Watershed Assessment of River Stability and Sediment Supply

North Fork of South Platte Watershed

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BACKGROUND AND GENERAL PROJECT DESCRIPTION

A Watershed Assessment of River Stability and Sediment Supply (WARSSS)[1] was made on the North Fork of the South Platte Headwaters watershed for the purpose of identifying which reaches and sub-watersheds fall into categories of low, moderate, or high risk for sediment pollution. Placement of a reach into one of these categories implies a certain set of recommendations for protection, management, monitoring, or restoration. The study is meant to be used as a tool to help direct future efforts that aim to improve the state of sediment pollution in the watershed.

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[1] Watershed Assessment of River Stability and Sediment Supply (WARSSS) is a method for assessing sediment impairment developed by the EPA and Dr. Dave Rosgen, *[Rosgen, D.L. (2006). Watershed Assessment of River Stability and Sediment Supply (WARSSS). Wildland Hydrology Press. Fort Collins, CO].* This method is designed to "reveal significant, adverse influences of land uses on stream channel stability, sediment sources, and sediment yield that may affect the material beneficial uses of rivers and streams." It is intended to be used for watershed planning, TMDL assessments for clean sediment non-point source pollution, and a stability analysis for river restoration. A detailed website is available for information about the WARSSS methodology at http://www.epa.gov/warsss/index.htm.

Our overarching goal is to improve water quality and ecological condition of the Upper South Platte River watershed. The present study aims to add the North Fork to the set of completed drainages for which WARSSS has already been completed in the watershed. Due to the extent of human influence on many reaches of the North Fork, problems related to excess sediment and stream instability have been suspected. While the problem of sediment pollution and the need for mitigation has been recognized, the extent of the problem and locations of primary concern are not well documented. This study aims to fill this knowledge gap with a systematic assessment of all the reaches in the watershed using phase 1 and 2 of WARSSS. Risk ratings can be generally interpreted as follows:

- high - very high = priority for mitigation or restoration
- moderate = priority for monitoring or requiring further study
- low = priority for protection

WARSSS Resources

Results of the study were used to prepare three separate resources to evaluate the results. A GIS layer with all of the reaches assessed in this study was prepared to display WARSSS risk ratings on a map of the watershed. The map is intended to make it easy to associate specific segments with their position in the watershed, surroundings, property ownership, management, protection, etc. In addition to a WARSSS map for the North Fork drainage, we are also using the results of this study to add to the results of previous WARSSS studies of the other drainages in the South Platte Headwaters to produce a WARSSS map that covers the entire headwaters portion of the watershed. Our results are also organized into a simple database, and this is where all the specific findings and recommendations for each reach may be found. The database gives RLA results as well as risk ratings for each of the RRISSC factors, overall RRISSC rating scores, and a narrative summary of the assessment for each reach. The database is also where we provide specific recommendations for management, mitigation, monitoring, and recommendations for advancement to the third phase of WARSSS, the *Prediction Level Assessment (PLA).* Finally, the most significant findings and recommendations are summarized in this report.

RESULTS

RLA Phase

Phase 1, the *Reconnaissance Level Assessment (RLA),* was completed in April 2011. During this phase the watershed network was divided into 95 reaches and each reach was assessed individually. Using remote imagery, knowledge of land use, stream and valley classification,

and other basic information, we applied WARSSS RLA procedures to detect human impacts to sediment-related processes[2].

On 33 of the total 95 reaches, we determined that there was not enough evidence of significant human impact or land use change to warrant further assessment. These 33 reaches were placed in the "low risk" category.

On 59 reaches, significant land use or human impact factors were identified in the RLA phase. For these reaches, we documented the land use or nature of human impact that was detected as well as the specific sediment-related processes that might be impacted. These reaches were assessed further using the *Rapid Resource Inventory for Sediment and Stability Consequences (RRISSC)* in phase 2 of WARSSS.

