Chapter 3. Water Quantity Assessment

Surface water and groundwater contribute to the total amount of water within each subbasin of WRIA 31. This section provides an overview of what is currently known, for each subbasin, regarding the quantity of water:

- Entering, leaving, and distributed within the hydrologic system;
- Appropriated (allocated) and applied for in water rights;
- Currently being used, and projected future demand, by major use category.

Section 3.1 discusses the quantity of surface water flow in streams across the watershed. Section 3.2 provides an overview of streamflow data for the Columbia River adjacent to WRIA 31. Section 3.3 covers groundwater quantity, including hydrogeologic conditions and interactions between surface water and groundwater. Section 3.4 presents an overview of recorded water right appropriations and applications for new water rights in each subbasin, based on Ecology’s water rights database information. Section 3.5 presents estimates of current actual water use, and projected future water use, by subbasin. Section 3.6 presents the water balance, and preliminary discussion of water availability, by subbasin. Section 3.7 presents future water use projections.

3.1 Surface Water Quantity

As discussed in Chapter 2, WRIA 31 was divided into four subbasins for the purposes of this Level 1 assessment. From west to east those subbasins are Rock Creek, Wood/Alder Creeks, Glade/Fourmile Creeks and Kennewick. Both topography and precipitation decrease from west to east. The Rock Creek subbasin has an average elevation of 2,162 feet and receives the highest average annual precipitation of approximately16 inches. The Kennewick subbasin at an average elevation of 870 feet and receives the lowest average annual precipitation of approximately 8 inches.

The majority of the surface water in WRIA 31 flows in ephemeral (seasonal) streams that are dry in the summer months and respond rapidly to precipitation events during the winter. In terms of surface water flow, the two largest streams in the WRIA are Rock Creek and Alder Creek. The highest streamflows in the WRIA typically occur in Rock Creek. Alder Creek typically has lower streamflows than Rock Creek except for the summer months; a spring located near the mouth of Alder Creek provides a small perennial flow in its lowermost reach.

3.1.1 Streamflow Estimates

Limited streamflow gaging data are available for WRIA 31. The primary source of streamflow data for WRIA 31 is the USGS, who in the past maintained nine gaging stations in the WRIA. Data from these stations are summarized in USGS (1989). These gaging stations were located in three of the four subbasins (Figure 3-1); based on available data there have been no gaging stations established in the Kennewick subbasin.

Table 3-1 presents summary information on characteristics of the subbasins with a listing of streamflow gage stations in each.

Table 3-1. USGS Stream Gage Distribution by Subbasin

Subbasin Name	Drainage Area in Square Miles	Elevation in Feet: Average (Range)	Areal Percentage of WRIA 31	Daily Streamflow Stations [1]	Peak Streamflow Stations [1]
Rock Creek	258	2,162 (266 - 4,728)	16%	14036600 14036500	14036600
Wood/Alder Creeks	399	1,904 (233 - 4,213)	25%	14034350	14034350 14034325
Glade/ Fourmile Creeks	827	1,090 (256 - 3,596)	52%	None	14034100 14034280 14034270 14034320 14034040
Kennewick	110	870 (322 - 2,198)	7%	None	None

Notes:

1) See Table 3-2 for station names.

Table 3-2 lists the specific USGS gage stations including their measurement type (daily or peak flow), contributing drainage area, and period of record. Note that contributing drainage areas are identified by the USGS for their gages. Even though a gage may be located near the mouth of a major drainage, the contributing drainage area for that gage may be smaller than the total subbasin area. An example of this is the “Rock Creek near Roosevelt” gage (Station 14036600), located near the tribal long house at the mouth of Rock Creek, which drains 213 square miles out of the 258 square mile subbasin area. The reason for this area discrepancy is that Rock Creek does not drain all of the Rock Creek subbasin as defined for this assessment. As shown on Figure 3-1, there are a series of small streams draining the Rock Creek subbasin west of Rock Creek (Goodnoe Hills) that flow directly into the Columbia River, not Rock Creek. It is this drainage area that accounts for the area difference. This situation is common throughout the WRIA.

Also note that, for consistency with prior data collection efforts, the gage station names cited in this document are those established by the USGS; as a result, a station name indicating “near” a specific location may in fact not be in close proximity. For example, the “Rock Creek near Roosevelt” gage is located approximately 11 miles west of Roosevelt. Similarly, the “Rock Creek near Goldendale” gage (Station 14036500) is about 14 miles east of Goldendale. Station 14034040 is named “Bofer Canyon Trib near Kennewick”, but is located in the Glade/Fourmile, not Kennewick, subbasin (Figure 3-1).

Table 3-2. USGS Stream Gages in WRIA 31

Station No.	Station Name	Drainage Area in Square Miles	Type[1]	Period of Record	Years of Record
14034350	Alder Creek at Alderdale	197	Daily and Peak	1963-1968, 1981, 1982	8
14036600	Rock Creek near Roosevelt	213	Daily and Peak	1963-1968	6
14036500	Rock Creek near Goldendale	120	Daily	1911-1913	2
14034100	Fourmile Canyon near Plymouth	81.2	Peak	1962-1969	8
14034280	East Branch Glade Creek Tributary near Prosser	0.77	Peak	1962-1975	14
14034270	East Branch Glade Creek near Prosser	50.3	Peak	1962-1977	16
14034320	Dead Canyon Trib near Alderdale	0.62	Peak	1955-1974	20
14034325	Alder Creek near Bickleton	8.35	Peak	1963-1977	15
14034040	Bofer Canyon Trib near Kennewick	1.53	Peak	1965	1

Notes:

1) Daily refers to a continous gaging station. The USGS publishes mean daily discharge in cfs from continuous stations. Peak refers to a crest stage station that reports only one instantaneous peak discharge in cfs per year.

Only three of the stations recorded continuous (daily) streamflow data and most of the stations operated for short periods of time in the 1960s and 1970s. Peak flow measurements have been collected at eight stations in the Rock Creek, Wood/Alder Creeks, and Glade/Fourmile Creeks subbasins during that time period; those data are summarized in Table 3-3.

Table 3-3. Summary of USGS Peak Flow Data for WRIA 31

Station No.	Station Name	Period of Record	Number of Peak Measure ments	% of Peaks > 0[1]	Range of Peaks in cfs
14034350	Alder Creek at Alderdale	1963-1968; 1981-1982	8	100%	68 - 17,600
14036600	Rock Creek near Roosevelt	1963-1968	6	100%	912 - 14,200
14034100	Fourmile Canyon near Plymouth	1962-1969	8	25%	0 - 559
14034280	East Branch Glade Creek Tributary near Prosser	1962-1975	14	21%	0 - 300
14034270	East Branch Glade Creek near Prosser	1962-1977	16	50%	0 - 500
14034320	Dead Canyon Trib near Alderdale	1955-1974	20	20%	0 - 17
14034325	Alder Creek near Bickleton	1963-1977	15	100%	0.5 - 992
14034040	Bofer Canyon Trib near Kennewick	1965	1	100%	47

Notes:

1) Peak flow values during some years are reported at 0 cfs, implying that there was no flow at the station during any part of the year.

The period of record data for the various gage stations are depicted graphically on Figure 3-2. Only two of these gages have records long enough to analyze for this assessment: Rock Creek near Roosevelt (Station 14036600) and Alder Creek at Alderdale (Station 14034350). These stations are located near the mouths of the respective creeks (Figure 3-1).

Additional miscellaneous streamflow spot measurements are also available from the USGS (1964; 1989) and Ecology (Davis 1993; Garrigues 1996), and have been compiled in Table 3-4. Streamflow spot measurements have also been collected along with water quality measurements in various WRIA 31 streams by the Eastern Klickitat Conservation District. Those spot flow measurements are presented with the corresponding water quality data in Chapter 4 (Water Quality Assessment).

In assessing whether or not it is appropriate to use historical gage data from several decades ago to gain insight into current conditions, it is important to evaluate whether climatic conditions or land use have changed significantly since the gage records were collected. As discussed in Section 2.5, the best indicator of long-term precipitation patterns is the Pacific Decadal Oscillation (PDO). Currently, Washington is believed to be experiencing a cool/wet PDO cycle. With the exception of the Rock Creek near Goldendale streamflow record (Station 14036500), all of the USGS streamflow data were also collected during a cool/wet PDO cycle.

Another important consideration when evaluating historical streamflow data is changes in land use that have occurred in a basin since the period of streamflow record ended. Land use changes can directly affect runoff in a basin. Typical land use changes that may be relevant to WRIA 31 include changes in impermeable area (e.g. development of rural areas) and vegetation characteristics (e.g., changing in or out of agricultural use, or changing crop types). With the exception of increased urban development in the Kennewick subbasin, changes in the irrigated acreage and irrigation practices represent the most significant land use change in the watershed. A combination of factors have reportedly led to reductions in quantity of water applied to crops (water duty), directly affecting the amount of return flow and resultant discharge in ephemeral drainages. Given the limited streamflow data, all of the available data are included as part of this Level 1 assessment recognizing this potential change in irrigation practice over the period of record.

Table 3-4. Miscellaneous Streamflow Spot Measurements in WRIA 31

Source	Stream	Date	Discharge in cfs	Source	Stream	Date	Discharge in cfs	Source	Stream	Date	Discharge in cfs
USGS[1]	Bofer Canyon	1/23/82	16.0	USGS[1]	Fourmile Canyon	4/18/80	0.00	USGS[1]	Rock Creek near Roosevelt, WA	8/25/73	0.00
USGS[1]	Glade Creek Tributary	2/3/63	16.5	USGS[1]		5/13/80	0.01	USGS[1]		2/14/77	6.51
USGS[1]	Glade Creek	2/3/63	965	USGS[1]		6/16/80	0.02	USGS[1]		6/3/77	3.15
USGS[1]	East Branch Blade Creek Tributary	2/12/69	18.1	USGS[1]		7/15/80	0.03	USGS[1]		8/12/77	0.00
USGS[1]	Glade Creek At Mouth	4/18/80	10.3	USGS[1]		8/13/80	0.04	USGS[1]		7/18/80	46.6
USGS[1]		5/14/80	8.46	USGS[1]		9/13/80	0.05	USGS[1]		5/14/80	17.4
USGS[1]		6/16/80	9.37	USGS[1]	Sixprong Creek	3/4/82	0.75	USGS[1]		6/16/80	7.26
USGS[1]		7/15/80	8.77	USGS[1]	Alder Creek at Alderdale, WA	8/25/73	0.54	USGS[1]		7/15/80	1.20
USGS[1]		9/13/80	8.69	USGS[1]		2/14/77	0.65	USGS[1]		8/13/80	0.03
USGS[1]		9/15/80	11.1	USGS[1]		6/3/77	0.40	USGS[1]		9/15/80	0.00
USGS[1]		10/14/80	10.4	USGS[1]		8/12/77	3.35	USGS[1]		10/14/80	0.05
USGS[1]		11/18/80	13.5	USGS[1]	Pine Creek (1)	3/4/82	21.6	USGS[1]		11/18/80	3.65
USGS[1]		12/15/80	12.5	USGS[1]		4/19/82	14.5	USGS[1]		12/15/80	34.6
USGS[1]		1/13/80	12.5	USGS[1]		5/24/82	1.24	USGS[1]		1/13/81	56.9
USGS[1]		2/18/81	14.8	USGS[1]	Pine Creek (2)	3/4/82	22.6	USGS[1]		2/18/81	383
USGS[1]		3/16/81	10.5	USGS[1]		4/19/82	15.7	USGS[1]		3/16/81	44.1
USGS[1]		4/13/81	9.50	USGS[1]		5/24/82	1.38	USGS[1]		4/13/81	21.0
USGS[1]		5/12/81	10.4	USGS[1]	Pine Creek (3)	4/19/82	16.8	USGS[1]		5/12/81	11.9
USGS[1]		6/15/81	9.68	USGS[1]		5/24/82	1.46	USGS[1]		6/15/81	6.21
USGS[1]		7/13/81	9.72	USGS[1]	Pine Creek (4)	3/4/82	28.7	USGS[1]		7/13/81	0.77
USGS[1]		8/11/81	9.10	USGS[1]		4/19/82	15.8	USGS[1]		8/11/81	0.00
USGS[1]		9/15/81	11.0	USGS[1]		5/24/82	1.82	USGS[1]		9/15/81	0.00
USGS[1]		10/13/81	12.3	USGS[1]	Pine Creek (5)	3/4/82	30.7	USGS[1]	Luna Gulch Tributary	1/9/53	123
Ecology[2]		5/31/92	10.2	USGS[1]		4/19/82	17.2	USGS[1]	Squaw Creek	12/29/11	1.11
Ecology[3]		5/10/95	15.61	USGS[1]		5/24/82	1.98	USGS[1]		2/19/12	49.3
Ecology[3]		9/26/95	13.18	USGS[1]	Pine Creek (6)	3/4/82	29.4	USGS[1]		4/1/12	8.64
USGS[1]	Dead Canyon Tributary	1/23/82	0.20	USGS[1]		4/19/82	18.7	USGS[1]	Rock Creek	8/1/52	0.14
USGS[1]	Alder Creek near Bickleton, WA	5/13/64	0.41	USGS[1]		5/24/82	1.94	Klickitat Conserv. District[5]	Various	Various	N/A
USGS[1]		2/18/65	2.98	USGS[1]	Wood Gulch	2/14/77	0.10				
USGS[1]		2/1/67	4.32	USGS[1]		7/6/77	0.00				
USGS[1]		2/19/68	12.1	USGS[1]		8/12/77	0.00				
USGS[1]		3/7/73	1.03	USGS[4]	Rock Creek	1/19/53	2580				
USGS[1]		1/23/74	10.0	USGS[4]		12/2/55	2870				
USGS[1]		4/3/75	3.84	USGS[1]		2/9/61	1460				
USGS[1]		2/14/77	0.25	USGS[1]		2/3/63	1930				
USGS[1]		6/3/77	0.05	USGS[1]		12/22/64	7700				
USGS[1]		8/12/77	0.00	USGS[1]		2/14/77	2.29				
USGS[1]	Juniper Creek	3/4/82	0.30	USGS[1]		6/3/77	1.38				
USGS[1]	Fourmile Canyon near Plymouth, WA	1/23/82	91.4	USGS[1]		8/12/77	0.18				

Notes:

1 From USGS (1989)

2 From Davis (1993)

3 From Garrigues (1996)

4 From USGS (1964)

5 Misc. streamflow measurements from various WRIA 31 streams from mid-1990s to present. These data are being compiled and will be included in the final report.

The following sections present a summary of the surface water quantity conditions in each subbasin of WRIA 31. Where sufficient data were available, median and low flow conditions were calculated as the 50- and 90-percent exceedance values from the available streamflow data. The 90-percent exceedance flow is typically used to represent low flows because it is exceeded 90 percent of the time. In other words, flows are lower than the 90-percent exceedance flow only 10 percent of the time. The 50 percent exceedance flow is the best estimate of average streamflow conditions based on the available data.

Rock Creek Subbasin

Rock Creek drains 258 square miles in the western part of WRIA 31. Surface water discharge from the subbasin can be approximated using the USGS stream gage on Rock Creek near Roosevelt (Station 14036600; Figure 3-1). The gage was maintained for 6 water years, from 1963-1968. A water year is defined as starting on October 1 and ending on September 30 of the following year. Water years are numbered for the calendar year in which they end. For example, water year 1968 runs from October 1, 1967, to September 30, 1968. The entire period of record for this station occurred during a cool/wet PDO cycle (Figure 3-2). Therefore, streamflow statistics calculated using this gage record could overestimate long-term average conditions.

The mean daily flows for the six-year period of record for the Rock Creek gaging station range between 0 and 77 cubic feet per second (cfs), as presented on Figure 3-3. Rock Creek is typically a seasonal stream with no flow during the summer months. The exception is the summer of 1965 where flows were maintained due to an especially wet winter and spring (Figure 3-4). Results for monthly median (50 percent exceedance) and low (90 percent exceedance) flows are presented on Figure 3-4. Both median and low flows during August, September, and October are zero. Streamflow is only present on a consistent basis from December through May each year.

The Rock Creek hydrograph (Figure 3-3) demonstrates the relatively “flashy” nature of streamflow in this subbasin (high intensity, short duration flows). Following precipitation events, the rising limb of the hydrograph is relatively steep, indicating a rapid streamflow response as a result of the bedrock terrain and relatively steep slopes in the subbasin. It is inferred that snowmelt runoff in the higher elevation headwaters helps sustain flows into early spring. Although there are numerous springs mapped in the Rock Creek subbasin (discussed in Section 3.3), groundwater discharges from the Wanapum Basalt, through which the creek incises, provide insufficient baseflow to sustain flows into the dry season.

Wood/Alder Creeks Subbasin

The Wood/Alder Creeks subbasin drains 399 square miles in the west-central part of WRIA 31. Surface water flow from the subbasin can be approximated by the USGS stream gage on Alder Creek at Alderdale (Station 14034350). The gage was maintained for 8 complete water years from 1963-1968 and 1981-1982. For this assessment, analysis of the streamflow record for this station was limited to water years 1963-1968 to maintain a common period of record for comparison with Rock Creek data. Precipitation and runoff during the 1981-1982 was above average, and including these data would lead to greater streamflow estimates than derived from the 1963-1968 period. The entire period of record for this station occurred during a cool/wet PDO cycle. Therefore, streamflow statistics calculated using this gage record could overestimate long term average conditions.

The mean daily flows during water years 1963-1968 for the Alder Creek gaging station ranged from 0.6 to 5.2 cfs, as presented on Figure 3-3. Streamflow at the stream gage in Alder Creek is typically maintained throughout the year because the station was located immediately downstream from a perennial spring in Alder Creek canyon (Brown 1979). The spring provides a relatively constant discharge of around 0.8 cfs. Results for Alder Creek monthly median (50 percent exceedance) and low (90 percent exceedance) flows are presented on Figure 3-4. Both median and low flows are roughly the same as the spring discharge of 0.8 cfs during June through December. Streamflow increases during the winter as a response to increased precipitation and runoff.

Comparison of the Rock Creek and Alder Creek hydrographs (Figure 3-3) indicates that Alder Creek streamflows are generally more “flashy” than those measured in Rock Creek. The rising limbs of the Alder Creek hydrograph are typically more abrupt than the Rock Creek hydrograph. Like Rock Creek, Alder Creek is incised into basalt bedrock (primarily Saddle Mountains Basalt), but overburden (loess) covers much of uplands surrounding the stream valley in the upper subbasin (refer to Figure 2-3 in Chapter 2). However, the Rock Creek subbasin generally has more natural vegetation (grasslands, forest and shrublands) than the more heavily cultivated upper reaches of the Alder Creek subbasin (refer to Figure 2-15 in Chapter 2). Like the Rock Creek subbasin, there are several springs mapped in the Alder Creek subbasin (Section 3.3) but, with the exception of the large spring upstream of the mouth (discussed above), they appear to provide little baseflow to Alder Creek. Compared to Rock Creek, the Alder Creek subbasin receives less precipitation and less snowmelt runoff. We infer that less available snowmelt runoff is also a reason why Alder Creek flows are less sustained through the early spring season, and thus appear more “flashy” in response to individual rain events.

Glade/Fourmile Creeks and Kennewick Subbasins

There are no daily streamflow data available for either the Glade/Fourmile Creeks or Kennewick subbasins. Because of differences in elevations and precipitation patterns, the streamflow characteristics of these basins are quite different than other gaged basins within, or in the vicinity of, WRIA 31. Therefore it is difficult to estimate streamflow in these subbasins by correlation with streamflow data from other subbasins.

