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Lower Yakima River Suspended Sediment Total Maximum Daily Load Study

Water Quality Effectiveness Monitoring Report

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Water Quality Effectiveness Monitoring Report

by

Chris Coffin, Robert Plotnikoff, and Ryan Anderson

May 2006

Waterbody Number: WRIA 37

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Abstract

The Washington State Department of Ecology is required, under Section 303(d) of the federal Clean Water Act and U.S. Environmental Protection Agency regulations, to develop and implement Total Maximum Daily Loads (TMDLs) for impaired waters, and to evaluate the effectiveness of these water clean-up plans to achieve the needed improvement in water quality.

The *Lower Yakima River Suspended Sediment and DDT TMDL* was developed to reduce suspended sediment, turbidity, and the pesticide, DDT, in the lower reaches of the Yakima River. TMDL implementation is scheduled over 20 years with interim targets set at five-year intervals.

The fifth-year (2003) targets included meeting Washington State water quality criterion for turbidity in the lower Yakima River during the irrigation season. Also included was the requirement that non-Yakama Reservation tributaries to the lower mainstem – especially the major tributaries of Moxee Drain, Granger Drain, Sulphur Creek, and Spring Creek – achieve a maximum 90th percentile turbidity of 25 NTU at their mouths during the irrigation season. This report presents an assessment of the turbidity within the project area and the effectiveness of the TMDL in reducing agriculturally related sediment.

Sampling during the 2003 irrigation year demonstrated that sediment loads have been reduced in the agricultural drains and river, but improvement is needed to meet all of the targets. Of the four major agricultural drains, three met the criteria for turbidity, while the fourth failed to do so even though it had a sediment load reduction of approximately 80%. Mainstem turbidity requirements at the TMDL compliance point of Kiona Gauge did not meet the state water quality criterion of "5 NTU over background," and neither did the intermediate mainstem sampling sites at Sunnyside-Mabton Road and Euclid Bridge. However, comparing suspended sediment data at the Kiona site collected during 1995 and 2003, both loads and concentrations were greatly reduced in 2003.

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Introduction

The federal Clean Water Act established a process to identify and clean up polluted waters. Under the Act, every state has its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses for protection, such as cold water biota and drinking water supply, as well as criteria, usually numeric criteria, to achieve those uses.

Every two years, states are required to prepare a list of waterbodies – lakes, rivers, streams, or marine waters – that do not meet water quality standards. This list is called the 303(d) list or water quality assessment. To develop the list, the Washington State Department of Ecology compiles its own water quality data along with data submitted by local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data are reviewed to ensure that they were collected using appropriate scientific methods before they were used to develop the 303(d) list.

The Clean Water Act requires that a Total Maximum Daily Load or TMDL be developed for each of the waterbodies on the 303(d) list. A TMDL identifies how much pollution needs to be reduced or eliminated to achieve clean water. Then the local community works with Ecology to develop a strategy to control the pollution and a monitoring plan to assess effectiveness of the water quality improvement activities.

The goal of a TMDL is to ensure the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of the pollutant sources that cause the problem. The TMDL determines the amount of a given pollutant that can be discharged to the waterbody and still meet standards (the loading capacity) and allocates that load among the various sources.

If the pollutant comes from a discrete source (referred to as a *point* source) such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload allocation*. If it comes from a set of diffuse sources (referred to as a *nonpoint* source) such as general urban, residential, or farm runoff, the cumulative share is called a *load allocation*.

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A reserve capacity for future loads from growth pressures is sometimes included as well. The sum of the wasteload and load allocations, the margin of safety, and any reserve capacity must be equal to or less than the loading capacity.

Ecology submitted a TMDL for turbidity and DDT (dichlorodiphenyltrichloroethane) and its metabolites (DDT breakdown products: DDE, dichlorodiphenyldichloroethylene, and DDD, dichlorodiphenyldichloroethane[1]) to the U.S. Environmental Protection Agency (EPA) in 1998. It was approved later that year. The TMDL concluded that turbidity and DDT violations of

[1] Also referred to as Total DDT or t-DDT

Washington State water quality standards in the lower Yakima River basin could be primarily attributed to high levels of suspended sediment entering the river in return flows from agricultural irrigation. The goal of this ongoing TMDL implementation project is to meet turbidity and suspended sediment reduction targets that will protect aquatic communities and ultimately result in the lower mainstem of the Yakima River achieving human health criteria for DDT and its metabolites by the year 2017.

The original TMDL evaluation report, *A Suspended Sediment and DDT Total Maximum Daily Load Evaluation Report for the Yakima River* (Joy and Patterson, 1997), set a series of targets to be evaluated and achieved at five-year intervals beginning in 1997. The TMDL requires five years of implementation between each target date with the goal of achieving water quality criteria in 20 years.

The primary set of targets and the first round of effectiveness monitoring for the *Lower Yakima River Suspended Sediment and DDT TMDL* were scheduled for the year 2003. The TMDL, originally proposed for 1997, called for the first year of effectiveness monitoring to be in 2002. That date was extended one year because the TMDL was not approved by EPA until 1998. Those targets are:

- The Yakima River mainstem will comply with the turbidity target of not more than a 5 nephelometric turbidity unit (NTU) increase between the confluence of the Yakima and Naches rivers (river mile 116.3) and the Kiona Gauge near Benton City (RM 30). Use of a 90^{th} percentile frequency in determining turbidity compliance will be evaluated.
- All drains and tributaries within the project area will comply with the 90^{th} percentile turbidity target of 25 NTU at their mouths, including Moxee Drain, Granger Drain, Sulphur Creek, and Spring Creek.
- The efficacy of using total suspended solids (TSS) load targets for tributaries and drains where the 25 NTU target is not representative of total load reductions will be evaluated.
- Agreements between Washington State, the Yakama Nation, and the EPA that set DDT load allocations for the Yakama Reservation and management of basin water quality will be completed.

This 2003 effectiveness monitoring project examines the first three targets above. This study did not examine pesticide levels. Studies characterizing DDT concentrations and loads in the lower Yakima River are scheduled for 2007.

Data collected by the Roza-Sunnyside Board of Joint Control (RSBOJC), representing two of the project area's major irrigation districts, suggest that irrigation return flows leaving the lands irrigated by the Roza Irrigation District and the Sunnyside Valley Irrigation District (SVID) have shown significant improvements in reducing suspended sediments. (See the SVID website, www.svid.org/wcwq.htm). Additionally, information from the South Yakima Conservation District (SYCD), North Yakima Conservation District, and Benton Conservation District indicate that many growers have improved their irrigation methods since TMDL implementation began. Ecology personnel working in the Yakima River watershed have also noted, along with the widespread improvements to irrigation practices, visible reductions of turbidity in irrigation return flows.

To test the effectiveness of TMDL implementation, three separate but complementary studies by three government entities were designed that would allow a comprehensive examination of sediment loads entering the lower Yakima River.

1. Ecology's sampling effort focused on the mainstem of the Yakima River and on the major tributaries of Moxee Drain, Granger Drain, Sulphur Creek, and Spring Creek.
2. The South Yakima Conservation District (SYCD) undertook a project to characterize sediment loads (and other water quality parameters) in eight non-reservation, ungauged drains within the project area.
3. The Water Section of the Yakama Nation Environmental Management Program (YNEMP), partnering with the Wapato Irrigation Project, planned to measure sediment loads in drains and tributaries on the tribal lands of the Yakama Reservation.

The principal investigators in each of these projects met prior to the sampling season to coordinate sampling schedules, agree on appropriate sampling design and protocols, and discuss the shared use of equipment and personnel. While not every drain and tributary to the lower Yakima River was scheduled to be monitored, all of the major and most of the minor tributaries downstream of the mainstem sampling site at Parker Bridge were to be sampled under one of these three projects. Wide Hollow Creek, which enters the river upstream of the monitoring site at Parker Bridge, was not monitored. This creek had not been noted as a major source of sediment, and casual observation indicated this assumption was probably correct.

Ecology, with the assistance of the YNEMP staff, conducted effectiveness monitoring sampling for the *Lower Yakima River Suspended Sediment and DDT TMDL* during the irrigation season of 2003. Return flows in four major irrigation drains described in the original TMDL evaluation report (Joy and Patterson, 1997) and five mainstem Yakima River sites were sampled approximately every two weeks from April 1 through October 15, 2003. Samples were collected in accordance with a Quality Assurance Project Plan developed jointly by the Yakama Nation Environmental Management Program (YNEMP) and Ecology (Coffin, 2003). Samples were analyzed for turbidity, TSS, and total non-volatile suspended solids (TNVSS).

The associated projects by the SYCD, examining minor, off-reservation drains, and by the YNEMP, examining tributaries on the Yakama Reservation, were developed to run concurrently with the Ecology project and provide data to allow a mass balance of sediment loads in the lower Yakima River. Unfortunately, a loss of data from reservation drains and tributaries prevented a mass balance analysis and a more complete characterization of sediment movement in the lower Yakima River.

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Background

The Yakima River is located in central Washington State and flows generally southeast from the eastern slopes of the mid Cascades and the southern slopes of the Wenatchee Mountains to its confluence with the Columbia River near the city of Richland.

The upper Yakima basin, water resource inventory area (WRIA) 39, includes the Kittitas Valley, an area of intensively cultivated and irrigated field crops such as timothy hay, grains, corn, and alfalfa. Turbidity, sediment, and pesticide problems have been documented in some tributaries to upper reaches of the river, and an approved TMDL is currently being implemented on the upper Yakima River. The first round of effectiveness monitoring for the *Upper Yakima Basin Suspended Sediment, Turbidity and Organochlorine Pesticide Total Maximum Daily Load* (Creech and Joy, 2002) is scheduled to begin in 2006.

The *Lower Yakima River Suspended Sediment and DDT TMDL* focuses on the area of the river downstream of the confluence of the Naches and Yakima Rivers (RM 116.3) in WRIA 37. This area is agriculturally diverse and intensively irrigated, relying on irrigation water provided by the Yakima River and its tributaries.

The upper and lower Yakima basins are separated by the Yakima River Canyon, approximately 20 miles of arid shrub-steppe and steep basalt canyon lying approximately north-south between the Kittitas and Yakima valleys. It is assumed that activities in the upper river basin can, and do, affect the water quality of the river's lower reaches; however, because of the nature and separation of these distinct areas, individual TMDLs have been established to address the problems specific to each basin.

The Yakima and Naches rivers supply irrigation water for approximately 339,000 acres of cropland in the lower Yakima Valley. From 50% to 100% of the water delivered to the lower basin from the Naches River and upper Yakima River is diverted for irrigation and hydropower generation during the irrigation season (Molenaar, 1985). As the lower Yakima River travels downstream, some of the diverted water is returned to the mainstem through agricultural return drains, subsurface flow, and operational spills from the many irrigation canal systems. The remainder is lost to evaporation or used in plant production and direct consumption.

Most of the water in the Yakima River system is managed by the U.S. Bureau of Reclamation. Snowmelt and precipitation are held in storage in high mountain reservoirs and delivered to irrigation districts and growers via natural waterways (rivers and creeks) and man-made canals. Diversions to the canals begin in mid-April and end in mid-October. Water distribution from canals to farms is primarily managed by irrigation districts.

In many past years during the irrigation season, nearly all of the water in the mainstem was diverted out of the mainstem for irrigation by the time it passed the Sunnyside Valley Irrigation District diversion dam near Parker (RM 103.8), leaving the reach immediately downstream of the diversion dewatered and nearly dry. This became a concern among fishery and water resource managers. Instream flow limits were established in 1994, setting a minimum target of

300 cubic feet per second (cfs) that would remain in the river and provide water to maintain flow through fish ladders and around irrigation diversions.

