MISSION CREEK WATER QUALITY RESTORATION PHASE I

Mission Creek
Flow Improvement Appraisal

July 9, 2018

Washington Department of Ecology • Contract No. WQC-2016-ChCoNR-00239

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CHELAN COUNTY
Natural Resources
Department

MISSION CREEK FLOW IMPROVEMENT APPRAISAL

Prepared for:
Chelan County Natural Resource Department

Project No. 120045-011A • July 9, 2018

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Executive Summary

The Mission Creek Basin, a subbasin of the Wenatchee River Basin, suffers from low streamflow in the late summer and fall, and from a limited reserve of water for permit-exempt groundwater uses. To address these two water needs, Chelan County Natural Resources Department (CCNRD) is working with local landowners to evaluate options for improving water supplies for both instream uses and modest continued growth of rural domestic uses. CCNRD hired Aspect Consulting, LLC (Aspect) to conduct an appraisal analysis of options to improve flow in Mission Creek.

The Mission Creek Flow Improvement Appraisal (Appraisal) evaluates eight alternatives to meet these goals:

1) Water banking (e.g., retiring a small, existing irrigation use to provide for additional rural domestic growth)
2) Converting some surface water users to greater reliance on groundwater
3) Converting some surface water users to a pump station on the Wenatchee River—with an equal quantity of their surface water rights converted to the State Trust Water Right Program
4) Converting some surface water users to a different source from regional water systems, such as the Icicle-Peshastin Irrigation District (IPID) or City of Cashmere
5) Augmenting critical season low flows with a harvest-time pump-and-dump of groundwater into Mission Creek
6) Mitigating new impacts of permit-exempt uses through small off-channel storage
7) Mitigating new impacts of permit-exempt uses through stream restoration with alluvial water storage
8) Exchange of permit-exempt debits on the Mission Basin reserve to the Wenatchee River Basin reserve through modification of basin divides based on the hydrogeology

These alternatives were studied at varying levels of analysis. Some, like a new Wenatchee River pump station and pipeline supply to Mission Creek (Alternative 3), are at the conceptual stage. Others, such as streamflow augmentation through a harvest-time pump-and-dump (Alternative 5), alluvial water storage (Alternative 7), and source exchange (Alternative 8), have proceeded to pilot stage.

Conceptual-level cost estimates are presented in Table ES-1. The cost estimates reveal a large difference in costs per acre-foot due to the range of scale offered by each alternative. Some alternatives are only suitable for expanding the domestic reserve (e.g., Alternative 1). Others can affect real and measurable change in the Mission Creek hydrograph during low-flow periods (e.g., Alternatives 3 and 4). The alternatives are not mutually exclusive. CCNRD could combine the alternatives or phase them in for incremental success over time.

Table ES-1. Cost Estimate Summary[a]

Alt	Description	Capital Cost	20-year O&M	Permitting Costs	Total Costs	Cost per Acre-Foot
1	Water Banking[a]	$125,000	--	$12,500	$137,500	$6,000
2	Surface Water Right to Groundwater Transfer[b]	--	$24,000	$25,000	$49,000	$27,000
3	Wenatchee Pump Exchange[c]	$9,235,000	$1,940,000	$244,000	$11,419,000	$20,000
4A	Regional Water Provider[c]	$4,436,000	$700,000	$122,000	$5,258,000	$9,200
4B	Regional Water Provider w/ JSDC Conversion[c]	$4,616,000	$700,000	$131,000	$5,447,000	$9,500
5	Groundwater Streamflow Augmentation[d]	$266,000	$180,000	$25,000	$471,000	$8,400
6	Localized Reservoir Flow Augmentation[e]	$416,000	$160,000	$40,000	$616,000	$57,600
7	Alluvial Water Storage[f]	$91,000	$60,000	$12,000	$163,000	$8,300
8	Reserve Exchange[g]	$0	$0	$0	$0	$0

Notes:

a) Cost estimate details are provided in Appendix F.
b) Costs reflect bank seeding for 23 acre-feet as shown in Table 6, costs do not include administrative and start-up costs.
c) Costs based on irrigation of 5 acres of pears with microspray, approximately 12 acre-feet per year; does not include costs for drilling new well, O&M over 20-years does include replacement of pump.
d) Alternatives 3 and 4 are based on providing irrigation supply for 250 acres of pears with cover using microspray.
e) Harvest period only.
f) Cost estimate is based on construction of a 10 acre-foot lined reservoir.
g) Costs reflect streamflow restoration of an 8,450-foot section that averages 60 feet wide with a 1- to 4.5-foot-deep incision and 4.1 percent gradient.
h) Costs assumes implementation is conducted through existing accounting and reporting program.

While the alternatives reviewed are not yet prioritized, there is sufficient information to make recommendations for further study and implementation of projects.

The recommended alternatives to increase the domestic reserve in the Mission Basin are a combination of water banking, surface water right conversion to groundwater, construction of a small off-channel reservoir, alluvial water storage, and updating the basin boundaries (Alternatives 1, 2, 6, 7, and 8). Alternative 8, the reserve exchange, is the lowest-cost option to extend the existing reserve. This alternative, with Washington State Department of Ecology's (Ecology) approval, provides short-term relief under the existing reserve and rule framework while additional efforts are pursued.

Increasing late season streamflows is much more challenging and require regional efforts identified in Alternatives 3, 4a, and 4b. These alternatives are multimillion dollar projects and are not carried forward as recommended alternatives for an initial phase of work. Table ES-2 provides a summary of costs associated with the recommended alternatives evaluated in this appraisal-level analysis. The combination of projects shown in Table ES-2 is expected to cost approximately $748,000.

Table ES-2. Recommended Pilot Project Year-One Cost Estimate Summary

Alt	Description	Capital Cost	1-year O&M	Permitting Costs	Total Costs	Costs per Acre-
1	Water Banking	$125,000	--	$12,500	$137,500	$6,000
2	Surface Water Right to Groundwater Transfer	--	$15,000	$25,000	$40,000	$26,200
6	Localized Reservoir Flow Augmentation	$416,000	$8,000	$40,000	$464,000	$42,400
7	Alluvial Water Storage	$91,000	$3,000	$12,000	$106,000	$5,100
8	Reserve Exchange	--	--	--	--	--
Total		$632,000	$26,000	$89,500	**$748,000**	

1 Background and Purpose

The Chelan County Natural Resources Department (CCNRD) has long been concerned with improving the health of the Mission Creek Subbasin (Mission Basin). With the onset of watershed planning in the Wenatchee River Basin, CCNRD has expressed a preference for the development of water-resource solutions that both enhance instream flows and preserve opportunities for modest (e.g., estimated at 1.38[1] to 2.19[2] percent) residential growth, to avoid a regulatory closure of Mission Basin.

The Mission Basin provides water for agriculture within the Mission, Brender, and Yaksum valleys. It is also home to approximately 21 percent of the total population within the Wenatchee River Basin, including a portion of the City of Cashmere, and is an area that continues to experience growth. The uppermost portion of the watershed is largely managed by the U.S. Forest Service (USFS) and includes some privately owned forest. The lower watershed is dominated by commercial agriculture and urban development.

Mission Creek has a history of very low streamflow and water quality issues. The creek is included on the 303(d) listing for instream flow, Dichlorodiphenyltrichloroethane (DDT)/ Dichlorodiphenyldichloroethylene (DDE), fecal coliform, temperature, dissolved oxygen, and pH. Limited water availability for out-of-stream uses and low stream flows in the Mission Creek Watershed were identified as high priorities by the Wenatchee Watershed Planning Unit (WWPU) in their 2006 Wenatchee Watershed Plan (WWPU, 2006). The plan made recommendations that resulted in the updated Wenatchee Instream Resource Protection Program (Washington Administrative Code [WAC] 173-545) that established minimum instream flows and set aside a 0.03 cubic feet per second (cfs) reservation of water for future development (reserve). Figure 1 depicts the minimum instream flows with the daily median discharge from 2003 through 2016 of Mission Creek measured at Washington State Department of Ecology's (Ecology) control station 45E070, which excludes Brender Creek.

The reserve established in the 2008 rule amendment (WAC 173-545-90) was intended to provide domestic water supply for 2 years. However, growth was slower than anticipated; and after 2 years, only approximately 15 percent of the reserve was used (Dally, 2011a). An updated audit of permit-exempt uses in all of the Wenatchee subbasins concluded that the Mission Basin reserve would be fully depleted in approximately 2014 (Aspect, 2013), and is updated here in Chapter 9 and Appendix E.

In response to the pressures on instream and out-of-stream uses in the Mission Basin, CCNRD began engaging with local stakeholders to help identify viable solutions to the water supply issues. These included numerous landowner meetings, which led to development of the alternatives presented in this appraisal for increasing streamflow and increased water availability for growth.

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[1] Washington Office of Financial Management high estimate for Chelan County, plus additional growth as used in the 2006 Wenatchee Watershed Plan.

[2] Washington Office of Financial Management high estimate for Chelan County used in the Wenatchee Coordinated Cost Reimbursement.

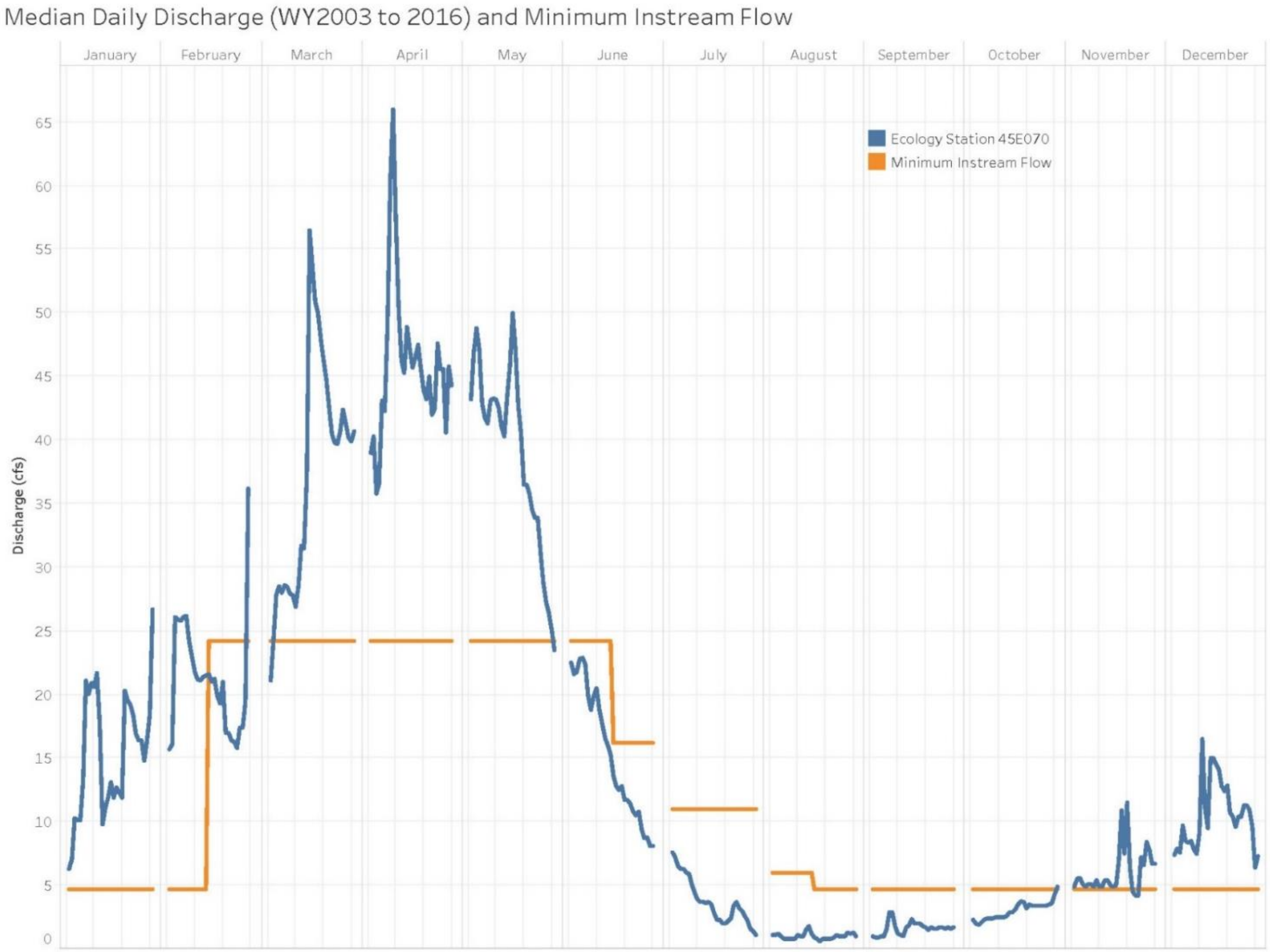

Figure 1. Ecology Station (45E070) and Minimum Instream Flow Hydrographs

The following discusses the regulatory context, hydrogeologic environment, and habitat and water quality conditions of the Mission Basin.

1.1 1983 Instream Resource Protection Program

The Instream Resources Protection Program (IRPP) for the Wenatchee River Basin, Water Resource Inventory Area (WRIA) 45, was established to protect water quality, wildlife, fish, and other environmental values, as well as aesthetics, recreation and navigation, and to meet certain future out-of-stream water needs. Under Chapter 173-545 WAC, the IRPP effectively limits, and in some cases prohibits, the further issuance of consumptive water rights that could affect instream flows in stream reaches. Originally adopted in 1983, the IRPP specified minimum instantaneous flows in reaches defined by five control stations located throughout the basin. When instream flows are not met, approximately 45 junior water rights (those with a post-1983 priority date) are required to discontinue use until flows in the stream are higher than those specified in the IRPP. Regulation of junior water rights occurs in approximately 6 out of every 10 years. The only purpose of use not subject to interruption under the 1983 IRPP was single domestic and stock watering uses (except feedlots).

1.2 2008 IRPP Update

As part of the watershed planning process, the WWPU recommended that the existing 1983 IRPP be amended (effective January 2008) to include a quantity of water not subject to regulation when instream flows are not met. Through an overriding consideration of the public interest (OCPI) determination[3], the updated 2008 IRPP established a total reservation of 4.0 cfs of consumptive-use impacts for the Wenatchee River mainstem and all tributaries (reserve). The mainstem reservation includes up to 1.0 cfs for the upper mainstem and tributaries (i.e., above Tumwater Canyon), and 3.5 cfs for the lower mainstem and tributaries (but limited to a total of 4.0 cfs), based on an overall habitat loss of not more than 1.5 percent. In addition, each tributary reservation is limited to the amount of water required to meet projected 2025 demand, or that which would result in not more than 1 percent habitat loss—whichever is greater.

Specific to Mission Creek, the reservation is limited to a reduced short-term interim quantity until the following conditions are fulfilled:

- The interim reservation is limited to 0.03 cfs, which was to terminate after 2 years (ending 2010). A cumulative impacts assessment would then be used to determine if outdoor water use associated with post-1983 permit-exempt use interferes with the flows established in the 1983 IRPP. Additional rulemaking would be required to increase the quantity of the Mission Reservation.

  Although the interim period for the reservation has expired, the reserve was only estimated to be approximately 24 percent allocated (Dally, 2011b). Therefore, Ecology and CCNRD

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[3] Although the Supreme Court subsequently held that Ecology did not have the ability to create reserves of water under instream flow rules in the *Swinomish* decision (2013), the Washington State Legislature subsequently confirmed the reliability of the reserve created by Ecology in WAC 173-545 under Senate Bill 6513.

mutually agreed to extend the interim reserve until the quantities are fully allocated, or until rule making is initiated.

1.3 Domestic Reserve

As specified by WAC 173-545-090(1)(c), beneficial use of the reserve is limited to permitted and permit-exempt uses consisting of domestic irrigation associated with a residence; domestic water requirements associated with municipal, commercial, and industrial purposes; and stock water.

The Wenatchee Reserve Accounting Review (Aspect, 2013) estimated reserve allocation to permit-exempt uses through 2025 using actual consumptive water-use rates in the historic low-flow month of September and residential growth projections from the Watershed Management Plan (WWPU, 2006).

The minimum quantity of reserve required to develop homes that are supported exclusively by exempt wells was estimated to be 0.75 cfs. This leaves approximately 3.25 cfs available for new water right appropriations under the reserve after permit-exempt needs are satisfied through the Year 2025 (Aspect, 2013). The Mission Basin is subject to an interim reserve of 0.03 cfs (13.5 gallons per minute (gpm), which was estimated to be depleted in approximately 2013 (Aspect, 2013).

1.4 Consumptive Use Analysis for Reserve Accounting

In its evaluation of reserve methodology and accounting in 2013, Aspect Consulting, LLC (Aspect summarized how consumptive use of permit-exempt uses were tracked. The principle is to quantify consumptive-use impacts in September to ensure that the 1 to 2 percent habitat loss in the low-flow month (on which the reserve framework was based) was not violated (Aspect, 2013). For Mission Creek, the following assumptions are made for tracking permit-exempt uses:

- Estimates for indoor consumptive water use for parcels using on-site sewage systems range from 15 percent (Aspect, 2010) to 50 percent (Skagit Rule, WAC 173-503a). For Mission Creek, an indoor consumptive use value of 30 percent (Upper Kittitas Rule, WAC 173-539A) was initially chosen because it is relatively conservative and has precedence in a water management policy for a local basin having climatic and geologic conditions that are similar to WRIA 45.

- A total indoor water use of 200 gallons per day (gpd) was assumed, consistent with recommendations in the Washington State Department of Health (WDOH) Water System Design Manual (WDOH, 2009), and supported by average winter use in the Methow River basin.

- Mission Creek indoor consumptive use was calculated to be 60 gpd (Aspect, 2012).

- Outdoor consumptive water use was estimated by determining the average extent of irrigation occurring on parcels subject to the reserve and then applying an irrigation demand for a reference crop during the month of September. For Mission Creek, average lawn size was determined to be 0.072 acres (approximately 3,000 square feet).

- Total consumptive use per permit-exempt use in Mission Creek averages 630 gpd per residence in September consumptive-use equivalents (Aspect, 2013). This means that for a 0.03 cfs reserve, 30 houses can be served by the reserve.

In 2018, following passage of Engrossed Substitute Senate Bill (ESSB) 6091, Ecology developed a guidance for estimating water use by permit-exempt wells. Based on Ecology’s recommended assumptions an additional two parcels are served by the reserve, which extended the reserve into 2015.

1.5 Mission Creek Hydrogeology

The Project area is located in the Chiwaukum graben within the Cascade Crystalline Core of the North Cascades geologic province. The Chumstick Formation, a nonmarine sedimentary deposit, dominates the surficial geology. The Chumstick Formation is a white sandstone with varying amounts of shale, conglomerate, fanglomerate, and rare siliceous tuff (Tabor et al., 1982). The Chumstick Formation has undergone deformation resulting is sedimentary beds dipping steeply west-northwest. Subsequent weathering (e.g., erosion) has resulted in the present landscape, with deeply incised north-south trending canyons, and deposition of recent alluvial deposit in the valley bottom.

CCNRD conducted groundwater-surface water monitoring in 2008/2009 to evaluate the interaction between Mission Creek and the shallow aquifer. These data suggest that most of Mission Creek is a losing reach with exception of the Yaksum Creek confluence (Ecology, 2003; AMEC, 2010). Streamflow monitoring for the pilot project conducted as part of this appraisal reached a similar conclusion, except a potential gaining reach was detected above Sherman Canyon.

Brender Creek was not included in the 2008/2009 CCNRD effort nor the 2016 pilot studies; however, the lower portion of Brender Creek was evaluated as part of Alternative 8. Long-term visual evidence by CCNRD, City of Cashmere, and IPID suggest that Brender Creek flow is very consistent, even at low flow. Springs are noted on U.S. Geological Survey topographic maps; therefore, it is likely groundwater influences Brender Creek through the canyon.

Yaksum Creek was also not included in the 2008/2009 CCNRD effort nor the 2016 pilot studies. Local landowner input would likely be needed to begin baseline characterization of this tributary to Mission Creek.

1.6 Mission Creek Storage Assessment

In 2006, the County completed a Multipurpose Water Storage Assessment in the Wenatchee River Watershed (MWG, 2006). Several off-channel and lake-enhancement projects were identified as potential opportunities to augment storage in the Mission Basin. All proposed project sites had a high cost-per-acre-foot relative to current state and federal storage investments (e.g., ranged in cost from $8,000 to $57,800 per acre-foot). The primary issues regarding these projects are funding limitations and permitting challenges, as they are located on federal land managed by the USFS with restrictions on development. They also provide a small benefit in terms of water supply (0.5 to 1.0 cfs per project for 30 days).

1.7 Fish Use of the Mission Basin

The Mission Basin is a spawning area for steelhead and contains spawning and rearing habitat for steelhead and coho salmon. It is also a potential rearing area for spring Chinook salmon, although no known spawning has been observed. The Washington Department of Fish and Wildlife (WDFW) tracks fish presence in Mission Creek. The following preliminary data were available for adult steelhead for 2015:

- Lower Mission Creek (as of May 12, 2015): 13 wild steelhead and 3 hatchery fish detected. Overall estimates included 97 wild and 22 hatchery fish.
- Upper Mission Creek (as of May 2, 2015): Overall estimates included 23 wild steelhead and 15 hatchery fish.
- Sand Creek (as of May 2, 2015): five wild steelhead were detected. Overall estimates included 37 wild fish.

1.8 Habitat in the Mission Basin

The "Upper Columbia River Regional Technical Team (UCRRTT) Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region" (Biological Strategy; UCRTT, 2014) contains habitat information for Mission Creek. Appendix E of UCRTT 2014 document contains factors affecting habitat conditions, including:

- Channelization of lower Mission, Brender, and Yaksum creeks
- Loss of channel sinuosity and floodplain function
- Low or nonexistent flows with associated high instream temperatures in lower Mission Creek disrupt distribution and abundance of native species, particularly in summer
- Degraded water quality and increased sediment delivery
- Soil compaction

WDFW performed weighted usable area (WUA) evaluations for Mission Creek in 2013. Two sites were evaluated: one near river mile (RM) 8.0 and the other at RM 2.5. The results of this study are not available at this time.

1.9 Fish Passage Barriers in the Mission Basin

The Biological Strategy identified several culverts throughout the watershed that are passage barriers when flows in Mission Creek are available. A fish-barrier inventory was completed for CCNRD by Harza/BioAnalysts in 2005. In 2008, CCNRD asked the UCRRTT to do a barrier prioritization to help inform CCNRD on how best to target fish-barrier removal projects. CCNRD has this information on file.

1.10 Water Quality in the Mission Creek Basin

The Wenatchee Basin is the subject of a Total Maximum Daily Load (TMDL) allocation. TMDL documents are available on Ecology's website. Mission Creek and tributaries are listed for temperature, fecal coliform, and DDE/DDT.

1.11 Summary

This appraisal analysis evaluates options to improve instream flow and establish a domestic reserve. There are habitat, fish passage, and water quality problems that stakeholders will have to address. The priority is to increase streamflow in Mission Creek as a first step and allow for minimal continued growth within the Mission Basin.

2 Alternative 1 – Water Banking

Water banking may offer options to extend the reserve for permit-exempt uses in Mission Creek and provide some limited stream-flow improvement. The water bank acts as an intermediary, bringing together buyers and sellers of water rights with predictability on the validity of the water right, the geographic area where it can be used, and for what purposes (e.g., domestic, commercial). The overall goal of a water bank is to facilitate water transfers using market forces. In Washington State, the legislature has identified additional objectives of water banking in Revised Code of Washington (RCW) 90.42.100, which include:

- Making water supplies available when and where needed during times of drought
- Improving streamflows and preserving instream values during fish-critical periods
- Reducing water transaction costs, time, and risk to purchaser
- Facilitating fair and efficient reallocation of water from one beneficial use to another
- Providing water supplies to offset impacts related to future development and the issues of new water rights
- Facilitating water agreements that protect upstream community values while retaining flexibility to meet critical downstream water needs in times of scarcity

Some of the analysis for this alternative was adapted from similar water-banking efforts Aspect has led or coled in such locations as Kittitas County and Spokane County for the 2016 Water Supply and Demand Forecast, and for private water banks, and modified for applicability to Mission Creek. Specific bank operation and administration decisions will need to be made by CCNRD as described in greater detail herein. Additional background on water banking is provided in Appendix B.

2.1 Water Banking Defined

The traditional definition for water banking is an institutional mechanism used to facilitate the legal transfer and market exchange of water (Clifford et al., 2004). However, the term “water banking” is used to refer to a variety of water management practices that extend beyond the traditional definition. Although water-banking definitions and approaches differ, the common goal is to move water to where it is needed most.

2.2 Water Bank Functions

Water bankers provide various services to meet instream and out-of-stream water demands. The type of water-bank model used, and the problems being solved will have case-specific governance factors dictated by individual trust water right agreements with Ecology and county code. There are four structural/ownership models of water banking that have emerged in Washington. These different structures are generally based on funding type, bank administration, and bank purpose:

1) Public (e.g., Kittitas County Water Bank, City of White Salmon Water Bank)

2) Quasi-government (e.g., Dungeness Water Bank, which is a county/non-profit partnership)
3) Nongovernmental Organizations (NGO) (e.g., banks managed by Washington Water Trust)
4) Private (e.g., Upper Kittitas water banks, which operates for profit)

In the Mission Basin, a water bank operated by CCNRD that builds on the existing reserve framework would be the most straightforward to implement.

2.3 Incentives for Water Bank Participation

There are a number of reasons why existing and future water users in the Mission Basin would potentially participate in a water bank. The incentives are related to a number of factors, some of which are still in flux given potential Legislative actions. Incentives for participation include:

- **Mitigation source for new exempt wells.** With the reserve in WAC 173-545-090 for the Mission Basin nearing depletion, a water bank could allow continued exempt uses to occur.

- **Interruptibility of new water-right permits.** The adoption of the instream flow in Mission Creek means that the only new water rights issued in Mission Creek would be interruptible due to low-flow conditions during most summer weeks of the year. A water bank could provide a mitigated source of water for new permits.

- **Existing interruptibles.** There are seven existing interruptible water-right holders that might seek greater reliability of water use, depending on crop choices. A water bank could offer options to transition to noninterruptible uses.

2.4 Water Bank Operational and Management Considerations

There are a number of operational and management elements that must be considered when considering the “business” of developing and managing a water bank. Those elements include water banking roles, services, business decisions, and design. These elements are important because they will dictate who the water bank serves, water-bank pricing, sustainability and longevity, and managing the resource amongst other competing demands. Table 1 summarizes some of the key banking functions and the potential departments within each county that could have a participatory role:

Table 1. Summary of Potentially Affected County Departments under Water Banking

Chelan County	Formation	Operations	Management
Natural Resources Department	X	X	X
Auditor		X	X
Treasurer	X	X	
Public Works		X	X
Assessor		X	
Community Development	X	X	X
Flood Control Zone District			

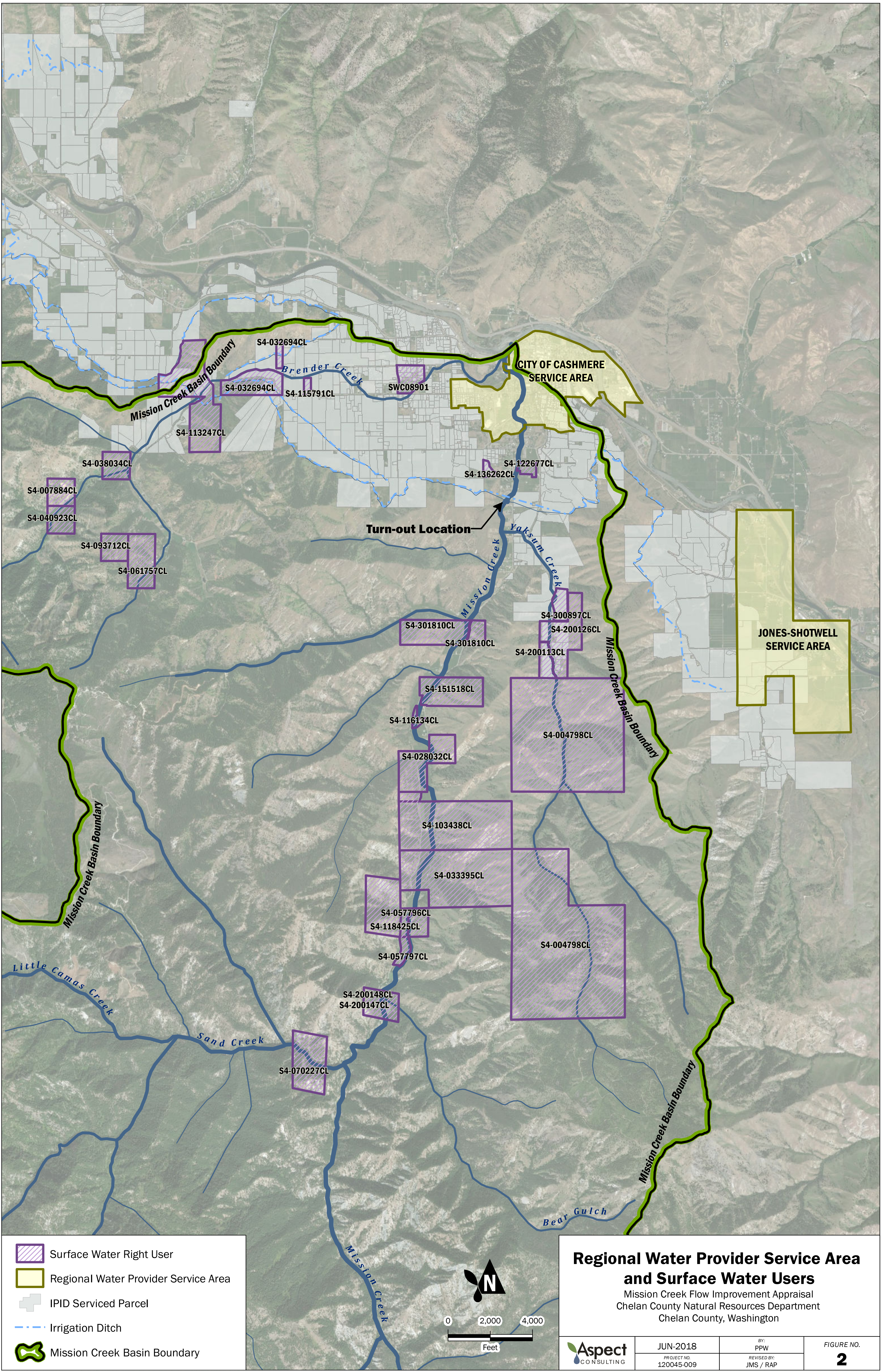
2.5 Opportunities for a Targeted Water Right Purchase

Aspect evaluated potential rights that could seed a water bank in the Mission Basin. These same rights have the potential to assist in several other alternatives being evaluated in this appraisal, including surface-to-ground transfers or being exchanged for another source (e.g., regional purveyor, Wenatchee pump station). Based on a review of Ecology's water-right files, the following water rights were determined to be large enough to warrant consideration for inclusion in this appraisal. Table 2 and Figure 2 provides a summary of these rights.

Table 2. Select Surface Water Rights

Water Right Number	Water Right Type	Priority Date	Instant. Rate (cfs)	Instant. Quantity (gpm)	Annual Volume (acre-feet)	Irrigated Acres	Purpose
S4-004798CL	Claim L		372		320	150	DG IR ST
S4-070227CL	Claim L		0.08		160	40	IR ST
S4-061757CL	Claim L				1.6	40	DG IR
S4-113247CL	Claim L			11	17.6	40	IR
S4-028032CL	Claim L			120		28	IR
S4-151518CL	Claim L			60	13	27	IR
S4-103438CL	Claim L	1/01/1885	0.4		102	32	IR ST
S4-033395CL	Claim L		0.313		113	25	IR
S4-300897CL	Claim		1		5	24.8	IR
SWC08901	Cert	1/11/1963	0.41		80	20	DS IR
S4-093712CL	Claim L			25	15	20	IR
S4-115791CL	Claim L					20	DG IR
S4-200113CL	Claim L			100	70	20	IR
S4-032694CL	Claim L		0.5		80	20	IR
S4-040923CL	Claim L		1		64	16	IR ST
S4-118425CL	Claim L			120	32	16	IR
S4-038034CL	Claim L		0.16		61	15	DG IR
S4-136262CL	Claim L			50	10	12	IR
S4-007884CL	Claim L					40	IR
S4-122677CL	Claim L		0.12		10	10	IR
S4-200126CL	Claim L		26		35	10	IR
S4-116134CL	Claim L			60	40	10	IR
S4-200147CL	Claim L		1		10	10	DG IR
S4-200148CL	Claim L		1		10	10	DG IR
S4-057797CL	Claim L				36.57	7.17	IR
S4-057796CL	Claim L				48.3	9.47	IR
S4-301810CL	Claim		0.02		872	8.74	NR

Notes:
DG - Domestic General; IR – Irrigation; ST - Stock Watering; NR - Not Recorded



▨ Surface Water Right User

🟨 Regional Water Provider Service Area

▧ IPID Serviced Parcel

-·-· Irrigation Ditch

🟩 Mission Creek Basin Boundary

Regional Water Provider Service Area and Surface Water Users

Mission Creek Flow Improvement Appraisal
Chelan County Natural Resources Department
Chelan County, Washington

Aspect CONSULTING	JUN-2018	BY: PPW	FIGURE NO.
	PROJECT NO. 120045-009	REVISED BY: JMS / RAP	2

Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekFlowAugmentation_120045_011_06\Delivered\FlowImprovementAppraisalAnalysis\03 Regional Water Provider Service Area and Surface Water Users.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 6/7/2018 || User: rpepin || Print Date: 6/7/2018

These water rights were adapted into a map book that summarizes their attributes, locations, overlays the authorized places of use with parcel landowners, and estimates current irrigation (Appendix A).

Aspect and CCNRD met with local landowners to review this information and determine their interest in potentially participating in one or more of the alternatives being evaluated in this appraisal. During the course of reviewing the map book, it became apparent that in many cases, the actual location of irrigation did not perfectly line up with the authorized (or asserted-for claims) places of use outlined in the map book. As such, in some cases, the estimates of current use under-predict actual use. Generally, irrigating outside one's place of use is still considered beneficial use under Ecology's Tentative Determination Policy 1120, although a change authorization is needed to correct the irrigated area. If one of the rights in the map book were selected for acquisition, in whole or in part, then a formal tentative determination of the extent and validity of the water right would be accomplished at that time.

2.6 Estimated Cost

Launching a new Mission Basin water bank will include costs to seed, administer, and start up the bank. These costs can be challenging to predict, given the uncertainty in local market conditions and the degree to which County departments can readily integrate the new business function. For the purposes of this analysis and building on a previous evaluation done by Aspect on potential acquisitions for CCNRD (Aspect 2012), Table 3 depicts potential bank seeding, bank longevity, and mitigation-certificate costs scaled by different levels of acquisition.

Because the amount of water associated with each exempt use in the Mission Basin is relatively small, and assuming that this trend continues (or is forced to continue through banking rules), then a relatively small irrigation acquisition could allow for modest predicted growth to continue for decades to come. Prices would likely be affordable based on the mitigation certificate analysis and assumptions presented in Table 3.

Permitting costs are tied to the number of water rights acquired to seed the water bank. Transactional costs to transfer an acquired water right into the bank is estimated at $10,000 per water right with an additional cost of $2,500 associated with trust conveyance negotiations (Table 4). Administration of the water bank is estimated to cost 25 percent of the bank-seeding costs, or approximately $2,500 per house or $5,500 per consumptive acre-foot. In this example, it is assumed a single transaction would cover the quantities necessary to offset 10 acres of outdoor irrigation.

Table 3. Bank Seeding and Potential Mitigation Certificate Costs

Outdoor irrigation covered under an alternative authorization (acres)[1]	Reserve quantity made available (September consumptive use equivalents, cfs)	Number of homes supported[2]	Mission Basin growth rate from Watershed Management Plan (homes/year)	Years reserve depletion is delayed	Reserve depletion date[3]	Bank Seeding Costs[4]
1	0.005	5	6.9	1	2018	$10,000
2	0.01	10	6.9	1	2018	$20,000
3	0.015	15	6.9	2	2019	$30,000
4	0.02	20	6.9	3	2020	$40,000
5	0.025	26	6.9	4	2021	$50,000
6	0.03	31	6.9	4	2021	$60,000
7	0.035	36	6.9	5	2022	$70,000
10	0.05	51	6.9	7	2024	$100,000
15	0.075	77	6.9	11	2028	$150,000
20	0.1	102	6.9	15	2032	$200,000
25	0.125	128	6.9	18	2035	$250,000
30	0.15	153	6.9	22	2039	$300,000
35	0.175	179	6.9	26	2043	$350,000

Notes:

[1] The Interim Mission Basin reserves are established as 0.03 cfs. Alternative authorizations might include water from irrigation purveyors, state-based water rights, water banking, etc.

[2] Number of homes supported considering combined indoor and outdoor September consumptive use per residence of 0.00098 cfs (630 gpd) for Mission Creek Basin (Aspect, 2013).

[3] Mission reserve was originally estimated to be depleted in 2013 (Aspect, 2013).

[4] Acquisition is estimated at $10,000 per acre, and water bank administration is anticipated to be quarter the cost of bank seeding.

Table 4. Water Banking Cost Estimate Summary

Alt	Description	Capital Cost	20-years O&M	Permitting Costs	Total Costs	Costs per Acre-Foot
1	Water Banking[a]	$125,000	--	$12,500	$137,500	$6,000

Notes:

a) Costs reflect bank seeding for 23 acre-feet as shown in Table 3; costs do not include administrative and start-up costs.

2.7 Recommendations and Next Steps

Water banking is a viable option for extending the Mission Basin reserve and providing opportunities for new growth. As shown in Table 4, a modest investment to seed a water bank could supply domestic water for new growth for years to come. It offers some limited benefit to improving instream flows as well. However, the magnitude of water needed to meet instream flow targets is substantially higher, so it is unlikely that water banking alone would be a solution for both of the issues (instream and out-of-stream) currently facing Mission Creek. Likely, water banking, in conjunction with another option would be most beneficial.

In order to launch a water bank for the Mission Basin, Aspect recommends the following key next steps:

1) Meet with local stakeholders, including landowners who have rights that could seed the bank to discuss how the bank would operate and quantities of water targeted.
2) Meet internally with County departments to review how new bank procedures would overlay with current county business practices.
3) Meet with Ecology to discuss how a trust water agreement and permitting framework would be developed.
4) Identify a revenue source for an initial acquisition. Establish cost-recovery guidelines, so the bank can be self-sustaining after initial seeding is complete.
5) Network with local landowners or run an auction to identify and acquire a water right.
6) Use the conservancy board or a front-loaded application process with Ecology to move the water right into trust and secure a trust water agreement for its management.
7) Develop outreach materials and building permit guidelines to offer new mitigated rights in the Mission Basin.

3 Alternative 2 – Surface Water Right to Groundwater Transfer

Transferring water users relying on surface water rights from Mission Creek to groundwater sources could improve instream flows in Mission Creek by retiming the impact to streamflows due to irrigation

This transfer is dependent on whether increased groundwater use is reliable, valid rights exist for transfer, current or new wells are authorized, and landowners are willing to voluntarily participate in such a program (or can be incentivized to do so).

3.1 Hydrogeologic Framework

A conceptual hydrogeologic framework was created to evaluate the merits of this alternative relative to the other alternatives in this appraisal. This framework includes the following attributes and assumptions:

- Approximately 9 gpm per acre is necessary for peak water demand.
- A typical orchard is a 10-acre block and a single well will serve each block.
- Well separation distance is approximately 500 feet, due to size of orchard blocks and geography of the Mission Creek canyon.
- Specific capacity of the typical well completed in the semiconfined Chumstick Formation is 0.3 gallons per minute per foot (gpm/ft), and 3.9 gpm/ft for wells completed in the semiconfined alluvial aquifer.

The low transmissivity of the Chumstick aquifer requires well completion depths capable of providing 320 feet of available drawdown and sufficient separation or pumping schedule to limit pumping interference, or impairment to surrounding groundwater users. The semiconfined alluvial aquifer is limited in horizontal and vertical extent, which reduces the number of wells that can sustainably pump groundwater from the aquifer.

3.2 Permitting Strategy

There are two potential strategies for implementing this alternative: 1) reliance on existing groundwater rights, or 2) issuing new groundwater rights mitigated by an existing surface water right.

The first strategy is the easiest to permit. This strategy requires a landowner that has a surface and a groundwater right (perhaps in a primary/supplemental relationship). In this scenario, they could defer pumping their surface right (or donate it to trust) and have greater reliance on their groundwater right. A number of landowners we coordinated with have both surface supplies and wells that they use conjunctively to meet their irrigation demand.

A second strategy requires issuance of a new, water-budget neutral, groundwater right, either because no groundwater authorization exists now, or the groundwater authorization is smaller than the full irrigation demand currently supplied by surface supplies. This strategy is possible if Ecology concludes the groundwater withdrawals be offset by a trust conveyance of surface supply on Mission Creek (e.g., water-budget neutral).

3.3 Candidate Water Rights

The most suitable candidates are water right holders that have both a surface water and groundwater right. The ideal candidate will have existing infrastructure to allow for conversion during the critical season to switch from their surface water diversion to an irrigation well.

The surface water right map book, summarized in Appendix A provides an overview of potential candidate water rights. Next steps include identifying groundwater rights in the Mission Basin and engaging stakeholders to assess favorability with piloting a temporary conversion.

3.4 Estimated Cost

Costs under this alternative are presented in Table 5 and include permitting costs, construction conversion costs, and pumping costs:

- **Permitting Costs**: Permitting could span the range from a short-term donation for a simple 1-year pilot, to a full conservancy board or front-loaded permit authorization for a new groundwater permit coupled with a permanent trust conveyance of the surface water right. For the purposes of this appraisal, we assume the permitting cost range could be on the order of $5,000 for a pilot to $25,000 for a full conversion.

- **Construction Conversion Costs:** Construction costs could be essentially zero if a farmer has existing infrastructure in place, to on the order of $85,000 if a new well[4] needs to be constructed.

- **Pumping Cost:** Converting a farmer from a gravity to a pumped supply will likely require some kind of stipend, either annually or as one-time cost to cover pumping operation and maintenance costs. For a 5-acre supply, increased O&M would be on the order of $460 and so a one-time cost of $24,000—to cover replacement of pump with 15-year life is considered to cover a 20-year pumping effort (no stipend provided thereafter).

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[4] Example new well construction presumes an 8-inch-diameter well completed to a depth of 400 feet below ground surface, and a 7.5 to 10 horsepower (hp) pump capable of supplying 5 acres of orchard.

Table 5. Surface Water Right to Groundwater Transfer Cost Estimate Summary

Alt	Description	Capital Cost	20-years O&M	Permitting Costs	Total Costs	Costs per Acre-Foot
2	Surface Water Right to Groundwater Transfer[a]	--	$24,000	$25,000	$49,000	$27,000

Notes:

a) Costs based on irrigation of 5 acres of pears with microspray, approximately 12 acre-feet per year, does not include costs for drilling new well, O&M over 20-years does include replacement of pump.

3.5 Recommendations and Next Steps

Aspect recommends that CCNRD:

- Work with the landowners with whom a positive relationship has been built to identify a volunteer who will participate in a pilot project for a surface to ground transfer.
- Identify a landowner with surface water right and groundwater right.
- Perform due diligence on surface water right for transfer to ground.
- Perform due diligence on well and infrastructure to determine if the existing infrastructure is suitable for supplying water demand during low-flow periods (July through September).

Such an effort will allow CCNRD to better scope the likelihood that this alternative should be included in the overall mix of projects designed to benefit Mission Creek instream flow and extension of the domestic reserve. Such a next step could likely be accomplished at a low initial cost and provide a high value of practical learning about the groundwater reliability and cost of full-scale implementation. Given the low yield from wells completed in the Chumstick Formation, this alternative is more feasible when combined with a small reservoir storage for satisfying peak demand.

4 Alternative 3 – Wenatchee Pump Exchange

Some watersheds have solved tributary instream flow and out-of-stream pumping issues by evaluating pump stations that exchange mainstem water to tributary water uses. For example, similar situations exist in the Wenatchee Basin with the Pioneer Water Users Association pump station (constructed), IPID Pump Station (in evaluation under the Programmatic Environmental Impact Statement [PEIS]), and Cascade Orchard Irrigating Company (also in PEIS evaluation). Under this scenario, Aspect prepared a conceptual summary of how a pump station on the Wenatchee River could be used to supply existing Mission Creek surface water users by piping water from the Wenatchee River, and leaving existing Mission Creek supplies in trust to offset those diversions. The potential benefits of this alternative include:

1) Provide instream flow benefit in Mission Creek through the exchange of water from the Wenatchee River and the cessation of Mission Creek diversions.
2) Provide instream flow benefit in Mission Creek through direct augmentation (e.g., pump-and-dump) of Wenatchee River water (subject to water quality and fish-attraction considerations).
3) Provide extension of the domestic reserve by allowing Mission Creek water users to debit the Wenatchee mainstem reserve instead of the smaller Mission Basin reserve.

4.1 Engineering Framework

A conceptual engineering framework was created to evaluate the merits of this alternative relative to the other alternatives in this appraisal. This framework includes the following attributes and assumptions:

- A new surface water pump station along the Wenatchee River with a combined motor output of approximately 600 hp.
- A flow rate capacity of approximately 2,600 gpm at 660 feet (total dynamic head [TDH]) to serve a target of 250 acres.
- Providing end-of-line service pressures of approximately 50 pounds per square inch (psi) at the southern limit of irrigated acreage in Mission Creek drainage (Mission Creek Subarea).
- While the exact location of a proposed pump station was not evaluated, there appears to be suitable candidate sites near the confluence of Mission Creek and the Wenatchee River.
- Infrastructure would include concrete pump structure (e.g., wetwell), vertical turbine pumps, fish screens, power supply, and controls.
- Approximately 8,000 linear-feet (LF) of 16-inch-diameter pipeline would be required from the pump station to the Mission Creek Subarea. It is assumed that this pipeline would be high-pressure rated (300-psi) steel pipeline through developed urban roadway corridors.
- Within the Mission Creek Subarea, an additional 12,500 LF of 16-inch-diameter polyvinyl chloride pipe (PVC); 6,250 LF of 12-inch PVC; and 6,250 LF of 8-inch PVC would be

required to extend service to the southern limit of existing irrigated acreage within the Mission Creek Subarea.

- On-farm improvements (e.g., filter, screens, and connections) were not included in the cost estimates, but could be required depending on water-quality concerns. We understand that some farms already have these improvements in place to deal with water-quality issues on Mission Creek.
- In this analysis, Aspect did not attempt to locate a specific alignment, as that would likely need to be negotiated with individual landowners to ensure appropriate easements could be obtained and to minimize disturbance to existing orchards and properties. This would be completed if this alternative moved forward into a feasibility study.

4.2 Permitting Framework

Of the alternatives considered in this appraisal, this alternative would require the most expansive permitting authority. These would include a myriad of construction-related permits, as well as new water-right permit authority. For water-right permit authority, each of the Mission Creek users accepting water from a pipeline exchange would convey their water rights into trust (requiring a Report of Examination (ROE) for each right and a trust water agreement), and the new pump station would require a new permit. If the permit were managed in conjunction with the trust conveyances, it should be water-budget neutral and not conflict with the Wenatchee Instream Flow rule.

Permits associated with this alternative would likely include the following:

- Multiple water-right permits (trust, diversionary)
- Section 10/Section 404 permit (U.S. Army Corps of Engineers [USACE])
- Hydraulic Permit Approval (WDFW)
- Section 401 Water Quality Certification (Ecology)
- Shoreline Substantial Development Permit
- State Environmental Policy Act (SEPA) Determination
- Critical Areas Ordinance Compliance
- Floodplain Development Permit
- Other general local (city and county) permits (e.g., building, fill and grade, right-of-way)

4.3 Estimated Conceptual Cost

Costs under this alternative are presented in Table 6 and include permitting, construction, and pumping costs:

- **Permitting Costs**: Permitting costs would be high due to the number of permits required and transfer of water rights into trust to mitigate for diversion from the Wenatchee River. Assuming an overall permitting estimate of 5 percent of the project cost, permitting costs are estimated at $244,000. SEPA scoping would be helpful for this project to better estimate permitting levels of effort.

- **Construction Costs:** Construction costs would be substantial due to construction of a new pump station and pipeline to serve Mission Creek water users. The conceptual capital cost is $9,235,250.

- **Pumping Costs:** The annual costs to deliver water to Mission Creek users is estimated at $97,400. Of this, $57,000 are attributed to power consumption.

Table 6. Wenatchee Pump Exchange Cost Estimate Summary

Alt	Description	Capital Cost	20-years O&M	Permitting Costs	Total Costs	Costs per Acre-Foot
3	Wenatchee Pump Exchange[a]	$9,235,000	$1,940,000	$977,000	$12,152,000	$20,000

Notes:
a) Based on providing irrigation supply for 250 acres of pears with cover using microspray.

4.4 Recommendations and Next Steps

This alternative represents both the most significant opportunity to solve problems long-term and the most expensive and challenging to implement. Landowner interest in this alternative was only marginal, which could make it difficult to obtain funding. Although this project is not fatally flawed, given the potential for other alternatives to make incremental progress in meeting the Appraisal objectives, Aspect recommends this alternative be deprioritized to later phases of implementation. If implementation of the other alternatives results in unsatisfactory progress to CCNRD and other stakeholders, then a detailed feasibility study would be the logical next step to evaluate this alternative further. CCNRD will likely need to engage in a robust stakeholder process at that time.

5 Alternative 4 – Regional Water Provider

The IPID, Jones-Shotwell Ditch Company (JSDC), and the City of Cashmere all have service areas that overlap the Mission Basin. If these regional water purveyors can serve Mission Creek water users, then this alternative could improve instream flows in Mission Creek. This alternative evaluates the potential for converting existing users to these regional service providers. Figure 2 shows the service areas of the regional water purveyors.

5.1 Icicle-Peshastin Irrigation District

The Regional Water Provider Alternative includes a new service turnout from the existing IPID canal system near Cashmere. Based on discussion with Chelan County and IPID personnel, a new turnout could be sited upstream of the Mission Creek siphon (see Figure 3). Service criteria and assumptions include the following:

- Providing 2,600 gpm capacity to serve 250 acres with 558 acre-feet.
- End-of-line service pressures of approximately 50 psi at the southern limit of irrigated acreage in the Mission Creek Subarea.
- Gravity pressure from the canal may be sufficient to provide flow to the majority of existing irrigated areas within the Mission Creek Subarea; however, pumping will be required for approximately one-third of the acreage in the southern extent, due to higher elevations.
- A combined pumping horsepower of approximately 50 hp and flow-rate capacity of approximately 850 gpm at 175 feet (TDH) could be required to serve the southern extent.
- The exact location of the pump station was not characterized in this phase; however, there appear to be suitable candidate sites near the intersection of Mission Creek Road and Mission Creek at approximately MP 3.2.
- Pump infrastructure would include equipment housing (e.g., shed), centrifugal pumps, miscellaneous plumbing, power supply, and controls.
- Approximately 12,500 LF of 16-inch-diameter PVC; 6,250 LF of 12-inch PVC; and 6,250 LF of 8-inch PVC would be required to extend service to the southern limit of existing irrigated acreage within the Mission Creek Subarea.
- On-farm improvements (e.g., filter, screens, and connections) were not included in the cost estimates, but could be needed depending on water quality concerns. We understand that some farms already have these in place to deal with water-quality issues on Mission Creek.
- Additional major improvements include approximately 500 LF of 20-inch-diameter standard dimension ration (SDR) 11 high-density polyethylene (HDPE) pipe (approximately 16-inch inside diameter) from the existing IPID canal to the Mission Creek Subarea valley floor. Challenging construction of this element includes abovegrade configuration on steep slope with concrete anchors.

Construction permits associated with this alternative are the most straightforward of those considered and primarily include local (city and county) building and right-of-way permits. However, the water-right permitting strategy is complex, but not unprecedented. Under this alternative, IPID would only provide such service if an equivalent amount of water were added to their diversionary authority as is being retired (trusted) on Mission Creek. IPID has diversions on Peshastin and Icicle Creeks. If 2,600 gpm (5.8 cfs) of additional supply were added to IPID's service area, that would create a 5.8 cfs deficit in Icicle and/or Peshastin Creeks and a commensurate 5.8 cfs benefit in Mission Creek.

This kind of cross-tributary tradeoff has been permitted before by Ecology (e.g., Tieton to Cowiche water-user conversions), but requires robust landowner and regulating agency coordination. Since Icicle and Peshastin Creeks have their own water-supply limitations, this could be challenging. It may be possible to coordinate additional conservation improvements in either Icicle or Peshastin Creeks, such that the 5.8 cfs deficit does not accrue on that tributary, but rather on the Wenatchee River. For example, if 5.8 cfs of savings is generated through the Icicle Strategy (PEIS ongoing) above the Guiding Principles targeted by the Icicle Workgroup for flow augmentation in that basin, then a similar trade-off for Mission Creek benefit may be viewed as a positive. In such an instance, a minimum of trust conveyances from water users on Mission Creek coupled with new diversion authority for IPID would be necessary.

5.2 Jones-Shotwell Ditch Company

JSDC has rights to irrigate approximately 400 acres in the lower Mission Basin. Although direct service of Mission Creek water users is not practical, a variation of the IPID regional service alternative was considered in this appraisal, which could avoid the impacts to Icicle and/or Peshastin Creeks discussed above.

A portion of the JSDC and IPID service areas overlap. If JSDC served some of the IPID customers, that would free up capacity in IPID's system to serve an equal quantity of Mission Creek water users. If water rights held by Mission Creek water users were trusted, then Mission Creek would benefit, and it would be water-budget neutral on Icicle/Peshastin Creeks, and the Wenatchee River at the JSDC diversion.

There would be increased costs to the JSDC system, but no additional costs associated with permitting or leveraging improvements in Icicle/Peshastin Creeks.

5.3 City of Cashmere

If Mission Creek water users were served by the City of Cashmere, it could create a flow benefit in Mission Creek. Aspect compared the map book of water rights (Appendix A) with the City's service area (Appendix B); very few options exist to convert such rights. The opportunities that do exist are very low in the Mission Basin, which diminishes the value of this alternative. Since the City of Cashmere provides treated domestic supplies and the Mission Creek users need water for agricultural irrigation, the suitability and cost of this service was viewed as challenging. For this reason, this regional service provided was not pursued in more detail in this appraisal.

5.4 Estimated Costs

Costs under this alternative are presented in Table 7 and include permitting, construction, and pumping costs:

- **<u>Permitting Costs</u>**: Of all the infrastructure-based alternatives, this alternative includes the fewest number of permits. However, similar to the Wenatchee Pump Exchange alternative, a number of surface water rights will be placed into the TWRP—estimated at $100,000 to convey 10 water rights. Based on construction estimates, additional permitting costs are estimated at $122,000. The permitting costs are estimated at $131,000 when including the IPID-JSDC conversion.

- **<u>Construction Costs:</u>** Construction costs are substantial due to construction of a new pipeline to serve Mission Creek water users. The conceptual capital cost is $4,435,500. Conversion of a portion of the IPID service to JSDC adds $180,000 in construction costs for the necessary pump station and pipeline.

- **<u>Pumping Costs:</u>** The annual cost to deliver water to Mission Creek is estimated at $35,450.

Table 7. Regional Water Provider Cost Estimate Summary

Alt	Description	Capital Cost	20-years O&M	Permitting Costs	Total Costs	Costs per Acre-Foot
4A	Regional Water Provider[a]	$4,436,000	$700,000	$490,000	$5,626,000	$9,200
4B	Regional Water Provider w/ JSDC Conversion[a]	$4,616,000	$700,000	$526,000	$5,842,000	$9,500

Notes:

a) Based on providing irrigation supply for 250 acres of pears with cover using microspray.

5.5 Recommendations and Next Steps

Similar to Alternative 3, this alternative represents a significant opportunity to solve problems long-term and is expensive and challenging to implement. Landowner interest in this alternative was marginal, which could make it difficult to obtain funding. Although this project is not fatally flawed, given the potential for other alternatives to make incremental progress in meeting the Appraisal objectives, Aspect recommends this alternative be deprioritized to later phases of implementation. If implementation of the other alternatives results in unsatisfactory progress to CCNRD and other stakeholders, then a detailed feasibility study would be the logical next step to evaluate this alternative further. CCNRD will need to engage in a robust stakeholder process at that time.

6 Alternative 5 – Streamflow Augmentation

Pumping groundwater to augment streamflow is an alternative that could meet both of the CCNRD objectives for Mission Creek. Further, it could create additional instream-flow benefit and, if reliable, could provide a basis for extension of reserve quantities. Because the hydrologic relationship between Mission Creek and the associated aquifers is not well understood or documented, and because this relationship is key to understanding the viability of both this alternative and Alternative 2 (Surface-to-Ground Transfers), CCNRD met with local landowners to discuss options to clarify these issues.

During these meetings, the landowners were very receptive to greater clarity on how significantly their wells were connected to Mission Creek, the long-term reliability of those wells, aquifer characteristics, and the potential for implementation of this alternative in the future. The potential for learning was so great with willing landowner participation, that a long-term aquifer test was envisioned as a first step that could transition into a long-term “harvest-time pump augmentation program,” wherein landowners could help augment Mission Creek with groundwater discharges from their existing wells when those wells would otherwise be shut off during times of fruit harvest.

CCNRD met with Ecology, WDFW, and the Yakama Nation to explore options on evaluating this alternative. CCNRD applied for and received a preliminary permit to pilot this effort in 2016 (Appendix D). Unique to the other alternatives, which were examined conceptually, Alternatives 2, 5, 7, and 8 were explored through implementation of a pilot studies; and, therefore, represent the most intensive data collection effort relative to the other alternatives evaluated in this appraisal.

6.1 Engineering Framework

The Streamflow Augmentation Alternative includes retrofit of existing groundwater wells to allow for seasonal pumping from groundwater to Mission Creek. To conform to available grant funding and landowner interest, existing wells were used that were not necessarily optimum for the overall investigation goals, but nevertheless advanced the learning of this proof-of-concept option. Five existing irrigation were used to test the concept and evaluate aquifer conditions. Retrofit improvements included pump replacement and reconstruction of wellheads to allow for diversion of groundwater to Mission Creek. Combined total capacity of the wells is approximately 205 gpm (0.46 cfs).

A conceptual engineering framework was created to evaluate the merits of this alternative relative to the other alternatives in this appraisal. This framework includes the following attributes and assumptions for retrofitting five wells:

- Replacement of well pumps. Total combined horsepower of pumping improvement is expected to be very small (less than 10 horsepower total).
- Replacement of well cap, including approximately 4 feet of well upper casing.
- Installation of pitless adapter fitting (and associated appurtenances) and reconstruction of uppermost casing, cap, etc.
- New plumbing and conveyance from each wellhead to Mission Creek (approximately 1,000 LF of 2- and 3-inch-diameter PVC).

- Installation of control valves.
- Discharge structure (energy dissipation / passive aeration).

6.2 Permitting Framework

Permits associated with this alternative are moderately complex relative to other alternatives, due to the discharge into Mission Creek, which may require either National Discharge Pollution Elimination System (NDPES) permit due to point discharge (if discharged to surface water) or State Waste Discharge Permit if infiltrated prior to discharge. Other potential permits associated with this alternative may include Underground Injection Control (UIC)—for infiltration, if performed, or complete suite of aquatics permits (e.g., Sections 10, 401, 404, Hydraulic Project Approval (HPA), etc.) depending on magnitude of impact to stream. General local (city and county) level permits, such as building, and fill and grade permits, as well as right-of way, may also be required.

6.3 Estimated Costs

A conceptual cost estimate was developed using the five irrigation wells tested during the pilot study as a proxy for typical retrofitting wells and installing the necessary infrastructure. Costs under this alternative are presented in Table 8 and include permitting, construction, and pumping costs, as described in more detail below:

- **Permitting Costs**: Permitting costs associated with this alternative are estimated based purely on total construction costs at $25,000, and do not include cost for an individual NPDES permit, assuming it would be exempt or covered under a general permit.

  Under the potential to evaluate reallocation of exempt wells in the Mission Basin to the Wenatchee River where appropriate, we estimate a hydrogeologic study on the order of $35,000 would be needed, along with Ecology and stakeholder meetings and an updated Reserve Accounting report submitted by CCNRD.

- **Construction Costs:** Construction costs are based on wellhead rehabilitation and installation of small pipeline and discharge structure at the five wells tested during the pilot study, and is estimated at $265,000, or approximately $70,000 on an individual well basis.

- **Pumping Cost:** Annual O&M is estimated at $9,176 for operation of five wells. The pumping cost is estimated at $1,300 for power and associated fees.

Table 8. Groundwater Streamflow Augmentation Cost Estimate Summary

Alt	Description	Capital Cost	20-year O&M	Permitting Costs	Total Costs	Costs per Acre-Foot
5	Streamflow Augmentation[a]	$266,000	$180,000	$25,000	$471,000	$8,400

Notes:

a) Harvest period

6.4 Recommendations and Next Steps

There is potential for streamflow augmentation using groundwater wells to provide short-term emergency drought relief along priority habitat reaches. However, augmentation is limited in the Mission Creek Watershed due to loss of streamflow to ground (losing reaches) and trying to meet the instream flow metric at the control station (45E070) is challenging.

The pilot study (Appendix C) found that the quantity and size of wells necessary to satisfy the peak deficit limits the suitability of augmentation alone to improve instream flow in the Mission Creek Watershed. Augmenting streamflow with groundwater is effective when the source aquifer can produce a sufficient quantity of water, and the stream and source aquifer are separated by a very low hydraulic conductivity unit (clay or sandstone). Augmentation is less effective when the source aquifer cannot produce large quantities of water, groundwater recovery from pumping is slow, and the stream loses water to ground. Recommended next steps are as follows:

- Identify priority habitat reaches.
- Characterize groundwater quality to determine suitability for aquatic health and recharge pathways.
- Implement a numerical model to identify the location, timing, and quantity of streamflow improvements and deficits. A monitoring network of new or existing wells (that satisfy measurement quality objectives) is necessary for model calibration and testing.

7 Alternative 6 – Localized Reservoir Flow Augmentation

Although regional storage in the Mission Basin was considered (MWG, 2006), the potential for small on-farm storage emerged as a potential alternative during the landowner meetings. Because of the size of reservoirs proposed, it is likely that this would be better suited to meeting the domestic reserve expansion goal rather than instream flow augmentation, but it is possible that both could occur.

The Localized Reservoir Flow Augmentation Alternative includes construction of small (5- to 10-acre-foot) lined ponds, which may be used for instream flow mitigation of new exempt uses. The concept involves pond filling during times of relative water surplus (e.g., spring freshet period) and subsequent release, particularly during low-flow periods (e.g., late summer and fall) to offset new consumptive appropriations.

Under this scenario, a 10-acre-foot reservoir could supply enough consumptive-use mitigation to supply four additional houses, based on current metrics used by the County for the Mission Basin reserve accounting (Aspect, 2013).

7.1 Engineering Framework

A conceptual engineering framework was created to evaluate the merits of this alternative relative to the other alternatives in this appraisal. This framework includes the following attributes and assumptions.

Filling of the ponds could be accomplished either from Mission Creek itself or with a small groundwater well source in continuity with Mission Creek using a small-diameter pipeline conveyance. Assumptions for pond improvements include:

- Approximately 8,000 cubic yards of grading (cut-and-embankment construction)
- Approximately 1,300 tons of import liner bedding material (e.g., granular, rock-free material)
- Approximately 4,400 square yards of 60-mil HDPE geomembrane liner
- Inlet/outlet works and emergency overflow/spillway

To offset potential temperature-related impacts associated with stored water (discharging to Mission Creek), improvements could include an infiltration gallery (similar to septic drain field) that would allow for injection of water into the subsurface for geothermal treatment prior to subsurface conveyance to Mission Creek. Infiltration gallery improvements are included in the estimate.

7.2 Permitting Framework

Permits associated with this alternative may require either a NDPES permit due to point discharge (if discharged to surface water) or State Waste Discharge Permit (if infiltrated prior to discharge). Other potential permits may include UIC (for infiltration, if performed) or a complete suite of aquatics permits (e.g., Sections 10, 401, 404, HPA, etc.), depending on magnitude of impact to stream. General local-level (city and county) permits related to building, fill and grade, and right-of-ways may also be required. A storage permit may be required from Ecology, as well as a diversionary right to fill the reservoir, and potentially a trust water right to protect the water once released.

7.3 Estimated Cost

Costs under this alternative are presented in Table 9 and include permitting, construction, and pumping costs:

- **Permitting Costs**: Permitting costs associated with this alternative are estimated based on construction costs at $40,000; this does not include an individual NPDES permit, assuming that discharge to ground would be utilized.
- **Construction Costs:** Construction costs are moderate at $415,500 for a lined, 10-acre-foot reservoir.
- **Pumping Cost:** Annual O&M is estimated at $8,426 to maintain the reservoir and associated equipment. Pumping cost is estimated at approximately $1,300 for power and associated fees.

Table 9. Localized Reservoir Flow Augmentation Cost Estimate Summary

Alt	Description	Capital Cost	20-yearO&M	Permitting Costs	Total Costs	Costs per Acre-Foot
6	Localized Reservoir Flow Augmentation[a]	$416,000	$160,000	$40,000	$616,000	$57,600

Notes:

a) Cost estimate is based on construction of a 10-acre-foot, lined reservoir.

7.4 Recommendations and Next Steps

Small storage with localized reservoirs for streamflow augmentation is a viable option for extending the Mission Basin reserve, and potentially improving streamflow. This alternative has the highest cost per acre foot of water, but has a modest capital costs relative to the regional alternatives.

Next steps for CCNRD are:

- Identify a potential landowner to implement a demonstration project.
- Evaluate potential temperature affects from stored water, and feasibility for an infiltration gallery to mitigate temperature.
- Evaluate streamflow augmentation for potential measurable improvement at the Ecology control gage.

8 Alternative 7 – Alluvial Water Storage

Construction of alluvial water storage offers multiple benefits that include improvement to aquatic and riparian habitat, water quality, and increase in water storage that can be used to mitigate for new out-of-stream uses (Aspect, 2018). In rural areas, this option may be one of the only types of projects that can provide both instream and out-of-stream benefits at a reasonable cost.

Reintroduction of large-wood structures to the stream channel would increase hydraulic roughness and slow flow velocities. These structures are expected to raise local in-channel and subsurface water elevations, and trigger sediment deposition and bed aggradation.

Importantly, these structures are expected to act as porous, natural dams that impound water, increasing the overall *in situ* surface water storage along the Poison Creek project area. In addition, reaggradation of the bed will raise the in-channel surface water elevation and increase the volume of subsurface water storage and decrease the groundwater inflow rate. Together, these changes are expected to increase riparian water availability and baseflow amounts and improve water quality (temperature and sediment loads). Furthermore, the thinning of small-diameter trees outside of the riparian zone, for implementation in the in-channel structures, is likely to improve upland soil moisture availability and, therefore, improve forest resilience to fire and drought.

Chelan County recently completed construction of a pilot alluvial water storage project on Poison Creek, a tributary to Mission Creek (NSD, 2017). This included construction and permitting of an engineered wood structure that increases water storage by reconnecting the channel with the floodplain through aggradation of channel sediments. The resulting retention of water increases instream flows into the dry season through a natural release of water from the alluvial sediments. A schematic of this approach and the relative increase in storage potential is shown in the figure below.

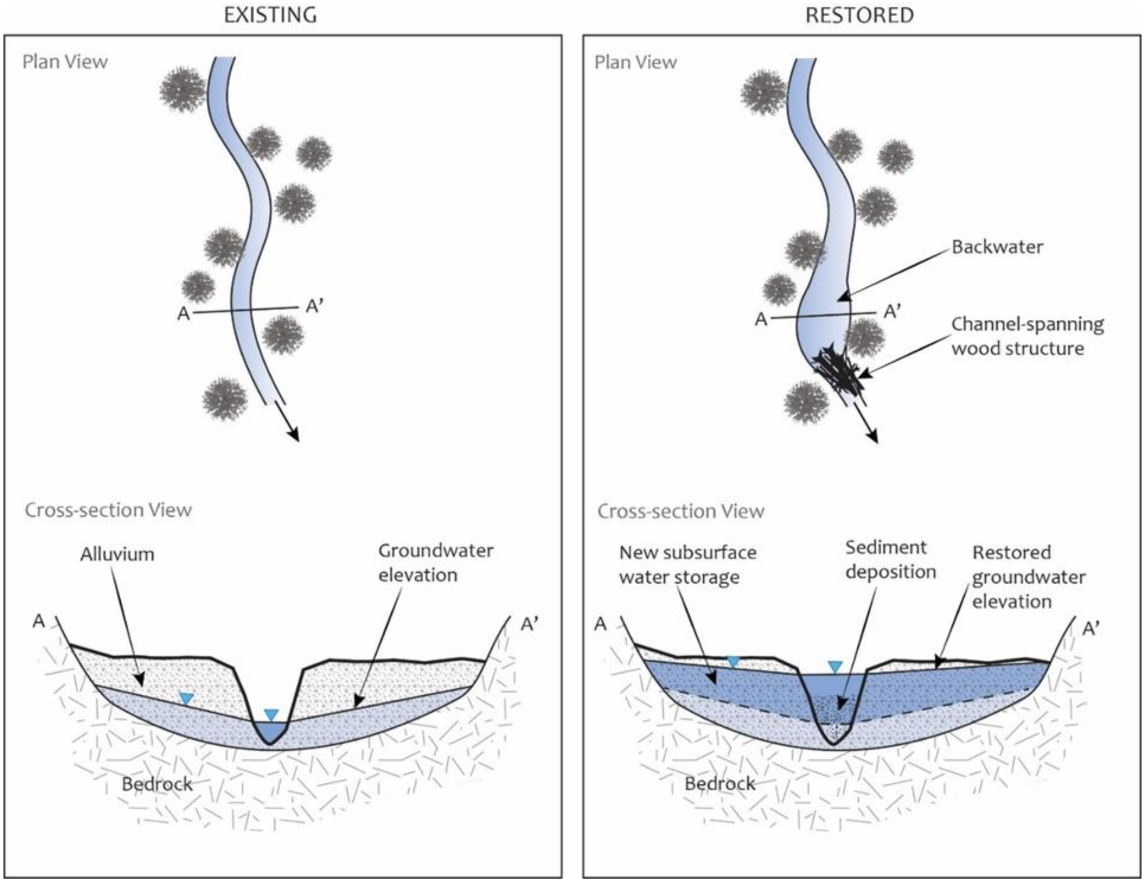

Figure 3. Conceptual diagram of the effect of stream restoration on in situ *water storage: a channel-spanning wood structure slows local flow velocity and creates a backwatered reach, resulting in sediment deposition and increased surface and subsurface water storage.*

8.1 Engineering and Geomorphologic Framework

Logs and wood (racking) bundles will be used to create channel-spanning wood structures that effectively act as a porous dam. Structures will extend 30 to 40 feet along the length of the channel. Logs will be placed at an angle to the channel, and some portion will be entangled with riparian trees, where possible, for stability. Racking bundles will be used to fill holes in the structure and will be held in place by additional large wood placed on top.

Reintroduction of channel-spanning wood structures to the stream channel would include the following components:

- **Wood Bundles:** Thinned material will be bundled to a diameter of 2 to 4 feet using biodegradable (manila) rope. Bundles will be placed both horizontally and vertically (see typical structure sequence in Appendix D Plan Set) and used to fill spaces between placed logs and the channel banks to decrease structure porosity.

- **Logs < 8 inches in diameter at breast height (DBH):** Logs will be harvested from standing live stems, away from riparian zone, so that there is a negligible effect on riparian shade.

Alternatively, downed logs < 8 inches DBH may also be used. No standing snags will be used.

- **Key pieces:** Where larger diameter (≥ 8 inches DBH) downed logs are available, they will be cut with chain saws to allow for transport and placement in the channel without dragging or causing soil erosion. In some locations, downed logs with intact root wads were identified, and these represent prime candidates for key pieces for the in-channel structures.

Construction will be accomplished entirely with hand tools. Standing live stems will be felled with chain saws and rigging. Logs will be hand-carried in such a way as to minimize soil erosion. Chain saws will be refueled on a spill pad at least 20 feet from the edge of the channel.

8.2 Permitting Framework

The permitting approach for alluvial water storage projects would consider the following construction- and reservoir-related activities. An evaluation of reservoir permitting pathways was presented to Ecology on January 16, 2018. Subsequent to consultation, Ecology recommended the permit-less option (Option 4, County Code only) as the favorable pathway to implement an alluvial water storage pilot study. Permitting options are included here for future decision-making purposes.

8.2.1 Construction Permitting

The construction of alluvial water storage projects using channel-spanning wood structures could utilize live-standing and/or dead trees. Use of live-standing trees >8 inches DBH would likely require a Forest Practice Application (FPA) from WDNR and a Hydraulic Project Approval (HPA) from WDFW, a spotted owl habitat assessment, and payment for harvest of live standing trees >8 inches DBH; WDFW fish passage criteria are not applicable to this project.

The following best practices would be applied to selection of trees:

- Harvest of trees currently providing shade to the stream will be avoided. If a specific tree that is near the stream is desired, the construction manager will use a densitometer to check available shading and make a judgement call on whether use of that tree would reduce overall shading.
- Harvest of standing snags will be avoided.
- Construction methods will avoid dragging logs or causing soil erosion.
- The project may use dead and downed material as key pieces, where appropriate.
- Import and placement of key pieces via machinery or helicopter could be considered, where access and budget allow.

8.2.2 Reservoir Permitting

Alluvial water storage projects meet the definition of a reservoir under RCW 90.03.370, as they impound water and release it. This fill-and-release behavior of the reservoir can be predicted, modeled, and measured with sufficient state-of-the-science to meet Ecology’s four-part water-right test for a new appropriation.

Option 1: Traditional Reservoir Permit

This option assumes the alluvial water storage is analogous to any other surface reservoir, and that diversion of water into the on-channel reservoir occurs during the spring runoff when water is available for appropriation.

This permitting option uses the Lake Roosevelt Incremental Storage Release project as an analogous permitting project. In this option an application pursuant to RCW 90.03.255 would be filed for diversionary right, and a second application for a reservoir permit would be filed under RCW 90.03.370 and WAC 173-157. Existing data on the magnitude of storage and rates of release from engineering consultant Natural System Design (NSD) for the Poison Creek Pilot Project would be used for the application quantities (NSD, 2017). The reservoir right would clarify the dual purposes for which release of water would occur.

Following issuance for the diversionary right and reservoir permit, a development schedule would be used to assess, monitor, track, and measure both filling and release of the reservoir over a variety of water years. Once both Ecology and Chelan County felt that reservoir behavior was adequately predictable, certificates would be issued. To protect the water released from the reservoir, Chelan County would apply to convey the water released into the Trust Water Right Program. A monthly trust schedule would be created based on actual observed data, in the same way that a trust schedule was specified for the Lake Roosevelt or Sullivan Lake projects. Chelan County would enter into a trust water agreement with Ecology dedicating one-third of the releases to instream flow and two-thirds to mitigate new exempt uses in addition to the current reserve. The Trust Water Agreement would also ensure the County maintained the reservoir in perpetuity and include mitigation-quantity reporting requirements integrated into the current 5-year reports the County already provides to Ecology on exempt wells under WAC 173-545-090.

Option 2: Preliminary Permit

If Ecology felt additional information was critical to obtain before issuing a final permit, it could instead issue a preliminary permit in response to an application by Chelan County. Ecology uses preliminary permits to obtain additional information regarding water availability, detriment to public welfare, beneficial use, impairment of existing rights, or other relevant questions about the project (POL 1030). A preliminary permit, itself, does not authorize beneficial use; however, a preliminary permit can be combined with a temporary permit (RCW 90.03.250) to authorize beneficial water use. While Chelan County believes that sufficient information is available to warrant moving directly to permitting in Option 1, it is open to considering a preliminary permit framework if Ecology believes it is warranted for this project.

Option 3: Rule Amendment

When Ecology drafted the instream-flow rule and associated reserve for Mission Creek (WAC 173-545-150), they contemplated future rule updates as evidenced in the text of the rule in several subsections. Although Chelan County has completed an assessment of future uses in Mission Creek and is in the process of working with Ecology on ensuring exempt uses are appropriately allocated at the basin and subbasin level, a rule amendment has not been proposed to date. Given the new rule emphasis in ESSB 6091, we understand that revised rulemaking could be an option to streamline future permitting.

Under this scenario, Chelan County could provide sufficient information to allow the interim reserve in Mission Creek to be increased and finalized based on the Poison Creek alluvial water reservoir.

There are other reasons that WAC 173-545 could be updated (e.g., such an amendment is proposed as part of the Icicle Strategy) and there may be some synergy in such an approach.

Option 4: Permit-Less Option

Ecology asked Chelan County to consider whether a permit-less option could work as well, which would help reduce any workload impacts of the options discussed above. We initially expressed some questions regarding whether due process and regulatory authority standards would be met with such an option, but endeavored to identify how it could work. In short, Chelan County must report to Ecology on compliance under the rule every 5 years, including an audit of exempt uses it authorizes. Similarly, Chelan County must make legal and physical availability findings that do not impair existing water rights.

Chelan County could amend its county code to specifically authorize this project as a water supply technique being employed in the county. It could monitor and measure its effectiveness as described in Option 1, without Ecology trust-water oversight. It could associate or “charge” initial exempt wells in the Mission Basin to WAC 173-545-090 and future exempt wells to the Poison Creek reservoir project and report on those findings every 5 years to Ecology to provide transparency in accounting. Ecology’s instream flow interests would be protected by review and auditing Chelan County’s accounting system every 5 years to ensure that the one-third benefit to instream flow from the project was being maintained. Due process would be served through county building permits, which can be appealed if an existing user believes they are impaired. If additional coordination were warranted, Ecology and Chelan County could enter into a memorandum of understanding (MOU) for the project outlining these responsibilities in greater detail.

8.3 Estimated Cost

Costs under this alternative are presented in Table 12 and include planning and design, permitting, and construction costs:

- **Planning and Design Costs**: Planning and design costs associated with this alternative are estimated at $20,000 to perform site assessment and develop planning and design documents. These costs are incorporated into the capital costs.

- **Permitting Costs:** Permitting costs associated with this alternative are estimated at $12,000 to complete FPA, HPA, and county-code development and reporting requirements.

- **Construction Cost:** Construction costs are low at $91,000 to construct structures along an 8,450 feet section of stream that averages 60 feet wide with 1- to 4.5-foot-deep incisions and has a gradient of 4.1 percent.

Table 10. Localized Reservoir Flow Augmentation Cost Estimate Summary

Alt	Description	Capital Cost	20-years O&M	Permitting Costs	Total Costs	Costs per Acre-Foot
7	Alluvial Water Storage	$91,000	$60,000	$12,000	$163,000	$8,300

8.4 Recommendations and Next Steps

Alluvial water storage offers a holistic approach to extend the domestic reserve and improve water quality. The cost per acre foot is modest; however, additional study is necessary to evaluate the benefits to streamflow from year to year and for a range of average and low precipitation years.

Next steps are to:

- Record a covenant for stream restoration projects that are charged to the domestic reserve.
- Incorporate alluvial water storage into County code and the County reserve auditing system.
- Continue studies to evaluate duration and volume of water available for mitigating the domestic reserve, and water-quality benefits.

9 Alternative 8 – Reserve Exchange

The Wenatchee Watershed Planning Unit established subwatersheds based on hydrologic characteristics. This alternative evaluates the demarcation of the Mission and Wenatchee basins based on the hydrogeology. Determining which surface water body groundwater withdrawals debit will allow CCNRD to maintain a more accurate reserve accounting. Additionally, with passage of ESSB6091, the Mission Creek Basin reserve is evaluated based on Ecology's new consumptive-use guidance. A detailed analysis is provided in Appendix E.

9.1 Hydrogeologic Framework

Mission Creek and Brender Creek leave their respective canyons and flow across a glacial terrace. The glacial terrace is the area of interest for defining the boundary between the Mission Basin and the Lower Wenatachee River Basin based on hydrogeology. The surrounding Chumstick Formation sandstone forms the structural basin that hosts unconsolidated sedimentary units. Mission Creek flows atop a clayey sand and gravel deposit (alluvium) that is stratified with clayey units that both perch and confine water-bearing zones. A clayey unit extends past Woodring Canyon within the Mission Canyon and up Brender Canyon.

Mission Creek and Brender Creek appear to have incised older unconsolidated deposits (e.g., glacial lacustrine sediments). For example, clayey appears discontinuous between the terminus of Mission Canyon and Woodring Canyon. The discontinuous nature of the unit is presumed to represent where fluvial action has a channelized-portions layer. Whereas, Brender Creek has not incised the underlying units, likely due to smaller volume and lower intensity peak flow events. It is our interpretation that the clayey unit is a glacial lacustrine unit that largely separates the primary water-supply unit from the Mission Creek and Brender Creek. The clayey, glacial lacustrine unit forms a semiconfining layer across the greater Cashmere Sedimentary Basin.

Pumping groundwater for permit-exempt beneficial use within the hydrogeologic defined basin is anticipated to transmit stream depletion onto the Wenatchee River. Present day Brender Creek and Mission Creek are hydraulically separated from the primary water supply aquifer within the hydrogeologic basin due to:

- The vertical separation between potentiometric surfaces that suggests an unsaturated condition exists between surface water and groundwater.
- The presence of a thick (~20 feet) clayey unit that forms a confining unit that effectively increases that hydraulic continuity of the aquifer with the Wenatchee River.

Defining the Mission Basin on hydrogeologic characteristics adds the Cashmere Sedimentary Basin to the Lower Wenatchee River Basin and truncates the Mission Basin to near the terminus of Brender and Mission canyons. This potential change of the basin boundary reallocates reserve quantities from the Mission Basin to the Lower Wenatchee Basin.

9.2 Consumptive Use

Following passage of ESSB 6091, Ecology developed a guidance for estimating water use by permit-exempt domestic wells. Ecology's recommendation for estimating consumptive use is to assume 60 gallons per day per capita (gpd/capita) and a consumptive use (CU) percentage of 10 percent of total indoor use. In CCNRD's assessment of the reserve through 2011 (Aspect, 2013), the accounting assumed 200 gpd per exempt well, based on WDOH Water System Design Manual (WDOH, 2009) and a consumptive factor of 30 percent. In addition, outdoor CU was estimated through aerial imagery analysis of irrigated area on parcels served by permit-exempt wells. The aerial analysis revealed that parcels in the Mission Basin, served by permit-exempt wells, have an average irrigated area of 0.17 acres. This is the largest average-irrigated-area-per-parcel highest-total irrigation requirements for the Wenatchee Basin.

Using Ecology's recommended assumptions and actual growth rates through 2016 results in the following reserve accounting changes from the previous analysis.

