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INTRODUCTION

GeoEngineers, Inc. (GeoEngineers) is providing technical support to the Washington State Department of Ecology (Ecology) and the Watershed Restoration and Enhancement (WRE) Committees for Water Resource Inventory Areas (WRIAs) 7, 8 and 9. This memorandum provides a summary of the deliverable for Work Assignment GEO102, Task 4, WRIA 9 Consumptive Use Estimates.

BACKGROUND AND CONTEXT

The Streamflow Restoration Act (SRA, Chapter 90.94 Revised Code of Washington [RCW]) specifies that by June 30, 2021, Ecology must establish a WRE Committee and adopt a WRE Plan in the Duwamish-Green Watershed (WRIA 9). The Duwamish-Green (WRIA 9) Watershed Restoration and Enhancement Plan (Plan) must include projects and actions that offset the consumptive use from future domestic permit-exempt wells (PE wells¹). Consumptive water use is water that is evaporated, transpired, consumed by humans, or otherwise removed from an immediate water environment. For watershed planning purposes, consumptive use is water that is drawn from groundwater via a domestic PE well and not replaced through the septic system, irrigation return flow, or other means.

Growth projections and projections for number and location of new domestic PE well connections within WRIA 9 were developed by King County and GeoEngineers (GeoEngineers 2019) for purposes of the Plan. This memorandum summarizes the methods used to estimate consumptive water use associated with the new well connections and provides results for three water use scenarios. Methodology is based on Appendix A of Ecology's Net Ecological Benefit guidance (Ecology 2019) and documented in further detail in the Consumptive Use Estimates Workplan prepared by the GeoEngineers team.

CONSUMPTIVE WATER USE METHODOLOGY

Measurement of consumptive water use in any setting is difficult, and it is virtually impossible for residential groundwater use, which must account for both indoor and outdoor use. PE wells are generally unmetered, so supply to each home is usually unknown, let alone the amount that is lost to the groundwater system. Therefore,

¹ "PE wells" is used to refer to new homes associated with new permit-exempt wells and also new homes added to existing wells, including homes on group systems relying on permit-exempt wells.

we are limited to estimating consumptive use based on projections of future growth, local patterns and trends in water use, and generally accepted and reasonable assumptions. Water use data from local water purveyors may be useful as a check on calculated estimates but must be used with caution. Homes that pay for municipal water tend to exhibit different water use behaviors, including water saving appliances and reduced landscape watering, that reduce usage compared to homes on wells.

The two categories of household consumptive water use are indoor use and outdoor use. The methodology used to estimate these quantities for WRIA 9 are described in the following sections.

Indoor Consumptive Use

Indoor consumptive use was estimated using Ecology guidance, which was based on groundwater monitoring and modeling studies conducted by the U.S. Geological Survey in several areas of Washington. There are two basic elements to estimating indoor consumptive use:

- Amount of total water used. Ecology's guidance recommends an assumption of 60 gallons per person per day as a reasonable estimate of indoor water use. To estimate indoor usage per well, the per capita usage was multiplied by the average rural household size, estimated by King County as 2.73 people per household.
- Percentage of total water used that is consumptive. Ecology guidance recommends that 10% of the total indoor water use is considered consumptive when a home is on a septic system. (All indoor water use is considered consumptive for homes with sewer connections.) Areas projected to be served by PE wells are outside of sewer service areas, so the 10% assumption was applied for all projected indoor water use.

Outdoor Consumptive Use

Outdoor water use is typically the larger portion of domestic single-family residential water use, with irrigation of lawn and garden being the dominant outdoor water use component. The GeoEngineers team conducted a subbasin-specific assessment to determine typical outdoor water use patterns, namely the typical size of irrigated lawn, garden, and landscaping areas associated with newer residential development and irrigation water needs, which vary by crop and climate. The consumptive use estimate assumes that current rural residential landscaping practices and outdoor water use will continue over the 20-year planning horizon.

Irrigated Footprint Analysis

The GeoEngineers team conducted an aerial photo-based analysis of irrigated lawn and garden area for 211 parcels in eight of the WRIA 9 subbasins. Parcels used for the irrigated footprint analysis were selected based on recent (2006-2017) building permits for new single-family residential homes not served by public water. All new home building permit sites in WRIA 9 were included in the analysis; permits for accessory dwelling units (ADUs) or reconstruction/remodel were excluded.

