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A Suspended Sediment and DDT Total Maximum Daily Load Evaluation Report for the Yakima River

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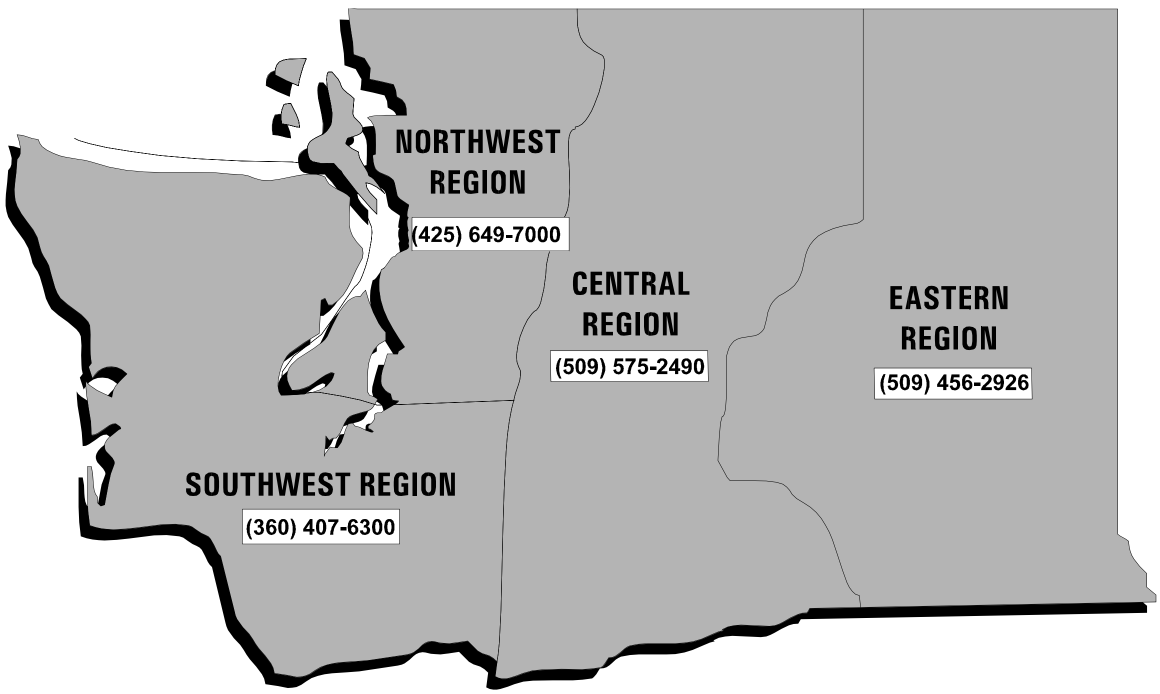

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A Suspended Sediment and DDT Total Maximum Daily Load Evaluation Report for the Yakima River

by
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Abstract

The Washington State Department of Ecology (Ecology) conducted a total maximum daily load (TMDL) evaluation of the lower Yakima River basin in 1994-1995. The TMDL was conducted in cooperation with the USEPA and the Yakama Indian Nation, who are also water quality managers in the basin. The TMDL evaluation focused on total suspended sediment (TSS) and DDT loads from irrigated agricultural areas during the irrigation season. Historical and TMDL data indicated significant correlations between TSS and turbidity, and between TSS and total DDT (t-DDT= DDT+DDE+DDD). Turbidity targets for main stem and tributary sites were recommended with an implementation schedule spanning 15 years. The Washington State Class A turbidity criterion was applied to the main stem to control TSS loading. Turbidity will be limited to a 5 NTU increase in the 86.4 mile reach between the confluence of the Yakima and Naches River and Benton City. A 90th percentile turbidity target of 25 NTUs (56 mg/L TSS) for the tributaries and return drains was recommended to significantly reduce t-DDT loads and to protect aquatic communities from TSS effects. The target will require the largest return drains to reduce TSS loads 70% or more during an irrigation season with normal water availability. Based on the current correlation equation, tributary TSS concentrations will need to be further reduced to 7 mg/L to meet the 1 ng/L DDT chronic toxicity criterion for protection of aquatic life. However, more data from tributaries for TSS and t-DDT at lower TSS concentrations are needed to confirm this target.

Acknowledgments

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We are indebted to many people who helped make this project successful. Bob Barwin and Max Linden of the Ecology Central Regional Office were instrumental in the project design and plan phase, and kept us focused throughout the project Also, our thanks to Ray Hennekey and Chris Coffin who have shepherded the project through the local coordination process to make our work much easier. Thanks to Bill Beckley and Jannine Jennings of the Yakama Indian Nation Environmental Protection Program. They have been extremely insightful and cooperative during the entire study, and their comments on draft reports and their work on inter-governmental agreements are greatly appreciated. Alan Hennings, Ben Cope, and Dan Robison of USEPA Region 10 have been great partners in doing this TMDL in a new way. Greg Fuhrer of USGS, Portland has been an extremely helpful source of data on the Yakima River; as has Onni Perala of the Roza Irrigation District. We would like to extend our thanks to Dale Davis of the EILS Toxics Unit for his cooperation in collecting and funding additional pesticide analyses, and for his review of the draft report. Thanks too, to Will Kendra, EILS Watershed Assessments supervisor, for his support, guidance, and patience throughout the project. Thanks to Randy Coots for his graphics help, and a special thanks to Barbara Tovrea for typing, editing, and formatting the manuscript.

Executive Summary

Purpose and Approach

The lower Yakima River basin is located in south-central Washington State. It is one of the most intensively irrigated and agriculturally diverse areas in the United States. Suspended sediment and persistent pesticide loads from irrigated agricultural areas of the lower Yakima River basin have long been recognized as serious impairments to water quality. Recent water quality evaluations by the US Geological Survey (USGS) have indicated that some improvements have been made, but beneficial uses are still impaired by sediment and sediment-borne pollutants like DDT from irrigation returns (Rinella *et al.,* 1992b, 1993). Consequently, several reaches of the lower Yakima River and several of its tributaries do not meet numerous state water quality criteria and federal guidelines (Ecology, 1994a, 1995). As a result, these water bodies have been placed on the Washington State's 303(d) list.

The Clean Water Act directs Ecology to perform a total maximum daily load (TMDL) analysis for contaminated waters on the 303(d) list. Ecology had determined that turbidity and DDT represent key water quality impairments on the 303(d) list in the lower Yakima River basin. In response, Ecology conducted a TMDL study to evaluate controls of suspended sediment, the primary cause of the turbidity criteria violations, and a major source DDT transport in the lower basin during the irrigation season. Ecology believes the control of suspended sediment generation and transport during the irrigation season will result in far-reaching water quality and fish habitat improvements in the Yakima Basin.

In addition, the TMDL needed to be coordinated with the Yakama Indian Nation (YIN) since the Yakama Indian Reservation covers over forty percent of basin, but is outside of the state's jurisdiction. The Yakama Indian Nation and Ecology joined in a data-sharing and cooperative monitoring agreement for the project. Like Ecology, the YIN and the US Environmental Protection Agency (USEPA) share similar Clean Water Act and TMDL responsibilities on the Yakama Indian Reservation. They are developing plans, and are undertaking actions to address suspended sediment loads in drains and tributaries from the Reservation. Ecology, the YIN, and the USEPA will continue to coordinate their efforts to improve water quality in the Yakima River

The TMDL evaluation project was undertaken in two phases by the Environmental Investigations and Laboratory Services (EILS) program at Ecology. Phase I tasks included:

- water quality monitoring,
- a historical data review,
- suspended sediment criteria development based on beneficial use impairments, and
- ranking of subbasins relative to their suspended sediment problems.

Phase I results focused work for Phase II. The main objective of Phase II was to recommend suspended sediment reduction targets to protect aquatic life in the main stem and in tributaries of the lower Yakima project area. Targets were to be based on relationships between suspended solids and Washington State criteria for turbidity and DDT. Tasks during Phase II included:

- additional turbidity and suspended sediment monitoring to establish TMDL control and compliance sites,
- a comparison of turbidity results between agency laboratories,
- additional pesticide data collection in major return drains,
- development of a suspended sediment mass balance for the lower Yakima basin during the 1995 irrigation season, and
- establishment of cooperative working relationships with tribes, federal agencies, conservation districts, and other groups in the lower basin.

Additional data were obtained from the USGS, US Bureau of Reclamation (USBR), the YIN, and the North and South Yakima Conservation Districts. Monitoring and evaluation focused on drains and tributaries in the most heavily irrigated areas of the lower Yakima. Data evaluation, jurisdictional issues, and the TMDL strategy were discussed with, and reviewed by technical staff from the Ecology Central Regional Office (CRO), Region 10 of USEPA, and the YIN Environmental Protection Program.

Findings

Flow, Turbidity and TSS

The Yakima River and Naches River serve as irrigation supply water for approximately 339,200 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). In some past years, nearly all water was diverted out of the main stem at the Sunnyside Dam. This became a concern among fishery and water resource managers. Diversion limits were placed in 1994, so that at least 300 cubic feet per second (cfs) must spill over the dam to the lower river. The lower basin slowly recovers some of the water diverted for irrigation through surface and subsurface returns. Many irrigation return drains and tributaries enter the river from the project area and the Yakama Indian Reservation. Most of the returning water contains elevated levels of suspended sediments, pesticides, nutrients, bacteria, and oxygen demanding substances. Several small municipalities and industrial sources also discharge into the river, but supply a fairly small cumulative volume (10 cfs) during the irrigation season.

Two very different irrigation season flow regimes were monitored during 1994 and 1995. Irrigation diversions were severely limited in 1994 because water availability for irrigation was the lowest on record. The 1995 season saw normal water availability. Water availability and use had a direct impact on suspended sediment loading from tributaries and irrigation return drains. Tributaries and drains associated with lands with senior water rights (*i.e.*, only minor reductions in water use) maintained elevated TSS concentrations and turbidities both years. For example, the median turbidities at Moxee Drain and Granger Drain exceeded 50 NTU, the level at which displacement of salmonids can occur, in 1994 and 1995. However, tributaries and return drains from lands affected by lower water use in 1994 resulted in lower mean TSS concentrations and turbidities. In 1994, Sulphur, Spring, and Snipes creeks had median turbidities below 25 NTUs. Salmonid feeding and growth are affected at turbidities above 25 NTUs. In 1995, the median turbidities of Sulphur Creek and Spring Creek were above 25 NTU, while the 90th percentile turbidities for Sulphur, Spring, and Snipes creeks exceeded 50 NTU. In turn, main stem concentrations of TSS and turbidity increased between 1994 and 1995 as TSS loading from tributaries increased. Median and 90th percentile turbidities at main stem sites monitored in 1994 remained below 25 NTU. In 1995, 90th percentile turbidities of the four sites below the Yakima River at Parker exceeded 25 NTU. In both years, turbidity increased by more than 5 NTUs between the confluence of the Yakima and Naches River and Benton City.

A TSS loading balance was calculated from the data collected during the 1995 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's 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 Spring and Snipes Creeks' combined TSS load was 46 tons/day. The combined TSS load from the Yakama Reservation drains and tributaries was 75 tons/day. Approximately 1.5 tons/day came from municipal or industrial sources. Ungaged tributaries and instream sources also accounted for substantial loads during the irrigation season.

Using 1994 and 1995 monitoring data generated in this TMDL evaluation, a regression was developed of turbidity as a function of TSS. The following linear regression equation was based on 646 data pairs from river, canal, drain, and tributary sites with TSS concentrations less than 1000 mg/L:

$$\log_{10} \text{Turbidity} = 0.871 * \log_{10} \text{TSS} - 0.145$$

The equation had a coefficient of determination (r^2) of 0.956, which means 96% of the data variability is explained by the TSS data. Such a high correlation is somewhat unusual, but it may be because a ratio turbidimeter was used for all analyses, and because the geographic and seasonal scope of the data was more focused than other studies of this kind.

Pesticides

Nonionic pesticides have been used extensively on the agricultural crops of the Yakima Valley since at least the 1950s. In general, the organochlorine compounds, such as DDT, dieldrin, and endosulfan, have been the most frequently detected pesticides in basin waters, sediments, and biota due to their persistence in the environment and heavy use in the past. 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. Samples collected by USGS during the NAWQA survey indicate that DDT is still present in the main stem at concentrations above criteria. There is some indication that t-DDT burdens in fish tissues are declining, although there are not enough data to confirm this trend. Fish in the lower Yakima River still have one of the highest concentrations of DDT in the country (Rinella *et al.,* 1993). These findings resulted in a Washington State Department of Health advisory in 1993 recommending that people eat fewer bottom fish from the lower basin (Department of Health, 1993).

In 1995, whole water samples were analyzed for 46 pesticides at Granger Drain, Spring Creek, Sulphur Creek, and the Yakima River at Euclid Bridge as part of the TMDL evaluation. Organochlorine, organophosphate, and nitrogen-containing pesticides were frequently detected at all sites. Total DDT was detected above the human health and aquatic life chronic toxicity criteria at all sites on three or more sampling dates. The t-DDT samples analyzed had concentrations from 0.004 µg/L to 0.357 µg/L, and a median of 0.0083 µg/L. The median concentration, and most sample results, were similar to what has been reported in recent years for these sites. However, one sample collected at Granger Drain contained 0.357 µg/L t-DDT. It was twice the previously highest concentration of t-DDT detected since 1968.

Additional pesticides detected in water at concentrations above criteria or guidelines were: azinphos-methyl, chlorpyrifos, malathion, diazinon, and propargite. Both azinphos-methyl and chlorpyrifos are highly toxic insecticides used on many fruit and vegetable crops. Preventing seasonal entry of these newer pesticides into basin waters deserves further investigation.

The t-DDT concentrations in the small mouth bass and carp tissue samples collected in 1995 from the Yakima River at Euclid exceeded the Ecology screening guideline by an order of magnitude. The bass sample had a higher concentration than bass previously analyzed in the lower basin, and the carp sample was at the higher end of the range of values observed. Dieldrin was also detected in the bass and carp samples at concentrations exceeding the 0.7 µg/kg screening guideline by an order of magnitude. The carp sample's 15 µg/kg total chlordane concentration exceeded the human health screening level of 8.3 µg/kg. Total PCBs (polychlorinated biphenyls) in both the carp and bass also exceeded the screening guideline for human health risk. Other pesticides detected, but below guideline concentrations, were: heptachlor expoxide, hexachlorobenzene, and trifluralin.