	200 GPD, 30 Percent CU	**60 GPD/Capita, 10 Percent CU**
Reserve Depletion Year	2013	2015
Number Parcels Served [1]	31	33

1 – Assumes one house per parcel (2.04 persons per house) and all parcels have outdoor use

The actual growth rate (parcels per year) from 2008 through 2016 is 5.13, which is lower than the 6.86 parcels per year assumed in the Wenatchee Watershed Management Plan (WWPU, 2006).

9.3 Estimated Cost

The costs associated with this alternative are administrative and are associated with the Reserve Allocation Report by CCNRD to Ecology.

Table 11. Reserve Exchange Cost Estimate Summary

Alt	**Description**	**Capital Cost**	**20-years O&M**	**Permitting Costs**	**Total Costs**	**Costs per Acre-Foot**
8	Reserve Exchange	$0	$0	$0	$0	$0

Notes:

9.4 Recommendations and Next Steps

Basins are more accurately defined when hydrogeologic characteristics are considered along with topography. The hydrogeologic characteristics allow for water resource managers to accurately account where surface water impacts are likely to accrue due to growth in permit-exempt water use. This appraisal level review is based on well logs provided by drillers for domestic and municipal water supply. This level of analysis and dataset may not provide the level of certainty necessary change the Basin boundaries for administration of the reserve for permit-exempt beneficial use. Aspect recommends CCNRD work with stakeholders and Ecology to determine what level of certainty is necessary to carry forward modification of the Mission Basin boundary. An example of work plan elements should include:

- Installation of instream piezometers and monitoring wells in a transect to monitor water levels and vertical gradients overtime; and

- Detailed collection of lithology over maximum 2-feet centers, and water levels during monitoring well installation.

Additionally, Aspect recommends CCNRD:

- Update the outdoor consumptive use analysis by increasing the number of parcels evaluated with aerial imagery and a window survey to determine if the 0.17-acre area is representative of the Mission Basin. For example, a 10 percent reduction in average lawn size translates into 4 parcels.
- Evaluate parcels authorized under the reserve to determine if irrigation is attributed to a state water right.
- Work with local stakeholder concerning implementation of outdoor water-use conservation measures to limit outdoor lawn irrigation.
- Implement a geographic interface for allocating parcels to basin reserves to prevent misappropriations.

10 Conclusions

This analysis evaluated eight strategies to improve instream flow and establish a domestic reserve in the Mission Basin. While the alternatives reviewed are not yet prioritized, there is sufficient information to make recommendations for further study and implementation of projects. This appraisal concludes improving the domestic reserve in the Mission Basin would best be accomplished through a combination of water banking, surface water right conversion to groundwater, construction of a small off-channel reservoir, and exchanging a portion of the Mission Basin reserve debits to the Wenatchee Basin reserve (Alternatives 1, 2, 6, 7, and 8). The following more detailed conclusions can be drawn from the appraisal:

- Water banking appears to be a viable natural resource management strategy that would primarily benefit extension of the domestic reserve, with some smaller potential for instream-flow benefits. The Water Banking alternative has a relatively low capital cost ($125,000) and the lowest cost per acre-foot ($6,000).
- A direct comparison between the Wenatchee Pump Exchange and Regional Water Provider options is possible. The Regional Water Provider alternative offers a better value at nearly one-half the costs. However, this comes at approximately $4.5M in capital costs, extensive negotiation and study to evaluate the feasibility of implementation. The lower capital cost alternatives are more difficult to directly compare due to unknown administrative costs and impracticability to implement at a regional scale.
- Transferring Surface Water Rights to Groundwater has low total costs ($49,000) and mid-high costs per acre-foot ($27,000); however, due to the local geology, careful consideration is necessary in siting irrigation wells to ensure a reliable supply. In contrast, streamflow augmentation via pumping groundwater (Alternative 5) has mid-range total costs ($471,000) and low-range costs per acre-foot ($8,400); however, due to the geology, year-to-year withdrawal of groundwater can lead to an increase potential for stream depletion within Mission Basin with no reduction in surface water withdrawals. Even-though streamflow augmentation has a lower cost per acre-foot, it is more practical when the objective is localized flow improvement.
- The Localized Reservoir Flow Augmentation alternative has a relatively moderate capital cost ($416,000) and the highest costs per acre-foot ($57,600) over a 20-year period; however, this alternative offers a reliable method to capture winter runoff for mitigation for permit-exempt wells. It is not practicable to scale this option up to a regional solution.
- The Alluvial Water Storage alternative is one of the lowest cost per acre foot ($8,300) options. This alternative requires additional study to determine the quantity of water available for mitigation of the domestic reserve; however, it offers additional water-quality benefits. This alternative is also consistent with water-resource solutions sought under ESSB 6091 and offers a model demonstration project for streamflow restoration.
- Revising the basin based on hydrogeology allows for a more accurate reserve accounting. Evaluation of the hydrogeology in the lower Mission Basin indicates that at least 17 parcels (0.015 cfs) currently charged to the Mission Basin reserve withdraw water from the Wenatchee Basin. Additionally, applying the ESSB 6091 consumptive-use guidance extends

the Mission Basin reserve by 0.0002 cfs. The combination of reallocating permit-exempt water use and applying Ecology's consumptive-use guidance extends the Mission Basin reserve 2 years based on actual growth. This is the lowest costs alternative to implement. All costs are associated with existing reserve accounting and reporting program.

Based on this analysis, it is recommended that CCNRD meet with local stakeholders to review options and proceed towards implementation of several of the alternatives that provide more immediate success, while continuing to evaluate long-term options.

11 References

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12 Limitations

Work for this project was performed for the Chelan County Natural Resources Department (Client), and this report was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

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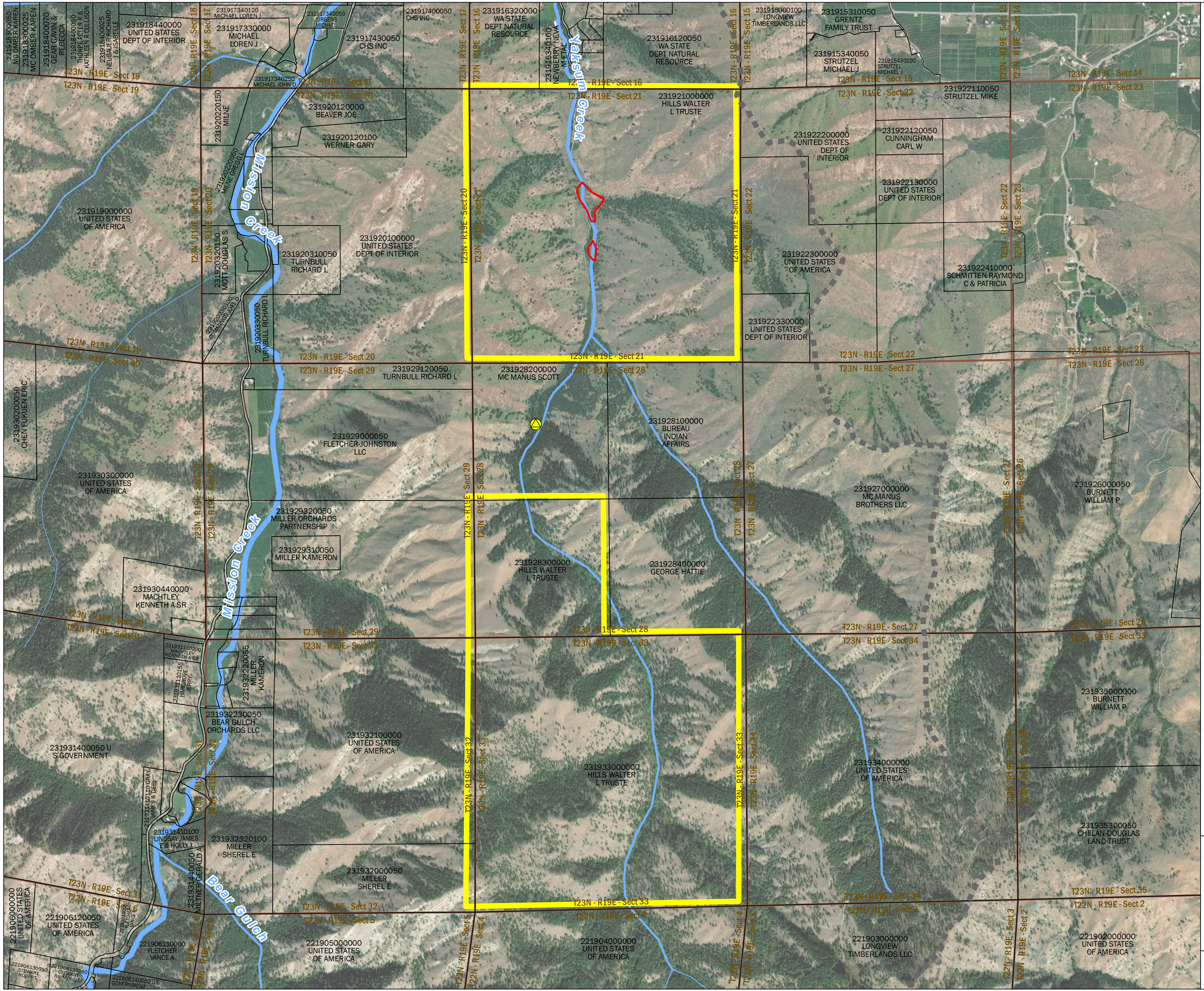
APPENDIX A

Mission Creek Water Right Review Map Book (Aspect, 2015)



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info

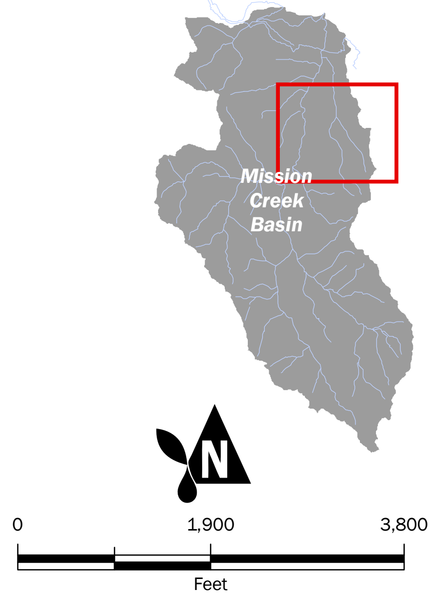
Water Right Number: S4-004798CL
Water Right Type: Claim L
Purpose: Domestic (General), Irrigation, Stock Watering
Irrigated Acres: 150
Instantaneous Rate (cfs): 372
Annual Volume (acre-feet): 320
Name On Water Right: HILLS, WALTER L.

Note:

Irrigation ranges from 4.2 to 5.1 acres from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

🟥	Aerial Photo Delineated Irrigated Areas
🟨	Water Right Place of Use (from Ecology GWIS)
▲	Approximate Point of Withdrawal for Given Water Right
☐	Sections
▨	Mission Creek Basin Boundary
☐	Tax Parcels

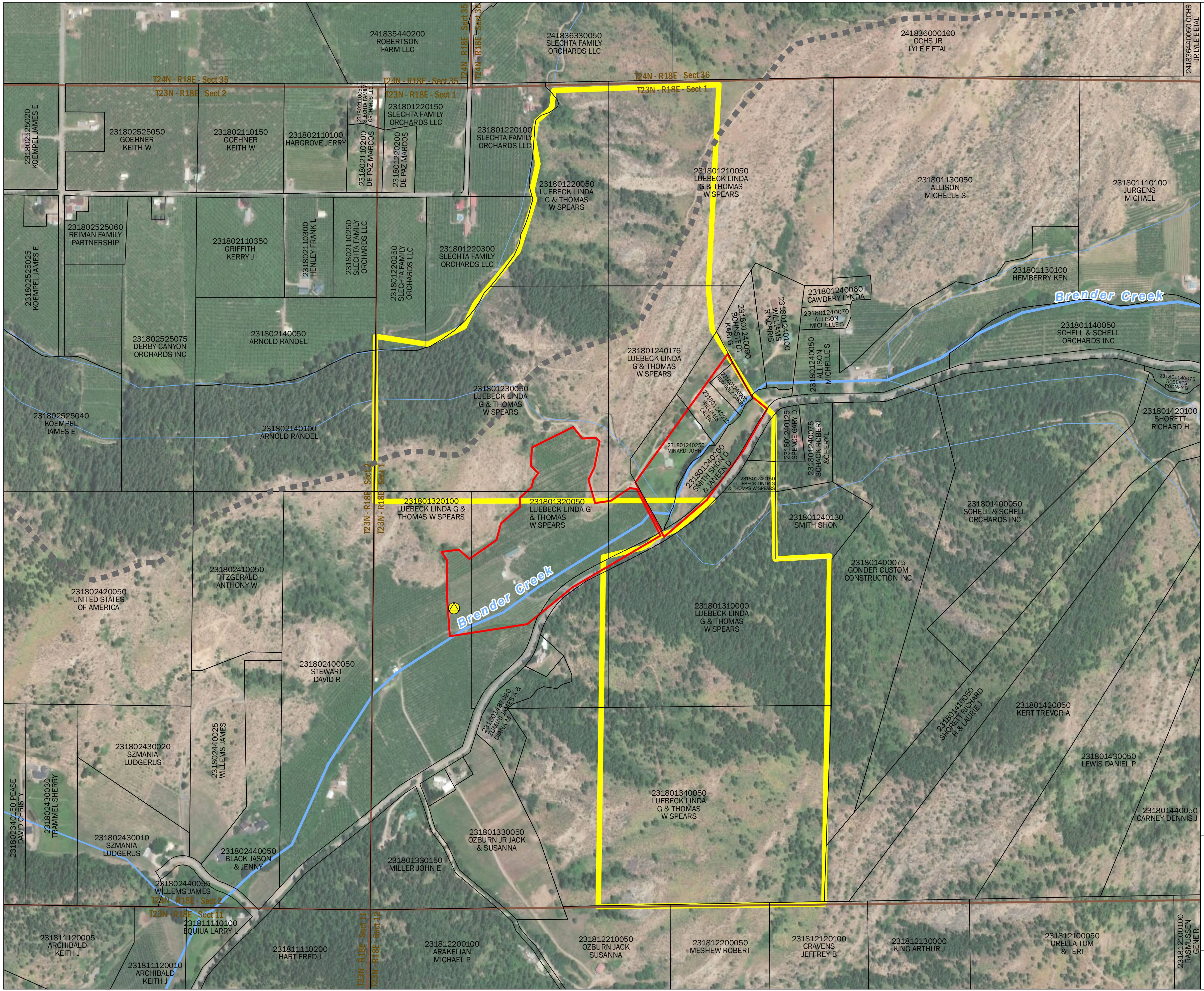


S4-004798CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO.
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	A-1

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trullen || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-113247CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 40
Instantaneous Rate (cfs):
Annual Volume (acre-feet): 17.6
Name On Water Right: SPEARS, BEVE T

Note:

Irrigation of approximately 30 acres is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

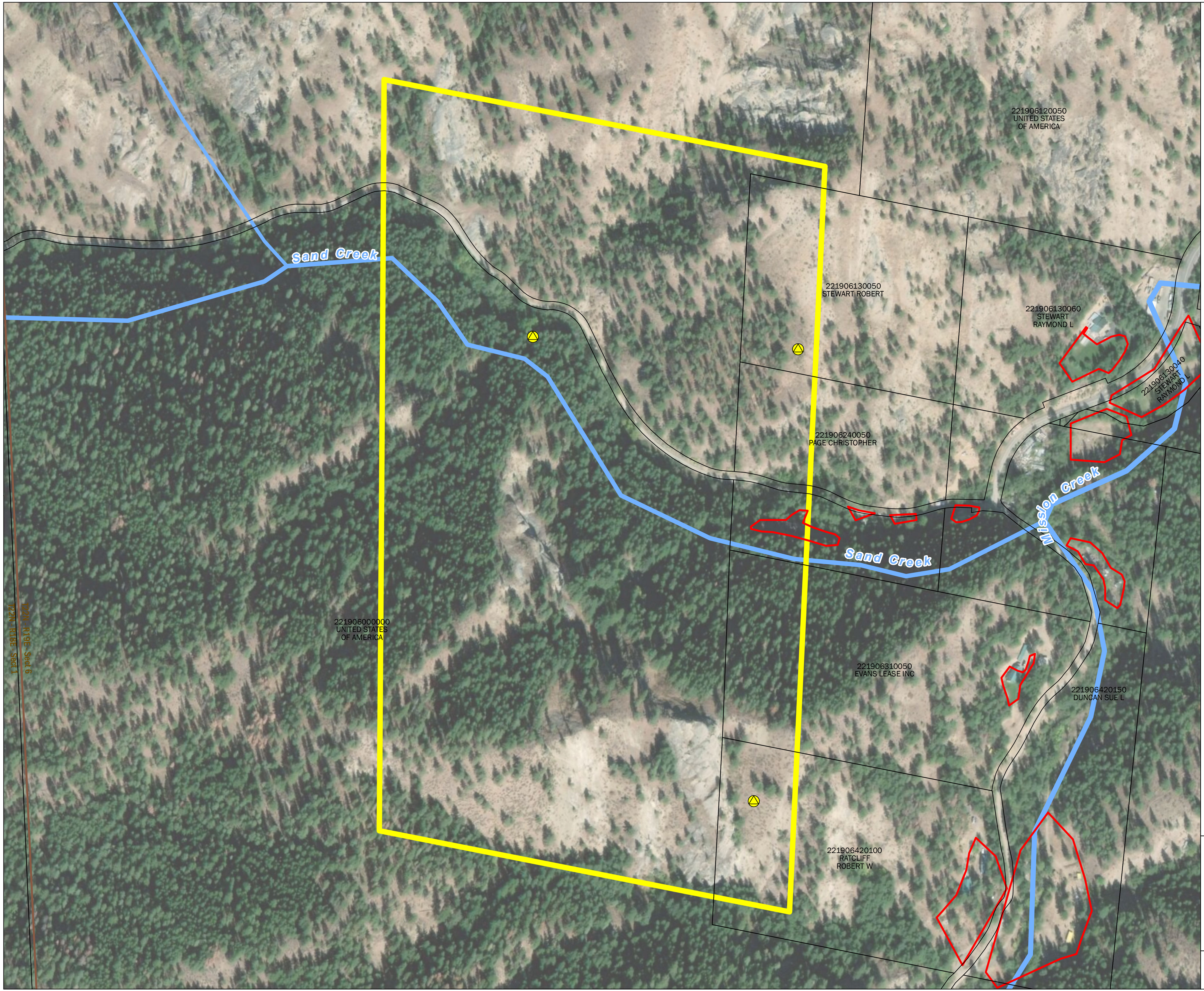
🟥	Aerial Photo Delineated Irrigated Areas
🟨	Water Right Place of Use (from Ecology GWIS)
●	Approximate Point of Withdrawal for Given Water Right
☐	Sections
⬚	Mission Creek Basin Boundary
☐	Tax Parcels

S4-113247CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO. A-2
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-070227CL
Water Right Type: Claim L
Purpose: Irrigation, Stock Watering
Irrigated Acres: 40
Instantaneous Rate (cfs): 0.08
Annual Volume (acre-feet): 160
Name On Water Right: STEWART, LEO

Note:

Irrigation ranges from 8.0 to 8.4 acres from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

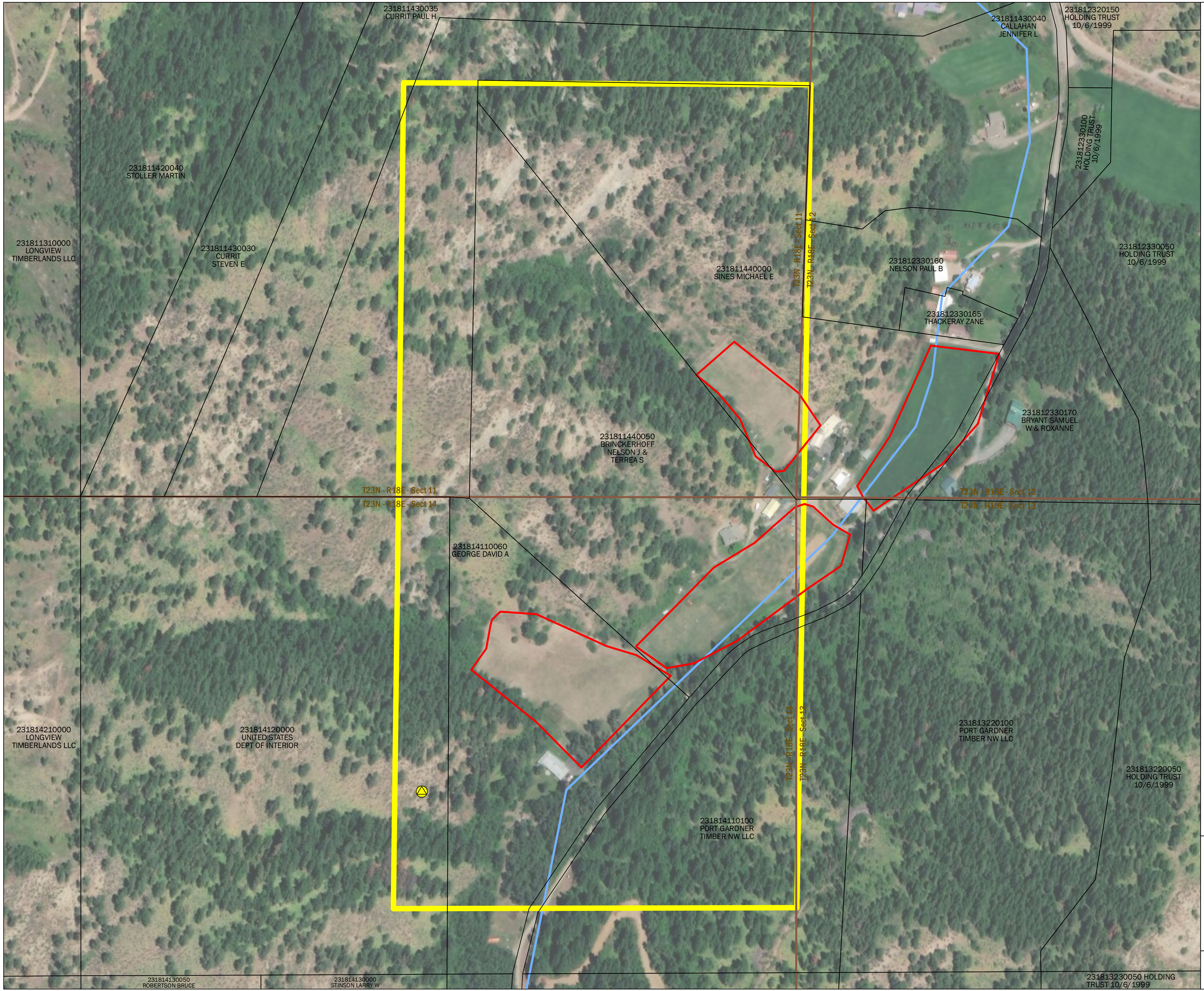
🟥	Aerial Photo Delineated Irrigated Areas
🟨	Water Right Place of Use (from Ecology GWIS)
▲	Approximate Point of Withdrawal for Given Water Right
☐	Sections
⬚	Mission Creek Basin Boundary
☐	Tax Parcels

S4-070227CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO.
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	A-3

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-061757CL
Water Right Type: Claim L
Purpose: Domestic (General), Irrigation
Irrigated Acres: 40
Instantaneous Rate (cfs):
Annual Volume (acre-feet): 1.6
Name On Water Right: ,

Note:

Irrigation ranges from 8.5 to 11.0 acres from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

🟥	Aerial Photo Delineated Irrigated Areas
🟨	Water Right Place of Use (from Ecology GWIS)
▲	Approximate Point of Withdrawal for Given Water Right
☐	Sections
⬚	Mission Creek Basin Boundary
☐	Tax Parcels

S4-061757CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING

JUL-2018	BY: PPW	FIGURE NO.	
PROJECT NO. 120045-009	REVISED BY: JE / RAP	A-4	

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018

Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info

Water Right Number: S4-007884CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 40
Instantaneous Rate (cfs):
Annual Volume (acre-feet):
Name On Water Right: DEJONG, KARL H.

Note:

Irrigation ranges from 7.0 to 9.0 acres from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

🟥	Aerial Photo Delineated Irrigated Areas
🟨	Water Right Place of Use (from Ecology GWIS)
▲	Approximate Point of Withdrawal for Given Water Right
☐	Sections
⬚	Mission Creek Basin Boundary
☐	Tax Parcels

0 150 300
Feet

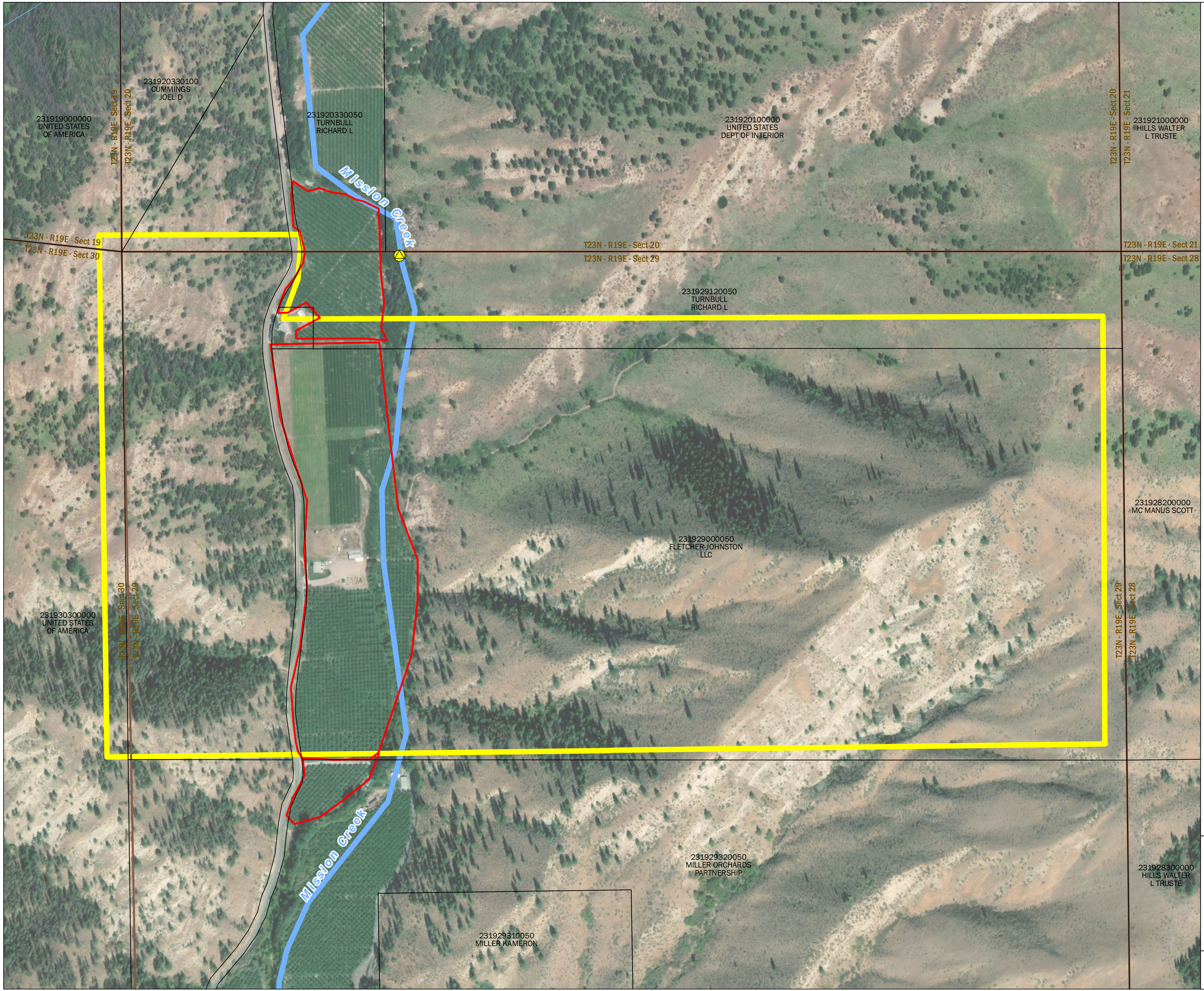
S4-007884CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING

JUL-2018	BY: PPW	FIGURE NO.
PROJECT NO. 120045-009	REVISED BY: JE / RAP	A-5

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info

Water Right Number: S4-103438CL
Water Right Type: Claim L
Purpose: Irrigation, Stock Watering
Irrigated Acres: 32
Instantaneous Rate (cfs): 0.4
Annual Volume (acre-feet): 102
Name On Water Right: MC WILLIAMS, ROBERT A

Note:

Irrigation of approximately 30.1 acres is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

Aerial Photo Delineated Irrigated Areas
Water Right Place of Use (from Ecology GWIS)
Approximate Point of Withdrawal for Given Water Right
Sections
Mission Creek Basin Boundary
Tax Parcels

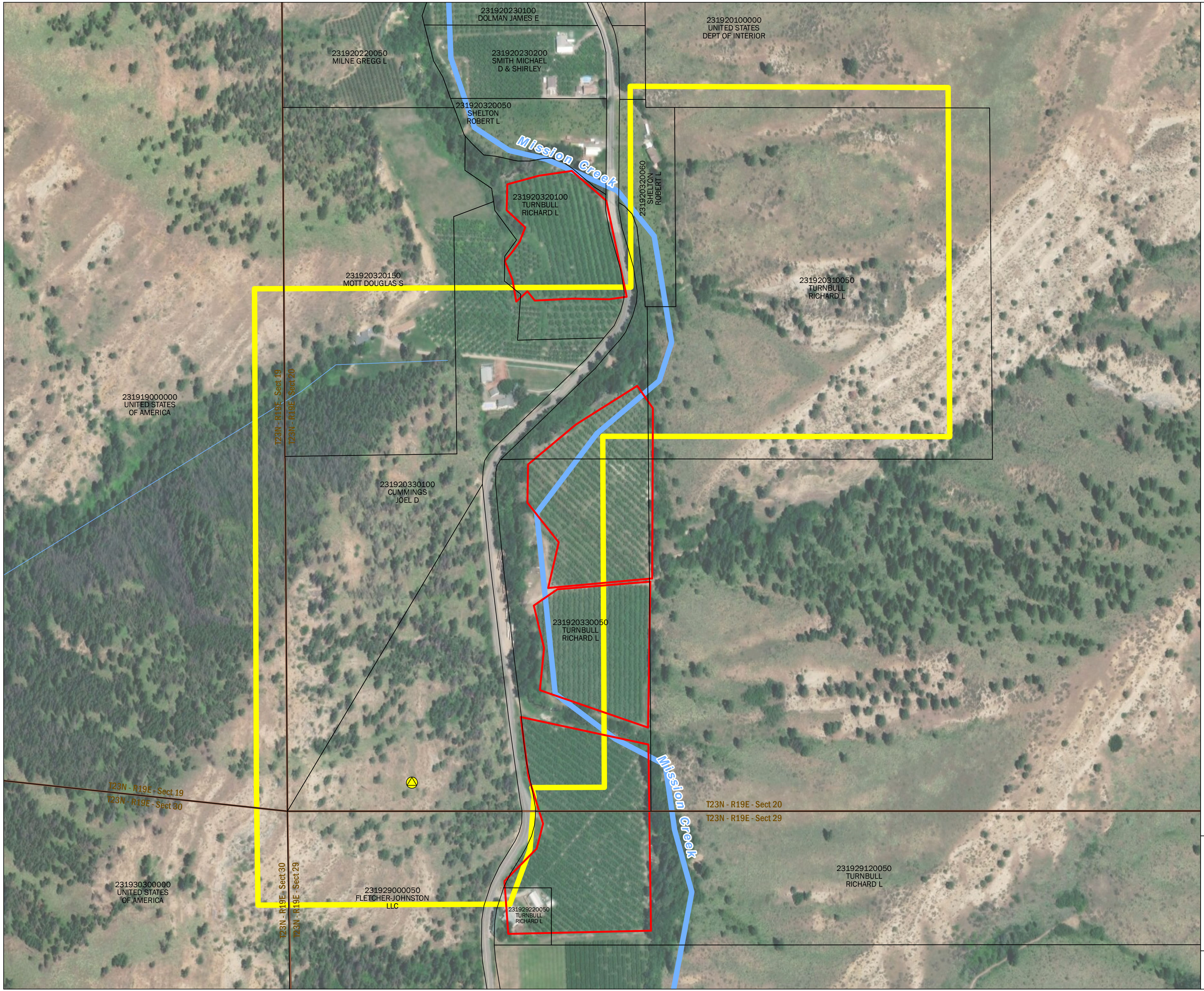
S4-103438CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING

JUL-2018	BY: PPW	FIGURE NO.
PROJECT NO. 120045-009	REVISED BY: JE / RAP	A-6

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Water Right Document Info
Water Right Number: S4-028032CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 28
Instantaneous Rate (cfs):
Annual Volume (acre-feet):
Name On Water Right: WATERS, J. T.

Note:

Irrigation of approximately 28.6 acres is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

- 🟥 Aerial Photo Delineated Irrigated Areas
- 🟨 Water Right Place of Use (from Ecology GWIS)
- ⚠ Approximate Point of Withdrawal for Given Water Right
- ☐ Sections
- ⬚ Mission Creek Basin Boundary
- ☐ Tax Parcels

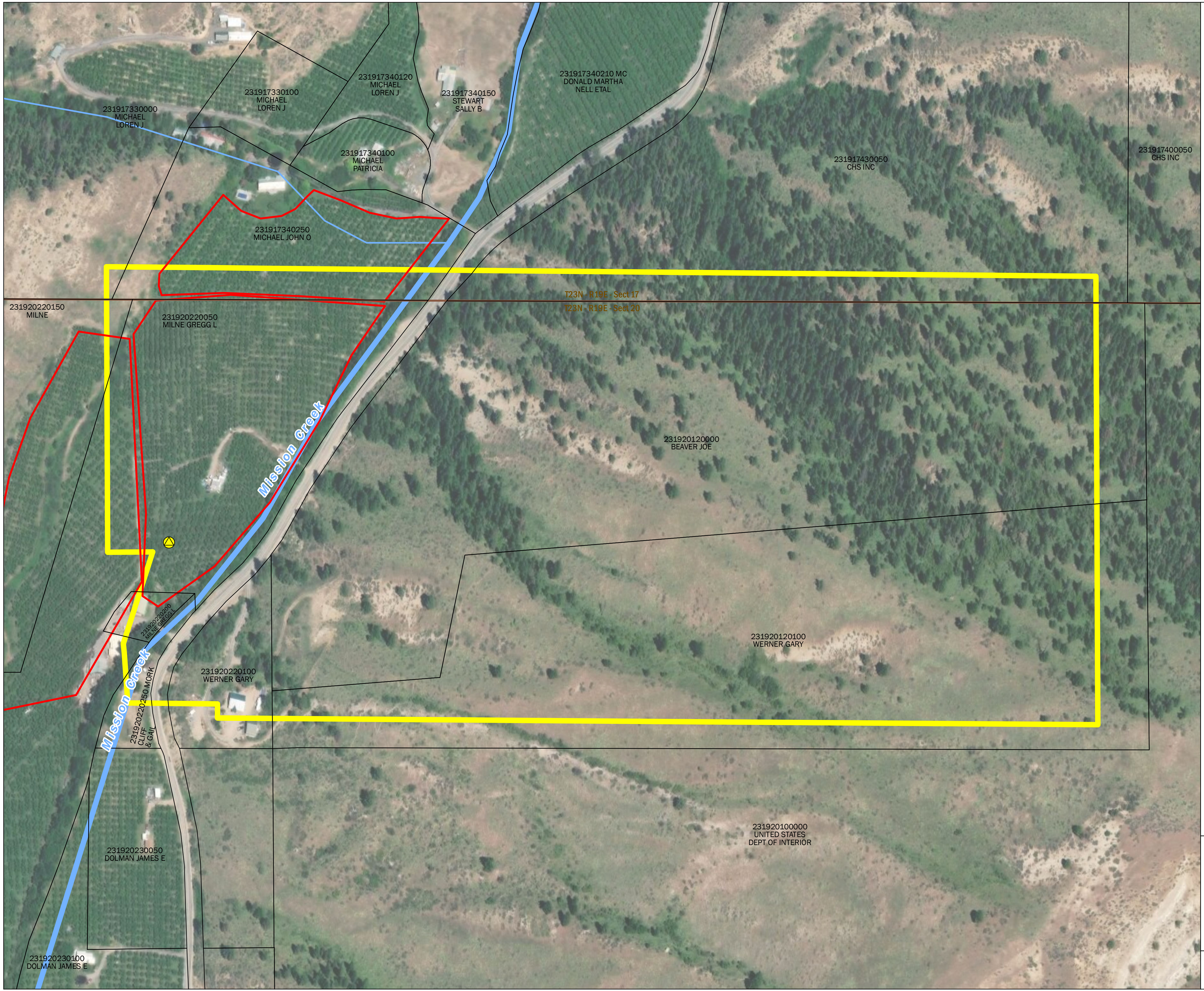
S4-028032CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO. A-7
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	

Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-151518CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 27
Instantaneous Rate (cfs):
Annual Volume (acre-feet): 13
Name On Water Right: MALLOCK, GEORGE E

Note:

Irrigation ranges from 19.6 to 24.2 acres from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

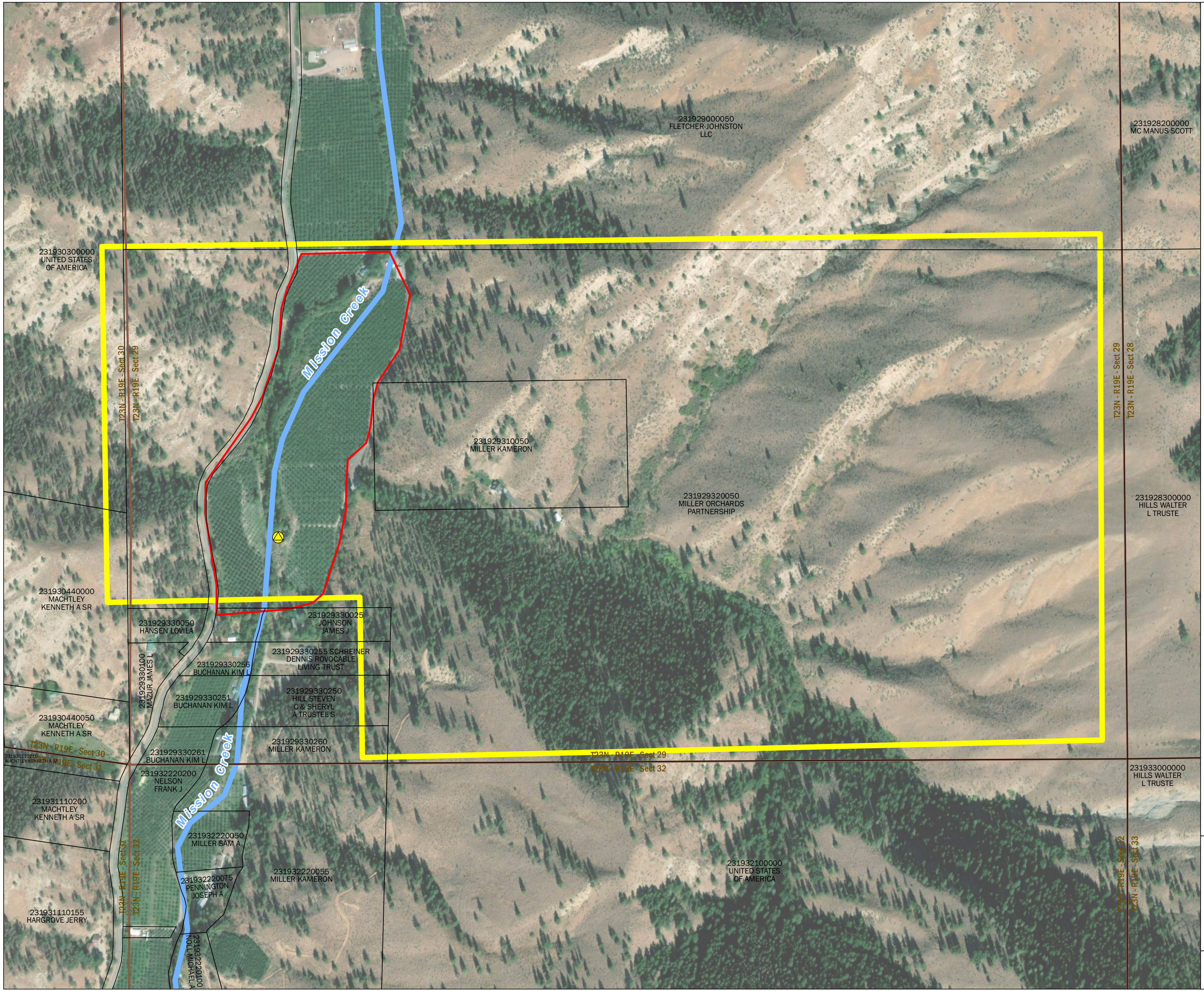
Aerial Photo Delineated Irrigated Areas
Water Right Place of Use (from Ecology GWIS)
Approximate Point of Withdrawal for Given Water Right
Sections
Mission Creek Basin Boundary
Tax Parcels

S4-151518CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO.
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	**A-8**

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

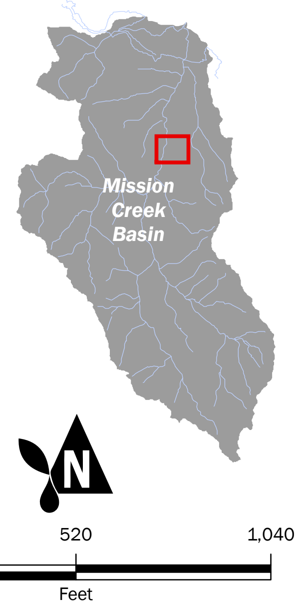
Water Right Document Info
Water Right Number: S4-033395CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 25
Instantaneous Rate (cfs): 0.313
Annual Volume (acre-feet): 113
Name On Water Right: DOYLE, HOMER

Note:

Irrigation of approximately 29 acres is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

- 🟥 Aerial Photo Delineated Irrigated Areas
- 🟨 Water Right Place of Use (from Ecology GWIS)
- ▲ Approximate Point of Withdrawal for Given Water Right
- ☐ Sections
- ⬚ Mission Creek Basin Boundary
- ☐ Tax Parcels

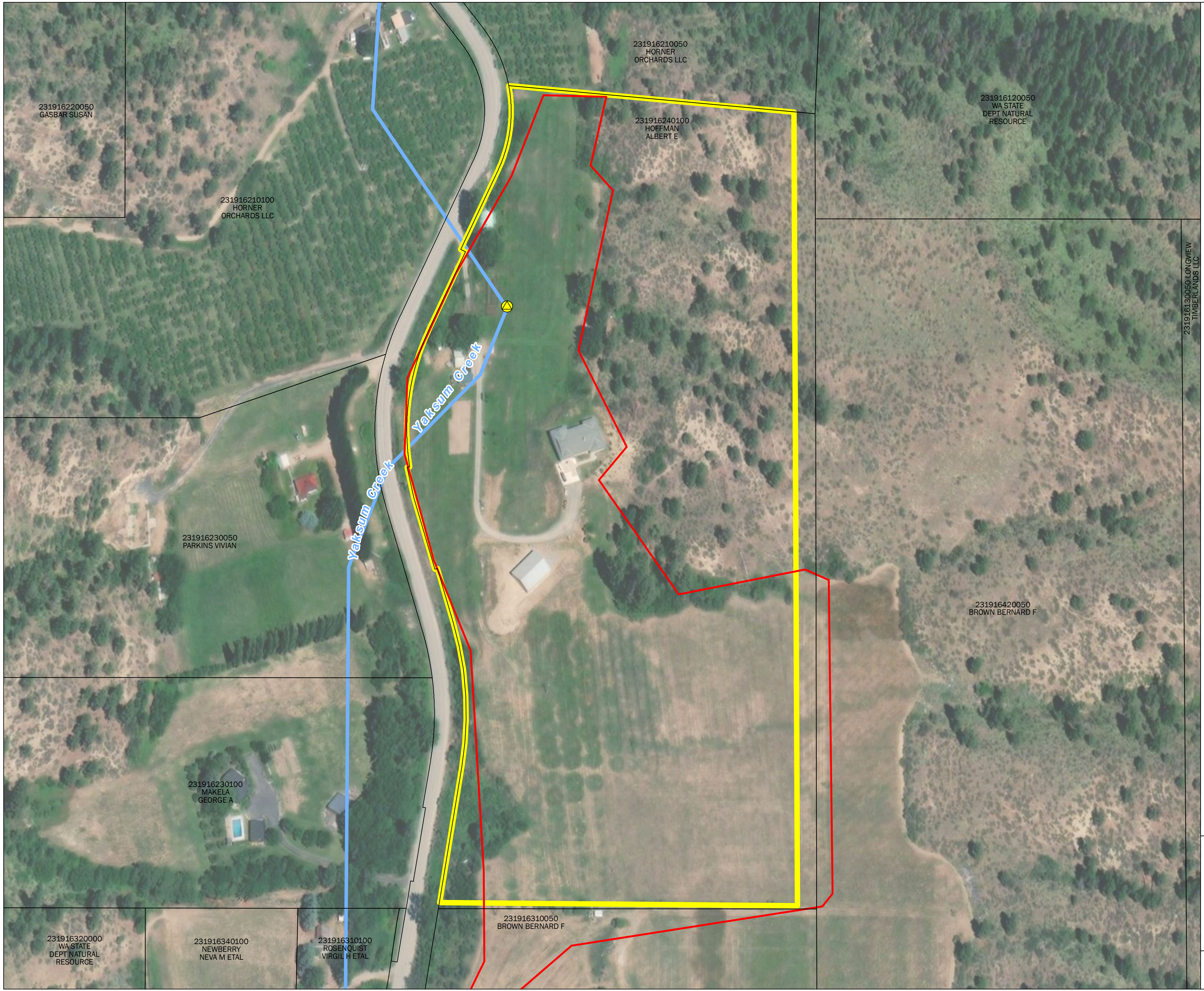


S4-033395CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO. **A-9**
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-300897CL
Water Right Type: Claim
Purpose: Irrigation
Irrigated Acres: 24.8
Instantaneous Rate (cfs): 1
Annual Volume (acre-feet): 5
Name On Water Right: HOFFMAN, MABEL

Note:

Irrigation of approximately 16.1 acres is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

Aerial Photo Delineated Irrigated Areas
Water Right Place of Use (from Ecology GWIS)
Approximate Point of Withdrawal for Given Water Right
Sections
Mission Creek Basin Boundary
Tax Parcels

S4-300897CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING

JUL-2018	BY: PPW	FIGURE NO. **A-10**
PROJECT NO. 120045-009	REVISED BY: JE / RAP	

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018

Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: SWC08901
Water Right Type: Cert
Purpose: Domestic (Single), Irrigation
Irrigated Acres: 20
Instantaneous Rate (cfs): 0.41
Annual Volume (acre-feet): 80
Name On Water Right: ,

Note:

Irrigation ranges from 25.0 acres to 32.0 acres from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

- Aerial Photo Delineated Irrigated Areas
- 🟨 Water Right Place of Use (from Ecology GWIS)
- ▲ Approximate Point of Withdrawal for Given Water Right
- ☐ Sections
- Mission Creek Basin Boundary
- Tax Parcels

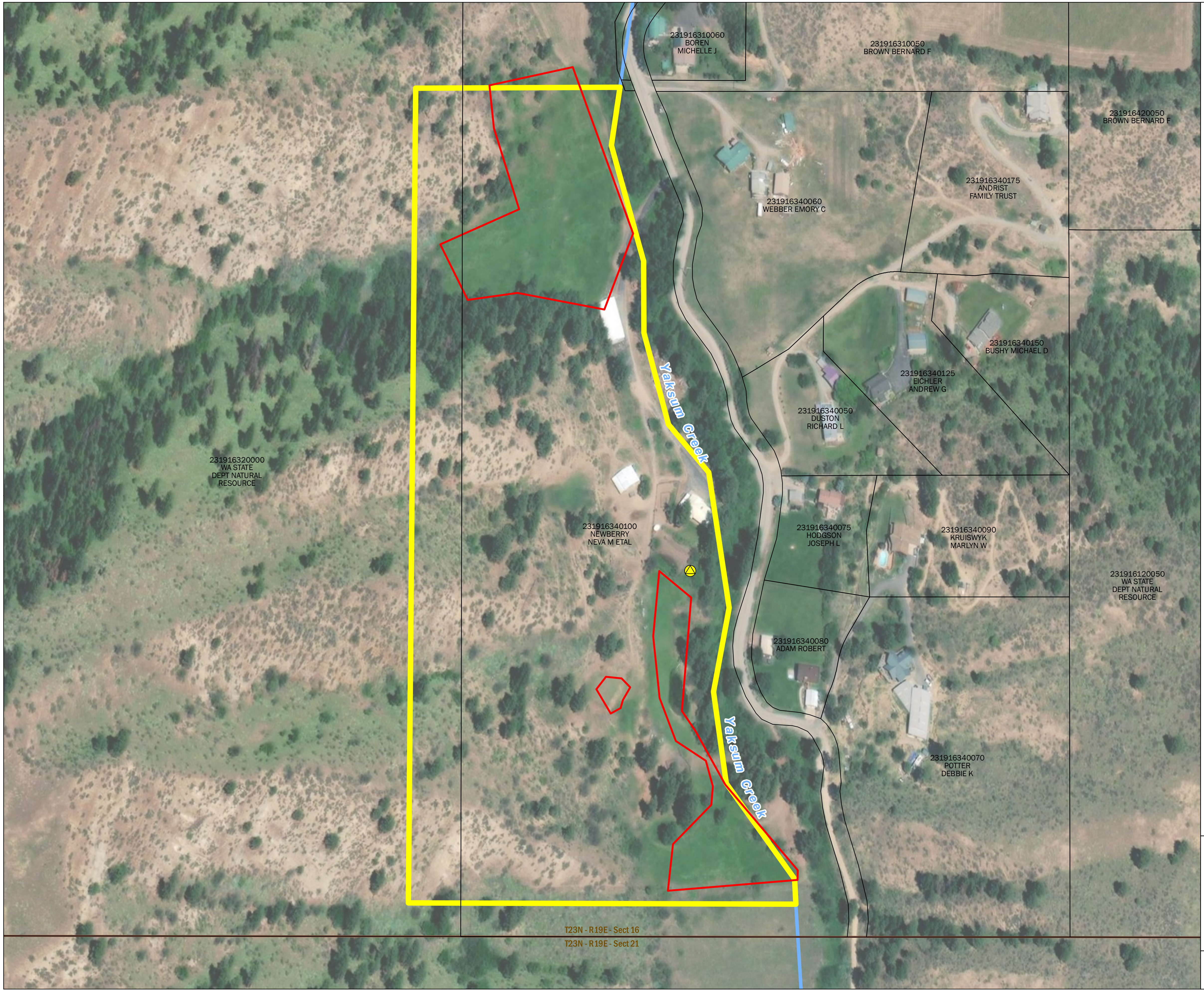
SWC08901

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING

JUL-2018	BY: PPW	FIGURE NO.	
PROJECT NO. 120045-009	REVISED BY: JE / RAP	A-11	

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045\009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: lrulen || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-200113CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 20
Instantaneous Rate (cfs):
Annual Volume (acre-feet): 70
Name On Water Right: ,

Note:

Irrigation ranges from 1.0 to 4.8 acres from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

- Aerial Photo Delineated Irrigated Areas
- Water Right Place of Use (from Ecology GWIS)
- ▲ Approximate Point of Withdrawal for Given Water Right
- ☐ Sections
- Mission Creek Basin Boundary
- Tax Parcels

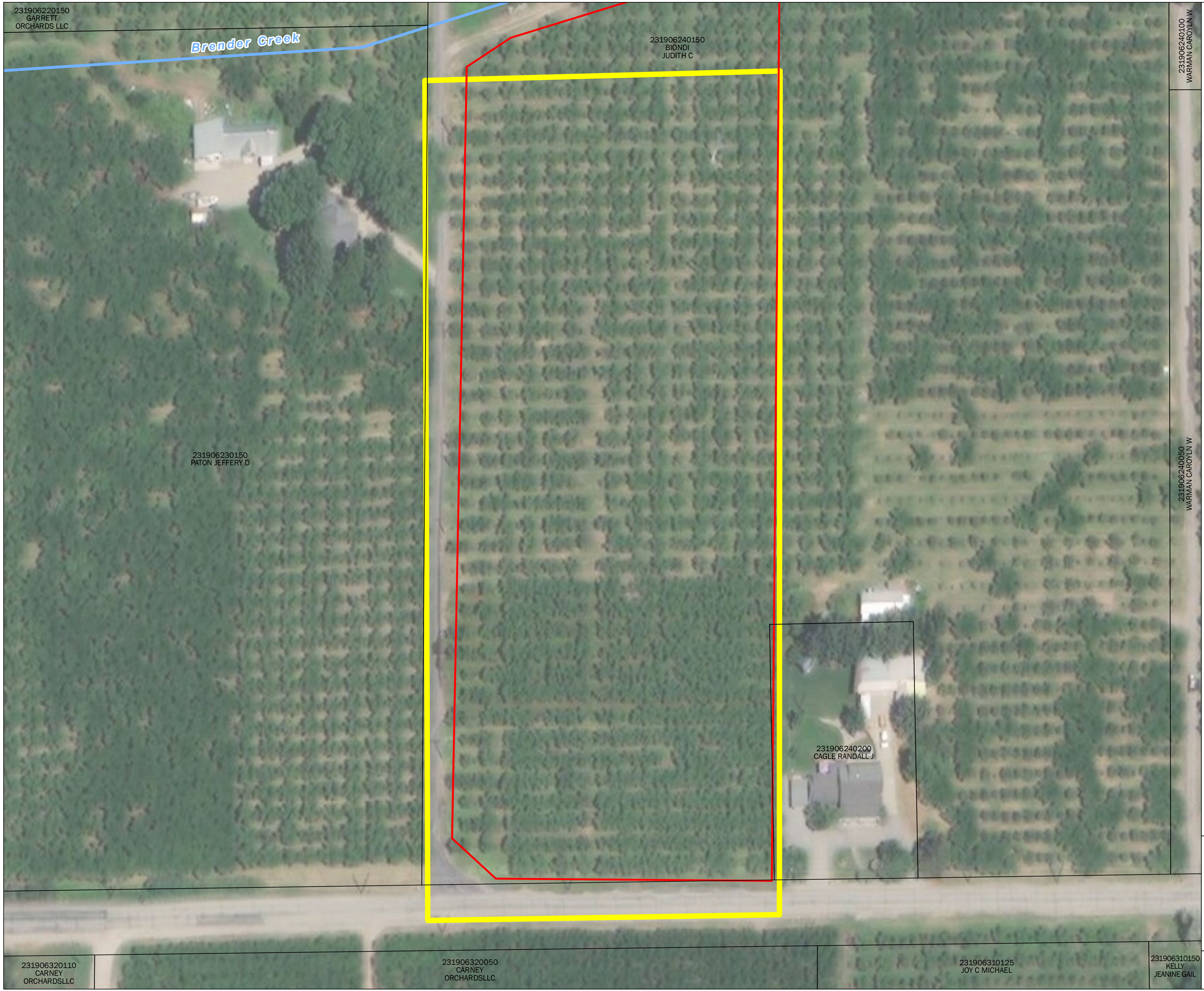
S4-200113CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING

JUL-2018	BY: PPW	FIGURE NO.
PROJECT NO. 120045-009	REVISED BY: JE / RAP	A-12

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-115791CL
Water Right Type: Claim L
Purpose: Domestic (General), Irrigation
Irrigated Acres: 20
Instantaneous Rate (cfs):
Annual Volume (acre-feet):
Name On Water Right: SLECHTA, DOYLE B

Note:

Irrigation of approximately 5.8 acres is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

🟥	Aerial Photo Delineated Irrigated Areas
🟨	Water Right Place of Use (from Ecology GWIS)
▲	Approximate Point of Withdrawal for Given Water Right
☐	Sections
⬚	Mission Creek Basin Boundary
☐	Tax Parcels

S4-115791CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018 PROJECT NO. 120045-009	BY: PPW REVISED BY: JE / RAP	FIGURE NO. **A-13**

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018

Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-093712CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 20
Instantaneous Rate (cfs):
Annual Volume (acre-feet): 15
Name On Water Right: BRENDER, MELVIN B

Note:

There is no irrigation from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

Aerial Photo Delineated Irrigated Areas

Water Right Place of Use (from Ecology GWIS)

Approximate Point of Withdrawal for Given Water Right

Sections

Mission Creek Basin Boundary

Tax Parcels

N

0 150 300
Feet

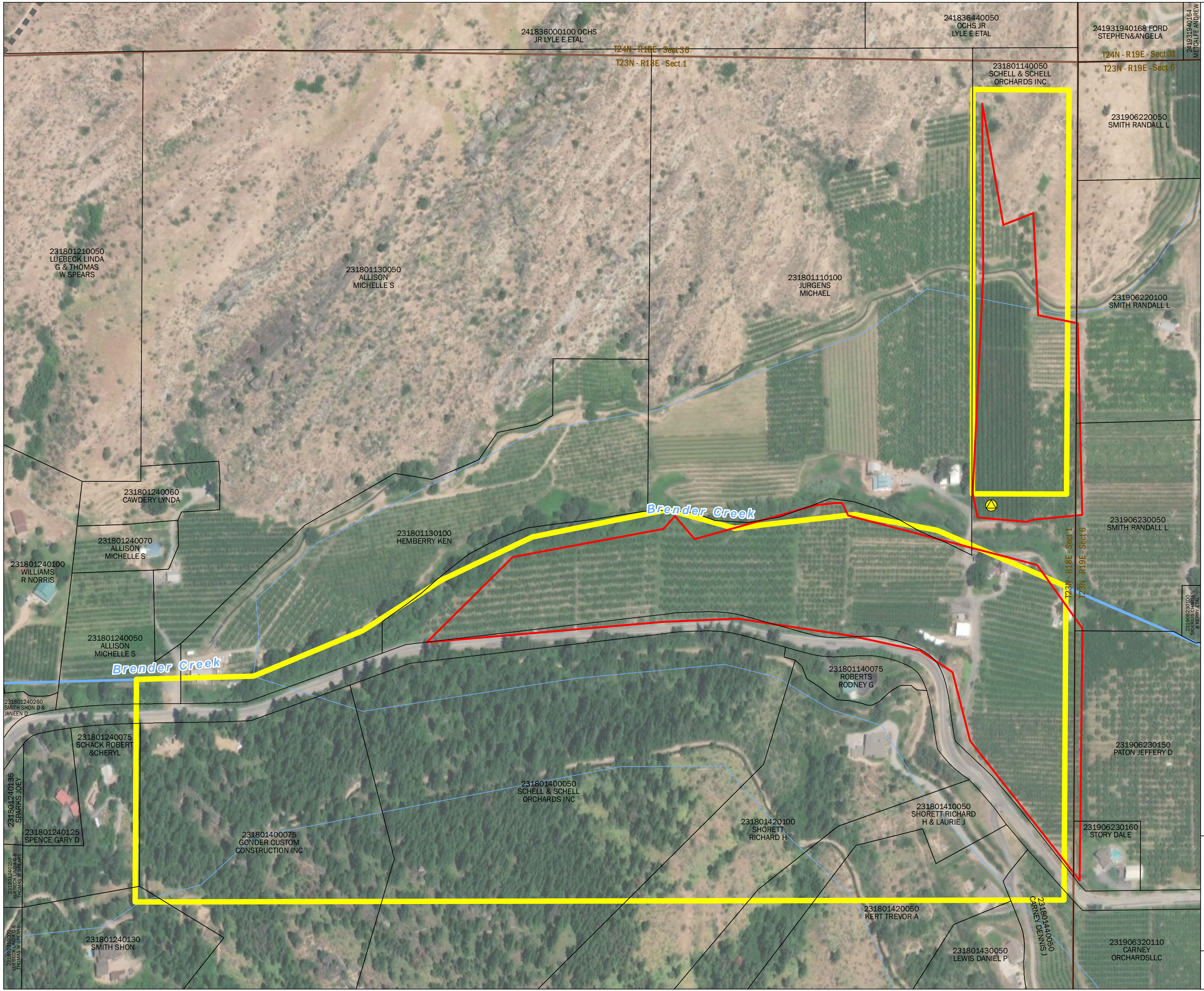
S4-093712CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING

JUL-2018	BY: PPW	FIGURE NO.
PROJECT NO. 120045-009	REVISED BY: JE / RAP	A-14

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info

Water Right Number: S4-032694CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 20
Instantaneous Rate (cfs): 0.5
Annual Volume (acre-feet): 80
Name On Water Right: SCHELL, A. ELIZABETH

Note:

Irrigation of approximately 22.8 acres is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

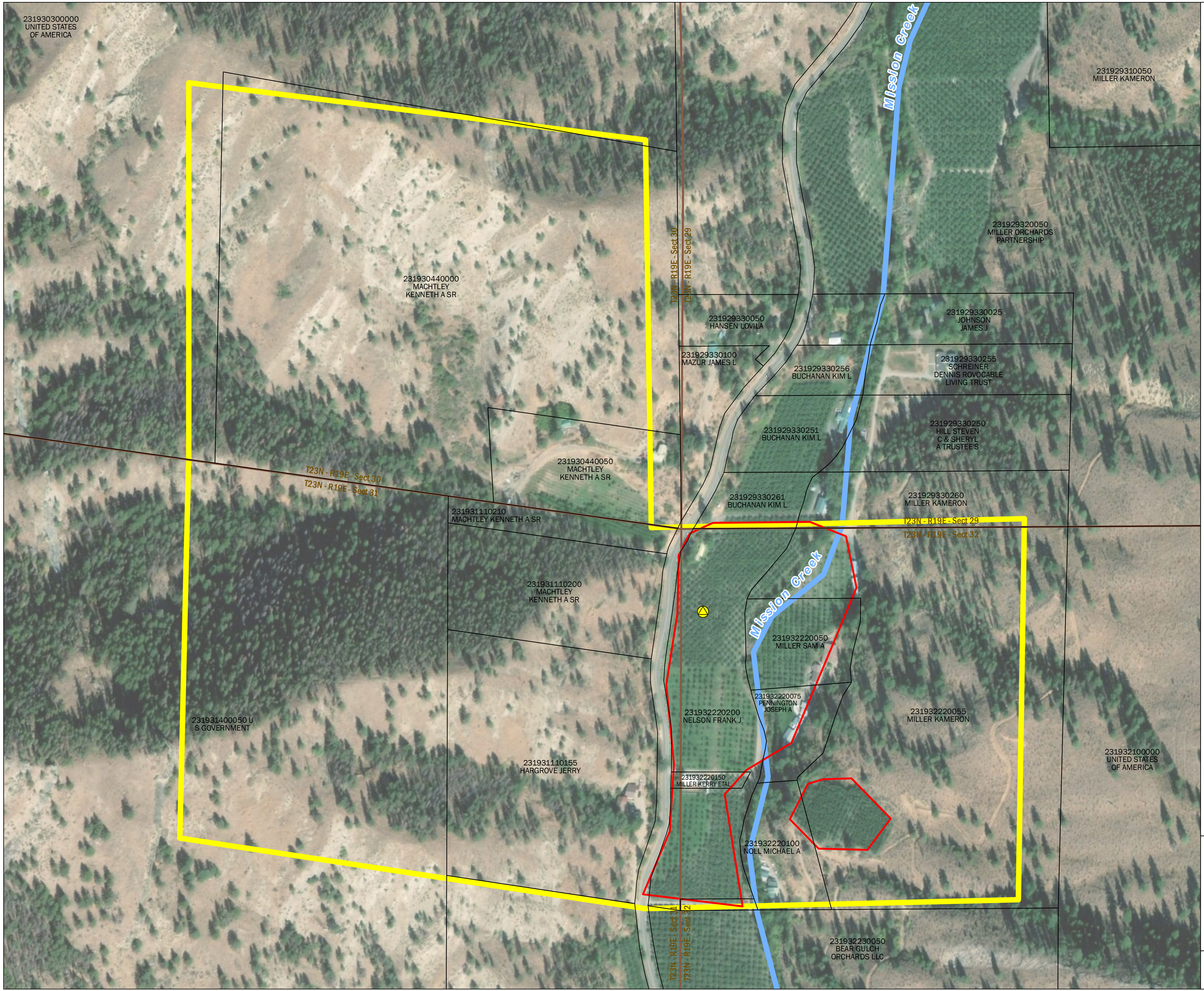
🟥	Aerial Photo Delineated Irrigated Areas
🟨	Water Right Place of Use (from Ecology GWIS)
▲	Approximate Point of Withdrawal for Given Water Right
☐	Sections
◌	Mission Creek Basin Boundary
☐	Tax Parcels

S4-032694CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING
JUL-2018
PROJECT NO. 120045-009
BY: PPW
REVISED BY: JE / RAP
FIGURE NO. **A-15**

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-118425CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 16
Instantaneous Rate (cfs):
Annual Volume (acre-feet): 32
Name On Water Right: DOLMAN, C D

Note:

Irrigation ranges from 14.8 to 17.1 acres from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

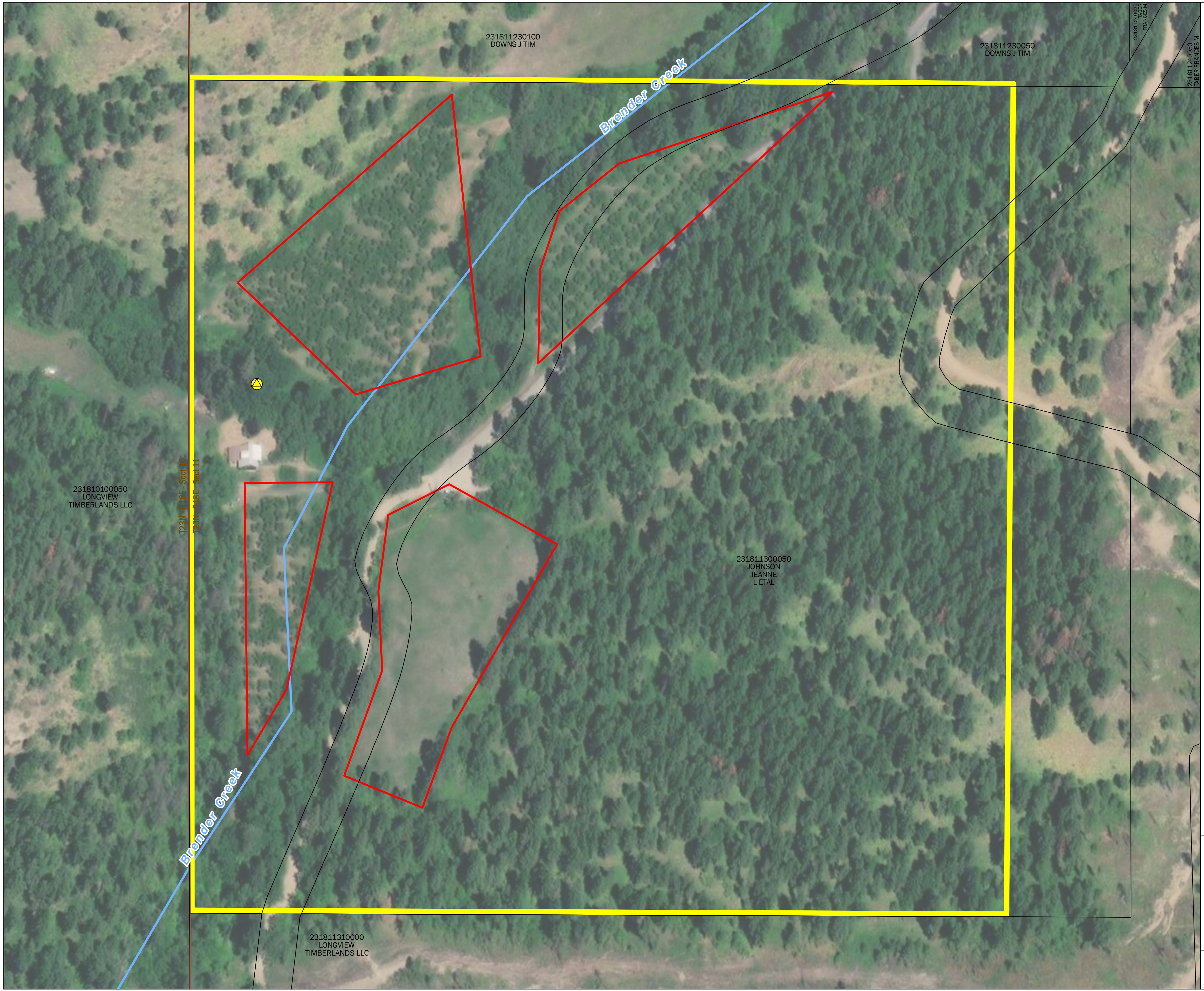
🟥	Aerial Photo Delineated Irrigated Areas
🟨	Water Right Place of Use (from Ecology GWIS)
●	Approximate Point of Withdrawal for Given Water Right
☐	Sections
◌	Mission Creek Basin Boundary
☐	Tax Parcels

S4-118425CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO.
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	A-16

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-040923CL
Water Right Type: Claim L
Purpose: Irrigation, Stock Watering
Irrigated Acres: 16
Instantaneous Rate (cfs): 1
Annual Volume (acre-feet): 64
Name On Water Right: TABER, WARREN D.

Note:

Irrigation of approximately 6.3 acres is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

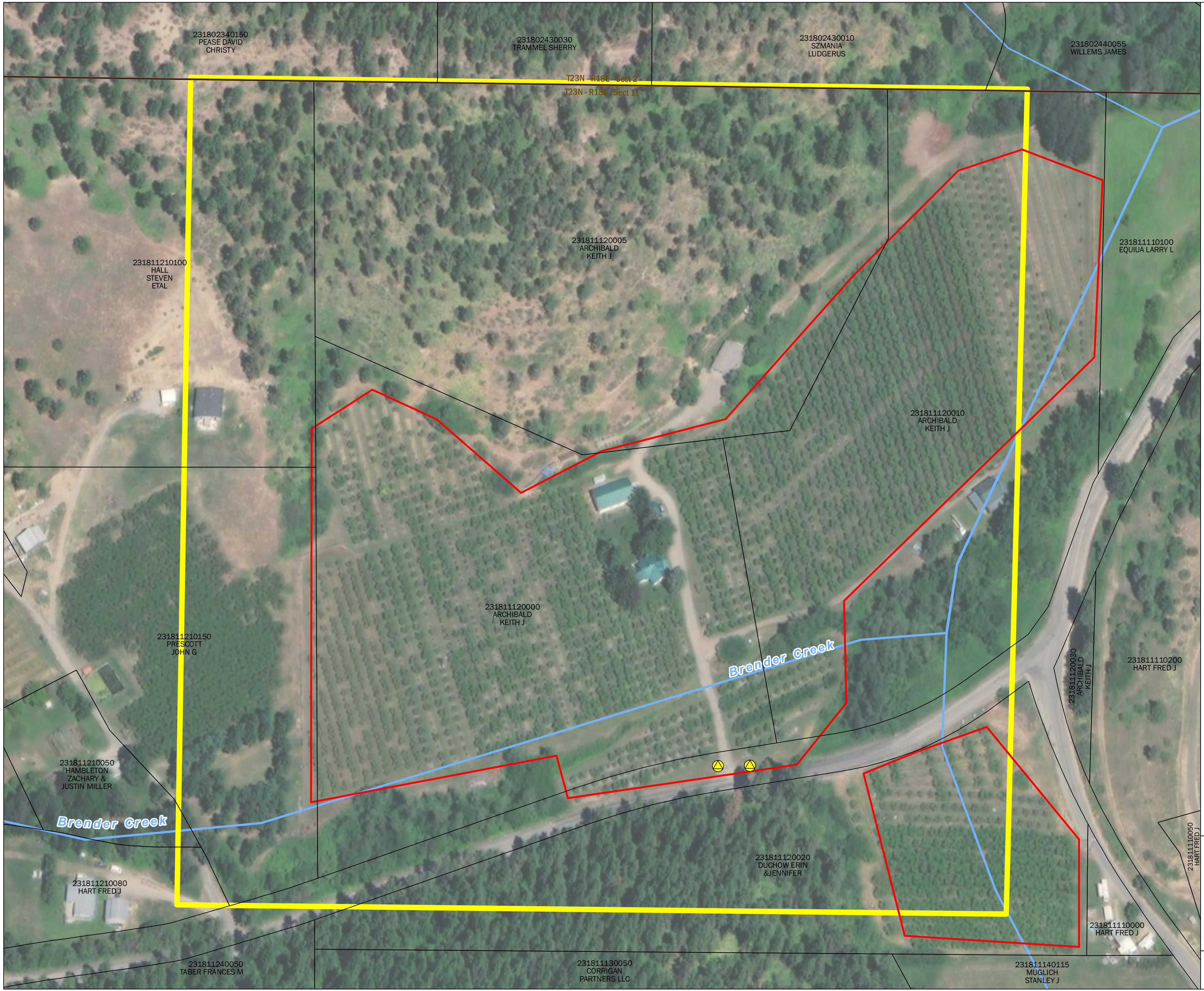
- ▭ Aerial Photo Delineated Irrigated Areas
- ▭ Water Right Place of Use (from Ecology GWIS)
- △ Approximate Point of Withdrawal for Given Water Right
- ▭ Sections
- ▭ Mission Creek Basin Boundary
- ▭ Tax Parcels

S4-040923CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO.
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	A-17

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-038034CL
Water Right Type: Claim L
Purpose: Domestic (General), Irrigation
Irrigated Acres: 15
Instantaneous Rate (cfs): 0.16
Annual Volume (acre-feet): 61
Name On Water Right: METCALF, DORTHY B.

