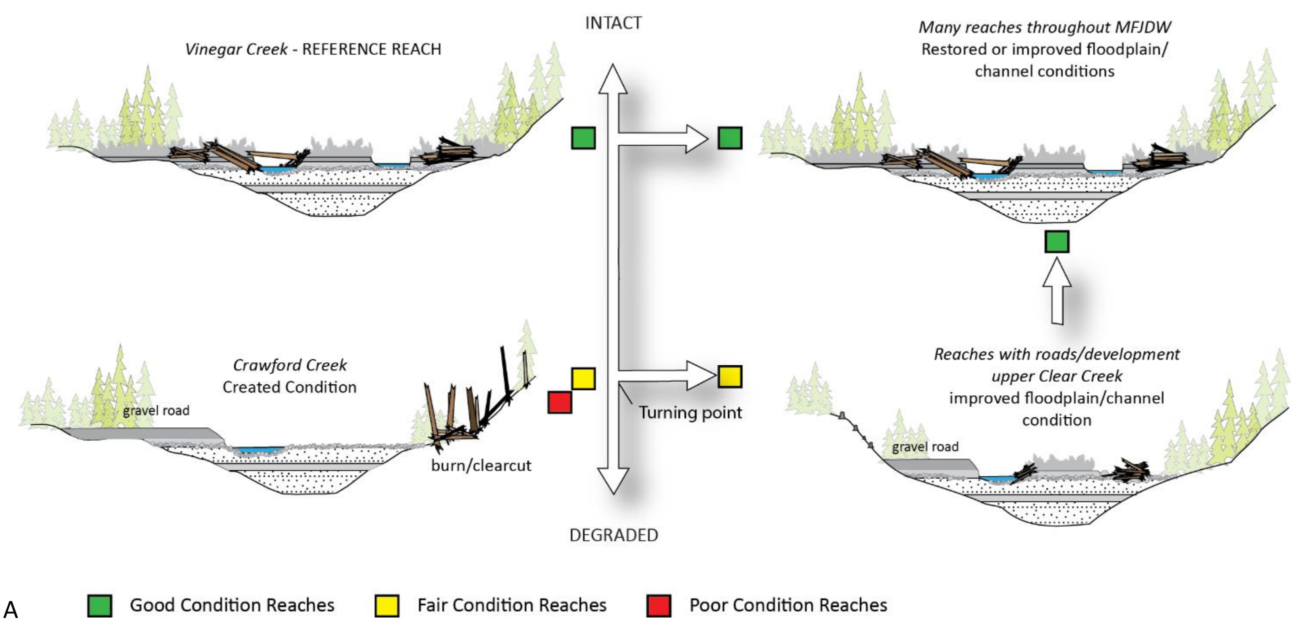
Figure 14. Arrangement of river style variants around the reference reach for the Low-moderate sinuosity gravel bed river style. Ticks and crosses indicate the geomorphic condition based on assessment of geoindicators for each degree of freedom (channel, planform, and bed).