The only periodic streamflow data from the Glade/Fourmile Creeks subbasin are from five USGS peak flow gaging stations that were maintained mainly in the 1960s and 1970s (Figures 3-1 and 3-2; Tables 3-2 and 3-3). These five stations record only the highest (peak) streamflow that occurred during each water year of record. The two most important gages to examine are Fourmile Canyon (Station 14034100) and East Branch Glade Creek (Station 14034270) because they each represent a significant drainage area of the subbasin (Table 3-2). The Fourmile Canyon station was maintained for 8 years and indicated no streamflow for six of the eight years at that station. The East Branch Glade Creek station was maintained for 16 years and indicated no flow during eight of those years. Of the eight years with flow, four of those years only recorded a peak flow of 0.1 cfs, leaving only four years with significant peak flows (5 to 500 cfs).

There are no flow data (peak or miscellaneous measurements) available for the Kennewick subbasin. Incident precipitation and agricultural return flows are the two sources of intermittent streamflows in these subbasins.

The available peak flow data for the Glade/Fourmile Creeks subbasin suggest that the presence of surface water in that subbasin is intermittent, even during the winter, and should not be considered a consistent source of water at any time during the year. Because of similarities in precipitation between the Glade/Fourmile Creeks subbasin and the Kennewick subbasin, the presence of surface water should also be disregarded as a consistent source of water in the Kennewick subbasin.

Miscellaneous streamflow measurements have been taken at the mouth of Glade Creek on 22 occasions in 1980, 1981, 1992, and 1995 (Table 3-4). Historically there has been little or no flow in most reaches of Glade Creek during the summer (Garrigues 1996). The USGS peak flow data confirm that in most years there is no water in the upper reaches of the Glade Creek system. Garrigues (1996) concluded that most of the flow in Glade Creek is likely from groundwater (baseflow) and the late summer flow observed during the 1990s at the mouth of Glade Creek is likely due to shallow groundwater return flow from local irrigation.

3.1.2 Summary of Streamflow Characteristics

Streamflow characteristics vary between the four subbasins of WRIA 31 according to precipitation, elevation, and groundwater contribution. The only subbasins with year-round surface water on an annual basis appear to be Rock Creek and Wood/Alder Creeks. The Rock Creek and Alder Creek drainages are approximately the same size (Table 3-2). A direct comparison of surface water runoff between the Rock Creek subbasin and Wood/Alder Creeks subbasin is achieved by comparing the unit area runoff values from the stream gage in each subbasin (Figure 3-5). Unit area runoff (UAR) is the streamflow quantity divided by the contributing watershed area. For example, if the mean monthly discharge was 5 cfs at a stream gage having a watershed area of 100 square miles (mi^2), the UAR would be 5cfs/100 mi^2 or 0.05 cfs/mi^2.

As indicated on Figure 3-5, winter streamflow is typically sustained at much higher levels in Rock Creek than in Alder Creek, a result of greater winter precipitation within the Rock Creek subbasin. Rock Creek also typically has a greater magnitude and duration of spring runoff, which is likely the result of additional snow storage and melt runoff at higher elevations in the subbasin. This is consistent with the hydrologic regimes defined by DNR (refer to Section 2.5). A larger percentage of the Rock Creek subbasin is dominated by ‘rain-on-snow’ and ‘snow’ hydrologic regimes (see Figure 2-13 in Chapter 2) than the Wood/Alder Creeks subbasin.

The very limited streamflow in the Glade/Fourmile Creeks and Kennewick subbasins is nearly all baseflow (fed by groundwater discharge), except during periods of high intensity precipitation events. The baseflow component of streamflow in this subbasin is likely artificially higher than predevelopment conditions due to irrigation return flows.

3.1.3 Flood Flows

Estimates of the magnitude and frequency of floods (peak flows) are used by engineers in the design of bridges, culverts, dams and embankments and by land-use managers to assess the hazards related to floods (Sumioka et al. 1997). The typical way to report the frequency of flood events is using recurrence intervals. For example, a flood with a recurrence interval of 10 years has a 10 percent chance of occurring during any given year; a flood with recurrence interval of 100 years has a 1 percent chance of occurring in any given year. Generally at least 10 years of record, of which 75 percent of the years need to have peak flows greater than zero, is considered the minimum necessary to calculate peak streamflow statistics (U.S. Water Resources Council 1981). Of the peak flow data available for WRIA 31 (Table 3-3), only Alder Creek near Bickleton has a sufficient period of record.

Sumioka et al. (1997) estimated the magnitude and frequency of floods for Alder Creek near Bickleton as part of a flood frequency analysis of all suitable gaging station data for Washington State. The estimated instantaneous flood discharges for that station were 171, 530, 805, 1060, and 1370 cfs for 2-, 10-, 25-, 50- and 100-year floods, respectively.

3.2 Columbia River and Yakima River Flow Data

The Columbia River adjoins and is the largest source of appropriated water in WRIA 31 (discussed in Section 3.4). This source of water supply is of critical importance for the existing economy and population, and to support future growth within the watershed. This section provides a brief overview of available flow data for the main stem Columbia River adjoining WRIA 31, which includes the John Day Pool (Lake Umatilla) and the lower portion of McNary Pool (Lake Wallula). John Day Dam is located at river mile 216, just downstream of WRIA 31's western boundary. McNary Dam is located at river mile 292, near Plymouth (Glade/Fourmile subbasin) and downstream of the confluences of the Yakima and Snake Rivers with the Columbia (Figure 3-1).

The Federal Columbia River Power System (FCRPS) was constructed and is managed by three federal agencies: the Bonneville Power Administration, U.S. Bureau of Reclamation, and Army Corps of Engineers. The system consists of 31 dams on the main stem of the Columbia River and its tributaries. The dams are maintained for hydroelectric power production, irrigation, municipal and industrial uses, inland navigation, and flood control.

The Yakima River is also not part of WRIA 31; however, large quantities of water are imported from the Yakima River into the Kennewick subbasin for irrigation purposes by the Kennewick Irrigation District (KID) and the Columbia Irrigation District (CID). Therefore, available flow data from the portion of the Yakima River adjacent to these canal diversions are also summarized briefly in this section.

3.2.1 Columbia River Instream Flow Program

To provide for preservation of wildlife, fish, aesthetic, and other environmental values, and navigational uses, Washington Administrative Code (WAC) 173-563 defines minimum instantaneous and minimum weekly average flows throughout the year at seven main stem Columbia River locations including John Day and McNary Dams. These instream flow rules apply to surface water diversions from the main stem Columbia River in Washington State as well as groundwater withdrawals in the state issued after the establishment of minimum in-stream flows in 1980 and determined by Ecology to have a "significant and direct impact" on Columbia River flows.

These regulatory minimum instream flows are considered appropriated water rights with priority dates at the effective date of the WAC 173-563 rule (June 24, 1980). Therefore, the instream flow rights are junior (subordinate) to existing water rights subsequent to that date. The instream flow rights are also junior to any federal agency or tribal reserved water right established before that date. These pre-1980 rights are, therefore, referred to as "uninterruptible water rights," whereas post-1980 water rights are referred to as "interruptible." In other words, Ecology legally can interrupt use of the junior "interruptible" rights when minimum instream flow conditions defined in WAC 173-563 are not met. Communication with Ecology's Central Regional Office (CRO) indicates that Columbia River water rights have been subject to interruption under WAC 173-563 only one time since 1980 which was during the 2001 drought year. Based on historical flow data, Ecology anticipates that this condition should occur once every 20 to 26 years (Phil Crane, personal communication, June 17, 2004), and has included similar language as a condition on water right permits issued since 1980.

Section 3.4.4 summarizes the relative proportion of appropriated water rights for main stem Columbia River diversions in WRIA 31 having priority dates before and after the June 24, 1980 date.

Ecology may reduce the minimum instream flow requirements by up to 25 percent during low flow years as defined in WAC 173-562-050, and authorize water right appropriations that would conflict with the provisions of WAC 173-563, when deemed to be in the overriding public interest, as defined in WAC 173-563-080.

The WAC 173-563 instream flow rules do not apply to applications for new Columbia River water rights for which Ecology makes a decision on or after July 27, 1997. Water right applications considered for approval or denial after that date will be evaluated for possible impacts to fish and existing water rights in consultation with appropriate local, state, and federal agencies and Native American tribes. There are currently 27 water right applications for diversion of Columbia River water in WRIA 31, pending decision by Ecology. The applications request a sum total instantaneous right of 485 cfs.

3.2.2 Streamflow Data for Columbia River Near WRIA 31

Streamflow data for the Columbia River (adjacent to WRIA 31) is primarily collected by the U.S. Army Corps of Engineers (Corps) who operate both McNary and John Day Dams. Water that flows through the turbines in the dams and spills over the dams are reported in hourly and daily average discharge values. The period of record from McNary Dam (upstream) is from January 1, 1964 to the present. The period of record from John Day Dam (downstream) is from April 22, 1968 to the present. Only two years of streamflow data exist from the stretch of Columbia River adjacent WRIA 31 and above the Snake River confluence (i.e., in Kennewick area) – collected by the USGS near Pasco (gage #12154000) from October 1, 1964 to September 30, 1966.

Mean daily discharge values calculated from 34 years of data (water years 1969-2003) at both McNary and John Day Dams are presented in the upper plot on Figure 3-6.

Discharge values are given in units of thousands of cubic feet per second (kcfs). The Columbia at McNary Dam typically has slightly less flow than at the downstream John Day Dam. This difference is attributed to inflow from tributaries between the two dams including Rock, Alder and Glade Creeks from WRIA 31 as well as the John Day River and other tributaries from Oregon. Flows in the Columbia are highly regulated upstream of both McNary and John Day Dams. Peak streamflow is typically delayed until the summer (June-July) and minimum flows occur in early autumn (September-October). Peak precipitation in the Columbia Basin typically occurs in mid-winter, so the timing of peak streamflow in the Columbia is delayed by storage and release of water in snowpacks (upper elevations) and in reservoirs behind dams.

Mean daily discharge values were also compared for the concurrent period of record for McNary Dam and the USGS stream gage at Pasco (lower plot on Figure 3-6). The difference between the two hydrographs is the result of inflow primarily from the Snake River which joins the Columbia between the Pasco gaging station and McNary Dam. The streamflow regulation is evident particularly during the summer months in each hydrograph. The streamflow signal abruptly changes over a range of approximately 30 kcfs as the result of the diurnal fluctuations of power generation from the dams.

The 34 year period (water years 1969-2003) was also used to calculate 50 percent and 90 percent exceedance flows (average and low flows, respectively) at both McNary and John Day Dams (Figure 3-7). Exceedance flows were typically calculated monthly, although the months of April, June, and July were split based on time periods established for minimum instream flows (WAC 173-563-040). Based on these statistics, average flows (50 percent exceedance) met minimum average weekly instream flows (WAC 173-563-040[3]) for all time periods at both dams. During low flow years (90 percent exceedance) minimum average weekly instream flow requirements were met at both dams during October, November, December, January, February, March, April 1-15, June 16-30, and sometimes September. These instream flow minimums are typically not met at both dams from mid-April through August during these low flow years, although the June 16-30 time period does meet the regulatory minimums (Figure 3-7).

Figure 3-8 presents the past five water years of flow data at McNary and John Dams in comparison to regulatory instream flow minimums. Minimum instream flows are defined for the weekly average flows in thousands of cubic feet per second (kcfs). By regulation, the weekly average flow is defined as the average of the daily average flow from Monday through Sunday each week. These values were calculated and compared to minimum instream flow values for each dam from October 1998 through September 2003 (Figure 3-8). The only extended period when instream flows were not met was during the summer of 2001. 2001 was a particularly dry year in the Pacific Northwest which led to uncharacteristically low streamflow volumes throughout most of that year. Based on the statistics from the last 34 years of streamflow data for this stretch of the Columbia, there will be years like this where the summer minimum instream flows cannot be met. As stated above, Ecology CRO estimates that low flow conditions like those observed in 2001 should occur every 20 to 26 years.

In short, the main stem Columbia River minimum instream flow targets are met at both dams during statistically average water years, but not during the late season during statistically drier water years.

3.2.3 Streamflow Data for Yakima River Near WRIA 31

The availability of streamflow for the Yakima River, as it is relevant to WRIA 31 is from USGS streamflow data collected upstream of the Kennewick Irrigation District diversion point at Prosser Dam (USGS Station # 12508990 “Yakima River at Mabton”), and upstream of the Columbia Irrigation District diversion point at Horns Rapids Dam (USGS Station # 12510500 “Yakima River at Kiona”). Mean daily discharge values calculated from 32 years of data (water years 1971-2002) at these two USGS gages on the Yakima River are presented on Figure 3-9. Discharge values are given in units of cubic feet per second (cfs).

The Yakima River at Mabton typically has slightly less flow than at the downstream Kiona station. This difference is attributed to inflow from tributaries between the two stations. Flows in the Yakima are highly regulated upstream of the stations. Peak streamflow is typically delayed until the spring (March) and minimum flows occur during the late summer to early autumn (August-October) (Figure 3-9). Streamflow is held fairly constant, around 5,000 cfs, during much of the summer, presumably for irrigation of agricultural lands in the Yakima Valley. Streamflow typically drops sharply during July and remains low for the remainder of the water year. Flows gradually increase starting in late-October.

3.3 Groundwater Quantity

This section discusses general groundwater conditions for the principal geologic units within WRIA 31. From the surface down (youngest to oldest), the geologic units of primary significance with respect to WRIA 31 groundwater are:

- Alluvium and Flood Deposits (unconsolidated overburden)
- Saddle Mountains Basalt
- Wanapum Basalt
- Grande Ronde Basalt

Groundwater in WRIA 31 occurs mainly within the Columbia River Basalt (CRB) Group (Saddle Mountains, Wanapum, and Grande Ronde Basalts) and, in places, within some of the sedimentary units between basalt flows that collectively make up the Ellensburg Formation. Groundwater in the basalts occurs primarily at the tops of the individual flows (“flow top”) that became vesicular (porous) as gas bubbles escaped the flows during cooling, and/or at the flow bottoms where molten lava encountered water (“pillow”). Flow tops and pillows are usually porous and permeable, and therefore transmit water more readily than the intervening massive portion of the basalt flow “interior”. A flow top is normally present for each flow, while pillows range from relatively thick units to completely absent. Collectively, the flow tops and bottoms are referred to as interflow zones. In some locations, the interflows may be completely unproductive in terms of groundwater flow. Because a single basalt formation (e.g., Wanapum Basalt) encompasses multiple individual basalt flows, it can encompass multiple hydrostratigraphic units – a layered sequence of aquifer zones within the interflows separated by flow interiors serving as aquitards.

Geologic structure plays a large role in groundwater occurrence and flow in WRIA 31. WRIA 31 is dominated by an east-west-trending interior synclinal basin bordered to the north and south by anticline ridge systems with abundant folding and faulting. The interior basin is generally characterized by greater hydraulic conductivity within aquifer units and a larger capacity for groundwater supply. This is due in part to the thicker and more porous basalt interflow zones in the basin created when the basalt flows crystallized (cooled) under water in a large gently sloped depression (Packard et al. 1996). Sedimentary deposits are also thicker in basins than along ridge tops. These two factors lead to generally more productive aquifer zones in the interior basin area than in the anticlinal ridges to the north and south of it.

Geologic structures also affect the continuity and distribution of water-bearing zones within the basalt bedrock. Folds and faults can disrupt the continuity of the permeable interflow zones. For example, near Glade Creek, a series of faults offset the Wanapum and Saddle Mountains Basalts. Although the majority of the groundwater flow is downward across the WRIA, a local upward gradient from the Wanapum to the Saddle Mountains Basalt has been documented adjacent to this fault zone (Packard et al. 1996). Fault zones in the WRIA are often associated with low permeabilities that impede groundwater flow.

Erosional canyons can also limit lateral continuity of shallower groundwater-bearing zones. This dissection of the basalt surface can restrict lateral movement of groundwater, and thus limit the productivity of shallower aquifer systems. Deeply incised creek valleys are common in the western portion of the WRIA. Rock Creek, in particular, has eroded through the Wanapum Basalt, leaving disconnected islands of Wanapum Basalt that provide only minor sources of groundwater in some areas. The Saddle Mountains Basalt is similarly dissected in the Wood/Alder Creek subbasin and where it occurs in the eastern portion of the Rock Creek subbasin.

In some areas, the sedimentary units that are interbedded with the basalt flows are also water bearing units. These formations, however, change composition laterally and pinch out altogether in places. In the interior basin region, sedimentary units tend to be thicker and have a more coarse sandy composition and, thus, can form regionally significant water bearing units. In the Kennewick and Plymouth areas, flood gravels are present along the Columbia River; in these areas, the gravels make up a local unconfined aquifer that can be highly productive. However, overburden deposits in the rest of the WRIA are often unsaturated with only occasional isolated saturated pockets. In general, the localized deposits of alluvium can be highly variable in composition (from clay to gravel), with significant groundwater occurrence limited only to the coarse-grained (sand and gravel) portions. In the Glade/Fourmile subbasin, a shallow aquifer (referred to as the Alluvial Aquifer) occurs within the overburden.

3.3.1 Groundwater Recharge and Discharge

This section summarizes the current understanding of water entering (recharging) and leaving (discharging) the groundwater system in WRIA 31.

Groundwater Recharge

Groundwater recharge within WRIA 31 occurs primarily through the infiltration of precipitation and return flows from irrigation, and secondarily as seepage from surface water and other anthropogenic sources (e.g., septic system return flows). Figure 3-10 shows the USGS' estimated average annual groundwater recharge rates across WRIA 31 for current (1975) conditions (Bauer and Vaccaro 1990). These estimates were developed using a deep percolation model for the entire Columbia Plateau regional aquifer system to represent both predevelopment and developed (1975) land use conditions. "Predevelopment" refers to the time prior to significant land modification by human activity. Figure 3-11 presents the modeled predevelopment average annual groundwater recharge rates. The model used precipitation, temperature, streamflow, soils, land use, and altitude data to compute plant transpiration, soil evaporation, snow accumulation, snowmelt and sublimation, and evaporation of intercepted moisture, all of which factored into groundwater recharge estimates.

The modeling made use of daily climatic data for the period 1956-1977. Daily changes in soil moisture, plant interception, and snowpack were computed and accumulated. Recharge was computed when soil moisture exceeded the soil's field capacity. Irrigation return flows were considered in the modeling, based on data collected from irrigation districts throughout the Columbia Plateau. The reported results from the modeling represent the long-term average from simulation of the 22-year period.

The USGS' model provides average annual recharge estimates for both developed (1975) and predevelopment land use conditions. Deep percolation recharge simulations were conducted for discrete zones covering the majority of the model area. In regions with limited soils and stream gaging data, linear regressions were used to back calculate recharge for the full model area coverage. Figures 3-10 and 3-11 (1975 and predevelopment conditions, respectively) represent the combined results of the deep percolation simulations and the extrapolated recharge based on regression analysis.

The predevelopment recharge distribution was estimated by converting current commercial/industrial, irrigated agriculture, and dryland agriculture land uses to predevelopment land uses (e.g., sage, forest, grassland, sand/barren).

Using the USGS' estimated average annual recharge rates for developed (1975) and predevelopment conditions, the average annual groundwater recharge volume can be estimated for each subbasin. Because the USGS' recharge polygons represented a range in recharge rates, the midpoint of their range was assigned as the average for each polygon. A recharge rate of 12.5 inches/year was assigned for the >10 inch/year polygons. Annual recharge volumes by subbasin were then calculated for this assessment by multiplying the USGS' annual recharge rates by subbasin area. Table 3-5 presents the developed (1975) and predevelopment recharge volume estimates (acre-feet/year) by subbasin, and the sum for all of WRIA 31.