Note:

Irrigation of approximately 16.8 acres is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

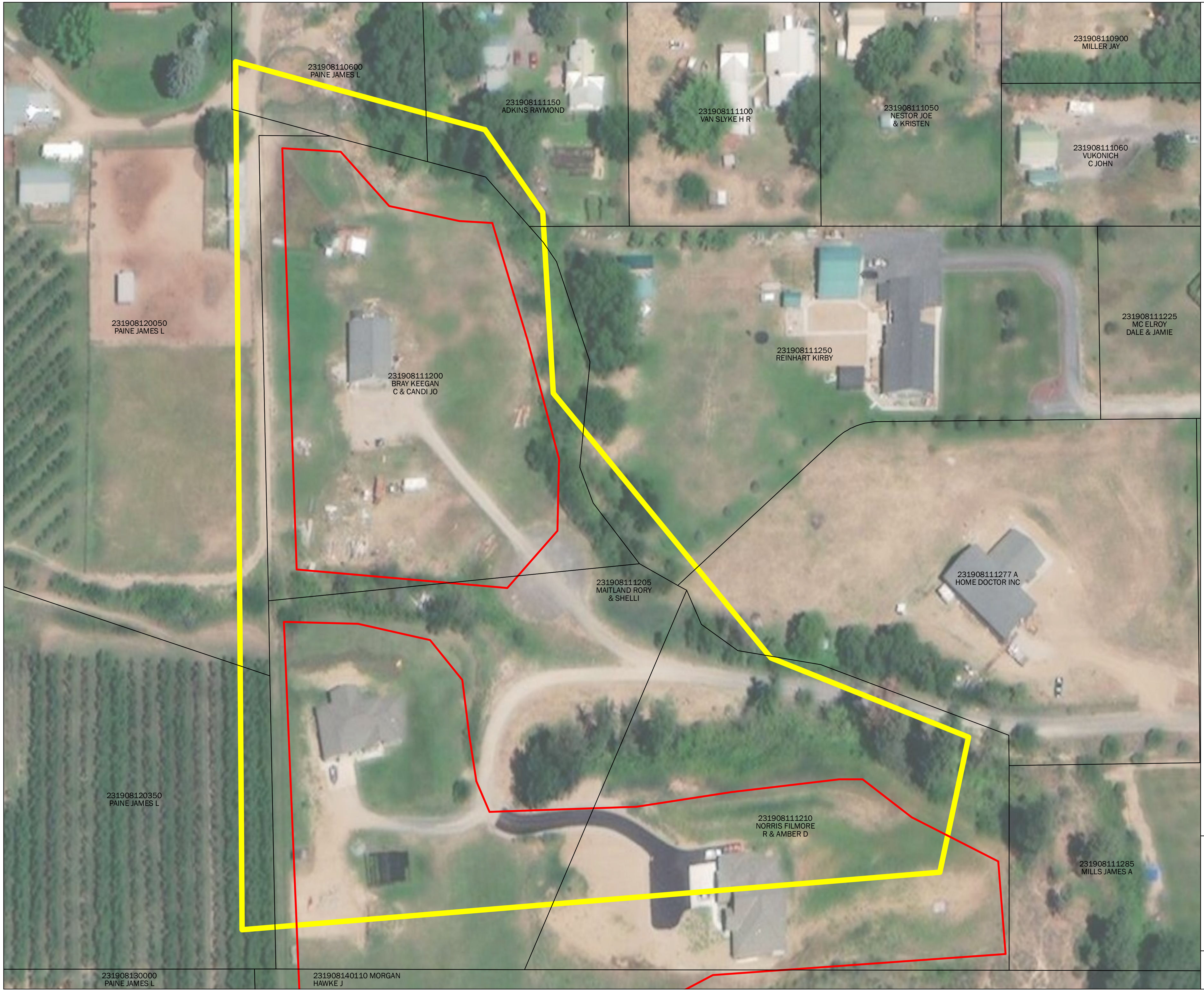
🟥 Aerial Photo Delineated Irrigated Areas
🟨 Water Right Place of Use (from Ecology GWIS)
▲ Approximate Point of Withdrawal for Given Water Right
☐ Sections
◌ Mission Creek Basin Boundary
☐ Tax Parcels

S4-038034CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO. A-18
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-136262CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 12
Instantaneous Rate (cfs):
Annual Volume (acre-feet): 10
Name On Water Right: BRUNNER, VERNON D

Note:

Irrigation ranges from 0.0 to 5.3 acres from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

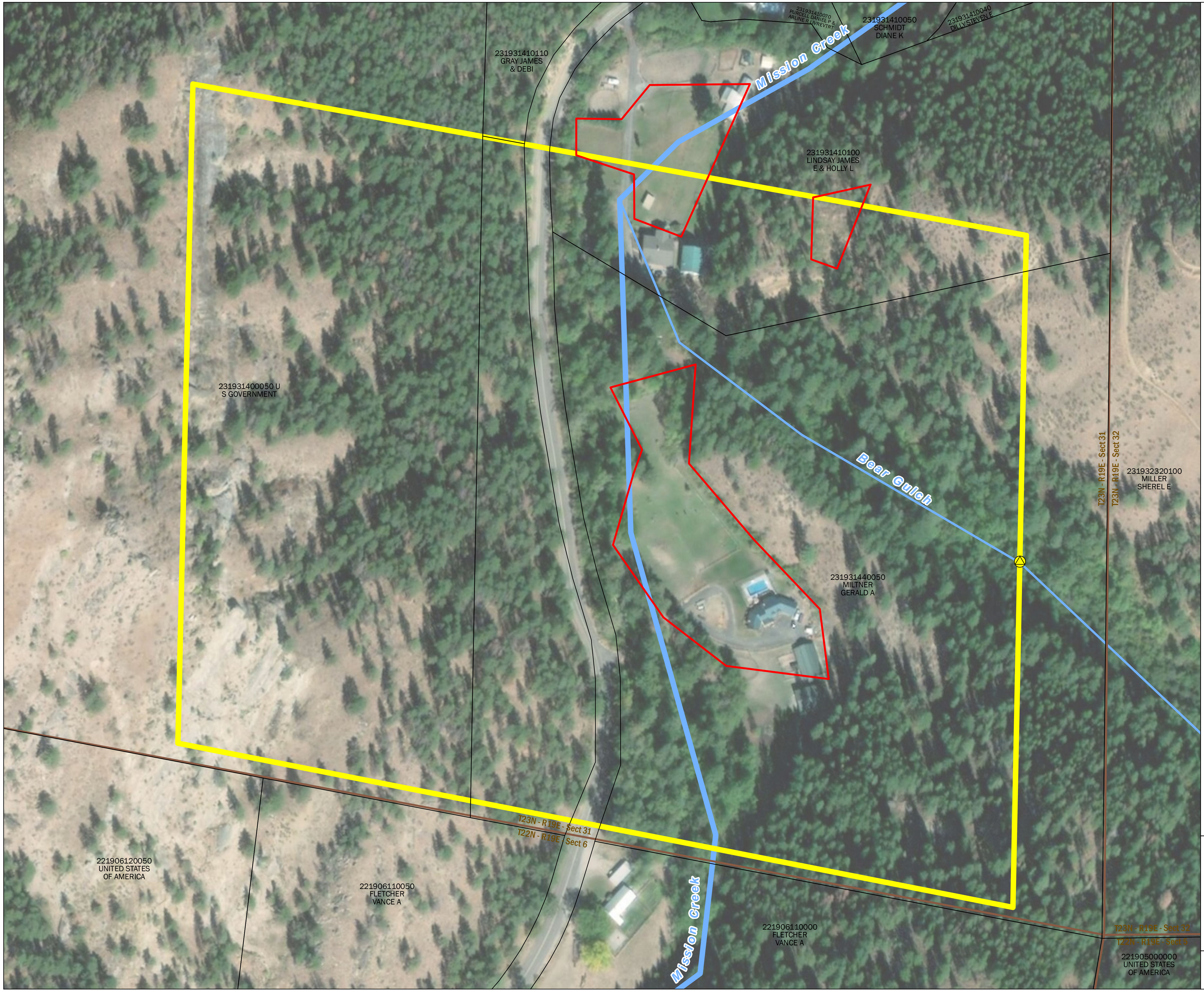
Aerial Photo Delineated Irrigated Areas
Water Right Place of Use (from Ecology GWIS)
Approximate Point of Withdrawal for Given Water Right
Sections
Mission Creek Basin Boundary
Tax Parcels

S4-136262CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO. A-19
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-200148CL
Water Right Type: Claim L
Purpose: Domestic (General), Irrigation
Irrigated Acres: 10
Instantaneous Rate (cfs): 1
Annual Volume (acre-feet): 10
Name On Water Right: ,

Note:

Irrigation ranges from 4.5 to 4.7 acres from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

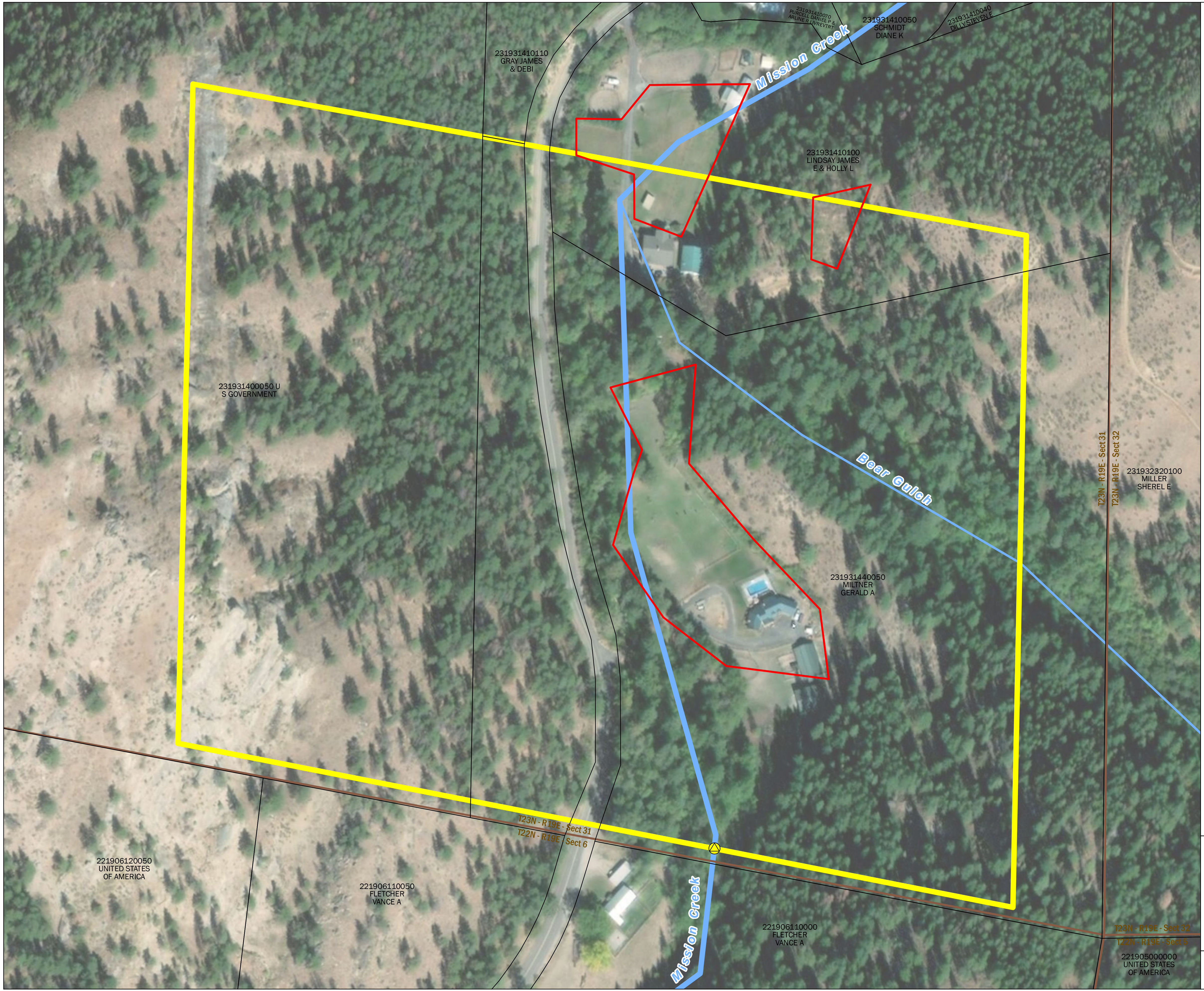
🟥	Aerial Photo Delineated Irrigated Areas
🟨	Water Right Place of Use (from Ecology GWIS)
▲	Approximate Point of Withdrawal for Given Water Right
☐	Sections
⬚	Mission Creek Basin Boundary
☐	Tax Parcels

S4-200148CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO.
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	A-20

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info

Water Right Number: S4-200147CL
Water Right Type: Claim L
Purpose: Domestic (General), Irrigation
Irrigated Acres: 10
Instantaneous Rate (cfs): 1
Annual Volume (acre-feet): 10
Name On Water Right: ,

Note:

Irrigation ranges from 4.5 to 4.7 acres from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

Aerial Photo Delineated Irrigated Areas
Water Right Place of Use (from Ecology GWIS)
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Mission Creek Basin Boundary
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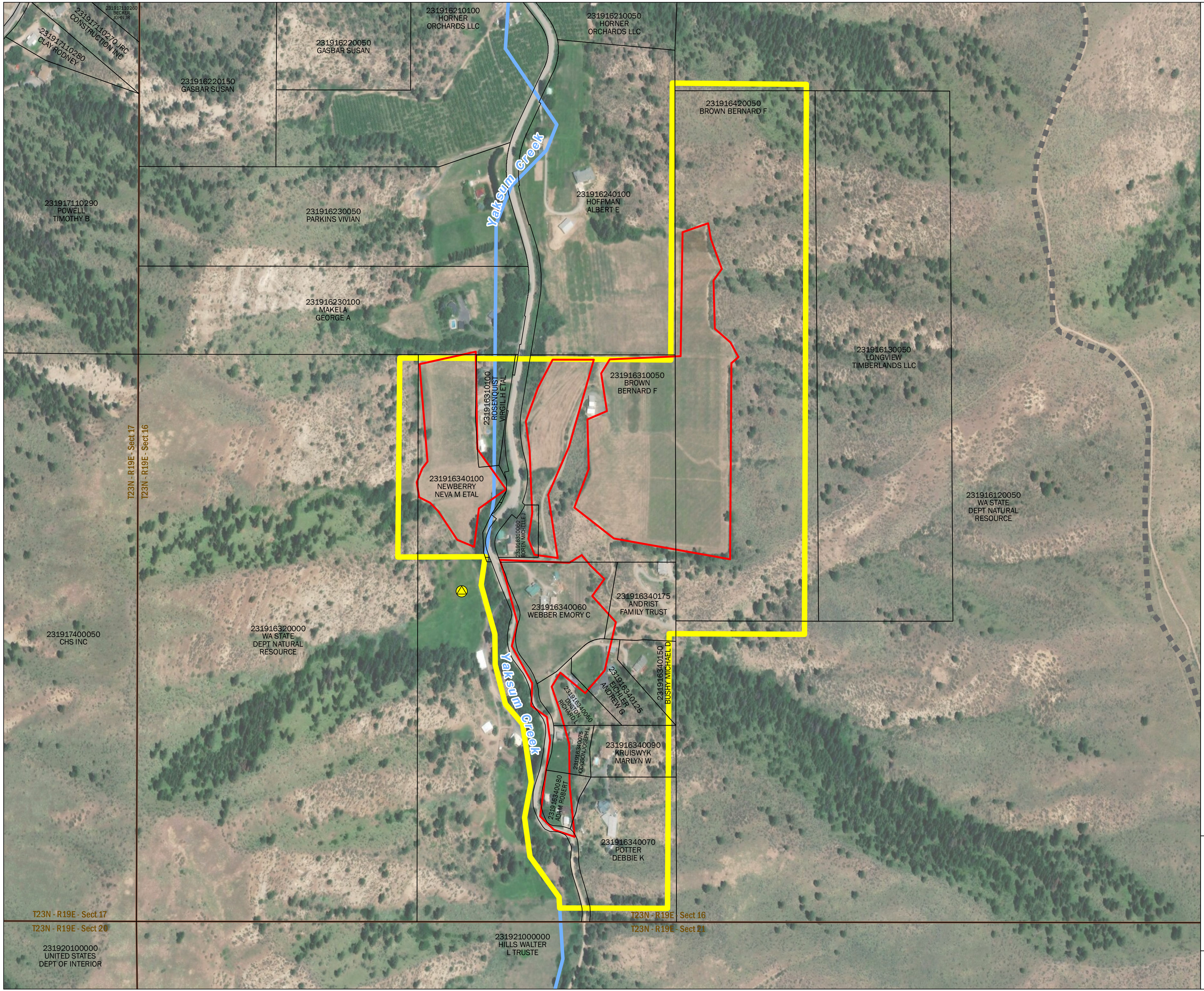
S4-200147CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING

JUL-2018
PROJECT NO. 120045-009
BY: PPW
REVISED BY: JE / RAP
FIGURE NO. **A-21**

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info

Water Right Number: S4-200126CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 10
Instantaneous Rate (cfs): 26
Annual Volume (acre-feet): 35
Name On Water Right: ,

Note:

Irrigation of approximately 34.2 acres is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

- 🟥 Aerial Photo Delineated Irrigated Areas
- 🟨 Water Right Place of Use (from Ecology GWIS)
- △ Approximate Point of Withdrawal for Given Water Right
- □ Sections
- ⬚ Mission Creek Basin Boundary
- ▭ Tax Parcels

S4-200126CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

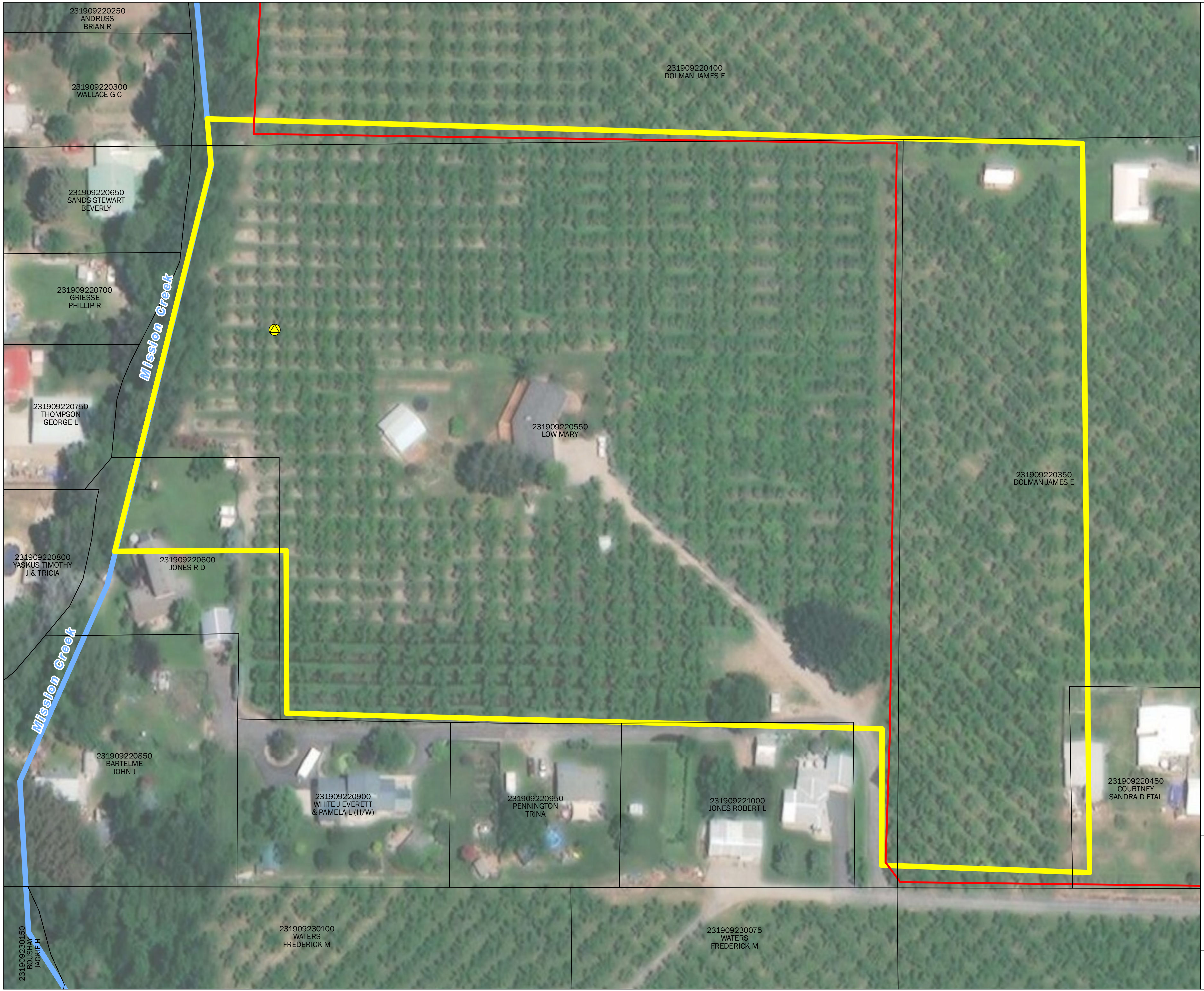
Aspect CONSULTING

JUL-2018
PROJECT NO.
120045-009

BY:
PPW
REVISED BY:
JE / RAP

FIGURE NO.
A-22

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-122677CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 10
Instantaneous Rate (cfs): 0.12
Annual Volume (acre-feet): 10
Name On Water Right: COLLINS, ELBY

Note:

Irrigation of approximately 14.8 acres is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

- Aerial Photo Delineated Irrigated Areas
- Water Right Place of Use (from Ecology GWIS)
- Approximate Point of Withdrawal for Given Water Right
- Sections
- Mission Creek Basin Boundary
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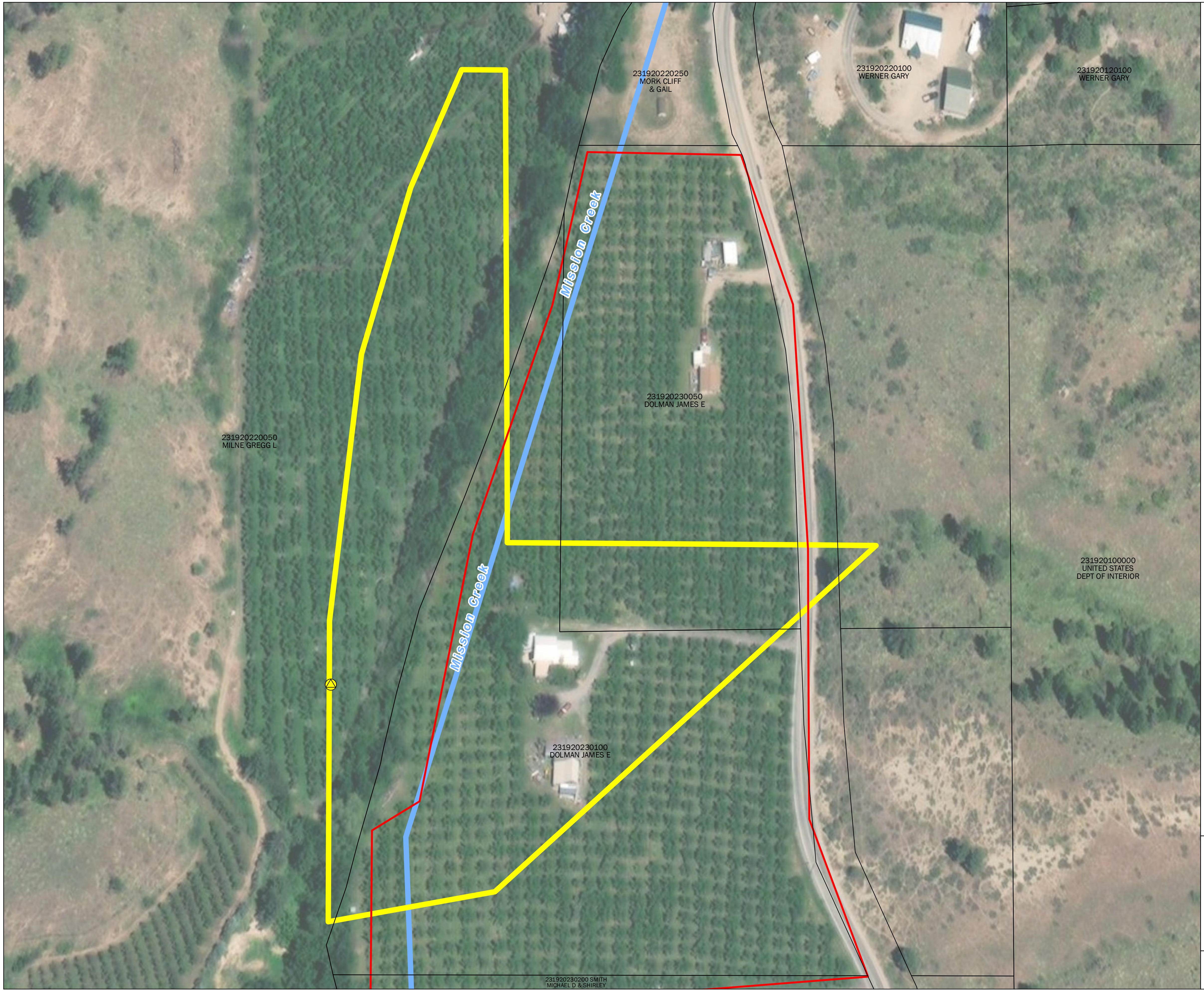
S4-122677CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING

JUL-2018	BY: PPW	FIGURE NO.	
PROJECT NO. 120045-009	REVISED BY: JE / RAP	A-23	

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trullen || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-116134CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 10
Instantaneous Rate (cfs):
Annual Volume (acre-feet): 40
Name On Water Right: DOLMAN, JAMES E

Note:

Irrigation of approximately 10.4 acres is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

- Aerial Photo Delineated Irrigated Areas
- Water Right Place of Use (from Ecology GWIS)
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S4-116134CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO.
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	**A-24**

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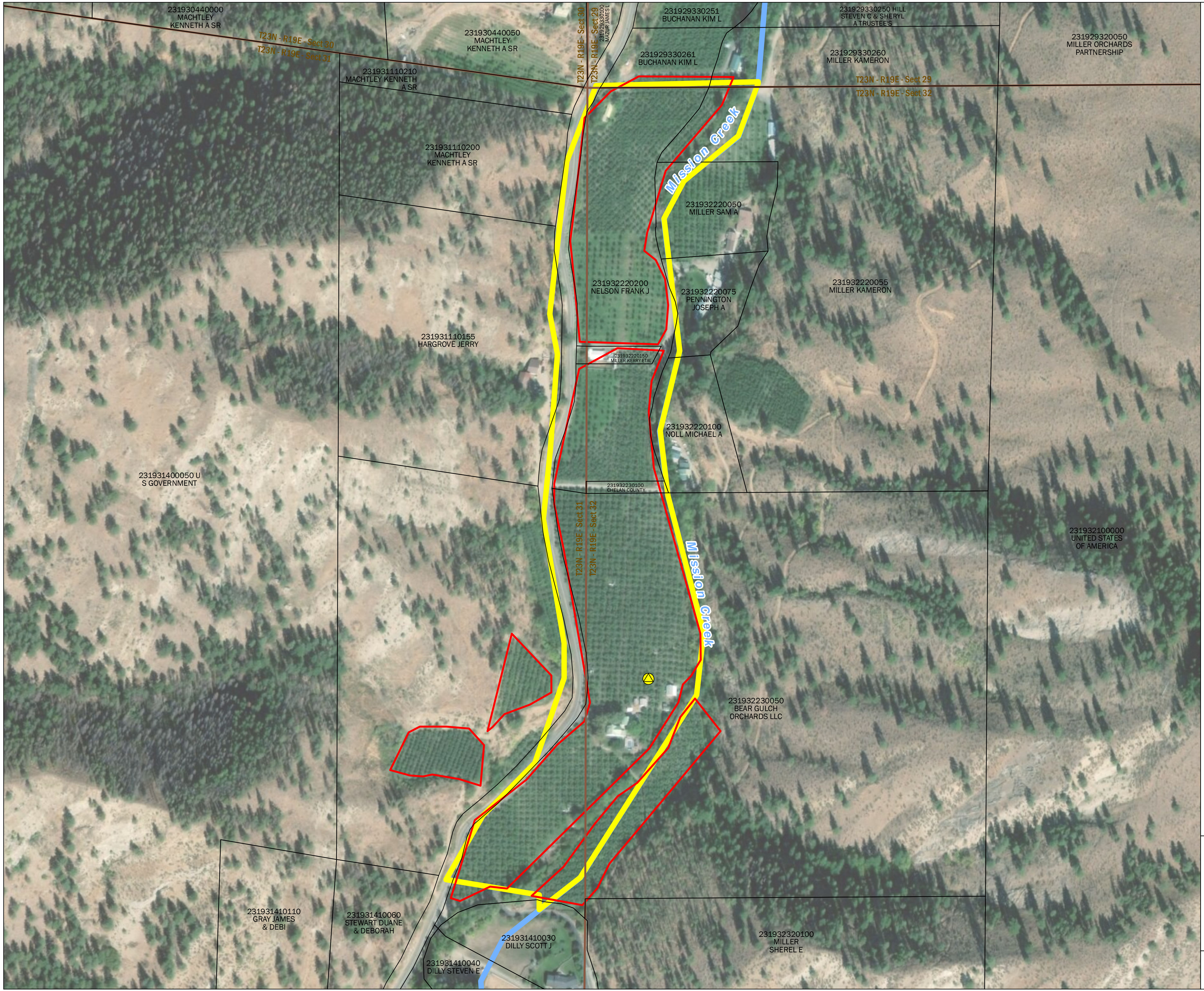

Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info

Water Right Number: S4-057797CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 7.17
Instantaneous Rate (cfs):
Annual Volume (acre-feet): 36.57
Name On Water Right: ,

Note:

Irrigation of approximately 22 acres consistent is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

🟥	Aerial Photo Delineated Irrigated Areas
🟨	Water Right Place of Use (from Ecology GWIS)
▲	Approximate Point of Withdrawal for Given Water Right
☐	Sections
⬚	Mission Creek Basin Boundary
☐	Tax Parcels

S4-057797CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO. **A-25**
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	

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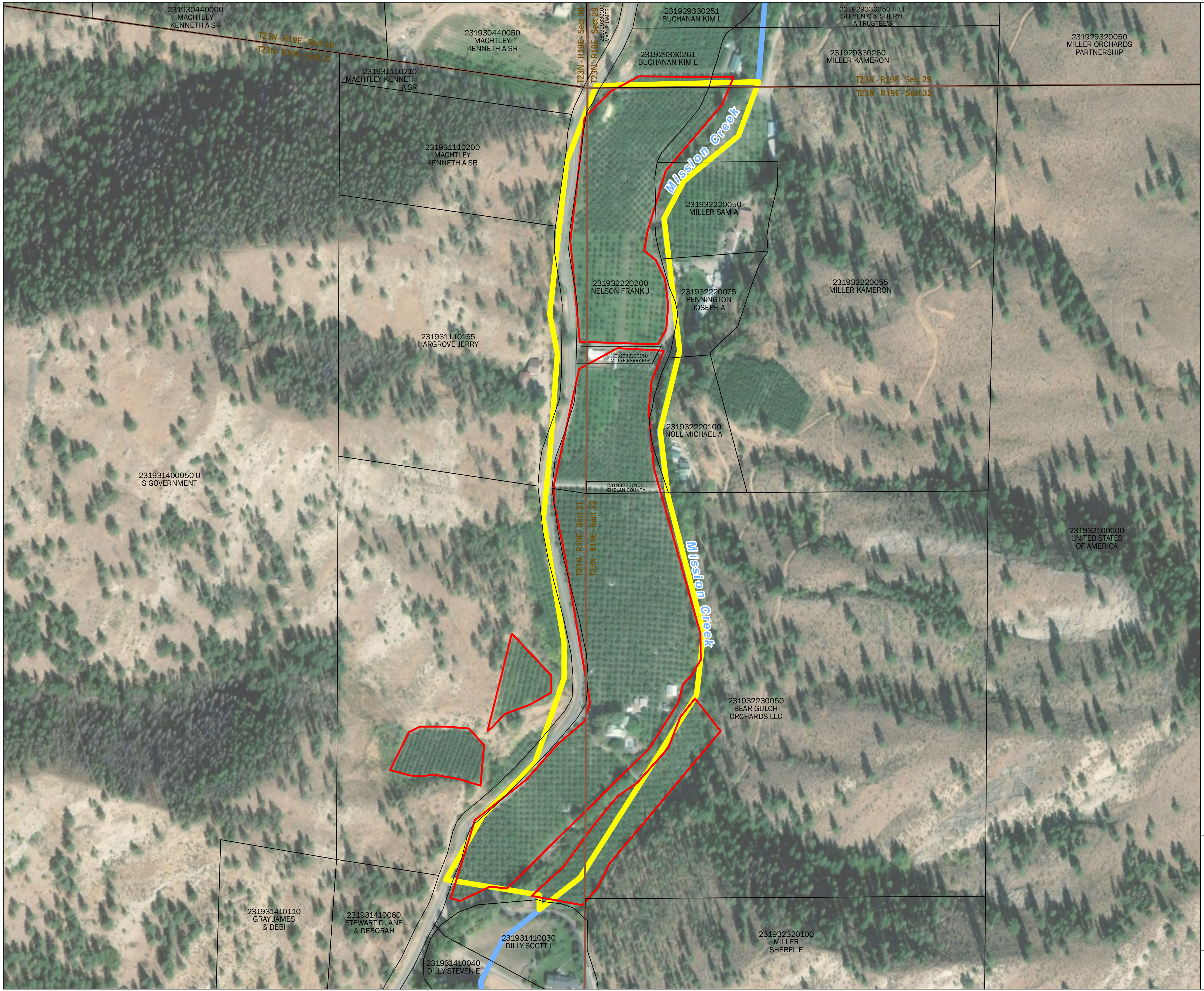

Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-057796CL
Water Right Type: Claim L
Purpose: Irrigation
Irrigated Acres: 9.47
Instantaneous Rate (cfs):
Annual Volume (acre-feet): 48.3
Name On Water Right: ,

Note:

Irrigation of approximately 22 acres consistent is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

- Aerial Photo Delineated Irrigated Areas
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- ☐ Sections
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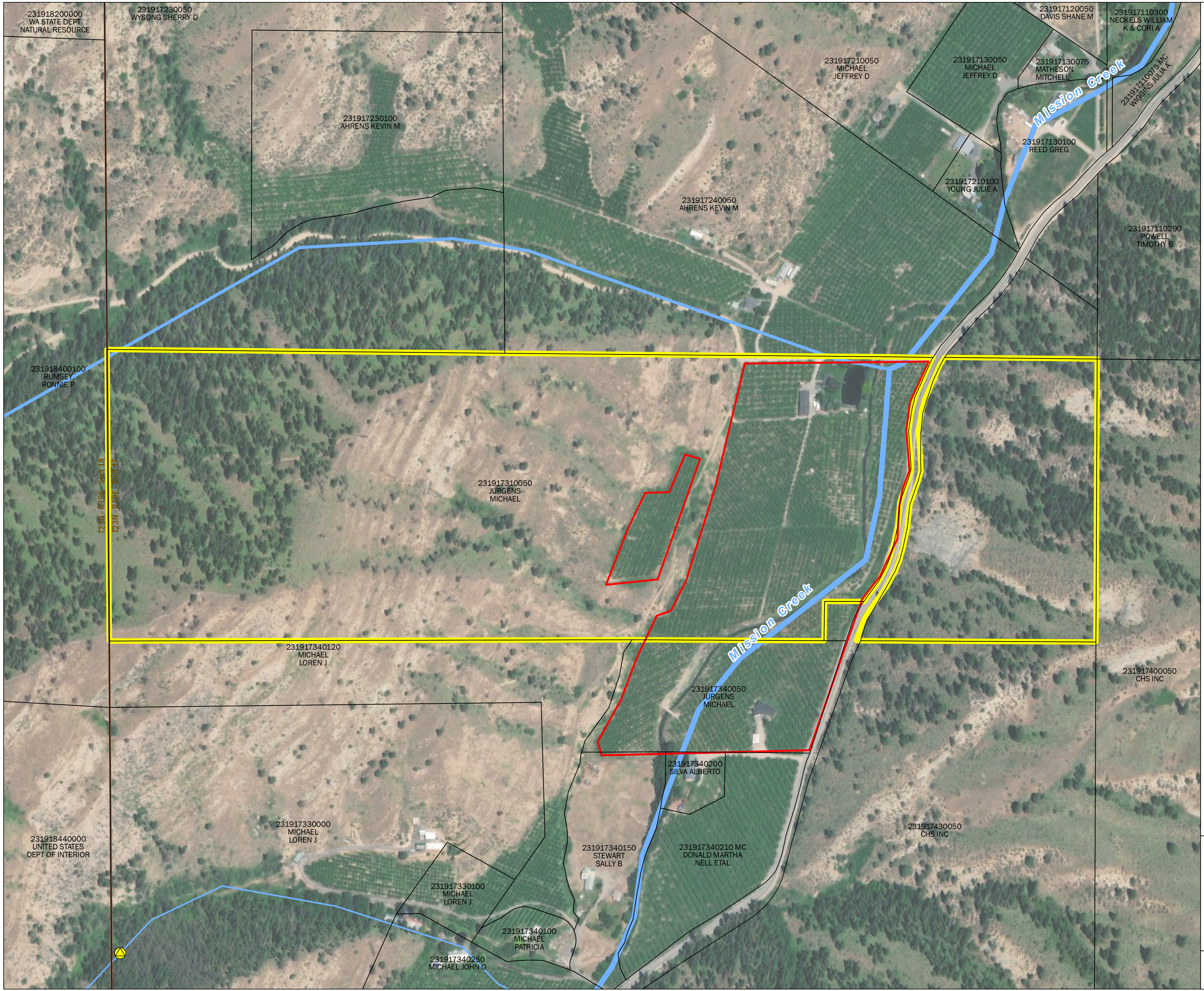
S4-057796CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING

JUL-2018	BY: PPW	FIGURE NO.
PROJECT NO. 120045-009	REVISED BY: JE / RAP	A-26

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Water Right Document Info
Water Right Number: S4-301810CL
Water Right Type: Claim
Purpose:
Irrigated Acres: 8.74
Instantaneous Rate (cfs): 0.02
Annual Volume (acre-feet): 872
Name On Water Right: JURGENS, MICHAEL

Note:

Irrigation of approximately 18.7 acres is consistent from 1998 to 2013.

1) Google Earth imagery for all water rights is available for analysis in 1998, 2005, 2006, 2009, 2011, and 2013.
2) Imagery displayed on this map is dated July, 2010 (from Esri/Microsoft).

- 🟥 Aerial Photo Delineated Irrigated Areas
- 🟨 Water Right Place of Use (from Ecology GWIS)
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- ☐ Sections
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S4-301810CL

Mission Creek Water Rights Technical Assistance
Chelan County Department of Natural Resources
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: PPW	FIGURE NO. A-27
	PROJECT NO. 120045-009	REVISED BY: JE / RAP	

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MissionWaterRightReview_MapBook.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018

APPENDIX B

Water Banking

Aspect
CONSULTING

WATER BANKING APPRAISAL

Mission Creek Flow Improvement Appraisal
Alternative 1

Prepared for: Chelan County Natural Resources Department

Project No. 120045 • July 6, 2018

Aspect Consulting, LLC

Daniel R Haller

Daniel R. Haller, PE, CWRE
Principal Engineer
dhaller@aspectconsulting.com

Jason M. Shira, LHG
Project Hydrogeologist
jshira@aspectconsulting.com

V:\120045 Chelan County\Deliverables\Mission Creek\Centennial Grant Reporting\Water Banking\Water Banking Appraisal_Alternative 1.docx

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1 Water Banking

Water banking may offer options to extend the reserve for permit-exempt uses in the Mission Basin and provide some limited stream-flow improvement. The water bank acts as an intermediary, bringing together buyers and sellers of water rights with predictability on the validity of the water right, the geographic area where it can be used, and for what purposes (e.g., domestic, commercial). The overall goal of a water bank is to facilitate water transfers using market forces. In Washington State, the legislature has identified additional objectives of water banking in the Revised Code of Washington (RCW) 90.42.100, which include:

- Making water supplies available when and where needed during times of drought.
- Improving stream flows and preserving instream values during fish-critical periods.
- Reducing water transaction costs, time, and risk to the purchaser.
- Facilitating fair and efficient reallocation of water from one beneficial use to another.
- Providing water supplies to offset impacts related to future development and the issues of new water rights.
- Facilitating water agreements that protect upstream community values while retaining flexibility to meet critical downstream water needs in times of scarcity.

Some of the analysis for this alternative was adapted from similar water-banking efforts Aspect Consulting, LLC (Aspect) has led or co-led in such locations as Kittitas County and Spokane County for the 2016 Water Supply and Demand Forecast, and for private water banks, and modified for applicability to Mission Creek. Specific bank operation and administration decisions will need to be made by Chelan County Natural Resources Department (CCNRD) as described in greater detail herein.

1.1 Water Banking Defined

The traditional definition for water banking is an institutional mechanism used to facilitate the legal transfer and market exchange of water (Clifford et al., 2004). However, the term “water banking” is used to refer to a variety of water management practices that extend beyond the traditional definition. Although water-banking definitions and approaches differ, the common goal is to move water to where it is needed most.

Water banking is facilitated by an institution (the water bank) that operates as a broker, clearinghouse, or market maker. This can be a County, City, Irrigation District, Washington State Department of Ecology (Ecology), a nonprofit entity, a private corporation, or others. A clearinghouse serves mainly as a repository for bid and offer information (e.g., a website where buyers and sellers can post opportunities). Brokers connect or solicit buyers and sellers to create sales (e.g., water attorneys), and a market maker attempts to identify buyers and price water to sell (e.g., a farmer who is retiring or Ecology developing water from storage).

Many banks pool water supplies from willing sellers and make them available as credits to willing buyers. Generally, a water bank sets the rules of water bank operations, determines which rights can be banked, certifies water quantities entering and leaving banks, sets terms and prices, and facilitates the regulatory requirements (Figure 1). In Washington, many of these actions are defined in the Trust Water Right Agreement (TWRA) between the water bank and Ecology. These business functions include determining which rights can be banked, certifying water quantities entering and leaving banks, and setting some of the rules of water bank operation, such as quantities and locations of water banking.

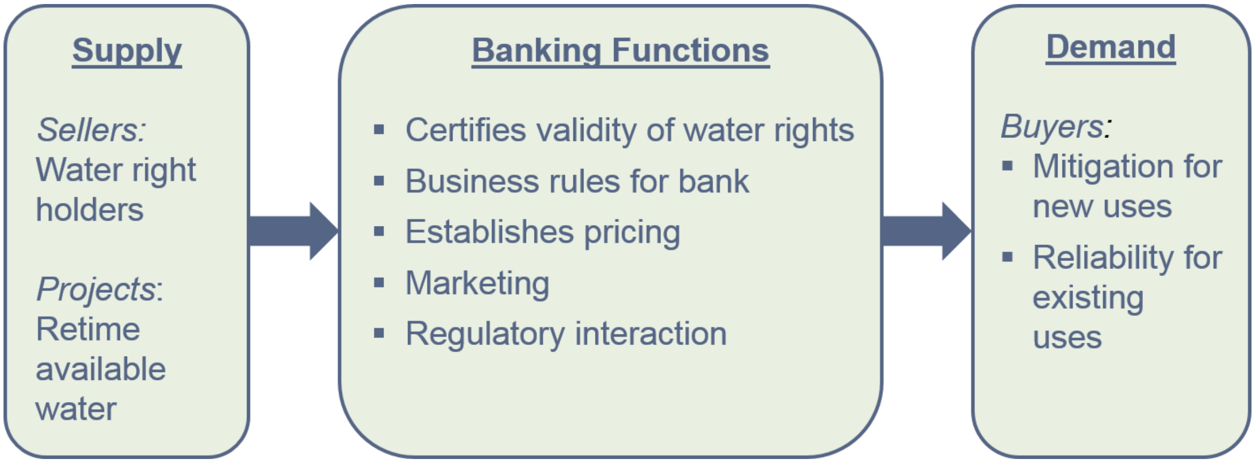

Figure 1. Water Banking Overview

1.2 Water Banking Authority

States authorize banking in a variety of ways. Authorization ranges from explicit water banking legislative action with oversight provided by state agencies, to implied water banking policies and legislation that facilitates transfers, to watershed-level actions, to the use of federal policies to support activities. In Washington, water banking has been authorized by the legislature through House Bill 1640 (2003) and the amendment of RCW Chapter 90.42, with Ecology providing regulatory oversight. In the Mission Basin, no additional regulatory authority is necessary to create a water bank. For water banking in Chelan County, CCNRD can rely on the existing statutory framework provided in RCW 90.42.

1.3 Water Bank Functions

Water bankers provide various services to meet instream and out-of-stream water demands. Each trust water right agreement and the driving water management goal along with who the water bank serves will dictate the type of water bank model used and for what purposes. There are four structural/ownership models of water banking that have emerged in Washington. These different structures are generally based on funding type, bank administration, and bank purpose:

1) Public (e.g., Kittitas County Water Bank, City of White Salmon Water Bank)
2) Quasi-Government (e.g., Dungeness Water Bank, which is a county/nonprofit partnership)
3) Nongovernmental Organizations (NGO) (e.g., banks managed by Washington Water Trust)
4) Private (e.g., Upper Kittitas water banks, which operates for profit)

In the Mission Basin, a water bank operated by CCNRD that builds on the existing reserve framework would be the most straightforward to implement.

1.4 Water Bank Models and Metrics

Water banks participate in water transactions for a variety of purposes and over varying water quantities, from residential groundwater-use mitigation of less than 1 acre-foot,[1] to permitted water rights leases and sales for thousands of acre-feet. There are also differences in the amount of consumptive and nonconsumptive water transacted from water banks, based on purpose and types of water use. To compare different banks and model types, it is important to consider consistent units and specific metrics (e.g., cost per unit, and units transacted). For the purposes of this report, a unit of mitigation is the quantity of water a water bank does business in.

The most important emerging metric for water banking is basing transfers on consumptive use rather than total use. This is the case in the Mission Basin, where reserve accounting is tracked based on September consumptive-use equivalents that correlate to the 1 to 2 percent habitat loss during the low-flow month, on which the reserve was predicated.

Consumptive use is defined in several Ecology laws, rules, and policies in varying ways, including:

- “Water that is transpired by plants at the place of use, water that escapes from a reasonably efficient conveyance system or from the place of use but does not become return flows and water that is contained within a product or within a production byproduct” (Ecology, POL1210).
- “Consumptive use includes crop evapotranspiration, and water evaporated during irrigation applications (e.g., spray, canopy and wind losses)” (Ecology, 2018).
- “Consumptive use means use of water whereby there is a diminishment of the water source” (Washington Administrative Code [WAC] 173-500-050(5)).
- "Annual consumptive quantity’ means the estimated or actual annual amount of water diverted pursuant to the water right, reduced by the estimated annual amount of return flows, averaged over the two years of greatest use within the most recent five-year period of continuous beneficial use of the water right” (RCW 90.03.380).

Consumptive use has emerged as a common water bank metric because in many over-appropriated or seasonally limited basins in Washington, downstream junior appropriators rely on return flows as part of their water supply availability. In such situations, any increase in consumptive use would result in actual or presumptive impairment of third parties. Detailed calculations of consumptive use are becoming a standard in the water-banking industry, often requiring engineers, hydrogeologists, or other scientific professionals to interpret historical beneficial use using aerial photographs coupled with scientific literature and real-time data (e.g., Washington Irrigation Guide, AgriMet, AgWeatherNet, and others). Figure 2 is a conceptual representation of the consumptive water budget.

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[1] An acre-foot is a unit of volume equal to the amount of water required to cover on acre of land with a foot of water. There are 325,851 gallons in 1 acre-foot.

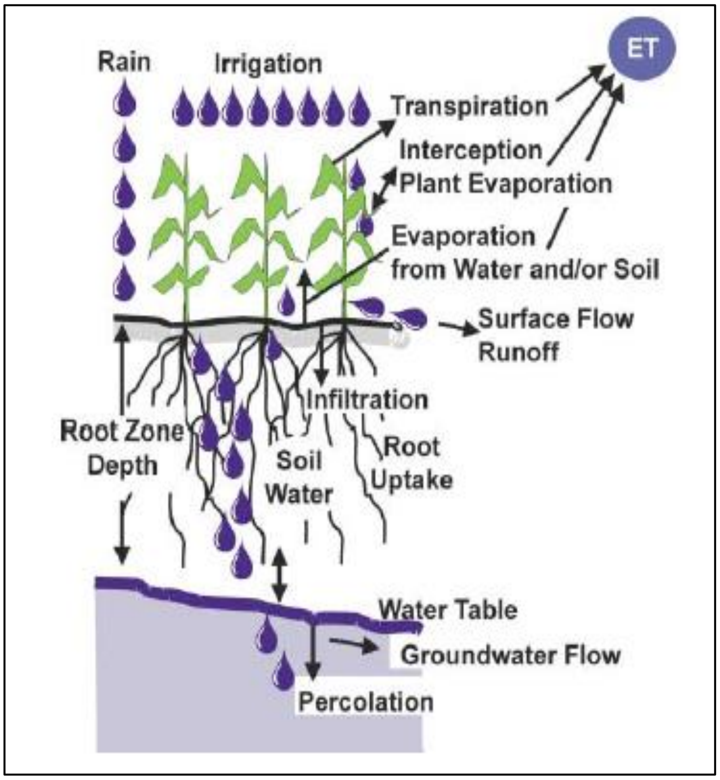

Figure 2. Components of Consumptive Use[2]

Consumptive-use metrics are also used in water banking for nonagricultural purposes, including domestic use, stock-water use, and commercial and industrial uses. For example, Ecology adopted the Upper Kittitas Rule, WAC 173-539A, which describes how domestic consumptive uses will be allocated in the context of water banks operating in the rule area:

> *Consumptive use will be calculated using the following assumptions: Thirty percent of domestic in-house use on a septic system is consumptively used; ninety percent of outdoor use is consumptively used; twenty percent of domestic in-house use treated through a wastewater treatment plant which discharges to surface water is consumptively used (WAC 173-539A-050(3)).*

Although not explicitly stated in WAC 173-545-090, consumptive use is the metric by which the current Mission Basin reserve is administered, based on the rule adoption framework that was related to habitat loss (which occurs by increased consumptive use in a basin). A future water bank in the Mission Basin would likely build on this consumptive-use framework.

1.5 Water Banking Seeding Mechanisms

There are two primary concepts of water availability that drive water banking and seeding mechanisms: physical availability and legal availability. Some water banks make water physically available from their supply for withdrawal/diversion. Other water banks simply address legal availability, so a new diversion/withdrawal will not impair another user.

---

[2] Irrigation Efficiency, Encyclopedia of Water Science (Howell, 2003)

An example of a water bank that supplies physical water is the Lake Roosevelt Incremental Storage Release Project. For this bank, water is made physically available for use by storing and releasing water from Lake Roosevelt (Figure 3). Individual users who desire water from this bank must enter into a water service contract with Ecology's Office of Columbia River, along with a permit to use water. All the users from this bank physically access some of the water that is released, although there is some flexibility on the timing of releases relative to the timing of diversions, which are intended to maximize fish benefit in the Columbia River.

Examples of banks trying to solve legal availability issues are the Yakima Basin water banks. In the Yakima Basin, the Bureau of Reclamation withdrew all unappropriated water on May 10, 1905, for the development of several irrigation projects. Because of this, any new use in the Yakima Basin must be neutral with respect to the Yakima Basin's total water supply available (TWSA) at a gaging station on the Yakima River known as Parker (labeled PARW on Figure 4). This TWSA neutrality prevents impairment of the Bureau of Reclamation right or other senior water rights in the basin. To meet this requirement, water rights have been placed into the Trust Water Rights Program (TWRP) to offset new uses and ensure TWSA is not impacted at Parker. However, the new uses are not necessarily coupled to the banked water in a way that ensures physical access to the water in the bank. In this example, it can be possible to mitigate for impacts to other water users, address legal availability of water, and not physically divert any of the banked water. The management of the Yakima Basin is illustrated on Figure 4.

In the Mission Basin, water for new permit-exempt uses would likely be incorporated into the current reserve framework, based on September consumptive-use equivalents. Traditional bank seeding would be from a retired irrigation right (or portion thereof). The consumptive use associated with that right would be enrolled into the water bank, and an estimate of the number of houses that could be added, based on consumptive use available in September to be debited, would be calculated.

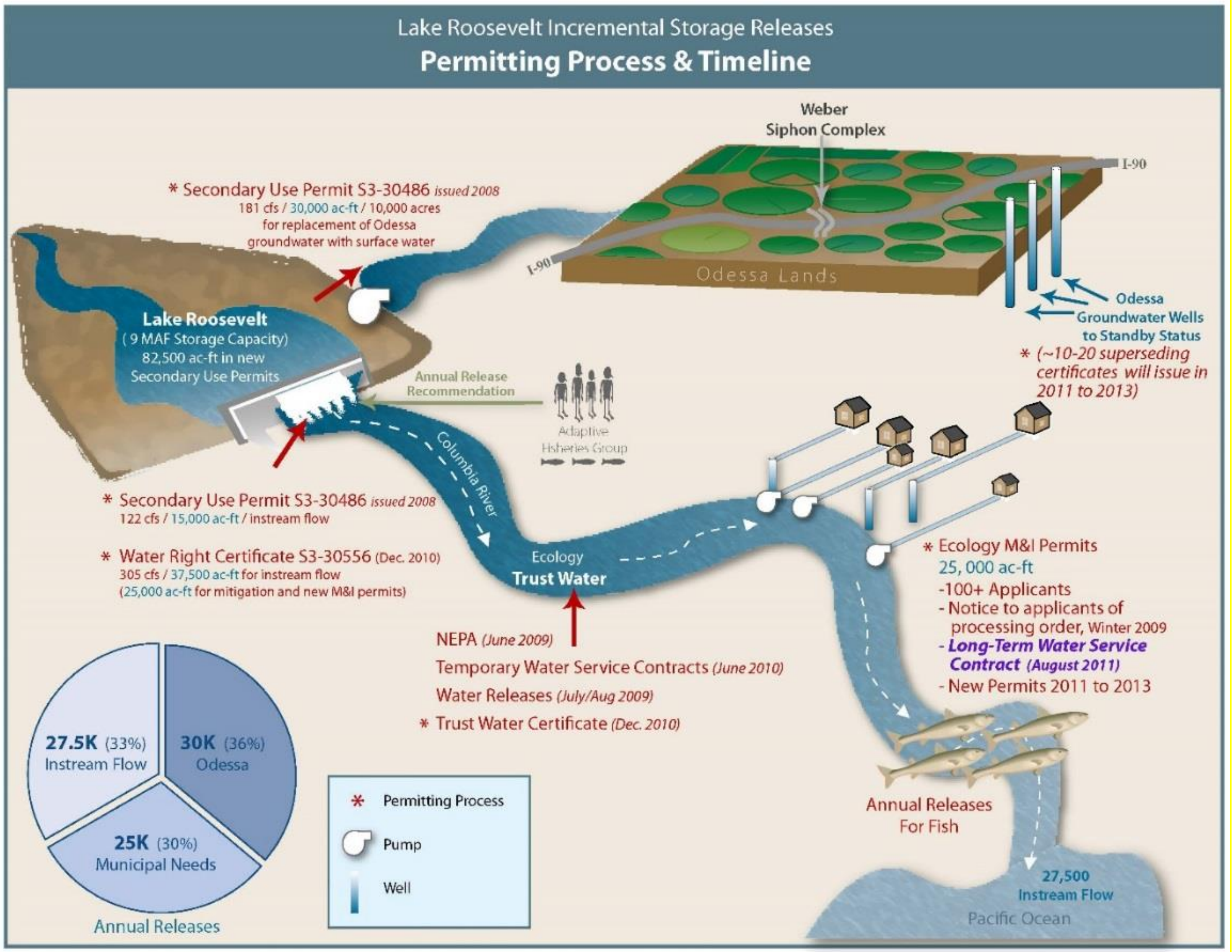

Figure 3. Example of Physical Availability

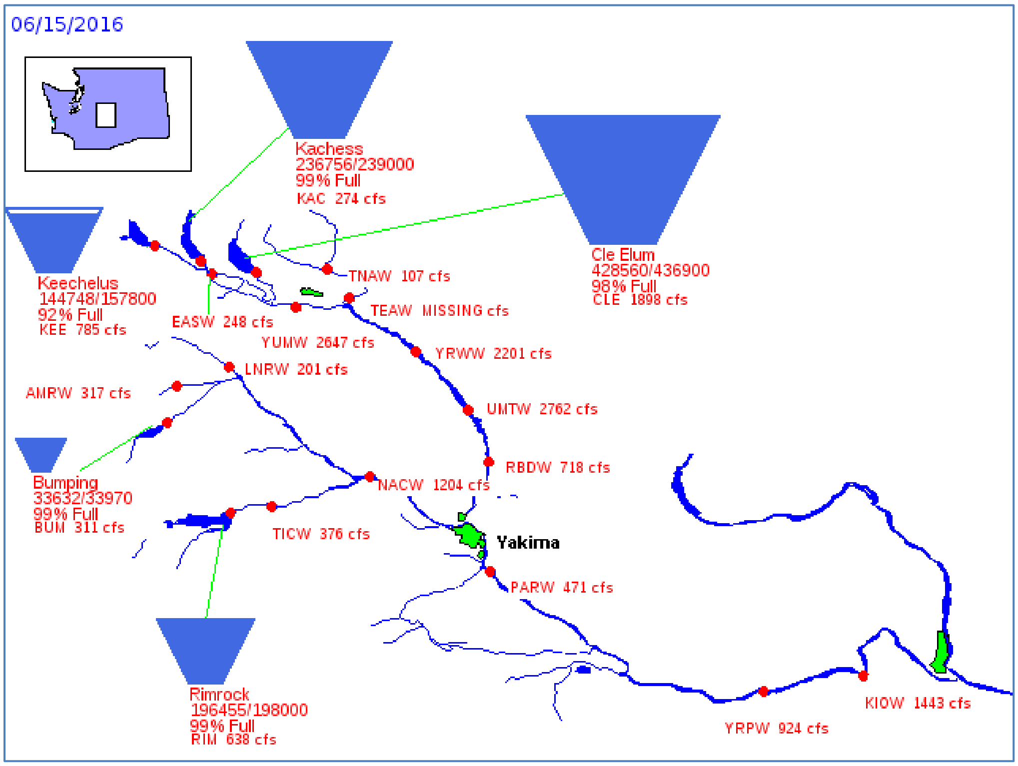

Figure 4. Water Supply Model for Yakima Basin

1.6 Washington State Market Activity and Participation

This section discusses Washington's water allocation framework, water banking policy, water banking programs, and compares the water banking models and compares their effectiveness in solving current and anticipated water problems.

1.6.1 Washington Water Allocation Framework

Washington, like other western states, has a prior appropriation framework for water allocation. In times of limited water availability, those who put water to beneficial use first (senior priority dates), have the right to the full use of the water before subsequent users (junior priority dates)—in other words, "first in time, first in right." In dry years, this allocation framework creates a system of "haves" and "have-nots." Those with earlier priority dates enjoy the right to use the full extent of their water right, while those with later priority dates often cannot. Water banking provides a market-based approach to solve this problem by allowing senior water to be reallocated for new uses.

An illustration of how the prior appropriation system works in Washington is described below for the Mission Subbasin (Figure 5). Senior water right holders that predate the adoption of the original 1983 Instream Resources Protection Program (IRPP) always receive a full allocation of water irrespective of the type of water year. The next most senior right in the base is the instream flow rule, adopted in 1983 and updated in 2006. The 1983 flows, which were updated in 2006, are met completely in some years (e.g., wet years) and incompletely in other years (e.g., average/dry years). In 2006, following consensus-based watershed planning, the 4 cubic feet per second (cfs) Wenatchee Reserve (including Mission Subbasin) was adopted, which created a "firm" or "noninterruptible" reservation of water with the same priority date that was confirmed by the Legislature in SB6513. Finally, there are 56 junior water users in the Wenatchee basin who are interrupted whenever weekly instream flows are not met, 7 of which are interrupted specifically by Mission Creek flow targets in WAC 173-545-050.

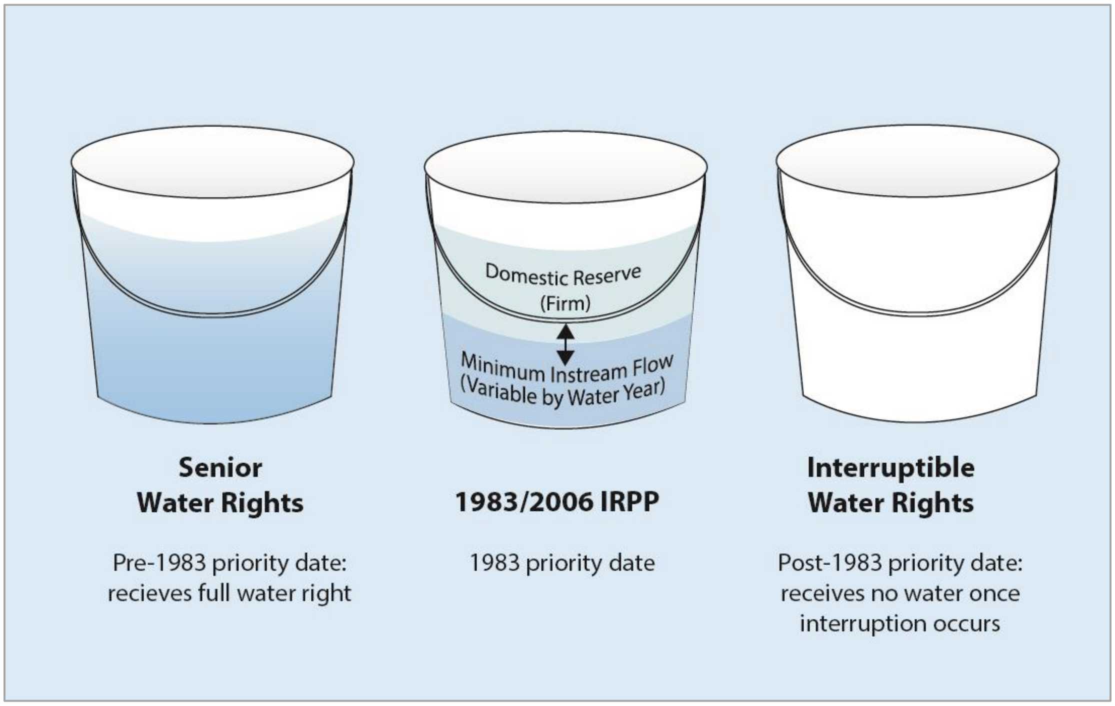

Figure 5. Prior Appropriation System in Mission Creek

1.6.2 Washington Water Banking Statutory Review

1.6.2.1 Water Banking Authority

Washington's statute governing water banking is authorized in RCW 90.42.[3] While the concept and use of the term water bank has been around for years, comprehensive state-wide water banking legislation was not passed by the Legislature until 2009.[4] A trust water right is any water right acquired by the state for management in the TWRP on a temporary and/or permanent basis. The TWRP provides a way to legally hold water rights for future uses without concern for the relinquishment for nonuse per RCW 90.14.140(2)(h). Water rights are typically held in trust to benefit instream flows or preserve groundwater, to protect them from relinquishment, to be considered beneficially used, or to offset new out-of-stream uses.

While in the TWRP, the water right maintains its original priority date, with a specified place of use (stream reach or aquifer), an instantaneous and annual quantity (typically specified as a monthly schedule), and a period of use (e.g., irrigation season, or year-round). These instream-flow water-right attributes are necessary for the trust water right to be beneficially used and account for the water right as instream flow to offset (mitigate) new water uses. Ecology's use of a water right it holds in

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[3] A Yakima Basin trust water statute also exists in RCW 90.38; however, it focuses strictly on the trust water right statute applicable to that County and is not applicable in the Mission Basin.

[4] See in general RCW 90.42.100 through 130.

trust is typically governed by a TWRA, which is a contract between the state and the owner of the water right describing the terms of trust.

Trust water rights are considered beneficially used when they are exercised for incremental enhancement of instream flow. Ecology can provide notice of exercise of trust rights through a public notification process via the internet.[5]

Ecology has a statutory role in setting up water banks via the TWRP, though day-to-day administration of the banks range from full Ecology administration (e.g., Port of Walla Walla, Lake Roosevelt, Sullivan Lake, Cabin Owners) to third-party administration (e.g., Dungeness, Walla Walla). Potential water-bank managers need to reliably fill this function in a way that meets the public trust standard. Managers currently include local government, such as counties or cities, creation of a watershed-based water resource management entity, nonprofit NGO's, or private companies or individuals. The TWRP provides the fundamental authority for water banking. The source water right that is "banked" is held by Ecology in the TWRP. To use the water for out-of-stream mitigation, or issue mitigation credits from the bank, the TWRA specifies many of the rules such as location, quantities that can be used for mitigation, and the quantity of the mitigation credit. The water is held in the TWRP until its diversion authority is formally conveyed to the buyer. Ecology policy requires the use of the TWRP to ensure water availability at the new location, because it is a mechanism to protect water from other intervening users. Typically, this involves four procedural steps in the example of a potential Mission Creek water right acquisition related to fallowing a small irrigation parcel:

1) Attributes of a senior water right are changed, either by Ecology or a local conservancy board, including:
    a. The purpose of use, typically changed to instream flow and mitigation of new out-of-stream uses.
    b. The place of use changed from the former appurtenant land to the portion of river or aquifer where the bank will operate.
    c. The point of diversion is eliminated and replaced with a description of the "primary" and "secondary" reaches of the trust water right. The "primary" reach is quantified based on total use from the historical point of diversion to the historical return flow point. The "secondary" reach is quantified as the consumptive portion of the right below the historical return flow point (Figure 6).
    d. Extent and validity of the water right is analyzed.

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[5] http://www.ecy.wa.gov/programs/wr/market/trstdocs. html

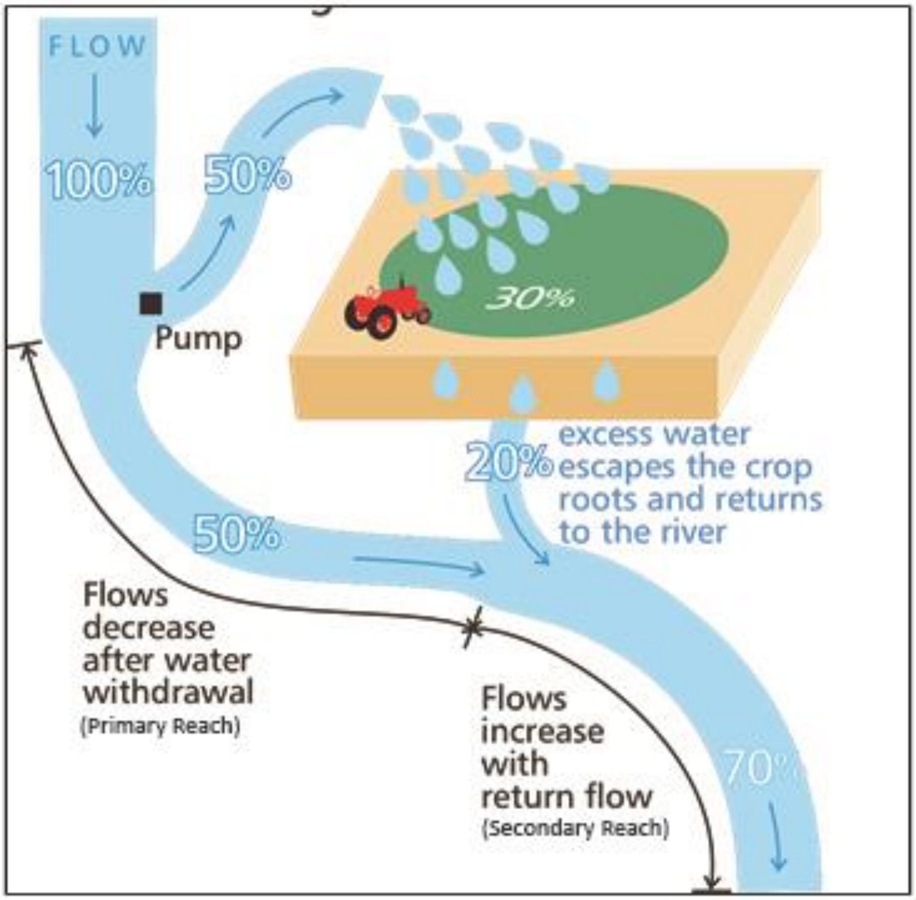

Figure 6. Primary/Secondary Reach Example

5) Water is conveyed to trust by a contract or deed. Ecology must have ownership interest in the water right seeding the bank in order for it to reside in the trust program for water banking purposes.
6) A TWRA is adopted. The TWRA is a contract that describes the conditions under which Ecology will hold the water right in trust and release and/or permit water from the water bank, explaining the purposes, metrics, and the water-right processing framework.

   New mitigated water rights are issued by Ecology and debited from the water bank. Chelan County would be authorized to issue mitigation certificates for permit-exempt uses and Ecology would issue Reports of Examination (ROE) and permits for all other uses. Accounting ensures that new “withdrawals” do not exceed the original “deposit.”

Although Washington’s TWRP was authorized in 1991, water banks have only significantly expanded in the last 10 years in response to several factors, including:

- River basin closures (i.e., basins closed to new water uses, such as in Upper Kittitas County, or diminished initial reserves as in the Mission Basin).
- Adoption of new instream flows rules (e.g., Dungeness water exchange).

- Response to local collaboration to solve water supply problems (e.g., Walla Walla, White Salmon, Little Spokane and Methow Valley banks).
- Through new legislative focuses (e.g., Office of Columbia River (OCR), Cabin Owner bank).

1.6.2.2 Water Banking Case Law

Case law on water-rights issues has been evolving based on several relevant recent decisions and will continue to affect water rights decisions in the state, given that several more key decisions are pending. Below is a summary of significant legal cases that impact water-bank development.

- ***Postema v. Pollution Control Hearings Board*** (Supreme Court of the State of Washington, 2000). This decision defined the “one molecule” standard for instream flow impairment, meaning impairment does not need to be physically measurable. Deminimus impacts can constitute impairment via demonstration using scientifically acceptable methods.
- ***Swinomish Indian Tribal Community v. Ecology*** (Supreme Court of the State of Washington, 2013). This decision invalidated reservations-established in rule for new water uses, including exempt wells, created through amendments to the Skagit instream flow rule. It also determined that Ecology went beyond its statutory authority in applying overriding consideration of the public interest (OCPI) to rulemaking that conflicted with the established instream flows. SB6513 was passed in 2016 in response to the uncertainty that the Swinomish decision caused on the Wenatchee Reserve, which was adopted in somewhat parallel circumstances.
- ***Foster v. Ecology*** (Supreme Court of the State of Washington 2015). In this decision, the Washington Supreme Court (Court) reversed Ecology’s approval of the City of Yelm permit. The approval of this permit was based on the use of OCPI and an out-of-kind mitigation package. Ecology uses OCPI as a tool to approve water-right permits when water availability is limited, but it believes the public benefits of approval outweigh any impacts on stream flows. This decision implies a fundamental change on how water-short basins can access water. The implication of this ruling is that no permanent water right will be able to rely on anything other than water-for-water mitigation, in time and in place, and no amount of out-of-kind or out-of-time mitigation can offset even *de minimis* (one molecule) impacts to adopted instream flows. This ruling makes it imperative that banks appropriately match supply and demand spatially and temporally.
- ***Whatcom County v. Hirst*** (Supreme Court of the State of Washington, 2016). In this decision, the Court reversed a lower court decision that directed local governments to follow Ecology’s interpretation of instream flow rules in determining water availability. This Court decision rescinds that direction, noting that the Growth Management Act (GMA) places an independent responsibility to ensure water availability on counties, not on Ecology. The decision also noted that the fact that county provisions are wholly consistent with Ecology’s regulations does not, by itself, render them consistent with GMA requirements. In addition, this ruling imposes a strict standard for county review of cumulative impairment from exempt wells due to rural development.

Case law on exempt use, impairment of instream flows, conjunctive management of surface and groundwater, county building permit and Growth Management Act (GMA) responsibilities, and OCPI standards continue to be clarified by the court system. There is a corresponding trend towards county co-management with Ecology of the risk of future curtailment and the associated impacts on property values, on the ability to develop property, and on property transactions when instream flows are not met.

Ecology and counties are exploring ways to comanage risk based on the direction being provided by the courts, such as the evaluation of water-bank feasibility for particular basins. In addition, Ecology recently prepared a guidance document on the subject (*Finding Rural Domestic Water Solutions While Protecting Instream Resources*; Ecology, 2016a). The 2016 Legislature is considering numerous bills in the wake of the Hirst decision that may have implications on how exempt wells in the Mission Subbain are managed.

1.7 Incentives for Water Bank Participation

There are a number of reasons why existing and future water users in the Mission Basin would potentially participate in a water bank. The incentives are related to a number of factors, some of which are still in flux given potential Legislative actions. Incentives for participation include:

- **Mitigation source for new exempt wells.** With the reserve in WAC 173-545-090 for the Mission Basin depleted, a water bank could allow continued exempt uses to occur.
- **Interruptibility of new water right permits.** The adoption of the instream flow in Mission Creek means that the only new water rights issued in Mission Creek would be interruptible due to low-flow conditions during most summer weeks of the year. A water bank could provide a mitigated source of water for new permits.
- **Existing interruptibles.** There are seven existing interruptible water-right holders that might seek greater reliability of water use depending on crop choices. A water bank could offer options to transition to noninterruptible uses.

1.8 Water Bank Activity and Prices

There are numerous water banks operating in Washington State (Figure 7), with more being created each year. Selection of the type of water-banking model is dependent on the regulatory environment, timing of the need for water-bank development relative to regulatory actions, and ability of Ecology and counties to agree on the standards for the legal and physical availability of water.

Price, or the amount of money paid for one unit (not including fees), and volume of units transacted is highly variable between water-banking models, as shown in Table 1 (Ecology, 2016b). Public water banks have the lowest overall price per unit and price per acre-foot, but with the lowest number of units transacted to date. Private water banks account for the highest cost per unit and cost per acre-foot, and include the highest number of units transacted. Private water banks appear to the be the most productive based on the number of units transacted, but the units transacted is skewed in favor of private water banks based on the nature of regulatory actions related to rural growth and scale of Upper Kittitas County in the Yakima Basin. A summary of transaction differences between public and private banks is shown on Table 1. Figure 8 provides a summary of the locations and types of water banks operating in Washington.

Table 1. Summary of Price of Water charged by Public/Private Water Banks (transactional fees not included)

	Cost of Water/Unit	Cost/acre-foot consumptive
Public		
Average	$920	$1,290
Minimum	$60	$3,600
Maximum	$1,700	$1,000
Quasi-government/NGO		
Average	$1,500	$7,350
Minimum	$1,000	$3,600
Maximum	$2,000	$11,100
Private		
Average	$5,250	$41,600
Minimum	$1,250	$27,000
Maximum	$10,000	$131,200

Notes:
Excludes annual rate programs and lease programs
Data collected through spring 2015

The prices in Table 1 reflect both water-bank seeding and water-bank administration/permitting costs. For the purposes of this study, we have assumed that water rights could be acquired for $10,000/acre of land as a rough estimate. In practice, actual acquisition price may be higher or lower than this number, subject to local market conditions.

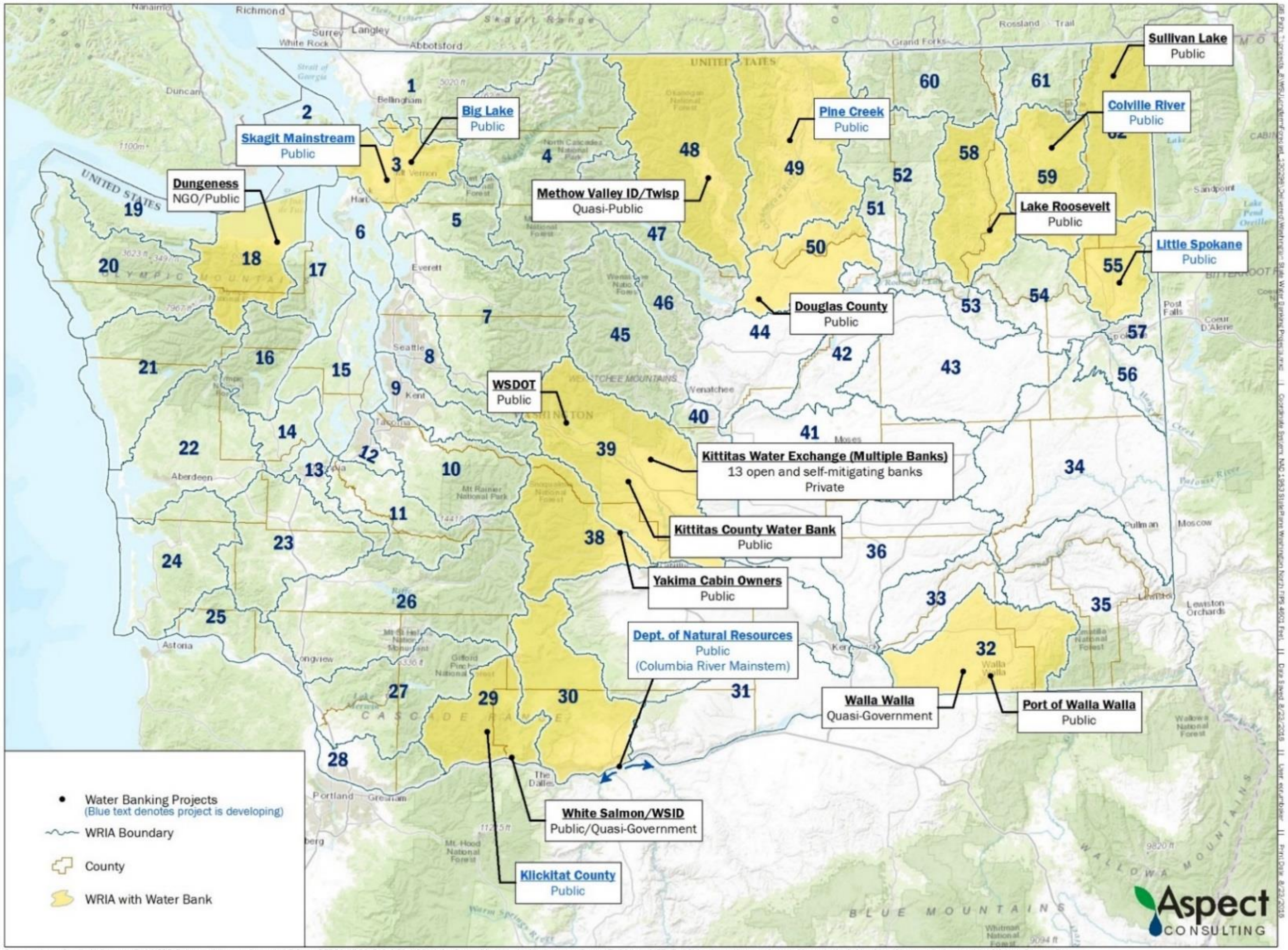

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Figure 7. Water Banking in Washington State by WRIA

Price, or the amount of money paid for one unit (not including fees), and volume of units transacted is highly variable between water-banking models, as shown in Table 1 (WSU/Aspect/UU 2016).

1.9 Evaluation of Four Active Water Banking Models

To provide additional detail on how different water banks were formed and have influenced the market, the following sections summarize four different water banks.

1.9.1 Yakima Basin Cabin Owners (Public)

The Yakima Basin Cabin Owners (Cabin Owners) water bank is a public water bank operated by Ecology. Washington State Senate Bill 6861, with an effective date of June 7, 2006, provided guidance to Ecology to develop a water bank to solve curtailment issues associated with junior Cabin Owners water needs by providing administrative and seed funds to develop the water bank. Ecology seeded this bank with a senior irrigation water right they purchased, and are using Reclamation's Storage Exchange Contract to convert the seasonal right to year-round authority. Because there is robust storage in the basin that is managed to meet federal instream flow targets, they can manage it and mitigate instream flow impacts from Cabin Owners for year-round uses based on seasonal irrigation-bank seeding. As of 2016, Ecology has conveyed 200 units of mitigation at a rate of $60/unit and $3,600/acre-foot consumptive.

More information is available at http://www.ecy.wa.gov/programs/wr/cro/sb6861.html.

1.9.2 Dungeness Water Exchange (Public/NGO Partnership)

The Dungeness Water Exchange is a public/NGO partnership water bank operated by Clallam County and Washington Water Trust (WWT). The Dungeness Water Management Rule, Chapter 173-518 WAC, went into effect on January 2, 2013, and required new uses of groundwater to be mitigated. Ecology provided administrative and seed funds to develop the water bank through the acquisition of senior irrigation rights, which were, in this case, appropriate because it was determined that mitigation was not necessary outside the irrigation season. A portion of the bank involves development of infrastructure projects to retime and recharge high-flow events to augment base flow through groundwater augmentation. As of 2016, WWT and Clallam County have conveyed an estimated 50 units of mitigation at a rate of $1,000/unit and $11,100/acre-foot consumptive.

More information is available at http://www.washingtonwatertrust.org/water-exchange and http://www.ecy.wa.gov/programs/wr/instream-flows/dungeness.html.

1.9.3 Walla Walla Water Exchange (Quasi-government)

The Walla Walla Water Exchange is a quasi-government water bank operated by the Walla Walla Watershed Management Partnership (WWWMP). The Walla Walla River Basin Rule, Chapter 173-532 WAC, was amended in September 2007 to require new outdoor irrigation uses of groundwater under the permit exemption to be mitigated. Ecology provided state administrative and seed funds to develop the water bank through the acquisition of senior irrigation rights. Only irrigation season offsets are being provided, so the use of irrigation rights for bank seeding is appropriate. As of 2016, WWWMP has conveyed less than 10 units of mitigation at a rate of $2,000/unit and $3,600/acre-foot consumptive.

More information is available at http://www.wallawallawatershed.org/partnership/participate/138-wb-ewmp.

1.9.4 Yakima Basin Water Exchanges (Private Sector)

The Yakima Basin Water Exchanges are predominately a series of private water banks operated by for-profit corporations. The Yakima Basin Water Exchanges began when Ecology enacted a series of emergency groundwater rules in Upper Kittitas County beginning on July 16, 2009, requiring all new permit exempt groundwater uses to be mitigated. On January 22, 2011, Ecology formalized the permanent Upper Kittitas Ground Water Rule, Chapter 173-539 WAC, cementing groundwater mitigation requirements.

The State of Washington, through Ecology, has used public funds to provide regulatory administrative services (issuing Water Budget Neutral Determinations) and regulatory oversight, but has not participated in the development of water banks. Private investors have seeded their own water banks and manage all of the administration. Seeding has occurred through acquisition of senior irrigation rights, and either the use of the Bureau of Reclamation Storage Exchange Contract to cover off-season impacts, or use of private on-site storage-and-release ponds for off-season mitigation. As of 2016, the 11 private water banks in the Yakima Basin have conveyed an estimated 700 units of mitigation at rates ranging from $1,250 per mitigation unit, $41,600/acre-foot consumptive, to $10,000 per mitigation unit, $72,900/acre-foot consumptive.

More information is available at http://www.ecy.wa.gov/programs/wr/cro/wtrxchng.html.

1.10 Water Bank Operational and Management Considerations

There are a number of operational and management elements that must be considered when considering the “business” of developing and managing a water bank. Those elements include water-banking roles, services, business decisions, and design. These elements are important because they will dictate who the water bank serves, water-bank pricing, sustainability and longevity, and managing the resource amongst other competing demands.

1.10.1 Water Bank Roles

When considering the operating structure of a water bank, there are many different roles and responsibilities that are required by the formation, operation, and maintenance of a water bank. These roles can be handled completely by one entity or responsibility can be delegated to separate entities with different timelines.

Some water-bank roles include:

- Deciding on the water-bank model
- Developing water-bank framework and implementation
- Seeking funding

- Seeding the water bank
- Constructing projects/funding for seeding activities
- Operating the water bank
- Integrating the water bank with current county business functions
- Ensuring customers use the water bank
- Marketing the water bank

The CCNRD is capable of providing all of these roles in the Mission Basin, although it would be an expanded effort over current management of the reserve.

1.10.2 Water Bank Services

Water banks can fill a variety of services when it comes to meeting out-of-stream and instream water demands. Each water bank model will dictate who the water bank will eventually serve and for what reason.

1.10.3 Water Bank Business Decisions

When developing a water bank, the CCNRD will need to consider a number of different business options regarding how to functionally operate the water bank. These issues are often resolved through County ordinances coupled with input from citizen's and policy advisory groups. Here are some of the common business decisions CCNRD could face in setting up a water bank:

- **Who to serve –** What types of mitigated uses will be allowed? Understanding the customer the bank is trying to reach is critical for bank success.
- **Where to serve –** Which geographic region(s) to serve? Should services be limited to particular regions (e.g., Mission Basin)?
- **Quantities available for sale –** What is the water unit size(s) for sale? There are trade-offs to consider between bank longevity and what the bank sells. This typically manifests itself in discussions and policies regarding allowable lawn size, since consumptive-use impacts from outdoor lawn watering have the biggest impact on debits from the bank.
- **New uses/Existing uses –** What existing uses will be allowed? Will all exempt and permitted uses be allowed initially by the bank (e.g., domestic, lawn irrigation, agricultural irrigation, commercial/industrial use, and stock watering), or will some be prioritized over others (e.g., domestic uses first)?
- **Pricing and Packages –** How much to charge? Will different mitigation packages be offered to accommodate multiple customer values or will customers be expected to conform to a single land-use choice? Will there be difference in price between indoor-only vs. outdoor uses to incentivize smaller lawn sizes? How will other uses be priced (e.g., stock water, commercial/industrial uses)? Will pricing be flat rate or include an escalator to incentivize conservation? How will use be verified (e.g., individual meters, aerial photo review)?

- **Cost recovery –** Will cost recovery include water/development cost and/or administration? Will administrative costs be recovered? Price signals undoubtedly affect bank participation, although a regulatory imperative will soften the price reaction.
- **Longevity/Sustainability –** How long will the water bank operate with a particular project or water-right seeding? In general, the less the bank tries to accommodate individual user preferences, the longer a particular mitigation source seeding the bank will last. For example, requiring new uses to conform to new construction standards (e.g., water use-efficient appliances), small lawn sizes, and conservation-based indoor uses would stretch bank seeding the furthest. Allowing variable lawn sizes (e.g., with commensurately higher consumptive use), more generous indoor allowances, and including existing uses (which may have less-efficient practices or larger water needs) will all reduce bank longevity or require more frequent bank seeding.
- **Bank administration –** There are trade-offs between customer choices and ease in bank administration. In general, the more a bank tries to accommodate individual customer preferences, the more complex it is for a bank to operate, the higher the administrative cost, and the greater the effort it takes to ensure compliance (e.g., code enforcement).

Each of these choices has potential impacts on the departments within the County that will need to interact with the water bank. Table 2 summarizes some of the key banking functions and the potential departments within each county that could have a participatory role:

Table 2. Summary of Potentially Affected County Departments under Water Banking

Chelan County	Formation	Operations	Management
Natural Resources Department	X	X	X
Auditor		X	X
Treasurer	X	X	
Public Works		X	X
Assessor		X	
Community Development	X	X	X
Flood Control Zone District			

1.10.4 Water Bank Design

As an institution, a water bank can be designed to accomplish various public-interest goals of value to the region. For example, the bank can be designed to prevent exceedingly high water market prices, moving too much water from one region to the next (e.g., upstream to downstream, tributary to mainstem), moving too much water from one user group to another (e.g., agriculture to municipal, or rural-growth limitations), speculative hoarding of mitigation credits, and other undesirable conditions. CCNRD could decide to engineer limitations by adopting business rules on the marketplace to ensure sustainability into the future. Essentially, this is a trade-off between free market principles and social engineering around what is perceived to be "fair" or of value in the Mission Basin. For example, some guidelines or business rule topics could include:

- Establishing water pricing standards
- Defining mitigation credit unit size
- Defining specific quantities to preserve or to develop incentives to access, such as price breaks
- Reserving tributary basin water for in-tributary basin use only or allowing portability for reverse transfer of mitigation credits back to their point of origin
- Determining the degree to which administrative costs are discounted, if at all
- Creating trading zones divided up by tributaries, control points, or subwatersheds
- Establishing market longevity goals (i.e., perpetuity, short-term, long-term)
- Develop a Citizen's Advisory Board to review policy issues

The importance of these business rule topics is typically a function of four factors:

1) How much water is available for bank seeding? The more water that is available, the less important the need to adopt stringent business rules that will promote bank longevity.
2) How is the basin managed? The terms of agreement between the water bank and Ecology relative to basin management may influence the importance of tributary versus mainstem reservations.
3) How variable is rural demand? If demand in rural areas can be classified into one or two mitigation credit sizes that represent the super-majority (e.g., 90 percent) of homes, then customer response to fewer mitigation credit offerings will be favorable and administrative costs will be less.
4) How cost-effective are the mitigation credits? The cost of mitigation credits relative to standard connection fees for municipal systems, and relative to the overall cost of new home construction, will help determine whether pressure for administrative cost subsidies will arise.

1.10.5 Building Permit Processes

A key change anticipated to be needed if CCNRD creates a water bank will be educating both county staff and the public on how the water-banking process intersects with the building-permit process, along with filing and recording of mitigation certificates. Under the current Mission Creek reserve framework, Chelan County debits building-permit issuances to the reserve, and no other accounting is required. Under a new water bank, if current county models are followed, Chelan County would issue mitigation certificates that would be recorded against the parcel demonstrating that suitable mitigation has been provided. It may also be possible to amend the rule and "add quantities" to the existing reserve and retain the current banking system, but rule amendments may be more challenging to obtain than a trust water agreement.

1.10.6 New Compliance Efforts under Water Banking

Depending on the types of mitigation certificates sold and assumptions and quantities on which they are based, various levels of new compliance and code enforcement could be imposed by the County as part of a water bank. These could include the following:

- **Rural metering or water-use monitoring.** To ensure that mitigation certificates are offsetting new uses, some level of monitoring of new uses is typical. This could include standard metering of wells, which under Ecology's metering rule (WAC 173-173) would be read on at least a monthly basis with annual totals reported annually. Another option would be to have the County compile water-use information on a 5-year interval, which was the negotiated framework between Ecology and Chelan County under the Wenatchee IRPP (WAC 173-545). This reporting approach is not necessarily metered, and would include aerial-photo and crop-duty estimates for lawn use.
- **Exceedance of mitigation certificates.** Compliance with mitigation certificates can either be at the individual user level or at the bank level. Some water banks require individual user compliance with reporting to Ecology (e.g., private banks in Kittitas County). Other water banks (e.g., Kittitas County Public Health) have selected bank compliance, because it allows for some attenuation of individual customer issues, while still being protective of the overall bank purpose. For example, if a bank presumes an average person/household residency, there will be some homes with more and some homes with less people, with water use varying accordingly. Bank-wide compliance would help the County avoid unnecessary enforcement situations where a mitigation certificate for three people per house is being compared against a six-person/house residency, because elsewhere in the bank there is likely a one-person/house offsetting use.
- **Lawn size.** This is the code enforcement issue that is the most straightforward to track, and the one that is likely to most affect the water bank because of the consumptive nature of the use. If a water bank selects a small outdoor irrigation footprint (e.g., 500 square feet), compliance could be generally enforced through infrequent "windshield" surveys or aerial photo review.

Irrespective of who operates the bank and how it is seeded, there will likely be some increased code enforcement administration that the County must assume to provide regulatory agencies and third parties confidence that the bank is operating as assumed.

1.11 Opportunities for a Targeted Water Right Purchase

Aspect evaluated potential rights that could seed a water bank in the Mission Basin. These same rights have the potential to assist in several other alternatives being evaluated in this study, including surface to ground transfers or being exchanged for another source (e.g., regional purveyor, Wenatchee pump station). Based on a review of Ecology's water-right files, the following water rights were determined to be large enough to warrant consideration for inclusion in this study.
Table 3 provides a summary of these rights.

