BOISE RIVER ENHANCEMENT NETWORK

- We are a network of people that live, work and play in the Boise River watershed dedicated to promoting the ecological enhancement of the river

Photo by Liz Paul, Idaho Rivers United

Boise River Geomorphology

Literature Review | Network Feedback | Enhancement Priorities

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Introduction

At the 2011 workshop titled "Lower Boise River: From Vision to Reality," when participants were asked what should happen next, the most common response was: "continue this group and develop a plan." Three years later, a group has been formed, the Boise River Enhancement Network (BREN). Boise River Enhancement Network participants envision a healthy Boise River that enriches the Valley's quality of life. Through a grant from the Bureau of Reclamation, the group is widening its membership, developing structure, performing outreach, and developing a watershed plan for how BREN can enhance the Boise River. As part of this planning effort, identifying the key issues and possible solutions associated with geomorphology of the Lower Boise River is critical (LBR), despite a general lack of familiarity with the term geomorphology within the community. Geomorphology is the study of how the earth's surfaces change over time. The LBR is an alluvial river, meaning it is composed of a moving landscape of river deposited sediments, rather than erosion of bedrock found in the headwater streams of the Upper Boise. The geomorphology of the Lower Boise includes changes to river's shape (form) as well as erosion, deposition and riparian function (processes) that drive those changes over time.

Purpose

The purpose of this document is to provide a framework for the Geomorphology section of the BREN Boise River Enhancement Plan. This is a living document that will continue to be updated with new information and revised based on expert opinion and public input. It is meant to be the reference from which the BREN plan will draw its information. This document presents the major findings in the literature, some of which are disputed among agency and professionals. This document is divided into the following sections:

Summary. This provides a brief narrative overview of the information contained within this document.

Part I: **Existing Information**. This section contains an overview of the existing literature pertaining to geomorphology of the Boise River. Overall conclusions from pertinent existing reports are summarized and the issues and solutions identified within those plans are outlined. Much of this information was used in a public meeting on November 12th, 2014, in which feedback was solicited and recorded.

Part II: **Network Feedback**. This section contains the feedback from the BREN participants on geomorphological issues. This includes information from the October, 2011 workshop and from participants at the November 12th, 2014 geomorphology meeting. At the meeting, feedback on issues, solutions, additional literature, and expert reviewers was collected.

Part III: **Enhancement Priorities**. This section presents the results of the review process and identifies the key issues and enhancement priorities.

References

Summary

The LBR has been transformed from a meandering, braided gravel bed river that supported large runs of salmon to a channelized, regulated urban and agricultural river that provides flood control, irrigation water conveyance and recreational opportunities to residents of the Treasure Valley. Extensive alterations to the floodplain and hydrograph have resulted in a large suite of geomorphic changes to this alluvial river system. These changes include a floodplain that has been drastically narrowed and disconnected from the current hydrology, a hyporheic zone (where the local groundwater table and surface water are interacting) that has been significantly reduced, channel substrate that has become armored and embedded, instream habitat that has been simplified and sloughs and side channels that have been reduced. The dramatic anthropogenic induced changes to the hydrology and floodplain have created a geomorphic environment that is not aligned with the current hydrology, resulting in impacts to several critical ecosystem processes. Although there are pervasive conditions that affect the entire LBR, each reach and site has its own specific suite of conditions that need to be evaluated on the appropriate scale.

Current channel capacity ranges between 3,500 cfs and 10,000 cfs, although channel capacity varies in time and space due to changing conditions. However, flood damage increases drastically above 6,500 cfs. Prior to channelization, high flows would spread across the historically wide floodplain. Over the years, levees have been built and enlarged by individual land owners, cities, counties, and local flood districts, many of which are unstable. Levees surrounding old gravel pits that now serve as ornamental ponds with little habitat value are considered to be flood hazards as they may increase flood risk and result in “pit capture,” which can alter the river channel. Large snags, vegetation and debris are removed from sections of the river for recreation safety and flood control reasons. As a result of historic levee construction and current maintenance practices, the highly narrowed river channel lacks roughness elements and in-stream complexity that historically provided habitat for fish and other aquatic organisms. The current channel form results in velocities that preclude refuge for salmonids in many locations during the spring and summer and create an abundance of shallow pool or glide habitat in the late fall, winter and early spring.

Successful enhancement of the LBR relies heavily on reconnecting the main channel with sloughs, hyporheic zone and sediment transport processes. Actions to improve natural river processes and enable the river to restore natural forms on its own will bring the greatest ecosystem benefit. Enhancement of the Boise River must focus on current and future conditions and not seek to restore historic conditions which would be difficult or impossible. Constructed river enhancement structures must be able to be maintained by the current hydrology and therefore be in balance with the current hydrologic and geomorphic setting. Protecting existing floodplain areas that are in connection with the current hydrology is an enhancement priority. The creation, protection and enhancement of a “meander belt” within which the river is permitted to operate through its own processes would bring widespread

ecosystem benefits. Other enhancement options include cooperative improvement projects; changes to the flow regime; better utilization of existing ponds; reconnecting floodplains through removal of levees and rip-rap and/or re-contouring of the floodplain; creating side channels; modification of debris and snag removal practices; removal of property from within the floodplain through land swaps, zoning changes, buyout of property, easements, and implementation of stricter codes and ordinances; and installation of rock barbs, large boulders, and bioengineered bank structures, among others. Each reach has its own suite of geomorphic issues and solutions and the system would benefit from an in depth geomorphic assessment and site specific evaluation.

