



WRIA 4 WATER USE STUDY

Prepared for Washington State Department of Ecology

October 2019

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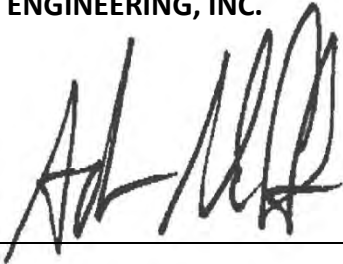
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Washington State Department of Ecology
WRIA 4 Water Use Study
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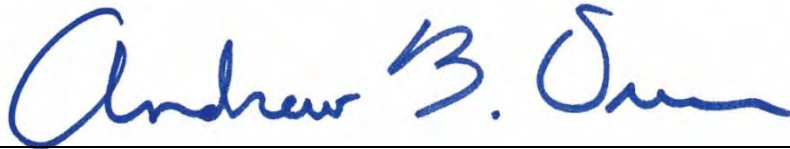
This report summarizes the findings of a water rights and water use investigation and evaluation in Water Resource Inventory Area (WRIA) 4, in Washington State. This report describes and documents the data used and analysis performed.

Sincerely,


RH2 ENGINEERING, INC.

A handwritten signature in black ink, appearing to read "Adam Neff".

Adam Neff, LHG

A handwritten signature in blue ink, appearing to read "Andrew B. Dunn".

Andy Dunn, LHG

A handwritten signature in blue ink, appearing to read "Jim Bucknell".

Jim Bucknell, Water Rights Expert

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WRIA 4 Water Use Study

Executive Summary

Purpose of the Study

This study was funded through Section No. 3012 of Engrossed Substitute Senate Bill 6095, passed during the 2018 Legislative Session. This study was undertaken to estimate the current annual water use under existing consumptive water rights within Water Resources Inventory Area (WRIA) 4 – Upper Skagit.

Water Right Data Organization

The starting point of the investigation was data extracted from the Washington State Department of Ecology's (Ecology) Water Right Tracking System (WRTS) database, which included water rights identified as having points of diversion or points of withdrawal (POD/W) located within WRIA 4. This database includes only State-issued water rights and claims and does not include water rights created through beneficial use of water from a permit-exempt well.

There are a total of 769 water rights with POD/W located within WRIA 4. Only 211 of those water rights are State-issued water rights, with the remainder being claims. The summary of these water rights with respect to the water right type and source of water is contained in **Table ES1**.

**Table ES1
 Inventory Table Water Right Summary**

Water Right Type	Surface Water	Ground Water	Both	Reservoir	Total
Certificate	143	37	0	9	189
Change to Certificate	4	4	0	0	8
Permit	5	4	0	1	10
Change to Permit	0	1	0	0	1
Change to Claim	2	1	0	0	3
State-Issued Subtotal	154	47	0	10	211
Long Form Claim	102	151	2	0	255
Short Form Claim	62	240	1	0	303
Claim Subtotal	164	391	3	0	558
Grand Total	318	438	3	10	769

The database was expanded and improved upon to populate it with additional information used in the analyses performed as part of this study. The resultant work product is referred to as the Inventory Table and is included as **Attachment 1** (electronic form) to this report.

For older (pre-1965) surface water rights that did not have an annual authorized use volume assigned at issuance (53 water rights), values were assigned in the Inventory Table through assumptions identified in this report specific to the purpose of use.

Ecology identified the geographic extent of 34 sub-basins located within WRIA 4. The 34 sub-basins were identified by Ecology because they have the potential for existing and future water uses to have negative impacts on streamflow. These 34 sub-basins only cover a portion of the total WRIA 4 area. Based on POD/W locations mapped for each water right, only 22 of the sub-basins contained a water right POD/W.

Attributes of the water rights with POD/W located within the identified sub-basins are summarized in this report.

Current Water Use Calculations

The report focuses on water rights that are consumptive to the water source; therefore, non-consumptive water rights for reservoirs, fish propagation, mill ponds, and hydropower were excluded from the current use analyses and comparisons.

Current water use estimates were made for consumptive State-issued water rights only. The current water use estimates vary from accurate (metering data) to less accurate (rules of thumb). The data and assumptions used in the calculations and estimates are included in this report. The current water use data is included in the Inventory Table.

Comparison of Water Rights and Current Water Use

A comparison of the consumptive State-issued water rights, broken out by purpose of use, and the estimated current use was performed for each of those water rights in WRIA 4 in the Inventory Table. These comparisons were then lumped by individual sub-basin. This comparison could only be made for 13 sub-basins, since these were the only sub-basins that contained consumptive State-issued water rights. An analysis also was performed on the State-issued water rights within WRIA 4 with POD/W located outside of the identified sub-basins.

The findings suggest that the assumption used in calculating the water right authorized use for municipal water rights that did not have an annual volume assigned through the permitting process grossly overestimated the water right annual volume. To eliminate the suspected error, a separate analysis was performed comparing State-issued water rights with the annual volume specified against the estimated current water use (**Table ES2**). This analysis shows that current water use is only approximately 37 percent of the water right authorized use in WRIA 4.

Table ES2
WRIA 4 State-Issued Water Rights with Qa Specified and Estimated Current Annual Water Use Under Those Water Rights

Purpose of Use	Water Right Limit (afy)	Estimated Current Use (afy)	Percent Used
Municipal	3,542.7	1,399.9	40%
Domestic Multiple	143.7	57.2	40%
Domestic Single	41.5	8.8	21%
Commercial and Industrial	188.1	0.0	0%
Irrigation	703.4	220.9	31%
Stockwater	2.6	2.7	104%
Recreation – Beautification	343.2	151.0	44%
Total	4,965.2	1,840.5	37%
Excludes State-issued water rights with no annual volume specified, non-consumptive uses, reservoir water rights, water use under claims, water use under permit-exempt wells, and water use occurring outside of a water right.			

RH2 Engineering, Inc., (RH2) concludes that the results shown in **Table ES2** represent the best estimate of current use compared to authorized use, by purpose of use, for water rights in WRIA 4. It includes those State-issued water rights in which the authorized annual volume is specified and includes the estimated current annual water use under those water rights.

Under State-issued water rights in WRIA 4, municipal water use is the largest current beneficial use—followed by irrigation, recreation-beautification, domestic multiple, domestic single, and stockwater. There was no identified current use occurring under any of the State-issued water rights for commercial and industrial use.

Background

The Washington State Department of Ecology (Ecology) retained RH2 Engineering, Inc., (RH2) to prepare a report addressing Water Resources Inventory Area (WRIA) 4 – Upper Skagit. This report includes an Inventory Table (**Attachment 1**) of the water rights and their attributes, including estimated current annual water use (total volume of water withdrawn from a well or surface water body) by purpose under those water rights, broken out by specific sub-basins. The analysis of WRIA 4 contained within this study is limited to land located within the United States and does not include any of the Skagit River Watershed lying within Canada. No attempt was made in this report to look at the fate of the water, with respect to whether it is consumptive or non-consumptive to the environment within a particular purpose of use (**Figure 1**).

WRIA 4 includes land in Whatcom, Skagit, and Snohomish counties in Washington State (**Figure 2**). The mean annual discharge of the Skagit River near Concrete, Washington U.S. Geological Survey ((USGS) Gage 12194000) is 15,100 cubic feet per second (cfs), which is nearly 11 million acre-feet per year. The 34 sub-basins identified by Ecology for analysis include only a small portion of WRIA 4 (**Figure 3**). The sub-basins were provided to RH2 by Ecology. The sub-basins represent tributaries to the larger rivers and contain streams that were considered by a broad group (Ecology, Washington Department of Fish and Wildlife, Swinomish Tribe, Upper Skagit Tribe, Sauk-Suiattle Tribe, and Skagit County) to be susceptible to negative impacts from future growth and associated water use. In this report, the term “State-issued water rights” is used to indicate water rights that are permits, certificates, certificates of change, or change authorizations (whether the original water right was a permit, certificate, or claim). These water rights have been reviewed by Ecology and generally are considered to be more accurate than water right claims, which were filed by the claimant, but not reviewed for accuracy by Ecology or its predecessor agencies.

This report includes a comparison of the annual volume authorized (Qa) and an estimate of the current annual volume used for various purposes of use in WRIA 4 for the State-issued water rights.

This report does not include summaries or analyses of water rights or current annual water use for hydropower, fish propagation, and mill pond water rights, which are considered to be fully non-consumptive.

Since the intent of this report was to start with the existing water right record and estimate current annual water use under a sub-set of the water rights, this report does not include an estimate of the total annual water use in WRIA 4, and does not document or detail water use that occurs under water right claims, permit-exempt wells, or without the benefit of a water right.

The layout and structure of this report is as follows:

- First, a glossary is provided to define terms found in the report.
- Second, the set up and layout of the Inventory Table with respect to the water rights, water right attributes, current measured use, and current estimated use is described.

The Inventory Table is used for all water right organization, calculations, and analysis performed and described throughout the remainder of this report.

- Third, the Inventory Table is analyzed, and water right attribute results are summarized for each sub-basin and the area outside of the sub-basins.
- Fourth, sources of metering data and the methodology and calculations for estimating current water use for each purpose of use are identified.
- Fifth, the annual authorized use limits in the State-issued water rights are compared to the current water use under each of those water rights and are summarized by purpose of use for each sub-basin and the areas outside of the sub-basins.
- Sixth, a WRIA-wide analysis of the State-issued water rights, only including those water rights that have annual volumes explicitly specified, is compared to the current water use under those water rights.
- Seventh, conclusions are presented based on the data and analyses performed.

Glossary

Acre-Feet per Year (afy) – Unit of measure for the annual volume allowed under both surface and ground water rights. One acre-foot is equal to 43,560 cubic feet, or 325,851 gallons.

Additive – Water right accounting term. Attributes of a water right are assumed to be additive, unless specified otherwise in the water right document record. It is a relationship term. An additive attribute of a water right can be associated with the instantaneous rate, annual volume, or irrigated acres. An example of an additive attribute on a water right is if a municipal water supplier got a water right for municipal supply under an older water right and was issued a more recent water right to allow that municipal supplier to serve additional customers. If both water rights were for 100 afy, the annual volume of both rights would add up to 200 afy.

Application – Water right phase. This is the document that is submitted by an applicant requesting to obtain a water right. The steps in the standard water right process are as follows. An application is submitted. Ecology provides a Report of Examination detailing its findings on whether a water right can be granted or not. If a water right can be granted, then a Permit is issued. Once the water has been put to full beneficial use, a Certificate is issued.

Authorized Use – Term used in this report when referring to the volume of water that is identified as the water right limit, directly on the water right document, or that has been calculated if no annual volume was originally assigned.

Certificate – Water right phase. This is a State-issued water right documenting beneficial use.

Certificate of Change – Water right phase. This is a State-issued water right for a document that was originally a claim but was put through the water right change application process and for which a tentative determination of extent and validity (perfection) has been made.

Change-ROE – Water right phase. This is a State-issued water right that documents when a certificate was put through the water right change application process and approved; however, the water authorized under the water right has not yet been fully used, consistent with the change authorization.

Claim – A water right document. A claim is simply that, a claim to a water right for a water use that predates the water right permitting system. A claim may represent a perfected water right, but it is not confirmed as valid until the extent and validity is determined in a general water right adjudication (a legal proceeding). See also Long Form Claim and Short Form Claim.

Consumptive Use – Term used in this report to identify water rights that are used for a consumptive beneficial use. This includes uses such as municipal, domestic multiple, domestic single, irrigation, commercial and industrial, and stockwater.

Cubic Feet per Second (cfs) – Unit of measure for the instantaneous rate of diversion allowed under a surface water right. One cfs is equal to 448.83 gallons per minute.

Gallons per Day (gpd) – Unit of measure for the daily withdrawal allowed under certain purposes of use authorized under the ground water permit exemption. For example, 5,000 gpd for single or group domestic supply is equal to an average constant withdrawal rate of 3.47 gallons per minute, and if extrapolated out for a full year, is equal to 5.6 afy.

Gallons per Minute (gpm) – Unit of measure for the instantaneous rate of withdrawal allowed under a ground water right. For example, 448.83 gpm is equal to 1 cfs.

Long Form Claim – A water right document, usually containing details about water use, filed by an individual or company during one of the claim registration filing periods and not reviewed for accuracy or completeness by Ecology. Long form claims usually include information on the claimed purposes of use, claimed date of first use, claimed source location, claimed instantaneous rate, claimed annual volume, claimed acres irrigated, and claimed place of use, but long form claims are not a State-issued water right.

Non-Additive – Water right accounting term. Attributes of a water right can be non-additive, if specified in the water right document record. It is a relationship term. A non-additive attribute of a water right can be associated with the instantaneous rate, annual volume, or irrigated acres. An example of a non-additive attribute on a water right is if a field is irrigated by water from a stream under an older water right and a well under a younger water right. If the irrigated acres and annual volume granted under the surface water right is sufficient to meet the demand, assuming 10 afy for irrigation of 5 acres, then the subsequently issued groundwater right would be identified in the report of examination as being non-additive with respect to the irrigated acres and annual volume. The total number of irrigated acres under both water rights would be equal to 5, and the total annual volume under both water rights would be limited to 10 afy.

Non-Consumptive Use – For this report, non-consumptive use refers to the entire purpose of use, as opposed to determining the fate of the water after beneficial use. In this report non-consumptive uses are uses where the water is returned immediately to the environment and not used consumptively. Examples include water for fish propagation at a hatchery, water used for hydropower, and water used to maintain the water level in a log pond.

Permit – Water right phase. This is a State-issued water right that grants the authority to use water, where the full quantities of water allowed in the permit have not yet been documented as having been put to full beneficial use (certificated).

Priority Date – This date is the date of application for a State-issued water right, or the claimed date of first beneficial use under a water right claim. Under prior appropriation, water rights with older priority dates (senior) get to take water before water rights with younger priority dates (junior) get to take water. This system clearly defines who gets water and who has to stop taking water in times of shortage (the junior water right is shutoff first). This is generally referred to as “first-in-time, first-in-right.”

Point of Diversion (POD) – Identified on a surface water right as the location where water can be taken from a surface water body. When used collectively with Point of Withdrawal (see definition below) in this report it is abbreviated as POD/W.

Point of Withdrawal (POW) – Identified on a ground water right as the location where water can be taken from a well or other groundwater extraction infrastructure. When used collectively with Point of Diversion (see definition above) in this report it is abbreviated as POD/W.

Qa – This is the maximum allowed annual volume. Listed in acre-feet per year for both surface water and ground water rights.

Qi – Instantaneous rate. This is the maximum rate at which water may be diverted or withdrawn from the source. It is listed in cubic feet per second for surface water rights and gallons per minute for ground water rights.

Report of Examination (ROE) – A detailed decision document prepared by Ecology in the processing of a water right application. It is essentially the “findings of fact” related to the water right application. In order to issue a permit, Ecology must find that there is water available for appropriation for a beneficial use, and the appropriation thereof as proposed in the application will not impair existing rights or be detrimental to the public welfare. If a water right application can be approved, a ROE is issued, followed by a Permit.

Short Form Claim – A water right document, usually containing few details, filed by an individual or company during one of the claims registration filing periods and not reviewed for accuracy or completeness by Ecology. Short form claims are not a State-issued water right. Short form claims usually only include information on the claimed purpose of use and place of use and generally provide very little information of value in determining the validity of the claimed water right.

State-issued Water Right – For the purposes of this report, a State-issued water right is a water right document that is at one of the following water right phases: permit; certificate; certificate of change; Change-ROE; or superseding certificate.

Superseding Certificate – Water right phase. This is a State-issued water right that documents when a certificate has been altered through the processing of a water right change application and then put back to beneficial use under the new attributes.

Inventory Table – Water Right Information

Ecology provided RH2 with a spreadsheet from its Water Right Tracking System (WRTS) database. This spreadsheet included the WRIA 4 water rights with the Document Status identified as Active. This spreadsheet contained two sheets, one titled “Requested Documents Report,” and one titled “Print Version.” The “Requested Documents Report” sheet was used as the starting point for creation of the Inventory Table. The Inventory Table was created under this study to organize, expand upon, and analyze the different water rights that exist in WRIA 4.