There are several irrigation return drains and tributaries entering the lower Yakima River within the project area and from the Yakama Nation's tribal reservation. Studies by Ecology, United States Geologic Survey (USGS), and local conservation and irrigation districts indicated that much of the diverted water returning to the river contained elevated levels of suspended sediments, pesticides, nutrients, and bacteria. Several small municipalities and industrial facilities also discharge into the river, but these account for a relatively small cumulative volume during the irrigation season (Joy and Patterson, 1997).

Much of the land that lies to the south of the lower Yakima River is within the Yakama Reservation and under the sovereign jurisdiction of the Yakama Nation. The Yakama Nation does not recognize the authority of Washington State to regulate water quality on the mainstem Yakima River where the river borders the reservation (i.e., from Ahtanum Creek at RM 106.9 to the Mabton-Sunnyside Bridge at RM 59.8). The EPA has not yet taken a position on whether that section of the river may be subject to state or tribal jurisdiction. However, since the Yakima River is on the state's 303(d) list of threatened or impaired waterbodies, the state acted on its responsibility to improve and protect water quality. Water quality scientists, technicians, and educators from both the Yakama Nation and Ecology have maintained a cooperative partnership to monitor conditions and promote appropriate water management practices.

By applying Washington's water quality standards and the TMDL to the section of the river bordering the reservation, the state does not intend to prejudice the Yakama Nation's jurisdictional claim. The TMDL should not be construed to grant, enlarge, diminish, or in any way affect the scope of governmental authority of the Yakama Nation, the State of Washington, or the EPA. A Memorandum of Agreement between Ecology, the Yakama Nation, and EPA was drafted in 1996 to better define the unique jurisdictional partnership that exists on this portion of the river, but it was never finalized.

Historically, the primary mode of final water delivery to crops in the project area has been rill and furrow irrigation. Water is routed through pipes and canals and delivered to the highest elevation of a farm field, and then allowed to flow downhill across the surface of the fields through a series of parallel furrows to the lower end of the field. Excess water is collected at the lower end of the field and either routed to other fields lower in elevation or allowed to collect in drains that carry the water, often high in suspended sediment, into canals, tributaries, or drains eventually emptying into the Yakima River.

The soils in the area tend to be fine-grained loess, very low in organic content and highly prone to hydraulic erosion. This soil, combined with the often steep local topography, creates a situation that without careful irrigation management can cause excessive erosion and high concentrations of suspended sediments. In the last several decades, much of the irrigated lands have been converted to drip and sprinkler irrigation methods, but because of cultural practices, economics, and convenience, rill and furrow irrigation is still used by some as the method of choice for many of the crops grown throughout the Yakima basin.

Comprehensive water quality monitoring studies of the Yakima River basin were performed in the mid to late 1970s (Ecology, 1979) with several studies evaluating sediment loading in various parts of the basin (CH2M Hill, 1975; Boucher, 1975; SCS, 1978; Corps of Engineers, 1978; Nelson, 1979; Boucher and Fretwell, 1982). Much of the work indicated that irrigation practices directly affected suspended sediment concentrations and turbidity in the lower Yakima River and return drains from March through October. Peak suspended sediment concentrations in the mainstem occurred in April through June when streamflows were high, snowmelt occurred, and irrigation of freshly tilled fields commenced. Further, these historical assessments also showed that suspended sediment loads and concentrations began to rapidly increase in the river at Union Gap (RM 107), near the confluence of Moxee Drain and the Yakima River (Joy and Patterson, 1997).

The USGS National Water Quality Assessment (NAWQA) for the Yakima River (1989-90) confirmed some previous study findings that resident fish in the lower Yakima River had one of the highest concentrations of DDT in the country (Rinella et al., 1993). As a result of those findings, the Washington State Department of Health (DOH) issued an advisory in 1993 that recommended limiting the consumption of bottom fish captured from the lower Yakima basin (WA Department of Health, 1993). Because of the NAWQA studies and the DOH advisory, the correlation between DDT pesticide and the presence of sediment eroded from farmland came into the public focus.

DDT was used extensively in the Yakima Valley to improve crop yields for about 30 years after its introduction in the early 1940s. The pesticide was effectively banned in the United States by the EPA in 1972, after its adverse effects on birds and other wildlife and its cancer-causing potential became well known (Rinella et al., 1993). In general, organochlorine compounds, such as DDT, dieldrin, and endosulfan, have been the most frequently detected pesticides in basin waters, sediments, and biota due to their heavy use in the past and persistence in the environment. Documented concentrations of total DDT in the water were highest in the early 1970s. In the mid-1970s and early 1980s, DDT was not detected in samples routinely collected by the USGS, most likely because of the higher detection limit of the analysis method employed (Joy and Patterson, 1997).

Under the Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201A WAC), the lower Yakima River is designated as a Class A river and, as such, has certain uses that are protected. Sediment and pesticides in the lower Yakima River have had a noted effect on some of the characteristic uses designated by the Washington Administrative Code (WAC) for Class A waters.

In the 1995 document by the Yakima Valley Conference of Governments, *Yakima River Basin Water Quality Plan,* suspended sediment, turbidity, and pesticides were identified as causing impairments to domestic water supply, primary and secondary contact recreation, aesthetic enjoyment, and fish and wildlife habitat.

The Lower Yakima River Suspended Sediment and DDT TMDL report compared EPA and fishery resource literature citations to sediment and turbidity levels in the Yakima River study area to document likely impairments of aquatic communities, especially salmonid health and habitat. Sediment and turbidity can also impair the use of water for irrigation, a protected use.

The DDT and sediment TMDL on the lower Yakima River was a direct result of the river not meeting state standards and the beneficial uses designated for this waterbody not being achieved.

Ecology began sampling for the TMDL in 1994, with monitoring being completed in 1995. During this same period, local conservation districts were developing on-farm sediment control programs and demonstration projects to assist with and educate growers on soil erosion prevention. Many changes in water management have occurred in the Yakima River basin since the early 1990s. Minimum instream flow targets have been set for the river, remote monitoring and delivery control are continuing to undergo modernization on larger irrigation districts, and major investments are being made to improve irrigation methods that will increase water-use efficiency and reduce erosion.

Extensive implementation activities have been initiated within the project area and on the Yakama Reservation since the approval of the TMDL in 1998. Primary among these activities has been an effort to encourage growers to adopt one or more "best management practices" (BMPs) aimed at reducing erosion from fields and drains. Cost-share programs, technical assistance projects, adoption of a strict water quality policy in the major irrigation districts, and other programs were developed to facilitate changes in irrigation practices. One example of a cost-share program is the RSBOJC State Revolving Fund (SRF) Low Interest Loan Program. This program allowed the irrigation districts to use SRF loan funds to assist growers at a very low interest rate as a funding source for conversion to non-erosive irrigation methods. The Yakama Nation has also implemented their own on-reservation education and assistance projects funded through grants from EPA and others. The desired result of all of these programs is the reduction of suspended sediment in irrigation returns, and ultimately the elimination of DDT and its metabolites from being transported to the Yakima River and beyond.

TMDL Summary

The *Lower Yakima River Suspended Sediment and DDT TMDL* (Joy and Patterson, 1997) was developed to address two of the most significant pollutants in the lower Yakima River system: suspended sediment and DDT. The effects on aquatic communities and human health criteria were both considered in the analysis. Three approaches were used to calculate recommended total suspended sediment (TSS) and DDT targets and nonpoint source load allocations for the Yakima River and its tributaries in the 2003 study area:

1. ***Turbidity criterion*** - Using the correlation of TSS concentrations to turbidity values, TSS targets on the mainstem Yakima River are based on the turbidity criterion of "5 NTU above background" as stipulated in the Washington Administrative Code (Chapter 173-201A WAC).

2. ***Fisheries (aquatic biota) support*** - Using the narrative criteria to protect aquatic life, a 25 NTU turbidity and corresponding 56 mg/L TSS targets were applied to irrigation return drains and tributaries as a fish health threshold consistent with the scientific literature.

3. ***Pesticides criteria*** - Based on the correlation of TSS to Total DDT (t-DDT), long-term TSS reduction goals were set for return drains and tributaries to achieve the t-DDT water quality criterion for protection of aquatic life from chronic toxicity. Targets to meet human health criteria will be assessed as progress is made toward the aquatic life criterion.

Five, ten, 15, and 20 year goals were set with the final target of meeting human health criteria for t-DDT and reducing TSS and turbidity to protect aquatic communities in the lower Yakima River and its tributaries. The targets are as follows:

5 years (originally 2002 but extended to 2003)

- The mainstem Yakima River will comply with the turbidity target of not more than a 5 NTU increase between the confluence of the Yakima and Naches rivers (RM 116.3) and the Kiona Gauge at Benton City (RM 30). Use of a 90th percentile frequency in determining turbidity compliance will be evaluated.

- All drains and tributaries within the project area will comply with the 90th percentile turbidity target of 25 NTU at their mouths, including Moxee Drain, Granger Drain, Sulphur Creek, and Spring Creek.

- The efficacy of using TSS load targets will be evaluated for tributaries and drains where the 25 NTU target is not representative of total load reductions.

- Agreements will be completed between the State of Washington, Yakama Nation, and the EPA that set load allocations for the Yakama Reservation and management of basin water quality.

10 years (2007)

- The mouths of all tributaries and drains, and all points within all basin tributaries and drains, will comply with the 90th percentile turbidity target of 25 NTU.
- The 7 mg/L TSS target developed to meet the DDT chronic aquatic toxicity criterion will be re-evaluated using additional data and historical pesticide use analysis.
- Target controls and a strategy will be developed to meet the DDT human health criteria for fish and water.
- The mainstem Yakima River will comply with the turbidity target of not more than a 5 NTU increase between the confluence of the Yakima and Naches rivers (RM 116.3) and the Van Geisan Road Bridge (RM 8.4) at West Richland.

15 years (2012)

- All tributaries and drains, and the mainstem Yakima River, will comply with the 1 ng/L DDT chronic aquatic toxicity criterion, which corresponds to the present 7 mg/L TSS target or its modified form (see 10 year).
- A control strategy will be established to meet DDT human health criteria using TSS or other targets.

20 years (2017)

- The DDT human health criteria for fish and water will be met.

In 1995, during the initial TMDL evaluation, a TSS loading balance was calculated from data collected throughout the irrigation season. The cumulative impact of tributary and drain loadings on reaches of the lower Yakima River was clearly seen. For example, in the later part of the irrigation season, the Moxee Drain TSS load (35 tons/day) exceeded the Naches River load (27 tons/day), even though the average water volume of the Naches River was 14 times that of Moxee Drain. Granger Drain contributed an average 60 tons of TSS/day. The TSS load from Sulphur Creek was 110 tons/day, and the combined TSS load from Spring and Snipes creeks was 46 tons/day. The total TSS load from the Yakama Reservation drains and tributaries was 75 tons/day. Approximately 1.5 tons/day came from municipal or industrial sources. Ungauged tributaries and instream sources also accounted for substantial loads during the irrigation season (Joy and Patterson, 1997).

Monitoring data generated from Ecology's 1994-95 TMDL evaluation study and previous USGS studies were used to develop linear regression equations for turbidity and DDT as functions of TSS. These statistical studies indicated that there was an extremely high correlation between turbidity and TSS (as suspended sediment) and between TSS and DDT as well. The goal of the *Lower Yakima River Suspended Sediment and DDT TMDL* became obvious: reducing TSS (as suspended sediment) would correspondingly reduce both turbidity and DDT.

Targets set by the TMDL for 2003 identified all drainages of the lower Yakima River and specifically named Moxee Drain, Granger Drain, Sulphur Creek, and Spring Creek as the focus for implementation and monitoring activities for the first five-year goal. These latter four waterbodies represented a majority of sediment loading during the 2003 TMDL evaluation period.

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Methods

Reduction of turbidity is used as a method to address high loads of suspended sediment and the associated pesticide DDT. The evaluation of turbidity as representative of sediment loading is part of this effectiveness monitoring project and is a requirement of the TMDL Implementation Plan. Several statistical expressions were calculated in order to best identify the location and severity of TSS pollution to individual mainstem reaches. The results are intended to assist with future decisions (adaptive management) that will continue to improve water quality in this lower portion of the Yakima River drainage.

