The Pre-Dam Hydrology of the Mid-Columbia Basin

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Columbia River Basin Overview

The hydrology of the Mid-Columbia Basin (MCB) is of little popular interest primarily because there appears to be none – It's just dry Shrub-Steppe. Pasco, WA receives just 8" of annual rainfall while, for comparison, Tucson, AZ gets 12" of rain. (I have observed people water skiing behind pickup trucks in central Tucson during the monsoon season.)

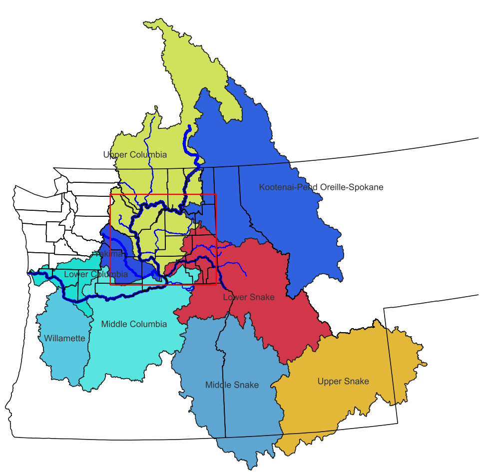

Figure 1. Primary subbasins of the Columbia River basin.

The Columbia River basin and its sub-basins are shown in Fig. 1. The Columbia drains precipitation from Northern Oregon, Idaho, Western Montana, a large portion of British Columbia and a bit of Wyoming. The main tributaries in the MCB are the Yakima and Snake Rivers. But, the Umatilla, Walla Walla, Wenatchee, Okanogan, and Spokane Rivers also contribute to the Columbia. And just for good measure let's throw in Crab Creek and the Walla Walla River. The Flathead, Clark Fork and Pend Oreille Rivers drain much of Montana and Idaho. Many smaller Canadian tributaries contribute to the Columbia. The Canoe River is the northern most tributary in the Columbia Basin. I will ignore the Willamette, Umatilla, and other rivers that are below Nary Dam as these don't have influence over the regional hydrology.

The Mid-Columbia Basin Rainfall

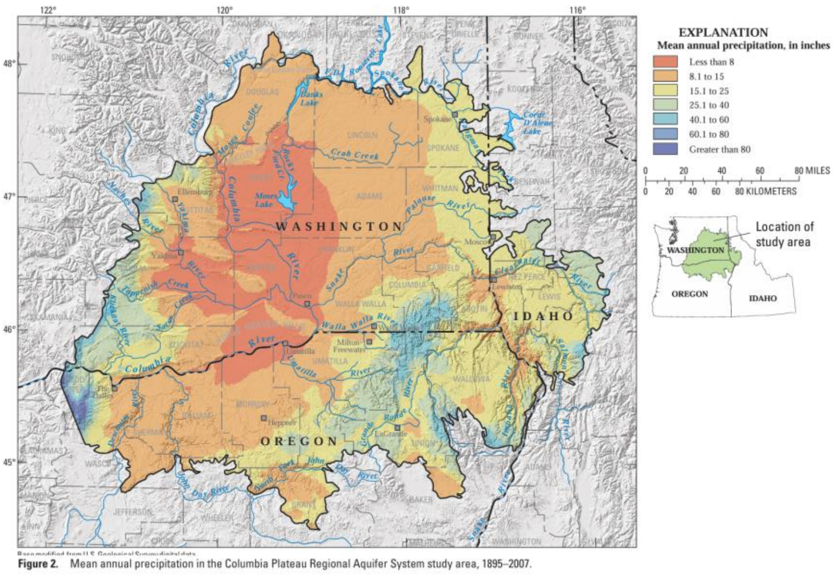

Figure 2. Mean Annual Precipitation in the MC from Fig. 2 of Kahle, 2011

Fig. 2 published by Kahle et al. (*Kahle, S.C., Morgan, D.S., Welch, W.B., Ely, D.M., Hinkle, S.R., Vaccaro, J.J., and Orzol, L.L., 2011, Hydrogeologic framework and hydrologic budget components of the Columbia)* shows the mean annual rainfall for the MCB. Note that the darker red areas, receiving less than 8” of rain per year, correspond closely to the Ringold, Ellensburg and Umatilla formations consisting of unconsolidated overburden. These also correspond to regions where major irrigation systems have been built. To the east, the Palouse region receives increasingly more rain up to 25” near the border with Idaho.