The three largescale sucker composite samples collected from the Yakima River at Euclid in 1995 contained from 2,276 µg/kg to 3,728 µg/kg t-DDT. Dieldrin and total PCB concentrations in the 1995 samples also exceeded wildlife guidelines. These data indicate that pisciverous wildlife are still likely at risk from exposure to t-DDT, dieldrin, and other pesticides in Yakima River fish.

Using 1995 monitoring data generated in this TMDL evaluation and previous USGS and Ecology data, a regression was developed of t-DDT as a function of TSS. The best linear regression equation based on 71 data pairs from river and tributary sites with detectable t-DDT concentrations (expressed as nanograms per liter, or ng/L) was:

$$\log_{10} \text{t-DDT} = 0.953 * \log_{10} \text{TSS} - 0.820$$

The equation had a coefficient of determination (r^2) of 0.747. Data collected in 1995 were not significantly different from previously collected data, and tributary data were not significantly different from main stem data, so all data were grouped. Other pesticides either had too few data, or no significant association with TSS was found.

Total Maximum Daily Load Recommendations

Since suspended sediment and DDT are two of the most significant pollutants in the Yakima River Basin, it is necessary to set nonpoint source reduction targets through load allocations in the study area. Three approaches were used to recommend TSS and DDT targets and nonpoint source load allocations for the Yakima River and its tributaries in the study area:

1. ***Turbidity criterion*** -Using the correlation of TSS concentrations to turbidity values, TSS targets on the main stem Yakima River will be based on the turbidity standard of 5 NTU above background.
2. ***Fisheries (aquatic biota) support*** - Using the narrative criteria to protect aquatic life, a 25 NTU turbidity or 56 mg/L TSS target will apply 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 t-DDT, long-term TSS reduction goals will be 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 to the aquatic life criterion is made.

The TMDL-related activities include re-evaluation work and further target development. The targets based on aquatic community effects should be met in 15 years so that an evaluation of ways to meet DDT human health criteria can be done within 20 years. Limiting DDT uptake by aquatic organisms may require an entirely different approach, but that will be difficult to know until substantial reductions in TSS and associated DDT loadings are accomplished. These are necessary components of the phased-TMDL approach. The effectiveness of individual control measures to reduce soil erosion in irrigated agricultural areas is fairly well understood, but the overall effectiveness of all measures implemented in the basin, and the rate at which they will be adopted under current economic and political conditions is uncertain. The scheduling of targets and TMDL-related activities are proposed as follows:

5 years (2002)

- Yakima River main stem 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 gage at Benton City (RM 30).
- All drains and tributaries within the project area will comply with the 90th percentile turbidity target of 25 NTU at their mouths, especially Moxee Drain, Granger Drain, Sulphur Creek, and Spring Creek.
- The efficacy of using TSS load targets for tributaries and drains where the 25 NTU target is not representative of total load reductions will be evaluated.
- Agreements between the State of Washington, Yakama Indian Nation, and the U.S. Environmental Protection Agency that sets load allocations for the Yakama Reservation, and management of basin water quality will be completed.

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 to meet the DDT human health criteria in fish and water will be developed.
- Yakima River main stem will comply with the turbidity target of not more than a 5 NTU increase between the confluence of the Yakima and Naches Rivers and the Van Geisan Road bridge at West Richland (RM 8.4).

15 years (2012)

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

20 years (2017)

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

TSS reductions necessary to meet the turbidity TMDL targets were estimated from the 1994 and 1995 data. Main stem TSS concentrations in both years would have required reductions of approximately 50% to stay within the 5 NTU limit at Kiona. The main stem loading would be adequately reduced to meet the 5 NTU limit if project area and Yakama Reservation tributaries complied with the recommended 25 NTU target. The TSS load from project area tributaries and drains to the Yakima River would have been reduced by approximately 207 tons/day in 1995. The 25 NTU target will require the largest return drains to reduce TSS loads 13% to 93% in an irrigation season with normal water availability, like 1995. Under conditions of limited water availability like in 1994, some of these same return drains would have easily meet the target while others would still have needed reductions of 25% to 90%.

Based on the regression equation, the turbidity-related TMDL target of 56 mg/L TSS at mouths of drains could reduce t-DDT concentrations to 7 ng/L. That would reduce t-DDT loading to the Yakima River by more than 66%. The 7 mg/L TSS target for compliance with the 1 ng/L aquatic toxicity criterion for DDT will require substantial reductions of TSS loads in most tributaries -- from 30% to 99%. However, model simulation results suggest the 1 ng/L DDT criterion might not be attained in the river, even if the TSS concentrations in the drains were reduced to the 7 mg/L TSS target. Background t-DDT residuals carried in the river from upstream or in resuspended sediment would become the dominant sources of t-DDT in the lower Yakima River. These inputs could continue to cause DDT concentrations to exceed the criterion. Instream and out-of-basin sources are more difficult to predict and control, and could likely prevent complete water quality compliance in the main stem.

The TSS to t-DDT regression developed from data collected to date shows a greater variability in the lower region of the regression where TSS concentrations are less than 70 mg/L. DDT data are lacking for the lower TSS concentration range. Therefore, as more DDT samples are collected from return drains and tributaries that approach compliance with the interim turbidity TMDL target of 25 NTU (56 mg/L TSS), the regression can be re-calculated.

The suspended sediment and turbidity reductions recommended in the TMDL evaluation provide direction to Ecology for planning, funding, and executing specific actions in priority subbasins. Ecology will hold public workshops in cooperation with conservation and agricultural outreach agencies to discuss all aspects of the TMDL with local growers, water purveyors, and other interested parties in the lower Yakima River basin. At that time, implementation plans and schedules for these recommendations (or alternatives that meet water quality standards, protect fish health and habitat, and protect designated uses) will be formulated.

Implementation of the TMDL will remove turbidity, DDT, DDE, and DDD from the list of contaminants impairing water quality in the lower Yakima River and several of its tributaries. Other pesticide and nutrient-caused impairments on the 303(d) list may be eliminated by implementing this TMDL. For example, future monitoring may show that concentrations of endosulphan, heptachlor, endrin and other chlorinated pesticides similar to DDT are reduced by measures set-up for suspended sediment and DDT removal.

The YIN and USEPA have similar Clean Water Act responsibilities on the Yakama Indian Reservation. They are developing plans, and are undertaking actions to address suspended sediment loads in drains and tributaries from the Yakama Reservation. Ecology, the Yakama Indian Nation, and the USEPA will continue to coordinate their efforts to improve water quality in the Yakima River. Some TSS load allocations in the lower Yakima River will need to be negotiated between these governments and agencies as part of the public process.

Introduction

Problem Description

Suspended sediment and persistent pesticide loads from irrigated agricultural areas of the lower Yakima River basin have long been recognized as serious impairments to water quality. The effects of soil erosion on the landscape, and the effects of sediment and dichlorodiphenyl-trichloroethane (DDT) on aquatic resources have been the focus of numerous activities by several agencies. However, few of these past actions have been coordinated between agencies or systematically directed within the basin. As a result, the basin-wide effectiveness of these actions in alleviating suspended sediment and DDT problems has not been documented. In addition, *The Yakima River Basin Water Quality Plan* (Yakima Valley Council of Governments, 1995) and recent water quality evaluations by the US Geological Survey (USGS) have indicated that beneficial uses are still impaired by sediment and sediment-borne pollutants like DDT from irrigation returns (Rinella *et al.,* 1992b, 1993). Consequently, several reaches of the lower Yakima River and several of its tributaries do not meet numerous state water quality criteria and federal guidelines (Ecology, 1994a, 1995).

The Washington State Department of Ecology (Ecology) is responsible for protecting the quality of water resources and implementing Clean Water Act programs within the state. Chapter 90.48 of the Revised Code of Washington directs Ecology to control and prevent pollution of state waters. Under the requirements of Section 303(d) of the Federal Clean Water Act, Ecology must identify waters which are not meeting water quality standards. The Clean Water Act further directs Ecology to perform a total maximum daily load (TMDL) analysis for contaminated waters on the 303(d) list. Ecology has determined that turbidity and DDT represent key water quality impairments in the lower Yakima River basin. Consequently, Ecology is conducting a TMDL evaluation to control suspended sediment as the primary cause of the turbidity criteria violations, and a major source of DDT transport in the lower basin during the irrigation season. Ecology believes that the control of suspended sediment generation and transport during the irrigation season will result in far-reaching water quality and fish habitat improvements in the Yakima Basin.

Project Strategy and Objectives

The TMDL evaluation project was undertaken in two phases by the Environmental Investigations and Laboratory Services (EILS) Program at Ecology. Phase I tasks included:

- water quality monitoring
- a historical data review
- suspended sediment criteria development
- definition of beneficial use impairments
- ranking of subbasins relative to their suspended sediment problems

Subbasin monitoring activities took place in the upper and lower Yakima basins during the last half of the 1994 irrigation season. Additional data were obtained from the US Bureau of Reclamation (USBR), the Yakama Indian Nation (YIN), and the North and South Yakima Conservation Districts. Analysis of monitoring data from 1994 and previous years verified that the lower Yakima valley required more immediate attention to reduce suspended sediment loading (Joy and Patterson, 1994). The historical data review, and research into criteria development and reduction of beneficial uses, suggested that fish and aquatic life protection were immediate needs. Protection of human health from exposure to DDT was recognized as a long-term goal of the TMDL. Ecology presumes it may require a more complex or different approach to meet this long-range goal.

The main objective of Phase II was to recommend suspended sediment reduction targets to protect aquatic life in the main stem and in the major subbasin tributaries of the lower Yakima. Targets were to be based on relationships between suspended solids and Washington State criteria for turbidity and DDT. Tasks during Phase II included:

- additional turbidity and suspended sediment monitoring to establish TMDL control and compliance sites
- comparisons of turbidity results between USBR, YIN, USGS, and Ecology laboratories
- additional pesticide data collection in major return drains
- development of a suspended sediment mass balance for the lower Yakima basin during the 1995 irrigation season
- establishment of cooperative working relationships with YIN, USBR, USGS, conservation districts, and other groups in the lower basin

Monitoring and evaluation focused on drains and tributaries in the most heavily irrigated areas of the lower Yakima. Suspended sediment monitoring of tributaries in the lower Yakima basin outside the project area, on the Yakama Reservation, was conducted in cooperation with the YIN to better define suspended sediment loads to the river from the project area tributaries. Monitoring was also conducted in cooperation with the EILS Toxics Investigations Section, USBR, USGS, and the North and South Yakima Conservation Districts.

Data evaluation, jurisdictional issues, and the TMDL strategy were discussed with, and reviewed by, technical staff from the Ecology Central Regional Office (CRO), the U.S. Environmental Protection Agency Region 10 (USEPA), and the YIN.

The results of the TMDL evaluation contained in this report recommend:

- a turbidity limit in the Yakima River to protect fish health and habitat
- turbidity and suspended sediment limits for individual drains and tributaries in the project area to meet the turbidity limit in the river, and to protect fish health and habitat in the drains
- suspended sediment goals for individual drains and tributaries to meet water column DDT criteria that protects aquatic life
- a proposal to evaluate ways to meet DDT human health criteria within 20 years

The suspended sediment and turbidity reductions recommended in the TMDL evaluation provide direction to Ecology for planning, funding, and executing specific actions in priority subbasins. Ecology will hold public workshops in cooperation with conservation and agricultural outreach agencies to discuss all aspects of the TMDL with local growers, water purveyors, and other interested parties in the lower Yakima River basin. At that time, implementation plans and schedules for these recommendations (or alternatives that meet water quality standards, protect fish health and habitat, and protect designated uses) will be formulated.

Implementation of the TMDL will remove turbidity, DDT, DDE, and DDD from the list of contaminants impairing water quality in the lower Yakima River and several of its tributaries. Other pesticide and nutrient-caused impairments on the 303(d) list may be eliminated by implementing this TMDL. For example, future monitoring may show that concentrations of endosulphan, heptachlor, endrin and other chlorinated pesticides similar to DDT are reduced by measures set up for suspended sediment and DDT removal.

The YIN and USEPA have similar Clean Water Act responsibilities on the Yakama Indian Reservation. They are developing plans, and are undertaking actions to address suspended sediment loads in drains and tributaries from the Yakama Reservation. Ecology, the Yakama Indian Nation, and the USEPA will continue to coordinate their efforts to improve water quality in the Yakima River. Some TSS load allocations in the lower Yakima River will need to be negotiated between these governments and agencies as part of the public process.

The Lower Yakima River Basin

The lower Yakima River basin contains approximately 3,300 square miles (mi^2) in south-central Washington (Figure 1). The basin encompasses the area from Cowiche Mountain, Selah Gap, and the Rattlesnake Hills on the north; the Cascade foothills to the west; the Simcoe Mountains and Horse Heaven Hills to the south; to the Columbia River on the east. The upper Yakima River (1,800 mi^2) and Naches River (1,100 mi^2) basins are located upstream of the lower basin, and feed the remaining 128 miles of the Yakima River that flows southeasterly through the basin. Most of the basin is fairly arid with average annual rainfall of less than 20 inches per year. As a result, no natural perennial tributaries enter the river from its drier east side (Molenaar, 1985). Natural streams that enter the river from the higher and wetter west side are Ahtanum Creek, Toppenish Creek, and Satus Creek.

The basin is located in Yakima and Benton counties. Approximately 1,390 mi^2 of the lower basin, over 42%, lies within the Yakama Indian Reservation. Most of the basin is ceded lands of the YIN; a small area of the southeastern corner is ceded lands of the Walla Walla, Umatilla, and Cayuse Tribes.

