Analysis of Rain Catchment in WRIA 17

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Introduction

Current rulemaking in Water Resource Inventory Area (WRIA) 17 focuses on setting instream flows for the following creeks/streams: Big Quilcene, Chimacum, Donovan, Little Quilcene, Ludlow, Piddling, Salmon, Snow, Tarboo and Thorndyke. Some WRIA 17 individuals may elect to use rainwater for indoor domestic use and/or outdoor irrigation. Rainwater collection and use could impact streams that Ecology is trying to protect through rulemaking. To better understand how rainwater collection and use could impact streams, Ecology analyzed the potential impact of rainwater as a sole source for domestic use and as an augmentation source for outdoor irrigation only.

Ecology conducted some of the analysis using a model based on historic local precipitation. Historic precipitation data for the Quilcene (51 inches) was used for the Big Quilcene, Little Quilcene, Donovan and Spencer subbasins. Historic precipitation data for the Chimacum (29 inches) was used for the Chimacum, Ludlow, Piddling, Taboo, Thorndyke, Salmon and Snow subbasins. The model enables the user to choose cistern size, roof size and desired water use to test the feasibility of various scenarios. The model assumes 80% capture from rooftops. The 20% loss assumption is an effort to account for rainwater lost due to first flush diverters, evaporation and spillover or splash-out from the gutters during hard rains.

The model unrealistically portrays how precipitation occurs – namely that average monthly precipitation occurs on a daily basis. For example, if average precipitation in June is 3 inches, the model assumes that it rains $1/10^{th}$ of an inch every day. In reality, of course, rain falls in batches. This becomes an issue when average summer monthly precipitation is met through infrequent rain storms separated by a few weeks. This pattern makes it more difficult to avoid periods where the cistern empties out during the summer. Thus, the model underestimates how often a cistern will, in reality, empty out during the summer.

Furthermore, the model does not account for the fact that average precipitation does not occur every year. For example, during the period of 1961-1990 average Chimacum precipitation was 28.9 inches. The range of precipitation during that period swung from a low of 19.9 inches in 1976 (31% below the mean) to a high of 40.3 inches in 1983 (39% above the mean). Because of these issues, it seems probable that people would size their rain catchment system with an added safety factor – enough cushion to withstand typical year to year variability, probably on the order of about 15-20% – but not designed to meet drought conditions as that would likely be too expensive as it would require a significantly larger roof.

Analysis of Rainwater as a Sole Source for Domestic Use

We assessed the impact of one new home using rainwater as the sole source of potable (drinkable) water supply with 100 gallons per day (gpd) indoor use and no outdoor use. We combined the smallest roof size and smallest cistern that enable a consistent use of 100 gpd without the cistern becoming less full year after year which would be unsustainable. For simplicity, the model assumes that everyone moves in February 1 with a full cistern. Realistically, if someone were to spend the money for a catchment system that supplies 100% of their potable needs, they would start collecting rainwater before moving in or pay the small added cost to fill the tank (10,000 gallons would cost about $1,000). The model goes out 200 years to neutralize the effect of starting with a full cistern. Our goal was to make the model reflect normal conditions after the cistern has reached an equilibrium with supply and demand and no longer reflect the initial full storage. See results in Table 1 and 2 below.

Table 1. Chimacum Precipitation Pattern Building Permit Scenario (100 gpd)

Cistern Size (Gallons)	Minimum Roof (square feet)	Total Annual Gallons Used	Lowest Cistern Level in Gallons (October)	Summer (Jun-Sep) Rainwater Caught (Gallons)	End of May Cistern Level (Gallons)
8,000	2,620	36,500	850	6,230	7,060
10,000	2,620	36,500	2,850	6,230	9,060

Table 2. Quilcene Precipitation Pattern Building Permit Scenario (100 gpd)

Cistern Size (Gallons)	Minimum Roof (square feet)	Total Annual Gallons Used	Lowest Cistern Level in Gallons (October)	Summer (Jun-Sep) Rainwater Caught (Gallons)	End of May Cistern Level (Gallons)
8,000	1,765	36,500	10	5,220	6,980
10,000	1,765	36,500	2,010	5,220	8,980

The driver is roof square footage. We found that starting with a larger cistern (30,000 gallons) that is full would enable slightly less roof square footage. However, when roof square footage is lowered, the cistern's carryover decreases every year and thus one low precipitation year or a few moderately low years would force the homeowner to truck in water on a regular basis. This is especially true in areas receiving precipitation amounts similar to that of the Chimacum subbasin. For the Chimacum subbasin patterned precipitation, only a roof size of at least 2,620 s.f. is self sustaining year to year. For the Quilcene subbasin patterned precipitation, a much smaller roof is required.

An 8,000 gallon cistern is adequate for both subbasin types. However, as seen above, increasing the cistern volume capacity by 2,000 gallons provides a safety valve for those years where average precipitation does not occur during the summer (the cistern still fills up in the spring even with below average precipitation during the winter). Combined with the ability to reduce use below 100 gpd when needed and a larger roof, this is probably an adequate safety margin.

Summer Capture and Use

For those concerned that rain catchment could be harmful to instream flows or other water rights, there is typically more concern about summer rain catchment than winter. As will be subsequently explained, neither is of concern for indoor potable use only, and winter rain catchment is a larger concern when rainwater is being captured for summertime irrigation. According to a [1981 Water Supply Bulletin No. 54] for Eastern Jefferson County, actual evapotranspiration (portion of water lost to the air or used by the plant) exceeds soil moisture utilization in both Port Townsend and Quilcene (see Figures 1 and 2 below from page 31).

Figure 1. Port Townsend Evapotranspiration

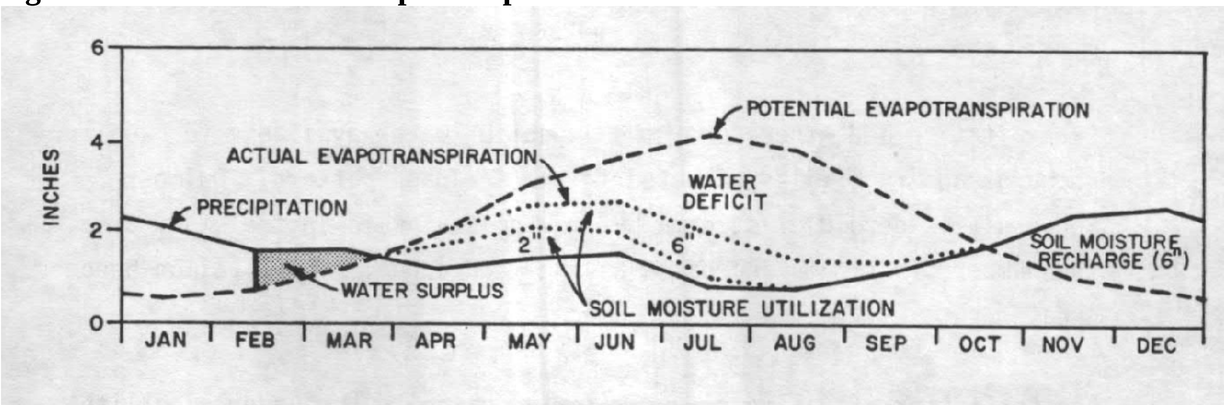
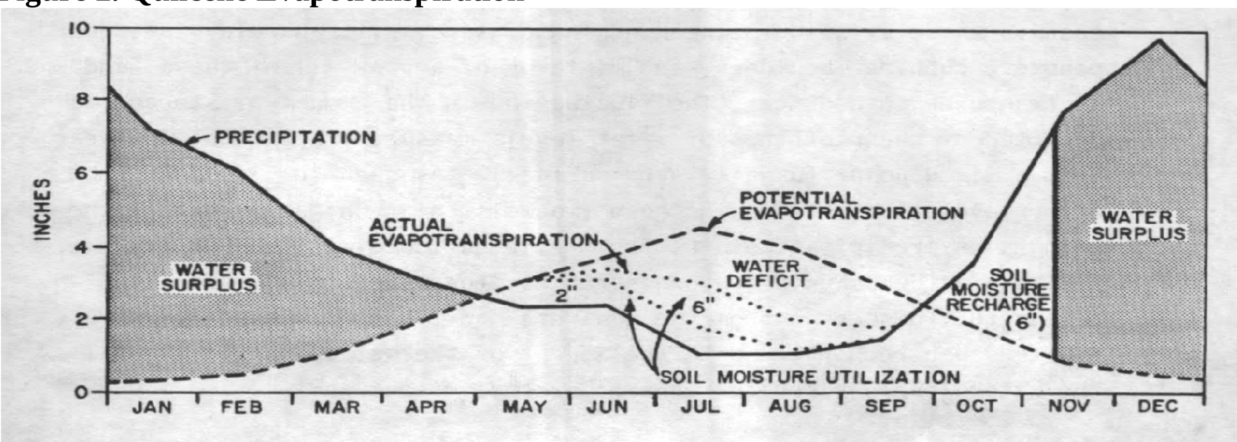


Figure 2. Quilcene Evapotranspiration



The above figures help illustrate the fate of summer precipitation – most of the rain is evapotranspirated due to the water deficit. Indeed, much of the rainwater never makes it past the forest canopy itself. If rain does manage to reach the ground, it is quickly consumed by the local vegetation. Some summer rain, of course, does manage to find its way to the aquifer or a stream. Intuitively, aquifer recharge occurs predominantly in deforested or partially deforested areas due to the lower evapotranspiration rates there. Surface water contributions occur in areas close to the stream where drainages are prevalent. As the distance from the stream increases, the ability of summer rain to contribute toward streamflow, either through baseflow or surface runoff, decreases due to the potential evapotranspiration vs. actual evapotranspiration gap (the local vegetation craves more water than is available). To better understand the fate of summer precipitation, we studied summer rainfall events and correlative increases in streamflow.