Additional Columns

In creating the Inventory Table, the Requested Documents Report was amended as follows:

The following columns were added:

- Sub-Basin
- Land Use
- Non-Consumptive Use (Yes/No)
- Notes
- Changes to the Qi (instantaneous rate) and associated Units of Measure columns:
 - The Qi column was split into “Additive” and “Non-Additive” columns to allow for more accurate representation of the nature of related water rights.
 - The resulting three columns were duplicated such that the units of gallons per minute (ground water) and cubic feet per second (surface water) could be accounted for in different columns to avoid unit confusion and make calculations easier.
- Changes to the Qa (annual volume) column:
 - The column was split into “Additive” and “Non-Additive” columns to allow for more accurate representation of the nature of related water rights.
- Changes to the Irrigated Acres column:
 - The column was split into “Additive” and “Non-Additive” columns to allow for more accurate representation of the nature of related water rights.

Inventory Table – Water Right Data Population

The following edits and additions were made to the Inventory Table to prepare the data for analysis.

Water Right Purposes of Use

The purposes of use included on water rights in WRIA 4 fall within the following categories:

- Municipal
- Domestic Multiple
- Domestic Single
- Domestic General (when the number of connections is not defined on water right claims)
- Commercial and Industrial (includes mining)
- Irrigation
- Stockwater
- Power
- Fish Propagation
- Fire Protection
- Recreation – Beautification

Water Right Lineage

For all certificates of change, Change-ROE, and superseding certificates, only the most recent water right authorization was retained. If it still existed, the original water right entry was deleted. The priority date for the most recent authorization was modified to be consistent with the priority date of the original water right. Sometimes, this field is incorrectly populated with the date a change application was received in WRTS, as opposed to the original priority date of the water right that is retained throughout the change process.

Points of Diversion/Withdrawal Outside of WRIA 4

The mapped locations of the points of diversion (POD) and points of withdrawal (POW) were cross-referenced with the WRTS data table. This comparison identified which sub-basin each water right POD/W (point of diversion or withdrawal) was located in and identified 13 water right POD/W that are located physically outside the boundaries of WRIA 4, but that are incorrectly identified as being in WRIA 4 in the WRTS data table. The water rights falling in this category are documented in **Table 1** so that Ecology can update the WRTS data appropriately.

Table 1
Water Right Documents in WRTS Table but Mapped Outside of WRIA 4

Water Right Record Document Number	Name	Mapped WRIA Location
G1-24923CWRIS	Carla & Leroy Lange	WRIA 1
G1-0155190CL	Ray Jungbluth	WRIA 3
G1-143795CL	W. J. Richmyer	WRIA 3
G1-146784CL	Carl M. Nieshi	WRIA 3
S1-110801CL	Cap Galloway	WRIA 1
S1-119841CL	Donald M. Hicks	WRIA 1
S1-120499CL	William D. Aho	WRIA 1
S1-128799CL	Ernest C. Nolte	WRIA 1
S1-133644CL	Merle L. Gallman	WRIA 1
G1-046694CL	Charlotte Bust	WRIA 3
G1-066870CL	James H. Hanson	WRIA 3
G1-075016CL	Paul O. Krick	WRIA 3
G1-125342CL	Grant L. Sims	WRIA 3

These water rights are shown in red text in the Inventory Table, but were excluded from additional analysis in WRIA 4.

Points of Diversion/Withdrawal in Multiple Sub-Basins

This exercise also identified four water rights that contain POD/W in multiple sub-basins within WRIA 4. The water rights with POD/W located in two different sub-basins are shown in **Table 2**, are shown as two distinct row entries, and are displayed in the Inventory Table using bold font.

Table 2
Water Rights with POD/W Located in Two Sub-Basins

Water Right Record Document Number	Name
G1-23230CWRIS	WA Fish & Wildlife Dept - NWRO
S1-*14396CWRIS (SWC 6995)	V. Laurent
G1-160345CL	Cecil E. Inman
G1-077005CL	Ray M. Wine

The instantaneous rate, annual volume, and irrigated acres were divided proportionately between the two sub-basins for each water right based on how many POD/W are in each sub-basin.

Municipal Purpose of Use

With the clarification of the definition for municipal water supply purposes as provided by the Legislature in 2003 in Revised Code of Washington (RCW) 90.03.015, and Ecology's Water Resources Program Policy (POL-2030 2003 Municipal Water Law Interpretive and Policy Statement) on the law, an effort was made to review all domestic multiple water rights to see if they should now be classified as being for municipal water supply purposes of use. If RH2 believed that a water right met the definition and should be classified as being municipal, the purpose of use was changed in the Inventory Table, and the word municipal is shown in green text. RH2's opinion on any particular water right should not be construed as binding on Ecology. Ecology reserves the right to consider the facts of each water right and each beneficial use on a case-by-case basis to determine if it qualifies as being for municipal water supply purposes, at such time as an investigation is warranted.

State-Issued Water Rights with Multiple Purposes of Use

For water rights with multiple purposes of use, a separate row for that water right was created with one purpose of use displayed on each row. The instantaneous rate, annual volume, and irrigated acres were then divided between the purposes of use, such that the total of all rows for a water right would equal the maximum extent of that water right. The split among different purposes of use was based on information contained within the original report of examination, which usually contains a breakdown of how the total annual volume was calculated by purpose of use. If information was lacking, then the largest anticipated use was assigned the additive volume, and the secondary use was assigned a non-additive volume, such that the annual volume of that water right did not exceed the water right limit in the Inventory Table.

The text in each row for this type of water right was then changed to italics in the Inventory Table.

This segregation was only done on State-issued water rights and was not attempted on claims, long form claims, or short form claims due to the lack of information.

In addition, if two different crops or different irrigation methods were utilized under a water right, a separate row was created for each to allow for consistency in the total irrigation requirement calculation within the Inventory Table.

Long Form and Most Recent Claims

Each of the 257 long form and most recent (1998 claims registry opening period) claim water right documents were reviewed with the intent of inserting missing data into the Inventory Table. The data contained on the water right claim forms, but missing from the WRTS data, often included the Claimed Date of First Use, Claimed Instantaneous Rate, Claimed Annual Volume, and Claimed Irrigated Acres. The claimed values on the water right document for instantaneous rate, annual volume, and irrigated acres were included in the Inventory Table as opposed to the currently used value for each category contained on the water right claim forms.

Short Form Claims

Short form claims typically do not contain detailed information on the different purposes of use, instantaneous rate, annual volume, or irrigated acres. For this reason, no attempt was made to try to review the 303 short form claim documents to populate those columns of the Inventory Table. Rows in the Inventory Table containing short form claims are highlighted gray.

Combined Surface and Ground Water Rights

Water rights with both a surface water point of diversion and ground water point of withdrawal under one water right are a special category of water right (identified as starting with a B1- in the water right tracking system and Inventory Table). Rows in the Inventory Table containing multi-source water rights are displayed with blue text. There are three of these water rights (all water right claims) in WRIA 4.

Reservoir Water Rights

Reservoir water rights authorize the storage of water. Rows in the Inventory Table containing reservoir water rights are highlighted green. There are ten State-issued reservoir water rights, and no claims, in WRIA 4.

Land Use

GIS was used to populate the land use column of the Inventory Table. The land use listed is the county land use designation found at the center of the water right place of use.

Non-Consumptive Water Uses

Non-consumptive water uses were defined based on the water right record and the definition of non-consumptive water use contained in Ecology Water Resources Program Policy 1020. Under this policy, a water right is still considered to be for a non-consumptive use even if there is a bypass reach between the point of diversion and point of return. The most common non-consumptive water uses include fish propagation, power (hydropower), mill pond or log pond, and recreation – beautification. In a few instances, a typically non-consumptive use (recreation–beautification) was considered to be consumptive because the water does not return to the source stream (Lake Tyee). Rows in the Inventory Table containing non-consumptive water uses under water rights are highlighted yellow. There are 55 State-issued water rights, excluding reservoir water rights, and 6 water right claims, that have been designated as being non-consumptive in WRIA 4 through this study.

Unspecified Annual Volume

As was common historic practice, many older surface water certificates (prior to approximately 1965) do not contain an annual volume limit for authorized use, just an instantaneous rate limitation. When this was encountered, an authorized annual volume of use for the water right was estimated. The fact that the annual volume was estimated was noted in the Inventory Table. The authorized annual volume of use was assigned as follows:

- Domestic (Single and Multiple) – 1 afy per home/connection, which is consistent with the authorized use under ground water rights issued by Ecology in WRIA 4 during this same time period.
- Irrigation – 2 acre-feet per acre, which is consistent with the authorized use under ground water rights issued by Ecology in WRIA 4 during this same time period.
- Municipal – RH2 assumed continuous diversion/withdrawal of the Qi over the full year. This estimate represents the maximum authorized use possible and is consistent with how many municipal water suppliers view these type of water rights (although it may or may not accurately reflect their actual use patterns).
- Commercial and Industrial – Assume 10 afy.
- Domestic (for camps, campgrounds, and RV parks) – Assume 10 afy.
- Stockwater – Assume 5 afy. This is an assumption based on a herd size of approximately 220 cows.

No annual volume limit for authorized use was assigned to any of the non-consumptive uses (hydropower, fish propagation, and mill pond) because of their non-consumptive nature. No annual volume was assigned for fire protection because water used for fire protection or fire suppression only occurs in case of fire and is not an ongoing use of water.

Inventory Table Water Right Summary

Table 3 identifies the water rights included in the final Inventory Table.

Table 3
Inventory Table Water Right Summary

Water Right Type	Surface Water	Ground Water	Both	Reservoir	Total
Certificate	143	37	0	9	189
Change to Certificate	4	4	0	0	8
Permit	5	4	0	1	10
Change to Permit	0	1	0	0	1
Change to Claim	2	1	0	0	3
State-Issued Subtotal	154	47	0	10	211
Long Form Claim	102	151	2	0	255
Short Form Claim	62	240	1	0	303
Claim Subtotal	164	391	3	0	558
Grand Total	318	438	3	10	769

The total water right number of 769 differs from the original 785 water rights in the WRTS table due to the 13 water rights that are mislocated as being in WRIA 4, and 3 water rights that are duplicated in the database due to both the original water right and subsequent water right change authorizations being shown as active.

Water Rights by Sub-Basin

This section of the report contains a description of the water rights in the WRIA 4 sub-basins based on their POD/W location. It is important to note that the sub-basins identified in this section only cover a portion of WRIA 4; there are many water rights falling outside these sub-basins within WRIA 4.

In the sub-basin map obtained from Ecology, there are 34 sub-basins within WRIA 4 (**Figure 3**). Twenty-two of those basins contained water right POD/W within them, while 12 contained no mapped POD/W. The sub-basins without water right POD/W mapped in them are as follows:

- All Creek
- Boyd Creek
- Clark Creek
- Flume Creek
- Hilt Creek
- Illabot Creek
- Miller Creek
- Ossterman Creek
- Rinker Creek
- Savage Creek
- Tenas Creek
- White Creek

The 22 sub-basins containing water right POD/W within them are summarized in **Table 4**, as well as the water rights with POD/W located outside of any of the sub-basins.

Table 4
Water Right Type by Sub-Basin Summary

Sub-Basin	Certificate	Permit	Long Form Claim	Short Form Claim	Total
Aldon Creek	0	0	1	1	2
Bacon Creek	0	0	0	1	1
Barr Creek	5	0	1	0	6
Big Creek	0	0	1	0	1
Boulder Creek	2	0	0	0	2
Corkindale Creek	1	0	2	4	7
Diobsud Creek	2	0	1	1	4
Everett Creek	1	0	6	7	14
Finney Creek	0	0	1	4	5
Grandy Creek	9	0	6	4	19
Gravel Creek	2	0	2	0	4
Hobbit Creek	0	0	1	0	1
Irene Creek	0	0	0	1	1
Jackman Creek	1	0	6	0	7
Jordan Creek	2	0	0	0	2
Mill Creek	0	0	1	0	1
O'Brien Creek	1	0	0	0	1
Olson Creek	3	1	2	3	9
Prairie Creek	4	0	5	2	11
Pressentin Creek	0	1	0	0	1
Rocky Creek	1	0	0	0	1
Sutter Creek	0	0	0	1	1
Sub-Basin Total	34	2	36	29	101
Outside Sub-Basin Total	163	9	222	274	668

The water rights with POD/W falling within the identified sub-basins represent just 13 percent of the total water rights in WRIA 4. The remaining water rights have POD/W falling within WRIA 4, but outside of the sub-basins (**Figure 4**). A description of the water rights with POD/W contained within each sub-basin are described in the following sections. In sub-basins where there are a significant number of State-issued water rights (i.e. permits and/or certificates), the details of which are not easily summarized by text, tables have been included to provide additional detail about the purpose of use, annual volume of use, and percentage of use.

Aldon Creek

This sub-basin contains the POD/W for two water rights: one long form claim and one short form claim. The purpose of use on each claim is identified as Domestic General. The total annual volume claimed is 2 afy for the long form and is not identified for the short form.

Bacon Creek

This sub-basin contains the POD/W for one short form claim water right. The purpose of use on the claim is identified as Domestic General, Stockwater, and Irrigation. The total annual volume claimed is not identified.

Barr Creek

This sub-basin contains the POD/W for six water rights including five certificates and one long form claim. The purpose of use on each certificate is Domestic Single, and the purpose of use on the claim is identified as Domestic General. The total annual volume authorized is 5 afy, and the total annual volume claimed is 1 afy.

Big Creek

This sub-basin contains the POD/W for one long form claim water right. The purpose of use on the claim is identified as Domestic General. The total annual volume claimed is 1 afy.

Boulder Creek

This sub-basin contains the POD/W for two water right certificates. The purpose of use on each certificate is Municipal. The total annual volume authorized is 27 afy.

Corkindale Creek

This sub-basin contains the POD/W for seven water rights, including one certificate, two long form claims, and four short form claims. The purpose of use on the certificate is Stockwater, the purposes of use on the long form claims include Stockwater, Irrigation, and Domestic General, and the purpose of use on the short form claims include Domestic General, Stockwater, and Irrigation. The total annual volume authorized is 5 afy. The total annual volume claimed is 328.7 afy under the long form claims and is not specified under the short form claims.

Diobsud Creek

This sub-basin contains the POD/W for four water rights, including two certificates, one long form claim, and one short form claim. The purposes of use on the two certificates are Domestic Single and Stockwater, the purposes of use on the long form claim is Domestic General and Irrigation, and the purposes of use on the short form claim is Domestic General and Irrigation. The total annual volume authorized under the certificates for Domestic Single is 1.5 afy and for Stockwater is 0.12 afy additive and 0.5 afy non-additive. The annual volume claimed is 80 afy

for irrigation of 40 acres under the long form claim and is not specified under the short form claim.

Everett Creek

This sub-basin contains the POD/W for 14 water rights, including 1 certificate, 6 long form claims, and 7 short form claims. The purposes of use on the certificate are Domestic Single and Irrigation. The purposes of use on the long form claims include Domestic General, Stockwater, and Irrigation. The purposes of use on the short form claims include Domestic General, Stockwater, and Irrigation. The total annual volume authorized under the certificate for Domestic Single is 1 afy and for Irrigation is 4 afy for irrigation of 2 acres. The total annual volume claimed is 13 afy under the long form claims and is not specified under the short form claim.

Finney Creek

This sub-basin contains the POD/W for five water rights, including one long form claim and four short form claims. The purpose of use on the long form claim is Domestic General. The purposes of use on the short form claims include Domestic General and Stockwater. The total annual volume claimed is 1 afy under the long form claim and is not specified under the short form claims.

