12. WATER BALANCE

The hydrologic cycle forms the technical basis for watershed planning. The traditional method for expressing the hydrologic cycle is through a water balance. A physical water balance uses measured data or scientific methods to estimate current and future water use and availability.

This chapter begins with a description of the basis for a water balance including background issues and related studies (Section 12.1 – 12.3). The objective and level of detail are in Sections 12.4 and 12.5. Following this, in Section 12.6, is a summary and presentation of the results of the Methow Basin water balance and the sensitivity of those results. Section 12.7 provides a description of what data were used, and how they were used to create the water balance. The final section, Section 12.8 describes the quality of and uncertainties related to the data and methods.

12.1 Physical Water Balance

This section discusses the methodology of creating a physical water balance, what the balance can illustrate, and the accuracy or sensitivity of this information. In a regulated watershed, an assessment that evaluates legal rights against water use and availability is often called a water balance. This section does not include such a water balance; however, a discussion and comparison of allocated water and actual water use is included in Section 11.5.

12.1.1 Hydrologic Cycle

A schematic of the hydrologic cycle is shown in Figure 12-1. A complete understanding of the hydrologic cycle at the watershed scale involves an inventory of the water inputs, outputs and storage within the watershed - a water balance. The physical water balance expresses the primary variables (input, output and change in storage) of the hydrologic cycle through a simple relationship:

$$\text{Input} = \text{Output} + /\text{- Change In Storage}$$

This equation is a conservative statement that assures that all the water within the watershed is accounted for and that water cannot be lost or gained.

The hydrologic cycle can be altered by humans. Water storage and transport affect the timing of surface water movement through the system in both the streamflow, evaporative and groundwater phases. Land use and cover changes alter infiltration, evaporation, transpiration and run-off rates. Water use for domestic and irrigation purposes changes the timing and rates of almost all phases of the hydrologic cycle. The water balance must therefore include these human uses as well.

12.2 Background Issues

As described in previous sections, the Methow basin is a hydraulically closed system. Surface water flows exiting the basin are well documented through data at the USGS gage on the Methow River near Pateros, and virtually all water in the system originates from precipitation that falls in the basin as rain or snow. Therefore, the Methow basin lends itself to a water balance using precipitation inputs and surface water flow outputs as primary balance components. For the water quantity component of watershed planning, the ability to effectively address allocation of water in relation to water availability is a primary goal. A water balance provides an effective tool for this purpose.

12.3 Previous Studies

Several studies have been completed which include partial or whole water balance estimates. Published reports include:

1. Technical Supplement to the Hydrographic Atlas Okanogan-Methow River Basins Study Area, Orsborn and Sood (1973)
2. Water in the Methow River Basin, Washington, Walters and Nasser (1974)
3. The Water Resources of the Methow Basin, Milhous, Sorlie, and Richardson (1976)
4. Recent Water Use in the Methow River Valley: An Estimate, Ecology (1991)
5. Water Budget for the Methow Basin, Golder Associates, Inc. (1993)
6. Use of a Precipitation-Runoff Model to Simulate Natural Streamflow Conditions in the Methow River Basin, USGS (2001).

12.4 Objective and Level of Detail

The watershed planning process is designed to bring stakeholders together as a group to determine the future of water management in their basin. The water balance is an important part of this process because it represents the integration of each watershed study component. Therefore, the objective of the water balance is to provide a tool that can easily be understood and utilized by a diverse group of people for assessing allocation of water within Methow sub-basins.

Issues related to the application of a water balance to watershed planning include:

a) The relative magnitudes of each hydrologic parameter are aggregated at a sub-basin geographic scale and a monthly time scale. This format can be easily implemented in a spreadsheet, but lacks the fine scale necessary for site-specific studies. Therefore, it provides a basis for management strategies that will affect hydrologic features at a comparable scale.

b) The water balance provides a basic assessment of groundwater surface water interaction at a sub-basin scale. Most hydrologic parameters in a water balance are directly measured (precipitation, water use, etc.), while others, such as groundwater, are calculated as a "residual" in the water balance equation.

c) The water balance only provides a basic assessment of water availability for habitat needs. Habitat management issues may require additional "fine scale" assessment to quantify water availability for habitat purposes.

d) The hydrologic simulations conducted by the USGS are a rigorous method for determining a basin scale water budget, due to the detailed simulation of the natural processes of the basin, generally, on a smaller time-step. While simulations can provide more detailed information they can also be difficult to calibrate, manipulate and explain in the context of an allocation decision. In addition they are highly dependent on the accuracy, density and distribution of available data.

For this study of the Methow Basin, the level of detail is a monthly and annual water balance at the sub-basin scale. The eight sub-basins used in the analysis are described in Table 3-1. Average annual and monthly climatic and streamflow data, computed using 1991 – 2000 time frame, are used in the analysis. Finally, the water balance was created using a simple spreadsheet that clearly displays each component and it's relative influence on the water balance.

