River Corridor Protection and Management

FACT SHEET

Colorado Water Conservation Board

Overview

For most early settlements in the arid west, the benefits of locating along a river as a source of irrigation, power, and transport outweighed the risks of occasional flooding. Over the past century, small outposts alongside Colorado's waterways have grown into large towns and cities with millions of dollars in investment. Despite warnings from periodic floods[1], development in the corridor of Colorado's waterways continued to flourish. In addition to thousands of highway and utility structures, the Colorado Water Conservation Board (CWCB) estimates that approximately 65,000 homes and 15,000 commercial and industrial business structures are located in Colorado's floodplains. [2]

Colorado residents are well aware of the ability of the Rocky Mountains to capture moisture and create localized weather patterns. The Rockies provide residents a reason and ability to live here – sunshine, snow, forests, and water. Yet the water that flows from higher terrain into the life-providing valley streams does not arrive in regular increments. While spring snowmelt is the typical cause of rising creeks and rivers, significant rain events have frequently been associated with destructive flooding. When heavy rainfall is combined with development practices that have increased the rate and volume of runoff (i.e., stormwater) and intense wildfires which can strip away the ability of forests to retain water, flooding becomes a question not of if, but when.

The reaction to historic floods has typically been to straighten, dredge, armor, and levee streams in an attempt to protect infrastructure. In interim periods, docile creeks create a sense of security, and new development creeps further into river corridors. As recent events in September of 2013 demonstrated, however, our current methods of relying solely on FEMA-generated flood maps to reduce flood risk offers limited protection as even properties located far away or high above creeks were affected. As a matter of physics, streams can become highly energetic during a flood event, and those years of floodplain alteration have destabilized rivers and increased the potential for catastrophic flood damage. Meanwhile, water quality and riverine ecosystem health have declined during periods of low water.

Fundamental Principles of River Systems

Until recently, river management has largely focused on water and how to withhold, contain, or withstand the force of its flow within a stream channel. Streams, however, are complex systems that do complicated work. In their natural state, streams gather, store, and move water. However, it is important for understanding stream processes to realize that streams and rivers are not only moving water - streams also move sediment and woody debris from mountain peaks to the sea.

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[1] Historic floods include but are not limited to Boulder (1894), Pueblo (1921), Denver (1912 and 1965), Big Thompson Canyon (1976), and Fort Collins (1997).
[2] http://www.coemergency.com/2010/01/historical-colorado-flood-events.html

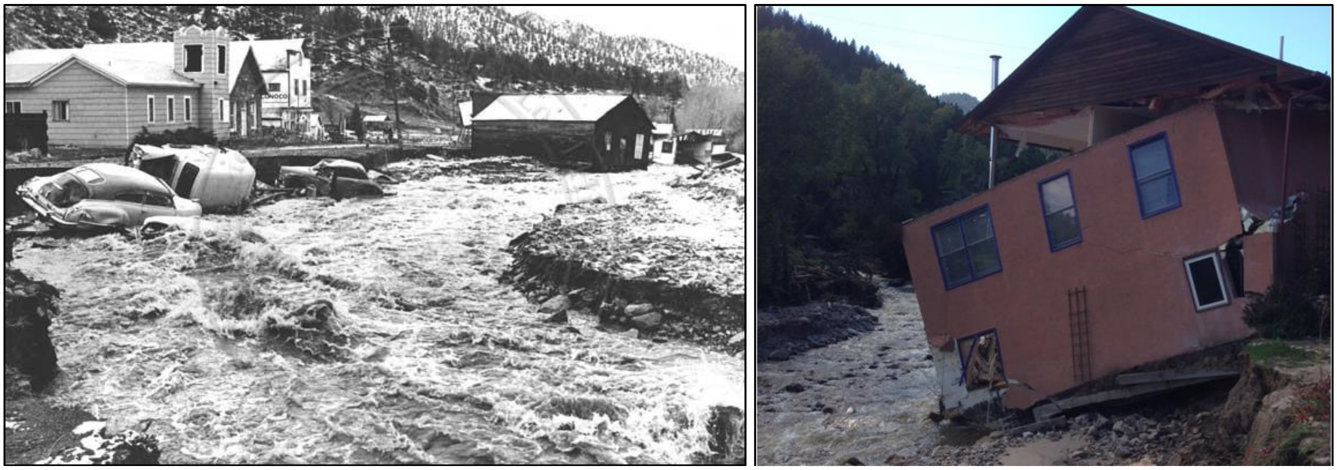

Figure 1: Flood damage in Jamestown from 1913 (not shown) 1969 (left image courtesy of the Carnegie Branch Library/Boulder Historical Society) and 2013 (right image courtesy of Tom Browning) indicate channel migration hazards inherent to a high gradient waterway.