Grandy Creek

This sub-basin contains the POD/W for 19 water rights (plus 1 reservoir certificate), including 9 certificates, 6 long form claims, and 4 short form claims. The purposes of use, annual volume, and percentage of total use for the certificates are shown in **Table 5**. The purposes of use on the long form claims include Domestic General, Stockwater, and Irrigation. The purposes of use on the short form claims include Domestic General and unspecified. The total annual volume authorized under the consumptive certificates is 597.2 afy. The total annual volume claimed is 12.6 afy under the long form claims and is not specified under the short form claims.

Table 5
State-Issued Water Rights by Purpose of Use in Grandy Creek Sub-Basin

Purpose of Use	Annual Volume (afy)	Percentage of Use
Domestic Single	2.0	0.3%
Domestic Multiple	29.0	4.9%
Municipal	141.0	23.6%
Irrigation	82.0	13.7%
Recreation – Beautification	343.2	57.5%
Fish Propagation	Non-consumptive	NA
Total	597.2	100 %

Gravel Creek

This sub-basin contains the POD/W for four water rights, including two certificates and two long form claims. The purposes of use on the certificates are each Domestic Single and Irrigation. The purposes of use on the long form claims include Domestic General, Stockwater, and Irrigation. The total annual volume authorized under the certificates for Domestic Single is 2 afy and for Irrigation is 62 afy for irrigation of 31 acres. The total annual volume claimed is 4 afy under the long form claims.

Hobbit Creek

This sub-basin contains the POD/W for one long form claim water right. The purpose of use on the claim is identified as Domestic General and Stockwater. The total annual volume claimed is 2 afy.

Irene Creek

This sub-basin contains the POD/W for one short form claim water right. The purpose of use on the claim is identified as Domestic General. The total annual volume claimed is not specified.

Jackman Creek

This sub-basin contains the POD/W for seven water rights, including one certificate and six long form claims. The purpose of use on the certificate is Commercial and Industrial. The purposes of use on the long form claims include Domestic General, Stockwater, and Irrigation. The total annual volume authorized under the certificate for Commercial and Industrial is 10 afy. The total annual volume claimed is 9.2 afy under the long form claims.

Jordan Creek

This sub-basin contains the POD/W for two water right certificates. The purpose of use on both certificates is Fish Propagation, which is a non-consumptive use as defined in this study, for the Washington Department of Fish and Wildlife Marblemount Hatchery.

Mill Creek

This sub-basin contains the POD/W for one long form claim water right. The purpose of use on the claim was not specified. The total annual volume claimed was not specified.

O'Brian Creek

This sub-basin contains the POD/W for one water right certificate. The purpose of use on the certificate is identified as Irrigation. The total annual volume authorized under the certificate is 80 afy for irrigation of 40 acres.

Olson Creek

This sub-basin contains the POD/W for nine water rights, including three certificates, one permit, two long form claims, and three short form claims. The purposes of use, annual volume, and percentage of total use for the certificates and permit are shown in **Table 6**. The purposes of use on the long form claims include Domestic General, Stockwater, and Irrigation. The purposes of use on the short form claims include Domestic General and Irrigation. The total annual volume authorized under the consumptive certificates and permit is 25.93 afy. The total annual volume claimed is 87,121 afy under the long form claims and is not specified under the short form claim.

Table 6
State-Issued Water Rights by Purpose of Use in Olson Creek Sub-Basin

Purpose of Use	Annual Volume (afy)	Percentage of Use
Domestic Single	2.0	7.7%
Domestic Multiple	5.0	19.3%
Irrigation	14.5	55.9%
Commercial and Industrial	4.07	15.7%
Stockwater	0.36	1.4%
Fire Protection	As needed	NA
Fish Propagation	Non-consumptive	NA
Total	25.93	100%

Prairie Creek

This sub-basin contains the POD/W for 11 water rights, including four certificates, five long form claims, and two short form claims. The purposes of use, annual volume, and percentage of total use for the certificates are shown in **Table 7**. The purposes of use on the long form claims include Domestic General, Irrigation, and Stockwater. The purposes of use on the short form claims include Domestic General and Irrigation. The total annual volume authorized under the consumptive certificates is 622.7 afy. The annual volume claimed is 19,731 afy under the long form claims and is not specified under the short form claim.

Table 7
State-Issued Water Rights by Purpose of Use in Prairie Creek Sub-Basin

Purpose of Use	Annual Volume (afy)	Percentage of Use
Domestic Single	2.0	0.3%
Domestic Multiple	4.0	0.6%
Irrigation	609.0	97.9%
Stockwater	7.7	1.2%
Power	Non-consumptive	NA
Total	622.7	100%

Pressentin Creek

This sub-basin contains the POD/W for one water right permit. The purpose of use on the permit is identified as Municipal. The total annual volume authorized is 30 afy.

Rocky Creek

This sub-basin contains the POD/W for one water right certificate. The purpose of use on the certificate is identified as Domestic Single. The total annual volume authorized is 0.5 afy. The water right in this sub-basin contains another POD/W outside of the sub-basin.

Sutter Creek

This sub-basin contains the POD/W for one short form claim water right. The purpose of use on the claim is identified as Domestic General. The total annual volume claimed is not specified.

Remainder of WRIA 4 (Outside of Defined Sub-Basins)

The area outside of all the sub-basins contains the POD/W for 668 water rights, including 163 certificates, 9 permits, 222 long form claims, and 274 short form claims. The purposes of use, annual volume, and percentage of total use for the State-issued water rights are shown in **Table 8**. The total annual volume authorized under the consumptive State-issued water rights is 24,313.84 afy. The annual volume claimed is 29,204 afy under the long form claims and is not specified under the short form claim.

Table 8
State-Issued Water Rights by Purpose of Use in WRIA 4 Outside of Defined Sub-Basins

Purpose of Use	Annual Volume (afy)	Percentage of Use
Municipal	21,443.70	88.2%
Domestic Multiple	293.65	1.2%
Domestic Single	47.50	0.2%
Irrigation	1,538.89	6.3%
Commercial and Industrial	978.00	4.0%
Stockwater	12.10	0.1%
Power	Non-consumptive	NA
Fire Protection	As needed	NA
Fish Propagation	Non-consumptive	NA
Total	24,313.84	100%

Calculations of Current Water Use

Current (from the past 5 years) water use for each purpose of use under all State-issued water rights was obtained, calculated, or estimated. This section identifies the methods and data used for each purpose of use. No site visits or interviews with water right holders were conducted to ground truth the water use conclusions.

Municipal Water Supply

Water Use Efficiency Reports

Under the Municipal Water Law, certain municipal water right holders are required to submit water use information on an annual basis to the Washington State Department of Health (DOH). DOH makes this data available through its Sentry database, which is accessible on the internet. Within these reports, the value provided under “Total Water Produced and Purchased (TP) – Annual Volume” was the value used in this study. The available data for each public water system is included in **Appendix A**. The current use data entered into the Inventory Table was for the most recent year of data for the public water systems listed in **Table 9**.

Table 9
Water Use Efficiency Data Used as Current Water Use

Public Water System	Use (afy)	Most Recent Year
Cape Horn Maintenance Co, Inc.	82.0	2018
Cascade River Community Club	14.4	2018
Pressentin Creek Community Club	8.0	2018
River Lane Community Club	1.8	2018
Sauk Mountain Estates	4.4	2018
Seattle City Light – Diablo	39.6	2017
Seattle City Light – Newhalem	52.7	2017
Skagit County PUD 1 – Cedargrove	30.8	2017
Skagit County PUD 1 – Rockport	9.9	2017
Skagit County PUD 1 – Skagit View Village	11.3	2017
Timberline Travelers Park	2.7	2018
Town of Darrington	262.7	2018
Town of Concrete	811.4 ¹	2017
¹ RH2 (2015) documented that the metering data provided by the Town of Concrete includes water that is used to maintain reservoir levels, but that returns to the environment without moving through the Town’s distribution system. Water entering the Town distribution system is likely closer to 284 afy (35 percent of diverted volume).		

Ecology Metering Database

Some water right holders are required to submit water use metering data to Ecology as a condition of their water rights. Ecology maintains a database of this information that is more detailed than the DOH Water Use Efficiency reports in that it identifies the volume pumped from specific sources as opposed to the composite total water produced from all sources. However, this database is very limited for WRIA 4. Ecology currently only has 12 meters in the database. Of those meters, four are associated with the Town of Darrington, two are associated with the Skagit County Public Utility District (PUD) Marblemount Water System (municipal use and mitigation), one is for Puget Sound Energy’s Upper Baker Water System, one is for filling of Lake Tye, two are for non-consumptive hydropower generation associated with Puget Sound Energy’s Baker River Project, and two are for users that have not been reporting their water use. The Ecology metering database data that was entered into the Inventory Table was for the water systems and water rights identified in **Table 10**. Town of Darrington data was excluded because the Town is not located in one of the WRIA 4 sub-basins of interest and Water Use Efficiency report data was used instead. The others were excluded because they are non-consumptive or because no data is available.

Table 10
Ecology Metering Database Data Used as Current Use

Public Water System	Use (afy)	Most Recent Year
Puget Sound Energy – Upper Baker Water System G1-28744P	8.7	2018
Skagit PUD – Marblemount (municipal) G1-28137P	5.8	2017
Skagit PUD – Marblemount (mitigation) G1-28137P	4.2	2017
Lake Tyee (Lake Filling) SWC 11357 and S1-00500C	151	2017

Single and Multiple Domestic

Residential

Current water use estimates for single homes and small group domestic residential water systems were taken from a report for WRIA 4 being prepared simultaneously by Aspect Consulting, LLC (Aspect). In that report, Aspect determined that 0.21 afy was a reasonable per home estimate for current water use in WRIA 4.

Campgrounds

Some domestic water rights are for things such as camps and campgrounds. For these water rights, an attempt was made to correlate the water right to a particular public water system in DOH’s Sentry database. If the water system was identified as inactive, then the use was assumed to be zero. If the water system was identified as active, then the water facilities inventory form was reviewed to identify the types of uses. The DOH *Water System Design Manual (Appendix B)* was then used to estimate the annual volume anticipated for each user.

For Forest Service campgrounds, the annual quantity was based on the number of campsites available, with assumptions of an average 50-percent occupancy rate, 50 gallons per day (gpd) per camper water use, an average of 4 campers per site, and campground operations from June 1st through September 30th (122 days), annually. This calculation produces an annual volume of just under 0.04 afy per campsite.

For non-Forest Service campgrounds and RV parks, the annual quantity was based on the DOH Sentry water system database information to determine the total number of connections and the number of those that are full time. Full-time connections were considered to use 0.21 afy, consistent with a residential domestic connection. Part-time connections were assumed to use an average of 0.07 afy. This part-time connection value was obtained from metering data

provided to Ecology for a water right change application processed for the Burlington KOA (YS RV Resort LLC), located in WRIA 3. This annual volume equals an annual average of 65 gpd per part-time connection.

For visitors' centers, offices, and restrooms specifically called out in the water right documents and associated with tourist destinations, an assumption of 2 afy of water use was assigned to each.

Irrigation

Initially, the Washington State Department of Agriculture – Agricultural Land Use database (Washington State Department of Agriculture, 2019) was reviewed for identification of irrigated acres, crops grown, and whether irrigation has occurred. However, this dataset was limited for WRIA 4 and does not include all fields that are cleared and farmed. For this reason, RH2 chose to use the method described in the following section.

Aerial Photos, Washington Irrigation Guide, and Ecology Guidance 1210

For irrigation water rights, the following methodology was used. First, aerial photos were reviewed in Google Earth within the State-issued water right places of use. Two acreage numbers were documented in the Inventory Table based on that aerial photo analysis: 1) the acres of total cleared land, and 2) the acres of estimated irrigated land.

The total cleared land acres represent the maximum acreages that could be irrigated currently. The estimated irrigated acres were based on review of several years of aerial photos (2005 to 2016) looking for green crops later in the summer and/or irrigation actively occurring. Calculations made in this report use the estimated irrigated acres. When the place of use boundaries did not line up exactly with a parcel or field boundary, acreage outside of the water right place of use, but contiguous, was included. Irrigation occurring fully outside of a water right place of use was not documented in the Inventory Table or in this report.

Review of aerial photos identified four primary crop types. The crops being grown in WRIA 4 within the place of use of a State-issued water right include pasture/turf, berries (raspberries and blueberries), garden, and Christmas trees. The Washington Irrigation Guide (WIG), with its crop irrigation requirements (CIR) for the Concrete, Washington station, was used across WRIA 4 (**Appendix C**). The WIG identifies the CIR needed such that the crop is not stressed by water shortage in an average year. Said another way, on average, every other year the crop will experience water availability stress. However, for a WRIA-wide assessment, this value is reasonable to use. The CIR values used for each crop type are shown in **Table 11**.

Table 11
Crop Irrigation Requirements

Crop Type	CIR (inches)	Source
Pasture/Turf	14.79	1992 WIG (pasture/turf)
Berries	16.25	1985 WIG (raspberries)
Garden ¹	10.00	Estimated
Christmas Trees ²	6.00	Estimated

¹ Garden is usually row crops. CIR for some standard row crops include carrots at 5.91 inches, cucumbers at 2.49 inches, green beans at 3.27 inches, peas at 5.43 inches, potatoes at 7.48 inches, raspberries at 16.25 inches, sweet corn at 7.01 inches, and tomatoes at 6.08 inches. Based on the typical crops grown, it was assumed that the average crop irrigation requirement for a diverse vegetable garden in this area would be 10.00 inches.

² Christmas Trees are only sometimes irrigated. When irrigation does occur, it is often in a few heavy doses over the early irrigation season (assume 3 doses of 2 inches for a total of 6 inches). Pacific Northwest Extension (2003).

For irrigation calculations the following parameters and equation are used:

$$TIR = \frac{CIR}{Ea}$$

Where:

TIR = Total Irrigation Requirement

CIR = Crop Irrigation Requirement

Ea = Irrigation Application Efficiency

Review of aerial photos also allowed for identification of the most likely irrigation method used on the crops. The irrigation application efficiency for these different irrigation methods is shown in **Table 12**.

Table 12
Irrigation Application Efficiencies

General	Method Specific	Application Efficiency (%)	
		Range	Average
Sprinkler	Moving Big Gun	55 to 75	65
Sprinkler	Periodic Move (Hand line)	60 to 85	75
Micro-irrigation	Trickle/Drip	70 to 95	88

From Ecology Water Resources Program GUID-1210 (2005).

If the irrigation method could not be directly determined through aerial photo analysis, the assumption used is that pasture/turf is irrigated using a moving big gun, gardens and Christmas trees are irrigated with a periodic-move hand line, and berries are irrigated with trickle/drip. The average irrigation application efficiency has been used in all total irrigation requirement calculations.

Calculations for each crop type and irrigation method used under a water right are contained in the Inventory Table. The TIR (in feet) when multiplied by the acres irrigated is the annual volume used. Therefore, for a pasture/turf field that is being irrigated using a moving big gun that is 1 acre in area, the annual volume used is equal to 1.90 afy (14.79 inches divided by 65 percent and divided by 12 inches per foot and then multiplied by 1 acre).

Stockwater

DOH provides drinking water estimates for stock as part of its *Water System Design Manual* (2009). Drinking water use data from that document, for animals that could be expected to be found in WRIA 4, is shown in **Table 13**.

Table 13
Stockwater Use

Livestock Drinking	Gallons per day	Acre-feet per year
Beef, yearling	20	0.022
Cattle or Steers	12	0.013
Dairy	20	0.022
Dry Cows or Heifers	15	0.017
Chickens (per 100 birds)	10	0.011
From DOH <i>Water System Design Manual</i> (2009).		

To be conservative toward identifying the likely maximum use, 20 gpd per animal was used for all cows and cattle.

The Washington State Department of Agriculture (WSDA) Washington Dairy Farms – 2018 GIS data shows the location of licensed Grade A cow milk dairy milking facilities in Washington State. No licensed dairy facilities were shown to exist in WRIA 4. For this reason, it is believed that most cow/cattle stock located in WRIA 4 are associated with beef cattle operations, or smaller “hobby” and specialty farms.