2.3 STAGE THREE OF THE RIVER STYLES FRAMEWORK: GEOMORPHIC RECOVERY POTENTIAL

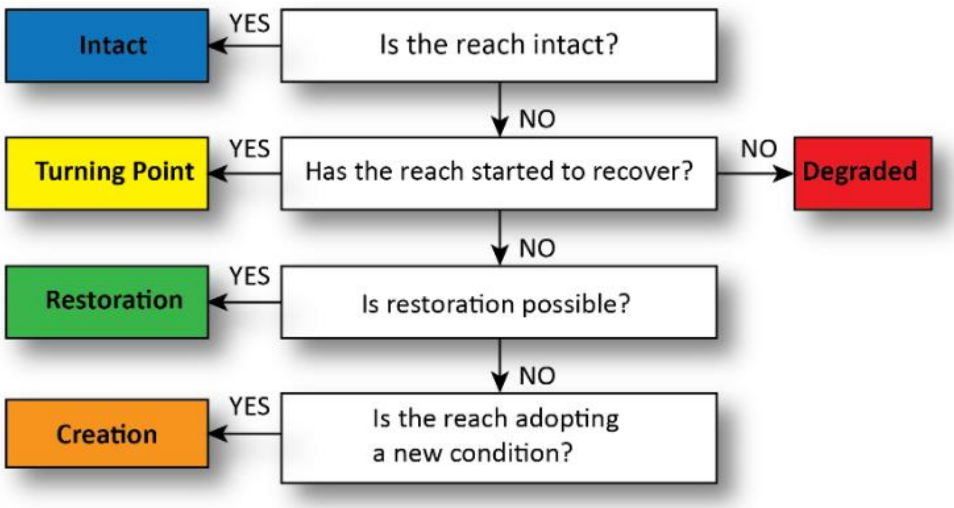
The ability to assess the recovery potential of reaches and predict future change is the subject of Stage Three of the River Styles framework. This process leverages the baseline survey of river character and behavior and geomorphic condition assessments, and is accomplished in two steps. First, the trajectory of river change is determined. The recovery trajectory of each reach is assessed by determining if the reach is intact, requires restoration, is in a degraded state, or is possibly poised to become a created river style. Second, the river recovery potential is determined by assessing limiting factors in the watershed along with catchment position and proximity to intrinsic pressures. The output of Stage Three is a watershed scale map of River recovery potential and is the last major analysis leading to development of a strategic management plan for the MFJDR.

2.3.1 TRAJECTORY OF RIVER CHANGE

The trajectory of river change for every river style reach is determined by plotting each variant onto an evolutionary diagram that shows conceptual cross sections and their geomorphic attributes, and processing each one through a decision tree shown in Figure 15B. As an example, Figure 15A shows two variants of the Low-moderate sinuosity planform-controlled discontinuous floodplain river style along a "degradation pathway" that is a scale between Intact and degraded geomorphic conditions. Because an intact variant of this river style does not exist in the MFJDW, the cross section representing the reference condition sits at the top (i.e., the 'reference reach'). Cross sections representing variants in gradually worsened geomorphic condition appear lower on the pathway. The poor-condition variant sits at the base. If a reach is showing signs of improvement, it may advance to a position on the right of the diagram, on a *recovery pathway* (Section 6.1). If the reach cannot move laterally to an improved condition, it proceeds from a turning point downward to a more degraded position.



A



B.

Figure 15. A. Evolutionary diagram for the Low-moderate sinuosity planform-controlled discontinuous floodplain river style with geomorphic condition plotted alongside a "degradation pathway"; and B. A decision tree for determining trajectory of change for individual reaches. A is adapted from Figure 11.4 of Brierley and Fryirs (2005); B is reproduced from Figure 10.4.

2.3.2 DETERMINING RECOVERY POTENTIAL

Rivers are constantly evolving and regardless of where they currently sit on a degradation pathway, they may move onto a *recovery* pathway given favorable conditions. But a reach positioned on a recovery trajectory may or may not have the *potential* to move along that pathway in the timeframe of 50-100 years. The recovery potential of river style reaches is the key analysis of Stage Three. Figure 16 summarizes the following factors that interplay to determine the recovery potential of a stream:

1. *River Character and Behavior (Section 4, Stage One)*: the form-function associations of each stream type dictate the definition and interpretation of river styles and their downstream patterns in tributaries.

2. *Capacity for Adjustment (Section 5, Stage Two):* represents the sensitivity of channel, planform, and bed material characteristics. Sensitive reaches show increased suceptibility to disturbance effects, while resistant reaches show resistance to disturbance effects.

3. *Geomorphic condition Assessment (Section 5, Stage Two):* geoindicators define adjustment potential of reaches and river evolution diagrams identify the extent of geomorphic change. Reaches compared to a reference condition are rated Intact, good, fair and poor geomorphic condition.

4. *Position of reaches in the catchment (Section 6, Stage Three):* it is Important to consider linkages between subcatchments, and particularly between up and downstream reaches. Disturbance responses may be propagated to downstream reaches and become detrimental if good condition reaches lie downstream of degraded ones.

5. *Limiting Factors and Pressures* (*Section 6, Stage Three*): these include land and water management practices that threaten the conservation of intact reaches throughout the watershed. In the MFJDW these include ranching operations (grazing and hayfield agriculture) and water diversion through canal networks, and road building and maintenance, but in the past included intense logging and mining operations.