The basis for evaluation of improvement in lower Yakima River turbidity conditions was comparison of downstream monitoring sites to upstream "background" conditions. The background conditions were determined by measuring turbidity at the Yakima River @ Terrace Heights Bridge (RM 113.2) monitoring site (Figure 1 and Table 1). This background station is just downstream from the confluence of the Naches and Yakima rivers (RM 116.3) and upstream of the influence of the agricultural return drains and wastewater returns to the lower reaches of the river. Data from Terrace Heights Bridge were compared to data from four downstream sites on the mainstem of the river. Four additional sites near the mouths of major tributaries were also monitored.

Data from all the sites were compared with data from the original TMDL study (Joy and Patterson, 1997) in 1995. The original study was carried out during 1994 and 1995, but in 1994 included data from only part of the irrigation season, June – October. Also, 1994 was considered to be a lower than normal water-year. Because of those data anomalies, this effectiveness monitoring study compares data from 2003 to only that from 1995.

The TMDL established the "critical period" as occurring during the irrigation season (approximately mid April through mid October, depending on water supply). Therefore, the results for turbidity characterization in this effectiveness monitoring study are also limited to the irrigation season. Similar methods, employing depth and width integrated sampling techniques, were used in both the 1995 and the 2003 studies.

Quality Assurance Project Plan

A draft Quality Assurance (QA) Project Plan was prepared prior to the start of sampling; however, the document was not finalized until July 2003 (Coffin, 2003). The delay was primarily due to difficulty in resolving issues of legal protocol concerning documents describing agreements between Ecology (the State of Washington) and the Yakama Nation. It was ultimately decided that the two entities would not share a single document, although the Yakama Nation shared many aspects of this study, including planning, field work, and water quality analysis. There were no substantive changes to the draft QA Project Plan after sampling began.

The QA Project Plan was followed as written except when local access or safety conditions would not permit sampling and also as described below:

- The sampling site on Sulphur Creek was incorrectly described as Sulphur Creek @ McGee Road. It should have been listed as Sulphur Creek @ Holaday Road. The Holaday Road site is approximately ½ mile upstream from McGee Road.
- The period of study was changed to include only the 2003 irrigation season. It was originally planned to include part of the 2002 irrigation season, and although some sampling was done in that year, it is not included in this report.
- Some sampling dates were changed from the original plan, but no dates were altered or substituted based on influences that may have affected water quality.
- Laboratory services were originally supplied by Alliance Analytical Laboratory in Yakima, Washington, but the company ceased operation approximately half-way through the study. All subsequent samples needing laboratory analysis were shipped to Ecology's Manchester Environmental Laboratory near Port Orchards, Washington.
- During sampling events, most of the sites were evaluated for pH, temperature, dissolved oxygen, and conductivity. Those data are not included in this report.

Sampling Locations

Sampling sites in the four major irrigation return drains specifically named in the TMDL's fifth-year target, Moxee Drain, Granger Drain, Sulphur Creek, and Spring Creek, were selected to be representative of the water in those drains that enters the Yakima River. Mainstem sites were selected based on accessibility, safety, and similarity to sites sampled in the original 1995 TMDL evaluation monitoring. A map of the sites is provided as Figure 1, while a list of the sites can be found in Table 1.

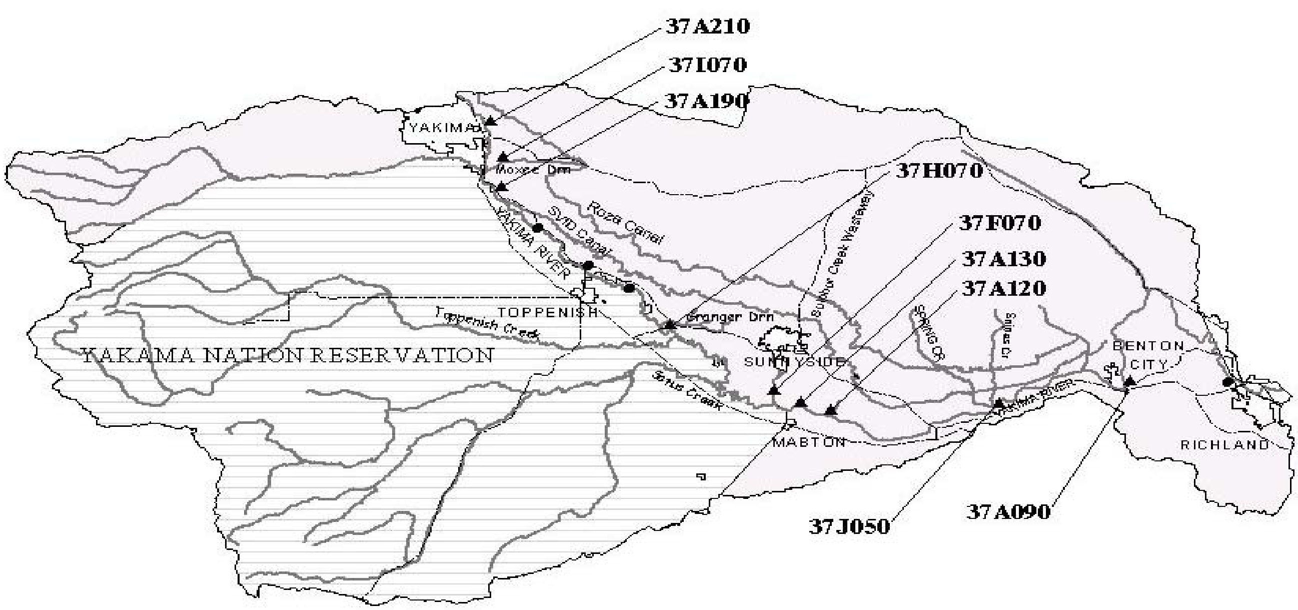

Figure 1. Map of the lower Yakima River watershed showing 2003 sampling locations with Ecology site numbers.

Table 1. Monitoring site ID numbers and river mile locations.

Monitoring Sites	Station Number	River Mile (RM)
Mainstem		
Yakima River @ Terrace Heights Bridge	37A210	113.2
Yakima River @ Parker Bridge	37A190	104.6
Yakima River @ Mabton/Sunnyside Bridge	37A130.	59.8
Yakima River @ Euclid Bridge	37A120	55.0
Yakima River @ Kiona Bridge	37A090	29.8
Irrigation return drains		
Moxee Drain @ Birchfield Road	37I070	1.4
Granger Drain @ sheep barns in Granger	37H070	0.62
Sulphur Creek @ Holaday Road	37F070	0.8
Spring Creek near mouth	37J050	0.1

Sampling Schedule

A sample from each site was collected during each of the bi-weekly sampling events. Sampling started at approximately 7 AM at the most upstream location (Terrace Heights Bridge). The sampling team sampled at subsequent downstream locations as the day progressed, with one exception: Staff sampled the Yakima River at Kiona prior to taking the last sample of the day at Spring Creek, which is upstream of Kiona.

It was intended that each site be sampled every two weeks beginning at the start of the irrigation season 2003 and continuing until the end of the irrigation season 2003. In general, samples were taken according to this schedule. At times the intended schedule was deviated from because of staff scheduling or laboratory conflicts.

Field Methods

All sites except Moxee Drain, Granger Drain, and Spring Creek were sampled from bridges above the streams using a US-DH-59 or a US-DH-76 attached to a rope tether for collection of a depth and width-integrated, isokinetic sample. At Moxee Drain, Granger Drain, and Spring Creek, samples were taken with a US-DH-81 sampler while wading. Sampling was done following USGS recommended protocols for the Equal-Width-Increment (EWI) method (Wilde et al., 1999) and as described in the associated QA Project Plan (Coffin, 2003).

Monitoring sites transected the stream in a line perpendicular to the direction of flow. The width of the channel was divided into sections that represented equal widths of the stream cross section. It was intended that each transect would have ten or more vertical sampling locations; however, in some instances where debris accumulated on bridge supports, or other complications arose, staff reduced the number of vertical sampling locations per transect. In some cases, staff moved the vertical sampling location laterally across the transect to the nearest flowing water accessible to the sampler. Samples were collected using FISP (Federal Interagency

Sedimentation Project) designed samplers that permitted retrieval of a depth-integrated sample at each vertical point along each transect. When samples were taken from bridges with a US-DH 59 or US-DH 76, sub-samples were collected at each point on the transect, and composited into a 2000 or 3000 mL sample container. At least 1500 mL, and generally not more than 2000 mL, were collected at each sampling location according to the EWI sampling method. Specific methods and equipment used to collect samples at each station were recorded on field data sheets.

Laboratory Analysis

Samples were analyzed in the laboratory for turbidity using Standard Method 2130B, employing a HACH 2100N ratio-turbidimeter. The primary laboratory, Alliance Analytical Laboratory, was accredited by the state for all procedures performed. It was intended that the project send samples to Alliance Analytical throughout the study; however, the laboratory closed mid-way through the duration of the project. As a consequence, project staff sent samples to Ecology's Manchester Environmental Laboratory. Manchester Laboratory also employed a HACH 2100N ratio turbidimeter.

Determining Loads and Flows

Sediment loads were determined by converting TSS concentrations (mg/L) into tons per day using daily mean flow information from the U.S. Bureau of Reclamation, USGS, Selah-Moxee Irrigation District, Sunnyside Valley Irrigation District, and the Union Gap Irrigation District. Flow data were downloaded from Bureau of Reclamation and USGS websites and collected through personal communications with all of the aforementioned entities. When flow data were not available or representative of the sampling site, an estimate was made using upstream and downstream gauges and calculating for any known input or diversions. At the Spring Creek site, instantaneous flows were collected at the time of sampling from staff gauges located just upstream of the site. Stages from the staff gauges were converted to flows using rating curves provided by the RSBOJC.

It was assumed that all flow data were an estimate, as measurement methods and changes in streambed morphology can cause errors in excess of 10%. Sediment load formulas are partially based on flow estimates and are, thus, subject to cumulative error. A Beales Ratio Estimator (Thomann and Mueller, 1987) was used to convert TSS concentration data and mean flows into load values.

Data Quality

Collection of data in the field was performed by a team of two to four water quality technicians. Data were recorded on field notes, and any questions regarding data entry or quality were discussed and resolved by the field team as soon as possible after discovery, usually before finishing the day's sampling run. Data provided by the laboratories were subject to two, and sometimes three, reviews before being released as final. All data used in statistical analyses were checked for accuracy by the authors and by peer review.

Quality Assurance

Sampling duties were alternated between personnel with the other(s) assisting and observing for anomalies that might affect the quality of the sample. Whenever a situation arose that might put the quality of a sample(s) in jeopardy, it was discussed by the team; if it was determined that there was a question of quality, the sample was discarded and a new sample collected.

A replicate sample was taken at one site per sampling day and transported to the laboratory for analysis along with the other samples. The project goal of 10% replicates was surpassed by taking one replicate for every day that sampling occurred. There were 15 replicates for 135 samples (11%). Each replicate sampling site was chosen randomly for each day with the random number generator function of MS Excel. Replicate samples were taken in the same manner as, and within a few minutes after, the primary sample.

Ecology's data quality goal for the coefficient of variation (CV) of samples for TSS and turbidity requires that more than 90% of the sample replicate pairs are less than 20% CV. CV was calculated by dividing the standard deviation by the mean of the replicate pairs. Replicate sampling conducted in the field resulted in meeting Ecology's data quality goals (Table A1, Appendix A).

Both of the laboratories employed have a written quality assurance/quality control protocols document. Alliance Analytical Laboratory was accredited by the Washington State Department of Ecology for the methods used in this project.