The Basin Snow Pack

Shown in Fig. 3 will be an elevation contour map of the Columbia basin along with the main river system. We can understand how water enters the Columbia if we somewhat arbitrarily color elevations above 4000’ in white to represent the winter snow pack. Elevations from 1000’ to 3000’ feet we arbitrarily color green as these regions east of the Cascades generally get some snow but rapidly melt in the spring and do not have an extended snow pack. Below about 1000’ we use brown where we get little if any snow and snow melts in a few days. This coloration also corresponds roughly with the local ecology. In the white snowpack areas, we have alpine lakes and tall brushes and stunted pine trees. The intermediate areas are dominated by pine forests or grass lands with significant snowfall and rain supporting a variety of flora and fauna. Finally, the low lands below 1000’ correspond to the Shrub-Steppe ecosystem and are considered quite arid. Per usclimatedata.com, Missoula gets 14”, Spokane 17” and Pasco 9” while Tucson gets 12” and Seattle gets 37” of rain. The important point to understand is that an enormous region of snowmelt must flow into the Columbia River Basin and a majority of it has to flow through the quite arid MCB area and out through the narrow Wallula Gap just south of Pasco.

Fig. 3. Contour map of the Columbia Basin watershed colored to emphasize where snow accumulates. It also will include the DEM derived flow map and I need to learn how to use GDAL to merge and warp the tiles.

Ground Water Flow

Fig. 4 published by Kahle et al. shows the general flow pattern of ground water from into the MCB. The coloring is a relative estimate of the ground water elevation and generally follows that of the ground elevation. But focus for a moment on the boundary and how water crossed this boundary. Water flows into the MCB via the river system and some water may enter the water table from the rivers but in general underground water feeds into ground water from melting snow at higher elevations. How it does so is of considerable interest.

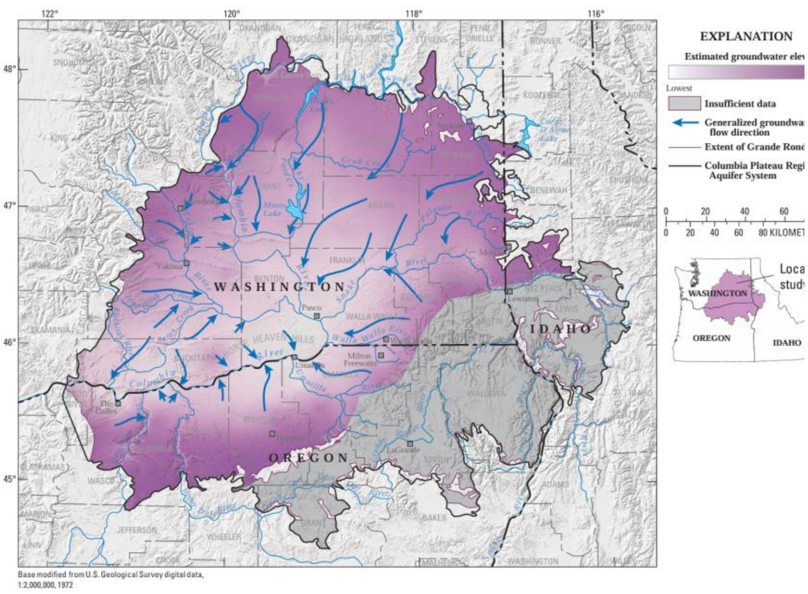

Figure 9. Generalized groundwater levels and directions of lateral groundwater movement for the Grande Ronde unit, Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho (modified from Vaccaro, 1999 and Snyder and others, 2010).

