Anthropogenic Effects on Floodplain Geomorphology: Naches River, Washington

By: Tiffany Bishop

Geography Undergraduate

Central Washington University

6/11/2009

Floodplains are unique ecosystems, adjusting with greatly varying flows, while still sustaining through periods of drought or flood. The occurrences and disturbances that happen to the rivers inhabiting these floodplains directly affect their geomorphology. Mountain-based rivers, such as the Naches River of Washington's Southern Cascade Range, historically received higher pulses of runoff during the spring freshet due to snowmelt runoff. This paper examines the possible effects of decreasing or eliminating those pulses through their retention in reservoir lakes, and how these changes may affect floodplain geomorphology. Air photos, topographic maps, climographs, and hydrographs of the Little Naches and Bumping Rivers, which are tributaries to the Naches River, were analyzed in an effort to identify the possible effects of snowmelt retention. Results indicate a relationship between river discharge regulation and channel complexity, sinuosity, and channel frequency, – i.e., the floodplain of the unregulated Little Naches River is has maintained complexity and increased sinuosity while that of the Bumping River has decreased complexity, channel frequency and sinuosity. River restoration is becoming an increasingly important issue as we continue to learn the effects of anthropogenic changes to the riverine ecosystem. In the Pacific Northwest, salmon populations have been severely affected by these many effects on the ecosystem. As we move forward in attempting to recover these areas, floodplain function is one of many factors that must be investigated and rehabilitated if we hope to restore the ecosystem.

Introduction:

Floodplains are unique ecosystems, adjusting greatly with varying flows, while sustaining through periods of drought or flood. The geomorphology of the rivers inhabiting these floodplains is directly affected by the occurrences and disturbances that affect the floodplains. Mountain-based rivers, such as the Naches River of Washington's Southern Cascades Range (Figure A), historically received higher pulses of runoff during the spring freshet due to snowmelt runoff.

The Naches River has two tributaries that exhibit vastly different flow regimes. The Little Naches River is an unregulated stream that displays a natural, high peak, spring freshet discharge that decreases quickly in conjunction with the decline in snowmelt supply. Conversely, the Bumping River is a highly regulated stream, with snowmelt runoff retained in the Bumping Lake reservoir behind Bumping Dam, which was built in 1910. Water from Bumping Lake is released later in the summer as regulated irrigation flows for the Yakima Basin. Could this change in the hydrologic regime create changes in the geomorphology of the river's floodplain?

This paper examines the possible geomorphic effects of regulating the discharge of a river system through the retention and detained release of the spring freshet in reservoir lakes. Specifically, I examined the two floodplains of the Little Naches River and four floodplains of the Bumping River and examined the following aspects of floodplain geomorphology: channel complexity, channel frequency, and channel sinuosity. Channel complexity helps determine the past and present channel type of the river channel, and is divided into four categories: straight, meandering, braided, and channelized. Channel frequency is, in part, determined by channel complexity, where braided streams are comprised of multiple channels, and meandering stream are typically one to two channels, and straight and channelized streams are single channels. Channel sinuosity helps determine the method of dissipation of energy throughout the stream channel.

River restoration is becoming an increasingly important issue as we continue to learn the effects of anthropogenic changes to the riverine ecosystem, and how those changes affect threatened and endangered species, such as salmonids. As we move forward in attempting to recover these areas, floodplain function is one of the many areas that must be investigated and rehabilitated if we hope to restore the ecosystem.