RRISSC Phase

During the RRISSC phase, we made site visits to each of the 59 reaches for which significant impacts were detected in RLA. RRISSC procedures include a more detailed rapid assessment of sediment-related factors. Each reach was assessed for impacts related to the following factors: mass erosion, roads, surface erosion, streamflow change, streambank erosion, in-channel mining, direct channel impacts, channel enlargement, aggradation, channel evolution, and degradation. Then, based on these individual factor scores, an overall RRISSC rating is assigned, and specific recommendations can be made for each reach. The number of reaches in each risk category, by factor, is summarized for the watershed in table 1.

DISCUSSION

A general definition and description of each sediment influencing factor was presented in the 2009 South Platte Headwaters WARSSS paper and is attached as Appendix 1. Here we will discuss how each factor applies to the North Fork of the South Platte drainage.

[2] RLA considers the following land uses: urban development, silviculture, agriculture, stream channelization, fires, floodplain impacts (flood control, clearing, vegetation removal, dredging, levees), reservoirs, diversions, depletions, grazing, roads, and mining. The potential for impacts of these land uses were related to the following sediment-related processes: surface erosion, mass erosion, streamflow change, channel processes, and direct channel impacts to determine if there is a potential for significant human impact worth considering in more detail.

Table 1 Summary of RRISSC ratings for various sediment-related processes through the South Platte Headwaters watershed

factor	number of reaches with RRISSC ratimg				
	very low	low	moderate	high	very high
mass erosion	87	6	1	1	0
	92%	6%	1%	1%	0%
roads	65	16	14	0	0
	68%	17%	15%	0%	0%
surface erosion	72	20	1	2	0
	76%	21%	1%	2%	0%
streamflow change	81	4	1	4	5
	85%	4%	1%	4%	5%
streambank erosion	81	10	1	2	1
	85%	11%	1%	2%	1%
in-channel mining	93	2	0	0	0
	98%	2%	0%	0%	0%
direct channel impacts	64	11	7	3	10
	67%	12%	7%	3%	11%
channel enlargement	74	8	6	5	2
	78%	8%	6%	5%	2%
aggradation/excess sediment	78	12	3	1	1
	82%	13%	3%	1%	1%
channel evolution/ successional states	92	0	0	1	2
	97%	0%	0%	1%	2%
degradation	57	12	8	6	12
	60%	13%	8%	6%	13%
overall RRISSC	**45**	**25**	**20**	**3**	**2**
	47%	26%	21%	3%	2%

Mass Erosion

There are two segments where human impacts on mass erosion were identified as a potentially significant sediment sources. On Duck Creek at the old Geneva Basin ski area, a steep hillslope adjacent to the creek upstream from the ski area location appears to be at some risk due to possible vegetation and development impacts. The extent and nature of this problem would have to be quantified in PLA to determine if the risk of slope failure is in fact increased from human impact. The second segment with potential mass erosion issues is from Robert's Tunnel to Grant along the north fork where there is a large, steep hill of material on the south side of the river. The hillside is mostly devoid of vegetation and there is only a very thin buffer on the edge of the river. This hill appears to be man-made and the function or purpose is unknown. The steep angle of the hill and the proximity to the river make it a 'high' risk for sediment input. Steps should be taken to mitigate this situation, and these may involve re-vegetation of the hillside and buffer and re-shaping the hill to decrease its angle.

Roads

Roads were observed to be an extensive impact throughout the watershed with moderate severity on 15% of the segments and low or very low severity on the remainder. In the upper segments of the watershed, run-off was observed running on the road in several locations. Additionally, there are places where creeks run across the road surface because culvert location or size is not adequate. Both these situations present significant sources of sediment to waterways and damage roads. Without continued maintenance or reconstruction of inadequate crossings, many areas where these problems exist will continue to become worse. The other major road impact in the drainage is in places where a road is directly adjacent to the creek or river. Often, the presence of a road has altered the alignment of the creek and/or the function of its floodplain. In places where maintained dirt roads are adjacent to a stream, road grading and erosion deposit material directly into the waterway. Two examples of this are along Geneva Creek and the North Fork in Hall Valley.