Figure 3. 2003 May-October Chimacum Flows & Precipitation

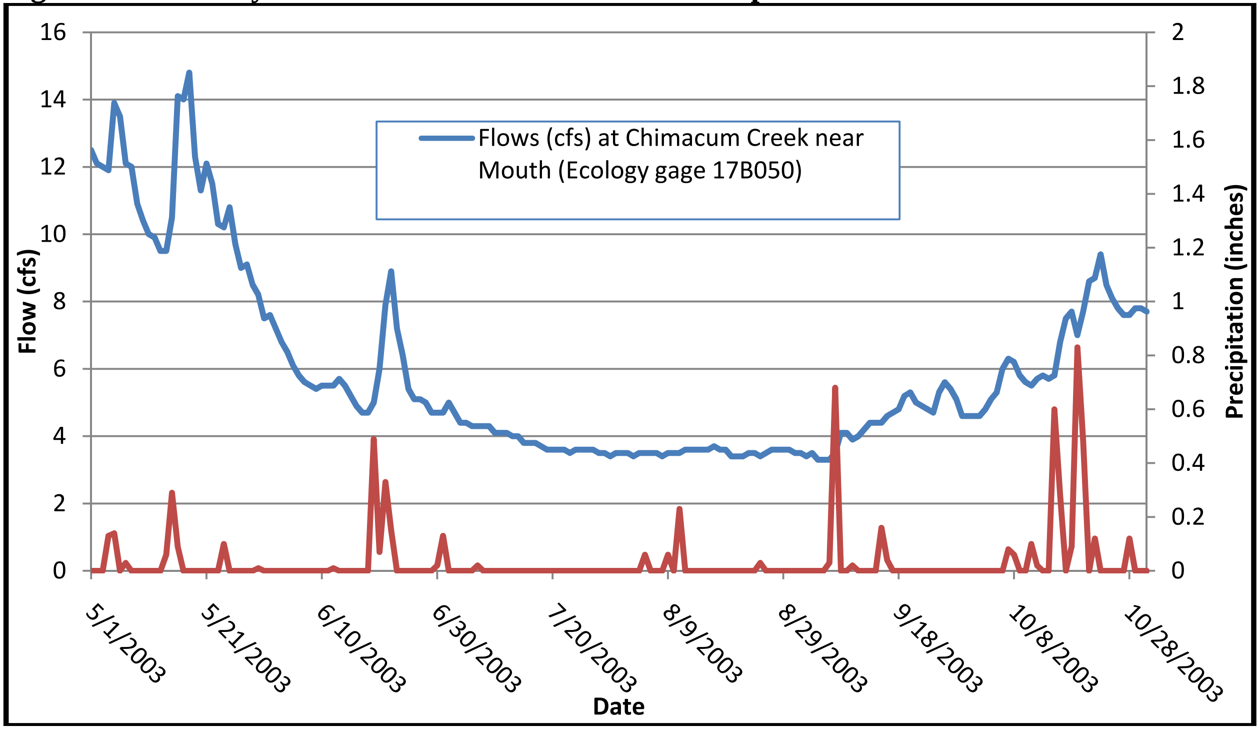
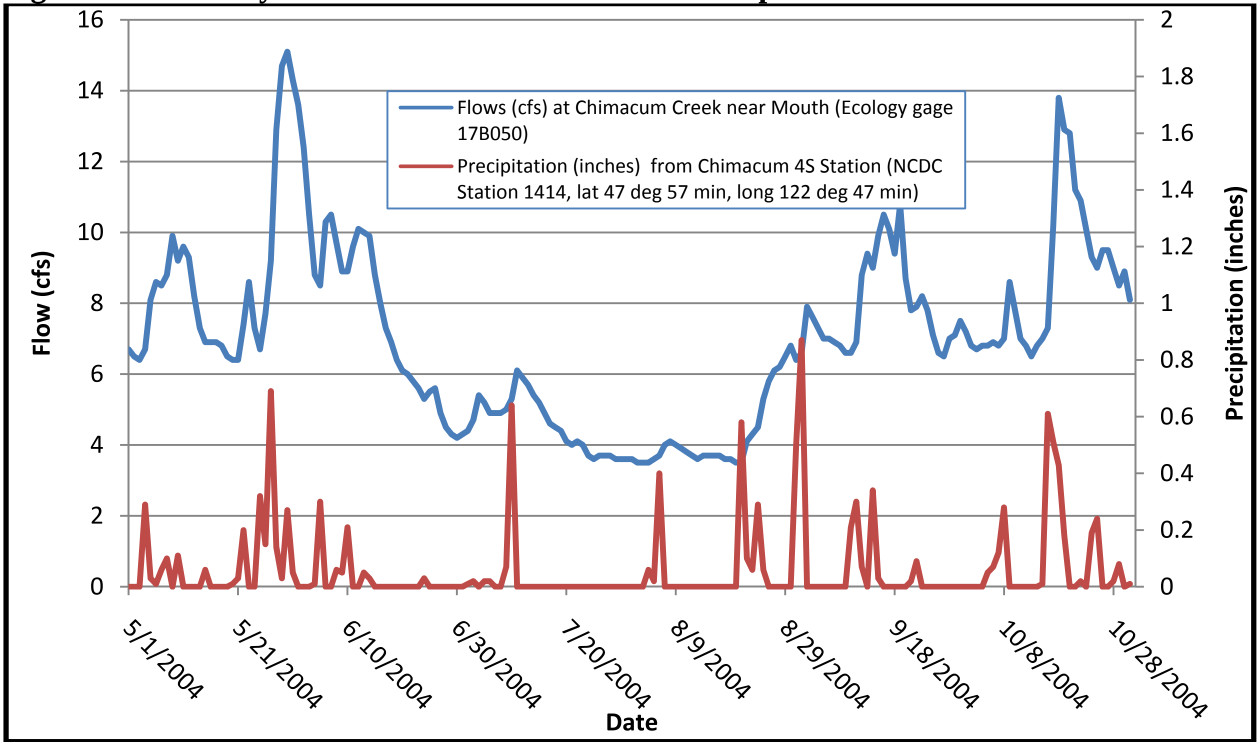


Figure 4. 2004 May-October Chimacum Flows & Precipitation



We used this data to estimate the percentage of summer precipitation in a basin that directly influences streamflow. We chose to focus on Chimacum Creek as we expect this subbasin to experience far more growth than any other and thus the potential cumulative impact from rain catchment is greatest there. Some new homes will be built near the creek or a tributary of the creek, and some new homes will be built a significant distance away from the creek or tributaries thereof. The attempt of this analysis was to ascertain the subbasin-wide *average* impact that a rain catchment system as a home's sole source of potable supply would have on the creek during the summer.

Precipitation in the Chimacum Subbasin varies from 20 inches in the northern portion of the subbasin to 35 inches in the southwest portion (See Figure A1, Appendix A). We used data from the weather station in the community of Center, which is in a band of precipitation that receives approximately 30 inches a year, according to the Precipitation-Frequency Atlas of the Western United States.

It would be a mistake to assume that a rainfall event recorded in the town of Center always occurs uniformly subbasin-wide. However, this analysis requires an estimation of how much precipitation occurs throughout the subbasin when a precipitation event is recorded at the weather station. To arrive at this estimate, we calculated the area (acres) of each precipitation band and multiplied it by the average annual amount of precipitation (inches) that particular band receives. The results were summed and we divided the result by total acres. We found the average annual precipitation for the entire subbasin was 26.9 inches, based on precipitation bands. Results are in Table 3 below.

Table 3. Calculations and Methodology for Converting Precipitation Recorded at the Weather Station in Center, WA to a Subbasin-wide Average

Precipitation Band (inches)	**Acres**	**Precipitation*Acres**
30	6,830.8	204,924.7
35	3,289.6	115,136.6
25	9,692.7	242,316.5
20	4,200.1	84,002.6
Totals	24,013.2	646,380.4
Average Annual Basin-Wide Precipitation:		26.9
Average Annual Precipitation at Weather Station:		31
Average Annual Basin-Wide Precipitation Divided by Average Annual Precipitation at Weather Station:		0.87

The weather station is in the 30 inch band. While the average of the band is 30 inches of precipitation, it actually represents a flux of 27.5 inches (where it borders the 25 inch band) to 32.5 inches (where it borders the 35 inch band). The weather station is located slightly closer to the 32.5 inch border (See Figure A1, Appendix A). Thus, for the purpose of this analysis, it is assumed that the weather station typically receives approximately 31 inches/year. When 26.9 is divided by 31 a ratio of 0.87 is attained. Thus, when it rains 1 inch at the weather station, on average the entire subbasin typically receives 0.87 inches. We used this ratio to estimate how much precipitation fell subbasin-wide from a storm recorded at the gage.