12.5 Existing Data

Components of a physical water balance are either directly measured or derived through their relationship with available data. In the Methow basin, data includes

1. Streamflow (Section 5),
2. Precipitation (Section 4),
3. Temperature (Section 4),
4. Land use/ land cover (Section 9),
5. Population (Sections 9 and 10),
6. Municipal water use (Section 10), and
7. Agricultural water use (Section 10).

Each of these components is aggregated to the sub-basin scale. The source and analysis of these data are discussed in its respective section, noted in parenthesis.

12.6 Water Balance Methodology

The method used to create the physical water balance focuses on the accounting of water that flows past the core stream gage network along the mainstem Methow. Data is either used directly or used to calculate each water balance component. These components are then summed on a monthly basis within each sub-basin and compared to measured streamflow.

The units used in a water balance are, by convention, inches and acre-feet. Values expressed in inches are typically used to compare the relative magnitude of the components of the water balance within a sub-basin. Values expressed in acre-feet are typically used to compare the relative magnitude of the components of the water balance between sub-basins. This is an important distinction. An inch of water in a large sub-basin represents more water than an inch of water in a small sub-basin.

The following components are incorporated for each sub-basin water balance on both a monthly and annual time step. Monthly values for the following components can be seen in Tables 12-3 – 12-8.

1. Precipitation: Derived by computing area-weighted averages of monthly PRISM data (Section 4.3) within a GIS.
2. Snow accumulated: The proportion of precipitation that accumulates as snowpack reported as snow water equivalent..
3. Rainfall + Melt: The amount of water released from snowpack plus the amount of precipitation falling as rain. Water released from snowpack is calculated using a simple temperature model based on degree-day melting rate.
4. Observed Run-off: Mean monthly run-off, based on measured streamflows at USGS stream gages. Run-off from within the contributing sub-basin area is calculated by subtracting flow from upstream gages.
5. Uncorrected Residual: The difference betweencalculated rainfall + melt and run-off is a residual that represents the estimated total consumptive use and sub-surface flow within each sub-basin.
6. Irrigated Net Use: This includes transpiration and evaporation “lost” due to crop irrigation. An upper limit for the amount of consumptive use from irrigated land is estimated based on irrigated acreage within each sub-basin and the crop irrigation requirements for alfalfa, orchards (apples), and pasture/turf. Irrigation efficiency estimates were varied between 50% and 70% to determine impacts; 70% efficiency is used for the presented case. This parameter does not include stock watering.
7. Non-irrigated Net Use: The transpiration portion of consumptive use from non-irrigated land is incorporated using the estimated forested and shrub/herbaceous acreages for each sub-basin. Typical annual transpiration rates were chosen for four forest types (firs, pines, spruce, aspen) and one shrub. Annual rates were distributed to monthly values using the monthly distribution of evapotranspiration rates measured from Douglas Fir.
8. Domestic Net Use: Domestic use is incorporated through water use data obtained from the Town of Twisp. Three distinct water use cases were developed based on permanent, seasonal and exempt well use populations. More information on these three cases can be found in Section 10. Case 2 is used for the presented case.

9. Irrigation Bypass: Water that bypasses a stream gage during the irrigation season as a result of irrigation canals is incorporated in the water balance based on an estimate of the proportion of the peak diversion from that sub-basin that is delivered to another sub-basin. Positive values indicate a net import of water from another sub-basin. Negative values represent a net export of water to another sub-basin.
10. Net Residual: The difference between the predicted run-off and observed run-off. This component can represent several processes including sub-surface flow (groundwater and irrigation return flows), sublimation from snowpack, water storage in the unsaturated zone and evaporation from water surfaces.

A description of each water balance calculation follows.

12.6.1 Annual Water Balance

The general approach for the annual water balance on a sub-basin basis is:

$$P = RO + CU + IB + NR + \Delta S \qquad [1]$$

Where

P = Precipitation, an externally modeled component, based on measured data.
RO = Runoff, a measured component, based on streamflow.
CU = Consumptive use, a calculated component, based on measured data.
IB = Irrigation bypass, measured component.
NR = Net residual calculated through the water balance.
ΔS = Change in storage, measured variable, currently managed inter-annual storage is not a factor in the Methow Basin.

All units are in inches. The annual water balance is applied for a water year, beginning in October and ending in September.

12.6.2 Monthly Water Balance

For the monthly water balance, snow accumulation and melt must be included, since precipitation falling as snow in one month may not be released as snowmelt until several months later. The general monthly water balance equation is as follows:

$$R + M = RO + CU + IB + NR + \Delta S \qquad [2]$$

Where

R = Rainfall, an externally modeled component, based on measure data.
M = Snowmelt an externally calculated component.