Each parcel was evaluated visually in Google Earth for irrigated lawn areas. Google Earth's historical imagery collection allowed for clearer identification of irrigated areas by comparing aerial photos spanning multiple seasons and years. Late summer imagery was particularly helpful in determining boundaries of irrigated (green) vs. non-irrigated (brown) grass areas. More often than not, the parcels did not demonstrate such a clear-cut distinction between green and brown spaces. It appears that many homeowners irrigate enough to keep lawns

alive but not lush (or comparable to commercial turf grass/golf course green). Delineating these irrigated spaces is subjective, and the GeoEngineers team tried to ensure consistency in the interpretation and results by having one GIS analyst evaluate all of the permit parcels in the WRIA. The irrigated area was delineated for each parcel based on several key assumptions:

- Landscaped shrub/flower bed areas were included in the irrigated footprint (not just lawn areas).
- Homes that did not show visible signs of irrigation were tracked as zero irrigated footprint.
- Homes or landscaping still under construction in the most recent Google Earth imagery were excluded.
- Native forest or unmaintained grass/pasture were not included in the irrigated footprint.
- Pre-existing agricultural land use was not considered part of the residential irrigation footprint.

Figure 1 shows examples of irrigated area delineation for two parcels in the Covington Creek subbasin. On each photo, the parcel boundary is shown in orange and the area identified as irrigated in white. For the example on the left, photos at different times of year showed a clear break between irrigated and non-irrigated grass.



Figure 1. Example Irrigated Area Delineations

Results of the irrigated footprint analysis are summarized in Table 1. The analysis covered eight of the nine subbasins in WRIA 9 with projected PE well connections. The Lower Green River subbasin (with four projected PE well connections) did not have any recent building permits for sites without purveyor-provided water service, so the average irrigated area for the adjacent Soos Creek subbasin was applied to the Lower Green River subbasin for purposes of consumptive use estimates.

TABLE 1. WRIA 9 IRRIGATED FOOTPRINT SUMMARY

Subbasin	Parcels Analyzed	Total Irrigated Area (ac)	Average Irrigated Area (ac)
Coal/Deep Creek	21	3.6	0.17
Covington Creek	13	5.2	0.40
Jenkins Creek	24	8.1	0.34
Lower Middle Green River	29	12.8	0.44
Middle Middle Green River	21	5.2	0.25
Newaukum Creek	38	11.7	0.31
Soos Creek	31	10.6	0.34
Upper Middle Green River	34	7.1	0.21
Full Analysis	211	64.2	0.30

Crop Irrigation Requirements

The amount of irrigation water required to grow and maintain vegetation depends on the crop, season, and local climate (temperature and precipitation) and thus varies by location throughout the WRIA. The Washington Irrigation Guide (WAIG) (NRCS 1997) includes an appendix listing net irrigation requirements for various common crops for 89 locations throughout Washington, derived from water use and meteorological data from the 1970s and 1980s. Since lawn is a fairly water-intensive crop and the most common target of residential irrigation, irrigation requirements for turf were used to estimate outdoor water needs.

Using the two WAIG stations within WRIA 9 (Seattle-Tacoma and Kent) and surrounding stations to the north, south, and east, the GeoEngineers team spatially interpolated crop irrigation requirements (CIRs) across WRIA 9 by creating a triangulated irregular network (TIN) surface between the WAIG station points. Since there are no stations east of Snoqualmie Falls, a lower value was imposed along the Cascade crest to enforce continued reduction in CIR with increasing precipitation. A value of 8 inches per year was used for the boundary value; this is believed to be a conservative value based on nearby Cascade foothill station estimates from an unpublished irrigation data set being developed by Washington State University (Peters et al., 2019). Values from the resulting TIN surface were averaged over each subbasin to estimate the irrigation requirement for each subbasin. This analysis was performed for both annual and summer (June-July-August) irrigation requirements to provide information to compare peak summer water use to annual use estimates. Figure 2 shows the locations of WAIG irrigation data stations and the interpolated distribution of annual turf irrigation requirements across WRIA 9. Table 2 summarizes the average values for both annual and summer CIRs for subbasins with projected PE well connections. Annual values were used for the consumptive use calculations described in this memo.