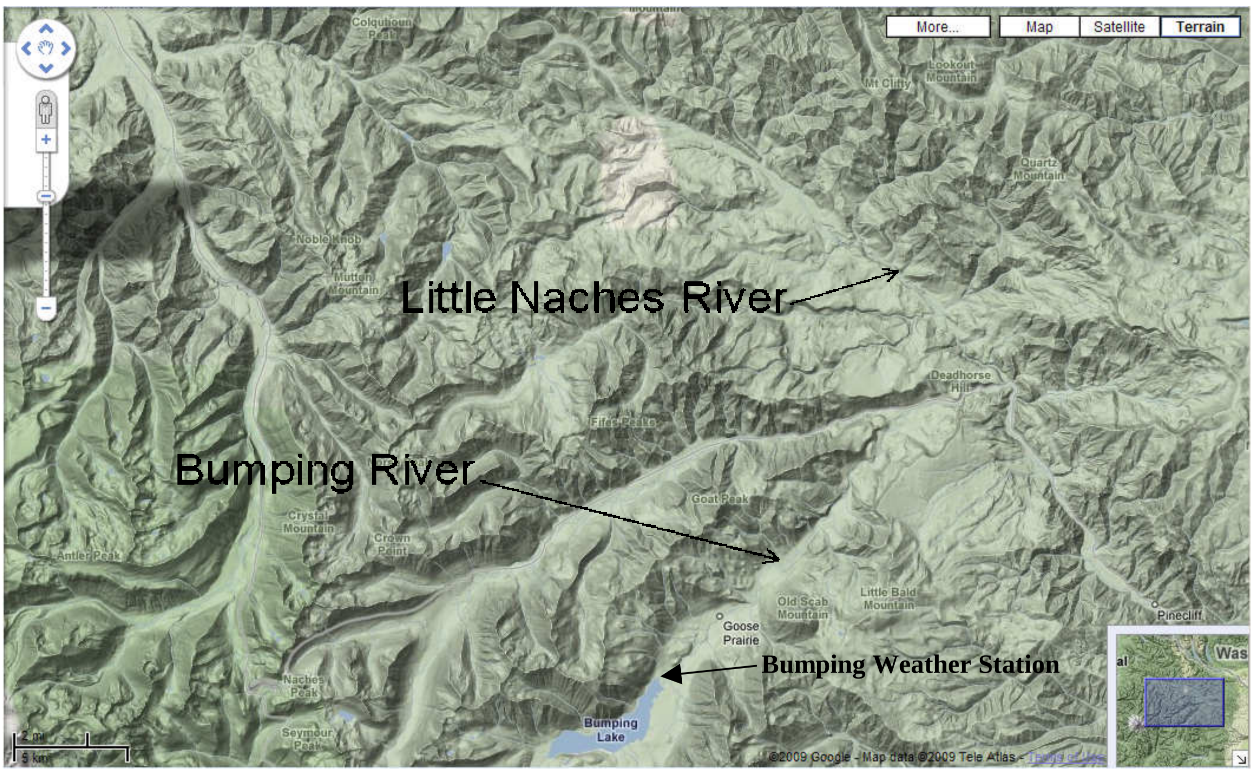

Figure A: Topographic Map of Naches River Study Sites. Data from www.googlemaps.com (2-09)

Literature Review:

Many studies point to the importance of floods in the creation and maintenance of floodplain geomorphology, along with the rejuvenation of riparian and aquatic habitat. On larger streams, geomorphic changes are driven by fluvial processes, including flooding and sediment load, as opposed to debris flow and landslide processes that influence smaller streams (Wondzell & Swanson, 1999).

Later augmentation can also result in artificially stabilized flow and channel patterns (Rood, et al, 2005). Stabilization of channel patterns can result in entrenchment of the channel due to increased erosive power. This subsequent channelization can also increase the gradient of the stream, cause bank erosion problems, and headward erosion of tributaries (Emerson, 1971). Increased stream gradient, combined with delayed, augmented discharge can increase the competence and capacity of the stream. This increase may have direct impacts on stream ecology because many native species depend on specific requirements of stream discharge as signals for progression in their life cycle (Brooker, 1985).

The frequency of these floods, along with the accumulation of sediment and organic matter that they carry, are among the most important factors regulating the existence and distribution of floodplain plant communities (Shankman, 1996). In turn, when these plant communities colonize braided channel bars, those bars acquire resistance to scour, which allows for expansion of the bar through both lateral and vertical accretion (Howard, 1996). Eventually, this creates a reduction in the frequency of channel modification, and only larger floods contain enough discharge to produce a change in channel morphology. Also, flood duration is as important a factor as intensity, when determining the degree of floodplain modification (Howard, 1996). Intense and prolonged floods become more infrequent when flow rates are regulated behind dams.

Dams also retain sediment, because they slow the flow of water and allow the sediment to deposit behind the dam. This creates sediment depletion in the water that is released from the dam. This depletion can cause a change in the sediment dynamics of the river downstream of the dam, which could lead to channel incision and a static channel configuration (Rood, et al, 2005), also known as channelization, when the stream channel is straightened and energy is dissipated by downcutting. The change in sediment dynamics directly affects channel migration, as sediment loads in rivers are a factor in the creation of point bars, which in turn, amplify sinuosity. When these sediments are removed from the system, point bar accretion is decreased while channel incision increases due to the increased erosive power of the stream.

Channel incision also directly affects the hyporheic zone surrounding the river by altering the extent of the zone, and location of upwelling and downwelling sites (Wondzell & Swanson, 1999). Small changes in the elevation of the stream can create disproportionately large changes in the surrounding aquifer, by changing both water table elevation and rerouting subsurface flow paths (Wondzell & Swanson, 1999). Channel incision can also cause degradation of the channel streambed, which is detrimental to the fauna existing there (i.e., macroinvertebrates and microinvertebrates), (Brooker, 1985)

Native flora and fauna have coordinated their life cycles over generations with the natural seasonality of river flows, and when flows are regulated growth and reproduction are impeded (Rood, et al, 2005). Floods disburse seed to new areas, along with fresh sediment creating new surfaces (Shankman, 1993). If the timing of these floods is delayed, then seed dispersal is similarly delayed. Delayed dispersal affects timing and degree of root implantation, and later, longer, augmented flows can inundate new growth, and even dislodge freshly rooted structures. . Regulation of flow could be affecting the entire stream ecosystem, well beyond surficial vegetation.