This ratio is not valid for every storm event but it is representative of what occurs over the long-term historic average. Furthermore, it appears that summer rainfall events are typically large in area, as Chimacum precipitation events frequently correlate to streamflow increases in other subbasins. Of course, all precipitation falling in the subbasin would not flow to the creek even under the most opportune conditions (see Figure A2, Appendix A for the topographic map of Chimacum Subbasin). Our intent was *not* to determine the percentage of precipitation that evapotranspiration prevented from flowing to the creek. Rather, the intent was to ascertain the subbasin-wide average impact that a house with a rain catchment system would have on the creek during the summer.

Actual streamflow data from 2003-2004 was compared to a fictional baseline streamflow scenario that, in the early and mid-summer analyses, uses linear regressions to estimate streamflow that would have occurred without a storm, and in the late summer analyses, assumes a static flow of 3.5 cubic feet per second (cfs) – the relatively consistent baseflow at that time of year. Using the 0.87 multiplier, we obtained the following results (see Appendix C for graphs and data):

- Early in the summer, an estimated 97.8% of the rain falling on the subbasin does not appear to contribute to streamflows.
- As the season progresses, that percentage increases to 98.4% mid-summer to a range of 99.1% to 99.7% late summer.

The differences in the late summer percentages are a function of the amount of rainfall. Only a storm of significant strength correlates to an observable increase in streamflows. Even with a relatively large storm (nearly ½ inch over a 3 day period), over 99% of basin precipitation did not appear to contribute to streamflows. Similar trends are likely throughout WRIA 17.

Flow in Chimacum Creek is typically low from June through September (JJAS). JJAS precipitation in Chimacum averages 4.8 inches. An estimated average of 98.5% of rainfall did not appear to influence streamflows during the summer of 2004. Thus, if a home with a 2,620 s.f. roof in the Chimacum subbasin captures 80% of the rain during the summer (given first flush and spillover) the homeowner will have captured 6,240 gallons. Of that, on a subbasin-wide average, 91 gallons (12.2 cubic feet) would have contributed to Chimacum Creek.

In 2003-2004 an average of 19 precipitation events occurred over the 122 day JJAS period. If this 12.2 cubic feet is spread out over the course of those 19 days, it correlates to a loss of streamflow of 0.0000074 cfs. In actuality, this cfs should be even lower as a higher number than 19 days should be used because the effect of the precipitation event typically lasts for a few days after the event, decreasing as time progresses. If we estimate that on average a precipitation event affects the creek for three days, the 0.0000074 cfs effect on streamflow decreases to 0.0000018 cfs. However, the above analysis is flawed as it assumes the water is captured and not released. What actually happens is the rainwater is captured, used indoors, and then returned to the ground through a septic system.

One would expect that the evapotranspiration rate of the water exiting the septic system a few feet below the surface would be substantially lower than the naturally occurring rainfall evapotranspiration rate. This is because the rainwater in the septic system did not have to first pass through a canopy (if there is one above the house), and then through ground vegetation and dry soil. An estimate used by the USGS in a study in Island County[1] suggests that indoor domestic water use is approximately 87% non-consumptive if that home disposes of waste water through a septic system. The 13% consumptive nature of indoor domestic use predominantly comes from evapotranspiration occurring in and around the leach field. This is an annual average – evapotranspiration is higher in the summer and lower in the winter.

Precipitation falling on land without a house or on a house without a rain catchment system is subject to an evapotranspiration rate of approximately 40-45%, less with increasing impermeable surfaces and/or decreasing forest cover. Given this discrepancy, the house with the rain catchment system is actually enabling more water to infiltrate into the aquifer, which benefits the nearest creek. This is likely still the case even if the household manages to conserve enough water to irrigate a small garden due to the large difference between evapotranspiration rates of "native" precipitation and the evapotranspiration rate of precipitation that falls on a house and is subsequently stored, used indoors and discharged underground.

It deserves mentioning that this rain catchment scenario is completely different from that of a well. A well extracts water from the aquifer, where the water is not subject to evapotranspiration (unless it is a very shallow well and there are deep roots near the well). That water is then pumped to the surface, used, and then returned to the subsurface (the leach field) where it is susceptible to some evapotranspiration.

If one assumes that the summer evapotranspiration rate of a leach field is approximately double the annual average of 13% (26%), then an individual on a well who is withdrawing 100 gpd for indoor use is essentially removing 26 gpd from the aquifer during the summer, possibly more or less depending on the local evapotranspiration rates. Using these assumptions, over the course of a 120-day summer that well owner would have removed 3,120 (26*120) gallons from the aquifer. WRIA 17 creeks and streams are very reliant, and often fully reliant, on groundwater for baseflow during the summer. In stark contrast to this well example, a house served by rain catchment is increasing aquifer recharge.

Winter Capture and Use

Early in the fall/winter, most precipitation contributes to soil moisture recharge. The remainder contributes to surface water runoff (more so during heavier precipitation events), aquifer recharge and, to a lesser extent, evapotranspiration. Depending on the amount of precipitation, soil saturation may take a month and a half (Quilcene, see Figure 2 above) to four months (Port Townsend, see Figure 1 above) to occur once there is no longer a water deficit. After soil saturation, nearly all precipitation contributes to aquifer recharge or surface water runoff (minor amounts are evapotranspirated and periodically some water is needed for re-saturation). Unlike a well, which continually withdraws groundwater from the aquifer with typically no regard to

[1] Estimated Water Use in the United States, US Geological Survey Circular 1080, online at http://pubs.er.usgs.gov/usgspubs/cir/cir1081

precipitation events occurring above ground, a house with a rain catchment system can only capture water when it is raining. The fate of winter precipitation is described above.

Obviously, more precipitation contributes to surface water runoff when it is raining than when it is not. Thus, by capturing water when it is raining and returning that water to the septic system when it may or may not be raining, a house with a rain catchment system for indoor use is actually enabling more of the precipitation to contribute to soil moisture replenishment and then, later in the fall/winter, to aquifer recharge. As with the summer example, this situation is favorable to any nearby creek because creeks rely on groundwater during the summer. And this is the opposite situation of a well, which is continually pumping groundwater and exposing a portion of that groundwater to a higher level of evapotranspiration or interflow that may eventually become surface water runoff.

Conclusion

The above analysis should not lead the reader to believe that Ecology is in any way advocating for deforestation or vegetation removal to free up more water for human consumption, nor that one can or should obtain a water right by decreasing evapotranspiration rates via deforestation or vegetation removal. Caselaw is definitive regarding the inability to obtain a water right via deforestation or vegetation removal even if it can clearly be shown that such a practice would in fact free up more water by reducing evapotranspiration. Forests serve many important functions – they provide habitat, climate mitigation via carbon sequestration, water quality benefits and lumber as well as other valuable resources.

Large-scale deforestation is fraught with negative consequences as is uncontrolled growth. Discussing the hydrologic benefits associated with a new house served by rain catchment should not be misconstrued as advocating for uncontrolled growth. Rather, it is simply acknowledging the impact to the hydrologic system of an individual house served by rain catchment. Of course, if a certain threshold of growth occurs, the individual "benefit" of a house served by rain catchment to a forest's water budget is typically dwarfed by the negative effects to the hydrologic cycle that such growth brings via the typical dramatic increase in impermeable surfaces and associated losses in aquifer recharge, should stringent low impact development protocols not be mandated. This is not as relevant in the Chimacum subbasin as current growth patterns are such that homes are built with semi-permeable gravel driveways off of existing streets. With enough growth, however, this growth scenario could, in theory at least, change. However, given current growth patterns that seems unlikely in this century.

Other negative issues often occur with rural growth as well, namely forest fragmentation, loss of habitat, and typically there are associated increases in vehicle miles traveled which increases climate pollution. Regarding climate change, it is interesting to note that evapotranspiration, like many other functions previously thought of in a static context, is dynamic in a climate changed world. As temperature increases, potential evapotranspiration increases non-linearly if precipitation does not change.[2] Thus, in a climate changed future the disparity between the fate

[2] Gregory J. McCabe1 & David M. Wolock. 2002. *Trends and Temperature Sensitivity of Moisture Conditions in the Conterminous United States*, Vol. 20: 19–29 et al.

of summer precipitation caught and used for indoor use versus the fate of precipitation not captured will be even greater.

Given the above analysis, it is the author's opinion that building permits issued in WRIA 17 based on rain catchment as the sole source of supply will not pose a threat to streams or senior water rights. In fact, such catchment systems will likely provide hydrologic benefits if viewed in isolation of possible increases in impermeable surfaces associated with significant growth in the subbasin. Building permits based on rainwater as the sole potable source are likely to be rare in areas receiving approximately 30 annual inches of rain due to the large square footage of roof required to enable a rather modest use of 100 gpd. In such instances, outdoor use (mostly consumptive) is likely to be exceedingly low, if any occurs at all. This is so because a homeowner will likely be concerned with having an adequate supply of potable water in the late summer/early fall and thus will not risk using valuable water for outdoor irrigation.