Table 3. Select Surface Water Rights

Water Right Number	Water Right Type	Priority Date	Instant. Rate (cfs)	Instant. Quantity (gpm)	Annual Volume (acre-feet)	Irrigated Acres	Purpose
S4-004798CL	Claim L		372		320	150	DG IR ST
S4-070227CL	Claim L		0.08		160	40	IR ST
S4-061757CL	Claim L				1.6	40	DG IR
S4-113247CL	Claim L			11	17.6	40	IR
S4-028032CL	Claim L			120		28	IR
S4-151518CL	Claim L			60	13	27	IR
S4-103438CL	Claim L	1/01/1885	0.4		102	32	IR ST
S4-033395CL	Claim L		0.313		113	25	IR
S4-300897CL	Claim		1		5	24.8	IR
SWC08901	Cert	1/11/1963	0.41		80	20	DS IR
S4-093712CL	Claim L			25	15	20	IR
S4-115791CL	Claim L					20	DG IR
S4-200113CL	Claim L			100	70	20	IR
S4-032694CL	Claim L		0.5		80	20	IR
S4-040923CL	Claim L		1		64	16	IR ST
S4-118425CL	Claim L			120	32	16	IR
S4-038034CL	Claim L		0.16		61	15	DG IR
S4-136262CL	Claim L			50	10	12	IR
S4-007884CL	Claim L					40	IR
S4-122677CL	Claim L		0.12		10	10	IR
S4-200126CL	Claim L		26		35	10	IR
S4-116134CL	Claim L			60	40	10	IR
S4-200147CL	Claim L		1		10	10	DG IR
S4-200148CL	Claim L		1		10	10	DG IR
S4-057797CL	Claim L				36.57	7.17	IR
S4-057796CL	Claim L				48.3	9.47	IR
S4-301810CL	Claim		0.02		872	8.74	NR

Notes: DG – Domestic General; IR – Irrigation; ST – Stock Watering; NR – Not Recorded

These water rights were adapted into a Mapbook in Google Earth that summarizes their attributes, locations, overlays the authorized places of use with parcel landowners, and estimates current irrigation (Attachment 1).

Aspect and CCNRD met with local landowners to review this information and determine their interest in potentially participating in one or more of the alternatives being evaluated in this study. During the course of reviewing the Mapbook, it became apparent that, in many cases, the actual location of irrigation did not perfectly line up with the authorized (or asserted-for claims) places of use outlined in the Mapbook. As such, in some cases, the estimates of current use underpredict actual use. Generally, irrigating outside one's place of use is still considered beneficial use under Ecology's Tentative Determination Policy 1120, although a change authorization is needed to correct the irrigated area. If one of the rights in the Mapbook were selected for acquisition, in whole or in part, then a formal tentative determination of the extent and validity of the water right would be accomplished at that time.

1.12 Estimated Cost

Launching a new Mission Basin water bank will include costs to seed, administer, and start up the bank. These costs can be challenging to predict, given the uncertainty in local market conditions and the degree to which County departments can readily integrate the new business function. For the purposes of this analysis and building on a previous evaluation done by Aspect on potential acquisitions for CCNRD (Aspect 2012), Table 4 depicts potential bank seeding, bank longevity, and mitigation certificate costs scaled by different levels of acquisition.

Because the amount of water associated with each exempt use in the Mission Basin is relatively small, and assuming that this trend continues (or is forced to continue through banking rules), then a relatively small irrigation acquisition could allow for modest predicted growth to continue for decades to come. Prices would likely be affordable based on the mitigation certificate analysis and assumptions presented in Table 4.

Permitting costs are tied to the number of water rights acquired to seed the water bank. Transactional costs to transfer an acquired water right into the bank is estimated at $10,000 per water right with an additional cost of $2,500 associated with trust conveyance negotiations (Table 5). Administration of the water bank is estimated to cost 25 percent of the bank-seeding costs, or approximately $2,500 per house or $5,500 per consumptive acre-foot. In this example, it is assumed a single transaction would cover the quantities necessary to offset 10 acres of outdoor irrigation.

Table 4. Bank Seeding and Potential Mitigation Certificate Costs

Outdoor irrigation covered under an alternative authorization (acres)[1]	Reserve quantity made available (September consumptive use equivalents, cfs)	Number of homes supported[2]	Mission Basin growth rate from Watershed Management Plan (homes/year)	Years reserve depletion is delayed	Reserve depletion date[3]	Bank Seeding Costs[4]
1	0.005	5	6.9	1	2018	$10,000
2	0.01	10	6.9	1	2018	$20,000
3	0.015	15	6.9	2	2019	$30,000
4	0.02	20	6.9	3	2020	$40,000
5	0.025	26	6.9	4	2021	$50,000
6	0.03	31	6.9	4	2021	$60,000
7	0.035	36	6.9	5	2022	$70,000
10	0.05	51	6.9	7	2024	$100,000
15	0.075	77	6.9	11	2028	$150,000
20	0.1	102	6.9	15	2032	$200,000
25	0.125	128	6.9	18	2035	$250,000
30	0.15	153	6.9	22	2039	$300,000
35	0.175	179	6.9	26	2043	$350,000

Notes:

1) The Interim Mission Basin reserves are established as 0.03 cfs. Alternative authorizations might include water from irrigation purveyors, State-based water rights, water banking, etc.

2) Number of homes supported considering combined indoor and outdoor September consumptive use per residence of 0.00098 cfs (630 gpd) for Mission Basin (Aspect, 2013).

3) Mission reserve was estimated to be depleted in 2013 (Aspect, 2013).

4) Acquisition is estimated at $10,000 per acre, and water bank administration is anticipated to be quarter the cost of bank seeding.

Table 5. Water Banking Cost Estimate Summary

Alt	Description	Capital Cost	20-year O&M	Permitting Costs	Total Costs	Costs per Acre-Foot
1	Water Banking[a]	$100,000	--	$12,500	$112,500	$5,500

Notes:

a) Costs reflect bank seeding for 23 acre-feet as shown in Table 6, costs do not include administrative and start-up costs.

Recommendations and Next Steps

Water banking is a viable option for extending the Mission Creek reserve and providing opportunities for new growth. As shown in Table 4, a modest investment to seed a water bank could supply domestic water for new growth for years to come. It offers some limited benefit to improving instream flows as well. However, the magnitude of water needed to meet instream flow targets is substantially higher, so it is unlikely that water banking alone would be a solution for both of the issues (instream and out-of-stream) currently facing Mission Creek. Likely, water banking in conjunction with another option would be most beneficial.

In order to launch a water bank for Mission Creek, Aspect recommends the following key next steps:

1) Meet with local stakeholders, including landowners who have rights that could seed the bank to discuss how the bank would operate and quantities of water targeted.
2) Meet internally with County departments to review how new bank procedures would overlay with current county business practices.
3) Meet with Ecology to discuss how a trust water agreement and permitting framework would be developed.
4) Identify a revenue source for an initial acquisition. Establish cost-recovery guidelines so the bank can be self-sustaining after initial seeding is complete.
5) Network with local landowners or run an auction to identify and acquire a water right.
6) Use the conservancy board or a front-loaded application process with Ecology to move the water right into trust and secure a trust water agreement for its management.
7) Develop outreach materials and building permit guidelines to offer new mitigated rights in the Mission basin.

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Limitations

Work for this project was performed for the Chelan County Natural Resources Department (Client), and this report was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

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APPENDIX C

Streamflow Augmentation Pilot Project

Aspect
CONSULTING

MEMORANDUM

Project No.: 120045-011

July 9, 2018

To: Mike Kaputa, Chelan County Natural Resources Department

Pete Cruickshank, Chelan County Natural Resources Department

From:

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7/9/2018

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Re: **Mission Basin Streamflow Augmentation and Water Right Conversion Pilot Project**

Aspect Consulting, LLC (Aspect) prepared this memorandum to summarize observations and findings regarding surface water and aquifer testing in the Mission Basin. The purpose of the study is to evaluate the feasibility of using groundwater as a water supply source for streamflow augmentation (augmentation) and potential change in source (surface water to groundwater) for irrigation water rights.

This memorandum was prepared for the Chelan County Natural Resources Department (CCNRD) to support an alternative (Alternative 5) evaluation under their Mission Creek Flow Improvement Appraisal (Appraisal). This study was funded by a Water Resources Watershed Plan Implementation and Flow Achievement grant (WRPIFA-CHCONR-00047) and a Centennial Clean Water Program grant (WQC-2016-ChCoNR-00239).

Introduction

Limited water availability for out-of-stream uses and low streamflow in the Mission Creek Watershed were identified as high-priority issues by the Wenatchee Watershed Planning Unit (WWPU) in their 2006 Wenatchee Watershed Plan (Plan; WWPU, 2006). The Plan made recommendations that resulted in the updated Wenatchee Instream Resource Protection Program (Washington Administrative Code [WAC] 173-545) that established minimum instream flows and set aside a reservation of water for future development (reserve). In this rule, the Mission Creek

Subbasin is subject to an interim reserve of 0.03 cubic feet per second (cfs). CCNRD and the WWPU conducted water-storage assessments and engaged local stakeholders to help identify viable solutions to the water supply issues in Mission Creek. Though opportunities are somewhat limited, targeted improvements are possible for streamflow, habitat, and water quality, and for out-of-stream domestic uses.

Pumping groundwater to augment streamflow and mitigate other water use is sometimes an effective strategy to create streamflow benefit. The objective of this study was to determine if the aquifer(s) are suitable for augmenting streamflow and supporting irrigation in the Mission Creek Watershed during periods of low streamflow (June to September; Project). CCNRD met with local landowners to discuss this alternative and Alternative 2 (Surface to Ground Transfer) of the Appraisal.

The landowners were very receptive to gaining greater clarity on how significantly their wells were connected to Mission Creek, their long-term reliability, aquifer characteristics, and the potential for implementation of these alternatives. In cooperation with willing landowners, a long-term aquifer test was envisioned as a first step that could transition into a long-term harvest-time pump augmentation program. The concept is that landowners could help augment streamflow with groundwater discharges from their existing wells when their pumps would otherwise be shut off to harvest fruit. Existing wells used in the Project were not optimum for the overall investigation goals; however, due to available grant funding and landowner interest, the infrastructure was sufficient (with modifications) to meet feasibility-level data-quality objectives.

CCNRD met with the Washington State Department of Ecology (Ecology), Washington Department of Fish and Wildlife (WDFW), and the Yakama Nation to explore options on evaluating this alternative. As a result, CCNRD applied for and received a preliminary permit to pilot this effort in 2016.

Summary of Results

Previous hydrogeologic studies of the Mission Creek Basin have been limited to surface water and groundwater interaction (Ecology, 2003 and AMEC, 2010). The primary purpose of this study was to evaluate hydrogeologic conditions to determine if streamflow augmentation and conversion of surface water right diversions to groundwater withdrawals were feasible.

Our findings suggest pumping groundwater to augment streamflow is best suited for providing mitigation (e.g., temperature or critical ripple depth) for fish passage at select areas during fish windows or during periods of drought. Pumping groundwater into Mission Creek to satisfy minimum instream flows is not an effective solution due to the following factors:

- Groundwater pumping effects on surface water are likely to occur above the Yaksum Creek confluence; therefore, the ability to disperse impacts from pumping groundwater out of the Mission Creek Basin and into the greater Wenatchee River Basin is limited above Yaksum Creek.
- Groundwater level recovery from pumping is slow where the aquifer is semiconfined. This limits the run time and density of wells to augment streamflow, due to pumping interference

or year-to-year carry over of pumping effects that can lead to long-term declining groundwater levels.

- Surface water infiltrates through the streambed below the Yaksum Creek, which creates a challenge to see flow benefit at Ecology station 45E070 because a larger discharge of water to the stream is necessary to satisfy the minimum instream flow deficit.
- The low transmissivity of the semiconfined Chumstick aquifer increases the potential for pumping interference and impairment. Additionally, water is not available from the semiconfined alluvial aquifer due to the low transmissivity and extent.
- Suboptimal water quality, due to reducing conditions (e.g., low dissolved oxygen) in the semiconfined aquifer, requires additional study to determine if emergency drought relief application of streamflow augmentation is advisable for reducing fish mortality.

Based on results of the pilot Project, we find that streamflow augmentation with groundwater is not well suited in the Mission Creek Watershed, due to the necessary quantity and size of wells to improve streamflow. Augmenting streamflow with groundwater is effective when the source aquifer can produce a sufficient quantity of water, and the stream and source aquifer are separated by a very low-hydraulic conductivity unit (clay or sandstone). Augmentation is less effective when the adequate groundwater is not available, groundwater recovery from pumping is slow, and the stream loses water to ground—which is the case in the Mission Basin. However, there is potential for streamflow augmentation using groundwater wells to provide short-term emergency drought relief along priority habitat reaches. Additional study is necessary to identify priority reaches, characterize groundwater quality to determine suitability for aquatic health, and model the location and timing of streamflow improvements and deficits.

The permitting pathway to convert water rights from surface water diversions to groundwater withdrawals is dependent on Ecology’s administration of groundwater bodies in the Mission Basin (Revised Code of Washington [RCW] 90.44.100). The Wenatchee Watershed Management Plan (WWPU, 2006) implies conjunctive management of surface water and groundwater resources. If Ecology administers groundwater and surface water as two separate sources, then a two-step permitting process is necessary, where the claim is placed into the Trust Water Right Program and used to mitigate the new groundwater withdrawal.

The low transmissivity of the Chumstick aquifer requires well completion depths capable of producing 320 feet of available drawdown and sufficient separation or pumping schedule to limit pumping interference and impairment to surrounding groundwater users. The semiconfined alluvial aquifer is limited in extent, which makes the aquifer susceptible to impairment. It is feasible to convert surface water diversions to groundwater withdrawals via the two-step permitting process, withdrawal with a properly drilled and constructed well, and an intermittent pumping schedule that allows for groundwater level recovery. The conversion is more feasible if peaking is satisfied with a surface water withdrawal during spring runoff or combined with small reservoir storage.

A summary of the technical results is provided below:

- The Chumstick aquifer has a transmissivity of approximately 50 square feet per day (ft2/day) and hydraulic conductivity of 0.2 feet per day (ft/d). The alluvial aquifer has a transmissivity of approximately 1,250 ft2/day and a hydraulic conductivity of 100 ft/d.

- Test Wells (TWs) were representative of both unconfined (TW-1, -2, and -6) and semiconfined conditions (TWs-4 and -5).
- Samples collected from TWs and the upper and lower surface water stations were analyzed for Dichlorodiphenyltrichloroethane (DDT)/ Dichlorodiphenyldichloroethane (DDD)/Dichlorodiphenyldichloroethylene (DDE), fecal coliform, orthophosphate, total phosphorous, nitrate, nitrite, total kjeldahl nitrogen, and total suspended solids. All results were below water quality screening levels or detection limits, with the following exceptions:
    - 4,4-DDE was detected at TW-1 at 2.3 and 2.1 nanogram per liter (ng/L), which is above the state surface water criteria for protection of aquatic organisms of 1 ng/L, but below the groundwater standard of 300 ng/L. While groundwater at TW-1 is suitable for potable use, it is not suitable for augmentation of streamflow.
    - Nitrate-N was detected in TW-1 and -2 at concentrations below groundwater standard of 10 mg/L.
- Average daily streamflow along the study corridor ranged from 8 to 30 cubic feet per second (cfs) during the duration of the Project. The streamflow at the Ecology gaging station ranged from 0 to 56 cfs during the same period.
- Comparison of streamflow between surface water stations indicate a losing condition between MC-Upper and MC-03 and gaining condition between MC-03 and MC-02. A losing condition appears to occur between MC-02 and MC-Lower Mission Creek.
- A basaltic dike was identified in the field near the location of OW-2 and MC-02. The location coincides with a measured increase in streamflow and a very low-yield water supply well that was used as an observation well (OW-2). OW-2 was the only well monitored with no influence from stream stage. The outcrop is not shown on publicly available geologic maps; however, basaltic dikes and sills are mapped elsewhere within the Chumstick Formation. This extrusion appears to behave as a barrier to groundwater flow, and results in localized compartmentalization of the Chumstick aquifer.

The stream response factors (time to induce pumping effects) for the wells completed in unconfined aquifers (TW-1, -2, and -6) are higher (1 to 270 days) than the semiconfined aquifers (0.03 to 0.5 days). The higher stream response factors and relatively quick recovery times (0.75 to 6 hours) of TW-1 and -2 suggest streamflow augmentation is more feasible in the lower unconfined aquifer.

Geological Framework

Structural setting, geologic history, and occurrence of groundwater provide the basis for our interpretation of the hydrogeology of the Project area. The Project area is sited in the Chiwaukum graben within the Cascade Crystalline Core of the North Cascades geologic province. Today, the sedimentary rocks of the Eocene Chumstick Formation are bounded by two major northwest-southeast trending fault zones: the Leavenworth Fault to the west and the Entiat Fault to the east. These faults separate the mainly sedimentary deposits of the Chumstick Formation from the surrounding metamorphic rocks and flood basalts of the Columbia River Basalt Group found to the south as shown on Figure C-1. The structural basin is internally folded and faulted and includes the Eagle Creek Fault Zone.

The Chumstick Formation is a nonmarine sedimentary deposit formed during a period of extensional tectonics after the cessation of the Late Cretaceous Laramide orogeny. The structural basin(s) hosting the Chumstick Formation were characterized by rapid subsidence and sediment accumulation, rapid lateral and vertical changes in sediment facies, changing paleocurrent pattern and sediment provenance, and syndepositional magmatism. Estimates on the depositional age of the Chumstick Formation range from 48 to 41 mega-annum (Ma) to less than 51 to 37 Ma (Enkelmann et al., 2015). Silling (1979) estimated the basin at 2km thick based on a gravity survey.

The Chumstick Formation is a white sandstone with varying amounts of shale, conglomerate, fanglomerate, and rare siliceous tuff (Tabor et al., 1982). Gresens (1983) notes several mafic to intermediate igneous rocks intruding the Chumstick Formation. Gresens (1983) also mapped basaltic (horneblende andesite) dikes in the Chumstick Formation in the upper portion of the Mission Creek basin. Field reconnaissance during the Project located an unmapped hornblende andesite dike ($142^o/45^o$ NE) located near surface water station MC-02 and observation well OW-02 as indicated on Figure C-2. Based on comparison of upstream and downstream continuous flow measurements and aquifer tests, this structure likely is a barrier to groundwater flow and compartmentalizes the aquifer.

Overlying the Chumstick Formation are alluvial sediments derived from subsequent erosion of the Chumstick Formation, resulting in an angular unconformity. Today, the channel of Mission Creek is an incised sand- to cobble- to bedrock-dominated channel within the valley bottom alluvial deposits. The Mission Creek valley is situated within the deeply-incised Chumstick Formation forming a NNE-SSW trending canyon. The canyon roughly follows the strike of the 20 to 50 degree west-northwest dipping beds, with the Mission Creek channel crossing multiple dipping sandstone beds.

A shallow alluvial aquifer is present in the Project area. In the lower reach observation well, OW-01 is a dug well completed in the water table aquifer. In the upper reach of the Project area the alluvial aquifer has a clayey confining unit overlying a sand and gravel layer. The clayey layer creates semiconfined aquifer condition. The underlying Chumstick Formation aquifer is semiconfined due to the alternating sequence of sandstone, shale, and tuffs where fine-grained beds and low-grade metamorphism form confining units. Evaluation of groundwater and surface water elevations and aquifer testing indicate the Chumstick Formation aquifer is in hydraulic continuity with the overlying alluvial aquifer and Mission Creek along the project area.

Well Selection and Permitting

The following section describes the methodology used in completing the Project. Implementation of the Project was greatly influenced by willingness of landowners and voluntary use of their existing well infrastructure and equipment to perform aquifer testing. Without their involvement, an augmentation study requiring new infrastructure would have required hundreds of thousands of dollars in drilling costs alone. To conform to available grant funding and landowner interest, existing wells were used that were not necessarily optimum for the overall investigation goals, but nevertheless advanced the learning of this proof-of-concept option.

Well Selection

Well selection began with a meeting held on May 20, 2015, with Mission Creek Basin landowners and CCNRD to discuss flow improvement concepts and collect feedback as part of an ongoing County-led watershed planning process. Four landowners expressed interest in pursuing future projects with CCNRD. A reconnaissance-level site visit was performed in November 2015 to evaluate seven irrigation wells for inclusion in a hydrogeologic evaluation. From the seven wells evaluated, six wells were selected for initial testing in April 2016. The six wells were selected based on landowner involvement, completion depths (wells completed in the Chumstick Formation were preferred over alluvium wells) and used solely for irrigation purposes. Following the April 2016 testing, it was determined that to meet standard data-quality objectives for the Project, sounding tubes and a video scan of each well was necessary to collect water-level data and well-construction details. One well, TW-3, was excluded from the Project due to sedimentation of the well.

Permitting

CCNRD submitted preliminary permit application materials for authorization to test wells on July 15, 2016. A preliminary permit for Water Right Application No. G4-33175 was issued October 31, 2016. The overall objective of the preliminary permit is to obtain sufficient hydrogeologic data to support a decision on the water right application for Ecology to evaluate water availability, impairment of existing rights, and whether the proposed withdrawal would be detrimental to the public welfare. CCNRD's application for a preliminary permit was to facilitate aquifer testing with the intent to collect necessary information to evaluate streamflow augmentation with groundwater and surface-to-groundwater transfers as alternatives in the Appraisal.

A Project planning meeting between CCNRD, WDFW, Yakama Nation, and Ecology took place in June 2016 to discuss the project goals and permitting pathway. CCNRD developed a quality assurance project plan (QAPP; Aspect, 2016) and obtained a construction stormwater general permit (WAR304325) to authorize discharge of dewatering water to Mission Creek, a preliminary permit (G4-33175) for approval to complete pumping tests in each irrigation well, and hydraulic project approval (2016-2-97+01) for the installation and maintenance of the temporary discharge structures.

Field Measurements

The following sections provide an overview of the deviations from the QAPP; locations of surface water stations, observations, and test wells; and a general description of well completions.

Acquisition of data primarily relied on dataloggers to collect pressure and flow rate readings from pressure sensors and flow meters. Field measurements were collected for quality assurance, quality control, and as back-up measurements in the event of data loss or equipment failure.

QAPP Deviations

The QAPP details the procedures for data collection and evaluation of aquifer parameters and water quality. During implementation of the project, three deviations from the QAPP occurred, including:

1. Elimination of TW-3 from study
2. Additional surface water gaging stations

3. Shorter duration pumping tests on TW-1 and -2

Surface Water Monitoring Locations

Surface water gaging stations were established along a 3.6-mile-long corridor of Mission Creek that ranges in elevation from 1,300 to 980 feet above mean sea level. Details and locations are presented in Table C-1 and on Figure C-2. The upstream and downstream surface water monitoring stations, MC-Upper and MC-Lower, were established to measure water quality parameters, stream stage, and flow. The surface water monitoring stations established within monitored corridor (MC-01, MC-02, and MC-03) were established to measure stream stage and change in stream flow between gaging stations. These stations were added after development of the QAPP, based on stakeholder input and anecdotal evidence of gaining and losing reaches along the corridor.

The distance between each of the gaging stations was approximately 1 mile, except for the distance between MC-02 and MC-03, which was 0.6 mile. The downstream gaging station (MC-Lower) bounds lower end of the project area to above Tripp Canyon, approximately 2.8 river miles from the Wenatchee River confluence. The upstream gaging station (MC-Upper) was located below the Wenatchee National Forest boundary adjacent to the uppermost orchard in Mission Creek, approximately 6.4 river miles upstream from the Wenatchee River confluence.

Groundwater Monitoring Wells

Groundwater monitoring occurred at two different well types: test wells (TW) and observation wells (OW). Water quality and continuous measurement of groundwater levels and discharge rates were collected at TWs and continuous water level measurements were collected at the OWs. Table C-2 provides an overview of the locations and observations made at the TWs and OWs.

Groundwater Well Locations

The TWs and OWs were located longitudinally along Mission Creek (Figure C-2). Mission Creek was broken into two reaches—upper and lower—based on field observation of a basaltic dike, stream discharge measurements, and static water level measurements:

- **Lower Reach –** TW-1 and -2 were located 170 feet apart, with OW-1 located between the two test wells. These wells were located at the downgradient portion of the lower reach (Figure C-2).
- **Upper Reach –** OW-3 was a domestic supply well located along the lower one-third of the upper reach. TW-4 was located approximately 1,200 feet south of OW-3. TWs-4, -5, and -6 were located along the upper one-half of the upper reach (Figure C-2). OW-4 was located 60 feet to the northeast of TW-6.

Well Construction

The TWs were completed in either alluvium or the Chumstick Formation. Detail on well construction and aquifer completion are provided in Table C-3 and Attachment C-1. A summary of well construction and water bearing units is provided below:

- TW-1 was drilled and cased to 43 feet below ground surface (bgs) and completed as open hole to 254 feet bgs via cable tool. The casing was driven 2 feet into sandstone of the Chumstick Formation and was sealed to 30 feet bgs. The casing does not provide a sufficient seal to prevent water from the overlying alluvium from entering the open hole. TW-1 captures water from the Chumstick Formation with a minor contribution from the overlying alluvium.

- TW-2 was initially drilled to 40 feet via air rotary. The well was cased and completed with 5 feet of well screen from 32 to 37 feet bgs. Subsequently, the steel casing and stainless-steel screen were removed. The well was deepened to 218 feet bgs via air rotary. An 8-inch-diameter PVC casing was installed and sealed to 45 feet bgs, approximately 4 feet into sandstone of the Chumstick Formation. A 7-inch-diameter PVC liner is perforated beginning at 70 feet bgs and extends to 228 feet bgs. TW-2 captures water from the Chumstick Formation with a minor contribution from the overlying alluvium (i.e., water from the overlying alluvium audibly cascades into the well).
- TW-3 was removed from the Project. The well was full of sediment and the pump was heavily damaged from pumping sand.
- TW-4 was drilled to 52.5 feet bgs via air rotary. Casing was installed to a depth of 41 feet bgs, perforated from 31 to 40 feet bgs, and sealed to 18 feet bgs. The bottom 12.5 feet of the well was completed as an open hole in sandstone and shale of the Chumstick Formation. TW-4 captures water from a sand and gravel unit located above the Chumstick Formation.
- TW-5 was drilled to a depth of 320 feet bgs via air rotary. The well was completed as open hole in the Chumstick Formation except for a 19-foot surface casing and seal through a sandy alluvium. TW-5 captures water from multiple water-bearing zones (bedding planes and primary porosity) within the Chumstick Formation.
- TW-6 was deepened to 340 feet bgs via air rotary from 280 feet bgs. The original driller’s report was not located, and the 6-inch-diameter PVC liner prevented video of the formation and well construction details. Based on construction of neighboring wells, it is presumed an 8-inch-diameter casing extends at least 40 feet through alluvium and the well is open to the Chumstick Formation. TW-6 captures water from the Chumstick Formation with a minor contribution from the overlying alluvium.

The OWs were completed as either alluvium or Chumstick Formation wells, and have construction details as follows:

- OW-1 was a dug well completed in alluvium. A driller’s log was not available.
- OW-2 was drilled to 400 feet bgs via air rotary. Casing and surface seal extend to 22 feet bgs. The well was completed as an open-hole and captures water from the Chumstick Formation.
- OW-3 was drilled to 79 feet bgs via air rotary. A casing extends through the alluvium to 39 feet bgs and is perforated from 21 to 34 feet bgs. The bottom 40 feet was completed as open hole in the Chumstick Formation. OW-3 captures water from a sand and gravel unit and the Chumstick Formation.
- OW-4 was drilled to 38 feet bgs via air rotary. A casing extends the entire length of the well and captures water from the alluvium through an open bottom.

Aquifer Tests

Short (less than 8-hour) pumping tests were conducted on the lower reach TWs (TW-1 and -2). The upper reach TWs (TW-4, -5, and -6) were continuously pumped for at least 26 days. During the pumping tests, water levels were collected in the nonpumping TWs and OWs. Table C-4 provides an overview of the aquifer testing conditions.

Data Analysis

The use of groundwater to augment streamflow depends on a sufficient quantity of water that meets water quality objectives and will not impact streamflow in an unacceptable time nor place. This section details the methods used to analyze the data collected during the field study. Field data was collected to evaluate hydraulic continuity between the aquifer and Mission Creek, aquifer characteristics, boundary conditions, and water quality with respect to Mission Creek's water quality impact listings (i.e., 303d listings).

Surface Water and Groundwater Hydrographs

Hydrographs, which illustrate rate of flow (discharge) or water level over time, are used to evaluate changes in streamflow and groundwater level due to influences from changes in climatic conditions (precipitation and barometric pressure), geography, and human activity (groundwater pumping). Continuous data was collected to enable evaluation of surface water and groundwater hydrographs.

Stream Stage and Flow

Surface water hydrographs were generated from 15-minute stage measurements. Table C-5 is the rating table used for continuous streamflow measurements. A rating curve describes the unique relationship between depth and streamflow for each gaging station. A rating curve for each temporarily established gaging station was used to convert the 15-minute stage measurements to a discharge. Discharge measurements were made over varying flow rates. Streamflow measurements made on October 28, 2016, were flagged as having "possible equipment malfunction;" these stage and flow rate measurements were excluded from the rating curves.

Due to the limited number of discharge-stage measurements and narrow range of discharges measured, a simple linear regression was used to describe the relationship between stream stage and flow rate. Average daily streamflow measured at the temporary gaging stations during the Project ranged from 8 to 30 cfs, as shown on Figure C-3. Ecology gaging station 45E070, located at the mouth of Mission Creek near the confluence with the Wenatchee River, measured 0 to 56 cfs during the same period.

Simultaneous measurement of stream flow at multiple locations allows for estimation of losing and gaining reaches along the stream corridor. To quantify gaining and losing reaches, a more detailed study was necessary to account for contributions from tributaries and return flow, and losses from withdrawals and evapotranspiration along the reach. Review of Figure C-3 suggests the stream loses flow along the length of the stream. An exception occurs between stations MC-03 and MC-02 where a greater amount of flow is observed in Mission Creek. This coincides with the location of an observed outcrop of a basaltic dike, suggesting that diking is perhaps constricting flow through the alluvium to the surface.

Groundwater Levels

The static groundwater levels in the TWs prior to conducting the aquifer tests are presented on Figure C-4. The relative barometric effect to total drawdown is small; therefore, a correction for barometric efficiency was not applied to the dataset. The influence of stream stage on groundwater levels was not apparent in the static water levels. Longer-term ambient groundwater monitoring may provide additional insight on well response and aquifer recharge due to changes in stream stage during peak-flow and low-flow events.

The full hydrograph for the OWs is presented on Figure C-5. The hydrograph shows recharge was occurring in OW-4, -3, and -1. However, the hydrograph for OW-2 is flat, which is an indication that OW-2 was not rapidly recharged. Due to the lack of recharge or response to stream stage OW-2 is interpreted as completed in a compartmentalized body of groundwater with little connection to Mission Creek, nor to the greater alluvial or Chumstick aquifers.

Pumping effects are discernable in the hydrographs for OW-1, -3, and -4. Pumping TW-1 and -2 had a rapid response on OW-1; whereas, the pumping effect on OW-3 from pumping TW-4 showed a delayed pumping effect due to removing water from storage and depressing the potentiometric surface in the alluvial aquifer.

Aquifer Characteristics

Aquifer parameters (hydraulic conductivity and transmissivity) and presence of boundary conditions are often determined by analysis of time-drawdown and recovery curves. Aquifer parameters were derived by calculating transmissivity using Jacob's straight-line method (Kruseman and de Ridder, 2000). Storativity was estimated based on aquifer condition (confined, semiconfined, or unconfined) and lithology for the unconfined condition. The presence of boundary conditions is presented as inflections in drawdown curves (Driscoll, 1986).

Aquifer Parameters

The hydraulic conductivity of the alluvial sediments is approximately 100 feet/day, and a transmissivity of 1,270 feet^2/day, assuming a saturated thickness of 13 feet. The underlying Chumstick Formation sandstone has a hydraulic conductivity of approximately 0.2 feet/day, and a transmissivity of 50 feet^2/day, assuming an average saturated thickness of 265 feet is captured by wells.

TW-1, -2, and -6 are completed in an unconfined aquifer, and TW-4 and -5 are completed in semiconfined aquifers. Storativity of the semiconfined aquifer is estimated at $1x10^{-3}$, and 0.15 for the unconfined aquifer. Table C-6 presents the aquifer characteristics derived from aquifer testing.

Drawdown curves for TW-1 and TW-2 were not analyzed due to excessive drawdown during pumping tests resulting in pump cavitation and high pressure at the wellhead discharge. Recovery curves for TW-1 and TW-2 were captured to facilitate analysis of aquifer parameters (see Figures C-6 and C-7 for recovery curves).

Boundary Conditions

The presence of boundary conditions was evaluated by analysis of drawdown curves. A positive boundary condition is indicative of a recharge boundary (e.g., stream), and a negative boundary condition indicates a potential barrier to groundwater flow (Driscoll, 1986). Figures C-8 thru C-10 present the drawdown and recovery curves used for analysis of these wells. Time-drawdown curves for TW-4, -5, and -6 indicate the presence of a potential recharge boundary following 2 to 8 days of testing.

The Project drawdown and recovery curves present a characteristic S-shaped-curve. TWs-1, -2, -5, and -6 were completed in Chumstick sandstone. The shape of the drawdown curves suggests that discharge from the aquifer is satisfied by double-porosity aquifer framework. For example, early in the pumping cycle, flow towards the well is entirely through fractures, or bedding planes, which have higher hydraulic conductivity and lower storage capacity. Later, the primary porosity of the sandstone layers (which have lower hydraulic conductivity and higher storage capacity) contributes flow to the fractures, which stabilizes drawdown. Finally, late in the pumping cycle, flow is entirely from the primary porosity of the sandstone layers.

The alluvial well TW-4 also shows a characteristic S-shaped curve; however, the mechanism is different due to the unconsolidated nature of the aquifer matrix. For TW-4, the early pumping is typical for a semiconfined aquifer, but later the curve flattens as flow drains from the pores in the overlying silty clay unit, then discharge is entirely from storage.

Well Yield

The well yield is derived as the specific capacity and available drawdown within the well. Specific capacity is a measure of well yield per unit drawdown, expressed as gallons per minute per foot (gpm/ft), and available drawdown is the height of water above the pump intake, minus 10 feet (to keep water above the intake). The yield of the alluvial well is approximately 90 gpm and the sandstone wells have a lower average yield of approximately 60 gpm. Table C-7 provides the specific capacity, available drawdown, and yield of the TWs.

Water Quality

Surface water sample results indicate an increase in fecal coliform count and nitrate from upstream to downstream. Surface water and groundwater quality sample results are presented in Table C-8 and laboratory reports are provided in Attachment 2.

Groundwater quality results indicate variability concerning the oxidation-reduction potential (ORP) and dissolved oxygen (DO) content. ORP and DO are often positively correlated. TW-6 and TW-5 indicate reducing conditions exists. This is consistent with field observation of weak sulfurous odor from TW-6 and strong odor from TW-5 during pumping.

Pesticide 4,4-DDE was detected in TW-1 at a concentration of 2.3 ng/L, and in the duplicate sample (BCC615) at 2.1 ng/L. These concentrations are above surface water quality criteria for protection of aquatic health (1.0 ng/L).

All other parameters for samples collected not mentioned above were either below detection limits or detected at levels below regulatory criteria.

Postcalibration of the conductivity sensor revealed that the measurements collected on November 7, 2016, were not accurate; actual conductivity of the stream is lower than measured.

Additional steps should be taken to characterize the water quality of potential streamflow augmentation wells for aquatic health, and geochemically “type” the water for purposes of understanding recharge pathways.

Surface Water Diversion to Groundwater Point of Withdrawal

Authority to convert a surface water right to a groundwater right is derived through several laws, including RCW 90.03.380, 90.44.100, and 90.54.020(9), provided the change occurs within the same source of water, water is available, in the public interest, and will not impair existing rights.

Same Source of Water

Figure C-4 shows the fluctuation of static water levels in the test wells, barometric pressure, and streamflow over a 1-week period. The hydrograph suggests the Chumstick (semiconfined and unconfined) and semiconfined alluvial aquifers are not in direct hydraulic continuity with Mission Creek, and likely not considered to be the same source of water.

A determination on water right administration is a consideration of both management and technical considerations. WWPU (2006) implies a conjunctive management of surface and groundwater resources. Alternatively, it is possible to obtain a new groundwater right by transferring a certificated surface water right to the Trust Water Right Program (TWRP) and using the trusted water right as mitigation for a new water budget neutral (WBN) groundwater right.

Based on local geology, aquifer conditions, and observed well yields, we have assumed the average well can produce about 75 gpm, which implies that one well will be required for every 8.3-acre orchard block at an average water duty of 9 gpm/acre.

Impairment Analysis

RCW 90.03.290 and RCW 90.44.060 require a determination that a water right change will not impair existing rights. Impairment was evaluated by calculating drawdown in a hypothetical neighboring well using the aquifer parameters in Table C-6, a storativity of 1×10^{-3} for semiconfined aquifers, an assumed distance of 400 feet between a proposed point of withdrawal and neighboring permitted or permit-exempt well, and the governing Theis equation (Theis, 1935). We assumed that an instantaneous quantity (Qi) of 75 gpm was necessary for an 8.3-acre orchard (or about 9 gpm/acre).

Continuously pumping a well completed in the Chumstick aquifer was calculated to result in approximately 7 feet and 68 feet of drawdown over a 1-day and 1-month period, respectively. For a well completed in the semiconfined alluvial aquifer, continuous pumping resulted in 2.6 feet and 5.6 feet of drawdown over a 1-day and 1-month period, respectively. Pumping groundwater from the Chumstick or alluvial aquifers for 1 day is not a cause for impairment. Due to the thickness of the Chumstick Formation 68 feet of additional drawdown may not constitute impairment; however, an additional 68 feet of drawdown in existing wells, which may not have sufficient available drawdown, may constitute impairment. An additional 5.6 feet of drawdown in the alluvial aquifer may constitute impairment due to the limited thickness of the semiconfined alluvial aquifer. Any impacts to surface water would be offset by the nondiversion of surface water.

Water Availability

Water availability is considered as two parts: legal availability and physical availability.

The specific capacity of tested wells is relatively low (average of 0.3 gpm/ft) for wells completed in the Chumstick Formation. The specific capacity for the TW-4, completed in the semiconfined alluvial aquifer, is higher at 3.9 gpm/ft; however, groundwater level decline was observed in OW-2, which suggests the semi-confined alluvial aquifer is limited in extent. The limited extent of the semiconfined alluvial aquifer makes it susceptible to impairment.

To satisfy peak demand (i.e., instantaneous quantity) for an 8.3-acre orchard, approximately 75 gpm is required. This instantaneous quantity requires a minimum of 250 feet and 19 feet of available drawdown in the Chumstick and alluvial aquifers, respectively. Given thinness of the semiconfined alluvial aquifer and observed decline during testing, it is reasonable to assume water is not available. Given the thickness of the Chumstick Formation water may be available; however, a reduction is water quality is anticipated with depth that may limit availability.

Regarding the legal availability of water, review of surface water rights in the Mission Basin revealed that most water rights are claims. Transfer of claims will require Ecology to review extent and validity of the water right and make a tentative determination of the beneficial use, and public notice.

While water may be legally available for groundwater withdrawal by mitigation with a surface water right, water physical availability is very limited.

Streamflow Augmentation

The goal for augmenting streamflow with groundwater in the Mission Basin was to increase streamflow during the low-flow season (e.g., June to September) and offset impacts from permit-exempt well withdrawals. Augmenting streamflow with groundwater is effective when the source aquifer can produce a sufficient quantity of water, and the stream and source aquifer are separated by a very low hydraulic conductivity unit (clay or sandstone). Augmentation is less effective when the source aquifer cannot produce sufficient quantities of water, groundwater recovery from pumping is slow, and the stream loses water to ground.

Stream depletion due to groundwater pumping is evaluated by calculating a stream response factor, which indicates how rapidly streamflow depletion will occur in response to pumping (Barlow and Leake, 2012). The stream response factors and recovery times for the Project are presented in Table C-9. The stream response factors for the wells completed in unconfined aquifers (TW-1, -2, and -6) were higher (1 to 270 days) than the semiconfined aquifers (0.03 to 0.5 days). The higher stream response factors and relatively quick recovery times (0.75 to 6 hours) of TW-1 and -2 suggest streamflow augmentation is more feasible in the lower unconfined aquifer.

The quantity of water necessary to increase streamflow to the minimum instream flow (WAC 173-545-60) during June for steelhead spawning (24.2 cfs) is 9.2 cfs during a median year and approximately 15.8 cfs during the 2015 drought year, as measured at Ecology gaging station 45E070. Augmenting the streamflow with wells would require 55 to 95 wells (of similar construction to those tested) pumping 75 gpm. This does not account for water that would be lost to ground prior to reaching Ecology’s gaging station.

Streamflow augmentation in the Mission Basin is not considered an effective solution for improving low-flow season flows due to the quantity of water necessary to meet the minimum instream flow criteria, potential for impairment to neighboring water rights, and groundwater availability.

The applicability of pumping groundwater to augment streamflow is more applicable to improving flow conditions for targeted reaches. Especially, for providing mitigation (e.g., temperature or critical ripple depth) for fish passage at select areas during certain times or during periods of drought. Additional study is necessary to identify priority reaches, characterize groundwater quality to determine suitability for aquatic health, and model the location and timing of streamflow improvements and deficits.

References

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Theis, C.V., 1935, The lowering of the piezometer surface and the rate and discharge of a well using ground-water storage, Transactions, American Geophysical Union, 16:519-24.

Washington State Department of Ecology (Ecology), 2003, Powerpoint Presentation: Preliminary Assessment of Surface Water and Ground-Water Interactions Within the Wenatchee River Watershed (WRIA 45), Investigations Conducted in Support of the Wenatchee River Temperature TMDL.

Wenatchee Watershed Planning Unit (WWPU), 2006, Phase III Wenatchee Watershed Management Plan, April 2006.

Limitations

Work for this project was performed for the Chelan County Natural Resources Department (Client), and this report was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

All reports prepared by Aspect Consulting for the Client apply only to the services described in the Agreement(s) with the Client. Any use or reuse by any party other than the Client is at the sole risk of that party, and without liability to Aspect Consulting. Aspect Consulting's original files/reports shall govern in the event of any dispute regarding the content of electronic documents furnished to others.

Attachments

Attachment C-1 – Well Logs
Attachment C-2 – Laboratory Reports
Table C-1 – Surface Water Stations
Table C-2 – Groundwater Monitoring and Test Locations
Table C-3 – Well Construction
Table C-4 – Aquifer Test Conditions
Table C-5 – Rating Table
Table C-6 – Aquifer Parameters
Table C-7 – Well Yield
Table C-8 – Water Quality Results
Table C-9 – Stream Response Factor
Figure C-1 – Mission Creek Basin Surficial Geology
Figure C-2 – Monitoring Locations
Figure C-3 – Surface Water Hydrographs
Figure C-4 – TWs Static Water Levels
Figure C-5 – OWs Water Levels
Figure C-6 – TW-1 Recovery Curves
Figure C-7 – TW-2 Recovery Curves
Figure C-8 – TW-4 Drawdown and Recovery Curves
Figure C-9 – TW-5 Drawdown and Recovery Curves
Figure C-10 – TW-6 Drawdown and Recovery Curves

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ATTACHMENT 1

Well Logs

TW-1

File Original and First Copy with
Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No. 84-25191

Permit No. ....

(1) OWNER: Name Ken Ahrens Address Rt 1 Cashmere Wash.

(2) LOCATION OF WELL: County Chelan NW¼ SW¼ NE ¼ Sec. 17 T. 23 N., R. 19 W.M.

Bearing and distance from section or subdivision corner See Application # 6

(3) PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☐ Irrigation ☒ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) ....

New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☒ Driven ☐
Reconditioned ☐ Rotary ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 8 inches.
Drilled 153 ft. Depth of completed well 153 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 8 " Diam. from +1 ft. to 43 ft.
Threaded ☐ .... " Diam. from .... ft. to .... ft.
Welded ☒ .... " Diam. from .... ft. to .... ft.

Perforations: Yes ☐ No ☒
Type of perforator used ....
SIZE of perforations .... in. by .... in.
.... perforations from .... ft. to .... ft.
.... perforations from .... ft. to .... ft.
.... perforations from .... ft. to .... ft.

Screens: Yes ☐ No ☒
Manufacturer's Name ....
Type .... Model No. ....
Diam. .... Slot size .... from .... ft. to .... ft.
Diam. .... Slot size .... from .... ft. to .... ft.

Gravel packed: Yes ☐ No ☒ Size of gravel: ....
Gravel placed from .... ft. to .... ft.

Surface seal: Yes ☒ No ☐ To what depth? 30 ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? .... Depth of strata ....
Method of sealing strata off ....

(7) PUMP: Manufacturer's Name ....
Type: .... H.P. ....

(8) WATER LEVELS: Land-surface elevation above mean sea level.... .... ft.
Static level 20 ft. below top of well Date ....
Artesian pressure .... lbs. per square inch Date ....
Artesian water is controlled by .... (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? Bendickson
Yield: 73 gal./min. with 142 ft. drawdown after 2 hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ....
Bailer test .... gal./min. with 50 ft. drawdown after 2 hrs.
Artesian flow .... g.p.m. Date ....
Temperature of water .... Was a chemical analysis made? Yes ☐ No ☒

(10) WELL LOG:

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

MATERIAL	FROM	TO
Topsoil Brown	0	2
Boulders ~~[illegible]~~ & gravel	2	41
Sandstone grey	41	56
Water at 56' Dark grey sandstone	56	80
Dark grey shale	80	135
Sandstone light grey —	135	153
Bedrock	153	
Picked up water from 56'		
On down		

RECEIVED
AUG 25 1977
DEPARTMENT OF ECOLOGY
CENTRAL REGIONAL OFFICE

Work started 7-1, 1977 Completed 7-12, 1971

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Tumwater Drilling Inc. (Person, firm, or corporation) (Type or print)

Address Rt 1 Box 133-C Leavenworth Wash.

[Signed] John G (Well Driller)

License No. 0353 Date 7-12, 1971

OK

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20

3

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No.
Permit No. G4 25191P

(1) OWNER: Name Ken Ahrens Address RT 1 Box 348 Cashmere

(2) LOCATION OF WELL: County Chelan — SW ¼ NE ¼ Sec. 17 T. 23 N., R. 19 W.M.

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☐ Irrigation ☒ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one)

New well ☐ Method: Dug ☐ Bored ☐
Deepened ☒ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☒ Jetted ☐

(5) DIMENSIONS: Diameter of well 8 inches.
Drilled ft. Depth of completed well 254 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: " Diam. from ft. to ft.
Threaded ☐ " Diam. from ft. to ft.
Welded ☐ " Diam. from ft. to ft.

Perforations: Yes ☐ No ☒
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes ☐ No ☒
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes ☐ No ☒ Size of gravel:
Gravel placed from ft. to ft.

Surface seal: Yes ☐ No ☐ To what depth? ft.
Material used in seal
Did any strata contain unusable water? Yes ☐ No ☐
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level ft.
Static level 10' ft. below top of well Date 2-16-0
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Air Bailer test 120 gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG:

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

MATERIAL	FROM	TO
Shale	154	164
Sand stone	164	174
Shale	174	180
Sandstone	180	230
Shale	230	234
Sandstone	234	254

RECEIVED
APR 17 1980
DEPARTMENT OF ECOLOGY
CENTRAL REGION OFFICE

Work started , 19 Completed 2/16, 1980

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Glessner Well Drilling (Person, firm, or corporation) (Type or print)
Address 142 S Texas E Wenatchee
[Signed] Wesley Glessner (Well Driller)
License No. 0154 Date 2/18, 1980

✓ DK 4.22.80

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20

TW-2

WATER WELL REPORT

State of Washington Date Printed: 31-Aug-2010

Log No. 0

Construction / Decommission: Original Construction

Construction

Notice of Intent #: 415904

CURRENT

Notice of Intent No.: W267184

Unique Ecology Well I.D. No. BCC614

Water Right Permit Number: G4-25191C

OWNER: AHRENS, KEVIN

OWNER ADDR 3916 MISSION CREEK RD
CASHMERE, WA 98815

Well Add: 3916 MISSION CREEK RD

City: Cashmere, WA 98815 County: Chelan

Location: SE 1/4 NW 1/4 Sec 17 T 23 R 19E EWM

Lat/Long: (s, t, r still REQUIRED) Lat Deg Lat Min/Sec

Long Deg Long Min/Se

Tax Parcel No.: 231917240050

PROPOSED USE: IRRIGATION

TYPE OF WORK: Owners's Well Number: (If more than one well) 2

NEW WELL Method: ROTARY

DIMENSIONS: Diameter of well: 8 inches

Drilled 40 ft. Depth of completed well 37 ft.

CONSTRUCTION DETAILS:

Casing installed: WELDED

8 " Dia from +3 ft. to 33 ft.

" Dia from ft. to ft.

" Dia from ft. to ft.

Liner installed:

" Dia from ft. to ft.

Perforations: No Used In:

Type of perforator used

SIZE of perforations in. by in.

Perforations from ft. to ft.

Perforations from ft. to ft.

Perforations from ft. to ft.

Screens: 1 K-Pac Location: 31

Manufacture's Name JOHNSON

Type: STAINLESS Model No. SLOTTED

Diam. 8 slot size: 40 from 32 ft. to 37 ft.

Diam. slot size: from ft. to ft.

Gravel/Filter packed: No Size of Gravel

Material placed from ft. to ft.

Surface seal: Yes To what depth 33 ft.

Seal method: Material used in seal BENT/CASING

Did any strata contain unusable water? No

Type of water: Depth of strata

Method of sealing strata off

PUMP: Manufacture's name

Type: H.P. 0

WATER LEVELS: Land-surface elevation above mean sea level: 0 ft.

Static level 10 ft. below top of well Date 06/08/2010

Artesian Pressure lbs per square inch Date

Artesian water controlled by

WELL TESTS: Drawdown is amount water level is lowered below static level.

Was a pump test made? No If yes, by whom

Yield: gal/min with ft drawdown after

Yield: gal/min with ft drawdown after

Yield: gal/min with ft drawdown after

Recovery data (time taken as zero when pump turned off)(water level measured from well top to water level

Time:	Water Level	Time:	Water Level	Time:	Water Level

Date of test:

Bailer test gal/min ft drawdown after hrs.

Air test 30+ gal/min w/ stem set at 25 ft. for 2 hours.

Artesian flow gpm Date

Temperature of water Was a chemical analysis made No

CONSTRUCTION OR DECOMMISSION PROCEDURE

Formation: Describe by color, character, size of material and structure. Show thickness of aquifers and the kind and nature of the material in each stratum penetrated. Show at least one entry for each change in formation.

Material	From	To
LOAM BLACK	0	9
COBBLES GRAVEL WET	9	26
CLAY SAND DAMP	26	28
COBBLES GRAVEL WET	28	38
SAND BROWN DAMP	38	40

RECEIVED
JUN 15 2011
DEPARTMENT OF ECOLOGY - CENTRAL REGIONAL OFFICE

Notes:

Work started 06/07/2010 Completed 06/08/2010

WELL CONSTRUCTION CERTIFICATION:

I constructed and/or accept responsibility for construction of this well and its compliance with all Washington well construction standards. Materials used and the information reported are true to my best knowledge and belief.

☑ Driller ☐ Engineer ☐ Trainee

Name: AUDIE MCCURDY License No.: 2690

Signature:

If trainee, Licensed driller is: License No.:

Licensed Driller Signature:

Drilling Company:

NAME: FOGLE PUMP & SUPPLY, INC. Shop: REPUBLIC

ADDRESS: PO Box 456
Republic, WA 99166

Phone: 5097752878 Toll Free: 8008453500

E-Mail: leslie@foglepump.com

FAX: 5097750498 WEB Site: www.foglepump.com

Contractor's Registration No.: FOGLEPS095L4 Date Log Created: 06/16/2010

WATER WELL REPORT

State of Washington Date Printed: 31-Aug-2010 Log. No. 0

Construction / Decommission: Original Construction

Construction Notice of Intent #: W267184 415905

CURRENT

Notice of Intent No.: W266808

Unique Ecology Well I.D. No. BCC614

Water Right Permit Number: G4-25191C

OWNER: AHRENS, KEVIN

OWNER ADDR 3916 MISSION CR RD
CASHMERE, WA 98815

RECEIVED
JUN 15 2011
DEPARTMENT OF ECOLOGY - CENTRAL REGIONAL OFFICE

Well Add: 3916 MISSION CREEK RD

City: Cashmere, WA 98815 County: Chelan

Location: SE 1/4 NW 1/4 Sec 17 T 23 R 19 EWM

Lat/Long: (s, t, r still REQUIRED) Lat Deg Lat Min/Sec

Long Deg Long Min/Se

Tax Parcel No.: 231917240050

PROPOSED USE: IRRIGATION

TYPE OF WORK: Owners's Well Number: (If more than one well)

DEEPENED Method: ROTARY

DIMENSIONS: Diameter of well: 8 inches

Drilled 244 ft. Depth of completed well 244 ft.

CONSTRUCTION DETAILS:

Casing installed: WELDED

8 " Dia from +2 ft. to 45 ft.

" Dia from ft. to ft.

" Dia from ft. to ft.

Liner installed: PVC

6 " Dia from 9 ft. to 244 ft.

Perforations: Yes Used In: LINER

Type of perforator used SKILL SAW

SIZE of perforations 1/8 in. by 7 in.

192 Perforations from 71 ft. to 228 ft.

Perforations from ft. to ft.

Perforations from ft. to ft.

Screens: 0 K-Pac Location:

Manufacture's Name

Type: Model No.

Diam. slot size: from ft. to ft.

Diam. slot size: from ft. to ft.

Gravel/Filter packed: No Size of Gravel

Material placed from ft. to ft.

Surface seal: Yes To what depth 45 ft.

Seal method: Material used in seal BENTONITE

Did any strata contain unusable water? No

Type of water: Depth of strata

Method of sealing strata off

PUMP: Manufacture's name

Type: H.P. 0

WATER LEVELS: Land-surface elevation above mean sea level: 0 ft.

Static level 40 ft. below top of well Date 08/02/2010

Artesian Pressure lbs per square inch Date

Artesian water controlled by

WELL TESTS: Drawdown is amount water level is lowered below static level.

Was a pump test made? No If yes; by whom

Yield: gal/min with ft drawdown after

Yield: gal/min with ft drawdown after

Yield: gal/min with ft drawdown after

Recovery data (time taken as zero when pump turned off)(water level measured from well top to water level

Time:	Water Level	Time:	Water Level	Time:	Water Level

Date of test:

Bailer test gal/min ft drawdown after hrs.

Air test 100+ gal/min w/ stem set at 243 ft. for 1 hours

Artesian flow gpm Date

Temperature of water Was a chemical analysis made No

CONSTRUCTION OR DECOMMISSION PROCEDURE

Formation: Describe by color, character, size of material and structure. Show thickness of aquifiers and the kind and nature of the material in each stratum penetrated. Show at least one entry for each change in formation.

Material	From	To
EXISTING	0	37
GRAVEL	37	40
SAND	40	41
SANDSTONE GRAY	41	60
SANDSTONE BROWN SOFT WET	60	63
SANDSTONE GRAY MEDIUM	63	75
SANDSTONE BROWN SOFT	75	80
SANDSTONE GRAY MEDIUM	80	87
SANDSTONE BROWN SOFT	87	114
SANDSTONE GRAY MEDIUM	114	166
SANDSTONE BROWN SOFT	166	169
SANDSTONE BROWN SOFT	169	172
SANDSTONE GRAY MEDIUM	172	218

Notes:

Work started 07/27/2010 Completed 08/02/2010

WELL CONSTRUCTION CERTIFICATION:

I constructed and/or accept responsibility for construction of this well and its compliance with all Washington well construction standards. Materials used and the information reported are true to my best knowledge and belief.

☑ Driller ☐ Engineer ☐ Trainee

Name: AUDIE MCCURDY License No.: 2690

Signature: Audie McCurdy

If trainee, Licensed driller is: License No.:

Licensed Driller Signature:

Drilling Company:

NAME: FOGLE PUMP & SUPPLY, INC. Shop: REPUBLIC

ADDRESS: PO Box 456
Republic, WA 99166

Phone: 5097752878 Toll Free: 8008453500

E-Mail: leslie@foglepump.com

FAX: 5097750498 WEB Site: www.foglepump.com

Contractor's Registration No.: FOGLEPS095L4 Date Log Created: 08/31/2010

Water Well Log - Page 2

415905

FOGLE PUMP & SUPPLY, INC.

Log No. 0

Notice of Intent No.: W266808

Unique Well I.D. No.: BCC614

Well Construction Details Continued:

Material	From	To
SANDSTONE BROWN SOFT	218	230
SANDSTONE GRAY MEDIUM	230	244

File Original and First Copy with
Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No. [illegible]
Permit No

TW-3

(1) OWNER: Name Richard L. Turnbull Address

(2) LOCATION OF WELL: County Chelan - NE¼ NW¼ Sec. 29 T. 23 N., R. 19 W.M.
Bearing and distance from section or subdivision corner See Attached

(3) PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☒ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one)
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☒ Driven ☐
Reconditioned ☐ Rotary ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 8 inches.
Drilled 200 ft. Depth of completed well 200 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 8" Diam. from +1 ft. to 36 ft.
Threaded ☐ ......" Diam. from ...... ft. to ...... ft.
Welded ☐ ......" Diam. from ...... ft. to ...... ft.

Perforations: Yes ☐ No ☒
Type of perforator used
SIZE of perforations ...... in. by ...... in.
...... perforations from ...... ft. to ...... ft.
...... perforations from ...... ft. to ...... ft.
...... perforations from ...... ft. to ...... ft.

Screens: Yes ☐ No ☒
Manufacturer's Name
Type ...... Model No.
Diam. ...... Slot size ...... from ...... ft. to ...... ft.
Diam. ...... Slot size ...... from ...... ft. to ...... ft.

Gravel packed: Yes ☐ No ☒ Size of gravel:
Gravel placed from ...... ft. to ...... ft.

Surface seal: Yes ☒ No ☐ To what depth? 25 ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes ☐ No ☐
Type of water? ...... Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: ...... H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level.... ...... ft.
Static level ? ft. below top of well Date
Artesian pressure ...... lbs. per square inch Date
Artesian water is controlled by ...... (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom?
Yield: ...... gal./min. with ...... ft. drawdown after ...... hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test 13 gal./min. with 27 ft. drawdown after 1.5 hrs.
Artesian flow ...... g.p.m. Date
Temperature of water ...... Was a chemical analysis made? Yes ☐ No ☐
498 gal in 15 min.

(10) WELL LOG:

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

MATERIAL	FROM	TO
Top soil [illegible]	[illegible]	[illegible]
Loam Sandy Boulders	2	25
[illegible]	25	36
B. Rock [illegible] gray	36	45
Hard Shale black	35	60
Brown Shale med hard	60	70
Brown Sandstone	70	115
Soft Brown stone	115	120
[illegible] black hard	120	140
[illegible]stone	140	165
Shale black [illegible]	165	180
[illegible] Shale black	180	200

RECEIVED
OCT 1[illegible] 1977
DEPARTMENT OF ECOLOGY
CENTRAL REGIONAL OFFICE

Work started 8-19 19.. Completed 9-1 19..

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Tumwater Drilling Inc. (Person, firm, or corporation) (Type or print)

Address Rt1 Box 133C Leavenworth

[Signed] ...... (Well Driller)

License No. 0383 Date 9-1 1977

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20

TW-4

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Start Card No. W 36792
UNIQUE WELL I.D. # AAJ 531
Water Right Permit No. 414475

(1) **OWNER:** Name ROBERT A. McWILLIAMS Address 2425 MISSION CRK. RD. CASHMERE WA 98815

(2) **LOCATION OF WELL:** County CHELAN SE 1/4 NW 1/4 Sec. 29 T. 23 N., R. 19 W.M.

(2a) **STREET ADDRESS OF WELL** (or nearest address) (SAME)

(3) **PROPOSED USE:** ☐ Domestic ☒ Irrigation ☐ DeWater Industrial ☐ Test Well ☐ Municipal ☐ Other ☐
REPLACEMENT WELL

(4) **TYPE OF WORK:** Owner's number of well (If more than one) ______
Abandoned ☐ New well ☒ Deepened ☐ Reconditioned ☐ Method: Dug ☐ Cable ☐ Rotary ☒ Bored ☐ Driven ☐ Jetted ☐

(5) **DIMENSIONS:** Diameter of well 8 inches.
Drilled 53 feet. Depth of completed well 52½ ft.

(6) **CONSTRUCTION DETAILS:**
Casing installed: 8" Diam. from +1½ ft. to 41 ft.
Welded ☒ ______" Diam. from ______ ft. to ______ ft.
Liner installed ☐ ______" Diam. from ______ ft. to ______ ft.
Threaded ☐

Perforations: Yes ☒ No ☐
Type of perforator used ROTARY MILLS KNIFE
SIZE of perforations 1/8 in. by 1 in.
312 perforations from 31 ft. to 40 ft.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.

Screens: Yes ☐ No ☒
Manufacturer's Name ______
Type ______ Model No. ______
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel packed: Yes ☐ No ☒ Size of gravel ______
Gravel placed from ______ ft. to ______ ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal BENTONITE
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

(7) **PUMP:** Manufacturer's Name ______
Type: ______ H.P. ______

(8) **WATER LEVELS:** Land-surface elevation above mean sea level ______
Static level 11½ ft. below top of well Date 3-8-94
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) **WELL TESTS:** Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☒ If yes, by whom? ______
Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ______
Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest 70 gal./min. with stem set at 45 ft. for 1 hrs.
Artesian flow ______ g.p.m. Date 3-8-94
Temperature of water ______ Was a chemical analysis made? Yes ☐ No ☒

(10) **WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION**

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
BROWN CLAY	0	8
GRAVEL, CLAY, COBBLES —WATER BEARING—	8	15
BROWN LOAMY CLAY	15	28
GRAVELS WATER BEARING	28	40½
GREY SANDSTONE + SHALE	40½	53

MAR 28 1994

Work Started 3-8, 19 . Completed 3-8, 19 94

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME TUMWATER DRILLING INC. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address LEAVENWORTH, WASH.
(Signed) Britt Pfaff (WELL DRILLER) License No. 1249
Contractor's Registration No. TUMWADL 133[illegible] Date 3-[illegible], 19 94

(USE ADDITIONAL SHEETS IF NECESSARY)

ECL 050-1-20 (2/93)

N TW-5

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Application No.

Permit No. 774047081

(1) OWNER: Name Gerald Doyle Address

(2) LOCATION OF WELL: County Chelan SW ¼ SW ¼ Sec 29 T 23 N., R 19 W.M.

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☐ Irrigation ☑ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one)....

New well ☑ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☑ Jetted ☐

(5) DIMENSIONS: Diameter of well 8 inches.
Drilled 320 ft. Depth of completed well 320 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 8" Diam. from +1 ft. to 19 ft.
Threaded ☐ ......" Diam. from ...... ft. to ...... ft.
Welded ☑ ......" Diam. from ...... ft. to ...... ft.

Perforations: Yes ☐ No ☑
Type of perforator used
SIZE of perforations ...... in. by ...... in.
...... perforations from ...... ft. to ...... ft.
...... perforations from ...... ft. to ...... ft.
...... perforations from ...... ft. to ...... ft.

Screens: Yes ☐ No ☑
Manufacturer's Name
Type ...... Model No.
Diam. ...... Slot size ...... from ...... ft. to ...... ft.
Diam. ...... Slot size ...... from ...... ft. to ...... ft.

Gravel packed: Yes ☐ No ☑ Size of gravel:
Gravel placed from ...... ft. to ...... ft.

Surface seal: Yes ☑ No ☐ To what depth? 19 ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes ☐ No ☑
Type of water? ...... Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: ...... H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level....
Static level 10 ft. below top of well Date 11-12-87
Artesian pressure ...... lbs. per square inch Date
Artesian water is controlled by ...... (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☑ If yes, by whom?
Yield: 150+ gal./min. with ...... ft. drawdown after ...... hrs.
" " " "
EST AIR LIFT

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test ...... gal./min. with ...... ft. drawdown after ...... hrs.
Artesian flow ...... g.p.m. Date
Temperature of water ...... Was a chemical analysis made? Yes ☐ No ☑

(10) WELL LOG:

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

MATERIAL	FROM	TO
BROWN SAND	0	14
BROWN SANDSTONE	14	42
GRAY CLAY STONE TRACE OF WATER	42	68
GRAY SANDSTONE	68	180
BROKEN SANDSTONE TRACE OF WATER	180	181
GRAY SAND STONE	181	220
GRAY SANDSTONE BROKEN TRACE OF WATER	220	221
GRAY SAND STONE	221	319
BROKEN GRAY SANDSTONE WATER BEARING	319	320

1987
SPOKANE REGIONAL OFFICE

Work started 11-9, 1987 Completed 11-12, 1987

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Fogle Pump & Supply (Person, firm, or corporation) (Type or print)

Address 316 West 5th Colville WA

[Signed] Robert E Fold (Well Driller)

License No. 1405 Date 11-12, 1987

11/20/87

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

WATER WELL REPORT

State of Washington Date Printed: 25-Apr-2005 Log No. 5605

Construction/Decommission Original

Construction 174805 Construction Notice

CURRENT

Notice of Intent No.: W168633

Unique Ecology Well I.D. No AKM224

Water Right Permit Number:

DEPT OF ECOLOGY
Received
JUN 23 2005
CENTRAL REGION OFFICE

TW-6

PROPOSED USE: **DOMESTIC**

TYPE OF WOR Owners's Well Number: (If more than one well) 2

DEEPENED Method: **ROTARY**

DIMENSIONS Diameter of well: 8 inches

Drilled 60 ft. Depth of completed well 340 ft.

CONSTRUCTION DETAILS:

Liner installed:

6 " Dia from 5 ft. to 340 ft.

Casing installed **EXISTING**

" Dia from ft. to ft.

" Dia from ft. to ft.

" Dia from ft. to ft.

Perforations: **Yes** Used In: **Liner**

Type of perforator used **SKILL SAW**

SIZE of perforations 6 in. b 1/8 in.

150 Perforation from 260 ft. to 340 ft.

Perforation from ft. to ft.

Perforation from ft. to ft.

Screens: No K-Pac Location

Manufacture's Name

Type: Model No

Diam. slot size from ft. to ft.

Diam. slot size from ft. to ft.

Gravel/Filter packed: No Size of Gravel

Material placed fro ft. to ft.

Surface seal: No To what depth ft.

Seal method: Material used in seal **EXISTING**

Did any strata contain unusable water No

Type of water Depth of strata

Method of sealing strata off

PUMP: Manufacture's name

Type: H.P. 0

WATER LEVELS Land-surface elevation above mean sea level: 0 ft.

Static level 20 ft. below top of well Date 03/22/2005

Artesian Pressure lbs per square inch Date

Artesian water controlled by

WELL TESTS: Drawdown is amount water level is lowered below static level.

Was a pump test made No If yes, by whom

Yield gal/min with ft drawdown after

Yield gal/min with ft drawdown after

Yield gal/min with ft drawdown after

Recovery data (time taken as zero when pump turned off)(water level measured from well top to water level

Time:	Water Leve	Time:	Water Leve	Time:	Water Leve

Date of test:

Bailer test gal/min ft drawdown after hrs.

Air test 50 gal/min w/ stem set at 340 ft. for 1 hours

Artesian flow gpm Date

Temperature of water Was a chemical analysis made No

OWNER: **MILLER, KAMERON**

OWNER ADDR: **1425 MISSION CR. RD. CASHMERE, WA 98815**

Well Street Address: **MISSION CR. RD.** D

City: **Cashmere, WA 98815** County: **CHELAN**

Location: **NW** 1/4 **NW** 1/4 Sec **32** T **23** R **19E** EW

Lat/Long: (s, t, r still REQUIRED) Lat Deg Lat Min/Sec

Long Deg Long Min/Se

Tax Parcel No.:

CONSTRUCTION OR DECOMMISSION PROCEDURE

Formation: Describe by color, character, size of material and structure. Show thickness of aquifiers and the kind and nature of the material in each stratum penetrated. Show at least one entry for each change in formation.

Material	From	To
EXISTING WELL	0	280
GRANITE HARD GRAY	280	340

Notes:

Work starte 03/21/2005 Complete 03/22/2005

WELL CONSTRUCTION CERTIFICATION:

I constructed and/or accept responsibility for construction of this well and its compliance with all Washington well construction standards. Materials used and the information reported are true to my best knowledge and belief.

☑ Driller ☐ Engineer ☐ Trainee

Name: **MARTY RUGO** License No.: **2038**

Signature: Marty Rugo

If trainee, Licensed driller is: License No.:

Licensed Driller Signature

Drilling Company:

NAME: **FOGLE PUMP & SUPPLY, INC.** Shop: **REPUBLIC**

ADDRESS: **PO Box 456**
Republic, WA 99166

Phone: **5097752878** Toll Free: **8008453500**

E-Mail: **foglewest@rcabletv.com**

FAX: **5097750498** WEB Site: **www.foglepump.com**

Contractor's Registration No.: **FOGLEPS095L4** Date Log Created: 04/25/200

OW-2

WATER WELL REPORT

State of Washington   Date Printed: **26-May-2015**   Log No. **0**

Construction / Decommission: Original Construction Notice

Construction

CURRENT

Notice of Intent No.: **WE20787**

Unique Ecology Well I.D. No **BIN376**

Water Right Permit Number:

OWNER: **TURNBULL, RICHARD**

OWNER ADD **2255 MISSION CRK RD**
CASHMERE, WA 98815

Well Add **2255 MISSION CRK RD**

City: **Cashmere, WA 98815**   County: **Chelan**

Location: **SW** 1/4 **SW** 1/4 Sec **20** T **23** R **19** EW

Lat/Long: (s, t, r still REQUIRED)   Lat Deg   Lat Min/Sec
Long Deg   Long Min/Se

Tax Parcel No.: **231920330050**

PROPOSED USE: **DOMESTIC**

TYPE OF WORK: Owners's Well Number: (If more than one well)

NEW WELL   Method: **ROTARY**

DIMENSIONS: Diameter of well: **8** inches

Drilled **400** ft.   Depth of completed well **400** ft.

CONSTRUCTION DETAILS:

Liner installed:

" Dia from ft. to ft.

Casing installed **WELDED**

8 " Dia from **+2** ft. to **22** ft.

" Dia from ft. to ft.

" Dia from ft. to ft.

Perforations: **No**   Used In:

Type of perforator used

SIZE of perforations in. by in.

Perforations from ft. to ft.

Perforations from ft. to ft.

Perforations from ft. to ft.

Screens: **0**   K-Pac Location:

Manufacture's Name

Type: Model No

Diam. slot size: from ft. to ft.

Diam. slot size: from ft. to ft.

Gravel/Filter packed: **No**   Size of Gravel

Material placed fro ft. to ft.

Surface seal: **Yes**   To what depth **22** ft.

Seal method: Material used in seal **BENT/CASING**

Did any strata contain unusable water **No**

Type of water   Depth of strata

Method of sealing strata off

PUMP: Manufacture's name

Type: H.P. **0**

WATER LEVELS Land-surface elevation above mean sea level: **0** ft.

Static level **2** ft. below top of well Date **05/20/2015**

Artesian Pressure lbs per square inch Date

Artesian water controlled by

WELL TESTS: Drawdown is amount water level is lowered below static level.

Was a pump test made **No**   If yes, by whom

Yield: ☐ gal/min with ☐ ft drawdown after ☐

Yield: ☐ gal/min with ☐ ft drawdown after ☐

Yield: ☐ gal/min with ☐ ft drawdown after ☐

Recovery data (time taken as zero when pump turned off)(water level measured from well top to water level

Time:	Water Level	Time:	Water Level	Time:	Water Level

Date of test:

Bailer test gal/min ft drawdown after hrs.

Air test **7** gal/min w/ stem set at **399** ft. for **1** hours

Artesian flow gpm Date

Temperature of water   Was a chemical analysis made **No**

CONSTRUCTION OR DECOMMISSION PROCEDURE

Formation: Describe by color, character, size of material and structure. Show thickness of aquifers and the kind and nature of the material in each stratum penetrated. Show at least one entry for each change in formation.

Material	From	To
LOME BROWN	**0**	**3**
COBBLES/CLAY GRAVEL/BRN/ SAND	**3**	**17**
SANDSTONE BROWN MED	**17**	**26**
SANDSTONE GRAY MED	**26**	**31**
SANDSTONE BROWN MED	**31**	**40**
SANDSTONE GRAY/SOFT DAMP	**40**	**41**
SANDSTONE GRAY MED	**41**	**89**
SANDSTONE GRAY/SOFT DAMP	**89**	**90**
SANDSTONE GRAY MED	**90**	**158**
SANDSTONE GRAY SOFT	**158**	**159**
SANDSTONE GRAY MED	**159**	**208**
SANDSTONE GRAY SOFT	**208**	**209**
SANDSTONE LT GRAY MED	**209**	**216**

Notes:

DEPT OF ECOLOGY
Received
DEC 14 2015
CENTRAL REGION OFFICE

Work starte **05/14/2015**   Complete **05/20/2015**

WELL CONSTRUCTION CERTIFICATION:

I constructed and/or accept responsibility for construction of this well and its compliance with all Washington well construction standards. Materials used and the information reported are true to my best knowledge and belief.

☑ Driller ☐ Engineer ☐ Trainee

Name: **AUDIE MCCURDY**   License No.: **2690**

Signature: Audie McCurdy

If trainee, Licensed driller is: License No.:

Licensed Driller Signature

Drilling Company:

NAME: **FOGLE PUMP & SUPPLY, INC.**   Shop: **REPUBLIC**

ADDRESS: **PO Box 456**
Republic, WA 99166

Phone: **5097752878**   Toll Free: **8008453500**

E-Mail: **cathys@foglepump.com**

FAX: **5097750498**   WEB Site: **www.foglepump.com**

Contractor's Registration No.: **FOGLEPS095L4**   Date Log Created: **5/26/2015**

Water Well Log - Page 2

FOGLE PUMP & SUPPLY, INC.

Log No. 0

Notice of Intent No.: **WE20787**

Unique Well I.D. No.: **BIN376**

Well Construction Details Continued:

Material	From	To
SANDSTONE BROWN SOFT	216	218
SANDSTONE GRAY MED	218	246
SANDSTONE COAL GRAY/MED	246	251
SANDSTONE GRAY MED	251	275
COAL BLACK SOFT	275	276
SANSTONE GRAY MED	276	299
SHALE GRAY MED/SOFT	299	308
SANDSTONE GRAY MED/SOFT	308	400

OW-3

File Original and First Copy with
Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No. DC
Permit No.

(1) OWNER: Name ROBERT McWILLIAMS Address 2425 MISSION CK. RD. CASHMERE

(2) LOCATION OF WELL: County CHELAN N/2 ¼ NW ¼ Sec. 29 T. 23 N., R. 19 W.M.

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☒ Industrial ☐ Municipal ☐ Irrigation ☒ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one)

New well ☒ Deepened ☐ Reconditioned ☐

Method: Dug ☐ Cable ☐ Rotary ☒ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 8 inches.

Drilled 79 ft. Depth of completed well 78½ ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 8" Diam. from +1½ ft. to 39 ft.

Threaded ☐ " Diam. from ft. to ft.

Welded ☒ " Diam. from ft. to ft.

Perforations: Yes ☒ No ☐

Type of perforator used ROTARY STAR

SIZE of perforations 1/4 in. by 1 in.

200 perforations from 21 ft. to 34 ft.

perforations from ft. to ft.

perforations from ft. to ft.

Screens: Yes ☐ No ☒

Manufacturer's Name

Type Model No.

Diam. Slot size from ft. to ft.

Diam. Slot size from ft. to ft.

Gravel packed: Yes ☐ No ☒ Size of gravel:

Gravel placed from ft. to ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.

Material used in seal BENTONITE

Did any strata contain unusable water? Yes ☐ No ☐

Type of water? Depth of strata

Method of sealing strata off

(7) PUMP: Manufacturer's Name

Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level....

Static level 5½ ft. below top of well Date 3-23-87

Artesian pressure lbs. per square inch Date

Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level

Was a pump test made? Yes ☐ No ☒ If yes, by whom?

Yield: gal./min. with ft. drawdown after hrs.

" " " "

" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test

Bailer test 25 gal./min. with ft. drawdown after 1 hrs.

Artesian flow g.p.m. Date 3-23-87

Temperature of water Was a chemical analysis made? Yes ☐ No ☒

(10) WELL LOG:

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

MATERIAL	FROM	TO
BROWN SANDY LOAM	0	6
BROWN HARD CLAY + GRAVEL	6	13
SANDSTONE	13	15
CLAY, BIG GRAVEL + SAND	15	39
BROWN SANDSTONE	39	42
GREY SANDSTONE	42	56
FRACTURED SHALE	56	61
GREY SANDSTONE	61	79

RECEIVED
APR 1 3 1987
DEPARTMENT OF ECOLOGY
CENTRAL REGION OFFICE

Work started 3-20 1987 Completed 3-23 1987

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME TUMWATER DRILLING INC. (Person, firm, or corporation) (Type or print)

Address LEAVENWORTH, WASH.

[Signed] (Well Driller)

License No. 1249 Date 3-23 1987

(USE ADDITIONAL SHEETS IF NECESSARY)

OW-4

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. W112290
Unique Well I.D. # AEH437
Water Right Permit No.

(1) OWNER: Name **MILLER, SHEREL & LANITA** Address **1425 MISSION CR. RD. CASHMERE, WA 98815-**

(2) LOCATION OF WELL: County **CHELAN** - **SW** 1/4 **NW** 1/4 Sec **32** T **23** N., R **19E** WM

(2a) STREET ADDRESS OF WELL (or nearest address) ,

(3) PROPOSED USE: **DOMESTIC**

(4) TYPE OF WORK: Owner's Number of well (If more than one) **2**

NEW WELL Method: **ROTARY**

(5) DIMENSIONS: Diameter of well **8** inches

Drilled **38** ft. Depth of completed well **38** ft.

(6) CONSTRUCTION DETAILS:

Casing installed: **8** " Dia. from **+2** ft. to **38** ft.

WELDED " Dia. from ft. to ft.

" Dia. from ft. to ft.

Perforations: **NO**

Type of perforator used

SIZE of perforations in. by in.

perforations from ft. to ft.

perforations from ft. to ft.

perforations from ft. to ft.

Screens: **NO**

Manufacturer's Name

Type Model No.

Diam. slot size from ft. to ft.

Diam. slot size from ft. to ft.

Gravel packed: **YES** Size of gravel **5/8**

Gravel placed from **35** ft. to **38** ft.

Surface seal: **YES** To what depth? **18** ft.

Material used in seal **BENTONITE**

Did any strata contain unusable water? **NO**

Type of water? Depth of strata ft.

Method of sealing strata off **CASING**

(7) PUMP: Manufacturer's Name

Type **NONE** H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level ... ft.

Static level **12** ft. below top of well Date **07/01/99**

Artesian Pressure lbs. per square inch Date

Artesian water controlled by **CAP**

(10) WELL LOG E

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change in formation.

MATERIAL	FROM	TO
CLAY BROWN	**0**	**12**
CLAY BROWN GRAVEL	**12**	**24**
W/WATER	**24**	
DECOMPOSED SANDSTONE GRAY	**24**	**33**
SAND BROWN FINE	**33**	**38**
GRAVEL W/WATER	**38**	

CENTRAL REGION OFFICE
Received
JUL 21 1999
DEPT. OF ECOLOGY

Work started **07/01/99** Completed **07/01/99**

(9) WELL TESTS: Drawdown is amount water level is lowered below static level.

Was a pump test made? **NO** If yes, by whom?

Yield: gal./min with ft. drawdown after hrs.

Recovery data

Time	Water Level	Time	Water Level	Time	Water Level

Date of test / /

Bailer test gal/min. ft. drawdown after hrs.

Air test **30** gal/min. w/ stem set at **37** ft. for **1** hrs.

Artesian flow g.p.m. Date

Temperature of water Was a chemical analysis made? **NO**

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME ***FOGLE PUMP & SUPPLY, INC.***
(Person, firm, or corporation) (Type or print)

ADDRESS **REPUBLIC,WA 800-845-3500**

[SIGNED] Jon S. Ricard License No. **2341**

Contractor's
Registration No. **FOGLEPS095L4** Date 07/12/99

ATTACHMENT 2

Laboratory Reports

CASCADE ANALYTICAL, INC.
1-800-545-4206

(509) 662-1888
Fax: (509) 662-8183
3019 G. S. Center Road
Wenatchee, WA 98801

(509) 452-7707
Fax: (509) 452-7773
1008 W. Ahtanum Rd.
Union Gap, WA 98903

Batch: 648827
Client: Aspect Consulting/Yakima
Account: 17821
Sampler: Jason
PO Number:

--- Water Analytical Report ---

Report Date: 11/10/16

Aspect Consulting/Yakima
123 E Yakima Ave Suite 200
Yakima, WA 98901

Laboratory Number: 16-E033480
Sample Identification: MC-Lower 110716
Date Received: 11/ 7/16
Date Sampled: 11/ 7/16

Test Requested	Results	Units	RL	Method	Date Analyzed	Flags
Fecal Coliform MPN Water	330.	MPN/100mL		SM9221-E	11/ 7/16	

Approved By Name: Brianna Buschbach
Signature:

Function: Quality Manager

CASCADE ANALYTICAL, INC.
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Wenatchee, WA 98801

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Fax: (509) 452-7773
1008 W. Ahtanum Rd
Union Gap, WA 98903

Batch: 648827
Client: Aspect Consulting/Yakima
Account: 17821
Sampler: Jason
PO Number:

--- Water Analytical Report ---

Report Date: 11/10/16

Aspect Consulting/Yakima
123 E Yakima Ave Suite 200
Yakima, WA 98901

Laboratory Number: 16-E033481
Sample Identification: AAJ531110716
Date Received: 11/ 7/16
Date Sampled: 11/ 7/16

Test Requested	Results	Units	RL	Method	Date Analyzed	Flags
Fecal Coliform MPN Water	< 1.8	MPN/100mL		SM9221-E	11/ 7/16	

Approved By Name: Brianna Buschbach Signature:

Function: Quality Manager

CASCADE ANALYTICAL, INC.
1-800-545-4206

(509) 662-1888
Fax: (509) 662-8183
3019 G. S. Center Road
Wenatchee, WA 98801

(509) 452-7707
Fax: (509) 452-7773
1008 W. Ahtanum Rd
Union Gap, WA 98903

Batch: 648827
Client: Aspect Consulting/Yakima
Account: 17821
Sampler: Jason
PO Number:

--- Water Analytical Report ---

Report Date: 11/10/16

Aspect Consulting/Yakima
123 E Yakima Ave Suite 200
Yakima, WA 98901

Laboratory Number: 16-E033482
Sample Identification: Gerry 110716
Date Received: 11/ 7/16
Date Sampled: 11/ 7/16

Test Requested	Results	Units	RL	Method	Date Analyzed	Flags
Fecal Coliform MPN Water	< 1.8	MPN/100mL		SM9221-E	11/ 7/16	

Approved By Name: Brianna Buschbach
Signature:

Function: Quality Manager

CASCADE ANALYTICAL, INC.
1-800-545-4206

(509) 662-1888
Fax: (509) 662-8183
3019 G. S. Center Road
Wenatchee, WA 98801

(509) 452-7707
Fax: (509) 452-7773
1008 W. Ahtanum Rd
Union Gap, WA 98903

Batch: 648827
Client: Aspect Consulting/Yakima
Account: 17821
Sampler: Jason
PO Number:

--- Water Analytical Report ---

Report Date: 11/10/16

Aspect Consulting/Yakima
123 E Yakima Ave Suite 200
Yakima, WA 98901

Laboratory Number: 16-E033483
Sample Identification: AKM224110716
Date Received: 11/ 7/16
Date Sampled: 11/ 7/16

Test Requested	Results	Units	RL	Method	Date Analyzed	Flags
Fecal Coliform MPN Water	< 1.8	MPN/100mL		SM9221-E	11/ 7/16	

Approved By Name: Brianna Buschbach Signature:

Function: Quality Manager

CASCADE ANALYTICAL, INC.
1-800-545-4206

(509) 662-1888
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3019 G. S. Center Road
Wenatchee, WA 98801

(509) 452-7707
Fax: (509) 452-7773
1008 W. Ahtanum Rd
Union Gap, WA 98903

Batch: 648827
Client: Aspect Consulting/Yakima
Account: 17821
Sampler: Jason
PO Number:

--- Water Analytical Report ---

Report Date: 11/10/16

Aspect Consulting/Yakima
123 E Yakima Ave Suite 200
Yakima, WA 98901

Laboratory Number: 16-E033484
Sample Identification: MC-Upper 110716
Date Received: 11/ 7/16
Date Sampled: 11/ 7/16

Test Requested	Results	Units	RL	Method	Date Analyzed	Flags
Fecal Coliform MPN Water	6.80	MPN/100mL		SM9221-E	11/ 7/16	

Approved By Name: Brianna Buschbach Signature: B-B

Function: Quality Manager

Cascade Analytical uses procedures established by EPA, AOAC, APHA, ASTM, and FDA/BAM. Cascade Analytical makes no warranty of any kind the client assumes all risk and liability from the use of these results. Cascade Analytical, Inc.'s liability to the client as a result of use of Cascade's test results shall be limited to a sum equal to the fees paid by the client to Cascade Analytical, Inc. for analysis. PLEASE REVIEW YOUR DATA IN A TIMELY MANNER. DATA GAPS OR ERRORS AFTER THREE MONTHS WILL NOT BE OUR RESPONSIBILITY. THOUGH WE DO KEEP ALL ANALYTICAL DATA FOR SEVERAL YEARS, SAMPLES ARE DISPOSED OF AFTER SIX WEEKS.

