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DDT Contamination and Transport in the Lower Mission Creek Basin, Chelan County

Total Maximum Daily Load Assessment

October 2004

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DDT Contamination and Transport in the Lower Mission Creek Basin, Chelan County

Total Maximum Daily Load Assessment

by
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Environmental Assessment Program
Olympia, Washington 98504-7710

October 2004

303(d) listings addressed in this study:

Waterbody	Old Segment No.	New Segment No.	Years	Parameters
Mission Creek	WA-45-1011	DQO4NW	1996, 1998	4,4'-DDT, 4,4'-DDE, and DDT

Ecology EIM number: DSER0011

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Abstract

The Washington State Department of Ecology studied DDT in the lower Mission Creek basin during the spring and early summer of 2003. The study was conducted to address federal Clean Water Act section 303(d) listings and develop a total maximum daily load (TMDL) assessment.

DDT and ancillary parameters were analyzed in orchard soils, bed sediments, suspended particulate matter (SPM), and surface waters of Mission, Brender, and Yaksum creeks. Groundwater sampling also was done at two locations.

Results showed that orchard soils contain 5-10 kg DDT/hectare, and concentrations are much higher than in streambed sediments. DDT concentrations and composition in bed sediments are more comparable to SPM, suggesting sediment re-suspension as the primary form of instream transport under a spring flow regime. Approximately 75% of the DDT in the water column is particle-bound. No DDT was detected in groundwater at either of the two sampling locations.

Loads measured during 2003 were generally lower than those found during 2000, probably due to the lower streamflows in 2003. Yaksum Creek continues to deliver at least 80% of the DDT load to Mission Creek.

DDT-TSS regression equations predict that total suspended solids (TSS) concentrations in Brender and Yaksum creeks will need to be reduced to < 1 mg/l in order to meet a target DDT criterion of 1 ng/l t-DDT. Mission Creek should achieve a target DDT load if TSS in Yaksum Creek can be reduced by approximately 40%.

Recommendations include (1) reducing TSS in Yaksum and Brender creeks by preventing bank erosion or by other means of limiting transport of upland soils to streams, (2) conducting detailed assessments of soil input to streams, (3) assessing the influence of the Icicle and Peshastin Canals, and (4) evaluating the possibility of DDT transport through groundwater in lower Brender Creek.

Acknowledgements

The Wenatchee River Basin TMDL study is the result of a partnership between the Department of Ecology and the Water Resource Inventory Area (WRIA) 45 Water Quality Technical Subcommittee (consisting of Ecology TMDL staff and the WRIA 45 Watershed Planning Unit's Water Quality Subcommittee). Ecology authored this TMDL technical report for DDT, and the Water Quality Technical Subcommittee reviewed, discussed, and commented on the report.

The authors of this report would like to thank the following people for their contribution to this study:

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    - Will White and Pam Covey transported and tracked samples.
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Introduction

Mission Creek flows approximately 29 km from its headwaters high in the Cascades to its confluence with the Wenatchee River at the city of Cashmere in central Washington (Figure 1). The basin drains 241 km^2, mostly within the Wenatchee National Forest (WNF). Land use in the lower basin (downstream of the WNF boundary) is largely agriculture, with some rural and urban residential areas becoming denser near the mouth.

Although it only contributes 0.3% of the Wenatchee River discharge, Mission Creek was rated as the most polluted waterbody in the Wenatchee River watershed during a ranking process for the 1998 Wenatchee River Watershed Action Plan (WRWSC, 1998). Water quality problems in the Mission Creek basin include excessive fecal coliform bacteria, elevated temperatures, low dissolved oxygen, inadequate instream flow, and pesticides.

Basin Description

Streams in the Mission Creek basin demonstrate a seasonal flow regime typical for the east slope of the Cascades, with the highest discharges following snowmelt during the spring (Figures 2 and 3). Flows decline to minimums in early-to-mid autumn following dry summers, although Yaksum Creek and Brender Creek flows may increase during the spring and summer due to addition of irrigation water and operational spills from the Icicle and Peshastin canals. Major floods occur periodically; the last one was during February 1996. WRWSC (1998) noted that substantial riparian damage occurred as a result of this event, but the degree of scouring and bed load movement was not investigated.

The upper basin is characterized by steep slopes, deeply incised stream channels, and highly erodable soils from the Swauk and Chumstick sandstone formations. The valley becomes less confined in the lower basin, the grade shallower, and glacial and fluvial deposits have resulted in deep soils in the valley bottom. WRWSC (1998) notes that soils in the valley bottoms differ significantly among Mission (gravelly), Yaksum (loamy sand to sandy loam), and Brender creeks (clay, silt, and sandy loams). Logs of wells constructed near Mission and Yaksum creeks generally show the top 6-12 meters (m) as some combination of loam, sand, clay, and gravel. Although well depths vary widely (8-100 m), static water levels are typically 3-6 m below surface.

Pear and apple orchards constitute the primary agricultural use in the basin, with some additional alfalfa and hobby farms. Orchards flank Mission Creek in a narrow band from the urban boundary of Cashmere to near the WNF boundary. The lower 2 km of Yaksum Creek is in orchards where the confines of the valley are cultivatable. Orchards are also located in the Brender Creek canyon and are more extensive where the valley broadens on the west side of Cashmere.

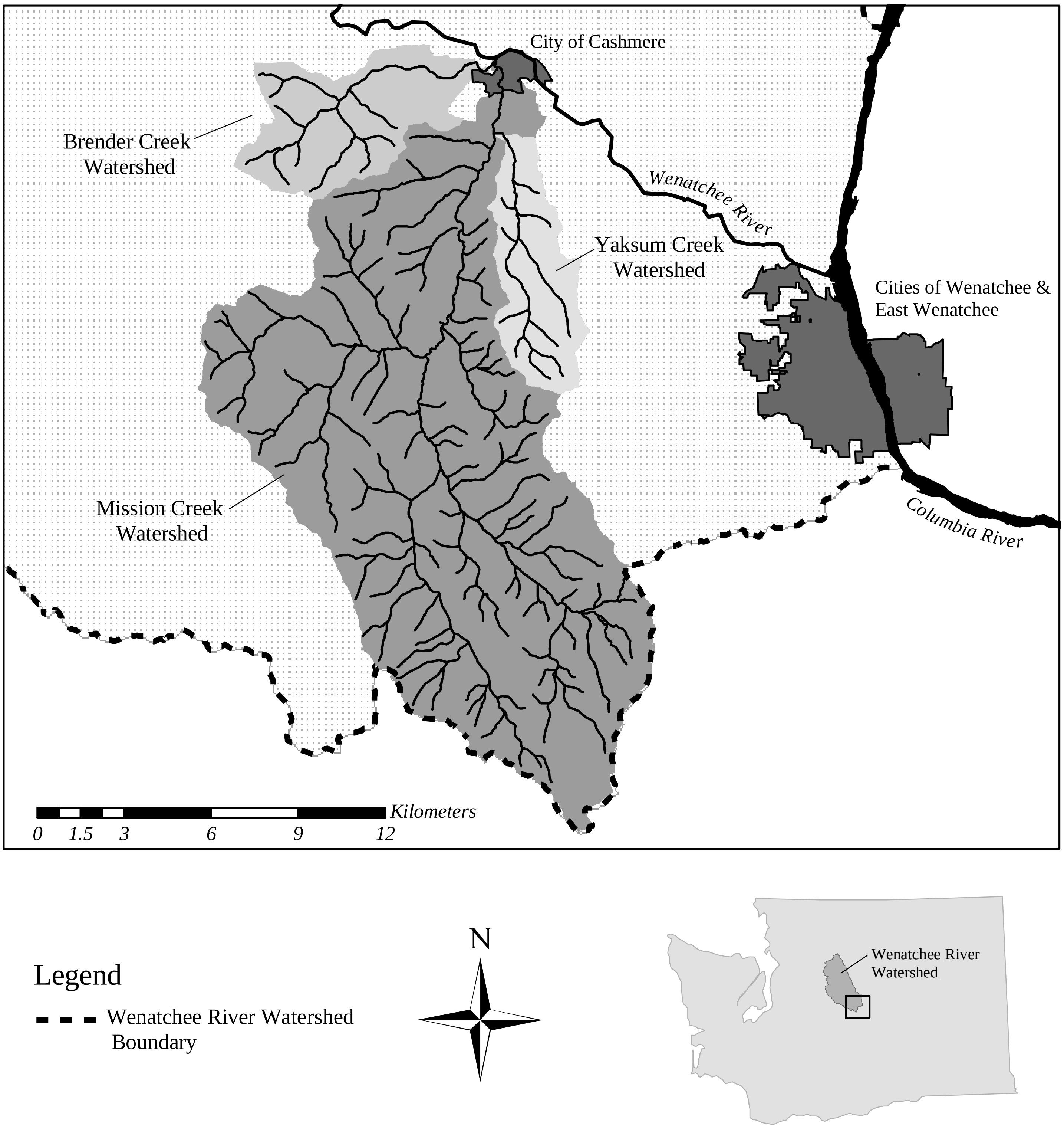

Figure 1. Brender, Mission, and Yaksum Creek Watersheds

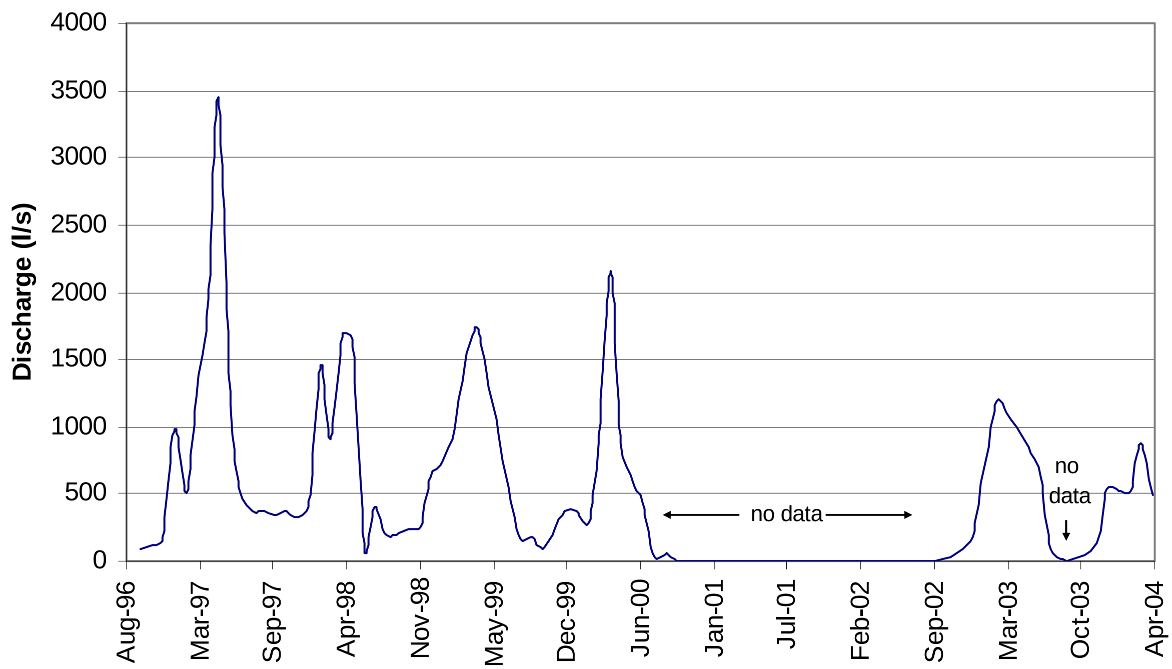

Figure 2. Mission Creek Flows at Cashmere, 1996 - 2004 (Ecology Station 45E070, Mission Creek nr. Cashmere)

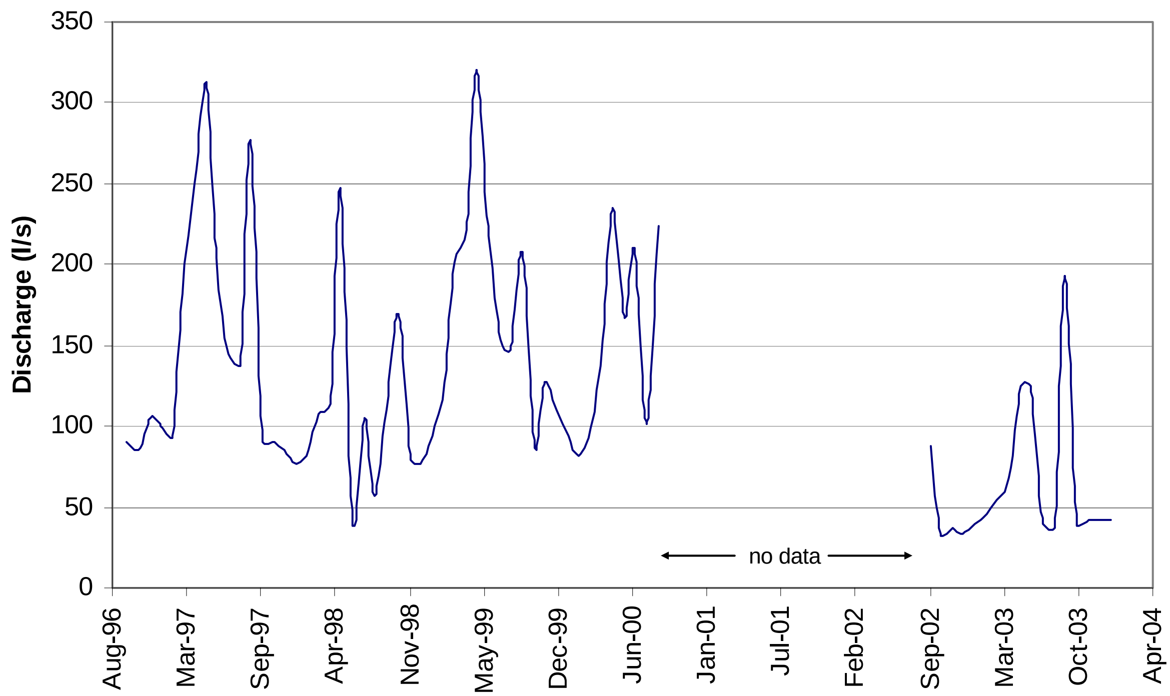

Figure 3. Brender Creek Flows at Cashmere, 1996 - 2004 (Ecology Station 45D070, Brender Creek nr. Cashmere)

Visual inspection of USGS topographic maps created during 1987-1989 and orthophotography from 1998 suggests that net loss of orchard land occurred in the late-1980s and 1990s, primarily from conversion to residential land use around the urban core of Cashmere. The largest converted tracts appear to be in the lower Brender Creek valley. There also appears to be limited conversion from orchards to alfalfa. Some new orchards have been planted since the late 1980s, primarily in the Mission Creek valley, but a rough estimate is 5-10% net loss of orchards for the entire basin.

The urban core of Cashmere (pop. 2,965; 2000 census) contains several kilometers of Mission Creek before it empties into the Wenatchee River. This reach has been largely channelized and its riparian area modified to accommodate the relative high density of residences. Eleven storm drains discharge directly to Mission Creek within the city limits, five in a one block area. It is not certain if storm drains discharge to Brender Creek which is located on the less developed west side of the city. There are no permitted discharges or point sources to any of the streams of the lower Mission Creek basin.

Background on DDT

DDT[1] is regularly found in waters near fruit orchards as it was used widely to control orchard pests such as the codling moth (*Carpocaspa Pomonella*) beginning in the mid-1940s. Nationally, peak use of DDT occurred during 1959 when 36 million kg (80 million pounds) was produced (Sittig, 1980). In 1958, the U.S. Department of Agriculture (USDA) began a program to phase out DDT for its insect control programs due to concerns about its persistence in the environment and toxicity to non-target organisms. Use declined steadily until 1972, when the U.S. Environmental Protection Agency (EPA) banned DDT for all uses except for emergencies.

4,4'-DDT can persist in the environment for decades, along with its primary aerobic metabolite 4,4'-DDE and the anaerobic breakdown product 4,4'-DDD. Their persistence is due to low vapor pressure and resistance to degradation, including photooxidation. DDT sorbs to sediments and particulate matter in the aquatic environment due to its low water solubility and high affinity for solids, especially solids with a high organic carbon content. Other aquatic fate processes for DDT compounds are volatilization and bioaccumulation, with biotransformation as the likely ultimate transformation process (Callahan et al., 1979). Transport of DDT to streams and movement within aquatic environments is often associated with erosion of contaminated soils and elevated loads of suspended solids as a result of erosion or sediment re-suspension (e.g., Johnson et al., 1988; Joy and Patterson, 1997).

Although banned over 30 years ago, DDT continues to be present at relatively high concentrations in the major streams of the lower Mission Creek basin. Since DDT remains stable for decades when bound to orchard soils (Harris et al., 2000), it is probable that contaminated orchard soils are the major source. Ecology found a positive correlation between

[1] Unless stated otherwise, DDT hereto after refers to:
4,4'-DDE (1,1-dichloro-2,2-*bis*[*p*-chlorophenyl]ethylene)
4,4'-DDD (1,1-dichloro-2,2-*bis*[*p*-chlorophenyl]ethane)
4,4'-DDT (1,1,1-trichloro-2,2-*bis*[*p*-chlorophenyl]ethane).
The sum of these compounds is total DDT (t-DDT).