Study Site:

The study site is located on two tributaries of the Naches River in the eastern portion of the Southern Cascades Range in Washington State. These tributaries flow from headwaters above 7000 feet and meet at an elevation of 2560 feet. The study site of the northern tributary, the Little Naches River, begins in the SE ¼ of the SE ¼ of the NE ¼ of section 9, Township 18N, Range 13 E, W.M., and runs in a southeasterly direction, ending in the SW ¼ of the SW ¼ of the SW ¼ of section 13, Township 18N, Range 13 E, W.M. The study site of the southern tributary, the Bumping River, begins in the SW ¼ of the NW ¼ of the SW ¼ of section 33, Township 17 N, Range 13 E, W.M., and runs in a northwesterly direction, ending in the SW ¼ of the SW ¼ of the SE ¼ of section 12, Township 17 N, Range 13 E, W.M., (Figure A).

The geology of the area is dominated by uplift of the Cascade Range. The Bumping Lake Pluton underlies Bumping Lake. Nearby, Old Scab Mountain is a rhyoclastic dome. Folding and faulting are also observed within the study area, as Bumping River follows a synclinal fold (Figure B). Furthermore, both Bumping and Little Naches Rivers occupy glacial valley stream bottoms composed of glacial outwash, and exhibiting low gradients of approximately 1% slope.

The climate of the study area is typified by orographic precipitation, but the Eastern Cascades suffer from a rainshadow effect. While the summit may receive up to 120 inches of precipitation per year, most of that as snow, the precipitation gradient declines quickly proceeding downslope and eastward. This limited precipitation typically occurs during the cool, wet winters, as opposed to the hotter, drier summers (Figure C). The red line in Figure C represents average annual yearly temperature at the Bumping weather station, and indicates high

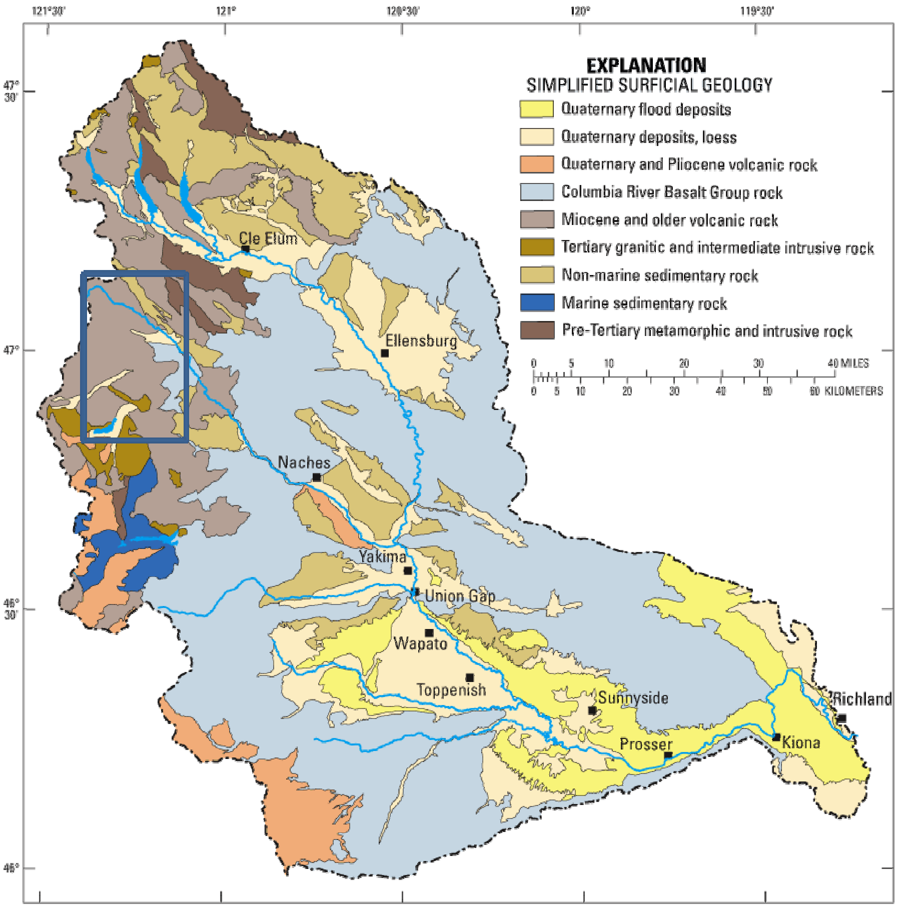

Figure B: Geologic Map of Study Area, Data from http://pubs.usgs.gov/sir/2006/5116/figure4.html (2-09)

summer temperature and lower winter temperatures. The blue bars represent average yearly precipitation, and indicate low precipitation in the summer months, and higher precipitation in the winter months. This winter precipitation is primarily comprised of snow, as lower winter temperatures rarely exceed freezing past mid-November.