Both are in units of inches. Note that by the end of the water year, cumulative rainfall plus melt is equal to total precipitation, assuming sublimation is negligible. Thus, the monthly and annual water balance approaches are compatible.

The methods used to estimate all components in the water balance are described below.

12.6.2.1Rainfall and Snow Accumulation/Melt

Snow accumulation (A) and melt (M) can be estimated on the basis of mean monthly precipitation and temperature. When mean monthly temperature (T) is below a base temperature, a fraction of the monthly precipitation (P) is added to the snowpack. The remaining fraction of the precipitation is added to rainfall (R):

For $T = T_b$

$$A = P * P_x \quad [3a]$$

$$R = P * (100\%-P_x) \quad [4a]$$

$$M = 0 \quad [5a]$$

where T_b is the base temperature, set to 0^oC for this study, and P_x is the fraction of precipitation, which becomes snow, set to 85% for this study. A, R, and M are in units of inches in the above equations. By using $P_x < 100\%$, the model allows for rainfall and snow accumulation to occur in the same month (rain on snow).

When temperature exceeds the base temperature, all precipitation is added as rainfall and the snowpack is melted according to the degree-day approach:

For $T > T_b$

$$A = 0 \quad [3b]$$

$$R = P \quad [4b]$$

$$M = C_x * (T-T_b) \quad [5b]$$

where C_x is a degree-day factor in units of inches/(^0C?day).

12.6.3 Runoff

Mean monthly runoff (RO) contributed by each sub-basin can be estimated from streamflow gage data. Average monthly streamflow is divided by total basin area to obtain average monthly run-off in inches.

12.7 Summary of Results

All water balance outputs presented in this section use the “Case 2” water use scenario (see Chapter 10), and assume a 70% irrigation efficiency (see Chapter 10). The water balance incorporate the consumptive loss based on irrigated area, and does not explicitly consider consumptive loss from canal seepage.

The annual water balance for the Methow Basin is shown on Figure 12-2. This figure displays the partitioning of water as a percentage of total annual precipitation that falls in the basin.

Figure 12-3 displays the relationship between total annual precipitation, observed run-off (based on streamflow) and all consumptive uses (crop irrigation, domestic, non-irrigated vegetation).

Table 12-2 displays the annual water balance for each sub-basin. The column headings are described in detail in Section 12.6. Total volumes are displayed in both AF and cfs.

Results of the monthly water balance are displayed in Tables 12-4 through 12-9. Detailed descriptions of the column headings can be found in Section 12.6. All numbers are reported in inches of water, for intra-basin comparison. The data from these tables are represented in graphical form in Figure 12-4 and 12-5. These figures present the "natural" portion of the water balance on a monthly basis: precipitation (including rain and snow), calculated run-off (calculated from rainfall plus snow melt), and observed run-off (based on measured streamflow) are included.

12.7.1 Discussion

Figure 12-2, the annual water balance, displays the basin-wide distribution of water availability and use. This figure shows the relative magnitudes of each component of the water balance. Annual Crop irrigation and domestic use account for less than 3% of water use in the basin. Run-off to the river, non-irrigated evapotranspiration (ET) and a net residual make up the largest percentage of water in the basin. Non-irrigated ET encompasses vegetation in the watershed that is not irrigated such as trees and shrubs (this is discussed more thoroughly in Chapter 10, Water Use).

The net residual shown in Figure 12-2 shows that a significant portion of water in the basin is not accounted for in surface processes and streamflow. "Net residual" can encompass several water components including, but not limited to, subsurface (groundwater) flow through the basin, inter-annual snow storage, sublimation from snowpack, unsaturated zone water storage and evaporation from water surfaces. For example, the annual basin-wide net residual is 626,122 AF. Groundwater has been estimated to account for approximately 340,000 AF of that net residual annually, leaving 286,122 AF of unaccounted water. Preliminary estimates of potential storage volumes in the physical processes described above (excluding groundwater) indicate that between 79,300 AF and 360,700 AF of water could be accounted for annually.

Minimum and maximum volume estimates for each of the four components of the net residual, as well as the source of data for each estimate are described as follows.

- Water Surface Evaporation: Land cover estimates from the MAPA project (1995) indicate that approximately 5,124 acres are covered by water. Assuming a rate of evaporation of 39 inches, based on pan evaporation at Oroville and Wenatchee gages (NOAA), evaporation from water surfaces could reach 16,946 AF.
- Snow Storage: Mullen, et al (1992) estimated water stored in glaciers in the basin to be approximately 5,112 acre-ft of water in approximately 512 acres of glaciers. Land cover estimates from the MAPA, 1995 project indicate that 9,152 acres of

land are covered by snow. Using Mullen's methods to estimate the water equivalent, results in 90,605 AF of water.