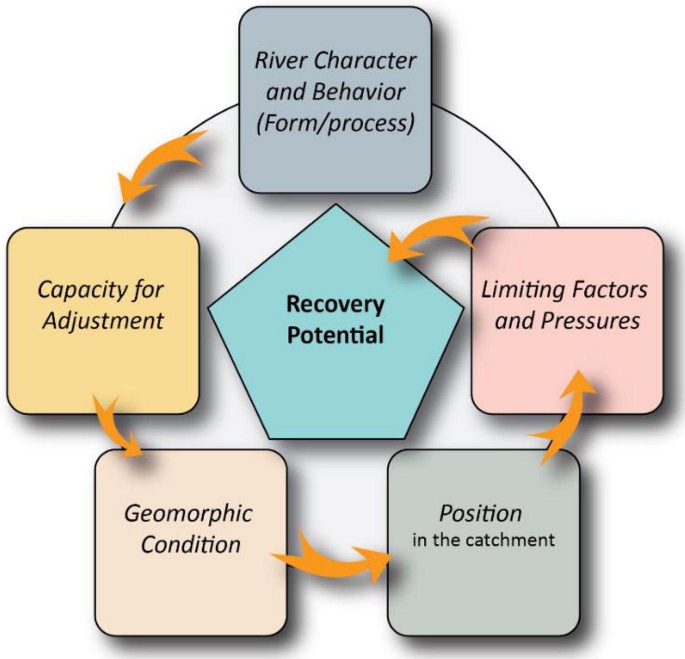


Figure 16. Flow chart showing factors influencing recovery potential of river styles Reaches.

The final step in determining recovery potential for individual reaches is to process the information through a flow chart designed to take into account the proper inputs depicted in Figure 16. As put forth by Brierley and Fryirs (2005), the recovery potential flowchart can be tailored to individual watersheds, and the version appropriate for the MFJDW is presented in Figure 17. The output from Stage Three analyses is a watershed map of reach recovery potential (Section 6.2.2).

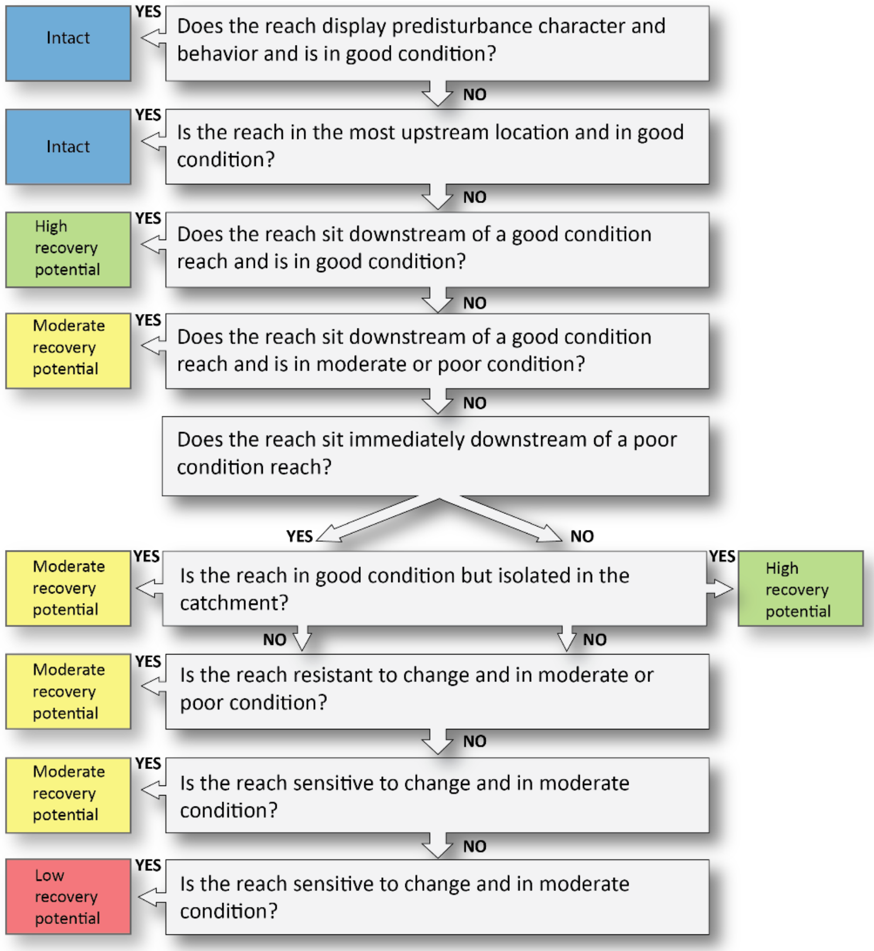


Figure 17. Flowchart for determination of recovery potential of a reach. Reproduced from Figure 11.12, Brierley and Fryirs (2005)