Human land uses that significantly alter the ability of a creek to transport *water **and** sediment* will likely cause a stream to become unstable and increase the likelihood that catastrophic erosion or sedimentation may occur during a flood event. The relationship between water in a stream and its ability to transport sediment is shown as a balancing scale (Figure 2). When any one or more of the variables of this scale change, the system is no longer in balance, and aggradation or degradation of the bed and banks may occur. Given time and freedom to make adjustments, a stream will adjust its slope and sediment transport capability toward an equilibrium condition.

Throughout North America, river scientists and managers are now bringing this principle of river “stability” into the management of river channels by recognizing that stable rivers carry water, sediment and debris, even during high water, without drastic changes occurring in the depth, width, length, or slope of the channel. The term “dynamic equilibrium” is often used to describe a naturally stable stream channel. The channel may shift its location over time but ultimately will maintain consistent dimensions and habitat values. Channels remain stable when they are not impeded by unnatural constrictions like undersized bridges and culverts and have excellent access to a vegetated floodplain. When development changes the relationship of the river with its floodplain or alters the ability of a channel to transport its water and sediment load, it becomes increasingly difficult to protect that development.

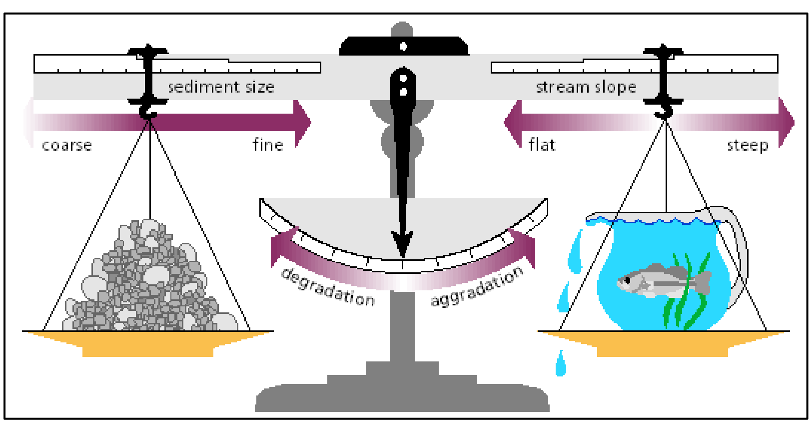

Figure 2: Lane’s Balance of Sediment Supply & Sediment Size with Slope (energy grade) & Discharge (Lane, E.W. 1955. “The Importance of Fluvial Morphology in Hydraulic Engineering.” In Proceedings of the American Society of Civil Engineers 81(745): 1-17.)

Flood Damage

Unbalanced rivers increase the risk of damage from flooding to our communities—and it's an expensive risk. Flash flooding represents the most frequent type of natural disaster in Colorado, resulting in significant property and infrastructure damage. Average ***annual*** flood losses in Colorado are estimated to be $83,000,000 in property damage based on data from 1911 to 2013 (inflation-adjusted 2013 dollars).[3] While inundation-related flood loss is a significant component of flood disasters, the predominant mode of damage in mountain communities is fluvial erosion.