- Snow Sublimation: Storck and Lettenmaier (1998) measured sublimation in Pacific Northwest basins to be between .01 inches/day and .04 inches/day depending on conditions. This results in a range of volumes of 57,268 AF to 229,072 AF
- Unsaturated Zone: Soils data obtained from USDA-NRCS STATSGO database indicate that as much as 0.25 inches of water can be held in the unsaturated zone. This assumption results in a total volume of 24,000 AF of water stored in the unsaturated zone annually.

Based on these data, the annual water balance appears reasonable.

Figure 12-3 and Table 12-1 display the annual water balance for each sub-basin. Figure 12-3 displays the relationship between total annual precipitation, observed run-off and all consumptive uses (crop irrigation, domestic, non-irrigated vegetation). Notice that the "Observed Run-off" for the Middle Methow basin is negative. Observed run-off is calculated using the difference in streamflow measurements at the entrance and exit of each sub-basin. A negative value for observed run-off describes a situation in which the amount of water flowing into the sub-basin from upstream, and precipitating on the sub-basin, is greater than the amount flowing out of the sub-basin via streamflow. This could represent groundwater recharge in the Middle Methow sub-basin.

In Table 12-1 the "Net Residual" of the Upper Methow carries a negative value indicating that an un-accounted for process is discharging water to the stream. Possible causes of this include discharge of groundwater or a discrepancy in the timing of snow accumulation and melt.

Results of the monthly water balance in Tables 12-4 through 12-9 show a pattern similar to that of the annual balance; the majority of precipitation runs off, evaporates from non-irrigated lands, or becomes part of the net residual. Water use for human needs makes up a very small portion of the total.

Figure 12-4 and 12-5 present the "natural" portion of the water balance on a monthly basis. These graphs show the difference in timing from when precipitation occurs (Precipitation) to when it becomes available as run-off (Rainfall + Melt). "Observed run-off" generally mirrors "Rainfall + Melt" values but can vary due the averaging of parameters used in calculating snowmelt over time and space. The difference between "Rainfall + Melt" and "Observed Run-Off" represents the "Uncorrected Residual". Uncorrected residuals are caused by several factors including run-off that goes to sub-surface flow, run-off that is used consumptively or uncertainties in snowpack and snow melt calculation assumptions (such as lapse rate, degree-day melt factor).

As discussed in the Water Use chapter (Chapter 10), there are many uncertainties inherent in water use estimates. The relative impact of these water use numbers on the annual water balance varies from component to component.

12.7.1.1 Non-Irrigated Lands Water Use:

Consumptive water use by non-irrigated lands (primarily forests) represents the largest consumptive use in the basin. Therefore, changes in values and assumptions related to forest structure, transpiration rate, basal area, etc., could have a significant impact on the water balance. Two forest compositions were compared in Chapter 10. Forest composition was changed to Lodgepole pine dominant (replacing all fir transpiration rates with pine transpiration rates). This resulted in a total decrease of 540,800 AF in consumptive water use by non-irrigated lands. This decrease equates to a 17% decrease in its contribution to the water balance.

12.7.1.2 Irrigated Lands Water Use:

Consumptive water use through the irrigation of cropland represents a relatively small percentage of the total water balance, approximately 2% annually. Irrigation efficiency includes only “on-farm” irrigation losses. Canal losses are not considered consumptive. Three efficiency values were evaluated to determine their effect on the water balance; 50%, 60% and 70%. Total volume of water used for these efficiencies ranged from 55,500 AF at 70% to 77,600 AF at 50% efficiency. This decrease in efficiency increases annual irrigation consumptive use impact on the basin water balance by less than 0.7%. The impact of efficiency improvements on the a sub-basin water balance would be greatest in basins where more irrigation occurs. In the Middle Methow, for example, an increase in efficiency from 50% to 70% decreases the percentage of water allocated to irrigation consumptive use by approximately 8%.

12.7.1.3 Domestic Water Use:

Consumptive water use by domestic users represents less than 0.07% of the total water balance. Three water use cases were discussed in Chapter 10 (Water Use). Case 1 water use represents a total consumptive volume of water equal to 904 AF. Case 3 water use represents a total consumptive volume equal to 1862 AF. As a percentage of the total water balance this range equates to difference of 0.05%.

12.7.1.4 Rainfall + Melt

Rainfall + Melt is calculated based on average sub-basin elevation and monthly temperature, as well as several snow accumulation and melt parameters extracted from literature. Because elevations, temperature and precipitation in the upper sub-basins varies greatly the timing and magnitude of this parameter could also vary. This would primarily affect the net residual.

