6.0 WATER BALANCE

The purpose of the water balance component of this assessment is to characterize the climatic, surface water, and groundwater components of the watershed. The water balance is intended for use as a screening tool to further evaluate water resources allocations within the watershed and to identify water balance components that may require further analysis during the next levels of watershed planning.

6.1 INTRODUCTION

Developing a water balance or water budget for the WRIA 53 watershed is difficult due to the lack of data and information on groundwater. No studies have quantified the groundwater which may be entering and/or exiting the watershed through the basalt interflows at the boundaries of the watershed. Preliminary studies from the GWMA have also found that groundwater recharge from the Columbia River may be minimal to non-existent. Also, no studies have been conducted to determine the migration of groundwater vertically between the basalt layers. In addition to the natural movement of groundwater between the basalt layers, migration of groundwater between the aquifers may be occurring through deep wells which are not cased through the individual basalt aquifers. Limited data is known for the shallow unconfined aquifer in the Hawk Creek drainage.

6.2 WATER BALANCE COMPONENTS AND METHODOLOGY

Specific known and/or estimated climatic, hydrologic, and hydrogeologic components are required to estimate the quantity of water entering and exiting the WRIA 53 basin. The basin is in a unique watershed, as the Columbia River bisects the watershed, effectively creating a northern and southern watershed. The values estimated for the water balance are only focused on the southern portion of the watershed, that area south of the Columbia River. The water balance is based on readily available data for the watershed, which is very minimal. Data for WRIA 53 was evaluated to attempt to develop an annual water balance.

The limits of WRIA 53 are defined from topographical divides. The southern portion of WRIA 53 encompasses those tributaries to Lake Roosevelt which are located between the Confluence of the Spokane River and Grand Coulee Dam. Although the watershed is based on surface water drainage, the regional bedrock aquifer systems cross the WRIA boundaries. In addition, much of the western and extreme eastern portions of the watershed are underlain by fractured basement granitic rocks. There is no large unconsolidated aquifer located within the WRIA 53 boundaries. Inferring groundwater entering and exiting the WRIA 53 watershed is difficult due to the numerous layered bedrock basalt interflow aquifers, in which groundwater flows can be defined by folds, faults, and discontinuous saturated intervals.

In order to develop a water budget, the following information must be assessed:

- Recharge from precipitation
- Inflow from Surface Water
- Inflow from Groundwater
- Evapotranspiration
- Consumptive use (irrigation and domestic)

- Outfall (SW & GW) from WRIA

The generalized hydrologic budget accounts for additions and losses of all water in the watershed in a specified time in an ideal hydrologic cycle. The hydrologic budget, or water balance can presented in a simplified equation, and can account for changes in the volume of water stored in the basin.

$$dS = P - E \pm R \pm U$$

where: dS = *change in total storage in the basin*
P = *precipitation*
E = *evapotranspiration*
R = *stream flow – stream outflow*
U = *groundwater inflow – groundwater outflow*

The water balance can be further defined by a steady state environment in which inputs equal outputs. The quantity of water entering each subbasin can be defined as:

Total Basin Inputs = PPT + GWI + SWI
where:
PPT = Precipitation
GWI= Groundwater Inflow
SWI= Surface Water Inflow

The quantity of water existing within the basin can be defined as:

Total Basin Outputs = ET + ND + GWO + SWO
where:
ET = Evapotranspiration
ND = Net Demand (consumptive use)
GWO= Groundwater Outflow
SWO= Surface Water Outflow

Utilizing the above referenced water balance equation assumes that on an annual basis, there is no change in water storage within the basin. Given this assumption, total annual basin inputs equal total basin outputs.

6.3 Water Balance – Hydrologic Components

The general lack of hydrologic data available for the area and much of the hydrologic system, especially the groundwater portion of the hydrologic system, makes estimating a water balance for the WRIA problematic. For this assessment we did not evaluate Lake Roosevelt. The following sections summarize what we know, or suspect, about the physical hydrologic components of the water balance in WRIA 53.

6.3.1 Precipitation and Evapotranspiration

As discussed earlier in this report, the portion of WRIA 53 covered by this assessment generally is semi-arid, with most precipitation occurring in the late autumn, winter, and spring. In addition, the bulk of this precipitation occurs in the form of snow, and depending on the weather conditions during the late winter and early spring melt-off, snow melt can be slow, rapid, or a combination of these. This is important because, slow melt-off's will facilitate infiltration into the ground while rapid melt-offs will promote rapid surface run-off with minimal infiltration. In the spring, summer, and fall, when precipitation occurs, it commonly comes as light rain or as brief, heavy thunderstorms. In the later case there is little infiltration and a brief, but heavy run-off event can occur.

