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TECHNICAL MEMORANDUM

TO: Roma Call, Washington Department of Ecology **DATE:** March 13, 2007
FR: Chris V. Pitre, L.Hg., Golder Associates **GOLDER REF:** 013-1500-010.005
RE: Barker Creek Rain Harvesting – Refined Evaluation of Potential Impacts on Streamflow
Ecology Contract: C0500008

Golder evaluated potential impacts of rain harvesting on streamflow and groundwater in November 2006 (Golder, 2006). Further refinement of that analysis is provided here. All analyses are based on a detailed hydrologic water balance of the Barker Creek drainage in Kitsap County that was developed in the watershed planning process of Water Resources Inventory Area (WRIA) 15 (Kitsap Peninsula; Golder, 2004).

1.0 BACKGROUND AND APPROACH

The impacts of the collection of rain water and its application to either seasonal irrigation alone, or for year-round domestic use were previously assessed. The effects of storage tank sizes ranging from 1,000 gallons to 20,000 gallons were considered. A set of assumptions were used to define the baseline condition, against which impacts of rain harvesting were estimated. These assumptions were conservative in that they illustrated worst case conditions (i.e., maximum impacts on summer stream flow). Under this worst case assessment, the maximum estimated impact on summer low streamflow from rain harvesting was a reduction of 9%, compared to a reduction of 20% from the withdrawal of an equivalent volume of groundwater directly from the Vashon Advance Outwash (Qva) aquifer, which is the first confined aquifer (without consideration of septic system recharge).

In this refined assessment, some key variables in the assessment assumptions were changed to more accurately reflect use of rainwater and hydrologic impacts. This refined evaluation considers the following additional variables:

- A different distribution of impacts between runoff and groundwater recharge. This results in a seasonal shift of a portion of the impacts from the summer to winter. Combined with the previous analysis, a range of possible impacts to streamflow is derived, rather than simply a worst case scenario.
- Return of water used for interior use to septic systems. This results in higher groundwater recharge and associated summer low streamflows, and represents probable actual practice in rural areas that do not have centralized sewer service.
- Additional graphic presentation of the findings, including comparison of streamflow impacts from rain harvesting with the withdrawal of an equivalent volume of groundwater from the Qva Aquifer, and the amount of demand satisfied by rain harvesting.

The refined evaluation is conducted only for the largest tanks considered in the original analysis (i.e., a 7,000 gallon tank for irrigation use only, and a 20,000 gallons tank for year-round use).

2.0 FINDINGS

Rain collection from an average residence in the Barker Creek drainage for year-round use (i.e., interior domestic use and exterior landscape irrigation) can satisfy a significant portion of the annual water demand (i.e., 72%). A 20,000 gallon tank will provide sufficient annual storage to use all of the rain falling on an average-sized residence in an average year. A larger tank would provide interannual storage to store water collected from wetter years for use in drier years.

Impacts of rain harvesting for year-round use, when combined with discharge of used water to septic systems, are reduced winter runoff and enhanced groundwater recharge. The net effect on the hydrologic cycle is to shift stormwater runoff during the winter to groundwater baseflow during the summer. This decreases peak winter streamflows (e.g., by 5%) and increases summer low streamflows (e.g., 12%) – both of which are conditions that improve aquatic habitat for salmonids compared to current conditions.

Rain harvesting for year-round use provides significant environmental and water supply benefits when combined with discharge of used water to septic systems, regardless of the size of the storage tank used.

The withdrawal of an equivalent amount of groundwater for year-round use from an aquifer in close hydraulic continuity with the stream results in an increase of winter flows (due to septic system return flows), and a decrease of low summer streamflows of approximately 4% – both a negative impact to salmon habitat.

Rain collection for irrigation use only in the Barker Creek drainage can be fully satisfied by a rainwater collection system with a 7,000 gallon tank. Use of rain water for irrigation alone is a consumptive use of water (i.e., water is removed from the terrestrial surface water and groundwater system, and lost to evapotranspiration). This results in a year-round reduction of streamflows, including less than 1% during the winter months, and up to 1.6% reduction during the critical low summer flow period.

The withdrawal of an equivalent amount of groundwater for irrigation use only from an aquifer in close hydraulic continuity with the stream results in a decrease of low summer streamflows by approximately 5%.

The above analysis in this memorandum is most applicable to rural areas where rooftop runoff of rain is discharged to the ground. Rooftop runoff of rain contributes a greater portion to stormwater runoff in urban areas. Where stormwater management consists of infiltration to groundwater, rain harvesting will have similar impacts as presented in this memorandum. Where stormwater management consists of directing runoff to streams, rain harvesting will have positive effects by reducing peak winter streamflows and positive impacts by increasing summer streamflow where used water is discharged to septic systems. Where stormwater management consists of directing runoff to Puget Sound, rain harvesting will have positive impacts by increasing summer streamflow where used water is discharged to septic systems.