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Results and Discussion

The sampling and analytical methodologies used for this 2003 evaluation project generated reliable characterizations of turbidity and sediment in the water column and provided consistent conclusions through a variety of analytical approaches. The depth and width integrated sampling strategy was designed to provide a representative sampling of existing conditions. The collective data enabled a comparison of existing and prior conditions, and allowed an estimate of the change in the intensity of the problem.

It was anticipated that the use of the complementary data produced by the three monitoring projects (Ecology, South Yakima Conservation District, and Yakama Nation) would allow a characterization of lower Yakima River conditions and increase the ability to determine sources of sediment. An unfortunate loss of data from the Yakama Nation's project prevented the use of any statistical or load analyses to pinpoint specific sources of sediment in the river. The existing sampling results show that there were a few large turbidity sources in early June that were not fully explained by the existing data, and that possibly could have been more understandable with a full complement of data.

Flow: 2003 and 1995

The seasonal flow regime for the two sampling years, 1995 and 2003, were somewhat different, but neither year was considered extreme in either high or low flows. Mean flows at the Kiona Gauge (RM 30) are shown in Table 4.

Natural flow from runoff gradually diminishes during the early irrigation season until most of the water in the rivers is managed as a controlled release from storage reservoirs by the U.S. Bureau of Reclamation, which can precisely regulate the flow regime and supply the specific amount of water needed for irrigation, hydropower, and instream flow demands. This is the beginning of "storage control", which is maintained throughout the rest of the irrigation season. The start date of storage control is variable, depending on precipitation, amount of water in storage, and available snowpack. The Bureau of Reclamation estimates June 24-26 as the average period for the beginning of storage control; however, in 2003 it began on about June 20 (Lynch, 2005). Internet published data from the Bureau of Reclamation's Yakima Project webpage indicate that pre-storage control flows at the Euclid Bridge Gauge ranged between 1820 and 6403 cfs in 2003. The post-storage control range was between 1234 and 1919 cfs.

A minimum flow target of 300 cfs is expected to pass the SVID diversion (Parker Dam) and remain in the main river channel. Additional water is collected by the river as it moves downstream past Granger Drain (approximately 45 cfs), Sulphur Creek (approximately 210 cfs), and other agricultural drains and tributaries. In these lower reaches, there are also a few irrigation diversions that remove water from the river. Downstream of the SVID diversion, the Yakima River flows through several areas with a relatively low gradient and some areas with a deep channel. The low flows during storage control, as well as the stilling effect of the low gradient, will likely allow some of the sediment delivered to the river via the agricultural drains to settle in the river's channel.

Turbidity Observations

Turbidity conditions at the background site ranged from a low of 3.0 NTU in September 2003 to a high of 13.6 NTU on May 28, 2003 (Table 2). The Yakima River station at Kiona Bridge had its highest recorded turbidity measurement of 29 NTU on June 10, 2003. Kiona is considered the compliance point to determine whether limits set by the TMDL are being met.

Table 2. Mainstem turbidity results in nephelometric turbidity units (NTU).

Bolded areas indicate an occurrence of the downstream monitoring site having turbidity greater than 5 NTU above the background site (Terrace Heights Bridge) and a violation of the Washington State turbidity criterion. Data for Kiona Bridge on 4/16/03 indicates an exceedence of over 5 NTU but does not exceed the 95% confidence limit set by quality assurance data.

Sampling Date	Terrace Heights Bridge (background) 37A210	Parker Bridge 37A190	Mabton-Sunnyside Bridge 37A130	Euclid Bridge 37A120	Kiona Bridge 37A090
4/16/03	4.76	4. 86	**10.5**	**10.5**	9.87
4/29/03	5.5	5.1	7	6.5	7.4
5/13/03	3.6	4	6.5	6.2	6
5/28/03	13.6	14.4	**21.6**	**21.9**	**24**
6/10/03	10.1	11.2	**25**	**26.6**	**29.3**
6/24/03	3.9	3.4	8.9	7.1	3.7
7/15/03	4.5	4.4	7.6	7.3	3.5
7/29/03	4.8	5.2	7.1	6.2	3
8/12/03	3.4	3.7	*	5.4	3.6
8/19/03	3.4	3.5	6	4.9	2.9
9/2/03	3	3.2	5.1	4.3	2.1
9/16/03	5.9	6.5	5.4	4.6	2.6
10/1/03	7.7	7.2	5.4	3.7	2.3
10/15/03	4.1	3.7	3.4	3.9	2.0

* no sample taken

Sources of suspended sediment and associated turbidity included the upper Yakima River and the Naches River, instream deposits, small tributaries, and agricultural return drains to the lower Yakima River. Most of the non-reservation tributaries to the lower reaches of the Yakima River are associated with agricultural return flows. None of the tributaries and drains monitored by either Ecology or the SYCD have a significant watershed or snowpack to augment irrigation return water released into their channels. Satus Creek and Toppenish Creek, on the Yakama Reservation, do have significant watersheds and may have upper basin areas contributing spring meltwater to the lower Yakima River from April through June, but no data from the reservation were available.

The highest turbidity measurements recorded for this study were from Granger Drain. The highest measurement of 41.8 NTU was recorded in mid April 2003, at the start of the irrigation season (Table 3). The occurrence of this turbidity measurement corresponds with the first deliveries of water to the fields and the season's first irrigation cycle over freshly cultivated and planted soil. This is similar to the first flush of a precipitation event, and thus transports a large amount of suspended sediment. Evidence of turbid water arising from agricultural drainage was also observed as elevated turbidity in the downstream reaches of the Yakima River.

Table 3. Individual turbidity results in nephelometric turbidity units (NTU) for the major tributaries at each sampling during the irrigation season.

Mean and 90th percentile (Excel©) turbidity is calculated from the sampling data.

Sampling Date	Moxee Drain 37I070	Granger Drain 37H070	Sulphur Creek 37F070	Spring Creek 37J050
4/16/03	18.8	41.8	11.3	10
4/29/03	20.5	27.2	8.1	11.9
5/13/03	20	24.4	11.4	12.5
5/28/03	21.8	22.1	15.2	19.5
6/10/03	15.1	15.8	21.4	16.6
6/24/03	11	7	10.5	15.9
7/15/03	8.1	8.1	7.7	9.3
7/29/03	12	10	5.9	6
8/12/03	12	15	6.7	12
8/19/03	12	18	6.1	9.4
9/2/03	15	27	6.4	10
9/16/03	11	33	6.8	7.7
10/1/03	10	35	5.2	5.2
10/15/03	11	27	7.9	3.1
Mean Turbidity	14	22	9	11
90th Percentile Turbidity (Excel©)	20	34	14	16

Numerical Difference from Background Conditions

Tributary sources demonstrating a major influence on mainstem turbidity during the 1995 sampling included Moxee Drain, Granger Drain, Sulphur Creek, and Spring Creek. Due to the loss of data from the Yakama Reservation project, no mass balance was completed for the river and tributaries in 2003; however, it can be assumed that these same tributaries influenced the turbidity of the mainstem sites just downstream of their confluences and possibly at successive downstream sites. Moxee Drain is one of several tributaries and drains between the background site at Terrace Heights Bridge and Parker Bridge (Figure 1). Granger Drain and Sulphur Creek, which enter the Yakima River upstream of the Mabton-Sunnyside Bridge site, are in a reach of the river with the heaviest concentration of return drains and tributaries. The Mabton-Sunnyside Bridge serves as the downstream boundary of the Yakama Reservation. Euclid Bridge is four miles downstream, and only a few small drains contribute to the intervening reach. Spring Creek is downstream of the Euclid site. It is also just downstream of the Chandler Canal, a major diversion of water for power generation and for water supply to the Kennewick Irrigation District. Spring Creek, joined by Snipes Creek near its confluence with the Yakima River, contributes to the cumulative turbidity measurements at the Kiona site.

Water quality characteristics can vary considerably between days, and even within a single day, at any sampling station. The distance from the background station at Terrace Heights Bridge to the downstream compliance point at Kiona Bridge is approximately 83 river miles. Depending on flow conditions, travel time during the irrigation season can range from 4 to 6 days (McKenzie, 2006). It should be noted that during the mid to late irrigation season, 85% or more of the water flowing past the Terrace Heights Bridge site is diverted out of the mainstem Yakima River for irrigation before reaching Kiona Bridge. Further, the river's flow will increase from a low of approximately 300 to 400 cfs just below the SVID diversion (RM 103.8) to approximately 2000 to 3000 cfs at the Kiona Gauge (RM 29.9). This indicates that 80% or more of the water passing the Kiona Bridge has entered the river through agricultural return drains, tributaries, sub-surface flow, or unknown sources located downstream of the SVID diversion structure and the background site at Terrace Heights Bridge.

A series of comparisons for daily turbidity measurements were made between the "background" station (Yakima River at Terrace Heights) and each successive downstream mainstem station (Figure 2). The results indicate that downstream sites commonly exceeded the 5 NTU criteria early in the irrigation season, and that by late June the turbidity measurements began to decline at all lower mainstem Yakima River stations.

The high turbidity observed early in the irrigation season (pre-storage control) generally corresponds with higher flows in the mainstem, which occur as runoff from mountain snowmelt and precipitation travels through filled storage reservoirs or down unregulated tributaries to the Yakima River.

The elevations in turbidity during higher spring flows may be partially due to the re-suspension of sediment deposited during previous years as well as contributions from the major tributaries. High turbidity observed in the lower mainstem on 4/16, 5/28 and 6/10 (Table 2) were on days that the mean flow past the Euclid Gauge was above 5500 cfs. On these same dates, the major tributaries (Moxee, Granger, Sulphur, and Spring) generally had relatively high turbidity compared to that in the latter half of the irrigation season (Table 3). On the two other sampling dates in the early part of the season, 4/29 and 5/13, flows at Euclid were significantly lower at 3731 and 2328 cfs, and high turbidity was not noted. The small tributaries being measured by the SYCD did show elevated turbidity (approximately 10 to 30 NTU) during the early half of the season, but flows in these smaller drains were relatively low, ranging between approximately 1 to 10 cfs (Zuroske, 2005) and probably had only a minor effect on the mainstem. In 1995 a similar pattern was seen at the Kiona site with generally higher turbidity occurring in the pre-storage control period as opposed to the period after storage control was implemented.

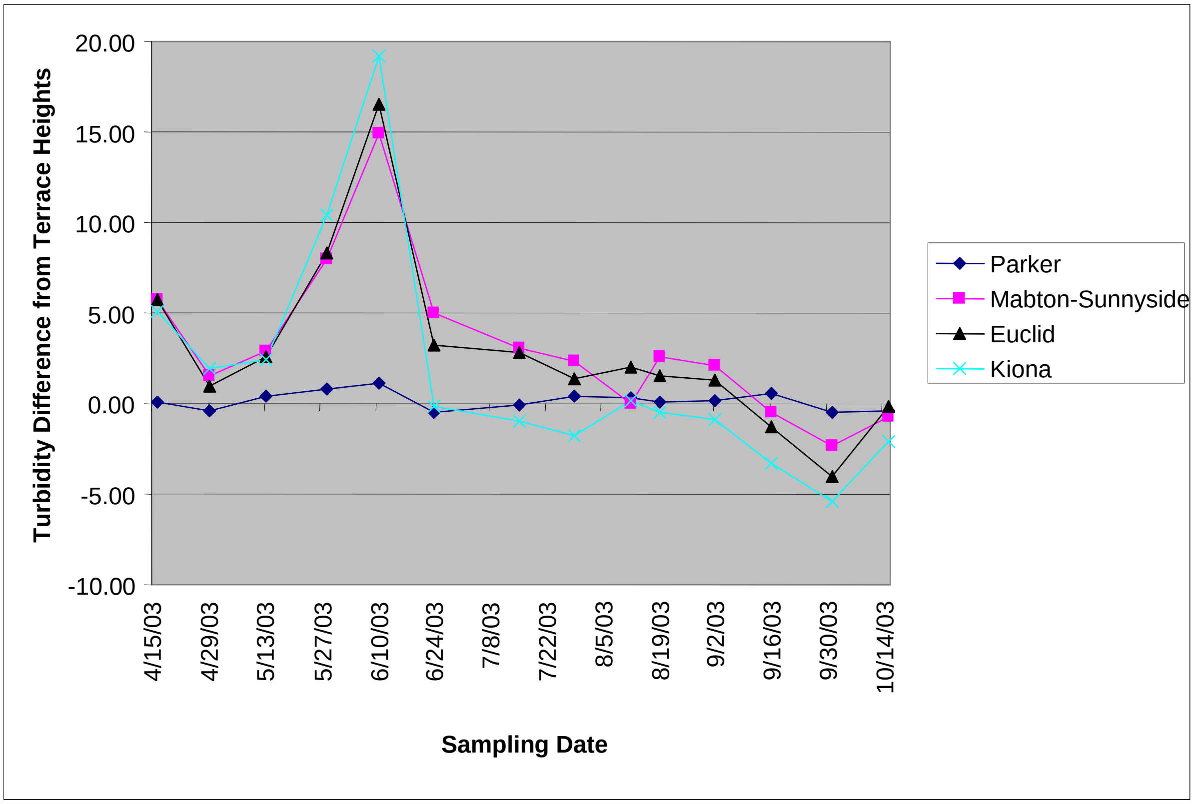

Figure 2. The difference from background (Terrace Heights Bridge) at the four downstream sampling sites in the Yakima River (in NTU).