In areas receiving more annual rainfall, especially upwards of 50 inches, a much smaller roof is required and thus, building permits issued on rain catchment would theoretically be more prevalent. In wet areas like this, larger roofs and cisterns could enable summertime outdoor irrigation (consumptive use). In these wet areas, however, any capture and storage of winter/early spring precipitation for summer gardening would be extremely *de minimus* compared to the very large amount of water surplus then (see Figure 2 above). Moreover, similar to what occurs in the Chimacum Subbasin, one would expect that summer capture would not have otherwise appreciably contributed to streamflows primarily because potential evapotranspiration rates exceed actual evapotranspiration rates throughout WRIA 17 during the summer.

Analysis of Rainwater as an Augmentation Source for Outdoor Irrigation Only

The Washington State Irrigation Guide lists crop duties for various locations throughout the state. It lists irrigation duties for Quilcene but none for Chimacum. Of the locations included, Olga, San Juan Islands bears the closest resemblance to Chimacum based on precipitation and temperature patterns. Thus, Olga irrigation duties were used for Chimacum.

Other than apples, clover and raspberries, turf or pasture requires the most water. Therefore, to estimate on the high side of potential water use, we used a turf/pasture water duty for this analysis. Also, in order to simulate "worst case" conditions, we assumed that every new home built outside the water service area will use large-scale rain catchment for irrigation. We looked only at homes outside the water service area because we assumed that the high maintenance and cost of rain catchment systems (about $1 per gallon of storage, decreasing with much larger systems) will preclude people with access to municipal water from installing such systems. This analysis assumes residential building permit trends from 1990-2006 will continue, and that all new houses outside the water service area will be built with adequate roof square footage and cistern volume to enable 5,000 s.f. of irrigated garden area.

Irrigation and Cistern Volume Assumptions – Chimacum

In Chimacum (29 inches annual precipitation), 5,000 s.f. of pasture or turf would require about 41,100 gallons of irrigation. To deliver this through rain catchment would require a minimum of a 2,953 s.f. of roof and a 35,000 gallon cistern. In normal years, the cistern would still have approximately 3,700 gallons at the end of September. This appears to be an adequate safety valve. Of course, increasing the roof square footage would build more resiliency into the system, but that may not always be an option.

Irrigation and Cistern Volume Assumptions – Quilcene

In Quilcene (51 inches annual precipitation), 5,000 s.f. of pasture or turf would require approximately 39,500 gallons of irrigation. To deliver this through rain catchment would only require a minimum of a 1,537 s.f. of roof and a 35,000 gallon cistern. Far less square footage is required compared to Chimacum-patterned precipitation due to the 23 additional inches of annual precipitation. In such a case, the cistern would be low in September even in normal years (1,617 gallons at the end of September). Again, increasing the square footage of the roof would provide more resiliency.

Determining the Net Effect of Rain Catchment - Discussion

In the above scenarios, the cistern fills over the course of the winter and is fully topped at 35,000 gallons in late April/early May. Soil moisture is replenished by early November in the Quilcene (see Figure 2 above). There is no data on when this occurs in Chimacum. Given that soil moisture is fully replenished in mid-February in Port Townsend (see Figure 1 above), it seems likely that in Chimacum, soil moisture content would be fully replenished by late December (Chimacum receives about 10 more inches of precipitation than Port Townsend).

After soils are saturated, nearly all precipitation goes to surplus either as surface runoff or as aquifer recharge. The rain catchment system would cause a very minor, local temporal delay in the transition from rainwater providing soil moisture replenishment to rainwater going to surplus. This would very likely be immeasurable due to the relatively small amount of rainwater captured on the roof compared to the large amount of rainwater falling in the area surrounding the house. Furthermore, because groundwater is not a static system, a localized unsaturated anomaly in the soil would not last long due to the propensity of dynamic systems to move toward a state of equilibrium.

The percentage of surplus water that goes to aquifer recharge versus surface water runoff varies based on local conditions. Streams typically have adequate quantities of water in the winter, especially when it is raining. Therefore, the portion of the surplus waters of concern are those that go to aquifer recharge - a portion of which may eventually migrate to a stream and provide baseflow during the summer when water is critically scarce. Figure 5 (below) from a 2000 publication titled Stage 1 Technical Assessment as of February 2000 Water Resources Inventory Area 17 provides useful information on the estimated percentage of precipitation that contributes to recharge.

Table 4. Recharge Estimates for WRIA 17, courtesy of Stage 1 Technical Assessment as of February 2000 Water Resources Inventory Area 17

Sub Basin	Average Precip (in/yr)	Area (Acres)	Percent "Bedrock" Cover	Percent "Outwash" Cover	Percent "Till" Cover	Annual Recharge (af)	Annual Recharge (cfs)	Annual Recharge (in/yr)	Recharge as Percent of Precipitation	Annual Rejected Recharge (af)
Big Quilcene	51.9	51,509	92%	2%	5%	10,279	14.2	2.4	5%	3,653
Chimacum	27.2	23,681	5%	29%	62%	18,712	25.8	9.5	35%	846
Dabob-Thorndyke	39.3	33,116	2%	28%	67%	39,743	54.9	14.4	37%	11,985
Indian-Marrowstone	22.0	6,491	9%	7%	81%	3,002	4.1	5.5	25%	1
Little Quilcene	47.5	28,065	62%	8%	27%	14,652	20.2	6.3	13%	6,480
Ludlow	29.8	25,537	10%	17%	69%	21,237	29.3	10.0	33%	1,536
Miller	25.1	16,656	16%	6%	76%	8,115	11.2	5.8	23%	45
Quimper	21.5	18,514	5%	28%	61%	8,980	12.4	5.8	27%	2
Salmon-Snow	35.5	27,736	72%	7%	19%	9,461	13.1	4.1	12%	1,343
West Sequim Bay	28.2	24,136	76%	5%	18%	6,478	8.9	3.2	11%	65
WRIA 17 TOTAL	---	**255,441**	---	---	---	**140,659**	**194.3**	**6.6**	---	**25,956**

One can estimate the amount of precipitation that a rain catchment system caught that would have otherwise gone to groundwater recharge by multiplying the above *Recharge as a Percent of Precipitation* by 40,000 gallons, roughly the average of the Quilcene and Chimacum irrigation needs. This is a high estimate, as will be discussed later.

In the past, some stakeholders concerned about rain catchment's effects on instream flows and other water rights have raised concerns about summertime rainwater catchment, as the summer is when streams and water right holders need all the water they can get. Summertime rainwater capture for a 5,000 s.f. garden amounts to a low of 4,500 gallons in the Quilcene subbasin to 6,100 gallons in the Chimacum subbasin. The difference is because of the roof square footage required to fill up the cistern. If one compares the fate of summertime precipitation through rain catchment to a situation where there is no rain catchment system there is very little difference in the end result, the difference is about what vegetative species consumes the water.

In the rain capture scenario, the rainwater is captured for irrigation and consumption of whatever the homeowner chooses to irrigate. Unless one has very sophisticated equipment to monitor the exact needs of the vegetation, the garden typically is given more water than it needs – in some cases quite a bit more depending on the management style of the gardener. Either this excess water contributes to groundwater recharge or it is used by native trees and other vegetation with extended root systems under the garden. In the scenario without rain catchment, most of the summer precipitation would be evapotranspirated due the difference between actual and potential rates, and, on a subbasin-wide average, over 98% of the summer precipitation would not have contributed toward streamflow.

When one analyzes the difference in the fate of precipitation, it is important to consider the choice of the baseline scenario. One could compare a house with rain catchment to either a house without rain catchment (rainwater would augment an existing water supply) or to the natural environment without a house (building permit would not have been issued but for rainwater being the adequate source of water supply).

For this analysis (rainwater as an augmentation source for outdoor irrigation), the more apt comparison is comparing the rain catchment scenario to a house without rain catchment. In this baseline scenario (house without rain catchment), there would still be significant evapotranspiration occurring around the house as despite the fact that the endemic vegetation (including trees) was removed to make way for the footprint of the house, there is still a local water deficit in the summer nearly everywhere else (potential evapotranspiration rate exceeds actual evapotranspiration). Thus, despite the fact that there is less vegetation due to the footprint of the house, most of the rainwater that was captured during the summer would likely still have been evapotranspirated due to the summertime water deficit.

The exact degree of evapotranspiration would depend on many factors including, but not limited to, the amount of deforestation that occurred to make room for the home, the amount of semi-permeable and impermeable surfaces nearby, local canopy thickness, distance from the nearest creek, and local geology and hydrogeology. Capturing summer rainwater for outdoor irrigation, then, can best be viewed as a choice by the homeowner to favor one type of vegetation (the homeowner's garden) over the native vegetation. This issue warrants further discussion, as one should consider not only the role of the natural vegetation surrounding the house, but the natural vegetation that the garden replaced.

When one traditionally talks about gardening it is often viewed in the context of a new consumptive use. This is rightly so, because water is typically delivered from afar, or brought above ground via a well. The water would have naturally been somewhere else and now it is being consumed by the garden. The somewhere else (aquifer or surface water body) has less water than it otherwise would have.