Table 1**Effects of Rain Harvesting in the Barker Creek Drainage (Kitsap County)**

Scenario	Winter (Jan.) Peak Streamflow	Summer Low Streamflow	Comment
Year-Round Use (Domestic and Irrigation)			
Rain harvesting (20,000 gallon tank) – with septic system.	Decreased by up to 5% lower – salmon habitat benefit.	Increased by up to 12% – significant salmon habitat benefit.	Enhanced groundwater recharge. The bigger the storage tank, the greater the benefits.
Rain harvesting (20,000 gallon tank) – without septic system (indoor used water goes to sewer system).	Decreased by at least 8% – salmon habitat benefit.	Decreased by up to 9% – negative impact to salmon habitat.	The bigger the storage tank, the bigger the impacts.
Equivalent direct groundwater withdrawal with septic system.	Increased by 2% – negative impact for salmon habitat.	Decreased by approximately 4% – negative impact for salmon habitat.	Rain harvesting in lieu of direct groundwater withdrawal can reduce, remove or avoid existing and/or future impacts.
Irrigation Use			
Rain harvesting (7,000 gallon tank)	Decreased by less than 1% – salmon habitat benefit.	Decreased by between zero and 1.6% – negative impact to salmon habitat.	The bigger the storage tank, the bigger the impacts.
Equivalent groundwater withdrawal	Decreased by less than 1% – salmon habitat benefit.	Decreased by approximately 5% – negative impact for salmon.	Existing or future impacts are reduced, removed or avoided if rain harvesting is used in lieu of direct groundwater withdrawal.

3.0 ANALYSIS

Details of the previous water balance analysis, upon which the analysis in this technical memorandum is based, is presented in Golder (2006). Modifications to that analysis are described below.

3.1 Partitioning of Impacts Between Surface Water Runoff and Groundwater Recharge

The possible effects of rainwater harvesting on the water balance are predicted by comparing the water balance under baseline (current) conditions, and various rainwater harvesting scenarios. Effects of rain harvesting on the water balance considered in the previous analysis included:

- Reduction of precipitation that falls on the ground;

- Reduced water in soil moisture available for evapotranspiration; and,
- Changes in surface water runoff and groundwater recharge.

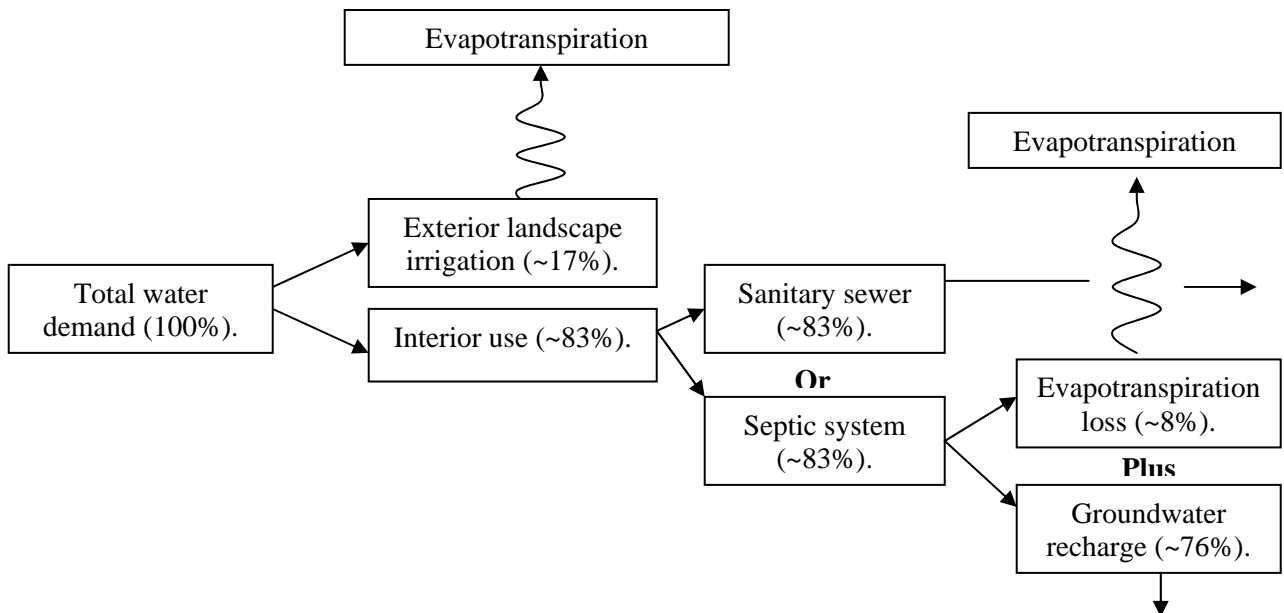
The changes in surface water runoff and groundwater recharge were distributed proportional to the total of each of the components. In reality, however, the distribution is not proportional to the total of each of the components. Distributing the impacts of rain harvested proportionally between recharge and runoff (as considered in earlier analysis; Golder, 2006) and wholly to runoff (additional analysis provided in this memorandum), provides a range of probable impacts to streamflow.

3.2 Septic System Recharge

Actual impacts to the hydrologic system include not only the harvest of rain, but also where the used rainwater is discharged.