Background is shown as the line at 0.00. A difference of greater than 5 NTU above background is considered a violation of Washington State water quality standards.

During the early 2003 irrigation season, mainstem turbidity was widely variable at the three mainstem sites downstream of the Parker Bridge but appeared to stabilize during the period of storage control. The Yakima River exceeded 5 NTU over background on 3 out of 15 sampling days at sites below Parker Bridge; the Kiona Bridge site was out of compliance on two of those occasions (Figure 2). Each of the exceedences occurred prior to the onset of storage control. During the subsequent period of storage control, none of the nine sampling events recorded an increase in mainstem turbidity greater than 5 NTU above the background site at Terrace Heights.

During the latter two of the three occasions that the mainstem was out of compliance, none of the four major irrigation returns being monitored by Ecology exceeded the 25 NTU target. One of the eight small irrigation drains being monitored by SYCD exceeded the 25 NTU target on two occasions, 4/15 and 5/27 with flows of 3.62 and 1.58 cfs, respectively (Zuroske, 2005.). Sediment and turbidity contributions from tributaries on the Yakama Reservation are unknown.

Other than winter rain-on-snow and flood events (neither of which were noted to have occurred during 2003), the primary period of increased turbidity in the lower mainstem Yakima River appears to be coincident with high spring flows and early season irrigation operations. Because of the Bureau of Reclamation's system of high mountain storage reservoirs in the upper Yakima basin and the entrapment of snowmelt in those reservoirs, large spring runoff events and sustained high flows that may flush and redistribute accumulated sediment are rare.

Sediment loads in the mainstem Yakima River and drains have been significantly reduced over the course of the TMDL implementation. In 1995, the Kiona Bridge sampling site averaged 680 tons/day in the early season from April through June, 135 tons/day during July through October, and 546 tons/day of sediment over the entire irrigation season (although an irrigation canal bank failure did contribute to high loads in late April and early May of 1995). Because loading calculations are directly related to flow and sediment concentration, average flows at Kiona over the entire irrigation season and in the early season (April through June) were lower in 2003 when compared to 1995; average flows in the 2003 late season were higher than 1995; and average sediment concentrations were lower in all of the 2003 seasons (Table 4).

Table 4. Comparison of average sediment loading in tons/day and TSS concentration in mg/L at Kiona Bridge for the sampling years of 1995 and 2003.

Averages are given for the entire irrigation season, as well as the first and second halves of the season. Load calculations are made using a Beales Ratio Estimator. Flows are averaged from USGS daily means.

Kiona Bridge 37A090	1995 Averages			2003 Averages		
	Mean flows (cfs)	Sediment loads in tons/day	TSS concentration in mg/liter	Mean flows (cfs)	Sediment loads in tons/day	TSS concentration in mg/liter
Full irrigation season	3360	546	40	3220	176	18
Mid April through June	5330	680	58	4090	413	33
July through mid October	1890	135	27	2560	25	6

TSS – Total suspended solids

Data from 2003 indicate that suspended sediment loads at Kiona Bridge had been reduced by approximately 67% overall, by 39% in the early season, and by 81% in the late season, when compared to 1995. Adjusting these loads for the variations in the flow regimes between the two years would suggest a somewhat smaller reduction during the full and early seasons and a larger reduction in the late season.

A similar pattern was observed for Granger Drain, which was the largest of the two measured tributaries failing to achieve the 5th-year TMDL target of a 90th percentile turbidity of 25 NTU. In 1995, Granger Drain had a season average of 62 tons/day, an April-June average of 42 tons/day, and a July-October average of 76 tons/day (Table 5). In 2003, Granger Drain averages were reduced to 12 tons/day during each of the three seasonal periods.

Table 5. Comparison of average sediment loading in tons/day and TSS concentration in mg/L at Granger Drain for the sampling years of 1995 and 2003.

Averages are given for the entire irrigation season, as well as the first and second halves of the season. Loads calculations are made using a Beales Ratio Estimator. Seasonal average 1995 flows are calculated using instantaneous measurements at the time of sampling, and 2003 flows are averaged from USGS daily means.

Granger Drain 37H070	1995 Averages			2003 Averages		
	Mean flows (cfs)	Sediment loads in tons/day	TSS concentration in mg/liter	Mean flows (cfs)	Sediment loads in tons/day	TSS concentration in mg/liter
Full irrigation season	50	59	440	47	12	101
Mid April through June	40	48	340	45	12	103
July through mid October	56	76	507	48	12	99

Determining Background Conditions and Compliance Using Statistical Expressions: a comparison of parameters

Turbidity measurements taken from each station in the lower Yakima River project area can be summarized using a variety of statistical expressions. Each of the expressions is a value describing the distributional characteristics from data collected at a station. Three statistical expressions were reported from data collected at each station: arithmetic mean, geometric mean, and 90th percentile (Table 6).

Table 6. A comparison of statistical parameters for turbidity at each of the sampling sites. Values are for the entire 2003 irrigation season and are in nephelometric turbidity units (NTU).

Sites	Mean (arithmetic)	Geometric Mean	90th Percentile (values are calculated using raw data (Excel©))
Mainstem			
Terrace Heights Bridge	5.6	5.1	10.1
Parker Bridge	5.7	5.1	11.2
Mabton-Sunnyside Bridge	9.2	7.8	21.6
Euclid Road Bridge	8.5	6.9	21.9
Kiona Bridge	7.3	4.8	24.0
Tributary			
Moxee Drain	14.2	13.6	20.5
Granger Drain	22.2	19.6	35.0
Sulphur Creek	9.3	8.6	15.2
Spring Creek	10.7	9.6	16.6

The arithmetic mean is calculated from untransformed data and tends to overestimate the central tendency of turbidity measurements. The geometric mean accounts for the log-normal distribution of turbidity measurements, providing a less biased estimate of the central tendency for observations. Turbidity estimates for the 90th percentile of the distribution were reported using untransformed data using the Excel® rank-order method.

One of the suggested comparisons for measuring improvement in turbidity at Kiona is by the comparison of background to downstream conditions using 90th percentile estimates. Comparison of 90th percentile estimates to background conditions is a conservative approach for evaluating effectiveness of the turbidity reduction efforts. However, this may be the most appropriate comparison given the high turbidity levels measured during portions of the 2003 year at mainstem and tributary stations. High turbidity levels are indicative of destructive physical dynamics that can, in many ways, be harmful to life stages and the habitat of salmonids, benthic macroinvertebrates, and aquatic macrophytes.

Using the 90th Percentile to Determine Change from Background Turbidity

Ninetieth percentile parameters were calculated for each mainstem and tributary station in the lower Yakima River project area based on untransformed data (Table 6). Figure 2 shows the mainstem turbidity levels that exceed 5 NTU over background (90th percentile background = 9.4 NTU) as well as those that are in compliance. Mainstem Yakima River stations include Mabton-Sunnyside, Euclid, and Kiona, all of which have 90th percentile turbidities that exceed the target turbidity level.

Because of the highest turbidity observations that occurred during the earlier portion of the irrigation season, the overall turbidity on the three lower mainstem stations exceeds the intended target. This means that the cumulative impact to aquatic life from sediment sources in these reaches could be significant. Regardless of the recent improvements made in these reaches for turbidity reduction, continued action is required in order to protect beneficial uses and meet the Washington State turbidity criterion.

Another interpretation of the 90th percentile that has been suggested is to require that 90% of the sampling events meet the 5 NTU criterion (i.e., of the 15 sampling runs in 2003, allow 1.5 (2) events that exceed the criterion). Using this interpretation would not have changed the findings of non-compliance, as the mainstem and Granger Drain both exceeded their respective compliance targets on more than two occasions; however, using this interpretation, the Kiona Bridge site would have met compliance criteria.

Significant Changes from Background on the Mainstem

Results from the one-tailed, pairwise comparisons using Dunnett's test are reported in Table 7. The test examined for significantly greater turbidity values at individual downstream mainstem stations when compared to "background" conditions at Terrace Heights Bridge. Significantly greater turbidity was noted between the background site and only one lower Yakima River site; Mabton-Sunnyside Bridge. This station was located below Sulphur Creek, Granger Drain, and several other irrigation returns and tributaries both on and off the Yakama Reservation. The cumulative impact from contributions of sediments from these sources was adequately high to degrade water clarity conditions in the mainstem Yakima River in at least one downstream reach. While there was not a statistically significant increase in turbidity when comparing Terrace Heights with Kiona, Kiona was out of compliance when comparing 90th percentile differences.

Table 7. Results of pairwise comparisons using the Dunnett test, 95% confidence interval, one-tailed ($p \leq 0.05$)

(Data were Log_{10} transformed prior to parametric analysis so as to provide a symmetrical distribution.) This test compares a set of treatments (downstream stations) against a control mean (Terrace Heights background station) to determine if there is a significant increase in turbidity.

Background	Parker Bridge	Mabton-Sunnyside Bridge	Euclid Bridge	Kiona Bridge
Terrace Heights Bridge	0.998	*0.033	0.157	1.00

*Significant difference from background turbidity observations

It has been hypothesized that TMDL successes in improving water clarity (decreasing suspended sediment) have allowed better light penetration which, in turn, has increased photosynthetic activity in the nutrient-rich river. Prolific aquatic plant growth (primarily rooted macrophytes) has been identified in the lower reaches of the Yakima River following implementation of the TMDL. Fine material may settle out of suspension once water velocity has declined in the vicinity of the macrophyte beds. The prolific growth is the subject of an ongoing eutrophication study by USGS, South Yakima Conservation District and Benton Conservation District. The study is funded largely through a Centennial Clean Water Fund grant.

The Kiona Bridge sampling site is an area of especially heavy aquatic plant growth. The aquatic plant beds appear to trap or filter fine sediment from the water column and improve clarity as the water moves downstream. In the latter part of the irrigation season, turbidity measurements at the Kiona Bridge site were significantly lower than the turbidity measurements at the background station of Terrace Heights Bridge (Table 2). Average sediment loads for the late season (July through mid October) at Kiona Bridge were approximately 25 tons/day. This compares to the upstream monitoring sites at Euclid Bridge and Sunnyside-Mabton Bridge that averaged 46 and 47 tons/day (Table 8), respectively, over the same period and had approximately twice the turbidity as Kiona (Table 2).

Table 8. Average sediment loads in tons/day, TSS concentrations in mg/L, and mean seasonal flows at all 2003 sampling sites.