Mr. Don McMoran, Director of Washington State University Skagit County Extension, was consulted regarding the typical number of cattle per acre in Skagit County for non-dairy operations. Mr. McMoran responded that 1 cow/cattle per acre is a common density in Skagit County.

One cow/cattle per acre was then multiplied by the acres within the stockwater water right place of use to estimate the number of cows/cattle utilizing water under that water right.

The estimated number of cows/cattle was then multiplied by 20 gpd (0.0224 afy) to estimate the volume of water used under a water right for stockwater. The calculation comes out to 0.0224 afy per acre within the place of use of each stockwater water right.

Commercial and Industrial

The commercial and industrial purpose of use covers a wide range of actual water uses. In WRIA 4, this is most often associated with mining operations (both aggregate and mineral extraction) and lumber mills (usually associated with water used for employee sanitation). There appears to be no current commercial and industrial use in WRIA 4 under stand-alone State-issued water rights.

Mining

For sand and gravel and bedrock aggregate mining operations, the Washington State Department of Natural Resources Surface Mining Reclamation Database was reviewed through the Washington Geologic Information Portal, Earth Resources Permit Locations website (accessed June 2019) to determine if there are active surface mine permit sites within the place of use of State-issued water rights. Aerial photos of the places of use also were reviewed to see if there appeared to be active mining occurring within the place of use. If both investigations suggested that there was no active mine on the site, then it was concluded that there was no current use. The database shows that there are eight active surface mine permit sites in WRIA 4, but none of them are located within the place of use of a State-issued water right.

For mineral extraction mining, the Washington State Department of Natural Resources (WADNR) website of abandoned mining sites was reviewed (accessed June 2019). A water right for the Azurite Mine Site (SWC 1109 in the name of Azurite Gold Company) was determined to have no current use since the site is identified as inactive and abandoned based on a WADNR publication (Wolff and others, 2002) located through that website.

Lumber Mill

The only large, operational, lumber mill identified in WRIA 4 is the Hampton Lumber Mill in the Town of Darrington. All other historic mills located in WRIA 4 appear to have closed. The Hampton Lumber Mill now receives its potable water from the Town of Darrington (Trepanier Engineering, 2001).

Fire Protection

Fire protection as a purpose of use in water rights is often associated with a home or business. On many of the water rights, no instantaneous rate or annual volume is specifically associated with this purpose of use. This purpose of use is only utilized during an emergency and does not represent an ongoing water use that occurs regularly. For this reason, the estimated current use was identified as 0 afy in the Inventory Table for this purpose of use under any water right.

Comparison of Current Water Use to Authorized Water Right Use Limits

This section of the report utilizes the Inventory Table, and the data and calculations contained in this report, to compare the authorized water use to estimated current water use on a WRIA-wide and sub-basin basis for all the State-issued water rights.

WRIA–Wide Water Right and Estimated Water Use

This analysis includes all State-issued water rights in WRIA 4, excluding those that are for reservoirs and fully non-consumptive water uses. **Table 14** breaks out and compares the water rights and the estimated water use on a WRIA-wide basis for the different purposes of use.

Table 14
WRIA 4 State-Issued Water Rights and Estimated Current Annual Water Use

Purpose of Use	Water Right Limit (afy)	Estimated Current Use (afy)	Percent Used
Municipal	21,641.7	1,403.1	6%
Domestic Multiple	331.7	82.6	25%
Domestic Single	63.5	13.4	21%
Commercial and Industrial	992.1	0.0	0%
Irrigation	2,390.4	842.2	35%
Stockwater	25.3	38.9	154%
Recreation – Beautification	343.2	151.0	44%
Total	25,787.9	2,531.2	10%
Excludes non-consumptive uses, reservoir water rights, water use under claims, water use under permit-exempt wells, and water use occurring outside of a water right.			

Figures 5 and 6 show the breakdown in the water right limit and estimated current use by purpose of use.

The following tables break out the water rights and estimated water use by purpose for State-issued water rights by sub-basin, excluding fully non-consumptive uses, water use under claims, water use under permit-exempt wells, water use occurring outside of a water right, and reservoir water rights. Only those purposes of use identified under a State-issued water right utilizing water from that sub-basin are shown in each table.

Barr Creek

The Barr Creek sub-basin has five single domestic surface water right certificates diverting from it. The water rights were all applied for on the same date (all have the same priority date of May 26, 1982) and were issued for the same rate and annual volume. The comparison of the water right and estimated use is contained in **Table 15**.

Table 15
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the Barr Creek Sub-Basin

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Domestic Single	5.0	1.1	22%

Boulder Creek

The Boulder Creek sub-basin has two municipal water rights held by the Cascade River Community Club. These are surface water rights that are no longer in use because the Cascade River Community Club switched to a ground water right (G1-20975C) with a well located outside of this sub-basin. The comparison of the water right and estimated use is contained in **Table 16**.

Table 16
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the Boulder Creek Sub-Basin

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Municipal	27.0	0.0	0 %

Corkindale Creek

There is a single stockwater water right certificate in the Corkindale Creek sub-basin. The water right annual volume of 5 afy was estimated since there was no annual volume specified on the water right. The comparison of the water right and estimated use is contained in **Table 17**.

Table 17
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the Corkindale Creek Sub-Basin

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Stockwater	5.0	2.3	46%

Diobsud Creek

There are two surface water certificates diverting water from this sub-basin. Each water right is for domestic single and stockwater. The stockwater annual volume is defined specifically on one of the water rights and considered a part of the volume granted for domestic single on the other. Regardless, the estimated stockwater use exceeds the water right limit. The large percentage exceedance should be taken in context since the numbers being used in the calculation are so small. The comparison of the water right and estimated use is contained in **Table 18**.

Table 18
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the Diobsud Creek Sub-Basin

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Domestic Single	1.5	0.4	27%
Stockwater	0.12	0.65	542%

Everett Creek

There is one surface water certificate within this sub-basin, which identifies two purposes of use; domestic single and irrigation. There are grass and Christmas trees planted within the place of use. It was estimated that the Christmas trees only were irrigated when they were first planted. The comparison of the water right and estimated use is contained in **Table 19**.

Table 19
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the Everett Creek Sub-Basin

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Domestic Single	1.0	0.2	20%
Irrigation	4.0	6.6	165%

Grandy Creek

There are a number of water rights diverting, withdrawing, and storing water from this sub-basin. This includes the Lake Tye, Creekside Camping, and Grandy Creek Resort public water systems. Lake Tye is filled with water from Grandy Creek. Since the water does not return from Lake Tye to Grandy Creek, it is considered consumptive. The U.S. Department of Interior Bureau of Fisheries used to operate a fish hatchery near the mouth of Grandy Creek, but that facility has been closed down for years and the site is overgrown. Irrigation occurring under water rights appears to be limited to garden and minor lawn watering. The comparison of the water right and estimated use is contained in **Table 20**.

Table 20
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the Grandy Creek Sub-Basin

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Municipal	141.0	62.4	44%
Domestic Multiple	29.0	16.2	56%
Domestic Single	2.0	0.4	20%
Irrigation	82.0	1.0	1%
Recreation – Beautification	343.2	151.0	44%

Gravel Creek

There are two surface water certificates diverting water from this sub-basin. Each water right is for domestic single and irrigation. The comparison of the water right and estimated use is contained in **Table 21**.

Table 21
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the Gravel Creek Sub-Basin

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Domestic Single	2.0	0.4	20%
Irrigation	62.0	18.3	30%

Jackman Creek

There is one surface water certificate within this sub-basin, which identifies the purpose of use as commercial and industrial for a mill, including the associated log pond, domestic, and fire protection uses. No annual volume was specified on the water right, so an estimate of 10 afy was assigned. No structures are visible within the place of use, so it is assumed that the mill is no longer in operation. The comparison of the water right and estimated use is contained in **Table 22**.

Table 22
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the Jackman Creek Sub-Basin

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Commercial and Industrial	10.0	0.0	0%

O'Brian Creek

There is one surface water certificate within this sub-basin. That certificate identifies the purpose of use as irrigation of 40 acres. No annual volume was specified on the water right, so an estimate of 80 afy (2 feet per acre water duty) was assigned. No irrigation appears to be occurring within the place of use. The comparison of the water right and estimated use is contained in **Table 23**.

Table 23
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the O'Brian Creek Sub-Basin

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Irrigation	80.0	0.0	0%

Olson Creek

There is one permit that has several purposes of use identified. The other water rights are single and multiple domestic uses associated with US Forest Service and National Park Service facilities. When the certificate is issued under this water right, the annual volume used under each purpose of use will be better defined. The comparison of the water right and estimated use is contained in **Table 24**.

Table 24
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the Olson Creek Sub-Basin

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Domestic Multiple	5.0	3.9	78%
Domestic Single	2.0	0.4	20%
Irrigation	14.5	1.5	10%
Commercial and Industrial	4.1	0.0	0%
Stockwater	0.36	0.47	131%

Prairie Creek

The two large surface water rights in this sub-basin are associated with a large ranch that has been referred to as the Sturgeon and Sauk Prairie Ranch in the past. The ranch includes water for domestic supply, irrigation, and stock. In addition, there is another certificate for domestic single. The place of use of the water right for stockwater is very large (over 1,000 acres), which factors into the calculation used to estimate current stockwater use. The comparison of the water right and estimated use is contained in **Table 25**.

Table 25
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the Prairie Creek Sub-Basin

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Domestic Multiple	4.0	0.8	20%
Domestic Single	2.0	0.4	20%
Irrigation	609.0	479.6	79%
Stockwater	7.7	30.5	396%

Pressentin Creek

There is one permit for municipal use (Pressentin Creek Community Club) identified in this sub-basin. The estimated current use was obtained from the water use efficiency reporting (**Appendix A**). The comparison of the water right and estimated use is contained in **Table 26**.

Table 26
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the Pressentin Creek Sub-Basin

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Municipal	30.0	8.0	27%

Rocky Creek

The Rocky Creek sub-basin has one single domestic surface water right certificate. This surface water certificate is one of the few that diverts from multiple sub-basins. For this reason, the water right and estimated use were divided between the two sub-basins. The comparison of the water right and estimated use in the Rocky Creek Sub-Basin is contained in **Table 27**.

Table 27
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the Rocky Creek Sub-Basin

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Domestic Single	0.5	0.1	20%

Remainder of WRIA 4 (Outside of Defined Sub-Basins)

The area outside of the sub-basins includes the majority of the water rights in WRIA 4. A majority of the State-issued water rights are within this geographic area. Consistent with the WRIA-wide assessment of the authorized amounts, the estimated current use is a small fraction of the water right limit. The comparison of the State-issued water rights and estimated use is

contained in **Table 28**. One of the reasons for this is that there are a number of old surface water certificates for municipal supply that only list a high instantaneous rate. When multiplied out over the entire year, these water rights calculate as having a very large annual volume. For instance, SWC 1172, which is one of three water rights held by the City of Seattle for municipal supply at Newhalem, identifies an instantaneous rate of 20 cfs, which equals 14,479 afy when utilized continuously over the entire year. The estimated water right annual volume of this one water right represents 56 percent of the WRIA 4 water right limit.

Table 28
State-Issued Water Rights by Purpose of Use Compared to Estimated Use in the Remainder of WRIA 4

Purpose of Use	Water Right Limit (afy)	Estimated Use (afy)	Percent Used
Municipal	21,443.7	1,332.7	6%
Domestic Multiple	293.7	61.6	21%
Domestic Single	47.5	10.0	21%
Irrigation	1,538.9	335.3	22%
Commercial and Industrial	978.0	0.0	0%
Stockwater	12.1	5.0	41%

Analysis of State-Issued Water Rights that Include an Annual Volume Compared to Estimated Current Water Use

In order to more accurately compare the annual volume issued under water rights with the estimated current use, a second comparison was performed using only State-issued water rights that had annual volumes assigned. This subset of the State-issued water rights includes 93 water rights in WRIA 4. The comparison of these water rights and estimated use is contained in **Table 29**.

Table 29
WRIA 4 State-Issued Water Rights with Qa Specified and Estimated Current Annual Water Use Under Those Water Rights

Purpose of Use	Water Right Limit (afy)	Estimated Current Use (afy)	Percent Used
Municipal	3,542.7	1,399.9	40%
Domestic Multiple	143.7	57.2	40%
Domestic Single	41.5	8.8	21%
Commercial and Industrial	188.1	0.0	0%
Irrigation	703.4	220.9	31%
Stockwater	2.6	2.7	104%
Recreation – Beautification	343.2	151.0	44%
Total	4,965.2	1,840.5	37%
Excludes State-issued water rights with no annual volume specified, non-consumptive uses, reservoir water rights, water use under claims, water use under permit-exempt wells, and water use occurring outside of a water right.			

Figures 7 and 8 show the breakdown in the Qa-specified water right limit and estimated current use by purpose of use.

The WRIA-wide results of this analysis suggest that 37 percent of the authorized water right annual volume is currently being used.

Conclusion

There are 769 water rights documented in WRIA 4 (Figure 9). Of these, 211 are State-issued water rights, 255 are long form claims, and 303 are short form claims.

Of the 211 State-issued water rights, 10 are for reservoirs and 55 are for non-consumptive uses such as fish propagation, mill ponds, and hydropower, leaving 146 State-issued water rights that were used in the comparison of authorized water right volume and estimated current use. Removing the State-issued water rights for which no annual volume was specified reduces the total number down to 93 water rights. Of the State-issued water rights, the largest annual volume authorized by purpose of use is for municipal and irrigation.

Of the 34 sub-basins identified by Ecology, only 22 have any water right POD/W located within WRIA 4. Fourteen of those sub-basins have State-issued water right POD/W located within them, of which 13 sub-basins contain consumptive State-issued water right POD/Ws.

Using all WRIA 4 State-issued water rights for consumptive uses, the estimated current water use is approximately 10 percent of the cumulative State-issued water right authorized annual volume. The largest estimated current use by purpose in WRIA 4 is municipal, followed by irrigation.

However, 53 older surface water rights (with a priority date older than approximately 1965) typically do not have annual volumes assigned. The assumption that the use associated with municipal water rights issued without an annual volume is equal to continuous diversion or pumping at the authorized instantaneous rate likely overestimates the actual use under those water rights. Comparison of the estimated current use with the water right annual volume estimates shows the magnitude of the possible discrepancy (**Table 14**).

Therefore, an additional analysis was performed that only included State-issued water rights for consumptive uses in which the annual volume was specified on the water right. This analysis included a total of 93 water rights in WRIA 4. In this comparison, the estimated current water use appears to be approximately 37 percent of the cumulative State-issued water right authorized annual volume (**Table 29**). The largest estimated current use by purpose in WRIA 4 under this modified analysis remained municipal, followed by irrigation.

It is RH2's opinion that 37 percent represents a more realistic estimate of current use to authorized use than the 10 percent calculated when considering all State-issued water rights.

Water right claims can represent valid vested water rights, but use under those water right documents was beyond the scope of this work and was not analyzed in this report.

No current water use was identified for any of the water rights issued by the State for commercial and industrial use. This could be due to the age of the water rights (many of them were issued more than 50 years ago) and the short-term or cyclic nature of some of the resource extraction industries being served (such as lumber mills and mines).

While not examined as part of this study, there are water uses in WRIA 4 that do not occur within the place of use of a State-issued water right. For these uses, it is possible that this water use is not covered by a water right (i.e. it is not an authorized use), is occurring under the ground water permit-exemption, or is occurring under a water right claim. No effort was made to document these uses since that was beyond the scope of this work.