Such is not always the case with rain catchment. True, some of the water would have been somewhere else in the winter. The rain captured in the cistern, if not captured, would first have gone to soil moisture replenishment, then to either aquifer storage or surface water runoff, with a low level of evapotranspiration occurring all the while, the exact rate differing depending on the degree of forest cover and percentage of evergreen versus deciduous species. In the summer, however, most of the water would not really have been somewhere else. Most of it would have been consumed by *something* else: the natural or landscaped vegetation around the house.

We should also not ignore the consumptive nature of the endemic vegetation in the area selected for the garden footprint prior to the clearing and planting of the garden. With few exceptions, garden plantings typically only consume water in the summer. In contrast, perennial endemic vegetation typically consumes water all year round (evergreen varieties more so than deciduous). While it is true that the garden requires summertime irrigation, in a forest setting the vegetation that was cleared to make way for the garden may have consumed more than the garden plantings due to the deeper and more elaborate root systems associated with the perennial endemic vegetation, notably Douglas Firs.

Douglas Fir forests can evapotranspirate up to 50 inches of water/year.[3] Even the thirstiest crop listed in the Washington State Irrigation Guide – raspberries – requires only 17.5 inches from May through September in Quilcene. Adding the summer precipitation that falls during that time period brings the total consumption of the raspberries to 26.8 inches. Thus, if one compares a

[3] Kittredge, Joseph, 1948, Forest influences: The Effects of Woody Vegetation on Climate, Water, and Soil with Applications to the conservation of Water and the Control of Floods and erosion. New York, McGraw-Hill, 394 p.

5,000 s.f. garden of raspberries enabled by rainwater catchment to a 5,000 s.f. forested area in a setting such as WRIA 17, the planting of the garden, when combined with the associated endemic vegetative removal, may actually have the net effect of increasing aquifer recharge depending on the degree of forest cover that existed prior to the clearing of the site and the extent of the root system associated with nearby trees that would still exist under the garden.

As we noted earlier, nothing in this discussion should be construed to suggest that Ecology is condoning the removal of native vegetation or deforestation as a way to free up water. Furthermore, Ecology recognizes that many areas in WRIA 17 have already been deforested, so the above discussion is not always on point. This discussion merely conveys some of the many nuances involved with determining the net effect to the hydrologic system caused by a rain catchment system used for outdoor irrigation.

The above discussion illustrates the complexities and difficulties in quantifying the effect of rooftop rainwater collection systems used for outdoor irrigation. In sum:

- It is unrealistic to count all of the rainwater collected and used for outdoor irrigation as a net loss to the hydrologic system.
- It is difficult to quantify the actual hydrologic deficit, if any, created by the addition of a rain catchment system designed for outdoor irrigation without making a host of assumptions.
- A garden supplied by rain catchment in a forest setting may actually have the net effect of increasing aquifer recharge, depending on the comparative baseline chosen.

Analysis

Building permit data was examined for each subbasin. We averaged the total building permits issued outside the public water service areas from 1990-2007.[4] We then multiplied the average by 15 to estimate the number of new homes to be built over the next 15 years. To look at the "worst case" scenario, we assumed all homes outside a public water service area would want to take advantage of rain catchment as a source augmentation to a well. Other assumptions used in the analysis:

- Every new house built in areas outside the water service areas in WRIA 17 will be built with a 35,000 gallon cistern for irrigation of a 5,000 s.f. garden.
- 100% of Lost Recharge$_{x\ \text{sub-basin}}$ would eventually become flow in the particular stream that the rulemaking is setting minimum instream flows. (This is obviously not the case – see nuances above and not all aquifer recharge ultimately contributes to streamflows, some flows into the Sound and some is intercepted by water right holders for irrigation.)

[4] 1990 was chosen as the starting point because there were comparatively very few building permits issued prior to 1990. In reality, it appears that annual building permits issued will likely decrease due to the current economic crisis.

The maximum amount of precipitation that the rainwater catchment system may have deprived the aquifer of in an individual subbasin is determined by:

2023 Annual Lost Recharge$_{x\ \text{sub-basin}}$ = (40,000 gallons) x (estimated % precipitation that goes to aquifer recharge) x (estimated building permits issued for next 15 years)

Table 5. Estimate of Total Building Permits Issued, 2009-2023 and Resultant Potential Impact Assuming 100% of New Homes are Built with a 35,000 Gallon Cistern

Year	Ludlow	Salmon	Snow	Chimacum	Piddling	Thorndyke	Tarboo	Donovan	Little Quilcene	Big Quilcene	Spencer
Estimate of Total Building Permits Issued (15 years at 1990-2006	30	3	3	139	7	25	26	9	60	26	0
Estimated Percentage of Precipitation that Contributes to Aquifer Reharge	33	12	12	35	35	37	37	13	13	5	N/A
Annually Lost Recharge (thousands of gallons)	346,500	11,118	11,118	1,707,794	85,750	323,750	336,700	40,950	273,000	45,500	N/A
Annually Lost Recharge (acre-feet)	1.06	0.03	0.03	5.24	0.26	0.99	1.03	0.13	0.84	0.14	N/A
Annual Lost Recharge (cubic feet)	46,320	1,486	1,486	228,299	11,463	43,279	45,010	5,474	36,495	6,082	N/A
Lost Recharge (annualized flow in CFS))	0.00147	0.00005	0.00005	0.00723	0.00036	0.00137	0.00143	0.00017	0.00116	0.00019	N/A

As can be seen, even under this "worst case" scenario that overestimates the effect of rain catchment for outdoor irrigation, the hit to the stream is only a high of 7/1,000th cfs in Chimacum Creek. Under this scenario, it would take 20 years of growth (total of 182 new homes) in the Chimacum sub-basin to reach the point where Chimacum Creek's streamflows are decreased by 1/100th cfs, and every new home would have to be equipped with a 35,000 gallon cistern.

Ecology's rule on permit exempt wells prevents this from happening – only 109 building permits could be issued based on a permit-exempt well as the source of water supply. If the house is served by a municipality, it is highly unlikely that homeowners will invest tens of thousands of dollars on a rain catchment system when they could simply use a municipal supply at a much lower cost. Thus, after the 109 building permits based on a permit exempt well are exhausted, new building permits will only be issued based on municipal supply or rain catchment as the source of water supply. Given that there is a significant roof square footage requirement to catch enough rainwater for indoor domestic use alone, it would take a very large roof to enable both indoor domestic use and outdoor irrigation of 5,000 s.f. of garden (In areas receiving Chimacum-patterned precipitation {29 inches}, a 5,570 s.f. roof and 42,000 gallon cistern would be required). Extensive proliferation of homes with this large of a cistern and roof, even if combined with an outbuilding, seems unlikely.

Conclusion

Rain catchment systems are likely to be relatively rare due to current economics - the high cost of a 35,000 gallon cistern, the low cost of water and the limited economic gain that a 5,000 s.f. garden produces. Barring changes to the rule, once permit exempt wells are no longer available for building permit issuance, rain capture and municipal water will be the only sources of supply. Some new homes, if combined with a barn or other outbuilding with a large roof, may be able to catch enough rain to enable both indoor use and outdoor irrigation. One would expect the growth trends of such homes would not resemble trends in the 1990s and early 2000s due to the increased costs that rain catchment brings, the increased maintenance associated with treating rainwater to potable standards and the large roof required to sustain limited indoor and outdoor use. Thus, if it would take 20 years of growth at 1990-2006 patterns to cause a worst-case $1/100^{th}$ cfs decrease in Chimacum Creek flow, one would think that it would take another 40 years, if not longer, to cause another $1/100^{th}$ cfs decrease in flow.

Given the above analysis, it is the author's opinion that if rainwater is captured from a roof and used as a source for outdoor irrigation in WRIA 17, it will not pose a threat to streams or senior water rights.