Table 3-5. Estimated Annual Groundwater Recharge Volumes by Subbasin

Subbasin	Subbasin Area (acres)	Predevelopment Recharge (acre-ft/year)	Developed (1975) Recharge (acre-ft/year)	% Change (Predevelopment to Developed)
Rock Creek	165,084	21,906	22,385	2%
Wood/Alder Creeks	255,282	24,690	28,092	14%
Glade/Fourmile Creeks	529,275	13,211	53,150	300%
Kennewick	70,596	1,598	20,464	1,180%
Total WRIA 31	**1,020,230**	**61,405**	**124,090**	**102%**

Using this methodology, an estimated 124,090 acre-feet of annual groundwater recharge occurs on average under developed conditions within WRIA 31, and 61, 405 acre-feet of annual groundwater recharge is projected to have occurred under predevelopment conditions. The recharge rate more than doubles between predevelopment and developed conditions due to the addition of irrigation return flows. Surface water (Columbia River) and groundwater (primarily from deep aquifers) were used for the widespread development of irrigated agriculture that started in the late 1960s and peaked in the 1970s (Bauer and Vaccaro 1990).

Under predevelopment conditions, recharge rates are greatest in the western part of the WRIA, in the Rock and Wood/Alder subbasins, and lowest in the Glade/Fourmile and Kennewick subbasins to the east. This reflects the natural decrease in precipitation from west to east. From predevelopment to developed conditions, recharge increases by only a small amount in Rock and Wood/Alder subbasins and by much greater amounts in the Glade/Fourmile and Kennewick subbasins where the majority of the WRIA's irrigated agriculture occurs (compare Figure 3-10 and 3-11). Under the developed condition evaluated by the USGS, recharge is greatest in the Glade/Fourmile subbasin by more than double that recorded in each of the other subbasins. Based on groundwater quality data (discussed further in Section 4) and groundwater level data (discussed below) from the Glade/Fourmile subbasin, the effect of this increased recharge is apparent in the shallower aquifer systems (Alluvial Aquifer and Saddle Mountains Basalt), but not in the deeper Wanapum Basalt aquifer.

The USGS estimates uncertainties of up to 25 percent in recharge estimates developed using the deep percolation model, with greater errors (as a percentage of recharge) occurring in more arid areas. The USGS' modeling of recharge relied upon climate data from a time period (1956-1977) within an inferred cool/wet cycle of the PDO. However, Bauer and Vaccaro (1990) also note that the average annual precipitation from the 22-year period used for the modeling was slightly less than the 100-year average annual precipitation. Despite the uncertainties, the USGS' recharge estimates represent the most comprehensive and reliable regional estimates available.

Groundwater Discharge

Most groundwater recharge entering WRIA 31 ultimately discharges to surface waters within the watershed or to the Columbia River; however, some groundwater enters and leaves the watershed via deep groundwater flow systems. Based on the available data, the regional groundwater discharge to surface water in WRIA 31 occurs along the Columbia River to the south and east of the WRIA. The most common forms of groundwater discharge within the WRIA are the springs. Figure 2-3, in Chapter 2, shows locations of springs across the WRIA. A detailed map of major spring locations is available for the Klickitat County portion of WRIA 31 (Brown 1979), and springs in Benton and Yakima Counties were based on mapped locations on USGS 7.5 minute topographic quadrangle maps.

Based on the available data, it is apparent that the majority of the springs are located in the western part of WRIA 31 - in the Rock Creek and Wood/Alder Creeks subbasins. These subbasins are characterized by more rugged terrain caused by streams eroding into and dissecting the underlying basalt units. The result is truncated basalt interflow zones, such that aquifer units in the basalts are discontinuous and disconnected from recharge sources. The water flowing in these discontinuous aquifer zones discharges along seepage faces in the canyons. The majority of the springs emanate from the Wanapum and Saddle Mountains Basalt units. The Grande Ronde Basalt is rarely exposed, and only a few springs were mapped as discharging from this unit in the southwest corner of Rock Creek subbasin along the Columbia River.

Only isolated springs are present in the eastern part of the WRIA in the more arid Glade/Fourmile Creeks and Kennewick subbasins. The terrain in these areas is gentler and creeks do not incise as deeply into underlying water bearing units. Although a shallow Alluvial Aquifer is present within the overburden of the Glade/Fourmile subbasin, the available data sources indicate only two major springs within the entire subbasin (Figure 2-3).

3.3.2 Groundwater Occurrence and Flow Directions

The groundwater characteristics of the principal geologic units in WRIA 31 (described in Section 2.3) are discussed briefly below (from oldest to youngest).

Grande Ronde Basalt. Although the Grande Ronde is present beneath all of WRIA 31, relatively few wells in WRIA 31 are completed in the Grande Ronde. The wells that are present are generally deep and used for irrigation. However, there are shallower wells screened in the unit and located in the Rock Creek subbasin near the Columbia River where the Grande Ronde is exposed at or near the surface. In some areas, groundwater elevations have declined with time in the overlying Wanapum Basalt, forcing a number of wells to be redrilled to tap the Grande Ronde Aquifer.

Figure 3-12 depicts groundwater elevation contours and inferred flow directions within the Grande Ronde and the locations of wells completed in the unit. The groundwater elevation contours were developed by the USGS (Bauer et al. 1985) and represent Spring 1983 conditions (prior to start of irrigation). Groundwater in the Grande Ronde generally flows from the higher elevations in the northern portion of the WRIA and ultimately discharges into the Columbia River. A significant portion of flow, however, is part of the regional groundwater flow system, originating north of the WRIA and discharging into the Columbia (Bauer et al. 1985).

Hydrographs presented on Figures 3-15 and 3-16 show groundwater levels over time for Grande Ronde wells located in the Rock Creek and Wood/Alder Creeks subbasins, respectively. These groundwater elevation data were obtained for this assessment from Ecology's Central Regional Office (CRO). Locations of wells monitored for water levels by Ecology CRO are shown as red circles on Figures 3-12, 3-13, and 3-14; those wells for which water level hydrographs are presented here are labeled with their unique well number assigned by Ecology. Except as noted on individual well hydrographs, the hydrographs for each subbasin are plotted with a consistent vertical scale so that the magnitude of groundwater elevation changes over time between wells in the subbasin is readily apparent.

Based on these hydrograph data, water levels in the Grande Ronde are generally stable with only minor declines since the late 1960s, when groundwater withdrawals for irrigation started to become a common practice. There are few groundwater elevation data for the Grande Ronde Basalt in WRIA 31. Based on comparison of regional groundwater elevation contours between the Grande Ronde and Wanapum Basalt units (Figures 3-12 and 3-13), it appears that throughout most of the WRIA the hydraulic gradient (and thus groundwater flow direction) is downward from the Wanapum into the Grande Ronde, except in the vicinity of the Columbia River.

Wanapum Basalt. The Wanapum Basalt provides the largest source of groundwater supply in WRIA 31, particularly for large capacity irrigation wells. Figure 3-13 depicts regional groundwater elevation contours for the Wanapum Basalt (Spring 1983 data), and the locations of existing wells completed in the unit used to develop those contours (from Bauer et al. 1985). This figure also includes contours representing change in groundwater elevation over a two year period from Spring 1983 to Spring 1985 (Lane and Whiteman 1989). Inferred groundwater flow directions are also depicted.

Groundwater in the Wanapum generally flows from north to south, but in some places local flow is directed toward individual drainage basins. A groundwater divide is aligned with the Horse Heaven Hills to the north and northwest within the WRIA. On the scale of the WRIA as a whole, groundwater in the Wanapum generally flows from this divide to the south and discharges into the Columbia River. However, where the Horse Heaven Hills separate the Glade/Fourmile and Kennewick subbasins, a groundwater divide separates flow to the northeast (toward Kennewick) from flow to the south, with discharge to the Columbia River in both cases. In the Glade Creek vicinity, groundwater in Wanapum is interpreted to flow toward the central syncline basin surrounding the main stem of Glade Creek, then flow south to the Columbia River. This extensive groundwater elevation trough may be due, in part, to long-term groundwater declines in response to large irrigation withdrawals. Farther to the west, groundwater flow in the Wanapum is interpreted to converge in the lower reach of Rock Creek (Figure 3-13), with presumed discharge to springs there. However, Brown (1979) mapped relatively few springs there (Figure 2-3).

The Wanapum is continuous beneath most of the WRIA except in the west where streams have locally eroded through its entire thickness. The inferred extent of the Wanapum (from Bauer et al. 1985) is shown in light blue on Figure 3-13. Based on comparison of groundwater elevation contours for Wanapum and the overlying Saddle Mountains Basalts (Figures 3-13 and 3-14), and evaluation of the Ecology CRO water level data from wells in different aquifers, the hydraulic gradient within the Wanapum and between the Wanapum and the Saddle Mountains Basalt is generally downwards. However, faults parallel to the Central Syncline induce a local upward gradient to the west of Glade Creek (Packard et al. 1996). The difference in head elevations between the Wanapum and the overlying Saddle Mountains indicates the presence of a confining layer that restricts flow between the two units. Groundwater quality data from the two aquifers in the Glade/Fourmile subbasin (discussed in Section 4) further supports limited groundwater flow between these units.

Lane and Whiteman's (1989) contours representing change in groundwater elevation in the Wanapum between 1983 and 1985 show significant declines in water levels in some areas of the WRIA during this two year period (Figure 3-13). The onset of irrigation in the late 1960s and its rapid growth in the early 1970s caused increased groundwater withdrawals. As a result, declines in head within the aquifer reach 40 feet over this two year period in the western Glade/Fourmile subbasin. Hydrographs for Wanapum Basalt wells completed in the four subbasins are presented in Figures 3-15 through 3-19, and show water level declines of varying magnitude.

Saddle Mountains Basalt. The Saddle Mountains Basalt is present in the central and eastern parts of the WRIA. A significant number of wells drilled into the Columbia River Basalts are completed in the Saddle Mountains Basalt, but yields are generally small to moderate. Figure 3-14 depicts the extent of the Saddle Mountains, groundwater elevation contours, and the wells completed in the unit (from Bauer et al. 1985), inferred flow directions, and contours of the change in groundwater elevation between 1983 and 1985 (Lane and Whiteman1989).

The groundwater divide along the Horse Heaven Hills (northern boundary of the WRIA) divides groundwater flow between the Yakima River Basin to the north and the Columbia River to the south. The saturated portion of the Saddle Mountains aquifer in the Kennewick subbasin is isolated by the Horse Heaven Hills anticline to the west, with groundwater flowing to the northeast into the Columbia River. The Saddle Mountains Basalt is generally unsaturated in the higher elevations along the Horse Heaven Hills.

Based on the change in groundwater elevation between Spring 1983 and Spring 1985, the water levels in the Saddle Mountains Basalt changed little across most of the WRIA and increased in a portion of the Glade/Fourmile subbasin (Figure 3-18). Where there was a measured decline in water levels, it is small (10 feet) compared to the declines observed in the underlying Wanapum in that area. Hydrographs for wells completed in the Saddle Mountains Basalt across the subbasins are presented on Figures 3-16 through 3-19. They show increases in water levels with time or, at most, minimal declines. The increases in water level are most pronounced in the Glade-Fourmile subbasin where large-scale irrigation, and thus irrigation return flow infiltration, occurs. The majority of water used for irrigation in this subbasin does not originate from wells completed within the Saddle Mountains, but instead is imported from the Columbia River, or pumped from the deeper Wanapum and Grande Ronde Basalts. Thus, the declining water levels due to pumping of the Wanapum are reflected in rising water levels due to infiltration of return flows into the Saddle Mountains. The presence of a local confining unit (Mabton Interbed) between the Wanapum and Saddle Mountains Basalt helps to hydraulically isolate the two aquifer systems.

3.3.3 Groundwater Conditions and Hydraulic Continuity by Subbasin

This section provides an overview of groundwater conditions by hydrologic subbasin within WRIA 31. This includes a qualitative assessment of long term hydrographs for wells completed in the Saddle Mountains, Wanapum, and Grande Ronde Basalt units within each subbasin. Hydrographs were plotted for select wells that were monitored by the Ecology CRO and a property owner (Andrews Farms) that provided data for this assessment. Wells selected for hydrograph development were based on length of water level records, distributed geographic coverage, and variable depth of well completions into the different Basalt units. Figures 3-15 through 3-19 present the hydrographs for the 13 selected wells, segregated by subbasin, and their locations are labeled on the groundwater elevation maps for each of the respective basalt units (Figures 3-12, 3-13, and 3-14). Well information for the selected wells is presented in Table 3-6.

Table 3-6. Information Regarding Wells Used for Water Level Hydrographs

Subbasin	Well ID	Ground Surface Elevation (ft)	Depth to Top of Open Area (ft)	Elevation of Top of Open Area (ft)	Completion Aquifer
Rock	211234	1680	495	1185	Wanapum
	211231	1938	508	1430	Wanapum
	211232	580	116	464	Grande Ronde
Wood/Alder	211238	2220	215	2005	Saddle Mountains
	208632	910	1102	-192	Wanapum
	211244	2305	1474	831	Grande Ronde
Glade/Fourmile	211259	650	345	305	Saddle Mountains
	211260	500	264	236	Saddle Mountains
	211269	298	372	-74	Wanapum
	211266	435	525	-90	Wanapum
	211249	730	1469	-739	Wanapum
	208682	1252	1415	-163	Grande Ronde
Kennewick	211270	442	555	-113	Wanapum

This section also addresses hydraulic continuity between groundwater and surface water, based on available geologic, groundwater flow, and spring discharge information. Hydraulic continuity refers to the hydraulic interaction between surface and groundwater within the watershed. A surface water body that loses water to the groundwater system is referred to as "losing." Conversely, surface waters that receive flow from groundwater are referred to as "gaining." There are varying degrees of hydraulic continuity between groundwater and surface water depending largely on the horizontal and vertical position of the groundwater aquifer relative to the surface water body and the presence or absence of low-permeability materials or structural controls between the two. In WRIA 31, shallow alluvial aquifers, where present, typically have significant hydraulic connection with streams. Conversely, groundwater in deeper basalt aquifers has limited connection to streams within the WRIA and principally discharges to the Columbia River.

Rock Creek Subbasin

There is limited information available about groundwater conditions in the Rock Creek subbasin. The subbasin is dominated by incised stream valleys and discontinuous aquifer systems created by the incised canyons. The Saddle Mountains Basalt is absent in all but this subbasin’s eastern area, and the Wanapum is deeply eroded, occasionally exposing the Grande Ronde in places including along the mainstem of Rock Creek. Although a majority of wells are completed in the Wanapum, the water supply from this unit is generally limited and can be unreliable because of the lack of aquifer continuity. In addition, some groundwater supply is taken from springs in the subbasin, particularly in the north where springs are most abundant (Brown 1979).

Hydrographs are presented on Figure 3-15 for select wells within the subbasin. The plots are presented at a larger scale for this subbasin than for the others, based on the limited variations in water levels over time. The hydrographs for the two wells completed in the Wanapum show minor variability and no significant trend in water levels with time. Well 211232 was drilled into the Grande Ronde and depicts an abrupt water level rise in the early 1980s followed by a relatively stable trend until 1992 when the well was decommissioned.

Hydraulic connection between the groundwater in the Wanapum Basalt and surface water in this subbasin is theoretically good, based on the abundance of springs in the area (Figure 2-3) and the exposure of interflow zones by incised canyons. Overburden is scarce, and the Wanapum is generally exposed at the surface, allowing for a direct hydraulic connection between surface water and groundwater. Although there are considerable springs mapped in this subbasin, the quantity of groundwater discharging into Rock Creek is insufficient to maintain year-round flow, as discussed in Section 3.1.1.

Wood/Alder Creeks Subbasin

The Wood/Alder Creeks subbasin is similar to the Rock Creek subbasin in that it has numerous incised stream valleys and springs. The shallow basalt units are highly dissected, but not to as great a degree as in the Rock Creek subbasin. Deeper wells completed in the Wanapum below the base of the stream valleys can produce considerable water since these deeper aquifers are not dissected and thus have greater continuity. Many of the domestic wells in the northern part of the subbasin are drilled into the Selah and Mabton sedimentary interbeds of the Ellensburg Formation. These interbeds are thicker and sandier in the Bickleton vicinity and, thus, have a greater potential for groundwater production than elsewhere in the subbasin (Brown 1979).

Rabanco provided for this assessment more detailed information about the shallow groundwater system in the area of the Roosevelt Regional Landfill, located northeast of Roosevelt between Wood Gulch and Pine Creek (Mains 2004). In this area, the Pomona

Member of the Saddle Mountains Basalt forms the shallowest aquifer in the area and is underlain by the Selah Formation which acts as a thick regional aquitard. Hydraulic conductivities in the Pomona vary between $4x10^{-4}$ and $5x10^{-5}$ cm/s. Groundwater flow velocities in the Pomona are laterally variable and have been calculated to be anywhere from 10 to 2,000 ft/yr. Hydraulic conductivity of the underlying Selah aquitard is measured to be orders of magnitude lower than in the Pomona (10^{-7} and 10^{-8} cm/s). Consequently, the Selah effectively limits downward migration of shallow groundwater to deeper aquifer systems in this area.

Figure 3-16 depicts hydrographs for wells completed in the Saddle Mountains, Wanapum, and Grande Ronde Basalts across the subbasin. The majority of groundwater withdrawals in this subbasin are from the Wanapum Basalt. Well 208632 shows over a 200 foot decline in groundwater elevation within the Wanapum since 1978. By contrast, water levels in well 211238, completed in the overlying Saddle Mountains Basalt, remain constant or even increase slightly during the period of record. Such patterns demonstrate large-scale pumping of irrigation water from the Wanapum Basalt and corresponding increased recharge into the Saddle Mountains Basalt from irrigation return flows. Water levels in the Grande Ronde Basalt remain relatively constant with only minor declines over the 20-year record, reflecting the limited number of wells completed in this unit.

Surface water and groundwater in the basalts appear to be well connected across much of the subbasin. The exposure of Saddle Mountains and Wanapum Basalts at the ground surface in the west, central, and southern portions of the subbasin and the presence of numerous springs indicate that groundwater is in direct connection with stream valleys. However, as in the Rock Creek subbasin, groundwater discharge quantities are insufficient to maintain year-round streamflow in this subbasin, except near the mouth of Alder Creek (refer to Section 3.1.1).

Glade/Fourmile Creeks Subbasin

The southern portion of the Glade/Fourmile subbasin is dominated by irrigated agriculture that relies primarily on water from the Columbia River and deep Wanapum Basalt aquifers. Groundwater flow is generally north to south from the Horse Heaven Hills anticline to the Columbia River. Across most of the subbasin, the hydraulic gradient is downward from the Saddle Mountains to the underlying Wanapum, but there is evidence that northwest of Glade Creek the gradient reverses and water flows upward from the Wanapum into the Saddle Mountains (Packard et al. 1996). The interior basin region of the subbasin is generally characterized by thicker Basalt flows, which translates into thicker aquifer units. The sedimentary Mabton and Selah interbeds generally act as local aquitards, isolating the Saddle Mountains from the Wanapum and creating a considerable difference in head between the two basalt units.