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Figures

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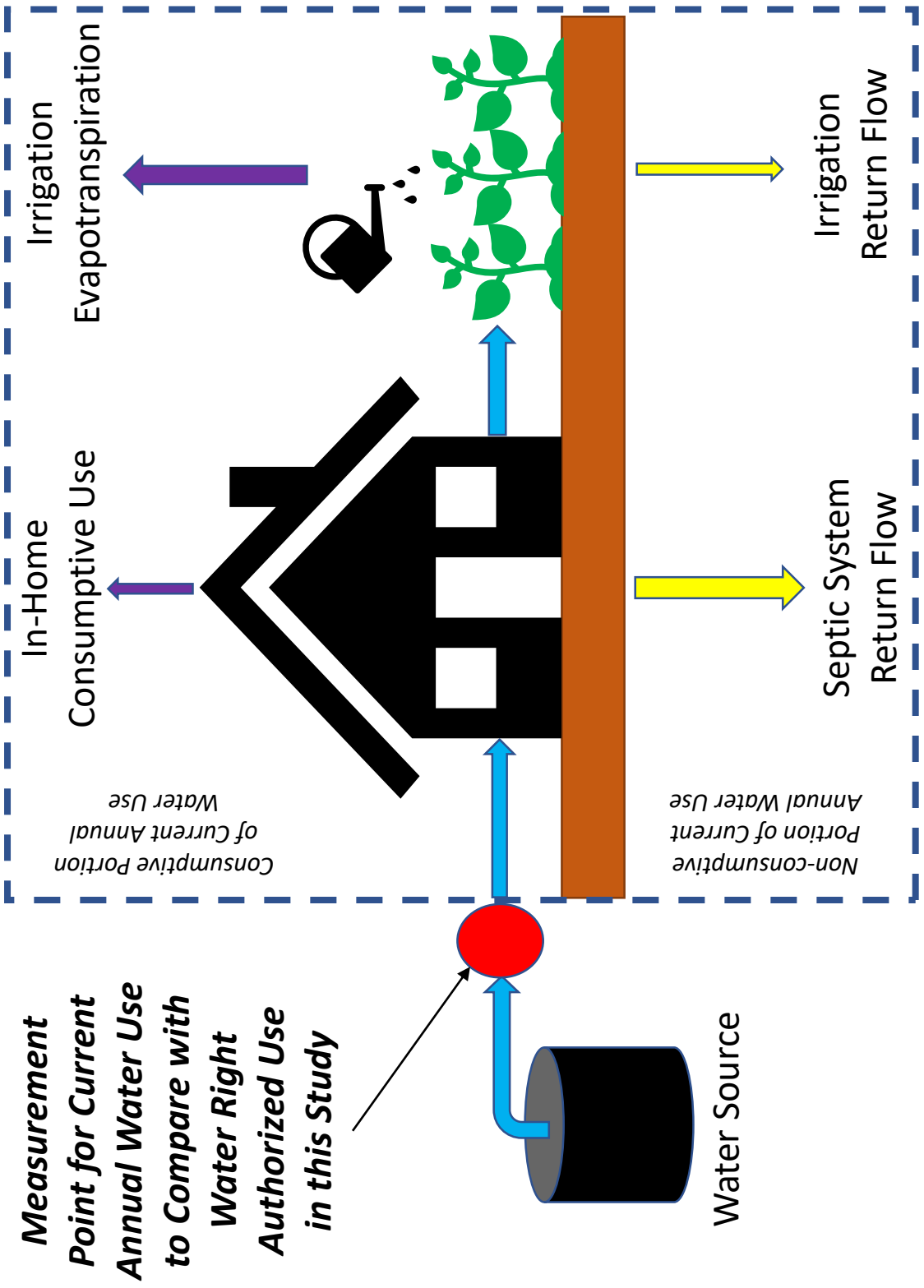
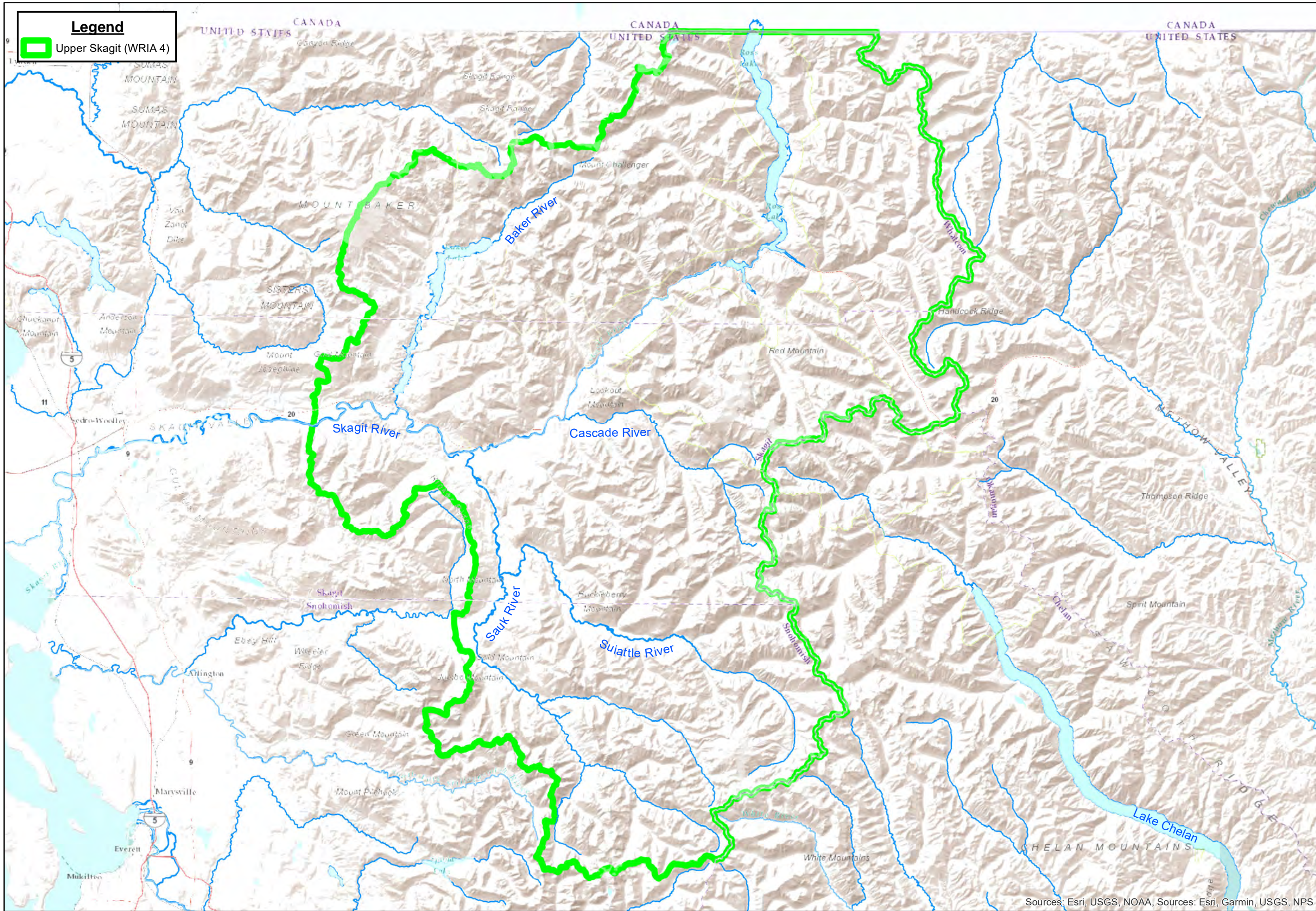



Figure 1. Current Annual Water Use Measurement Point for this Study



Legend
 Upper Skagit (WRIA 4)

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Vicinity Map



HERE, Garmin, (c) Mapbox, and OpenStreetMap contributors.

Figure 2
WRIA 4 - Upper Skagit Overview Map
Washington Department of Ecology
WRIA 4 Water Use Study

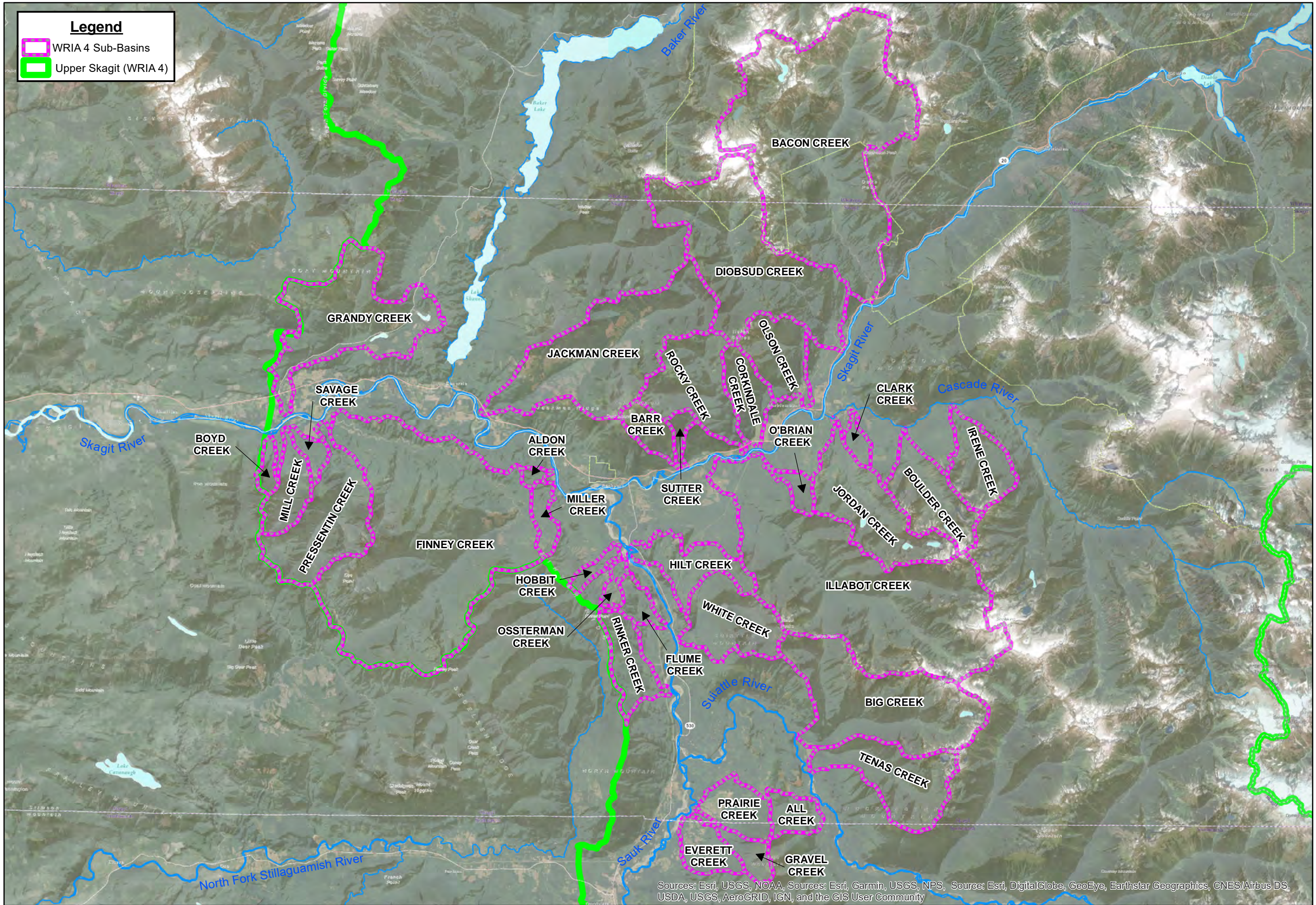


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Sources: Esri, USGS, NOAA, Sources: Esri, Garmin, USGS, NPS

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Legend

- WRIA 4 Sub-Basins
- Upper Skagit (WRIA 4)

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Vicinity Map



Figure 3
WRIA 4 - Upper Skagit
Sub-Basins Map
 Washington Department of Ecology
WRIA 4 Water Use Study

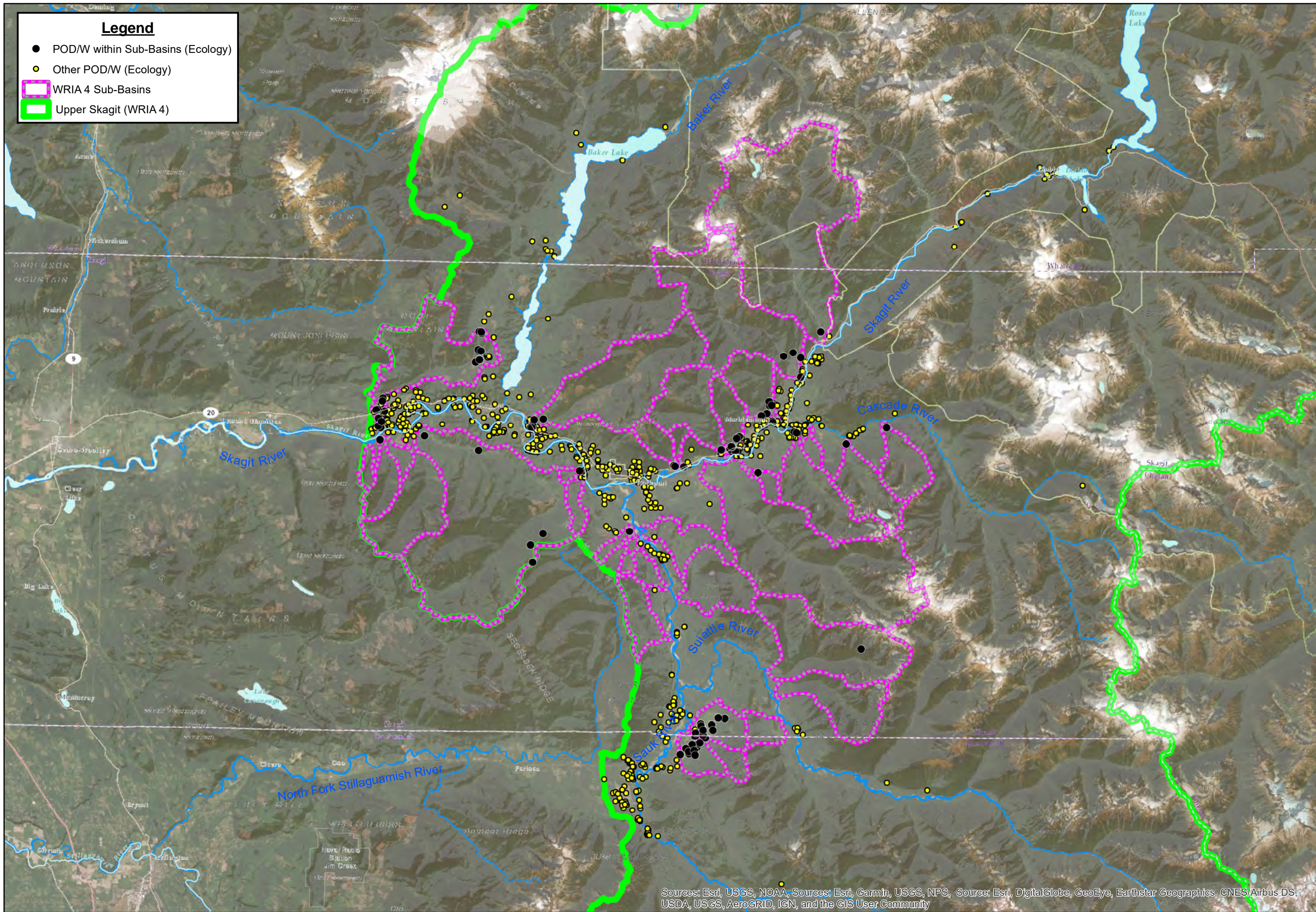


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Sources: Esri, USGS, NOAA, Sources: Esri, Garmin, USGS, NPS, Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Legend

- POD/W within Sub-Basins (Ecology)
- Other POD/W (Ecology)
- ▭ WRIA 4 Sub-Basins
- ▭ Upper Skagit (WRIA 4)

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Vicinity Map



HERE, Garmin, (c) StreetMap contributors,

Figure 4
WRIA 4 - Upper Skagit
POD/W Distribution Map
Washington Department of Ecology
WRIA 4 Water Use Study



1 inch = 24,000 feet
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 DRAWING IS FULL SCALE WHEN BAR MEASURES 1"