Appendix A

Figure A1. Chimacum Subbasin Banded Precipitation

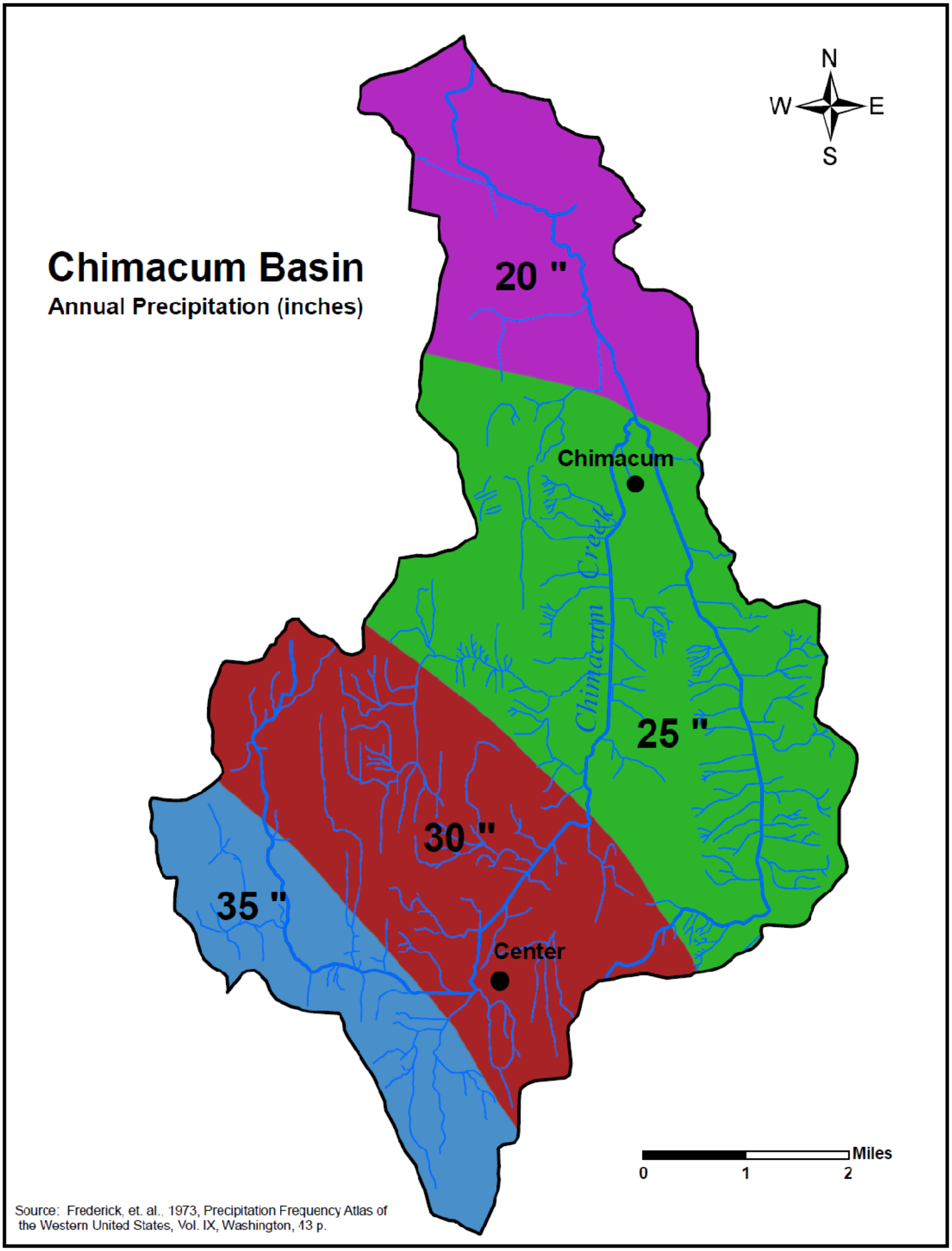
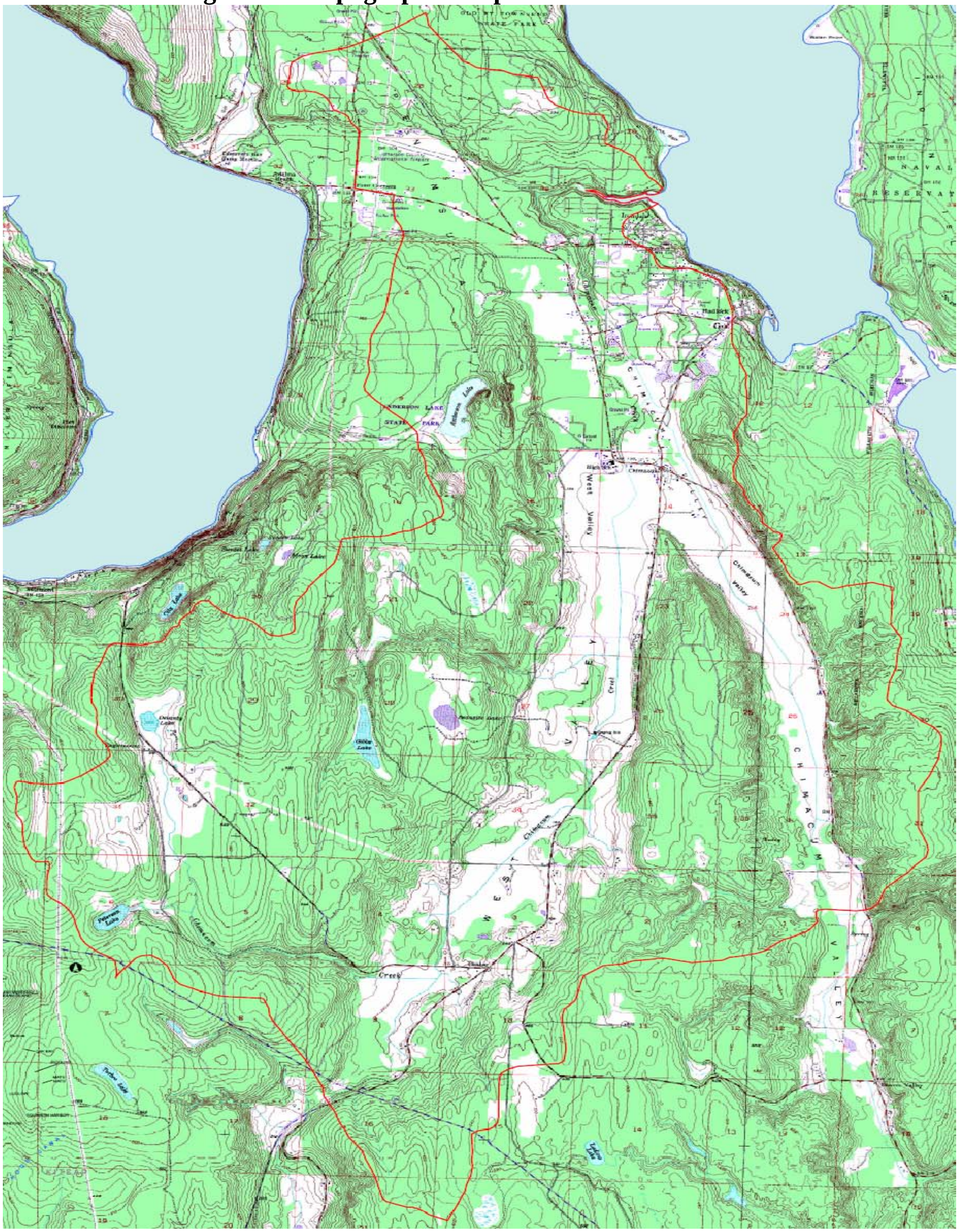


Figure A2. Topographic Map of Chimacum Subbasin

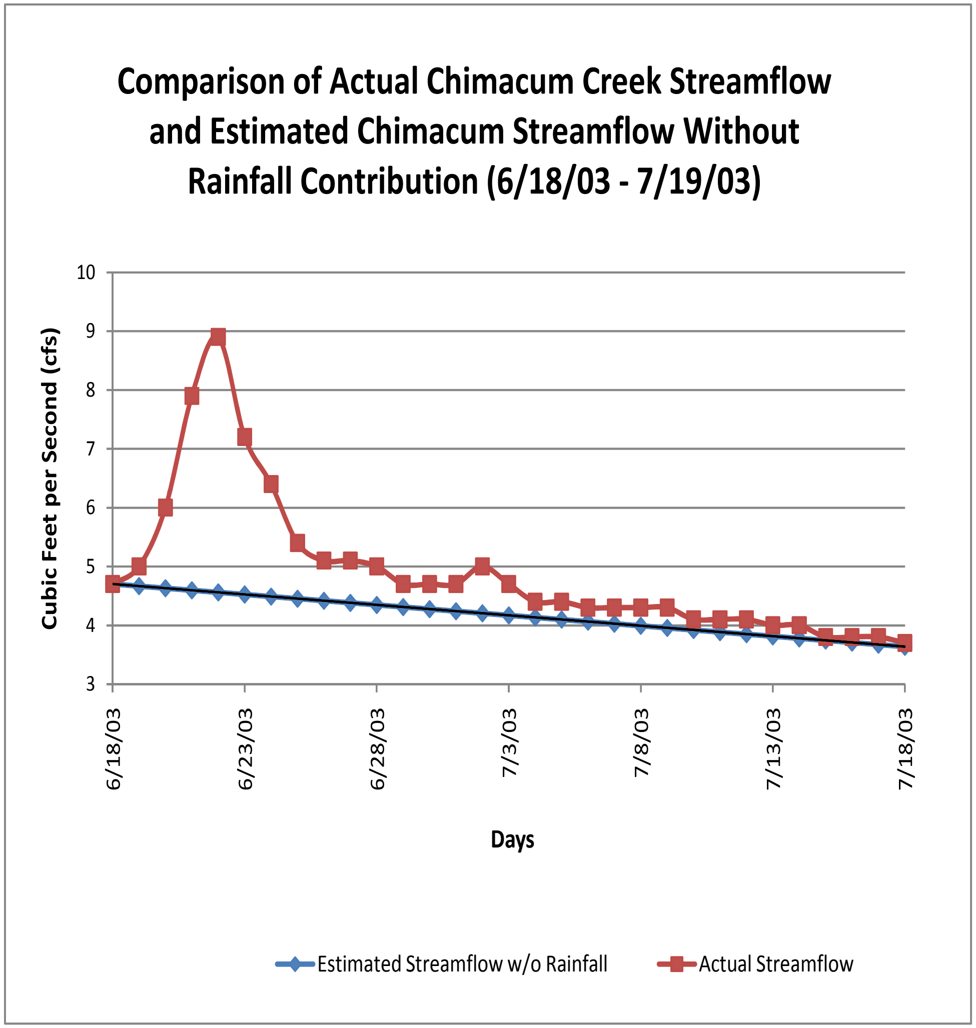


Appendix B

Figure B1. Early Summer Simulation 2003

Area between red and blue lines = estimated volume of rainwater that precipitation added to Chimacum Creek. Area is calculated by summing the trapezoids under the curve. Area of each trapezoid=h*(a+b)/2; a and b = the difference between actual and estimated flow; h always = total seconds = 60*60*24=86,400	Square footage, Chimacum Subbasin:	
	1,031,544,400	square feet = 23,681 acres