Sampling site	2003 Full Irrigation Season			April Through June, 2003			July Through October, 2003		
	Load tons/day	Mean flow (cfs)	TSS mg/L	Load tons/day	Mean flow (cfs)	TSS mg/L	Load tons/day	Mean flow (cfs)	TSS mg/L
Yakima River @ Terrace Heights Bridge	147	3690	12	183	5140	15	71	2600	10
Yakima River @ Parker Bridge	97	2370	12	116	3590	15	42	1460	10
Yakima River @ Sunnyside-Mabton Bridge	224	2600	23	423	4180	34	47	1410	12
Yakima River @ Euclid Bridge	223	2600	22	436	4180	35	46	1410	12
Yakima River @ Kiona Bridge	176	3220	18	413	4090	33	25	2560	6
Moxee Drain @ Birchfield Road	9	50	59	12	53	81	6	48	42
Granger Drain @ Sheep barns in Granger	12	47	101	12	45	103	12	48	99
Sulphur Creek @ Holaday Road	16	190	28	21	230	39	10	170	18
Spring Creek @ mouth	6	70	34	7	64	42	6	75	28

TSS – total suspended solids

Turbidity Criterion and the Correlation of Turbidity and TSS

The *Lower Yakima River Suspended Sediment and DDT TMDL* used Washington State's turbidity criterion to address suspended sediment because of the strong correlation found between turbidity and TSS in the lower Yakima River basin. Monitoring data from the original TMDL evaluation in 1994 and 1995 were used to develop a linear regression of turbidity as a function of TSS. The details of the relationship are discussed in Appendix 2 of *A Suspended Sediment and DDT Total Maximum Daily Load Evaluation Report for the Yakima River* (Joy and Patterson, 1997).

The linear regression equation, based on 646 data pairs from river, canal, drain, and tributary sites with TSS concentrations less than 1,000 mg/L, was obtained on logarithmic (base 10) transformed data and is expressed as:

$$\log_{10} \text{Turbidity} = 0.871 * \log_{10} \text{TSS (mg/L)} - 0.145$$

This equation had a coefficient of determination (r^2) of 0.956, which means that approximately 96% of the data variability is explained by the TSS data.

A similar linear regression performed using the data generated during the 2003 TMDL effectiveness monitoring project, using all 125 data pairs from mainstem and drain sampling sites, resulted in the equation:

$$\log_{10} \text{Turbidity} = 0.734911 * \log_{10} \text{TSS (mg/L)} - 0.0741554$$

This equation had a coefficient of determination (r^2) of 0.935, which means that approximately 94% of the data variability is explained by the TSS data.

The above two equations offer disparate correlations between TSS and turbidity at the ranges commonly found in the lower Yakima River TMDL project area. The regression using 2003 data indicated that, for a given turbidity, the corresponding TSS value is higher in 2003 than it was in 1994-95. For example, using the 1994-95 data, a turbidity of 25 NTU correlated with a TSS value of approximately 56 mg/L. Data from 2003 draw a correlation of 25 NTU to approximately 101 mg/L of TSS. The change in correlations is supported by similar findings by the South Yakima Conservation District (SYCD) during their 2003 study of ungauged drains within the project area (Zuroske, 2005). The change may indicate that fine particulates were apparently less prevalent in the suspended sediment in the lower Yakima River during 2003 than during 1995.

The 2003 TMDL targets called for a 90th percentile turbidity limit of 25 NTU at the mouths of all irrigation drains within the project area. The turbidity limit was set to correspondingly limit the suspended sediment concentration to 56 mg/L, as based on the prior TSS/turbidity correlation. Both values were considered moderately protective of aquatic communities according to literature at the time (Joy and Patterson, 1997). As Figures 3 and 4 indicate, three of the drains achieved turbidity goals, but only two of the drains reduced suspended sediment concentrations sufficiently to meet the “moderately protective” TSS target of 56 mg/L. A similar pattern was noted in the SYCD ungauged drain study. In this study turbidity measurements above 25 NTU were rare (only two occurrences in over 110 sampling events), but suspended sediment concentration (SSC) was above 56 mg/L approximately 25% of the time (Zuroske, 2005). Using the 2003 TSS/turbidity correlation above, the 25 NTU limits set by the TMDL will need to be further lowered to 16 NTU to meet the concentration of 56 mg/L and thus be protective of aquatic communities.

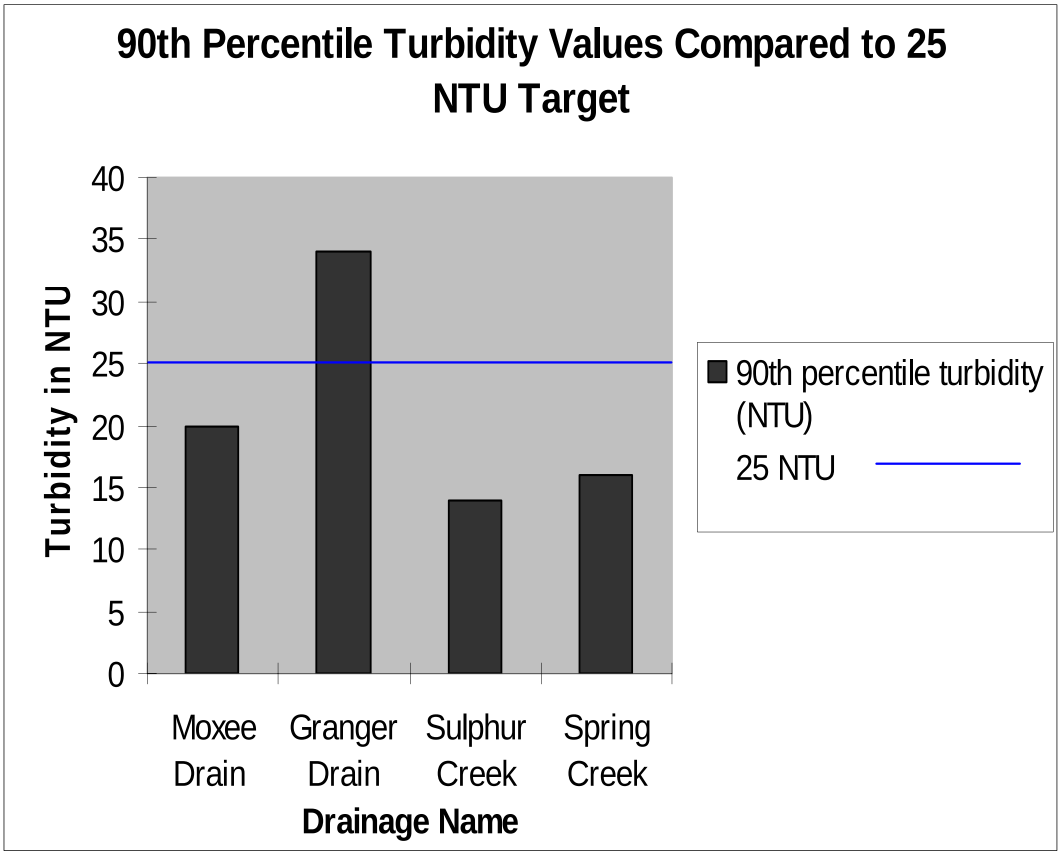

Figure 3. Comparison of the 2003 irrigation season's 90th percentile turbidity results and the 25 NTU turbidity target set by the TMDL for each of the major agricultural drains. Turbidity was measured at the mouths of the drains where they discharged into the Yakima River. Three of the drains achieved the turbidity target.

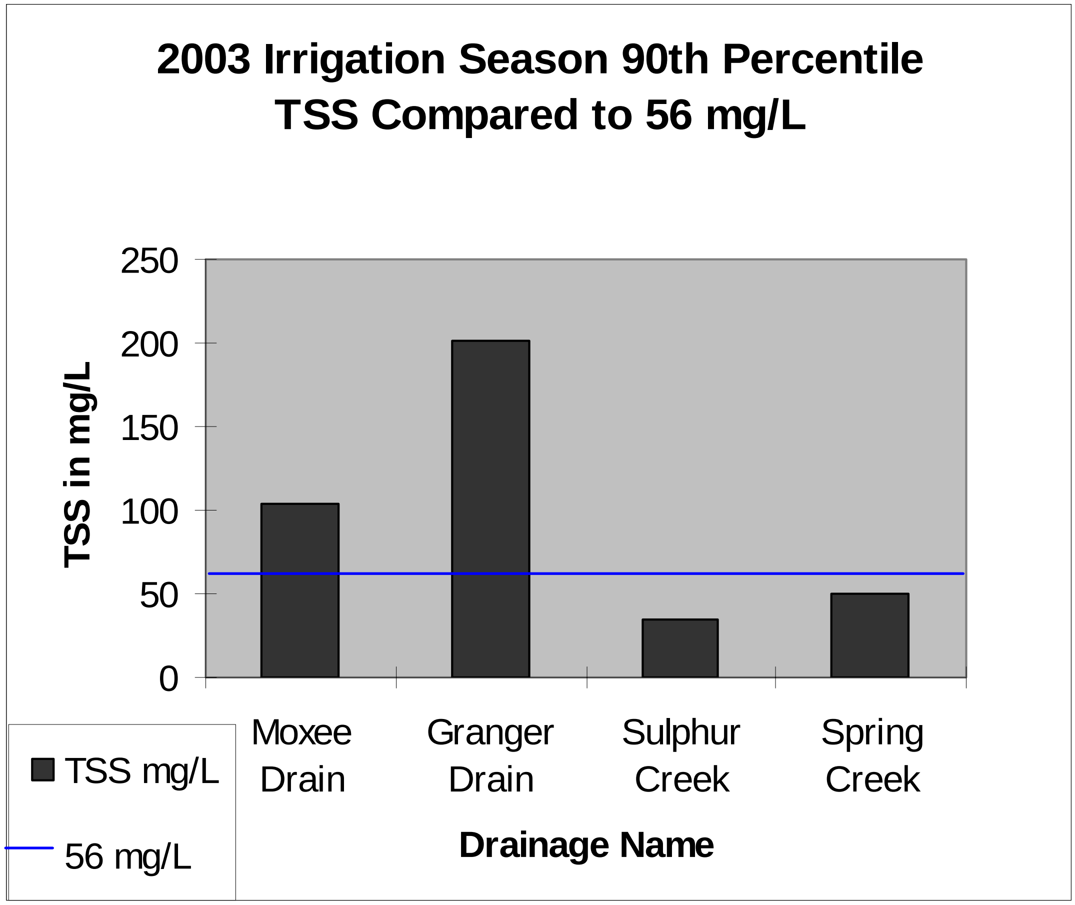

Figure 4. Comparison of the 2003 irrigation season's 90th percentile TSS results to the target of 56 mg/L of TSS for each of the major agricultural drains. TSS and turbidity were measured at the mouths of the drains as they entered the Yakima River. Two of the drains achieved their TSS target.

In addition to a changing relationship between TSS and turbidity, the relationship between TSS and DDT also appears to be changing. This effectiveness monitoring project did not examine concentrations of DDT; however, the USGS determined during their 1999-2000 NAWQA sampling of the Yakima River that the prevalence and detection of DDT and its metabolites is decreasing when compared to NAWQA sampling performed a decade earlier (Fuhrer et al., 2004).

These comparisons indicate that it will be necessary to develop new correlations for both TSS/turbidity and TSS/DDT while examining the tenth-year TMDL targets, which will also include determining pesticide loading in the lower Yakima River and its tributaries. It continues to be appropriate to focus on sediment loads as well as turbidity, to be assured that reductions in suspended sediment are adequate to meet the goals of the TMDL and protect the beneficial uses and biota of the Yakima River.