The Yakima River basin fishery, especially the salmon fishery, is a key natural resource. The Yakima River basin was one of the largest contributors to the Columbia River salmon fishery before 1900 (Yakima Valley Council of Governments, 1995). Salmon have important game and commercial value, and hold cultural and religious significance for the Yakama People. The Yakima basin salmon population rapidly declined with the onset of water diversion and land and resource development in the basin. Local overfishing, and pressures from ocean and Columbia River overfishing, and Columbia River dam construction also contributed to Yakima River fishery declines. Once numerous, sockeye (*Oncorhynchus nerka*), coho (*O. kisutch*) and summer chinook (*O. tshawytscha*) salmon runs are now extinct. Spring and fall chinook, and steelhead (*O. mykiss*) runs continue to exist in much reduced numbers (Yakima Valley Council of Governments, 1995; Embrey and Watson, 1992). Other dominant fish species in the basin include: chiselmouth, redside shiner, northern squawfish, largescale sucker, speckled dace, mountain whitefish, torrent sculpin, and carp. Rainbow trout, bass, brown trout, and brook trout are present in the basin and are popular game fish (Embrey and Watson, 1992).

Several public and private plans and projects have been implemented or are underway to protect and enhance fish, wildlife and water resources in the basin. The Yakima River basin is considered the best candidate for reviving salmon populations in the Columbia River basin through spawning habitat development (Bonneville Power Administration, 1985). These projects vary in scope from backyard conservation measures that enhance riparian habitat, to the multi-million dollar Yakima River Basin Water Enhancement Project.

The lower Yakima basin is rural in character. Agricultural uses comprise 30% of the land area in the basin, and are primarily located close to the Yakima River. Another 52% of the basin is range land, 15% is forest land, 1% is wetland, and 2% is in urban or industrial use (Figure 2). The lower basin population is approximately 220,000. Yakima is the largest city with 58,700 residents, and is located at the head of the basin. Other towns with over 2,500 residents include: Selah, Union Gap, Wapato, Toppenish, Sunnyside, Grandview, Prosser, and West Richland.

The lower Yakima River basin is one of the most intensively irrigated and agriculturally diverse areas in the United States. A vast and complex irrigation network has allowed the Yakima Valley to become a leading producer of tree and vine fruit, corn, hops, mint, asparagus, milk, and beef. Reservoir and water delivery operations managed by USBR provide the water necessary to irrigate most of these crops. The USBR also manages the system for flood control, power generation, and fishery management. Approximately 500 mi^2 of irrigated land in the lower Yakima River basin are served by several small districts and companies, and by four major irrigation districts: Roza, Wapato, Sunnyside Valley, and Kennewick. Excess water from fields, canals, and through subsurface ground water transport is routed to other delivery canals for reuse, or into return drains. The major irrigation return drains and operational spillways to the Yakima River include:

- the Roza Power Return
- Wide Hollow Creek
- Moxee Drain
- Marion Drain
- Granger Drain
- Sulphur Creek Wasteway
- Spring Creek and Snipes Creek

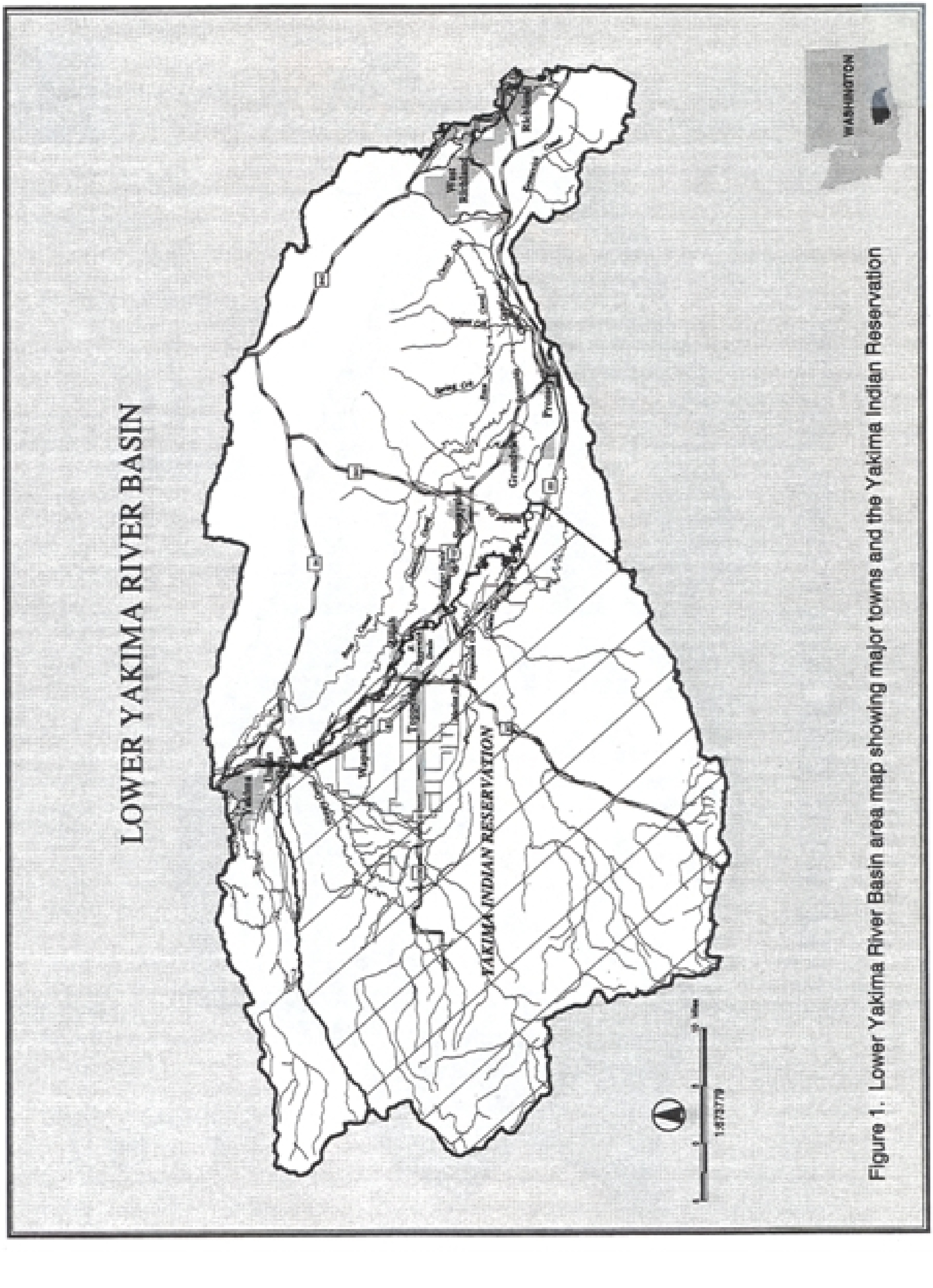


Figure 1. Lower Yakima River Basin area map showing major towns and the Yakima Indian Reservation

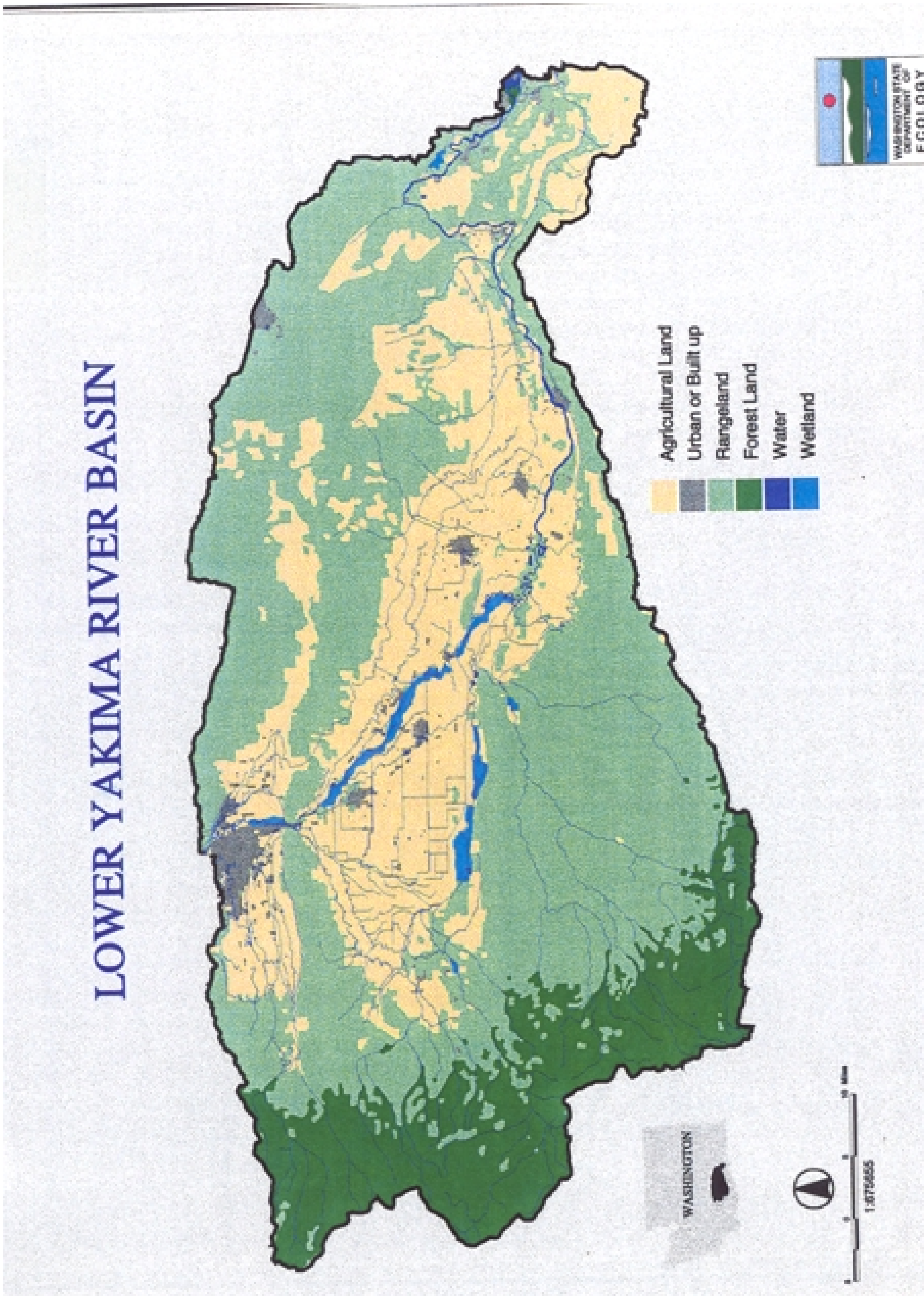


Figure 2. Lower Yakima River Basin land use and hydrology.

Water rights and water conservation issues are closely tied to management of the irrigation system and the quantity and quality of water in the lower basin. A water rights adjudication for the Yakima River basin that began in 1977 to clarify water allocation is still underway. Droughts and competing uses for water have compelled irrigation districts and growers to develop additional sources and storage, and to modernize delivery systems for conservation and water quality improvements.

Project Area

The TMDL project encompassed the entire Yakima Basin, but focused on the lower Yakima River in areas where the state has Clean Water Act jurisdiction. Tributaries from the U.S. Army Yakima Training Center, and the U.S. Department of Energy Hanford Site are outside of the state's jurisdiction, but were not significant contributors to the irrigation season suspended sediment evaluation. Yakama Indian Reservation tributaries are also outside of the state's jurisdiction, but estimates of suspended sediment loading from these tributaries to the main stem Yakima River were necessary to estimate loading from the project area. A data sharing and cooperative monitoring agreement for the project was reached between Ecology and the YIN to measure loads from these tributaries, and it was fully implemented during Phase II.

The Yakama Indian Nation does not recognize the authority of the state to regulate water quality on the main stem Yakima River where it borders the reservation (i.e., from the Mabton-Sunnyside bridge at river mile 59.8 to Ahtanum Creek at river mile 106.9). The USEPA has not yet taken a position whether that section of the river may be subject to state or tribal jurisdiction. However, since the main stem Yakima River is on the state's 303(d) list of threatened or impaired water bodies, the state acted on its responsibility to improve and protect water quality. By applying Washington's water quality standards in the TMDL to that section of the river, the state does not intend to prejudice the YIN's jurisdictional claim. This TMDL should not be construed to grant, enlarge, diminish, or in any way affect the scope of governmental authority of the Yakama Indian Nation, the State of Washington, or the US Environmental Protection Agency. The YIN, the USEPA, and Ecology plan to cooperatively manage the main stem until the jurisdictional issue is settled.

Therefore, the TMDL project area includes the main stem river, and all eastern (left bank) drainages to the Yakima River, and those western (right bank) drainages outside of the Yakama Reservation, which are active during the irrigation season (March through October), from the Roza Canal diversion at river mile 127.9 to the confluence with the Columbia River.

Water Quality Status and Previous Studies

The lower Yakima River and the tributaries under the jurisdiction of the state fall into one of two water quality classifications (Table 1). The main stem river from its mouth through the lower basin and to river mile (RM.) 185.6 at Cle Elum is Class A. The Yakima River's classification carries a special temperature variance of 21°C. All tributaries are Class A, except Sulphur Creek, which is Class B. Beneficial and characteristic uses for Class A and B waters are listed in Table 1. The Yakima River has historically supported all of the listed uses. Water bodies on the Yakama Indian Reservation are evaluated by the USEPA and the Yakama Indian Nation, and are not classified by the state.

Several reaches in the lower Yakima River basin are not meeting state water quality standards. Fourteen river or tributary segments and one lake in the basin are identified on the most recently submitted 303(d) list (Ecology, 1996a). Pesticides, PCBs, temperature, fecal coliform bacteria, ammonia, phosphorus, pH, dissolved oxygen, and turbidity criteria violations occur (Table 2). Inadequate instream flows which cause beneficial use losses have also been listed for some reaches. Wastes from some agricultural practices, irrigation return drains, municipal and industrial treatment plant effluents, run-off from poorly managed forest and range practices, and urban runoff have been identified as pollutant sources.