Date	Actual Flow in cfs	Estimated Trended Flow w/o Rainstorms	(Precipitation in inches from NCDC Station 1414)*0.9	Days	Area of Trapezoid
6/18/2003	4.7	4.7	0	0	
6/19/2003	5	4.6645	0.49	1	14,494
6/20/2003	6	4.629	0.07	2	73,721
6/21/2003	7.9	4.5935	0.33	3	202,068
6/22/2003	8.9	4.558	0.15	4	330,415
6/23/2003	7.2	4.5225	0	5	303,242
6/24/2003	6.4	4.487	0	6	198,310
6/25/2003	5.4	4.4515	0	7	123,617
6/26/2003	5.1	4.416	0	8	70,524
6/27/2003	5.1	4.3805	0	9	60,631
6/28/2003	5	4.345	0	10	59,378
6/29/2003	4.7	4.3095	0	11	45,166
6/30/2003	4.7	4.274	0.02	12	35,273
7/1/2003	4.7	4.2385	0.13	13	38,340
7/2/2003	5	4.203	0	14	54,367
7/3/2003	4.7	4.1675	0	15	57,434
7/4/2003	4.4	4.132	0	16	34,582
7/5/2003	4.4	4.0965	0	17	24,689
7/6/2003	4.3	4.061	0	18	23,436
7/7/2003	4.3	4.0255	0.02	19	22,183
7/8/2003	4.3	3.99	0	20	25,250
7/9/2003	4.3	3.9545	0	21	28,318
7/10/2003	4.1	3.919	0	22	22,745
7/11/2003	4.1	3.8835	0	23	17,172
7/12/2003	4.1	3.848	0	24	20,239
7/13/2003	4	3.8125	0	25	18,986
7/14/2003	4	3.777	0	26	17,734
7/15/2003	3.8	3.7415	0	27	12,161
7/16/2003	3.8	3.706	0	28	6,588
7/17/2003	3.8	3.6705	0	29	9,655
7/18/2003	3.7	3.635	0	30	8,402
7/19/2003	3.6	3.6	0		2,808
7/20/2003	3.6				
7/21/2003	3.6				

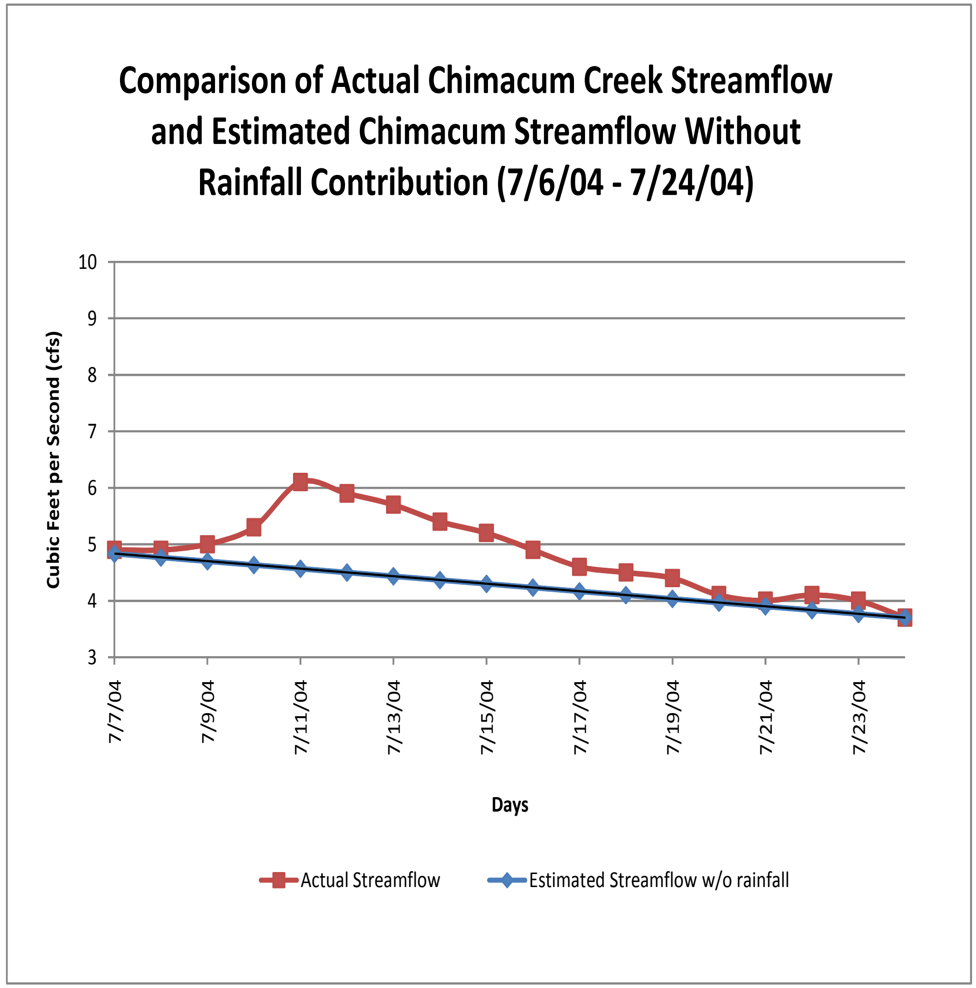


Sum of trapezoids (estimated storm contribution to stream in cubic feet) : 1,961,928
Total volume of 6/19/03 - 7/7/03 precipitation across all of Chimacum Subbasin (cubic feet): 104,014,060
Estimated % rain that contributes to streamflow (sum of trapezoids/87% of total volume): 2.17%

Figure B2. Mid-Summer Simulation 2004

Area between red and blue lines = estimated volume of rainwater that precipitation added to Chimacum Creek. Area is calculated by summing the trapezoids under the curve. Area of each trapezoid=h*(a+b)/2; a and b = the difference between actual and estimated flow; h always = total seconds = 60*60*24=86,400	Square footage, Chimacum Subbasin:	
	1,031,544,400	square feet = 23,681 acres

Date	Actual Flow in cfs	Estimated Trended Flow w/o Rainstorms	Precipitation in inches from NCDC Station 1414	Days	Area of Trapezoid
7/6/2004	4.9	4.9	0.02	0	
7/7/2004	4.9	4.8333	0	1	2,881
7/8/2004	4.9	4.7666	0	2	8,644
7/9/2004	5	4.6999	0.07	3	18,727
7/10/2004	5.3	4.6332	0.64	4	41,770
7/11/2004	6.1	4.5665	0	5	95,053
7/12/2004	5.9	4.4998	0	6	126,736
7/13/2004	5.7	4.4331	0	7	115,219
7/14/2004	5.4	4.3664	0	8	99,382
7/15/2004	5.2	4.2997	0	9	83,544
7/16/2004	4.9	4.233	0	10	67,707
7/17/2004	4.6	4.1663	0	11	47,550
7/18/2004	4.5	4.0996	0	12	36,033
7/19/2004	4.4	4.0329	0	13	33,156
7/20/2004	4.1	3.9662	0	14	21,639
7/21/2004	4	3.8995	0	15	10,122
7/22/2004	4.1	3.8328	0	16	15,885
7/23/2004	4	3.7661	0	17	21,648
7/24/2004	3.7	3.7	0	18	10,104
7/25/2004	3.6				
7/26/2004	3.7				
7/27/2004	3.7				
7/28/2004	3.7				