Hydrographs for wells in each of the basalt units are presented on Figures 3-17 and 3-18. For the Saddle Mountains Basalt, well 211259, and to a lesser degree well 211260, both show marked increases in groundwater elevation since the mid- to late-1970s (Figure 3-17). These increases track the steady use of irrigation, with return flow infiltration, in the subbasin. Water level declines on a similar order of magnitude are observed for some wells completed in the Wanapum Basalt (wells 211249 and 208682; Figure 3-18), reflecting the increase in groundwater pumping from this aquifer since the mid- to late-1970s. Most notably, well 208682 shows declines of greater than 300 feet since 1978.

The well was redrilled twice to accommodate declining water levels, with the last redrill tapping into the top of the Grande Ronde Basalt. Water level declines in Wanapum wells 211266 and 211269 and increases in Saddle Mountains well 211260 are more muted than the other trends in the subbasin. These wells are located adjacent to the Columbia River (Figures 3-13 and 3-14). The good connection between the Wanapum and Saddle Mountains Basalts and the Columbia River, as well as the weak upward gradient in the area, may help buffer changes in water levels, compared to those observed in the areas farther north. In addition, irrigation along the Columbia relies more on river diversions than Wanapum pumping, resulting in less decline in local Wanapum water levels.

Hydraulic connection between the groundwater and surface waters in the Glade/Fourmile Creeks subbasin appears to be more limited than in the western part of the WRIA. Only a few isolated springs are mapped (Figure 2-3), indicating a limited amount of groundwater discharge. Additionally, most of the subbasin is covered by a layer of unconsolidated overburden, so that there is no direct connection between the basalt units and the land surface in these areas. However, there is also no aquitard separating the Saddle Mountains aquifer and the overburden, which can allow infiltrating surface water to move downward through the overburden into the Saddle Mountains. The larger stream valleys do incise into the top of the Saddle Mountains providing the potential for direct groundwater- surface water interaction in localized areas. However, overall, the lack of streamflow in this subbasin confirms that groundwater discharge provides negligible baseflow to streams of this subbasin.

Kennewick Subbasin

The Kennewick subbasin has a distinct groundwater flow system from the other subbasins in WRIA 31. The Horse Heaven Hills anticline forms a northwest-southeast trending groundwater divide, which directs groundwater flow in this subbasin to the northeast into the Columbia River. Complex faulting and folding occurs along the anticline, truncating water bearing interflow zones within the basalt units. Specifically, Golder (2001) notes thrust faults in the Richland Junction and Kennewick area that parallel the Horse Heaven Hills anticline system. The fault planes are generally filled with fine grained pulverized rock (gouge material and fault breccia) that creates a local low-permeability boundary to aquifers within the basalt unit.

Additionally, a thick flood gravel unit was deposited along the eastern flank of the Horse Heaven Hills at the end of the last glaciation. These gravels form the uppermost unsaturated aquifer in the region. Groundwater migrates from the gravels into the underlying Saddle Mountains Basalt, recharging that aquifer (Golder 2001). Wells in the Kennewick area are completed in the flood gravels, Saddle Mountains, and Wanapum Basalts.

Ecology CRO has been regularly monitoring water levels in only one well in the Kennewick subbasin, thus a single hydrograph (Wanapum Basalt) is prepared (Figure 3-19). Water levels in the well are stable and show little decline over the 7-year period of record (1988-1995). Data from more wells in the area and over a longer period of time would provide better control on long term water level trends in the aquifer units of the Kennewick subbasin.

Since much of the subbasin is covered by permeable gravel deposits, the hydraulic connection between surface water and groundwater should be very good. In addition to Columbia River diversions, water from the Yakima River is diverted into the subbasin via the Columbia Canals that traverse the flood gravel areas. Much of the canals' lengths are unlined, and they thus lose considerable water. In the USGS' modeling of predevelopment and developed-condition groundwater recharge, the Kennewick subbasin had the largest relative increase – nearly 13 fold – in recharge when changing from predevelopment to developed conditions (Table 3-5). In the absence of long-term water level data, these modeling results suggest that shallow groundwater systems are being recharged significantly by irrigation return flows and canal leakage. Springs are not mapped within the subbasin.

3.4 Water Rights

This section summarizes the amount of water currently appropriated for use through existing water rights in each subbasin. Applications for new water rights are also discussed. Actual water consumption is typically very different from the amount of water appropriated for use within the basin. Therefore, estimates of actual water use are included in Section 3.5.

3.4.1 Methods

The water rights analysis for this Level 1 Assessment summarizes recorded water rights (certificates and permits), water claims, and applications for new water rights by size and type of use in WRIA 31. For clarification, the terms water right application, permit, certificate, and claim are defined as follow:

- An *Application* is a request submitted to obtain a new water right or transfer/change an existing water right from the Department of Ecology. There are separate applications for these two processes. For this assessment, only applications for new water rights are evaluated. Change applications are not evaluated here since they can not enlarge the original right and thus do not represent a request for new water.
- A *Permit* is permission given to water right applicants by the state to develop a water right. Water rights are perfected when water right applicants follow the provisions outlined in their permit, using water for the purposes and up to the limits (instantaneous rate and annual volume) stated in the permit. Water right permits remain in effect until the water right certificate is issued, if all terms of the permit are met, or the permit has been canceled.
- A *Certificate* is issued by Ecology to certify that water users have the authority to use a specific amount of water under certain conditions. These conditions are based on beneficial use of water as defined by the water right permit. The water right certificate is a legal document recorded at the county auditor's office. The certificate completes the process of obtaining a water right. Once a certificate is issued, no expansion (enlargement) is allowed under the water right.
- A *Claim* is a statement of claim to a water use that began before the State Water Codes were adopted, and is not covered by a permit or certificate. A claim may

represent a valid water right if it describes a surface water use that began before 1917 or a groundwater use that began before 1945, a water right claim that was filed with the state during an open filing period designated under RCW 90.14 (the Water Rights Claim Registration Act), or is covered by the groundwater exemption.

All water rights are issued with the authority for both maximum instantaneous quantities (maximum rate of water use at any one time), and the maximum annual volume of water allowed. Water right applicants are only assigned an instantaneous quantity, as the annual volumes are assigned during the permitting stage. Water right statutes also include specific provisions that can result in relinquishment of all or a portion of a water right due to discontinued beneficial use. Therefore, only active water right permits, certificates, claims, and applications are analyzed in this report. All rejected, cancelled, or relinquished water rights were not considered. Note that the status of water right applications is not known and Ecology can approve or deny these applications.

The analysis of water rights in this section is based solely on information from Ecology's Water Rights Tracking System (WRTS), provided by Ecology's Central Regional Office in February 2004. The location of the point of withdrawal for each water right record is recorded in WRTS to the nearest section in the township/range/section system. Water rights, claims, and applications were therefore assigned to specific WRIA 31 subbasins based on the location of the center point of the section of withdrawal on record. Single water rights with multiple sources were assigned a location based on the first listed point of withdrawal.

A water right can have more than one recorded beneficial use, but the amount allocated for each of these uses is not listed in the WRTS. For the purposes of this assessment, the first beneficial use listed was assumed to be the primary beneficial use.

The WRTS database is a compilation of the information provided by water users through the application process. Many records, especially claims, are missing information including amount of water allocated.

Because of the missing data and the inexact nature of identifying the location of water right diversions/withdrawals based on the section, the information provided here is considered preliminary and is intended to provide a general understanding of water appropriation within WRIA 31. More detailed assessment of individual water rights would require obtaining the specific water right file from Ecology.

3.4.2 Analysis

Table 3-7 presents the existing information on water rights permits and certificates, water claims, and water right applications by subbasin and differentiated by primary beneficial use. In Table 3-7, water right certificates + permits are separated into surface water and groundwater sources. Note that springs are listed as a surface water source in the WRTS database.

Based on the WRTS database, there are 459 water right certificates and permits issued in WRIA 31. The total water appropriated through these water rights is 2,072,181 acre-feet per year. One surface water certificate in the Glade/Fourmile subbasin is designated for hydroelectric power production at McNary Dam. This right is for 1,266,577 acre-feet/year, which represents approximately 61 percent of total water appropriations for WRIA 31. Since hydroelectric power production is primarily a non-consumptive water use, it is useful to examine the water appropriated without the McNary Dam certificate. The total water appropriated without the McNary Dam right is 805,603 acre-feet per year.

Excluding the McNary Dam water right, the relative proportion of the total WRIA 31 annual water rights (certificates + permits) among the four subbasins is as follows:

- Rock Creek: 1 percent;
- Wood/Alder Creeks: 2 percent;
- Glade-Fourmile Creeks: 84 percent; and
- Kennewick: 13 percent

Normalizing the appropriated water by subbasin area, the appropriated annual water uses per acre (acre-feet/year per acre, or feet/year) are as follow:

- Rock Creek: 0.04 feet/year;
- Wood/Alder Creeks: 0.06 feet/year;
- Glade-Fourmile Creeks: 1.3 feet/year; and
- Kennewick: 1.4 feet/year.

Table 3-7. Recorded Water Rights, Claims, and Applications by Beneficial Use for Each Subbasin

Groundwater Certificates and Permits			Surface Water Certificates and Permits			Claims			Applications		
Primary Listed Beneficial Use	Number of Records	Sum of Listed Qa (AFY)	Primary Listed Beneficial Use	Number of Records	Sum of Listed Qa (AFY)	Primary Listed Beneficial Use	Number of Records	Sum of Listed Qa (AFY)	Primary Listed Beneficial Use	Number of Records	Sum of Listed Qi (cfs)
Rock Subbasin											
Domestic Multiple	1	144	Commercial/Industr.	1	4,851	Domestic General	61	0	Highway	1	1
Irrigation	7	475	Domestic	2	3	Irrigation	4	0	Irrigation	3	0
Not Indicated	8	959	Not Indicated	8	24	Not Indicated	12	0	Stock Watering	2	0
Stock Watering	5	183	Stock Watering	7	24	Stock Watering	272	0			
			Wildlife	2	1						
Subbasin Totals:	21	1,762	Subbasin Totals:	20	4,903	Subbasin Totals:	349	0	Subbasin Totals:	6	1
Wood / Alder Subbasin											
Commercial/Industr.	1	30	Irrigation	2	2,568	Domestic	151	0	Domestic	2	1
Domestic Multiple	1	8	Not Indicated	6	69	Not Indicated	9	0	Heat Protection	1	2
Irrigation	12	11,043	Stock Watering	1	1	Stock Watering	316	0	Irrigation	11	81
Municipal	1	104							Stock Watering	1	12
Not Indicated	11	1,383									
Stock Watering	3	152									
Subbasin Totals:	29	12,720	Subbasin Totals:	9	2,638	Subbasin Totals:	476	0	Subbasin Totals:	15	96
Glade / Fourmile Subbasin											
Domestic Multiple	9	432	Commercial/Industr.	1	9	Domestic General	84	0	Commercial/Industr.	4	3
Fire Protection	1	121	Irrigation	89	595,936	Irrigation	4	0	Domestic Multiple	5	21
Frost Protection	1	131	Not Indicated	11	3,879	Not Indicated	11	0	Fire Protection	1	1
Irrigation	33	64,613	Power	1	1,266,577	Stock Watering	37	0	Irrigation	35	468
Not Indicated	41	4,556	Stock Watering	14	8,239				Mining	2	1
Stock Watering	2	19	Wildlife Propagation	1	3,455				Stock Watering	1	46
									Storage	1	20
Subbasin Totals:	87	69,871	Subbasin Totals:	117	1,878,095	Subbasin Totals:	136	0	Subbasin Totals:	49	560
Kennewick Subbasin											
Commercial/Industr.	6	1,292	Heat Exchange	2	2,720	Domestic General	838	0	Irrigation	28	63
Domestic	2	37	Irrigation	8	36,745	Irrigation	123	0	Stock Watering	4	1
Domestic	18	2,048	Municipal	2	19,280	Not Indicated	12	0			
Fire Protection	1	19	Not Indicated	7	3	Stock Watering	38	0			
Irrigation	72	8,169	Rec./Beautification	1	0						
Not Indicated	48	31,534	Stock Watering	1	27						
Stock Watering	8	319									
Subbasin Totals:	155	43,417	Subbasin Totals:	21	58,775	Subbasin Totals:	1011	0	Subbasin Totals:	32	64
WRIA Totals:	**292**	**127,769**	**WRIA Totals:**	**167**	**1,944,411**	**WRIA Totals:**	**1972**	**0**	**WRIA Totals:**	**102**	**720**

Notes: AFY: Acre-feet/year; cfs: Cubic feet per second.

Table 3-8 lists the WRIA 31 water rights (permits + certificates) by recorded water source, with differentiation by groundwater and surface water sources. Note that the source names are taken verbatim from those listed in WRTS. The analysis of water right certificates and permits reveals that an significant quantity of surface water (1.9 million acre-feet/year) is appropriated for use in the WRIA, with more than 99.9% of that annual volume from the Columbia River (including Lake Umatilla/Lake Wallula) system. The Columbia River is the source for approximately 94 percent of all appropriated water in WRIA 31 (Table 3-8). Excluding the McNary dam hydroelectric water right, the Columbia River is the source for approximately 84 percent of total annual appropriations in the WRIA. As discussed in Section 3.1, the availability of surface water in WRIA 31, apart from the Columbia River, is extremely limited.

Table 3-8. Sources for Groundwater and Surface Water Certificates and Permits for all of WRIA 31 (Including McNary Dam Water Right)

Source	Annual Water Right Volume in Acre-Feet/Year	Percentage of Total Appropriated Rights
Groundwater Certificates and Permits		
WELL	120,409	5.8%
INFILTRATION TRENCH	5,600	0.3%
Not Identified	1,760	0.1%
Total Groundwater:	*127,769*	*6%*
Surface Water Certificates and Permits		
COLUMBIA RIVER	1,701,416	82%
LAKE UMATILLA	214,129	10%
LAKE WALLULA	28,633	1.4%
POND	90	<0.01%
SPRING	68	<0.01%
CHAPMAN CREEK	50	<0.01%
PINE CREEK	16	<0.01%
ROCK CREEK	6.0	<0.01%
KNAPP SPR *	1.0	<0.01%
SIX PRONG CREEK	1.0	<0.01%
IMRIE SECTION 18	0.6	<0.01%
IMRIE SECTION 19	0.6	<0.01%
Total Surface Water:	*1,944,411*	*94%*
Totals for WRIA:	**2,072,181**	**100%**

The total annual water rights were also compiled for the entire WRIA based on the listed primary beneficial use of the right (Table 3-9). It is clear that the majority of water appropriated for use in WRIA 31 is for hydroelectric power production (roughly 61%). Again, ignoring the water right for McNary Dam, it becomes clear that irrigation is the dominant appropriated use of water in WRIA 31 (89%) (Table 3-10).

Table 3-9. Summary of Water Rights by Primary Listed Beneficial Use (Including McNary Dam Water Right)

Primary Beneficial Use	Appropriated Annual Water Rights in Acre-Feet/Year	Percentage of Total Appropriated Rights
Power	1,266,577	61%
Irrigation	719,664	35%
Not Indicated	42,475	2.0%
Commercial/Industrial	6,181	0.3%
Municipal	19,384	0.9%
Stock Watering	8,965	0.4%
Wildlife Propagation	3,459	0.2%
Heat Exchange	2,720	0.1%
Domestic Multiple	2,634	0.1%
Fire Protection	140	0.01%
Frost Protection	131	0.01%
Domestic General	37	0.00%
Fish Propagation	3	0.00%
Recreation/Beautification	0	0.00%
Total	**2,072,371**	**100%**

Note: Total annual water right quantity differs slightly from that in Table 3-8 because this quantity includes reservoir rights.

Table 3-10. Summary of Water Rights by Primary Listed Beneficial Use (Excluding McNary Dam Hydroelectric Right)

Primary Beneficial Use	Appropriated Annual Water Rights in Acre-Feet/Year	Percentage of Total Appropriated Rights
Irrigation	719,664	89%
Not Indicated	42,475	5.3%
Commercial/Industrial	6,181	0.8%
Municipal	19,384	2.4%
Stock Watering	8,965	1.1%
Wildlife Propagation	3,459	0.4%
Heat Exchange	2,720	0.3%
Domestic Multiple	2,634	0.3%
Fire Protection	140	0.02%
Frost Protection	131	0.02%
Domestic General	37	0.00%
Fish Propagation	3	0.00%
Recreation/Beautification	0	0.00%
Total	**805,794**	**100%**

Note: Includes reservoir rights.

The spatial distribution of appropriated water rights (certificates + permits) is shown on Figure 3-20. In general terms, the largest concentration of water rights occurs in the Kennewick subbasin, corresponding to the largest concentration of population. The rest of the rights are dispersed among the other subbasins, with the largest appropriations and number of rights located near the Columbia River (Figure 3-20). The distribution of applications for new water rights has a similar spatial distribution as the issued certificates and permits (Figure 3-21).

The distribution and nature of water rights certificates/permits and applications by subbasin, based on the WRTS records, are summarized briefly below. As discussed above, none of the WRTS records for water claims have recorded water quantities.

Rock Creek Subbasin

The Rock Creek subbasin has a total of 396 water right certificates, permits, claims and applications. The majority of these are claims (349), and there isn't any information about the total amount of water associated with these claims. Most of the water claims in the subbasin have stock watering listed at the primary beneficial use (Table 3-7). According to WRTS, the largest annual appropriation of water is a single commercial/industrial surface water right (Columbia River diversion) for 25,416 acre-feet per year in the far southwestern corner of the subbasin. However, Ecology recently approved an application for change to this water right to add cooling water for electrical power generation (Cliffs Project) as a use; that change is not yet reflected in the WRTS database. As part of that change, Goldendale Aluminum's annual total water use was documented as 17,048 acre-feet/year, which includes 4,851 acre-feet/year of consumptive water use and 12,197 acre-feet/year of non-consumptive water use (Klickitat County Water Conservancy Board 2002). The large non-consumptive use portion is returned to the Columbia River so it has no net effect on WRIA 31 groundwater or streams; consequently only the 4,851 acre-feet/year consumptive use is considered throughout this assessment. Because of this single large right, commercial/industrial use represents the single largest water use appropriated in this subbasin as depicted graphically on Figure 3-22. Table 3-11 presents the total annual groundwater and surface water rights by water source in the Rock Creek subbasin.

Table 3-11. Cumulative Recorded Water Rights by Source, Rock Creek Subbasin

Source	Annual Water Right Volume in Acre-Feet/Year	Percentage of Total Appropriated Rights
Groundwater Certificates and Permits		
WELL	1,762	26%
Total Groundwater:	*1,762*	*26%*
Surface Water Certificates and Permits		
LAKE UMATILLA	4,851	73%
SPRING	44	< 0.01%
ROCK CREEK	6	< 0.01%
IMRIE SECTION 18	1	< 0.01%
IMRIE SECTION 19	1	< 0.01%
Total Surface Water:	*4,903*	*74%*
Totals for Subbasin:	**6,664**	**100%**

Note: Only the non-consumptive portion of the Goldendale Aluminum right is considered.

According to the WRTS, there are 6 applications for new water rights pending decision by Ecology in this subbasin. Instantaneous withdrawal rates requested are listed for only one of the applications (1 cfs). The distribution of this subbasin's pending applications, by section, is depicted on Figure 3-21.

Wood/Alder Creeks Subbasin

The Wood/Alder Creeks subbasin water rights are issued primarily for irrigation use (89 percent; Figure 3-22). Of these rights, a majority of the water is from groundwater sources. Twelve groundwater rights comprise 83 percent of all the water appropriated annually in the subbasin (Table 3-12). Two Columbia River surface water rights for irrigation account for the remaining 17 percent of annual water appropriations. Most of the 476 water claims in the subbasin are for either domestic/general use or stock watering (Table 3-7).