Approximately 70% of the Kitsap Peninsula population use septic systems in rural areas, with the remainder discharging their wastewater to a centralized sewer service in more urbanized areas. The majority of the urbanized population also has water delivered to them by a purveyor.

On the Kitsap Peninsula, 83% of the water used year-round for domestic purposes is used for interior use that is subsequently discharged as wastewater, and 17% is used for exterior landscape irrigation. Irrigation water is assumed to be applied at an agronomic rate and results in no return flow. Interior use water is relatively constant year-round and is assumed in this analysis to be recharged to groundwater via septic systems. Evaporation over the septic field causes a 10% reduction of the water discharged from the septic system (i.e., past the root zone; Sapik and others, 1988). This equates to 76% of the total water demand going to deep groundwater recharge.



3.3 Results

The analysis assumes an average roof size of approximately 2,000 square feet, and precipitation of approximately 50 inches which is average for the Barker Creek drainage on the Kitsap Peninsula.

3.3.1 Year-Round Domestic Use

A 20,000 gallon storage tank will capture all rain falling on the average roof size, and satisfies approximately 72% of typical demand (Table 2, Figure 1). The analysis assumes that water is first applied to meet interior demand, and then to meet irrigation demand. In the scenario analyzed (i.e., average roof size and demand), the amount of precipitation limits the available supply. Demand can be met if the roof size and tank size are increased, or conservation reduces demand.

Streamflow may be reduced as a result of rain harvesting during the winter months of November through April (Table 3, Figure 2). Streamflow during the summer months (i.e., May through October) are increased as the rainwater harvested and stored during the winter being used and returned to the hydrologic system through septic systems (i.e., increases of streamflow by up to 12%).

The largest reduction of streamflow is in November, when the rain that would otherwise runoff to streams is captured (i.e., between 2% and 28% reduction in streamflow). The range of values represents whether the rain intercepted by harvesting would otherwise runoff directly to streams, or whether a portion of it would otherwise recharge to the ground.

The withdrawal of an equivalent volume of groundwater from the Qva aquifer results in a constant year-round reduction in streamflow. However, when expressed as a percentage of streamflow, impacts are approximately three times greater during the critical low summertime streamflows than the maximum impacts from rain harvesting (i.e., a 4% reduction of streamflow during July through September; Table 3).

3.3.2 Summer Irrigation Use Only

Enough rain can be captured with a 7,000 gallon storage tank to provide the full average irrigation demand of a typical single residence. All of the rain falling on the roof collection system during the months of June through October is captured (Table 1). The tank is almost completely filled in October, when there is no irrigation occurring, and is full by November. After November, there is no rain capture until the following June (i.e., the tank overflows).

Minimal impacts to streamflow occur for most of the year (i.e., between zero and 1.7% reduction of streamflow in all months except for November; Table 3, Figure 3). During the summer, most of the precipitation lands on dry soil and is lost to evapotranspiration.

The largest impact is in November, when the rain that would otherwise runoff to streams is captured in the filling of storage tanks (i.e., between 3% and 21% reduction in streamflow; Table 3). The range of values represents whether the rain intercepted by harvesting would otherwise runoff directly to streams, or whether a portion of it would otherwise recharge to the ground.

The withdrawal of an equivalent volume of groundwater from the Qva aquifer results in a constant year-round reduction in streamflow of 0.14 cubic feet per second (cfs). However, when expressed as a percentage of streamflow, impacts are approximately three times greater during the critical low summertime streamflows than the maximum impacts from rain harvesting (i.e., a 4.7% reduction of streamflow during July through September; Table 3).

4.0 DISCUSSION

The analysis presented is specific to the Barker Creek drainage. This drainage was selected for analysis because of the availability of a well-developed water balance that could be used for such analysis. Average hydrologic monthly conditions were assumed, and the range of potential impacts was derived assuming different responses of the hydrologic system to rain harvesting that spans the probable response (i.e., whether the intercepted rain would otherwise runoff directly to streams or whether a portion of it would otherwise recharge to the ground). The following discussion provides additional context for the results.

4.1 Rain Harvest Systems

A summary of rain harvest systems was provided for the San Juan watershed planning work (WRIA 2; Mayo, 2004). The average roof size of rain collection systems in WRIA 2 is on the order of 3,000 square feet, or 50% larger than the average roof size assumed in this technical memorandum. A 50% larger roof size would adequately satisfy the 28% supply deficiency in the analysis presented here.

Rain harvest systems are typically 85% efficient, with 15% of the rain released for flushing of the system, lost to minor evaporation and other losses (Mayo, 2004). This is not considered in the analysis presented here.

The tank size was selected based on adequacy to provide for all of the demand (i.e., 7,000 gallon tank for irrigation use only) or what was needed to capture all of the average precipitation (i.e., 20,000 for year-round use). Drier years may cause shortfalls in supply, while wetter years may allow the capture of additional water that could be stored and saved for a following dry year if a larger storage tank is used.