The earliest comprehensive water quality monitoring studies of the Yakima River basin were performed in the mid- to late-1970's during the 208 planning process (Ecology, 1979). Ecology, USGS, Washington State University (WSU), Conservation Districts, and USBR intensively sampled irrigated areas of the lower Yakima River. Many studies evaluated annual and seasonal sediment loading in various parts of the basin (CH2M Hill, 1975; Boucher, 1975; SCS, 1978; Corps of Army Engineers, 1978; Nelson, 1979; Boucher and Fretwell, 1982). Much of the work indicated that irrigation practices directly affects suspended sediment concentrations and turbidity in the lower Yakima River and return drains from March through October. Sediment eroded from fields is deposited during the irrigation season in drains and the main channel. During storm events in the non-irrigation season, this sediment can move back into the water column (SCS, 1978). Peak suspended sediment concentrations in the main stem occurs in April through June when stream flows are high, snowmelt occurs, and irrigation of freshly tilled fields commences.

Table 1. Class A (excellent) and Class B (good) characteristic uses, freshwater quality criteria, and special conditions for the lower Yakima River and tributaries (WAC 173-201A)

	Class A	Class B
General Characteristics:	Shall meet or exceed the requirements for all or substantially all uses.	Shall meet or exceed requirements for most uses.
Characteristic Uses:	Shall include, but not be limited to the following: Water Supply (domestic, industrial, agricultural); Stock Watering; Fish and Shellfish: Salmonid and Other fish migration, rearing, spawning, and harvesting, Crustaceans and Other shellfish rearing, spawning, and harvesting; Wildlife Habitat; Recreation (primary contact, sport fishing, boating, and aesthetic enjoyment); Commerce and Navigation.	Shall include, but not be limited to the following: Water Supply (industrial, agricultural); Stock Watering; Fish and Shellfish: Salmonid migration, rearing, and harvesting; Other fish, Crustaceans and Other shellfish rearing, spawning, migration, and harvesting; Wildlife Habitat; Recreation (secondary contact, sport fishing, boating, and aesthetic enjoyment); Commerce and Navigation.
Water Quality Criteria:		
Fecal Coliform	Shall both not exceed a geometric mean value of 100 colonies/100 mL, and not have more than 10% of all samples obtained for calculating the geometric mean exceeding 200 colonies/100 mL	Shall both not exceed a geometric mean value of 200 colonies/100 mL, and not have more than 10% of all samples obtained for calculating the geometric mean exceeding 400 colonies/100 mL
Dissolved Oxygen	Shall exceed 8 mg/L	Shall exceed 6.5 mg/L
Total Dissoved Gas	Shall not exceed 110% of saturation at any point of sample collection.	Same as Class A
Temperature (Special Condition for lower Yakima River only)	Shall not exceed 21.0°C.due to human activities. When natural conditions exceed 21°C., no increase allowed which raises receiving water temperature greater than 0.3°C; nor increases at any time shall exceed t=34/(T+9)	Same as Yakima River Special Condition
Temperature	Shall not exceed 18.0°C.due to human activities. When natural conditions exceed 18°C., no increase allowed which raises receiving water temperature greater than 0.3°C; nor increases at any time shall exceed t=28/(T+7)	
pH	Shall be within the range of 6.5 to 8.5 with a human-caused variation within a range of less than 0.5 units	Same as Class A
Turbidity	Shall not exceed 5 NTU over background when the turbidity is 50 NTU or less, or have more than a 10% turbidity increase when background is more than 50 NTU.	Shall not exceed 10 NTU over background when the turbidity is 50 NTU or less, or have more than a 20% turbidity increase when background is more than 50 NTU.
Toxic, radioactive, or deleterious materials	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 upon those waters, or adversely affect public health as determined by the department.	Same as Class A
Aesthetic Values	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.	Shall not be reduced by dissolved, suspended, floating, or submerged matter not attributed to natural causes, so as to affect water use or taint the flesh of edible species

Table 2. Lower Yakima River basin waterbodies identified in the 1994 303(d) list as not meeting water quality standards (Ecology, 1994), and additions (*) made for the 1996 submittal to USEPA for approval (Ecology, 1996).

Waterbody Segment Number	Name	Parameter Exceeding Standards
WA-37-1010	Yakima River from Mouth to Toppenish Creek (rm 80.4)	Temperature, pH, Fecal Coliform, Ammonia, DDT, 4-4'-DDE, 4-4'-DDD, PCB-1254, PCB-1260, Aldrin, Endosulfan, Dieldrin, Heptachlor*, Heptachlor Expoxide*, Instream Flow*, Turbidity*, Parathion*, Endrin*
WA-37-1012	Snipes Creek	DDT, Dissolved oxygen*, Temperature*
WA-37-1014	Spring Creek	DDT
WA-37-1020*	Yakima River from Toppenish Creek to Sunnyside Dam Bridge (rm 103.8)	Temperature, Instream Flow, PCB-1260, DDT, 4-4'-DDE, Dieldrin
WA-37-1024	Granger Drain	DDT, 4-4'-DDE, 4-4'-DDD, Dieldrin, Endosulfan, Fecal Coliform, Dissolved oxygen*, Temperature*, pH*, Ammonia*
WA-37-1030	Sulphur Creek Wasteway	DDT, 4-4'-DDE, 4-4'-DDD, Dieldrin, Endosulfan, Temperature*
WA-37-1040	Yakima River from Sunnyside Dam Bridge to Naches River (rm 116.3)	Fecal Coliform
WA-37-1047	Wide Hollow Creek	DDT, 4-4'-DDE, 4-4'-DDD, Dieldrin, Endosulfan, Fecal Coliform, Dissolved oxygen*, Temperature*
WA-37-1048	Moxee Drain (Birchfield Drain)	DDT, 4-4'-DDE, 4-4'-DDD, Dieldrin, Endosulfan, Dissolved oxygen*, Temperature*, Malathion, Fecal Coliform, pH*, Chlorpyriphos*
WA-37-2105*	Spring Creek (trib. to Bachelor Cr.)	Temperature
WA-37-9030	Giffen Lake	Total Phosphorus
WA-38-1010	Naches River from mouth to Tieton River (rm 17.5)	Temperature, pH
WA-39-1010	Yakima River from Naches River (rm 116.3) to Wilson Creek (rm 147)	DDT, 4-4'-DDE, Dieldrin
WA-39-1012*	Wenas Creek	Instream flow
WA-39-1110	Selah Ditch	Ammonia, Chlorine, Dissolved oxygen

These historical assessments also showed that suspended sediment loads and concentrations begin to rapidly increase in the river at Union Gap (RM 107). Below this point, much of the main stem river flow is diverted, and is then gradually augmented by irrigation return flows. Suspended sediment loads from drains below RM 106 continue to increase main stem turbidity. Irrigation season data compiled and evaluated by Rinella *et al.,* (1992a) showed that main stem and return drain suspended sediment concentrations and turbidities were similar in the lower basin. The data indicated the worst sediment loading sources in the lower Yakima River basin were the following drains:

- Sulphur Creek
- Moxee Drain
- Granger Drain
- Marion Drain
- Wide Hollow Creek

These subbasins were the focus of best management practices (BMPs) implementation and education efforts including: field sedimentation and water recycling pond installations; conversion of orchards from furrow to sprinkler irrigation techniques; drain sedimentation pond construction; and extension service/conservation district education and demonstration program development.

Through the 1980's and early 1990's fish tissue, water, and bed and suspended sediment samples were analyzed by several agencies throughout the lower basin. Compilations of data also were written (Molenaar, 1985; Rinella *et al.,* 1992a). Some examples of monitoring activities were:

- USBR conducted monthly monitoring at several sites along the irrigation network, and special studies (Mueller and George, 1984; STORET, 1996);
- USGS conducted sediment, pesticide, and other water quality monitoring from 1986 to 1991 in the first round of their National Water Quality Assessment (NAWQA) Program study;
- USGS summarized much of the water quality data collected before 1985 as part of their NAWQA study (Rinella *et al.,* 1992a);
- USGS and the YIN, USEPA, North Yakima, South Yakima and Benton Conservation Districts performed special monitoring programs on tributaries and irrigation return drains (Zaragoza, 1992; North Yakima Conservation District, 1993; Payne and Sumioka, 1994); and
- Ecology conducted routine monitoring and special studies throughout the basin in response to point source and nonpoint source concerns (Johnson and Newman, 1983; Johnson and Joy, 1984; Hopkins *et al.,* 1985; Johnson *et al.,* 1986; Kendra, 1988; Joy, 1990; STORET, 1996).

Systematic sampling and analysis of fish, sediment and water for organochlorine contamination by Ecology brought to light the widespread residue problem in the Yakima River basin (Johnson *et al.,* 1986). The USGS NAWQA project continued to focus public attention and resources on the potential health threat from DDT and other pesticides. They clearly demonstrated that high concentrations of DDT and its metabolites have been archived in agricultural soils, stored in canal benthic sediments, and have continuously washed-out with suspended sediments in the water column (Rinella *et al.,* 1993). Of special concern, fish tissue burdens of DDT and its breakdown products [total DDT (t-DDT) = DDT + DDE + DDD] have been among the highest detected in the United States (Rinella *et al.,* 1993). These findings resulted in a Washington State Department of Health advisory in 1993 recommending that people eat fewer bottom fish from the lower Yakima River basin (Department of Health, 1993). Further studies now are being conducted to assess the additional health risks native people in the Columbia River basin may incur because of diets rich in fish, some of which may be contaminated (CRITFC, 1994).

Regulatory Status and Background

Ecology has pursued a policy of voluntary compliance with emphasis on education, technical and financial assistance, and incentives for best management practices (BMP) implementation in irrigated agricultural areas (Ecology, 1979; Ecology, 1992). The Section 208 Irrigated Agriculture Water Quality Management Plan gave primary water quality management authority to the local conservation districts (Ecology, 1979). The conservation districts (CDs) were to:

- make annual assessments to determine water quality problem areas based on data collected from advisory agencies such as Ecology and the U.S. Geological Survey (USGS);
- identify farmers with problems based on investigations by the CD, and from citizen or agency complaints;
- recommend BMPs for problem farms; and
- handle all but the most intractable problems.

Ecology has had to reassess its nonpoint source control management strategy in the light of new federal Coastal Zone Act Reauthorization Amendment, Clean Water Act, Endangered Species Act requirements, new state legislative requirements, and civil lawsuits. In addition, nonpoint sources are responsible for a majority of the state's water bodies failing to meet state and federal water quality standards (Ecology, 1994a). These factors have resulted in an increased presence by Ecology in agricultural areas with:

1. more definitive agreements with CDs concerning actions on water quality problems from agricultural practices (*i.e.,* signing memorandum of agreements between Ecology and individual CDs, and establishing a statewide dairy permit procedure),
2. more attempts by Ecology to fund and stimulate local solutions to control nonpoint pollution,
3. more Ecology enforcement resources being allocated to agricultural pollution problems, and
4. more water quality assessments and total maximum daily load (TMDL) evaluations in areas identified as having nonpoint source pollution problems.

Methods

Sample Collection and Field Measurement

Locations of the 1994 Phase I water quality monitoring in the lower Yakima basin are shown in Figure 3. Site descriptions are presented in Table 3. Samples for turbidity and TSS were collected from each site on consecutive days, twice monthly from June through October. Samples were collected on consecutive days in order to assess daily variability. Sites on the Yakama Indian Reservation were monitored periodically during 1994 by YIN Environmental Protection Program staff.

During Phase II, 14 sites were located within the project area on canals, tributaries, drains, and the main stem river in 1995. Turbidity levels and suspended sediment concentrations were monitored to establish background and control points (Figure 4 and Table 3). Samples were collected from these locations every other week throughout the irrigation season since seasonal variability had not been adequately established.

Additionally, seven Yakama Reservation drains and tributaries were monitored bi-weekly between March and October 1995, in cooperation with YIN Environmental Protection Program staff (Figure 4). Turbidity and suspended sediment samples were collected to evaluate loading to the lower river from the Yakama Reservation, which is out of the project area. Mean daily discharge data were provided by the YIN Water Resources Program for all sites except for Subdrain 35 and East Toppenish Drain. Discharge for Subdrain 35 was calculated from instantaneous measurements of velocity and cross-section. East Toppenish Drain flow measurements had been discontinued without our knowledge, so no data were collected.

Main stem control points were located at the Yakima River at Harrison Bridge (RM 121.7), and the Naches River at Old Naches Highway (RM 3.7). These sites provided water quality monitoring points of each upstream subbasin above the project area. Discharge data for these two sites were taken from two nearby USBR Hydromet stations: Naches River near Yakima (RM 0.6), and Yakima River below Roza Dam (RM 127.7). It is recognized that distances between monitoring and discharge sites may result in loading calculation errors.

Discharge data were used from a combination of sources. Instantaneous flow data were collected at Spring Creek. A USBR rating curve was used for Snipes Creek. A continuous discharge monitoring station, and a rating curve were re-established at an inactive USGS site at Granger Drain. A regression equation was developed to obtain discharge data for Moxee Drain. The equation used data collected in 1994 by Ecology at near the mouth of the drain, and 1994 data collected by North Yakima Conservation District at Birchfield Road.