Part I: Overview of Current Literature

Although many studies discuss the geomorphology of the Boise River to some extent (see Appendix A), the following section summarizes the issues, solutions and conclusions from key pieces of literature. We have chosen to present short sections that summarize the main points in bulleted format regarding the overall river conditions and issues, overall solutions, and then reach-specific issues and solutions.

The geomorphology of the Boise River has not been as extensively investigated as other aspects (e.g. water quality). Due to the need for a high-level geomorphic assessment, a *Geomorphic Assessment of the Lower Boise River, Idaho* (Richardson and Guilinger 2015) was prepared as part of the BREN effort. This report is the most current and complete assessment of the geomorphic issues surrounding the Boise River, and will be included as an Appendix (like this document) to the BREN Boise River Enhancement Plan. Readers should reference this document for a more detailed discussion of the current and target geomorphic conditions on the LBR.

Overall Lower Boise River Condition and Issues from Literature Review

- The LBR has been transformed from a meandering, braided gravel bed river that supported large runs of salmon to a channelized, regulated, urban river that provides flood control and irrigation water to more than 1,200 square miles of land (MacCoy 2006).
- The current hydrograph has been highly modified from historical conditions, which has resulted in a large suite of geomorphic changes. Flow modifications in addition to channelization have significantly altered the character of the river – the system is now part river, part canal and part drain (USACE 1995).
- Due to development and channelization, capacity of the Boise River channel through the lower watershed varies between 3,500 cfs and 10,000 cfs. Below 6,500 cfs, flooding is limited to pastureland, low laying farmland, gravel pits near the river and a few buildings. Flood damage dramatically increases above 10,000 cfs (USACE 2006).

- When discharges measured below Lucky Peak and at Glenwood are 180 cfs and 242 cfs respectively (typical for fall, winter and early spring), pools (or shallow glides) dominate all sections of river (Asbridge and Bjornn 1988).
- Prior to major hydraulic and geomorphic modification, the river's connection to the floodplain and hyporheic zone, variable hydrograph and overall geomorphic setting allowed for the formation and maintenance of many side channels (MacCoy 2006).
- Change in hydrologic regime and the construction of levees has caused the lower river to incise to the point where backwater sloughs and wetlands associated with hyporheic zones have diminished (MacCoy and Blew 2005).
- Average bankfull width has been reduced to less than one half of its historic width, with reductions upstream of Eagle Island being the most extreme (MacCoy 2006).
- Historic channel forms and parafluvial surfaces (sediment bars and floodplain deposits) have almost disappeared from the LBR (MacCoy 2006).
- Historically, sloughs were abundant downstream of Eagle Island, but many have been converted to irrigation ditches or drains (MacCoy 2006). Historic sloughs below Eagle Island averaged 10m wide (from 3 to 60 m) and were located as far as 1.5km from the channel (MacCoy and Blew 2005). These sloughs were formed and maintained by large floods, which no longer occur under the existing regulated hydrologic regime.
- The Boise River Reconnaissance Study (USACE 1995) identified the following issues:
    - Levees have been built and enlarged along the river by individual landowners, Ada and Canyon Counties, and local flood districts – some are easily erodible.
    - Low flow conditions have led to growth of trees and brush encroaching on the river channel.
    - Urban development is continually encroaching on the floodplain.
    - Common practice (at time of article) for irrigation companies to install temporary gravel dams in order to raise water surface for diversion. These dams are washed away during spring flooding and the process is continued every year.
    - Channel capacity varies with time and location due to changing streambed conditions.
- Multiple gravel extraction ponds and residential neighborhood landscape ponds have been developed along the Boise River, typically bordered by push up berms which are typically of uncertain structural integrity. These may be susceptible to pit capture, which could result in a head cut or other river channel instability issues (USACE 2006, USACE 2013, City of Boise 2014). Though some researchers find pit capture to be less of an issue, and see opportunities for enhancement in existing gravel ponds in appropriate locations (Richardson and Guilinger 2015).
- Qualitative measures of embeddedness (the infilling of interstitial space between particles with fine sediment (sand and/or silt) and substrate size indicate that the river bed is "armored" (MacCoy and Blew 2005) – estimates range from 50-75% armoring depending on reach. The

Boise River substrate is cobble dominated with embeddedness varying (up to 74% near Middleton) (Asbridge and Bjornn 1988), but has generally been reported to increase in a downstream direction (Mullins 1999). Cobble substrate is dominant in all areas except from Caldwell to the confluence with the Snake (MacCoy 2006).

- In the summer, water velocities are too high and temperatures are too high in the lower reaches to create ideal trout habitat (Asbridge and Bjornn 1988).
- The main channel lacks roughness elements (rock, large wood, etc.) that provide habitat diversity, cover, and velocity breaks for salmonids (Asbridge and Bjornn 1988).
- Snags, vegetation and debris are removed to make the river safer for tubers and other river users. Flood Control District 10 removes trees and debris in the downstream planning area and in the vicinity of the West Boise Wastewater Treatment Plant (City of Boise 2014).
- There is a lack of undercut banks, which would provide habitat and cover for salmonids (Asbridge and Bjornn 1988).
- Cover is especially poor in the winter when pool habitat is pulled away from the banks where almost all of the cover exists (Asbridge and Bjornn 1988).
- Lower reaches lack data – more data is available in upper reaches (MacCoy 2006).