DDT loads and total suspended solids (TSS) in water samples collected during 2000, but transport of orchard soils appears to be a slow process in the Mission Creek basin due to the lack of significant erosion or conveyance systems such as rill irrigation returns. Current orchard practices include grass or other ground cover which virtually eliminates soil erosion from orchards.

Historic Pesticide Data

In 1992, the Washington State Pesticide Monitoring Program (WSPMP) administered by the Washington State Department of Ecology (Ecology) began including lower Mission Creek as a target water sampling site due to the high density of fruit orchards in the basin (Davis, 1993). Several pesticides were detected during the initial year of sampling and during the subsequent two years until Mission Creek was dropped from the WSPMP target site list after 1994. A total of eight water samples and one rainbow trout fillet sample were analyzed from Mission Creek during 1992-1994 (Davis, 1993; Davis and Johnson, 1994; Davis et al., 1995; Davis, 1996).

Ecology conducted more extensive sampling in three Mission Creek basin streams during 2000 and found elevated concentrations of pesticides in all three streams (Serdar and Era-Miller, 2002). Among the pesticides found, DDT was the most frequently detected and most consistently found at concentrations above water quality standards (Table 1). High DDT concentrations and high DDT loads in Yaksum Creek indicated that most of the DDT loads in Mission Creek were contributed by Yaksum Creek.

Table 1. Summary of Mission Creek Samples Analyzed for DDT by Ecology, 1992-2000.

Location	Station name	Year	Sample type	n	n detected	t-DDT range
Mission Cr. @ Cashmere	WSTMP	1992-1994	water	8	3	nd*– 25 ng/l
"	"	1993	fish tissue	1	1	363 ng/g
"	2MC	2000	water	5	5	1.3 – 6.9 ng/l
Mission Cr. @ WNF	11MC	2000	"	5	0	nd**
Brender Cr. @ mouth	3MC	"	"	5	5	4 – 39 ng/l
Yaksum Cr. nr. mouth	7MC	"	"	5	5	23 – 92 ng/l

t-DDT criterion = 1 ng/l
nd = not detected
*detection limit = 50 ng/l
**detection limit = 2 – 12 ng/l

Davis et al. (1995) also found DDT in Mission Creek fish above levels derived to protect human health from consumption of contaminated fish tissue (Table 1). Complete data from these surveys are in Appendix B.

Water and fish tissue samples analyzed by Ecology exceeded the state surface water quality standards established to provide beneficial uses of surface waters, such as aquatic habitat and fish consumption. Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses are impaired by pollutants.

Waters placed on the 303(d) list require the preparation of Total Maximum Daily Loads (TMDLs), a key tool in the work to clean up polluted waters. TMDLs identify the maximum amount of a pollutant allowed to be released into a waterbody so as not to impair uses of the water, and allocate that amount among various sources.

Table 2 shows the 303(d) listings for pesticides in the Mission Creek basin. The current (i.e., 1998) listings are for DDT compounds (4,4'-DDE, 4,4'-DDT, t-DDT) and azinphos-methyl in Mission Creek. However, dropping azinphos-methyl was recommended due to the lack of a formal water quality rule or standard for this chemical (Serdar and Era-Miller, 2002).

The most recently proposed list (2002/2004) includes all of the 1998 listed parameters and also recommends including 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT in water for Mission, Brender, and Yaksum creeks. The 2002/2004 list also recommends retaining azinphos-methyl in Mission Creek, but this parameter was not addressed in the present study.

Table 2. Mission Creek Pesticide Parameters on the 1998 303(d) List and Status on the 2002/2004 303(d) List.

Name	Segment	Parameter	Medium	1996 List?	1998 List?	Recommended* for 2002/2004 List?
Mission Cr.	DQ04NW	DDT (total)	water	Y	Y	Y
"	"	4,4'-DDE	fish tissue	Y	Y	Y
"	"	4,4'-DDT	fish tissue	Y	Y	Y
"	"	4,4'-DDE	water	N	N	Y
"	"	4,4'-DDD	water	N	N	Y
"	"	4,4'-DDT	water	N	N	Y
"	"	Azinphos-methyl	water	N	Y	Y
Brender Cr.	FB41UG	4,4'-DDE	water	N	N	Y
"	"	4,4'-DDD	water	N	N	Y
"	"	4,4'-DDT	water	N	N	Y
Yaksum Cr.	XL42OT	4,4'-DDE	water	N	N	Y
"	"	4,4'-DDD	water	N	N	Y
"	"	4,4'-DDT	water	N	N	Y

*All recommendations are for Category 5; polluted waters that require a TMDL.

Applicable Water Quality Criteria

Washington State

Water quality standards for surface waters of Washington State are set in Chapter 173-201A of the Washington Administrative Code (WAC). Lower Mission Creek and its tributaries are designated as a Class A streams under Ch. 173-201A WAC. Characteristic uses of Class A waters include, but are not limited to:

i) Water supply (domestic, industrial, agricultural)
ii) Stock watering
iii) Fish and shellfish (migration, rearing, spawning, and harvesting)
iv) Wildlife habitat
v) Recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment)
vi) Commerce and navigation

Ch. 173-201A-040 WAC includes a provision that "Toxic, radioactive, or deleterious material concentrations shall be below those which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent on those waters, or adversely affect public health as determined by the department [Ecology]." The numeric criteria to protect aquatic life from DDT exposure spelled out in Ch. 173-201A-040 WAC are driven largely by harmful effects to the most sensitive aquatic species, particularly eggshell thinning in piscivorous birds exposed to DDT (EPA, 1980). The chronic criterion for DDT is 1 ng/l – a concentration not to be exceeded as a 24-hour average (Table 3). The acute criterion – not to be exceeded at any time – is three orders of magnitude higher at 1,100 ng/l.

Table 3. Water Quality Criteria for DDT to Protect Aquatic Life and Human Health.

Parameter	Aquatic Life – Chronic[a] (ng/l)	Aquatic Life – Acute[b] (ng/l)	Human Health[c] – Tissue (ng/g)	Human Health[c] – Water (ng/l)
4,4'-DDE	1	1,100	32	0.59
4,4'-DDD	1	1,100	45	0.83
4,4'-DDT	1	1,100	32	0.59
t-DDT	1	1,100	ne	ne

[a]Not to be exceeded as a 24-hour average
[b]Not to be exceeded at any time
[c]For consumption of organisms and water
ne = not established

National Toxics Rule

In 1992, the U.S. Environmental Protection Agency (EPA) promulgated the National Toxics Rule (NTR, 40 CFR 131.36) which established numeric, chemical-specific water quality criteria for all priority pollutants in order to bring states into compliance with the Clean Water Act. NTR human health criteria were derived from acceptable levels of fish tissue and water consumption, although water ingestion is considered a negligible DDT exposure pathway for humans. Acceptable fish tissue concentrations, based on a one-in-one-million excess lifetime cancer risk, are 32 ng/g for 4,4'-DDE and 4,4'-DDT, and 45 ng/g for 4,4'-DDD. The NTR uses a bioconcentration factor of 53,600 (EPA, 1980) to translate acceptable tissue concentrations to criteria for water – 0.59 ng/l for 4,4'-DDE and 4,4'-DDT, and 0.83 ng/l for 4,4'-DDD.

Objectives of the Present Study

The present study is an assessment of DDT contamination and transport in the Mission Creek basin and an analysis of the resulting dynamics of DDT in the aquatic environment. A quantitative assessment of DDT loads in Mission Creek and its tributaries had previously been made in 2000 (Serdar and Era-Miller, 2002), but these data were of limited use without more detailed information about mechanisms of transport and dynamics of DDT in streams. A better understanding of these processes was sought in order to tailor efforts to control or remove DDT from these streams.

Objectives of the present study were to:

1. Obtain representative data on dissolved and solid-phase DDT concentrations in the water column, ancillary parameters, and discharges in Mission Creek and its major tributaries.

2. Locate areas within each sub-basin that may actively transport pesticides into the surface waters by erosion of upland soils. Where feasible, characterize concentrations of DDT in terrestrial soils found to be transported to streams.

3. Determine if DDT is present in shallow groundwater. If so, estimate net contributions or losses of DDT from groundwater in the Mission Creek basin.

4. Obtain representative data on concentrations of DDT and ancillary parameters in sediments from depositional areas.

5. Estimate DDT loads and loading via the pathways investigated. Assign load allocations for specific transport mechanisms at key locations.

6. Complete a TMDL assessment report which includes all of the elements required by EPA Region 10. Include recommendations for DDT source control, based on quantitative analysis and/or qualitative observations.

Methods

Study Design

Sampling was conducted April-June, 2003. The Quality Assurance Project Plan describes the sampling and analysis plan designed to meet the project objectives (Serdar and Era-Miller, 2003). Various types of samples were collected to assess transport of DDT to streams as well as instream DDT dynamics. Upland soils were analyzed to assess whether DDT is sequestered at significant concentrations in representative orchard lands and in publicly-managed areas such as school yards and city parks. Bed sediments were collected from depositional areas to assess the degree to which sediments act as an aquatic sink. Suspended particulate matter (SPM) was analyzed for DDT to assess the proportion of water column concentrations and loads attributable to the solid phase. Whole and filtered water column samples were collected to assess the proportion of DDT in the dissolved phase. Shallow groundwater was sampled to assess it as a possible DDT conveyance mechanism. Although the study design included plans to collect stormwater runoff to assess transport of upland soils to streams, these samples were never obtained due to logistical problems and a drier than normal spring (precipitation was 30% below normal during the three-month study period).

Sampling Locations

Stream sample locations (Figure 4) were selected based on the type of data desired. Water samples and SPM were collected at stream mouths to assess total loading and at groundwater sampling locations to assess similarity between surface water and groundwater. Groundwater sampling was done based on availability of groundwater in piezometers. Bed sediments were collected where fine depositional material was available. Accessibility was a factor in selecting all sampling locations. A complete description of each sampling location is in Appendix C.

Upland soil samples were collected from five orchards each in the Mission Creek basin and Yaksum Creek sub-basins, and from three orchards in the Brender Creek sub-basin. Orchards were selected for sampling by compiling lists of addresses on sections of roads running alongside orchards. A list of parcel owners provided by the Chelan County Assessor's Office was then cross-matched against these addresses. Parcel owners were telephoned in a sequence designed to avoid sampling consecutive parcels, informed of the study, and asked for permission to sample. If permission was granted, owners were questioned about the history of their parcels. Parcels that did not contain orchards between the early 1950s and mid-1960s were eliminated from consideration as were parcels that had undergone major soil disturbance or conversion to other land use. Locations are not shown in order to preserve the anonymity of private land owners.

Upland soils were also collected from five public properties in urban Cashmere: three school ball fields and two small city parks (Figure 5). Sites were selected following consultation with the Cashmere School District and the City of Cashmere to ensure soils were native or had not been severely disturbed in the previous 50 years, and that the land had not been used as orchards or for other agriculture in the previous 50 years.

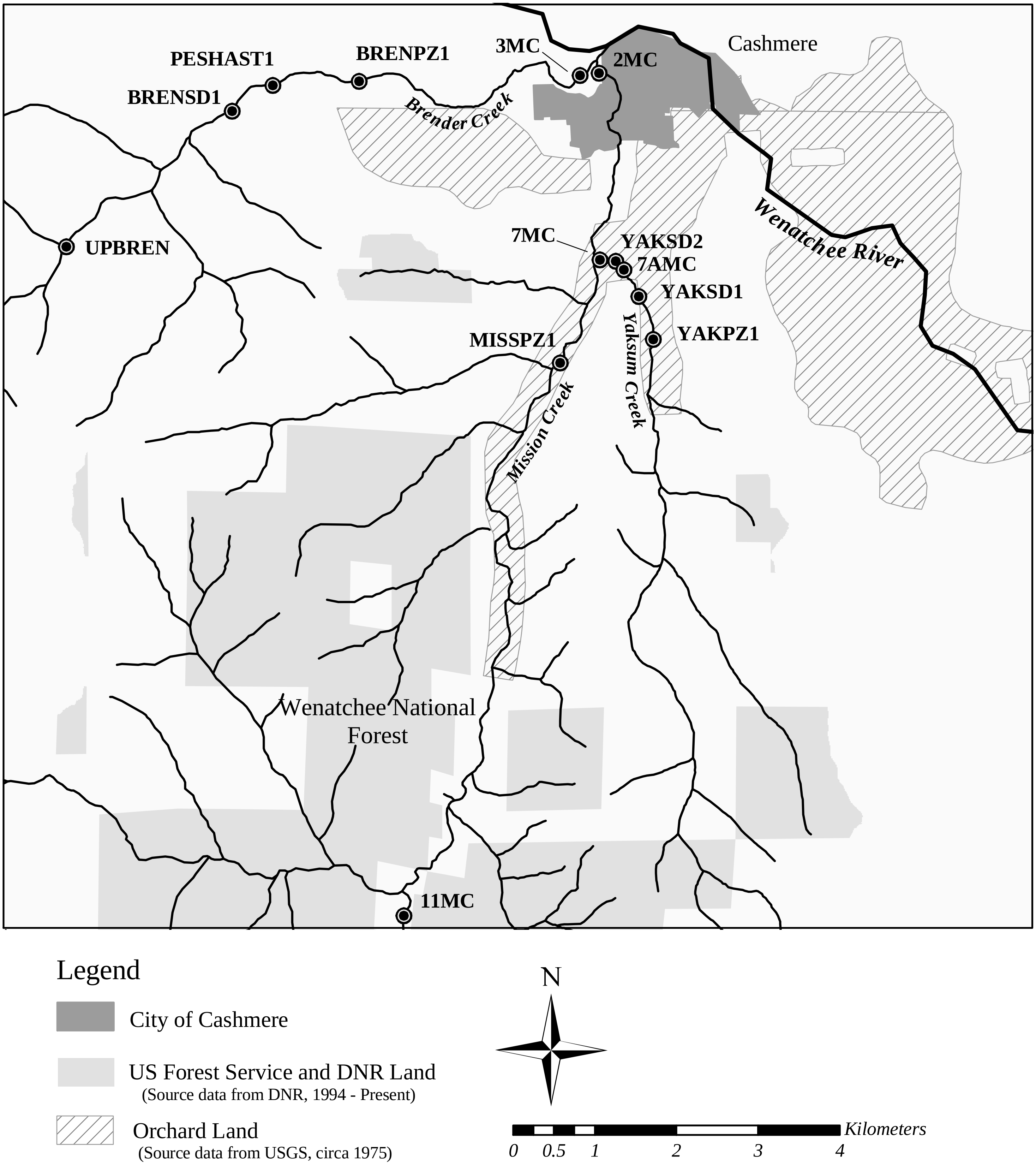

Figure 4. Water and Sediment Sampling Stations for the Mission Creek TMDL Study

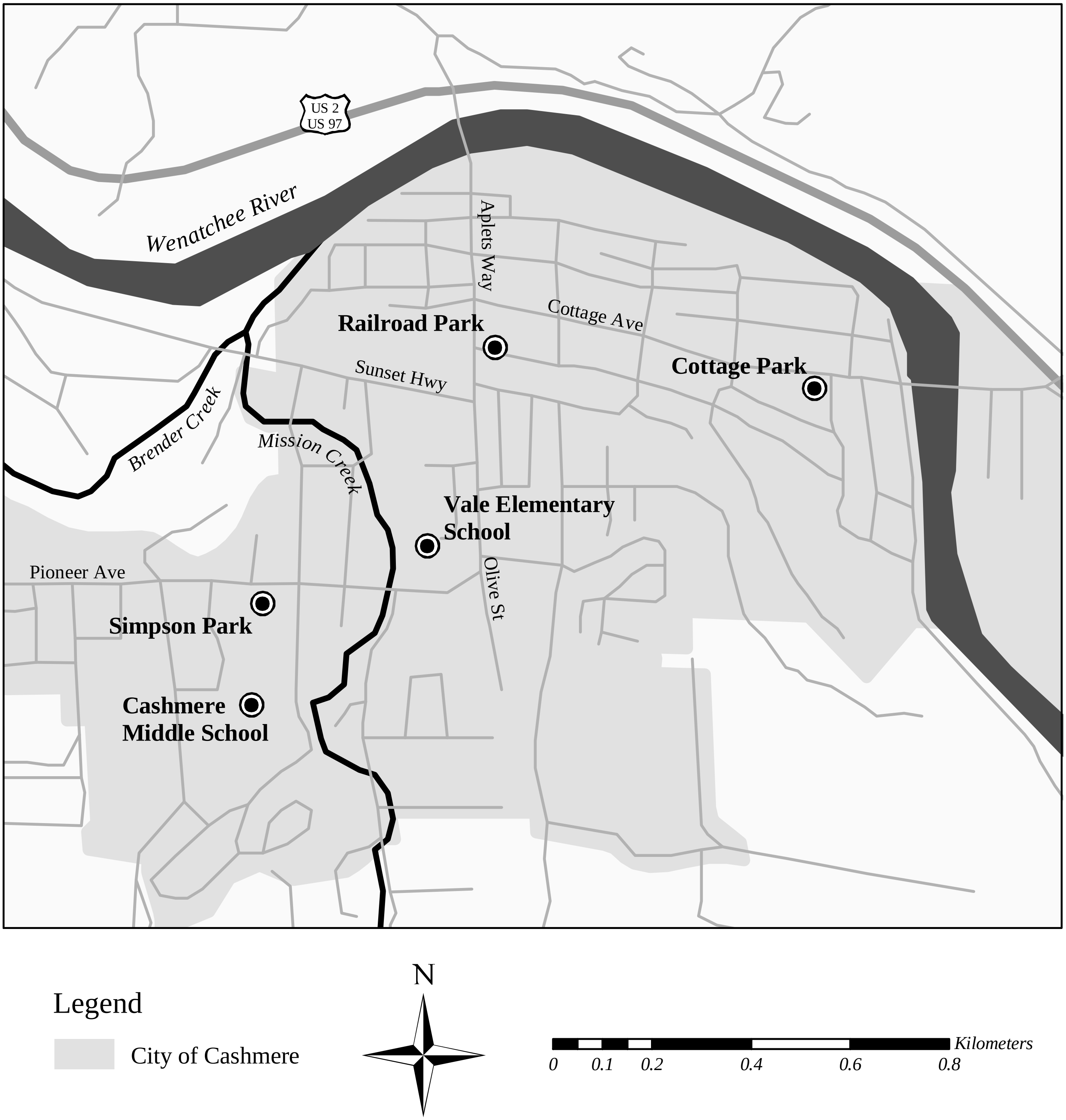

Figure 5. Urban Soil Sampling Stations for the Mission Creek TMDL Study. Samples from All Five Stations were Combined to Form Replicate Composite Samples (Urban A and Urban B).