There are 15 recorded applications for new water rights pending in this subbasin. The total quantity of additional water applied for is 96 cfs (annual volumes are not recorded for applications). Eleven of the 15 applications are for irrigation use and they comprise 81 of the 96 cfs total for the subbasin (Table 3-7).

Table 3-12. Cumulative Recorded Water Rights by Source, Wood/Alder Creeks Subbasin

Source	Annual Water Right Volume in Acre-Feet/Year	Percentage of Total Appropriated Rights
Groundwater Certificates and Permits		
WELL	12,720	83%
Total Groundwater:	*12,720*	*83%*
Surface Water Certificates and Permits		
COLUMBIA RIVER	2,568	17%
CHAPMAN CREEK	50	0.3%
PINE CREEK	16	0.1%
SPRING	2	0.01%
KNAPP SPR *	1	0.01%
SIX PRONG CREEK	1	0.01%
Total Surface Water:	*2,638*	*17%*
Totals for Subbasin:	**15,358**	**100%**

Glade/Fourmile Creeks Subbasin

The water rights issued for the Glade/Fourmile Creeks subbasin account for 93 percent of all the water rights appropriated in WRIA 31. The water rights for the subbasin are dominated by one right issued for hydroelectric power generation at McNary Dam for 1.26 million acre-feet per year (Table 3-7). Ignoring this water right due to its primarily non-consumptive use, irrigation becomes the dominant listed beneficial use for water rights in the subbasin (97 percent of total; Figure 3-23). Annual appropriations in this subbasin represent 83 percent of the WRIA's total appropriations, when the McNary Dam right is excluded.

There are currently 33 and 89 irrigation water rights in the subbasin from groundwater and surface water sources, respectively. The largest amount of water appropriated for irrigation comes from surface water sources, primarily the Columbia River (Table 3-13). There are 35 additional water right applications for irrigation use listed in the WRTS database. The majority of the 136 water claims in the subbasin are for domestic/general use (Table 3-7).

There are 49 recorded applications for new water rights pending in this subbasin, with a cumulative instantaneous rate of 560 cfs. One of the applications is for storage (20 cfs). Excluding that application, nearly 87 percent of the water applied for is to be used for irrigation (Table 3-7).

Table 3-13. Cumulative Recorded Water Rights by Source, Glade/Fourmile Subbasin (Excluding McNary Dam Right)

Source	Annual Water Right Volume in Acre-Feet/Year	Percentage of Total Appropriated Rights
Groundwater Certificates and Permits		
WELL	69,871	100%
Total Groundwater:	*69,871*	*10%*
Surface Water Certificates and Permits		
COLUMBIA RIVER	395,610	58%
LAKE UMATILLA	209,276	31%
LAKE WALLULA	6,514	1%
SPRING	17	0%
Total Surface Water:	*611,417*	90%
Totals for Subbasin:	**681,288**	**100%**

Kennewick Subbasin

Water rights in the Kennewick subbasin are more evenly split among surface and groundwater sources than the other subbasins (Table 3-7). Essentially all of the surface water rights are for Columbia River diversions. The primary beneficial use listed for a majority of the water indicated in the subbasin is irrigation (Figure 3-23). Note that there is a large number of groundwater rights without a purpose of use recorded in WRTS, and those rights constitute more than 31,500 acre-feet/year or roughly 31 percent of the total appropriations for the subbasin. The Kennewick subbasin is the only subbasin within WRIA 31 that has water rights recorded for municipal use (total of 19,280 acre-feet per year). The City of Kennewick has the largest municipal water right (15,680 acre-feet per year) for diversion from the Columbia River. The City of Kennewick also has two groundwater rights for a total of 10,400 acre-feet per year, for which primary beneficial use was not indicated in WRTS. This WRTS information is consistent with the information presented in the City of Kennewick's Water System Plan (2002). The majority of the 1,011 recorded claims in the subbasin are for domestic/general use (Table 3-7).

There are 32 recorded applications for new water rights pending in this subbasin, with a cumulative instantaneous rate of 64 cfs, essentially all of which (63 cfs) is requested for irrigation use (Table 3-7).

Table 3-14. Cumulative Recorded Water Rights by Source, Kennewick Subbasin

Source	Annual Water Right Volume in Acre-Feet/Year	Percentage of Total Appropriated Rights
Groundwater Certificates and Permits		
WELL	36,057	35%
INFILTRATION TRENCH	5,600	5.5%
Not Identified	1,760	1.7%
Total Groundwater:	*43,417*	*42%*
Surface Water Certificates and Permits		
COLUMBIA RIVER	36,561	35.8%
LAKE WALLULA	22,119	21.6%
POND	90	0.1%
SPRING	5	<0.01%
Total Surface Water:	*58,775*	58%
Totals for Subbasin:	**102,192**	**100%**

3.4.3 Summary of Water Rights

Appropriated water rights in WRIA 31 are dominated by Columbia River diversions and groundwater withdrawals (84 and 16 percent, respectively, of total annual appropriations, excluding the McNary Dam hydroelectric water right). Water imported from the Columbia River system, especially for irrigation purposes, will add to surface water runoff and groundwater recharge within the WRIA study area. This concept is addressed in greater detail in the water balance for the WRIA subbasins (Section 3.6).

Excluding the McNary Dam hydroelectric water right, the overwhelming majority of water rights are issued with irrigation listed as the primary beneficial use (89% of current annual water appropriations). Likewise, 85 percent of the new (instantaneous) water right quantities applied for in the WRIA is for irrigation use.

3.4.4 "Interruptible" Water Rights for Main Stem Columbia River

According to Ecology's WRTS database, there are 132 water rights (permits + certificates) issued for the main stem Columbia River with points of diversion within WRIA 31 (thus considered WRIA 31 water rights). These rights collectively represent a cumulative annual volume of roughly 1.96 million acre-feet/year. Of these, 42 rights have priority dates after June 24, 1980, and are referred to as "interruptible rights" as discussed in Section 3.2.1. As stated in Section 3.2.1, these water rights have been subject to interruption only one time since 1980 – occurring in 2001 – and it is expected that these low flow conditions would occur once every 20 to 26 years.

These "interruptible rights" total approximately 1.33 million acre-feet of water annually. However, a majority of this water is for instream use (roughly 1.27 million acre-feet/year for hydroelectric power generation at McNary Dam), leaving approximately 67,000 acre-feet/year of water rights for out-of-stream use that is subject to regulation (interruption) by Ecology under the provisions of WAC 173-563. The remaining 90 water rights have priority dates on or before June 24, 1980, with a cumulative appropriated annual volume of approximately 630,000 acre-feet/year that can be considered "uninterruptible" under WAC 173-563.

In short, excluding the McNary Dam hydroelectric water right, approximately 10 percent of the appropriated annual volume of Columbia River water for WRIA 31 is "interruptible" under WAC 173-563, and 90 percent is not, based on the priority date. Based on Ecology's WRTS database, there are currently 27 pending applications for new Columbia River water rights in WRIA 31; the cumulative instantaneous diversion rate for these applications is 485 cfs.

3.5 Current Water Use

Actual average water use is typically less than the amount of water appropriated for use by water rights. This occurs because water rights recorded in the WRTS may represent rights no longer being exercised and/or development of the appropriated resources may be constrained by a variety of factors. Therefore, it is important to make estimates of water use, rather than rely on appropriated water rights, in order to develop a preliminary water balance and begin assessment of the availability of water to meet future demand within each of the four WRIA 31 subbasins. Water use is typically not metered with the exception of large water purveyors (e.g., municipalities and Public Utility Districts). However, this is gradually changing following the state's promulgation of the Metering Rule (Chapter 173-173 WAC) that became effective in January 2002. This rule requires metering of all new permits for surface water diversion, existing surface water rights greater than 1 cfs, and any right for surface water or groundwater withdrawal that is determined by Ecology to affect surface water containing critical salmonid stocks. To date, Ecology's priority for metering water use has been their 16 identified "fish critical" WRIAs, of which WRIA 31 is not one.

Because water use across WRIA 31 is not accurately measured, preliminary estimates of actual water use are developed for this Level 1 Assessment based on available information and numerous assumptions. The water use estimates are intended to represent average current conditions. In fact, actual use may vary for any given time period due to factors such as temperature, precipitation, or cropping practices.

For this assessment, water use is estimated for the major categories of irrigation, residential, and non-residential (e.g., commercial/ industrial) use. A discussion of the methods and results of estimating each of these water uses is presented below. From the information gathered in Section 3.4, it is clear that the largest amount of water appropriated in the WRIA is for irrigation use. Therefore, estimating the actual amount of water used for irrigation is of greatest importance, and is discussed first.

3.5.1 Estimated Irrigation Water Use

Annual irrigation water use (acre-feet/year) by subbasin is estimated by multiplying the irrigated area (acres) in that subbasin by a representative annual irrigation requirement, or water duty (feet/year). While it is a simple methodology, the challenge is obtaining, for each subbasin, an accurate accounting of the irrigated acreages by crop type and assigning a representative average water duty for each crop type.

Because of the importance of estimating irrigation water use for this assessment, the WRIA 31 Planning Unit recommended retaining the services of IRZ Consulting LLC, of Hermiston, Oregon, to provide estimates of irrigated acreages for each WRIA 31 subbasin, and an assessment of crop rotation within those acreages. IRZ Consulting provides expertise in using satellite imagery for agricultural planning as well as irrigation engineering and water conservation, and has considerable experience with irrigation practices in WRIA 31.

Irrigation Acreage Estimates

Using satellite imagery and crop rotation records from 2001, IRZ Consulting estimated total non-irrigated (dryland) and total irrigated acreages for each of the four subbasins. The total irrigated acres were divided into acres of permanent crops (orchards and vineyards) and acres of seasonal row crops (potatoes, corn, beets, alfalfa, etc.). Figure 3-24 presents IRZ Consulting's agricultural land use classification (dryland, irrigated row crop, irrigated permanent crop) for WRIA 31 based on analysis of the recent satellite imagery. Table 3-15 presents their corresponding acreage estimates by subbasin.

Table 3-15. Agricultural Acreages by Subbasin

Subbasin	Total Acres	Total Acres in Agricultural Production	Total Dryland Acres	Acres of Permanent Crops	Acres of Row Crops	Total Irrigated Acres	% of Total Acres in Irrigation
Rock Creek	165,084	7,284	7,284	0	0	0	0%
Wood/Alder Creeks	255,282	43,366	39,568	759	3,039	3,798	1%
Glade/Fourmile Creeks	529,275	315,088	184,079	11,303	119,706	131,009	25%
Kennewick	70,596	14,937	12,158	2,746	32	2,778	4%
Total WRIA 31	**1,020,237**	**380,675**	**243,089**	**14,808**	**122,777**	**137,585**	**13%**

Data from IRZ Consulting (2004).

As is evident visually from Figure 3-24, the vast majority (95 percent) of WRIA 31's irrigated land occurs in the Glade/Fourmile subbasin, with 3, 2, and 0 percent occurring in Wood/Alder, Kennewick, and Rock Creek subbasins, respectively. The Glade/Fourmile subbasin also includes 76 percent of the dryland farming acreage in WRIA 31, with Wood/Alder, Kennewick, and Rock Creek subbasins comprising 16, 5, and 3 percent, respectively.

In addition to estimating the agricultural acreages, IRZ Consulting estimated typical row crop rotations as a percentage of total row crop acres, based on 2001 records from five representative farms in the Glade/Fourmile subbasin. The crop rotation estimates account for the practice of double cropping (e.g., peas followed by sweet corn during same growing season), as well as planting wheat cover crops for erosion control. Consequently, the sum of the individual crop percentages within a rotation equates to greater than 100 percent of the total row crop acres. This is important since a crop's water duty applies to a single growing season. Where double cropping occurs, both crops' full water duties must be accounted for in estimating annual irrigation water use for that acreage.

Table 3-16 presents the typical crop rotation percentages, taken as the average of percentages from the five representative farms in the Glade/Fourmile subbasin. Because this subbasin comprises nearly all irrigated agriculture in WRIA 31, this typical rotation is assumed to apply to all subbasins for this assessment. Multiplying each crop's relative percentage by total row crop acres provides the" effective acres" for each row crop that are used in calculating irrigation water use by subbasin. By accounting for double cropping and cover crop planting, the total effective irrigated row crop acreage for WRIA 31 is approximately 211,400 acres (Table 3-16), which is 72 percent higher than the total acres of row crops in irrigation (approximately 122,800 acres; Table 3-15).

Table 3-16. Effective Row Crop Acreages Accounting for Typical Row Crop Rotation

		Effective Row Crop Acreages by Subbasin			
Row Crop	**% of Total Row Crop Acres**	**Rock Creek**	**Wood/ Alder**	**Glade/ Fourmile**	**Kennewick**
Wheat (cover)	62%	0	1,890	74,457	20
Potatoes	31%	0	930	36,630	10
Sweet Corn	20%	0	614	24,181	6
Wheat	19%	0	565	22,265	6
Field Corn	17%	0	529	20,829	6
Carrots	8%	0	249	9,816	3
Grass Seed	5%	0	152	5,985	2
Sugar Beets	3%	0	103	4,070	1
Onions	3%	0	85	3,352	1
Peas	2%	0	73	2,873	1
Alfalfa	1%	0	43	1,676	0
Total	**172%**	**0**	**5,233**	**206,134**	**55**

Crop rotation percentage data from IRZ Consulting (2004). Refer to text for details.

Based on their experience in the watershed, IRZ Consulting estimated that the permanent crop acres are split approximately 50 percent in orchards (e.g., apples and cherries) and 50 percent in vineyards. Table 3-17 presents the corresponding estimates of irrigated orchards and vineyards by subbasin.

A copy of IRZ Consulting's (2004) report is included as an attachment at the end of this chapter.

Table 3-17. Estimated Acres of Orchards and Vineyards

Subbasin	Total Acres in Permanent Crops	Assumed Acres in Orchards	Assumed Acres in Vineyards
Rock Creek	0	0	0
Wood/Alder	759	380	380
Glade/Fourmile	11,303	5,652	5,652
Kennewick	2,746	1,373	1,373
Total WRIA 31	**14,808**	**7,404**	**7,404**

Data from IRZ Consulting (2004).

Representative Water Duties

To generate irrigation use estimates on the subbasin scale, it is necessary to apply estimated crop water duties that are representative on that large scale. Because 95 percent of the irrigated land in WRIA 31 occurs within the Glade/Fourmile subbasin, it is appropriate to apply water duties that are principally representative for this area of the WRIA. During the June 2004 watershed reconnaissance, we discussed water duties with a pair of the larger irrigators in the Glade/Fourmile subbasin. From these discussions, it is clear that water duty can differ across the subbasin, partly as a result of soil type. In general terms, the northern portion of the subbasin is underlain by finer-grained (siltier) soils with greater moisture holding capacity; the southern portion of the subbasin has areas of sandier soils with higher infiltration rates and lower moisture holding capacity. This is consistent with hydrologic soil types mapped across the subbasin, with Type A soils (higher infiltration, lower moisture retention) occurring only in the southern portion of the subbasin (refer to Figure 2-8 in Chapter 2). Consequently, for this subbasin, higher water duties are generally required in the south than in the north to ensure the same water availability within the crops' root zones throughout the growing season.

The Washington Irrigation Guide (USDA 1985) provides representative consumptive water use estimates for numerous crop types at locations within and near WRIA 31, including Bickleton, McNary, Kennewick, and Prosser. For a given crop cultivated in WRIA 31, these water duties typically vary by 20 to 40 percent for these four locations. Bickleton is in a slightly cooler and wetter portion of the WRIA than the Glade/Fourmile subbasin in which most of the irrigation use occurs. However, it is also in an area of extensive Type C (greater moisture holding capacity) soils, such as those that occur in some of the western portion of the Glade/Fourmile subbasin. Consequently, Bickleton was retained as one of the four stations included in the averaging of water duties applied to all of WRIA 31. Although actual crop consumptive uses vary annually based on temperature and precipitation, the Irrigation Guide values are widely accepted as reasonable estimates in water use planning.

Irrigation efficiencies of 76 and 70 percent were applied to the consumptive uses for row crops and orchards, respectively, to estimate the annual water duties (water applied).

Irrigation efficiency is the ratio of the water quantity consumed by the plant to the water quantity applied, and accounts for losses to evaporation during application and return flow (deep percolation and runoff). Recognizing that a variety of irrigation methods are used within WRIA 31, the efficiency applied to row crops was the average of those for new generation center pivot (85-90 percent) and old generation center pivot systems (75 percent) (Benton County Water Conservation Board 2000). These values do not include return flow. For this assessment, we reduced that average by 5 percent to account for return flow, resulting in an estimated 76 percent efficiency for row crops. For orchards/vineyards, that document's 75 percent efficiency (minus return flow) was reduced 5 percent for return flow, resulting in an estimated 70 percent efficiency.

Since the relative percentage of orchard acreage in apples vs. cherries is uncertain, it is assumed for this assessment to be split 50 percent for each. Given that the Irrigation Guide consumptive uses for these two crops are very similar, the 50/50 assumption does not add significant uncertainty to the estimate of total irrigation use for any subbasin. In addition to the Irrigation Guide consumptive uses, an assumed 2 feet/year of water for cooling/frost protection was added to the orchard water duty.

The assumed annual water duties for each crop are listed in Table 3-18.

Irrigation Water Use Estimates

Using the acreage and average water duty estimates described above, annual irrigation water use (acre-feet/year) for each crop is estimated by multiplying the irrigated area (acres) by the annual water duty applied for that crop (feet/year). This provides estimated irrigation use for each crop type in each subbasin. The estimates are then summed to estimate total irrigation use on the subbasin scale. Table 3-18 presents, for each subbasin, the estimated annual irrigation quantities for each crop, along with the cumulative irrigation water use for all crops.

Because Kennewick Irrigation District (KID) and Columbia Irrigation District (CID) divert and convey Yakima River water largely for residential lawn and garden (non-agricultural) irrigation in the Kennewick subbasin, this residential irrigation use was estimated from information obtained from the districts. Bureau of Reclamation authorizes KID to divert water from the Yakima River at Prosser Dam, from where it is conveyed via the Chandler Canal to the Chandler Power and Pumping Plant. At Chandler, approximately 56 percent of the total water diverted is used to hydraulically pump (by suction) the water for irrigation into KID's gravity-flow canal system starting at Chandler. However, this "power water" is returned to the Yakima River, never reaching WRIA 31, and is thus not considered here. Under its contract with Bureau of Reclamation, KID is currently allowed up to 95,855 acre-feet/year of irrigation water subject to maximum monthly allotments and rationing during drought years (2004 allotment is rationed to 82 percent). KID estimates conveyance, seepage, and overspill losses from their mostly unlined canals totaling approximately 26 percent, thus delivering approximately 71,000 acre-feet/year of water to its customers for use on 20,200 irrigable acres. CID diverts 60,385 acre-feet/year of water from the Yakima River near Horn Rapids (north of West Richland), from where it gravity flows in mostly unlined canals to irrigate roughly 10,000 acres within the Kennewick subbasin. Lacking other information, we estimate conveyance losses from the CID canals as an equivalent percentage (26 percent) to those of the KID canals.