Overall Solutions Identified in Literature Review

- Protect existing areas that already possess target geomorphic conditions (Richardson and Guilinger 2015).
- Preserve and maintain areas with existing high quality floodplain, habitat and function (USACE 2013, Richardson and Guilinger 2015, USACE 2006).
- Restoration of chemical, physical and biological condition is dependent on reconnecting the main channel with sloughs, hyporheic zone and physical transport processes (MacCoy and Blew 2005).
- Remove property within floodplain through land swaps, zoning changes, buyout of property, emergency access easements, and more restrictive floodplain codes/ordinances (USACE 2006).
- Improve natural river processes enabling river to create and maintain natural forms on its own (Richardson and Guilinger 2015).
- Flow changes:
    - Modification of reservoir operations to allow annual flushing of channel near 6,500 cfs to recover channel capacity (USACE 2006).
    - To achieve higher winter flows, relax flood control rule curves and utilize existing stream channel maintenance flow water (BoR and IDFG storage) (Leitzinger 2000).
    - Work with irrigators, BoR, Army Corps, and others to achieve a more natural river flow pattern and ramping rates (City of Boise 2014).
    - Investigate obtaining water rights (City of Boise 2014).

- Manage bank erosion as a natural process and allow the river to move where possible (City of Boise 2014).
- Coordinate with Boise Planning and Development Services and Boise Public Works Department to develop plans for using Boise Parks and Recreation land for flood mitigation/reconnect the river and the floodplain (City of Boise 2014).
- Remove or improve existing irrigation structures (Richardson and Guilinger 2015).
- Inventory and analyze ponds for recreational, aquatic, terrestrial habitat values, and pit capture potential (City of Boise 2014).
- Fill or partially fill existing ponds (USACE 2013).
- Participate in habitat improvement projects to mitigate for removal of debris and snags, i.e., connecting and rehabilitating side channels (Spatial Dynamics et al. 1999).
- Develop criteria for debris/snag removal with interested agencies and irrigation entities (City of Boise 2014).
- Force river processes enabling the river to create improved forms (Richardson and Guilinger 2015).
- Install barbs and large boulder placement (USACE 2002).
- Construct forms that the river can maintain (Richardson and Guilinger 2015).
- Create side channels for fish spawning & rearing (USACE 2013) and river function (Weast 2004)

Reach Specific Issues and Solutions Identified in Literature

Though various reaches are utilized in the literature, we have selected to use the Richardson and Guilinger (2015) reaches and attempted to place other author's reaches and sites in the most appropriate location.

Reach 1: From Diversion Dam to Ridenbaugh Canal Diversion (Barber Pools)

Issues

- Upstream of Eagle Island (applies to reaches 1-3) bankfull width has been reduced from 900 to 140 ft in response to the altered hydrologic regime resulting from upstream dams.
- Downstream of Lucky Peak Dam, low sediment loads create "clean water" which has a high erosive capacity with which it picks up and transports available sediment (mainly from eroding banks and tributaries). Much of the sediment is deposited starting near the head of Eagle Island, where it is manipulated for flood risk reduction and irrigation water delivery (USACE 2013).
- Richardson and Guilinger (2015) identified the following issues within this reach:
    - Low gradient channel with sand dominated substrate (with deposits up to 6 feet deep)

- Bank erosion causing channel widening and high width to depth ratio
- Homogenous bed and little to no in-stream structure
- Little to no floodplain connection

Solutions

- Richardson and Guilinger (2015) identified the following solutions within this reach:
    - Establishing mid-channel bars, islands and well vegetated inset floodplain between the existing terraces is the most geomorphically important enhancement for Reach 1.
    - Protection of existing wetland habitats that are connected to river processes should be maintained.
    - Modification or Removal of Barber Dam would allow for the passage of this sediment and bed scour/incision to restore the natural gradient and flow regime but would likely impact floodplain wetlands by lowering the water table.
    - Bioengineering bank stabilization to reduce bank erosion and widening (note: this potentially limits inset floodplain formation)
    - Place mid-channel structures to encourage island formation (note: may enhance bank erosion and inset floodplain formation)
    - Add in-stream structure (wood) to improve hydraulic complexity and reduce homogeneity

Reach 2: Ridenbaugh Canal Diversion to Americana Boulevard

Issues

- Bed armoring – at a site near Eckert Road, the substrate was 68% cobble and about 12% gravel (Mullins 1999).
- The Boise River Channel Assessment performed as part of the Boise Parks and Stewardship Plan (ATEC 1999) identified the following issues and stakeholder desires (applies to part of reach 3):
    - Desire to control channel changes for predictability and to protect health and welfare.
    - The river should be able to meander within boundaries (appropriate belt width).
    - There is a desire for sediment (including mid-channel bars) and large woody debris loads to be controlled. However, it is recognized that removal of these features leads to lower channel stability.
    - The channel is overly straightened.
    - There are undersized bridge openings.
    - Bank erosion should be reduced (stakeholder desire).
    - Past design treatments have had unintended negative consequences.
    - There is no coordinated design across owners and managers.

- There is a need for equipment access to the stream. (stakeholder desire).
- Aesthetic, pollution control, and fish and wildlife values should be protected and enhanced.
- Cost of solutions must be controlled.