Sample Collection

Upland Soils

Two composite samples of upland soil were obtained from each sub-basin or land-use category during June 2003 in a manner similar to that described by Rogowski et al. (1999). A starting point was established near the center of the largest orchard, yard, or open space for each property and two sub-sample sites – "A" and "B" – were then paced off at 100-ft distances at a relative compass bearing of 90˚. For parcels with smaller areas, sample locations were chosen simply for representative ground cover and to avoid sampling near the property edges.

Soils were collected from 10-cm diameter holes excavated to a depth of 5 cm using stainless steel trowels. The 0-5 cm depth was chosen because this is the horizon most likely to be eroded with loss of cover. Sampling work by Harris et al. (2000) showed the top 5 cm of orchard soils contains the highest concentrations of DDT, and Willett et al. (1994) found the highest DDT residues near the surface of former orchards despite having been plowed over. Soil loosened from the roots of overlying vegetation – grass in most cases – was included with the sample. "A" and "B" sub-samples were placed into separate stainless steel bowls, covered with aluminum foil, and kept on ice. Corresponding sub-samples from each property were thoroughly mixed together to form "A" and "B" composites, then placed in appropriate sample containers (Appendix D) for analysis of DDT, zinc (Zn), boron (B), grain size, total organic carbon (TOC), and moisture content.

Groundwater

Shallow groundwater was analyzed along Mission and Yaksum creeks using 1.25-cm (i.d.) piezometers driven into the streambed. The sampling plan called for analysis of groundwater from three sites in the Yaksum Creek sub-basin and one site each in the Mission and Brender sub-basins. However, a number of piezometers installed at various locations in each sub-basin yielded groundwater at only one site each in Yaksum and Mission creeks.

An upland piezometer was installed near the streambed piezometer in Yaksum Creek to determine the hydraulic gradient in this gaining reach. Water levels were determined using a calibrated electric well probe. Once installed, piezometers were developed by continual pumping until a sand or gravel pack was formed and the groundwater appeared to be completely free of solids and turbidity. Piezometers were capped and tagged with a unique Ecology well identifier following development.

Samples were collected in May and June, 2003 by purging three well volumes using a peristaltic pump fitted with Silastic® tubing. Fresh tubing was installed on the pump following purging, and the piezometer contents were pumped into appropriate sample containers for analysis of DDT, boron, total dissolved solids (TDS), total suspended solids (TSS), and TOC.

Bed Sediments

Streambed sediments were collected from depositional areas located by visual observation during surveys in April and June, 2003. Sediments were collected separately at depths of 0-2 cm and 2-5 cm at stations where depositional material was ≥ 5 cm, but only the top 2 cm was collected at sites where sediments were shallower.

Samples were collected using a Petite Ponar® grab sampler to maintain integrity of the sample. Samples were divided into 0-2 cm and 2-5 cm layers. Aliquots were collected from the grab sampler by gently siphoning or decanting overlying water, then scooping out the appropriate layer using a stainless steel spoon while avoiding contact with the sides of the sampler. Surface and sub-surface aliquots from three grabs were homogenized separately in stainless steel bowls then placed in appropriate jars for analysis of DDT, zinc, grain size, TOC, and percent solids.

Suspended Particulate Matter

Suspended particulate matter (SPM) was collected from the mouth of Brender Creek and from Mission Creek just upstream of the Brender Creek confluence during April 2003. Sedisamp II model 101IL continuous-flow centrifuges were used to collect the SPM in a manner described by Serdar et al. (1997). Water was pumped to each centrifuge from a stainless steel intake strainer anchored near mid-channel at mid-depth on each stream. All tubing was Teflon® except for Silastic® tubing used on the pump head. Centrifuge bowl parts are constructed of high quality stainless steel.

Water from Mission Creek was centrifuged at an average rate of 4.0 l/min for 18 hours, yielding 54 g of material (dry weight) from approximately 4,251 l processed. Based on the net weight of the SPM sample and an average intake water TSS concentration of 18 mg/l, SPM removal efficiency was calculated to be 71%. However, this may be an underestimate based on previous experience which has shown the actual capture of solids to generally exceed 75% (Yake, 1993).

Brender Creek water was pumped into the centrifuge at an average of 5.1 l/min for 15 hours to net 36 g (dry) from approximately 4,564 l processed. Removal efficiency, based on an average intake water TSS of 16 mg/l, was 49%.

Composite samples of centrifuge intake and discharge were also analyzed to assess whole water column DDT concentrations (intake water) and dissolved DDT concentrations (discharge water). Samples of intake and discharge water were also periodically collected for analysis of boron, TSS (intake water only), settleable solids (SS, intake water only), TDS (discharge water only), and TOC.

Water Column Grabs

Water column grab samples were collected during groundwater and SPM sampling events. Samples were collected using a hand-held bottle for water less than one foot deep or a U.S. Geological Survey (USGS) depth-integrating sampler for deeper water. The depth-integrating sampler consists of a DH-81 adapter with a D-77 cap and 1-liter jar assembled so that water contacts only Teflon® or glass. Samples were collected by slowly lowering the sampler to the bottom then immediately raising the sampler at the same rate at three points (quarter point transect) across each stream. Sample bottles were filled to proportionally equal levels with each successive grab until the bottles were full. Whole water column samples were analyzed for DDT, boron, TSS, SS, and TOC.

Additional grab samples were collected for filtration at the Ecology Headquarters building using a 0.45 µm pore Teflon® filter (142 mm dia.) mounted in a stainless steel filter bed. Water was forced through the filter using a peristaltic pump fitted with Silastic® tubing. Filtration was done within 24 hours of sample collection and placed in appropriate sample bottles for analysis. Dissolved (filtered) water column samples were analyzed for DDT, boron, TDS, and TOC.

Field Measurements

Field measurements of discharge, pH, specific conductance (SC), and temperature were recorded during all sampling events. Discharge was measured using USGS Stream Gaging Procedure (196) and a Swoffer Model 2100 TSR or a Marsh-McBirney, Inc. Model 201 flow meter. pH was measured using an Orion Model 250 temperature-compensating pH meter. SC was measured using a YSI Model 33 S-C-T meter. Temperature readings were done with both the pH and S-C-T meters. Geographical positions were recorded at all sampling locations using a Magellan NAV 5000 global positioning receiver.

To avoid sample contamination, all surfaces coming in contact with the samples were pre-cleaned by scrubbing with Liquinox® detergent, followed by sequential rinses with hot tap water, de-ionized water, acetone, and hexane. While in the field, all samples for laboratory analysis were kept on ice in a clean cooler. Upon returning from the field, samples were refrigerated at 4°C in the Ecology Headquarters chain-of-custody room then transported to Manchester Environmental Laboratory via lab courier the following business day.

Laboratory Analysis and Data Quality

Samples were analyzed using the analytical methods shown in Table 4. Analyses were performed at Manchester Environmental Laboratory except for grain size (Analytical Resources, Inc., Tukwila, WA).

In general, analysis of water, sediment, and soil samples for DDT was acceptable. Reporting limits for water samples were at or below target concentrations in most cases due to the use of large volume injection techniques. All samples for DDT analysis were analyzed within holding times.

Table 4. Analytical Methods and Reporting Limits.

Parameter	Reporting Limit	Sample Prep Method	Analysis Method
Soil/sediment			
DDT analogs	0.3 ng/g dw	Mod. of SW3510, SW3620, and SW3660B	GC/ECD (SW8081)
Total zinc	5.0 µg/g dw	SW3050B	ICP/MS (EPA 200.8)
Total boron	5.0 µg/g dw	SW3050B	ICP/MS (EPA 200.8)
Percent solids	0.1%	na	Gravimetric (SM 2540G)
Grain size	0.1%	na	Sieve-pipet (PSEP, 1986)
TOC	0.10%	na	Combust./NDIR (PSEP-TOC)
Whole/dissolved water			
DDT analogs	0.3 ng/l	SW3510	GC/ECD (SW8081)
Total boron	0.025 µg/l	EPA 200.8	ICP (EPA 200.8)
TDS	1 mg/l	Filtration	Gravimetric (SM 2540C)
TSS	1 mg/l	na	Gravimetric (SM 2540D)
SS	0.2 ml/l/hr	na	Gravimetric (EPA 160.5)
TOC	1.0 mg/l	na	Combust./NDIR (EPA 415.1)

na = not applicable

In most cases, calibrations, surrogate and matrix spike recoveries, and laboratory control samples were within quality control (QC) limits. Exceptions and other problems with DDT analyses were:

- One batch of water samples (nos. 03228224 – 8234) had higher reporting limits for 4,4'-DDT (0.5 ng/l) due to laboratory blank contamination and call into question the usability of the 4,4'-DDT result from sample no. 03228230 which had the same reported concentration as the blank (0.1 ng/l). This result is flagged with a b.

- Several of the continuing calibration standards used for analysis of water sample nos. 03268224 – 03268242 drifted below established QC limits. Results for 4,4'-DDT are qualified as estimates (J) and may be biased low.

- Recoveries for the surrogate DCB were below QC limits in water samples 03268236 and 03268242 and in sediment samples 03158156, 03158171, 03258330, 03258335, 03258336, and 03264108. Results for 4,4'-DDD and 4,4'-DDT are qualified as estimates (J). Results for 4,4'-DDE and 4,4'-DDT in sample nos. 03258330 and 03264107 are also estimated due to low TMX recovery.

- Analysis of Standard Reference Material (SRM 1941b; NIST Organics in Marine Sediment) were below certified values (Table 5). The low recoveries for 4,4'-DDE (57%) and 4,4'-DDD (48%) suggest sample results may be biased low.

Table 5. Analysis of SRM 1941b by Manchester Environmental Laboratory (MEL).

Parameter	Certified value (ng/g, dw)	MEL value (ng/g, dw)
4,4'-DDE	3.22 ± 0.28	1.84 J
4,4'-DDD	4.66 ± 0.46	2.22
4,4'-DDT	1.12 ± 0.42[a]	0.60 NJ

[a]Reference value, not certified
J = estimated concentration
NJ = there is evidence that the analyte is present, and the concentration shown is an estimate

High laboratory precision was calculated from duplicate analysis of samples. Relative percent differences (RPDs) averaged 2% (range 0-4%) for DDT compounds analyzed in water and 12% (range 0-26%) for DDT compounds analyzed in sediment and soils. Complete results of laboratory duplicates are in Appendix E.

Quality of laboratory data for analysis of metals and conventional parameters was good. Laboratory duplicates averaged 4% RPD for zinc analysis, 2% RPD for boron, and generally less than 5% RPD for conventionals (Appendix E).

Data Analysis

Statistical analysis was conducted using SYSTAT® 9.01 (SPSS, Inc.). A Spearman rank-order correlation coefficient was used to determine the relationship between zinc and sand content in bottom sediments. The Spearman correlation coefficient is a non-parametric version of the Pearson correlation coefficient, based on the ranks of data rather than actual values.

Regression of TSS on t-DDT was carried out using SYSTAT® simple linear models. Data were tested for normality using Kolmogorov-Smirnov test with a 2-tail Lilliefors transformation. Data were log-transformed after raw data were found to be not normally distributed. Log transformation also reduced the number of outliers and reduced the leveraging effect of some samples when the linear regression models were applied.

Results of 2003 Sampling

DDT Concentrations in Upland Soils

Soils collected from orchards in the Mission, Brender, and Yaksum creek basins were fairly uniform in particle size as were soils from urban areas (Table 6). Soils were composed of 70 – 80% sand except for one of the Brender composites which contained more clay and total organic carbon (TOC) than other samples.

Table 6. Grain Size Distribution (% in each fraction) and TOC Content (%) of Upland Soils (0-5 cm).

Location	Date	Solids (%)	Gravel (>2,000 µm)	Sand (2,000–62.5µm)	Silt (62–3.9 µm)	Clay (< 3.9 µm)	TOC
Mission "A"	6/23/03	89.4	5	78	15	2	2.61
Mission "B"	6/23/03	83.3	4	77	16	3	4.48
Brender "A"	6/23/03	85.3	1	72	23	3	4.16
Brender "B"	6/23/03	83.4	5	66	22	7	7.02
Yaksum "A"	6/24/03	84.7	3	76	17	3	4.37
Yaksum "B"	6/24/03	79.1	5	78	14	3	6.22
Urban "A"	6/23/03	78.3	3	78	17	2	2.96
Urban "B"	6/23/03	84.5	6	76	15	3	2.73

DDT concentrations in orchard soils were very high, with concentrations of t-DDT ranging from 5,500 to 21,000 ng/g (Table 7). Concentrations of DDT in orchards were elevated approximately 20 times compared to urban areas. DDT composition among orchard samples was fairly uniform (average of 54% 4,4'-DDE, 41% 4,4'-DDT, and 5% 4,4'-DDD) with the exception of Mission "A" which had an unusually high 4,4'-DDD content (1,360 ng/g, 25% of t-DDT). t-DDT in urban soils contained 68% 4,4'-DDE, 32% 4,4'-DDT, and <1% 4,4'-DDD on average.

Table 7. Concentrations of DDT (ng/g dw) in Upland Soils (0-5 cm).

Location	Date	4,4'-DDE		4,4'-DDD		4,4'-DDT		t-DDT
Mission "A"	6/23/03	3,600	J	1,360		540		5,500
Mission "B"	6/23/03	5,500		160		3,900		9,600
mean ± range		4,600 ± 1,000		760 ± 600		2,200 ±1,700		7,600 ± 2,000
Brender "A"	6/23/03	3,300		78	J	5,200	J	8,600
Brender "B"	6/23/03	5,100		74		2,760		7,900
mean ± range		4,200 ± 900		76 ± 2		4,000 ± 1,200		8,200 ± 400
Yaksum "A"	6/24/03	8,800		130		12,000		21,000
Yaksum "B"	6/24/03	4,400		63		3,400		7,900
mean ± range		6,600 ± 2,200		100 ± 30		8,000 ± 4000		14,000 ± 7,000
Urban "A"	6/23/03	390		3		240		630
Urban "B"	6/23/03	190		1		66		260
mean ± range		290 ± 100		2 ± 1		150 ± 90		440 ± 190

J = estimated concentration

DDT Concentrations in Bottom Sediments

Table 8 shows grain size distribution and TOC content of surficial (0-2 cm) and sub-surface (2-5 cm) sediments collected from Brender and Yaksum creeks. As noted previously, no depositional material could be found in lower Mission Creek, but upper Mission Creek sediments were sampled upstream of the Wenatchee National Forest (WNF) boundary.

Table 8. Grain Size Distribution (% in each fraction) and TOC Content (%) of Surficial (0-2 cm) and Sub-surface (2-5 cm) Bottom Sediments.

Location	Layer (cm)	Date	Solids (%)	Gravel (>2,000 µm)	Sand (2,000–62.5µm)	Silt (62–3.9 µm)	Clay (< 3.9 µm)	TOC	
Brender Creek									
BRENSD1	0-2	4/15/03	38.1	1	52	42	5	5.91	
"	"	6/17/03	60.8	0	83	14	3	1.58	
BRENSD1	2-5	6/17/03	60.5	1	83	13	3	1.45	
3MC	0-2	4/15/03	45.3	0	64	33	3	3.09	
"	"	" (rep.)	45.4	0	64	33	3	3.08	
"	"	6/17/03	69.7	1	95	3	0	0.62	
3MC	2-5	4/15/03	45.4	0	57	41	2	3.89	
Yaksum Creek									
YAKSD1	0-2	4/10/03	23.4	5	51	41	3	6.29	
"		6/17/03	52.9	17	71	10	2	0.85	
YAKSD1	2-5	4/10/03	44.8	17	64	17	2	5.24	
YAKSD2	0-2	4/15/03	36.2	1	62	33	4	3.38	
"	"	6/17/03	58.2	1	70	26	3	1.25	
YAKSD2	2-5	4/15/03	50.9	1	67	26	6	2.70	
"	"	6/17/03	63.3	0	70	26	4	1.18	
Mission Creek									
11MC	0-2	4/15/03	73.5	0	95	4	0	0.10	U
"	"	6/17/03	77.7	0	99	1	0	0.10	U

U = undetected at concentration shown

Sediments were composed primarily of sand-sized particles followed by varying proportions of silt. The degree to which the samples were composed of silt is reflected in TOC concentrations, with the coarsest samples having little or no measurable organic carbon.