2.4 STAGE FOUR OF THE RIVER STYLES FRAMEWORK: IMPLICATIONS FOR MANAGEMENT

The River Styles framework emphasizes long-term planning for river recovery by identifying pathways to restored conditions, and manipulation of the bed and channel where necessary to achieve river rehabilitation as a means to aid natural recovery. The steps for creating a tributary Habitat improvement plan using the River Styles framework are shown graphically in Figure 18, and includes:

- Create a catchment-framed physical vision
- Identify target conditions for river rehabilitation
- Prioritize management efforts based on geomorphic condition and recovery potential of each reach
- Monitor and audit improvement to geomorphic condition following management action

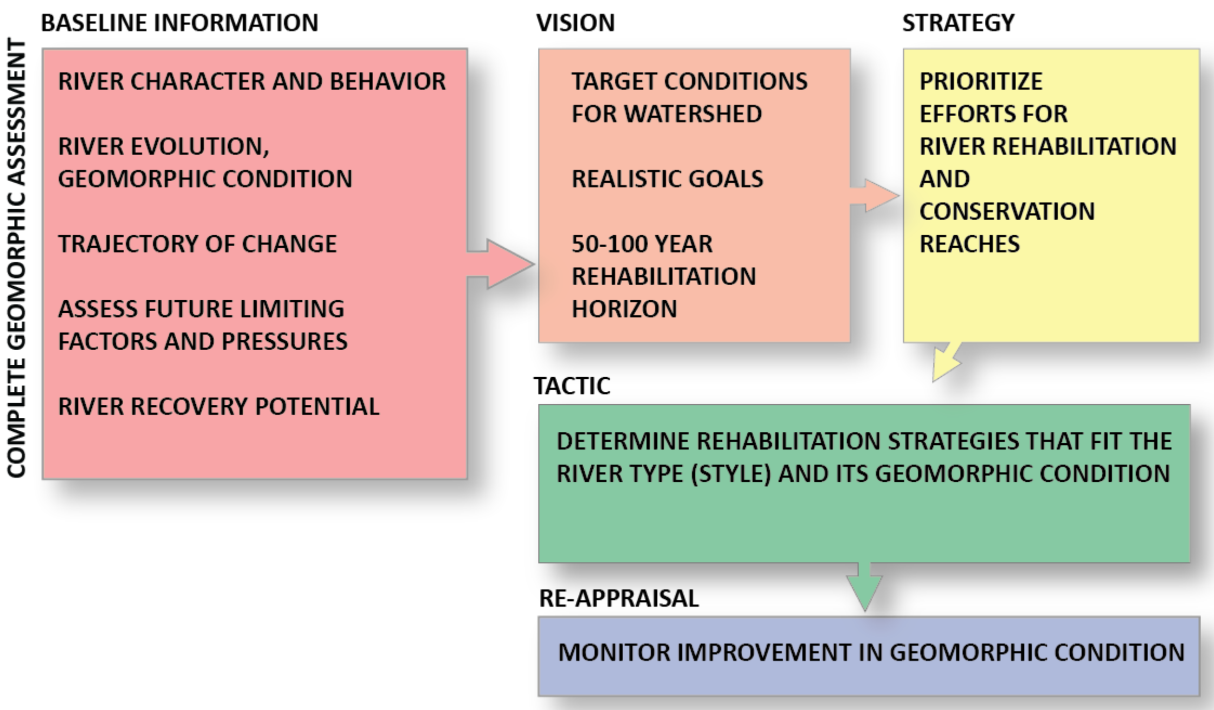


Figure 18. Workflow for developing and implementing prioritized management reaches in the Middle Fork John Day Watershed. Reproduced from Brierley and Fryirs (2005).