Fluvial (river-related) erosion refers to streambed and streambank erosion associated with the sudden and catastrophic physical adjustment of stream channel dimensions (width and depth) and location that can occur during flooding. Much of this damage occurs where rivers have been separated from their floodplains by some kind of development thus containing erosive energy in the channel. Other examples are where rivers are unable to transport their sediment due to a constriction in the channel (e.g. culvert, weir, road embankment) which creates a sediment deficit downstream, or where excessive inputs (e.g. massive soil erosion from a burn scar) build up the river bed and exacerbate overbank flows. In these instances, a stream is likely to become destabilized and is more prone to sudden lateral or vertical shifting which may produce unexpected consequences for surrounding landowners. The dollar cost of such damage may well be equaled by other economic losses including diminished recreation opportunities, impaired ecological functions, and long-term channel instability.

Floodplain Access and Channel Evolution

Cutting a river off from its floodplain by building levees, berms and roadways, armoring with stone, or dredging a channel will cause a river to adjust through physical change. The result of containing greater flows in the channel (i.e., preventing access to the floodplain) is to increase the erosive power (friction) that must be resisted by the channel boundary materials; i.e., the rocks, soil, vegetation, or manmade structures that make up the bed and banks of the river. Figure 3 shows a common scenario of channel evolution process as described by Stanley Schumm (1984). It is important to note that this diagram only illustrates channel response at one location. There are equally profound physical adjustments that occur upstream and downstream from the site of a river corridor alteration as bed degradation (head cuts) migrate up through the system and aggradation in the form of sedimentation occurs downstream. Similarly another common form of channel evolution may occur where a stream starts in a stable condition but is overloaded with sediment from upstream sources and quickly aggrades (i.e. fills in) its channel spilling out onto the surrounding floodplain with significant destructive potential.

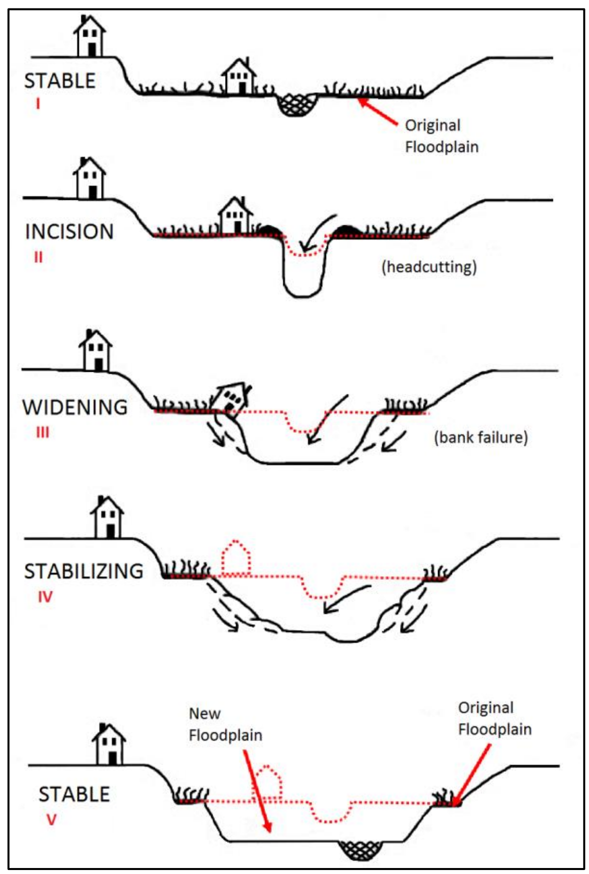

Figure 3: Schumm Model of Channel Evolution

[3] http://cwcb.state.co.us/water-management/flood/Documents/ColoradoFloodMitigationPlanUpdate2013.pdf

It is important to recognize the temporal aspect of channel response to change. Fluvial systems are energized by episodic events. Channel adjustment in response to management practices or encroachments may take effect immediately but may also persist for decades depending on the sensitivity and morphology of the stream channel, the magnitude of alteration, and the frequency of high flow events.