DDT concentrations in bottom sediments are shown in Table 9. Yaksum Creek sediments had DDT concentrations an order of magnitude higher, on average, than Brender Creek sediments. Concentrations in Yaksum Creek sediments ranged from 350 - 3,500 ng t-DDT/g, while Brender

Creek sediments were 26 – 870 ng t-DDT/g. Only a trace amount of DDT (0.2 ng 4,4'-DDE/g) was detectable at the upper Mission Creek location. Differences between surface and sub-surface samples at the same locations were relatively small, indicating that sediment characteristics are vertically homogenous in the top 5 cm.

Four of the five locations where surficial sediments were twice sampled showed a marked increase in the proportion of sand, and decreases in silt and TOC between the April and June sampling events. The loss of TOC during this period resulted in lower DDT concentrations since most of the differences in DDT concentrations within sites appears to be related to TOC levels. DDT concentrations normalized to organic carbon (OC) content are similar across date and depth at each location, except in Yaksum Creek where surficial sediments are an average of 30% higher than sub-surface sediments.

Table 9. Concentrations of DDT (ng/g dw) and Organic Carbon Normalized t-DDT (ng/g OC) in Bottom Sediments.

Location	Layer (cm)	Date	4,4'-DDE		4,4'-DDD		4,4'-DDT		t-DDT	OC-norm. t-DDT
Brender Creek										
BRENSD1	0-2	4/15/03	**350**		**120**		**400**		**870**	**15,000**
"	"	6/17/03	**140**		**27**		**96**		**263**	**17,000**
BRENSD1	2-5	6/17/03	**140**		**26**	J	**85**	J	**251**	**17,000**
3MC	0-2	4/15/03	**79**		**37**		**9**		**125**	**4,000**
"	"	" (rep.)	**78**		**33**		**10**		**121**	**3,900**
"	"	6/17/03	**15**		**9**	J	**2**	J	**26**	**4,200**
3MC	2-5	4/15/03	**74**		**41**		**8**		**123**	**3,200**
Yaksum Creek										
YAKSD1	0-2	4/10/03	**1,600**		**240**	J	**1,400**	J	**3,240**	**52,000**
"		6/17/03	**260**	J	**89**	J	0.4	U	**349**	**41,000**
YAKSD1	2-5	4/10/03	**1,000**		**140**		**820**		**1,960**	**37,000**
YAKSD2	0-2	4/15/03	**1,800**		**290**		**1,400**		**3,490**	**103,000**
"	"	6/17/03	**420**		**110**		**580**		**1,110**	**89,000**
YAKSD2	2-5	4/15/03	**1,200**		**240**		**700**		**2,140**	**79,000**
"	"	6/17/03	**410**		**96**		**370**		**876**	**74,000**
Mission Creek										
11MC	0-2	4/15/03	**0.2**	J	0.3	U	0.3	U	0.2	**200**
"	"	6/17/03	0.4	U	0.3	U	0.3	U	0	0

Detected values in **bold**
J = estimated concentration
U = undetected at concentration shown

t-DDT in sediments across sites was composed of 54% 4,4'-DDE, 29% 4,4'-DDT, and 17% 4,4'-DDD on average. The average proportion of 4,4'-DDD was much higher than in upland soils, especially at BRENSD2 which had consistently higher proportions of 4,4'-DDD than at other sediment sampling locations (31% vs. 11%).

DDT Concentrations in Suspended Particulate Matter

Conventional parameters of centrifuge water and DDT concentrations in suspended particulate matter (SPM) are shown in Tables 10 and 11, respectively. TSS concentrations were similar at Mission (2MC) and Brender (3MC) creeks, although TDS was about twice as high at 3MC. TOC concentrations were similar between sites and were primarily confined to the dissolved phase (centrifuge discharge), based on differences between intake and discharge samples. TOC in the solid (SPM) phase was 2½ times higher in 3MC compared to 2MC.

DDT concentrations in Mission Creek SPM were two orders of magnitude lower than typical concentrations in Yaksum Creek bottom sediments and three orders of magnitude lower than average orchard soil concentrations. Brender Creek SPM was more comparable to the creek's bottom sediments, but was still approximately 30 times lower than average orchard soil DDT concentrations from the Brender sub-basin.

Table 10. Conventional Parameters in Centrifuge Water.

Location	Date	TSS (mg/l)		SS (ml/l/hr)		TDS (mg/l)		TOC (mg/l)
Mission Creek								
2MC – Centrifuge intake	4/9-10/03	18		0.4	U	n/a		2.4
2MC – Centrifuge discharge	"	n/a		n/a		148		2.4
Brender Creek								
3MC – Centrifuge intake	4/9-10/03	16		0.4	U	n/a		2.6
3MC – Centrifuge discharge	"	n/a		n/a		312		2.3

U = undetected at concentration shown
n/a = not analyzed

Table 11. Concentrations of DDT in Suspended Particulate Matter (ng/g dw).

Location	Date	% Solids	TOC (%)	4,4'-DDE		4,4'-DDD		4,4'-DDT		t-DDT
Mission Creek										
2MC	4/9-10/03	56.0	3.05	10		0.8		5.7		16
Brender Creek										
3MC	4/9-10/03	35.6	7.54	180		79	J	29	J	290

J = estimated concentration

DDT Concentrations in Surface Water and Shallow Groundwater

Most of the conventional water quality parameters measured during the study (Table 12) appear to fall into the range of usual values for the streams assessed (WRWSC, 1998). The filterable solids in whole water (i.e., TSS) had very little settleable solids (SS) as a component – the only measurable SS was 0.1 ml/l/hr at BRENPZ1 – indicating that very little if any of the TSS load during the spring contributes to the formation of bed sediments.

TOC concentrations were similar to those previously reported by Serdar and Era-Miller (2002). Based on differences between paired whole water and filtered samples, almost all of the OC is dissolved at each location.

Flows in Mission Creek were typical for the seasons while Brender and Yaksum creeks had flows substantially below normal (WRWSC, 1998; Serdar and Era-Miller, 2002). The 4/10/03 Yaksum Creek discharge measurement may underestimate actual conditions but very low water levels made accurate measurements unobtainable.

DDT concentrations in whole and filtered surface water ranged from 0.1 to 130 ng/l t-DDT, except at Mission Creek above the WNF boundary (11MC) where no DDT was detected (Table 13). The highest DDT concentrations in surface water were from the lower Yaksum Creek sites (7AMC and 7MC). t-DDT in whole water across sites were composed of 54% 4,4'-DDE, 30% 4,4'-DDT, and 16% 4,4'-DDD on average.

In Yaksum Creek, DDT concentrations increased markedly – up to an order of magnitude – downstream of YAKPZ1. Results also suggest that Yaksum Creek entrains substantial particle-bound DDT in the relatively short reach between 7AMC and 7MC, although there are no paired samples to support this supposition.

DDT concentrations in Mission Creek show an increase between MISSPZ1 and 2MC. The confluence of Yaksum Creek and Mission Creek, which is located between MISSPZ1 and 2MC, probably accounts for the increased DDT concentrations between these sites.

Brender Creek DDT concentrations were intermediate with respect to Yaksum and Mission creeks. Unlike the other streams, however, DDT concentrations in Brender Creek decreased between the upstream (BRENPZ1) and downstream (3MC) stations. The Peshastin irrigation spill sampled upstream of BRENPZ1 had a t-DDT concentration an order of magnitude lower than whole water at BRENPZ1.

The BRENPZ1 t-DDT composition was similar to other sites, but whole water from 3MC had an unusual "fingerprint" composed of much higher 4,4'-DDD compared to other sites (31% vs. 14%). Aside from one sediment sample in Yaksum Creek, the only other samples collected for this study with the "high 4,4'-DDD fingerprint" were bottom sediments and SPM from 3MC.

Approximately 20-80% of t-DDT was in dissolved form, based on results of paired whole water and filtered water samples. Mission Creek (2MC) paired samples indicate that 25% of the t-DDT was in the dissolved phase, which agrees well with the calculated dissolved fraction from the SPM sample (28%). In Brender Creek, however, dissolved t-DDT fractions calculated from paired sample analysis was in poor agreement with SPM (73% and 0%, respectively). The high dissolved fraction was probably due to poor TSS removal efficiency by the centrifuge used for Brender Creek.

No DDT was detected in groundwater samples collected from the Mission and Yaksum Creek sub-basins, suggesting that DDT is not traveling through groundwater in either gaining (Yaksum) or losing (Mission) reaches. However, the groundwater sampling for this project was limited and may not represent all potential groundwater pathways in the lower Mission Creek basin. Information obtained following sampling revealed a large groundwater input to Brender Creek exists in the reach river mile (RM) 1.1-1.5. Absent any significant DDT load from groundwater, this input could account for the dilution in DDT concentrations between BRENPZ1 and 3MC. This reach was not sampled during the present study but should be considered for sampling in any subsequent surveys of DDT in groundwater.

Table 12. Conventional Parameters in Surface Water and Shallow Groundwater.

Location	Sample Type	Date	Discharge (l/s)	TSS (mg/l)		SS (ml/l/hr)		TDS (mg/l)		TOC (mg/l)
Mission Creek										
2MC	Whole water	4/9-10/03	**1,048**	**18**		0.4	U	n/a		**2.4**
"	"	5/29/03	**920**	**19**		0.4	U	n/a		**1.4**
"	"	6/24/03	**328**	**4**		0.1	UJ	n/a		**1.4**
2MC	Filtered water	4/9-10/03	**1,048**	n/a		n/a		**148**		**2.4**
"	"	6/24/03	**328**	1	U	n/a		**138**		**2.4**
MISSPZ1	Whole water	5/29/03	n/a	**11**		0.4	U	n/a		**1.5**
"	"	6/24/03	n/a	**3**		0.1	UJ	n/a		**1.3**
MISSPZ1	Groundwater	5/29/03	n/a	**3**		n/a		**240**	J	**1.1**
"	"	6/24/03	n/a	**1**		n/a		**225**		**1.5**
11MC	Whole water	5/28/03	**681**	**7**		0.4	U	n/a		**1.1**
"	"	6/24/03	**246**	**2**		0.1	UJ	n/a		**1.1**
Brender Creek										
3MC	Whole water	4/9-10/03	**67**	**16**		0.4	U	n/a		**2.6**
"	"	5/29/03	**68**	**18**		0.4	U	n/a		**1.8**
"	"	6/24/03	**131**	**4**		0.1	UJ	n/a		**1.5**
3MC	Filtered water	4/9-10/03	**67**	n/a		n/a		**312**		**2.3**
"	"	6/24/03	**131**	1	U	n/a		**195**		**2.6**
BRENPZ1	Whole water	5/29/03	n/a	**36**		0.4	U	n/a		**2.2**
"	"	6/24/03	n/a	**22**		**0.1**	J	n/a		**1.8**
Peshastin Canal										
PESHAST1	Whole water	6/25/03	n/a	n/a		n/a		n/a		n/a
Yaksum Creek										
7AMC	Whole water	4/10/03	**0.2**	1	U	0.4	U	n/a		**2.5**
"	"	" (rep)	**0.2**	**1**		0.4	U	n/a		**2.6**
"	"	6/24/03	**16**	**14**		0.1	UJ	n/a		**1.8**
"	"	" (rep)	**16**	**15**		**0.1**	J	n/a		**1.6**
7AMC	Filtered water	4/10/03	**0.2**	n/a		n/a		**360**		**2.3**
	"	6/24/03	**16**	**1**		n/a		**82**		**3.3**
7MC	Whole water	5/28/03	**16**	**47**		0.4	U	n/a		**2.4**
"	"	" (rep)	**16**	**45**		0.4	U	n/a		**2.2**
YAKPZ1	Whole water	5/29/03	n/a	**4**		0.4	U	n/a		**2.0**
"	"	6/24/03	n/a	**2**		0.1	UJ	n/a		**1.6**
YAKPZ1	Groundwater	5/29/03	n/a	**8**		n/a		**308**	J	**1.5**
"	"	6/24/03	n/a	**3**		n/a		**311**		**1.5**

Detected values in **bold**
J = estimated concentration
U = undetected at concentration shown
UJ = undetected at estimated concentration shown
n/a = not analyzed

Table 13. Concentrations of DDT (ng/l) and Boron (µg/l) in Surface Water and Shallow Groundwater.

Location	Sample Type	Date	4,4'-DDE		4,4'-DDD		4,4'-DDT		t-DDT	Boron	
Mission Creek											
2MC	Whole water	4/9-10/03	0.3	J	0.3	U	0.1	J	0.4	38	
"	"	5/29/03	1.3		0.2	J	0.9		2.4	25	U
"	"	6/24/03	1.6		0.5		1.1	J	3.2	31	
2MC	Filtered water	4/9-10/03	0.1	J	0.3	U	0.5	U	0.1	38	
"	"	6/24/03	0.3	J	0.3	UJ	0.3	NJ	0.6	29	
MISSPZ1	Whole water	5/29/03	0.3	J	0.3	U	0.1	Jb	0.4	25	U
"	"	6/24/03	0.4		0.3	U	0.2	J	0.5	31	
MISSPZ1	Groundwater	5/29/03	0.3	U	0.3	U	0.5	U	n/c	69	
"	"	6/24/03	0.3	U	0.3	U	0.5	U	n/c	92	
11MC	Whole water	5/28/03	0.3	U	0.3	U	0.5	U	n/c	25	U
"	"	6/24/03	0.3	UJ	0.3	UJ	0.4	UJ	n/c	25	U
Brender Creek											
3MC	Whole water	4/9-10/03	2.3		1.0		0.3	J	3.6	44	
"	"	5/29/03	3.6		2.1		1.3		7.0	28	
"	"	6/24/03	3.1		2.1		0.8	J	6.0	28	
3MC	Filtered water	4/9-10/03	1.6		0.8		0.2	J	2.6	45	
"	"	6/24/03	1.8		1.2		0.5	J	3.5	29	
BRENPZ1	Whole water	5/29/03	17		4.4		10		31	25	U
"	"	6/24/03	11		3.5		5.1	J	20	25	U
UPBREN	Whole water	6/25/03	n/a		n/a		n/a		n/a	29	
Peshastin Canal											
PESHAST1	Whole water	6/25/03	1.8		0.4		1.0	J	3.2	25	U
Yaksum Creek											
7AMC	Whole water	4/10/03	14		5.3		6.0		25	52	
"	"	" (rep)	12		4.0		5.2		21	55	
"	"	6/24/03	28		10		17	J	55	25	U
"	"	" (rep)	27		10		24	J	61	25	U
7AMC	Filtered water	4/10/03	10		3.6		4.2	J	18	54	
	"	6/24/03	9.1		4.1		5.1	J	18	25	U
7MC	Whole water	5/28/03	62		22		49		133	25	U
"	"	" (rep)	59		22		47		128	25	U
YAKPZ1	Whole water	5/29/03	3.5		2.6		5.1		11	25	U
"	"	6/24/03	3.2		2.8		2.1		8.1	25	U
YAKPZ1	Groundwater	5/29/03	0.3	U	0.3	U	0.5	U	n/c	40	
"	"	6/24/03	0.3	U	0.3	U	0.5	U	n/c	41	
Centrifuge Blank		4/10/03	0.5		0.1	J	0.1	J	0.7	25	U
Field Blank		5/29/03	0.3	UJ	0.3	UJ	0.5	UJ	n/c		
"		6/25/03	n/a		n/a		n/a		n/a	25	U
Filter Blank		6/24/03	0.3	U	0.3	U	0.5	UJ	n/c	25	U

Detected values in **bold**
Shaded values exceed criteria
J = estimated concentration
U = undetected at concentration shown
UJ = undetected at estimated concentration shown
b = concentration shown is less than 5 times the amount found in an associated laboratory blank
NJ = there is evidence that the analyte is present and the concentration shown is an estimate
n/c = not calculated   n/a = not analyzed

Zinc and Boron Concentrations

Zinc (Zn) was analyzed in soils to assess whether soil fortification with this micronutrient resulted in elevated concentrations and could therefore potentially be used to link upland soils to the source of aquatic sediments. Zinc concentrations were fairly uniform in orchard soils, with an average concentration (202 µg/g) three times the concentration in urban soils. However, there are no data to indicate whether urban soils had been treated with zinc. Other data from Washington State suggest typical zinc concentrations in soils are lower than those in the present study. Rogowski et al. (1999) found zinc concentrations in background Columbia River basin surface soils to range from 32 – 56 µg/g, and deeper (approximately 0.5 m) soils in the Yakima and Spokane river basins had median zinc concentrations of 51 and 53 µg/g, respectively (San Juan, 1994).

Zinc concentrations in Brender and Yaksum creek sediments were lower than in orchard soils but were two-to-six times background (11MC) concentrations. Differences in zinc concentrations among sediment samples probably reflect differences in sand content. The Spearman correlation coefficient between zinc and sand was -0.752, indicating a strong inverse link between the two parameters and explains the decline in zinc concentrations between samples collected in April and June, 2003.

