WASHINGTON REALTORS
TYPICAL RURAL LARGE LOT RESIDENTIAL DEVELOPMENTS IN WESTERN WASHINGTON

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by

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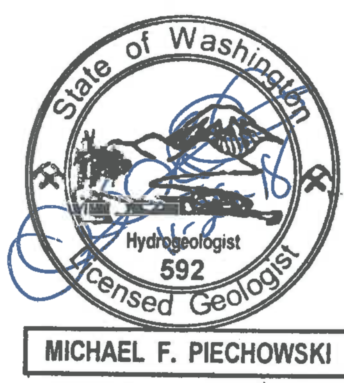

Water-Balance Analysis
Typical Rural Large Lot Residential Developments in Western Washington
November 29, 2018

Introduction and Scope

This narrative has been prepared for Bill Clarke and Washington REALTORS® documenting our water-balance analysis of typical rural large-lot residential developments in Western Washington. This evaluation is based on our analysis of an existing development in Thurston County (County) with ten adjacent 5-acre parcels and focuses on the changes to the total water balance as a result of development. This example is considered to have pre- and post-development conditions that are typical of rural, exempt well-based development in much of Western Washington.

Our approach used aerial imagery available from Thurston County and through Google Earth. We traced the outlines of the homes, driveways, roads, and cleared areas on each of the ten parcels, then calculated the relative areas of each parcel that changed from pre-development conditions (which appeared to be a second-growth forest based on the earliest aerial imagery reviewed). For this discussion, we presumed that each of the homes is served by an individual well and individual on-site septic system and calculated water use based on recent census data and regional studies.

Site Setting and Topography

The study area is located near the northern margin of the Maytown Upland in Thurston County, south of Tumwater. The study area is situated on the southern margin of a small upland. The upland has an undulatory surface that was sculpted by the most recent continental glaciation. The features in this area generally trend from the north-northeast to the south-southwest, with lineations corresponding to the presumed direction of glacial motion. According to the USGS topographic quadrangle of the area, the site has an elevation of approximately 370 feet along the northern margin; the elevation steadily drops to 310 feet at the southern boundary of the study area.

General drainage patterns in the area tend to follow the local topography. This portion of the upland containing the study area generally slopes to the south, so surficial drainage generally flows to the south. The slope is relatively gentle, with approximately five feet of drop per hundred feet.

Surface Water

The site is located in Water Resource Inventory Area 23, specifically within the Salmon Creek basin. The local surface water drainage is towards the south, but shifts to a more westerly direction approximately one mile south of the site. The nearest significant surface water is Pitman Lake, approximately 5,600 feet to the south. The nearest significant surface stream is the Deschutes River which is approximately 1.5 miles to the east of the property. However, the USGS quadrangle indicates a number of marshy areas in the low-lying regions to the south of the site and ephemeral tributary creeks to Salmon Creek beginning approximately 1,000 feet east and west of the property. Salmon Creek is a tributary to the Black River, which flows into the Chehalis River, ultimately discharging to the Pacific Ocean at Grays Harbor.

Soils and Vegetation

The study area is mostly covered with Alderwood gravelly sandy loam with 8 to 15 percent slopes; a small portion of the site near the southern boundary has steeper slopes (US Department of Agriculture, Soil Conservation Service). The Alderwood gravelly sandy loam is a moderately well-drained soil. It forms on the top of glacial drift and generally has a dense low-permeability layer that restricts infiltration within 39 inches of land surface. This soil is considered to be a part of Hydrologic Group B and is not considered a hydric soil.

Site Geology

Site geology was determined by reviewing published geologic maps of the region. Logan (2009) mapped the site and surrounding area as Vashon till, which is a highly-compacted mixture of sand, gravel, silt, and clay that was deposited beneath and overridden by the latest continental glaciation. Typically, till has a relatively low permeability, though it may vary locally based on the composition and the degree of compaction. Review of nearby water well reports suggests that the till is generally over 50 feet thick in the area.

Water Balance Analysis

To assess potential post-development changes to the water balance of the groundwater and surface water systems in the area, we completed a water-balance evaluation of the property and proposed development on an annualized basis. This analysis concentrated on the changes to the property from the pre-development conditions (mature second-growth forest). We analyzed two water use scenarios.