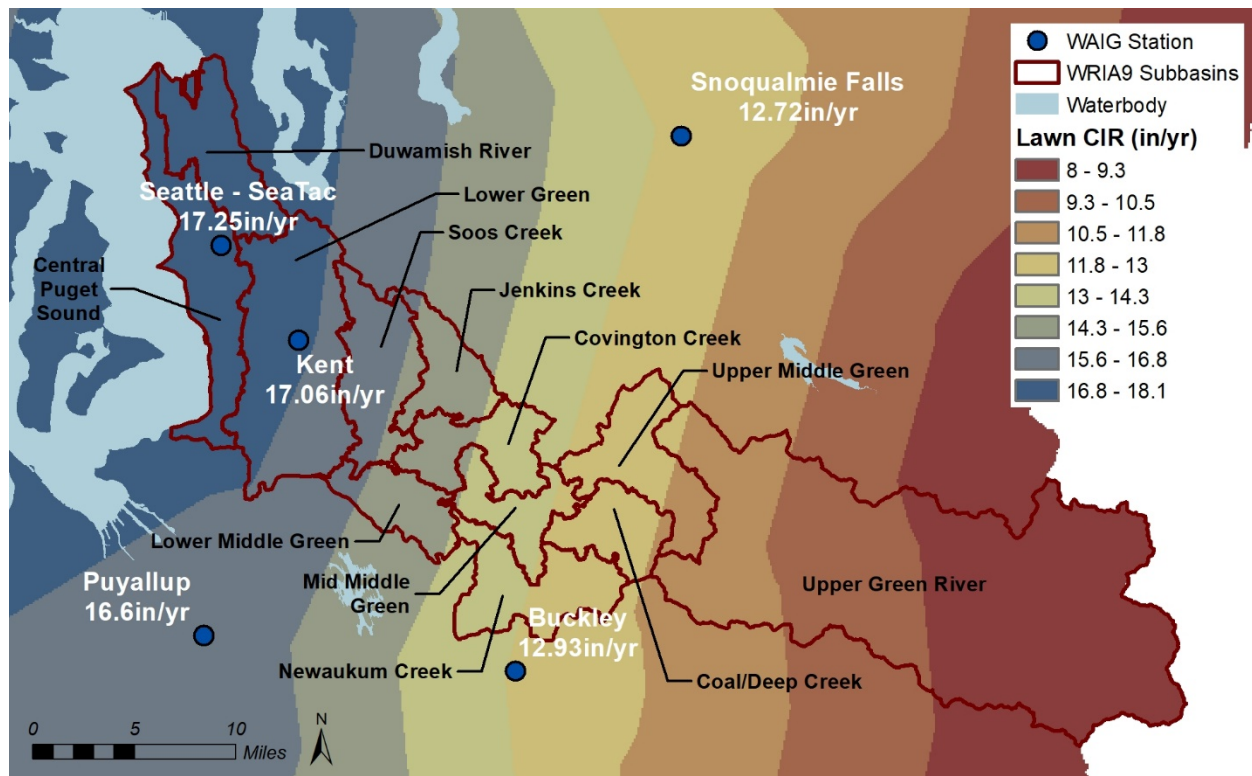


Figure 2. Spatial Distribution of Annual Turf Irrigation Requirement

TABLE 2. WRIA 9 CROP IRRIGATION REQUIREMENTS

Subbasin	Annual Turf CIR (in)	Summer (JJA) Turf CIR (in)
Coal/Deep Creek	12.26	10.57
Covington Creek	14.24	11.69
Jenkins Creek	14.99	12.16
Lower Green River	16.85	13.15
Lower Middle Green River	15.06	12.08
Middle Middle Green River	13.55	11.29
Newaukum Creek	13.07	11.00
Soos Creek	15.89	12.64
Upper Middle Green River	12.1	10.48
WRIA Average*	14.62	11.90

*Subbasins with projected PE wells only

The CIR is the net amount of external water required by the crop, accounting for precipitation inputs. Since irrigation systems are not 100% efficient, additional water must be supplied to ensure that crop needs are met. The application efficiency varies by the type of system (drip irrigation, microsprinklers, pivot sprinklers, etc.). For WRIA 9, the Ecology-recommended value of 75% was used to determine the water applied for irrigation.

Outdoor water use for each home was then estimated as the applied water for irrigation (computed as a depth) times the average irrigation area. The consumptive use fraction is substantially higher for outdoor use than indoor use (to a septic system) because most of the applied water is taken up by plants or evaporated. Based on the Ecology guidance, a consumptive use fraction of 80% was applied to the total outdoor water use, meaning that 80% of water used for outdoor watering does not return to the local groundwater system.

TOTAL CONSUMPTIVE USE

The methods described above were used to compute indoor and outdoor consumptive use per PE well connection. Totals for each subbasin were then computed by multiplying per home values by the projected number of PE well connections in each subbasin. The GeoEngineers team developed a consumptive use calculator (Excel spreadsheet) to compute consumptive use for projected PE well connections for each subbasin and the WRIA as a whole. Table 3 summarizes the consumptive use estimate, which assumes one home with the measured subbasin-average yard area per PE well. The consumptive use estimate for WRIA 9 is 247.7 acre-feet per year, as shown on Figure 3.