SPM samples from Mission Creek (2MC) and Brender Creek (3MC) had vastly different zinc concentrations. The zinc concentration in Mission Creek SPM more closely resembled the background bed sediment concentration while the Brender Creek SPM was similar to orchard soil concentrations. The differences in zinc parallel DDT concentrations in the SPM samples and may indicate that Mission Creek SPM is more diluted with uncontaminated material while orchard soils are a comparably greater component of Brender Creek SPM.

Overall, the pattern of zinc enrichment is orchard soils > sediments and urban soils > background sediments, with SPM variable depending on location. This pattern is what might be expected based on the practice of treating orchards with zinc, and the subsequent transport of orchard soils to streams. However, it appears that zinc concentrations have limited usefulness in tracing or geographically isolating the source(s) of material due to the lack of distinctively high concentrations in any of the media sampled.

Boron (B), another micronutrient added to deficient soils, was undetectable in all soil samples except for a low concentration (6.2 µg/g) in one of the Brender orchard composites (Table 14). In water, concentrations of boron were low to moderate, and appeared to have no relation to DDT concentrations (Table 13). Mission Creek water appeared to be slightly enriched in boron compared to background, while boron concentrations in Brender Creek are similar to those at a background location (UPBREN). When present, almost all of the boron was dissolved. Groundwater had higher boron concentrations than corresponding surface water samples, but the significance of this is uncertain. Like zinc, boron data collected for the present survey failed to provide useful information on contaminant pathways.

Table 14. Concentrations of Zinc and Boron in Upland Soils and Zinc in Bottom Sediments and Suspended Particulate Matter (µg/g dw).

Location/Sub-basin	Sample Type	Date	Zinc	Boron	
Mission Creek					
Mission “A”	Soil (0-5 cm)	6/23/03	**139**	5.0	U
Mission “B”	“	6/23/03	**222**	5.0	U
11MC	Sediment (0-2 cm)	4/15/03	**34**	na	
“	“	6/17/03	**16**	na	
2MC	SPM	4/9-10/03	**42**	na	
Brender Creek					
Brender “A”	Soil (0-5 cm)	6/23/03	**165**	5.0	U
Brender “B”	“	6/23/03	**276**	**6.2**	
BRENSD1	Sediment (0-2 cm)	4/15/03	**104**	na	
“	“	6/17/03	**60**	na	
“	Sediment (2-5 cm)	6/17/03	**57**	na	
3MC	Sediment (0-2 cm)	4/15/03	**141**	na	
“	“	“ (rep.)	**146**	na	
“	“	6/17/03	**83**	na	
“	Sediment (2-5 cm)	4/15/03	**145**	na	
“	SPM	4/9-10/03	**190**	na	
Yaksum Creek					
Yaksum “A”	Soil (0-5 cm)	6/24/03	**177**	5.0	U
Yaksum “B”	“	6/24/03	**231**	5.0	U
YAKSD1	Sediment (0-2 cm)	4/10/03	**120**	na	
“	“	6/17/03	**64**	na	
“	Sediment (2-5 cm)	4/10/03	**76**	na	
YAKSD2	Sediment (0-2 cm)	4/15/03	**97**	na	
“	“	6/17/03	**68**	na	
“	Sediment (2-5 cm)	4/15/03	**89**	na	
“	“	6/17/03	**63**	na	
Urban					
Urban “A”	Soil (0-5 cm)	6/23/03	**76**	5.0	U
Urban “B”	“	6/23/03	**67**	5.0	U

Detected values in **bold**
U = undetected at concentration shown
na = not analyzed

Discussion

DDT Sequestered in Upland Soils

Due to DDT's persistence in orchard soils (Blus et al., 1987; Harris et al., 2000), sequestered DDT remains a potential source of contamination to streams draining those orchard lands. Concentrations of DDT in soil suggest orchards in the lower Mission Creek basin currently contain 5 – 10 kg of t-DDT per hectare (1 hectare = 2.471 acres, Table 15). This estimate seems reasonable given DDT's long half-life in orchard soils (approximately two decades) and recommended application rates of DDT during its use in the 1950s and 1960s (Kilgemagi and Terriere, 1972; Martijn et al., 1993). For instance, the recommended DDT use on Okanogan valley fruit trees in British Columbia totaled 54 kg/hectare for the years 1960 – 1969 (B.C. Water Resources Service, 1973). More than two decades later Harris et al. (2000) found an average concentration of approximately 7,000 ng 4,4'-DDE/g in the top 5 cm of Okanogan (B.C.) orchard soil, comparable to the 4,000 – 7,000 ng 4,4'-DDE /g found in the present survey. Gross estimates of the amount of t-DDT currently sequestered in orchards of each sub-basin are 1 – 2 metric tons each in the Mission and Brender sub-basins, and approximately 300 kg in the smaller Yaksum sub-basin.

Table 15. Estimated t-DDT Sequestered in Orchards from Mission, Brender, and Yaksum Sub-basins.

Sub-basin	Mean DDT conc.[1] (ng/g, dw)	Kg DDT/hectare[2]	Orchard area[3] (hectare)	Total DDT in Sub-basin (kg)
Mission	7,600	5.4	249	1,300
Brender	8,200	5.8	292	1,700
Yaksum	14,000	10	31	310

[1]Top 5 cm of soil
[2]1 hectare = 2.471 acres
[3]Orchard areas remaining in production since 1968

Transport of soil from orchards to streams depends on a number of factors including soil type, ground cover, slope, and orchard practices such as irrigation methods and activities resulting in soil disturbance. Since many stream miles run directly through orchards with little buffer, delivery of DDT to streams may also depend on management of riparian areas. At some locations, slight bank erosion was observed in reaches that flowed through orchards, especially along Yaksum and Brender creeks where riparian buffers tended to be smallest. Aside from an instance where overspray from an irrigation sprinkler was observed to be transporting soils from a gravel driveway to a stream channel, the eroding banks were the only visible evidence of soils being delivered to streams. Episodic erosion during freshets may be the most fitting scenario to explain upland soil delivery to streams in the lower Mission Creek basin, but this has not been observed during Ecology's pesticide surveys.

Once in streams, heavier soil particles from contaminated orchard soils are diluted with other settling material – uncontaminated orchard soils or other uplands soils – to form bed sediments which become an intermediary for contaminant transport within streams. SPM collected during the present survey was probably lighter bed sediment material dislodged from the streambed. This assumption is based on the lack of observable upland soil delivery to streams and a closer similarity between bottom sediments and SPM than between orchard soils and SPM in terms of DDT concentrations and composition (e.g., percentage of 4,4'-DDD in t-DDT). However, the dynamics controlling the loading of these sediments and their residence times are unknown.

DDT Loads

Table 16 shows instantaneous DDT loads calculated at all water sampling locations for the present study. Loads were calculated using the following equation:

$$\textit{Instantaneous Load (mg/day)} = IC_w \times (10^{-6}\ mg/ng) \times IQ \times (86{,}400\ s/day)$$

Where:

- IC_w = instantaneous concentration of DDT in whole water (ng/l)
- IQ = instantaneous discharge (l/s)

Loads at MISSPZ1 and BRENPZ1were calculated using discharges estimated from 1995-1996 data collected at nearby Chelan County Conservation District (CCCD) stations. Discharge at these stations (4MC and 15MC corresponding to MISSPZ1 and BRENPZ1, respectively) was compared to seasonal paired discharge data from the stream mouths (2MC and 3MC), and the differences were expressed as factors. These factors were applied to the instantaneous discharges at 2MC and 3MC in order to calculate instantaneous discharges at MISSPZ1 and BRENPZ1, respectively.

The relatively high DDT loads in Mission Creek during May and June, 2003 were due to the high loads contributed by Yaksum Creek. Based on results from the MISSPZ1 site, the Mission Creek reach between 11MC and the Yaksum Creek confluence carries only a small load of DDT. Although Yaksum Creek appeared to account for only a small amount of the Mission Creek loads in April 2003, Yaksum Creek accounted for approximately 91% of DDT loading to Mission Creek during May and June, 2003 sampling.

Yaksum Creek itself carries high loads at 7AMC and 7MC. Although loads were not measured simultaneously at 7AMC and 7MC, it appears that significant entrainment of TSS occurs in this reach resulting in higher DDT loads at 7MC. Loads at YAKPZ1 were not calculated due to lack of discharge data, but elevated DDT concentrations suggest the potential for significant DDT loads at this location near the upstream extent of orchards along Yaksum Creek.

Brender Creek loads were moderate throughout the study at both 3MC and BRENPZ1. DDT loading at 3MC appears to occur as the stream emerges from Brender Canyon, several miles upstream of the mouth. During certain periods – as during June 2003 – at least some of this load stems from the Peshastin irrigation canal which is partially discharged to Brender Creek in the canyon reach.

t-DDT loads calculated from SPM at 2MC and 3MC were 26 mg/day and 27 mg/day respectively. At 2MC this agrees well with the water column results showing 75% (27 mg/day) of the total load in the solid phase, but water sampling results at 3MC indicated a particle-bound load of only 6 mg/day. Computation of solid-phase loads derived from SPM data are probably more representative of average conditions due to the large volume of water processed and long sampling duration used to obtain SPM samples.

Table 16. Instantaneous DDT Loads in Mission, Brender, and Yaksum Creeks, and the Peshastin Irrigation Canal During 2003.

Location	Date	Discharge (l/s)	TSS (mg/l)	TSS load (kg/day)	t-DDT (ng/l)	t-DDT load (mg/day)
Mission Creek						
2MC	4/9-10/03	1,048	18	1,630	0.4	36
"	5/29/03	920	19	1,510	2.4	191
"	6/24/03	328	4	113	3.2	91
MISSPZ1	5/29/03	1,012[1]	11	962	0.4	35
"	6/24/03	400[1]	3	104	0.5	17
Brender Creek						
3MC	4/9-10/03	67	16	93	3.6	21
"	5/29/03	68	18	106	7.0	41
"	6/24/03	131	4	45	6.0	68
BRENPZ1	5/29/03	26[1]	36	81	31	70
"	6/24/03	46[1]	22	87	20	79
Peshastin Canal						
PESHAST1	6/25/03	n/a	n/a	n/c	3.2	n/c
Yaksum Creek						
7AMC	4/10/03	0.2	<1	0.02	23	0.4
"	6/24/03	16	14	19	58	80
7MC	5/28/03	16	46	64	130	180
YAKPZ1	5/29/03	n/a	4	n/c	11	n/c
"	6/24/03	n/a	2	n/c	8.1	n/c

[1]Estimated discharge
n/a = not analyzed
n/c = not calculated

Comparison to Historical DDT Loads

Loads of t-DDT during early season (April) flows were substantially lower in 2003 compared to 2000 in the three streams sampled (Figures 6-8). Differences between years in Mission and Yaksum creeks were driven largely by discharge. Although April flows in Mission Creek were similar, the influence of Yaksum Creek loads is evident (Yaksum Creek provided an average of 81% of the Mission Creek DDT load during 2000). These differences are probably best explained by the onset of operational spills from the Icicle irrigation canal, which typically occurs during the second or third week of April (April 15 in 2003); Yaksum Creek was sampled prior to Icicle discharge in 2003 (April 10) but following the onset of the Icicle canal discharge in 2000 (April 24).

Brender Creek, which is largely influenced by operational spills from the Peshastin canal, saw substantial reductions in t-DDT loads and discharge in 2003 compared to previous measurements. Like the Mission/Yaksum system, the largest difference occurred during April flows, but May and June, 2003 loads were only 20-50% of those seen during the same months in 2000.

Although reductions in loads from 2000 to 2003 appear to be driven mainly by discharge, DDT concentrations were also lower in most instances. This may be due in part to lower TSS levels resulting from lower flows: The decreases in DDT concentrations are generally smaller when normalized to TSS concentrations. Since t-DDT loads are similar in cases where discharges are similar (except in the case of the anomalous Yaksum Creek April 2003 sample), it can be assumed that t-DDT loads will be comparable whether due to similarities in soil/sediment entrainment or volume discharged.

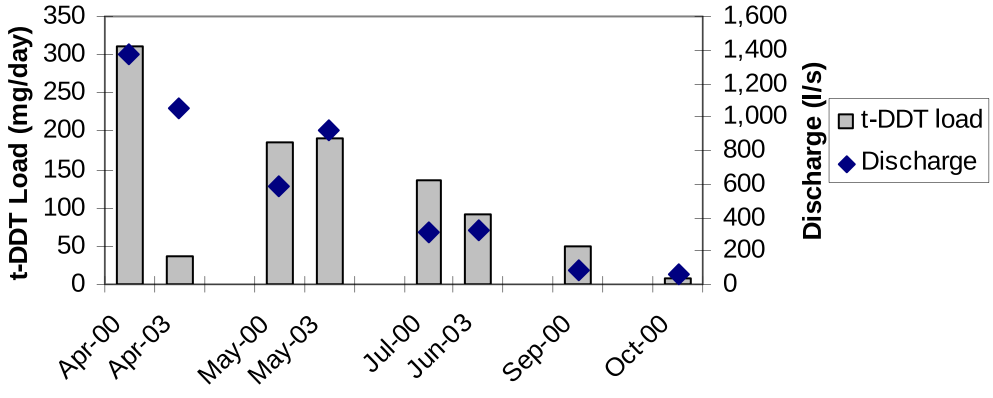

Figure 6. t-DDT Loads in Mission Creek (2MC) in 2000 and 2003.

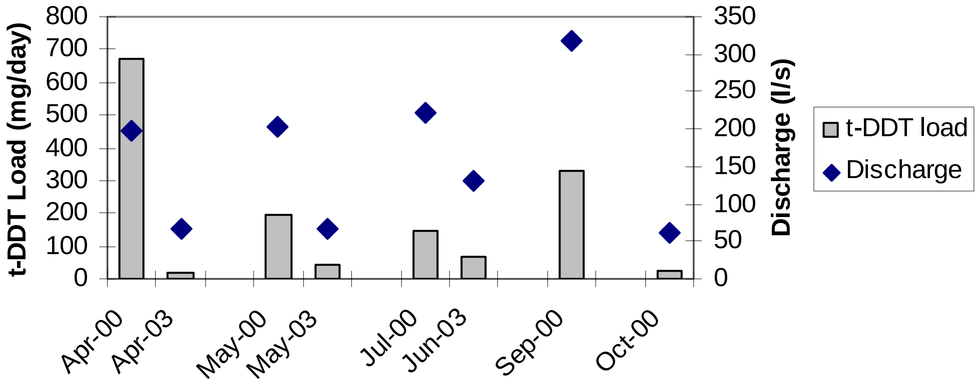

Figure 7. t-DDT Loads in Brender Creek (3MC) in 2000 and 2003.

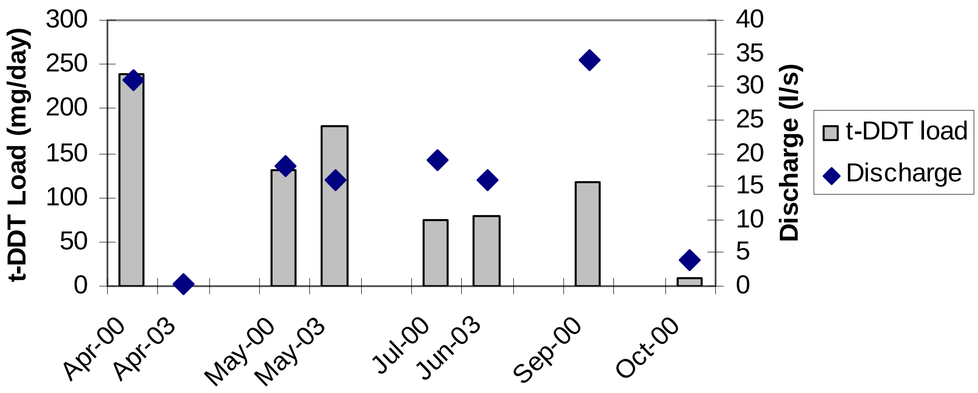

Figure 8. t-DDT Loads in Yaksum Creek (7MC and 7AMC) in 2000 and 2003.

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Numerical Water Quality and Load Reduction Targets

Selection of DDT Criteria

Selection of appropriate DDT criteria should be made not only to protect beneficial uses in the Mission Creek basin, but should also consider the Wenatchee River to which it empties. As discussed in the introductory sections of this report, there are two sets of relevant criteria: one set to protect aquatic life through chronic exposure (1 ng/l for DDT metabolites or t-DDT) and another set to protect human health through chronic exposure (0.59 ng/l for 4,4'-DDE and 4,4'-DDT, and 0.83 ng/l for 4,4'-DDD). Either set of criteria is potentially applicable in the Mission Creek basin. However, since fish tissue is the exposure medium used to develop both sets of criteria, the relative importance of each is speculative without a detailed assessment of fish consumption by humans and piscivorous wildlife. Currently, there is not a fishery in Mission Creek, and it has not been stocked since about 1989 (Art Viola, Washington Department of Fish and Wildlife, personal communication), though this does not preclude its future use as a viable fishery following improvements in water quality and fish habitat.