Figure 10 shows the basic precipitation patterns for the area. Average annual precipitation can be as high as approximately 15 inches per year in the highest portions of the area, and as low as approximately 9 inches per year at the lowest elevations. On barren, rocky surfaces much of this precipitation will be available to streams as surface run-off. We would infer that little, if any, precipitation on barren, rocky surfaces would contribute to ground water recharge because of the rapidity of run-off and/or the general scarcity of widespread, open, vertical pathways available for water to move downwards from the ground surface.

On naturally vegetated, minimally disturbed, permeable substrates, which in the WRIA consist predominantly of Pleistocene Cataclysmic Flood deposits and loess, it seems likely, as discussed earlier, that no more than 10 percent of the annual precipitation falling within the WRIA is available for groundwater recharge because of moisture retention capacity, run-off, and evapotranspiration. Even though most precipitation in the area occurs in cooler months when the evapotranspiration index is at its lowest, much of the moisture found in the soils as a result of infiltration is transported back into the atmosphere during the growing season. Given such a low water quantity available for potential aquifer recharge, one could assume that the recharge that occurs largely would be restricted to the highest precipitation areas on the highlands forming the southern and eastern portions of the WRIA.

Given these considerations we recommend the following with respect to precipitations contribution to the water balance in WRIA 53:

- For precipitation that falls on vegetated, permeable soils and substrates, approximately 1 to 10 percent is available for potential ground water recharge. Given the precipitation patterns measured for the area, this yields potential water quantities available to groundwater recharge between 0.09 inches to 1.9 inches per unit area per year for such areas.
- For precipitation on barren, rocky substrates a significant portion is available for direct run-off to streams. The quantity of water that can run-off to streams however, will vary greatly. During periods when the evapotranspiration index is high (due to elevated temperature and wind, and reduce atmospheric humidity) less water will be available as run-off. Conversely, during periods with a reduced evapotranspiration index there will be the potential for higher quantities of precipitation to run-off.

A complicating factor in determining the amount of precipitation available for run-off versus infiltration to groundwater is topography. Steeper topography will facilitate faster run-off to streams and less infiltration to groundwater. Flatter topography generally will facilitate increased infiltration because run-off is slower.

6.3.2 Surface Water Inflow and Outflow

As noted earlier, there is a general lack of stream flow data for the perennial streams (including Hawk Creek), intermittent streams, and springs in WRIA 53. In the absence of such data it is very difficult to make any credible estimate of surface water inflow and outflow in the WRIA.

Nevertheless, a few basic observations can be made. If the Columbia River is not considered as part of the WRIA 53 water balance, there is no surface water inflow into the WRIA. Therefore, all surface water within the WRIA is sourced directly from surface run-off of precipitation and discharge from groundwater systems via springs. As noted in the previous section, the total precipitation available for stream flow via surface run-off is related to soil and vegetation conditions, presence/absence of rock, barren surfaces, topography, and total precipitation. Given the semi-arid climate of the area reflected in seasonal wet and dry periods, many of the streams reliant predominantly on precipitation are intermittent and only flow during and immediately following the wet season and/or high precipitation events.

Streams that have a significant component of flow sourced from groundwater would be expected to flow through much, if not all, of the seasonal dry periods. The duration of flow in such streams through the dry season provides a very good indicator about the size and capacity of the aquifer system feeding the stream, including natural and artificial recharge and pumping impacts on source aquifers.

If additional information about stream flow within the WRIA is required for future planning efforts, a system of stream gauges and spring gauges might be established, at least in targeted areas, to better evaluate stream flow conditions.

6.3.3 Groundwater Inflow and Outflow

As noted earlier, there is little data available upon which to base WRIA specific estimates of aquifer conditions for any of the three main aquifer systems underlying the area. Nevertheless, we can make some basic observations about groundwater inflow and outflow that can inform future water resource planning and work in the WRIA.