The first water use scenario is based on the Washington State Department of Ecology (Ecology) guidance document, ESSB 6091 Streamflow Restoration Recommendations for Water Use Estimates. The water use estimates from Ecology's ESSB 6091 guidance document are higher than other water use estimates used by Ecology or in other studies, but are used for purposes of this analysis as the "High Water Use Scenario." Under the High Water Use Scenario, Ecology uses an average value of 60 gallons of indoor water use per day (gpd) per capita, a household size of 2.5 persons, and consumptive use of 10%. This results in 0.017 acre-feet per year (AF/year) of indoor consumptive water use. Ecology uses a figure of 0.39 AF/year of outdoor consumptive water use. This totals 0.407 AF/year of consumptive use, which averages to 363 gallons per day.

The second water use scenario is based on water use estimates that more closely track prior Ecology water use estimates, though are still conservative and so would tend to overestimate, rather than underestimate, consumptive water use. The second scenario is referred to in the analysis as "Moderate Water Use Scenario." Under this second scenario, water use is based on an average value of 66 gallons of indoor water use per day (gpd) per capita (Welch, 2014). Welch (2014) estimates outdoor water use per capita at 4, 29, 60, 86, 97, and 30 gpd for May, June, July, August, September, and October, respectively. Outdoor water use is presumed to be zero gpd per capita for the rest of the year. The Ecology guidance document uses 2.5 people per residence, so we used that same value in the Moderate Water Use Scenario. This value is consistent with the US Census, which calculated an average of 2.54 persons per household in Thurston County. The per-capita water use numbers listed above were multiplied by 2.5 to calculate total household use. With indoor consumptive use of 10% and outdoor consumptive use of 80%, the moderate water use scenario uses 0.018 AF/year as consumptive indoor use and 0.057 AF/year as outdoor consumptive use, for a total annual consumptive use of 0.076 AF/year, or about 68 gallons per day on average.

Under both scenarios, we presumed that water was withdrawn from a single private well on each parcel, with waste water dispersed via an on-site septic system for each parcel. The total water use (includes both consumptive and non-consumptive uses) in the Moderate Water Use Scenario is 0.25 AF/year. The daily use amounts in this scenario are approximately double those presented in Culhane and Nazy (2015) and Golder (2013), but these amounts were used in order to complete a conservative analysis. The total water use under the High Water Use Scenario, based on the ESSB 6091 Guidance Document is 0.67 AF/year, which is over 2.5 times more than the Moderate Use Scenario, and approximately five times that presented in Culhane and Nazy (2015) and Golder (2013).

Culhane and Nazy (2015) state that indoor use is only 10% consumptive, the remaining 90% is returned via septic infiltration, and that residential outdoor use is considered to be 80% consumptive, with 20% returned via infiltration. Other sources, such as Savoca (2010) suggest outdoor return flow can be as high as 40%. To stay conservative in our approach, we used the 80% consumptive value.

We used information presented in Drost (1999) to determine the rainfall and infiltration rate of the site. Based on information presented in Figures 4, 16, and 17 of Drost (1999), the study area receives 48 inches of rainfall, with 18 inches of that resulting in recharge to the aquifers beneath the site.

In a typical large-lot residential development, a portion of the lot is cleared for development and a home and driveway are constructed, adding impermeable surfaces to the property and potentially increasing runoff. In some cases, outbuildings such as garages, shops, or barns are also added. In Thurston County, site development is currently held to the standards presented in Chapter 15.05 of the Thurston County Code (County Code) and the 2016 Edition of the Drainage Design and Erosion Control Manual for Thurston County (Manual).

These standards require infiltration or dispersion of stormwater falling on impervious surfaces, with the intent to reduce runoff and erosion and enhance recharge to the subsurface. Additionally, per the County Code and the Manual, any disturbed soil must be amended to enhance infiltration, which will also serve to reduce runoff from the site. Studies indicate a significant increase in the infiltration rate of tilled, compost-amended soils (Brown and Cotton, 2011; Kays, et al, 2015). This is generally consistent with language in ESSB 6091 providing that "an applicant shall manage stormwater runoff on-site to the extent practicable by maximizing infiltration, including using low-impact development techniques, or pursuant to stormwater management requirements adopted by the local permitting authority, if locally adopted requirements are more stringent."