CASCADE ANALYTICAL, INC.

3019 G. S. Center Rd.
Wenatchee, WA 98801
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1-800-545-4206

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Union Gap, WA 98903
(509) 452-7707
Fax: (509) 452-7773

WATER ANALYSIS ORDER FORM

Batch#

	SAMPLE # 1	2	3	4	5
SEND RESULTS TO [✓ 1) Client] 2) Billing 3) Both	X →				→
SAMPLE REPRESENTS 1) Irrigation 2) Waste Water 3) Other Gw + Sw	↓				
SAMPLE BY [✓ 1) Client] 2) Quality Control 3) Cascade 4) Other	↓				

New Acct. # 17821

CLIENT NAME/ADDRESS
Aspect Consulting, LLC
123 E. Yakima Ave Suite 200
Yakima WA 98901

BILLING NAME/ADDRESS
Same

SAMPLER'S NAME Jason Shira

PHONE

E-mail jshira@aspectconsulting.com

E-mail

RELINQUISHED BY: (Signature) 1	DATE	RELINQUISHED BY: (Signature) 2	DATE	RELINQUISHED BY: (Signature) 3	DATE
	11/07/16				
(Printed) Jason Shira	TIME 14:55	(Printed)	TIME	(Printed)	TIME
RECEIVED BY: (Signature)	**DATE**	**RECEIVED BY: (Signature)**	**DATE**	**RECEIVED FOR LAB BY: (Signature)**	**DATE**
(Printed)	TIME	(Printed)	TIME	(Printed)	TIME

FORM MUST BE COMPLETED BEFORE ANALYSIS WILL BE PERFORMED.

33480	1	MC-Lower 110716	Sample Date 11/07/16 Sample Time 13:15
33481	2	AAJ531 110716	Sample Date 11/07/16 Sample Time 12:20
33482	3	Gerry 110716	Sample Date 11/07/16 Sample Time 11:00
33483	4	AKM224 110716	Sample Date 11/07/16 Sample Time 10:00
33484	5	MC-upper 110716	Sample Date 11/07/16 Sample Time 09:00

***METALS - circle type of analysis - T=total or D=dissolved**
Total N package = TKN, NO_3, NO_2, NH_3
Sample container received by client was sealed Yes ✓ No_____
Sample container received by laboratory was sealed Yes_____ No_____

(see legend on back)

		SAMPLE # 1	2	3	4	5
IRRIGATION WATER						
	Standard					
	GENERAL CHEMISTRY					
1135	pH					
1140	Conductivity					
1200	Solids-Dis. (TDS)					
1230	Solids-Susp. (TSS)					
1240	Tot. Phosphorus					
1250	Orthophosphate					
1260	Kjeldahl Nitrogen (TKN)					
1170	Nitrate+Nitrite					
1265	NO_3 (As N)					
1280	Ammonia					
1300	Biol. Oxy. Demand					
1310	Chem. Oxy. Demand					
1190	Sulfate (SO4)					
1180	Chloride (Cl)					
1150	Turbidity					
1320	Hexane Ext. Mat.					
1340	Alkalinity					
217	Total N Pkg					
	MICROBIOLOGY					
10040	Total Coliform MF					
10010	Fecal Coliform MF					
10041	Total Coliform MPN					
10011	Fecal Coliform MPN	X →				→
	METALS - TOTAL OR DISSOLVED					
1391	Antimony (Sb)					
1011	Arsenic (As)					
1025	Barium (Ba)					
1405	Beryllium (Be)					
1031	Cadmium (Cd)					
1045	Chromium (Cr)					
1215	Copper (Cu)					
1065	Iron (Fe)					
1075	Manganese (Mn)					
1081	Mercury (Hg)					
1435	Molybdenum (Mo)					
1051	Lead (Pb)					
1335	Nickel (Ni)					
1091	Selenium (Se)					
1105	Silver (Ag)					
1381	Thallium (Tl)					
1225	Zinc (Zn)					
	MINERALS					
1120	Calcium (Ca)					
1130	Magnesium (Mg)					
1115	Potassium (K)					
1110	Sodium (Na)					

Disclaimer:

Customer Signature:________________ Date 11/07/16

This form also serves as "Chain of Custody."

CASCADE ANALYTICAL, INC.

Sample Receipt Form

Date Received: 11/7/16 Time Received: 2:58 Initials: AR

Client Name: Aspect Consulting Project Name: WW

Temperature of cooler upon receipt: 11 °C Thermometer ID: #1

Custody seals: Intact Broken [✓ None] N/A

Chain of Custody Completed:

Client name, address, and phone number;	Yes	[✓ No]
Date and time of sampling;	[✓ Yes]	No
Test requests clear;	[✓ Yes]	No
Completed in ink;	[✓ Yes]	No
Signed by client;	[✓ Yes]	No

All samples received:		[✓ Yes]	No
All samples intact:		[✓ Yes]	No
Sample ID's match COC form:		[✓ Yes]	No
Appropriate containers used:		[✓ Yes]	No
Sufficient amount of sample for analysis:		[✓ Yes]	No
Correct preservative verified:	N/A	[✓ Yes]	No
Air bubbles in VOC, TTHM, or HAA5 samples:	[✓ N/A]	Yes	No
Sample(s) exceed hold time:		Yes	[✓ No]

Type of coolant: ? Ice Blue Ice None Other Comment: ______

Shipping Method: FedEx UPS USPS Brett & Sons [✓ Hand Delivered] CAI Sampled

Shipping Container: ? CAI Cooler CAI Cooler Box Client's Cooler None Other ______

Samples accepted for analysis: [✓ Yes] No

Reason for Rejection: ______

Name of Person Contacted: ______ Date Contacted: ______

Comments: ______

ALS Environmental
ALS Group USA, Corp
1317 South 13th Avenue
Kelso, WA 98626
T : +1 360 577 7222
F : +1 360 636 1068
www.alsglobal.com

November 16, 2016

Analytical Report for Service Request No: K1613678

Jason Shira
Aspect Consulting
123 E Yakima Avenue, Suite 200
Yakima, WA 98901

RE: Chelan County Natural Resources Dept#120045-11a-05 / 120045.011a

Dear Jason,

Enclosed are the results of the sample(s) submitted to our laboratory November 08, 2016
For your reference, these analyses have been assigned our service request number **K1613678.**

Analyses were performed according to our laboratory's NELAP-approved quality assurance program. The test results meet requirements of the current NELAP standards, where applicable, and except as noted in the laboratory case narrative provided. For a specific list of NELAP-accredited analytes, refer to the certifications section at www.alsglobal.com. All results are intended to be considered in their entirety, and ALS Group USA Corp. dba ALS Environmental (ALS) is not responsible for use of less than the complete report. Results apply only to the items submitted to the laboratory for analysis and individual items (samples) analyzed, as listed in the report.

Please contact me if you have any questions. My extension is 3376. You may also contact me via email at gregory.salata@alsglobal.com.

Respectfully submitted,

ALS Group USA, Corp. dba ALS Environmental

Gregory Salata

Gregory Salata, Ph.D.
Senior Project
Manager

ALS Environmental
ALS Group USA, Corp
1317 South 13th Avenue
Kelso, WA 98626
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www.alsglobal.com

Table of Contents

Acronyms

ASTM	American Society for Testing and Materials
A2LA	American Association for Laboratory Accreditation
CARB	California Air Resources Board
CAS Number	Chemical Abstract Service registry Number
CFC	Chlorofluorocarbon
CFU	Colony-Forming Unit
DEC	Department of Environmental Conservation
DEQ	Department of Environmental Quality
DHS	Department of Health Services
DOE	Department of Ecology
DOH	Department of Health
EPA	U. S. Environmental Protection Agency
ELAP	Environmental Laboratory Accreditation Program
GC	Gas Chromatography
GC/MS	Gas Chromatography/Mass Spectrometry
LOD	Limit of Detection
LOQ	Limit of Quantitation
LUFT	Leaking Underground Fuel Tank
M	Modified
MCL	Maximum Contaminant Level is the highest permissible concentration of a substance allowed in drinking water as established by the USEPA.
MDL	Method Detection Limit
MPN	Most Probable Number
MRL	Method Reporting Limit
NA	Not Applicable
NC	Not Calculated
NCASI	National Council of the Paper Industry for Air and Stream Improvement
ND	Not Detected
NIOSH	National Institute for Occupational Safety and Health
PQL	Practical Quantitation Limit
RCRA	Resource Conservation and Recovery Act
SIM	Selected Ion Monitoring
TPH	Total Petroleum Hydrocarbons
tr	Trace level is the concentration of an analyte that is less than the PQL but greater than or equal to the MDL.

Inorganic Data Qualifiers

*	The result is an outlier. See case narrative.
#	The control limit criteria is not applicable. See case narrative.
B	The analyte was found in the associated method blank at a level that is significant relative to the sample result as defined by the DOD or NELAC standards.
E	The result is an estimate amount because the value exceeded the instrument calibration range.
J	The result is an estimated value.
U	The analyte was analyzed for, but was not detected ("Non-detect") at or above the MRL/MDL. *DOD-QSM 4.2 definition* : Analyte was not detected and is reported as less than the LOD or as defined by the project. The detection limit is adjusted for dilution.
i	The MRL/MDL or LOQ/LOD is elevated due to a matrix interference.
X	See case narrative.
Q	See case narrative. One or more quality control criteria was outside the limits.
H	The holding time for this test is immediately following sample collection. The samples were analyzed as soon as possible after receipt by the laboratory.

Metals Data Qualifiers

#	The control limit criteria is not applicable. See case narrative.
J	The result is an estimated value.
E	The percent difference for the serial dilution was greater than 10%, indicating a possible matrix interference in the sample.
M	The duplicate injection precision was not met.
N	The Matrix Spike sample recovery is not within control limits. See case narrative.
S	The reported value was determined by the Method of Standard Additions (MSA).
U	The analyte was analyzed for, but was not detected ("Non-detect") at or above the MRL/MDL. *DOD-QSM 4.2 definition* : Analyte was not detected and is reported as less than the LOD or as defined by the project. The detection limit is adjusted for dilution.
W	The post-digestion spike for furnace AA analysis is out of control limits, while sample absorbance is less than 50% of spike absorbance.
i	The MRL/MDL or LOQ/LOD is elevated due to a matrix interference.
X	See case narrative.
+	The correlation coefficient for the MSA is less than 0.995.
Q	See case narrative. One or more quality control criteria was outside the limits.

Organic Data Qualifiers

*	The result is an outlier. See case narrative.
#	The control limit criteria is not applicable. See case narrative.
A	A tentatively identified compound, a suspected aldol-condensation product.
B	The analyte was found in the associated method blank at a level that is significant relative to the sample result as defined by the DOD or NELAC standards.
C	The analyte was qualitatively confirmed using GC/MS techniques, pattern recognition, or by comparing to historical data.
D	The reported result is from a dilution.
E	The result is an estimated value.
J	The result is an estimated value.
N	The result is presumptive. The analyte was tentatively identified, but a confirmation analysis was not performed.
P	The GC or HPLC confirmation criteria was exceeded. The relative percent difference is greater than 40% between the two analytical results.
U	The analyte was analyzed for, but was not detected ("Non-detect") at or above the MRL/MDL. *DOD-QSM 4.2 definition* : Analyte was not detected and is reported as less than the LOD or as defined by the project. The detection limit is adjusted for dilution.
i	The MRL/MDL or LOQ/LOD is elevated due to a chromatographic interference.
X	See case narrative.
Q	See case narrative. One or more quality control criteria was outside the limits.

Additional Petroleum Hydrocarbon Specific Qualifiers

F	The chromatographic fingerprint of the sample matches the elution pattern of the calibration standard.
L	The chromatographic fingerprint of the sample resembles a petroleum product, but the elution pattern indicates the presence of a greater amount of lighter molecular weight constituents than the calibration standard.
H	The chromatographic fingerprint of the sample resembles a petroleum product, but the elution pattern indicates the presence of a greater amount of heavier molecular weight constituents than the calibration standard.
O	The chromatographic fingerprint of the sample resembles an oil, but does not match the calibration standard.
Y	The chromatographic fingerprint of the sample resembles a petroleum product eluting in approximately the correct carbon range, but the elution pattern does not match the calibration standard.
Z	The chromatographic fingerprint does not resemble a petroleum product.

ALS Group USA Corp. dba ALS Environmental (ALS) - Kelso
State Certifications, Accreditations, and Licenses

Agency	Web Site	Number
Alaska DEC UST	http://dec.alaska.gov/applications/eh/ehllabreports/USTLabs.aspx	UST-040
Arizona DHS	http://www.azdhs.gov/lab/license/env.htm	AZ0339
Arkansas - DEQ	http://www.adeq.state.ar.us/techsvs/labcert.htm	88-0637
California DHS (ELAP)	http://www.cdph.ca.gov/certlic/labs/Pages/ELAP.aspx	2795
DOD ELAP	http://www.denix.osd.mil/edqw/Accreditation/AccreditedLabs.cfm	L14-51
Florida DOH	http://www.doh.state.fl.us/lab/EnvLabCert/WaterCert.htm	E87412
Hawaii DOH	Not available	-
ISO 17025	http://www.pjlabs.com/	L16-57
Louisiana DEQ	http://www.deq.louisiana.gov/portal/DIVISIONS/PublicParticipationandPermitSupport/LouisianaLaboratoryAccreditationProgram.aspx	03016
Maine DHS	Not available	WA01276
Minnesota DOH	http://www.health.state.mn.us/accreditation	053-999-457
Montana DPHHS	http://www.dphhs.mt.gov/publichealth/	CERT0047
Nevada DEP	http://ndep.nv.gov/bsdw/labservice.htm	WA01276
New Jersey DEP	http://www.nj.gov/dep/oqa/	WA005
North Carolina DWQ	http://www.dwqlab.org/	605
Oklahoma DEQ	http://www.deq.state.ok.us/CSDnew/labcert.htm	9801
Oregon – DEQ (NELAP)	http://public.health.oregon.gov/LaboratoryServices/EnvironmentalLaboratoryAccreditation/Pages/index.aspx	WA100010
South Carolina DHEC	http://www.scdhec.gov/environment/envserv/	61002
Texas CEQ	http://www.tceq.texas.gov/field/qa/env_lab_accreditation.html	T104704427
Washington DOE	http://www.ecy.wa.gov/programs/eap/labs/lab-accreditation.html	C544
Wyoming (EPA Region 8)	http://www.epa.gov/region8/water/dwhome/wyomingdi.html	-
Kelso Laboratory Website	www.alsglobal.com	NA

Analyses were performed according to our laboratory’s NELAP-approved quality assurance program. A complete listing of specific NELAP-certified analytes, can be found in the certification section at www.ALSGlobal.com or at the accreditation bodies web site.

Please refer to the certification and/or accreditation body's web site if samples are submitted for compliance purposes. The states highlighted above, require the analysis be listed on the state certification if used for compliance purposes and if the method/anlayte is offered by that state.

Case Narrative

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ALS ENVIRONMENTAL

Client:	Aspect Consulting	**Service Request No.:**	K1613678
Project:	Chelan County Natural Resources Dept# 120045-1	**Date Received:**	11/08/16
Sample Matrix:	Water		

Case Narrative

All analyses were performed consistent with the quality assurance program of ALS Environmental. This report contains analytical results for samples designated for Tier IV validation deliverables including summary forms and all of the associated raw data for each of the analyses. When appropriate to the method, method blank results have been reported with each analytical test.

Sample Receipt

Five water samples were received for analysis at ALS Environmental on 11/08/16. The samples were received in good condition and consistent with the accompanying chain of custody form. The samples were stored in a refrigerator at 4ºC upon receipt at the laboratory.

General Chemistry Parameters

Orthophosphate as Phosphorus by EPA Method 365.3:
The Relative Percent Difference (RPD) criterion for the replicate analysis in sample Batch QC was not applicable because the analyte concentration was not significantly greater than the Method Reporting Limit (MRL). Analytical values derived from measurements close to the detection limit are not subject to the same accuracy and precision criteria as results derived from measurements higher on the calibration range for the method.

No other anomalies associated with the analysis of these samples were observed.

Organochlorine Pesticides by EPA Method 8081

Elevated Detection Limits:
Insufficient sample volume was received to perform a Matrix Spike/Matrix Spike Duplicate (MS/MSD). A Laboratory Control Sample/Duplicate Laboratory Control Sample (LCS/DLCS) was analyzed and reported in lieu of the MS/MSD for these samples.

No other anomalies associated with the analysis of these samples were observed.

Approved by____

Chain of Custody

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ALS Environmental

CHAIN OF CUSTODY
74887

001

SR# K1613678
COC Set 1 of 1
COC#

Page 1 of 1

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www.alsglobal.com

Project Name: Chelan County Natural Resources
Project Number: 120045 - 01k
Project Manager: Jason Shira
Company: Aspect Consulting
Address: 123 E Yakima Ave Suite 200 Yakima WA
Phone # 509 895-5470
email: jShira@aspectconsulting.com
Sampler Signature:
Sampler Printed Name: Jason Shira

CLIENT SAMPLE ID	LABID	SAMPLING Date	SAMPLING Time	Matrix	NUMBER OF CONTAINERS	48H 300.0 / NO2	48H 300.0 / NO3	48H 365.3 / O Phos T	7D 8081B / Pest OC ULL	7D SM 2540 D / TSS LL	28D 353.2 / NO2 NO3 T	28D 365.3 / Phos T	28D ASTM D1426-08B / TKN	1	2	3	4	5	Remarks
1. MC-Upper 110716		11/07/16	09:00	W	6	X	X	X	X	X	X	X	X						
2. AKM224 110716		│	10:00	│	6	│	│	│	│	│	│	│	│						
3. Gerry 110716		│	11:00	│	6	│	│	│	│	│	│	│	│						
4. AAJ531 110716		│	12:20	│	6	│	│	│	│	│	│	│	│						
5. MC-Lower 110716		│	13:15	│	6	│	│	│	│	│	│	│	│						
6.																			
7.																			
8.																			
9.																			
10.																			

Report Requirements

___ I. Routine Report: Method Blank, Surrogate, as required
X II. Report Dup., MS, MSD as required
___ III. CLP Like Summary (no raw data)
___ IV. Data Validation Report
X V. EDD

Invoice Information

P.O.#
Bill To: Aspect Consulting

Turnaround Requirements

___ 24 hr.
X 48 hr.
___ 5 Day
___ Standard

Requested Report Date

Circle which metals are to be analyzed

Total Metals: Al As Sb Ba Be B Ca Cd Co Cr Cu Fe Pb Mg Mn Mo Ni K Ag Na Se Sr Tl Sn V Zn Hg

Dissolved Metals: Al As Sb Ba Be B Ca Cd Co Cr Cu Fe Pb Mg Mn Mo Ni K Ag Na Se Sr Tl Sn V Zn Hg

Special Instructions/Comments:

Two Coolers

*Indicate State Hydrocarbon Procedure: AK CA WI Northwest Other_____(Circle One)

Relinquished By:	Received By:	Relinquished By:	Received By:	Relinquished By:	Received By:
Signature	Signature	Signature	Signature	Signature	Signature
Printed Name Jason Shira	Printed Name ALS	Printed Name	Printed Name	Printed Name	Printed Name
Firm Aspect	Firm 11-8-16 10:30	Firm	Firm	Firm	Firm
Date/Time 11/7/16 14:15	Date/Time	Date/Time	Date/Time	Date/Time	Date/Time

PC Greg

Cooler Receipt and Preservation Form

Client Aspect Consultings Service Request K16 13678

Received: 11-8-16 Opened: 11-8-16 By: es Unloaded: 11-8-16 By: es

1. Samples were received via? USPS Fed Ex [✓ UPS] DHL PDX Courier Hand Delivered
2. Samples were received in: (circle) [✓ Cooler] Box Envelope Other ____ NA
3. Were custody seals on coolers? NA [✓ Y] N If yes, how many and where? 1-front

   If present, were custody seals intact? [✓ Y] N If present, were they signed and dated? [✓ Y] N

Raw Cooler Temp	Corrected. Cooler Temp	Raw Temp Blank	Corrected Temp Blank	Corr. Factor	Thermometer ID	Cooler/COC ID NA	Tracking Number NA	Filed
1.9	2.1	3.1	3.3	+0.2	360		~~1Z~~ es 11-8-16 J687660 7029	
0.7	0.6	1.3	1.2	-0.1	366		J187660 7010	

4. Packing material: [✓ Inserts] [✓ Baggies] Bubble Wrap Gel Packs [✓ Wet Ice] Dry Ice Sleeves ____
5. Were custody papers properly filled out (ink, signed, etc.)? NA [✓ Y] N
6. Were samples received in good condition (temperature, unbroken)? *Indicate in the table below.* NA [✓ Y] N

   If applicable, tissue samples were received: *Frozen* *Partially Thawed* *Thawed*
7. Were all sample labels complete (i.e analysis, preservation, etc.)? NA [✓ Y] N
8. Did all sample labels and tags agree with custody papers? *Indicate major discrepancies in the table on page 2.* NA ~~Y~~ [✓ N]
9. Were appropriate bottles/containers and volumes received for the tests indicated? NA [✓ Y] N
10. Were the pH-preserved bottles (*see SMO GEN SOP*) received at the appropriate pH? *Indicate in the table below* NA [✓ Y] N
11. Were VOA vials received without headspace? *Indicate in the table below.* [✓ NA] Y N
12. Was C12/Res negative? [✓ NA] Y N

Sample ID on Bottle	Sample ID on COC	Identified by:

Sample ID	Bottle Count Bottle Type	Out of Temp	Head-space	Broke	pH	Reagent	Volume added	Reagent Lot Number	Initials	Time

Notes, Discrepancies, & Resolutions:

Rec'd 5 bottles per sample, not 6.

RUSH

7/25/16

Page ____ ***of*** ____

General Chemistry

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Analytical Report

Client:	Aspect Consulting	**Service Request:**	K1613678
Project:	Chelan County Natural Resources Dept#120045-11a-05/120045.011a	**Date Collected:**	11/7/16
Sample Matrix:	Water	**Date Received:**	11/8/16
Analysis Method:	300.0	**Units:**	mg/L
Prep Method:	Method	**Basis:**	NA

Nitrite as Nitrogen

Sample Name	Lab Code	Result	MRL	Dil.	Date Analyzed	Date Extracted	Q
MC - Upper 110716	K1613678-001	ND U	0.10	2	11/08/16 16:08	11/8/16	
AKM224 110716	K1613678-002	ND U	0.10	2	11/08/16 15:29	11/8/16	
Gerry 110716	K1613678-003	ND U	0.10	2	11/08/16 15:39	11/8/16	
AAJ531 110716	K1613678-004	ND U	0.10	2	11/08/16 15:49	11/8/16	
MC - Lower 110716	K1613678-005	ND U	0.10	2	11/08/16 15:59	11/8/16	
Method Blank	K1613678-MB1	ND U	0.050	1	11/08/16 10:02	11/8/16	

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Analytical Report

Client:	Aspect Consulting	**Service Request:**	K1613678
Project:	Chelan County Natural Resources Dept#120045-11a-05/120045.011a	**Date Collected:**	11/7/16
Sample Matrix:	Water	**Date Received:**	11/8/16
Analysis Method:	300.0	**Units:**	mg/L
Prep Method:	Method	**Basis:**	NA

Nitrate as Nitrogen

Sample Name	Lab Code	Result		MRL	Dil.	Date Analyzed	Date Extracted	Q
MC - Upper 110716	K1613678-001	ND	U	0.10	2	11/08/16 16:08	11/8/16	
AKM224 110716	K1613678-002	**2.24**		0.10	2	11/08/16 15:29	11/8/16	
Gerry 110716	K1613678-003	ND	U	0.10	2	11/08/16 15:39	11/8/16	
AAJ531 110716	K1613678-004	**4.06**		0.10	2	11/08/16 15:49	11/8/16	
MC - Lower 110716	K1613678-005	**0.25**		0.10	2	11/08/16 15:59	11/8/16	
Method Blank	K1613678-MB1	ND	U	0.050	1	11/08/16 10:02	11/8/16	

Analytical Report

Client:	Aspect Consulting	**Service Request:**	K1613678
Project:	Chelan County Natural Resources Dept#120045-11a-05/120045.011a	**Date Collected:**	11/7/16
Sample Matrix:	Water	**Date Received:**	11/8/16
Analysis Method:	353.2	**Units:**	mg/L
Prep Method:	Method	**Basis:**	NA

Nitrate+Nitrite as Nitrogen

Sample Name	Lab Code	Result		MRL	Dil.	Date Analyzed	Date Extracted	Q
MC - Upper 110716	K1613678-001	ND	U	0.050	1	11/10/16 10:56	11/10/16	
AKM224 110716	K1613678-002	**2.22**		0.10	2	11/10/16 10:56	11/10/16	
Gerry 110716	K1613678-003	**0.055**		0.050	1	11/10/16 10:56	11/10/16	
AAJ531 110716	K1613678-004	**3.80**		0.10	2	11/10/16 10:56	11/10/16	
MC - Lower 110716	K1613678-005	**0.250**		0.050	1	11/10/16 10:56	11/10/16	
Method Blank	K1613678-MB1	ND	U	0.050	1	11/10/16 10:56	11/10/16	

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Analytical Report

Client:	Aspect Consulting	**Service Request:**	K1613678
Project:	Chelan County Natural Resources Dept#120045-11a-05/120045.011a	**Date Collected:**	11/7/16
Sample Matrix:	Water	**Date Received:**	11/8/16
Analysis Method:	365.3	**Units:**	mg/L
Prep Method:	None	**Basis:**	NA

Orthophosphate as Phosphorus

Sample Name	Lab Code	Result	MRL	Dil.	Date Analyzed	Q
MC - Upper 110716	K1613678-001	ND U	0.010	1	11/08/16 13:02	
AKM224 110716	K1613678-002	ND U	0.010	1	11/08/16 13:02	
Gerry 110716	K1613678-003	ND U	0.010	1	11/08/16 13:02	
AAJ531 110716	K1613678-004	ND U	0.010	1	11/08/16 13:02	
MC - Lower 110716	K1613678-005	ND U	0.010	1	11/08/16 13:02	
Method Blank	K1613678-MB1	ND U	0.010	1	11/08/16 13:02	

Analytical Report

Client:	Aspect Consulting	**Service Request:**	K1613678
Project:	Chelan County Natural Resources Dept#120045-11a-05/120045.011a	**Date Collected:**	11/7/16
Sample Matrix:	Water	**Date Received:**	11/8/16
Analysis Method:	365.3	**Units:**	mg/L
Prep Method:	Method	**Basis:**	NA

Phosphorus, Total

Sample Name	Lab Code	Result		MRL	Dil.	Date Analyzed	Date Extracted	Q
MC - Upper 110716	K1613678-001	**0.037**		0.010	1	11/08/16 16:20	11/8/16	
AKM224 110716	K1613678-002	ND	U	0.010	1	11/08/16 16:20	11/8/16	
Gerry 110716	K1613678-003	ND	U	0.010	1	11/08/16 16:20	11/8/16	
AAJ531 110716	K1613678-004	ND	U	0.010	1	11/08/16 16:20	11/8/16	
MC - Lower 110716	K1613678-005	**0.034**		0.010	1	11/08/16 16:20	11/8/16	
Method Blank	K1613678-MB1	ND	U	0.010	1	11/08/16 16:20	11/8/16	

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Analytical Report

Client:	Aspect Consulting	**Service Request:**	K1613678
Project:	Chelan County Natural Resources Dept#120045-11a-05/120045.011a	**Date Collected:**	11/7/16
Sample Matrix:	Water	**Date Received:**	11/8/16
Analysis Method:	ASTM D1426-08B	**Units:**	mg/L
Prep Method:	ASTM D3590-02(2006)(A)	**Basis:**	NA

Nitrogen, Total Kjeldahl (TKN)

Sample Name	Lab Code	Result	MRL	Dil.	Date Analyzed	Date Extracted	Q
MC - Upper 110716	K1613678-001	**0.44**	0.20	1	11/11/16 10:30	11/9/16	
AKM224 110716	K1613678-002	**0.57**	0.20	1	11/11/16 10:30	11/9/16	
Gerry 110716	K1613678-003	**0.49**	0.20	1	11/11/16 10:30	11/9/16	
AAJ531 110716	K1613678-004	**0.66**	0.20	1	11/11/16 10:30	11/9/16	
MC - Lower 110716	K1613678-005	**0.53**	0.20	1	11/11/16 10:30	11/9/16	
Method Blank	K1613678-MB1	ND U	0.20	1	11/11/16 10:30	11/9/16	

Analytical Report

Client: Aspect Consulting
Project: Chelan County Natural Resources Dept#120045-11a-05/120045.011a
Sample Matrix: Water
Service Request: K1613678
Date Collected: 11/7/16
Date Received: 11/8/16

Analysis Method: SM 2540 D
Prep Method: None
Units: mg/L
Basis: NA

Solids, Total Suspended (TSS)

Sample Name	Lab Code	Result		MRL	Dil.	Date Analyzed	Q
MC - Upper 110716	K1613678-001	**33.7**		1.0	1	11/09/16 14:03	
AKM224 110716	K1613678-002	**10.3**		1.0	1	11/09/16 14:03	
Gerry 110716	K1613678-003	**9.8**		1.0	1	11/09/16 14:03	
AAJ531 110716	K1613678-004	**2.4**		1.0	1	11/09/16 14:03	
MC - Lower 110716	K1613678-005	**38.9**		1.0	1	11/09/16 14:03	
Method Blank	K1613678-MB1	ND	U	1.0	1	11/09/16 14:03	
Method Blank	K1613678-MB2	ND	U	1.0	1	11/09/16 14:03	

Organochlorine Pesticides

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Client: Aspect Consulting **Service Request:** K1613678
Project: Chelan County Natural Resources Dept#120045-11a-05/120045.011a

Cover Page - Organic Analysis Data Package
Organochlorine Pesticides

Sample Name	Lab Code	Date Collected	Date Received
MC - Upper 110716	K1613678-001	11/07/2016	11/08/2016
AKM224 110716	K1613678-002	11/07/2016	11/08/2016
Gerry 110716	K1613678-003	11/07/2016	11/08/2016
AAJ531 110716	K1613678-004	11/07/2016	11/08/2016
MC - Lower 110716	K1613678-005	11/07/2016	11/08/2016

Analytical Results

Client:	Aspect Consulting	**Service Request:**	K1613678
Project:	Chelan County Natural Resources Dept#120045-11a-05/120045.011a	**Date Collected:**	11/07/2016
Sample Matrix:	Water	**Date Received:**	11/08/2016

Organochlorine Pesticides

Sample Name:	MC - Upper 110716	**Units:**	ng/L
Lab Code:	K1613678-001	**Basis:**	NA
Extraction Method:	EPA 3535A	**Level:**	Low
Analysis Method:	8081B		

Analyte Name	Result	Q	MRL	Dilution Factor	Date Extracted	Date Analyzed	Extraction Lot	Note
4,4'-DDE	ND	U	0.98	1	11/08/16	11/11/16	KWG1610173	
4,4'-DDD	ND	U	0.98	1	11/08/16	11/11/16	KWG1610173	
4,4'-DDT	ND	U	0.98	1	11/08/16	11/11/16	KWG1610173	

Surrogate Name	%Rec	Control Limits	Date Analyzed	Note
Tetrachloro-m-xylene	81	20-106	11/11/16	Acceptable
Decachlorobiphenyl	75	19-127	11/11/16	Acceptable

Comments:

Analytical Results

Client:	Aspect Consulting	**Service Request:**	K1613678
Project:	Chelan County Natural Resources Dept#120045-11a-05/120045.011a	**Date Collected:**	11/07/2016
Sample Matrix:	Water	**Date Received:**	11/08/2016

Organochlorine Pesticides

Sample Name:	AKM224 110716	**Units:**	ng/L
Lab Code:	K1613678-002	**Basis:**	NA
Extraction Method:	EPA 3535A	**Level:**	Low
Analysis Method:	8081B		

Analyte Name	Result	Q	MRL	Dilution Factor	Date Extracted	Date Analyzed	Extraction Lot	Note
4,4'-DDE	ND	U	1.1	1	11/08/16	11/11/16	KWG1610173	
4,4'-DDD	ND	U	1.1	1	11/08/16	11/11/16	KWG1610173	
4,4'-DDT	ND	U	1.1	1	11/08/16	11/11/16	KWG1610173	

Surrogate Name	%Rec	Control Limits	Date Analyzed	Note
Tetrachloro-m-xylene	87	20-106	11/11/16	Acceptable
Decachlorobiphenyl	81	19-127	11/11/16	Acceptable

Comments:

Client:	Aspect Consulting	**Service Request:**	K1613678
Project:	Chelan County Natural Resources Dept#120045-11a-05/120045.011a	**Date Collected:**	11/07/2016
Sample Matrix:	Water	**Date Received:**	11/08/2016

Organochlorine Pesticides

Sample Name:	Gerry 110716	**Units:**	ng/L
Lab Code:	K1613678-003	**Basis:**	NA
Extraction Method:	EPA 3535A	**Level:**	Low
Analysis Method:	8081B		

Analyte Name	Result	Q	MRL	Dilution Factor	Date Extracted	Date Analyzed	Extraction Lot	Note
4,4'-DDE	ND	U	0.98	1	11/08/16	11/11/16	KWG1610173	
4,4'-DDD	ND	U	0.98	1	11/08/16	11/11/16	KWG1610173	
4,4'-DDT	ND	U	0.98	1	11/08/16	11/11/16	KWG1610173	

Surrogate Name	%Rec	Control Limits	Date Analyzed	Note
Tetrachloro-m-xylene	88	20-106	11/11/16	Acceptable
Decachlorobiphenyl	81	19-127	11/11/16	Acceptable

Comments:

Analytical Results

Client:	Aspect Consulting	**Service Request:**	K1613678
Project:	Chelan County Natural Resources Dept#120045-11a-05/120045.011a	**Date Collected:**	11/07/2016
Sample Matrix:	Water	**Date Received:**	11/08/2016

Organochlorine Pesticides

Sample Name:	AAJ531 110716	**Units:**	ng/L
Lab Code:	K1613678-004	**Basis:**	NA
Extraction Method:	EPA 3535A	**Level:**	Low
Analysis Method:	8081B		

Analyte Name	Result	Q	MRL	Dilution Factor	Date Extracted	Date Analyzed	Extraction Lot	Note
4,4'-DDE	ND	U	0.99	1	11/08/16	11/11/16	KWG1610173	
4,4'-DDD	ND	U	0.99	1	11/08/16	11/11/16	KWG1610173	
4,4'-DDT	ND	U	0.99	1	11/08/16	11/11/16	KWG1610173	

Surrogate Name	%Rec	Control Limits	Date Analyzed	Note
Tetrachloro-m-xylene	86	20-106	11/11/16	Acceptable
Decachlorobiphenyl	78	19-127	11/11/16	Acceptable

Comments:

Analytical Results

Client:	Aspect Consulting	**Service Request:**	K1613678
Project:	Chelan County Natural Resources Dept#120045-11a-05/120045.011a	**Date Collected:**	11/07/2016
Sample Matrix:	Water	**Date Received:**	11/08/2016

Organochlorine Pesticides

Sample Name:	MC - Lower 110716	**Units:**	ng/L
Lab Code:	K1613678-005	**Basis:**	NA
Extraction Method:	EPA 3535A	**Level:**	Low
Analysis Method:	8081B		

Analyte Name	Result	Q	MRL	Dilution Factor	Date Extracted	Date Analyzed	Extraction Lot	Note
4,4'-DDE	ND	U	0.96	1	11/08/16	11/11/16	KWG1610173	
4,4'-DDD	ND	U	0.96	1	11/08/16	11/11/16	KWG1610173	
4,4'-DDT	ND	U	0.96	1	11/08/16	11/11/16	KWG1610173	

Surrogate Name	%Rec	Control Limits	Date Analyzed	Note
Tetrachloro-m-xylene	82	20-106	11/11/16	Acceptable
Decachlorobiphenyl	75	19-127	11/11/16	Acceptable

Comments:

Analytical Results

Client:	Aspect Consulting	**Service Request:**	K1613678
Project:	Chelan County Natural Resources Dept#120045-11a-05/120045.011a	**Date Collected:**	NA
Sample Matrix:	Water	**Date Received:**	NA

Organochlorine Pesticides

Sample Name:	Method Blank	**Units:**	ng/L
Lab Code:	KWG1610173-3	**Basis:**	NA
Extraction Method:	EPA 3535A	**Level:**	Low
Analysis Method:	8081B		

Analyte Name	Result	Q	MRL	Dilution Factor	Date Extracted	Date Analyzed	Extraction Lot	Note
4,4'-DDE	ND	U	0.96	1	11/08/16	11/11/16	KWG1610173	
4,4'-DDD	ND	U	0.96	1	11/08/16	11/11/16	KWG1610173	
4,4'-DDT	ND	U	0.96	1	11/08/16	11/11/16	KWG1610173	

Surrogate Name	%Rec	Control Limits	Date Analyzed	Note
Tetrachloro-m-xylene	81	20-106	11/11/16	Acceptable
Decachlorobiphenyl	76	19-127	11/11/16	Acceptable

Comments:

QA/QC Reports and Raw Data
Available Upon Request

TABLES

Table C-1. Surface Water Stations

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

LocID	River Mile	Latitude	Longitude	Parameters
MC-Lower	2.8	47.488353	-120.481679	WQ, S, F
MC-01	3.8	47.476769	-120.492246	S & F
MC-02	4.7	47.466062	-120.491899	S & F
MC-03	5.3	47.458476	-120.490121	S & F
MC-Upper	6.4	47.44375	-120.495549	WQ, S, F

Notes

WQ	sampled for water quality parameters
S	stream stage continuously measured
F	stream flow measured

Table C-2. Groundwater Monitoring and Test Locations

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

LocID	Latitude	Longitude	Parameters
Test Wells			
TW-1	47.488551	-120.483096	WQ, WL, Q
TW-2	47.488043	-120.483194	WQ, WL, Q
TW-4	47.457599	-120.491428	WQ, WL, Q
TW-5	47.453703	-120.492344	WQ, WL, Q
TW-6	47.44616	-120.495892	WQ, WL, Q
Observation Wells			
OW-1	47.488456	-120.483103	WL
OW-2	47.465966	-120.492160	WL
OW-3	47.460896	-120.491308	WL
OW-4	47.446264	-120.495682	WL

Notes

WQ	sampled for water quality parameters
WL	groundwater Level
Q	discharge flow rate

Table C-3. Well Construction

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

LocID	Ecology Well Tag	Diameter inches	Depth feet	Casing Depth feet - bgs	Seal feet-bgs	Open Interval feet - bgs	Source	Pump Setting feet - bgs	Static Water Level feet - bgs	TOC feet - ags	Landsurface Elevation feet - amsl	Cascading Well	Notes
TW-1	BCC613	8	254	42.5	30	open hole	Chumstick	236.8	16.6	1.9	981	Y	
TW-2	BCC614	8	244	45	33	70 - 90; 150 - 170; 190 - 208; 227 - 244	Chumstick	211.5	9.5	2	983	Y	iron staining below pump set
TW-4	AAJ531	8	53	41	18	21.5; 32.5; 43 - 53 open hole	Alluvium	43.3	10	2	1188	N	Fe/Mn scaling on casing
TW-5	NA	8	320	19	19	open hole	Chumstick	296.3	0	1.5	1212	N	"keyed" borehole
TW-6	AMK224	8	340	unknown	unknown	165 - 183: 205 - 223; 245 - 263; 285 - 302; 326 - 343	Chumstick	317.7	15.5	1.0	1276	N	
Observation Wells													
OW-1	NA	72	<40	<40	unknown	open bottom	Alluvium	--	12.6	2	981	--	
OW-2	BIN376	8	400	22	22	open hole	Chumstick	--	2.3	1.5	1135	--	
OW-3	NA	8	79	39	18	21 - 34; 39 - 79 open hole	Alluvium Chumstick	--	8.8	2	1167	--	
OW-4	AEH437	8	38	38	18	open bottom	Alluvium	--	13.2	2	1274	--	

Table C-4. Aquifer Test Conditions

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

LocID	Number	Phase Captured	Pumping Duration (days)	Average Pumping Flow Rate (gpm)	Flow Rate Stable
TW-1	1	Recovery	0.21	90	N
TW-1	2	Recovery	0.15	104	N
TW-2	1	Recovery	0.02	125	N
TW-2	2	Recovery	0.33	95	N
TW-2	3	Recovery	0.27	118	N
TW-4	1	Drawdown & Recovery	28.1	69	Y[1]
TW-5	1	Drawdown & Recovery	26.8	49	Y[2]
TW-6	1	Drawdown & Recovery	27.0	37	Y[3]

Notes

[1] stable within 10% of average flow rate after 1st hour

[2] stable within 10% of average flow rate after 2 days

[3] stable within 10% of average flow rate after 1.5 days

gpm - gallons per minute

`

Table C-5. Rating Table

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

LocID	Date	Flow (cfs)	Staff Gague (ft)	Notes
MC-Lower	10/18/2016	11.1	0.71	During pizo install, check JS for staff data
MC-Lower	10/28/2016	11.1	0.85	Possible Equipment Malfunction
MC-Lower	10/31/2016	15.4	0.85	
MC-Lower	11/1/2016	15.6	0.80	
MC-Lower	11/7/2016	12.8	0.75	
MC-Lower	11/15/2016	17.0	0.91	
MC-Lower	11/22/2016	11.1	0.69	
MC-Lower	11/28/2016	10.9	0.70	
MC-01	10/19/2016	10.1	0.40	During pizo install, check JS for staff data
MC-01	10/26/2016	20.1	0.74	
MC-01	11/1/2016	17.8	0.60	
MC-01	11/7/2016	11.8	0.50	
MC-01	11/22/2016	10.8	0.46	
MC-02	10/19/2016	10.4	0.60	During pizo install, check JS for staff data
MC-02	10/28/2016	11.3	0.76	Possible Equipment Malfunction
MC-02	11/1/2016	18.1	0.75	
MC-02	11/8/2016	12.4	0.66	
MC-02	11/16/2016	13.6	0.68	
MC-02	11/22/2016	11.1	0.61	
MC-03	10/19/2016	10.4	0.61	During pizo install, check JS for staff data
MC-03	11/1/2016	16.7	0.85	
MC-03	11/8/2016	11.1	0.72	
MC-03	11/16/2016	13.6	0.71	
MC-03	11/22/2016	11.0	0.68	
MC-Upper	10/18/2016	12.8	0.65	During pizo install, check JS for staff data
MC-Upper	10/28/2016	11.5	0.69	Possible Equipment Malfunction
MC-Upper	10/31/2016	22.9	0.80	Ran twice bc high flow #'s, both 22.9
MC-Upper	11/7/2016	14.3	0.68	
MC-Upper	11/15/2016	18.1	0.80	
MC-Upper	11/22/2016	11.6	0.63	
MC-Upper	11/28/2016	11.8	0.64	

Notes

cfs - cubic feet per second

ft - feet

Table C-6. Aquifer Parameters

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

LocID	Average Transmissivity	Aquifer Thickness	Hydraulic Conductivity	
	ft^2/d	ft	ft/d	cm/s
Alluvium	1270	13	100	4E-02
Chumstick	50	265	0.2	6E-05

Notes

a drawdown water level not stable or below measurement device, overprediction of specific capacity

NA not analyzed due to short pumping duration

cm/s - cubic meters per day

ft - feet

ft/d - feet per day

ft^2/d - square feet per day

Table C-7. Well Yield

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

Test Well	Specific Capacity	Available Drawdown	Yield
	gpm/ft	feet	gpm
TW-1	0.3	210	70
TW-2	0.4	192	80
TW-4	3.9	23	90
TW-5	0.2	286	50
TW-6	0.1	292	40

Notes

gpm - gallons per minute

gpm/ft - gallons per minute per foot

Table C-8. Water Quality Results

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

	LocID	TW-1	TW-1	TW-2	TW-4	TW-5	TW-5	TW-6	TW-6	MC-LOWER	MC-UPPER
	Sampling Date	11/1/2016	11/1/2016	11/1/2016	11/7/2016	10/31/2016	11/7/2016	10/31/2016	11/7/2016	11/7/2016	11/7/2016
	Sample Type	N	FD	N	N	N	N	N	N	N	N
Analyte	Unit										
Bacteria											
Fecal Coliform	cfu/100mL	< 2.0 UJ	< 2.0 UJ	< 2.0 UJ							
Fecal Coliform	MPN/100mL				< 1.8 U		< 1.8 U		< 1.8 U	**330**	**6.8**
Conventionals											
Nitrate as Nitrogen	mg/L	**2.69**	**2.7**	**3.16**	**4.06**		< 0.10 U		**2.24**	**0.25**	< 0.10 U
Nitrate-Nitrite	mg/L	**2.94**	**2.92**	**3.48**	**3.8**		**0.055**		**2.22**	**0.25**	< 0.050 U
Nitrite as Nitrogen	mg/L	< 0.10 U	< 0.10 U	< 0.10 U	< 0.10 U		< 0.10 U		< 0.10 U	< 0.10 U	< 0.10 U
ortho-Phosphate	mg/L	< 0.010 U	< 0.010 U	< 0.010 U	< 0.010 U		< 0.010 U		< 0.010 U	< 0.010 U	< 0.010 U
Phosphorus	mg/L	< 0.010 U	< 0.010 U	< 0.010 U	< 0.010 U		< 0.010 U		< 0.010 U	**0.034**	**0.037**
Total Kjeldahl Nitrogen	mg/L	**0.65**	**0.74**	**0.48**	**0.66**		**0.49**		**0.57**	**0.53**	**0.44**
Total Suspended Solids	mg/L	**3**	**2.9**	**1.4**	**2.4**		**9.8**		**10.3**	**38.9**	**33.7**
Field Parameters											
Dissolved Oxygen	mg/L	**12.6**		**10.9**	**4.0**	**0.1**	**0.2**	**3.5**	**4.2**	**11.3**	**11.3**
Oxidation Reduction Potential	mV	**32**		**44**	**35**	**-79**	**14**	**-29**	**40**	**39**	**40**
pH	pH units	**7.2**		**7.3**	**6.9**	**8.3**	**8.2**	**7.6**	**7.6**	**8.4**	**8.2**
Specific Conductance	uS/cm	**303**		**315**	**728**[a]	**289**	**751**[a]	**376**	**834**[a]	**444**[a]	**420**[a]
Temperature	deg C	**12.0**		**11.3**	**12.1**	**13.4**	**13.5**	**11.1**	**11.9**	**8.0**	**6.4**
Turbidity	NTU	**4**		**4**	**1**	**12**	**1**	**3.7**	**1**	**10**	**8**
Pest/Herbicides											
4,4'-DDD	ng/L	< 0.99 U	< 1.0 U	< 0.96 U	< 0.99 U		< 0.98 U		< 1.1 U	< 0.96 U	< 0.98 U
4,4'-DDE	ng/L	**2.3**	**2.1**	< 0.96 U	< 0.99 U		< 0.98 U		< 1.1 U	< 0.96 U	< 0.98 U
4,4'-DDT	ng/L	< 1.4 UJ	< 1.4 UJ	< 0.96 U	< 0.99 U		< 0.98 U		< 1.1 U	< 0.96 U	< 0.98 U

Notes

a - calibration error, measured value higher than actual due to

Bold - detected

cfu/100 mL - colony forming units per 100 milliliters

MPN/100 mL - most probable number per 100 milliliters

MPN/100 mL - most probable number per 100 milliliters

mg/L - milligrams per liter

mV - millivolts

uS/cm - microsiemens per centimeter

deg C - degrees Celsius

NTU - Nephelometric Turbidity Units

ng/L - nanograms per liter

Table C-9. Stream Response Factor

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

Test Well	Aquifer Type	Aquifer	Transmissivity ft^2/d	Storativity --	Hydraulic Diffusivity ft^2/d	Distance to Stream[1] ft	Stream Response Factor days	Recovery[2] days
TW-1	unconfined	Chumstick	50	0.15	3E+02	300	270	0.03
TW-2						40	4.8	0.1
TW-4	semi-confined	Alluvial	1270	1E-03	1E+06	200	0.03	5.1
TW-5		Chumstick	50		5E+04	150	0.5	14.8
TW-6	unconfined			0.15	3E+02	250	1.25	1.3

Notes

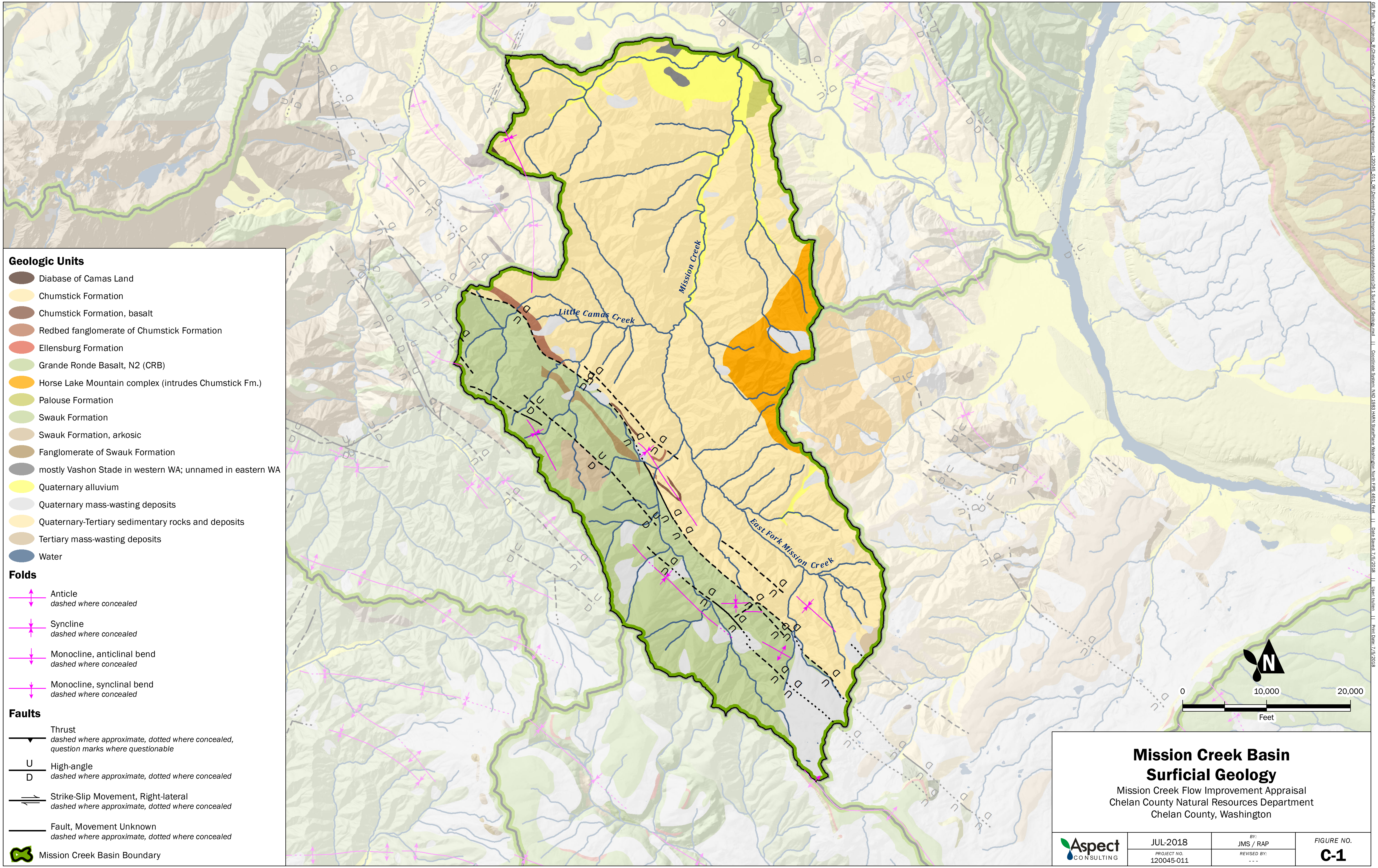
1) Distance to stream is the shortest distance

2) Recovery as 95% of drawdown, except TW-6 at 93% of drawdown

ft - feet

ft^2/d - square feet per day

FIGURES

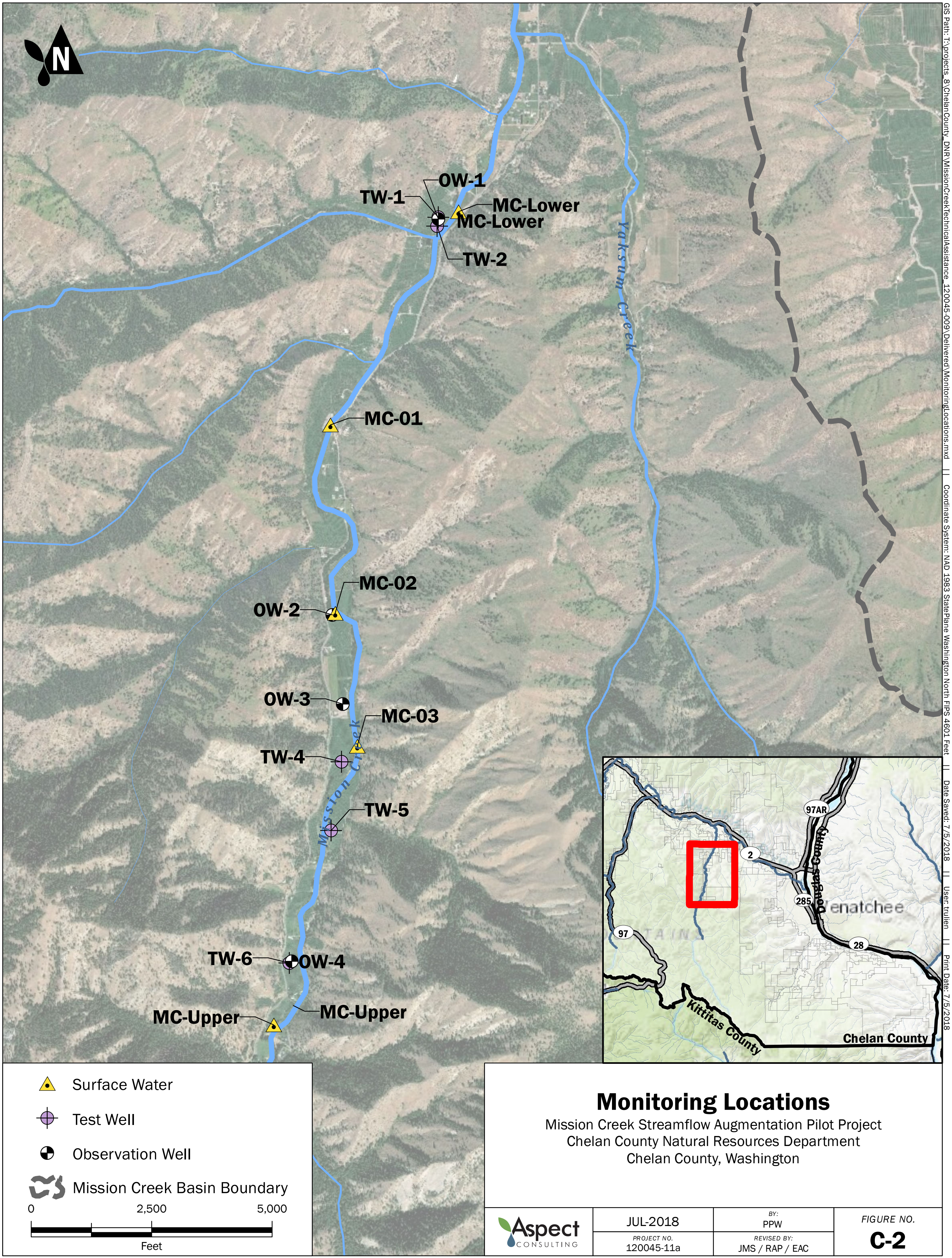


Mission Creek Basin Surficial Geology

Mission Creek Flow Improvement Appraisal
Chelan County Natural Resources Department
Chelan County, Washington

Aspect CONSULTING	JUL-2018	BY: JMS / RAP	FIGURE NO. **C-1**
	PROJECT NO. 120045-011	REVISED BY: - - -	

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekFlowAugmentation_120045_011_06\Delivered\FlowImprovementAppraisalAnalysis\06-1 Surficial Geology.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trulien || Print Date: 7/5/2018



Monitoring Locations

Mission Creek Streamflow Augmentation Pilot Project
Chelan County Natural Resources Department
Chelan County, Washington

JUL-2018	BY: PPW	FIGURE NO.
PROJECT NO. 120045-11a	REVISED BY: JMS / RAP / EAC	**C-2**

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekTechnicalAssistance_120045-009\Delivered\MonitoringLocations.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/5/2018 || User: trullen || Print Date: 7/5/2018

Basemap Layer Credits || Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

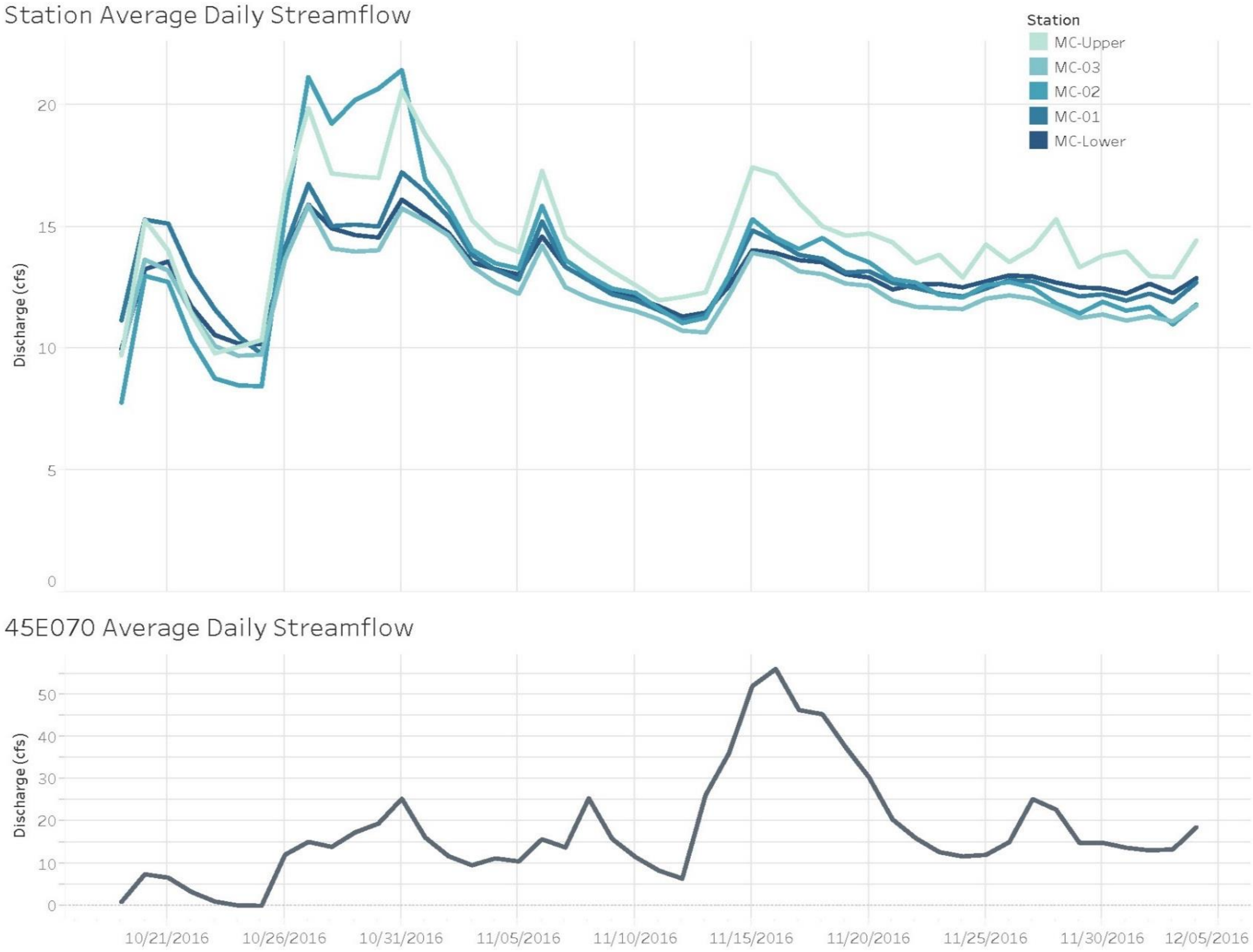


Figure C-3

Surface Water Hydrographs

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

Aspect Consulting
07/06/2018
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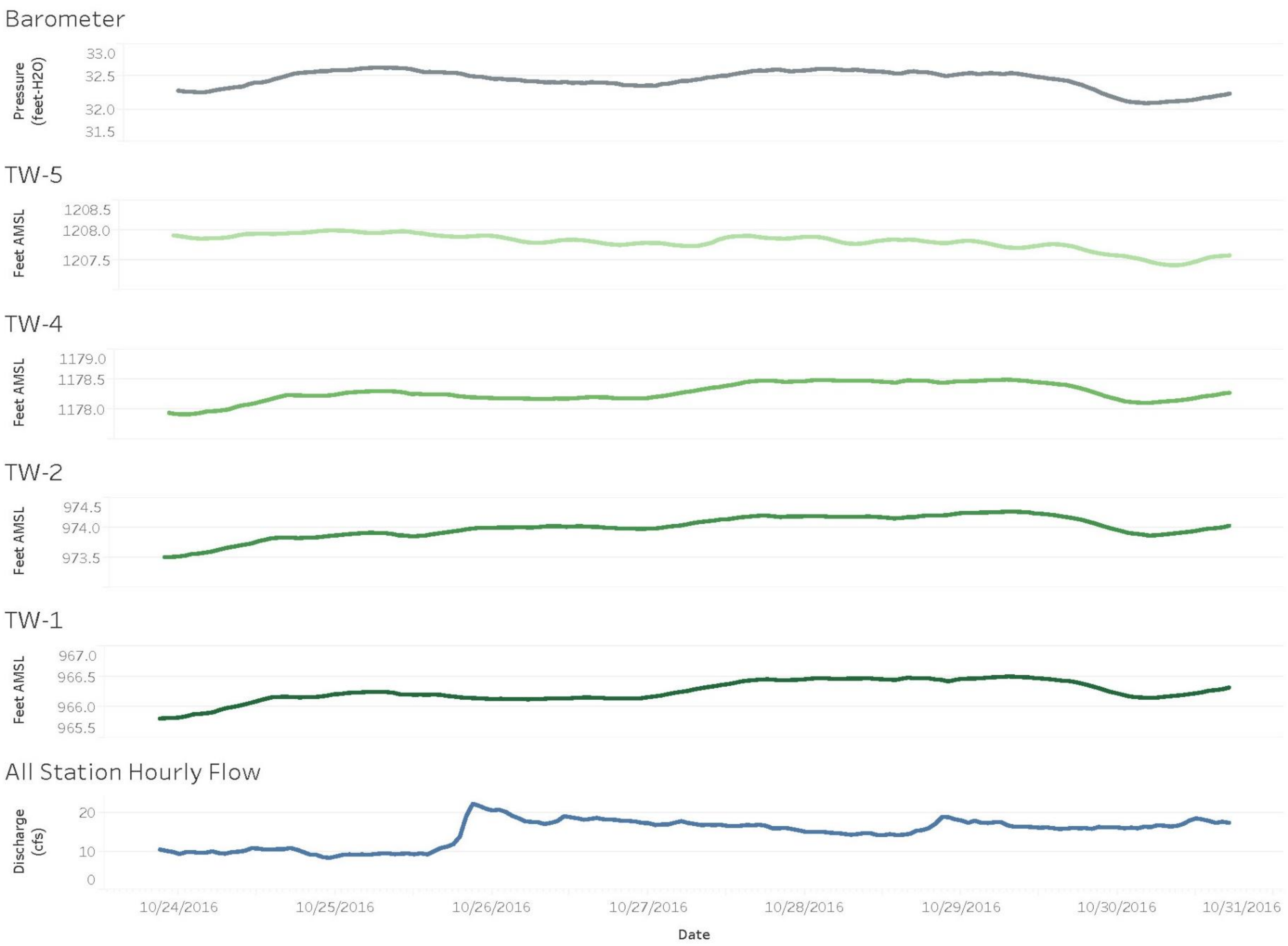

Figure C-4
TWs Static Water Levels

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

Aspect Consulting
07/06/2018
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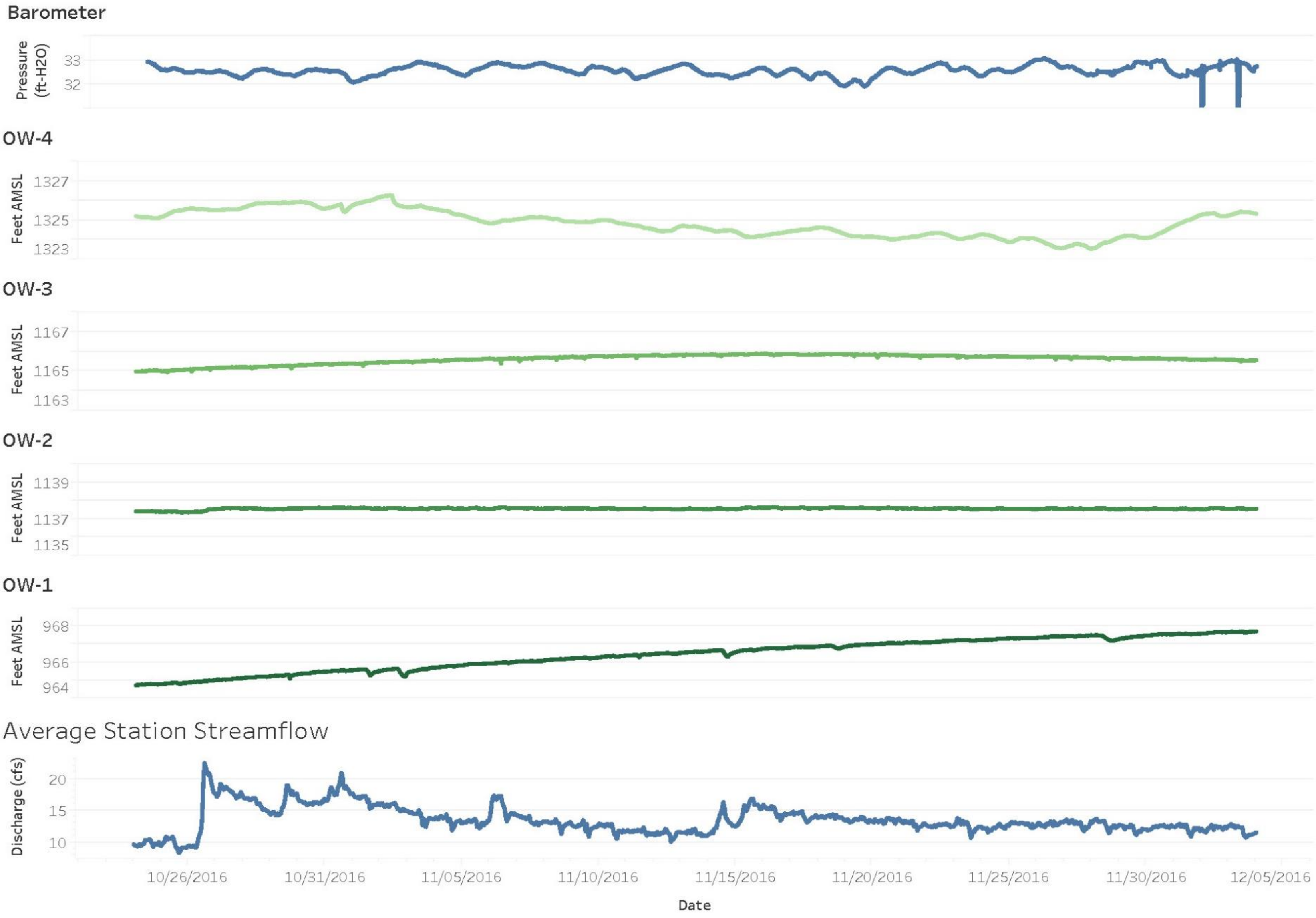

Figure C-5

OWs Water Levels

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

Aspect Consulting
07/06/2018
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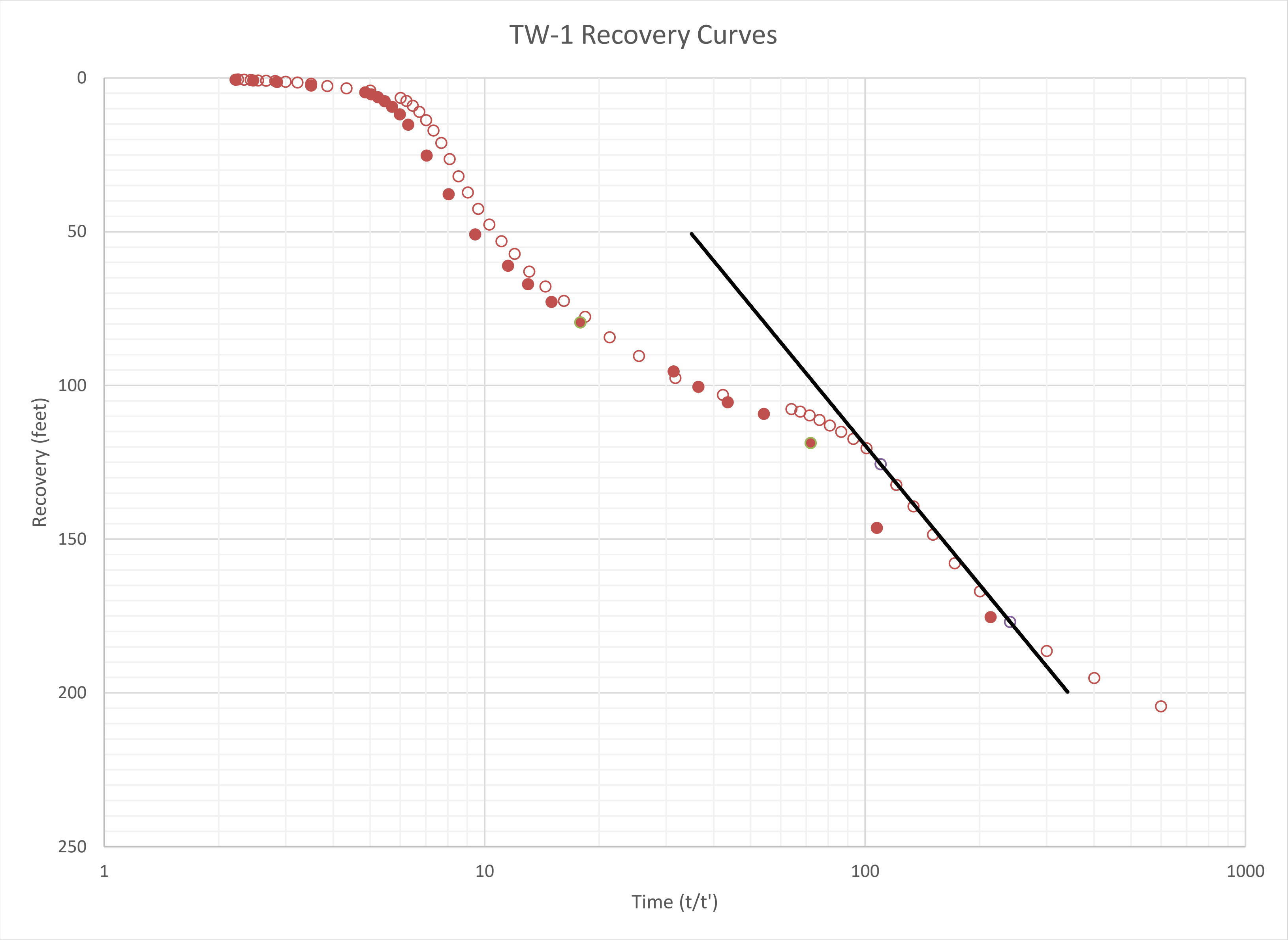

Aspect Consulting
07/06/2018
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Figure C-6
TW-1 Recovery Curves

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

Temp

Font

Use ‘

Date

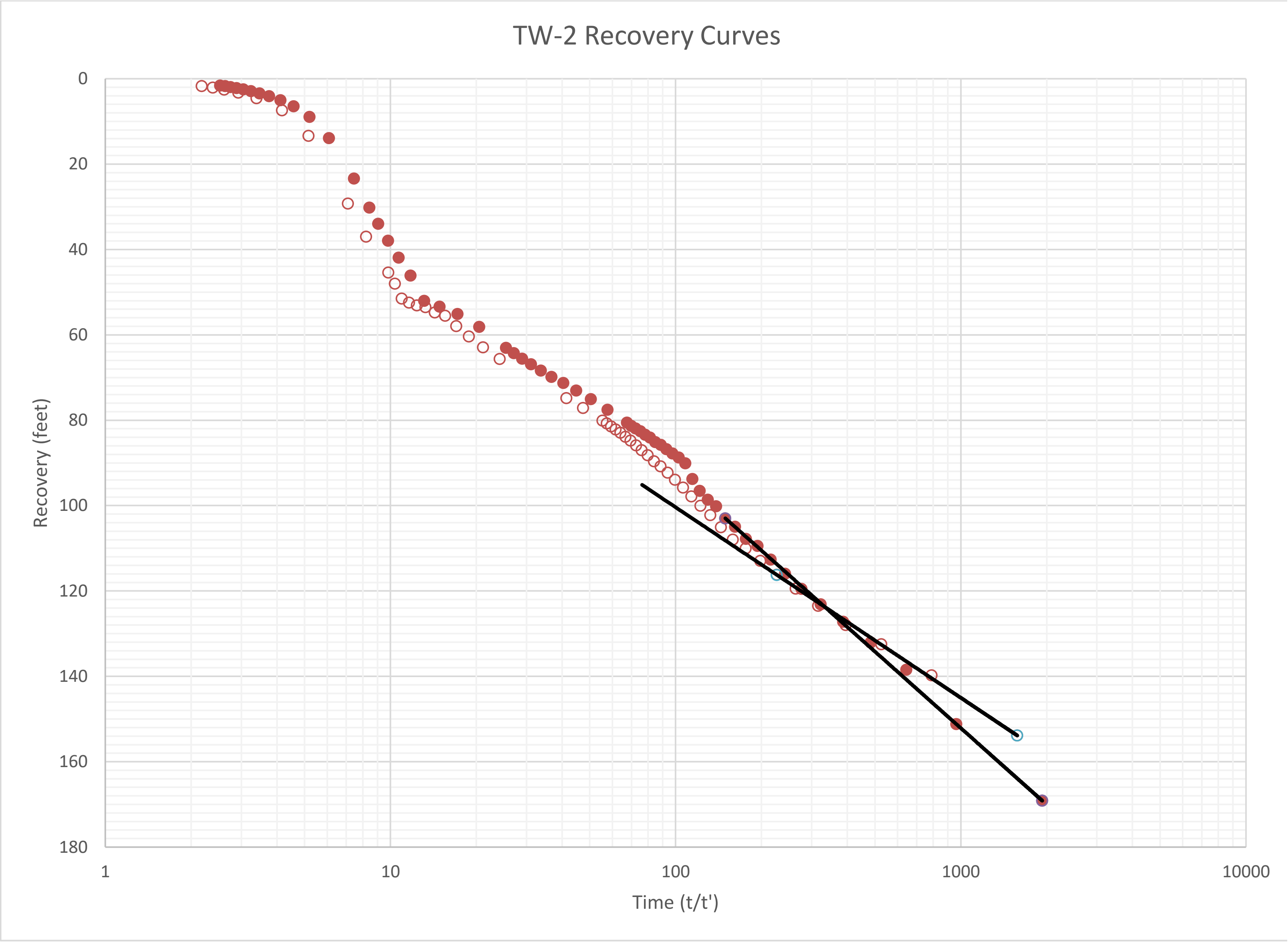

Figure C-7
TW-2 Recovery Curves

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

Aspect Consulting
07/06/2018
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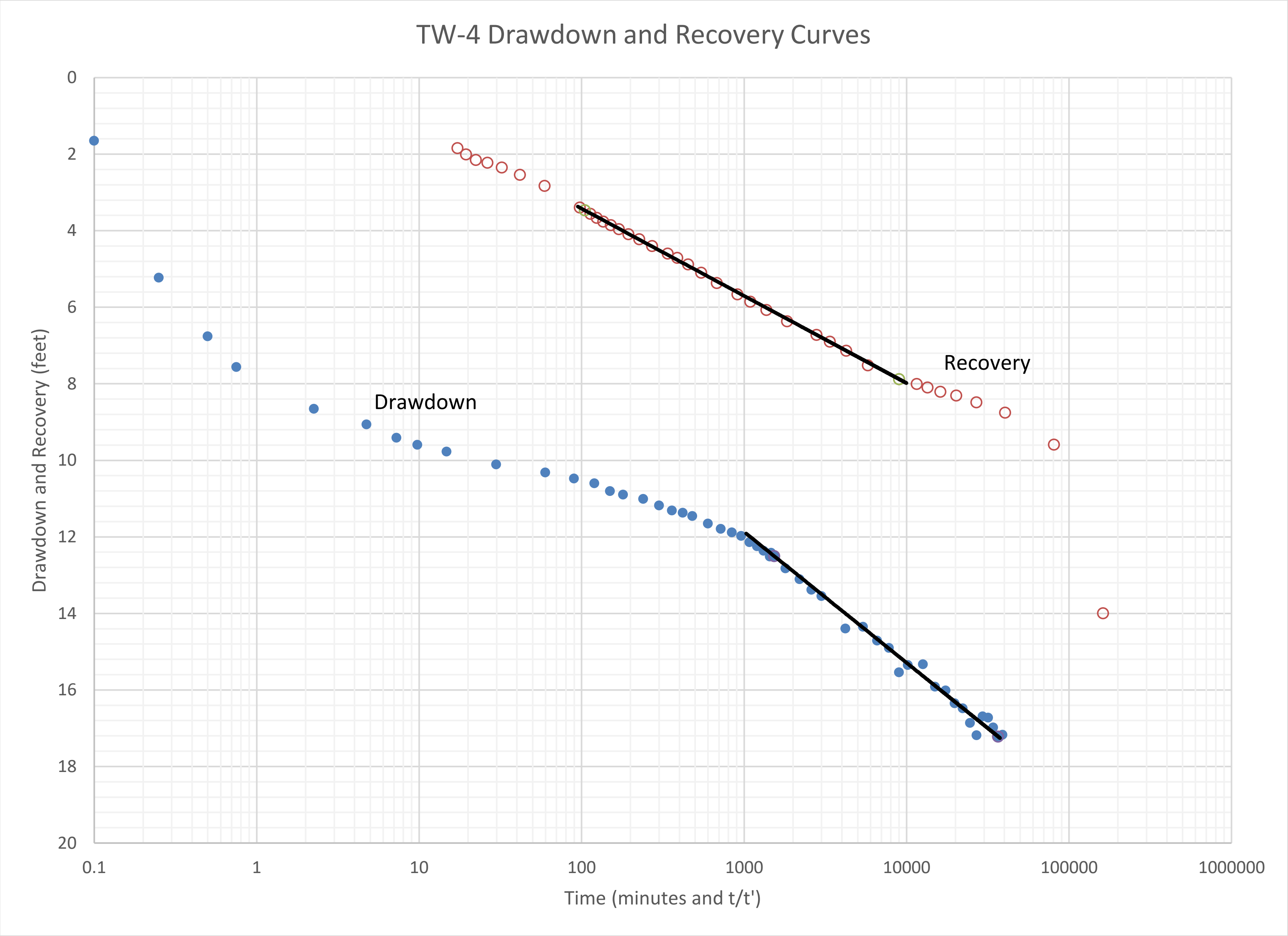

Aspect Consulting
07/06/2018
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Figure C-8
TW-4 Drawdown and Recovery Curves
Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

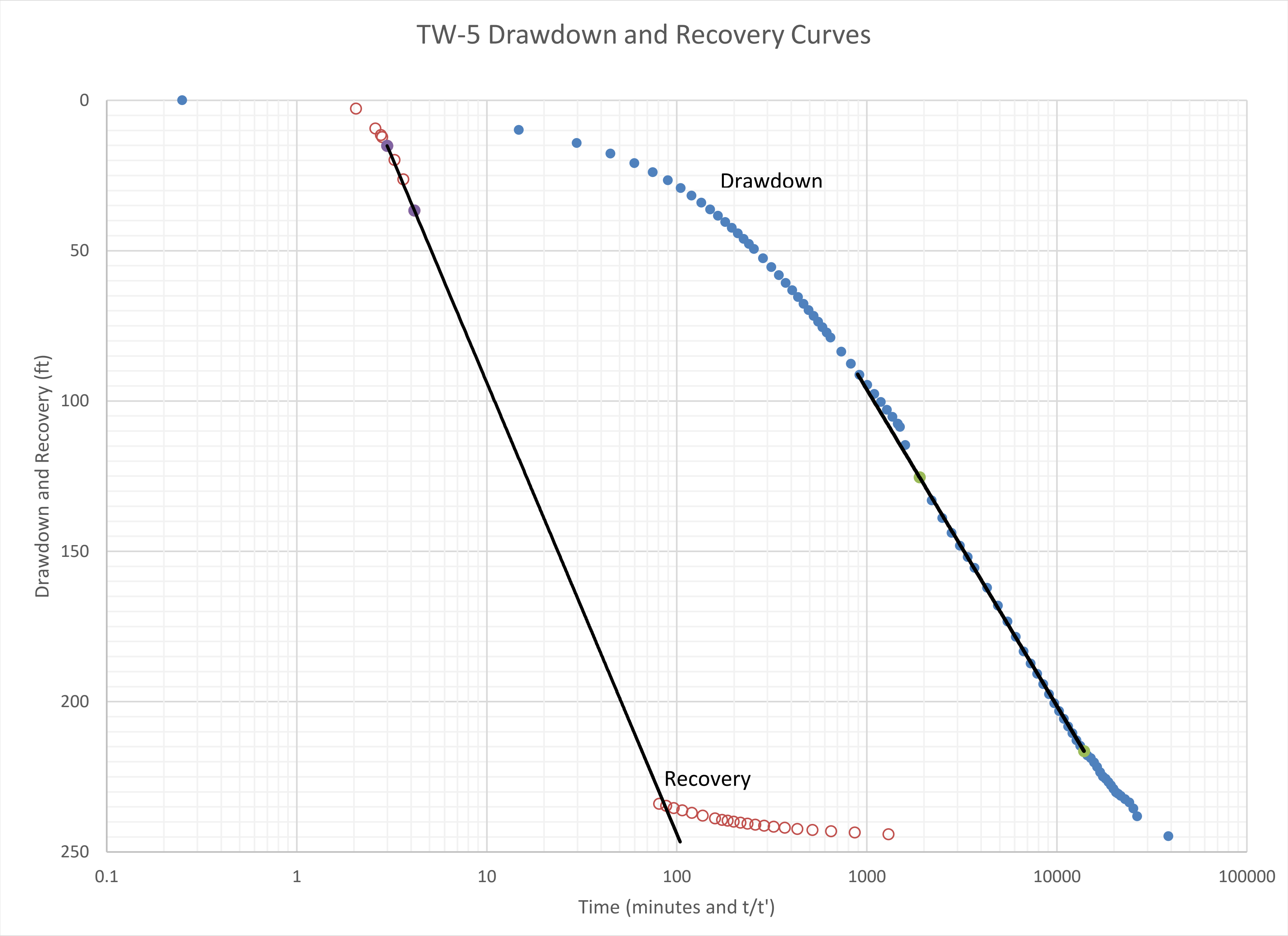

Figure C-9

TW-5 Drawdown and Recovery Curves

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

Aspect Consulting
07/06/2018
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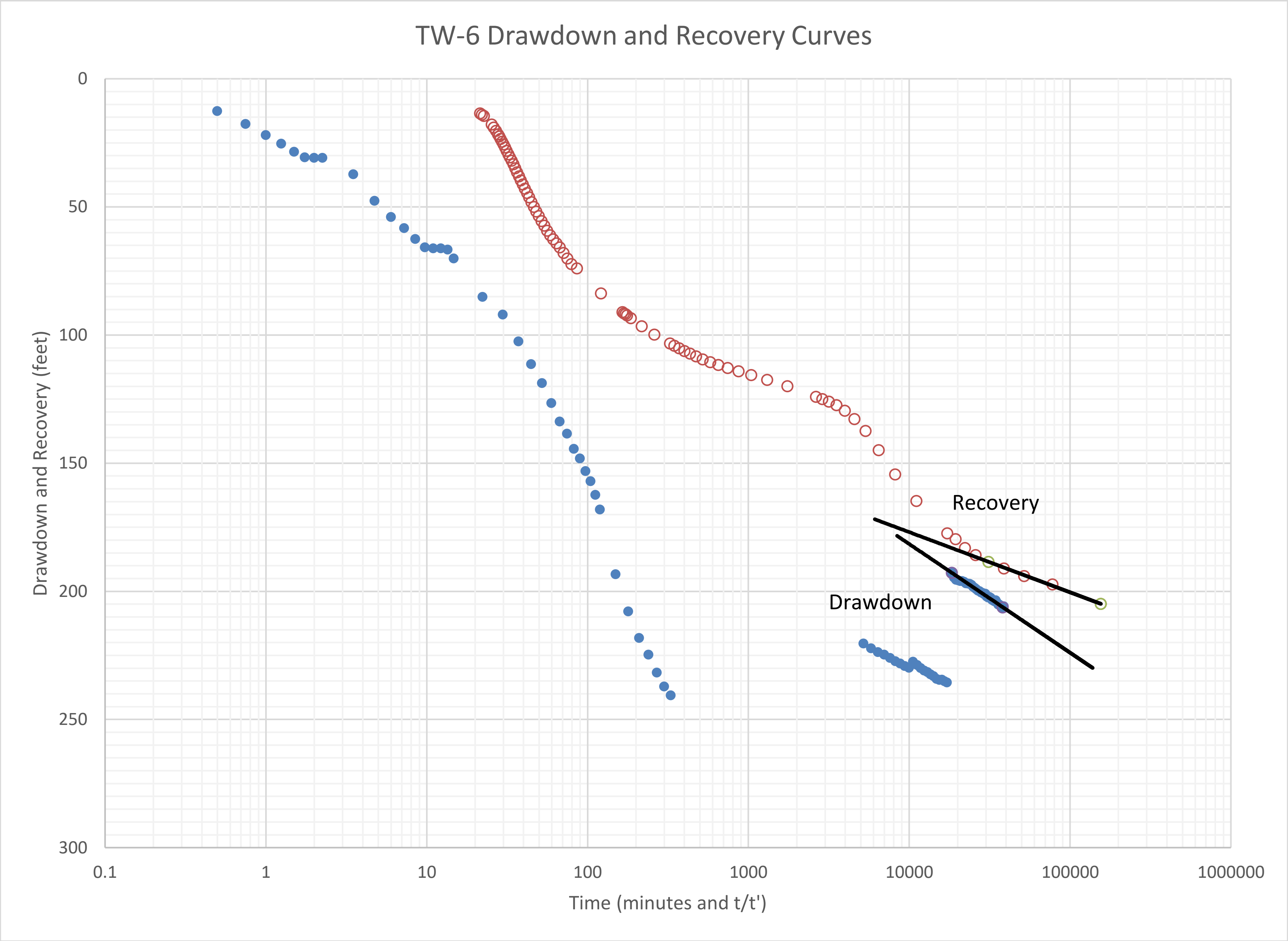

Figure C-10

TW-6 Drawdown and Recovery Curves

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

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Median Daily Discharge (WY2003 to 2016) and Minimum Instream Flow

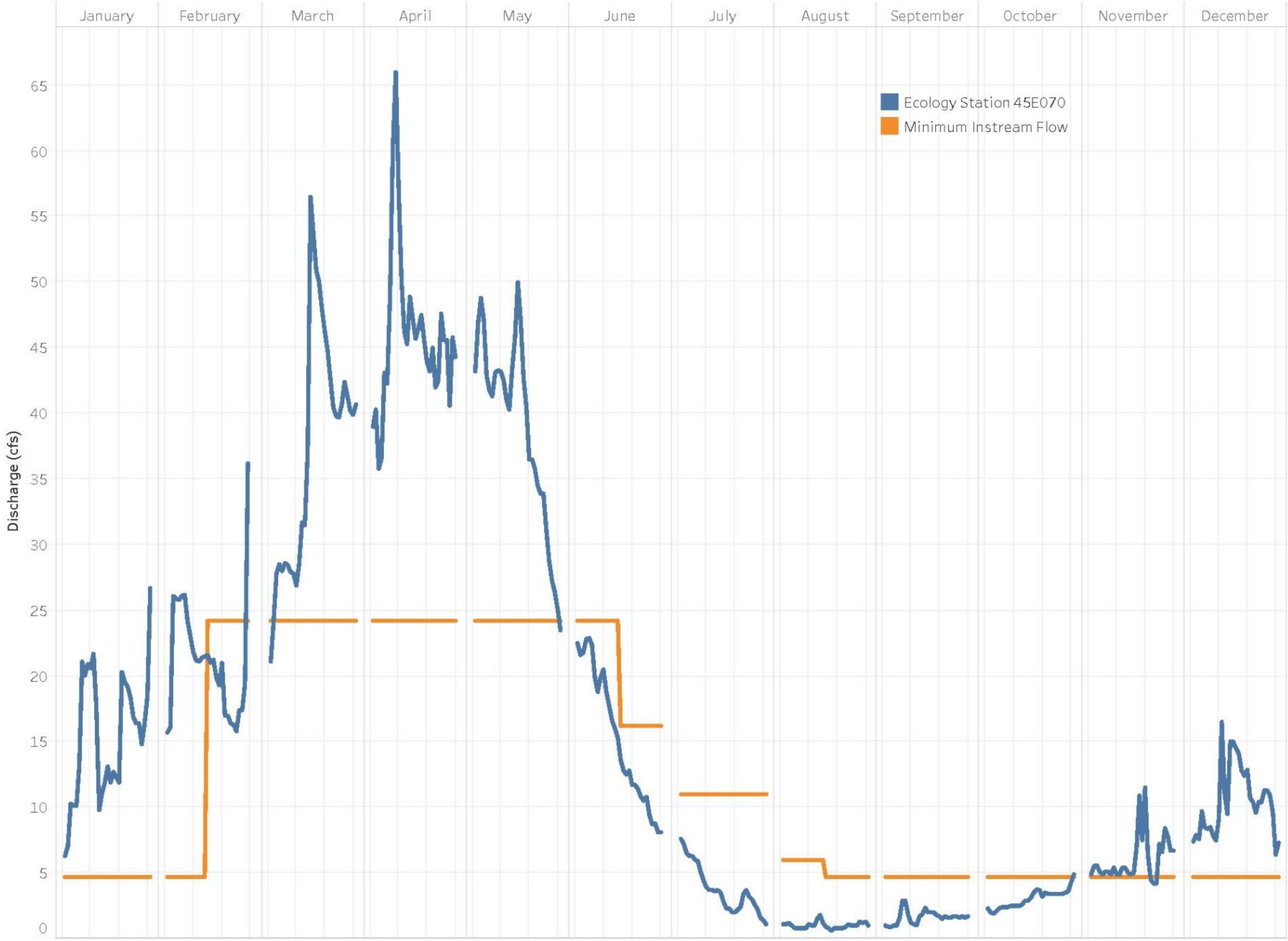

Figure C-11

Ecology Station 45E070 Hydrograph

Project No. 120045, Mission Creek Augmentation Pilot Project, Cashmere, WA

Aspect Consulting
07/06/2018
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APPENDIX D

Alluvial Water Storage Pilot Project

To: Pete Cruickshank and Mike Kaputa; Chelan County Natural Resources

From: Susan Dickerson-Lange, PhD, Tim Abbe, PhD, PG, and John Soden, MS, PWS;
Natural Systems Design

Date: April 3, 2017

Re: Mission Creek, Phase I Assessment: Water Conservation Through Stream Restoration

BACKGROUND

Introduction

Mission Creek, in Chelan County, Washington, flows into the Wenatchee River near Cashmere, Washington. The lower 6 miles of Mission Creek flow through an agricultural valley, with surface withdrawals from the creek utilized for orchard irrigation. The upper portion of the basin includes federally and state-managed lands in addition to private timber land and residences. Dry season streamflow in Mission Creek is over-allocated, resulting in water shortages. Key issues of concern are dry season water quantity and quality, which impact the health of the spring Chinook and summer steelhead runs and availability of irrigation water.