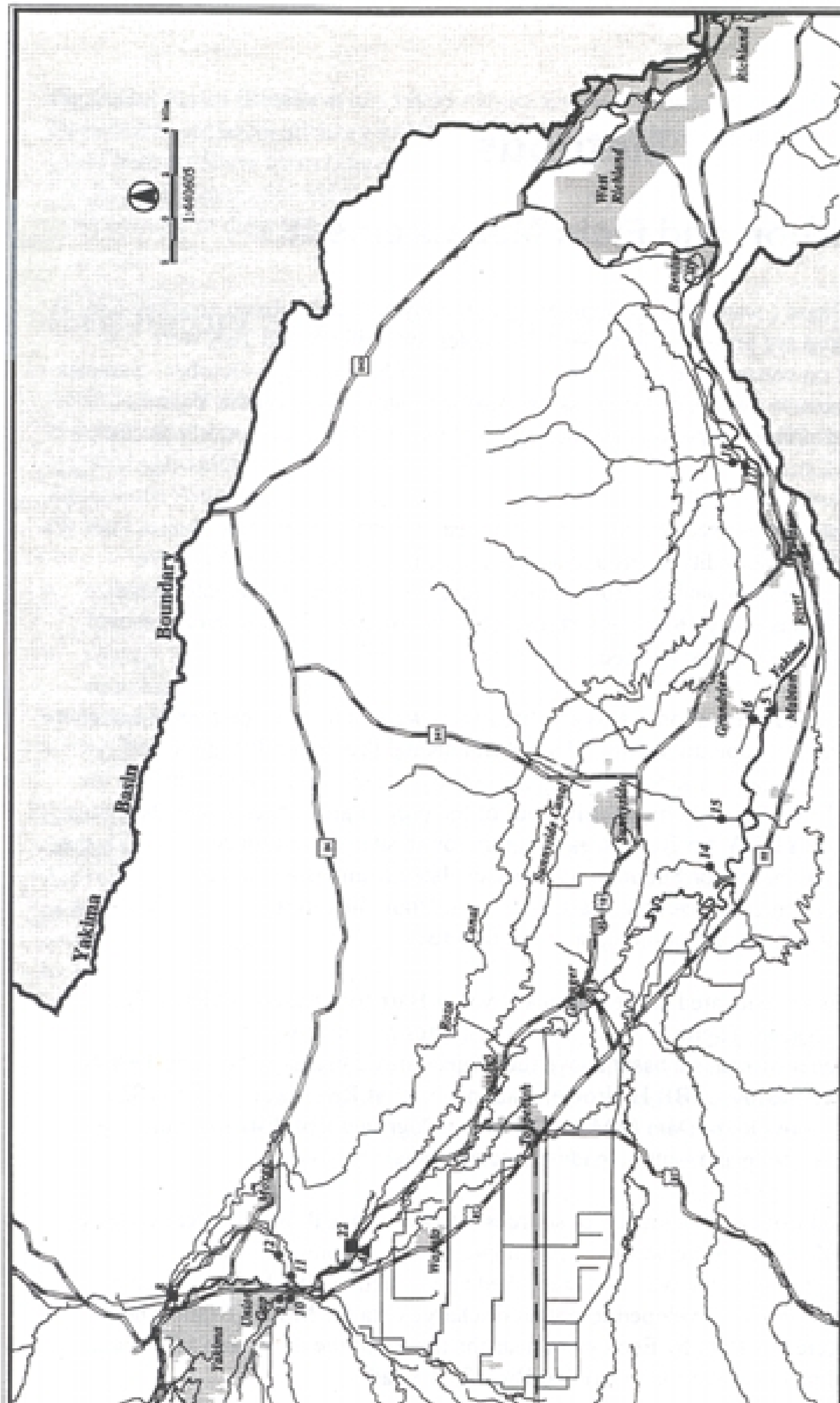


Figure 3. Phase I (1994) monitoring stations in the lower Yakima Basin used for the total maximum load evaluation.

Table 3 Sampling Sites for the lower Yakima River total maximum daily load project area 1994 and 1995. Also included are sites out of the project area on the Yakama Reservation sampled in 1995.

Map ID	Year	Site Description	Agency	Latitude	Longitude
		Main stem sites			
1	95	Yakima River at Harrison Rd. Bridge north of Selah	Ecology	464041	1202929
2	95	Naches River at Rt 12 on Old Naches Rd. bridge	Ecology	463755	1203511
3	95	Yakima River at Parker, north of Sunnyside canal diversion	Ecology	463022	1202707
4	94	Yakima River at Parker - below Sunnyside Dam off old railroad bridge	Ecology	462950	1202630
5	94 - 95	Yakima River at Euclid Rd. bridge south of Grandview	Ecology	461345	1195500
6	95	Yakima River at Kiona bridge near Benton City	Ecology	461513	1192837
7	95	Yakima River at Van Giesen bridge in West Richland	Ecology	461750	1191956
		Project Area Tributary and Drain sites			
8	94	Roza Canal power return below powerhouse	Ecology	463658	1202716
9	94	Wide Hollow Creek at Union Gap	Ecology	463244	1202844
10	94	Ahtanum Creek at Fulbright Park	Ecology	463218	1202844
11	94	Moxee Drain on Yakima Valley Hwy	Ecology	463216	1202725
12	95	Moxee Drain at Birchfield Road	NYCD/USBR	463246	1202613
13	94 - 95	Granger Drain at sheep barn in Granger	Ecology/USBR	462039	1201111
14	94	Drainage Improvement District #7 at Wendell Phillips Rd.	Ecology	461533	1200351
15	95 - 95	Sulphur Creek Wasteway at Holaday Rd. and Midvale Rd.	Ecology/USBR	461504	1200108
16	94	Grandview Drain at Case Rd.	Ecology	461345	1195530
17	96 - 95	Spring Creek on west side of Hess Rd.	Ecology	461402	1194102
18	94	Snipes Creek at Old Empire Hwy.	Ecology	461433	1194048
19	95	Snipes Creek south of Old Inland Empire near Chandler Canal	Ecology/USBR	461403	1194102
		Project Area Irrigation Supply sites			
20	95	Roza Canal at 11 mile, head of powerhouse	Ecology	463659	1202834 *
21	95	Roza Canal at Beam Rd north of Granger	Ecology	462500	1200900
22	94	Sunnyside Canal at Burke Rd.	Ecology	462947	1202557
23	95	Sunnyside Canal at Beam Rd. north of Granger	Ecology	462239	1200959
24	95	Roza Canal at Ray Rd. north of Sunnyside	Ecology	462220	1195727
25	95	Sunnyside Canal at Maple Grove Rd. northwest of Sunnyside	Ecology	462130	1200220
26	95	Roza Canal at Wilgus Rd. northeast of Grandview	Ecology	461720	1194950
27	95	Sunnyside Canal at East King Tull Rd north of Prosser	Ecology	461438	1194511
28	95	Kennewick Canal on McBee Rd. south of Benton City	Ecology	461431	1192849
		Reservation Tributary and Drain sites (out of TMDL project area)			
29	95	Toppenish Drain at Blue Heron Rd.	YIN	462204	1201500
30	95	Subdrain 35 at Connie Rd north of Hwy 223	YIN	462011	1201348
31	95	Marion Drain at Hwy 223 and Indian Church Rd.	YIN	461952	1201154
32	95	Toppenish Creek at Indian Church Rd. south of Hwy 223	YIN	461852	1201153
33	95	Satus Creek at N. Satus Rd. north of Hwy 22	YIN	461623	1200844
34	95	South Drain at Hwy 22 under railroad tracks	YIN	461535	1200757
35	95	Satus 303 at Hwy 22 east of Newquist Rd.	YIN	461302	1200108

Abbreviations: Ecology = Washington Dept. of Ecology; NYCD = North Yakima Conservation Dist.;
' USBR = US Bureau of Reclamation; YIN = Yakama Indian Nation

Map ID refers to sites on Figures 3 and 4.

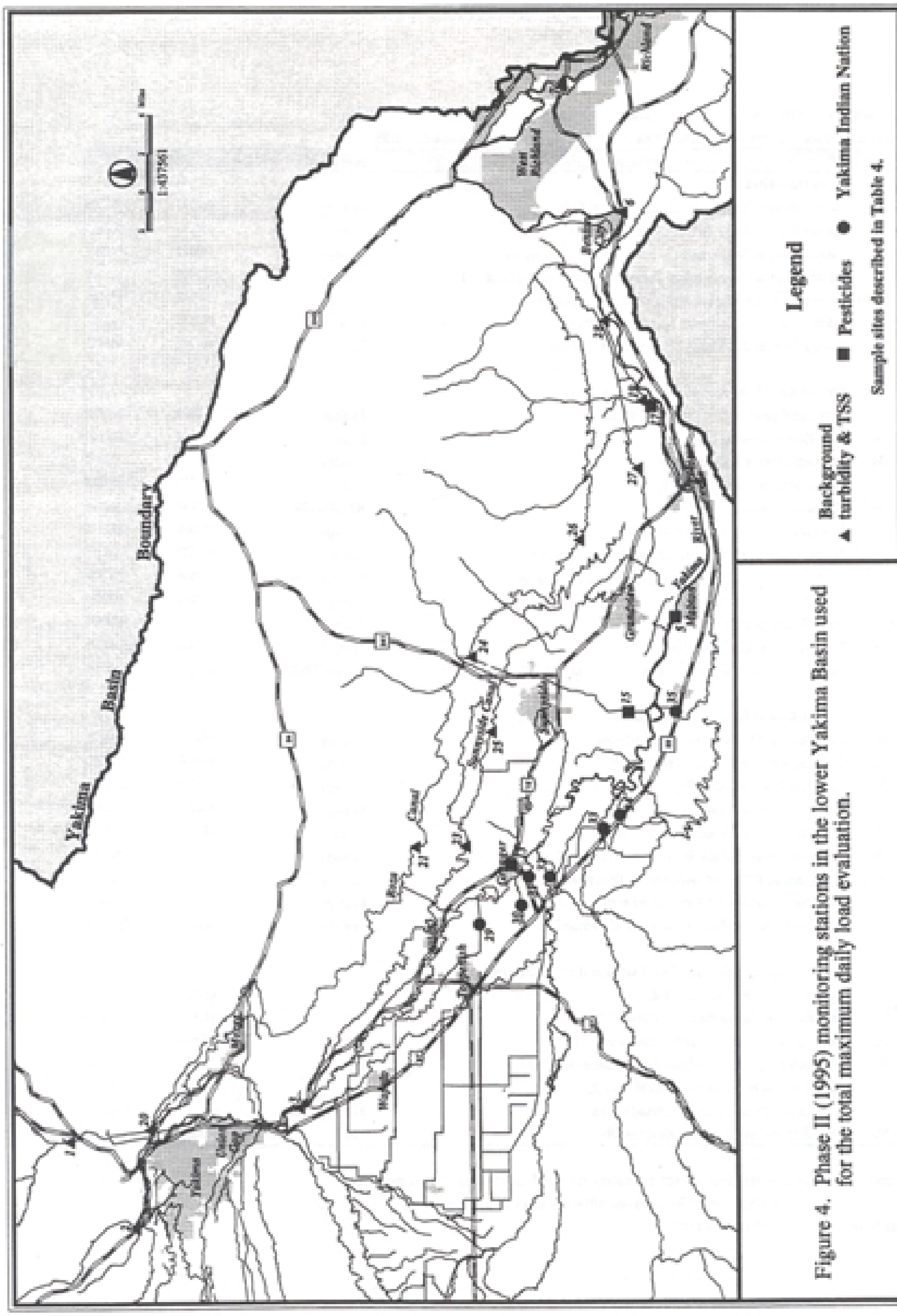


Figure 4. Phase II (1995) monitoring stations in the lower Yakima Basin used for the total maximum daily load evaluation.

Discharge data were used from the following USBR Hydromet stations:

- Roza Canal at Roza Dam
- Roza Canal at 11 Mile
- Yakima River at Terrace Heights
- Yakima River near Parker
- New Reservation Canal
- Sunnyside Canal
- Sulphur Creek near Sunnyside
- Yakima River at Euclid Road near Grandview
- Yakima River at Prosser

USGS gaging data were used from stations located at the Yakima River above Ahtanum Creek, and the Yakima River at Kiona.

In the 1995 Phase II monitoring, an expanded set of water quality analyses were conducted on samples taken from selected locations. Water column pesticide samples were collected monthly, March through September 1995, from Granger Drain, Sulphur Creek, Spring Creek, and the Yakima River at Euclid Bridge at RM 55 (Figure 4). Fish were also collected from the Yakima River in the vicinity of Euclid Bridge. Muscle tissue and whole fish composite samples were analyzed for pesticide residues. Monitoring sites were also established in the Granger Drain watershed to compare suspended sediment, bacteria, nutrient, and dissolved oxygen conditions in 1995 to 1991. Capacitive depth probes were installed at selected sites on the Granger Drain to establish continuous flow records. Stage to flow relationships were developed at those locations. Granger Drain subbasin bacteria and nutrient results will be discussed in a subsequent report. All data collected during the TMDL surveys and used in this report will be provided in a Data Supplement. The supplement will be available upon request.

Field sampling and measurement followed the protocols outlined for Ecology projects (Watershed Assessments Section, 1993). In 1994 and 1995, 10 percent of the water quality samples collected were replicated in order to assess total variability in field sampling and laboratory analysis. All samples were handled according to EILS and Ecology protocols (Ecology, 1994b; Watershed Assessments Section, 1993). For pesticides, sampling protocols followed those described in Davis (1993) that were developed from the Illinois EPA (1987) field methods manual. One site was selected during each pesticide survey for replication. A matrix spike and matrix spike duplicate were required to check for analytical bias and precision (Ecology, 1994b). Analytical procedures, precision limits, and details on quality assurance measures are discussed in Appendix 1.

Historical Data Compilation

In order to assess historical water quality in Phase I and II of the project, a database was created for sample results collected in the Yakima River Basin from 1970 to present. Sources of data include the following:

- USGS database of water quality data through 1985 (this includes data collected by other agencies), created as part of the Yakima NAWQA Project (Rinella, et al. 1992a);
- USBR data through 1994, retrieved from STORET (1996);
- Ecology Ambient Monitoring Program data - PCSTORET;
- 1991 South Yakima Conservation District Granger Drain Study (Zaragoza, 1992);
- Kittitas County CD Monitoring data (Kittitas Conservation District, 1994); and
- North Yakima Conservation District Moxee Drain 1994 and 1995 Monitoring Data (North Yakima Conservation District, 1995).

Quality Assurance/Quality Control

Replicate Samples

Replicate precision for parameters sampled in 1994 and 1995 is reported in Appendix 1, Table 1B. The precision statistic used is the percentage of replicate pairs with a coefficient of variation (CV) less than 20%. The CV for a set of replicate samples is the standard deviation divided by the mean. The CV for pesticides was calculated for all pesticides detected. Acceptable precision for pesticide replicates has not been established. For TSS and turbidity the Washington State Department of Ecology Ambient Monitoring Program has a quality assurance goal of 90% of the replicate pair CV less than 20% (Hopkins, 1994). With the exception of 1994 TSS, our data set met the Ambient Program goal. One value collected from DID #7 on July 11, 1994, of 144 mg/L was determined to be erroneous based on the sample turbidity and site observation. This value was removed from the data set. The remaining replicates were averaged for subsequent data analysis.