Sources: Esri, USGS, NOAA, Sources: Esri, Garmin, USGS, NPS, Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Figure 5. WRIA 4 - State-Issued Water Right Limit by Purpose of Use (afy)
Water Right Total = 25,787.9 afy

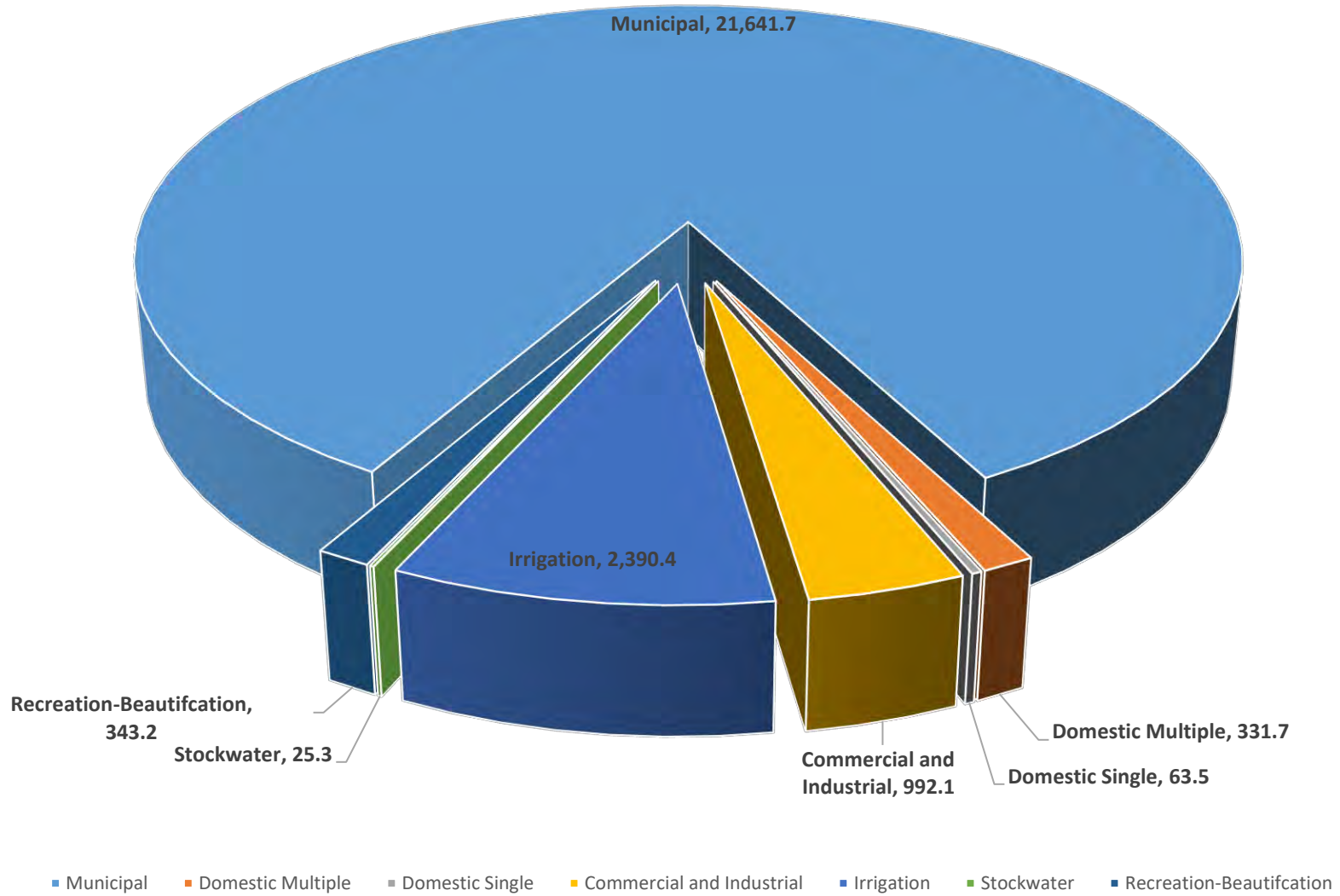
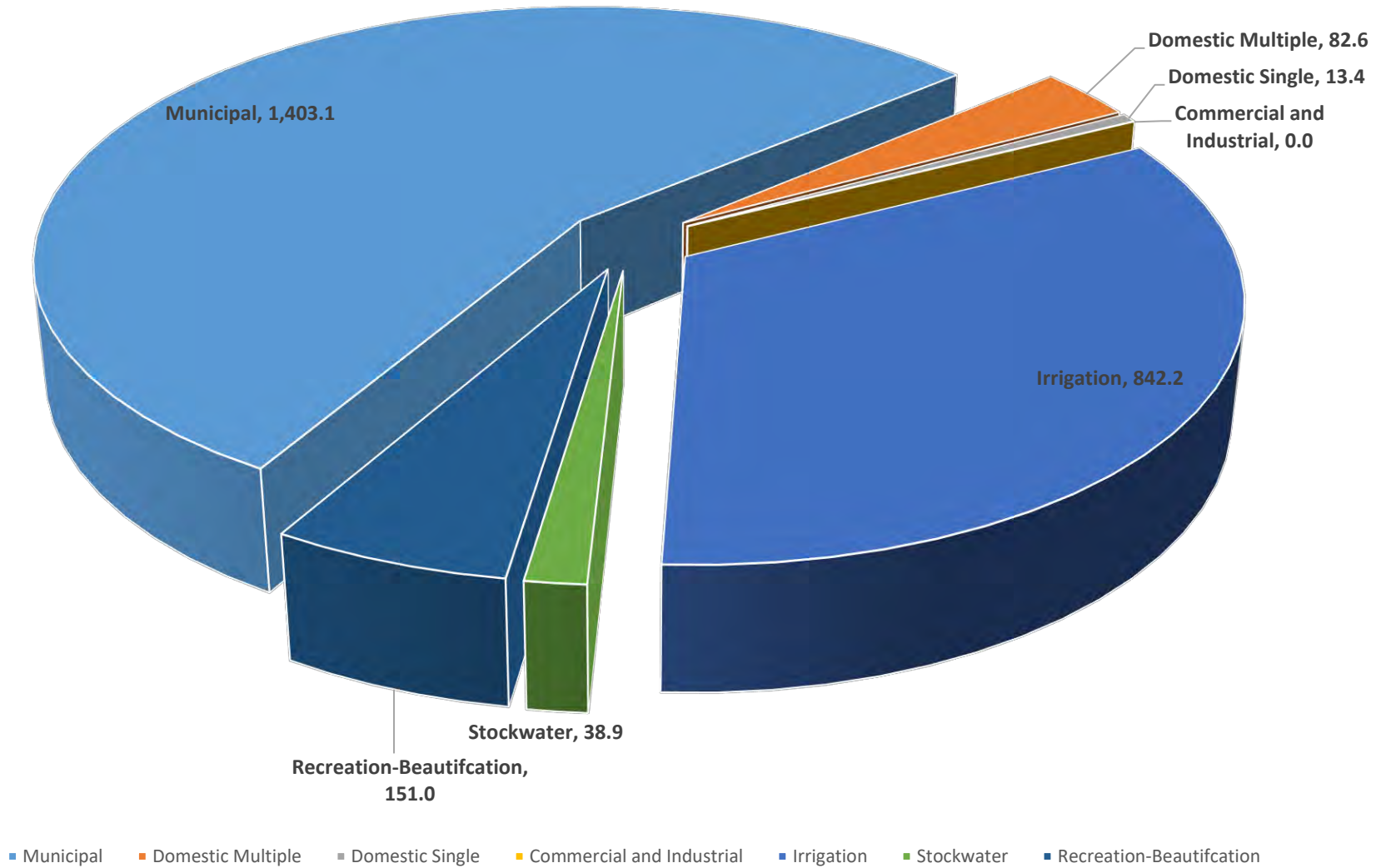
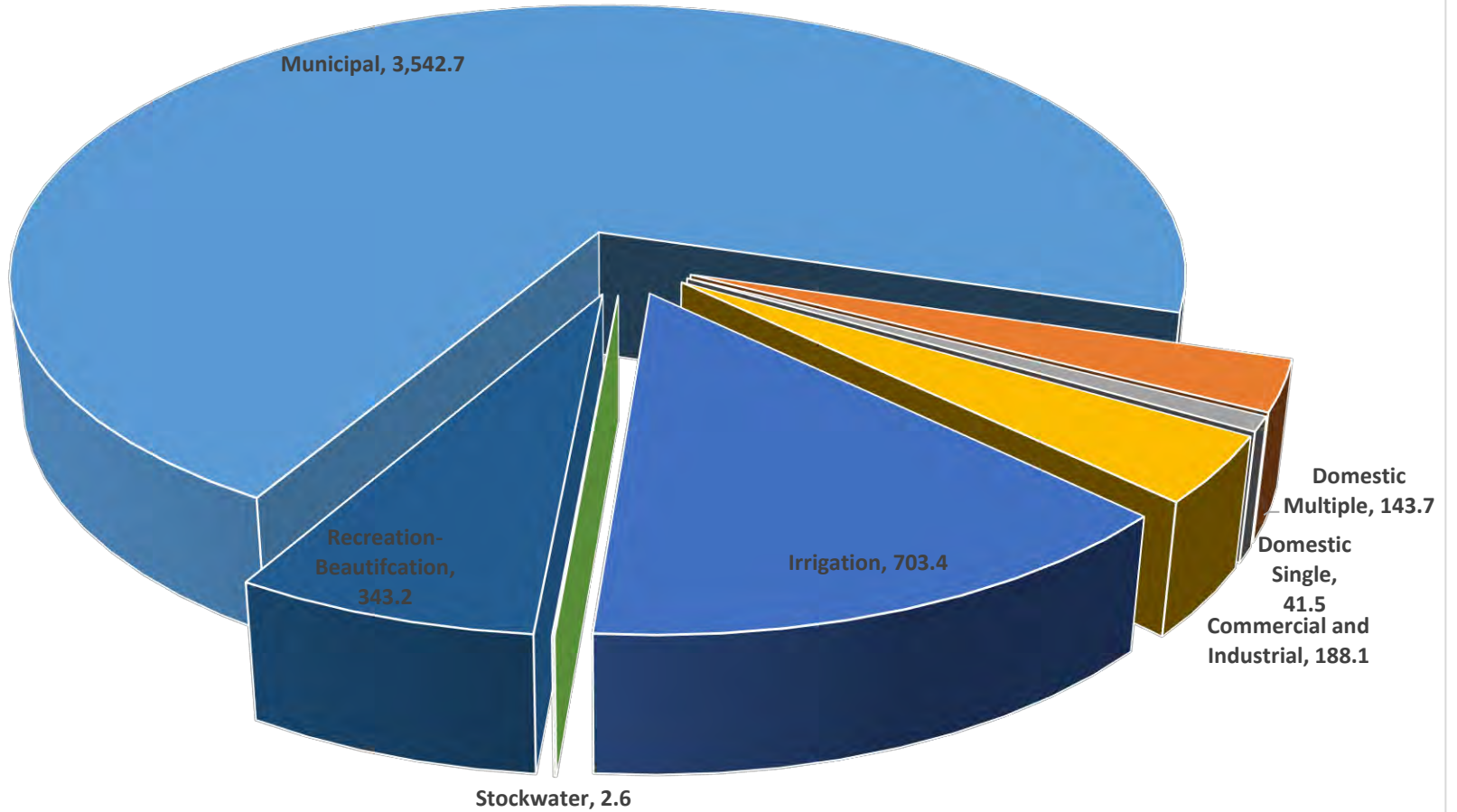


Figure 6. WRIA 4 - State-Issued Water Right Estimated Current Use by Purpose of Use (afy)
Total Estimated Current Use = 2,531.2 afy

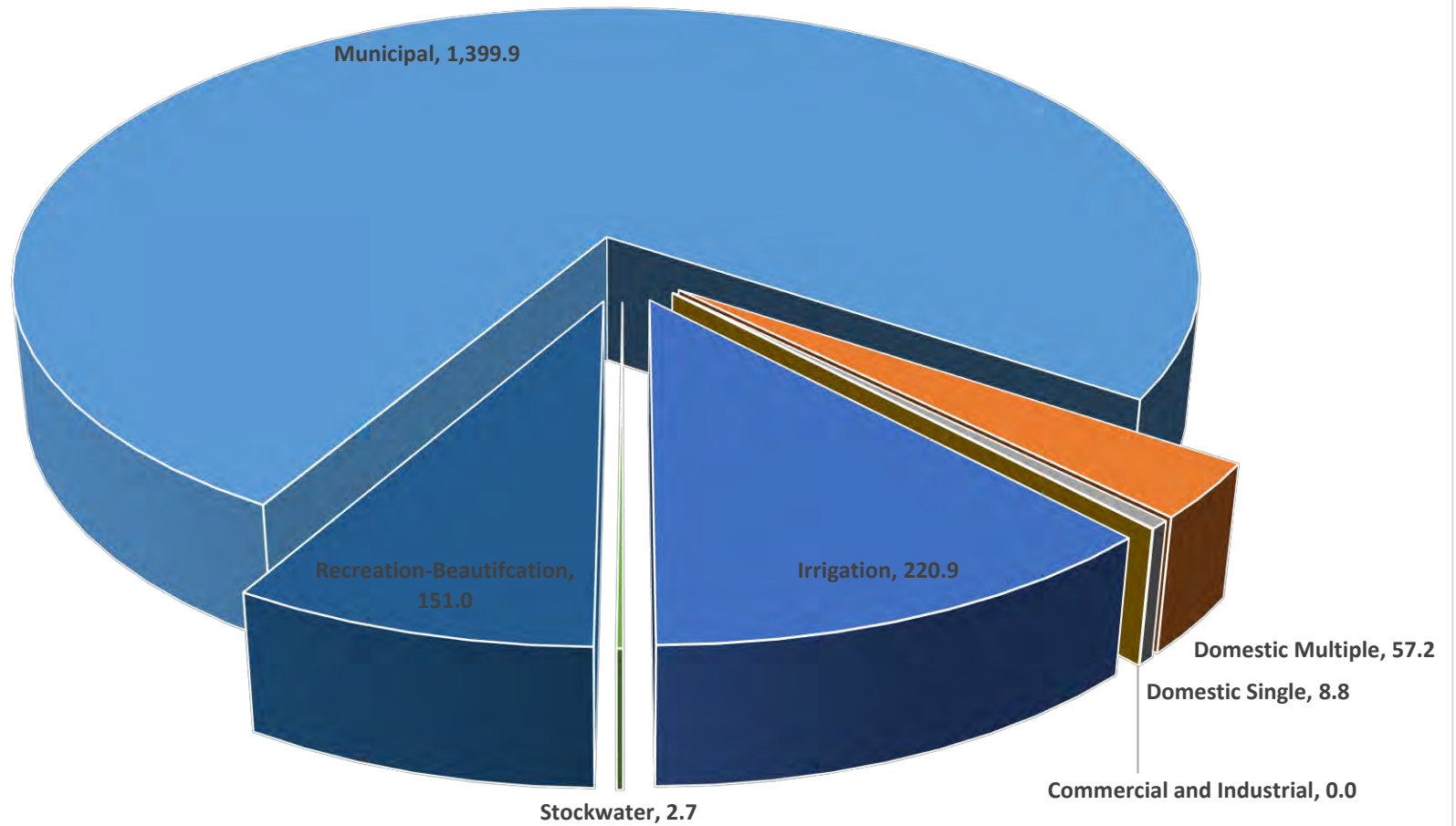


**Figure 7. WRIA 4 - State-Issued Water Right Limit by Purpose of Use (afy)
Only Including Water Rights with Annual Volume Specified
Water Right Total = 4,965.2 afy**



■ Municipal ■ Domestic Multiple ■ Domestic Single ■ Commercial and Industrial ■ Irrigation ■ Stockwater ■ Recreation-Beautifcation