Below the town of Grant, most of the length of the North Fork is paralleled by Highway 285. While the WARSSS methodology did tend to pick up on the potential direct impacts of the highway on river stability (much of the river was re-shaped to accommodate the highway) with high scores in the roads and direct channel impacts categories, we actually found very little evidence that these impacts were resulting in an unstable river. In general, these segments of the North Fork are either natural boulder/bedrock reaches or reaches that were engineered with boulders. Therefore we have several segments that scored high or very high for the direct channel impacts from the road, but that ultimately received a more moderate overall RRISSC rating.

Surface Erosion

From the watershed perspective the majority of the segments (97%) have very low or low risk ratings for surface erosion. While there is some impact from impervious surfaces and vegetation shifts in isolated areas, overall the impact over the entire watershed is very small. Most of the land beyond the bottom of the main canyon is wilderness. One exception to this situation is in and around the Town of Bailey were the percent of impervious surfaces increases. This condition raises the risk level to moderate.

There are two segments (one on Duck Creek and the other on Geneva Creek) that received high risk ratings for surface erosion. On both of these segments floodplain vegetation has been converted to road or disturbed surface. On Duck Creek at the old Geneva Basin ski area, there is an enormous stockpile of sand adjacent to the creek. A sediment fence has been installed between the sand and the creek to minimize input, but this is a short term solution as effectiveness of sediment fences generally decrease with time. If the sand storage is a long term situation it should be moved further from the creek. There is ample space to do this. Revegetation of the stockpile and the buffer between it and the creek would also be good measures to take to reduce this potential source.

Streamflow Change

The major impact to streamflow in the drainage is augmentation from Robert's Tunnel. Upstream from the tunnel and in the side drainages there is little to no disturbance to the amount and timing of streamflow. Very low and low risk ratings make up 89% of the segments, 1% is moderate because of the influence of Duck Lake. Below the tunnel outlet, the remaining 10% are rated high or very high depending on the stream type. Streams in a canyon landscape (B/G) are less susceptible to instability due to streamflow changes (rated high). Meadow streams (C) or entrenched streams (F) are more susceptible to instability due to streamflow changes (rated very high). While the WARSSS method for evaluation of risk highlighted the segments of the North Fork below the tunnel for this reason, we were unable to identify many signs of instability. The system seems to have adjusted or been adequately engineered and hardened to handle the added streamflow without either aggrading or degrading. Channel adjustment and re-engineering has probably been a long process from when Roberts Tunnel was first activated, but the current situation appears to be a much more stable system than the risk ratings would indicate. For this reason, when we compiled data for the overall RISSCC ratings on these reaches, we decreased the importance of the streamflow risk ratings to reflect the apparent stability.

Streambank Erosion

For the majority of the watershed (96%) streambank erosion was very low or low risk as a sediment source. There were some natural levels of bank erosion observed in meandering meadow streams (C, E, and D_B channels) where the vegetation was largely unimpacted and the floodplain was well connected. The remaining 4% of segments were rated moderate to very high due to vegetation shifts and direct channel impacts. The alterations to the stream that lead to this increased risk rating were a vegetation shift (willows to meadow grasses) and an increase in bank height ratio (connectivity to the floodplain decreased because bank height increased). These types of impacts were rarely seen on the smaller tributary reaches, with one major exception being the segment of Geneva Creek at the confluence of Burning Bear, where bank erosion is likely a very high source of sediment and channel instability.

Along the Main stem of the North Fork, in every segment where these impacts were observed, the channel was also artificially hardened and/or straightened to mitigate bank erosion. Similar to the situation with road influence and streamflow below the tunnel, the methodology indicates that streambank erosion risk increased but when other modifications and field observations are taken into account streambank erosion is not considered to be a significant increased source of sediment.

One particularly interesting example of high bank erosion was found on an unnamed gulch (segment #94) that crosses CR 110 near Bailey. The culvert and road fill at this crossing has created a deeply incised gully with very unstable banks. Streambank erosion risk is very high for this segment.

In-channel Mining

From the perspective of sediment pollution, in-channel mining is not a contributing source of degradation. 100% of the segments are rated very low or low risks from in-channel mining. Historic mining high in the watershed may have increased sediment input at one time, mining within stream channels appears never to have been widely practiced in this watershed. While in-channel mining impacts are rare here, mining in general is fairly widespread in the headwaters regions. The effects of mining activity tend to be indirect effects of access roads and other.