- Richardson and Guilinger (2015) identified the following issues within this reach:
    - Channel confinement by levees and riprap; poor floodplain connection
    - Low sinuosity, with many straight sub-reaches
    - High in-stream velocity
    - Low in-stream hydraulic complexity, few obstructions aside from bridge piers
    - High width-to-depth ratio at low flow
    - Poorly defined thalweg

Solutions

- The Boise River Channel Assessment performed as part of the Boise Parks and Stewardship Plan (ATEC 1999) Identified the following solutions and stakeholder desires within this reach (applies to part of reach 3):
    - Create a meander belt within which the channel can migrate. This involves limiting development within the 100 year floodplain.
    - Increase bridge spans.
    - Shape back slopes at specific sites and provide plantings to stabilize banks.
    - Install rock barbs at appropriate sites.
    - Design treatments to repair unstable banks within fluvial geomorphic principles.
    - Install appropriate vehicle access points where stability can be ensured.
    - Create riparian buffers to absorb channel deposits and debris in the stream.
    - When there is disagreement among owners and managers within the area, concurrence should be used over consensus.
    - Consider long term costs of treatments. Cheaper short term fixes that do not consider fluvial geomorphic principles will be more expensive in the long term.
- Richardson and Guilinger (2015) identified the following solutions within this reach:
    - Establishing a well-defined thalweg with more frequent side-channels and associated instream obstructions will emulate more natural geomorphic morphology without disregarding the existing real constraints associated with an urban river corridor.
    - Install low profile, bank barb structures to force thalweg definition/sinuosity without significantly impacting flood conveyance. These structures could also host riparian vegetation which provides long-term structure and cover.
    - Install obstructions (boulder clusters, wood and/or constructed riffles) to force flow contraction and expansion to create localized pools and hydraulic diversity.

- Protect Loggers Creek, riparian buffers and any areas where the active floodplain has not been developed.
- Enhance connectivity at identified side channels and/or alcoves for improved geomorphic function and flood conveyance.
- Promote bank erosion and channel migration where accessible; remove riprap and levees; force lateral migration with in-stream obstructions

Reach 3: Americana Boulevard to Eagle Island

Issues

- Richardson and Guilinger (2015) identified the following issues within this reach:
  - Generally the same as Reach 2.
  - Structures and obstructions are more common than in reach 2, primarily man-made. There is little or no large woody material (LWM).
  - Regulated peak flows and limited sediment transport have greatly diminished channel processes resulting in a single-threaded reach lacking channel dynamics.
  - Levees prevent floodplain connection.

Solutions

- Richardson and Guilinger (2015) identified the following solutions within this reach:
  - Establishing a well-defined and sinuous thalweg with more frequent side channels and associated in-stream obstructions to emulate a more geomorphic morphology without disregarding the constraints of an urban river.
  - Where feasible, levees can be set back to improve floodplain connection and flood conveyance.
  - Protect existing side channels – especially those immediately downstream of Willow Lane Park – and established riparian areas near Willow Lane Park, Veteran's Memorial Bridge and Glenwood Bridge.
  - Remove or improve existing irrigation structures.
  - Build engineered riffles to create vertical hydraulic variability where lateral hydraulic variability is unrealistic due to constraints.
  - As with Reach 2, build a series of in-stream low-profile bank barb structures along otherwise straight, homogenous sub-reaches to strategically force flow convergence toward alternating banks to establish a well-defined thalweg.
  - Build engineered log jams or boulder obstructions.
  - Place LWM into off-channel features.
  - Excavate side channels or improve inlets/outlets to existing side channels.

- Excavate pools adjacent to newly installed in-stream structures.

Reach 4: Eagle Island – North and South Channels

Issues

- From Eagle Island to Eagle Road the north channel has been reduced from 790 ft to 400 ft and the south channel from 390 ft to 150 ft (MacCoy 2006).
- Flow split around Eagle Island is dynamic and changing due to development downstream, quarry development, shifting of streambed gravels, and movement of push up diversion at head of island by irrigators (USACE 2006).
- Natural gravel accumulation at the head of Eagle Island is removed by irrigators to protect their diversion (USACE 2006).
- There is little topographical relief in the Eagle Island area to mitigate flooding – restricted channel capacity and lack of conveyance capacity makes Eagle Island the highest risk area along the Boise corridor (USACE 2006).
- The area below Eagle Island is susceptible to sedimentation because of the relatively flat gradient to the river channel compared to upstream (USACE 1995).
- The head of Eagle Island area was a historically wide, braided floodplain with active, laterally migrating channels and frequent flooding, the current condition is a single channel on the north and south side of the island (USACE 2013).
- Richardson and Guilinger (2015) identified the following issues within this reach:
    - Poor floodplain connection; levees and rip-rap create two single-thread channels with low sinuosity.
    - Large, expansive floodplain areas are blocked by levees.
    - Many large ponds have been excavated, but they lack connection to the floodplain, and there is a potential for “pit capture.”
    - Lack of in-stream hydraulic complexity. The major in-stream structure is the concrete structure that partially regulates flow at the head of Eagle Island.

Solutions

- Richardson and Guilinger (2015) identified the following solutions within this reach:
    - Maintain split flow conditions while strategically improving in-stream hydraulic complexity with large woody material, and improve channel migration and floodplain activation by removing or setting back levees allowing flood access to underdeveloped areas and gravel pits where feasible.
    - Protect existing riparian areas like those around Eagle Road Bridge.

  - Modify inactive gravel pits as flood retention ponds and create a connection between them and the hydrology of the river. Where feasible, create floodways using existing interconnected ponds, low swales and streets to focus floodwaters away from existing buildings.
  - Make steps towards filling inactive gravel pits to restore floodplain.
  - Install obstructions (boulder clusters and/or wood) to force flow contraction and expansion to create localized pools and hydraulic diversity.
  - A series of low-profile instream barb structures similar to Reaches 2 and 3 would be appropriate.
  - Install engineered log jams for increased structure and to force channel migration where appropriate.