Accounting for the losses, we estimate KID and CID together provide almost 116,000 acre-feet/year of water to customers for irrigation in the Kennewick subbasin. The estimated irrigation use for the IRZ-identified (assumed commercial) permanent crop acreages in the Kennewick subbasin (14,000 acre-feet/year) was then subtracted from this total, leaving 102,000 acre/feet-year that we identify as residential irrigation (Table 3-18).

Note that KID has received a new water right to divert 22,610 acre-feet/year of Columbia River water for irrigation of 4,637 acres. Development of this new water right is currently in the planning stage (pumping and conveyance facilities not yet built), thus it is not factored into these irrigation use estimates.

By this analysis, we estimate that nearly 623,000 acre-feet/year of water is used for irrigation supply on average across all of WRIA 31. The Glade/Fourmile subbasin accounts for 79 percent of this use (492,000 acre-feet/year), while the Kennewick and Wood/Alder subbasins respectively account for 19 and 2 percent of the total WRIA irrigation use (116,000 and 15,000 acre-feet/year, respectively). As discussed above, no irrigated acreage is identified in the Rock Creek subbasin, therefore, no irrigation use is calculated for it.

This relative distribution of irrigation use by subbasin is consistent with the distribution of irrigation water rights (92, 6, and 2 percent of total in Glade/Fourmile, Kennewick, and Wood/Alder subbasins, respectively), when it is considered that the vast majority of irrigation water used in the Kennewick subbasin is permitted from the Yakima River system (KID and CID diversions) as described above. Note that KID and CID are in the process of evaluating a Pump Exchange Proposal with Bureau of Reclamation, in which their Yakima River diversions (gravity flow) would be replaced by pumped diversions from the Columbia River downstream of the Yakima River confluence. Pending environmental and economic evaluation, the outcome of that proposal remains uncertain.

Table 3-18. Estimated Irrigation Water Use by Subbasin

		Rock Creek		Wood/Alder		Glade/Fourmile		Kennewick	
Crop	Avg. Water Duty in ft/yr	Effective Acres in Irrigation	Estimated Water Use in ac-ft/yr	Effective Acres in Irrigation	Estimated Water Use in ac-ft/yr	Effective Acres in Irrigation	Estimated Water Use in ac-ft/yr	Effective Acres in Irrigation	Estimated Water Use in ac-ft/yr
Seasonal Row Crops									
Wheat (cover)	0.9	0	0	1,890	1,784	74,457	70,287	20	19
Potatoes	2.9	0	0	930	2,666	36,630	104,996	10	28
Sweet Corn	2.2	0	0	614	1,364	24,181	53,746	6	14
Wheat	2.8	0	0	565	1,601	22,265	63,055	6	17
Field Corn	2.9	0	0	529	1,514	20,829	59,641	6	16
Carrots	2.2	0	0	249	547	9,816	21,533	3	6
Grass Seed	3.8	0	0	152	582	5,985	22,916	2	6
Sugar Beets	3.9	0	0	103	399	4,070	15,715	1	4
Onions	3.5	0	0	85	295	3,352	11,633	1	3
Peas	2.2	0	0	73	161	2,873	6,358	1	2
Alfalfa	3.6	0	0	43	154	1,676	6,073	0	2
Permanent Crops									
Orchards*	4.9	0	0	380	1,865	5,652	27,776	1,373	6,748
Vineyards	5.0	0	0	380	1,899	5,652	28,276	1,373	6,869
Irrigation Supplied by KID and CID									
Residential**		0	0	0	0	0	0	27,454	102,000
Subbasin Totals		0	**0**	5,992	**14,832**	217,437	**492,005**	30,255	**115,734**
Proportion of Total WRIA 31 Use:			**0%**		**2%**		**79%**		**19%**
WRIA 31 Estimated Total Annual Irrigation Use in Acre-Feet/Year:								**622,571**	

*: Assumed average water duty for orchards is average of net irrigation requirement for apples and cherries, plus 2 ft/yr for cooling water.

**: Back-calculated based on total acreage and water distribution data obtained from KID and CID, and subtracting acreage and estimated use for (assumed commercial) permanent crops.

3.5.2 Estimated Public Water System Water Use

Information on the public water systems (PWS) located in WRIA 31 was compiled from the state Department of Health (DOH) PWS databases, and divided into subbasins based on the location of each PWS water source. From the DOH databases, 36 Group A and 157 Group B PWS (193 total PWS) were identified in WRIA 31. A Group A PWS serves 15 or more residential connections, or 25 or more people per day for 60 or more days per year. A Group B PWS serves 2 to 14 residential connections or less than 25 persons per day. More than three quarters of the PWS for WRIA 31 are located in the Kennewick subbasin, corresponding to the largest population in the WRIA. The City of Kennewick operates the largest PWS in the WRIA, serving 60,780 people in 2000, or 95 percent of the PWS-supplied population in the WRIA. In the DOH database, PWS water use includes water used for both residential (domestic) and non-residential (e.g., commercial and industrial) purposes. Table 3-19 presents the DOH PWS information for the 193 PWS in WRIA 31. Water use estimated for these two generalized use categories is discussed in the following subsections.

PWS-Supplied Residential Usage

Information regarding water used from the City of Kennewick PWS was obtained from the City of Kennewick Water System Plan (2002). The City of Kennewick produced a total volume of approximately 3,406 million gallons of water in 2000, of which 69.4 percent, or 7,251 acre-feet/year, was used for residential purposes (Table 3-19). For a served residential population of 60,780, this equates to a residential (domestic) per capita water use of approximately 110 gallons per person per day (termed gallons per capita day; gpcd).

An attempt was made to find contact information and contact all other WRIA 31 PWS serving over 100 people as determined from the DOH database. The Plymouth Water District reportedly produced a total volume of 3.2 million gallons of water in 2003. According to the DOH database, the Plymouth Water District serves a population of 190, all through residential connections. Based on this reported 2003 use, the per capita residential use is only 46 gpcd, which is quite low relative to most estimates used for water system planning.

The Roosevelt Water District, operated by Klickitat Public Utility District (PUD), is also included in Table 3-19 although it was not included as a PWS in the DOH database. Although the water district is not included in the database, communications with Klickitat PUD revealed that they currently serve 26 connections, and the average daily demand is 434 gpd per equivalent residential unit (ERU) with an estimated 3 persons per ERU. This equates to a per capita use of 145 gpcd. All water produced by the Roosevelt Water District was assumed to be for residential use.

Note that current USGS (Lane 2004) county-wide domestic water use estimates are 115 gpcd for all of Benton County and 157 gpcd for all of Klickitat County (both counties extend beyond the geographic limits of WRIA 31).

Annual residential water use for all other PWS was estimated by multiplying the reported resident population served by an assumed average watershed-wide use of 120 gpcd, and converting that volume of water into acre-feet per year. The 120 gpcd estimate is considered reasonable based on information in Kennewick's Water System Plan, discussions with Klickitat PUD, and the other available information for WRIA 31.

PWS-Supplied Non-Residential Usage

The DOH PWS database reports the number of residential and total connections. The difference between the total number of connections and residential connections was assumed to be the number of non-residential connections. Non-residential use water estimates tend to be more uncertain than residential use estimates since there can be far greater variability in non-residential use per non-residential connection (e.g., a spigot at a public park vs. a large industrial facility). Based on the PWS information, there are 1,990 non-residential connections in WRIA 31. Of those, 1,808 are served by the City of Kennewick PWS.

Information on the total non-residential water use by the City of Kennewick PWS was obtained from the City of Kennewick Water System Plan (2002). Municipal use, which is categorized by City of Kennewick separately from domestic, commercial, and industrial uses, is included as non-residential use in this assessment. City of Kennewick produced approximately 3,406 million gallons of water in 2000, of which 30.6 percent (or 3,202 acre-feet/year) was considered non-residential based on 1998-2000 historical category usage (Table 3-19).

Excluding the City of Kennewick, there are six WRIA 31 PWS serving more than five non-residential connections. An attempt was made to find contact information and contact these PWS to obtain their estimates of annual water use, but none could be reached. However, three of the PWS were parks so an estimate of 34 gpd per non-residential connection (averaged for a year-round water use) was applied to each park based on information from Maryhill State Park, located on the Columbia River just downstream of WRIA 31 (Watershed Professionals Network 2004). Lacking other data, this estimate of water use per non-residential connection was applied for other parks, resorts, and schools (Table 3-19).

In addition to the PWS serving more than five connections, the DOH database was queried for Group A PWS that reportedly only served one non-residential connection. The assumption in this case was that these systems are using a relatively large amount of water in order to be classified as a Group A system with only one connection. There were eight such PWS in WRIA 31. An attempt was made to find contact information and contact these PWS to obtain their estimates of annual water use. The Roosevelt Regional Landfill was the only one of these PWS reached and they estimated their water use at 12,000 gpd, which is approximately 13 acre-feet/year (Table 3-19).

All remaining PWS with unresolved non-residential water use estimates were cross-referenced to Ecology's WRTS database to find if they could be associated with a specific water right. This process identified three PWS which were assumed to be using their entire annual water appropriation.

The methodologies outlined above provided water use estimates for 1,901 of the 1,990 non-residential PWS connections in WRIA 31. Lacking other data, water usage for the 89 remaining non-residential connections was estimated using the water use per non-residential connection that was calculated from the City of Kennewick Water System Plan (e.g., 3,202 acre-feet/year distributed over 1,808 non residential connections). This corresponds to roughly 1.77 acre-feet/year per non-residential connection, or 158 acre-feet/year for those 89 connections. Although it is a highly uncertain assumption, the non-residential water use represented by these connections is expected to be a small percentage of estimated total water use in any one subbasin.

Table 3-19. Estimated Public Water System Water Use (Sheet 1 of 4)

PWS ID	PWS Name	Grp	Res. Popul.	# Res. Connect.	# Non-Res. Connect.	# Total Connect.	Estimated Annual Residential Water Use (ac-ft/yr)	Estimated Annual Non-Residential Water Use (ac-ft/yr)
	Rock Creek Subbasin							
37516	GOLDEN RANCH WATER SUPPLY	B	23	10	0	10	3	0
39940	EKONE WATER SYSTEM	B	10	4	1	5	1	2
40989	PASTURE POINT TRIBAL FISHING ACCESS	B	0	0	13	13	0	0.5
22644	CALDWELL-DAVIS FARM	B	5	2	0	2	1	0
	Rock Creek Subbasin Total:		*38*	*16*	*14*	*30*	*5*	*2*
	Wood / Alder Creeks Subbasin							
51613	**ROOSEVELT REGIONAL LANDFILL [1]**	**A**	**0**	**0**	**1**	**1**	**0**	**13**
51610	BICKLETON SCHOOL WATER SUPPLY	A	6	2	3	5	1	0.1
51344	SUNDALE FRUIT COMPANY LLC	A	21	5	10	15	3	18
54513	NORTH ROOSEVELT WATER ASSN	A	18	13	2	15	2	4
58926	BLUEBIRD INN	A	0	0	2	2	0	0.1
20018	ROOSEVELT SCHOOL DISTRICT 403	B	0	0	1	1	0	0.04
20020	1ST PRESBYTERIAN CHURCH BICKLETON	B	4	1	0	1	1	0
20456	MCBRIDE HEREFORD RANCHES INC	B	10	3	0	3	1	0
39936	JENSEN WATER SYSTEM	B	6	4	0	4	1	0
39943	WHITMORE SYSTEM 1, LAWRENCE	B	11	5	0	5	1	0
	ROOSEVELT WATER DISTRICT [1, 2]	--	91	26	0	26	15	0
	Wood/Alder Subbasin Total:		*167*	*59*	*19*	*78*	*25*	*35*
	Glade / Fourmile Subbasin							
48846	CUSTOM AG SERVICES	A	0	0	1	1	0	2
49666	BYBEE, CLYDE W.	A	16	5	1	6	2	2
50370	WATTS BROS CORN PROCESSING PLANT	A	0	0	1	1	0	2
58215	NINE CANYON RANCH	A	49	12	3	15	7	5
47776	COLUMBIA CREST WINERY	A	0	0	3	3	0	5
55466	DESERT HOUSE CAFE & GROCERY	A	15	8	2	10	2	4
50397	ROOSEVELT PARK	A	0	0	3	3	0	5
45615	ALDERDALE WATER ASSN	A	115	30	0	30	15	0
55467	WATTS BROS FARMS	A	37	13	10	23	5	18
55463	PATERSON ELEMENTARY SCHOOL	A	3	2	1	3	0	2
60459	PATERSON HEIGHTS WATER ASSN	A	56	25	4	29	8	7
58342	**PLYMOUTH WATER DISTRICT [1]**	A	190	66	0	66	10	0
50408	CROW BUTTE PARK	A	8	2	62	64	1	2
41369	AGRI NORTHWEST GRAIN ELEVATOR	B	2	1	2	3	0	4
36446	RIVER RIDGE WINERY	B	2	1	4	5	0	7
41189	SHORT PLAT 1649 WATER SYSTEM	B	22	5	0	5	3	0
11998	LONGLEY POTATO COMPANY	B	2	1	0	1	0	0
60988	CANOE RIDGE VINEYARD	B	0	0	1	1	0	2
15856	WHITCOMB	B	5	2	0	2	1	0
17045	HORRIGAN FARMS	B	8	2	0	2	1	0
46128	COUNTY WELL	B	2	1	1	2	0	2
39934	ANDREWS, ROBERT	B	8	4	0	4	1	0
36582	BARBEE ORCHARDS RIVER RANCH	B	5	3	10	13	1	18
55736	ENGBRETSON WATER SYSTEM	B	8	3	0	3	1	0
22363	WHEEL HOUSE WHEEL UI GROUP	B	3	1	0	1	0	0
38000	AGRI NORTHWEST MCNARY FARM WS	B	0	0	5	5	0	9
56899	PRIOR WATER SUPPLY	B	8	2	0	2	1	0
26722	PRIORS MOBILE HOME COURT	B	0	0	0	0	0	0
36407	SANDPIPER MOBILE HOME PARK	B	22	8	0	8	3	0
35473	SANDPIPER IMPROVEMENT DISTRICT	B	21	8	0	8	3	0
49932	COLUMBIA RIVER SEED	B	1	1	0	1	0	0
	Glade/Fourmile Subbasin Total:		*608*	*206*	*114*	*320*	*66*	*93*

Table 3-19. Estimated Public Water System Water Use (Sheet 2 of 4)

PWS ID	PWS Name	Grp	Res. Pop.	# Res. Conn.	# Non-Res. Conn.	# Total Conn.	Estimated Annual Residential Water Use (ac-ft/yr)	Estimated Annual Non-Residential Water Use (ac-ft/yr)
			Kennewick Subbasin					
51620	COLUMBIA COLSTOR INC [3]	A	0	0	1	1	0	35
47723	FINLEY ELEMENTARY SCHOOL (NEW)	A	0	0	1	1	0	0.04
48063	GUNDERSON NORTHWEST INC	A	0	0	1	1	0	2
58247	GOODNIGHT WATER SYSTEM	A	46	13	0	13	6	0
47782	WSP KENNEWICK DETACHMENT	A	0	0	2	2	0	4
50341	SANTIAGO ESTATES COUNTRY VIEW	A	309	103	0	103	42	0
50113	AGRIUM - KENNEWICK AREA	A	0	0	1	1	0	2
47508	WELCHS [3]	A	0	0	1	1	0	596
59638	THE HOMESTEAD MANUFACTURED HOUSING	A	300	104	0	104	40	0
45757	EATON PARK SUBDIVISION	A	50	21	0	21	7	0
58730	KID - LID 502	A	117	44	0	44	16	0
52204	PERRYS FINLEY SHOPPER	A	0	0	2	2	0	4
54056	**KENNEWICK, CITY OF [1]**	A	60,780	17,149	1,808	18,957	7,251	3,202
52174	KELLEYS ESTATES	A	99	51	0	51	13	0
59395	METZ WATER ASSOCIATION	A	250	90	0	90	34	0
59873	GOOD NEIGHBORS WATER ASSN	A	40	18	0	18	5	0
57412	SUNDANCE IMPROVEMENT ASSOCIATION	A	100	26	0	26	13	0
47762	BENTON COUNTY TWO RIVERS PARK	A	2	1	7	8	0	0
51638	CHEATORS WELL WATER SYSTEM	B	6	3	2	5	1	4
8262	G & R MAYO WATER SYSTEM	B	5	2	0	2	1	0
8294	TRI-CITY FABRICATING	B	0	0	1	1	0	2
8341	GORDON WATER SYSTEM	B	5	2	0	2	1	0
8877	ROBBINS, ED WATER SYSTEM	B	6	3	0	3	1	0
9001	DICKINSON WATER SYSTEM	B	5	2	0	2	1	0
9112	BEAVER WATER SYSTEM	B	4	2	0	2	1	0
36399	SUNDOWN ESTATES	B	8	5	0	5	1	0
9679	MEHLENBACHER, QUENTIN WATER SYSTEM	B	5	2	0	2	1	0
9801	MARQUEZ WATER SYSTEM	B	4	2	0	2	1	0
10155	GIER WATER SYSTEM	B	5	3	0	3	1	0
10202	COOPER, GERALD WATER SYSTEM	B	8	3	0	3	1	0
10248	HOWARD WATER SYSTEM	B	8	2	0	2	1	0
10303	STACY WATER SYSTEM	B	3	2	0	2	0	0
10640	VOGEL COMMUNITY WELL	B	10	4	0	4	1	0
10714	MICHAELIS WATER SYSTEM	B	10	4	0	4	1	0
10746	WOOD, MELVIN WATER SYSTEM	B	3	2	0	2	0	0
10837	KNIGHT WATER SYSTEM	B	7	3	0	3	1	0
10858	FINLEY STORAGE	B	0	0	1	1	0	2
44505	COLUMBIA PARK - SOCCER	B	0	0	1	1	0	2
11194	BERGES, JAMES A. WATER SYSTEM	B	4	3	0	3	1	0
38471	Part IV Properties Well	B	18	7	0	7	2	0
11354	SUAREZ, JOSE	B	6	2	0	2	1	0
11372	SANDERS, LLOYD WATER SYSTEM	B	10	4	0	4	1	0
11374	ADAMS FARM	B	2	1	0	1	0	0
11471	BOTTORFF, FRED - DUPLEX	B	5	2	0	2	1	0
11484	BOTTORFF, FRED - GUM STREET	B	8	3	0	3	1	0
11901	BREWER, OLIVER G. WATER SYSTEM	B	6	2	0	2	1	0
11999	CARVER WATER SYSTEM	B	8	4	0	4	1	0
57654	MARTIN WELL	B	16	4	0	4	2	0
12240	CONNER WATER SYSTEM	B	0	0	1	1	0	2
12249	KING, RUBY WATER SYSTEM	B	13	5	0	5	2	0

Table 3-19. Estimated Public Water System Water Use (Sheet 3 of 4)