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Conclusions

Since 1995, turbidity levels have declined considerably in the four major irrigation return flows – Moxee Drain, Granger Drain, Sulphur Creek, and Spring Creek – identified by Joy and Patterson in their 1994-95 TMDL evaluation study. Additionally, sediment loading and turbidity in the mainstem lower Yakima River have declined. This TMDL effectiveness monitoring study was designed to examine whether these improvements achieved compliance with the 2003 targets set by the *Lower Yakima River Suspended Sediment and DDT TMDL*. This study also evaluates the efficacy of continued use of the 25 NTU compliance targets, to meet sediment reductions in tributaries and drains.

The 2003 targets called for:

- *The mainstem Yakima River will comply with the turbidity target of not more than a 5 NTU increase between the confluence of the Yakima and Naches rivers (RM 116.3) and the Kiona Gauge at Benton City (RM 30). Use of a 90th percentile frequency in determining turbidity compliance will be evaluated.*

  The mainstem Yakima River did not meet the turbidity goal of 5 NTU, or less, over background during the complete irrigation season (April through October), but it has shown reductions in turbidity and an overall seasonal reduction of sediment loading by approximately 67%. The difference between the 90th percentile turbidities for Terrace Heights Bridge (background) and for the compliance point at Kiona Bridge was 10.4 NTU. When turbidity was analyzed from samples taken only during the period that the Yakima River was operated under the Bureau of Reclamation's "storage control" regime (approximately late June through October), the river did not violate turbidity targets.

  Using only a 90th percentile target may not indicate the true turbidity relationship between stations. Comparison of 90th percentile values between background and downstream indicated non-compliance, while statistical analysis of all the data from Terrace Heights Bridge and Kiona Bridge indicated that the downstream turbidities (Kiona) were not significantly greater than the background turbidities (Terrace Heights).

- *All drains and tributaries within the project area will comply with the 90th percentile turbidity target of 25 NTU at their mouths, including Moxee Drain, Granger Drain, Sulphur Creek, and Spring Creek.*

  Three of the four major irrigation return flows met their fifth-year (2003) goal of a 90th percentile turbidity of 25 NTU or less during the entire sampling period (April through October). They were Moxee Drain, Sulphur Creek, and Spring Creek. Granger Drain did not achieve the 90th percentile goal of 25 NTU, but nevertheless has steadily improved since 1995.

Of the eight smaller, ungauged drains monitored by the South Yakima Conservation District (SYCD) as part of this study, only one, DR 27, exceeded the 25 NTU target. That occurred on two occasions in the early sampling season with turbidities of 30 and 29 NTU and flows of less than 4 and 2 cfs, respectively (Zuroske, 2005).

Data from the Yakama Reservation was not available so it is unknown what influence drains and tributaries from this area may have had on the lower Yakima River. The TMDL could not require compliance or impose Washington State water quality standards on Yakama Reservation lands or waters; however, the load model developed during the TMDL evaluation indicated that meeting the turbidity criterion at Kiona Bridge would require meeting the 25 NTU targets at the mouths of all tributaries to the lower Yakima River, including those from the Yakama Reservation.

- *The efficacy of using total suspended solids (TSS) load targets will be evaluated for tributaries and drains where the 25 NTU target is not representative of total load reductions.*

Two of the four major tributaries, Moxee Drain and Granger Drain, did not meet the TSS concentration goal of 56 mg/L; however, sediment loads have still been reduced in each of these tributaries by approximately 60% and 85%, respectively. Of the eight drains monitored by the SYCD, five of the drains and approximately 25% of the total samples did not meet the suspended sediment concentration (SSC) of 56 mg/L (Zuroske, 2005). (TSS and SSC are different laboratory methods and may not be precisely comparable. SYCD used an SSC analysis method while the TMDL was based on a TSS analysis.) Data from Ecology's 2003 sampling indicates that meeting the target concentration of 56 mg/L TSS would require a turbidity of 16 NTU or less. Sediment load reduction goals recommended to be even moderately protective of aquatic communities cannot be met using the turbidity target of 25 NTU.

No aquatic life studies were completed for this report. The complete impact of the elevated turbidity and TSS conditions on aquatic communities can only be determined if the sensitivity of critical life stages of endemic aquatic life that occur in the mainstem of the lower Yakima River is known.

Recommendations

Based on the findings of the 2003 TMDL effectiveness monitoring, the following recommendations can be made:

- Reduce the turbidity targets at the mouths of all irrigation drains and tributaries to 16 NTU. This new target would help to achieve the 56 mg/L TSS concentration and be in line with the literature recommendations for the protection of aquatic communities. The correlation between turbidity and total suspended solids (TSS) should be reevaluated during the scheduled 2007 effectiveness monitoring and be adjusted as necessary to meet the sediment concentration targets.

- The contribution of large loads of sediment during the early spring operation of the drains needs further investigation. This will include more sampling of all drains and a commitment to collect quality data by Ecology, EPA, and the Yakama Nation. Further examination of seasonal variations in turbidity may allow a refinement of the "critical period" and help focus and prioritize implementation projects to target the high spring sediment loads.

- Implementation activities, which have included best management practice (BMP) installation, education, outreach, and enforcement, appear to have been highly effective. Ongoing partnerships, monitoring projects, and BMP implementation involving all jurisdictional entities and water users in the lower Yakima basin need to be continued and supported.

- The interpretation of the mainstem turbidity criterion requiring no greater than a 5 NTU increase over background needs to be examined. This study did not answer whether lower mainstem sites may have been in compliance because sources of TSS have been reduced or because of instream hydrologic and/or biological processes.

- Continued implementation work needs to take place in Granger Drain and Moxee Drain to reduce TSS concentrations.

- Other data sets and flow data should be analyzed as they become available to determine the cause of the increased turbidities on days when the mainstem is out of compliance but return flows in the four targeted agricultural drains – Moxee Drain, Granger Drain, Sulphur Creek, and Spring Creek – are under 25 NTUs. Partnerships with the Yakama Nation, conservation districts, irrigation districts, and others should be maintained and encouraged so that data continue to be produced and trends can be tracked.

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Appendices

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Appendix A. Data Tables

Table A1. Quality Assurance (QA) Sample Results

SIGHT NAME	SITE #	DATE	SAMPLE TIME	SITE TURB (NTU)	QA DUP TURB (NTU)	LAB DUP TURB (NTU)	SITE TSS (mg/L)	QA DUP TSS (mg/L)	LAB DUP TSS (mg/L)	SITE SAMPLE FIXED SOLIDS (mg/L)	QA FIXED SOLIDS (mg/L)	LAB DUP FIXED SOLIDS (mg/L)	SITE SAMPLE VOLATILE SOLIDS (mg/L)	QA VOLATILE SOLIDS (mg/L)	LAB DUP VOLATILE SOLIDS (mg/L)
Yak R at THB[1]	37A210	4/1/03	8:33	12.6	12.2	12.4	24.6	26.3	25.7	18.4	21.3	20.9	6.2	5.0	4.8
Yak R at Euclid[1]	37A120	4/16/03	13:50	10.5	10.3	10.3	27.3	26.7	27.2	23.2	22.7	23.1	4.1	3.9	4.1
Yak R @ Kiona[1]	37A090	4/29/03	16:04	7.4	7.6	8.0	15.8	15.5	16.3	12.5	12.5	12.8	3.3	3.0	3.5
Granger Drain[1]	37H070	5/13/03	10:46	24.4	23.8	23.9	103	101.5	101.5	97.0	95.5	95.5	5.5	6.0	6.0
Granger Drain[1]	37H070	5/28/03	10:55	22.1	21.7	21.7	61	60.5	60.0	54.0	55.5	55.5	7.0	5.0	4.5
Yak R at Kiona[1]	37A090	6/10/03	13:35	29.3	28.3	28.7	77.5	78.5	78.0	70.5	71.5	71.0	7.0	7.0	7.0
Yak R at Euclid[1]	37A120	6/24/03	14:45	7.1	6.5	6.5	14.3	14.0	14.0	11.5	10.8	11.0	2.8	3.2	3.0
Moxee Drain[2]	37I070	7/15/03	9:03	8.1	7.5	7.6	23	23	23	20	21	21	3	2	2
Yak R at THB[2]	37A210	7/29/03	6:20	4.8	4.7	None	11	11	11	9	9	9	2	2	2
Sulphur Crk[2]	37F080	8/12/03	11:25	6.7	6.8	None	18	18	18	16	16	16	2	2	2
Moxee Drain[2]	37I070	8/19/03	7:46	12	12	12	41	41	41	37	37	37	4	4	4
Yak R at Kiona[2]	37A090	9/2/03	12:04	2.1	2.1	2.1	5	5	5	4	4	4	1	1	1
Sulphur Crk[2]	37F080	9/16/03	10:16	6.8	6.7	6.8	17	16	*41site/ 41dup	15	14	*39site/ 39dup	2	2	2
Spring Crk[2]	37J050	10/1/03	14:47	5.2	5.5	*10site/ 11dup	17	20	*12site/ 12dup	16	18	*11site/ 11dup	1	2	1
Spring Crk[2]	37J050	10/15/03	13:49	3.1	3.5	*11site/ 11dup	13	13	13	11	11	12	2	2	1

[1] Indicates sample analysis performed by Alliance Analytical Laboratory in Yakima, Washington.
[2] Indicates sample analysis performed by Manchester Environmental Laboratory in Port Orchard, Washington.
* Lab duplicate was taken from a field sample other than one used for the field QA. Entry indicates value for the field (site) sample and for the lab duplicate (dup).

Table A2. Sampling Data

Yakima River @ Terrace Heights Bridge (37A210)						
DATE	TIME	TURBIDITY (NTU)	TSS (mg/L)	TOTAL FIXED SS (mg/L)	TOTAL VOLATILE SS (mg/L)	FLOW @ SAMPLING (CFS)
4/1/2003	8:00	12.6	24.6	18.4	6.2	6481.00
4/16/2003	8:17	4.76	9.1	6.2	2.9	5013.19
4/29/2003	7:57	5.5	8.0	5.0	3.0	4623.38
5/13/2003	7:52	3.6	7.3	5.0	2.3	3536.84
5/28/2003	8:15	13.6	34.5	29.0	5.5	7120.26
6/10/2003	7:08	10.1	24.7	21.3	3.4	7824.72
6/24/2003	8:00	3.9	8.2	6.0	2.2	3258.12
7/15/2003	7:52	4.5	10.0	8.0	2.0	3239.41
7/29/2003	6:03	4.8	11.0	9.0	2.0	3386.43
8/12/2003	7:27	3.4	9.0	7.0	2.0	3112.63
8/19/2003	6:52	3.4	10.0	8.0	2.0	2952.27
9/2/2003	7:10	3	7.0	6.0	1.0	2358.96
9/16/2003	7:35	5.9	10.0	8.0	2.0	2134.88
10/1/2003	8:10	7.7	12.0	11.0	1.0	2130.56
10/15/2003	7:30	4.1	7.0	6.0	1.0	1424.37

Yakima River @ Parker Bridge (37A190)						
DATE	TIME	TURBIDITY (NTU)	TSS (mg/L)	TOTAL FIXED SS (mg/L)	TOTAL VOLATILE SS (mg/L)	FLOW @ SAMPLING (CFS)
4/1/2003	10:30	12.5	29.4	24.7	4.7	6588.5
4/16/2003	9:40	4.86	9.9	7.0	2.9	4166.6
4/29/2003	9:35	5.1	8.2	5.5	2.7	2887.9
5/13/2003	9:50	4	8.3	6.3	2.0	1755.4
5/28/2003	9:57	14.4	30.5	25.0	5.5	5016.2
6/10/2003	8:30	11.2	26.0	22.7	3.3	5907.3
6/24/2003	9:50	3.4	9.2	7.0	2.2	1691.4
7/15/2003	9:42	4.4	9.0	7.0	2.0	1623.7
7/29/2003	7:24	5.2	13.0	10.0	3.0	1606.5
8/12/2003	9:30	3.7	9.0	8.0	1.0	1610.1
8/19/2003	8:10	3.5	9.0	7.0	2.0	1571.8
9/2/2003	8:20	3.2	9.0	6.0	3.0	1528.2
9/16/2003	8:36	6.5	11.0	9.0	2.0	1309.6
10/1/2003	9:36	7.2	14.0	12.0	2.0	1396.1
10/15/2003	8:40	3.7	8.0	7.0	1.0	987.6