Reach 5: Eagle Island to Indian Creek Basalt Flow in Caldwell

Issues

- Below Eagle Island, particularly below Caldwell, the historic river had a sandy substrate, sand bar surfaces and a wide variety of channels (MacCoy and Blew 2005). This reach is currently confined to one main channel and the sloughs have almost all been converted to drains.
- Gravel and sand bars were historically dominant downstream of Eagle Island, but these features have either stabilized or have been exposed (MacCoy 2006).
- Parafluvial surfaces colonized by riparian vegetation are no longer part of the river system between Star and Caldwell (MacCoy and Blew 2005) due to altered flow regime.
- From Eagle Road to Middleton bankfull width was reduced from 520 ft to 280 ft (MacCoy 2006)
- A study site near Middleton showed the river was composed of 47% silt and sand and 36% gravel and mostly run habitat with no pools at the time of the study (Mullins 1999).
- Richardson and Guilinger (2015) identified the following issues within this reach:
  - Poor floodplain connection; levees and rip-rap; primary floodplain connections in the form of localized back bar channels and alcoves.
  - Primarily single thread channel with limited channel migration
  - High in-stream velocity
  - Low in-stream hydraulic complexity, few observed LWM
  - Poorly defined thalweg

Solutions

- Richardson and Guilinger (2015) identified the following solutions within this reach (and for Reach 6):

- Promote split flows and island formation with broad, densely vegetated riparian area and active floodplain.
- Utilize constructed log jams over the short term and naturally recruited large woody material over the long term to promote and maintain split flows, side channels, and a degree of hydraulic complexity.
- Remove or set-back levees and rip rap allowing floodplain access and channel migration where feasible.
- Establish broad riparian buffers (greater than 1000ft) to promote riparian development.
- Protect existing in-stream LWM.
- Protect any areas within the existing floodplain that have not been developed.
- Promote channel migration, build log jams, remove or improve irrigation structures, excavate or improve side-channel inlets and outlets, like other reaches.

Reach 6: Caldwell to Mouth of the Boise River

Issues

- From Caldwell to the mouth, bankfull width was reduced from 620 ft to 250 ft. (MacCoy 2006)
- At the mouth of the Boise River the substrate was composed of 49% silt and sand at the time of the study (Mullins 1999)
- Richardson and Guilinger (2015) identified the following issues within this reach:
    - Primarily single-threaded.
    - Aquatic vegetation trapping silt in stretches – very few scour pools, which are only associated with rare, primarily human-made in-stream structure.
    - Poor/discontinuous riparian buffer and erosive bank materials
    - Vast network of discontinuous levees and rip-rap have resulted in over-widening of channel given the existing flow regime.
    - Little to no in-stream hydraulic complexity.

Solutions

- Richardson and Guilinger (2015) identified the following solutions within this reach (and for Reach 5):
    - Promote split flows and island formation with broad, densely vegetated riparian area and active floodplain.
    - Utilize constructed log jams over the short term and naturally recruited LWM over the long term to promote and maintain split flows, side channels, and a degree of hydraulic complexity.

- Remove or set-back levees and rip rap allowing floodplain access and channel migration where feasible.
- Establish broad riparian buffers (greater than 1000ft) to promote riparian development.
- Protect existing in-stream LWM.
- Protect any areas within the existing floodplain that have not been developed.
- Promote channel migration, build log jams, remove or improve irrigation structures, excavate or improve side-channel inlets and outlets, like other reaches.

Part II: Network Feedback

November 12th, 2014 Geomorphology Meeting

At this meeting, participants were provided handouts detailing the overall conclusions, issues and solutions from a preliminary literature review. Fifteen participants provided written comments and feedback. Although not all participants in the meeting provided written feedback, they all participated in the discussion which consisted of small group discussions and a presentation of ideas to the larger group on issues and solutions. Their written feedback is summarized in the table below. It is important to realize that this table represents the desires and input of the participants, and not the scientific community.

Issues and Solutions Identified

ISSUES	SOLUTIONS
Geomorphology issues • Most of the river channel is over widened, especially in lower reaches • Floodplain is confined • River lacks well-designed thalwag • There is bank erosion from constant flows • Constant flows have over-stabilized banks • Lack of vegetation in side channels • Side channels have been removed and developed • The river bed is armored and cobble-dominated except from Caldwell to confluence • Lack of roughness elements, undercut banks	• Historic conditions as a reference point is not realistic – must work within current constraints and have realistic goals • 1st priority protect existing high quality, functioning floodplain and side channel areas (i.e. North Channel in Eagle) • Determine appropriate width based on geomorphic/hydrologic setting and width depth ratio for river to function • Identify "low hanging fruit" opportunities for restoration/reconnection to floodplain • Reintroduce willow– root systems are good • Re-evaluate removal of instream debris • Reconnection of side channel and tributaries - below Barber pool, Walling Creek reconnection
Geomorphology – Lower Reaches • Lower reaches have farmland up to the river; the river is over widened, there is little riparian cover and the bed is armored	• Install instream structures to allow river to create braided system and increase diversity, especially woody debris • Outreach to farming communities
Research gaps • Lack of understanding of how the current channel geometry is related to current hydrology	• Need to establish the 1.5 year flood flow and elevation • Economic analysis of the benefits of a