The study sites are dominated by coniferous forest, including Douglas fir and ponderosa pine, with an understory that includes snowberry bush and fescue. The study sites have also been highly impacted by human occupation. The Bumping River site has been predominately impacted by camping and trail usage, including cross-country skiing and snowmobiling. Bumping River has also been somewhat impacted by timber harvest. The Little Naches River has been heavily impacted by timber harvest, with nearly 35% of the harvestable timber being cut by 1992. The Little Naches was also used as a main trail for mountain passage to Western

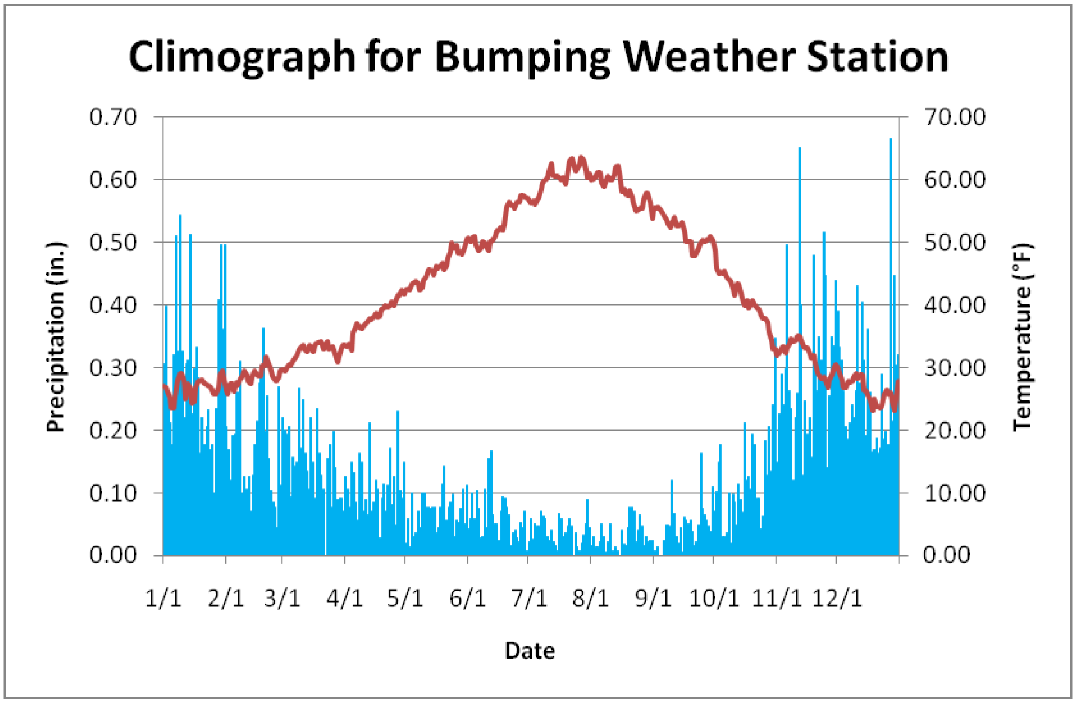

Figure C: Climograph for Bumping Weather Station, located near Bumping Lake Dam (Figure A),

Data from http://www.usbr.gov/pn/hydromet/yakima/yakwebarcread.html (4-09)

Washington in the middle to late 1900s. Heavy grazing of sheep and cattle occurred in the 1880s through the 1950s.

The hydrographs of the two rivers vary greatly, as the Little Naches River is largely unregulated, and the Bumping River is highly regulated through retention of its spring freshet in Bumping Lake (Figure D; Figure E). The unregulated flow of the Little Naches River exhibits the expected spring freshet from winter snowmelt providing a quick burst of 900 cfs flow into the system in mid-May. This increased discharge allows for seed dispersal of riparian vegetation. The subsequent dewatering allows for emergent plants to stabilize their root structure. The regulated flow of the Bumping River decreases the amount of high discharge, now only 700 cfs, and delays that high flow until early June. This later spring flow limits seed dispersal, while the later, more substantial flows following limit the stabilization of new growth and can inundate that new growth as well.

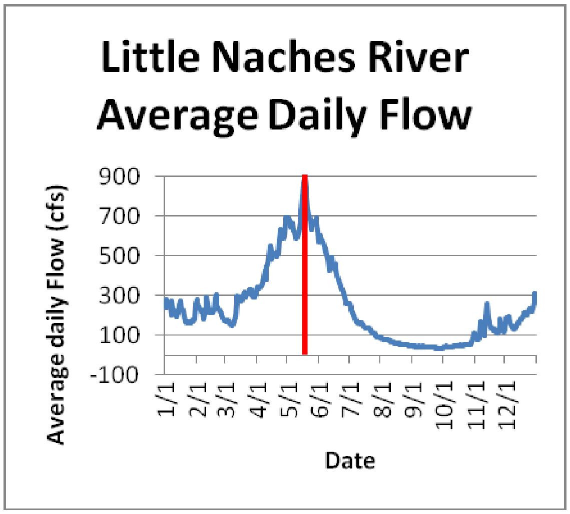

Figure D: Hydrograph of the Little Naches River, Data from http://www.usbr.gov/pn/hydromet/yakima/yakwebarcread.html (4-09)