The Chelan County Natural Resource Department (CCNRD) requested that Natural Systems Design (NSD) conduct a restoration and water conservation assessment for the upper portion of Mission Creek. The primary purpose of this project is to estimate the historic loss of water storage from channel incision and valley erosion in Mission Creek, and, conversely, to quantify the potential for water conservation and storage through restoration. The assessment focuses on the river valley upstream of the main agricultural valley, from approximately the confluence of the main stem Mission Creek with Sand Creek (RM 7).

This analysis is the initial phase of a larger vision for assessment, implementation, and monitoring to utilize geomorphic restoration as a strategy for water augmentation during the low flow season. Broadly, we envision the following phases:

Phase 1. Pilot assessment in Mission Creek (described in this memorandum)

Phase 2. Pilot engineering design and implementation in 1-2 reaches of Mission Creek, followed by monitoring and additional implementation depending on observed aggradation rates

Phase 3. Design and implementation in more extensive network of Mission Creek tributaries

The basis for this assessment is that the valley bottom serves as a critical reservoir for both alluvial sediment and water. Land use changes and disturbances that result in the erosion of large quantities of sediment out of the valley network or the loss of natural surface storage such as wetlands effectively result in a loss of *in-situ* water storage. Reduced surface and subsurface water storage within the river network subsequently results in lower streamflow during the dry season. Extensive stream restoration therefore has the potential to increase storage of alluvial sediment and water, and therefore augment low flows during the dry season. Increased in-situ storage of sediment and water simultaneously provides aquatic and terrestrial ecosystem benefits, including improved water quality, riparian water availability, forest health, and fire resilience.

Upland water storage

Numerous upland hydrologic processes contribute to the critical watershed function to store and transport water to the stream network. Components of upland water storage include snowpack, soil moisture, groundwater, and surface water (natural and built). Each of these reservoirs contributes water to streamflow, and the amount and timing of available water depends on the rate of water export from the watershed, both from evapotranspiration (i.e., loss to the atmosphere as water vapor) and from the routing of water to and through the channel network.

Historic and current land use impacts such as timber harvest, road-building, beaver trapping, and in-channel wood removal have generally resulted in channel incision (i.e., down-cutting) throughout the Pacific Northwest (Collins *et al.*, 2002; Phelps, 2011; Pollock *et al.*, 2014; Abbe *et al.*, 2015, 2016). The result is increased erosion and downstream sediment transport and a deeper channel network that is laterally disconnected from its floodplain. Consequently, during periods of high flow, large volumes of water are rapidly conveyed out of the watershed without spilling over-bank and recharging shallow groundwater. During the dry season, the lower elevation of the incised channel relative to the shallow groundwater elevation sets up a hydraulic gradient that drives flow from alluvial groundwater storage into the channel (Beechie *et al.*, 2008). Thus, incised channels typically reduce shallow groundwater storage in the riparian zone.

Therefore, the overarching goals of a restoration strategy to conserve water are to:

(1) Maximize in-situ water storage, and

(2) increase summer baseflow.

Restoration of natural geomorphic processes that store and retain water and sediment have multiple hydrological and ecological benefits, including addressing current issues with overallocation of surface water, improving riparian ecosystem health and resilience to drought and fire by increasing shallow groundwater availability, improving aquatic ecosystem health by increasing instream flows and decreasing water temperature and sediment loads, and increasing aquatic habitat complexity.

Projected climate change impacts will reduce upland water storage in the form of snowpack and soil moisture, and speed the transport of water to the channel network (Elsner *et al.*, 2010). This depletion and early release of natural water storage is projected to result in decreased baseflow (i.e., low flow) during the dry season. For example, average unregulated August streamflow in the Wenatchee River (modeled at Monitor, WA) is projected to decrease by 50-65% by the end of the century (Hamlet *et al.*, 2013). However, restoration actions that initiate increased storage of alluvial sediments and water have the potential to dampen climate change impacts on the baseflow hydrograph.

Relevant Previous Work

Water Storage Estimates

Previous assessments of flow conditions and water storage potential have been completed in the Wenatchee basin. Low flows and dewatering (i.e., no flow) and high stream temperatures are reported as issues of concern (Montgomery Water Group, 2006; Schneider and Anderson, 2007). In a preliminary assessment of potential for water storage and low flow augmentation from surface water impoundment by Montgomery Water Group (2006), three project locations within Mission Creek were identified.

Two sites for off-channel reservoirs were identified, including one within the East Fork Mission Creek basin and one near the existing Mission Creek Lake (Montgomery Water Group, 2006). The East Fork Mission Creek off-channel reservoir would provide 95 acre-feet of storage for an estimated construction cost of $58,000/acre-foot and an instream flow benefit of 1.2 cfs for 30 days during the late summer. The Mission Creek Lake reservoir would provide 51 acre-feet of storage for $25,000/acre-foot with an instream flow benefit of 0.5 cfs for 30 days during the summer.

One site for an instream reservoir was proposed at Little Camas Creek for 926 acre-feet of storage at an estimated cost of $8,000 per acre-foot with a flow benefit of 12.9 cfs for 30 days (Montgomery Water Group, 2006). This project received the third highest ranking in the cost-benefit assessment. However, potential impacts from reductions in downstream flow due to the large size of the reservoir relative to annual flow volume were noted. Stream channel restoration on Peavine Canyon, Poison Canyon, and Sand Creek were considered and the potential volume of water storage was stated to be very small, but no supporting analysis was provided. A follow-up study assessed potential costs and benefits of the identified projects, but the Mission Creek reservoirs were excluded from this analysis (Anchor QEA, 2011).

Legacy Impacts and Restoration Potential

Across the Pacific Northwest, the history of extensive timber harvest, splash-damming, instream wood removal, beaver trapping, and floodplain grazing has resulted in widespread loss of beaver ponds and floodplain water bodies, incision of stream channels, and a loss of instream channel and habitat complexity (Collins *et al.*, 2002; Phelps, 2011). The legacy of these historical impacts is reduced surface water storage, increased sediment transport and related effects on water quality, disconnection from floodplains and the associated functions to store sediment and water, and degradation of aquatic habitat (Abbe and Montgomery, 2003).

Two general categories of incision, and the related lowering of the shallow groundwater, have been identified: channel incision and valley incision. Where the channel bed has incised relative to the floodplain, in-channel sediment storage is reduced and a hydraulic gradient is set up between the shallow groundwater and the in-channel water elevation. The gradient drives increased flow from the alluvial sediments and into the channel, where the water is rapidly exported from the watershed. The result is early de-watering of the floodplain, resulting in lower baseflows, and mortality of riparian vegetation with shallow roots (Beechie *et al.*, 2008). By implementing restoration actions which raise the bed elevation, the hydraulic gradient is diminished and water is stored in alluvial sediments later into the dry season, which, in turn, makes shallow water available to riparian vegetation and contributes more water to instream baseflows (Tague *et al.*, 2008).

Where channel incision is not slowed or reversed by restoration actions, the morphology of the stream follows a cycle in which channel incision is followed by valley widening and the development of an inset floodplain (Figure 1, after Schumm, Harvey, & Watson (1984)). Alternatively, continuing channel incision can also reach the bedrock, resulting in almost complete loss of alluvial sediments combined with down-cutting of the bedrock (Stock *et al.*, 2005). Widespread erosion due to logging and grazing was identified in the Mission Creek basin and strategies to increase sediment storage in the channel network were implemented in the mid-1900s (Figure 1). Although bedrock incision has not been widely noted in the Mission Creek basin, the Stock *et al.* (2005) investigation suggests that valley-scale lowering has likely occurred over much of the region. Additionally, we observed one location with in-channel bedrock exposure during our field assessment of East Fork Mission Creek, suggesting the evacuation of alluvial sediments (see below).

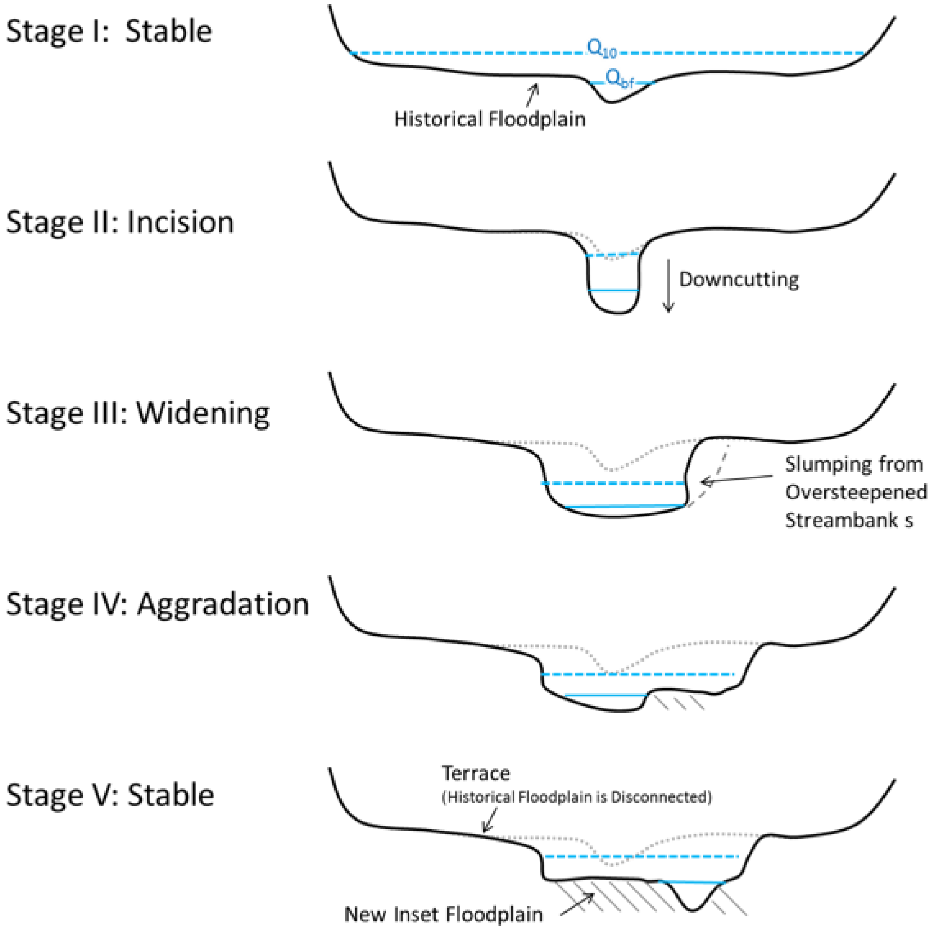


Figure 1. Illustration of the channel evolution model (Schumm et al., 1984) in which channel incision (stage II) is followed by widening and the development of an inset floodplain, which effectively represents a net lowering of the alluvial base of the valley.

Previous Erosion Control Efforts

Historic photos of Peavine Canyon show the presence of terraces and wooden check dam structures which were built by the Civilian Conservation Corps (CCC) to slow erosion around the 1930s-1950s (Figure 2). In August 2016, NSD and the CCNRD visited Peavine Canyon, which is thought to be the site documented in the historic photographs (Matt Karrer, USFS, personal communication). No check dam structures were visible, but slope breaks along the first-order, ephemeral channel were evident. We infer that the check dam structures lie underneath the sediments that have accumulated in the last several decades. The comparison between historical and current conditions, along with numerous exposed tree roots on the hillslopes (Figure 3) suggest that sandstones from the surrounding Chumstick Formation is contributing large amounts of sediment to the channel network. In summary, these observations indicate the presence of a large hillslope sediment source and support the feasibility of restoration actions to initiate extensive bed and valley aggregation.

Figure 2. Historical photos from the mid-1900s (a, b, c), compared to photo taken at nearby location in August 2016 (d): US Forest Service sign explaining soil erosion issues and rehabilitation efforts of the 1930s-1950s (a), rock-terrace structure intended to slow hillslope erosion (b), wooden check dam structure intended to store sediment in ephemeral channel (c), inferred location of wooden check dam structures in Peavine Canyon, which are presumed to be complete buried where there are regularly spaced topographic steps along the channel (d).

Figure 3. Photographs of exposed tree roots on hillslopes (a, b), which provide evidence of at least 6 inches of hillslope erosion of the underlying Chumstick Formation sandstone.

Water Storage Potential of Restoration Actions

The result of both channel and valley down-cutting is the net export of alluvial sediments out of the watershed, which is effectively a loss of alluvial water storage. In addition, the scarcity of in-channel wood and beaver complexes is effectively a loss of surface water storage. The extent to which alluvial sediment and water storage can be restored depends on the extent of restoration. Wood accumulations in Olympic Peninsula rivers have been shown to affect the channel and floodplain by up to 35 feet (Abbe, 2000). By increasing hydraulic roughness (i.e., resistance to flow), in-channel wood accumulations increase local sedimentation rates and raise the elevation of the water surface (Abbe and Montgomery, 2003; Pollock *et al.*, 2014). Thus, restoration actions such as the implementation of channel-spanning wood structures, re-introduction of beavers, or construction of beaver dam analogs ultimately increase storage of both alluvial sediment and water (Figure 4, from Hafen and Macfarlane (2016)).

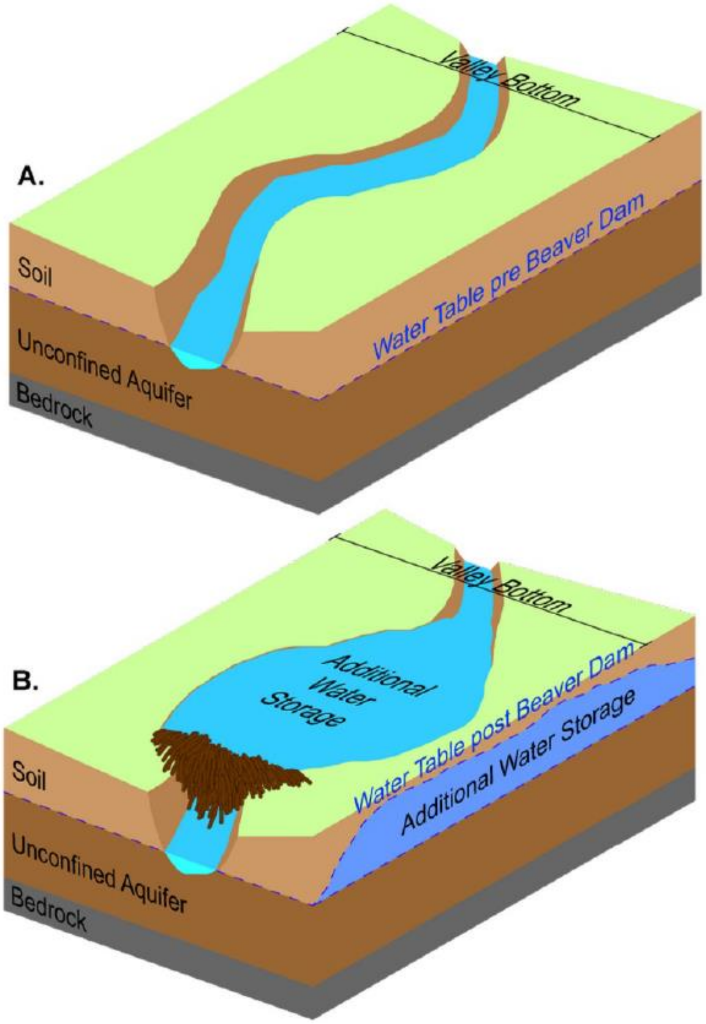


Figure 4. Illustration of the effect of adding beaver dam analogs to a channel: (A) Before restoration the elevation of the shallow groundwater is controlled by the water surface elevation in the incised channel, and (B) after restoration the water surface in the channel is elevated along with the elevation of the local groundwater, representing an increase in both surface and subsurface alluvial water storage. Figure from Hafen & Macfarlane (2016).

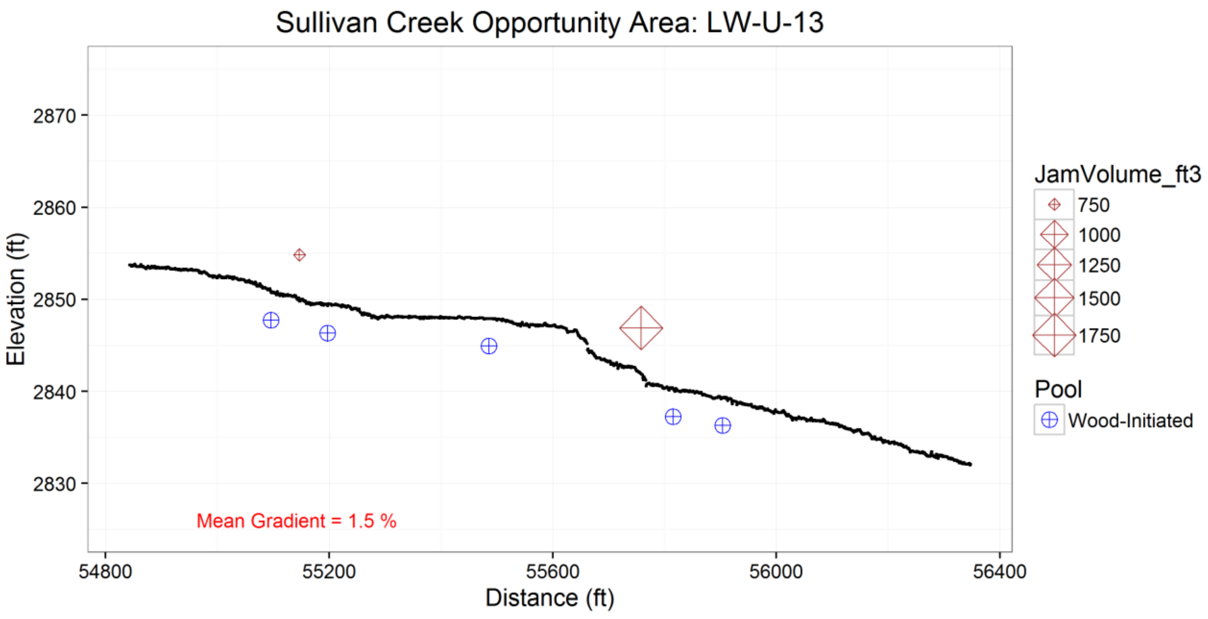


Figure 5. Topographic profile (black line) along a reach at Sullivan Creek, a tributary to the Pend Oreille River, Washington. Brown diamonds show locations of large wood jams and blue circles show locations of wood-initiated pools. Note that the large wood jam in the middle of the profile is holding approximately 7 feet of aggraded sediments.

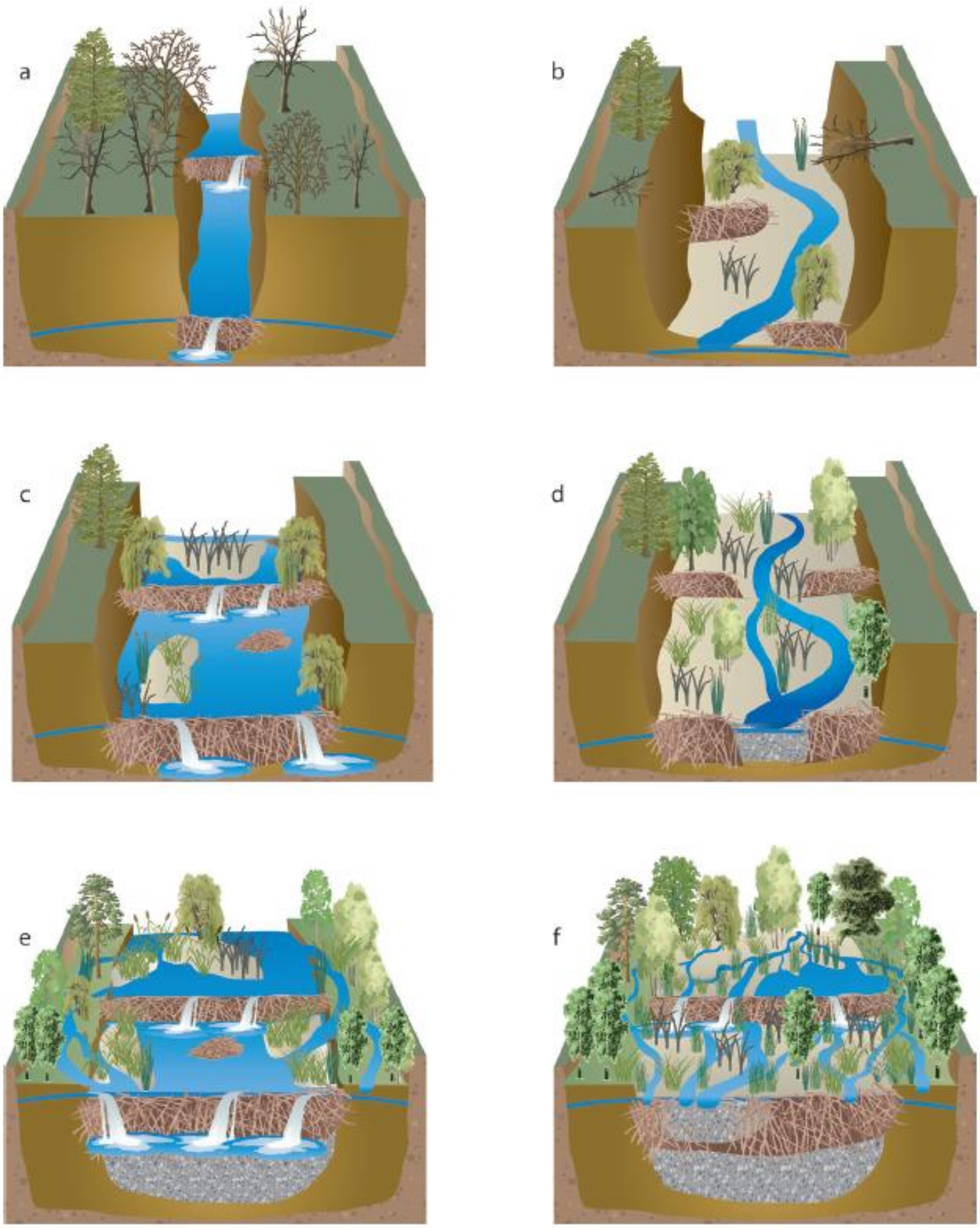


Figure 6. Illustration of the sequence of effects from beaver dams on channel and valley agraddation and local groundwater elevations from Pollock et al. (2014)**. Beaver dams raise water surface and groundwater elevation in incised channels (a), but high stream power ultimately leads to widening and development of an inset floodplain (b). Beaver dams in this lower stream power regime again raise water surface and groundwater elevation (c). The result is channel and valley aggraddation (d), which ultimately leads to reconnection with floodplain (e), development of floodplain side channels (f), and sustained increased storage in alluvial sediments and groundwater.**

The crux of the idea of using restoration actions to increase alluvial water storage is to use in-channel wood structures to create local areas of backwater where both water and sediment are stored. Backwatered areas such as beaver ponds act as surface water storage, which raise the local surface water elevation and, consequently, the surrounding groundwater elevation (Figure 4, note annotations for "Additional Water Storage" and "Water table post Beaver Dam"). The lower flow velocities also allow for deposition of sediment, which raises the elevation of the channel bed and reduces local stream gradient (Abbe and Montgomery, 2003; Abbe and Brooks, 2013) (Figure 5). Re-aggradation of the incised channel reduces the hydraulic gradient between the shallow groundwater elevation and the in-channel water surface elevation, and slows the drainage of the shallow groundwater reservoir (Beechie *et al.*, 2012; Fouty, 2013). Both observational and modeling studies have demonstrated that re-aggradation of incised reaches can results in a 10-20% increase in baseflow early in the dry season (Tague *et al.*, 2008; Ohara *et al.*, 2014). Widespread restoration has been considered as a strategy to increase water storage in incised streams. Emmons (2011) estimated 97,000 acre-feet of "restorable" groundwater storage if all impaired reaches were re-aggraded in the meadows of the Sierra Nevada, California. Fouty (2013) estimated an increase in surface and subsurface water storage of 40-53 acre-feet/mile from restoration actions on Camp Creek, an incised stream in the Wallowa-Whitman National Forest in Oregon.

Each channel-spanning structure implemented as part of restoration actions will also form a backwater pool, which increases surface water storage, raises the water surface elevation, and slows the drainage of the shallow groundwater (Figure 4). Previous studies quantifying the volume of water stored behind beaver dams in southeast Alaska and Russia found average winter (i.e., maximum) values of 0.28 to 1.01 acre-feet per pond, depending on the height of the dam and the length of the backwater area (Beedle, 1991; Klimenko and Eponchintseva, 2015; Hafen and Macfarlane, 2016). Backwater pools are temporary, however, because where streamflow is impounded velocity decreases and sediment is deposited, which results in channel aggradation. This is the primary geomorphic goal of restoration. These geomorphic changes subsequently raise shallow groundwater and therefore improve the health of the riparian vegetation. In turn, healthy riparian forests provide a source for abundant in-channel wood that repeatedly creates backwater effects and prevents incision (Collins *et al.*, 2012). Thus, in the fully restored state, additional water storage includes both surface water bodies created from in-channel wood and alluvial (subsurface) water storage.

In addition to reintroducing local backwatered areas and re-aggrading incised reaches, the restoration of valley elevation is also theoretically possible where the entire valley has been lowered from channel incision followed by widening. For example, the almost complete loss of alluvial sediments and subsequent valley down-cutting has been documented in the Teanaway River watershed in Kittitas County, WA (Stock *et al.*, 2005). In order to address restoration of these drastically impacted systems, Pollock et al., (2014) proposed a conceptual model for the use of beaver dams or beaver dam analogs to raise both the channel and valley elevation, and the amount of alluvial sediment and water stored (Figure 5). A large-scale re-aggradation and restoration of a lowered valley network following evacuation of the alluvium would require substantial hillslope sediment input, which is clearly present in the Mission Creek watershed.

Previous investigations are clear that restoration increases local groundwater storage. However, the extent to which gains in baseflow may be diminished from restored riparian vegetation remains a key uncertainty. With increased availability of shallow groundwater, the plant community and/or transpiration rates may shift. Studies have demonstrated mixed results and suggest that the effects of restoration on baseflow may depend strongly on local hydrologic conditions. For example, Tague *et al.* (2008) observed increased baseflow early in the summer season, but found that by late summer the increases in baseflow were offset by increased evapotranspiration losses from restored riparian vegetation. Another study in a northern California meadow utilized hydrologic modeling to assess restoration effects and found that although groundwater storage increased, local in-meadow baseflow decreased while downstream baseflow increased (Hammersmark *et al.*, 2008). In contrast, Essaid and Hill (2014) found that modeled baseflow decreased both in-meadow and below the restored meadow, which they attribute to groundwater recharge that is driven by contributions from upslope groundwater and hillslope runoff mechanisms rather than overbank flow, as in the Hammersmark *et al.* (2008) and Ohara *et al.* (2014) investigations. Despite local variations in dominant hydrological processes, all studies demonstrate additional groundwater storage and groundwater input to the stream, which suggests healthier riparian vegetation and lower summer stream temperatures (Bogan *et al.*, 2003; Baird *et al.*, 2005; Loheide *et al.*, 2009).

Approach

To estimate water conservation potential from restoration in Mission Creek, Phase 1 included a field assessment in two study reaches, estimation of water storage potential from field data in the two study reaches, and extrapolation of reach-scale estimates to the watershed-scale. Phase 2 is proposed to include engineering design and implementation for restoration actions in 1-2 pilot locations, and phase 3 would include implementation in a larger portion of the stream network.

Field Assessment and Findings

Field Assessment of Geomorphic Conditions

This assessment included a reconnaissance-level field investigation of geomorphic conditions in two study reaches: Poison Canyon and East Fork Mission Creek (Map 1). Both reaches were selected in consultation with CCNRD staff because previous observations of incised conditions and high feasibility for restoration without adjacent roads. The field assessment included estimates of the vertical extent of stream incision, measurements of stream and floodplain morphology, characterization of sediment grain sizes, and qualitative assessment of relevant geomorphic features such as floodplain connectivity. NSD and CCRND staff visited the two field sites on 9 November 2017. Subsequently, we analyzed field observations in conjunction with spatial datasets to extend the geomorphic assessment and make quantitative estimations of water storage potential along the length of the study reaches. The availability of a lidar-derived digital elevation model (3-feet (ft) resolution) of Poison Canyon allows for more sophisticated geomorphic analysis than in East Fork Mission Creek, where topographic data is based on USGS 40-ft data.

In both study reaches, floodplain sediments were characterized via test pits, observations of cut bank stratigraphy, and estimates of grain size distributions of the channel bed. Sand is dominant with some gravels, cobbles, and organic materials. Observations of sand as the main component of the alluvial sediments are congruent with the location of the study reaches within the Chumstick and Swauk Formations. These geologic layers consist of Eocene (~45 million years old) aged sedimentary rocks, with extensive sandstone that is known to be highly erodible (Gresens *et al.*, 1981).

Poison Canyon

Three geomorphic conditions along an 8500-ft section of Poison Canyon were identified from field observations and cross-sectional analysis of the topography: (1) Wetland complexes, (2) moderately incised reaches, and (3) severely incised reaches (Map 2, Figure 7).

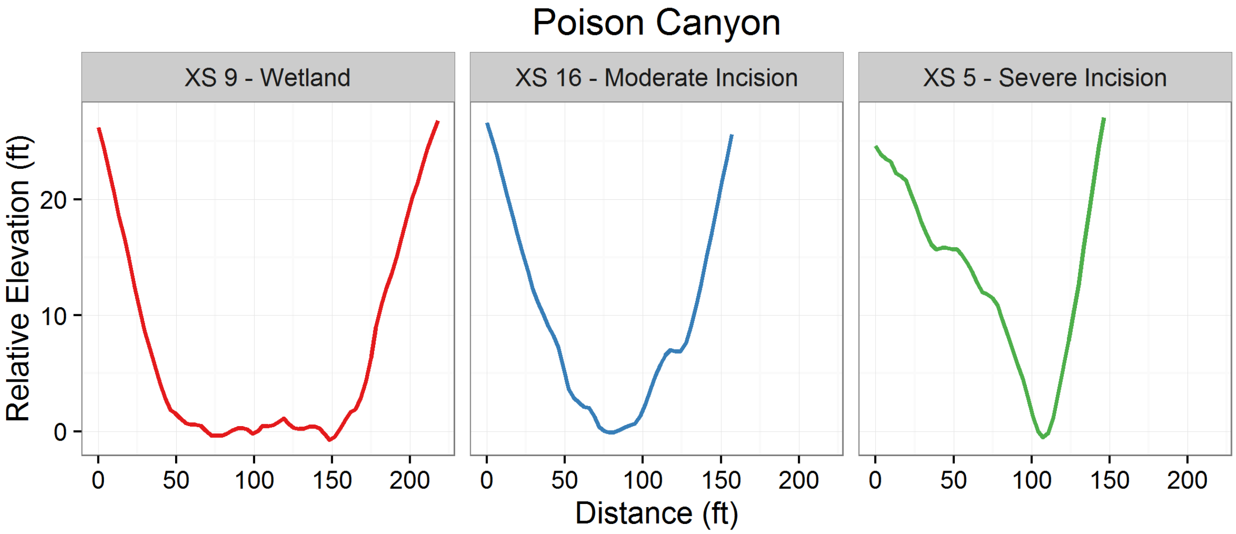


Figure 7. Topographic profiles from Poison Canyon showing elevation relative to local water surface (feet) from left bank to right bank (i.e., looking downstream) across three representative cross sections in a wetland reach, a moderately incised reach and a severely incised reach. See locations on Map 2.

Figure 8. Photos of wetland reaches in Poison Canyon showing wood as the downstream hydraulic control (left) and shallow height (0.5-1') from water surface to bank (right).

Figure 9. Photos of severely incised reaches in Poison Canyon.

Two 1000 to 2000-ft long wetland complexes were identified from observations and spatial data. These complexes represent 36% of the total channel length included in the field investigation, and are characterized by low gradient, multiple shallow channels, and flat valley bottom topography (Figure 6). Within the wetland complexes, average valley width is 100 feet, based on the digital elevation model at the delineated reaches. Field investigation identified the hydraulic control as instream large wood at the downstream end, in addition to numerous locations throughout these wetland complexes (Figure 8). These reaches provide a local demonstration for the potential effect of restoration on alluvial sediment and water storage. Observations of suggest that wood currently acts as a hydraulic control and placement of in-channel wood pieces and structures in incised reaches will initiate sediment storage and alter the channel-floodplain morphology of the reach.

Moderately incised reaches were observed to have a 2-3 ft elevation difference between the channel bed and the closest floodplain terrace (Figure 7). In these reaches, average valley width is 60 feet. Moderately incised reaches account for approximately 21% of the channel length investigated.

Severely incised reaches were observed to have a 4-5 ft or larger elevation gradient between the channel bed and floodplain, and were associated with cutting through large deposits of sediments from alluvial fans or landslide deposits (Figure 7 and Figure 9). In these reaches, average valley width is 50 feet. Severely incised reaches extend over approximately 43% of the channel length investigated.

East Fork Mission Creek

Moderately incised conditions were observed along a 3300-ft long reach of East Fork Mission Creek, starting at the crossing with USFS Road 7100, which has been decommissioned (Map 3). Channel morphology and sediment distributions were estimated at four locations, and depths from the top of bank to the channel bottom range from 2.2 to 6.1 feet. An inset floodplain was observed at one location (XS 3, Map 3), and the inset floodplain surface was located 3.9 feet lower than the relict floodplain. Average depth from the top of the bank to the channel bottom is estimated to be 4.9 feet. Average valley width in the East Fork Mission Creek study reach is approximately 130 feet, based on the digital elevation model (Figure 10).

Channel and floodplain sediments are dominated by sand and gravel (Figure 11). Channel bed sediments consist of 10-40% sand, 10-90% gravel, and 5-40% cobbles. Boulders were present in the channel at the highest location in the reach (XS 4, Map 3). Floodplain sediments consist primarily of sand from 0-2-feet depth. We observed sandstone bedrock in the channel in one location near XS 3 (Figure 12, Map 3).

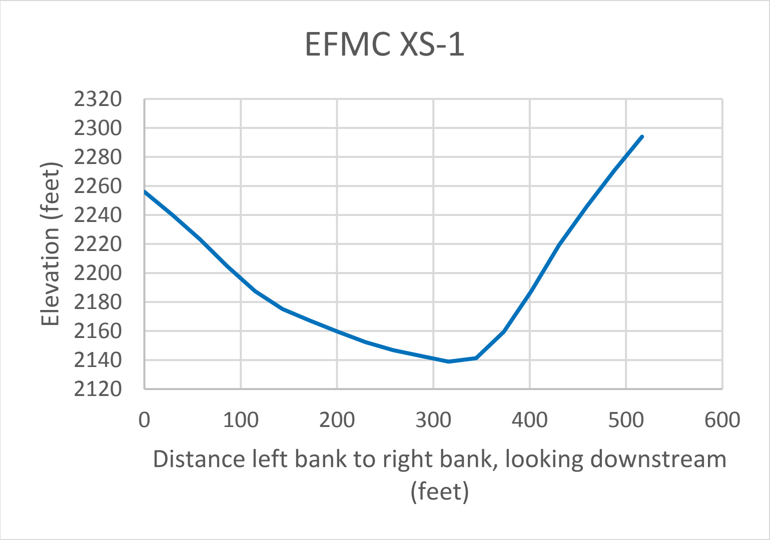


Figure 10. Example topographic profile across East Fork Mission Creek, based on 40-ft USGS digital elevation model.

Figure 11. Photos of channel and floodplain sediments along East Fork Mission Creek.

Figure 12. Photo of bedrock in the channel of East Fork Mission Creek.

Preliminary Restoration Assessment for Mission Creek

Assessment of the two study reaches in conjunction with widespread effects from historic impacts suggest that incision and channel disconnection from the floodplain is common in the Mission Creek watershed. Under these impaired conditions, Mission Creek is likely transporting more water and sediment out of the channel network earlier in the season as compared to reference (historic) conditions. Potential downstream impacts of increased and earlier water and sediment transport include decreased baseflows, higher stream temperatures, increased sediment load, and increased flood peaks.

Restoration actions such as placement of in-channel wood pieces, implementation of beaver dam analogs, or construction of engineered log jams are likely to initiate channel bed aggradation and the storage of both alluvial sediment and water. Field evidence provides examples of the role of wood in this watershed for providing hydraulic control, reducing the local stream gradient, and storing alluvial sediment.

The identification of geomorphically distinct reaches in Poison Canyon additionally provides a framework for restoration options (Figure 7, Map 2). Where the stream is severely incised, restoration actions would halt incision and re-aggrade the channel bed. There is less opportunity in these reaches to increase alluvial sediment and water storage because aggradation will occur only in the narrow corridor of the channel until lateral connectivity is restored. However, these reaches are acting as sediment source, and restoration actions are needed to maintain current alluvial sediment and water storage rather than contributing to a net export of stored sediments. Moderately-incised reaches present high opportunity to both aggrade the channel bed, and to ultimately store additional sediment in the floodplain. This channel and floodplain aggradation together represents a higher volume increase for additional sediment and water storage. Lastly, wide wetland complexes where the channel is not incised represent high potential for valley aggradation, with larger increases in sediment and water storage than channel aggradation alone.

Restoration actions will re-initiate fluvial processes to store alluvial sediment and water, to reconnect the channel to its floodplain, and to recruit large wood into the channel (Beechie et al., 2008; Tague et al., 2008; Collins et al., 2012; Pollock et al., 2014). In addition to the estimated contribution to streamflow presented below, increasing alluvial sediment and water storage will have benefits to water quality, aquatic habitat complexity, and riparian water availability.

Quantitative Estimation of Water Storage Potential

Reach-scale estimates

We used the field data and published values to estimate potential for water storage and low flow augmentation in Mission Creek. In particular, we included current conditions and estimated low and high bounds on how much subsurface water could be stored *in situ* in the two study reaches under low and high scenarios of aggradation from restored conditions. The low estimate consists of re-aggradation of incised channels only, whereas the high estimate consists of re-aggradation of both channel and valley. Both the low and high estimates include the same approximate volume of new surface water storage that would be introduced as a result of implementing channel spanning wood structures that create backwatered areas. These reach-scale estimated volumes were then spatially extrapolated to the watershed-scale based on stream gradient.

Methods

Subsurface Alluvial Water Storage

The potential change in subsurface alluvial storage was estimated based on simplified valley geometry, after Emmons (2013). In cross-sectional area, the current zone of **unsaturated** sediments is approximated as two triangles, which extend horizontally from the valley edges to the channel edge, and vertically from the channel edge to the depth of the incised channel (Figure 13a). The construction of these unsaturated triangle assumes that the elevation of the incised channel is approximately the same as the water surface elevation in the channel. By implementing restoration actions that raise the channel bed elevation and the water surface elevation in the channel, the vertical dimension of the unsaturated triangle is shortened (Figure 13b).

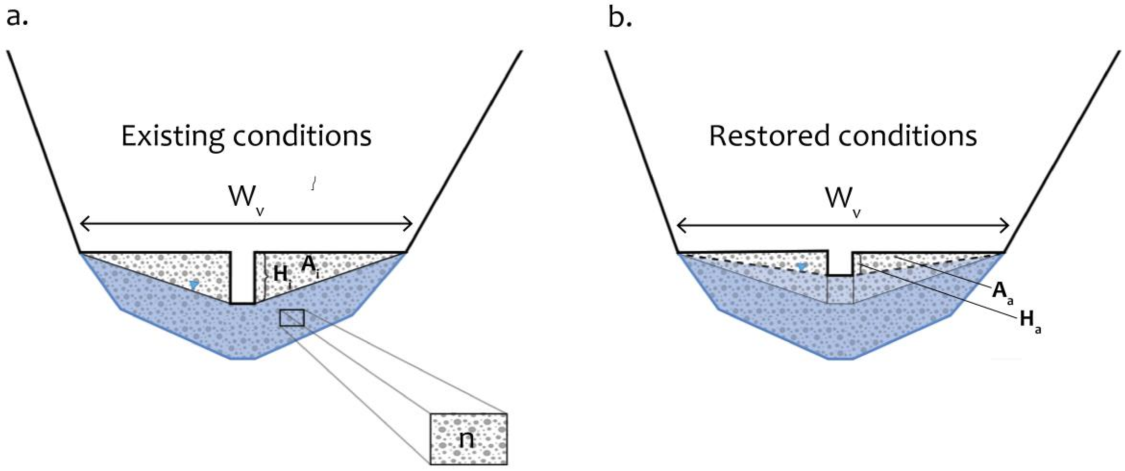


Figure 13. Conceptual diagram of valley cross-section under existing (a) and restored (b) conditions. See text for symbol definitions.

Under both existing and restored conditions, the simplified groundwater surface (i.e., the groundwater flow line) is sloped from the valley edges, where local groundwater elevation is influenced primarily by hillslope water inputs (surface and subsurface), and the channel, where the local groundwater elevation is influenced primarily by the water surface elevation in the channel. Thus, the slope of this surface becomes less steep between existing and restored conditions because the water elevation at the channel is controlled by the channel bed elevation and water surface elevation, both of which shift upward with aggradation and backwatering. When calculating the increased subsurface water storage from re-aggradation of the channel bed, we ignore the water surface elevation of the water in the channel and use the channel bed elevation as the water surface elevation (e.g., Figure 13). These estimates are therefore conservative, and reflect additional storage during the low flow season. Added in-channel surface water storage is considered separately from added subsurface storage (see *Reach-Scale Estimates for Surface Water Storage*).

The change in subsurface alluvial water storage is approximated from the geometry of the cross-sectional area of the alluvial valley. The areal difference between the two unsaturated triangles on either side of the channel (i.e., one rectangle for computations) under existing conditions and under restored conditions represents a newly saturated area under restored conditions. The newly saturated subsurface area is effectively an increase in alluvial groundwater storage (Figure 13).

The following equations were therefore used to compute the change in water storage from restoration in a single reach.

The area of half of the unsaturated zone (i.e., one triangle) under existing, incised conditions, A_i (Figure 14a), is given as half of the product of the height from bed elevation to floodplain elevation, H_i, and half of the valley width, $W_v/2$:

$$A_i = \frac{H_i \times \frac{W_v}{2}}{2}$$

The area of half of the unsaturated zone (i.e., one triangle) in aggraded conditions, A_a (Figure 14b), is given as half of the product of the height from aggraded bed elevation to floodplain elevation, H_a, and half of the valley width, $W_v/2$:

$$A_a = \frac{H_a \times \frac{W_v}{2}}{2}$$

The area of newly saturated triangle, A_s (Figure 14c), is the difference between the two unsaturated triangles:

$$A_s = A_i - A_a$$

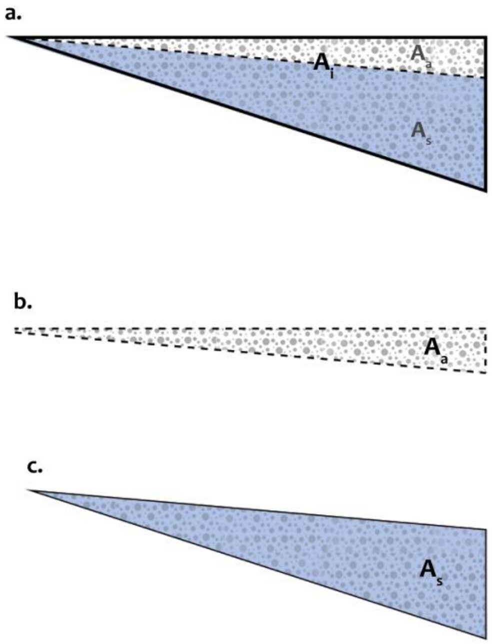


Figure 14. Conceptual diagram of the three triangles for which area is calculated.

The volume of water storage in the newly saturated wedge of alluvial sediments, V_s (Figure 15), is computed as the cross-sectional area of the valley (i.e., two triangles, or $2A_s$), multiplied by the porosity (n) of the sediments (i.e., the interstitial space between the sediment grains which fills with water under saturated conditions, and is a function of grain size, shape, and sorting), multiplied by the reach length (L_r):

$$V_s = 2A_s \times n \times L_r$$

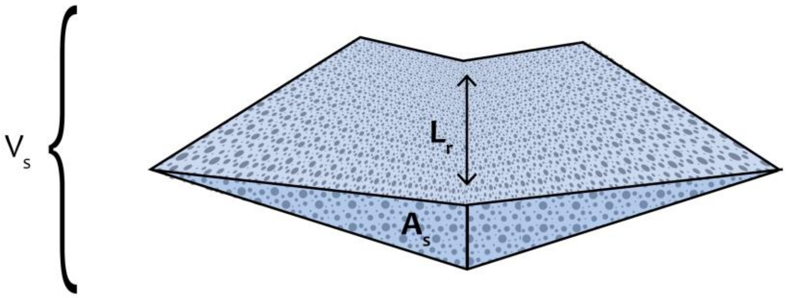


Figure 15. Conceptual diagram of the volume of water storage restored from channel aggradation.

Although the porosity of sediments is naturally variable, we used 35% porosity (i.e., n=0.35) for all of the calculations. This simplification is based on published values for sand and gravel (Morris and Johnson, 1967), the location of the field site within two similar geologic formations (i.e., the Chumstick and Swauk Formations), and field observations of fairly homogeneous floodplain sediments.

We bracketed the calculations via low and high values for aggradation potential. The low scenario estimates channel bed aggradation only. The potential amount of channel aggradation under restored conditions is based on average channel depths observed in the field and from spatial analysis, minus a restored bank height of 1 ft. The high scenario estimates the additional aggradation of the valley floor, resulting from additional sediment storage triggered by restored lateral connectivity between the channel and floodplain.

We estimate the additional water storage from the valley aggradation as a rectangular volume added to the wedge estimated from channel aggradation (Figure 16).

The volume of the additional rectangular volume from valley aggradation, V_v, is the product of the height of valley aggradation (H_v), the valley width (W_v), the porosity (n), and the reach length (L_r), where:

$$V_v = H_v \times W_v \times n \times L_r$$

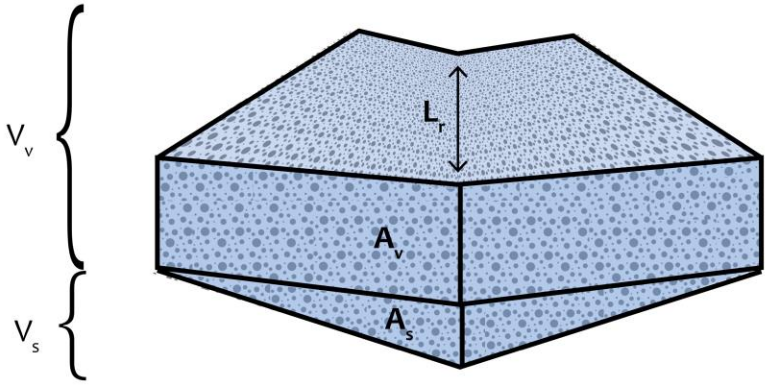


Figure 16. Conceptual diagram of the volume of water storage restored from channel aggradation and additional valley aggradation.

Thus, total volume of restored water storage for a channel and valley aggradation scenario is computed as:

$$V_{total} = V_v + V_s$$

Reach-Scale Estimates for Subsurface Alluvial Storage

Based on partial availability of high-resolution (3-ft) topographic data, we used two approaches: 1) a lumped approach in East Fork Mission Creek, and 2) a geomorphically explicit approach in Poison Canyon. We then applied results from the two reaches to extrapolate to the watershed.

The East Fork Mission Creek analysis relied on 40-ft topographic data. Thus, we used field observations from four cross-sections (Map 3) to determine an average height from bed elevation to floodplain (H_i) and valley width (V_w). We then used these average values to estimate the additional storage from restoration along the entire reach.

In Poison Canyon, high-resolution lidar data are available. Thus, we tested a refined approach in which we mapped geomorphic units (described above, Map 2) and used valley width and reach length from the mapped units along with field observations of average depth of incision by geomorphic unit in our estimation of additional storage from restoration.

Estimation of Streamflow Contribution from Subsurface Alluvial Storage

We estimated the magnitude and duration of the streamflow contribution by additional subsurface alluvial storage in each study reach. Robust quantification of groundwater-surface water interactions requires a sophisticated numerical model to account for time-varying flow rates and multi-dimensional subsurface flow paths. We made major simplifying assumptions to approximate the streamflow benefit from the restored water volume, including: (1) perpendicular lateral flow from shallow groundwater into the channel (rather than oblique to the channel), (2) a single saturated hydraulic conductivity (k_{sat}) of 100 meters/day for coarse sand or gravel (Heath, 1982), (3) a constant gradient based on the slope of the shallow groundwater table from hillslope to restored surface water elevation, and (4) groundwater flux through channel sidewalls only, neglecting upwelling from the channel bottom. Thus, the flux of water from the shallow groundwater to the channel (Q) is approximated as:

$$Q = k_{sat} \times \Delta z \times Area_{channel\ walls}$$

The lateral gradient, Δz, and the wetted area of the channel walls ($Area_{\text{channel walls}}$) depend on the depth to the restored surface water elevation. The restored surface water depth is approximated as 20% of the bank height under restored conditions. Thus, Δz is the ratio between 80% of the bank height (i.e., the hydraulic drop from the valley side to the channel) and half of the valley width ($W_v/2$). The area of the channel walls is the wetted surface area through which the additional storage flows laterally to reach the channel. This surface is approximated as the product of 80% of the restored bank height (H_a), the reach length (L_r), and porosity (n), all multiplied by 2 to include both sides of the channel:

$$Area_{channel\ walls} = \ 0.8H_a \times L_r \times n \times 2$$

In this way, both the flux (Q) and the duration of additional streamflow (V_s/Q or V_{total}/Q, for the low and high restoration scenarios, respectively) from lateral drainage of shallow groundwater can be estimated. The duration of flow augmentation is approximated as the total volume divided by the constant flux (given as a volume per time), but the flux would actually vary through time.

Including Additional Surface Water Storage at the Reach-Scale

To estimate the additional surface water storage from backwatered areas triggered by in-channel wood structures (e.g., Figure 4b), we computed the ideal density of structures along the reach and estimated a water storage volume per structure. Similar to an artificial impoundment, surface water storage volume from in-channel wood structures is positively correlated to valley width and structure spacing (i.e., area of potential storage) and negatively correlated with valley slope. Thus, low-relief reaches with wider valley bottoms will have greater storage potential per in-channel wood structure versus steeper channels with naturally confined valleys where storage potential is low.

We therefore estimated additional surface water storage based on the average reach gradient and a target aggradation height of 3 ft to estimate the backwater influence of each structure and the ideal treatment density.

Results

In East Fork Mission Creek, we computed alluvial water storage potential of 7 and 18 acre-feet along the 3300 ft study reach for the channel aggradation (i.e., low) and valley aggradation (i.e., high) scenario, respectively (Table 1). The computations are based on a low scenario of 3 ft of channel aggradation to a high scenario of 3 feet of channel aggradation and an additional 3 ft of valley aggradation. In the 8540 ft study reach in Poison Canyon, we computed alluvial water storage potential of 3 and 11 acre-feet for the low and high scenario, respectively.

In both reaches, we normalized the results to determine water storage potential as a volume per length of restored reach, in acre-feet per mile. The lumped approach in East Fork Mission Creek provided a larger water storage estimate on a per-length basis, due to the larger valley width. Thus, we applied the mean of the two reaches for the low and high scenarios, 6.4 acre-feet/mile and 20.1 acre-feet/mile, to bracket the range of water storage potential via extrapolation to the watershed-scale. Spatially variable valley width is not explicitly considered in the extrapolation, but, by using the mean value from East Fork Mission Creek and Poison Canyon, the estimate accounts for a range of valley widths.

Table 1. Potential subsurface alluvial water storage estimated for two study reaches.

Study Reach	Study Reach Length (ft)	Study Reach Average Width (ft)	Study Reach Average Gradient (%)	Average Incised Depth (ft)	Average Valley Aggradation (ft)	Channel: Total Acre-feet	Channel: Estimated Flux	Channel: Total Acre-feet/mi	Channel + Valley: Total Acre-feet	Channel + Valley: Total Acre-feet/mi	Channel + Valley: Estimated Flux
Poison Canyon	8540	60	4.1	Varies from 1 to 4.5	3.3	3.1	0.12 cfs for 13 days	1.9	18.3	11.3	0.12 cfs for 80 days
East Fork Mission Creek	3300	130	4.3	4.4	3.3	6.7	0.02 cfs for 160 days	10.8	18.1	28.9	0.02 cfs year-round
Mean of two reaches								6.4		20.1	

Table 2. Potential surface water storage from backwatered areas.

Average Stream Gradient (fraction)	Aggradation Height (ft)	Upstream Influence of Structure (ft)	Maximum Density of Structures per Mile	Estimated Width of Backwater Pond (ft)	Estimated Surface Water Storage per Structure (acre-feet)	Estimated surface water storage per mile (acre-feet/mi)
0.01	3	300	18	40	0.41	7
0.03	3	100	53	30	0.10	5
0.05	3	60	88	20	0.04	4

Based a channel gradient of 1-5% and target aggradation height of 3 ft, we estimate a backwater influence and a fully implemented treatment density (Table 2). For example, at an average stream gradient of 3%, a fully implemented treatment density would consist of ~50 structures per mile. We estimate the volume of surface water behind each structure at 0.1 acre-feet per structure based on the geometry of a 3% stream gradient, a 3-ft aggradation height, and a ponded width of 30 ft. This estimate is lower than previously published values for beaver ponds of 0.28-1.01 acre-feet/pond (Beedle, 1991). The increased surface water volume from 50 structures per mile at a volume of 0.1 acre-feet per structure equates to 5 acre-feet/mile of additional surface water storage.

We apply this estimate of 5 acre-feet/mile of surface water storage to extrapolate to the watershed-scale.

Extrapolation to watershed-scale

Methods

The purpose of watershed-scale extrapolation of these computations is to estimate the upper-bound for the potential to restore water storage if restoration actions were implemented across some percentage of all feasible reaches. This analysis assumes that the incised conditions observed in the study reaches are representative of conditions across the watershed, and neglects spatial variability in channel and valley morphology. To extrapolate to the watershed-scale we utilized existing channel location data from the National Hydrography Dataset, and excluded reaches in agricultural valleys. We then flagged the presence or absence of a road adjacent to the channel in order to account for constraints on restoration actions where a road might be impacted.

We computed the gradient of each section of the channel network, and excluded channels with a gradient higher than 10% from analysis. The average gradient along the East Fork Mission Creek study reach is approximately 4.3%, and the average gradient along Poison Canyon is 4.1%. Poison Canyon is somewhat steeper in places, but the presence of wide, alluvial wetlands where hydraulic grade is controlled by the presence of in-channel wood (discussed above) suggest that restoration actions are feasible for reducing gradient and storing alluvial sediment. Current research indicates that beavers typically build dams in perennial stream channels with slopes of less than 6%, and that beaver dam analogs can be constructed on reaches with higher stream power to initiate similar responses, including backwatering and aggradation (Pollock *et al.*, 2014). Furthermore, the inferred storage of sediment trigged by CCC structures in the ephemeral first-order channel in Peavine Canyon (gradient = 6.8%) supports the feasibility of restoration actions in higher gradient reaches (Figure 2). However, these higher gradient reaches may have less impact on alluvial water storage than on alluvial sediment storage. As such, we computed watershed-scale potential for restored water volumes based on application of restoration actions to all upland reaches in two gradient bins: below 5% and below 10% (Map 4).

Although valley width and morphology will vary with gradient, we used the simplifying assumption that the volume per distance estimates for potential water storage based on analysis in the two study reaches are applicable to the rest of the channel network. Extrapolation to the watershed-scale includes estimates of additional sub-surface and surface water storage.

Results

Estimates for potential increases in alluvial water storage from restoration range widely based on restoration scenario and the length of the stream network that was included in each estimate. The lowest potential water storage results from a low restoration scenario (i.e., channel aggradation only), applied to a small fraction of the lowest gradient reaches in the stream network (Figure 17, red lines on left-hand plot). The highest values were estimated for valley restoration applied to a large fraction of all reaches with a gradient under 10%.

Based on the premise that the most feasible restoration strategy will include implementation in lower gradient reaches, reaches without roads, and only a fraction of the possible reaches, in Table 3 we present estimated water storage values for a subset of the results shown in Figure 17. Table 4 presents the same results, but for alluvial subsurface storage only, in order to separate out subsurface versus surface storage.

The magnitude the streamflow flux provided by additional alluvial water storage scales with the length of the treated stream network (Figure 18). The additional streamflow contributions range from 0.02 to 1.7 cfs. In these estimates, the duration of streamflow contribution depends only on the restoration scenario (Figure 18). This result is an artifact of the simple estimation methods: both the subsurface volume and the streamflow flux scale linearly with length, so length of stream network treated essentially cancels out.

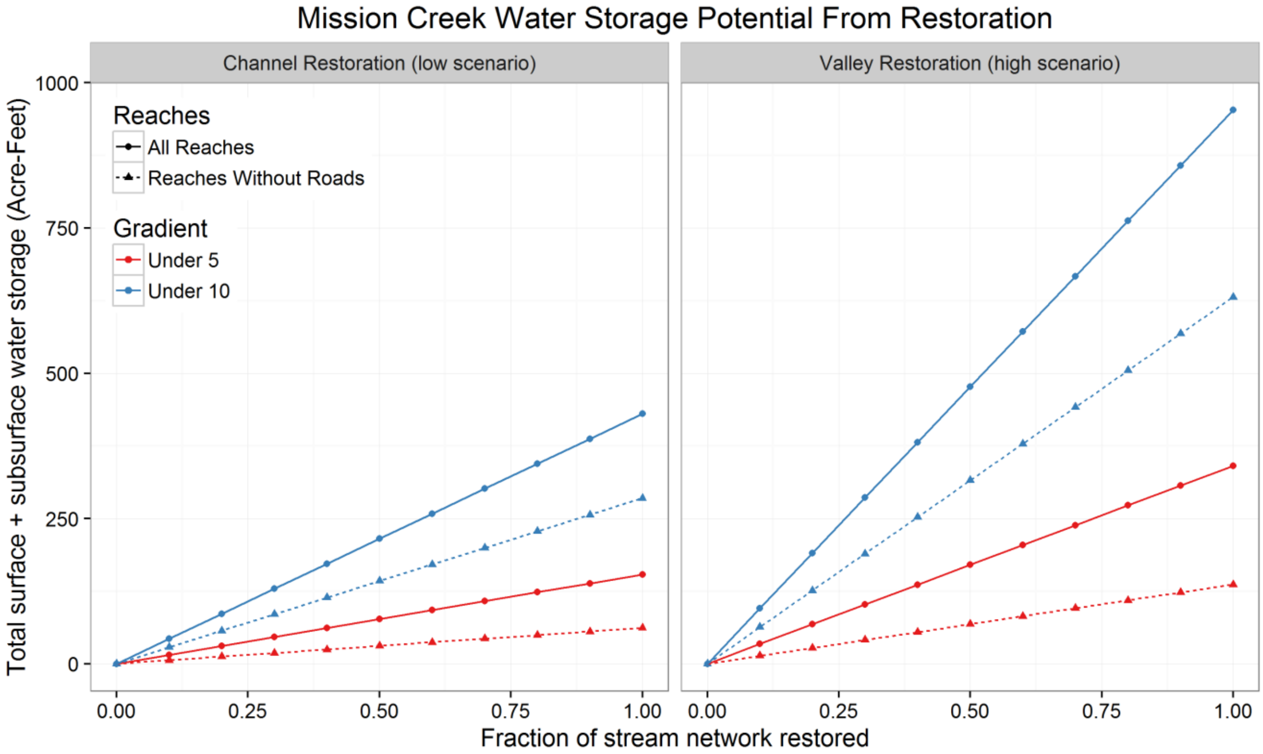


Figure 17. Potential alluvial water storage the low and high restoration scenarios, as a function of the fraction (0 to 1) of the treatable channel network to which restoration actions are applied. Colors indicate the maximum stream gradient of reaches included in the estimate (<5% and <10%), and symbols and line types further indicate the inclusion of all reaches under that gradient threshold, or only reaches that are not adjacent to roads.

Table 3. Potential total additional water storage (acre-feet), including subsurface alluvial storage and surface storage from backwatered areas, for the low and high restoration scenarios, to a percentage (10-50%) of the treatable channel network, which is based on a threshold for average gradient (<5% or <10%) and which excludes all reaches that are adjacent to roads.

Restoration Scenario	**Gradient Threshold for Restoration Potential (%)**	**Total Length of Treatable Stream Network (i.e., below gradient threshold and not adjacent to a road) (mi)**	Subsurface storage (acre-feet) from treating **10%** of Stream Network	Subsurface storage (acre-feet) from treating **20%** of Stream Network	Subsurface storage (acre-feet) from treating **30%** of Stream Network	Subsurface storage (acre-feet) from treating **40%** of Stream Network	Subsurface storage (acre-feet) from treating **50%** of Stream Network
Channel Restoration (low scenario)	< 5	5	6	12	18	25	31
Channel Restoration (low scenario)	< 10	25	29	57	86	114	143
Valley Restoration (high scenario)	< 5	5	14	27	41	55	68
Valley Restoration (high scenario)	< 10	25	63	126	189	252	316

Table 4. Potential subsurface alluvial water storage (acre-feet) only (i.e., excluding additional surface water storage from backwatered areas) for the low and high restoration scenarios, applied to a percentage (10-50%) of the treatable channel network, which is based on a threshold for average gradient (<5% or <10%) and which excludes all reaches that are adjacent to roads.

Restoration Scenario	**Gradient Threshold for Restoration Potential (%)**	**Total Length of Treatable Stream Network (i.e., below gradient threshold and not adjacent to a road) (mi)**	Subsurface storage (acre-feet) from treating **10%** of Stream Network	Subsurface storage (acre-feet) from treating **20%** of Stream Network	Subsurface storage (acre-feet) from treating **30%** of Stream Network	Subsurface storage (acre-feet) from treating **40%** of Stream Network	Subsurface storage (acre-feet) from treating **50%** of Stream Network
Channel Restoration (low scenario)	< 5	5	3	7	10	14	17
Channel Restoration (low scenario)	< 10	25	16	32	48	64	80
Valley Restoration (high scenario)	< 5	5	11	22	33	44	55
Valley Restoration (high scenario)	< 10	25	51	101	152	202	253

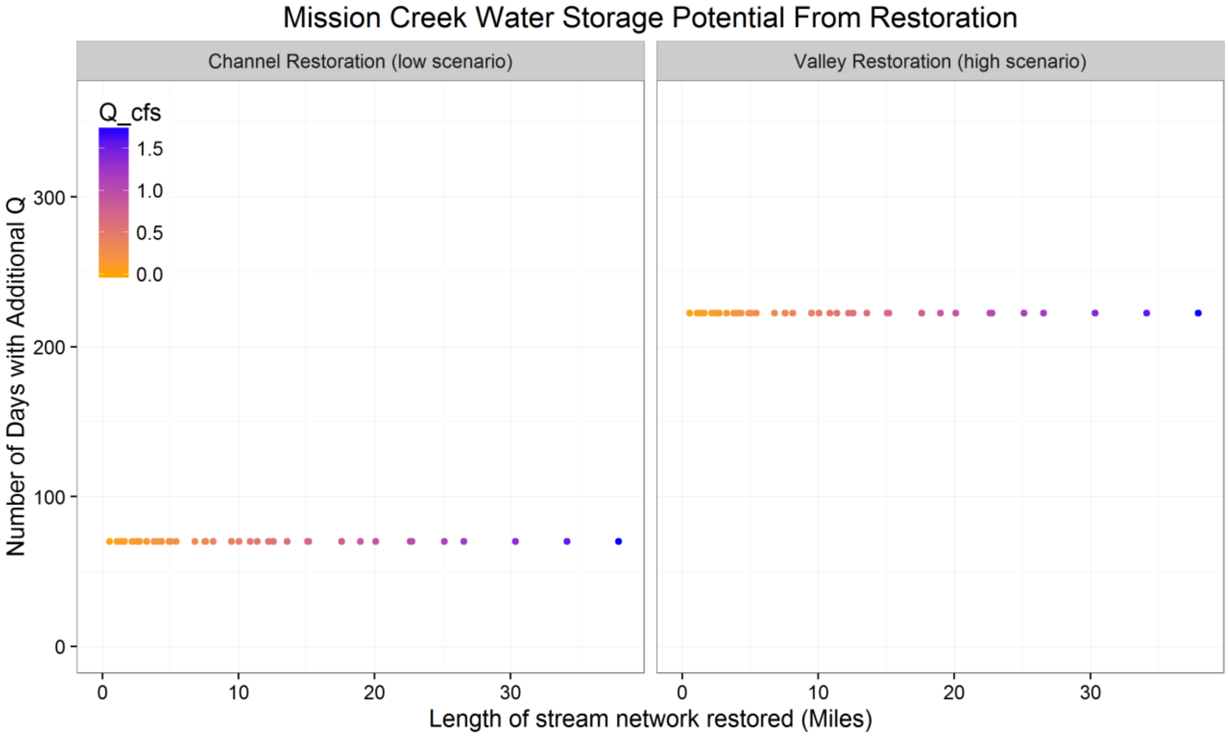


Figure 18. Potential contribution to streamflow (Q, in cfs) from subsurface alluvial water storage in the low (left) and high (right) restoration scenarios. The streamflow contribution (symbolized by color) varies as a function of the length of the stream network restored (x-axis, miles). The number of days (y-axis) of that given streamflow contribution is constant in each scenario because both the additional storage and the additional Q scale linearly with length of the stream network restored.

Discussion

Uncertainties

This approach neglects uncertainties related to how evapotranspiration rates and timing may change with an increase in the elevation of the shallow groundwater (Tague *et al.*, 2008). Therefore, this analysis demonstrates that more water will theoretically be available, and that the additional water storage will be partitioned between baseflow augmentation and transpiration by riparian vegetation. Additional water availability for riparian vegetation is likely to increase the resilience of the riparian forest to fire and insect outbreaks (Grant *et al.*, 2013), but will also reduce the baseflow effect by an unknown amount. In addition, previous work has suggested a positive feedback as it relates to water storage and restoration: water holding capacity of alluvial material increases as a function of the proportion of organic matter in the floodplain (Hudson, 1994). Thus, restoration that raises shallow groundwater levels and contributes to healthier or more productive riparian vegetation may also increase the contribution of organic matter to the floodplain sediments and therefore increase the amount of water stored and to decrease the rate of release.

This analysis makes numerous simplifying assumptions: homogenous floodplain sediments, constant valley width and depth of incision, and lateral groundwater flow at a constant rate. Thus, these estimates are simply a first-order estimate for watershed-scale water storage potential, and the local effects of restoration actions will vary substantially with channel and valley morphology. The true additional alluvial water storage and contribution to baseflow would be a complex function of riparian transpiration, timing of the onset of baseflow (i.e., when the water surface elevation in the channel drops below the elevation of the shallow groundwater), spatial heterogeneity in sediments, time-varying sub-surface flow rate, and the routing of water through the channel network. A thorough assessment would require numerical modeling of sub-surface flows.

Comparing Infrastructure Versus Restoration

We estimate a cost of $4700/acre-foot of additional surface and subsurface water storage from restoration. This estimate is based on an estimated cost of $1000/in-channel structure and a median implementation density of 53 structures/mile (Table 2), along with estimated surface and subsurface water storage of 11.4 acre-feet/mile (Table 1 and Table 2). For comparison estimates for the implementation costs of additional storage for previously considered infrastructure projects in the Mission Creek watershed range from $8000-58000/acre-foot. Note that costs associated with operations and maintenance (O&M), potential negative habitat impacts, and increased downstream risks are not included in either estimate, but are likely to be much higher for an infrastructure approach than a restoration approach.

Preliminary Restoration Concepts

Recommendations for Next Steps

We recommend design, implementation, and monitoring of a pilot project in Poison Canyon. With three geomorphically-distinct reach types, there is opportunity to both initiate sediment storage and aggradation processes and to reverse the loss of sediment, and therefore alluvial water, storage in severely incised reaches.

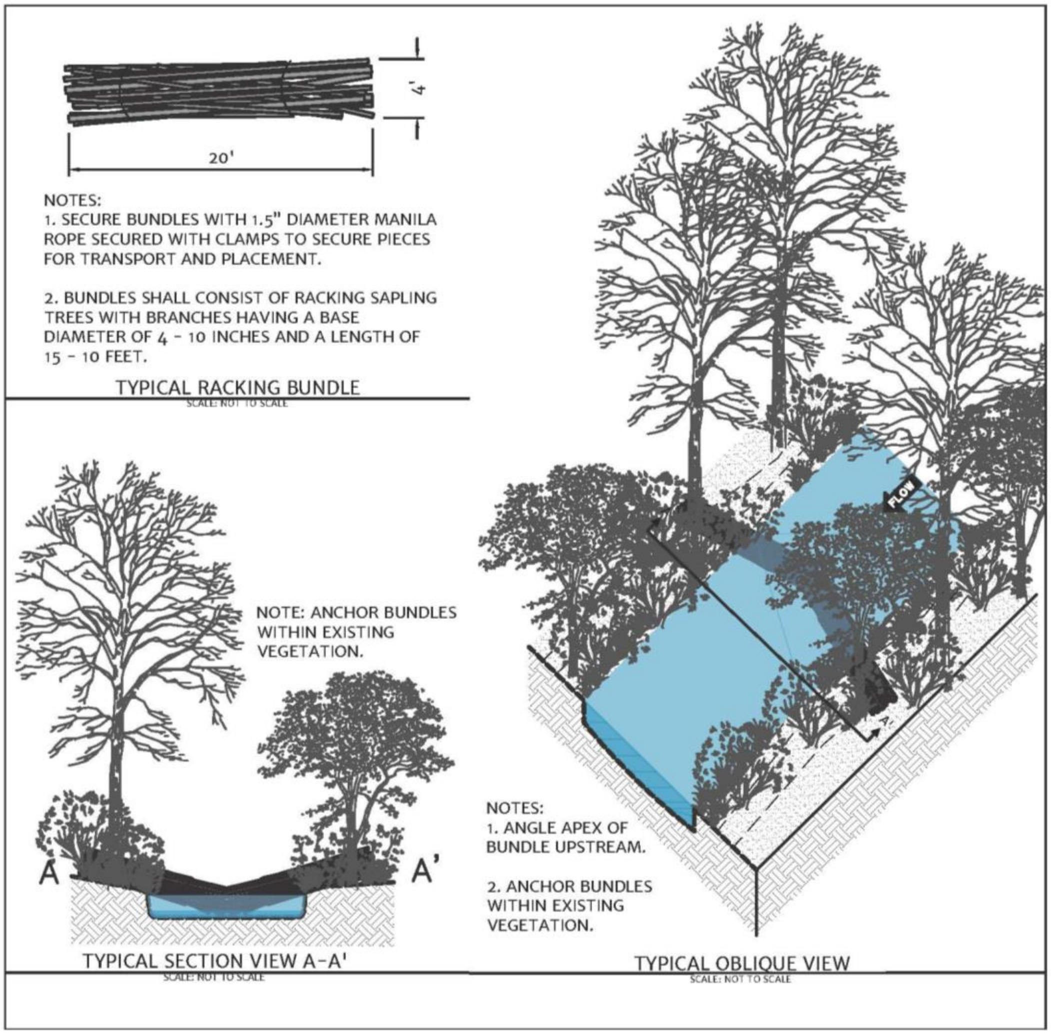
In particular, we recommend design and implementation of channel-spanning wood structures, along with pre-and post-implementation quantification of the elevation of local groundwater, channel bed elevation, and water surface elevation. Monitoring of downstream streamflow. Before and after project implementation would also support future efforts to quantify the hydrologic effect of restoration

In-Channel Structures

Due to access constraints in Poison Canyon and the relatively small width of the channel and valley, implementation via hand tools is likely to be feasible in this reach.