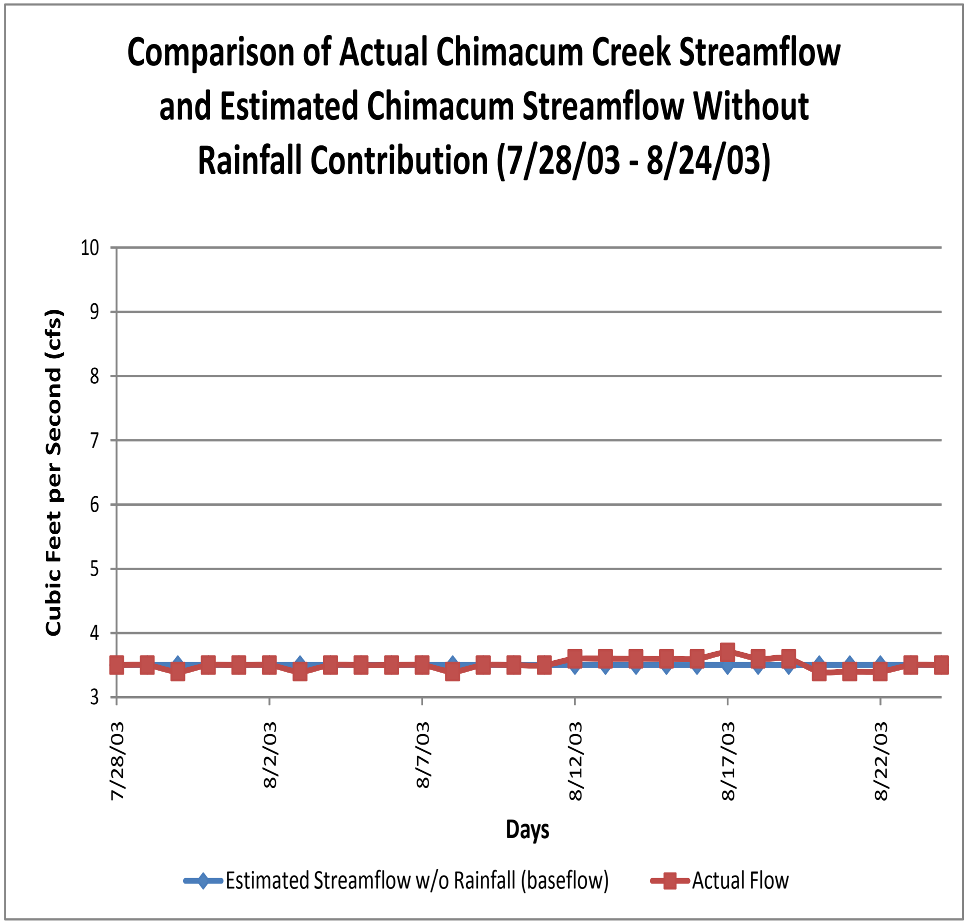


Sum of trapezoids (estimated storm contribution to stream in cubic feet) : 855,801
Total volume of 7/6/04 - 7/10/04 precipitation across all of Chimacum Subbasin (cubic feet): 61,033,044
Estimated % rain that contributes to streamflow (sum of trapezoids/87% of total volume): 1.61%

Figure B3. Late Summer Simulation 2003

Area between red and blue lines = estimated volume of rainwater that precipitation added to Chimacum Creek. Area is calculated by summing the trapezoids under the curve. Area of each trapezoid=h*(a+b)/2; a and b = the difference between actual and estimated flow; h always = total seconds = 60*60*24=86,400	Square footage, Chimacum Subbasin:	
	1,031,544,400	square feet = 23,681 acres

Date	Actual Flow in cfs	Estimated continued baseflow at 3.5 cfs	Precipitation in inches from NCDC Station 1414	Days	Area of Trapezoid
7/28/2003	3.5	3.5	0	0	
7/29/2003	3.5	3.5	0	1	0
7/30/2003	3.4	3.5	0	2	0*
7/31/2003	3.5	3.5	0	3	0
8/1/2003	3.5	3.5	0	4	0
8/2/2003	3.5	3.5	0	5	0
8/3/2003	3.4	3.5	0	6	0*
8/4/2003	3.5	3.5	0	7	0
8/5/2003	3.5	3.5	0.06	8	0
8/6/2003	3.5	3.5	0	9	0
8/7/2003	3.5	3.5	0	10	0
8/8/2003	3.4	3.5	0	11	0*
8/9/2003	3.5	3.5	0.06	12	0
8/10/2003	3.5	3.5	0	13	0
8/11/2003	3.5	3.5	0.23	14	0
8/12/2003	3.6	3.5	0	15	4,320
8/13/2003	3.6	3.5	0	16	8,640
8/14/2003	3.6	3.5	0	17	8,640
8/15/2003	3.6	3.5	0	18	8,640
8/16/2003	3.6	3.5	0	19	8,640
8/17/2003	3.7	3.5	0	20	12,960
8/18/2003	3.6	3.5	0	21	12,960
8/19/2003	3.6	3.5	0	22	8,640
8/20/2003	3.4	3.5	0	23	0*
8/21/2003	3.4	3.5	0	24	0*
8/22/2003	3.4	3.5	0	25	0*
8/23/2003	3.5	3.5	0	26	0
8/24/2003	3.5	3.5	0	27	0



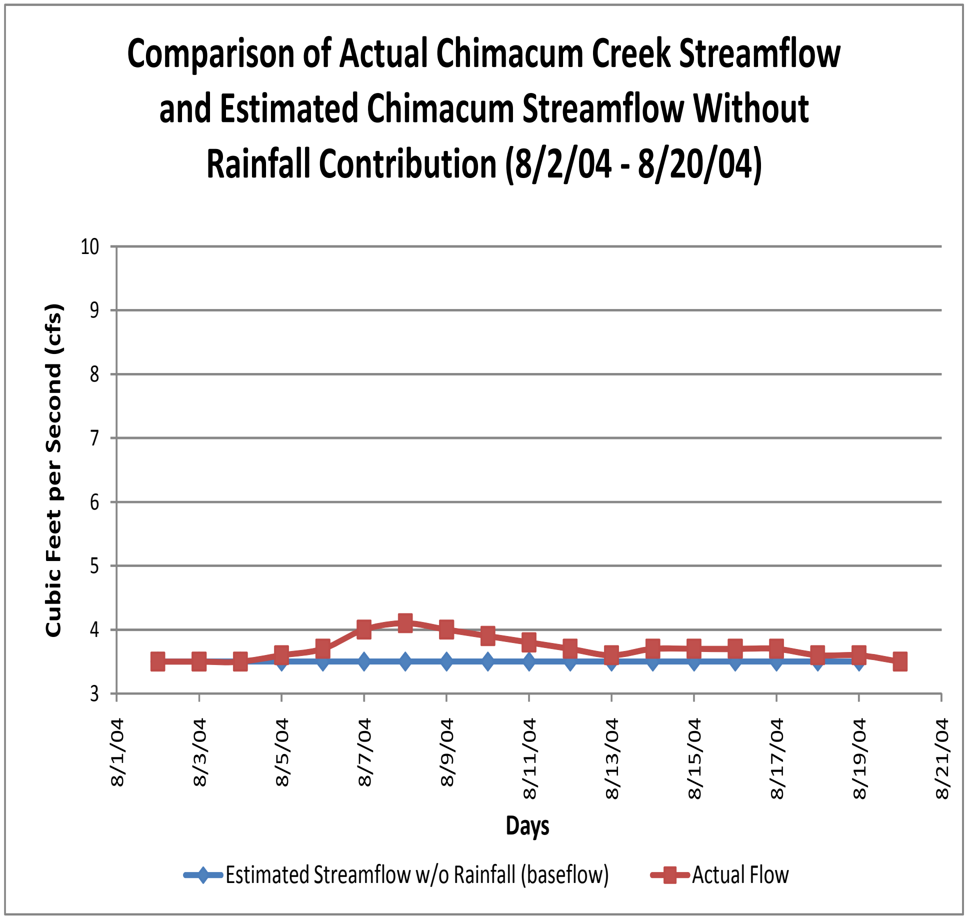
Sum of trapezoids (estimated storm contribution to stream in cubic feet) : 73,440
Total volume of 8/5/03 - 8/11/03 precipitation across all of Chimacum Subbasin (cubic feet): 30,086,712
Estimated % rain that contributes to streamflow (sum of trapezoids/87% of total volume): 0.28%

*=actually negative value if 3.5 cfs is used as baseline

Figure B4. Late Summer Simulation 2004

Area between red and blue lines = estimated volume of rainwater that precipitation added to Chimacum Creek. Area is calculated by summing the trapezoids under the curve. Area of each trapezoid=h*(a+b)/2; a and b = the difference between actual and estimated flow; h always = total seconds = 60*60*24=86,400	Square footage, Chimacum Subbasin: 1,031,544,400 square feet = 23,681 acres

Date	Actual Flow in cfs	Estimated continued baseflow at 3.5 cfs	Precipitation in inches from NCDC Station 1414	Days	Area of Trapezoid
8/2/2004	3.5	3.5	0	0	
8/3/2004	3.5	3.5	0	1	0
8/4/2004	3.5	3.5	0.06	2	0
8/5/2004	3.6	3.5	0.02	3	4,320
8/6/2004	3.7	3.5	0.40	4	12,960
8/7/2004	4	3.5	0	5	30,240
8/8/2004	4.1	3.5	0	6	47,520
8/9/2004	4	3.5	0	7	47,520
8/10/2004	3.9	3.5	0	8	38,880
8/11/2004	3.8	3.5	0	9	30,240
8/12/2004	3.7	3.5	0	10	21,600
8/13/2004	3.6	3.5	0	11	12,960
8/14/2004	3.7	3.5	0	12	12,960
8/15/2004	3.7	3.5	0	13	17,280
8/16/2004	3.7	3.5	0	14	17,280
8/17/2004	3.7	3.5	0	15	17,280
8/18/2004	3.6	3.5	0	16	12,960
8/19/2004	3.6	3.5	0	17	8,640
8/20/2004	3.5	3.5	0	18	4,320



Sum of trapezoids (estimated storm contribution to stream in cubic feet) : 336,960
Total volume of 8/5/03 - 8/11/03 precipitation across all of Chimacum Subbasin (cubic feet): 41,261,776
Estimated % rain that contributes to streamflow (sum of trapezoids/87% of total volume): 0.94%