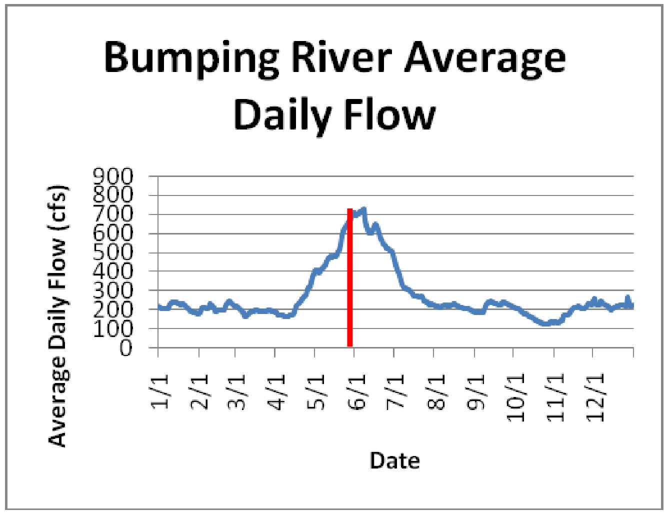

Figure E: Hydrograph of Bumping River, Data from http://www.usbr.gov/pn/hydromet/yakima/yakwebardread.html (4-09)

Methods:

River systems evolve over time scales ranging from a single flood event occurring in days, to decades, to thousands of years. As such, the time interval of forty years was chosen as an intermediary between these time intervals. Air photos from 1949 and 1992 were examined in an effort to locate, delineate, and quantify the changes that occurred in floodplain geomorphology, and if any differences existed between regulated and nonregulated flow. First, topographic maps were examined to locate floodplains with similar characteristics: slope, type, and width (Figure F). Two floodplains were chosen on the Little Naches River (LN1, LN2, Figure F), and four floodplains exhibited similar characteristics on the Bumping River (B1, B2, B3, B4, Figure F). These floodplains were then located on both sets of air photos, and measurements of sinuosity, channel frequency, and channel type were noted. These data were then compared for changes between the two sets of air photos as the changes that occurred over a forty year interval of both anthropogenic influence through regulated flow in the Bumping River, and natural, seasonal flow on the Little Naches River. Similarly, the changes in the characteristics of sinuosity, channel frequency, and channel type over time were then compared between the two rivers to determine if regulation of flow had an effect on these characteristics.