Direct Channel Impacts

Direct channel impacts are evaluated by assessing any activity, development or change that directly affects the dimension, pattern, or profile of a stream channel. 78% of the segments have a very low or low risk rating for this factor in the North Fork watershed. Almost none of the headwaters and smaller 1st and 2nd order tributaries have seen significant direct impact.

Along the main stem of the North Fork and its larger tributaries (Hall Creek and Geneva Creek), the story is quite different. 22% of all segments were rated moderate to very high risk, and most of these are along reaches of the larger rivers and creeks. The most common impact to the channel was the presence of a road which impacted the alignment of the channel and the form and function of the floodplain. Vegetation shifts are the other most common direct impact on channels in the watershed, and on many reaches both of these factors exist together.

The majority of the segments (all except 2) that have a high risk from direct channel impacts are in the Hwy 285 corridor. Along much of the North Fork between Grant and Bailey, the North Fork channel has been severely altered to accommodate the alignment of Highway 285 and/or re-engineered and hardened as part of the Roberts Tunnel trans-basin diversion. Along most of North Fork through the Hwy 285 corridor, the degree of direct channel impact is very high, but stream stability consequences do not appear to be severe. Thus, these segments tend to have lower overall RRISSC scores that would be indicated by the high degree of direct disturbance that they have been subject to.

There are 2 segments on the larger tributaries where direct channel impacts are suspected of having very significant stability consequences. The first is in Hall Valley where a dirt road was constructed right alongside the creek. In addition to being a direct source of sediment, construction of the road required realignment, straightening, steepening and narrowing of the Hall Creek channel. PLA is recommended to better understand how these direct channel impacts effect sediment transport and stability of the reach.

The second tributary segment that received a high risk rating for the degree of direct channel impact is on Geneva Creek near Burning Bear Ranch. This private in-holding obviously has a very different land use pattern than the neighboring reaches of Geneva Creek. Shrub removal and intensive livestock have apparently caused a complete shift in riparian vegetation from the willow-shrub community (which is ubiquitous along the entire rest of Geneva Creek) to sparse , heavily grazed meadow grasses. The stream in this segment shows multiple signs of instability and incompetence at moving sediment through the system. It is a high risk for aggradation and evolution towards a braided channel, and there is ample evidence that this process is already well underway.

Channel Enlargement

Channel enlargement risk is influenced by streamflow changes, streambank erosion and direct channel impacts. Therefore, the WARSSS methodology picks up on these major stressors at play on the main stem of the North Fork (flow augmentation from Robert's Tunnel and road development) which drives the risk rating for enlargement on these segments to to moderate, high and very high for 14% of the segments. As we described earlier, these straightened and

hardened reaches have not shown much susceptibility to instability or erosion at all, so despite the fairly high enlargement scores in WARSSS, overall RRISSC ratings for instability by this means are modersate to low.

On Geneva Creek at Burning Bear, the risk of channel instability via enlargement is very high. The exceptions are on Geneva Creek at Burning Bear Creek where sediment deposits have cause widening of the channel and on an Unnamed Creek where a culvert under CR 110 has caused a major downcut and channel enlargement. Both will be described in the red-flag discussion.

Aggradation/Excess Sediment

95% of the segments are rated very low or low for the risk of aggradation. Of the remaining 5%, all other segments besides one were rated moderate for aggradation. The one critical segment is, again, on Geneva Creek at Burning Bear. On this section of Geneva Creek, the channel is aggraded to the point that it is no longer a single-thread channel, and for much of its length appears to now be a wide, shallow, braided D-type stream. Above and below this segment, riparian vegetation has maintained stability of a naturally narrow and deep channel that effectively transports sediment. These reaches could serve as valuable reference reaches in efforts to restore the ailing Burning Bear reach of Geneva Creek.