Beaver Dam Analog – Wood Bundles

The construction of simulated beaver dams would involve the installation of bundled woody material that has been harvested locally. Thinned material could be bundled to a diameter of 2-4 ft using biodegradable (manila) rope at two to three locations along the bundle length (Figure 19). Typical bundle lengths would be based on channel widths and potential to secure the bundles to adjacent riparian trees. Single bundles or bundles placed end to end can be installed within the channel, anchored to existing riparian vegetation (Figure 19) or using simple, small diameter batter (angled) posts.



TYPICAL RACKING BUNDLE

NOTES:
1. SECURE BUNDLES WITH 1.5" DIAMETER MANILA ROPE SECURED WITH CLAMPS TO SECURE PIECES FOR TRANSPORT AND PLACEMENT.

2. BUNDLES SHALL CONSIST OF RACKING SAPLING TREES WITH BRANCHES HAVING A BASE DIAMETER OF 4 - 10 INCHES AND A LENGTH OF 15 - 10 FEET.

TYPICAL SECTION VIEW A-A'

NOTE: ANCHOR BUNDLES WITHIN EXISTING VEGETATION.

TYPICAL OBLIQUE VIEW

NOTES:
1. ANGLE APEX OF BUNDLE UPSTREAM.

2. ANCHOR BUNDLES WITHIN EXISTING VEGETATION.

Figure 19. Example of typical racking bundle comprised of 10 - 20 ft poles <10-inch diameter. Bundles are bound to a diameter of 4 ft using 1.5-inch manila rope and clamps at two locations. Shown is a typical installation of two wood bundles placed end to end and anchored within existing vegetation to create a low-lying beaver dam analog.

Beaver Dam Analog – Post Lines

Lines of posts, or pickets, driven into the channel provide a stable platform in which to rack large wood or weave smaller branches and racking material (Figure 20). These structures have been implemented as beaver dam analogs to initiate aggradation, particularly where the availability of riparian trees to provide anchoring is lacking (Pollock *et al.*, 2012). These structures also provide potential sites for future beaver dam complexes, which would substantially increase the footprint and the benefit of the project.

Figure 20. Example of beaver dam analog using a post line and weaving (Photograph from Pollock et al. (2012)).

Large Riparian Wood Placement

Where sufficiently large riparian trees are present, mechanical pulling ("tree tipping") or felling into the channel is another option for adding channel-spanning wood structures (Benda et al., 2016). The required length and diameter of riparian trees, along with the number and placement ("racking") will all scale with channel morphology and hydraulics. This method can be combined with either the post lines or wood bundle methods to increase materials racking and aggradation.

Recommended Next Steps

Recommended next steps for pilot implementation in Poison Canyon include:

- Collection of field data, including:
  - Topographic survey
  - Identification of location and type of structures for placement
    - Based on minimum spacing, availability of materials, and construction feasibility.
  - Assess morphology to inform sizing of structure
- Assess local hydrology and hydraulics
- Complete conceptual treatment typical designs based on field data and stability calculations
- Complete proposed conditions analysis and a design report
- Begin permitting process with relevant agencies

List of Maps

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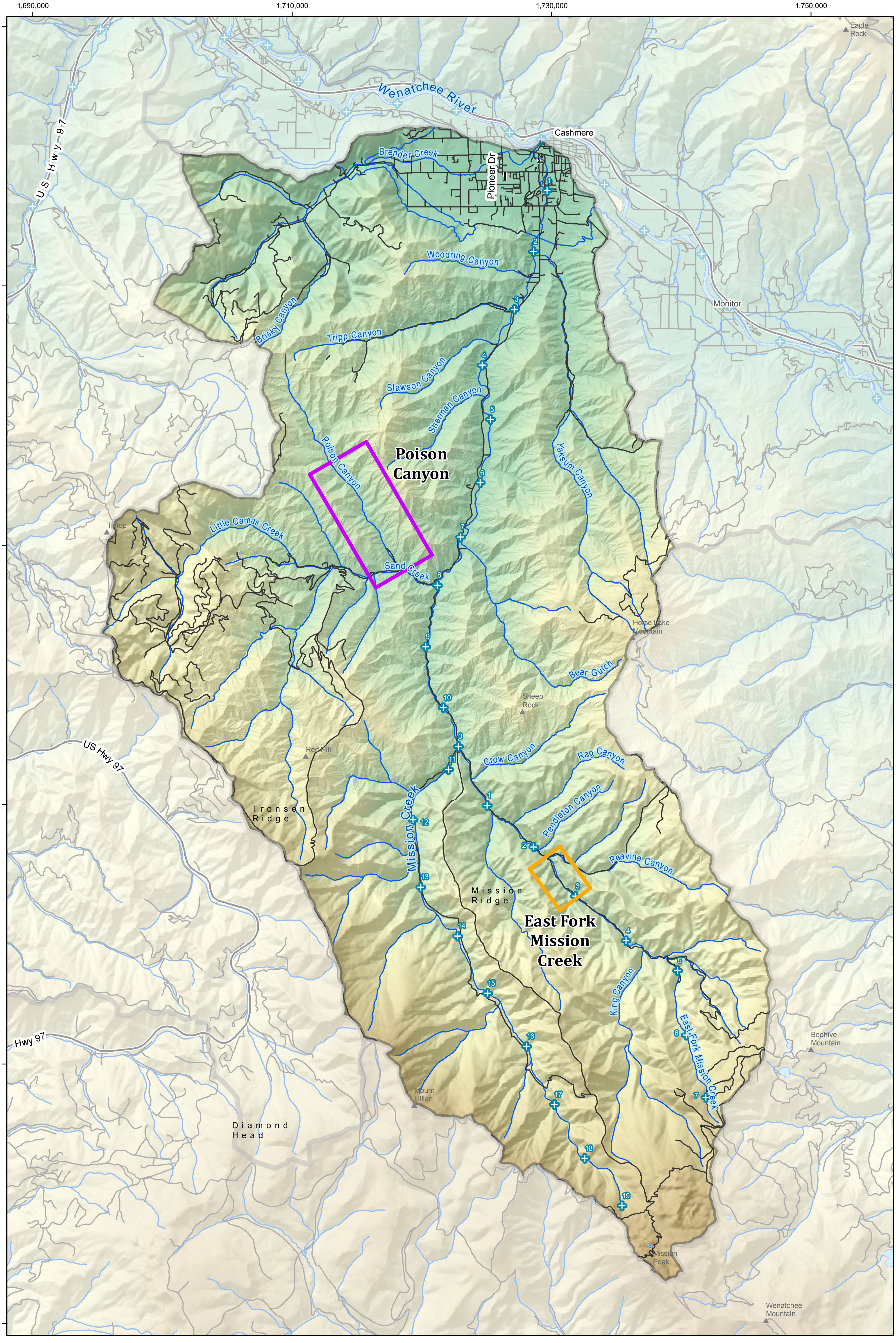


Map 1. Overview of watershed and study reach locations

Mission Creek, Chelan County, Washington

Data Sources: USGS 10-m Digital Elevation Model, Stream Network and Sub-basin boundaries from National Hydrography Dataset,

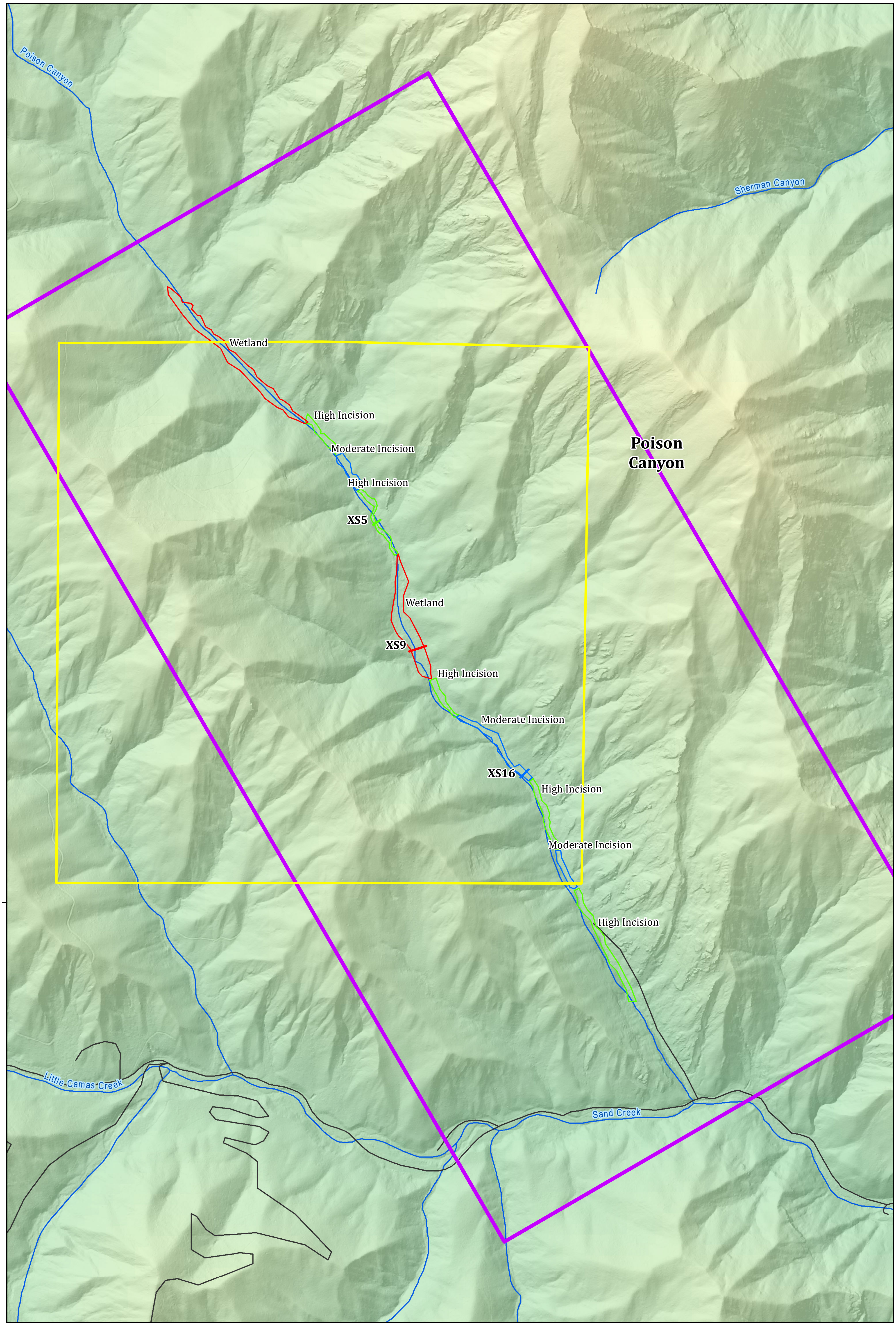
Lambert conformal conic projection, NAD 1983
State Plane Coordinate System

N
0 1 2 3 Miles

Natural Systems Design

▲ Mountain Summit
Roads
Streams
✚ River Mile Marker
▭ Poison Canyon Study Reach
▭ EF Mission Creek Study Reach

Susan Dickerson-Lange and Shawn Higgins, NSD Date: 4/3/2017 1_Mission_Overview.mxd



Map 2. Poison Canyon Study Reach

Mission Creek, Chelan County, Washington

Data Sources: USGS 10-m Digital Elevation Model, Stream Network and Sub-basin boundaries from National Hydrolography Dataset, Local hillshade from 1-m lidar Digital Elevation Model (Chelan County)

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System

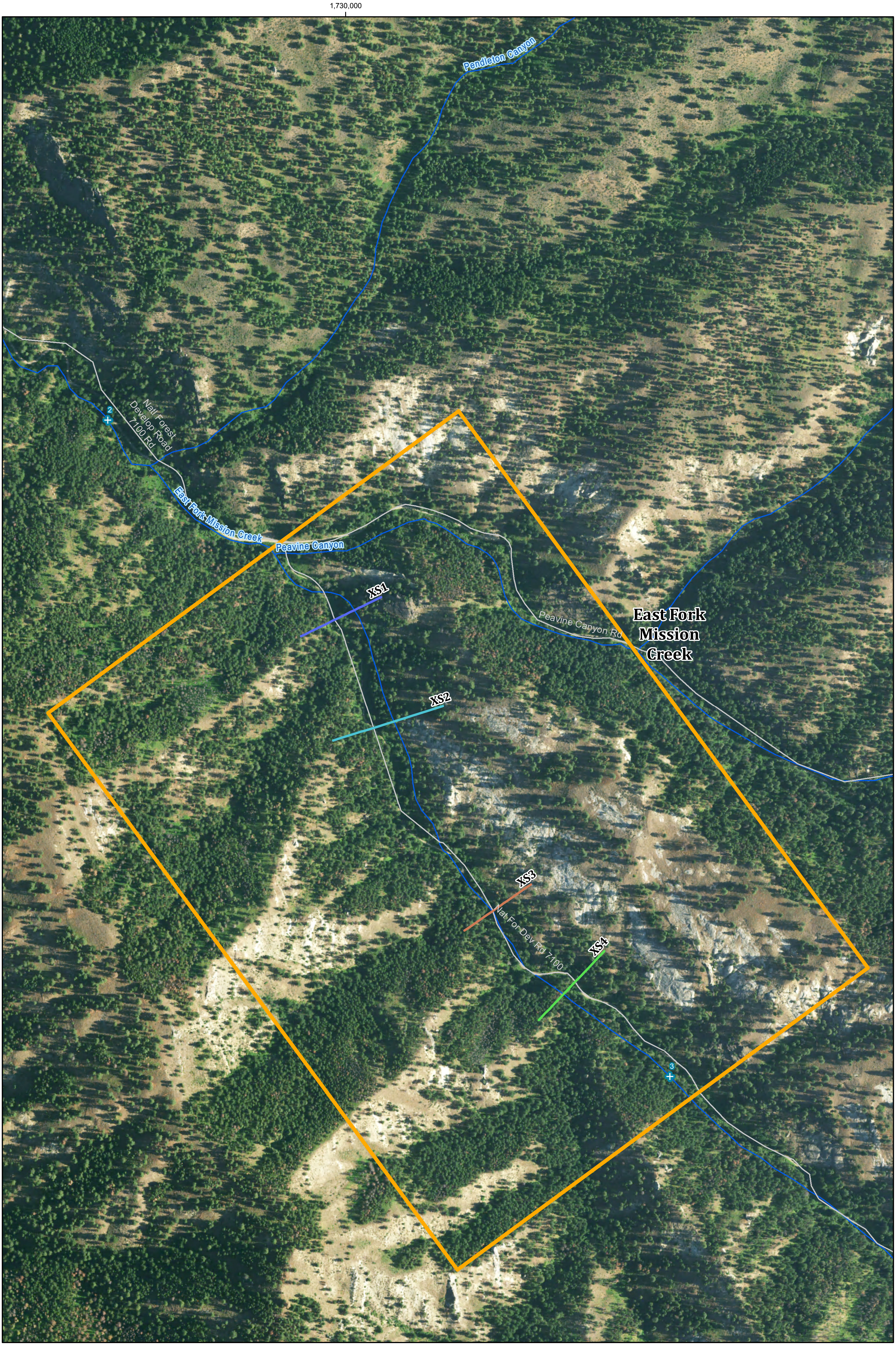
N

0 500 1,000 1,500 Feet

▲ Mountain Summit
✚ River Mile Marker
Roads
Study Reach
Streams
WDNR Parcel

Natural Systems Design

Susan Dickerson-Lange and Shawn Higgins, NSD Date: 4/3/2017 2_Mission_Poison.mxd



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Map 3. East Fork Mission Creek Study Reach

Mission Creek, Chelan County, Washington

Data Sources: USGS 10-m Digital Elevation Model, Stream Network and Sub-basin boundaries from National Hydrography Dataset, USDA NAIP Imagery

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System

N

0 300 600 900 Feet

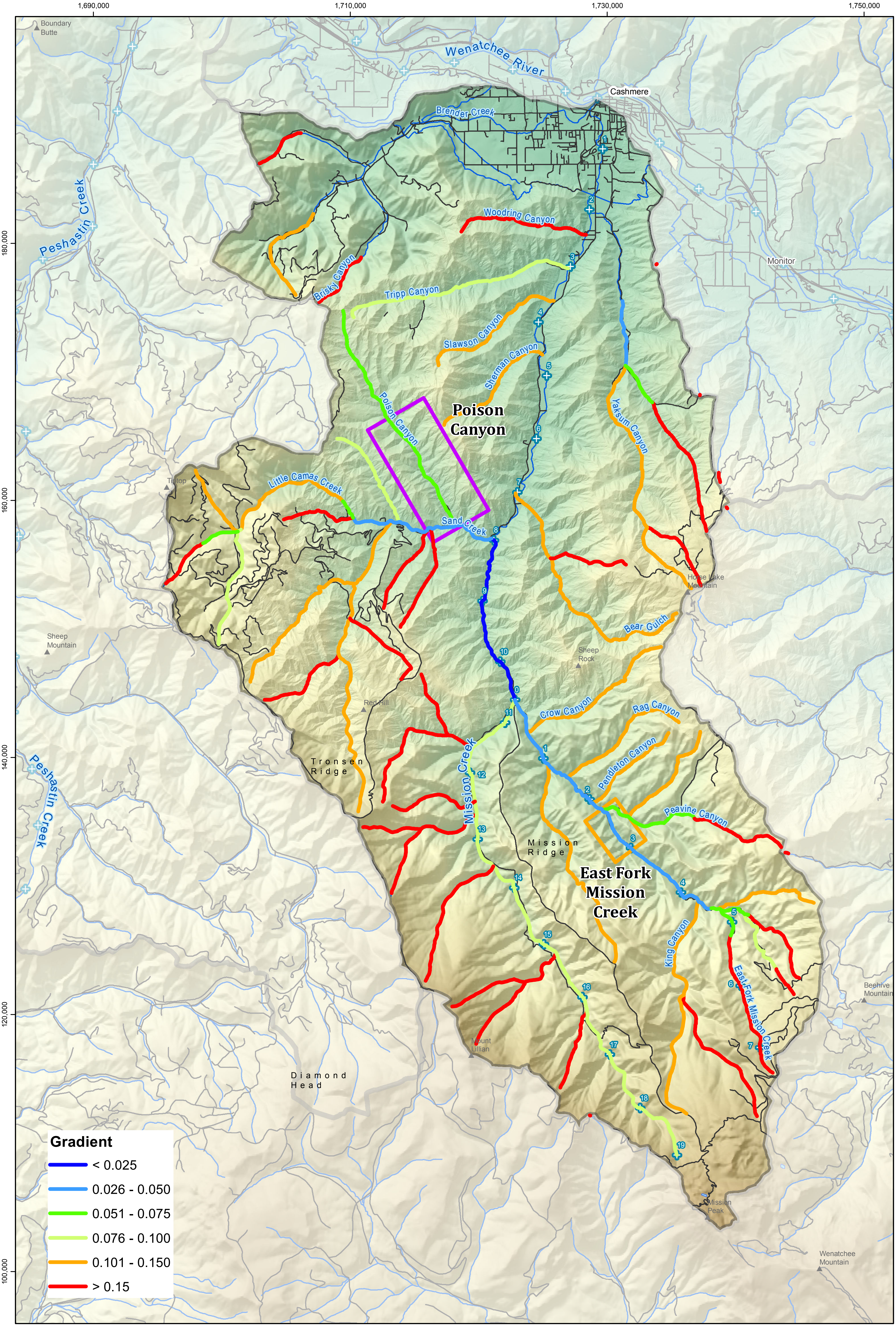
Natural Systems Design

▲ Mountain Summit

✚ River Mile Marker

Roads

Streams



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Map 4. Average stream gradient by reach

Mission Creek, Chelan County, Washington

Data Sources: USGS 10-m Digital Elevation Model, Stream Network and Sub-basin boundaries from National Hydrography Dataset,

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System

N

0 0.5 1 1.5 2 2.5 Miles

▲ Mountain Summit

Roads

Streams

Natural Systems Design

To: Pete Cruickshank and Mike Kaputa; Chelan County Natural Resource Department

From: Mike (Rocky) Hrachovec, PE; Tim Abbe, PhD, PG; Susan Dickerson-Lange, PhD; and John Soden, MS, PWS; Natural Systems Design

Date: 6/30/2017

Re: Basis of Design for Mission Creek Phase II: Poison Canyon Pilot Project

BACKGROUND

Introduction

The design team at Natural Systems Design (NSD) has worked collaboratively with Chelan County Natural Resource Department (CCNRD) to develop a restoration design for the Phase II Poison Canyon Pilot Project. The purpose of this memorandum is to summarize the basis of design for the design drawing plan set ("Plan Set") for the project. The Plan Set and this basis of design memorandum are intended to support the permitting process (see Permit Conditions, below), and therefore include:

- Map with locations of the proposed structures
- Typical structure drawings with cross-section and profile
- Typical channel dimensions with ordinary high water mark (OHWM) and 100-year flood height shown, and
- Quantities of materials.

The project design was developed from field assessments conducted on 9 November 2016 and 9 May 2017, a site visit with representatives of WA Department of Natural Resources (WDNR) and WA Department of Fish and Wildlife (WDFW) conducted on 18 April 2017, 1-dimensional hydraulic modeling, spatial analysis of lidar data, and several discussions between the design team and CCNRD.

Poison Creek flows through Poison Canyon, and is a tributary to Sand Creek, which is a tributary to Mission Creek, which joins the Wenatchee River near Cashmere, Washington. The CCNRD is planning for a stream restoration project in the portion of Poison Creek that crosses WDNR land ownership, from approximately River Mile (RM) 0.4 to 1.0, starting at the confluence of Poison Creek with Sand Creek ("Project Area").

The project is considered the Phase II pilot project for a broader effort to pursue water storage and sediment retention through stream restoration in Mission Creek, where dry season water quantity and quality are key issues of concern. A Phase I assessment identified appropriate conditions in the Project Area for implementing restoration actions intended to locally store alluvial sediment and water, reduce local stream gradient, and re-aggrade the channel bed elevation in target locations. The assessment found that extensive stream restoration has the potential to store water and augment low flows by 0.8 to 1.5 cubic feet per second (cfs) during the dry season in Mission Creek, while simultaneously providing aquatic ecosystem benefits. The motivation for and scientific basis of this approach is described in detail in the final report to CCNRD: "Mission Creek, Phase I Assessment: Water Conservation Through Stream Restoration", dated 12 May 2017.

Project Goals and Expected Benefits

The primary goal of this project is to re-introduce large wood structures to the stream channel in order to increase hydraulic roughness and slow flow velocities. These structures are therefore expected to raise local in-channel and subsurface water elevations, and trigger sediment deposition and bed aggradation.

Since a substantial portion of the Project Area is moderately to severely incised, raising water surface elevation and re-aggrading the bed will substantially improve lateral hydrologic connectivity and geomorphic function. Importantly, these structures are expected to act as porous, natural dams that impound water, increasing the overall in-situ surface water storage along the Project Area. In addition, re-aggradation of the bed will raise the in-channel surface water elevation and increase the volume of subsurface water storage and decrease the groundwater inflow rate. Together, these changes are expected to increase riparian water availability and baseflow amounts, and improve water quality (temperature and sediment loads). Furthermore, the thinning of small diameter trees outside of the riparian zone, for implementation in the in-channel structures, is likely to improve upland soil moisture availability and therefore improve forest resilience to fire and drought.

BASIS OF DESIGN

Permit Conditions

A site visit to the Project Area was conducted on 18 April 2017 to discuss the conceptual design and permitting conditions. The visit included Danielle Munzing (Biologist) and Marty Mauney (Forester) from WDNR, Amanda Barg (Area Habitat Biologist) from WDFW, Pete Cruickshank and Mike Kane from CCNRD, and John Soden from NSD. The conceptual approach for the Poison Canyon pilot project as well as the broader context for water conservation through restoration were discussed.

Key points that form the permit conditions for this project include:

- The use of live standing trees > 8" diameter at breast height (DBH) would likely require a Forest Practice Application (FPA) from WDNR and a Hydraulic Project Approval (HPA) from WDFW, a spotted owl habitat assessment, and payment for harvest of live standing trees >8"DBH.
- The project may use any dead and downed material. Many of the potential project sites have existing dead and down material that is larger than 8" DBH and will work as key pieces.
- Harvest of trees currently providing shade to creek will be avoided. If it is determined that a specific tree that is near to the creek is desired, the construction manager will need to have a densitometer to check available shading and make a judgement call on whether tree in question will reduce overall shading.
- Harvest of standing snags will be avoided.
- WDFW fish passage criteria are NOT applicable to the project.
- Construction methods will avoid dragging logs or causing soil erosion.

Thus, to fit this project within desired construction window and current secured funding the project will harvest standing live trees that are <8" DBH only, which will not require a FPA but will require an HPA.

Due to the remote nature of the site and the goal of minimizing construction disturbance to vegetation and soils, construction methods will rely on hand tools and forestry methods to cut and move wood into place. No tracked or wheeled equipment will be used.

For future projects, two possibly viable routes to use larger wood are:

1. Work through processes for FPA, spotted owl habitat assessment, and agreement with WDNR for a payment schedule, and/or
2. Import large wood and place via machinery or helicopter, where access and budget allow.

Field Assessment

Observations from field assessments conducted on 9 November 2016 and 9 May 2017 are incorporated in the restoration design for Poison Creek. The sole infrastructure consideration related to the potential mobilization of placed wood is a wooden culvert under Forest Service (FS) Road 7104, just upstream of the confluence of Poison Creek and Sand Creek (Figure 1). However, this culvert is protected from possible damage from a log jam failure by large boulders in Poison Creek near RM 0.2. (Figure 2). There is an unmaintained trail that follows Poison Creek up the valley. Valley width ranges from 20 to 100 feet, and the elevation of the channel bed relative to the floodplain ranges from 6 inches in a wetland complex to over 6 feet in severely incised reaches (see Phase 1 Report for additional geomorphic assessment). Floodplain sediments consist primarily of sand, with redox coloring present and depth to groundwater of 2.7 feet (9 May 2017, Figure 3). Channel sediments consist dominantly of sand and gravels, with exposed bedrock observed in two locations.

Riparian vegetation consists of coniferous and deciduous trees, shrubs and grasses. Dense stands of relatively young conifers are interspersed with exposed sandstone bedrock on hillslopes. Landslide deposits and scarps were observed.

Figure 1. Poison Creek flowing through wooden culvert under FS Road 7104, just upstream of the confluence with Sand Creek (i.e., near RM 0.0). Photograph taken on 9 November 2016.

Figure 2. Large boulders in Poison Creek at RM 0.2. Note that the creek is visible flowing through the boulders, and is approximately 4 feet wide, for scale. Photograph taken on 9 November 2016.

Figure 3. Test pit showing floodplain sediments on the left bank near RM 0.6. Photograph taken on 9 May 2017.

Geomorphology

In addition to the field observations noted above, geomorphic considerations that were incorporated in the design include longitudinal and vertical extent of incision, cross-sectional morphology, longitudinal slope and morphology, and potential for erosion through floodplain sediments. A Relative Elevation Model (REM) was constructed from a lidar digital elevation model in order to detect the vertical extent of incision and to characterize current hydrologic connectivity. The topo-bathymetric lidar data were acquired by Quantum Spatial in August 2015 and include average ground return point density of 12.8 points per square meter for a vertical accuracy of 0.054 m in non-submerged locations (TetraTech and QuantumSpatial, 2015). To construct a REM, the digital elevation model is processed to de-trend the channel gradient and express the ground surface elevation of the valley bottom topography relative to the adjacent river channel using a Kernel Density method (Olsen *et al.*, 2014). The resultant surface is a REM, which highlights local variations in the floodplain surface. The REM map and elevation profiles across the channel and floodplain were then used to identify the longitudinal extent of incision. Three geomorphic conditions were identified from the REM analysis and field observations: (1) Wetland complexes, (2) moderately incised reaches, and (3) severely incised reaches (Figure 4).

The lidar data were also used to construct a longitudinal profile along the Project Area, with particular focus on the difference in local average channel slope between the wetland complex and incised reaches. The wetland complex serves as a local analog of sediment storage and water storage resulting from large wood maintaining the hydraulic grade, and the slope in the wetland complex is an indication of how much the channel slope could change from re-aggradation of the channel bed through restoration. For example, the average slope through the wetland complex is 3.6%, and is as low as 2.8% in a portion of the wetland complex (Figure 5). In contrast, the average slope through the moderately incised reach immediately below the wetland complex is 3.3%, suggesting that re-aggradation is feasible with the addition of in-channel wood.

The final geomorphic consideration of the design is the erodibility of the fine-grained channel and floodplain sediments. As the structures begin to slow water velocities and trigger upstream localized aggradation, a hydraulic head differential will develop between the upstream and downstream end of each structure. This water will flow along the exposed banks and may begin to erode into the bank margin. If vegetation or wood falls into this pocket it may result in minor lateral scour, especially if the erosion occurs gradually. A large storm event may trigger more significant erosion, particularly in the first 2-3 years. Increased bank erosion could ultimately result in the stream bypassing the channel-spanning structure by meandering around the structure, particularly where the riparian forest is immature or absent. Since well-sorted sand is more erodible than larger sediment sizes or a more diverse range of sediment sizes, lateral channel migration is a key consideration at this Project Area. Thus, we considered two possible approaches to compensate: (1) place wood on the floodplain which will be recruited into the channel by the bank erosion, (2) install redundant structures in key locations to minimize hydraulic head differential, and (3) plan for some amount of maintenance in these structure locations. Placing additional wood on the floodplain is expensive and not guaranteed to become functional wood when recruited, and the budget for this project is limited to installation of a small number of structures. Thus, we recommend planning for capacity to revisit and reinforce a portion of the proposed structure locations during the first 3 years following implementation.

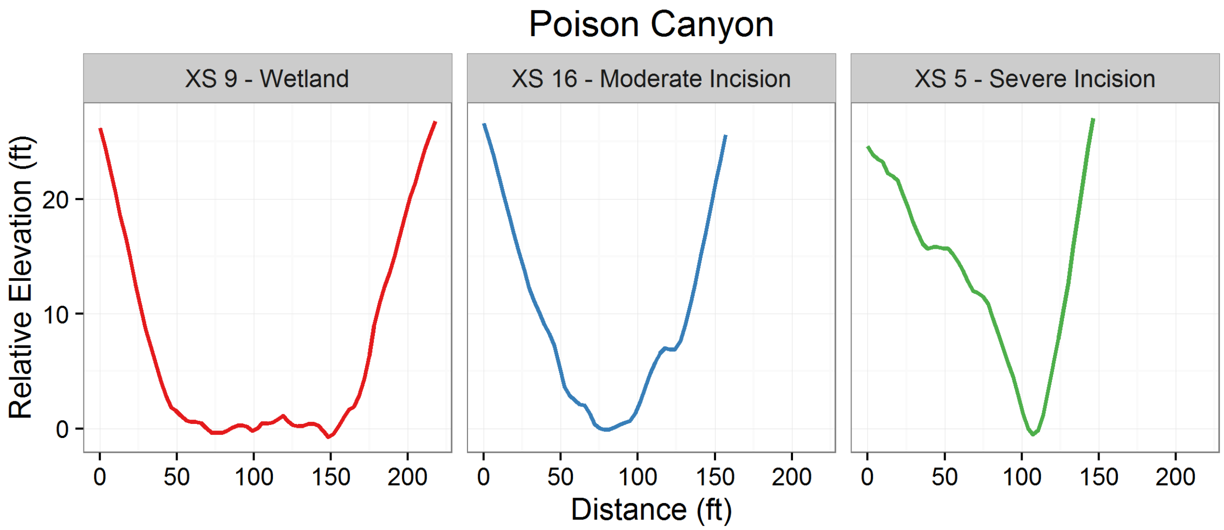


Figure 4. Topographic profiles from Poison Canyon showing elevation relative to local water surface (feet) from left bank to right bank (i.e., looking downstream) across three representative cross sections in a wetland reach, a moderately incised reach and a severely incised reach.

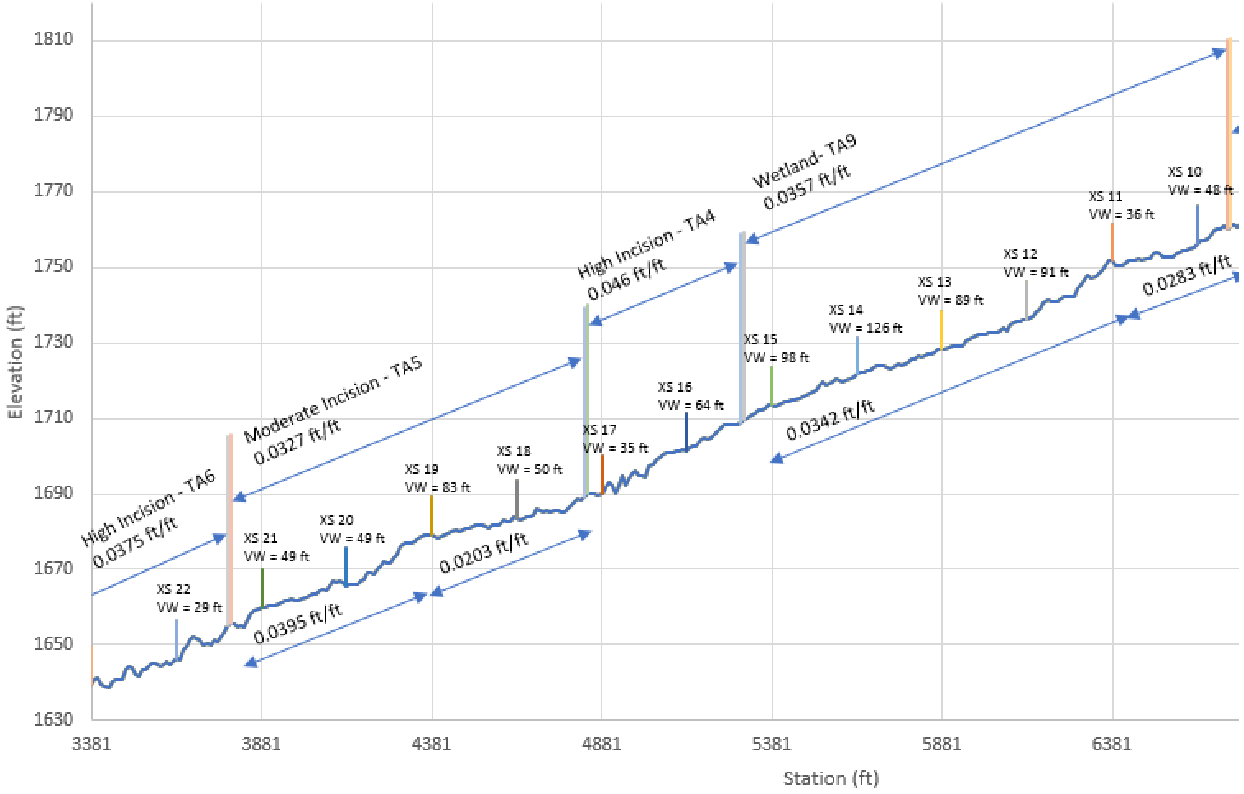


Figure 5. A portion of the longitudinal profile showing the local average slope by reaches that were field delineated on 10 November 2016, and by natural slope breaks.

Hydrology and Hydraulics

The hydrology and hydraulics of Poison Creek were assessed in order to inform the project design. Design-relevant streamflows, including the 2-, 10-, and 100-year floods, were derived using regression relationships implemented in USGS StreamStats Version 3.0 (Table 1). The equations implemented in StreamStats are based on drainage area (3.3 square miles), mean annual precipitation (19.1 inches) and region (Region 4). There are no validation data since there are no stream gages on Poison Creek, so the discharge values are considered estimates.

We implemented representative values for channel morphology based on field measurements, relevant design flows (described above), and roughness parameters (i.e., Manning's n) into 1-dimensional hydraulic equations to model the hydraulics of both existing and proposed conditions in the Project Area (Table 2, Figure 6). Values used for existing conditions channel morphology include channel width of 5 feet, channel depth of 3 feet, and valley width of 80 feet. Since the proposed wood structures are intended to serve as porous natural dams that impound water, we modeled proposed conditions with a completely obstructed, roughened channel in order to bracket the largest expected effect on hydraulics. To represent existing conditions in the wood-poor channel, we used typical Manning's n values of 0.035 in the channel and 0.07 on the floodplain. To represent a dramatic increase in hydraulic roughness from the implementation of large wood structures filling the channel, we adjusted the channel cross-sectional profile to be filled by wood and applied a Manning's n value of 0.15 to the channel and floodplain.

Table 1. Design-relevant streamflows at Poison Creek near the WDNR property boundary, derived using regression relationships implemented in USGS StreamStats Version 3.0.

Flow	Recurrence Interval (years)	Probability (%) of Occurrence in Any Given Year	Discharge (cfs)	Notes
Q2	2	50	10.8	Used as the discharge to estimate height of OHWM
Q10	10	10	28.4	
Q100	100	1	57.4	

Table 2. Water depth and flow velocity in channel and on floodplain, estimated from hydraulic equations for existing conditions and proposed conditions.

Flow	Existing Conditions: Depth in Channel	Existing Conditions: Channel Flow Velocity (fps)	Existing Conditions: Depth on Floodplain	Existing Conditions: Floodplain Flow Velocity (fps)	Proposed Conditions: Depth in Channel	Proposed Conditions: Channel Flow Velocity (fps)	Proposed Conditions: Depth on Floodplain	Proposed Conditions: Floodplain Flow Velocity (fps)
Q2	1.5	5.2	0	0	FULL[1]	1.1	0.6	0.7
Q10	2.1	6.7	0	0	FULL[1]	1.4	0.8	1.0
Q100	2.7	7.9	0	0	FULL[1]	1.6	1.1	1.3

[1] Channel modeled as totally obstructed by large wood structure, but designed to accommodate throughflow.

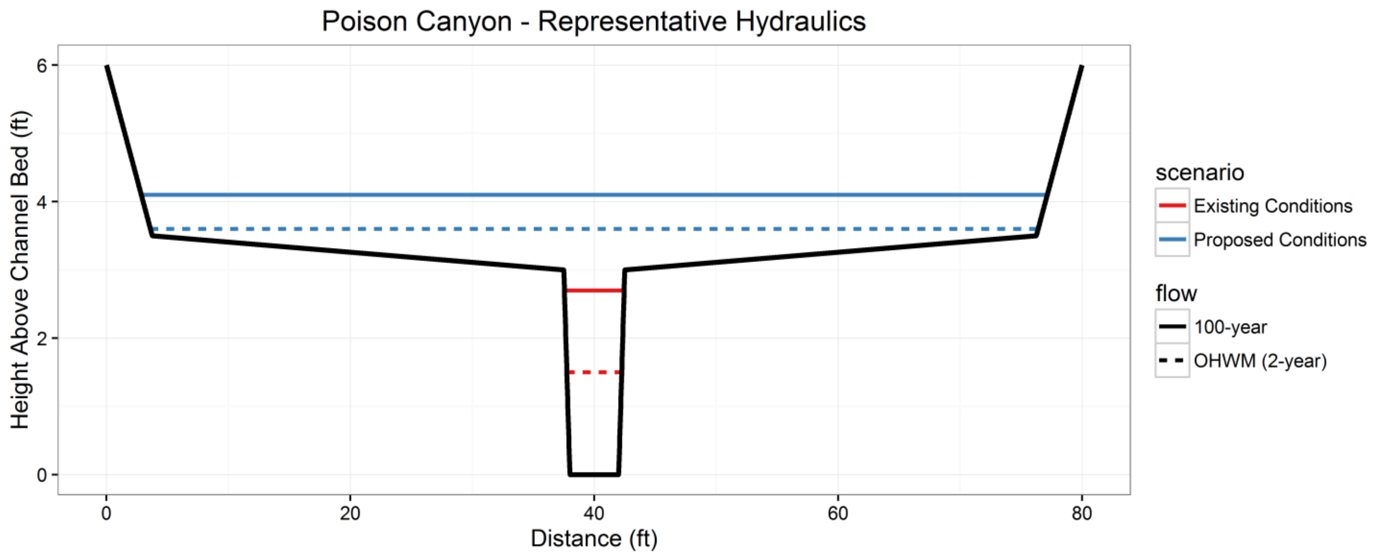


Figure 6. Representative cross-section showing OHWM (based on a recurrence interval of 2 years) and 100-year flow under existing conditions (red) and proposed conditions (blue). Note that the graph is vertically exaggerated to emphasize differences.

DESIGN COMPONENTS

Project Locations

Project locations were identified in the field based on geomorphic characteristics and the availability of sufficient wood to build a structure. In particular, projects were located in reaches that were identified as moderately to severely incised through analysis of the REM, longitudinal profile, and field observations. The availability of wood was noted in the field, and included downed large logs and standing live stems < 8" DBH outside of the riparian corridor.

Priority levels were determined qualitatively from field observations. A higher priority level was assigned to locations with wider valley morphology, and to structures that were placed to prevent head cut migration or incision into bedrock. Wider valleys are favored because of the larger available volume for subsurface and surface water storage under restored conditions. Preventing further incision is intended to retain as much natural alluvial water storage as the stream valley currently has. A secondary consideration in assigning priority levels was the spacing of structures, to avoid redundancy, and the availability of wood and riparian trees to entangle with. See the structure schedule in the Plan Set for notes on each location.

Photographs of select project locations are presented in Appendix A to provide additional context and to highlight features of select sites, but do not represent a full catalog of locations. The KMZ (Google Earth) file has been provided to CCNRD with locations of all proposed structures and georeferenced photographs of each location. In addition, all locations were flagged in the field with pink flagging tape.

Material Types

Wood Bundles

Thinned material will be bundled to a diameter of 2-4 feet using biodegradable (manila) rope. Bundles will be placed both horizontally and vertically (see typical structure sequence in Plan Set), and used to fill spaces between placed logs and the channel banks to decrease structure porosity.

Logs < 8" DBH

Logs will be harvested from standing live stems, away from riparian zone so that there is a negligible effect on riparian shade. Alternatively, downed logs < 8" DBH may also be used. No standing snags will be used.

Key pieces

Where larger diameter (≥ 8" DBH) downed logs are available, they will be cut with chain saws to allow for transport and placement in-channel without dragging or causing soil erosion. In some locations, downed logs with in-tact root wads were identified, and these represent prime candidates for key pieces for the in-channel structures.

Methods & Access

Construction will be accomplished entirely with hand tools. Standing live stems will be felled with chain saws and rigging. Logs will be hand-carried in such a way as to minimize soil erosion. Chain saws will be refueled on a spill pad at least 20' from the edge of the channel.

Crews will walk into the site from the approximately 0.4 mile access trail along Poison Creek, and will carry tools and supplies (e.g., manila rope). Parking is available at a pull-off on the south side of FS Road 7104, just to the west of the trailhead to the Project Area.

Architecture & Sequencing

Structures will be constructed from logs and wood bundles to create channel-spanning wood structures that effectively act as a porous wood dam. Structures will extend 30-40 feet along the length of the channel. Logs will be placed at an angle to the channel, and some portion will be entangled with riparian trees, where possible, for stability. Racking bundles will be used to fill holes in the structure and will be held in place by additional large wood placed on top. Sequencing of placements of logs and bundles is detailed in the plan set.

Material Quantities & Cost Estimating

The quantities of logs and bundles are provided with the structure schedule in the Plan Set.

A construction cost estimate is provided below (Table 3).

Table 3. Construction cost estimate for proposed structures.

Item #	Item Description	Quantity	Unit	Unit Price ($)	Amount ($)
1	Labor	22	DAY	$1,500	33,000
2	Manila Rope - 0.5" diameter	240	LF	$1	204

	Subtotal				*33,204*
	Taxes (as % of Construction Sub-Total)	*8.7%*			*2,889*
	TOTAL				**36,093**

LIST OF APPENDICES

Appendix A: Field Photographs of Proposed Locations

REFERENCES

Olsen, P.L., N.T. Legg, T.B. Abbe, and J.K. Radloff, 2014. A Methodology for Delineating Planning-Level Channel Migration Zones. https://fortress.wa.gov/ecy/publications/SummaryPages/1406025.html.

TetraTech and QuantumSpatial, 2015. Lower Wenatchee River Topobathymetric LiDAR. Bothell, WA.

APPENDIX A: FIELD PHOTOGRAPHS OF PROPOSED LOCATIONS

All photographs were taken on 9 May 2017.

Perched downed wood near proposed structure 2.

Perched downed wood near proposed structure 7, where the floodplain is low and wide.

Severe incision (up to 6 feet) near proposed structure 9, where there are very large cedars perched over the channel.

Bedrock in channel near proposed structure 10.

Moderately incised channel and adjacent conifers to entangle with at proposed structure 10.

Head cut downstream of proposed structure 10.

Looking downstream at Proposed structure 11.

Downed log with root wad to cut and haul as a key piece for proposed structure 12; located upslope from left bank.

Large downed log on right bank as key piece for proposed structure 15.

Large downed log perched across channel to use as a key piece for proposed structure 16.

Large downed log perched across channel to use as a key piece in proposed structure 18.

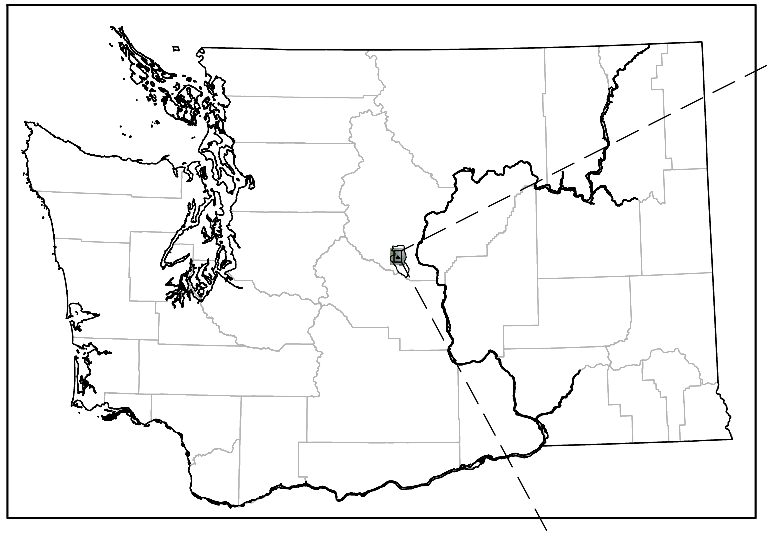
Large downed log perched across channel to use as key piece in proposed structure 19.

Appendix C

Project Plans

POISON CANYON RESTORATION PILOT PROJECT

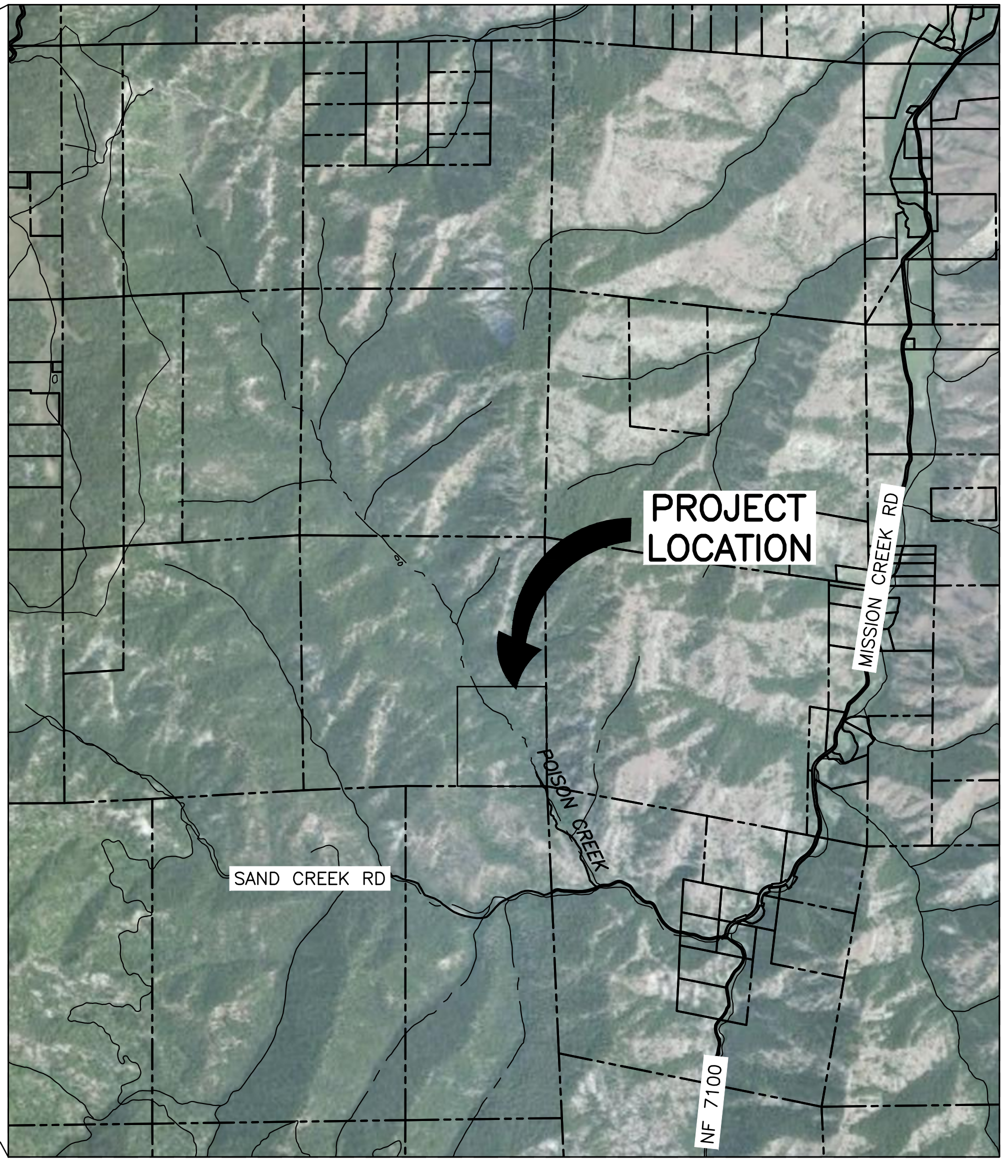
CHELAN COUNTY NATURAL RESOURCE DEPARTMENT



WASHINGTON STATE MAP

SCALE: 1" = 50 MILES

50 25 0 50 100



VICINITY MAP

SCALE: 1" = 2000'

N

DRAWING LIST	
SHEET NUMBER	SHEET TITLE
1	COVER SHEET
2	ACCESS AND STAGING
3	SITE PLAN
4	DETAILS
5	STRUCTURE SCHEDULE

CONTACT INFORMATION

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1900 N NORTHLAKE WAY, SUITE 211
SEATTLE, WA 98103
(206) 834–0175

CHELAN COUNTY NATURAL RESOURCE DEPARTMENT
411 WASHINGTON STREET, SUITE 201
WENATCHEE, WA 98801
(509) 667–6533

Jun 30, 2017 FINAL DESIGN

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Engineering Geologist 1151
Timothy B. Abbe

MICHAEL E. HRACHOVEC
36039

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Natural Systems Design

NAME OR INITIALS AND DATE	
DESIGNED	MH 5/9/17
CHECKED	SDL 5/26/17
DRAWN	KP 5/28/17
CHECKED	SDL 6/19/17

GEOGRAPHIC INFORMATION	
LATITUDE	47°26'30"N
LONGITUDE	120°31'30"W
TN/SC/RG	T23N/S36/R18E
DATE	6/30/17

POISON CANYON RESTORATION PILOT PROJECT

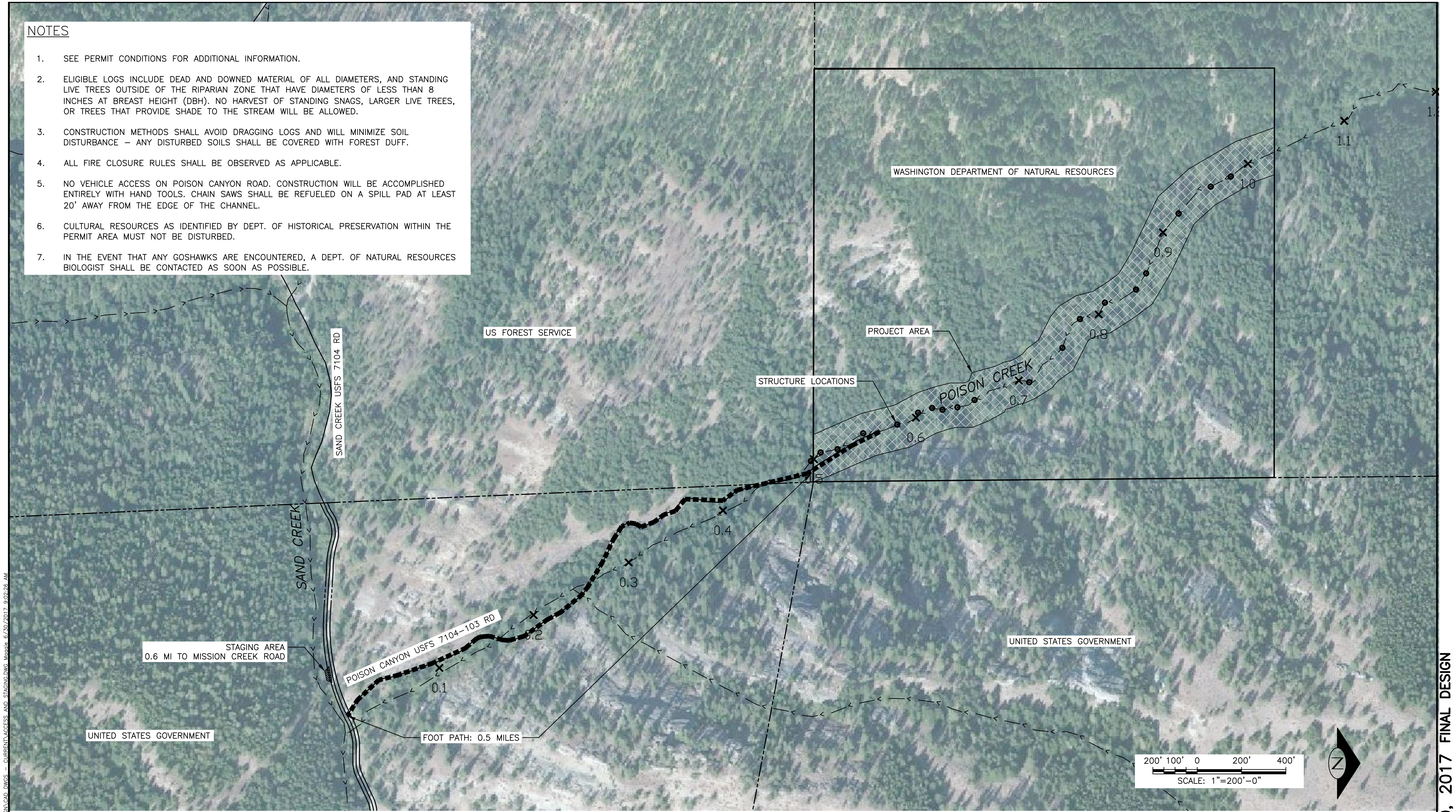
COVER SHEET

1

SHEET 1 OF 5

NOTES

1. SEE PERMIT CONDITIONS FOR ADDITIONAL INFORMATION.
2. ELIGIBLE LOGS INCLUDE DEAD AND DOWNED MATERIAL OF ALL DIAMETERS, AND STANDING LIVE TREES OUTSIDE OF THE RIPARIAN ZONE THAT HAVE DIAMETERS OF LESS THAN 8 INCHES AT BREAST HEIGHT (DBH). NO HARVEST OF STANDING SNAGS, LARGER LIVE TREES, OR TREES THAT PROVIDE SHADE TO THE STREAM WILL BE ALLOWED.
3. CONSTRUCTION METHODS SHALL AVOID DRAGGING LOGS AND WILL MINIMIZE SOIL DISTURBANCE – ANY DISTURBED SOILS SHALL BE COVERED WITH FOREST DUFF.
4. ALL FIRE CLOSURE RULES SHALL BE OBSERVED AS APPLICABLE.
5. NO VEHICLE ACCESS ON POISON CANYON ROAD. CONSTRUCTION WILL BE ACCOMPLISHED ENTIRELY WITH HAND TOOLS. CHAIN SAWS SHALL BE REFUELED ON A SPILL PAD AT LEAST 20' AWAY FROM THE EDGE OF THE CHANNEL.
6. CULTURAL RESOURCES AS IDENTIFIED BY DEPT. OF HISTORICAL PRESERVATION WITHIN THE PERMIT AREA MUST NOT BE DISTURBED.
7. IN THE EVENT THAT ANY GOSHAWKS ARE ENCOUNTERED, A DEPT. OF NATURAL RESOURCES BIOLOGIST SHALL BE CONTACTED AS SOON AS POSSIBLE.



LEGEND

—— >——	FLOW LINE	■■■■■■	ABANDONED ROAD/FOOT PATH
——-- ——	PARCEL LINE	————	ROAD
×	RIVER MILE	⊙	STRUCTURE LOCATION

Timothy B. Abbe

36039

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DATE	6/30/17

POISON CANYON RESTORATION PILOT PROJECT

ACCESS AND STAGING

2

SHEET 2 OF 5

Jun 30, 2017 FINAL DESIGN

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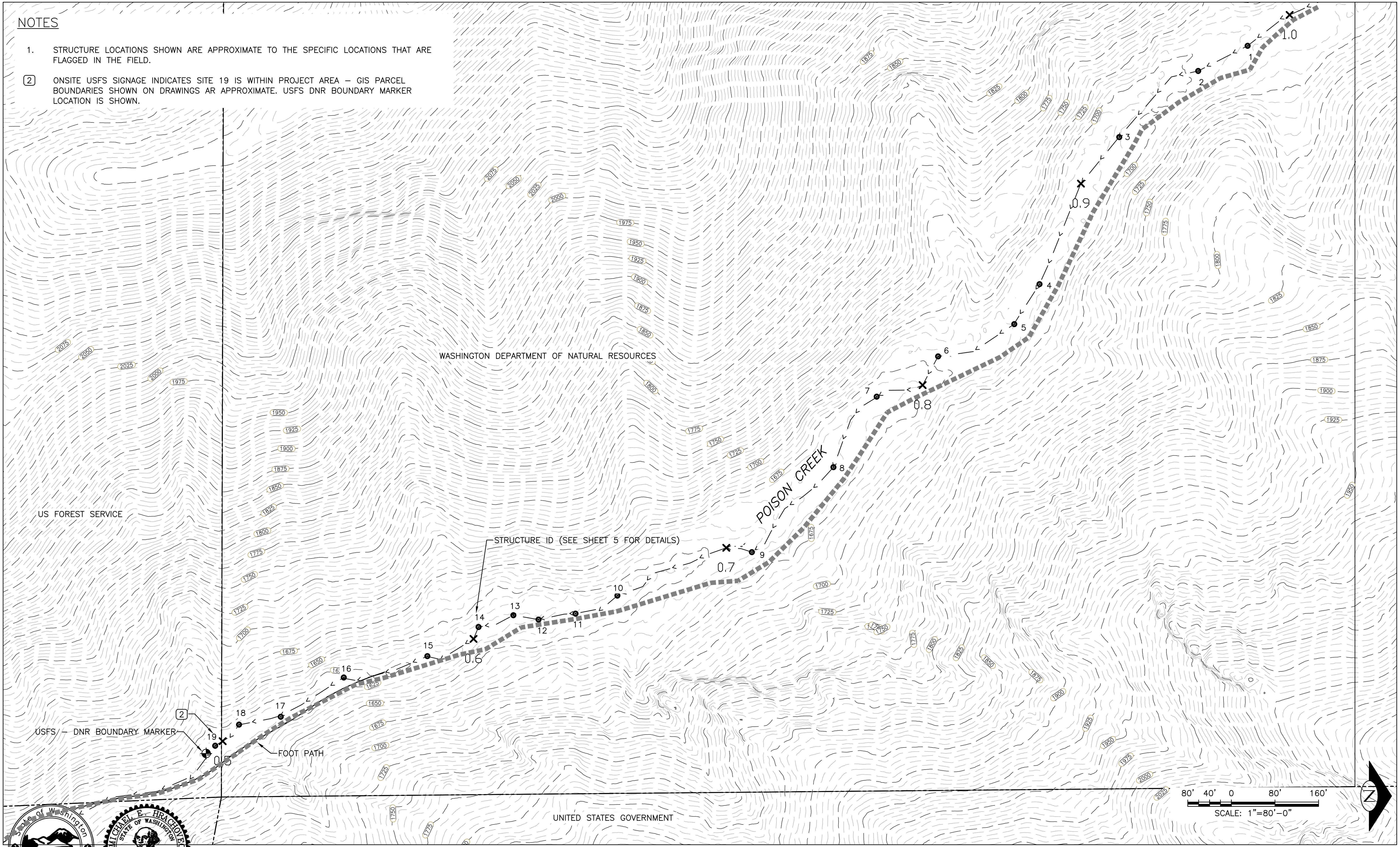
NOTES

1. STRUCTURE LOCATIONS SHOWN ARE APPROXIMATE TO THE SPECIFIC LOCATIONS THAT ARE FLAGGED IN THE FIELD.

② ONSITE USFS SIGNAGE INDICATES SITE 19 IS WITHIN PROJECT AREA – GIS PARCEL BOUNDARIES SHOWN ON DRAWINGS AR APPROXIMATE. USFS DNR BOUNDARY MARKER LOCATION IS SHOWN.



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DATE	6/30/17

POISON CANYON RESTORATION
PILOT PROJECT

SITE PLAN

3

SHEET 3 OF 5

Jun 30, 2017 FINAL DESIGN

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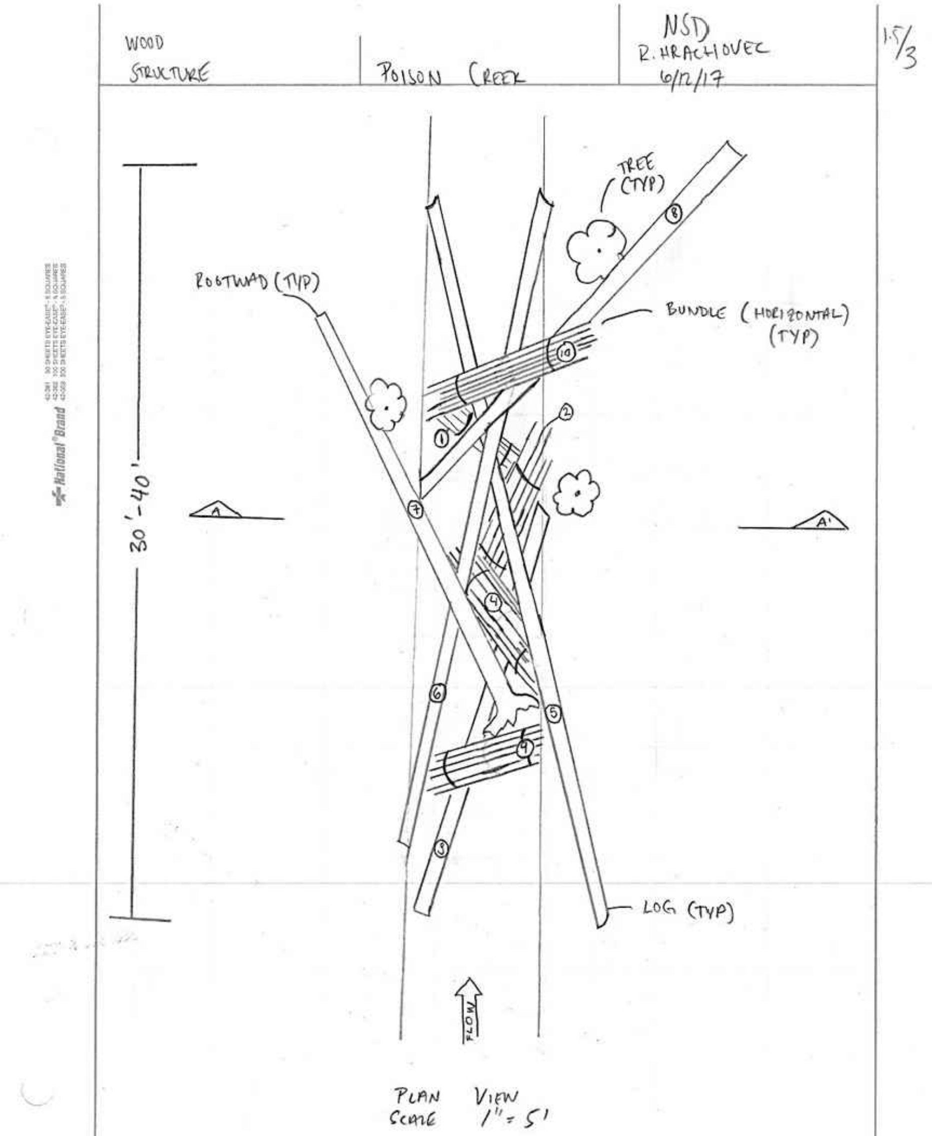
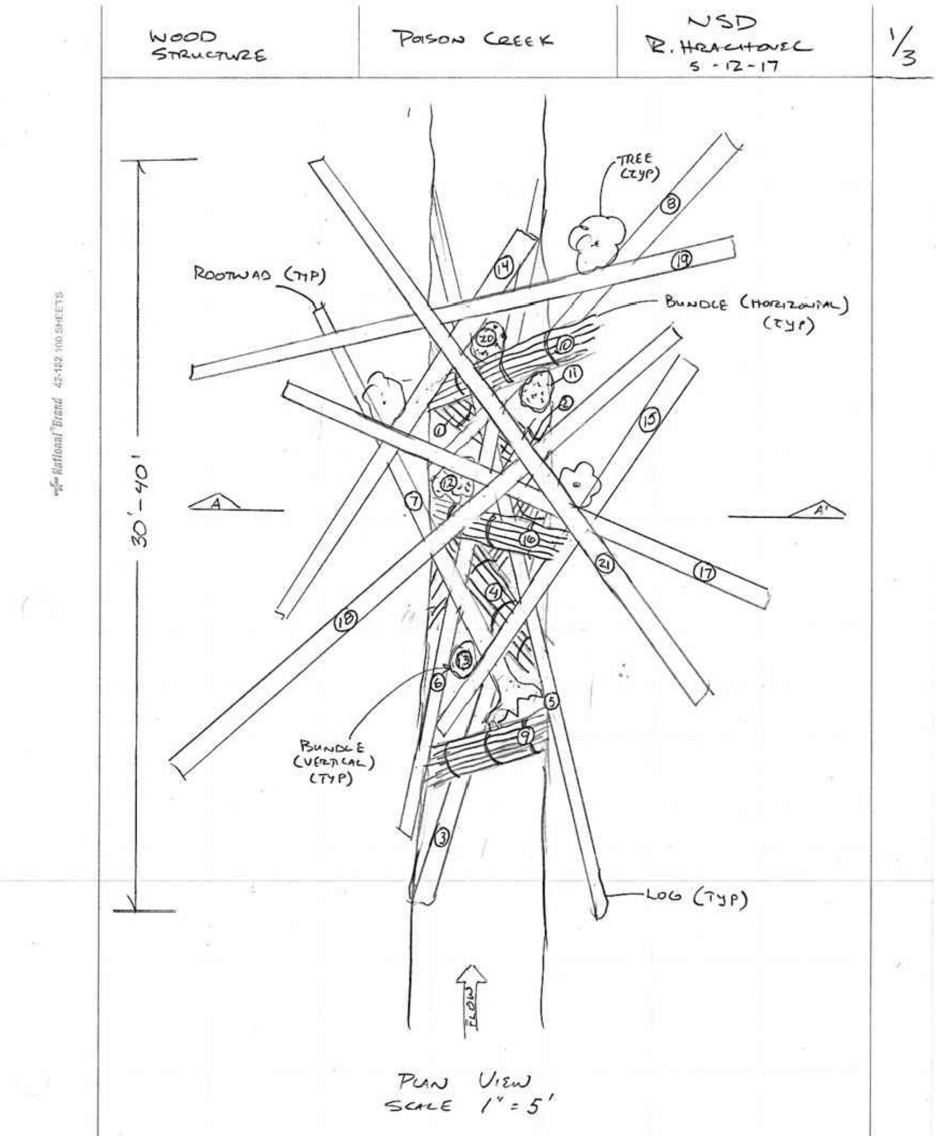
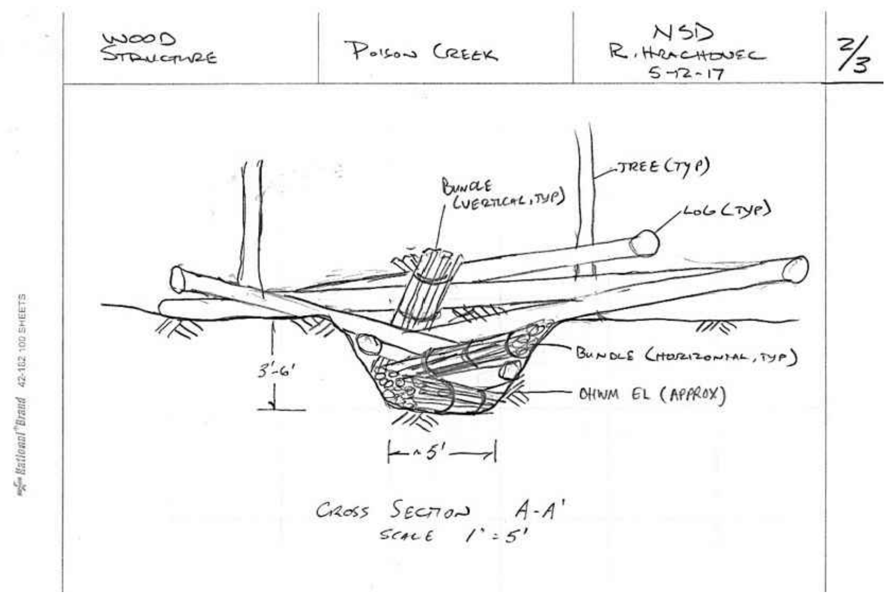


TYPICAL STRUCTURE SEQUENCE 1—10



TYPICAL STRUCTURE SEQUENCE 1—21



TYPICAL STRUCTURE SEQUENCE

SEQUENCE	LOG ①	ROOTWAD ②	BUNDLE ③	BUNDLE
		(IF AVAILABLE, IF NOT USE LOG)	HORIZONTAL	VERTICAL
1			1	
2			1	
3	1			
4			1	
5	1			
6	1			
7		1		
8	1			
9			1	
10			1	
11*				1
12*				1
13*				1
14*	1			
15*	1			
16			1	
17	1			
18	1			
19	1			
20				1
21	1			
TOTALS	10	1	6	4

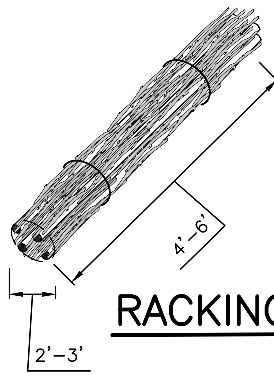
NOTES

* LAYER OMMITEED FOR SHALLOWER CHANNEL INSTALL.

① LOG: 6"–8" DBH, MIN 30' LONG. EXISTING LOGS WITHIN CHANNEL MAY BE ANY SIZE.

② ROOTWAD: 6"–8" DBH, MIN 20' LONG.

③ SEE DETAIL 1/4



NOTES

1. SECURE BUNDLES ON BOTH ENDS WITH 3 WRAPS WITH 0.5" DIAMETER MANILA ROPE SECURED WITH A SQUARE KNOT WITH 6" TAILS.
2. BUNDLES SHALL CONSIST OF SAPLING TREES AND BRANCHES HAVING VARYING DIAMETERS OF 0.5–3 INCHES AND A LENGTH OF 3–6 FEET.

RACKING BUNDLE DETAIL 1/4

NOTES

1. USE LOGS WITH ROOTWADS WHERE AVAILABLE.
2. OVERALL STRUCTURE HEIGHT CAN BE ADJUSTED IN FIELD AT THE DIRECTION OF THE CONTRACT OFFICER, PROVIDED THAT STRUCTURE HEIGHTS REACH 1 FOOT ABOVE THE TOP OF BANK AND THAT LOG PLACEMENT 17–21 REST ON THE ADJACENT FLOODPLAIN AND ARE ENTANGLED WITH RIPARIAN TREES WHERE POSSIBLE.
3. FOR LOCATIONS WHERE THE TOTAL AMOUNTS OF MATERIALS ARE REDUCED TO FIT THE CHANNEL, ONLY THE CONTRACT OFFICER WILL DIRECT THE ELIMINATION OF SPECIFIC LAYERS. THIS MAY INCLUDE INDIVIDUAL LOGS AND BUNDLES.
4. LARGER DIAMETER LOGS ARE PREFERRED. SMALLER DIAMETER INDIVIDUAL LOGS MAY BE USED PROVIDED THAT THE LOGS ARE SUFFICIENTLY LONG.
5. LOGS SHALL BE STRUCTURALLY SOUND AND SHALL RESIST PENETRATION FROM A SHARP KNIFE BEYOND 0.25 INCHES.

Engineering Geologist 1151
Timothy B. Abbe

Michael E. Hrachovec 36039

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POISON CANYON RESTORATION
PILOT PROJECT

DETAILS

4
SHEET 4 OF 5

Jun 30, 2017 FINAL DESIGN

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STRUCTURE #	NORTHING	EASTING	PRIORITY	PRIORITY NOTES	WOOD SOURCE	CONSTRUCTION NOTES	SIZE	LOGS	BUNDLES (HORIZONTAL)	BUNDLES (VERTICAL)
1	162060.2	1715816.9	HIGH	WIDE FLOODPLAIN, LOTS OF WOOD	ABUNDANT DOWNED WOOD	VERY LARGE STANDING CONIFERS ON LEFT BANK TO ENTANGLE WITH	TYPICAL	11	6	4
2	161969.5	1715863.0	HIGH	WIDE FLOODPLAIN, LOTS OF WOOD	ABUNDANT DOWNED WOOD AND LARGE LOG PERCHED OVER CHANNEL		TYPICAL	11	6	4
3	161824.7	1715984.3	HIGH	WIDE FLOODPLAIN, LOTS OF WOOD, EXISTING IN-CHANNEL WOOD TO BUILD FROM	DOWNED WOOD IN RIPARIAN AREA	LARGE CONIFER ON LEFT BANK TO ENTANGLE WITH, INCORPORATE EXISTING IN-CHANNEL WOOD	TYPICAL	11	6	4
4	161678.4	1716254.1	HIGH	WIDE FLOODPLAIN, LOTS OF WOOD	DOWNED WOOD TO USE, PERCHED LOG TO DROP INTO CHANNEL		TYPICAL	11	6	4
5	161632.2	1716327.3	HIGH	WIDE FLOODPLAIN, LOTS OF WOOD	DOWNED WOOD IN RIPARIAN AREA	MATURE TREES IN RIPARIAN TO ENTANGLE WITH	TYPICAL	11	6	4
6	161492.4	1716386.6	LOW	FEW RIPARIAN TREES TO ENTANGLE WITH, LESS WOOD AVAILABLE	NO DOWNED KEY PIECE, NEED TO HARVEST HILLSLOPE WOOD, LEFT BANK HAS 6-8" DBH WOOD		TYPICAL	11	6	4
7	161379.7	1716460.5	HIGH	WIDE FLOODPLAIN, LOTS OF WOOD	LARGE PERCHED LOG OVER CHANNEL	CONIFERS ON LEFT BANK TO ENTANGLE WITH	TYPICAL	11	6	4
8	161300.5	1716589.7	HIGH	WIDE FLOODPLAIN, LOTS OF WOOD; PREVENT HEADCUT FROM PROPOGATING UPSTREAM	LOTS OF DOWNED WOOD AND STANDING SMALL DIAMETER UPSLOPE FROM RIGHT BANK		TYPICAL	11	6	4
9	161150.8	1716745.7	MEDIUM	SEVERE INCISION WITH HIGH RISK OF BANK EROSION AND STRUCTURE FAILURE - THEREFORE, WILL REQUIRE MORE TIME TO BUILD, WILL REQUIRE 2-3X THE MATERIAL AS THE TYPICAL STRUCTURE	LARGE DOWNED LOGS ACROSS CHANNEL (MAY BE DIFFICULT TO PLACE - POSSIBLY SEVER ROOTS AND DROP IN), SOME TREES TO HARVEST UPSLOPE OF RIGHT BANK, BUT LESS WOOD HERE	ENTANGLE WITH PERCHED LOGS. BUILD THE ENTIRE SET OF STRUCTURES OR DO NOT BUILD	2-3X THE TYPICAL MATERIAL, INCLUDING 1.5X THE TYPICAL HEIGHT, 2X THE TYPICAL LENGTH, AND THE REMAINDER TO LOAD CHANNEL MARGINS	33	18	12
10	160904.1	1716825.5	HIGH	WIDE FLOODPLAIN, LOTS OF WOOD; PREVENT HEADCUT FROM PROPOGATING UPSTREAM	DOWNED ALDERS AROUND CHANNEL, STANDING TREES TO HARVEST ON RIGHT BANK SLOPE	TAKE ADVANTAGE OF MEANDERS, LAY LOG IN AT END OF MEANDER. LARGE CONIFERS TO ENTANGLE WITH	TYPICAL	11	6	4
11	160827.4	1716858.4	HIGH	WIDE FLOODPLAIN, LOTS OF WOOD; PREVENT FURTHER INCISION INTO BEDROCK	DOWNED LOGS UPSLOPE FROM RIGHT BANK	LARGE CONIFER ON RIGHT BANK TO ENTANGLE WITH	TYPICAL	11	6	4
12	160759.6	1716869.5	LOW	REDUNDANT OF ADJACENT STRUCTURES	DOWNED TREE WITH ROOTWAD UPSLOPE ON LEFT BANK, PLUS ADDITIONAL DOWNED LOGS	LARGE CONIFER ON LEFT BANK TO ENTANGLE WITH	TYPICAL	11	6	4
13	160713.4	1716861.4	HIGH	WIDE FLOODPLAIN, LOTS OF WOOD	DOWNED LOGS AND PERCHED LOGS TO USE AS IN-CHANNEL WOOD	LARGE CONIFERS ON RIGHT BANK TO ENTANGLE WITH	TYPICAL	11	6	4
14	160649.5	1716882.9	LOW	NARROW FLOODPLAIN	LARGE DOWNED LOG ON RIGHT BANK AS KEY PIECE. SMALL DIAMETER TREES TO HARVEST UPSLOPE FROM RIGHT BANK		TYPICAL - POSSIBLY USE LESS MATERIAL HERE	10	5	3
15	160555.6	1716936.5	LOW	NARROW FLOODPLAIN	SUFFICIENT DOWNED LOGS		TYPICAL	11	6	4
16	160402.3	1716975.7	LOW	NARROW FLOODPLAIN	LARGE DOWNED LOG PERCHED ACROSS CHANNEL, 6 SMALL DIAMETER TREES TO HARVEST UPSLOPE	LARGE CONIFER ON RIGHT BANK TO ENTANGLE WITH	TYPICAL	11	6	4
17	160286.7	1717047.6	LOW	NARROW FLOODPLAIN	ABUNDANT DOWNED WOOD ON RIGHT BANK		TYPICAL	11	6	4
18	160210.1	1717062.1	LOW	ONLY 50' UPSTREAM FROM #19, REDUNDANT	LARGE DOWNED LOG ACROSS CHANNEL		TYPICAL	11	6	4
19	160166.4	1717100.9	HIGH	WIDE FLOODPLAIN, LOTS OF WOOD, EXISTING IN-CHANNEL WOOD TO BUILD FROM	LARGE DOWNED LOGS ACROSS CHANNEL, AND DOWNED WOOD ON RIGHT BANK	INCORPORATE EXISTING IN-CHANNEL WOOD	TYPICAL	11	6	4
							TOTALS	230	125	83

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Timothy B. Abbe
1151

MICHAEL E. HRACHOVEC
36039

0 ½ 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT PLOTTED TO ORIGINAL SCALE.

Natural Systems Design

NAME OR INITIALS AND DATE
DESIGNED MH 5/9/17
CHECKED SDL 5/26/17
DRAWN KP 5/28/17
CHECKED SDL 6/19/17

GEOGRAPHIC INFORMATION
LATITUDE 47°26'30"N
LONGITUDE 120°31'30"W
TN/SC/RG T23N/S36/R18E
DATE 6/30/17

POISON CANYON RESTORATION PILOT PROJECT

STRUCTURE SCHEDULE

5

SHEET 5 OF 5

Jun 30, 2017 FINAL DESIGN

To: Pete Cruickshank, CCNRD

From: Susan Dickerson-Lange, PhD; John Soden, MS, PWS; and Tim Abbe, PhD, PEG, PHG; Natural Systems Design

Date: May 21, 2018

Re: Poison Canyon Monitoring Alluvial Water Storage – Preliminary Results

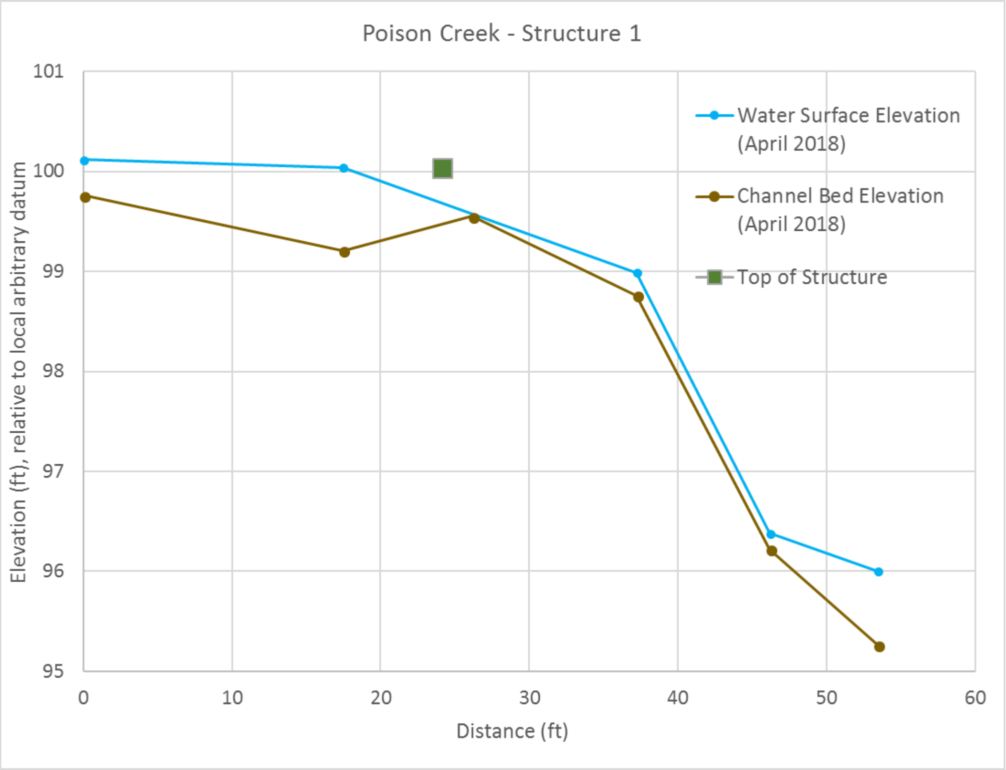
On 18 April 2018 we observed structure performance, collected survey data and measured discharge within the treatment reach of the Poison Canyon Alluvial Water Storage Pilot Project.