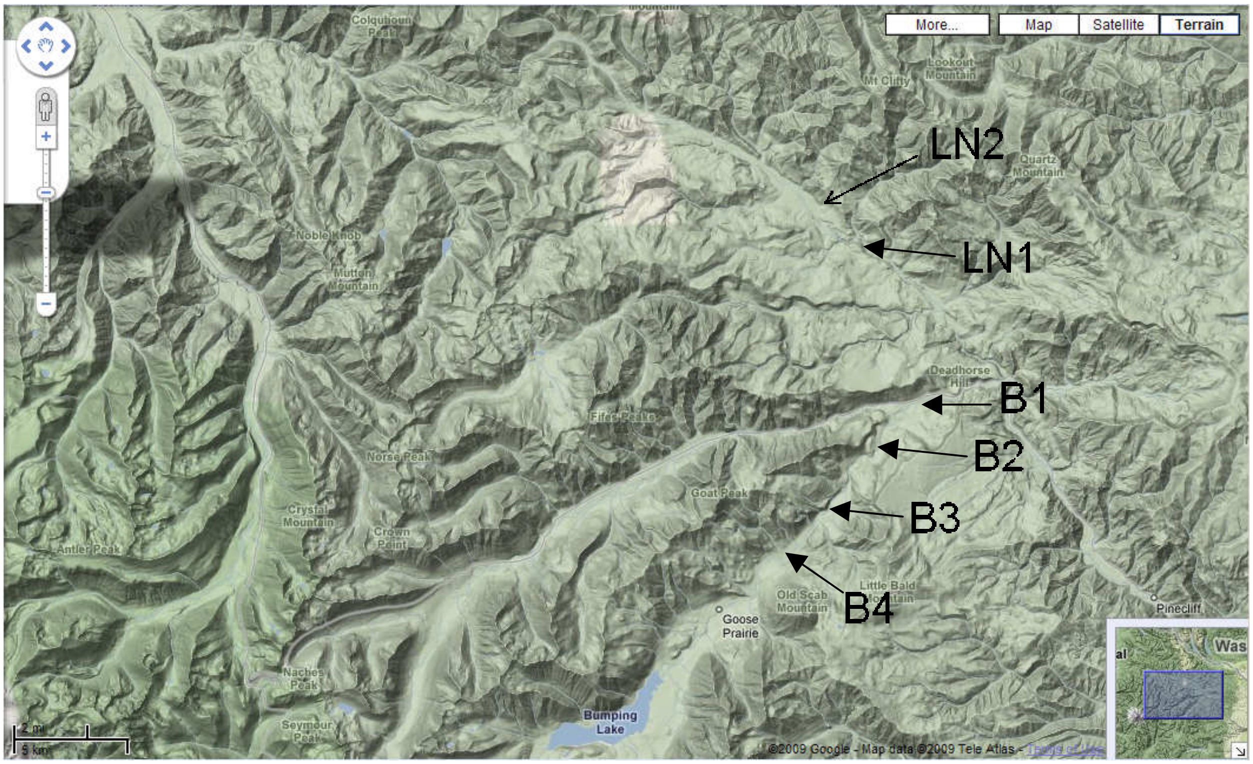

Figure F: Topographic Map of Floodplains, Data from www.googlemaps.com (2-09)

Results:

Little Naches River:

The Little Naches River contained two sites that exhibited the low gradient (1%) that comprised the study sites. The first site, LN1, displayed a braided stream in the 1949 air photo, and remained a braided stream in the 1992 air photo, but exhibited a decrease in channel frequency of many down to three (Figure G; Figure H). Channel sinuosity increased from 0.71 in the 1949 air photo, to 1.46 in the 1992 air photo, resulting in a 49% increase (Table A). The second site, LN2, displayed a meandering stream in the 1949 air photo, and maintained the meander in the

1992 air photo (Figure I; Figure J). Channel sinuosity increased from 0.8 in the 1949 air photo to 1.3 in the 1992 air photo, resulting in a 62% increase in sinuosity.

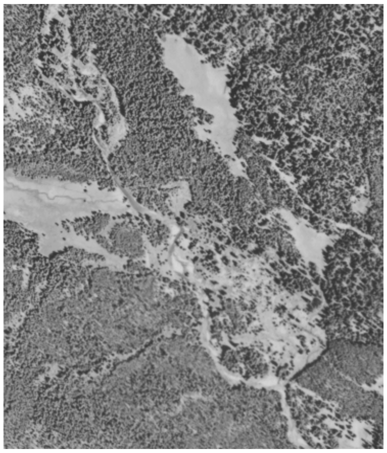

Figure G: 1949 Air Photo LN1, retrieved from CWU 3-09, #NL-NJ-10F-34

Figure H: 1992 Air Photo LN1, retrieved from USFS 4-09, #1892-14

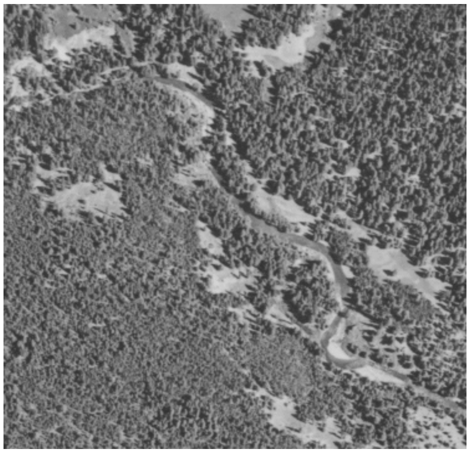

Figure I: 1949 Air Photo LN2, retrieved from CWU 3-09, #NL-NJ-10F-12

Figure J: 1992 Air Photo LN2, retrieved from USFS 4-09, #692-191

Bumping River:

The first Bumping River site, B1, was a meandering stream in the 1949 air photo, and the meander cutoff in the 1992 air photo (Figure K; Figure L). This resulted in a decrease in sinuosity from 1.92 to 1.15, a 40% decrease in sinuosity.

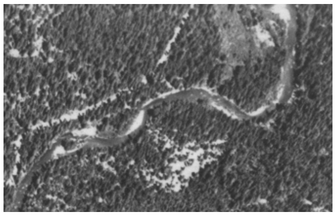

Figure K: 1949 Air Photo B1, retrieved from CWU 3-09, #NL16F-53

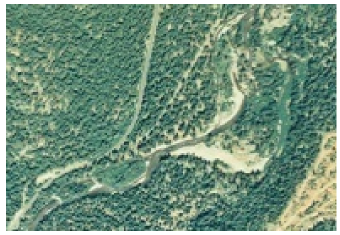

Figure L: 1992 Air Photo B1, retrieved from USFS 4-09, #692-186

The second Bumping River site, B2, reduced in channel complexity from a braided stream in the 1949 air photo to a meandering stream in the 1992 air photo (Figure M; Figure N). Channel frequency decreased from three channels in 1949 to one channel in 1992. This also decreased sinuosity 53%, from 2.25 to 1.19.