The demand assumed was that of a typical household supplied with water from a purveyor in the Kitsap Peninsula (i.e., 235 gallons per day). An added benefit of rainwater collection systems is that there is significant motivation for conservation where users manage their own water supply and are dependent upon a limited water supply source. For example, the typical demand in the San Juan Islands for residences dependent upon rain collection systems is 85 gallons per day (Mayo, 2004), which is consistent with an area with approximately half of the precipitation that occurs in the Barker Creek drainage.

4.2 Streamflow Impacts

Barker Creek is closed year-round to further consumptive appropriation under the authority of the Water Code (RCW 90.03) and the Fisheries Code (RCW 75.20.050). The basis of the closure was the perceived value of the aquatic resource for fisheries and no technical assessment was conducted to support the establishment of this closure.

A review of the principal negative influences for fish in WRIA 15 were reviewed for the watershed planning process (Golder, 2002). The most commonly identified problem to salmonid habitat is winter high streamflows. High flows are usually associated with accelerated runoff caused by land use practices (development). These high flows scour channels, increase erosion and the deposition of fine sediment, and wash out redds (fish egg nests). Therefore, stream closures during high flow winter months are not consistent with the protection and/or improvement of salmon habitat. The decrease of streamflows during this period by rain harvesting in conjunction with septic system use will presumably be beneficial for salmonids.

Low flow problems were the second most commonly identified problem for salmonid habitat. The negative effects of high winter streamflows and low summer flows are also documented by a recent instream flow study by the Washington Department of fish and Wildlife and Kitsap County (Beecher and others, 2006).

Minimum instream flows have been established for the Kitsap Peninsula (WAC 173-515). Of 14 streams for which numeric instream flows have been established and that have closure periods, 11 have closure periods that end in October, and three have closure periods that extend into November (Table 4):

Table 4

Streams With Numeric Instream Flow Regulations and Closure Periods

Number of Streams with Numeric Instream Flows with Open and Closed Periods (Creeks)	Closure Period
8 (Rendsland, Grover's, Steele, Strawberry, Olalla, Crescent, Purdy, Rocky)	June 1-Oct. 31
3 (Tahuya, Dewatto, Curley)	June 15-Oct. 31
1 (Anderson)	June 1-Nov. 15
1 (Big Beef)	May 15-Nov. 15
1 (Lackey)	June 1-Nov. 30

(Additional streams are closed year-round or are open year-round subject to meeting regulatory minimum instream flows.)

Presumably, seasonal stream closures are structured to maintain streamflows during critical periods of salmonid life cycles. Barker Creek is located in East Central Kitsap County. Streams in East Central Kitsap County may have salmonid life cycles representative of Barker Creek, including Grover's, Steele, Strawberry, Olalla and Curley Creeks. All of these streams have closed periods between June and October. Therefore, the increase of streamflows during this period by rain harvesting in conjunction with septic system use will be beneficial for salmonids.

The three streams with closure periods that extend into November drain to Hood Canal or South Puget Sound, and the salmonid life cycles in those streams may not be representative of salmonid life cycles specific to Barker Creek.

East Kitsap County streamflows are currently too high in the winter, and too low in the summer for the maintenance of good salmon habitat. The effects of rain harvesting in conjunction with septic system use are beneficial in that peak winter streamflows are decreased, and low summer flows are increased resulting in improved salmon habitat.

4.3 Considerations for Urban and Rural Settings

The assumption that used rain water is discharged to septic systems is important in the analysis presented in this technical memorandum. Areas without purveyor supplied water typically also do not have centralized sewer service and rely upon septic system for the discharge of used water.

Rooftop runoff of rain in urban areas contributes to stormwater runoff. Where stormwater management consists of infiltration to groundwater, rain harvesting will have similar impacts as presented in this memorandum.

Where stormwater management consists of directing runoff to streams, rain harvesting will have positive effects by reducing peak winter streamflows and positive impacts by increasing summer streamflow where used water is discharged to septic systems. Where stormwater management consists of directing runoff to Puget Sound, rain harvesting will have positive impacts by increasing summer streamflow where used water is discharged to septic systems.

5.0 REFERENCES

Beecher, H., T. Hegy, P. Nelson, R. Vadas, K. Folkerts, S. Boessow and R. Bazzell. Barker Creek Streamflow Study. Washington Department of Fish and Wildlife and Kitsap county. November 2006.

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Lane, R.C., 2004. Estimated domestic, irrigation, and industrial water use in Washington, 2000. USGS Scientific Investigations Report 2004-5015, 16 pp.

Mayo, R., 2004. The Hydrologic Impacts of Rainwater Catchment systems on the Groundwater of the San Juan Islands. White Paper, December 13, 2004.

Sapik, D.B., G.C. Bortleson, B.W. Drost, M.A. Jones and E.A. Prych, 1988. Groundwater resources and Simulation of Flow in Aquifers Containing Freshwater and Seawater, Island County, Washington. USGS WRI Report 87-4182.