<u>Alluvial Aquifer System</u>

The majority of the alluvial aquifer system near Lake Roosevelt likely is in hydraulic connection with the Lake and should be considered part of the Lakes water budget which is not a topic for this assessment. However, there may be small portions of this system that are not in connection with the Lake. The data currently available makes these areas difficult to identify. Future work might be done to better delineate these areas as it seems likely that they could be susceptible to over-pumping as well pumping increases.

Basalt Aquifer System

Portions of the basalt aquifer system flow towards Lake Roosevelt, and portions to the south away from Lake Roosevelt. Except in the immediate vicinity of the mouth of Hawk Creek, the only potential recharge source for the CRBG aquifer system is that small portion of annual precipitation that manages to infiltrate into the ground beneath the root zone. As noted earlier in this section, infiltration likely ranges between 0.09 inches to 1.9 inches per year per unit area, depending on vegetative cover, substrate properties, and topography.

Based on our general concept of CRBG hydrogeology, we interpret that such recharge will be limited predominantly to the upper 100 to 300 feet of the basalt system, depending on local topography, depth of erosion, and disruption of generally very low permeability to impermeable dense basalt flow interiors. This seems to be supported by hydrographs discussed earlier in this report as shallow wells seem to be show characteristics suggestive of some recharge while deeper wells are less likely to show this. In addition, ground water geochemical data currently being compiled and evaluated for the GWMA suggests shallow wells have a component of modern recharge that usually is lacking in deeper wells (GWMA, 2009c). The geochemical data collected from two wells at Davenport clearly show this trend.

Once infiltrating water recharges the shallow interflow zones, it will move within these layers, generally in the direction the layer is dipping. For the WRIA's western two subbasins, most of this flow will be towards the north, off the crest of the anticline lying along the southern boundary of the WRIA. This groundwater system likely is the source for most, if not all, of the springs seen on the slopes high above Lake Roosevelt. Unfortunately, no data was found to quantify the amount of water being discharged from these basalt aquifer system springs. In the eastern WRIA groundwater flow in the shallow portion of the basalt aquifer system generally will be to the south, although much of the groundwater potentially flowing off the highest portions of the WRIA north of Davenport will be intercepted in Hawk Creek canyon, which deeply incising through these generally south dipping layer.

Within deeper portions of the basalt aquifer system southwards directed groundwater flow is most likely occurring. Based on the limited geochemical data collected by GWMA, we infer that this groundwater is old and receives very little modern recharge. A portion of this southerly moving groundwater likely is intercepted by the Davenport municipal wells and the irrigation wells found in this area.

Water wells contribute significantly to outflow from the shallow and deeper basalt aquifer system. As noted earlier in this report, there is some evidence that in at least some areas, groundwater pumping in the shallower portions of basalt aquifer system is not exceeding recharge. However, there is compelling anecdotal evidence described by WRIA participants that suggests there are portions of the shallower basalt aquifer system where water level declines indicates ground water pumping is exceeding recharge. These areas appear to be those where the greatest concentrations of domestic wells are found.

Clearly the lack of pumping data (measuring both use and aquifer properties) coupled with the scarcity of water level data limits our ability to say more about basalt aquifer recharge and

discharge. This could be addressed in future work in the WRIA if this data gap is judged to important.

Pre-Basalt Basement Aquifer System

We know even less about this aquifer system than the other two. Anecdotal information provided by WRIA participants clearly indicates it is difficult to extract water from this system. This could be because of several reasons, ranging from very low porosity and permeability (which is likely), to limited recharge (again likely), to very low storage capacity (again likely). At this point we can say little more about this aquifer system.

6.4 Simplifying Assumptions

Water balances are used to evaluate the distribution of the various components of watershed hydrology between the overall watershed hydrologic system. The purpose of a water balance is to conduct a simple evaluation of the inflows and outflows of a basin. It is important to understand the limitations of simple eater balances, especially in basins where limited data is available.