Figure 4. Flow of ground water taken from Fig. 9 of Kahle, 2011

To oversimplify the hydrogeology, the basalt flows consist of columnar structures that provide some vertical flow but little horizontal flow. These are large hexagonal columns 2-4 feet across and up to 100' tall. These are separated by gaps of 2-6" and one can literally use one's feet to wiggle a huge columnar mass back and forth like a tine on a tuning fork. The columnar layers are separated by layers of broken rock (vesicular, rubbly or brecciated) that provide a major pathway for horizontal flow. In my observations the broken layers are usually of fist size and the total porous space may not be very large but water flows easily though these relatively wide interstitial spaces. Undoubtably sediment from alluvial layers deposited above have settled into the larger spaces of both the columns and broken layers.

Due to uplift a number or ridges have formed along the western slope of the cascades that extend out into the MCB. Thus, we can view, at least the western half of the MCB, as a series of anticlines and synclines that form barriers and conduits respectively for ground water flow. Anticlines and synclines can be imagined as underground, undulating ridges and valleys in terms the lay person can visualize. Near the basalt flow boundaries, water can enter the broken rock pathways and begin their flow towards the nearest river passing down the slope of an anticline via the broken rock layers and the along the lowest path of broken rock in the synclines. Note that the Horse Heaven Hills is a major anticline and is a barrier to ground water flow to the south and forces all this water through out through Wallula Gap.

Of some interest is the thickness of the vadose zone in our region. The vadose zone is that ground through which snow or rain water seeps vertically down until it reaches the water table and begins horizontal transport.

The ground water elevation map of Fig. 4 is a crude estimation of the general water flow pattern. For the most part, ground water does flow towards the nearest river. The exception is the region in the north east (the scablands) and the Palouse north of the snake river drainage. Crab creek and Moses Lake lie in this north eastern region but were mostly dry until the construction of the irrigation projects.

Near the western and northern boundaries, we have lots of old and impervious igneous rock uncovered during the ice age, that form a basement layer through which the ground water cannot penetrate. Here the water table is thin and its top lies near the surface and flows quickly into the sediments of the local stream bed. Vegetation has plenty of access to water year-round as the snow pack melts. Water coming from these snow packs enters our region primarily as surface flow but some then enters into the basalt formations and much of the water never sees the surface until it reaches the Columbia, Yakima or Snake rivers. It may reach the surface at many of the syncline valleys which form the smaller tributaries to the Yakima and Western side of the Columbia.

The eastern edge or the Palouse has a basalt underlayment bordered by the igneous rock of the Idaho Batholith. This area did not see extensive glaciation and I would presume is more broken and porous than the northern areas. Water from snow packs in Idaho probably percolates fairly deeply into the ground before entering the region identified in Fig. 4. For the most part the water table is deep into the basalt layers and does not reach the surface until it flows into the Columbia or Snake Rivers.

On the other hand, the rivers are clear measures of the depth of the water table along its shoreline and one can from Fig. 4 surmise that permeable vadose zone is thin along the western and northern edges but relatively thick along the north-eastern and eastern edges. On the south defined by the horse heaven hills there is little snow pack to feed underground water flow and the vadose zone is quite thick.

Now it is easy to see why the piles of silt and gravel we call the Ellensburg, Ringold and Umatilla formations are vadose zones that are hundreds of feet thick and get essentially no surface rainwater.

The Filling of the MCB aquifer

Recall however that for the approximately 7-10 Million years between the basalt flows and the ice age the region was covered with large lakes that Nick Zentner refers to as Ringold Lake. This undoubtably saturated the region down to the “Basement” layer. In the MCB, the basement layer may consist of igneous rock or highly compressed basalt. Remember the Grand Ronde Basalt is estimated to be as much as 17,000’ thick near Pasco. I doubt the bottom of this layer has much porosity left for water transport.

Generally, water escaped from the MCB to the south along a wide region bounded by the Cascades on the west and the Imnaha and Steens basalt formations further east and south. However, as the Horse Heaven Ridge formed the MBC became hydrologically isolated with only the Wallula gap -- only a couple of miles wide -- to drain an enormous snow pack extending a thousand miles north and hundreds of miles east. As the Horse Heavens rose so too did the water table in the MCB.