Table 2

Precipitation Supply and Use Demand

(all units in gallons per parcel unless otherwise noted)

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	Average Annual, Basin-Wide (cfs)
Average Monthly Precipitation ¹ (inches)	4.0	7.6	8.3	7.1	5.7	5.4	2.9	2.1	1.6	0.9	1.1	2.0	48.8	
Precipitation Falling on Roof ²	5,130	9,639	10,518	9,068	7,255	6,913	3,659	2,680	2,017	1,100	1,359	2,596	61,933	0.90
Year Round Interior & Exterior Use (20,000 gallon tank)														
Captured Rain	5,130	9,639	10,518	9,068	7,255	6,913	3,659	2,680	2,017	1,100	1,359	2,596	61,933	0.90
Month-End Tank Level	-	3,766	8,215	11,213	12,938	13,782	11,568	6,951	470	-	-	-		
Total Demand³	6,069	5,873	6,069	6,069	5,531	6,069	5,873	7,297	8,497	10,543	10,080	7,851	85,821	1.25
Supply-Demand Deficit	(939)	-	-	-	-	-	-	-	-	(8,973)	(8,721)	(5,254)	(23,887)	(0.35)
Interior Demand	6,069	5,873	6,069	6,069	5,531	6,069	5,873	6,069	5,873	6,069	6,069	5,873	71,507	1.04
Rainwater Discharged to Septic System	4,617	5,286	5,462	5,462	4,978	5,462	5,286	5,462	5,286	990	1,223	2,337	55,740	0.81
Summer Exterior (Irrigation) Use Only (7,000 gallon tank)														
Captured Rain	5,130	884	-	-	-	-	-	1,228	2,017	1,100	1,359	2,596	14,313	0.21
Month-End Tank Level	6,116	7,000	7,000	7,000	7,000	7,000	7,000	7,000	6,393	3,019	367	986		
Demand	-	-	-	-	-	-	-	1,228	2,624	4,474	4,010	1,977	14,314	0.21

1. PRISM data (Climate Source, 2000)

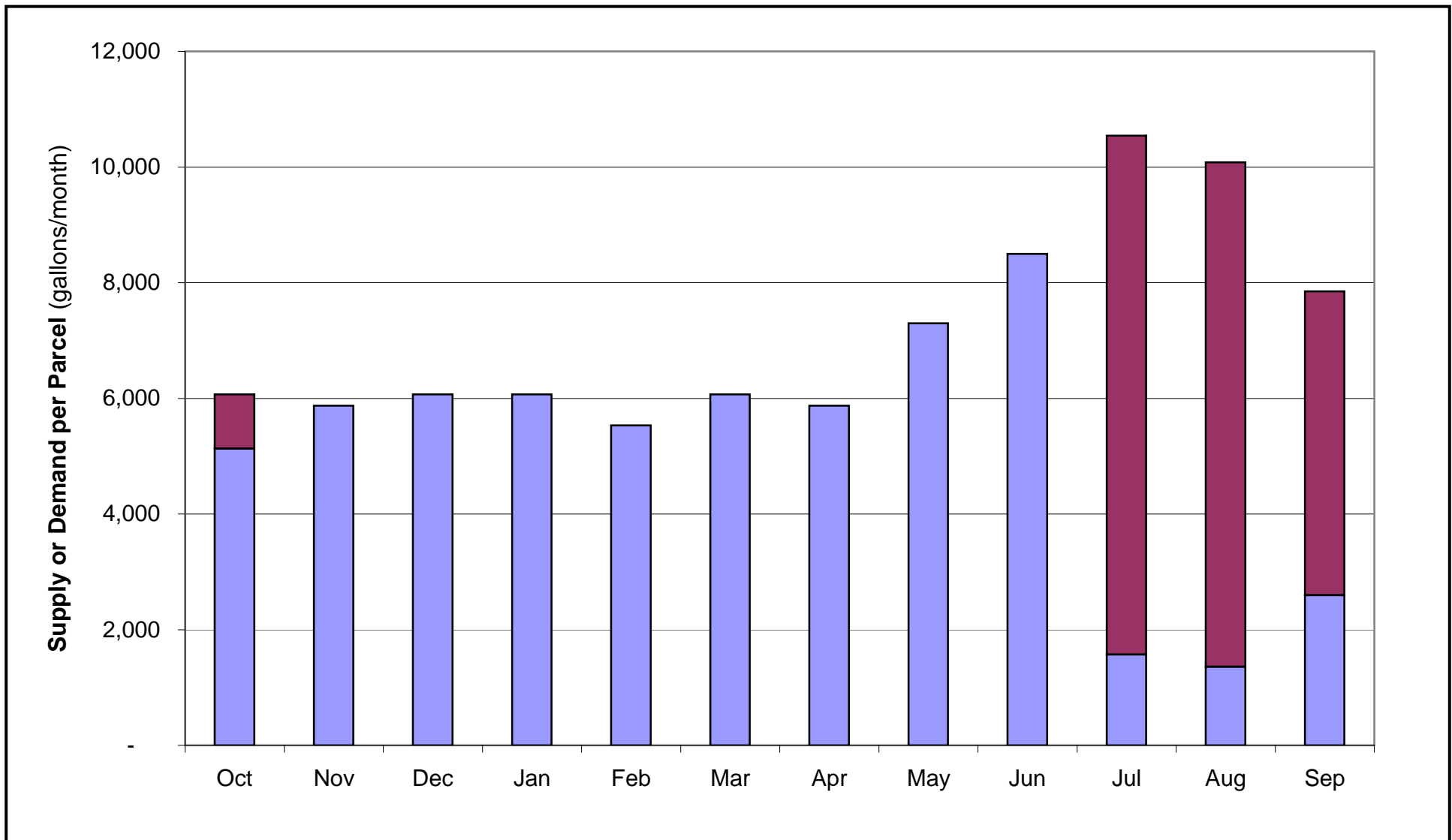
2. Roof area = 2,037 square feet (Ecology, 2006)