**Figure 8. WRIA 4 - State-Issued Water Right Estimated Current Use by Purpose of Use (afy)
Only Including Water Rights with Annual Volume Specified
Total Estimated Current Use = 1,840.5 afy**



■ Municipal ■ Domestic Multiple ■ Domestic Single ■ Commercial and Industrial ■ Irrigation ■ Stockwater ■ Recreation-Beautification

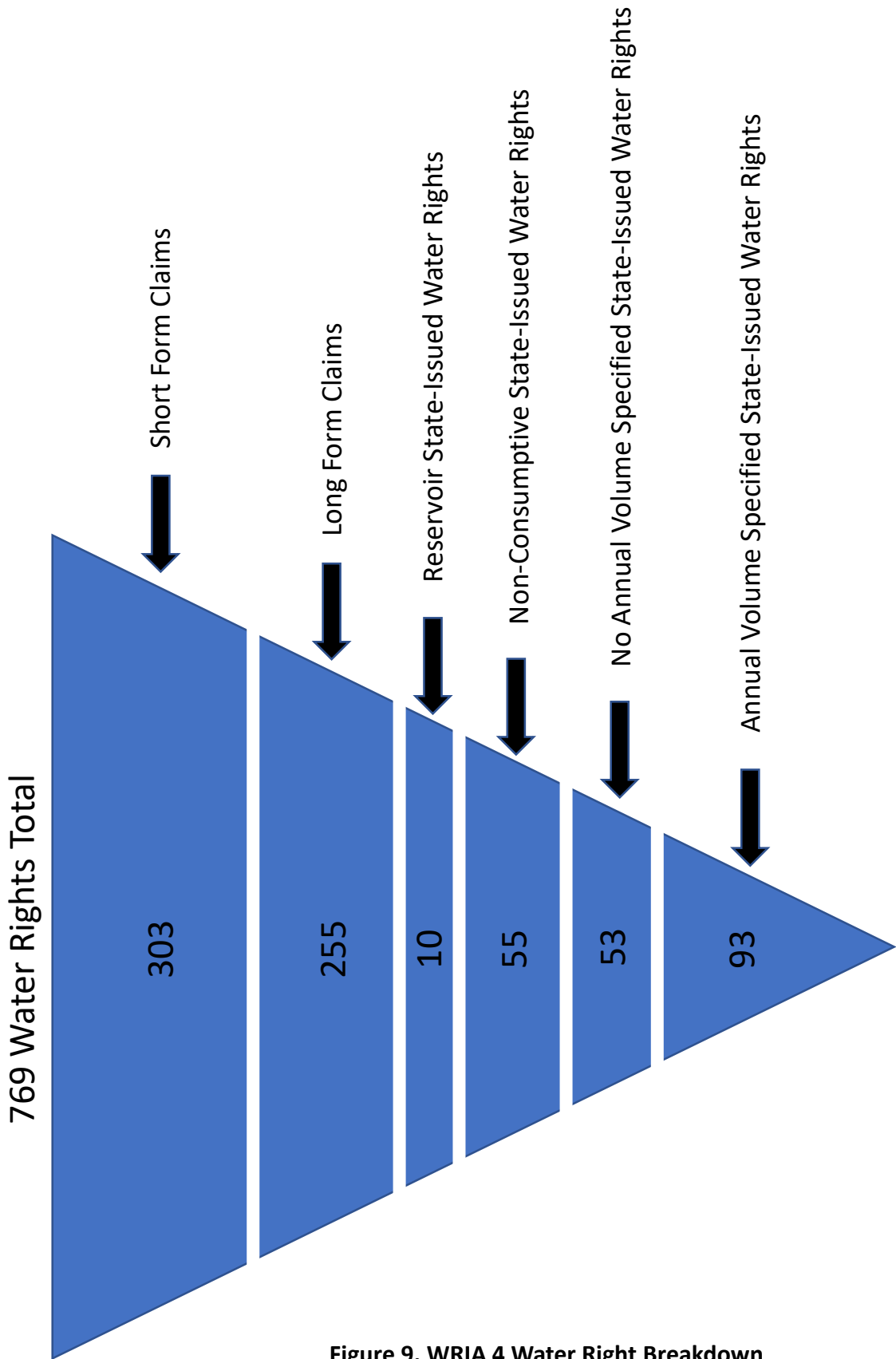


Figure 9. WRIA 4 Water Right Breakdown

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Appendices

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Appendix A

WUE Tables

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Cape Horn Maintenance Company

Public Water System ID No. 11060

G1-22613C - 300 gpm and 119 afy

Year	Annual Volume	
	(gallons)	(acre-feet)
2011	19,337,266	59.3
2012	16,835,446	51.7
2013	23,504,067	72.1
2014	20,408,335	62.6
2015	25,964,696	79.7
2016	21,471,355	65.9
2017	21,471,355	65.9
2018	26,719,420	82.0

Notes: 2011-2018 data from WUE reports.

Cascade River Community Club

Public Water System ID No. 11494

G1-20975C - 125 gpm and 200 afy

Year	Annual Volume	
	(gallons)	(acre-feet)
2010	3,496,400	10.7
2011	5,325,300	16.3
2012	2,902,500	8.9
2013	5,474,000	16.8
2014	6,468,000	19.8
2015	6,583,500	20.2
2016	4,244,867	13.0
2017	4,937,500	15.2
2018	4,686,600	14.4

Notes: 2010-2018 data from WUE reports.

Pressentin Creek Wilderness

Public Water System ID No. 69273

G1-26766P - 37 gpm and 30 afy

Year	Annual Volume	
	(gallons)	(acre-feet)
2011	288,300	0.9
2012	NR	NR
2013	38,781	0.1
2014	1,500,000	4.6
2015	1,506,700	4.6
2016	3,505,300	10.8
2017	5,848,400	17.9
2018	2,594,700	8.0

Notes: 2011-2018 data from WUE reports. NR - Not Reported. 2013 data appears to be in error.

River Lane Community Club

Public Water System ID No. 72773

G1-00554C - 50 gpm and 10 afy

Year	Annual Volume	
	(gallons)	(acre-feet)
2010	1,499,710	4.6
2011	1,718,200	5.3
2012	1,377,900	4.2
2013	1,069,700	3.3
2014	1,048,320	3.2
2015	701,500	2.2
2016	583,980	1.8
2017	596,650	1.8
2018	602,450	1.8

Notes: 2010-2018 data from WUE reports.

Sauk Mountain Estates
Public Water System ID No. 17049
G1-22601C - 100 gpm and 24 afy

Year	Annual Volume	
	(gallons)	(acre-feet)
2015	1,206,000	3.7
2016	NR	NR
2017	2,676,029	8.2
2018	1,427,000	4.4

Notes: 2015-2018 data from WUE reports. NR - Not Reported.

Seattle City Light - Diablo

Public Water System ID No. 19200

SWC 1005 and G1-00490C - 1,099 gpm and 90 afy

Year	Annual Volume	
	(gallons)	(acre-feet)
2009	10,518,000	32.3
2010	19,167,430	58.8
2011	22,962,699	70.5
2012	8,779,142	26.9
2013	8,641,714	26.5
2014	19,162,145	58.8
2015	21,403,572	65.7
2016	12,935,475	39.7
2017	12,915,429	39.6
2018	NR	NR

Notes: 2009-2017 data from WUE reports. NR - Not Reported.

Seattle City Light - Newhalem

Public Water System ID No. 59250

G1-00489C and G1-23722C - 800 gpm and 333 afy

Year	Annual Volume	
	(gallons)	(acre-feet)
2009	19,962,000	61.3
2010	14,064,681	43.2
2011	13,159,183	40.4
2012	15,303,600	47.0
2013	15,933,600	48.9
2014	16,426,800	50.4
2015	19,310,400	59.3
2016	16,203,600	49.7
2017	17,178,200	52.7
2018	NR	NR

Notes: 2009-2017 data from WUE reports. NR - Not Reported.

Skagit County PUD - Cedargrove

Public Water System ID No. 11917

GWC 6756-A and G1-25994C - 362 gpm and 62.8 afy

Year	Annual Volume	
	(gallons)	(acre-feet)
2008	8,494,372	26.1
2009	9,468,481	29.1
2010	7,837,943	24.1
2011	7,779,000	23.9
2012	8,289,000	25.4
2013	9,061,575	27.8
2014	9,069,196	27.8
2015	9,727,473	29.9
2016	9,077,765	27.9
2017	10,030,373	30.8
2018		

Notes: 2008-2017 data from WUE reports.

Skagit County PUD - Rockport

Public Water System ID No. 73600

G1-22623C and G1-25509C - 100 gpm and 38.6 afy

Year	Annual Volume	
	(gallons)	(acre-feet)
2008	3,168,178	9.7
2009	3,853,918	11.8
2010	4,896,936	15.0
2011	3,192,000	9.8
2012	3,027,000	9.3
2013	3,479,239	10.7
2014	3,769,186	11.6
2015	3,907,529	12.0
2016	3,117,935	9.6
2017	3,235,451	9.9
2018	NR	NR

Notes: 2008-2017 data from WUE reports. NR - Not Reported.

Skagit County PUD - Skagit View Village

Public Water System ID No. 96879

G1-20763P - 200 gpm and 38.4 afy

Year	Annual Volume	
	(gallons)	(acre-feet)
2008	3,470,613	10.7
2009	3,824,187	11.7
2010	3,882,657	11.9
2011	3,304,000	10.1
2012	3,676,000	11.3
2013	3,722,586	11.4
2014	3,342,813	10.3
2015	3,990,579	12.2
2016	3,756,490	11.5
2017	3,694,710	11.3
2018	NR	NR

Notes: 2006-2007 data from water system plan. 2008-2017 data from WUE reports. NR - Not Reported.

Timberline Travelers Park Water System

Public Water System ID No. 88398

G1-23091C and G1-25725C - 60 gpm and 25.5 afy

Year	Annual Volume	
	(gallons)	(acre-feet)
2010	63,793	0.2
2011	61,515	0.2
2012	61,291	0.2
2013	58,074	0.2
2014	152,510	0.5
2015	333,080	1.0
2016	835,608	2.6
2017	894,512	2.7
2018	894,512	2.7

Notes: 2010-2018 data from WUE reports. Data appears to be erroneously low for 2010-2014.

Town of Concrete Public Water System ID No. 03950 GWC 71-D - 750 gpm and 1,190 afy		
Year	Annual Volume	
	(gallons)	(acre-feet)
2009	394,200,000	1,209.8
2010	244,272,840	749.6
2011	216,021,600	662.9
2012	263,409,696	808.4
2013	263,325,600	808.1
2014	249,660,000	766.2
2015	244,404,000	750.0
2016	244,904,000	751.6
2017	267,004,800	819.4
2018	264,384,000	811.4
<p>Notes: 2009-2018 data from WUE reports. 2010 calculated use volume from 2012 water system plan was 262 afy. The source meter records overflow of the Town's reservoirs since everything is gravity driven. Actual use by customers is less than the metering data suggests.</p>		

Town of Darrington
Public Water System ID No. 17950

Year	Annual Volume	
	(gallons)	(acre-feet)
2009	118,082,797	362.4
2010	12,267,717	37.6
2011	82,196,792	252.3
2012	91,017,000	279.3
2013	94,767,900	290.8
2014	88,044,300	270.2
2015	78,804,337	241.8
2016	84,193,200	258.4
2017	91,471,000	280.7
2018	85,600,000	262.7

Notes: 2009-2018 data from WUE reports. 2010 data appears to be in error.

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Appendix B

Water System Design Manual Excerpts

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Water System Design Manual

December 2009



DOH 331-123 (REV. 12/09)

Table 5-2: Guide for Average Daily Nonresidential Water Demand

Type of Establishment	Water Used (gpd)
Airport (per passenger)	3 - 5
Apartment, multiple family (per resident)	50
Bathroom (per bather)	10
Boardinghouse (per boarder)	50
Additional kitchen requirements for nonresident boarders	10
Camp	
Construction, semi-permanent (per worker)	50
Day, no meals served (per camper)	15
Luxury (per camper)	100 - 150
Resort, day and night, limited plumbing (per camper)	50
Tourist, central bath and toilet facilities (per person)	35
Cottage, seasonal occupancy (per resident)	50
Club	
Country (per resident member)	100
Country (per nonresident member present)	25
Factory (gallons per person per shift)	15 - 35
Highway rest area (per person)	5
Hotel	
Private baths (2 persons per room)	50
No private baths (per person)	50
Institution other than hospital (per person)	75 - 125
Hospital (per bed)	250 - 400
Lawn and Garden (per 1,000 sq. ft., Assumes 1-inch per day (typical))	600
Laundry, self-serviced (gallons per washing per customer)	50
Livestock Drinking (per animal)	
Beef, yearlings	20
Brood Sows, nursing	6
Cattle or Steers	12
Dairy	20
Dry Cows or Heifers	15
Goat or Sheep	2
Hogs/Swine	4
Horse or Mules	12
Livestock Facilities	
Dairy Sanitation (milk room)	500
Floor Flushing (per 100 sq. ft.)	10
Sanitary Hog Wallow	100

Type of Establishment	Water Used (gpd)
Motel	
Bath, toilet, and kitchen facilities (per bed space)	50
Bed and toilet (per bed space)	40
Park	
Overnight, flush toilets (per camper)	25
Trailer, individual bath units, no sewer connection (per trailer)	25
Trailer, individual baths, connected to sewer (per person)	50
Picnic	
Bathhouses, showers, and flush toilets (per picnicker)	20
Toilet facilities only (gallons per picnicker)	10
Poultry (per 100 birds)	
Chicken	5 - 10
Ducks	22
Turkeys	10 - 25
Restaurant	
Toilet facilities (per patron)	7 - 10
No toilet facilities (per patron)	2 ½ - 3
Bar and cocktail lounge (additional quantity per patron)	2
School	
Boarding (per pupil)	75 - 100
Day, cafeteria, gymnasiums, and showers (per pupil)	25
Day, cafeteria, no gymnasiums or showers (per pupil)	20
Day, no cafeteria, gymnasiums or showers (per pupil)	15
Service station (per vehicle)	10
Store (per toilet room)	400
Swimming pool (per swimmer)	10
Maintenance (per 100 sq. ft.)	
Theater	
Drive-in (per car space)	5
Movie (per auditorium seat)	5
Worker	
Construction (per person per shift)	50
Day (school or offices per person per shift)	15

Source: Adapted from *Design and Construction of Small Water Systems* (AWWA, 1984), and *Planning for an Individual Water System* (American Association for Vocational Instructional Materials, 1982).