The working hypotheses of the Poison Canyon restoration project are:

1. Flow velocity will be slower immediate upstream of the in-stream wood structures than downstream,
2. The channel bed will aggrade upstream of the in-stream wood structures,
3. Re-aggradation of the channel bed elevation will increase the amount and duration of subsurface water storage due a reduction in the lateral (i.e., across valley) hydraulic gradient between the floodplain and the channel,
4. Increased sub-surface water storage will result in increased streamflow after the spring freshet (i.e., during the falling limb of the hydrograph and/or during the baseflow period), and
5. Increased sub-surface water storage will result in decreased stream temperature at or downstream of the increased storage.

Preliminary data analysis supports the occurrence of the hypothesized effects, but longer-term study is needed to understand effects on groundwater storage and baseflow contributions.

- Topographic survey demonstrates that the structures are slowing flow velocities and triggering re-aggradation in the channel bed upstream (Figure 1 and Figure 2). Local channel bed gradient above Structure 1 decreased from approximately 8% to 1%. Local channel bed gradient above Structure 5 decreased from approximately 3% to 1%.
- We observed two locations of channel bank seepage downstream of structure placements, which suggests inflow from the adjacent shallow alluvial aquifer. (Figure 3).
- Three out of the four paired discharge measurements show a 10-15% decrease in discharge downstream of the in-stream structures, suggesting that water is locally flowing into the subsurface (Table 1. Discharge measurements above and below selected in-stream wood structures on Poison Creek (data collected manually on 18 April 2018).). Assuming that uncertainty in each measurement is 5-15% of the discharge value, this difference may also be attributed to uncertainty.
- Time series data of sub-surface water elevations may help to understand the lateral groundwater flow (and therefore water storage) dynamics.



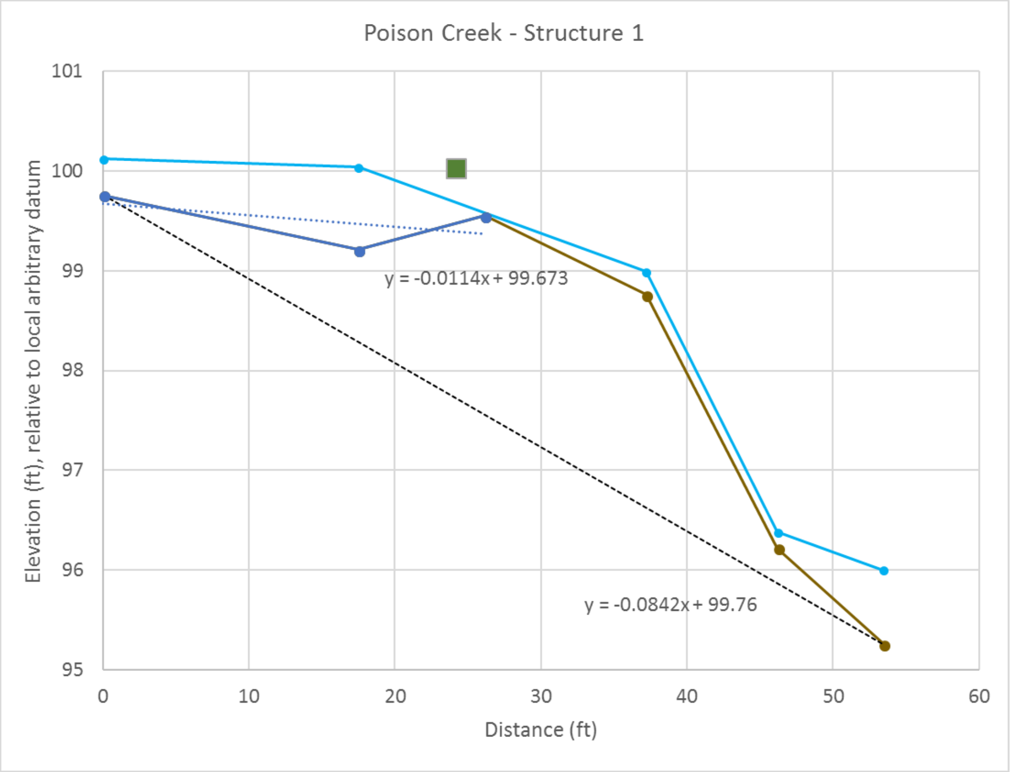
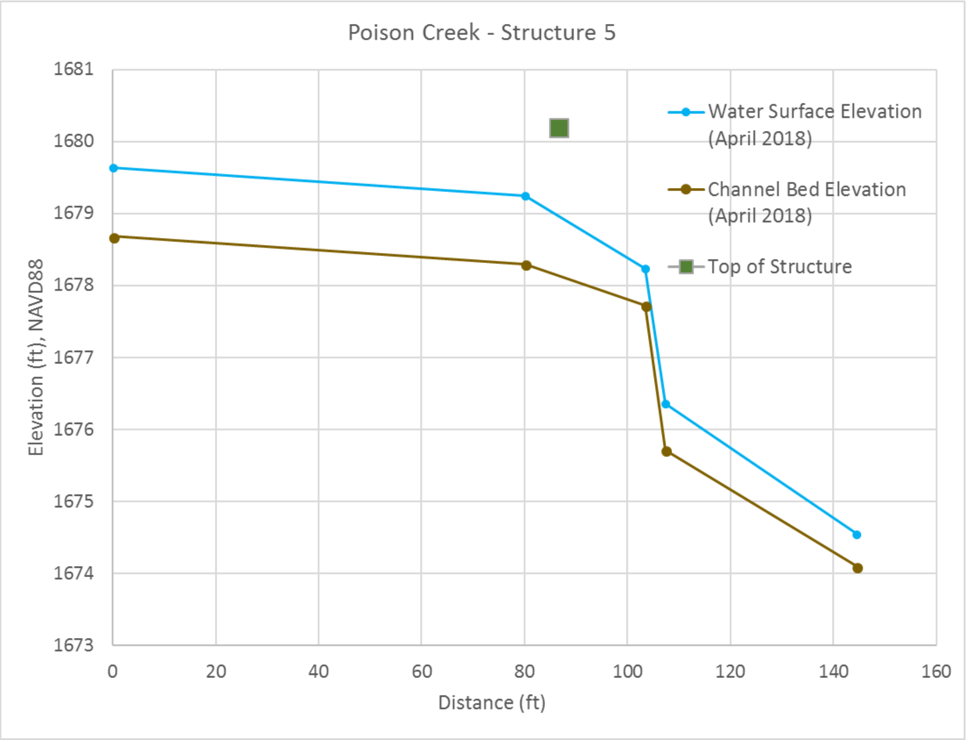


Figure 1. Top: Topographic profile of water surface and channel bed elevations (relative to local datum). The position and elevation of the top of Structure 1 is shown as a green square. Bottom: Same as above with linear regression lines showing average channel bed slope pre-project (black dash) and post-project (blue dash).



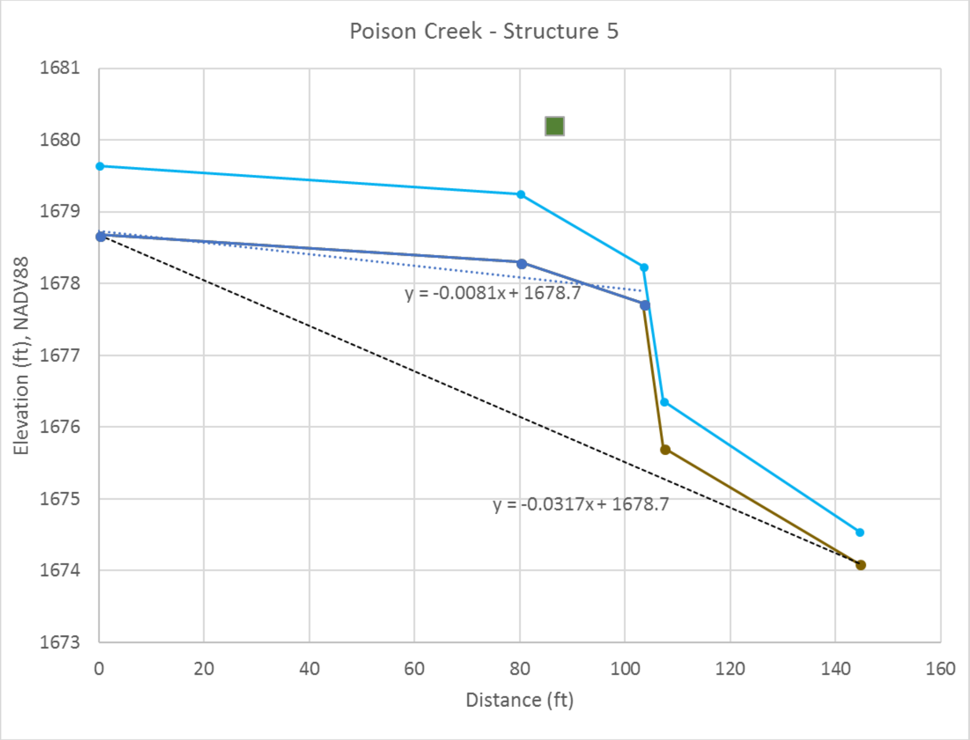


Figure 2. Top: Topographic profile of water surface and channel bed elevations (relative to local datum). The position and elevation of the top of Structure 1 is shown as a green square. Bottom: Same as above with linear regression lines showing average channel bed slope pre-project (black dash) and post-project (blue dash).

Figure 3. Evidence of bank seepage immediately downstream from Structure 5, on the left bank. Gravelometer for scale.

Table 1. Discharge measurements above and below selected in-stream wood structures on Poison Creek (data collected manually on 18 April 2018).

STRUCTURE	POSITION	Q (CFS)	COMPUTE 5% UNCERTAINTY	DIFFERENCE (US-DS)
Str1	US	1.07	0.05	**0.14**
Str1	DS	0.93	0.05	
Str5	US	1.22	0.06	**0.21**
Str5	DS	1.00	0.05	
Str7	US	1.38	0.07	**0.12**
Str7	DS	1.26	0.06	
Str17-18-19	US	0.99	0.05	**-0.08**
Str17-18-19	DS	1.07	0.05	

APPENDIX E

Reserve Exchange Technical Memorandum

Aspect
CONSULTING

MEMORANDUM

Project No.: 120045-011b-01

July 9, 2018

To: Mike Kaputa, Chelan County Natural Resources Department

Pete Cruickshank, Chelan County Natural Resources Department

From:

State of Washington
Hydrogeologist
3025
Licensed Geologist
Jason Michael Shira

7/9/2018

Jason Shira, LHG
Project Hydrogeologist
jshira@aspectconsulting.com

Tyson D. Carlson, LHG
Associate Hydrogeologist
tcarlson@aspectconsulting.com

Re: **Watershed Reserve Analysis**

The Wenatchee Watershed Planning Unit established subwatersheds based on hydrologic characteristics (Figure E-1); Aspect Consulting, LLC (Aspect) prepared this memorandum to examine the hydrogeologic characteristics. The purpose of the watershed reserve analysis is to evaluate the demarcation of the Mission and Wenatchee basins based on the hydrogeology. Determining which surface water body groundwater withdrawals debit will allow Chelan County Natural Resources Department (CCNRD) to maintain a more accurate reserve accounting. Additionally, with passage of Engrossed Substitute Senate Bill (ESSB) 6091, the Mission Creek Basin reserve is evaluated based on Washington State Department of Ecology's (Ecology) new consumptive-use guidance.

Summary of Findings

Defining the Mission Basin boundary with consideration of hydrogeologic characteristics, and evaluating the Mission Basin reserve based on Ecology's new consumptive-use guidance has the following impacts on the Mission Basin reserve:

- Fifteen parcels are reallocated to the Lower Wenatchee River Basin reserve.
- Two parcels are misappropriated to the Mission Reserve due to ministerial errors.
- The total reallocation is equivalent to 0.014 cubic feet per second (cfs).

- Applying the ESSB 6091 consumptive-use guidance extends the Mission Basin reserve by two parcels, or 0.0002 cfs.
- The total credit to the Mission Basin reserve due to reallocation and new consumptive-use calculation is 0.0142 cfs.
- The total number of parcels that have been charged to the Mission Reserve since 2008 incorporating the new hydrogeologic framework is 25. The available reserve will support 33 houses with outdoor use under the modified consumptive-use guidance from Ecology. The Mission Basin reserve was depleted in 2018, based on actual growth rates from 2008 through 2016.

Aspect (Aspect, 2013) determined that annual average outdoor consumptive-use is 898 gallons per day (gpd) over an average 0.17-acre area, based on aerial image analysis of 11parcels in the Mission Basin. The annual average outdoor consumptive-use in the Mission Basin represents approximately 25 percent of the average permit-exempt annual outdoor consumptive-use within the Wenatchee Basin, 243 gpd over a 0.06-acre area. It is possible to extend the reserve further through:

- Implementation of conservation measures to reduce outdoor water use.
- Revision of the outdoor consumptive-use analysis by increasing the sample number of parcels evaluated with aerial imagery and a window survey to determine if the 0.17-acre area is representative of the Mission Basin.
- A water right evaluation of parcels charged to the reserve to determine if irrigation is authorized by a state water right.

Groundwater withdrawals from wells completed in glaciofluvial sediments and Chumstick sandstone within the Cashmere sedimentary basin are likely to impact the Wenatchee River and not Mission Creek or Brender Creek as assumed by the surface hydrology. The basin divide is based on the following findings:

- Mission Creek and the primary water supply aquifer are hydraulically separated by an unsaturated zone and 10 feet of clay north of Jones Road to the city limits.
- Brender Creek and the primary water supply aquifer are hydraulically separated by an unsaturated zone and 20 feet of lacustrine clay across the Cashmere sedimentary basin to the city limits.

The primary water supply aquifer in the Cashmere sedimentary basin is in hydraulic continuity with the Wenatchee River. Additionally, the primary water supply aquifer hosted by the unconsolidated sediments in the Cashmere sedimentary basin are in hydraulic continuity with the groundwater hosted by Chumstick sandstone; therefore, groundwater withdrawals from the Chumstick sandstone within the Cashmere sedimentary basin are also in hydraulic continuity with the Wenatchee River.

The basis of our findings is presented below.

Background

The Wenatchee Watershed Plan establish a reserve of 4 cfs for the entire Water Resource Inventory Area (WRIA). The reserve is allocated by subwatershed and was estimated to provide a year-round reliable supply of water for specific future uses in WRIA 45 through 2025 in a manner that would not impair aquatic resources. The reserve includes use of groundwater or surface water sources depending on site-specific conditions. The reservation was split among subwatersheds and between the upper and lower watershed to ensure that sufficient water is available to service growth, based on water use forecasts and Growth Management Act population allocations.

The following water uses qualify for the reserve and would not be subject to interruption when instream flows are not met:

- Domestic use: Water to satisfy the human domestic needs of a household or business, including water used for drinking, bathing, sanitary purposes, cooking, laundering, care of household pets, and outdoor irrigation of up to 0.5 acres of associated lawn or garden per dwelling, and other incidental uses. For permit-exempt, domestic water use of groundwater sources, total outdoor watering for multiple residences shall be consistent with the groundwater permit exemption provisions in RCW 90.44.050.
- Municipal use: Water to satisfy uses (including residential, commercial, and industrial) that are provided by a municipal water system within its water service area.
- Stock water use (except feedlots): Water use must be consistent with the Chelan County Code, Section 11.88.030 or any subsequent amendments.

Water uses that are not provided for by the reservation include:

- New commercial or industrial uses that require water right permits and are located outside of a municipal purveyor’s water service area;
- New agricultural uses; and
- Any uses not specified under Reserved Uses.

Uses that are not eligible for water from the reserve will need to obtain water by acquiring valid water rights or water rights through a water bank.

Flexibility was built into the distribution of the reserve over the watershed. General rules that apply to the distribution of the reserve and to the approved use of reserve water are as follows:

- Wenatchee Watershed (WRIA 45) reservation cannot exceed 4 cfs in total, including:
  - Lower WRIA Reserve cannot exceed 3.5 cfs
  - Upper WRIA Reserve cannot exceed 1.0 cfs
- General rule for individual watershed reservations are limited to the greater of:
  - Amount projected to meet 2025 water use needs
  - Amount that does not exceed 1 percent habitat loss
  - With the following exception: Mission Creek**,** 0.03 cfs with conditions for 2 years after rule adoption.

Consumptive Uses Analysis

Following passage of ESSB 6091, Ecology developed a guidance for estimating water use by permit-exempt domestic wells. Ecology's recommendation for estimating consumptive use is to assume 60 gallons per day per capita (gpd/capita) and a consumptive-use (CU) percentage of 10 percent of total indoor use. In CCNRD's assessment of the reserve through 2011 (Aspect, 2013) the accounting assumed 200 gpd per exempt well, based on Washington Department of Health *Water System Design Manual* (WDOH, 2009) and a consumptive factor of 30 percent. In addition, outdoor CU was estimated through aerial imagery analysis of irrigated area on parcels served by permit exempt wells. The aerial analysis revealed that parcels in the Mission Basin, served by permit- exempt wells, have an average irrigated area of 0.17 acres. This is the largest average irrigated area per parcel and highest total irrigation requirements for the Wenatchee Basin.

Using Ecology's recommended assumptions and actual growth rates through 2016 results in the following reserve accounting changes from the previous analysis.

	200 GPD, 30 Percent CU	**60 GPD/Capita, 10 Percent CU**
Reserve Depletion Year	2013	2015
Number Parcels Served [1]	31	33

[1] Assumes one house per parcel (2.04 persons per house) and all parcels have outdoor use

The actual growth rate (parcels per year) from 2008 through 2016 is 5.13, which is lower than the 6.86 parcels per year assumed in the Wenatchee Watershed Management Plan (WWPU, 2006).

Mission Creek Basin

The Mission Creek Basin encompasses the watershed that drains surface water to Mission Creek above its confluence with the Wenatchee River. This includes the major tributaries (Brender and Yaksum creeks) to Mission Creek. Brender and Mission creeks historically drained into an oxbow of the Wenatchee River. It is presumed the oxbow was filled with building of the Cashmere Mill, and Mission and Brender creeks were rerouted to the east, around the mill site. Brender Creek was routed into the current Mission Creek location just above the confluence. Figure E-2 is the 1901 USGS topographic survey that shows the historic and current locations of the Mission Creek and Brender Creek.

The control station for the Mission Creek Basin is Ecology Station ID 45E070 for instream flows based on watershed planning (Washington Administrative Code [WAC] 173-545-060). The streamflow monitoring station is located at river mile (RM) 0.2 of Mission Creek, as shown on Figure E-2. The control station is upstream of the Brender Creek confluence with Mission Creek. Therefore, streamflow contribution from Brender Creek is not captured by the basin control station.

Regional Geology

Structural setting, geologic history, and occurrence of groundwater provide the basis for our interpretation of the hydrogeology of the project area. The Mission Basin is located within the Chiwaukum graben within the Cascade Crystalline Core of the North Cascades geologic province. Today, the sedimentary rocks of the Eocene Chumstick Formation are bounded by two major northwest-southeast trending fault zones: the Leavenworth Fault to the west and the Entiat Fault to the east. These faults separate the mainly sedimentary deposits of the Chumstick Formation from the surrounding metamorphic rocks and flood basalts of the Columbia River Basalt Group as shown on Figure E-3.

The Chumstick Formation is a consolidated nonmarine sedimentary deposit formed during a period of extensional tectonics after the cessation of the Late Cretaceous Laramide orogeny. The Chumstick Formation is a white sandstone with varying amounts of shale, conglomerate, fanglomerate, and rare siliceous tuff (Tabor et al., 1982). Overlying the Chumstick Formation are unconsolidated sediments deposited by glaciofluvial, eolian, and alluvial processes. The resultant overlying sedimentary deposits create an angular unconformity with the underlying Chumstick sandstone.

The unconsolidated sediments within the Cashmere sedimentary basin are primarily derived from glacial activity during the Pleistocene and into the Holocene. Alpine glaciers originating from Mount Stuart provided glacial material and meltwater to transport sand and gravel into the Cashmere Sedimentary Basin. Likewise, lake deposits (glacial lacustrine sediments) accumulated within the Cashmere Sedimentary Basin due to flooding behind temporarily damned Wenatchee River and Columbia River (e.g., Glacial Lake Missoula outburst floods). Following glacial activity, streams have been downcutting the glacial deposits, and surficial alluvial deposits have formed from modern stream processes.

Hydrostratigraphic Units

The area of interest (herein referred to as the Cashmere Sedimentary Basin) and surficial geology is shown on Figure E-4. Geologic unit and structural data from the Washington State Department of Natural Resources (DNR, 2018), and select water well log data from the Ecology's online water well database (Ecology, 2018; included as Attachment 1) were used to develop the subsurface interpretation. This interpretation is presented in cross section as Figures E-5 and E-6. Local data indicate that there are two principal geologic units within the area of interest. From younger to older, these are the unconsolidated quaternary sediments and the Chumstick Formation sandstone. The characteristics and distribution of each unit is described as follows:

- **Quaternary Sediments** – The quaternary sediments are comprised of glacial lacustrine, terrace, loess, and alluvial deposits. The thickness of the quaternary sediments ranges from less than 10 feet to greater than 115 feet thick across the Cashmere Sedimentary Basin from land surface to the top of the underlying consolidated Chumstick Formation sandstone.

  The sedimentary deposit is stratified with alternating well-sorted water-bearing sand and gravel units and poorly sorted clay units with gravel to cobbles. The clay units are laterally and vertically extensive, creating semiconfining aquifer conditions.

- **Chumstick Formation Sandstone** – The Chumstick Formation Sandstone (sandstone) is the basement rock of the Mission Creek Basin. The depth to sandstone across the Cashmere Sedimentary Basin is greater than 115 feet below ground surface. None of the located wells penetrate the full thickness of the Cashmere Sedimentary Basin.

Aquifer Characteristics

The aquifer is semiconfined, and vertically anisotropic due to stratification. The effective saturated hydraulic conductivity and transmissivity of the sedimentary deposits is approximately 400 feet/day and 20,000 square feet per day (ft^2/d), respectively, based on airlift tests. The hydraulic conductivity and transmissivity of the sandstone is approximately 0.2 feet/day and 50 ft^2/d, based on pumping tests.

Review of static water levels and well logs indicates water-bearing zones of the unconsolidated sedimentary and sandstone units are in hydraulic continuity. An upward vertical gradient from the sandstone units to the overlying unconsolidated sedimentary unit around the perimeter sedimentary basin. The higher potentiometric surface of sandstone aquifer in this area is due to the localized higher elevation recharge zones. A barrier to groundwater flow between the unconsolidated sedimentary unit and the sandstone is not present; however, the lower hydraulic conductivity of the sandstone unit results in attenuated pumping and recharge affects.

Hydrogeologic Conceptual Model

The Chumstick Formation sandstone forms the structural basin that hosts the unconsolidated sedimentary units. Directly overlying the sandstone are stratified glaciofluvial deposits that are the primary unit for water supply wells. Overlying the glaciofluvial deposits is a glacial lacustrine deposit that forms a locally extensive confining unit. Overlying, intervening, and possibly truncating the glacial lacustrine deposit are terrace deposits across a large central portion of the Cashmere Sedimentary Basin. Overlying and incising the glacial deposits are alluvial deposits derived from Mission Creek and Brender Creek, and small alluvial fan deposits derived from the steep surrounding hillsides.

Mission Creek flows atop a clayey sand and gravel deposit (alluvium) that is stratified with clayey units that both perch and confine water bearing zones. The glacial lacustrine unit appears to extend past Woodring Canyon within the Mission Canyon (approximately 940 feet above mean sea level [amsl]). and extends up Brender Canyon to an unknown elevation (greater than 1020 feet amsl).

Mission Creek and Brender Creek appear to have incised older unconsolidated deposits (e.g., glacial lacustrine sediments). For example, the glacial lacustrine layer appears discontinuous between the terminus of Mission Canyon and Woodring Canyon. The discontinuous nature of the glacial lacustrine clays is presumed to represent where fluvial action has channelized portions of the glacial lacustrine layer. Whereas, Brender Creek has not incised the underlying units as great as Mission Creek likely due to smaller volume and intensity peak flow events. It is our interpretation that the glacial lacustrine unit largely separates the primary water supply unit from the Mission Creek and Brender Creek forming a semiconfining unit across the greater Cashmere Sedimentary Basin.

Surface Water – Groundwater Interaction

Previous work (Ecology, 2003 and AMEC, 2010) indicated that Mission Creek loses surface water to groundwater below the Yaksum Creek confluence. Surface water losses to the ground occur under two scenarios: saturated, vertical downward gradient; or an unsaturated, infiltration under the influence of a matric potential. When the vertical profile between the surface water body and the water table are saturated, pumping groundwater can induce greater infiltration; however, pumping does not affect surface water when the vertical profile is unsaturated. To evaluate surface water and groundwater interaction the potentiometric surface of the unconsolidated sedimentary unit was mapped, and two cross-sections were developed.

The potentiometric surface of the unconsolidated sedimentary unit was mapped across the Cashmere Sedimentary Basin and terminus of Brender and Mission canyons to evaluate groundwater flow direction. 100 representative well logs were selected from Ecology's database and located to the parcel level. The potentiometric surface was derived using the static water level from the driller's log and ground surface elevation (USDA, 2018). The potentiometric map on Figure E-7 shows from south to north along Mission Creek that:

- Flow from Yaksum Canyon influences the potentiometric surface in Mission Canyon; and
- The groundwater flow direction generally follows Mission Creek.

Along Brender Creek, the potentiometric map shows that from west to east:

- Groundwater flow direction generally follows Brender Creek; and
- The hydraulic gradient increases across the terrace.

There is a shallow groundwater divide trending south-southwest to north-northeast near the center of the potentiometric map.

Comparison of potentiometric surfaces suggest Mission Creek and Brender Creek lose water to the ground. The vertical separation across the Cashmere Sedimentary Basin is sufficient to suggest that an unsaturated condition is present between the creeks and primary water supply aquifer.

Two cross sections are presented on Figures E-5 and E-6. The locations of the cross sections are presented on Figure E-4. Cross-section A-A' shows the thick confining unit (presumed glacial lacustrine) that persists across the western to central portion of the Cashmere Sedimentary Basin, and the associated potentiometric surface. Cross section B-B' shows a truncated confining unit and the influence of subsurface flow from Yaksum Canyon on the potentiometric surface. Cross-section B-B' highlights the discontinuous nature of the confining unit, and how the extent of a confining unit results in a semiconfining aquifer condition.

Conclusions

Pumping groundwater for permit-exempt beneficial use within the hydrogeologic defined basin is anticipated to transmit stream depletion onto the Wenatchee River. Present-day Brender Creek and Mission Creek are hydraulically separated from the primary water supply aquifer within the hydrogeologic basin shown on Figure E-8 based on:

- The vertical separation between potentiometric surfaces that suggests an unsaturated condition exists between surface water and groundwater.
- The presence of a thick (~20 feet) clayey unit that forms a confining unit that effectively increases that hydraulic continuity of the aquifer with the Wenatchee River.
- The potentiometric surface, shown on Figure E-8, is largely a representation of a semiconfined stratified aquifer hosted within the unconsolidated glaciofluvial sediments.

The present-day channels of Brender and Mission Creek follow the general pathway surface water flowed during the period the glaciofluvial sediments were deposited. The apparent groundwater divide may represent the stream corridors from Brender and Mission canyons during the period of glaciofluvial sediment deposition.

Defining the Mission Basin on hydrogeologic characteristics adds the Cashmere Sedimentary Basin to the Wenatchee River Basin and truncates the Mission Basin to near the terminus of Brender and Mission canyons. This potential change of the basin boundary reallocates reserve quantities from the Mission Basin to the Wenatchee Basin.

As seen on Figure E-8, changing the basin boundary reallocates 15 parcels to the Lower Wenatchee River Basin reserve. In addition, 2 parcels were mistakenly allocated the Mission Basin reserve. A total of 17 parcels, or 0.0154 cfs based on the revised consumptive-use calculations and boundary modification, should be reallocated to the Lower Wenatchee River reserve and reported in the next Reserve Allocation Report by CCNRD to Ecology in 2020. In addition, using the updated consumptive-use calculations extends the reserve from 2013 to 2015. A total of 25 parcels have been charged to the Mission Reserve since 2006 thru 2016, incorporating the new hydrogeologic framework. The available reserve will support 33 houses under the modified consumptive-use guidance from Ecology. Combined with the reallocation, the Mission Basin reserve is extended into 2018.

Recommendations and Next Steps

Basins are more accurately defined when hydrogeologic characteristics are considered along with topography. The hydrogeologic characteristics allow for water resource managers to accurately account where surface water impacts are likely to accrue due to growth in permit-exempt water use. This appraisal level review is based on well logs provided by drillers for domestic and municipal water supply. This level of analysis and dataset may not provide the level of certainty necessary change the Basin boundaries for administration of the reserve for permit-exempt beneficial use. Aspect recommends CCNRD work with stakeholders and Ecology to determine what level of certainty is necessary to carry forward modification of the Mission Basin boundary. An example of work-plan elements should include:

- Installation of instream piezometers and monitoring wells in a transect to monitor water levels and vertical gradients over time.
- Detailed collection of lithology over maximum 2-foot centers, and water levels during monitoring well installation.

Additionally, Aspect recommends CCNRD:

- Update the outdoor consumptive-use analysis by increasing the number of parcels evaluated with aerial imagery, and a window survey to determine if the 0.17-acre area is representative of the Mission Basin.
- Evaluate parcels authorized under the reserve to determine if irrigation is attributed to a state water right.
- Work with local stakeholder concerning implementation of outdoor water-use conservation measures to limit outdoor lawn irrigation.

- Implement a geographic interface for allocating parcels to basin reserves to prevent misappropriations.

References

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Limitations

Work for this project was performed for the Chelan County Natural Resources Department (Client), and this memorandum was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This memorandum does not represent a legal opinion. No other warranty, expressed or implied, is made.

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Attachments:

Figure E-1 – Mission Creek Basin
Figure E-2 – 1901 USGS Topographic Survey
Figure E-3 – Mission Creek Basin Surficial Geology
Figure E-4 – Cashmere Sedimentary Basin Surficial Geology
Figure E-5 – Cross Section A-A’
Figure E-6 – Cross Section B-B’
Figure E-7 – Groundwater Contours
Figure E-8 – Mission Creek Hydrogeologic Basin

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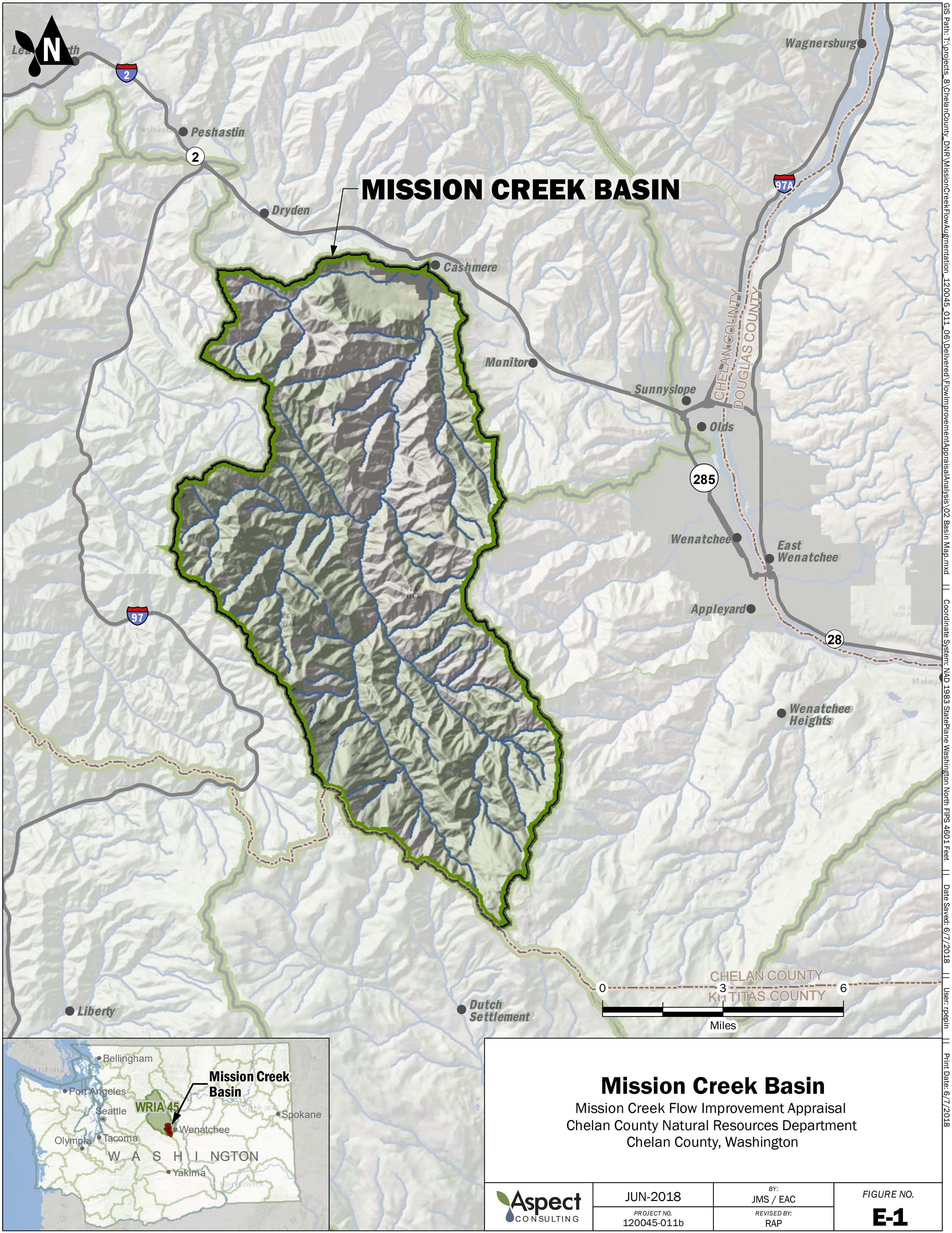
FIGURES



Mission Creek Basin

Mission Creek Flow Improvement Appraisal
Chelan County Natural Resources Department
Chelan County, Washington

Aspect CONSULTING	JUN-2018	BY: JMS / EAC	FIGURE NO.
	PROJECT NO. 120045-011b	REVISED BY: RAP	E-1

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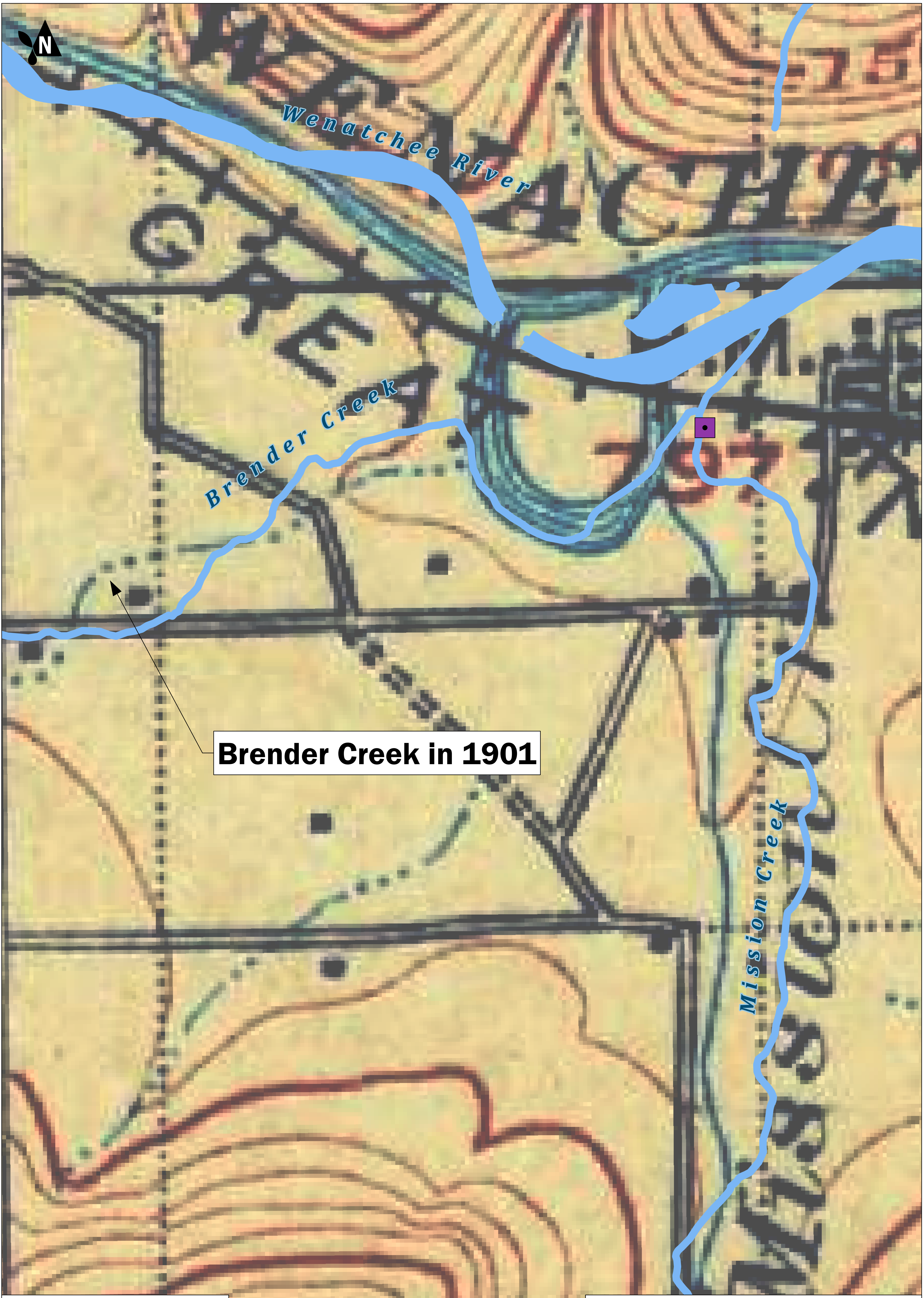
Basemap Layer Credits || Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap



■ Ecology Station ID 45E070

〜 Modern Water Bodies

0 375 750
Feet

1901 USGS Topographic Survey

Mission Creek Flow Improvement Appraisal
Chelan County Natural Resources Department
Chelan County, Washington

JUN-2018	BY: JMS / TDR	FIGURE NO.
PROJECT NO. 120045-011b-01	REVISED BY: - - -	E-2

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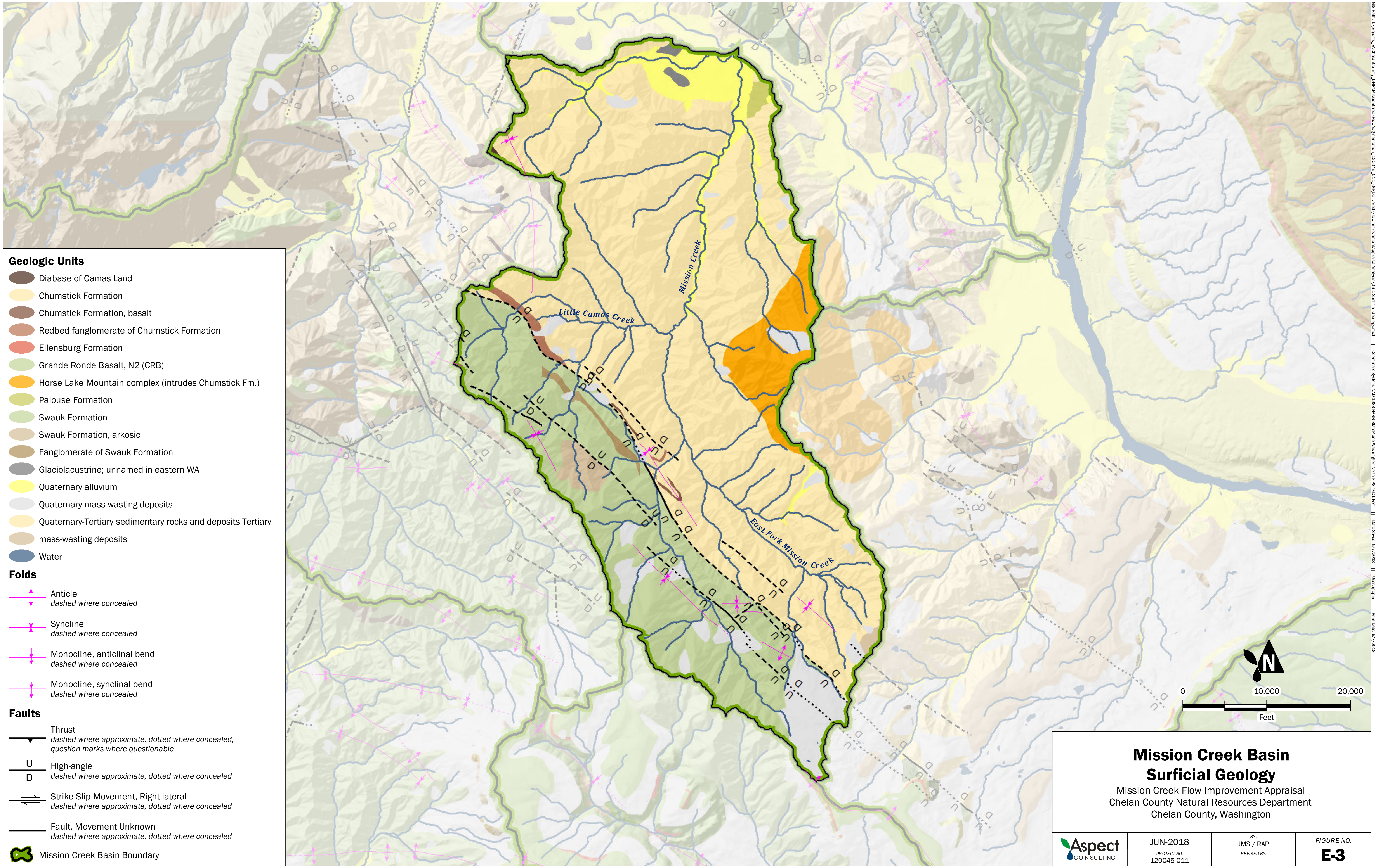


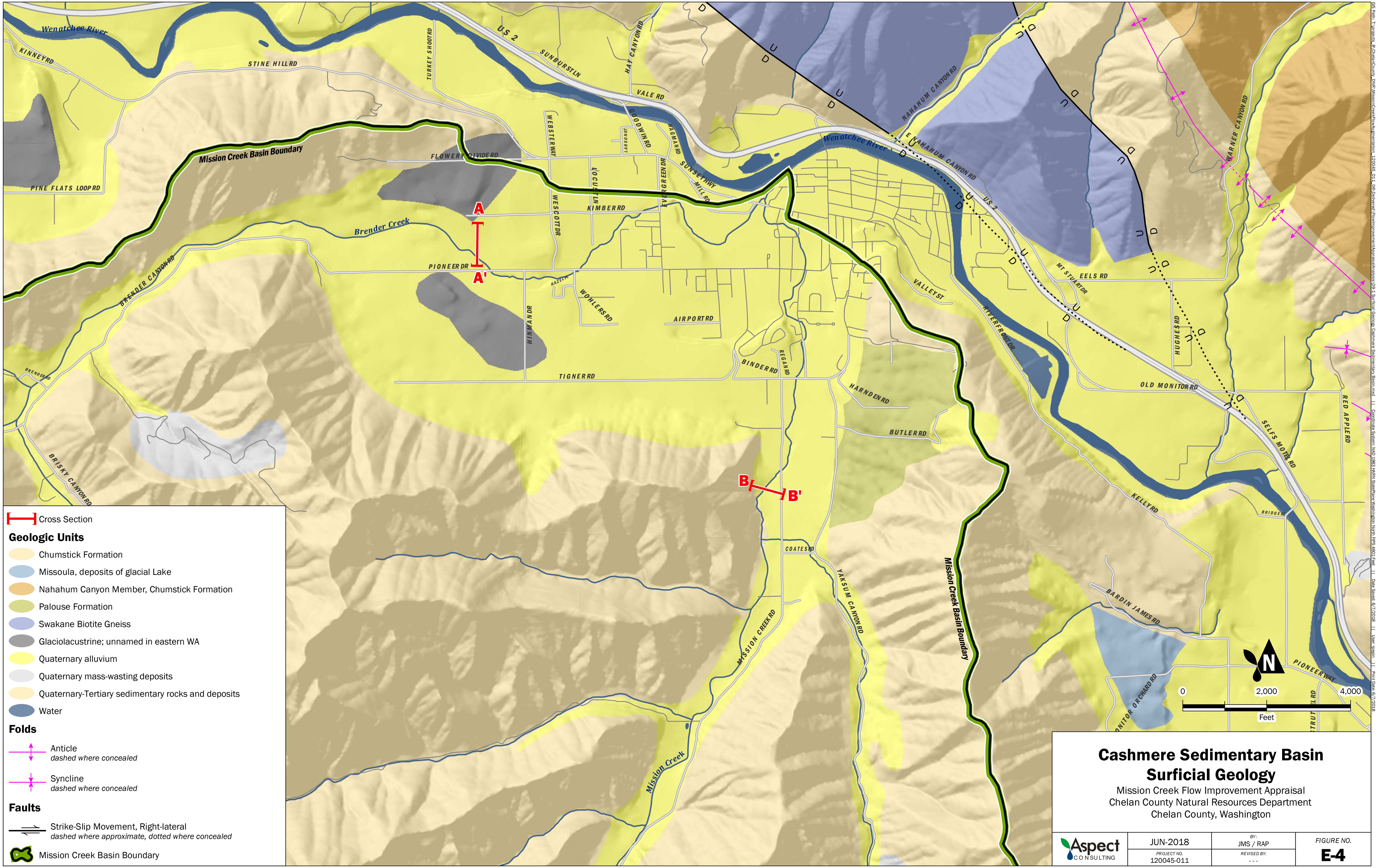
Mission Creek Basin Surficial Geology

Mission Creek Flow Improvement Appraisal
Chelan County Natural Resources Department
Chelan County, Washington

Aspect CONSULTING

JUN-2018
PROJECT NO. 120045-011
BY: JMS / RAP
REVISED BY: - - -
FIGURE NO. **E-3**

GIS Path: T:\projects_8\ChelanCounty_DNR\MissionCreekFlowAugmentation_120045_011_06\Delivered\FlowImprovementAppraisalAnalysis\06-1 Surficial Geology.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 6/7/2018 || User: rpepin || Print Date: 6/7/2018



Cashmere Sedimentary Basin Surficial Geology

Mission Creek Flow Improvement Appraisal
Chelan County Natural Resources Department
Chelan County, Washington

Aspect CONSULTING	JUN-2018	BY: JMS / RAP	FIGURE NO. **E-4**
	PROJECT NO. 120045-011	REVISED BY: - - -	

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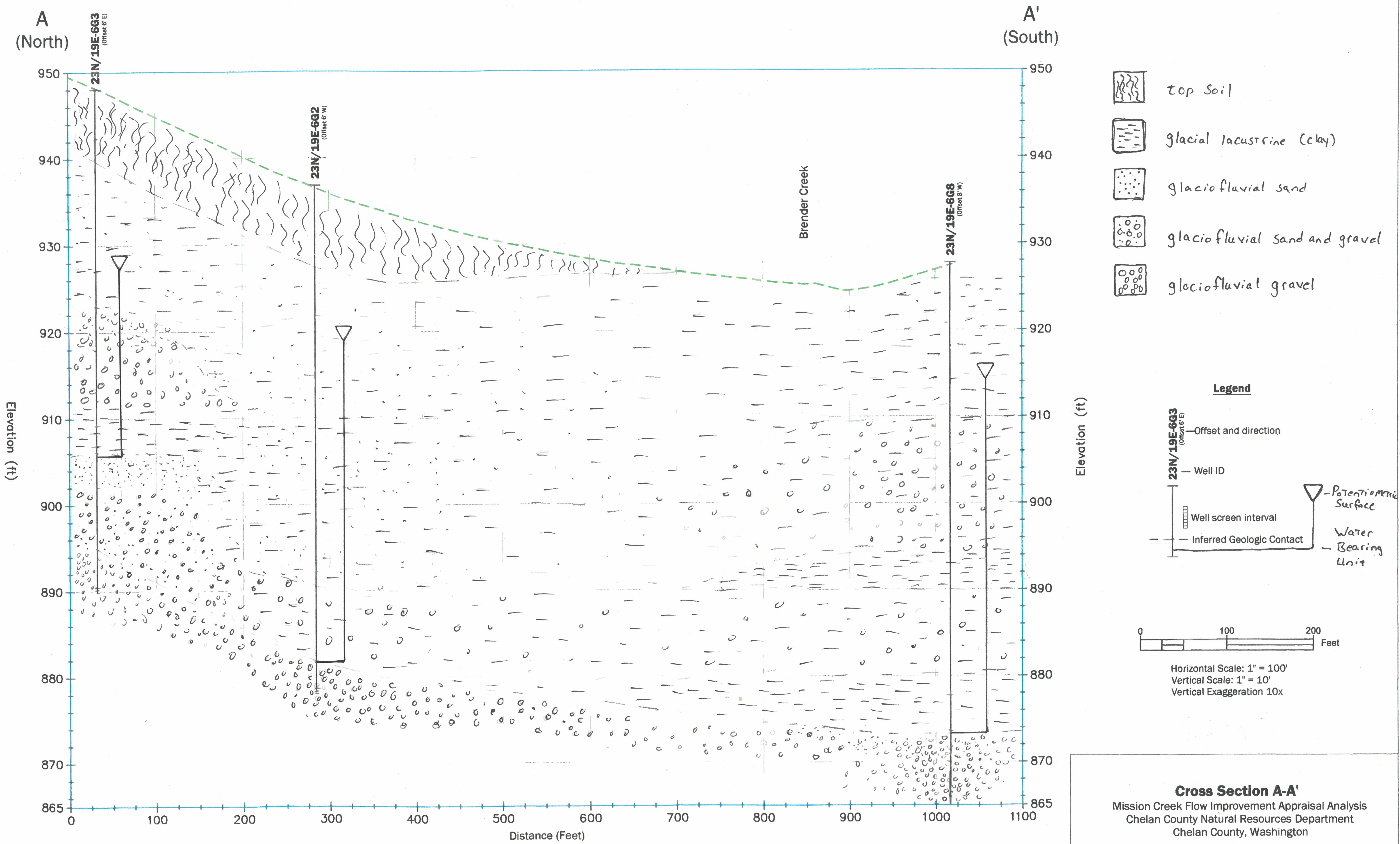

Cross Section A-A'

Mission Creek Flow Improvement Appraisal Analysis
Chelan County Natural Resources Department
Chelan County, Washington

Aspect CONSULTING	May-2018 PROJECT NO. 120045-011b-01	BY JMS/CMV REVISED BY -	FIGURE NO. E-5

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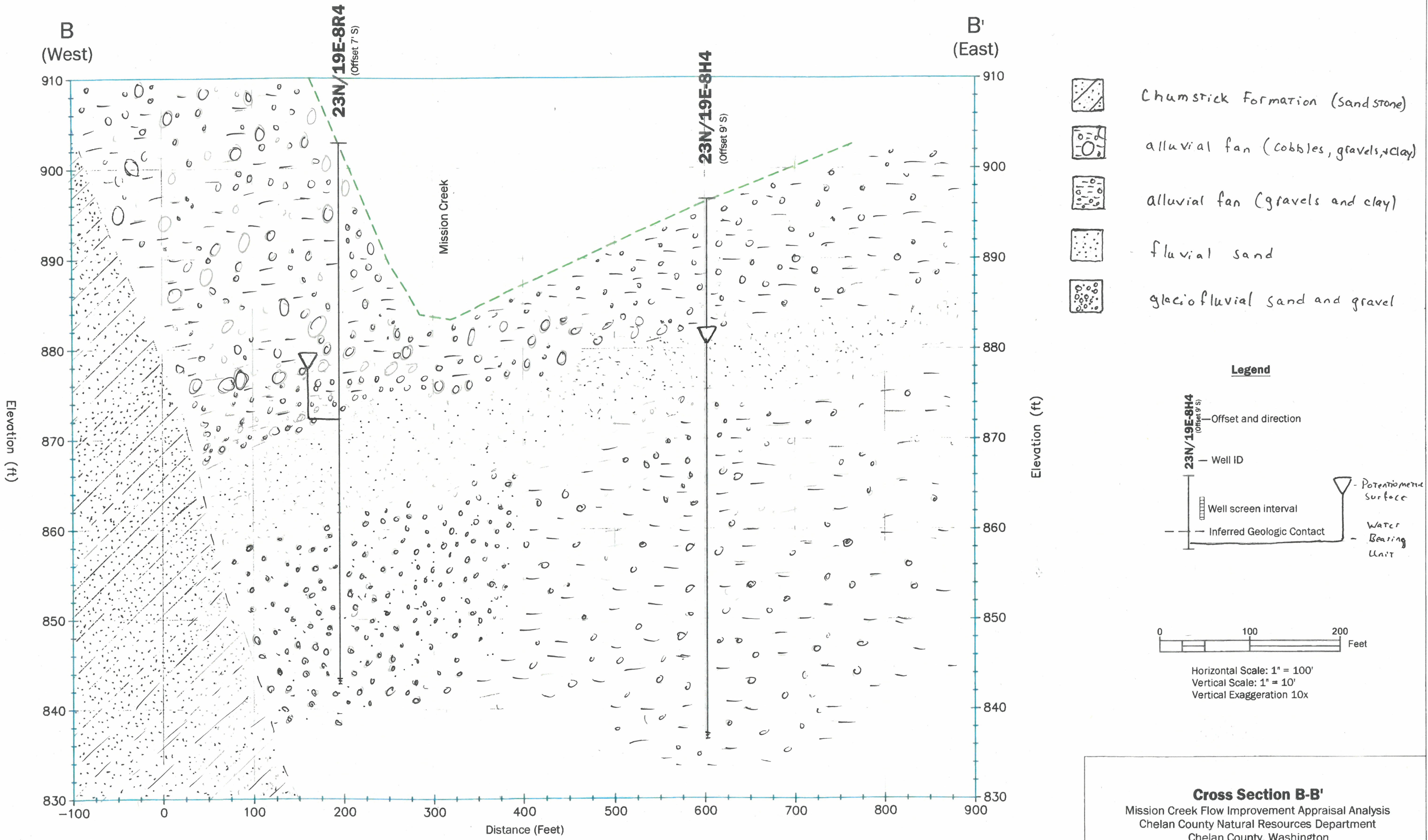

Cross Section B-B'

Mission Creek Flow Improvement Appraisal Analysis
Chelan County Natural Resources Department
Chelan County, Washington

Aspect CONSULTING	May-2018	BY: JMS/CMV	FIGURE NO. E-6
	PROJECT NO. 120045-011b-01	REVISED BY: -	

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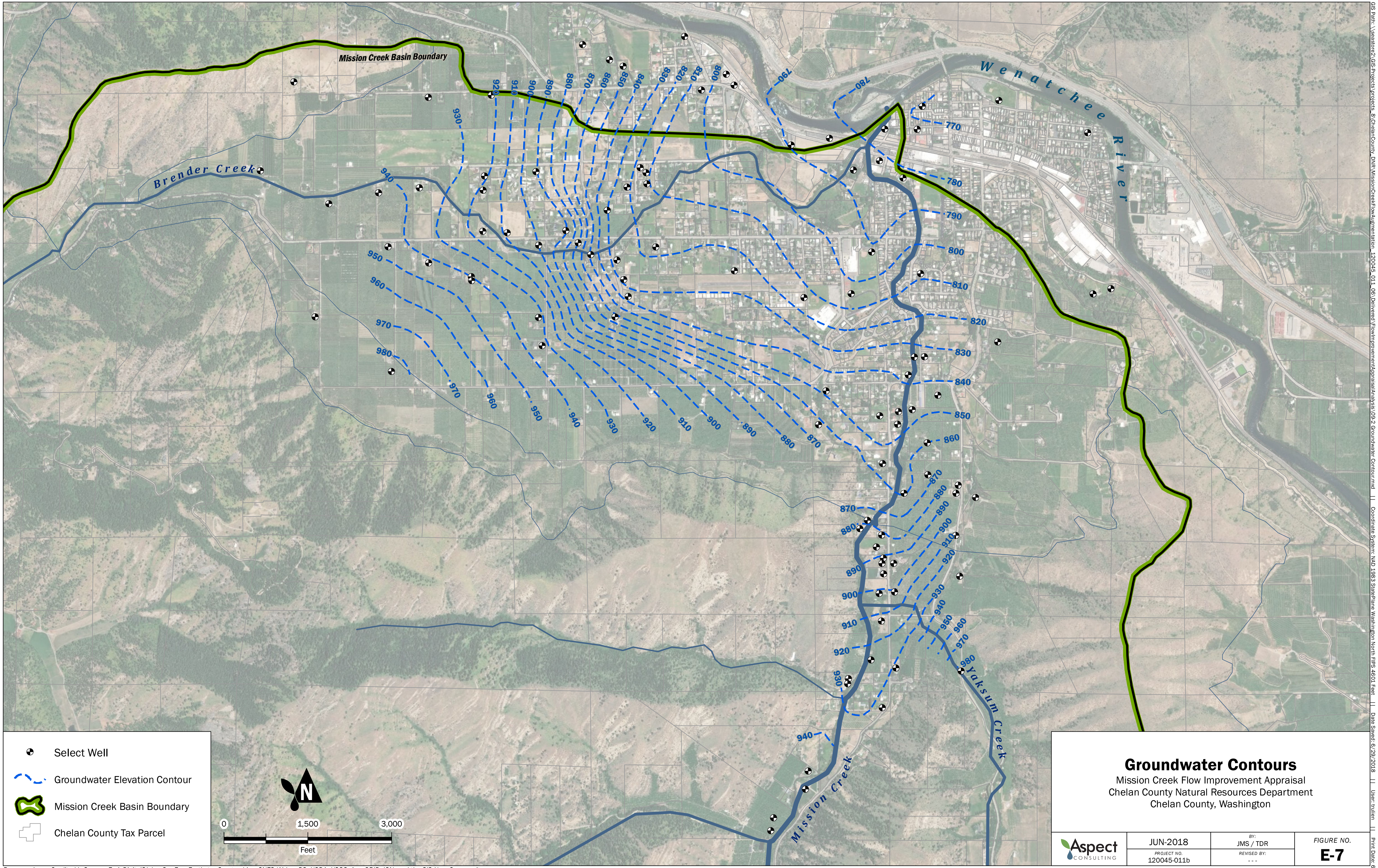

Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Groundwater Contours

Mission Creek Flow Improvement Appraisal
Chelan County Natural Resources Department
Chelan County, Washington

Aspect CONSULTING

JUN-2018	BY: JMS / TDR	FIGURE NO.
PROJECT NO. 120045-011b	REVISED BY: - - -	E-7

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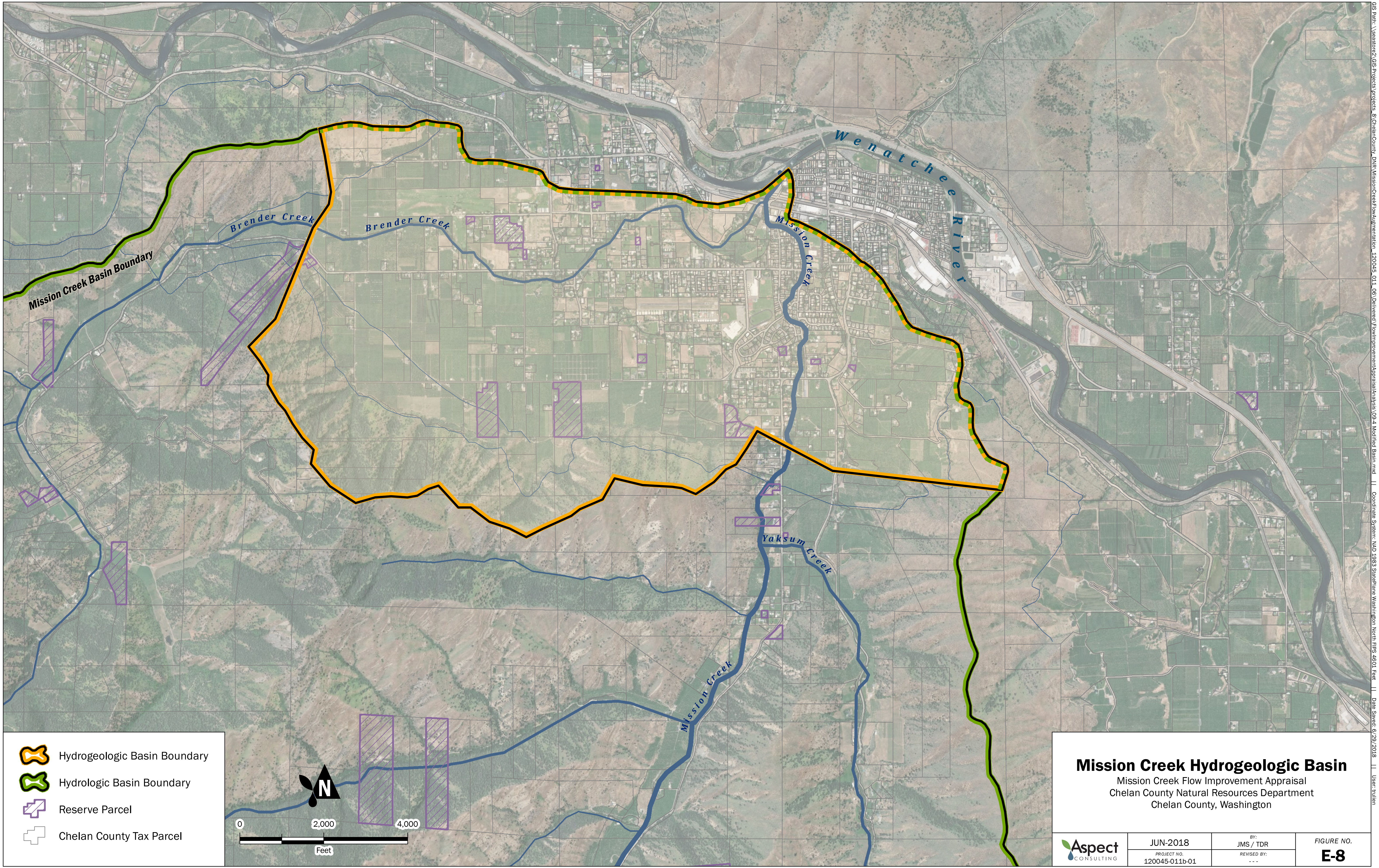

Mission Creek Hydrogeologic Basin

Mission Creek Flow Improvement Appraisal
Chelan County Natural Resources Department
Chelan County, Washington

Aspect CONSULTING	JUN-2018	BY: JMS / TDR	FIGURE NO. **E-8**
	PROJECT NO. 120045-011b-01	REVISED BY: - - -	

Basemap Layer Credits || Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

GIS Path: \\seastore2\GIS-Projects\projects_8\ChelanCounty_DNR\MissionCreekFlowAugmentation_120045_011_06\Delivered\FlowImprovementAppraisalAnalysis\09-4 Modified Basin.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 6/29/2018 || User: trulien

APPENDIX F

Conceptual Cost Estimates

Table F-1. Cost Estimate, Alternative 3, Wenatchee Pump Exchange

Project No 120045, Mission Creek Flow Improvement Appraisal,
Chelan County Department of Natural Resources

					Alternative 3	
Item	**Description**	**Unit**	**Unit Cost**	**QTY**	**Total Cost**	**Notes**
1.0	**General**				**$677,000**	
1.1	Mobilization (10% Construction Subtotal)	LS	$539,000	1	$539,000	10% of construction subtotal
1.2	TESC	LS	$37,000	1	$37,000	4,000 LF silt fence, $100/day CESCL @ 90day, $5,000 misc.
1.3	Temporary Traffic Control	LS	$101,000	1	$101,000	$100 / hr, 8 hr / day @ 120 day +$5,000 misc
2.0	**Site Preparation / Demo**				**$45,000**	
2.1	Clearing and grubbing	AC	$2,500	5	$12,500	$2,500 / acre. Average reasonable WSDOT low bids
2.2	Temporary Access Roads	LF	$50	500	$25,000	temporary grading to accommodate access to challenging areas
2.3	Site Grading	CY	$15	500	$7,500	miscellaneous grading
3.0	**Surface Water Pump Station (Wenatchee River)**				**$674,000**	
3.1	Miscellaneous Site Work	LS	$105,000	1	$105,000	COIC Pump Exchange, 6-cfs Alternative
3.2	Structure	LS	$60,000	1	$60,000	COIC Pump Exchange, 6-cfs Alternative
3.3	Screen	LS	$24,000	1	$24,000	COIC Pump Exchange, 6-cfs Alternative
3.4	Cleaning System	LS	$60,000	1	$60,000	COIC Pump Exchange, 6-cfs Alternative
3.5	Pumps	LS	$260,000	1	$260,000	COIC Pump Exchange, 6-cfs Alternative
3.6	Power Extension	LS	$50,000	1	$50,000	COIC Pump Exchange, 6-cfs Alternative
3.7	Controls	LS	$85,000	1	$85,000	COIC Pump Exchange, 6-cfs Alternative
3.8	Miscellaneous Site Plumbing	LS	$30,000	1	$30,000	COIC Pump Exchange, 6-cfs Alternative
4.0	**Pipeline**				**$4,066,250**	
4.1	16" Steel Pipeline - Paved Surface Restoration	LF	$200	8,000	$1,600,000	RS Means, $155 pipe + $5 ex + $5 backfill + $35 paved surface
4.1	16" PVC Pipeline - Paved Surface Restoration	LF	$80	12,500	$1,000,000	RS Means, $35 pipe + $5 ex + $5 backfill + $35 paved surface
4.2	12" PVC Pipeline - Paved Surface Restoration	LF	$70	6,250	$437,500	RS Means, $25 pipe + $5 ex + $5 backfill + $35 paved surface
4.3	8" PVC Pipeline - Paved Surface Restoration	LF	$63	6,250	$393,750	RS Means, $18 pipe + $5 ex + $5 backfill + $35 paved surface
4.4	Relocation of Existing Utilities and Structural Conflicts	LS	$250,000	1	$250,000	Allowance for misc relocation of unidentified utilities and structural conflicts
4.5	Pipeline Appurtenances (Air-Valves, Blow-Offs, Etc.)	LS	$25,000	1	$25,000	Assumes 4x air valve and 4x blow off
4.6	Stream Crossing	EA	$30,000	7	$210,000	Assumes hanging from existing bridge sufficient
4.7	Railway Crossing	LS	$150,000	1	$150,000	Assumes bore / jacked casing
	Construction Subtotal				**$5,462,250**	
	Washington State Sales Tax			8.2%	$448,000	8.2% per Department of Revenue
	Direct Cost Total (Hard Cost)				**$5,910,250**	
	Indirect Cost Total (Soft Cost)			25%	$1,478,000	Exhibit B-5 and B-6 of WSDOT Manual for Planning Level Cost Estimating (December 2012)
	Base Cost Total				**$7,388,250**	
	Contingency Reserves			25%	$1,847,000	
	Total Cost				**$9,235,250**	

Table F-2. Cost Estimate, Alternative 4, Regional Water Provider

Project No 120045, Mission Creek Flow Improvement Appraisal,
Chelan County Department of Natural Resources

Alternative 4						
Item	**Description**	**Unit**	**Unit Cost**	**QTY**	**Total Cost**	**Notes**
1.0	**General**				**$275,000**	
1.1	Mobilization (10% Construction Subtotal)	LS	$251,000	1	$251,000	10% of construction subtotal
1.2	TESC	LS	$24,000	1	$24,000	2,000 LF silt fence, $100/day CESCL @ 90day, $5,000 misc.
2.0	**Site Preparation / Demo**				**$16,250**	
2.1	Clearing and grubbing	AC	$2,500	1	$2,500	$2,500 / acre. Average reasonable WSDOT low bids
2.2	Temporary Access Roads	LF	$50	200	$10,000	temporary grading to accommodate access to challenging areas
2.3	Site Grading	CY	$15	250	$3,750	miscellaneous grading
3.0	**Pump Station**				**$240,000**	
3.1	Pump and Motor	EA	$15,000	3	$45,000	horizontal, centrifugal pumps
3.2	Automated Control, Panels and Switches, etc.	LS	$75,000	1	$75,000	Motor controls, pressure switches, water level monitoring equipment, telemetry / SCADA
3.3	Flow Meter	EA	$7,500	1	$7,500	12" mag meter (includes utility vault and meter)
3.4	Electrical / Power Supply	LS	$25,000	1	$25,000	3-phase power
3.5	Enclosure for Equipment	SF	$125	100	$12,500	Small shed building
3.6	Site Piping	LF	$300	150	$45,000	Site piping within 50' vicinity of pump station
3.7	Miscellaneous Site Improvements	LS	$5,000	1	$5,000	misc minor mechanical piping / drainage
3.8	Surface Restoration - Gravel Dressing / Access	SY	$25	1000	$25,000	Restoration immediate vicinity of site, minor gravel access
4.0	**Pipeline**				**$2,092,250**	
4.1	20" HDPE Pipe, Above Grade (Anchor Supported)	LF	$200	500	$100,000	RS Means, $62 / LF x 3 for difficult construction
4.2	16" PVC Pipeline - Gravel Surface Restoration	LF	$60	600	$36,000	RS Means, $35 pipe + $5 ex + $5 backfill + $10 gravel surface
4.3	16" PVC Pipeline - Paved Surface Restoration	LF	$80	12,500	$1,000,000	RS Means, $35 pipe + $5 ex + $5 backfill + $35 paved surface
4.4	12" PVC Pipeline - Paved Surface Restoration	LF	$70	6,250	$437,500	RS Means, $25 pipe + $5 ex + $5 backfill + $35 paved surface
4.5	8" PVC Pipeline - Paved Surface Restoration	LF	$63	6,250	$393,750	RS Means, $18 pipe + $5 ex + $5 backfill + $35 paved surface
4.6	Relocation of Existing Utilities and Structural Conflicts	LS	$50,000	1	$50,000	Allowance for misc relocation of unidentified utilities and structural conflicts
4.7	Pipeline Appurtenances (Air-Valves, Blow-Offs, Etc.)	LS	$10,000	1	$10,000	Assumes 2x air valve and 2x blow off
4.7	Connection with Existing System (At Canal)	LS	$5,000	1	$5,000	Turnout upstream of siphon
4.8	Stream Crossing	EA	$30,000	2	$60,000	Assumes hanging from existing bridge sufficient
	Construction Subtotal				**$2,623,500**	
	Washington State Sales Tax			8.2%	$215,000	8.2% per Department of Revenue
	Direct Cost Total (Hard Cost)				**$2,838,500**	
	Indirect Cost Total (Soft Cost)			25%	$710,000	Exhibit B-5 and B-6 of WSDOT Manual for Planning Level Cost Estimating (December 2012)
	Base Cost Total				**$3,548,500**	
	Contingency Reserves			25%	$887,000	
	Total Cost				**$4,435,500**	

Table F-3. Cost Estimate, Alternative 5, Groundwater Flow Augmentation

Project No 120045, Mission Creek Flow Improvement Appraisal,
Chelan County Department of Natural Resources

Alternative 3						
Item	**Description**	**Unit**	**Unit Cost**	**QTY**	**Total Cost**	**Notes**
1.0	**General**				**$22,000**	
1.1	Mobilization (10% Construction Subtotal)	LS	$14,000	1	$14,000	10% of construction subtotal
1.2	TESC	LS	$8,000	1	$8,000	500 LF silt fence, $100/day CESCL @ 30day, $2,500 misc.
2.0	**Site Preparation / Demo**				**$7,500**	
2.1	Demo Ex Wellhead / Plumbing	EA	$1,500	5	$7,500	Removal of existing wellhead / well cap
3.0	**Wellhead Rehabilitation**				**$62,500**	
3.1	Pitless Adapter	EA	$1,000	5	$5,000	Pitless adapters @ $100 + installation
3.1	Pump Replacement	EA	$7,500	5	$37,500	Assumes replacement with new small submersible pump
3.2	Wellhead Cap Replacement	EA	$1,500	5	$7,500	Replacement of upper few feet of casing, new well cap, etc.
3.3	Plumbing, (Valves, Meter, Site Piping, etc.)	EA	$2,500	5	$12,500	isolation valves, tees, meter, vaults check valve, etc.
4.0	**Pipeline and Discharge Structure**				**$53,500**	
4.1	2" to 3" Diameter PVC Pipeline, Hydroseed Surface	LF	$30	1,200	$36,000	RS Means, $3 pipe + $5 ex + $5 backfill + $10 topsoil / hydroseed surface
4.2	Energy Dissipater / Aerator	EA	$2,500	5	$12,500	Terminal structure for energy dissipation / aeration w/ permanent buried anchor
4.3	System Connections	EA	$1,000	5	$5,000	Connection to existing irrigation system
	Construction Subtotal				**$145,500**	
	Washington State Sales Tax			8.2%	$12,000	8.2% per Department of Revenue
	Direct Cost Total (Hard Cost)				**$157,500**	
	Indirect Cost Total (Soft Cost)			35%	$55,000	Exhibit B-5 and B-6 of WSDOT Manual for Planning Level Cost Estimating (December 2012)
	Base Cost Total				**$212,500**	
	Contingency Reserves			25%	$53,000	
	Total Cost				**$265,500**	

Table F-4. Cost Estimate, Alternative 6, Localized Reservoir Augmentation

Project No 120045, Mission Creek Flow Improvement Appraisal,
Chelan County Department of Natural Resources

Alternative 6						
Item	**Description**	**Unit**	**Unit Cost**	**QTY**	**Total Cost**	**Notes**
1.0	**General**				**$30,000**	
1.1	Mobilization (10% Construction Subtotal)	LS	$22,000	1	$22,000	10% of construction subtotal
1.2	TESC	LS	$8,000	1	$8,000	500 LF silt fence, $100/day CESCL @ 30day, $2,500 misc.
2.0	**Site Preparation / Demo**				**$5,000**	
2.1	Clearing	AC	$2,500	2	$5,000	$2,500 clearing
3.0	**Grading and Liner**				**$135,500**	
3.1	Grading	CY	$5	8000	$40,000	Assumes approximately 10 acre foot total capacity, 1/2 volume from cut and 1/2 volume from embankment.
3.1	Import Bedding for Liner	TN	$15	1300	$19,500	Clean , rock-free import material including compaction
3.2	Geomembrane Liner	SY	$15	4400	$66,000	HDPE, 60-mil liner
3.3	Inlet / Outlet Works and Appurtenances	LS	$10,000	1	$10,000	Pipe penetrations at immediate pond vicinity
4.0	**Supply and Discharge Facilities**				**$57,000**	
4.1	Water Supply Facility	LS	$35,000	1	$35,000	Small groundwater well adjacent to stream
4.2	6" Pipeline	LF	$35	200	$7,000	RS Means, $15 pipe + $5 ex + $5 backfill + $10 topsoil / hydroseed surface
4.3	Infiltration Facility	LS	$15,000	1	$15,000	Terminal structure for energy dissipation / aeration w/ permanent buried anchor
	Construction Subtotal				**$227,500**	
	Washington State Sales Tax			8.2%	$19,000	8.2% per Department of Revenue
	Direct Cost Total (Hard Cost)				**$246,500**	
	Indirect Cost Total (Soft Cost)			35%	$86,000	Exhibit B-5 and B-6 of WSDOT Manual for Planning Level Cost Estimating (December 2012)
	Base Cost Total				**$332,500**	
	Contingency Reserves			25%	$83,000	
	Total Cost				**$415,500**	

Table F-5. Cost Estimate, Alternative 7, Alluvial Water Storage

Project No 120045, Mission Creek Flow Improvement Appraisal,
Chelan County Department of Natural Resources

Alternative 6						
Item	**Description**	**Unit**	**Unit Cost**	**QTY**	**Total Cost**	**Notes**
1.0	**General**				**$5,000**	
1.1	Mobilization (10% Construction Subtotal)	LS	$5,000	1	$5,000	10% of construction subtotal
2.0	**Site Preparation**				**$7,500**	
2.1	Material Harvesting	DAY	$1,500	5	$7,500	Daily rate from Poison Creek Design. Assumes site prep and material harvesting will take 5 days across 8,540 foot stream section
3.0	**Structure Construction**				**$37,500**	
3.1	Placement of Key Pieces (≥8-inch DBH)	DAY	$1,500	20	$30,000	Assumes 20-days to place key pieces across 19 structures along a 8,540 foot stream section
3.2	Placement of Logs and Wood Bundles	DAY	$1,500	5	$7,500	Assumes 5-days to place wood bundles and logs to finish construction across 19 structures along a 8,540 foot stream section
	Construction Subtotal				**$50,000**	
	Washington State Sales Tax			8.2%	$4,000	8.2% per Department of Revenue
	Direct Cost Total (Hard Cost)				**$54,000**	
	Indirect Cost Total (Soft Cost)			35%	$19,000	Exhibit B-5 and B-6 of WSDOT Manual for Planning Level Cost Estimating (December 2012)
	Base Cost Total				**$73,000**	
	Contingency Reserves			25%	$18,000	
	Total Cost				**$91,000**	

Table F-6. Preliminary O&M Cost Estimate - Alternative 3

Project No 120045, Mission Creek Flow Improvement Appraisal,
Chelan County Department of Natural Resources

O&M Element	Unit Cost	Unit	Qty	Total Cost
Pipeline				**$6,300**
Preventative Maintenance				**$3,300**
Labor	$75	hr	40	$3,000
Equipment	$25	month	12	$300
Materials	$100	year	1	$100
Operations				**$1,500**
Labor	$75	hr	20	$1,500
Repair / Replacement (Labor, Equipment, Materials)				**$1,500**
Appurtenances	$25,000	year	0.05	$1,000
Misc.	$500	year	1.00	$500
Pump System				**$91,100**
Preventative Maintenance				**$9,900**
Labor	$75	hr	100	$7,500
Equipment	$200	month	12	$2,400
Materials	$1,000	year	1	$1,000
Operations				**$6,000**
Labor	$75	hr	80	$6,000
Repair / Replacement (Labor, Equipment, Materials)				**$18,200**
Mechanical and Electrical Appurtenances	$344,000	year	0.05	$17,200
Misc.	$1,000	year	1.00	$1,000
Power Consumption	**$0.0300**	**kwh**	**1,888,666**	**$57,000**
Total				**$97,400**

Table F-7. Preliminary O&M Cost Estimate - Alternative 4

Project No 120045, Mission Creek Flow Improvement Appraisal,
Chelan County Department of Natural Resources

O&M Element	Unit Cost	Unit	Qty	Total Cost
Pipeline				**$6,300**
Preventative Maintenance				**$3,300**
Labor	$75	hr	40	$3,000
Equipment	$25	month	12	$300
Materials	$100	year	1	$100
Operations				**$1,500**
Labor	$75	hr	20	$1,500
Repair / Replacement (Labor, Equipment, Materials)				**$1,500**
Appurtenances	$10,000	year	0.05	$1,000
Misc.	$500	year	1.00	$500
Pump System				**$29,150**
Preventative Maintenance				**$9,900**
Labor	$75	hr	100	$7,500
Equipment	$200	month	12	$2,400
Materials	$1,000	year	1	$1,000
Operations				**$6,000**
Labor	$75	hr	80	$6,000
Repair / Replacement (Labor, Equipment, Materials)				**$8,250**
Mechanical and Electrical Appurtenances	$145,000	year	0.05	$7,250
Misc.	$1,000	year	1.00	$1,000
Power Consumption	**$0.0300**	**kwh**	**162,092**	**$5,000**
Total				**$35,450**

Table F-8. Preliminary O&M Cost Estimate - Alternative 5

Project No 120045, Mission Creek Flow Improvement Appraisal,
Chelan County Department of Natural Resources

O&M Element	Unit Cost	Unit	Qty	Total Cost
Preventative Maintenance				**$3,900**
Labor	$75	hr	20	$1,500
Equipment	$200	month	12	$2,400
Materials	$1,000	year	1	$1,000
Operations				**$1,500**
Labor	$75	hr	20	$1,500
Repair / Replacement (Labor, Equipment, Materials)				**$3,500**
Mechanical and Electrical Appurtenances	$50,000	year	0.05	$2,500
Misc.	$1,000	year	1.00	$1,000
Power Consumption	**$0.0300**	**kwh**	**9,186**	**$276**
Total				**$9,176**

Table F-9. Preliminary O&M Cost Estimate - Alternative 4

Project No 120045, Mission Creek Flow Improvement Appraisal,
Chelan County Department of Natural Resources

O&M Element	Unit Cost	Unit	Qty	Total Cost
Preventative Maintenance				**$3,900**
Labor	$75	hr	20	$1,500
Equipment	$200	month	12	$2,400
Materials	$1,000	year	1	$1,000
Operations				**$1,500**
Labor	$75	hr	20	$1,500
Repair / Replacement (Labor, Equipment, Materials)				**$2,750**
Mechanical and Electrical Appurtenances	$35,000	year	0.05	$1,750
Misc.	$1,000	year	1.00	$1,000
Power Consumption	**$0.0300**	**kwh**	**9,186**	**$276**
Total				**$8,426**

Table F-10. Preliminary O&M Cost Estimate - Alternative 7

Project No 120045, Mission Creek Flow Improvement Appraisal,
Chelan County Department of Natural Resources

O&M Element	Unit Cost	Unit	Qty	Total Cost
Preventative Maintenance				**$1,800**
Labor	$75	hr	24	$1,800
Equipment	$200	month	0	$0
Materials	$1,000	year	0	$0
Operations				**$0**
Labor	$75	hr	0	$0
Repair / Replacement (Labor, Equipment, Materials)				**$1,000**
Mechanical and Electrical Appurtenances	$35,000	year	0.00	$0
Misc.	$1,000	year	1.00	$1,000
Total				**$2,800**