12.7.1.5Subsurface Flow

Subsurface flow is estimated to comprise approximately 50% of the total annual net residual. Figure 12-8 displays the net residual on a monthly basis for each sub-basin. Assuming that all other components comprising the net residual are relatively constant throughout the year, then the fluctuations in the net residual can be taken to represent changes in sub-surface flow on a monthly basis. This indicates that during the winter (November to March) the river is in equilibrium with groundwater or groundwater is discharging to rivers in almost every sub-basin. In early spring groundwater in the Middle and Lower Methow changes to a recharge state (e.g., streamflow recharges groundwater) returning to a discharge state (groundwater discharging to surface water) by early summer. The upper basins show continued recharge of groundwater into early spring, followed by a sharp change to a discharge state in mid-summer, returning to an equilibrium position by September and October. Comparison of September net residual values with seepage estimates provided by the USGS (Kimbrough et. al., 2002) at sub-basin outlets coincide well. Surface water recharges groundwater in the Methow Headwaters, groundwater discharges to surface water in the Upper Methow, equilibrium is seen in Middle Methow and groundwater discharges to surface water in the Lower Methow.

12.8 QA/QC

The described water balance approach makes use of the relatively abundant, complete (i.e., no significant gaps in time or location), current, and geographically relevant GIS, climate, and streamflow data available for the Methow basin. Most of the natural components of the water balance (precipitation, snow, run-off) are calculated directly from these data and averaged over time and across sub-basin areas. As a result, it is expected that the majority of any errors introduced (especially as they relate to the annual time scale) will be the result of problems with data collection or reporting, rather than the result of simulating unknown variables.

Monthly estimates of consumptive use employ the best available information to determine usage volumes including Census population numbers, measured municipal pumping, and land. Additional quality information on this data can be found in the Water Use section, Chapter 10.

Uncertainties could be introduced through the timing of monthly, estimated hydrologic losses. The results should not, however, result in significant error in estimated mean annual hydrologic losses. This is true because the hydrologic year begins in September, before major snow accumulation, and ends in October, after the snowpack has typically melted. Hence, by the end of the hydrologic year, cumulative rainfall plus snowmelt (water available for runoff or hydrologic losses) is equal to total precipitation.

Possible sources of inaccuracies include:

- Sub-basin Characteristics: Error may be introduced as the result of the averaging of data over sub-basin areas due to sub-basin boundary data set inaccuracies. Sub-basins were developed primarily using a combination of HUC 5 (USGS) and WAU (WaDNR) boundaries, which were then modified to represent areas contributing to Stream Management Units (Kauffman and Bucknell, 1976). Mean sub-basin elevations were taken from USGS 10m DEM. These values are used in estimating snowmelt and accumulation.

- Snow Water Equivalent Parameter Estimations: Snow Water Equivalent (SWE), is simulated rather than measured. Input data for the calculation includes monthly precipitation, monthly temperature, and mean sub-basin elevation. Several parameters are used to partition precipitation into rainfall and snow accumulation, and to distribute snow accumulation and melt over time. Due to lack of historical observed snowpack data across the basin, formal calibration of these parameters was not be possible. Furthermore, simulation of SWE is expected to be highly sensitive to all of the input data. While input mean monthly sub-basin precipitation likely has a high degree of certainty, temperature was based on only two recording stations located relatively close to one another.
- Sublimation: Sublimation is not included in the snow model. Neglecting sublimation may have contributed to the calculated residual. Sublimation data and calculation inputs are not measured in the basin and were therefore not included as a component.
- Consumptive use: Includes domestic, irrigation, and non-irrigation consumptive use.
  - Domestic use estimates are based on use by individual property owners with varying needs, most of which are on individual, un-metered systems: therefore estimation of use is expected to contain some inaccuracies. The magnitude of this difference is small in comparison to other parameters.
  - Irrigation use assumes that the amount of water used for irrigation is only what the plants need plus a blanket irrigation inefficiency value. Additionally, only representative crop species water needs can be accounted for in the estimates. Variability due to the methods of estimating irrigation water use is small in comparison to other parameters.
  - Non-irrigation consumptive use presents inaccuracies through the use of transpiration rates developed in different geographic and climatic regimes. Actual transpiration rates for forested lands in the Methow are not known. This method of estimation could have significant impact on the total water balance due to relative magnitude of this component.
- Observed Run-off calculations: Run-off calculations are assumed to be accurate, due to their relationship with measured streamflow gages.

TABLE 12-1

Annual Water Balance

Sub-Basin Name	Area Acres	Rainfall plus Snowmelt Acre-Ft	Observed Run-Off Acre-ft	Crop Irrigation Acre-ft	Domestic use Acre-ft	Non-Irrigated ET Acre-ft	Irrigation Bypass Acre-ft	Net Residual Acre-ft
Headwaters	233,011	874,537	376,701	2,495	32	279,309	893	215,755
Upper Methow	89,014	250,723	194,347	8,303	95	107,681	0	-59,859
Chewuch	331,163	803,070	287,008	4,769	137	410,752	8,926	98,489
Twisp	156,611	609,478	200,984	4,204	281	191,811	8,628	210,433
Middle Methow	30,763	46,401	-28,456	9,571	284	29,714	8,926	33,349
Lower methow	315,417	659,029	118,281	26,126	723	386,490	0	127,325
Total (Acre-Ft)	**1,155,979**	**3,243,238**	**1,148,866**	**55,468**	**1,551**	**1,405,757**	**27,372**	**625,493**
Total (cfs)		**4,480**	**1,587**	**155**(a)	**2.1**	**1,942**	**37.8**	**864.0**
Total (Acre-Ft)	**1,155,979**	**3,243,238**	**1,148,866**	**77,656**	**1,551**	**1,405,757**	**27,372**	**605,720**
Total (cfs)		**4,480**	**1,587**	**218**(b)	**2.1**	**1,942**	**37.8**	**836.0**