- For this analysis, the watershed hydrology components were based on data compiled by others, and which are very limited and sparse throughout the watershed.
- For this analysis, the extent of groundwater basins, specifically within the basalt bedrock aquifers could not be delineated. Basins within the regional Columbia River Basalt Group aquifers can be controlled by folding, faulting, and/or discontinuous saturated interflows. Estimating quantities of groundwater within the basalt bedrock aquifers was beyond the general scope of this assessment.
- For this analysis, groundwater inflow and outflows from the granitic bedrock aquifers was assumed to be negligible.
- The watershed boundaries were assumed to be identical to the surface water hydrology, but not the groundwater hydrogeology. Groundwater within the basin is influenced by a regional system that extends beyond the watershed boundaries to the east, west, and south.
- When conducting water balances, steady state (static) conditions are assumed to be an accurate representation of the hydrologic system within the watershed. In reality, watersheds are actually transient systems that are dynamically balanced between water inputs and outputs.
- Water balances are not adequate to evaluate the potential influence of an increase in groundwater use for watersheds with complex hydrology or large groundwater use. This is because groundwater use is dependent upon aquifer hydraulics, spatial and temporal characteristics and the capture of natural discharge and water balances cannot be used to accurately evaluate any of these factors (Bredehoeft et al., 1882; Bredehoft, 1997; Sophocleous, 1997).
- Water balances are only valid to describe existing conditions where sufficient empirical data is available. Water balances are widely recognized as inappropriate for predictive analysis due to the simplifying assumptions and the inability of the method to predict changes in hydrologic systems (Bredehoeft et al., 1982; Sokolov and Chapman, 1984).

For this assessment, sufficient empirical data was not available to complete a defensible water balance.

6.5 WATER BALANCE SUMMARY

The annual water balance for WRIA 53 cannot be developed at this time do to the limited aquifer and surface water data. The GWMA is currently developing an aquifer model that encompasses the area within WRIA 53. Once the groundwater parameters in the basalt aquifers are developed at the completion of that model, a more defined water balance can be developed.

For the inputs of the water balance, the following was determined:

- Precipitation: precipitation for the entire was determined to be about 124,256 acre-feet for the area north of the Columbia River, and 219,071 acre-feet for the area south of the Columbia River. Precipitation estimates for each of the subbasins are presented in Table 26.
- Groundwater inflow: groundwater located in the granitic basement rock in the eastern and western extents of the basin are insignificant, and can be assumed to be zero. For the basalt aquifers, they extend well beyond the watershed boundaries. Groundwater inflow from the west and east is not known. Groundwater inflow into the basalt aquifer from the north (Columbia River) appears to be minimal or negligible.
- Surface water inflow: for the watershed, there is no stream gauge data to evaluate this component. In respect to the southern half of the watershed, all streams are formed from precipitation or from springs. No major tributaries enter the southern portion of the watershed.

TABLE 26: ESTIMATE OF PRECIPITATION INPUT INTO WRIA 53 (assuming average of 12.555 inches of rain/year)

Sub-Basin	Acreage	Acre-Footage of Precip. – Northern WRIA 53	Acre-Footage of Precip. - Southern WRIA 53
Coulee Dam N	71,358.51	74,658.84	------
Brody Creek N	47,376.95	49,568.13	------
Coulee Dam S	37,691.81	-------	39,435.06
Brody Creek S	50,669.58	-------	53,013.05
Hawk Creek	119,065.14	-------	124,571.90
TOTAL		**124,226.97**	**217,020.01**

For the outputs of the water balance, the following was determined:

- Evapotranspiration: On naturally vegetated, minimally disturbed, permeable substrates, no more than 10 percent of the annual precipitation falling within the WRIA is assumed to be available for groundwater recharge because of moisture retention capacity, run-off, and evapotranspiration. Therefore, for precipitation that falls on vegetated, permeable soils and substrates, approximately 1 to 10 percent is available for potential ground water recharge. Given the precipitation patterns measured for the area, this yields potential

water quantities available to groundwater recharge between 0.09 inches to 1.9 inches per unit area per year for such areas. This would result in an evapotranspiration value of 90 – 99 percent of rainfall, or about 197,164 to 216,881 acre-feet.

- Net Demand: the net demand for the watershed under existing estimated conditions is estimated at 18,666 acre-feet of water.
- Groundwater outflow: this component is assumed to be a large number as the WRIA 53 southern watershed is the headwaters for the Columbia River Basalt Regional Aquifer system that extends throughout eastern and central Washington. This component is unknown at this time.
- Surface Water Outflow: no stream measurements are currently available for the tributaries in WRIA 53. Therefore, this component is unknown.

In summary, the following water balance is presented:

PPT + GWI + SWI = ET + ND +/- GWO +/- SWO

Where:
PPT = 219,071.98 AF
GWI = unknown
SWI = unknown
ET = 197,164.67 to 216,881.14 AF
ND = 18,666 AF
GWO = unknown
SWO = unknown