Comparison of Integrated and Grab Sample Methods

Regression analysis was performed using SYSTAT to determine if the relationship between integrated and grab samples differed significantly from a 1 to 1 relationship. Data were log-transformed to satisfy assumptions of homogeneity and normality. The difference was not significant for turbidity or TSS (Appendix 1, Figure 1A). The data were also partitioned at a TSS concentration of 30 mg/L to determine if a difference existed at lower or higher concentrations.

There was still no significant difference found in the collection methods. In addition, 97% of the TSS and turbidity pairs had CV less than 20%. Given these results, we were able to group historical TSS data for analysis without having to account for a difference in sampling method.

Comparison of Ecology and USGS Analysis Methods for TSS

Regression analysis was performed on analytical method data as described in Appendix 1 for differences between grab and integrated samples. There were no significant differences from the regression lines to the 1 to 1 line for the data set as a whole or the partitioned data. There is evidence of bias at higher concentrations (Appendix 1, Figure 1B) but with only 6 pairs of data the difference is not significant. The precision was somewhat less than TSS replicate samples, with only 70% of the CV < 20%. We would expect inter-laboratory precision to be lower than intra-laboratory precision, however.

These results enabled us to combine historical suspended sediment data that was analyzed by either of the two methods described above. During Phase II of the project, Ecology's Manchester Lab continued to use the EPA method.

Ratio Turbidimeter Comparison

Our 1994 and 1995 turbidity data appear to have a better linear relationship over a wider range of suspended sediment concentrations than has been historically demonstrated in irrigation return drain samples. The turbidity to TSS regression results are discussed in greater detail later in the report (see Total Maximum Daily Load Component and Appendix 2). Given the differences in turbidimeters, we did not compare our turbidity data to historical turbidity data. Ecology and YIN Environmental Protection Program turbidity results were strongly correlated, but not at a 1:1 relationship. Details of the comparisons are discussed in Appendix 2.

Water Quality Data Results

Hydrology

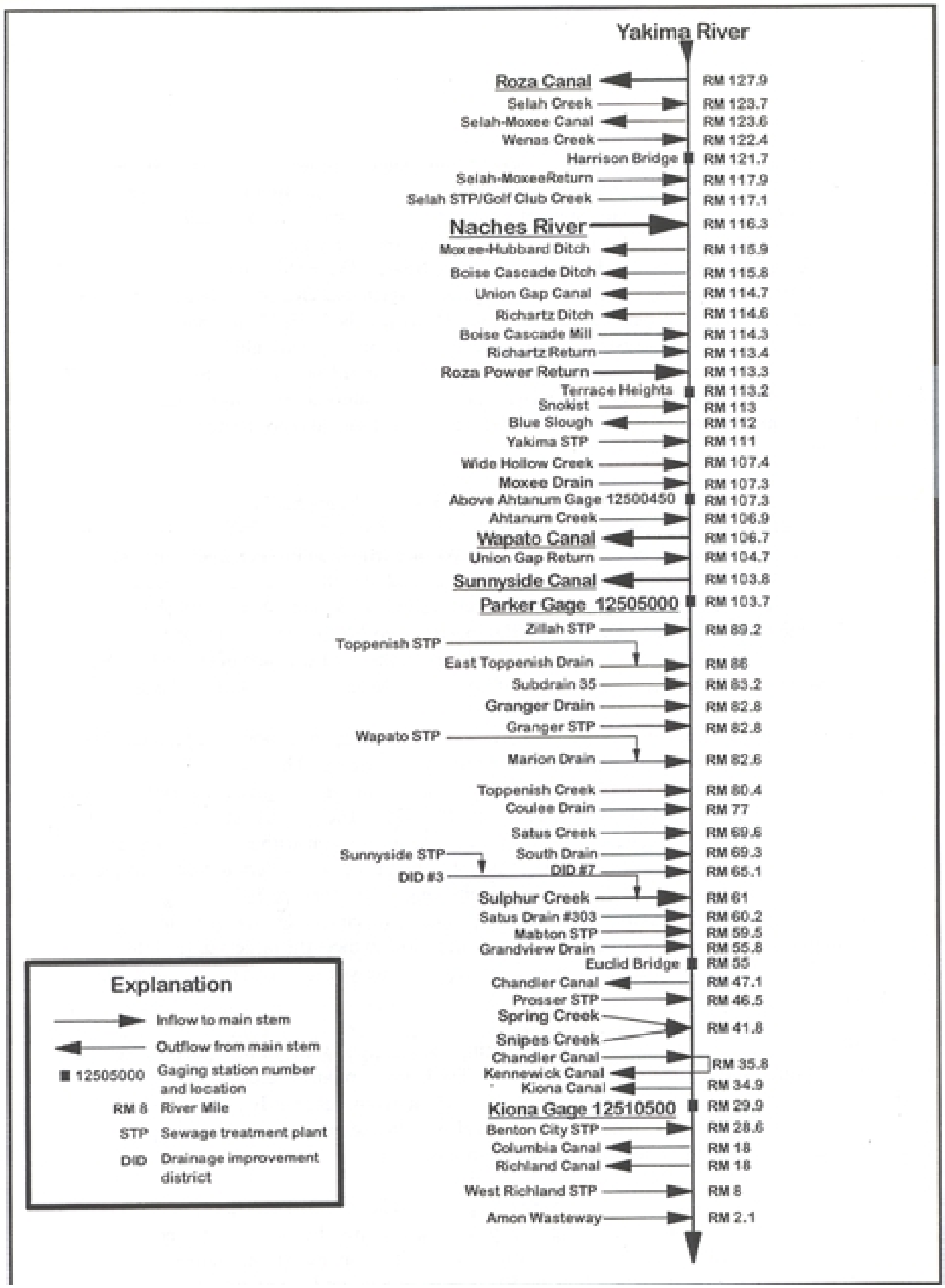
Suspended solids loading and transport in the lower Yakima River basin are closely tied to the complex basin hydrology during the irrigation season. Figure 5 depicts a simplified model of water flow direction in the lower Yakima River basin. The irrigation season commences in mid-to-late March and ends in mid-October. The Yakima River and Naches River serve as irrigation supply for approximately 339,200 acres of cropland in the lower 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). Four hydrologic points are worth noting and are highlighted in Figure 5:

1. the **Roza Irrigation Project** diversion at RM 127.9,
2. the **confluence of the Naches and Yakima Rivers** at RM 116.3,
3. the Wapato Irrigation Project's and Sunnyside Valley Irrigation District's diversions near **Parker** between RM 103.8 and RM 106.7, and
4. the long-term gaging station at **Kiona** (Benton City) at RM 29.9 upstream of which a majority of the large irrigation diversions and returns have occurred.

The Roza Irrigation Project (Roza Division) serves 72,500 acres of irrigated land on the upper slopes on the northeastern side of the lower valley. About half of the water diverted to the Roza Canal at the bottom of the Yakima River Canyon is used for hydropower generation, and is returned to the river with little change in water quality at RM 113.3. Up to 1,200 cfs can be diverted to serve irrigated lands. Operational spills from the canal seasonally occur at Sulphur Creek (RM 61), Snipes Creek (RM 41.8), and Corral Creek (RM 33.5).

The confluence of the Naches and Yakima Rivers is located at the city of Yakima. The Naches River supplies fairly high-quality water. The Naches basin has a few point source discharges, plus irrigation and hydropower returns. Timber harvest activities and reservoir sediment releases also are thought to increase suspended sediment concentrations in the river at times. The Yakima River has a few small diversions, tributaries, municipal and industrial source discharges, and irrigation returns between the Roza Project diversion and the confluence with the Naches River.

Since implementing conditions of the Northwest Power Planning and Conservation Act and Quackenbush Decision in 1981, the contribution of each river to the lower basin has been highly manipulated during the irrigation season to accommodate the needs of irrigators and fishery managers. In general, the upper Yakima River reservoirs are used to meet June to August irrigation needs, while the Naches River reservoirs are used for September and October. The "flip-flop" allows more acceptable flow regimes in the upper Yakima River for spring chinook salmon passage, spawning, and fish egg survival.


Yakima River
Roza Canal
RM 127.9
Selah Creek
RM 123.7
Selah-Moxee Canal
RM 123.6
Wenas Creek
RM 122.4
Harrison Bridge
RM 121.7
Selah-MoxeeReturn
RM 117.9
Selah STP/Golf Club Creek
RM 117.1
Naches River
RM 116.3
Moxee-Hubbard Ditch
RM 115.9
Boise Cascade Ditch
RM 115.8
Union Gap Canal
RM 114.7
Richartz Ditch
RM 114.6
Boise Cascade Mill
RM 114.3
Richartz Return
RM 113.4
Roza Power Return
RM 113.3
Terrace Heights
RM 113.2
Snokist
RM 113
Blue Slough
RM 112
Yakima STP
RM 111
Wide Hollow Creek
RM 107.4
Moxee Drain
RM 107.3
Above Ahtanum Gage 12500450
RM 107.3
Ahtanum Creek
RM 106.9
Wapato Canal
RM 106.7
Union Gap Return
RM 104.7
Sunnyside Canal
RM 103.8
Parker Gage 12505000
RM 103.7
Zillah STP
RM 89.2
Toppenish STP
East Toppenish Drain
RM 86
Subdrain 35
RM 83.2
Granger Drain
RM 82.8
Granger STP
RM 82.8
Wapato STP
Marion Drain
RM 82.6
Toppenish Creek
RM 80.4
Coulee Drain
RM 77
Satus Creek
RM 69.6
Sunnyside STP
South Drain
RM 69.3
DID #7
RM 65.1
DID #3
Sulphur Creek
RM 61
Satus Drain #303
RM 60.2
Mabton STP
RM 59.5
Grandview Drain
RM 55.8
Euclid Bridge
RM 55
Chandler Canal
RM 47.1
Prosser STP
RM 46.5
Spring Creek
Snipes Creek
RM 41.8
Chandler Canal
RM 35.8
Kennewick Canal
Kiona Canal
RM 34.9
Kiona Gage 12510500
RM 29.9
Benton City STP
RM 28.6
Columbia Canal
RM 18
Richland Canal
RM 18
West Richland STP
RM 8
Amon Wasteway
RM 2.1
Explanation
Inflow to main stem
Outflow from main stem
12505000 Gaging station number and location
RM 8 River Mile
STP Sewage treatment plant
DID Drainage improvement district

Several irrigation returns, diversions, point sources, and tributaries are located between the confluence and the Wapato Diversion dam at RM 106.7. The Yakima regional wastewater treatment plant (WWTP) is the largest point source in the lower basin. It discharges approximately 22 cfs to the river during the irrigation season, and applies another 1.5 cfs of industrial effluent to spray fields adjacent to the river. Nearby, Wide Hollow Creek and Ahtanum Creek have natural flows that are affected by irrigation diversions. Their combined discharge is usually less than 40 cfs from July through October. However, the Wide Hollow subbasin and areas near the city of Yakima have undergone rapid conversion from agriculture to residential/commercial uses in the past 20 years that may have had an influence on hydrology and water quality. Moxee Drain is the most significant irrigation return drain with an average irrigation season discharge of 80 cfs from an intensely farmed subbasin dominated by hop production.

At RM 106.7 is the Wapato Diversion, and at RM 103.8 is the Sunnyside Diversion Dam near **Parker**. Between RM 103.8 and RM 106.7, two irrigation districts divert half to three-fourths of the water available below the city of Yakima. The Wapato Irrigation Project diverts up to 2,000 cfs to serve 136,000 acres of irrigated land on the Yakama Indian Reservation. Toppenish Creek and other tributaries are used to serve additional reservation lands in the Wapato Project area. The Sunnyside Valley Irrigation District (SVID) diverts up to 1,280 cfs to serve 103,500 acres between the river and the Roza Irrigation District lands on the northeast side of the valley. SVID gets an additional, but undetermined amount of water from Roza District returns and lateral spills.

In some previous years, nearly all water was diverted out of the main stem at the Sunnyside Dam. This became a concern among fishery and water resource managers. The Yakima River Basin Water Enhancement Project bill, a Federal law signed in 1994, set minimum daily average flows of 300 to 600 cfs over Sunnyside Dam (Public Law 103-434). The flow target depends upon the year’s Total Water Supply Availability (TWSA). For example, a year with a low TWSA results in a 300 cfs target during the low-flow regulated period. Within a 24-hour period, flows are allowed to fluctuate to a minimum of 65% of the target limits, (e.g., 195 cfs at the 300 cfs target). The limits were set to maintain Yakima River fisheries, some of which had declined from inadequate water. In most years, water distribution is tightly controlled to meet the targets only in the months of July through October. However, in some low water years, targets are in effect during the entire irrigation season.

The remaining 103 miles of river in the lower basin slowly recover some of the water diverted for irrigation through surface and subsurface returns. The largest irrigation return drains, tributaries, and subsurface returns are located between Parker and the **Kiona** gage at Benton City (RM 29.9). Several small municipalities and industrial sources also discharge into the river, but supply a fairly small cumulative volume (10 cfs) during the irrigation season.

Other diversions for power and irrigation are also present. The Prosser Diversion Dam at RM 47 diverts water to the Chandler Canal and power plant. Target flows below the dam were established through Public Law 103-434 similar to the SVID Dam, except that actual flows over the dam may not decrease the target flow by 50 cfs (e.g., at a target flow of 300 cfs, more than

250 cfs must be allowed over the dam). Part of the Chandler Canal water is returned to the river through the power plant 11 miles downstream. The remaining water is pumped through a siphon to the Kennewick Irrigation District across the river from the plant. The Kennewick Irrigation District serves 19,170 acres.

The four largest tributaries between Parker and Kiona are: Toppenish Creek, Satus Creek, Sulphur Creek, and Spring/Snipes Creek. To varying degrees, all of their natural drainage patterns have been modified with constructed channels and networks to serve the irrigation projects where agriculture uses are present. Supply canals and wasteways deliver large volumes of water from outside these catchments. Mid-summer flows are increased by excess irrigation water and subsurface flow from return ditches, and by wasteway release water. Water tables also may be increased by the irrigation activity. The overall result is that natural drainage areas and precipitation effects may have little relationship to discharge volumes from most of these tributaries during the irrigation season.