3. Annual per capita use = 87 gpcpd (Lane, 2002), distributed monthly using purveyor data (Golder (2004). One residence per parcel. Population of 2.7 people per residence (US 2000 Census).

Table 3

Streamflow Changes
(cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean Annual
days per month	31	30	31	31	28.25	31	30	31	30	31	31	30	
BASELINE													
Precipitation	14.5	28.1	29.7	25.6	22.5	19.5	10.7	7.6	5.9	3.1	3.8	7.6	14.8
Based on evapotranspiration calculations .													
Evapotranspiration	4.2	4.9	3.4	3.2	4.5	6.3	9.3	13.5	17.1	5.8	2.2	3.0	6.5
Terrestrial Water	10.3	23.2	26.3	22.3	17.9	13.2	1.4	-5.9	-11.3	-2.7	1.6	4.5	8.4
Soil Moisture Recharge	10.3	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	4.5	1.7
Runoff + Recharge	0.0	19.7	26.3	22.3	17.9	13.2	1.4	0.0	0.0	0.0	0.0	0.0	8.4
Based on hydrograph separation.													
Total Streamflow	3.7	6.0	14.4	17.0	12.2	9.4	5.9	4.3	3.0	2.8	2.8	3.0	7.0
Baseflow	3.3	3.8	4.8	5.6	6.0	5.6	4.8	3.5	2.9	2.8	2.8	2.9	4.0
Qvt Baseflow	0.6	1.1	2.1	2.8	3.2	2.9	2.0	0.8	0.2	0.1	0.1	0.1	1.3
Qva Baseflow	2.7	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.7	2.7	2.7	2.7	2.7
Runoff	0.4	2.2	9.6	11.4	6.2	3.8	1.1	0.8	0.1	0.0	0.1	0.2	3.0
Underflow (non-returning recharge)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
YEAR-ROUND USE (20,000 gallon tank with Septic System)													
Total impacts of rain harvesting, plus septic system recharge.													
Change in Runoff + Recharge	0.8	-1.9	-0.8	-0.6	-0.4	-0.2	0.3	0.9	0.9	0.2	0.2	0.4	-0.02
Impacts distributed proportionally between runoff and recharge.													
Runoff	0.4	1.9	8.9	10.6	5.7	3.4	0.6	0.8	0.1	0.0	0.1	0.2	2.7
Recharge	0.8	16.0	16.5	11.1	11.8	9.5	1.1	0.9	0.9	0.2	0.2	0.4	5.7
Baseflow	3.4	4.0	5.0	5.8	6.3	5.9	5.0	3.6	3.0	2.9	2.9	3.0	4.2
Total Streamflow	3.9	5.8	13.9	16.4	12.0	9.3	5.6	4.5	3.1	2.9	3.0	3.2	7.0
Change in streamflow	0.1	-0.1	-0.4	-0.5	-0.2	-0.1	-0.3	0.1	0.1	0.1	0.1	0.1	-0.1
% Change in Streamflow	4%	-2%	-3%	-3%	-2%	-1%	-5%	3%	4%	4%	4%	4%	-1%
Impacts allocated to runoff.													
Total Streamflow	4.1	4.3	13.2	16.1	11.6	8.9	5.9	4.8	3.4	3.1	3.2	3.4	6.8
Change in Streamflow	0.4	-1.7	-1.2	-0.8	-0.6	-0.5	0.0	0.4	0.4	0.3	0.3	0.4	-0.2
% Change in Streamflow	11%	-28%	-8%	-5%	-5%	-5%	-1%	10%	12%	12%	12%	12%	-2.9%
Impacts of an equivalent groundwater withdrawal.													
Total Streamflow	3.7	6.0	14.6	17.3	12.6	9.7	6.1	4.3	2.9	2.7	2.7	2.9	7.1
Change in Streamflow	0.0	0.0	0.2	0.3	0.4	0.3	0.2	0.0	-0.1	-0.1	-0.1	-0.1	0.1
% Change in Streamflow	-1.2%	0.7%	1.4%	2.0%	3.4%	3.7%	3.4%	-0.2%	-3.8%	-4.6%	-4.5%	-3.8%	2.7%
IRRIGATION USE ONLY (7,000 gallon tank)													
Total impacts of rain harvesting.													
Change in Runoff + Recharge	0.0	-1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Impacts distributed proportionally between runoff and recharge.													
Runoff	0.4	2.0	9.6	11.4	6.2	3.8	1.1	0.8	0.1	0.0	0.1	0.2	3.0
Recharge	0.0	16.4	16.7	11.0	11.7	9.4	0.3	0.0	0.0	0.0	0.0	0.0	5.4
Baseflow	3.2	3.8	4.7	5.5	5.9	5.5	4.7	3.4	2.8	2.7	2.7	2.8	4.0
Total Streamflow	3.7	5.8	14.3	16.9	12.1	9.3	5.8	4.3	3.0	2.7	2.8	3.0	7.0
Change in streamflow	-0.1	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	-0.1
% Change in Streamflow	-1.5%	-3.4%	-0.6%	-0.6%	-0.8%	-1.0%	-1.3%	-1.4%	-1.6%	-1.7%	-1.6%	-1.6%	-1.1%
Impacts allocated to runoff.													
Total Streamflow	3.7	4.7	14.4	17.0	12.2	9.4	5.9	4.3	3.0	2.8	2.8	3.0	6.9
Change in streamflow	0.0	-1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
% Change in Streamflow	0%	-21%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-1.5%
Impacts of an equivalent groundwater withdrawal.													
Total Streamflow	3.6	5.9	14.3	16.8	12.1	9.2	5.8	4.2	2.9	2.7	2.7	2.9	6.9
Change in Streamflow	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14
% Change in Streamflow	-3.7%	-2.3%	-0.9%	-0.8%	-1.1%	-1.4%	-2.3%	-3.1%	-4.5%	-4.9%	-4.8%	-4.5%	-1.9%