Figure M: 1949 Air Photo B2, retrieved from CWU 3-09, #NL16F-52

Figure N: 1992 Air Photo B2, retrieved from USFS 4-09, #1892-25

The third Bumping River site, B3, was a meandering stream in the 1949 air photo, and the meander was cutoff in the 1992 air photo (Figure O; Figure P). Channel frequency increased from one channel to two channels, but the meander is in the process of cutting off, and should eventually taper down to one channel. Channel sinuosity decreased 12% from 1.22 in 1949 to 1.08 in 1992.

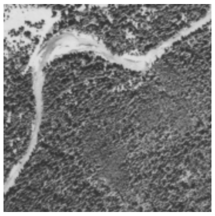

Figure O: 1949 Air Photo B3, retrieved from CWU 3-09, #NL16F-52

Figure P: 1992 Air Photo B3, retrieved from USFS 4-09, #1892-25

Finally, the fourth Bumping River site, B4, decreased in channel complexity from a braided stream in 1949 to a meandering stream in 1992 (Figure Q; Figure R). Channel frequency decreased from three channels in 1949 to one channel in 1992. Similarly, channel sinuosity decreased 16% from 1.32 to 1.11.

Figure Q: 1949 Air Photo B4, retrieved from CWU 3-09, #NL-10F42

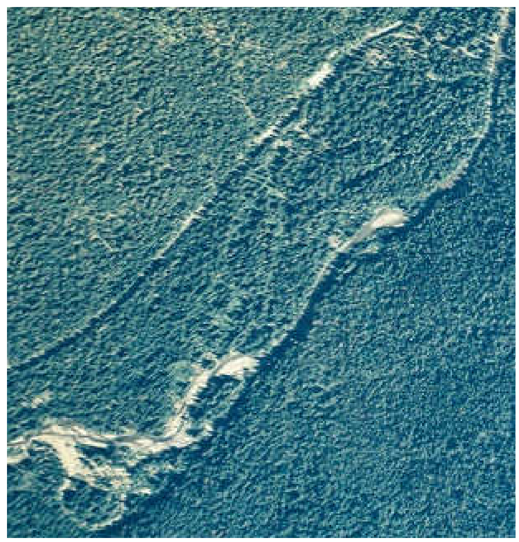

Figure R: 1992 Air Photo B4, retrieved from USFS 4-09, #1892-25

Channel Complexity:

For the unregulated flow of the Little Naches River, channel complexity was maintained as meandering at site LN2, but decreased slightly at site LN1, even though it has maintained a braided channel type. The regulated flows of the Bumping River sites have resulted in the simplification of the river channel. Two of the sites, B2 and B4, have decreased in channel complexity from braided streams to meandering streams. The two remaining sites, B1 and B3, have decreased in channel complexity by cutting off the meanders and straightening the stream

Study Site	Channel Type	Change in # of channels	Change in Sinuosity
Regulated Little Naches Site 1	Braided, but changing	Many down to 3	.71 to 1.46 = 49% increase
Regulated Little Naches Site 2	Meandering	0	0.8 to 1.3 = 62% increase
Unregulated Bumping Site 1	Cutoff meander	1	1.92 to 1.15= 40% decrease
Unregulated Bumping Site 2	Braided to meander	3 down to 1	2.25 to 1.19 = 53% decrease
Unregulated Bumping Site 3	Cutoff meander	1 to 2	1.22 to 1.08 = 12% decrease
Unregulated Bumping Site 4	Braided to meander	3 to 1	1.32 to 1.11 = 16% decrease

Table A: Regulated vs. Unregulated Stream Data Table

channel. This straightening of the stream channel results in the probable downcutting of the stream bed, entrenching the stream, and disconnecting the stream from its floodplain.

At this time the Bumping River is not in equilibrium, and the energy that would be dissipated through cutbank erosion is being forced elsewhere. The most likely outcome for this failed dissipation is a downcutting of the river bed, as erosive factors increase slope, which increases flow rates. In turn, increased flow rates amplify the competence of the stream, thus allowing for greater erosion as the stream continues its downcutting. Eventually, the stream could entrench, and separate from its floodplain. This could affect surrounding riparian vegetation, whose roots occupy the capillary zone just above the water table, where they are able to take up water and oxygen without the inundation that would occur at levels beneath the water table. When rivers entrench, they lower the water table in the hyporheic zone, thus lowering the capillary zone for the riparian vegetation. If entrenchment occurs too quickly, vegetation doesn't have time to adjust, and the decreased availability of water makes them prone to disease and mortality.

Channel Frequency:

While the Little Naches River has decreased channel frequency from many channels down to three channels at site LN1, the Bumping River sites B2 & B4 have both decreased at a greater rate to one channel. These channels exist in glacial till-filled valleys, and this type of substrate combined with the low slope exhibited should create braided streams. The rapid decrease of channel frequency on the Bumping River could also result in downcutting, as energy dissipated through multiple meanders is forced to one, straightened channel. As the river downcuts through the easily erodible material of glacial till, it will separate the river from the floodplain, and the myriad of nutrients and minerals available to be carried downstream could be cutoff as well. As mentioned above, vegetation roots will also be separated from the hyporheic zone by this downcutting of the river bed.