A reasonable, simple, and slightly conservative approach is to use the t-DDT criterion of 1 ng/l. Based on the average composition of water samples (56% 4,4'-DDE, 17% 4,4'-DDD, and 27% 4,4'-DDT), water with 1 ng/l t-DDT would typically meet the human health criteria for these compounds. This approach provides a more restrictive criterion for the sum of DDT compounds, which are almost always found in some combination, yet it also encompasses the criteria for these compounds taken individually. In the present study, all water samples with t-DDT < 1 ng/l met the individual criteria for 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT. If the human health criteria were selected individually as targets, this could theoretically double the t-DDT concentration before one of the targets was met (0.59 ng/l 4,4'-DDE + 0.83 ng/l 4,4'-DDD + 0.59 ng/l 4,4'-DDT = 2.0 ng/l t-DDT).

DDT Loads: Targets and Reductions Needed

Target loads (i.e., assimilative capacities) for t-DDT were calculated for Mission, Brender, and Yaksum creeks (Table 17). Target loads were calculated using the formula:

$$\textit{Target Load (mg/day)} = CC_w \times (10^{-6}\ mg/ng) \times HMQ \times (86{,}400\ s/day)$$

Where:

- CC_w = DDT criterion in whole water (ng/l)
- HMQ = harmonic mean discharge (l/s)

Harmonic mean discharge for Mission Creek at Cashmere is 138 l/s based on data from May 1996 through April 2004 (no data for water years 2000 and 2001). Discharge for Brender Creek at Cashmere is 86 l/s based on data from February 1997 through January 2004 (no data for water years 2000 and 2001). Yaksum Creek discharge has a harmonic mean of 18 l/s based on

15 measurements taken by the Chelan County Conservation District (1995-1996) and Ecology (2000, 2003).

Table 17. Load Reductions Required to Meet Target t-DDT Loads in Mission, Brender, and Yaksum Creeks.

Stream/Location	Harmonic Mean Discharge (l/s)	t-DDT Criterion (ng/l)	Target Load (mg/d)	Average t-DDT (ng/l)	Current Load (mg/d)	Load Reduction (mg/d)	Load Reduction (%)
Mission Creek – 2MC	138	1	12	3.2	38	26	69
Mission Creek – MISSPZ1	97	1	8.4	0.4	3.4	(5.0)	(150)
Brender Creek – 3MC	86	1	7.4	11	84	77	91
Brender Creek – BRENPZ1	37	1	3.2	26	83	80	96
Yaksum Creek – near mouth	18	1	1.6	62	96	94	98

( ) = reserve capacity

Discharges for MISSPZ1 and BRENPZ1 were estimated from 1995-1996 data collected at nearby CCCD stations. Discharge at these stations (4MC and 15MC corresponding to MISSPZ1 and BRENPZ1, respectively) was compared to paired discharge data from the stream mouths (2MC and 3MC), and the differences in harmonic means were expressed as factors. These factors were applied to the harmonic mean discharges for Mission Creek and Brender Creek in order to calculate discharges at MISSPZ1 (0.70 x 138 l/s = 97 l/s) and BRENPZ1 (0.43 x 86 l/s = 37 l/s), respectively.

Table 17 also shows current t-DDT loads for each stream using the formula:

$$\textit{Current Load (mg/day)} = AC_w \times (10^{-6}\ mg/ng) \times HMQ \times (86{,}400\ s/day)$$

Where:

- AC_w = average concentration of DDT in whole water (ng/l) based on pooled 2000 and 2003 data
- HMQ = harmonic mean discharge (l/s)

Current Loads are considered representative of average flow conditions since they were collected under flow regimes ± 25% of average.

The greatest t-DDT load reductions are required in Yaksum Creek (98% reduction) and Brender Creek where >90% reductions are required to meet target loads. Mission Creek at MISSPZ1 has a reserve capacity (i.e., amount below assimilative capacity) of 5 mg/day, whereas 2MC requires a 69% (26 mg/day) load reduction to meet its target load. Meeting the target load at 2MC should be achievable if the current t-DDT load in Yaksum Creek is reduced by approximately 30%. This should be possible even if the load at MISSPZ1 approaches its assimilative capacity.

In Brender Creek, current t-DDT loads at the upstream location (BRENPZ1) and at the mouth (3MC) are nearly equal as are the load reductions required to meet targets. The result of meeting the target load at BRENPZ1 would theoretically yield 3 mg/day reserve capacity at 3MC.

Overall, the Mission Creek system currently delivers more than six times its target load to the Wenatchee River (122 vs. 19 mg/day), based on the sum of loads from 2MC and 3MC. The current loading of t-DDT from Mission Creek represents approximately 2% of the assimilative capacity of the Wenatchee River (6,510 mg/day).

Relationship Between TSS and DDT Concentrations

Studies from the Yakima and Walla Walla rivers in eastern Washington have demonstrated a strong relationship between TSS and DDT concentrations in the water column (Joy and Patterson, 1997; Johnson et al., 2004). Although sediment loads in these basins are due largely to irrigation return water, Mission Creek basin data collected during 2000 also showed a positive correlation between DDT and TSS even though there is no evidence that overland irrigation returns exist (Serdar and Era-Miller, 2002).

To examine the relationship between TSS and DDT, pooled whole water (surface) samples collected during 2000 and 2003 were analyzed by regressing t-DDT on TSS following log transformation of the data (Table 18). The strongest relationship between TSS and DDT concentrations was in Yaksum Creek, followed by Brender Creek. In Mission Creek, there was essentially no relationship between these variables.

Table 18. Simple Linear Models for Relationships Between TSS (mg/l) and t-DDT (ng/l).

Stream	n	Linear model	F-ratio	R^2	P
Mission	10	t-DDT = $e^{(0.21 \times \text{InTSS}) + 0.96}$	0.24	0.03	0.639
Brender	10	t-DDT = $e^{(0.55 \times \text{InTSS}) + 1.09}$	5.07	0.39	0.054
Yaksum	10	t-DDT = $e^{(0.58 \times \text{InTSS}) + 2.38}$	22.0	0.73	0.002

Using the equations in Table 18, TSS concentrations < 1 mg/l in both Brender (at 3MC) and Yaksum creeks would be needed to reduce t-DDT concentrations to 1 ng/l. The model for Mission Creek is a poor fit and cannot be used to project needed TSS reductions, but TSS reductions in Yaksum Creek would also reduce t-DDT loads in Mission Creek (at 2MC) below target loads (Figure 9). The TSS-DDT regression equation for Yaksum Creek projects that the target load at 2MC would be met if Yaksum Creek TSS concentrations were reduced to an average of 12 mg/l from the current average of 20 mg/l, assuming 100% of the t-DDT load is from Yaksum Creek. Under scenarios where Yaksum Creek contributes 90% and 80% of the t-DDT load at 2MC, TSS would need to be reduced to 11 mg/l and 10 mg/l, respectively, in order to meet the target load.

Load reductions in Brender Creek at 3MC as a function of TSS are shown in Figure 10. Although the TSS-DDT regression equation for Brender Creek projects TSS <1 mg/l to meet target loads, substantial t-DDT load reductions may be achieved through more moderate TSS decreases at BRENPZ1. TSS and DDT concentrations at BRENPZ1 are much higher than 3MC while loads are similar, probably due to flow dilution. Presently, however, not enough data are available to establish a relationship between TSS and DDT at BRENPZ1.

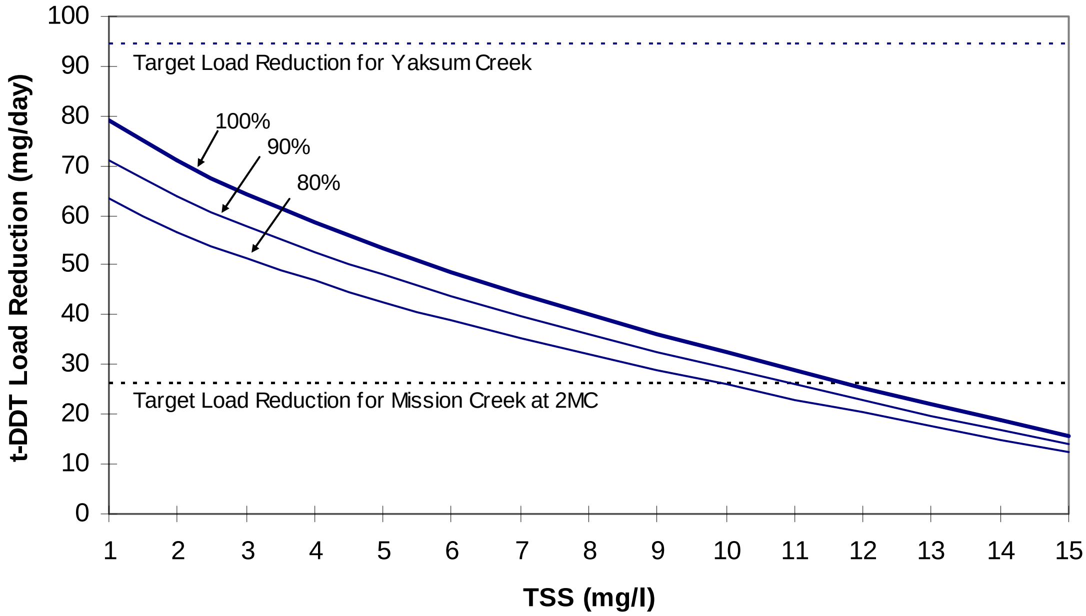

Figure 9. t-DDT Load Reductions as a Function of TSS in Yaksum Creek. T-DDT Load Reductions of 100%, 90%, and 80% are Shown to Evaluate Load Reduction Scenarios in Mission Creek at 2MC.

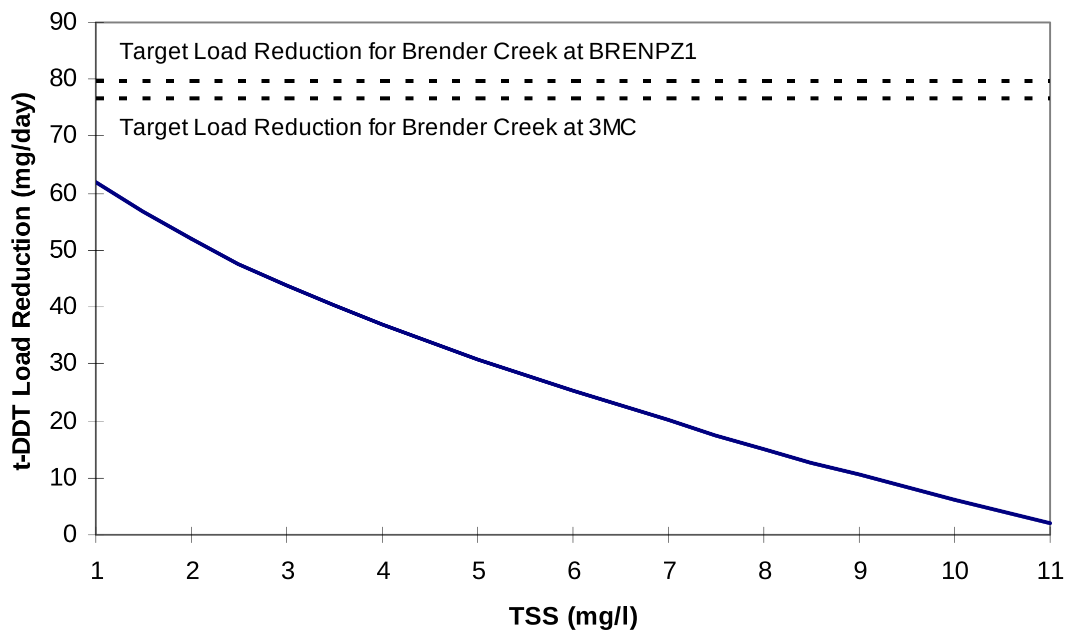

Figure 10. t-DDT Load Reductions as a Function of TSS in Brender Creek at 3MC.

Margin of Safety

This TMDL evaluation incorporates several assumptions which provide a margin of safety. The target numerical water quality criterion (1 ng/l) is conservative because at this concentration human health criteria will be met based on the typical composition of water samples (56% 4,4'-DDE, 17% 4,4'-DDD, and 27% 4,4'-DDT). In the present study, all water samples with t-DDT < 1 ng/l met the individual criteria for 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT. Conversely, selecting the human health criteria as targets could theoretically double the t-DDT concentration before the target was met (0.59 ng/l 4,4'-DDE + 0.83 ng/l 4,4'-DDD + 0.59 ng/l 4,4'-DDT = 2.0 ng/l t-DDT). The target numerical water quality criterion was used to calculate target loads.

The use of harmonic mean discharges to calculate target loads increases the margin of safety since harmonic means are lower than arithmetic means, especially in cases where discharge data have a wide spread. For instance, the harmonic mean discharge in Mission Creek (2MC) is 138 l/s whereas the arithmetic mean is 658 l/s. Target t-DDT loads calculated using the harmonic and arithmetic mean flows are 12 mg/d and 56 mg/d, respectively, with the former, more conservative target used in this assessment.

Seasonal Variation and Critical Conditions

This TMDL evaluation considers seasonal variation by using calculated loads from pooled 2000-2003 data which were collected over three seasons. Current Loads calculated from these data are considered representative of seasonally-adjusted average flow conditions since they were collected under flow regimes ± 25% of average.

Although data were not collected during rainfall events which may cause episodic loading of DDT, this condition would probably not result in DDT concentrations high enough to cause acute toxicity to aquatic organisms. The acute water quality criterion is one to three orders of magnitude higher than water column concentrations measured during the present and previous studies. The numerical target criterion for the TMDL was derived from DDT's toxicity due to accumulation in fish tissue, which depends on exposure over the course of weeks or months and is unaffected by short-term peaks in water column concentrations. However, data on loading to the aquatic system due to episodic rainfall events would be useful as previously acknowledged in the description of the project objectives and study design.

TMDL Effectiveness Monitoring Plan and Compliance Schedule

This TMDL evaluation recommends a monitoring plan in order to evaluate the effectiveness of best management practices, restoration of riparian areas, or other efforts to reduce DDT loading. The ultimate goal of these efforts would be to reduce t-DDT loading to the target loads in Table 17. However, it is recognized this may not be achievable in the near run. Any efforts to set interim targets and a compliance schedule should be based on the feasibility of implementing these efforts, requiring detailed knowledge of the local area and orchard and other land-use management practices, which is beyond the scope of the present study.

An approach to monitor the effectiveness of load reduction efforts could be conducted in two phases. The goal of Phase One would be to collect data for the establishment of interim targets. Phase Two would monitor the effectiveness in achieving the interim targets and provide data to evaluate the successes and failures of load reduction efforts. The following are recommendations for monitoring:

- Phase One would gauge the effects of initial efforts to reduce TSS in Yaksum and Brender creeks. Efforts to reduce TSS should be documented, and TSS should be monitored at downstream locations. A program to measure TSS and DDT concentrations in the water column should also be established in order to increase the statistical integrity of this relationship and to increase the confidence in the accuracy of targets. Locations near the mouths of Yaksum and Brender creeks, and Brender Creek at BRENPZ1, are recommended for further TSS and DDT monitoring. Interim t-DDT load targets could be set based on Phase One results.

- Phase Two would monitor the effectiveness of meeting interim t-DDT load targets. Efforts to reduce TSS in streams would be evaluated by monitoring TSS at downstream locations, and refinements may be suggested based on the success of reaching interim targets. As TSS and DDT levels decrease, finer adjustments will be needed to reduce DDT levels toward target levels, and the relationship between TSS and DDT may change. To detect these changes, TSS and DDT should continue to be monitored in the water column near the mouths of Yaksum and Brender creeks, and Brender Creek at BRENPZ1.

Water column sampling should be done using the field and laboratory methods described in the present study in order to obtain comparable data. The reporting limit for DDT compounds in water samples should be no higher than 0.5 ng/l. Discharge data should also be collected at all of the sampling locations in order to calculate loads.

Monitoring for TSS should be established at approximately 1-km intervals in Brender Creek and 0.5-km intervals in Yaksum Creek. Sites should include previously established locations (3MC, BRENPZ1, 7MC, 7AMC, and YAKPZ1). Sampling for TSS should also be conducted in Mission Creek at 2MC and at a location immediately upstream of the Yaksum Creek confluence. Sampling for TSS should occur every two weeks and should commence immediately in order to establish baseline conditions. Paired TSS/DDT sampling should be conducted monthly.

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Conclusions

Soils in orchards of the lower Mission Creek basin contain considerable quantities of DDT. This finding was observed in the Yaksum Creek sub-basin where concentrations are highest, as well as the Brender Creek sub-basin and along lower Mission Creek. DDT in the top 5 cm of orchards soils – averaging 7.6, 8.2, and 14 µg/g dw in Mission, Brender, and Yaksum sub-basins, respectively – is probably residual from heavy use as an insecticide during its introduction after World War II until the late 1960s. DDT is also present in the soils of public parks and school ball fields which were not in orchard production during this period, although the average concentration (0.44 µg/g dw) is about 20-fold lower than in orchards.