Summary of the MCB Hydrology

The alluvial deposits, of which the Ringold Formation is of central interest, are composed of clays, silts and gravels with widely varying degrees of free space and permeability to water. These deposits were formed by the ancient Ringold lakes prior to the Missoula floods and by the erosive action of the Missoula floods. The gravels are very porous, have a high permeability and water quickly flows down to the water table. The older clay and silt layers are much less permeable and can form barriers to water flow. Hydrologists refer to confined and unconfined ground water depending upon the relative permeability. But I get the impression that the clay and silt layers are highly discontinuous and I envision them as lenticular deposits extending perhaps up to a few miles in length or width but with most being much smaller. They would have locally diverted the flow of water through the vadose zone and possibly even formed local and shallow aquifers. But in general water found a way around these barriers and these impervious layers did not significantly impact the overall groundwater levels and flows.

H. H. Bauer and A. J. Hansen, Jr., “Hydrology of the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho,” U.S. GEOLOGICAL SURVEY, Report 96-4106. Bauer and Hansen provide a lot of data on the MCB aquifer. For example, the upper Pasco gravel deposits in the Pasco area have a top 100 to 200’ thick layer with high permeability of approximately 1 ft./day and a specific yield (porosity) of up to 20%. Underneath this top layer is a mixed remnant of the Ringold Formation also some 100 to 200 feet thick with a permeability of less than 0.1 ft./day and a porosity of approximately 1%. Beneath this are the basalt layers which have much less permeability and porosity. More importantly these basalt layers are sufficiently below the water table that water movement is very slow.

The general model, with Pasco as an example, is that surface water flows rapidly down through the gravel layer until it reaches the denser Ringold formation and then flows horizontally with slow seepage through the Ringold layers down to the water table. Near the river, the water table is in the Pasco gravel layers while up on Taylor Flats just north of Pasco the water table resides in the Ringold formation. Even higher up, as in the Saddle Mountains, the water table is in the basalt layer.

Never-the-less, the picture we get is that of a very arid region with a water table the reaches the surface only near the major tributaries of the Columbia. Hence most of the MCB is the classic Shrub-Steppe ecosystem that supports flora and fauna specifically adapted to such cold and arid conditions. Throughout most of the MCB and prior to construction of the dams, the water table was hundreds of feet below the surface.

Seasonal Variation of the MCB Hydrology

Prior to construction of the dams on the Columbia and its tributaries, these rivers showed high flows as the snowpack melted. These typically peaked in early June and by Fall many of the tributaries to the above-mentioned tributaries were mere streams. The Columbia was not a smooth flowing stream but rather had dozens of named rapids. With the exception of Coyote Rapids in the Hanford Reach and perhaps a few in Canada near the headwaters, all the rapids were flooded by the construction of dams. But more on that later.

As the MCB sees very little precipitation the majority of flora and fauna were confined to the near shore riparian region and we will cover the ecology of this near river habitat in a forthcoming rant.

The riparian zones along the river banks are often ignored while the Shrub-Steppe gets all the popular attention. But life existed primarily in the riparian zones and the hydrology of these areas is critical to our understanding of this region. Simply stated, were it not for the rivers and their riparian zones the MCB would be an unlivable hell hole. Understanding the cyclical hydrology of the riparian zones is important.

Prior to construction of the dams, the normal water level of the Columbia was much lower than we currently observe. The landscape was a wandering river that was mostly broad and flat and full of moving sandbars. Occasionally the river flow was interrupted by rapids with fairly gradual drops through relatively rounded rock. While risky to navigate in a wooden boat especially during high and low water we would probably give these rapids a class 1 or possibly 2 rating. Today, Coyote Rapids in the Hanford Reach is barely noticeable and would undoubtably wash out during high water and be a hull cruncher during low water.