TSS – total suspended solids
SS – suspended solids

Yakima River @ Mabton-Sunnyside Bridge (37A130)						
DATE	TIME	TURBIDITY (NTU)	TSS (mg/L)	TOTAL FIXED SS (mg/L	TOTAL VOLATILE SS (mg/L)	FLOW @ SAMPLING @ EUCLID (CFS)
4/1/2003	13:47	13.6	93.0	86.5	6.5	6469
4/16/2003	12:37	10.5	25.8	21.8	4.0	5488
4/29/2003	13:40	7	13.3	10.0	3.3	3698
5/13/2003	12:52	6.5	11.7	9.7	2.0	2350
5/28/2003	12:57	21.6	61.0	53.0	8.0	5584
6/10/2003	10:31	25	75.5	68.5	7.0	6469
6/24/2003	13:15	8.9	18.5	15.8	2.7	1526
7/15/2003	12:10	7.6	16.0	14.0	2.0	1426
7/29/2003	9:56	7.1	16.0	13.0	3.0	1322
8/12/2003						
8/19/2003	9:45	6	13.0	11.0	2.0	1418
9/2/2003	10:02	5.1	11.0	10.0	1.0	1322
9/16/2003	10:43	5.4	12.0	10.0	2.0	1474
10/1/2003	11:25	5.4	12.0	10.0	2.0	1354
10/15/2003	10:37	3.4	7.0	6.0	1.0	1410

Yakima River @ Euclid Bridge (37A120)						
DATE	TIME	TURBIDITY (NTU)	TSS (mg/L)	TOTAL FIXED SS (mg/L	TOTAL VOLATILE SS (mg/L)	FLOW @ SAMPLING (CFS)
4/1/2003	14:42	11.8	42.6	37.5	5.1	6469.00
4/16/2003	13:25	10.5	27.3	23.2	4.1	5488.00
4/29/2003	14:30	6.5	15.0	12.3	2.7	3698.00
5/13/2003	13:40	6.2	12.0	10.3	1.7	2350.00
5/28/2003	13:10	21.9	60.5	53.0	7.5	5648.00
6/10/2003	11:23	26.6	79.5	72.5	7.0	6469.00
6/24/2003	14:15	7.1	14.3	11.5	2.8	1526.00
7/15/2003	12:55	7.3	18.0	15.0	3.0	1434.00
7/29/2003	10:32	6.2	15.0	13.0	2.0	1322.00
8/12/2003	13:22	5.4	14.0	11.0	3.0	1571.00
8/19/2003	10:28	4.9	12.0	10.0	2.0	1418.00
9/2/2003	10:40	4.3	11.0	9.0	2.0	1322.00
9/16/2003	11:25	4.6	10.0	8.0	2.0	1466.00
10/1/2003	12:13	3.7	9.0	7.0	2.0	1354.00
10/15/2003	11:17	3.9	8.0	7.0	1.0	1410.00

Yakima River @ Kiona Bridge (37A090)						
DATE	**TIME**	**TURBIDITY (NTU)**	**TSS (mg/L)**	**TOTAL FIXED SS (mg/L**	**TOTAL VOLATILE SS (mg/L)**	**FLOW @ SAMPLING (CFS)**
4/1/2003	15:52	12.5	43.2	38.2	5.0	5725.73
4/16/2003	14:52	9.87	23.1	19.2	3.9	5476.09
4/29/2003	15:40	7.4	15.8	12.5	3.3	3587.99
5/13/2003	14:45	6	12.0	10.0	2.0	2098.34
5/28/2003	14:53	24	60.5	53.0	7.5	5844.37
6/10/2003	13:15	29.3	77.5	70.5	7.0	6373.16
6/24/2003	15:55	3.7	5.8	4.3	1.5	1152.17
7/15/2003	14:38	3.5	8.0	6.0	2.0	1309.47
7/29/2003	12:00	3	7.0	5.0	2.0	1626.85
8/12/2003	15:20	3.6	9.0	7.0	2.0	2521.17
8/19/2003	12:15	2.9	7.0	6.0	1.0	2752.01
9/2/2003	11:44	2.1	5.0	4.0	1.0	2721.83
9/16/2003	12:23	2.6	6.0	5.0	1.0	3411.46
10/1/2003	13:26	2.3	5.0	4.0	1.0	2796.37
10/15/2003	12:16	2.0	4.0	4.0	0.0	3016.23

Moxee Drain @ Birchfield Road (37I070)						
DATE	**TIME**	**TURBIDITY (NTU)**	**TSS (mg/L)**	**TOTAL FIXED SS (mg/L**	**TOTAL VOLATILE SS (mg/L)**	**FLOW @ SAMPLING (CFS)**
4/1/2003	9:41	31.1	230	220	10	56.60
4/16/2003	9:10	18.8	83.7	77.8	5.9	56.60
4/29/2003	8:47	20.5	119	110	9	66.20
5/13/2003	9:05	20	96	90.5	5.5	66.20
5/28/2003	9:10	21.8	108	99	9	62.90
6/10/2003	7:55	15.1	44.3	41.3	3	44.20
6/24/2003	9:07	11	37.5	34	3.5	39.05
7/15/2003	8:57	8.1	23	20	3	36.58
7/29/2003	6:57	12	39	35	4	41.00
8/12/2003	8:34	12	39	36	3	49.00
8/19/2003	7:38	12	41	37	4	47.40
9/2/2003	7:55	15	62	57	5	51.85
9/16/2003	8:11	11	41	39	2	55.65
10/1/2003	8:59	10	45	42	3	50.90
10/15/2003	8:07	11	45	42	3	57.04

Granger Drain @ Sheep Barns (37H070)						
DATE	TIME	TURBIDITY (NTU)	TSS (mg/L)	TOTAL FIXED SS (mg/L	TOTAL VOLATILE SS (mg/L)	MEAN DAILY FLOWS (CFS)
4/1/2003	11:35	4.85	21.8	18.4	3.4	19
4/16/2003	10:35	41.8	221	209	12	39
4/29/2003	11:35	27.2	151	140	11	42
5/13/2003	10:35	24.4	103	97	6	42
5/28/2003	10:44	22.1	61	54	7	48
6/10/2003	9:18	15.8	68.7	63.3	5.4	51
6/24/2003	18:05	7	13	10.8	2.2	49
7/15/2003	10:30	8.1	20	19	1	55
7/29/2003	8:42	10	24	22	2	51
8/12/2003	10:28	15	42	38	4	54
8/19/2003	8:48	18	61	56	5	48
9/2/2003	9:02	27	112	105	7	51
9/16/2003	9:27	33	178	169	9	47
10/1/2003	10:20	35	211	201	10	43
10/15/2003	9:32	27	142	134	8	38

Sulphur Creek Wasteway @ Holaday Road (37F080)						
DATE	TIME	TURBIDITY (NTU)	TSS (mg/L)	TOTAL FIXED SS (mg/L	TOTAL VOLATILE SS (mg/L)	FLOW @ SAMPLING (CFS)
4/1/2003	13:10	8.25	50.2	45.8	4.4	319.00
4/16/2003	11:45	11.3	36.2	31.7	4.5	369.00
4/29/2003	13:07	8.1	31	26.7	4.3	314.60
5/13/2003	12:25	11.4	34	30.5	3.5	234.16
5/28/2003	12:19	15.2	34	28	6	171.36
6/10/2003	9:56	21.4	65.7	59.3	6.4	190.40
6/24/2003	12:07	10.5	27.8	24.8	3	177.24
7/15/2003	11:32	7.7	21	18	3	145.52
7/29/2003	9:21	5.9	13	11	2	126.72
8/12/2003	11:38	6.7	18	16	2	150.57
8/19/2003	9:14	6.1	16	14	2	156.38
9/2/2003	9:44	6.4	17	15	2	191.06
9/16/2003	10:05	6.8	17	15	2	237.31
10/1/2003	10:54	5.2	13	11	2	153.40
10/15/2003	10:07	7.9	20	17	3	165.68

Spring Creek @ mouth (37J050)						
DATE	**TIME**	**TURBIDITY (NTU)**	**TSS (mg/L)**	**TOTAL FIXED SS (mg/L**	**TOTAL VOLATILE SS (mg/L)**	**FLOW @ SAMPLING (CFS)**
4/16/2003	16:11	10	31	26.7	4.3	69.15
4/29/2003	17:12	11.9	46.7	40.7	6	109.52
5/13/2003	16:05	12.5	40.5	37	3.5	53.88
5/28/2003	15:50	19.5	53.5	46.5	7	47.01
6/10/2003	14:42	16.6	47.3	43	4.3	52.23
6/24/2003	16:50	15.9	50.7	45.3	5.4	52.97
7/15/2003	15:25	9.3	30	27	3	68.90
7/29/2003	12:42	6	18	16	2	37.01
8/12/2003	16:30	12	42	38	4	53.58
8/19/2003	13:02	9.4	29	26	3	50.02
9/2/2003	13:21	10	33	29	4	128.15
9/16/2003	13:35	7.7	25	23	2	118.99
10/1/2003	14:43	5.2	17	16	1	69.95
10/15/2003	13:44	3.1	13	11	2	75.55

Table A3. Quality Assurance (QA) Results

Site Name	Site Number	Date	Time	Site Sample Turbidity (NTU)	QA Turbidity (NTU)	Site Sample TSS (mg/L)	QA TSS (mg/L)
Yak R at THB	37A210	4/1/03	8:33	12.6	12.2	24.6	26.3
Yak R at Euclid	37A120	4/16/03	13:50	10.5	10.3	27.3	26.7
Yak R at Kiona	37A090	4/29/03	16:04	7.4	7.6	15.8	15.5
Granger Drain	37H070	5/13/03	10:46	24.4	23.8	103	101.5
Granger Drain	37H070	5/28/03	10:55	22.1	21.7	61	60.5
Yak R at Kiona	37A090	6/10/03	13:35	29.3	28.3	77.5	78.5
Yak R at Euclid	37A120	6/24/03	14:45	7.1	6.5	14.3	14.0
Moxee Drain	37I070	7/15/03	9:03	8.1	7.5	23	23
Yak R at THB	37A210	7/29/03	6:20	4.8	4.7	11	11
Sulphur Crk	37F080	8/12/03	11:25	6.7	6.8	18	18
Moxee Drain	37I070	8/19/03	7:46	12	12	41	41
Yak R at Kiona	37A090	9/2/03	12:04	2.1	2.1	5	5
Sulphur Crk	37F080	9/16/03	10:16	6.8	6.7	17	16
Spring Crk	37J050	10/1/03	14:47	5.2	5.5	17	20
Spring Crk	37J050	10/15/03	13:49	3.1	3.5	13	13

THB = Terrace Heights Bridge

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Appendix B. List of Acronyms

BMP	best management practice
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
EPA	United States Environmental Protection Agency
NAWQA	National Water Quality Assessment
NTU	nephelometric turbidity unit
QA	Quality Assurance
RM	river mile
RSBOJC	Roza-Sunnyside Board of Joint Control
SRF	State Revolving Fund
SSC	Suspended Sediment Concentration
SVID	Sunnyside Valley Irrigation District
SYCD	South Yakima Conservation District
t-DDT	Total DDT; including DDT, DDD and DDE
THB	Terrace Heights Bridge
TMDL	total maximum daily load
TNVSS	total non-volatile suspended solids
TSS	total suspended solids
USGS	United States Geological Survey
WAC	Washington Administrative Code
cfs	cubic feet per second