TABLE 3. ANNUAL CONSUMPTIVE USE FOR ONE HOME WITH SUBBASIN AVERAGE YARD

Subbasin ID	# PE Wells Anticipated in Subbasin	Irrigated Area per Well (ac)	Per Well Consumptive Use (gpd)			Total Consumptive Use (af/yr)
			Indoor	Outdoor	Total	
Coal/Deep Creek	62	0.17	16.4	165.4	181.8	12.6
Covington Creek	41	0.40	16.4	452.0	468.4	21.5
Jenkins Creek	45	0.34	16.4	404.4	420.8	21.2
Lower Green River	4	0.34	16.4	454.6	471.0	2.1
Lower Middle Green River	84	0.44	16.4	525.8	542.2	51.0
Middle Middle Green River	100	0.25	16.4	268.8	285.2	31.9
Newaukum Creek	103	0.31	16.4	321.5	337.9	39.0
Soos Creek	83	0.34	16.4	428.7	445.1	41.4
Upper Middle Green River	110	0.21	16.4	201.6	218.0	26.9
WRIA 9 Aggregated	632	0.30	16.4	333.4	349.8	247.7

CONSUMPTIVE WATER USE SCENARIOS

The consumptive use calculator was also used to explore additional consumptive use scenarios. “Default” input parameters and values discussed in the methods section above can be modified to explore the effect of changes or uncertainties in individual assumptions. Based on requests from the technical workgroup and Committee, two additional scenarios were computed, and annual consumptive use results are summarized in Table 4 and Table 5:

1. One home with legal maximum 0.5-acre irrigated lawn area per PE well. Assumes 60 gallons per day per person indoor use and 0.5-acre outdoor irrigation use.
2. Legal right to 950 gallons per day (maximum annual average withdrawal) per well connection for indoor and outdoor household use. Assumes 60 gallons per day per person indoor use and remainder to outdoor use.

TABLE 4. ANNUAL CONSUMPTIVE USE FOR ONE HOME WITH 0.5-AC YARD

Subbasin ID	# PE Wells Anticipated in Subbasin	Irrigated Area per Well (ac)	Per Well Consumptive Use (gpd)			Total Consumptive Use (af/yr)
			Indoor	Outdoor	Total	
Coal/Deep Creek	62	0.5	16.4	486.4	502.8	34.9
Covington Creek	41	0.5	16.4	565.0	581.3	26.7
Jenkins Creek	45	0.5	16.4	594.7	611.1	30.8
Lower Green River	4	0.5	16.4	668.5	684.9	3.1
Lower Middle Green River	84	0.5	16.4	597.5	613.9	57.8
Middle Middle Green River	100	0.5	16.4	537.6	554.0	62.1
Newaukum Creek	103	0.5	16.4	518.5	534.9	61.7
Soos Creek	83	0.5	16.4	630.4	646.8	60.1
Upper Middle Green River	110	0.5	16.4	480.1	496.4	61.2
WRIA 9 Aggregated	632	0.5	16.4	546.3	562.7	398.4

TABLE 5. ANNUAL CONSUMPTIVE USE FOR ANNUAL AVERAGE 950 GPD WATER USE PER CONNECTION

Subbasin ID	# PE Wells Anticipated in Subbasin	Irrigated Area per Well (ac)	Per Well Consumptive Use (gpd)			Total Consumptive Use (af/yr)
			Indoor	Outdoor	Total	
Coal/Deep Creek	62	0.56	16.4	629.0	645.3	44.8
Covington Creek	41	0.52	16.4	629.0	645.3	29.6
Jenkins Creek	45	0.49	16.4	629.0	645.3	32.5
Lower Green River	4	0.47	16.4	629.0	645.3	2.9
Lower Middle Green River	84	0.51	16.4	629.0	645.3	60.7
Middle Middle Green River	100	0.54	16.4	629.0	645.3	72.3
Newaukum Creek	103	0.58	16.4	629.0	645.3	74.5
Soos Creek	83	0.48	16.4	629.0	645.3	60.0
Upper Middle Green River	110	0.55	16.4	629.0	645.3	79.5
WRIA 9 Aggregated	632	0.53	16.4	629.0	645.3	456.9

Daily usage rates shown in Table 3 through Table 5 represent annual average values. While indoor use generally does not vary much from month to month, outdoor water needs range from zero during the winter rainy season to more than three times the annual average during the peak of the summer. Since streamflows are lowest in late summer for most western Washington streams, the Committee may consider peak summer water use along with annual use when developing the WRE plan. It is important to remember that pumping rates are likely not equivalent to consumptive use impacts on stream depletion. While Ecology's NEB guidance recommends considering stream depletion impacts to be a steady-state equivalent, there may be circumstances within a watershed where that is not appropriate.