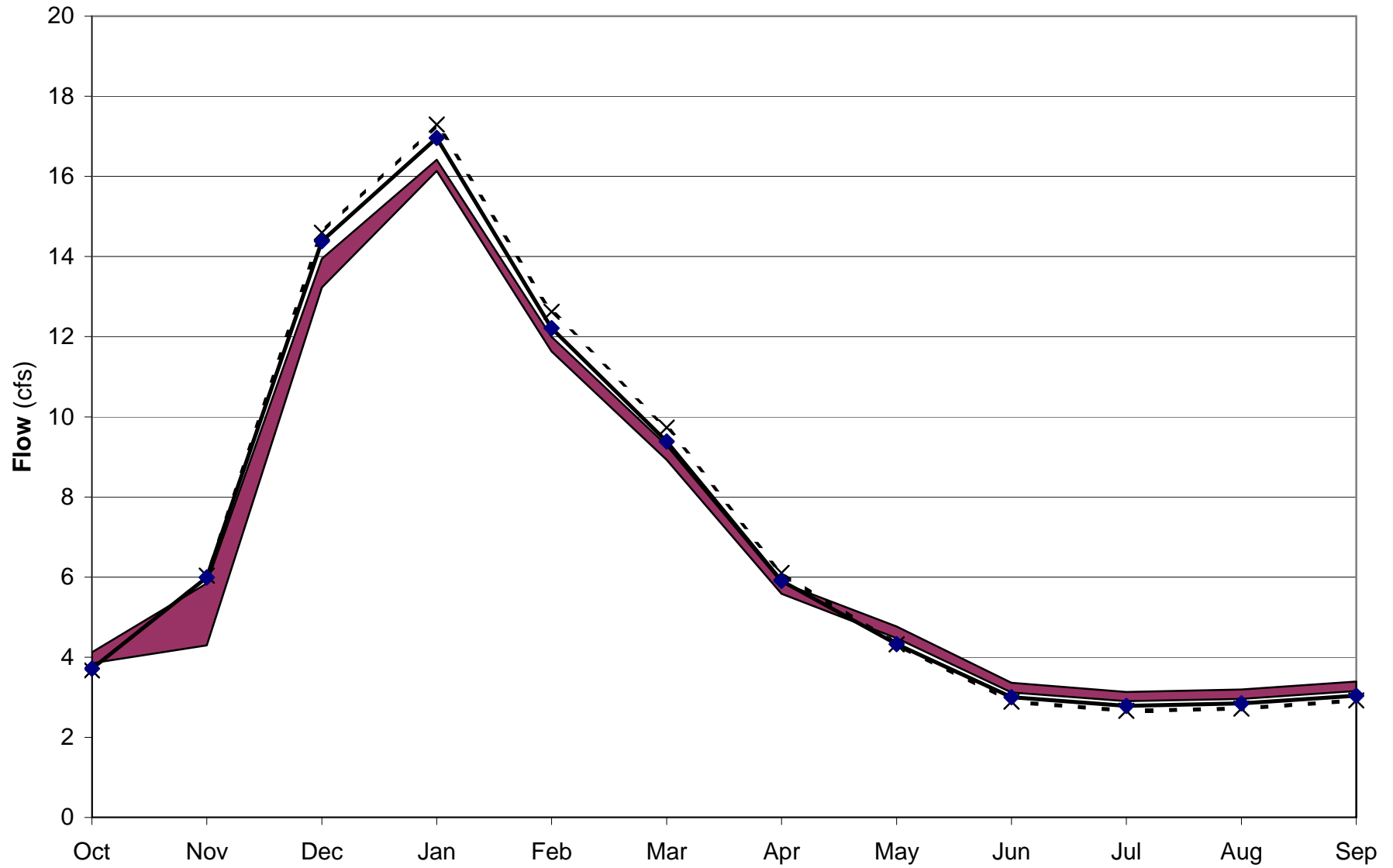
Year-Round Domestic Demand

Supply assumes a 2,037 sqft roof collection area.
 Demand is based on USGS (Lane, 2002),
 2.7 people per residence, and
 Kitsap PUD data.