In a typical project, site development activities will be confined to the area immediately surrounding the home and outbuildings, septic drainfield, driveway, and yard. Figure 1 presents an aerial image of the ten parcels in essentially their current condition. Figure 2 presents a historical aerial image from 1996 when only three of the sites were developed or under development and, what appears to be, second-growth forest covering the remaining seven parcels. Based on our analysis of the development pattern of these ten parcels, an average of 75,200 square feet of each lot was cleared for construction and landscaping, or approximately 34% of a 5-acre lot. Within the cleared area, approximately 16,900 square feet of impermeable surfaces (buildings and driveways) were added, approximately 8% of a 5-acre lot. The remaining cleared area (approximately 58,300 square feet, or 27% of a 5-acre lot, was generally converted to lawn and landscaped areas.

We have presumed that the soils disturbed during the clearing, grading, and development of the site were amended, tilled, and graded in accordance with County Code and Manual requirements. We have also presumed that water falling on impervious surfaces added during development will be infiltrated on site. The change from mature trees to grass lawn results in a reduced amount of canopy capture and evapotranspiration, the magnitude of this reduction is approximately 20% (Zhang, et al, 2004; Sanford and Selnick, 2013).

Additionally, where impervious surfaces, such as the house and driveway, occur no vegetation will grow and the evapotranspiration will be nearly zero. To be conservative, we estimate the evapotranspiration will decline in these areas by 90%.

The pre-development water balance of the property can be calculated using the following factors: precipitation, runoff, evapotranspiration, and recharge. The relationship between these factors can be described as follows:

$$N_P - N_R - N_{ET} = Recharge$$

Where:

$N_P = Precipitation$

$N_R = Runoff$

$N_{ET} = Evapotranspiration$

In the pre-development condition, the site receives 48 inches of precipitation (Drost, 1999). Evapotranspiration in Thurston County is generally estimated at 18 inches per year (Biever, 2017). Based on the surface geology, recharge is estimated at 18 inches per year (Drost, 1999), so the remaining 12 inches must be considered runoff.

The post-development condition is somewhat more complicated, as the consumptive use calculated earlier must be accounted for and the changes in the nature of the site must be evaluated. Precipitation remains unchanged. Approximately 65% of the 5-acre lot will also remain untouched. Therefore, this analysis only focuses on the portion of the lot that was changed during site development—the 35% of the area that was cleared during construction. Homes, outbuildings, and driveways were added, though compliance with current County stormwater requirements means that the water falling directly on these impermeable surfaces will be re-routed and infiltrated into the subsurface. These impervious surfaces will cover about 8% of a 5-acre lot.

The nature of the ground cover changed from mature trees to a grass lawn where the yard, drainfield, and reserve drainfield are located, other cleared areas were landscaped. This results in a commensurate decrease in evapotranspirative demand discussed earlier. However, in order to keep our analysis conservative, we elected to use three quarters of the earlier-stated decrease (15%). As stated earlier, for the impervious areas, the evapotranspiration rate will be reduced by approximately 90%. The amended soils in this area will have an enhanced infiltration capacity and will more readily accept rainfall, and County regulations require infiltration and dispersion of runoff, significantly reducing runoff from this portion of the property. As a conservative value, we reduced runoff by a quarter, to a value of nine inches per year.

Septic return flow will offset some of the water use on the property. Typically, 90% of the indoor use is considered to be returned to the drainfield (Culhane and Nazy, 2015, and Washington State Department of Ecology, 2018). However, we applied an evapotranspirative loss factor (ranging from 10% in May up to 30% in July and August) to the septic effluent return flow, as laterals may be within reach of plant and turf roots, resulting in the uptake of some of the effluent during hotter months. Finally, the water used outdoors is considered to be a largely consumptive use, with only 20% infiltrated into the subsurface (Culhane and Nazy, 2015).

With these factors, we are able to calculate a post-development water budget via the following relationship:

$$N_P - N_R - N_{ET} - N_{WW} + N_{OR} + N_{SR} = Recharge$$

Where:

N_P = *Precipitation*

N_R = *Runoff*

N_{ET} = *Evapotranspiration*

N_{WW} = *Well Withdrawal*

N_{OR} = *Outdoor Use Return Flow*

N_{SR} = *Septic Return Flow*

The results of this calculation are presented in Table 1.