Flood Hazard Mapping

Historically, landowners and local government have determined areas within river corridors susceptible to flood damage by relying on the standards and the flood hazard boundary maps provided by the Federal Emergency Management Agency (FEMA) though the National Flood Insurance Program (NFIP). More recently, the State of Colorado, through the CWCB, has established more stringent floodplain management standards that all communities are required to adopt. For inundation-related flood damage, these maps provide a good starting point to guide communities but are not without their limitations. For starters, communities need only adopt FEMA and the State of Colorado's minimum standards for flood hazard area regulation in order for their residents to be eligible to purchase flood insurance. The risk depicted in these maps is always uncertain because of limited data and the high spatial and temporal variability associated with hydrologic cycle, sediment load, and river mechanics. Moreover, the process of developing flood elevations assumes clear water conditions, ignoring sediment, ice, and debris transport. Colorado's narrow, steep valleys do not lend themselves to precise water surface elevation modeling exercises. Even with these challenges, FEMA's and the State of Colorado's minimal standards still allow for new development into mapped flood hazard areas without full regard for the river channel and floodplain dynamics, possibly further exacerbating flood loss, degrading river conditions, and increasing costs associated with flood recovery.

Of particular concern for Colorado's mountain valleys is that FEMA's NFIP maps are elevation-based, delineating ***only inundation*** hazards by applying a water surface elevation based standard (i.e. the 100- and 500-year base flood elevation). The maps do not consider fluvial erosion hazards or the dynamic nature of river systems which are prone to natural lateral movement due to fluvial erosion – particularly during a flood event. The NFIP maps represent a static impression of a dynamic system. In the Rocky Mountain region of Colorado where the landscape is often defined by steep, relatively narrow valleys, and highway infrastructure, private residences, and commercial properties located in close proximity to stream channels, the potential for catastrophic channel movement due to flooding is a particular concern. During 2008, one-third of all flood insurance claims nationwide were from areas outside of the 100-year floodplain.[4] This percentage has been observed to increase in mountainous areas where fluvial erosion may account for more flood damage than inundation. For this reason the NFIP maps are often inadequate as a sole indicator of flood hazards for mountain and Front Range communities. The "no encroachment" limits defined by the NFIP floodway do not necessarily provide for the river corridor width necessary for the channel to maintain a stable balance with its watershed inputs. In fact, FEMA's and the State of Colorado's regulations recognize that the NFIP standards offer *minimal* protection against inundation and erosion hazards, and they explicitly encourage communities to adopt more protective standards.

Fluvial Erosion Hazard Mapping

Fluvial erosion becomes a hazard when the stream channel that is undergoing adjustment due to its instability- threatens public infrastructure, houses, businesses, and other private investments. Fluvial erosion hazard (FEH) areas include the stream and land adjacent to the stream. A fluvial erosion map (or channel migration zone map) identifies an area where stream processes may occur that enable the stream to reestablish and maintain a

[4] http://www.floodsmart.gov/floodsmart/pages/flood_facts.jsp

stable slope and dimensions over time. The fluvial erosion hazard area is a calculated belt width-based corridor where erosion is minimized when the least-erosive or stream equilibrium conditions are achieved. FEH area boundaries attempt to capture lands most vulnerable to fluvial erosion in the near term and indicate the type, magnitude, and frequency of fluvial adjustments anticipated during flood events. The area can be mapped based on quality-assured fluvial geomorphic data (i.e., data that describe the physical form and process of a riverine system).