(a) –Assumes an irrigation period of 180 days and on-farm efficiency of 70%

(b) – Assumes irrigation period of 180 days and on-farm efficiency of 50%

TABLE 12-2

Comparison of Current and Previous Water Balance

Source	Rainfall plus Snowmelt Acre-Ft	Observed Run-Off Acre-ft	Crop Irrigation Acre-ft	Domestic use Acre-ft	Non-Irrigated ET Acre-ft	Net Residual Acre-ft
Golder Associates, 2002	3,243,238	1,148,866	55,468	1,551	1,405,757	626,122
Golder Associates, 1993	2,835,000	1,131,000	40,800		1,656,000	7,200
Milhous, et al., 1976.	2,875,000	1,162,000	27,100		1,623,500	617,000
Walters, et al., 1974	3,100,000	1,200,000	25,000		1,135,000	740,000

Table 12-3

Monthly Water Balance - Methow Headwaters

Month	Precip.	Cum. Precip.	Snow Accum. SWE	Rainfall + Melt	Observed Run-Off	Uncorrected Residual	Irrigated Net Use	Domestic Net Use	Non Irrigated Net Use	Irrigation Bypass	Net Residual (inches)
Oct	3.5	3.5	0.0	3.6	0.1	3.5	0.02	4.9E-05	1.2	0.00	2.2
Nov	7.2	10.7	6.1	1.0	0.3	0.7	0.00	4.8E-05	1.5	0.00	-0.8
Dec	6.5	17.2	11.7	1.0	0.2	0.8	0.00	4.9E-05	0.2	0.00	0.5
Jan	6.8	24.0	17.5	1.0	0.1	0.9	0.00	4.9E-05	0.2	0.00	0.7
Feb	4.9	28.9	21.6	0.7	0.0	0.7	0.00	4.4E-05	0.2	0.00	0.5
Mar	4.4	33.3	25.4	0.7	0.3	0.4	0.00	4.9E-05	0.2	0.00	0.2
Apr	2.9	36.2	27.9	0.5	1.8	-1.3	0.00	9.7E-05	1.4	0.00	-2.7
May	2.4	38.6	26.7	4.6	6.5	-1.9	0.02	1.9E-04	1.8	0.01	-3.8
Jun	1.9	40.5	21.9	7.6	6.4	1.2	0.02	2.4E-04	2.0	0.01	-0.8
Jul	1.3	41.8	13.3	10.9	3.0	7.9	0.02	3.3E-04	1.7	0.01	6.2
Aug	1.2	43.0	5.2	10.3	0.6	9.7	0.02	3.4E-04	2.2	0.01	7.5
Sep	2.0	45.0	0.7	3.1	0.1	3.0	0.02	1.4E-04	1.6	0.01	1.4
Total	**45.0**		**27.9**	**45.0**	**19.4**	**25.6**	**0.13**	**1.6E-03**	**14.4**	**0.05**	**11.1**

Uncorrected residual = difference between precipitation inputs and observed run-off
Net residual = Uncorrected residual minus consumptive uses

TABLE 12-4

Monthly Water Balance – Upper Methow

Month	Precip.	Cum. Precip.	Snow Accum. SWE	Rainfall + Melt	Observed Run-Off	Uncorrected Residual	Irrigated Net Use	Domestic Net Use	Non Irrigated Net Use	Irrigation Bypass	Net Residual (inches)
Oct	2.6	2.6	0.0	2.6	1.3	1.3	0.15	3.9E-04	1.2	0.00	-0.1
Nov	5.1	7.7	4.4	0.8	1.4	-0.6	0.03	3.7E-04	1.6	0.00	-2.2
Dec	5.9	13.6	9.4	0.9	1.4	-0.5	0.03	3.9E-04	0.2	0.00	-0.8
Jan	5.7	19.3	14.2	0.9	1.4	-0.5	0.03	3.9E-04	0.2	0.00	-0.8
Feb	3.5	22.8	17.2	0.5	1.2	-0.7	0.03	3.5E-04	0.2	0.00	-1.0
Mar	2.8	25.6	19.6	0.4	1.8	-1.4	0.03	3.9E-04	0.2	0.00	-1.7
Apr	1.7	27.3	19.1	3.6	3.2	0.4	0.03	7.6E-04	1.4	0.00	-1.1
May	1.6	28.9	15.4	6.7	6.0	0.7	0.14	1.5E-03	1.8	0.00	-1.3
Jun	1.4	30.3	8.1	10.2	3.8	6.4	0.16	1.9E-03	2.0	0.00	4.2
Jul	0.9	31.2	0.0	4.8	1.9	2.9	0.16	2.6E-03	1.8	0.00	1.0
Aug	1.1	32.3	0.0	1.1	1.6	-0.5	0.16	2.7E-03	2.2	0.00	-2.9
Sep	1.3	33.6	0.0	1.3	1.2	0.1	0.16	1.1E-03	1.6	0.00	-1.7
Total	**33.6**		**19.6**	**33.8**	**26.2**	**7.6**	**1.12**	**1.3E-02**	**14.5**	**0.00**	**-8.1**