Table 1: Pre- and post-development annual average water balance

Pre-development			Post Development (High Water Use, using Ecology's ESSB 6091 guidance)		Post Development (Moderate Water Use)	
	in/yr	gal/day	in/yr	gal/day	in/yr	gal/day
Precipitation	48	6,164	48	6,164	48	6,164
Runoff	-12	-1541	-9	-1156	-9	-1156
Evapotranspiration(1)	-18	-2,312	-11.6	-1486	-11.6	-1486
Well Withdrawal	0	0	-11.7	-597	-4.5	-229
Septic Return	0	0	2.6	135	2.9	149
Outdoor Return	0	0	1.7	89	0.3	13
Recharge	18	2,312	20.0	2,589	26.1	3353
			Total Change	277		1041

[1] Reduction prorated for combination of pervious and impervious surfaces

In the post-development condition, groundwater use from the planned well is partially offset by the infiltration of septic return flow and the partial infiltration of water used outside the home. The decrease in evapotranspiration of the developed area of the property, when coupled with the decreased runoff and increased infiltration capacity of the amended soils, results in an increase in the amount of water recharging the subsurface. Our analysis suggests that the resulting water balance of a project like this, under either water use scenario, more than completely offsets the consumptive use from the proposed well on the property, providing an increased amount of groundwater recharge under the post-development condition.

Seasonal Consideration

Under Ecology's ESSB 6091 water use estimates, the annual water balance indicates a 277 gallon per day increase per lot in average groundwater recharge. Using the lower water use estimates, as published by Culhane and Nazy (2015) and Golder (2013), the annual water balance indicates a 1,041 gallon per day increase per lot in average recharge due to the development.

However, these increases in groundwater recharge do not occur evenly over the year. The increase in recharge due to the reduction in runoff will occur mainly in the wet season. The reduction in evapotranspiration will occur mostly in the dry season. Water use, and consequently well production, will be higher in the dry season. Return from outdoor water use will occur mainly in the dry season. Returns from indoor use will occur year-round, largely unaffected by the seasonal changes in outdoor use.

If we consider the dry season to occur from May and October, assign the changes in water balance between wet and dry seasons accordingly, and presume that all the changes in recharge occur during this season, we can develop an approximate change in recharge for the dry season as shown on Table 2.

Table 2: Dry season change in recharge

	High Water Use	Moderate Water Use
	gal/day	gal/day
Precipitation	0	0
Runoff reduction	0	0
Evapotranspiration reduction	826	826
Well Withdrawal [1]	-1037	-292
Outdoor Return	89	13
Septic Return [2]	135	149
Total Change	13	695

[1] Average well production from May through October
[2] Average septic return flow from May through October

The effects of both the well production and the recharge will be attenuated relative to aquifer discharges to surface water due to both vertical and horizontal distance and the fact that the aquifers have substantial storage. Timing of recharge entering the aquifer will be attenuated by the sediments between the land surface and the aquifer. However, as indicated by Table 2, the increase in recharge even during the dry season should be larger than the consumptive use. Because of attenuation effects, the system should act largely in a steady-state manner. And certainly, any transient analysis on a time period shorter than wet and dry seasons is not warranted.

Conclusion

Based on our analysis of the historical development of ten five-acre lots, we have concluded that the consumptive water use and groundwater withdrawals of such a typical development are more than completely offset by the changes in evapotranspiration, reduction in runoff, and the septic return flows associated with the development. The year-round net annual water balance in the post-development condition is positive and results in additional infiltration to the subsurface.

The statements, conclusions, and recommendations provided in this report are to be exclusively used within the context of this document. They are based upon generally accepted environmental and hydrogeologic practices and are the result of analysis by Robinson Noble, Inc. staff. This report, and any attachments to it, is for the exclusive use of Bill Clarke and Washington REALTORS®. Unless specifically stated in the document, no warranty, expressed or implied, is made.