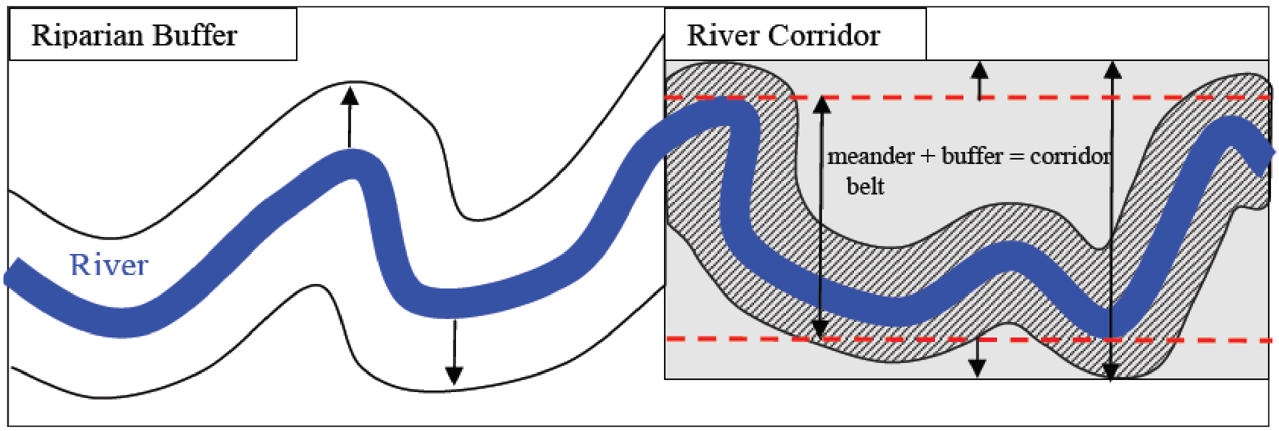

Figure 4: Comparing a buffer setback to a river corridor (Kline and Dolan, 2008).

River Corridor Protection

A stream stability assessment is an essential component of river corridor planning efforts proposed by CWCB in partnership with local governments, landowners, watershed associations, and regional planning commissions. Watershed plans, hazard mapping, and stream geomorphic assessments will support adoption and implementation of river corridor plans, thereby accounting for fluvial erosion hazards and maintaining stability of the stream system.

Ultimately the most effective method of long-term flood hazard reduction may be the establishment of a Fluvial Erosion Hazard Area Zone or Overlay District under municipal zoning by-laws. A more direct, but less effective option would be to adopt standard set-backs from streams. The selection of the set-back dimension may be guided by the width of the river corridor delineation.

Conclusion

River management success and flood hazard reduction, in the long term, will primarily be measured by our ability to solve problems at the watershed and river corridor scale, and secondarily, by how we resolve conflicts at individual erosion sites. From a physical standpoint, this means recognizing that rivers transport and deposit water ***AND*** sediment, and that natural stability and balance in the river system will depend on the river's opportunity to build and access a floodplain and create depositional features such as point bars, steps, and riffles to evenly distribute its water energy and sediment load in a sustainable manner (Kline and Cahoon, 2006).

Because rivers and waterways don't follow state and town boundaries, the approach to fixing these problems needs to cross political boundaries. The solution requires an individual, local, regional, State and Federal partnership that can work in watersheds to protect river corridors.

Sources of Additional Information

This document can be found at:
http://cwcb.state.co.us/environment/watershed-protection-restoration/Pages/main.aspx (Right side of page under "Additional Information")
CWCB Flood Info Website: http://cwcb.state.co.us/water-management/flood/Pages/main.aspx
Colorado Risk Map: http://coloradofloodrisk.state.co.us/PublicOutreach/Pages/Homeowners.aspx
Vermont River Management Program's Fluvial Erosion Documents: www.vtwaterquality.org/rivers.htm

Stream Assessment Protocols:

- Vermont Geomorphic Assessment Protocols
  http://www.vtwaterquality.org/rivers/htm/rv_geoassesspro.htm

- Watershed Assessment of River Stability and Sediment Supply
  http://water.epa.gov/scitech/datait/tools/warsss/
  http://www.wildlandhydrology.com/assets/CHANNEL_STABILITY_.pdf

- Framework for delineating channel migration zones: Washington State
  https://fortress.wa.gov/ecy/publications/summarypages/0306027.html

- Bridge and Culvert Assessment Protocol example
  http://www.vtwaterquality.org/rivers/docs/rv_SGAB&CProtocols.pdf

References

1. Kline, M. and B. Cahoon. 2006. Alternatives for River Corridor Management: Toward resolving river and land use conflicts in an economically and ecologically sustainable manner. Vermont Agency of Natural Resources. Montpelier, VT.
2. Kline, M and K. Dolan. 2008. River Corridor Protection Guide: A Fluvial Geomorphic-Based Methodology to Reduce Flood Hazards and Protect Water Quality. Vermont Agency of Natural Resources. Montpelier, VT.
3. Lane, E.W. 1955. The Importance of Fluvial Morphology in Hydraulic Engineering. Proceedings of the American Society of Civil Engineers, Journal of the Hydraulics Division, vol. 81, paper no. 745.
4. Schumm, S.A. 1984. The Fluvial System. John Wiley and Sons, New York.

Acknowledgements

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