The Yakima River from Kiona to the mouth has additional diversions and returns, but no gaging station is located in the river for those remaining 30 miles. The Columbia and Richland Canals are the most significant diversions in the reach. They occur at Horn Rapids Dam at RM 18.0. Together they can divert up to 280 cfs. Their wasteways are located before West Richland at RM 8.4. The last seasonally significant irrigation return is the Amon Wasteway at RM 2.1 for the Kennewick Irrigation District.

Study Period Water Balance

Two very different irrigation season flow regimes were represented in 1994 and 1995 (Figure 6). Irrigation diversions were severely limited in 1994 because water availability for irrigation was the lowest on record. River flows at Kiona were not as low as 1977 because of instream flow targets established for Parker. In 1994, flows at Parker were set at the 300 cfs target range. Junior water-right holders were limited to 37% of their contract allocations. The 1995 season saw normal water availability; instream flow targets at Parker were set at 500 cfs, and irrigators received all of their allocations. Table 4 summarizes the 1994 and 1995 seasonal flows at different points in the basin. Figure 6 compares the daily average discharge between the two years at Parker. Water supply in 1994 was about 60% of 1995, and the daily average discharge below Parker in 1994 was only 30% of the 1995 discharge. The average daily flow during the 1994 irrigation season measured at Kiona was 40% of the 1995 flow.

Table 4. Mean daily discharges (cfs) at various sites in the lower Yakima River during the 1994 and 1995 March - October irrigation season, and for the latter part of the season (July-October shaded values). ID=irrigation district

	Yakima River at Harrision Br.	Naches River	Roza ID	Yakima River above Ahtanum	Wapato Project	Sunnyside Valley ID	Yakima River below Parker	Sulphur Creek	Yakima River at Kiona
1994	829	959	407	2541	986	878	609	129	1398
	992	**579**	**360**	**2414**	**964**	**934**	**372**	**102**	**831**
1995	1270	1987	779	4171	1389	1009	2021	286	3537
	1334	**1109**	**879**	**3173**	**1537**	**1129**	**609**	**272**	**1883**

The amount and quality of water in the Yakima River between the Parker diversions and Kiona to support beneficial uses and to dilute irrigation returns flows is important. Over the entire 1994 irrigation season, the average daily flow at Parker supplied 45% of the Kiona flow. In 1995, on average 53% of the flow was supplied from Parker. However, distinct early and late irrigation season flow patterns were evident from observing the daily discharge records for the lower basin (Figure 6):

1. Early: March to mid-June when high water from snow-melt is still being routed down the river main stem past Parker,
2. Late: July to October when a majority of the water coming downstream is from storage releases, and is diverted for irrigation.

The average daily flow passing downstream at Parker from July to October in both years represented 25% to 75% of the monthly average flow measured at the Kiona gage.

Water discharge in the lower Yakima River basin during the 1995 irrigation season was measured at several sites by Ecology and various agencies: USGS, YIN, North Yakima Conservation District, and USBR. These discharge records were used with estimated values for unmonitored drains to construct a Yakima River flow balance sheet between Harrison Bridge (RM 121.7) and Kiona (RM 29.9). Watercourses were placed in eight general categories:

- **Major Upstream Sources**: the Naches River and Yakima River upstream of the lower basin;
- **Small Tributaries**: Wide Hollow and Ahtanum Creeks that appear to have insignificant additions of irrigation flow;
- **Off-Project Area Drains and Tributaries**: Yakama Reservation waters gaged and monitored by the Yakama Indian Nation, or ungaged drains identified from the reservation in the Corps of Army Engineers (1978) and U.S. Department of Interior (1974);
- **Project Area Drains and Tributaries**: Moxee and Granger Drains, and Sulphur, Spring, and Snipes Creeks that have significant additions of irrigation return water gaged by agencies;
- **Ungaged Project Area Returns:** identified in reports by the Corps of Army Engineers (1978) and U.S. Department of Interior (1974), that include irrigation drains and wasteways, drainage improvement district (DID) drains, and single field drains and springs;

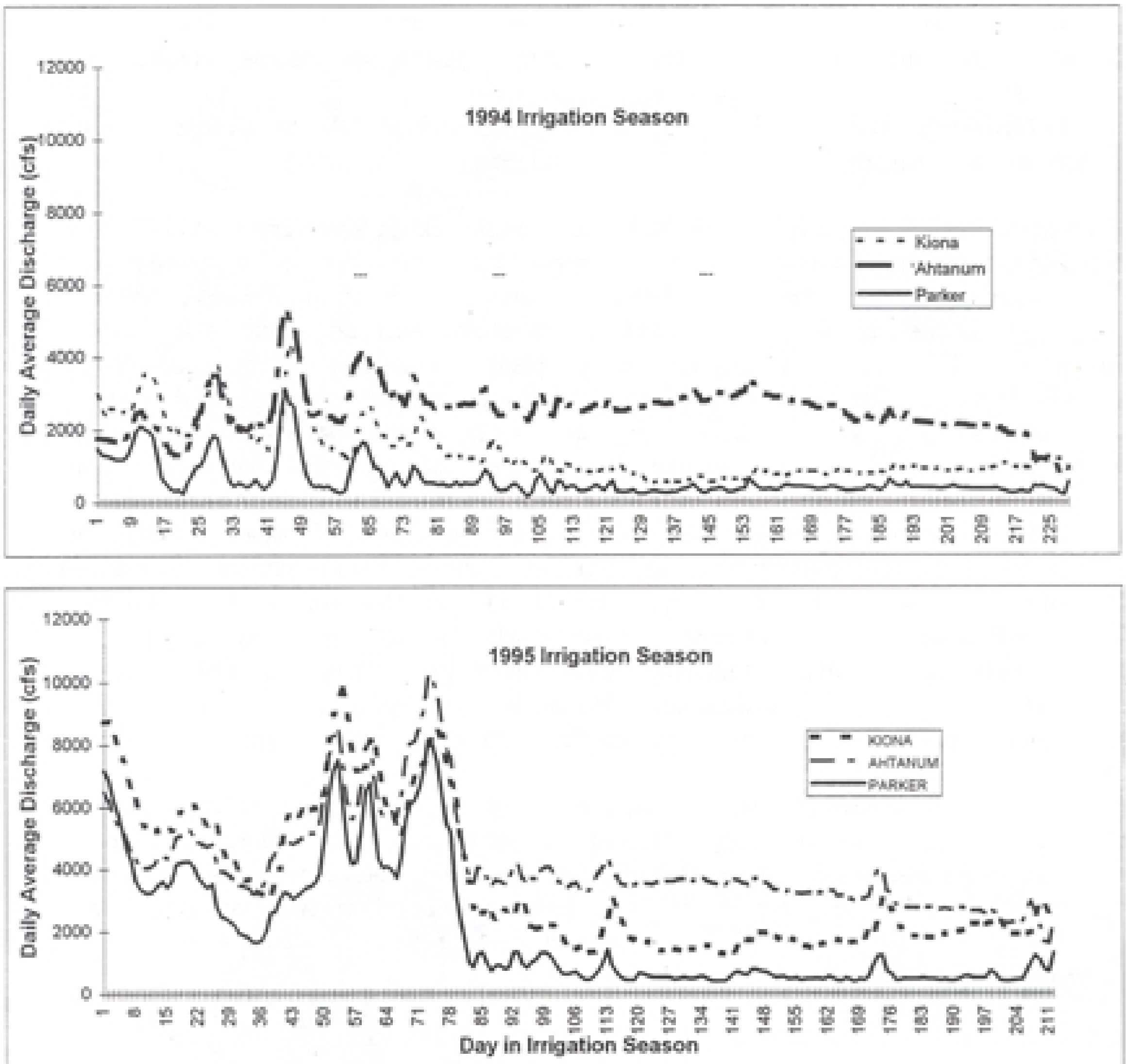


Figure 6. Lower Yakima River discharge at three gaging stations during the 1994 and 1995 irrigation seasons.

- **Irrigation Diversions**: Major diversions: Roza, Wapato, Sunnyside Projects; and Small Diversions: gaged withdrawal canals, or irrigation ditches identified in reports by the Corps of Army Engineers (1978), U.S. Department of Interior (1974), and Molenaar (1985);
- **Municipal and Industrial Point Sources**: four of the larger wastewater treatment plants, one large food processor, and one gravel operation; and
- **Power Generation Uses**: USBR Yakima Project hydroelectric facilities on the Roza Power Return and the Chandler Power Canal diversion and return.

The sum of the Roza Canal (at RM 11), Roza Power Return, Yakima River, and Naches River provided an average daily flow of 4,800 cubic feet second (cfs). This was 1,260 cfs more than was discharged at Kiona over the season. Irrigation diversions withdrew an average of 3,580 cfs per day. Approximately 1,680 cfs was supplied through return drains and tributaries on and off the project area. The municipal wastewater treatment plants and industrial facilities accounted for only 40 cfs. Subsurface irrigation returns, deeper groundwater sources, and local run-off from precipitation could supply some of the estimated daily average 460 cfs from unaccounted sources. The 460 cfs could also represent averaging and measuring errors in the water balance calculation.

Two sets of pie charts illustrate flow routing in the river for the entire 1995 irrigation season, and for the July to October later portion of the season (Figure 7 and 8). Two reaches are examined in each set of pie charts: Confluence to Parker, and Parker to Kiona. Data are also shown in Table 5. The water balance calculated for the entire season is helpful for comparisons to historical studies, and to evaluate the impact of the entire lower Yakima irrigation project. The July to October water balance is especially useful for examining the impact of irrigation returns on Yakima River water quantity and quality when the Parker to Kiona reach is most vulnerable.

The Naches and Yakima Rivers consistently supplied 70% of the water available above Parker. The Roza Power Return supplied nearly 20%. In this upper reach, all other sources accounted for 12% over the entire season's discharge. Only 6% came from these sources when calculated for the months of July to October. Over the irrigation season, 56% of the water above Parker was diverted to irrigation. However, in the July to October period, 80% of the water entering the upper reach was diverted.

Figure 7. 1995 lower Yakima River water balance during the irrigation season (March - October). Yakama Reservation (YIR) tributaries are not included in the TMDL project area.

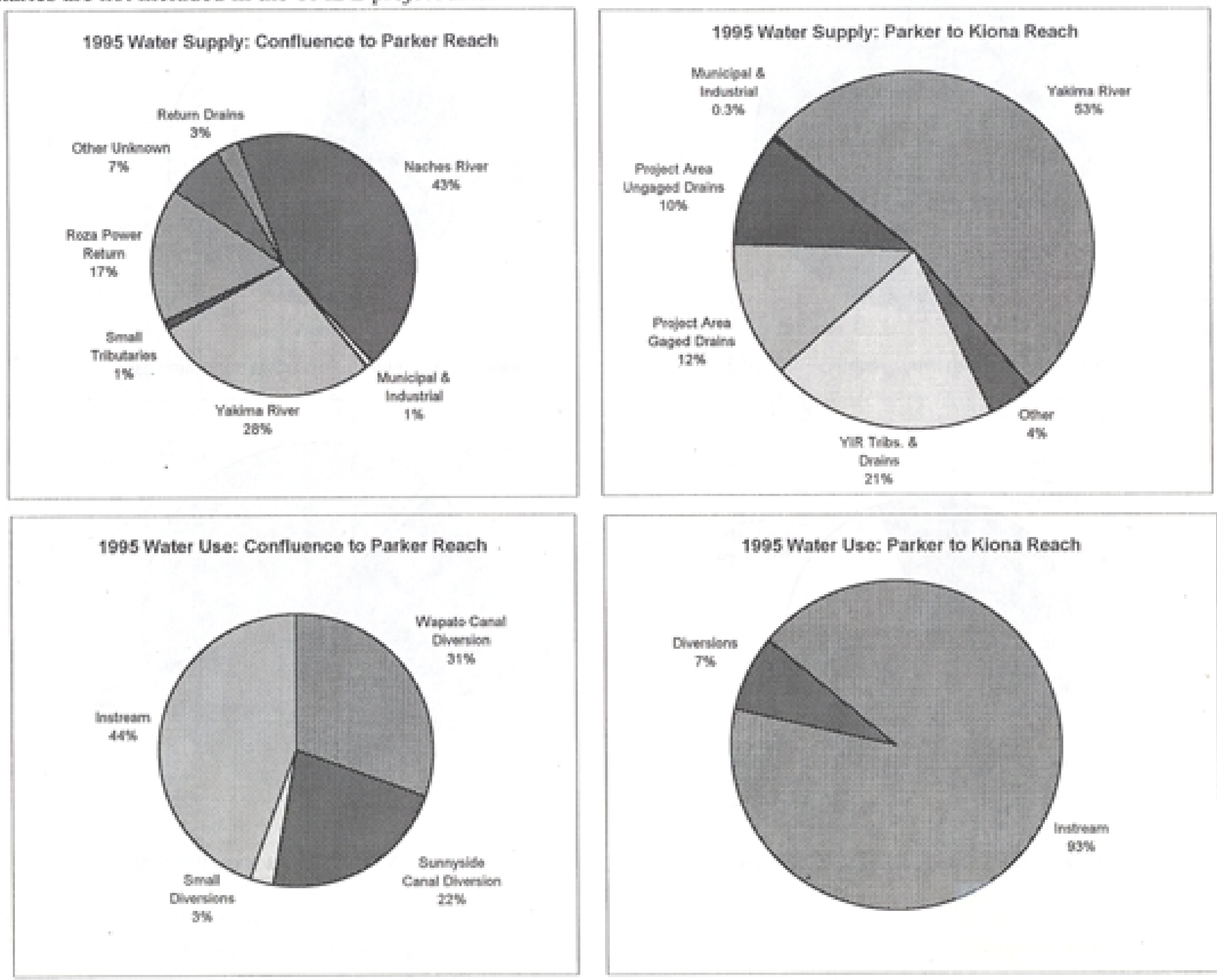


Figure 8. 1995 lower Yakima River water balance during the last part of the irrigation season (July - October). Yakama Reservati (YIR) tributaries are not included in the TMDL project area.