DDT concentrations in bottom sediments reflect those in orchard soils, to a limited degree. In Yaksum Creek where entrainment of orchard soils may have a more profound effect on DDT in bottom sediments, concentrations are about 10-20% of average orchard soils. Brender Creek sediments are more diluted, with concentrations typically 1-3% of average orchard soils of the Brender sub-basin. The dearth of fine depositional material in lower Mission Creek suggests little DDT is sequestered *in situ*. Deposits of mostly sandy material upstream of Wenatchee National Forest contained no measurable DDT, confirming, along with water column data, the conclusion that upper Mission Creek (above WNF) is not a source of DDT to lower Mission Creek.

Yaksum Creek water has the highest DDT concentrations, followed by Brender Creek and Mission Creek. DDT concentrations in Yaksum and Brender creeks always exceed the aquatic life water quality criterion of 1 ng/l and the human health criterion for 4,4'-DDE (0.59 ng/l) and 4,4'-DDD (0.83 ng/l). Most other Yaksum and Brender Creek samples also exceeded the human health criterion for 4,4'-DDT (0.59 ng/l) except at the Brender Creek mouth (2MC) which had an unusually low proportion of 4,4'-DDT compared to other sites. Two or more of these criteria were typically exceeded at the mouth of Mission Creek (2MC), but DDT concentrations were much lower upstream above the Yaksum Creek confluence. Yaksum Creek contributes approximately 80-90% of the DDT load in Mission Creek.

Detectable concentrations of DDT were not in the groundwater of Mission and Yaksum creek sub-basins during the present study. However, groundwater sampling coverage was very limited – only two piezometers were sampled during May and June 2003 – and areas of large groundwater input to Brender Creek (RM 1.1-1.5) were not sampled.

In the Mission Creek water column, 25% of the t-DDT concentration was dissolved, but the dissolved components were more variable in Brender and Yaksum creeks (20-80% of t-DDT). However, the relationship between total suspended solids (TSS) and DDT is particularly strong in Yaksum Creek, where it appears likely that a substantial portion of the TSS may originate from orchards. DDT is also a function of TSS concentrations in Brender Creek. In Mission Creek, which receives most of its DDT load but relatively little TSS from Yaksum Creek, there is no link between DDT and TSS.

Using a DDT criterion of 1 ng/l t-DDT, DDT-TSS regression equations project TSS concentrations in Brender and Yaksum creeks will need to be reduced to < 1 mg/l in order to meet the target DDT loads (i.e., assimilative capacities) in these streams. Mission Creek should meet the target DDT load if TSS in Yaksum Creek can be reduced by an average of 40% from current levels.

Recommendations

Total suspended solids (TSS) in Yaksum and Brender creeks should be reduced to concentrations < 1 mg/l in order to meet target loads. Although this may not be practical in the near run, significant reductions in DDT loads may be achieved by preventing bank erosion or by other means of limiting transport of upland soils to streams. A phased monitoring approach could be used to assess the effectiveness of TSS reduction efforts and to set interim t-DDT loading targets. Paired TSS/DDT monitoring should be conducted in Yaksum and Brender creeks to increase the reliability of projected DDT load reductions resulting from declines in TSS concentrations.

In Yaksum Creek, a detailed assessment of soil input is feasible due to the relatively small reach flowing through orchard lands. However, elevated DDT levels may persist due to the high concentrations of DDT found in bed sediments.

Locating soil input to Brender Creek will be more difficult due to the overall length of the reach flowing through orchard lands. However, the link between TSS and DDT indicates that limiting soil input will be necessary to reduce DDT concentrations in the water column. Due to the large inputs of groundwater in lower Brender Creek, the possibility of DDT transport through this mechanism should also be re-evaluated at this location.

At least some of the evaluation of soil transport to streams should be conducted during large rainfall events when visual observation or isolating sections of streams with high TSS can be done. Orchard and streamside observations should also be made during the peak of the irrigation season, especially in cases where irrigation water can provide the same soil transport potential as rainfall.

Icicle and Peshastin canals should be sampled to obtain representative DDT concentrations. An evaluation should be conducted to determine where these waterways may be entraining DDT. More information also is needed on their relative contributions to discharges in Mission, Brender, and Yaksum creeks, particularly with respect to bank erosion and sediment re-suspension caused by increased flows.

Adaptive Management Process

The Wenatchee River Basin TMDL study is the result of a partnership between the Department of Ecology and the Water Resource Inventory Area (WRIA) 45 Water Quality Technical Subcommittee (WQTS). The WQTS consists of Ecology TMDL staff and the WRIA 45 Watershed Planning Unit's Water Quality Subcommittee.

Ecology authored this TMDL technical report for DDT, and the WQTS reviewed, discussed, and commented on the report.

The data collection and literature review conducted for and presented in this technical report for the Wenatchee River basin represent the current state of knowledge for DDT in the watershed. It is the understanding of the WQTS that additional studies will be performed to fill data gaps and address unanswered questions, as determined by the WQTS.

Conclusions and recommendations currently presented in this technical report may be revised based on new data as they become available. It is also the understanding of the WQTS that any new data gathered from further study can be incorporated in the TMDL process in the *Summary Implementation Strategy* (SIS) or *Detailed Implementation Plan* (DIP) wherein recommendations and management strategies may be refined. This adaptive management approach is acceptable to both Ecology staff and the WQTS. Ecology will partner with stakeholders (interested parties) in the watershed to conduct studies addressing information gaps (e.g., monitoring).

Further monitoring for purposes of TMDL assessment will be addressed in the TMDL SIS and DIP. Any new science available as a result of these studies will be integrated into the SIS and DIP as new conclusions and management recommendations. Management strategies addressing both point (discrete) and nonpoint (diffuse) pollution sources are subject to this adaptive management approach.

References

B.C. Water Resources Service, 1973. Pesticide Use Study. *Prepared for* the Okanagan Study Committee by Water Resources Service, Pollution Control Branch, Victoria, B.C. Preliminary report No. 35.

Blus, L.J., C.J. Henny, C.J. Stafford, and R.A. Grove, 1987. Persistence of DDT and Metabolites in Wildlife from Washington State Orchards. Archives of Environmental Contamination and Toxicology 16:467-476.

Callahan, M.A., M.W. Slimak, N.W. Gabel, I.P. May, C.F. Fowler, J.R. Freed, P. Jennings, R.L. Durfee, F.C. Whitmore, B. Maestri, W.R. Mabey, B.R. Holt, and C. Gould, 1979. Water-Related Environmental Fate of 129 Priority Pollutants. U.S. Environmental Protection Agency, Office of Water Planning and Standards, Washington, D.C. EPA-440/4-79-029a.

Davis, D., 1993. Washington State Pesticide Monitoring Program - Reconnaissance Sampling of Surface Waters (1992). Washington State Department of Ecology, Olympia, WA. Publication No. 93-e09.

Davis, D., 1996. Washington State Pesticide Monitoring Program - 1994 Surface Water Sampling Report. Washington State Department of Ecology, Olympia, WA. Publication No. 96-305.

Davis, D. and A. Johnson, 1994. Washington State Pesticide Monitoring Program - 1993 Surface Water Sampling Report. Washington State Department of Ecology, Olympia, WA. Publication No. 94-164.

Davis, D., A. Johnson, and D. Serdar, 1995. Washington State Pesticide Monitoring Program - 1993 Fish Tissue Sampling Report. Washington State Department of Ecology, Olympia, WA. Publication No. 95-356.

EPA, 1980. Ambient Water Quality Criteria for DDT. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C. EPA 440/5-80-038.

Harris, M.J., L.K. Wilson, J.E. Elliott, C.A. Bishop, A.D. Tomlin, and K.V. Henning, 2000. Transfer of DDT and Metabolites from Fruit Orchard Soils to American Robins (*Turdus migratorius*) Twenty Years after Agricultural Use of DDT in Canada. Archives of Environmental Contamination and Toxicology 39:205-220.

Johnson, A., D. Norton, and B. Yake, 1988. Persistence of DDT in the Yakima River Drainage, Washington. Archives of Environmental Contamination and Toxicology. 17:289-297. Ecology Publication No. 88-e17.

Johnson, A., B. Era-Miller, R. Coots, and S. Golding, 2004. Draft Report: A Total Maximum Daily Load Evaluation for Chlorinated Pesticides and PCBs in the Walla Walla River. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-032. http://www.ecy.wa.gov/biblio/0403032.html

Joy, J. and B. Patterson, 1997. A Suspended Sediment and DDT Total Maximum Daily Load Evaluation Report for the Yakima River. Washington State Department of Ecology, Olympia, WA. Publication No. 97-321.

Kilgemagi, U. and L.C. Terriere, 1972. Persistence of DDT in Orchard Soils. Bulletin of Environmental Contamination and Toxicology 7(6): 348-352.

Martijn, A., H. Bakker, and R.H. Schreuder, 1993. Soil Persistence of DDT, Dieldrin, and Lindane Over a Long Period. Bulletin of Environmental Contamination and Toxicology 51:178-184.

PSEP, 1986. Recommended Protocols for Measuring Conventional Sediment Variables in Puget Sound. Prepared *by* Tetra Tech, Inc., Bellevue, Washington *for* U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, Seattle, Washington, and U.S. Army Corp of Engineers, Seattle District, Seattle, Washington. Final Report No. TC-3991-04.

Rogowski, D., S. Golding, D. Bowhay, and S. Singleton, 1999. Final Report – Screening Survey for Metals and Dioxins in Fertilizer Products and Soils in Washington State. Washington State Department of Ecology, Olympia, WA. Publication No. 99-309. http://www.ecy.wa.gov/biblio/99309.html

San Juan, C., 1994. Natural Background Soil Metals Concentrations in Washington State. Washington State Department of Ecology, Olympia, WA. Publication No. 94-115.

Serdar, D., A. Johnson, K. Seiders, B. Yake, and J. Cubbage, 1997. Polychlorinated Dibenzo-*p*-Dioxins and Dibenzofurans in Upper Columbia River Suspended Particulate Matter, 1990-1994. Washington State Department of Ecology, Olympia, WA. Publication No. 97-342.

Serdar, D. and B. Era-Miller, 2002. Pesticide Monitoring in the Mission Creek Basin, Chelan County. Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-022. http://www.ecy.wa.gov/biblio/0203022.html

Serdar, D. and B. Era-Miller, 2003. Quality Assurance Project Plan – Total Maximum Daily Load Study: DDT Contamination and Transport in the Lower Mission Creek Basin, Chelan County, Washington. Washington State Department of Ecology, Olympia, WA. Publication No. 03-03-103. http://www.ecy.wa.gov/biblio/0303103.html

Sittig, M., 1980. Priority Toxic Pollutants – Health Impacts and Allowable Limits. Noyes Data Corporation, Park Ridge, NJ.

Viola, Art, 2004. Washington Department of Fish and Wildlife, Olympia, WA. Personal communication. October 13.

Willett, L.B., A.F. O'Donnell, H.I. Durst, and M.M. Kurz, 1994. Intensive Grazing/Seasonal Dairying: The Mahoning County Dairy Program – Chapter 11: Soil Pesticides. The Ohio State University OARDC Research Bulletin 1190, D.L. Zartman (ed.).

WRWSC, 1998. Wenatchee River Watershed Action Plan. Wenatchee River Watershed Steering Committee, Wenatchee, WA.

Yake, W., 1993. Evaluation of Effluent Centrifugation: Lessons Learned. Washington State Department of Ecology, Olympia, WA. Publication No. 93-e62.

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Appendices

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Appendix A – Glossary of Acronyms, Symbols, and Units

Acronyms and Symbols

303(d) – Section 303(d) of the federal Clean Water Act
B - boron
CCCD – Chelan County Conservation District
DDD – 1,1-dichloro-2,2-bis(p-chlorophenyl)ethane (a.k.a. 4,4'-DDD)
DDE – 1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene (a.k.a. 4,4'-DDE)
DDT – 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane (a.k.a. 4,4'-DDT)
dw – dry weight
Ecology – Washington State Department of Ecology
EPA – U.S. Environmental Protection Agency
hectare – 2.471 acres
MEL – Manchester Environmental Laboratory
NIST – National Institute of Standards and Technology
NTR – National Toxics Rule
QC – quality control
RM – river mile
RPD – relative percent difference
SPM – suspended particulate matter
SRM – standard reference material
SS – settleable solids
t-DDT – total DDT (sum of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT in this report)
TDS – total dissolved solids
TMDL – Total Maximum Daily Load
TOC – total organic carbon
TSS – total suspended solids
µm – micron (micrometer, one millionth of a meter)
USDA – U.S. Department of Agriculture
USGS – U.S. Geological Survey
WAC – Washington Administrative Code
WNF – Wenatchee National Forest
WRWSC – Wenatchee River Watershed Steering Committee
WSPMP – Washington State Pesticide Monitoring Program
Zn – zinc

Units

l/s – liters per second (0.03531 cubic foot per second)
mg/d – milligrams per day
mg/l – milligrams per liter (parts per million)
mg/l/hr – milligrams per liter per hour
ng/g – nanograms per gram (parts per billion)
ng/l – nanograms per liter (parts per trillion)
µg/g – micrograms per gram (parts per million)
µg/l – micrograms per liter (parts per billion)

Appendix B – Historic DDT Data from the Mission Creek Basin

Table B-1. Historic Water Column DDT Data

Date	Location	Discharge (l/s)	4,4'-DDT (ng/l)	4,4'-DDE (ng/l)	4,4'-DDD (ng/l)	t-DDT (ng/l)	t-DDT Load (mg/d)
Mission Creek							
May-92	@ Mission Cr. Road (WSPMP)	190	u(50)	u(50)	u(50)	nd	nd
Apr-93	"	1,034	**2**	**2**	u(50)	**4**	**360**
Jun-93	"	432	**18**	u(50)	u(50)	**18**	**670**
Aug-93	"	87	u(50)	u(50)	u(50)	nd	nd
Oct-93	"	33	u(50)	u(50)	u(50)	nd	nd
Apr-94	"	1,215	u(50)	u(50)	u(50)	nd	nd
Jun-94	"	362	**12**	**13**	u(50)	**25**	**780**
Oct-94	"	51	u(50)	u(50)	u(50)	nd	nd
Apr-00	abv. Brender Cr. confl. (2MC)	1,378	**1.4**	**1.2**	u(11)	**2.6**	**310**
May-00	"	582	**1.7**	**1.3**	**0.7**	**3.7**	**186**
Jul-00	"	312	**1.7**	**2.3**	**1**	**5**	**135**
Sep-00	"	82	**2.4**	**3.1**	**1.4**	**6.9**	**49**
Oct-00	"	63	u(1.6)	**1.3**	u(1.6)	**1.3**	**7**
Apr-00	abv. WNF boundary (11MC)	749	u(12)	u(12)	u(12)	nd	nd
May-00	"	506	u(3.3)	u(3.3)	u(3.3)	nd	nd
Jul-00	"	283	u(1.6)	u(1.6)	u(1.6)	nd	nd
Sep-00	"	44	u(1.6)	u(1.6)	u(1.6)	nd	nd
Oct-00	"	49	u(1.6)	u(1.6)	u(1.6)	nd	nd
Brender Creek							
Apr-00	abv. Mission Cr. confl. (3MC)	199	**30**	**5.9**	**2.8**	**39**	**671**
May-00	"	204	**2.8**	**5.2**	**2.7**	**11**	**194**
Jul-00	"	223	**1.3**	**3.8**	**2.4**	**7.5**	**145**
Sep-00	"	317	**2.5**	**6.8**	**3**	**12**	**329**
Oct-00	"	61	u(1.5)	**2.4**	**1.8**	**4.2**	**22**
Yaksum Creek							
Apr-00	near mouth (7MC)	31	**30**	**48**	**11**	**89**	**238**
May-00	"	18	**30**	**38**	**16**	**84**	**131**
Jul-00	"	19	**12**	**25**	**8.6**	**46**	**76**
Sep-00	"	34	**13**	**20**	**6.6**	**40**	**118**
Oct-00	"	4	**5**	**12**	**5.9**	**23**	**8**

u=undetected at concentration in parentheses

Table B-2. Historic Fish Tissue DDT Data

Date	Location	Sample type	Mean (range) Length* (mm)	Mean (range) Weight* (g)	4,4'-DDT (ng/l)	4,4'-DDE (ng/l)	4,4'-DDD (ng/l)	t-DDT (ng/l)
9/13/93	Mission Cr. Near mouth (WSPMP)	Rainbow trout fillet	241 (210-263)	179 (113-230)	42	270	51	363

*Composite of 5 fish

Appendix C – Station Locations

Table C-1. Station Locations for 2003 Lower Mission Creek DDT TMDL Study.