• Lack of research on the economic value of ecosystem services of the Boise River	functioning river –i.e. blue ribbon trout stream • What is the value of ecosystem services?
Flow Management • Current flow management inhibits historic function of the river • Only Congress can change the rule curve – locked in to meet water rights	• Study of possible flow modifications and benefits of altering flow management • Identify solutions available within the current flow regime and identify problems that cannot be solved with the current flow regime.
Development • Continued development along floodplain • Few or weak ordinances to discourage development within floodplain • A lot of property along the Boise River is privately owned • Participation in and enforcement of flood insurance is low in the valley	• Easements, ordinances, increase setback from 200 feet to 300-700 feet. • Brainstorm incentive program (i.e. monitory, conservation-minded) to encourage land owners to allow restoration on their property • Incentivize good behavior – in effect penalizes poor behavior • Pursue ordinances that make new development ponds connect to river, have better habitat and possibly convey flood flows • Work with municipalities and counties so they are on the same page/understand flood risks • HWY 16 bridge is a good example of how new bridges should be built – expanded base • Harris Rach good example of set back from river
Instream Structures vs. Recreation and Flooding • Conflict between tuber safety and instream structures • Debris in the river can increase flood risk	• In high recreation areas consider low profile structures that are safe during summer flows but provide cover during winter flows • Establish Reach 2 as "recreational reach" and prioritize other reaches for instream habitat • Install low profile instream structures (such as boulders) in Reach 3 as proof of concept • New criteria to determine instream debris risk
Natural vs. Engineered solutions	• Examine Boise River and identify areas where natural solutions can work and where only engineered solutions can work • Don't follow one prescription • Remove rip-rap and replace w/bioengineering • Install log cribs instead of rock barbs • Permanent structure that can lay flat to help

	irrigators manage diversions without annual gravel use
Barber Dam • Acts as sediment trap; some flow modification • Aging infrastructure – if Barber Dam failed the immediate sediment release could have significant environmental impacts	• Create plan (goals) to retrofit Barber Dam to allow sediment to move downstream • Remove Barber Dam • Determine FERC relicensing timeline • Sediment release could recharge downstream processes
Gravel Pits and Ponds Along River • There are many discontinued gravel pits and ponds that can be susceptible to pit capture and also serve little environmental benefits	• Purchase these properties, fill, enhance and reconnect to floodplain • Use these ponds and gravel pits for temporary storage and conveyance of floodwater • Fill gravel ponds with mine tailings from Idaho City – or soil from development projects
Education • Complex topic that is difficult to understand • Important to clearly articulate issues to public to get stakeholder buy-in • Must change perception of what a "healthy" river is – e.g. Large wood is bad, in-stream bars and vegetation is bad, a straight river is good. • People believe restoring rivers is expensive and/or a waste of money	• Visualization tools and maps to help conceptualize projects and programs • Be clear on goals for each reach • Focus on solutions that address function • Paint a compelling picture of what a healthy river looks like, including a healthy river channel • What city has a better river? We have a chance to make Boise River example to other cities • Economic analysis
Cost • High cost for bank and channel maintenance	• Pursue funding opportunities via BREN and associated partners • Cost-Benefit Analysis

Part III: Enhancement Priorities

Primary Geomorphic Issue: Geomorphic setting is generally not connected with current hydrology.

- **Channel confinement:** Traditionally larger floodplain/ riverine system has been encroached upon by urban development, agriculture, flood control measures, etc.
- **Altered flow regime:** The altered flow regime has altered geomorphic function.
- **Channel form:** The channel has a poorly defined thalweg (the deepest part of the channel) with low instream hydraulic complexity, high width-depth ratio at low flows and high instream velocity at high flows.
- **Substrate:** Embeddedness and armoring have developed within the system as erosion and bank sediment transport processes are not functioning well.

Enhancement Priorities:

On the simplest level – the four enhancement priorities are (ranked):

1. **Protect** existing functional areas.
2. **Improve** natural river processes.
3. **Force River Processes** enabling the river to create improved forms.
4. **Construct** forms that the river can maintain.

1. Protect existing areas favoring target geomorphic conditions.

- **Protect land, water and in-stream structure supporting favorable geomorphic conditions.** Protecting existing areas is superior to creation of engineered areas.
- **Protect area within the active floodplain and/or meander belt width that has not been developed**. This provides the potential for future improvements.
- **Protect existing natural in-stream structure (LWM), especially those structures creating hydraulic complexity by forming/maintaining split flows, side channels, and large pools.** This action will need to be balanced with safety concerns regarding flood risk reduction and recreation.

2. Improve natural river processes enabling the river to restore natural forms on its own.

- **Allow the river to erode its banks and migrate in strategic locations.** This will simultaneously recruit sediment, form pools and point bars, increase sinuosity, and improve floodplain connection.
- **Enhance flows**. Particularly peak flows that promote channel dynamics and low flows that provide minimal habitat.

- **Remove or improve existing irrigation diversion dams enabling more natural flow and sediment transport.** Diversion dams act to restrict conveyance of flow and sediment, creating physically homogeneous backwater zones upstream of the diversion.
- **Remove or set-back levees where feasible enabling greater floodplain interaction.** Allowing the river access to larger areas of floodplain improves natural geomorphic process while improving flood storage and conveyance, which may reduce flooding in developed areas.
- **Establish an appropriate meander belt width where feasible**. Establishing an appropriate belt width will allow the river to function more naturally within a specified corridor while allowing a separate area for development and agriculture outside the belt width.
- **Reduce embeddedness by filtering silt and sand from stormwater by routing stormwater flow through existing or constructed wetlands**.

3. Force river processes enabling the river to create improved forms.

- **Where appropriate, build engineered log jams or boulder obstructions at the head of strategic point bars to force a percentage of flow across the back of the bar creating a back-bar side channel that is active across a wide range of flows.** Boulder clusters become less appropriate in most portions of Reaches 5 and 6 where the distance to bedrock (the source of boulders) is greatest.
- **Build engineered log jams to force channel migration into areas of accessible floodplain and away from developments or other vital infrastructure**. Promoting channel migration will recruit gravel, promote bar building, improve riffle-pool formation, and generally enhance hydraulic complexity.
- **Build engineered riffles with V-shaped cross-sections focusing flow into high-velocity chutes scouring pools downstream of the riffle.** This type of application can create vertical in-stream complexity where lateral dynamism (channel migration and bar building) is unrealistic due to constraints or unachievable due to channel confinement. This treatment is especially applicable in Reaches 2 and 3.
- **Reduce overall in-stream width-to-depth ratio by adding bank structure, creating islands (split flow) and improving riparian conditions.** Lower width-to-depth ratios improve thalweg development and improve shade and bank cover. This treatment is especially applicable in Reaches 1-3.