Channel Evolution

The process of channel evolution describes the general process of a channel that is changing from one morphological type to another. In a stable state, the channel does not evolve.; rather it tends to maintain a characteristic dimension, pattern, and profile without either aggrading or degrading. This factor has been especially interesting in the evaluation of the segments of the North Fork through the lower Highway 285 corridor. These segments have seen major human impact, and several other independent WARSSS factors would indicate a high risk of instability. However, a long history of channel immobility and stability contradicts this prediction. In its hardened, engineered state, and with its low sediment supply, this reach appears nevertheless to be maintaining its channel morphology, be it B, C or F, In this light, it makes sense that 97% of the segments were rated as a low risk for channel evolution and the increased sediment production that would ensue.

The reaches that did score as high risk for channel evolution were Geneva Creek at Burning Bear (where the evolution of a natural C/D_B channel system appears to be mostly converted already to a braided D channel following vegetation shift, lateral instability, and aggradation. The unnamed Gulch at CR 110 is also rated a high risk for evolution from C to G to F as a result of degradation and gulley formation caused by the road crossing and culvert.

Degradation

Degradation is perhaps the most extreme form of channel instability. On channels with excess, the bed can be degraded which effectively lowers base level by downcutting. Degraded, (downcut) channels become incised, entrenched, and separated from their floodplains which can even result in an overall drop in the water table elevation and complete shift in streamside vegetation in addition to a change in channel type (evolution). We identified 10 segments that appear to have some significant risk of degradation. 5 of the 10, (unnamed Gulch, Smelter creek, Jackwacker creek, Kenosha creek, Geneva Creek at Geneva Campground, and Crow Gulch) are degrading due to road crossings with bad culverts that either increase scour or are unable to handle floodflows (which increases the likelihood of the stream creating a new channel). At many of these sites, simply resizing the culverts to accommodate appropriate hydrology and sediment transport could solve the problem.

3 of the 10 (Sawmill Gulch, Slaughterhouse Gulch, North Fork in Hall Valley) are degrading due to entrenchment caused by realignment to roads in addition to the impacts from poorly designed culvert crossings. On these segments, reducing the risk would involve major eforts

Finally, there is the one segment of Geneva Creek at Burning Bear Creek where degradation risk is related to the possibility of avulsion and downcutting secondary to aggradation an excessive lateral migration. At this site, PLA analysis should be undertaken to determine whether channel reconstruction would be necessary in addition to vegetation treatments to re-stabilize this highly unstable reach.

POTENTIAL PROJECTS

Very High Risk

- Geneva Creek at Burning Bear Creek – This location is the highest priority for action that could reduce the impacts of stream instability and sediment pollution in the watershed. PLA is recommended to validate the RRISSC assessment and to develop mitigation strategies. We suspect that significant gains may be made here is reducing watershed sediment impacts, but that full channel reconstruction and floodplain revegetation may be necessary to restore this reach to a functional condition.
- NFSP from Roberts Tunnel to Grant – This segment scored as a high risk for sediment source primarily because it is flanked by a large artificial berm of loose material that is a high risk of mobilizing into the stream via surface or mass erosion. PLA analysis would be necessary to quantify these risks and developing a mitigation strategy

High Risk

- Unnamed Gulch @ CR 110 near Bailey – At this location, the road crossing and undersized, steepened shotgun culvert have caused extreme gulley formation, channel instability, and an enormous sediment source as the channel erodes in flash flood events. replace culvert with a better design
  NFSP in Bailey – This reach suffers from the encroachment of the Town of Bailey and Highway 285. It has virtually no riparian buffer, and the main bridge through town appears to be undersized. We recommend an investigation of possible ways to improve the small riparian buffer and a detailed analysis of bridge/culvert design to assess its ability to handle flood flows.
- Geneva Creek at CG Culverts – The road to Geneva Campground crosses Geneva Creek over a series of very small culverts that impound water at even moderately low flows and severely impede sediment transport. Redesign of this crossing is recommended.

Moderate Risk

There are numerous opportunities on the moderate-rated segments to improve stream stability and sediment issues by closing, removing and/or re-engineering roads, improving culverts and crossings. PLA on these sites would better quantify the costs and degree of improvement for potential projects on these middle-priority reaches.

Low Risk

Most of the drainage area and streams in this watershed have minimal human impact related to sediment and channel stability. Continued protected status is recommended.