Appendix C

Irrigation

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APPENDIX A - CLIMATIC STATIONS FOR CONSUMPTIVE USE

<u>LOCATION</u>	<u>PAGE</u>
ABERDEEN	1
ANACORTES	4
BATTLE GROUND	7
BELLINGHAM	10
BICKLETON	13
BLAINE	17
BREMERTON	20
BUCKLEY	23
CENTRALIA	26
CHELAN	29
CHEWELAH	33
CHIEF JOE DAM	37
CLE ELUM	41
CLEARBROOK	45
COLFAX	48
COLVILLE	52
CONCONULLY *	56
CONCRETE	60
CONNELL *	63
COULEE DAM	69
COUPEVILLE	70
DALLESPORT	74
DAVENPORT	78
DAYTON	82

CONCRETE

CONCRETE	48.55 LATITUDE												TOTAL
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
MEAN TEMPERATURE (F)	36.0	40.5	43.1	49.2	55.8	60.5	64.6	64.3	60.3	52.4	43.2	38.3	
TOTAL PRECIPITATION (IN)	10.34	7.55	6.92	4.47	3.08	2.49	1.42	1.99	3.73	6.70	9.44	11.36	69.49
EFFECTIVE PRECIP (IN)	.06	.59	1.39	2.61	2.14	1.88	1.06	1.42	2.41	1.44	.33	.00	15.33
ALFALFA	BEG 5/14		END 11/13										
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	.26	2.21	3.87	2.47	.33	.00	.00	.00	9.14
AV. PAN FACTOR	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	
CLOVER	BEG 5/14		END 11/13										
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	.59	2.93	4.74	3.16	.81	.02	.00	.00	12.25
AV. PAN FACTOR	.80	.80	.80	.80	.80	.80	.80	.80	.80	.80	.80	.80	
PASTURE/TURF	BEG 5/14		END 11/13										
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	.48	2.69	4.45	2.93	.65	.00	.00	.00	11.20
AV. PAN FACTOR	.76	.76	.76	.76	.76	.76	.76	.76	.76	.76	.76	.76	
APPLES W/COVER	BEG 5/12		END 11/13										
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	.05	3.41	5.90	4.07	1.30	.00	.00	.00	14.73
AV. PAN FACTOR	.40	.40	.40	.40	.60	.88	.96	.96	.92	.72	.40	.40	
APPLE W/O COVER	BEG 5/12		END 11/13										
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	.00	1.97	4.16	2.70	.33	.00	.00	.00	9.16
AV. PAN FACTOR	.36	.36	.36	.36	.44	.64	.72	.72	.68	.52	.36	.36	
GRAPES	BEG 6/10		END 11/13										
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	.00	.56	3.58	2.24	.01	.00	.00	.00	6.39
AV. PAN FACTOR	.40	.40	.40	.40	.40	.56	.64	.64	.60	.48	.40	.40	
RASPBERRY	BEG 3/31		END 11/13										
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	2.29	3.89	5.90	3.85	.33	.00	.00	.00	16.25
AV. PAN FACTOR	.32	.32	.32	.32	.84	.96	.96	.92	.68	.40	.32	.32	
STRAWBERRY	BEG 3/31		END 11/13										
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	.00	.52	.68	.41	.00	.00	.00	.00	1.62
AV. PAN FACTOR	.32	.32	.32	.32	.32	.40	.24	.32	.32	.32	.32	.32	

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CONCRETE

GREEN BEANS	BEG 7/9	END 11/13											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	.00	.00	.75	1.87	.65	.00	.00	.00	3.27
AV. PAN FACTOR	.00	.00	.00	.00	.00	.00	.35	.57	.76	.71	.00	.00	
CARROTS	BEG 3/31	END 11/13											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	1.78	3.05	1.08	.00	.00	.00	.00	.00	5.91
AV. PAN FACTOR	.00	.00	.00	.45	.74	.82	.66	.00	.00	.00	.00	.00	
FIELD CORN	BEG 6/10	END 11/13											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	.00	.00	2.54	3.35	1.14	.00	.00	.00	7.02
AV. PAN FACTOR	.00	.00	.00	.00	.00	.37	.50	.83	.88	.65	.00	.00	
SWEET CORN	BEG 6/10	END 11/13											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	.00	.00	3.40	3.61	.00	.00	.00	.00	7.01
AV. PAN FACTOR	.00	.00	.00	.00	.00	.37	.61	.88	.84	.00	.00	.00	
CRUCIFER	BEG 3/31	END 11/13											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	1.62	1.43	.00	.00	.00	.00	.00	.00	3.05
AV. PAN FACTOR	.00	.00	.00	.45	.71	.77	.00	.00	.00	.00	.00	.00	
CUCUMBER	BEG 7/9	END 11/13											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)*	.00	.00	.00	.00	.00	.00	.75	1.29	.45	.00	.00	.00	2.49
AV. PAN FACTOR	.00	.00	.00	.00	.00	.00	.35	.47	.71	.72	.63	.00	
DRY ONION	BEG 3/31	END 11/13											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	1.73	2.69	4.39	1.66	.00	.00	.00	.00	10.47
AV. PAN FACTOR	.00	.00	.00	.48	.73	.76	.75	.66	.00	.00	.00	.00	
GREEN ONION	BEG 3/31	END 11/13											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	1.24	1.39	.00	.00	.00	.00	.00	.00	2.63
AV. PAN FACTOR	.00	.00	.00	.44	.64	.76	.00	.00	.00	.00	.00	.00	
PEAS	BEG 3/31	END 11/13											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	2.51	2.92	.00	.00	.00	.00	.00	.00	5.43
AV. PAN FACTOR	.00	.00	.00	.50	.88	.90	.00	.00	.00	.00	.00	.00	
POTATO	BEG 6/10	END 11/13											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	.00	.00	2.85	3.58	1.05	.00	.00	.00	7.48
AV. PAN FACTOR	.00	.00	.00	.00	.00	.37	.54	.87	.86	.66	.00	.00	

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CONCRETE

	BEG 3/31		END 11/13										SEASON
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
RADISH	BEG 3/31		END 11/13										
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	1.15	.00	.00	.00	.00	.00	.00	.00	1.15
AV. PAN FACTOR	.00	.00	.00	.57	.62	.00	.00	.00	.00	.00	.00	.00	
SPINACH	BEG 3/31		END 11/13										
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	1.67	.00	.00	.00	.00	.00	.00	.00	1.67
AV. PAN FACTOR	.00	.00	.00	.46	.72	.00	.00	.00	.00	.00	.00	.00	
SPRING GRAIN	BEG 2/14		END 11/13										
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.46	2.50	1.99	.07	.00	.00	.00	.00	.00	5.02
AV. PAN FACTOR	.00	.69	.73	.88	.88	.64	.26	.00	.00	.00	.00	.00	
TOMATO	BEG 6/10		END 11/13										
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	.00	.00	2.15	2.95	.98	.00	.00	.00	6.08
AV. PAN FACTOR	.00	.00	.00	.00	.00	.37	.44	.76	.84	.64	.35	.00	
WINTER WHEAT	BEG 2/14		END 11/13										
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.26	.48	2.33	.02	.00	.00	.00	.00	.00	.00	3.08
AV. PAN FACTOR	.00	1.08	.94	.88	.85	.42	.12	.12	.12	.53	.84	.00	
SQUASH	BEG 7/ 9		END 11/13										
MONTHLY NET IRRIG REQUIRE(IN)	.00	.00	.00	.00	.00	.00	.75	1.29	.45	.00	.00	.00	2.49
AV. PAN FACTOR	.00	.00	.00	.00	.00	.00	.35	.47	.71	.65	.00	.00	

(WA210-VI-WAIG, OCTOBER 1985)

APPENDIX B

WASHINGTON STATE - WEST OF CASCADES
CIR - CROP IRRIGATION REQUIREMENT and CU - CROP CONSUMPTIVE USE

STATIONS

<u>STATION</u>	<u>PAGE</u>
ABERDEEN	2
ANACORTES	2
BATTLE GROUND	2
BELLINGHAM	3
BLAINE	3
BREMERTON	3
BUCKLEY	4
CENTRALIA	4
CLEARBROOK	4
CONCRETE	5
COUPEVILLE	5
ELMA	5
EVERETT	6
GRAPEVIEW	6
GRAYLAND	6
GRAYS RIVER	7
HOQUIAM	7
LONG BEACH	7
LONGVIEW	8
MONROE	8
MOUNT VERNON	8
OLGA	9
OLYMPIA	9
PACKWOOD	10
PORT ANGLES	10
PUYALLUP	10
QUILCENE	11
RAYMOND	11
SEATTLE-TACOMA	11
SEDRO WOLLEY	12
SEQUIM	12
SHELTON	12
SNOQUALMIE FALLS	13
TACOMA	13
TOLEDO	13
VANCOUVER	14

APPENDIX B

WASHINGTON STATE - WEST OF CASCADES
 CIR - CROP IRRIGATION REQUIREMENT and CU - CROP CONSUMPTIVE USE

CONCRETE		48.55 LATITUDE												TOTAL
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
MEAN TEMPERATURE (F)		36.5	40.1	44.0	49.9	56.1	60.5	64.5	64.7	60.4	52.5	43.2	38.4	
TOTAL PRECIPITATION (IN)		9.30	7.16	6.84	4.48	3.18	2.65	1.55	1.66	3.66	6.61	9.68	10.52	67.29
REFERENCE CROP ET (IN)		0.00	0.34	1.14	2.31	4.10	4.75	6.63	5.32	4.38	1.58	0.22	0.00	30.78
EFFECTIVE PRECIP (IN)		0.00	0.34	1.12	2.22	2.19	1.96	1.21	1.23	2.55	1.55	0.22	0.00	14.59
PASTURE/TURF														
	BEG END	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
CIR	3/ 3 11/23	0.00	0.00	0.00	0.00	1.71	2.55	5.09	3.82	1.61	0.00	0.00	0.00	14.79
CU		0.00	0.00	0.98	2.19	3.89	4.51	6.30	5.05	4.16	1.50	0.16	0.00	28.75
FIELD CORN														
	BEG END	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
CIR	6/25 10/ 7	0.00	0.00	0.00	0.00	0.00	0.00	2.05	3.47	2.27	0.00	0.00	0.00	7.78
CU		0.00	0.00	0.00	0.00	0.00	0.36	3.25	4.68	4.82	0.38	0.00	0.00	13.49

COUPEVILLE		48.20 LATITUDE												TOTAL
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
MEAN TEMPERATURE (F)		38.5	41.6	44.0	47.9	53.1	57.4	60.5	61.0	57.0	50.0	43.7	40.2	
TOTAL PRECIPITATION (IN)		2.44	1.80	1.78	1.56	1.49	1.25	0.80	0.93	1.32	1.67	2.45	2.82	20.31
REFERENCE CROP ET (IN)		0.20	0.65	1.48	2.67	3.90	4.45	5.27	4.23	2.94	1.32	0.36	0.07	27.55
EFFECTIVE PRECIP (IN)		0.20	0.59	1.03	1.04	1.07	0.91	0.60	0.66	0.90	0.96	0.36	0.07	8.40
PASTURE/TURF														
	BEG END	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
CIR	2/21 12/31	0.00	0.00	0.38	1.50	2.64	3.32	4.40	3.35	1.89	0.29	0.00	0.00	17.77
CU		0.00	0.15	1.41	2.54	3.70	4.23	5.01	4.02	2.79	1.25	0.34	0.07	25.51
FIELD CORN														
	BEG END	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
CIR	6/11 10/29	0.00	0.00	0.00	0.00	0.00	0.53	2.71	3.74	2.33	0.00	0.00	0.00	9.31
CU		0.00	0.00	0.00	0.00	0.00	1.32	3.32	4.40	3.23	1.08	0.00	0.00	13.36

ELMA		47.00 LATITUDE												TOTAL
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
MEAN TEMPERATURE (F)		39.0	42.5	44.6	49.0	54.8	59.6	63.2	63.8	59.9	52.5	44.7	40.6	
TOTAL PRECIPITATION (IN)		10.18	8.15	7.37	4.63	2.67	2.04	1.12	1.48	2.99	6.18	9.79	10.62	67.22
REFERENCE CROP ET (IN)		0.07	0.55	1.38	2.24	3.40	3.73	4.20	3.34	2.54	1.44	0.33	0.01	23.24
EFFECTIVE PRECIP (IN)		0.07	0.55	1.36	2.18	1.82	1.43	0.80	1.03	1.89	1.42	0.33	0.01	12.89
PASTURE/TURF														
	BEG END	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
CIR	2/11 12/31	0.00	0.00	0.00	0.00	1.41	2.12	3.18	2.14	0.52	0.00	0.00	0.00	9.38
CU		0.00	0.32	1.31	2.13	3.23	3.54	3.99	3.17	2.41	1.37	0.31	0.01	21.80
FIELD CORN														
	BEG END	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SEASON
CIR	6/11 10/29	0.00	0.00	0.00	0.00	0.00	0.00	1.92	2.46	0.90	0.00	0.00	0.00	5.28
CU		0.00	0.00	0.00	0.00	0.00	1.18	2.73	3.51	2.79	1.18	0.00	0.00	11.39

DETERMINING IRRIGATION EFFICIENCY AND CONSUMPTIVE USE

Resource Contact: Policy and Planning Section Effective Date: 10/11/05

References: RCW 90.03.290, RCW 90.03.380(1), RCW 90.44.100, POL 1120, POL 1210, PRO 1210

Purpose: The purpose of this document is to provide guidance to water resources staff for:

1. Determining irrigation efficiency; and
2. Determining consumptive use associated with irrigation.

Application:

1. Ecology frequently must estimate or determine irrigation efficiency, when issuing new water rights for irrigation purpose of use, when conducting tentative determinations of existing irrigation water rights, when evaluating trust water applications, when determining whether water is being wasted, in the context of adjudications, and in other situations.
2. Ecology must determine the consumptive use of an irrigation right:
 - a. When a change in purpose is proposed that could increase the consumptive use of a water right and such increase could result in impairment of existing water rights; and
 - b. When a change to enable irrigation of additional acres or an additional purpose of use is proposed, requiring application of the Annual Consumptive Quantity (ACQ) test¹.

Resources:

1. State of Washington Irrigation Guide (WIG), 1985 (amended 1990, amended 1992 for select western Washington crops)
2. Irrigation Requirements for Washington—Estimates and Methodology, 1982 (XB0925, reprinted 2001 EB1513)
3. National Irrigation Guide, 1997²
4. National Engineering Handbook, 1993³
5. WSU Public Agricultural Weather System (PAWS)⁴
6. Bureau of Reclamation AgriMet⁵

¹ See RCW 90.03.380. While an ACQ change requires averaging of the two highest years of consumptive use, consumptive increases that could lead to impairment may be evaluated using the highest year of consumptive use.

² <http://www.wcc.nrcs.usda.gov/nrcsirrig/irrig-handbooks-part652.html>

³ <http://www.info.usda.gov/CED/>

⁴ <http://index.prosser.wsu.edu/>

⁵ <http://www.usbr.gov/pn/agrimet/>

Table 1: Summary of Application Efficiency Ranges, Consumptive Use, and Return Flows¹

Method		Application Efficiency, E_a (%) ²		%Total Evaporated	% Total Use Consumed	Return Flow
		Range	Average, $E_{a_{avg}}$	%Evap	%CU, Average ³	%RF, Average ⁴
Surface:	Graded Furrow	50 – 80	65	5	70	30
	w/ tailwater reuse	60 – 90	75	5	80	20
	Level Furrow	65 – 95	80	5	85	15
	Graded Border	50 – 80	65	5	70	30
	Level Basins	80 – 95	85	5	90	10
	Flood	35 – 60	50	5	55	45
Sprinkler:	Periodic Move (Handline)	60 – 85	75	10	85	15
	Side Roll (Whirl-line)	60 – 85	75	10	85	15
	Moving Big Gun	55 – 75	65	10	75	25
	Solid-Set—Overtree	55 – 80	70	15	85	15
	Solid Set--Undertree	60 – 85	75	10	85	15
	Pop-Up Impact	60 – 85	75	10	85	15
Center-Pivot	Impact heads w/end gun	75 – 90	80	15	95	5
	Spray heads w/o end gun	75 – 95	90	10	100	0
	LEPA ⁵ w/o end gun	80 – 98	92	5	97	3
Lateral-Move	Spray heads w/hose feed	75 – 95	90	10	100	0
	Spray heads w/canal feed	70 – 95	85	10	95	5
Microirrigation:	Trickle/Drip	70 – 95	88	5	93	7
	Subsurface Drip	75 – 95	90	0	90	10
	Microspray	70 – 95	85	10	95	5

1. Calculate the actual water use from water meter data, power meter, or run-time data. In the absence of such data, the TIR (total irrigation requirement) = CIR / E_a , where CIR is the crop irrigation requirement from the WIG (Appendix B) and E_a is the case-specific application efficiency above.
2. %Evap is the portion of the total irrigation requirement that is evaporated due to factors other than crop ET.
3. Select appropriate %CU based on type of irrigation system. If calculated E_a is greater or less than $E_{a_{avg}}$, then %CU = $E_a + \%Evap$. CU = TIR x %CU.
4. Select appropriate %RF based on type of irrigation system. If calculated E_a is greater or less than $E_{a_{avg}}$, then %RF = 100 - %CU. RF = TIR x %RF
5. Low Energy Precision Application.

Attachment 1
Inventory Table
(Microsoft Excel electronic format only)