PWS ID	PWS Name	Grp	Res. Popul.	# Res. Connect.	# Non-Res. Connect.	# Total Connect.	Estimated Annual Residential Water Use (ac-ft/yr)	Estimated Annual Non-Residential Water Use (ac-ft/yr)
Kennewick Subbasin (continued)								
12455	MAXWELL/MOWREADER WATER SYSTEM	B	6	2	0	2	1	0
12477	ELLISON, ARIC WATER SYSTEM	B	7	2	0	2	1	0
12836	SCHULTZ WATER SYSTEM	B	4	2	0	2	1	0
12996	BURDETT WATER SYSTEM	B	7	2	0	2	1	0
13287	YODER, RICHARD WATER SYSTEM	B	4	1	0	1	1	0
14027	CAMPBELL S WELL	B	3	2	0	2	0	0
14198	HAAKENSON WATER SYSTEM	B	3	2	0	2	0	0
14309	GOLLADAY, ROGER WATER SYSTEM	B	4	2	0	2	1	0
14402	EDDEN, ELMER & HELEN WATER SYSTEM	B	9	2	0	2	1	0
14407	BAKER WELL	B	8	2	0	2	1	0
14444	MC BUEL WATER SYSTEM	B	7	2	0	2	1	0
14624	CARPENTER WELL	B	8	2	0	2	1	0
14702	HOUCHIN WELL 1	B	3	1	0	1	0	0
14790	H AND M WIRTA	B	4	2	0	2	1	0
14863	BASS, TAMARA WATER SYSTEM	B	4	2	0	2	1	0
15193	STACY, LARRY J.	B	6	1	0	1	1	0
15321	GARNER, DON	B	7	3	0	3	1	0
15558	RAINE, FRANK WATER SYSTEM	B	0	0	1	1	0	2
15618	LAMPSON WELL	B	8	2	0	2	1	0
15757	FLETCHER WATER SYSTEM	B	5	1	0	1	1	0
53212	SHORT AVENUE WATER SYSTEM	B	13	5	0	5	2	0
36455	BRANDON MOBILE HOME COURT	B	24	14	0	14	3	0
16337	GOECIA WATER SYSTEM	B	6	2	0	2	1	0
16404	POTIZO WATER SYSTEM	B	8	2	0	2	1	0
60318	HAYS TRAILER PARK	B	8	3	0	3	1	0
16993	RAEDER, CHARLES WATER SYSTEM	B	4	2	0	2	1	0
52254	PERKINS WATER SYSTEM	B	7	3	0	3	1	0
17575	ASSN OF WESTERN PULPPAPER WORKERS	B	0	0	1	1	0	2
17843	ADVANCED CONCRETE SPECIALIST, INC	B	0	0	1	1	0	2
18513	CRAM WELL	B	5	2	0	2	1	0
18807	RIVES, ED	B	8	3	0	3	1	0
18877	JOHNSON, JUDY M.	B	8	2	0	2	1	0
18932	JESERNIG, RUDY - SP 1116	B	10	4	0	4	1	0
18991	BARR WATER SYSTEM	B	5	2	0	2	1	0
55738	RICHARDSONS	B	5	2	0	2	1	0
19300	SOUTH FREMONT WATER SYSTEM	B	8	4	0	4	1	0
19304	YADAO, JUANITA	B	3	1	0	1	0	0
19525	ROE/DOBYNS WATER SYSTEM	B	5	2	0	2	1	0
19527	FLOWERS, ROBERT G AND ISABELLE M	B	5	2	0	2	1	0
19559	MYERS WATER SYSTEM	B	10	4	0	4	1	0
19613	CHAVEZ WATER SYSTEM	B	8	3	0	3	1	0
19651	ANDERSON, WILLIAM & DEBRA	B	5	2	0	2	1	0
19873	HART S SHORT PLAT 999	B	7	2	0	2	1	0
19940	WILSON/NUNEZ	B	5	2	0	2	1	0
19942	BIG TOE SALVAGE	B	0	0	1	1	0	2
19943	CULBERHOUSE, ROY	B	5	2	0	2	1	0
20010	GROVER S FRUIT & PRODUCE	B	10	4	0	4	1	0
36214	FOURTH PLACE WATER SYSTEM	B	13	5	0	5	2	0
20097	REAL, GEORGETTE	B	6	2	0	2	1	0
60132	COX, ROBERT D.	B	5	2	0	2	1	0
20443	GODWIN HOMES INC	B	5	2	0	2	1	0

Table 3-19. Estimated Public Water System Water Use (Sheet 4 of 4)

PWS ID	PWS Name	Grp	Res. Popul.	# Res. Connect.	# Non-Res. Connect.	# Total Connect.	Estimated Annual Residential Water Use (ac-ft/yr)	Estimated Annual Non-Residential Water Use (ac-ft/yr)
	Kennewick Subbasin (continued)							
20854	HALF ACRE GROCERY	B	4	2	0	2	1	0
20874	WILLIAMS COMPOUND WATER SYSTEM	B	5	2	0	2	1	0
53210	HAMILTON, D. WATER SYSTEM	B	20	6	0	6	3	0
21094	COBB, DONALD	B	5	2	0	2	1	0
55735	2J	B	8	3	0	3	1	0
21318	SHANE S WATER SYSTEM	B	8	4	0	4	1	0
21568	GALLAGHER WATER SYSTEM	B	5	2	0	2	1	0
21570	SCHMELZER WATER SYSTEM	B	5	2	0	2	1	0
21574	COOK WATER SYSTEM	B	5	2	0	2	1	0
55739	RICHARDSON WATER SYSTEM	B	5	2	0	2	1	0
21591	KEYES WATER SYSTEM	B	10	4	0	4	1	0
21597	CHAPIN WATER SYSTEM	B	5	2	0	2	1	0
21633	PERKINS TRACTS WATER SYSTEM	B	5	2	0	2	1	0
21635	ALLRED WATER SYSTEM	B	10	4	0	4	1	0
21666	REIL WATER SYSTEM	B	16	2	0	2	2	0
21973	BRYANT, BILL WATER SYSTEM	B	10	3	0	3	1	0
22292	THORNTON, NEWT G.	B	8	2	0	2	1	0
22319	TESSENDERLO KERLEY INC	B	0	0	2	2	0	4
22373	DOUGLASS WATER SYSTEM	B	5	2	0	2	1	0
60418	BEAUCHAMP-SCHMIDT CENTER SYSTEM	B	5	2	0	2	1	0
22422	GENERAL STORE	B	0	0	1	1	0	2
22433	BENTON CO FIRE DIST 1 STATION 2	B	2	1	0	1	0	0
22449	WASTE MANAGEMENT	B	0	0	1	1	0	2
22456	THOM WATER SYSTEM	B	4	2	0	2	1	0
22461	CHUCK S TRUCK REPAIR	B	3	1	1	2	0	2
35523	LAGUNA VISTA IMPROVEMENT ASSN	B	22	9	0	9	3	0
24211	WALLACE WATER SYSTEM	B	8	3	0	3	1	0
24213	BROCKMAN SHOP	B	0	0	1	1	0	2
24968	STEIN, ROBERT WATER SYSTEM	B	5	2	0	2	1	0
24998	SAPP, JAMES T	B	5	2	0	2	1	0
25101	EDDEN WELL	B	5	2	0	2	1	0
25115	FINLEY ROAD WATER SYSTEM	B	5	2	0	2	1	0
35524	BLANDS WELL	B	23	9	0	9	3	0
25126	PEREZ WATER SYSTEM	B	7	2	0	2	1	0
37418	GRATER WATER SYSTEM	B	5	2	0	2	1	0
25927	CARSON PUBLIC WATER SYSTEM	B	5	2	0	2	1	0
26343	PACIFIC HIDE & FUR DEPOT	B	3	1	0	1	0	0
54192	AGRIUM - FINLEY AREA	B	0	0	1	1	0	2
53214	RALLS WATER SYSTEM	B	20	8	0	8	3	0
28391	BALDWIN WATER SYSTEM	B	10	4	0	4	1	0
28753	WINDSOR, LEOLIA WATER SYSTEM	B	5	2	0	2	1	0
31408	SKEEN WATER SYSTEM	B	1	1	1	2	0	2
35959	WHITNEY WATER SYSTEM	B	10	2	0	2	1	0
40383	HIGHLAND MANOR ESTATES #1	B	8	2	0	2	1	0
56195	BAUMGARTNER WELL	B	7	2	0	2	1	0
55384	EMERSON WATER SYSTEM	B	5	2	0	2	1	0
28903	KENNEWICK KENN SUBSTATION	B	0	0	1	1	0	2
	Kennewick Subbasin Total:		*62,921*	*17,936*	*1,843*	*19,779*	*7,539*	*3,878*
	WRIA 31 TOTALS:		**63,734**	**18,217**	**1,990**	**20,207**	**7,635**	**4,009**

Notes: 1) PWS in **Bold** contain information obtained from the source that was used to calculate actual water use.
2) Roosevelt Water District was not listed as a PWS in the DOH database; information obtained from Klickitat PUD.
3) PWS assumed to use entire active water right listed in Ecologys WRTS database.

3.5.3 Estimated Non-Public Water Supply Water Use

Non-PWS water use includes water supplied by exempt wells for residential use (self-supplied) and water for non-residential use that is not from a PWS. Water use estimated from each group is discussed in the following subsections.

Self-Supplied Residential Usage

The self-supplied residential population for each subbasin was estimated by subtracting the resident population served by PWS from the total population for that subbasin (Table 3-20). The total population by subbasin was determined from GIS analysis of census block data from the 2000 U.S. Census. Using these methods, there is an estimated 3,833 self-supplied residents in the WRIA; approximately 60 percent of those reside in the Kennewick subbasin. Annual water use estimates for the self-supplied population were calculated assuming an average consumption of 120 gpcd and converting that volume of water into acre-feet per year (Table 3-20).

Table 3-20. Estimated Self-Supplied Residential Water Use

Subbasin	Total Population[1]	PWS-Supplied Population[2]	Self-Supplied Population	Estimated Annual Self-Supplied Residential Use in acre-ft/year
Rock Creek	504	38	466	63
Wood/Alder Creeks	488	167	321	43
Glade/Fourmile Creeks	1,308	608	700	94
Kennewick	65,267	62,921	2,346	315
WRIA 31 Totals:	**67,567**	**63,734**	**3,833**	**515**

Notes:

1) Total population calculated from GIS analysis of 2000 census block data.

2) Refer to Table 3-19.

While 515 acre-feet/year is the best estimate of self-supplied water use based on available information, a maximum self-supplied water use can also be estimated by assuming that each household of the self-supplied population fully uses the 5,000 gpd volume of water allowed without a water right from the state (exempt well). To estimate this water use, the self-supplied population was converted to a number of households, and each household was assumed to use 5,000 gpd. It was assumed that each household in the Rock Creek and Wood/Alder Creeks subbasins contains an average of 2.54 persons based on Klickitat County census figures (http://quickfacts.census.gov/qfd/states/53/53039.html). It was assumed that each household in the Glade/Fourmile Creeks and Kennewick subbasins contains an average of 2.68 persons based on Benton County census figures (http://quickfacts.census.gov/qfd/states/53/53005.html). Based on these data, we assume that the WRIA's 3,833 self-supplied persons occupy 1,446 households. Assuming each household uses 5,000 gpd every day, year-round, these 1,446 self-supplied households could use up to approximately 8,100 acre-feet per year in WRIA 31 (Table 3-21).

However, this estimated annual volume equates to a per capita water use of approximately 1,900 gpd, which is an order of magnitude above estimates typically used in water use planning anywhere in the state. This maximum value could be considered as a ‘worst-case scenario’ in watershed planning, but is considered a far less realistic use estimate than the 515 acre-feet/year estimate presented in Table 3-20.

Table 3-21. Estimates of Maximum Self-Supplied Residential Water Use

Subbasin	Self-Supplied Population	Self-Supplied Households[1]	Estimated Maximum Annual Self-Supplied Residential Water Use[2] in acre-feet/year
Rock Creek	466	183	1,028
Wood/Alder Creeks	321	126	708
Glade/Fourmile Creeks	700	261	1,463
Kennewick	2,346	875	4,903
WRIA 31 Totals:	**3,833**	**1,446**	**8,101**

Notes:

1) Assumes an average of 2.54 persons/household in Rock and Wood/Alder subbasins and 2.68 persons per household in Glade/Fourmile and Kennewick subbasins.

2) Assumes a maximum use for an exempt well of 5000 gallons per day per household.

Non-PWS Non-Residential Usage

Ecology’s WRTS water rights database (Section 3.4) was queried and cross-referenced to the PWS database to isolate any water right holders that had large permits or certificates for commercial/industrial purposes but were not listed as a PWS in DOH’s database. This revealed the large water right for Goldendale Aluminum’s smelter; the right is for a Columbia River diversion located on the downstream edge of WRIA 31. As discussed in Section 3.4.2, consumptive use under this right has been documented as 4,851 acre-feet/year. Other larger commercial/industrial water rights recorded in WRTS are assumed to be fully exercised for the purposes of this assessment (Table 3-22).

An additional category of non-residential water use in WRIA 31 is stock watering from exempt wells and developed springs. Groundwater withdrawal up to 5,000 gpd for stock watering is exempt from water right permitting, thus there is no readily available information to estimate such usage in the WRIA. Regardless, stock watering is considered to be a small component of total water use in the WRIA, especially relative to irrigation.

Table 3-22. Estimate of Non-PWS Non-Residential Water Use

Non-PWS Water Right Owner	Subbasin	Estimated Annual Commercial/ Industrial Water Use in acre-ft/year
Goldendale Aluminum [2]	Rock Creek	4,851
Gas-Ice Corporation [1]	Kennewick	480
Union Oil Co. [1]	Kennewick	211
Mercer Ranches, Inc [1]	Glade/Fourmile	8.7
Allied Chemical Corporation [1]	Kennewick	5
WRIA 31 Totals:		**5,556**

Notes:

1) Assumes full use of annual water right for commercial/ industrial use.

2) Consumptive use (Klickitat County Water Conservancy Board 2002).

3.5.4 Estimated Water Use by Subbasin

Table 3-23 presents the water use estimates by subbasin for each water use category (irrigation, residential, and non-residential). Based on the results of this Level 1 assessment, a total of roughly 640,000 acre-feet of water is used annually in WRIA 31. Irrigation represents the overwhelming majority (97 percent) of all water use in WRIA 31, which is consistent with the water rights analysis (Section 3.4). Residential and non-residential uses comprise only 1.3 and 1.5 percent, respectively, of the total water use in WRIA 31.

The Glade/Fourmile Creeks subbasin accounts for 77 percent of all the water use in WRIA 31, due to its very large irrigation water use. This also corresponds to the water rights data (Section 3.4), in that water rights (certificates and permits) issued for the Glade/Fourmile Creeks subbasin represent 83 percent of the water appropriated for the entire WRIA. It should be noted that the Glade/Fourmile Creeks subbasin is also the geographically largest subbasin in the WRIA. The Kennewick subbasin represents 96 percent of the residential water use in the WRIA. This is not surprising since roughly 97 percent of the WRIA 31 population resides in the Kennewick subbasin. Self-supplied residential water use, via exempt wells, is a negligible water use (0.1 percent of total) on the WRIA scale. Water withdrawal for non-residential (commercial/industrial) supply occurs predominantly in the Rock Creek subbasin (4,851 acre-feet/year for Goldendale Aluminum facility) and the Kennewick subbasin (4,574 acre-feet/year).

Table 3-23. Estimated Water Use by Subbasin in WRIA 31

Subbasin	Estimated Annual Water Use in Ac-Ft/Yr, by Use Category: Irrigation	PWS-Supplied Residential	Self-Supplied Residential	PWS-Supplied Non-Residential	Non-PWS Supplied Non-Residential	Subbasin Totals	Percent of Total WRIA 31 Use by Subbasin
Rock Creek	0	5	63	2	4,851	**4,921**	1%
Wood/Alder Creeks	14,832	25	43	35	0	**14,935**	2%
Glade/Fourmile Creeks	492,005	66	94	94	8.7	**492,268**	77%
Kennewick	115,734	7,539	315	3,878	696	**128,162**	20%
WRIA 31 Totals:	**622,571**	**7,635**	**515**	**4,009**	**5,556**	**640,287**	**100%**
Percent of Total WRIA 31 Use by Category:	**97.2%**	**1.2%**	**0.1%**	**0.6%**	**0.9%**	**100.0%**	

Because irrigation represents 97 percent of the total water use in WRIA 31, the simplifying assumptions used when estimating residential and non-residential water use from PWS and non-PWS sources have little impact on the accuracy of the water use estimates for the entire WRIA. If warranted, more detailed assessment of actual water use in WRIA 31 should focus primarily on improving estimates of irrigation water use, specifically refining the assumed crop water duties.

3.6 Subbasin-Scale Water Balances

One of the important objectives in a Level 1 Assessment is to develop supporting information to help address the question of the physical and legal availability of water. Although Ecology determines the legal availability of water for appropriation, this Level 1 Assessment provides useful information regarding the physical availability of water on the subbasin scale. Understanding water availability can start with calculating a water balance for a subbasin. The conventional water balance approach for the subbasin scale accounts for partitioning of precipitation into evapotranspiration (water evaporated from soil, rock, or open water plus water consumed [transpired] by growing plants), runoff becoming streamflow, and groundwater recharge on an annual basis. Ignoring water imported into and water used within a subbasin, this can be expressed as:

Precipitation = Evapotranspiration + Streamflow + Groundwater Recharge

As discussed in Section 3.3.1, the USGS (Bauer and Vaccaro 1990) used a detailed numerical model (Deep Percolation Model) to calculate the water balance for 53 basins on the Columbia Plateau, for the purpose of estimating recharge to the basalt aquifer system. Both developed and predeveloped land use scenarios were modeled for the study, where predeveloped refers to the time before European settlement and significant land use modification. Seven of the basins that were modeled encompass all of WRIA 31. These basins were not coincident with the subbasins used for the WRIA 31 assessment; therefore, the USGS model results were aggregated to the WRIA 31 subbasins using a weighted average technique. This technique averaged values from the USGS model for each basin based on their coincident areas with WRIA 31 subbasins. In the USGS model, Rock Creek, Chapman Creek, Old Lady Canyon, and Wood Gulch were lumped in one basin that relied on hydrologic and climatic data from the Rock Creek area. However, for our assessment, the USGS predeveloped water balance numbers for the Chapman Creek, Old Lady Canyon, and Wood Gulch areas have been separated from Rock Creek basin numbers. We have represented those areas using the USGS model data for the Pine Creek basin, which is assumed to be more hydrologically representative of those basins.

The USGS model results, aggregated to the WRIA 31 subbasins, represent the predevelopment ("natural conditions") water balance components of precipitation, evapotranspiration, streamflow, and groundwater recharge used for this subbasin-scale water balance.

The USGS study simulated conditions from the time period of the late 1950s through mid-1970s as their representation of developed conditions. Because irrigation use has increased substantially in WRIA 31 since that time, the water balance is updated in this Level 1 Assessment to more accurately reflect current conditions for water importation and use. The USGS predevelopment water balance calculations remain reliable estimates for precipitation as well as natural condition recharge and streamflow. However, the water balance data in the USGS report do not balance (i.e., water in does not equal water out) for each basin modeled. We assume this is because net soil moisture, retained plant moisture, and snow pack changes over the model simulation period were not reported as a portion of this balance. Therefore, we have adjusted the USGS model results to distribute the unaccounted-for water to evapotranspiration, streamflow, and recharge based on their reported relative proportions of the total water balance. The relative proportions of evapotranspiration vs. recharge vs. streamflow therefore remain the same for each subbasin, but their magnitudes change slightly from the USGS estimates. These adjusted values for the predeveloped condition are components of this water balance for current conditions.