4. Construct forms that the river can maintain.

- **Excavate side channels.** Side channels can simultaneously enhance geomorphic function, improve hydraulic complexity and reduce flood risk.
- **Place whole trees and pieces of LWM into off-channel features.** Large wood in side-channels, sloughs and alcoves promotes scour pool development during high flows, stabilizes banks, and provides shade/cover.

Data Gaps:

- Site specific geomorphic analyses.
- Accurate flow and inundation modeling below Glenwood Bridge.

References

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City of Boise. 2014. Boise River Resources Management & Master Plan. City of Boise Parks and Recreation, ID.

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Mullins, W.H. 1999. Biological assessment of the Lower Boise River, October 1995 through January 1998, Ada and Canyon Counties, Idaho. Water-Resources Investigations Report 99-4178. U.S. Geologic Survey, Boise, Idaho.

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Spatial Dynamics, Mary McCown, Agua Tierrra Environmental Consulting. 1999. Boise River Resource Management and Master Plan. Boise Parks and Recreation Department, Boise, Idaho.

Tiedemann, R. 2011. The ecology, effects of dams, and restoration of the black cottonwood (*Populus trichocarpa* T. & G.) forest community in the intermountain west. Doctor of Philosophy Dissertation, Rutgers, NJ.

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USACE. 1995. Lower Boise River and Tributaries, Idaho, Reconnaissance Study. U.S. Army Corp of Engineers, Walla Walla District.

USACE. 2002. Boise Parks and Recreation Department Stewardship Plan for the Riparian Corridor from Barber Park to Glenwood Bridge. Walla Walla District, U.S. Army Corp of Engineers.

USACE. 2006. Boise River After Action Review 2006 High Water Vicinity of the City of Eagle, Idaho. U.S. Army Corps of Engineers.

USACE. 2013. Boise River at Eagle Island Ecosystem Restoration Project Ada County, Idaho Draft Feasibility Report. U.S. Army Corp of Engineers.

Appendix A: BREN Geomorphology Database

The following table is a select portion of the BREN database showing all sources that include a discussion on geomorphology, though geomorphology may not be the primary focus of the citation.