Uncorrected residual = difference between precipitation inputs and observed run-off
Net residual = Uncorrected residual minus consumptive uses

TABLE 12-5

Monthly Water Balance - Chewuch

Month	Precip.	Cum. Precip.	Snow Accum. SWE	Rainfall + Melt	Observed Run-Off	Uncorrected Residual	Irrigated Net Use	Domestic Net Use	Non Irrigated Net Use	Irrigation Bypass	Net Residual (inches)
Oct	2.1	2.1	0.0	2.1	0.2	1.9	0.02	1.5E-04	1.2	0.00	0.6
Nov	4.0	6.1	3.4	0.6	0.2	0.4	0.00	1.4E-04	1.6	0.00	-1.2
Dec	3.6	9.7	6.5	0.5	0.2	0.3	0.00	1.5E-04	0.2	0.00	0.1
Jan	3.2	12.9	9.2	0.5	0.2	0.3	0.00	1.5E-04	0.2	0.00	0.1
Feb	2.5	15.4	11.3	0.4	0.1	0.3	0.00	1.4E-04	0.2	0.00	0.1
Mar	2.7	18.1	13.6	0.4	0.2	0.2	0.00	1.5E-04	0.2	0.00	-0.1
Apr	2.1	20.2	15.4	0.3	0.9	-0.6	0.00	2.9E-04	1.4	0.00	-2.1
May	2.4	22.6	13.8	4.8	3.3	1.5	0.02	5.9E-04	1.9	0.06	-0.5
Jun	2.6	25.2	8.5	8.5	3.3	5.2	0.02	7.3E-04	2.1	0.06	3.1
Jul	1.3	26.5	0.0	8.5	1.2	7.3	0.03	1.0E-03	1.8	0.06	5.4
Aug	1.3	27.8	0.0	1.3	0.4	0.9	0.03	1.0E-03	2.2	0.06	-1.4
Sep	1.2	29.0	0.0	1.2	0.2	1.0	0.02	4.2E-04	1.6	0.06	-0.7
Total	**29.0**		**15.4**	**29.1**	**10.4**	**18.7**	**0.17**	**5.0E-03**	**14.9**	**0.32**	**3.3**

Uncorrected residual = difference between precipitation inputs and observed run-off

Net residual = Uncorrected residual minus consumptive uses

Table 12-6

Monthly Water Balance – Middle Methow

Month	Precip.	Cum. Precip.	Snow Accum. SWE	Rainfall + Melt	Observed Run-Off	Uncorrected Residual	Irrigated Net Use	Domestic Net Use	Non Irrigated Net Use	Irrigation Bypass	Net Residual (inches)
Oct	1.1	1.1	0.0	1.1	0.3	0.8	0.49	3.3E-03	1.0	0.00	-0.7
Nov	2.4	3.5	0.0	2.4	-0.1	2.5	0.11	3.2E-03	1.2	0.00	1.2
Dec	3.1	6.6	2.6	0.5	-0.2	0.7	0.11	3.3E-03	0.2	0.00	0.4
Jan	2.7	9.3	4.9	0.4	-0.4	0.8	0.11	3.3E-03	0.2	0.00	0.5
Feb	1.7	11.0	6.3	0.3	-0.3	0.6	0.11	3.0E-03	0.2	0.00	0.3
Mar	1.4	12.4	5.2	3.3	-0.6	3.9	0.11	3.3E-03	0.2	0.00	3.6
Apr	1.0	13.4	1.0	5.5	-0.7	6.2	0.11	6.6E-03	1.1	0.00	5.0
May	1.1	14.5	0.0	1.1	-4.4	5.5	0.46	1.3E-02	1.5	0.70	2.9
Jun	1.0	15.5	0.0	1.0	-2.8	3.8	0.53	1.6E-02	1.6	0.70	1.0
Jul	0.8	16.3	0.0	0.8	-0.9	1.7	0.54	2.2E-02	1.4	0.70	-1.0
Aug	0.9	17.2	0.0	0.9	-0.8	1.7	0.54	2.3E-02	1.7	0.70	-1.3
Sep	0.8	18.0	0.0	0.8	-0.2	1.0	0.53	9.3E-03	1.3	0.70	-1.5
Total	**18.0**		**6.3**	**18.1**	**-11.1**	**29.2**	**3.73**	**1.1E-01**	**11.6**	**3.48**	**10.3**