As discussed in Section 3.3.1, the USGS' recharge model can have errors of up to 25 percent, particularly in low-precipitation areas similar to WRIA 31. Because this model is the basis for the predevelopment water balance, which in turn is used to calculate the current (developed) condition water balance, potential errors in the USGS model will propagate throughout these water balance calculations. As an example of uncertainty in the water balance, following the basin aggregation done for this assessment, the resulting subbasin-scale mean annual precipitation estimates used for the USGS model (1956-1977 precipitation record) are 3 to 20 percent lower from those developed from the PRISM data (1961-1990 precipitation record) presented in Section 2.5.1. By subbasin, the precipitation estimates are as follow:

Subbasin	Mean Annual Precipitation in Inches Used for USGS Model	Mean Annual Precipitation in Inches from PRISM Model	Percent Difference
Rock Creek	13.0	16.2	20%
Wood/Alder	9.6	10.8	11%
Glade/Fourmile	7.7	9.4	18%
Kennewick	8.0	8.2	3%

The PRISM precipitation data was not used for this water balance evaluation to maintain consistency with the rest of the component estimates (ET, runoff, and recharge) which were derived from the USGS model. The ET, runoff, and streamflow components are directly dependent on precipitation, but they would not necessarily vary in a linear relationship with changes in precipitation (e.g., greater precipitation may result in relatively larger proportion of runoff to streamflow etc.). Despite the inherent uncertainties, the USGS model is considered the most comprehensive regional water balance information available for this Level 1 Assessment.

To assess the current water balance of each subbasin in WRIA 31, estimated volumes of imported water and used water were added to the USGS modeled predeveloped conditions. In the current condition scenario, the water balance approach for a subbasin accounts for partitioning of precipitation and imported water into evapotranspiration, runoff becoming streamflow, groundwater recharge, and use on an annual basis expressed by:

Precipitation + Imported Water =

Evapotranspiration + Streamflow + Recharge + Consumptive Water Use + Return Flow (non-consumptive use)

Water use includes both consumptive use and non-consumptive return flow. Return flow represents water that is used but not consumed, and thus is returned to the watershed. Ultimately, consumptive use can be considered as evapotranspiration, and return flow is partitioned into streamflow via runoff and groundwater recharge via deep percolation.

Water is imported into WRIA 31 both from the Yakima River (by KID and CID), and directly out of the Columbia River by a number of water users and purveyors. The amount of water imported by the KID is 95,855 acre-feet/year. The amount of water imported by the CID is 60,385 acre-feet/year. This 156,240 acre-feet/year of imported water is distributed for irrigation use (residential and commercial) within the Kennewick subbasin.

Water imported from the Columbia River is more difficult to quantify because of the large number of entities that divert from the river. For the purposes of this assessment, it is assumed that, for each subbasin, the relative proportion of Columbia River water use to total water use is equal to the relative proportion of Columbia River water rights to total water rights. This is a reasonable assumption given that the imported water is largely used for irrigation supply. The exception is that, for the Rock Creek subbasin, the Goldendale Aluminum industrial water diversion is assigned as 100 percent Columbia River water, rather than by the water right proportions. In addition, for the Kennewick subbasin, the combined KID/CID use (Yakima River import) was subtracted prior to applying the percentage. Note that the very large McNary Dam water right for hydroelectric generation (refer to Section 3.4) is excluded from this analysis since none of that water is imported into the WRIA. Table 3-24 summarizes, for each subbasin, the relative percentages of Columbia River water rights to total rights, the estimated total water use (from Table 3-23), and resulting assumed water use supplied from the Columbia River. For the purposes of this assessment, water use supplied by WRIA 31 streams is considered negligible.

Table 3-24. Estimation of WRIA 31 Water Use Supplied by Columbia River

Subbasin	Total Annual Water Rights in ac-fy/yr	Columbia River Annual Water Rights in ac-ft/yr	Columbia River Water Rights as % of Total Rights	Total Annual Water Use in ac-ft/yr	Assumed Water Use from Columbia River Water in ac-ft/yr
Rock Creek	6,664	4,851	73%	4,921	4,851
Wood/Alder Creeks	15,358	2,568	17%	14,935	2,497
Glade/Fourmile Creeks	681,288	611,400	90%	492,268	441,771
Kennewick	102,192	58,680	57%	128,162	6,779
WRIA 31 Totals:	**805,501**	**677,499**	**84%**	**640,287**	**455,898**

Notes:
Water rights are sum of permits + certificates.
Excludes McNary hydroelectric right (Glade/Fourmile subbasin).
Columbia River water use for Rock Creek subbasin is set equal to Columbia River water rights, rather than by the water rights percentage (refer to text).
Kennewick subbasin water use excludes water imported from the Yakima River by KID and CID.

As with precipitation, water imported into the watershed will be partitioned into evapotranspiration, runoff becoming streamflow, groundwater recharge, and use. The estimated volumes of water import and use were added to the USGS predevelopment water balance for each subbasin to complete the water balance for current conditions. Key assumptions used to estimate the partitioning of water are outlined below.

The KID estimates that, of their total quantity of water imported from the Yakima River, 26 percent is lost through evaporation, seepage, and spillage in their conveyance system. Since most of the KID’s canal system is unlined and traverses areas of the Kennewick subbasin underlain by permeable Columbia River Gravels, it was assumed that most of the 26 percent loss was due to seepage loss through the bottoms of the canals. Therefore, for the purposes of this water balance, this 26 percent estimated loss is assumed to be split as 5 percent evaporation, 5 percent spillage (additional runoff), and 16 percent seepage (additional recharge). The remaining 74 percent of the water imported by the KID is delivered to its customers for residential and commercial irrigation. If the irrigation water is applied perfectly, all water used would be used by the irrigated vegetation and become additional evapotranspiration in the water balance. As described in Section 3.5.1, it is assumed that 5 percent of applied irrigation water becomes return flow; thus 95 percent of the water delivered is consumed, whether transpired by crops or lost to evaporation before the crops can use it. For the purposes of this water balance, the 5 percent return flow is assumed to be split as 3 percent to recharge and 2 percent to streamflow. Since the CID's canal system is very similar in function and design to the KID's, the same percentages were applied to water imported by the CID.

The remaining water used for irrigation in each subbasin was partitioned into import from the Columbia River and groundwater withdrawals. Diversion of Columbia River water for irrigation is assumed to generally be tightlined until it reaches the fields and thus have negligible conveyance losses. This delivered water is assumed to have the same relative proportion of return flow and consumption as described above for irrigation water imported from the Yakima River. Groundwater withdrawals are included in the return flow calculations as a negative value. These withdrawals are assumed to have negligible conveyance losses and have the same return flows as other irrigation uses.

The remaining non-irrigation water use in each subbasin is divided between residential and non-residential use from both PWS sources and self-supplied sources. The majority of the non-irrigation water from the Columbia River is from the City of Kennewick's large water right. The relative proportion of the source of the Kennewick PWS production (Columbia River vs. groundwater) is assumed to equal the proportion of the City's water rights for each source. Based on the availability of data from the City's water system plan (Kennewick 2002), water system distribution leakage (approximately 9 percent of production) was accounted for as a return flow to recharge. This recharge is offset by an estimated quantity of inflow and infiltration into the City's sewer system (approximately 16 percent of production), as reported in the City's Sewer System Plan (HDR Engineering 1996). Also contained in the Sewer System Plan was an estimate of wastewater discharge to the Columbia River of approximately 60 percent of production. This wastewater discharge is treated in this water balance as an export from the watershed (as water pumped from the river is import to the watershed). Based on typical domestic use in the State of Washington (Solley 1995), 12 percent of the delivered water is estimated to be a consumptive use. The remainder of the delivered water that is not discharged or consumed is divided between recharge (70 percent) and streamflow (30 percent). The final resultant split applied by this water balance for the Kennewick PWS water is as follows: 11 percent consumptive use, 18 percent recharge, 11 percent streamflow, and 60 percent treated wastewater discharge (export) to the Columbia River.

The remaining PWS systems and self-supplied systems were assumed to withdraw from groundwater sources. Therefore, calculations in the water balance were then only divided between residential and non-residential uses. Using domestic water use numbers for the State of Washington (Solley 1995), it is assumed that 12 percent of the residential uses are consumptive. Assuming non-residential uses are primarily for industrial supply, 13 percent was assumed to be consumptive use. It is assumed that the majority of discharges for these systems are to septic systems. Therefore, the return flows from these uses are assumed to contribute mostly to recharge equaling 70 and 78 percent for residential use and non-residential use, respectively (Solley 1995). The remaining return flows were applied to streamflow.

Table 3-25 presents the results of the current condition water balance.

Table 3-25. Current Condition Water Balance by Subbasin

	Inputs in ac-ft/yr		Outputs in ac-ft/yr					
			Natural Conditions			Total Use		
Subbasin	Precip.	Import	ET	Recharge	Total Streamflow	Consumpt. Use	Return Flows[1]	Export
Rock	179,268	4,851	107,013	18,793	53,461	4,926	-75	0
Wood/ Alder	204,964	2,497	152,851	16,275	35,837	14,200	-11,703	0
Glade/ Fourmile	338,663	441,770	312,598	12,671	13,394	467,686	-25,916	0
Kennewick	46,770	166,367	44,531	1,392	847	130,766	29,317	6,285

Note:

[1] Return flow numbers include in-basin groundwater withdrawals and reflect the net return flow to in-basin resources.

ET: Evapotranspiration.

The Natural Conditions and Precipitation components are taken from the USGS' regional recharge modeling (Bauer and Vacarro 1990), as aggregated to the WRIA 31 subbasins. The Total Use and Import components are calculated for this assessment (refer to text).

Import is water brought into the watershed from Yakima or Columbia Rivers. Export is water discharged directly to the Columbia River.

3.6.1 Comparison of Water Appropriation and Estimated Use

Table 3-26 summarizes, for each subbasin, the appropriated water rights by source (groundwater, surface water [streams and springs], and Columbia River) and the estimated current water use by source (including Yakima River). This table also includes the estimated natural recharge volume and current “net recharge” which sums the volumes of recharge (natural + return flow) minus the volume of groundwater withdrawal. This collective information is useful in beginning assessment of the physical availability of water within WRIA 31. However, the cumulative totals included in this table represent a water balance over the entire subbasin and do not reflect local variability. Of particular note, the recharge values represent an estimate of total subsurface water and do not specify recharge into specific aquifers from which groundwater pumping may occur. For example, much of the large-scale groundwater withdrawal for irrigation in the Glade/Fourmile subbasin is from the Wanapum Basalt Aquifer, whereas the irrigation return flows recharge the shallower Alluvial Aquifer and Saddle Mountains Basalt Aquifer systems (documented from groundwater level data [Section 3.3] and groundwater quality data [Section 4.2.2]). Localized geographic or aquifer-specific deficits or surpluses may be different than the subbasin-scale totals expressed here.

Based on this Level 1 Assessment, the estimated current annual water use is 65 percent of appropriated annual water rights for WRIA 31 as a whole. This percentage excludes the

KID/CID usage supplied from the Yakima River since those water rights are not within WRIA 31 (not included in Table 3-26).

Table 3-26. Summary of Appropriated Water Rights, Current Water Use, and Groundwater Recharge in WRIA 31

	Appropriated Annual Water Rights in ac-ft/yr				Estimated Current Annual Water Use (ac-ft/yr) by Supply Source				Estimated Annual Groundwater Recharge in ac-ft/yr	
Subbasin	Ground water	Surface Water	Columbia River	Total	Ground Water	Columbia River	Yakima River	Total	Natural	Current Net
Rock Creek	1,762	52	4,851	6,664	70	4,851	0	4,921	18,793	18,705
Wood/ Alder	12,720	70	2,568	15,358	12,437	2,497	0	14,934	16,275	4,260
Glade/ Fourmile	69,871	17	611,400	681,288	50,498	441,770	0	492,267	12,671	-23,124
Kennewick	43,417	95	58,680	102,192	5,804	6,829	115,618	128,251	1,392	18,982
WRIA 31 Totals:	127,770	233	677,499	805,501	68,809	455,947	115,618	640,374	49,131	18,823

Notes:

Water use supplied by WRIA 31 streams is considered negligible.

Water rights are permits + certificates, excluding non-consumptive McNary Dam hydroelectric right.

Current net recharge is a groundwater balance: natural recharge + return flow recharge - pumping withdrawal.

3.6.2 Water Use by Source

Of the 640,000 acre-feet/year of water used in WRIA 31, 71 percent is supplied from the Columbia River, 18 percent from the Yakima River, and 11 percent from groundwater sources. The proportion of annual water volume supplied from each of the three major sources varies substantially by subbasin as presented in Table 3-27. The Columbia River is the major supply for the Rock Creek and Glade/Fourmile Creeks subbasins, but the Rock Creek percentage is heavily skewed by Goldendale Aluminum's single large diversion. Groundwater is the major supply source only in the Wood/Alder Creeks subbasin, and Yakima River water is a supply source only for the Kennewick subbasin.

Table 3-27. Proportion of Subbasin Annual Water Use by Supply Source

Subbasin	Ground water	Columbia River	Yakima River	Total
Rock Creek	1%	99%	0%	100%
Wood/Alder	83%	17%	0%	100%
Glade/Fourmile	10%	90%	0%	100%
Kennewick	5%	5%	90%	100%

3.6.3 Groundwater Recharge and Withdrawal

As described in Section 3.3.1, return flows from irrigation using Columbia or Yakima Rivers water result in a net increase in groundwater recharge across WRIA 31 relative to conditions prior to the start of irrigation (predeveloped condition). In Table 3-26, current net recharge represents the groundwater balance (natural recharge plus return flow recharge minus groundwater pumping) for each subbasin. A positive net recharge indicates greater recharge to the groundwater system than pumping withdrawal from it, and vice versa. Note that current net recharge is different than current recharge (discussed in Section 3.3.1). Although they are rough estimates, comparison of the natural (predeveloped) and current net recharge values demonstrates general trends in sustainable use vs. overdraft of groundwater resources on the subbasin scale, as described below.

- In Rock Creek subbasin, there has been effectively no change in groundwater recharge from predeveloped to current conditions, consistent with the very small volume of groundwater use in this subbasin. This is consistent with stable water level trends observed for wells in this subbasin (Section 3.3.3).
- In Wood/Alder Creeks subbasin, the large volume of groundwater withdrawal results in current net recharge being roughly one quarter of predeveloped recharge. This is consistent with generalized assessment of groundwater level data across this subbasin. In some geographic areas of this subbasin, the Saddle Mountains Basalt shows rising water levels over time (return flow), but water levels in some Wanapum Basalt Aquifer wells show larger declines (Section 3.3.3).
- In Glade/Fourmile Creeks subbasin, there is a sizeable negative net recharge (-23,000 acre-feet/year), indicating that annual pumping withdrawal exceeds annual recharge with return flow. Although it is the largest subbasin, it has less natural recharge than Rock Creek or Wood/Alder subbasins because of its very low precipitation. The same basic pattern observed in the Wood/Alder subbasin groundwater levels is also observed in this subbasin: rising water levels in the Saddle Mountains Basalt and declining water levels in the Wanapum Basalt. However, in the Glade/Fourmile subbasin, the greatest observed water level decline in the Wanapum locally exceeds 300 feet (Section 3.3.3).
- In the Kennewick subbasin, there is a very large increase in recharge created by irrigation return flow from the large volume of imported Yakima River water. The one Kennewick subbasin well in Ecology's monitoring program showed no appreciable water level change over the period of record (Section 3.3.3).

As stated above, these subbasin-scale estimates and conclusions will not accurately reflect hydrologic conditions at all locations within a subbasin. The characteristics and uses of the different aquifers in a subbasin or smaller area need to be considered in evaluating water availability, and developing strategies for managing the existing water resources as part of the WRIA 31 watershed management plan. Calculating a groundwater balance (net recharge) on an aquifer-specific basis is beyond the scope of this Level 1 Assessment and would warrant collection of new data.

3.7 Future Water Use

A generalized assessment of future water use is useful for evaluating water management strategies as part of the overall watershed management plan. Demands for additional water currently exist within WRIA 31. As discussed in Section 3.4, there are 102 pending applications for water rights with a cumulative instantaneous withdrawal rate of 720 cfs in WRIA 31 (WRTS does not track requested annual quantities for applications).

Within WRIA 31, a primary anticipated change in water demand/use is due to growth in the City of Kennewick. Relative to Year 2000 water use, the City of Kennewick forecasts a water demand increase of 147 percent by the year 2021, based on population projections. This 15,400 acre-feet/year demand increase is equivalent to approximately 9 percent of the current total water use in the Kennewick subbasin. Table 3-28 summarizes this demand forecast from 2000 through 2021. In addition to residential growth, these projections assume a steady ramping up of industrial water use in Kennewick, culminating in approximately 11,000 acre-feet/year of industrial use by the year 2021. Therefore, these projections likely account for the majority of future growth in residential and commercial/industrial water demand in WRIA 31.

Table 3-28. City of Kennewick PWS Demand Forecast

	Water Demand in ac-ft/yr			
Year	**Residential**	**Non-Residential**	**Total**	**% Change from 2000**
2000	7,250	3,180	10,430	---
2007	8,220	6,980	15,200	46%
2015	9,480	12,020	21,500	106%
2021	10,120	15,680	25,800	147%

Source: City of Kennewick Water System Plan (April 2002).

Another projected future increase in water use is beneficial use of KID's 22,610 acre-feet Columbia River water right. This water will be put to use within the Kennewick subbasin, but infrastructure to make use of this new right has not yet been completed.

There has been a 46 percent increase in WRIA 31 irrigated acreage between 1992 and 2001, based on comparison of the1992 National Land Cover Data (Section 2.6) and IRZ Consulting (2004) work (Section 3.5.1). Much of this acreage increase has been accomplished by water conservation achieved through modern irrigation practices (delivering to the crops more of the water applied). Discussions with irrigators on the WRIA 31 Planning Unit (Andrews Farms and Mercer Ranch) regarding anticipated future irrigation water use indicate that much of the water conservation efficiencies have already been achieved, and future growth in irrigated agriculture will require additional appropriations of water from the state. Their opinion is that, based on current uncertainty in obtaining such new appropriations, it is appropriate to assume for this assessment that irrigation water use (outside of KID) will remain generally stable for the foreseeable future. There is abundant additional irrigable land in WRIA 31 that could be put into agricultural production if new irrigation supplies could be permitted.

Future water demand in WRIA 31's vast rural area is expected to maintain slow growth. Based on the state Office of Financial Management (OFM) data (June 2004), Benton and Klickitat County populations increased 22 and 9 percent, respectively, over the past 10 years (1994 through 2004); however, the bulk of the Benton County growth occurred in the metropolitan areas of Kennewick, Richland, and West Richland. OFM has also projected resident population change for the period 2000 through 2025 for each county in the state. Table 3-29 presents OFM's projected low, intermediate, and high percentage population increases (relative to 2000) for Benton and Klickitat Counties. While there is considerable variability between the low and high estimates, the intermediate county-wide estimates are in the range of 30 to 35 percent growth over the next 20 years (1.2 to 1.4 percent per year), with the higher rates of growth expected in Klickitat County.

Table 3-29. Population Projections for Benton and Klickitat Counties, 2000-2025

	Projected Percent Increase in County Population by 2025		
County	Low Estimate	Intermediate Estimate	High Estimate
Benton	10%	30%	58%
Klickitat	14%	35%	60%

Notes:

Changes are relative to year 2000.

Data are total resident population projections from state Office of Financial Management (2002).

The Benton County Comprehensive Plan (using 1995 OFM data) forecasts a 31 percent population increase for Benton County's unincorporated rural areas for the time period 1996 to 2016. This projected rate of change, 1.6 percent increase per year, is slightly higher than the intermediate county-wide growth rates described above. As described in Section 3.5, non-irrigation water use in rural areas (self-supplied and smaller-PWS-supplied residential) currently accounts for a relatively small quantity of water, and a small percentage of total water use, for WRIA 31 as a whole. It is expected that this relative contribution to WRIA-wide water use will not change in the foreseeable future.