Attachments

Figure 1 – Current Aerial Map
Figure 2 – Historical Aerial Map

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ATTACHMENTS

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Note: Imagery from Thurston County GIS 2015 Aerials

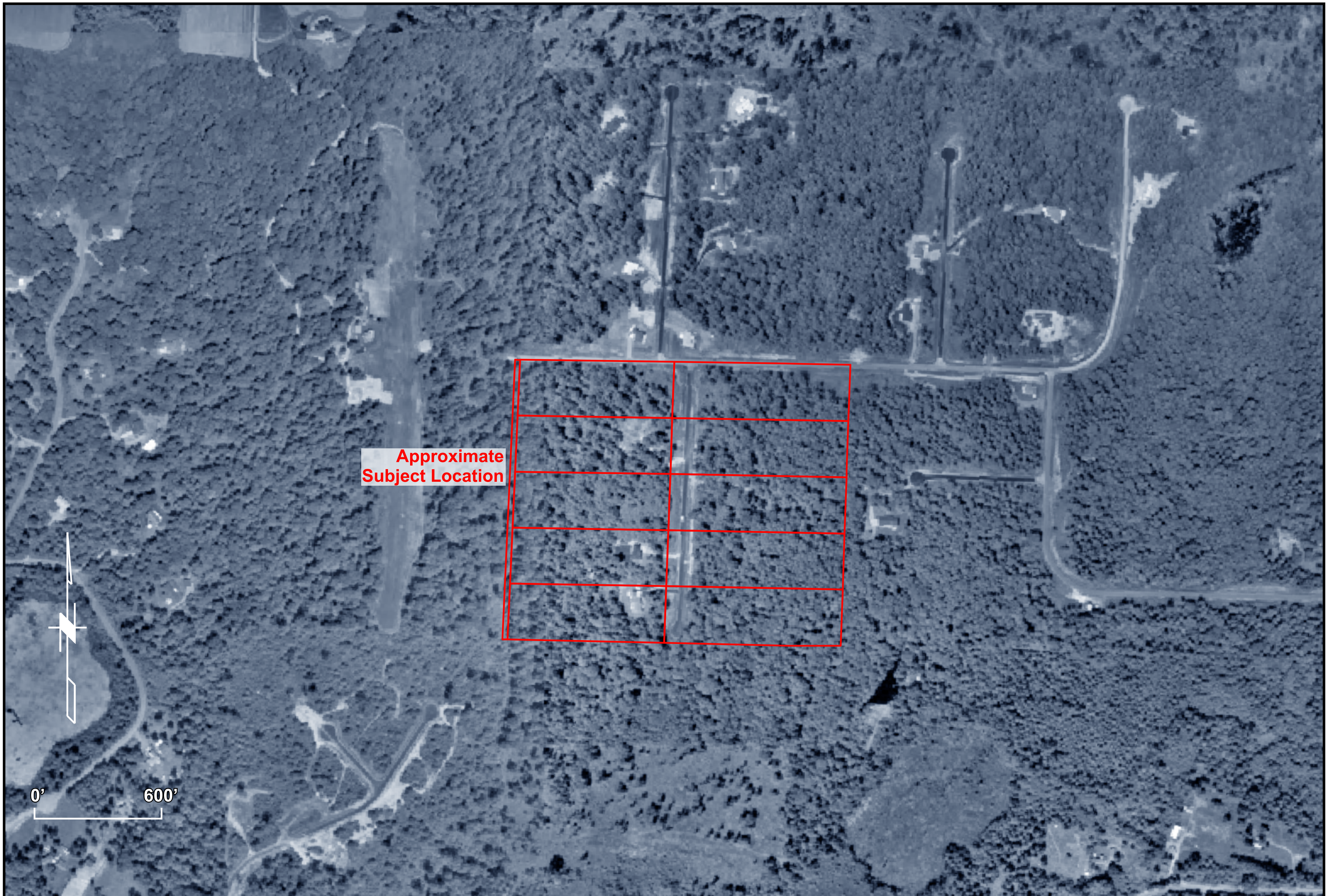
PM: MFP
November 2018
3321-001A

Thurston County
T 17 N/R 02 W - 25
Scale 1" = 600'

Figure 1

Current Aerial Map

Washington Realtors: Water Balance Analysis



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Note: Imagery from Thurston County GIS 1996 Aerials

PM: MFP
November 2018
3321-001A

Thurston County
T 17 N/R 02 W - 25
Scale 1" = 600'

Figure 2

Historical Aerial Map

Washington Realtors: Water Balance Analysis