- Not Satisfied by Rain Harvesting (28% of total annual demand)
- Satisfied by Rain Harvesting (72% of total annual demand)

**FIGURE 1:
 Year-Round Demand Satisfied by
 Rain Harvesting**



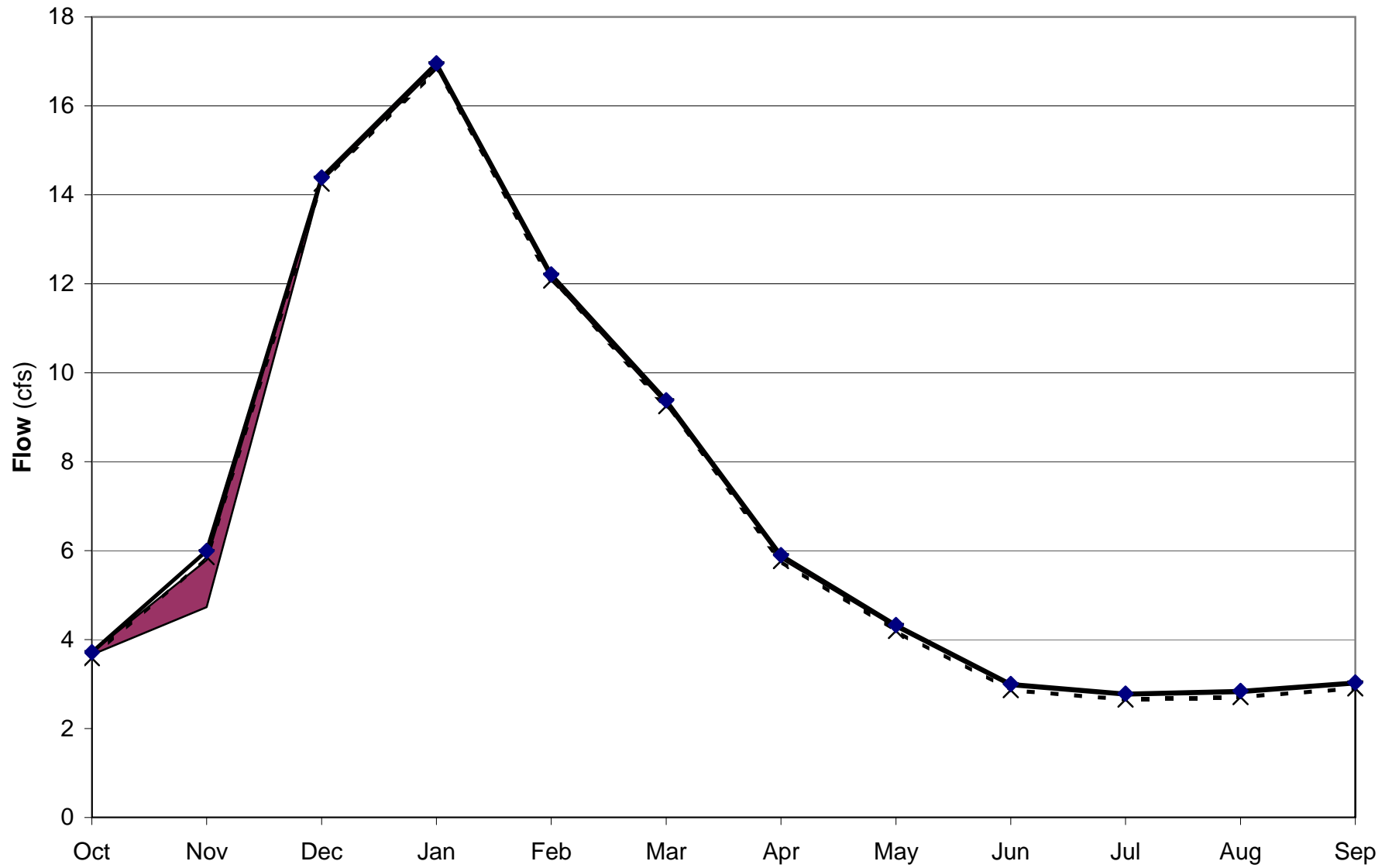


- Range of Flows Under Rain Harvesting Conditions
- Flows With Equivalent Groundwater Withdrawal
- Baseline

20,000 gallon storage tank

FIGURE 2:
Streamflows With Rain Harvesting for Year-Round Use





- Range of Flows Under Rain Harvesting Conditions
- Flows With Equivalent Groundwater Withdrawal
- Baseline

7,000 gallon storage tank

FIGURE 3:
Streamflows With Rain Harvesting for Irrigation Use