Station	Latitude*	Longitude*	Sample type	Date (2003)	Short Description
2MC	47˚31.281' N	120˚28.625' W	SPM whole water filtered water	4/9 – 4/10 4/9 – 6/24 4/9 – 6/24	Mission Creek near mouth
MISSPZ1	47˚29.300' N	120˚28.850' W	whole water groundwater	5/29 – 6/24 5/29 – 6/24	Mission Creek near 3910 Mission Creek Road
11MC	47˚25.573' N	120˚30.635' W	bed sediment whole water	4/15 – 6/17 5/28 – 6/24	Mission Creek on USFS land
3MC	47˚31.272' N	120˚28.640' W	bed sediment SPM whole water filtered water	4/15 – 6/17 4/9 – 4/10 4/9 – 6/24 4/9 – 6/24	Brender Creek near mouth
BRENPZ1	47˚31.167' N	120˚30.800' W	whole water	5/29 – 6/24	Brender Creek near 6850 Pioneer Drive
PESHAST1	47˚31.133' N	120˚31.650' W	whole water	6/25	Peshastin Canal
BRENSD1	47˚30.967' N	120˚32.050' W	bed sediment	4/15 – 6/17	Brender Creek near 7440 Pioneer Drive
UPBREN	47˚30.067' N	120˚33.650' W	whole water	6/25	Upper Brender Creek
7MC	47˚29.986' N	120˚28.479' W	whole water	5/28	Yaksum Creek at Mission Creek Road
YAKSD2	47˚29.950' N	120˚28.250' W	bed sediment	4/15 – 6/17	Yaksum Creek downstream of Coates Road
7AMC	47˚29.917' N	120˚28.233' W	whole water filtered water	4/10 – 6/24 4/10 – 6/24	Yaksum Creek at Coates Road
YAKSD1	47˚29.750' N	120˚28.083' W	bed sediment	4/10 – 6/17	Yaksum Creek near 4351 Yaxon Canyon Road
YAKPZ1	47˚29.467' N	120˚27.933' W	whole water groundwater	5/29 – 6/24 5/29 – 6/24	Yaksum Creek near 4041 Yaxon Canyon Road
RRPARK	47˚31.233' N	120˚28.117' W	soil	6/23	Railroad Park
CASHMIDS	47˚30.900' N	120˚28.483' W	soil	6/23	Cashmere Middle School
COTTPARK	47˚31.242' N	120˚27.583' W	soil	6/23	Cottage Park
VALEELEM	47˚31.492' N	120˚28.250' W	soil	6/23	Vale Elementary School
SIMSPARK	47˚31.008' N	120˚28.467' W	soil	6/23	Simpson Park

*All datum are NAD 27

Appendix D – Containers

Table D-1. Containers.

Parameter	Container	Preservation	Holding Time
Soil/Sediment			
DDT analogs, Percent solids	4-oz glass jar w/certificate of analysis, Teflon® lid liner	cool to 4° C	7 d extraction 14 d analysis (1 yr if frozen)
Zinc, boron	4-oz glass jar	cool to 4° C	6 mo (2 yr if frozen)
Grain size	8-oz plastic jar	cool to 4° C	6 mo
TOC	2-oz glass jar	cool to 4° C	14 d (6 mo if frozen)
Water			
DDT analogs	1-gallon glass jar w/certificate of analysis, Teflon® lid liner	cool to 4° C	7 d extraction 40 d analysis
Boron	500 ml HDPE bottle	HNO_3 to pH<2	6 mo
TDS	500 ml w/m poly bottle	cool to 4° C	7 d
TSS, SS	1-liter widemouth poly bottle	cool to 4° C	7 d
TOC	60 ml narrowmouth poly bottle	cool to 4° C, HCl to pH<2	28 d

Appendix E – Quality Assurance Results

Table E-1. Laboratory Precision Data for DDT Analysis.

Sample no.	Sample name	Station	Matrix	Type	Analyte	Result	Qual.	Mean	Units	RPD
03228224	YAK-SW	7MC	whole water	lab dup.	4,4'-DDE	63		62.5	ng/l	2%
03228224	LDP1	7MC	whole water	lab dup.	4,4'-DDE	62			ng/l	
03228224	YAK-SW	7MC	whole water	lab dup.	4,4'-DDD	22		22	ng/l	0%
03228224	LDP1	7MC	whole water	lab dup.	4,4'-DDD	22			ng/l	
03228224	YAK-SW	7MC	whole water	lab dup.	4,4'-DDT	48		49	ng/l	4%
03228224	LDP1	7MC	whole water	lab dup.	4,4'-DDT	50			ng/l	
03158171	YAK-1 TOP	YAKSD1	sediment	lab dup.	4,4'-DDE	1700		1600	ng/g	13%
03158171	LDP1	YAKSD1	sediment	lab dup.	4,4'-DDE	1500			ng/g	
03158171	YAK-1 TOP	YAKSD1	sediment	lab dup.	4,4'-DDD	250	J	240	ng/g	8%
03158171	LDP1	YAKSD1	sediment	lab dup.	4,4'-DDD	230			ng/g	
03158171	YAK-1 TOP	YAKSD1	sediment	lab dup.	4,4'-DDT	1400	J	1450	ng/g	7%
03158171	LDP1	YAKSD1	sediment	lab dup.	4,4'-DDT	1500			ng/g	
03264111	YAKSOILA	Yaksum “A”	soil	lab dup.	4,4'-DDE	9600		8750	ng/g	19%
03264111	LDP1	Yaksum “A”	soil	lab dup.	4,4'-DDE	7900			ng/g	
03264111	YAKSOILA	Yaksum “A”	soil	lab dup.	4,4'-DDD	130		130	ng/g	0%
03264111	LDP1	Yaksum “A”	soil	lab dup.	4,4'-DDD	130			ng/g	
03264111	YAKSOILA	Yaksum “A”	soil	lab dup.	4,4'-DDT	10000		11500	ng/g	26%
03264111	LDP1	Yaksum “A”	soil	lab dup.	4,4'-DDT	13000			ng/g	

J = estimated concentration

Table E-2. Field Precision Data for DDT Samples.

Sample no.	Sample name	Station	Matrix	Type	Analyte	Result	Qual.	Mean	Units	RPD
03228224	YAK-SW	7MC	whole water	field rep.	4,4'-DDE	63		61	ng/l	7%
03228228	YAK-REP-SW	7MC	whole water	field rep.	4,4'-DDE	59			ng/l	
03228224	YAK-SW	7MC	whole water	field rep.	4,4'-DDD	22		22	ng/l	0%
03228228	YAK-REP-SW	7MC	whole water	field rep.	4,4'-DDD	22			ng/l	
03228224	YAK-SW	7MC	whole water	field rep.	4,4'-DDT	48		47.5	ng/l	2%
03228228	YAK-REP-SW	7MC	whole water	field rep.	4,4'-DDT	47			ng/l	
03268231	YAK WHOLE	7AMC	whole water	field rep.	4,4'-DDE	28		27.5	ng/l	4%
03268234	REP WHOLE	7AMC	whole water	field rep.	4,4'-DDE	27			ng/l	
03268231	YAK WHOLE	7AMC	whole water	field rep.	4,4'-DDD	10		10	ng/l	0%
03268234	REP WHOLE	7AMC	whole water	field rep.	4,4'-DDD	10			ng/l	
03268231	YAK WHOLE	7AMC	whole water	field rep.	4,4'-DDT	17	J	20.5	ng/l	34%
03268234	REP WHOLE	7AMC	whole water	field rep.	4,4'-DDT	24	J		ng/l	
03158161	YAK WHOLE	7AMC	whole water	field rep.	4,4'-DDE	14		13	ng/l	15%
03158162	REP WHOLE	7AMC	whole water	field rep.	4,4'-DDE	12			ng/l	
03158161	YAK WHOLE	7AMC	whole water	field rep.	4,4'-DDD	5.3		4.65	ng/l	28%
03158162	REP WHOLE	7AMC	whole water	field rep.	4,4'-DDD	4			ng/l	

J = estimated concentration

Table E-2 (cont'd). Field Precision Data for DDT Samples.

Sample no.	Sample name	Station	Matrix	Type	Analyte	Result	Qual.	Mean	Units	RPD
03158161	YAK WHOLE	7AMC	whole water	field rep.	4,4'-DDT	6		5.6	ng/l	14%
03158162	REP WHOLE	7AMC	whole water	field rep.	4,4'-DDT	5.2			ng/l	
03168170	BREN-2-TOP	BRENSD2	sediment	field split	4,4'-DDE	79		78.5	ng/g	1%
03168174	REP TOP	BRENSD2	sediment	field split	4,4'-DDE	78			ng/g	
03168170	BREN-2-TOP	BRENSD2	sediment	field split	4,4'-DDD	37		35	ng/g	11%
03168174	REP TOP	BRENSD2	sediment	field split	4,4'-DDD	33			ng/g	
03168170	BREN-2-TOP	BRENSD2	sediment	field split	4,4'-DDT	8.6		9.05	ng/g	10%
03168174	REP TOP	BRENSD2	sediment	field split	4,4'-DDT	9.5			ng/g	

Table E-3. Laboratory Precision Data for Metals and General Parameters.

Sample no.	Sample name	Station	Matrix	Type	Analyte	Result	Qual.	Mean	Units	RPD
03158155	MI SPM	2MC	SPM	lab dup.	zinc	41		41.5	ug/g	2%
03158155	LDP1	2MC	SPM	lab dup.	zinc	42			ug/g	
03168169	BREN-1-TOP	BRENSD1	SPM	lab dup.	zinc	102		104.5	ug/g	5%
03168169	LDP1	BRENSD1	SPM	lab dup.	zinc	107			ug/g	
03158161	YAK WHOLE	7AMC	whole water	lab dup.	boron	53		52.5	ug/l	2%
03158161	LDP1	7AMC	whole water	lab dup.	boron	52			ug/l	
03228224	YAK-SW	7MC	whole water	lab dup.	boron	25	U	nc	ug/l	nc
03228224	LDP1	7MC	whole water	lab dup.	boron	25	U		ug/l	
03264111	YAKSOILA	Yaksum "A"	soil	lab dup.	boron	5	U	nc	ug/g	nc
03264111	LDP1	Yaksum "A"	soil	lab dup.	boron	5			ug/g	
03228226	BREN-SW	3MC	whole water	lab dup.	TSS	18		18	mg/l	0%
03228226	LDP1	3MC	whole water	lab dup.	TSS	18			mg/l	

Table E-3 (Cont'd). Laboratory Precision Data for Metals and General Parameters.

Sample no.	Sample name	Station	Matrix	Type	Analyte	Result	Qual.	Mean	Units	RPD
03268234	REP WHOLE	7AMC	whole water	lab dup.	TSS	15		15	mg/l	0%
03268234	LDP1	7AMC	whole water	lab dup.	TSS	15			mg/l	
03158165	YAK DIS	7AMC	filt. water	lab dup.	TDS	361		359.5	mg/l	1%
03158165	LDP1	7AMC	filt. water	lab dup.	TDS	358			mg/l	
03228232	YAK-PIEZ-GW	YAKPZ1	whole water	lab dup.	TDS	311		307.5	mg/l	2%
03228232	LDP1	YAKPZ1	whole water	lab dup.	TDS	304			mg/l	
03268237	BREN-DIS	3MC	filt. water	lab dup.	TDS	199		195	mg/l	4%
03268237	LDP1	3MC	filt. water	lab dup.	TDS	191			mg/l	
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	PCTSOL	51.5		50.87	%	1%
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	PCTSOL	50.3			%	
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	PCTSOL	50.8			%	
03158163	MI DIS	2MC	filt. water	lab dup.	TOC	2.3		2.35	mg/l	4%
03158164	LDP1	2MC	filt. water	lab dup.	TOC	2.4			mg/l	
03168178	BREN-2-SUB	BRENSD2	sediment	lab dup.	TOC	4.23		3.887	%	11%
03168178	LDP1	BRENSD2	sediment	lab dup.	TOC	4.01			%	
03168178	LDP2	BRENSD2	sediment	lab dup.	TOC	3.42			%	
03228228	YAK-REP-SW	7MC	whole water	lab dup.	TOC	2.1		2.15	mg/l	5%
03228228	LDP1	7MC	whole water	lab dup.	TOC	2.2			mg/l	
03264108	MISOILB	Mission "B"	soil	lab dup.	TOC104	4.42		4.51	%	3%
03264108	LDP1	Mission "B"	soil	lab dup.	TOC104	4.42			%	
03264108	LDP2	Mission "B"	soil	lab dup.	TOC104	4.69			%	

Table E-3 (Cont'd). Laboratory Precision Data for Metals and General Parameters.

Samp. No	Sample name	Station	Matrix	Type	Analyte	Result	Qual.	Mean	Units	RPD
03264108	MISOILB	Mission "B"	soil	lab dup.	TOC70	4.4		4.483	%	3%
03264108	LDP1	Mission "B"	soil	lab dup.	TOC70	4.39			%	
03264108	LDP2	Mission "B"	soil	lab dup.	TOC70	4.66			%	
03268234	REP WHOLE	7AMC	whole water	lab dup.	TOC	1.6		1.6	mg/l	0%
03268234	LDP1	7AMC	whole water	lab dup.	TOC	1.6			mg/l	
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	Gravel	0.6		1.067	%	68%
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	Gravel	0.7			%	
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	Gravel	1.9			%	
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	Sand	66.6		67.4	%	2%
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	Sand	69.2			%	
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	Sand	66.4			%	
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	Silt	25.2		25.5	%	3%
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	Silt	24.9			%	
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	Silt	26.4			%	
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	Clay	7.7		6.067	%	23%
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	Clay	5.2			%	
03168180	YAK-2-SUB	YAKSD2	sediment	lab trip.	Clay	5.3			%	

U = undetected at concentration shown

Table E-4. Field Precision Data for Metals and General Parameters.

Sample no.	Sample name	Station	Matrix	Type	Analyte	Result	Qual.	Mean	Units	RPD
03168170	BREN-2-TOP	BRENSD2	sediment	field split	zinc	141		143.5	ug/g	3%
03168174	REP TOP	BRENSD2	sediment	field split	zinc	146			ug/g	
03158161	YAK WHOLE	7AMC	whole water	field rep.	boron	53		54	ug/l	4%
03158162	REP WHOLE	7AMC	whole water	field rep.	boron	55			ug/l	
03268231	YAK WHOLE	7AMC	whole water	field rep.	boron	25	U	nc	ug/l	nc
03268234	REP WHOLE	7AMC	whole water	field rep.	boron	25	U		ug/l	
03228224	YAK-SW	7MC	whole water	field rep.	boron	25	U	nc	ug/l	nc
03228228	YAK-REP-SW	7MC	whole water	field rep.	boron	25	U		ug/l	
03158161	YAK WHOLE	7AMC	whole water	field rep.	TSS	1	U	nc	mg/l	nc
03158162	REP WHOLE	7AMC	whole water	field rep.	TSS	1			mg/l	
03228224	YAK-SW	7MC	whole water	field rep.	TSS	47		46	mg/l	4%
03228228	YAK-REP-SW	7MC	whole water	field rep.	TSS	45			mg/l	
03268231	YAK WHOLE	7AMC	whole water	field rep.	TSS	14		14.5	mg/l	7%
03268234	REP WHOLE	7AMC	whole water	field rep.	TSS	15			mg/l	
03268231	YAK WHOLE	7AMC	whole water	field rep.	SS	0.1	UJ	nc	ml/l/hr	nc
03268234	REP WHOLE	7AMC	whole water	field rep.	SS	0.1	J		ml/l/hr	
03228224	YAK-SW	7MC	whole water	field rep.	SS	0.4	U	nc	ml/l/hr	nc
03228228	YAK-REP-SW	7MC	whole water	field rep.	SS	0.4	U		ml/l/hr	
03158161	YAK WHOLE	7AMC	whole water	field rep.	SS	0.2	U	nc	ml/l/hr	nc
03158162	REP WHOLE	7AMC	whole water	field rep.	SS	0.2	U		ml/l/hr	
03228224	YAK-SW	7MC	whole water	field rep.	SS	0.4	U	nc	ml/l/hr	nc
03228228	YAK-REP-SW	7MC	whole water	field rep.	SS	0.4	U		ml/l/hr	

Table E-4 (Cont'd). Field Precision Data for Metals and General Parameters.

Sample number	Sample name	Station	Matrix	Type	Analyte	Result	Qual.	Mean	Units	RPD
03158161	YAK WHOLE	7AMC	whole water	field rep.	TOC	2.5		2.55	mg/l	4%
03158162	REP WHOLE	7AMC	whole water	field rep.	TOC	2.6			mg/l	
03228224	YAK-SW	7MC	whole water	field rep.	TOC	2.4		2.25	mg/l	13%
03228228	YAK-REP-SW	7MC	whole water	field rep.	TOC	2.1			mg/l	
03268231	YAK WHOLE	7AMC	whole water	field rep.	TOC	1.8		1.7	mg/l	12%
03268234	REP WHOLE	7AMC	whole water	field rep.	TOC	1.6			mg/l	
03168170	BREN-2-TOP	BRENSD2	sediment	field split	TOC	3.09		3.085	%	0%
03168174	REP TOP	BRENSD2	sediment	field split	TOC	3.08			%	
03168170	BREN-2-TOP	BRENSD2	sediment	field split	Gravel	0.5		0.25	%	nc
03168174	REP TOP	BRENSD2	sediment	field split	Gravel	0			%	
03168170	BREN-2-TOP	BRENSD2	sediment	field split	Sand	63.8		63.8	%	0%
03168174	REP TOP	BRENSD2	sediment	field split	Sand	63.8			%	
03168170	BREN-2-TOP	BRENSD2	sediment	field split	Silt	33.1		33.05	%	0%
03168174	REP TOP	BRENSD2	sediment	field split	Silt	33.0			%	
03168170	BREN-2-TOP	BRENSD2	sediment	field split	Clay	3.4		3.35	%	3%
03168174	REP TOP	BRENSD2	sediment	field split	Clay	3.3			%	

J = estimated concentration
U = undetected at concentration shown
UJ = undetected at estimated concentration shown