Uncorrected residual = difference between precipitation inputs and observed run-off
Net residual = Uncorrected residual minus consumptive uses

Table 12-7

Monthly Water Balance - Twisp

Month	Precip.	Cum. Precip.	Snow Accum. SWE	Rainfall + Melt	Observed Run-Off	Uncorrected Residual	Irrigated Net Use	Domestic Net Use	Non Irrigated Net Use	Irrigation Bypass	Net Residual (inches)
Oct	3.8	3.8	0.0	3.8	0.3	3.5	0.04	6.5E-04	1.2	0.00	2.2
Nov	7.9	11.7	6.7	1.2	0.4	0.8	0.01	6.3E-04	1.6	0.00	-0.8
Dec	8.0	19.7	13.5	1.2	0.4	0.8	0.01	6.5E-04	0.2	0.00	0.6
Jan	7.9	27.6	20.2	1.2	0.3	0.9	0.01	6.5E-04	0.2	0.00	0.7
Feb	5.5	33.1	24.9	0.8	0.3	0.5	0.01	5.9E-04	0.2	0.00	0.3
Mar	4.2	37.3	28.5	0.6	0.6	0.0	0.01	6.5E-04	0.2	0.00	-0.3
Apr	2.3	39.6	30.4	2.7	1.7	1.0	0.01	1.3E-03	1.4	0.00	-0.4
May	1.6	41.2	27.7	5.3	4.5	0.8	0.04	2.6E-03	1.9	0.13	-1.2
Jun	1.4	42.6	21.4	8.7	4.2	4.5	0.05	3.2E-03	2.0	0.13	2.3
Jul	1.0	43.6	11.3	12.1	2.0	10.1	0.05	4.3E-03	1.8	0.13	8.1
Aug	1.2	44.8	1.7	7.2	0.5	6.7	0.05	4.5E-03	2.2	0.13	4.3
Sep	1.9	46.7	0.0	1.9	0.2	1.7	0.05	1.8E-03	1.6	0.13	-0.1
Total	**46.7**		**30.4**	**46.7**	**15.4**	**31.3**	**0.32**	**2.2E-02**	**14.7**	**0.66**	**15.6**

Uncorrected residual = difference between precipitation inputs and observed run-off

Net residual = Uncorrected residual minus consumptive uses

Table 12-8

Monthly Water Balance – Lower Methow

Month	**Precip.**	**Cum. Precip.**	**Snow Accum. SWE**	**Rainfall + Melt**	**Observed Run-Off**	**Uncorrected Residual**	**Irrigated Net Use**	**Domestic Net Use**	**Non Irrigated Net Use**	**Irrigation Bypass**	**Net Residual (inches)**
Oct	1.8	1.8	0.0	1.8	0.2	1.6	0.13	8.3E-04	1.2	0.00	0.3
Nov	4.0	5.8	3.4	0.6	0.2	0.4	0.03	8.0E-04	1.6	0.00	-1.2
Dec	4.0	9.8	7.6	0.6	0.2	0.4	0.03	8.3E-04	0.2	0.00	0.2
Jan	3.7	13.5	11.5	0.6	0.2	0.4	0.03	8.3E-04	0.2	0.00	0.1
Feb	2.6	16.1	14.1	0.4	0.2	0.2	0.03	7.5E-04	0.2	0.00	-0.1
Mar	2.2	18.3	15.8	0.3	0.2	0.1	0.03	8.3E-04	0.2	0.00	-0.1
Apr	1.4	19.7	13.5	3.4	0.3	3.1	0.03	1.6E-03	1.4	0.00	1.6
May	1.4	21.1	9.4	6.1	0.7	5.4	0.12	3.3E-03	1.9	0.00	3.4
Jun	1.3	22.4	2.7	5.8	1.1	4.7	0.14	4.1E-03	2.0	0.00	2.5
Jul	0.7	23.1	0.0	3.5	0.6	2.9	0.14	5.5E-03	1.8	0.00	1.0
Aug	1.0	24.1	0.0	1.0	0.3	0.7	0.14	5.8E-03	2.2	0.00	-1.7
Sep	1.0	25.1	0.0	1.0	0.3	0.7	0.14	2.3E-03	1.6	0.00	-1.1
Total	**25.1**		**15.8**	**25.1**	**4.5**	**20.6**	**0.99**	**2.7E-02**	**14.7**	**0.00**	**4.9**

Uncorrected residual = difference between precipitation inputs and observed run-off
Net residual = Uncorrected residual minus consumptive uses