Author(s)	Date	Title	Area/Extent
Petrich, C.R. (SPF Water Engineering)	n.d.	Treasure Valley Hydrology - Power Point Presentation	Lower Boise watershed
Rob Richardson and James Guilinger (BOR)	2015	Geomorphic Assessment of the Lower Boise River, Idaho	Lower Boise River
City of Boise, Ada County, Boise County, Idaho Department of Lands	2014	Interagency Foothills Management Plan - Draft	Boise Foothills
Kanashiro, E.A. (BSU)	2013	A New Framework for Flooding Control in Regulated River Systems	Boise River, Arrowrock to Glenwood Bridge
USACE, Walla Walla District	2013	Boise River at Eagle Island Ecosystem Restoration Project, Draft Environmental Assessment	Boise River at Eagle Island
USACE, Walla Walla District	2013	Boise River at Eagle Island Ecosystem Restoration Project, Feasibility Report	Boise River at Eagle Island
Karie Pappani, Delwyne Trefz, and Jason Miller, Idaho State SWCC	2012	Lake Lowel Watershed (17050114SW004_06) Total Maximum Daily Load Implementation Plan for Agri	Lake Lowell watershed
Starr (prepared for FEMA)	2011	Discovery Report, FEMA Region X, Lower Boise Watershed, Idaho	Lower Boise watershed
Campbell, C., Davis-Butts, K., Gariglio, F. and W. Reeder	2011	Effects of Vegetation in Channels: A summary of findings regarding vegetation interactions with chann	Lower Boise watershed
Johnson, A. (BSU)	2011	Evapotranspiration in the Riparian Zone of the Lower Boise River with Implications for Groundwater Flo	Boise River near downtown Boise
Teidemann, R.	2011	The ecology, effects of dams, and restoration of the black cottonwood (*Populus trichocarpa* T. & G.) fo	Lower Boise watershed
Idaho Department of Environmental Quality (IDEQ)	2010	Lake Lowell TMDL: Addendum to the Lower Boise River Subbasin Assessment and Total Maximum Dail	Lake Lowell
RIME	2010	Treasure Valley Future Water Demand, Draft	Lower Boise watershed
Lower Boise Watershed Council and IDEQ	2008	Lower Boise River Implementation Plan Total Phosphorus	Lower Boise watershed
U.S. Bureau of Reclamation	2007	Finding of No Significant Impact and Final Environmental Assessment: Pioneer Irrigation District Propos	Boise River, Caldwell
Johnson, J. and Paquin, L.	2007	Modeling Groundwater Interactions using Analytic Element Methods and LiDAR	Boise River at Eagle Island
Natural Resources Conservation Service	2007	Lower Boise - 17050114 - Subbasin Profile	Lower Boise watershed
U.S. Army Corps of Engineers	2006	Boise River After Action Review 2006 High Water Vicinity of the City of Eagle, Idaho	Boise River near Eagle, Idaho
Hortness, J.E.	2006	Estimating low-flow frequency statistics for unregulated streams in Idaho	Idaho, statewide
Skinner, K.D.	2006	Estimating streambed seepage using head as a tracer on the Lower Boise River, Canyon County, Idaho	Lower Boise watershed
MacCoy, D.E. (USGS)	2006	Fish communities and related environmental conditions of the Lower Boise River, Southwestern Idaho,	Lower Boise River, Ada County to Canyon County
MacCoy, D.E. and D. Blew (USGS)	2005	Impacts of land-use changes and hydrologic modification on the Lower Boise River, Idaho, USA	Lower Boise River
Hardy, M.A., Parliman, D.J. and I. O'Dell	2005	Status of and changes in water quality monitored for the Idaho statewide surface-water-quality networ	Idaho, statewide
Ecovista	2004	Boise, Payette, and Weiser Subbasins Management Plan	Boise, Payette and Weiser Subbasins
Interim Legislative Committee on Natural Resources	2004	Treasure Valley Working Group, Final Report Draft	Lower Boise watershed
Beierlie, A. (BSU)	2004	Unnatural Contract: Boise's Comprise with Nature	Boise River, Ada County
MacCoy, D.E. (USGS)	2004	Water-quality and biological conditions in the Lower Boise River, Ada and Canyon Counties, Idaho, 199	Lower Boise River, Ada County to Canyon County
Trout Unlimited, Quadrant Consulting, Inc., CH2M Hill, Philip Willian	2003	Boise River Side Channel Project at Harris Ranch: Assessment and Recommendations	Boise River at Harris Ranch
Idaho Department of Environmental Quality	2003	Implementation Plan for the Lower Boise River Total Maximum Daily Load	Lower Boise watershed
USACE, Walla Walla District	2002	Barber Pool Conservation Area Inventory and Analysis	Boise River near downtown Boise
USACE, Walla Walla District	2002	Barber Pool Conservation Area Master Plan	Boise River near downtown Boise
Bliss, J.D. and P.R. Moyle	2001	Assessment of the sand and gravel resources of the Lower Boise River valley area, Idaho. Part One: Ge	Boise River basin
Idaho Department of Environmental Quality	2001	Blacks Creek Subbasin Assessment	Blacks Creek
Idaho Department of Environmental Quality	2001	Fivemile and Tenmile Creek Subbasin Assessment	Fivemile and Tenmile Creeks
Idaho Department of Environmental Quality	2001	Indian Creek Subbasin Assessment, Draft	Indian Creek
U.S. Bureau of Reclamation	2001	Land Use Effects on the Quality of Storm Water Runoff in the Boise Valley	Boise Valley
Idaho Department of Environmental Quality	2001	Lower Boise River Nutrient & Tributary Subbasin Assessment	Lower Boise river tributaries
Idaho Department of Environmental Quality	2001	Lower Boise River Nutrient Subbasin Assessment	Lower Boise River
Idaho Department of Environmental Quality	2001	Lower Boise River Tributary Subbasin Assessment Appendices List	Lower Boise river tributaries
Idaho Department of Environmental Quality	2001	Mason Creek Subbasin Assessment	Mason Creek
U.S. Army Corps of Engineers	2001	Preliminary Restoration Plan, Section 1135, Boise River below Barber Dam, Idaho	Boise River below Barber Dam
Spatial Dynamics (for the City of Boise)	2000	Public Lands Open Space Management Plan for the Boise Foothills	Boise Foothills

Hortness, J.E. and D.C. Werner (USGS)	1999	Stream channel cross sections for a reach of the Boise River in Ada County, Idaho	Boise River, Barber Dam to Ada/Canyon County boun
Spatial Dynamics, Mary McCown, Agua Tierrra Environmental Consu	1999	Boise River Resource Management and Master Plan	Boise River, Barber Park to Glenwood Bridge
Idaho Department of Environmental Quality	1999	Lower Boise River TMDL: Subbasin Assessment Total Maximum Daily Loads	Lower Boise watershed
Parliman, D.J. and J.M. Spinoza (USGS)	1998	Ground-water quality in northern Ada County, Lower Boise River Basin, Idaho, 1985-96	Lower Boise watershed
Mullins, W.H. (USGS)	1998	Water-quality conditions of the Lower Boise River, Ada and Canyon Counties, Idaho, May 1994 through	Boise River, Ada County and Canyon County
Shalkey Walker Associates, Inc.	1995	Boise River System Recreation Study, Phase II	Boise River watershed, including North, Middle and S
Stacy, S.M.	1993	When the River Rises: Flood Control on the Boise River 1943-1985	Lower Boise watershed
Findorff, D.D. and D.R. Reichmuth	1991	Conceptual Design Drawnings: Boise River Management Plan, Phase II	Boise River, Ada County
Findorff, D.D. and D.R. Reichmuth	1991	Conceptual Design Report: Boise River Management Plan, Phase II	Boise River, Ada County
Frenzel, S.A.	1988	Physical, Chemical and Biological Characteristics of the Boise River from Veterans Memorial Parkway,	Boise River from Veterans Memorial Parkway to Star
Lewis, R.E. and H.W. Young	1982	Thermal springs in the Lower Boise River Basin, south-central Idaho	Lower Boise Basin
Idaho Department of Health, Engineering and Sanitation Division	1962	Report of Pollution Problems in the Boise River: Ada and Canyon Counties, Idaho, 1959-1962	Boise River, Ada County and Canyon County
Renner, F.G.	1936	Conditions Influencing Erosion on the Bosie River Watershed	Boise River, Arrowrock to Snake River confluence