Currently, the Dams have raised the water level and hidden the original river channel. The Ellensburg Daily Record has some excellent pictures after Wanapum Dam fractured and the Wanapum Lake was drained about 25 feet below normal run-of-the-river flows. It was curious to personally see broad flats of silt with an obvious deep center channel. This channel was perhaps a fifth or less of the original dam filled width. All that flatland was once deep and luxurious wetland and riparian habitats.

As noted above the rate of snowmelt primarily drives the river flow and water levels. During the high-water stage from April through June, flatlands along the river were flooded forming important wetlands. Richland, WA for example is a relatively flat area between the Yakima and Columbia Rivers and is prone to flooding. The “Miracle Mile” is a large dike constructed to prevent the historical flood of 1948 from inundating the downtown business area. The important point is that these intermittent wetlands saturated the ground near the water’s edge and cause ground water to flow away from the river raising the adjacent water table closer to the surface. This temporary increase allowed the roots of riparian flora to reach the water table and enabled the riparian zone to extend further inland. What you now see as flat lake water was once an as broad riparian habitat with a sometimes-raging river running through its middle. It would have been a luxurious place to live with rich ground for crops, abundant wildlife, sturgeon larger than a man running rampant and a seemingly unending flow of salmon. 10,000 years ago, back in Kennewick Man’s days, the traveler needed had to keep an eye out for the occasional unhinged mastodon, a marauding pack of Dire wolfs, belligerent Grizzly Bears and some nasty ol’ cats you knew were quietly watching. “Lions and Tigers and Bears, Oh My.”

Oddly despite its central location of three major rivers the Pasco basin was not a major trading hub for the native population. Rather Kettle Falls and the Dalles were the central trading sites. Most people nomadically moved through the area fishing, hunting and gathering. Remember that the living ground was only a few miles in width. Beyond that was dry basalt, arid shrub steppe or at best hot grasslands. It would be easy for a band of 50 people to over hunt and over use a local region of this riparian habitat in a few weeks and have to move up-river 10 or 15 miles (a day’s travel) to find renewed resources. Fortunately, the natives of this land understood that some balance of use was required and left enough behind that the habitat renewed itself withing a year or possibly two. It is a fundamental concept of the American Indian philosophy and religion.

Summary

In summary the MCB had a broad wetland and riparian habitat that followed the main river channels. The Columbia and its tributaries would have been impossible to cross during flood season. And any traveler through this region might occasionally detour to high dry ground to avoid local flooding. The natives would know which high points were good spring campsites. At key points, such as the Sentinel

Gap through the Saddle Mountains and Wallula Gap through the Horse Heaven Hills, the traveler would take a day and traverse through the gaps without making camp. Much better ground lay a few miles up or downstream. Like Celio Falls, the gaps may have allowed the construction of fish traps and been key points for Salmon harvest. Beyond that the traveler would encounter nomadic bands of Native Americans who for the moment were quite protective of their seasonal fishing camp. A stranger approaching such a group would have been wise to approach politely but in all likely hood would be accepted as a bringer of news.

If traveling north from Wallula Gap the rare traveler could opt to cross the MCB Shrub-Steppe plateau to reach Kettle Falls. But, in the heat of Summer, this would have been series of oasis hopping trips and drive a need to be quick about it. Others might choose the longer route following the Columbia and stay in the riparian corridor. Undoubtably there would have been fording points that a small band of natives may consider home. Fording, with family in tow, might entail some planning for safety and waiting a day or two to watch water levels would be in order.

The lone traveler with good water skills might stop briefly before crossing perhaps preferring the wilder expanses and the hunting opportunity between camps. A good traveling hunter might find this a source for trade as the valleys would have been good hunting for deer, moose and elk. And you don't want to be a bad shot if tackling a lion or bear.

But all this pastoral picture is based upon the cyclic flooding of the old Columbia and the seasonal variation in water levels that affect so much of life in the region. In a separate rant, we address how damming the Columbia and the construction of the Central Basin Irrigation Project impacted the hydrology. Then eventually, when I get the guts to write about things which I do not know much, we will address the local ecology.