Sinuosity:

The Little Naches River has maintained and even increased its sinuosity. Increased sinuosity results in the transportation of nutrients and minerals across the floodplain, as cutbank materials are deposited in point bars, they create new areas for vegetation to take hold. The decrease in sinuosity of all four of the Bumping River sites could result in a decrease of transportation of these same nutrients across the Bumping River floodplain. As the Bumping River straightens and entrenches, these valuable nutrients and minerals could be lost to the floodplain system, as they are carried away in waters that have increased the competency and capacity through the increase in flow from downcutting and straightening of the channel.

Conclusion:

Overall, the unregulated Little Naches River has exhibited few anthropogenic effects. Channel complexity has been maintained, channel frequency has been maintained at one site, and is decreasing slowly at the other site, and sinuosity has increased at both sites from 49-62%. The Bumping River sites are all changing to a simplification of the channel, with meanders cutting off, braided channels dropping to meandering channels, channel frequency dropping from multiple channels to one channel, and channel sinuosity decreasing 12 to 53%. This channelization of the Bumping River may result in vegetation change, as roots are separated from the capillary zone from the drop in the level of the hyporheic zone, which may be brought on by downcutting of the channel. Mineral and nutrient cycling within the floodplain may be affected as well, as cutbanks and point bars transform to straight channels that carry away sediments, instead of depositing them along riverbanks where vegetation and microorganisms can utilize them. Further study needs to be done to fully understand the implications of regulation of flow on stream ecosystems.

Further Study:

On the ground stream measurements would be the next step in this research project. Only through fully understanding the nature of these rivers can we understand the full implications of the effects of discharge regulation. Bankfull measurements and width to depth ratios would help determine if the river is, in fact, dissipating its energy through downcutting. Channel roughness would help determine the expected channel complexity, and the degree of deviation from that expected complexity that is observed. Substrate embeddedness would help determine the sediment load within the stream, and whether that is exhibited as bedload or suspended load helps to further determine the competence of the stream. The presence or absence of large woody debris in the stream can also affect channel complexity. Similarly, storm events can affect channel complexity, and bring about changes in frequency and sinuosity. The measurement of storm event frequency, duration, and intensity could aid in deeper understanding of the many factors of river channel geomorphology.

Once the factors of geomorphic change have been fully investigated, ecosystem change should also be researched. As mentioned above, downcutting of the riverbed could negatively affect riparian vegetation, or create opportunities for invasive species to take root. Research into possible changes in this vegetation, including disease, mortality, or change in species could be helpful in repairing the ecosystem. As flora changes, so does the fauna that occupies that vegetation, and the river that borders it. Salmon species, including bull trout and steelhead, are federally listed as endangered species. Dramatic changes to their ecosystems will only further complicate their threatened existence. If we attempt to recover the species, we must address all the factors that affect their survival. The hyporheic zone is virtually ignored in recovery plans, yet it is the area of greatest influence for egg development, at a time of immobility, when changes in discharge could decimate populations. Furthermore, many insects also incubate in the hyporheic zone, and grow to become the fodder for fry and fingerling salmonid populations. Insect larvae are also negatively affected by changes in discharge regulation. When river flows are regulated, many factors affecting endangered salmonid populations are affected, and further research into these changes needs to be completed if we hope to restore the species.

Bibliography:

Brooker, M. P. (1985). The Ecological Effects of Channelization. *The Geographical Journal*, 63-69.

Emerson, J. W. (1971). Channelization: A Case Study. *Science*, 325-326.

Howard, A. D. (1996). Modelling Channel Evolution and Floodplain Morphology. In M. G. Anderson, D. E. Walling, & P. D. Bates, *Floodplain Processes* (pp. 15-62). John Wiley & Sons Ltd.

Rood, S. B., Samuelson, G. M., Braatne, J. H., Gourley, C. R., Hughes, F. M., & Mahoney, J. M. (2005). Managing River Flows to restore Floodplain Forests. *Frontiers in Ecology and the Environment*, 193-201.

Shankman, D. (1993). Channel Migration and Vegetation Patterns in the Southeastern Coastal Plain. *Conservation Biology*, 176-183.

Shankman, D. (1996). Stream Channelization and Changing Vegetation Patterns in the U.S. Coastal Plain. *American Geographical Society*, 216-232.

Wondzell, S. M., & Swanson, F. J. (1999). Floods, channel change, and the hyporheic zone. *Water Resources Research*, 555-567.

Yakima Hydromet Archive Data Access. (2009, May). Retrieved April 15, 2009, from United States Bureau of Reclamation:
http://www.usbr.gov/pn/hydromet/yakima/yakwebarcread.html