Total Water Use and Comparison to Water Purveyor Data

Water use data from water purveyors to rural areas in the central Puget Sound were obtained as one benchmark for comparison with estimated PE well usage. Covington Water District, serving about 18,000 customers in southern King County, and Snohomish County Public Utilities District #1 (Snohomish County PUD), serving about 20,000 customers in central and northern Snohomish County, each provided metered water use data from 2015 and 2017. In addition, Snohomish County compiled annual water demand forecasts from water system plans for 17 water purveyors operating in the county. Table 6 (next page) summarizes the available water purveyor data. Reported values are total water use, not consumptive use. For the two metered systems providing data, the average annual use is approximately 220 gpd per household. About 160 gpd is attributed to indoor uses (year-round) and 50 to 70 gpd (averaged over twelve months) to outdoor uses. Note that outdoor use is typically concentrated over about three months during the summer, which equates to rates of 150 to 200 gpd of outdoor watering for those three months.²

² 50 gpd over 12 months is equivalent to 200 gpd over 3 months, both totaling about 18,000 gallons

TABLE 6. WATER PURVEYOR HOUSEHOLD WATER USE DATA

Water Purveyor	Average Annual Water Use (gpd)	Average Winter Water Use (gpd)	Average Summer Water Use (gpd)
<i>Metered Water Use Data[†]</i>			
Covington Water District	200	150	300
Snohomish County PUD [‡]	237	170	370
<i>Comprehensive Plan Forecast</i>			
Alderwood	169		
Cross Valley*	234		
Edmonds	201		
Gold Bar	171		
Highland*	200		
Marysville	168		
Monroe	170		
Mukilteo	179		
Olympic View	189		
Roosevelt*	383		
Silver Lake	177		
Snohomish	190		
Snohomish County PUD*	190		
Stanwood	282		
Startup*	250		
Sultan	190		
Three Lakes*	191		
<i>*Average Rural Non-City</i>	<i>241</i>		

[†]Data from 2015 and 2017 [‡]Average use for parcels ≥1 acre *Rural (non-city) water provider

Note: Reported values are total water use, not consumptive use.

Since most water purveyors charge customers by the amount of water delivered (not just consumptively used)—and in some cases at increased rates as water use goes up—metered water users may exhibit more water conservation behaviors than unmetered users. Total water use breakdowns for the projected PE well scenarios are presented in Table 7. Estimated indoor use of 164 gpd for the PE well scenarios is very consistent with the water purveyor data (based on metered winter water use), between 150 and 170 gpd.

Average annual total use for PE wells estimated from this analysis (see Table 7) are considerably higher, however, due to outdoor use estimates 6 to 8 times greater than average metered use: 420 gpd estimated for PE wells versus 50 to 70 gpd for metered users on an average annual basis or 1,400 gpd estimated for PE wells versus 150 to 200 gpd³ for metered users on average during the summer. The magnitude of this difference seems unlikely to be accounted for strictly by price pressures and thus suggests that assumptions in this analysis regarding watering behavior are generally conservative. For example, studies have shown that

³ Metered summer usage for several individual homes in the Covington Water District showed outdoor usage ranging from 25 gpd to 2,693 gpd for July-August 2015.

most residential lawn watering is conducted at a deficit level to maintain some growth and green color (Water Research Foundation 2016), versus the assumption of watering for optimal growth of commercial crops (like a sod farm for turf grass) implicit in the WAIG crop irrigation requirements. Because of the uncertainty inherent in estimating growth patterns, domestic PE well pumping rates, and potential changes in outdoor watering practices, conservative assumptions for future new household water use, and outdoor water use in particular, are justified.

TABLE 7. ESTIMATED PERMIT-EXEMPT WELL TOTAL WATER USE

Scenario	Average Annual Water Use (gpd)	Average Indoor Use (gpd)	Average Annual Outdoor Use (gpd)	Average Summer Outdoor Use (gpd)
1 home, average measured yard	581	164	417	1,361
1 home, 0.5 ac yard	847	164	683	2,246
1 home using 950 gpd (annual average)	950	164	786	n/a

Note: Reported values are total water use, not consumptive use.

REFERENCES

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- Water Research Foundation, 2016. Residential End Uses of Water, Version 2. Executive Report. Published April 2016.

Attachment:

Figure 3. WRIA 9 Estimated Consumptive Use from Projected Permit-Exempt Wells 2018-2038

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