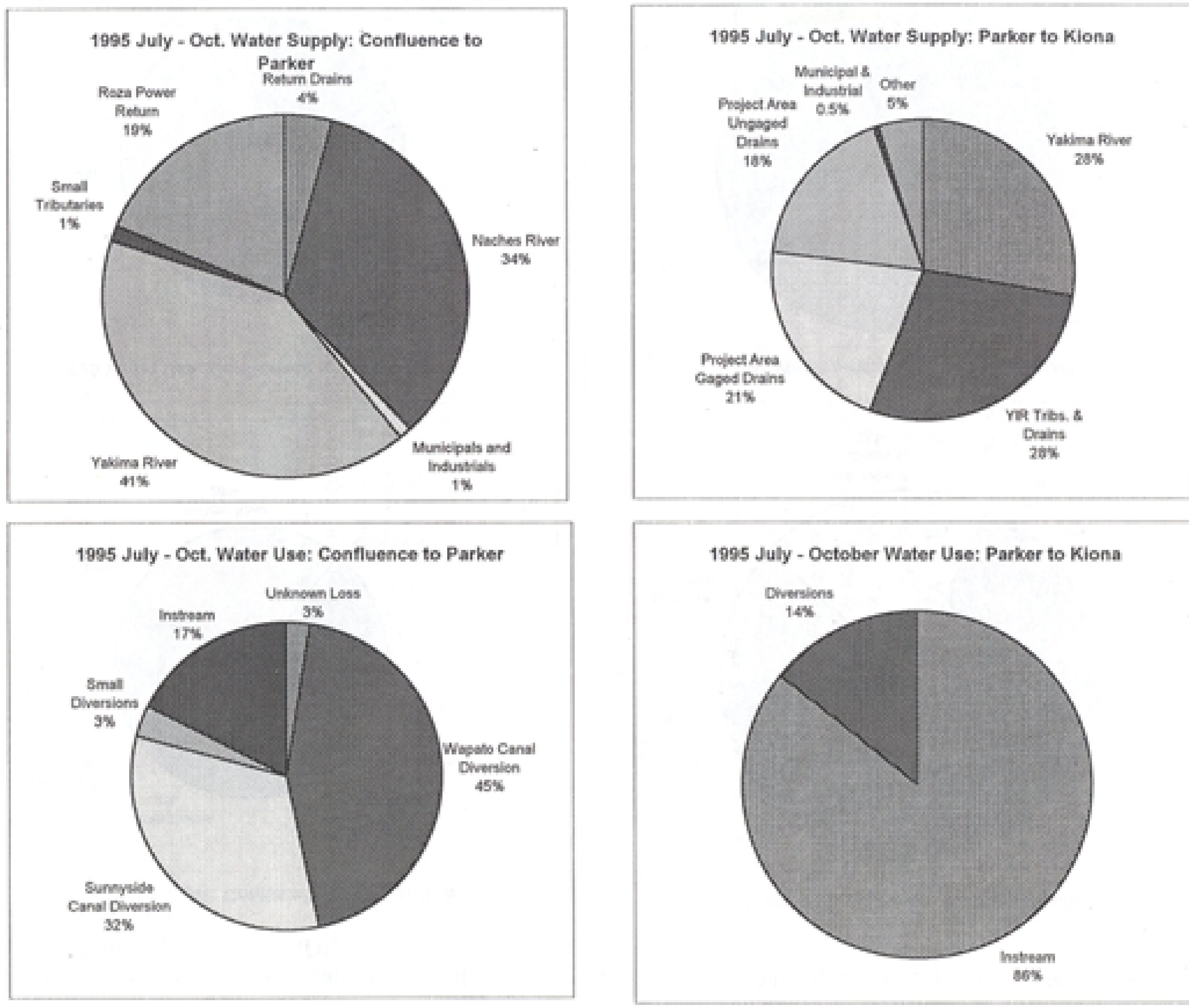


Table 5. Water balance values for two reaches of the lower Yakima River during the 1995 irrigation season: average daily discharge (in cfs) over the entire March to October season, and the last part of the season (July to October).

Confluence to Parker Reach

Water Supply Balance	Yakima River	Naches River	Roza Power Return	Small Tributaries	Municipal & Industrial	Return Drains	Other Unknown
March to October	1270	1987	763	47	36	132	313
July to October	1334	1109	604	47	36	132	

Water Use Balance	Wapato Canal	Sunnyside Canal	Small Diversions	Instream	Unknown Losses
March to October	1389	1009	119	2020	
July to October	1537	1129	119	609	88

Parker to Kiona Reach

Water Supply Balance	Yakima River	YIR Tribs.* & Drains	Project Area Gaged Drains	Project Area Ungaged Drains	Municipal & Industrial	Other
March to October	2020	784	465	390	10	150
July to October	609	614	466	390	10	106

Water Use Balance	Instream	Irrigation Diversions
March to October	3537	283
July to October	1883	312

* Yakama Indian Reservation tributaries and drains are not within the TMDL project area, but contribute to the reach.

Below Parker, the seasonal average flow passed over the Sunnyside Dam supplied 53% of the flow of the lower reach. Most of the flow passed in March through June, since only 28% of the water in the lower reach in the months of July to October came from the upper reach. In contrast, tributaries and drains comprised a much larger share of the flow during the later period compared to the whole season. For example, Sulphur Creek, contributed 7.5% of the daily average flow over the irrigation season, and 12% during the late part of the season. Municipal, industrial, and other sources remain fairly stable, but insignificant, in their percentage contribution to the Parker to Kiona reach.

Over the entire irrigation season, less than 10% of the water delivered to the lower reach was diverted for irrigation. In the months of July to October, only 14% was diverted. The remainder of the water during both calculation periods was present in the channel at the Kiona gage. Losses to ground water, losses to the hyporheic zone beneath the channel, or water taken by direct pumping were not apparent.

Solids

Turbidity and TSS Criteria

The Washington State turbidity criteria do not contain a strict numeric measurement, rather they are based on the relative change above "background." For Class A waters (Chapter 173-201A-030-2 WAC):

> Turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background is more than 50 NTU.

Class B waters are allowed a 10 NTU increase over background turbidities of 50 NTU or less, or a 20 percent increase when background turbidity is greater than 50 NTU.

The Washington criteria do not set a maximum acceptable turbidity level based on beneficial use considerations, but they do limit the effect of an identified source on raising the turbidity in the receiving water. Background conditions are further defined in Washington as ". . . the biological, chemical, and physical conditions of the water body, outside the area of influence of the discharge under consideration" and, for several discharges to a waterbody, ". . . immediately upgradient from each discharge" except in headwaters where, ". . . it may be necessary to use the background conditions of a neighboring or similar watershed . . ." (Chapter 173-201A-020 WAC). The criteria have been used for point source, and construction-related run-off water quality compliance.

In 1994, the Idaho Division of Environmental Quality adopted turbidity criteria specifically for protection of cold water biota represented by an indicator species, salmonids. The criteria set maximum increases of turbidity from nonpoint sources over background, and they also set duration (IDAPA 16 01.02 Section 250.02c.iv):

> In surface waters supporting or capable of supporting salmonid fisheries, turbidity, as the result of nonpoint source activities, shall not exceed background turbidity measured at comparable discharge by 50 NTU instantaneously or 25 NTU for 10 days.

Although these criteria specify "shall not exceed background," the 50 NTU level is based on scientific data suggesting that displacement of salmonids occurs at 50 NTU (Lloyd *et al.*, 1987; Harvey, 1989). The 25 NTU for 10 days limit is based on literature showing that salmonid feeding and growth are affected by prolonged exposure to turbidity over 25 NTU (Sigler *et al.*, 1984; Harvey, 1989).

There are no USEPA or Washington State numeric water quality criteria for total suspended sediment. TSS can be addressed, however, through the state narrative criteria, which are used to control toxic, radioactive, and deleterious materials, and to maintain aesthetic values (Table 1). The Washington State Water Quality Criteria for Class A and Class B waters also state that, "Water quality of this class shall meet or exceed the requirements for . . . salmonid (and other fish) migration, rearing, spawning (Class A only for salmonids), and harvesting."

USEPA guidance documents have classified impairment of aquatic habitat or organisms due to TSS as follows (Mills *et al.*, 1985):

TSS Concentration	Impairment
< 10 mg/L	improbable
< 100 mg/L	potential
> 100 mg/L	probable

Similar ranges of TSS concentrations were earlier suggested by the National Academy of Sciences (1973):

TSS Concentration	Aquatic Community Protection Level
<25 mg/L	High
25 - 80 mg/L	Moderate
80 - 400 mg/L	Low
>400 mg/L	Very Low

None of the turbidity criteria or TSS guidance concentration ranges consider both prolonged exposure of aquatic organisms to elevated turbidity or suspended sediment levels with a maximum level of exposure. Idaho's criteria for cold water fisheries addresses some duration issues, but the criteria are still tied to background levels. Newcombe and MacDonald (1991) and Waters (1995) emphasize the importance of looking at both concentration and duration of suspended sediment to assess impacts to salmonids and other species. Although larger juvenile and adult salmon can withstand short periods of high turbidity and TSS concentrations, they will avoid chronically turbid water (Lloyd *et al.,* 1987; Bjornn and Reiser, 1991). This may be why sport fishing is also affected when TSS concentrations persist at low levels over a period of a week or more. However, events of two to four days with turbidities from 10 NTU to 60 NTU may disrupt feeding and territorial behavior of some juvenile salmon (Berg, 1982; Bjornn and Reiser, 1991). Newcombe and MacDonald (1991) compiled spring and fall chinook and steelhead data from several research papers. These are the primary species of concern in the Yakima River basin. The data are summarized in Table 6. According to these data, prolonged exposure to TSS concentrations under 100 mg/L can seriously effect salmonid fry health and growth.

Macroinvertebrate populations and other fish species are also sensitive to chronically turbid conditions, but fewer data have been collected on these aquatic communities (Waters, 1995). Some data presented by Newcombe and MacDonald (1991) indicate macroinvertebrate populations may experience lethal conditions, or avoid habitat when TSS concentrations are as low as 8 mg/L for 60 days.

Table 6. Summary of suspended sediment effects on selected salmonids commonly present in the Yakima basin (Newcombe and McDonald, 1991), (*) indicates estimated concentration.

Species	**Concentration (mg/L)**	**Duration (hours)**	**Effect**
Chinook Salmon	1400*	36	10% mortality of juveniles
	488	96	50% mortality of smolts
	82,000	6	60% mortality of juveniles
	19,364	96	50% mortality of smolts
	1.5-2.0	1,440	Gill hyperplasia, poor condition of fry
	6	1,440	Reduction in growth rate
	75	168	Harm to quality of habitat
	84	336	Reduction in growth rate
	1,547	96	Histological damage to gills
	650	1	Homing performance disrupted
Whitefish	16,613	96	50% mortality of juveniles
	0.7	1	Overhead cover abandoned
Salmon (general)	8	24	Sport fishing declines
Steelhead	84	336	Reduction in growth rate
Rainbow Trout	19,364	96	50% mortality of smolts
	157	1728	100% mortality of eggs
	21	1152	62% reduction in egg to fry survival
	37	1440	46% reduction in egg to fry survival
	7	1152	17% reduction in egg to fry survival
	90	456	5% mortality in sub-adults
	171	96	Histological damage
	50	1848	Reduction in growth rate
	100	1	Avoidance response

1994 and 1995 TSS and Turbidity

Irrigation season data collected during 1994 and 1995, as well as historical data, were compared to the 25 and 50 NTU threshold turbidities suggested by Harvey (1989) in the Idaho development document for cold water fisheries, and to the 10 mg/L and 100 mg/L TSS boundaries recommended by USEPA for defining potential and probable water quality problems. The median and 90th percentile values are plotted for data comparison. Tributary data were plotted on a logarithmic scale because of their broad data range.

In 1994, water quality monitoring began in late June. Comparison of 1994 and 1995 data include late June through October data only. Ecology's Ambient Monitoring Program data for the Yakima River at Kiona, and the Yakima River at Terrace Heights are included. Due to their relatively small impact, four sites, Wide Hollow Creek, Ahtanum Creek, Drainage Improvement District #7 (DID #7) drain, and Grandview Drain, were monitored in 1994 but not in 1995. These limitations should be kept in mind when viewing the data.

Main stem Yakima River TSS and turbidity are compared to the threshold values in Figure 9 and 10. In 1994 and 1995, median and 90th percentile TSS concentrations were generally in the 10 mg/L to 100 mg/L range that indicates a potential impairment to aquatic habitat. The 90th percentile values were noticeably higher in 1995 and approached 100 mg/L at Yakima at Kiona. Median and 90th percentile turbidities at main stem sites monitored in 1994 remained below 25 NTU. In 1995, 90th percentile turbidities of the four sites below Yakima at Parker exceeded 25 NTU. Lower values at these downstream sites in 1994 were likely due to low water delivery, and lower flows from irrigation returns. In both years, TSS and turbidity increased downstream, especially below Parker.

Figure 11 illustrates TSS and turbidity values at tributary sites. In 1994, Moxee Drain and Granger Drain had median and 90th percentile TSS concentrations above the 100 mg/L level of probable impairment. The median TSS values were above the 10 mg/L level of potential impairment at three additional project sites: Sulphur Creek, Grandview Drain, and Spring Creek. In 1995, a year with full water allocation, the median TSS concentrations at all sites were greater than 10 mg/L. In addition to Moxee and Granger Drains, Sulphur and Spring Creeks had median TSS concentrations greater than 100 mg/L. Snipes Creek had a 90th percentile TSS concentration above 100 mg/L. Turbidity values followed similar trends to TSS. In 1994 and 1995, the median turbidities at Moxee and Granger exceeded 50 NTU, the level at which displacement of salmonids can occur. None of the other sites in 1994 had median turbidities above 25 NTU, that level at which salmonid feeding and growth are affected. But in 1995, the median turbidities of Sulphur Creek and Spring Creek were above 25 NTU, while the 90th percentile turbidities for Sulphur, Spring, and Snipes creeks exceeded 50 NTU.

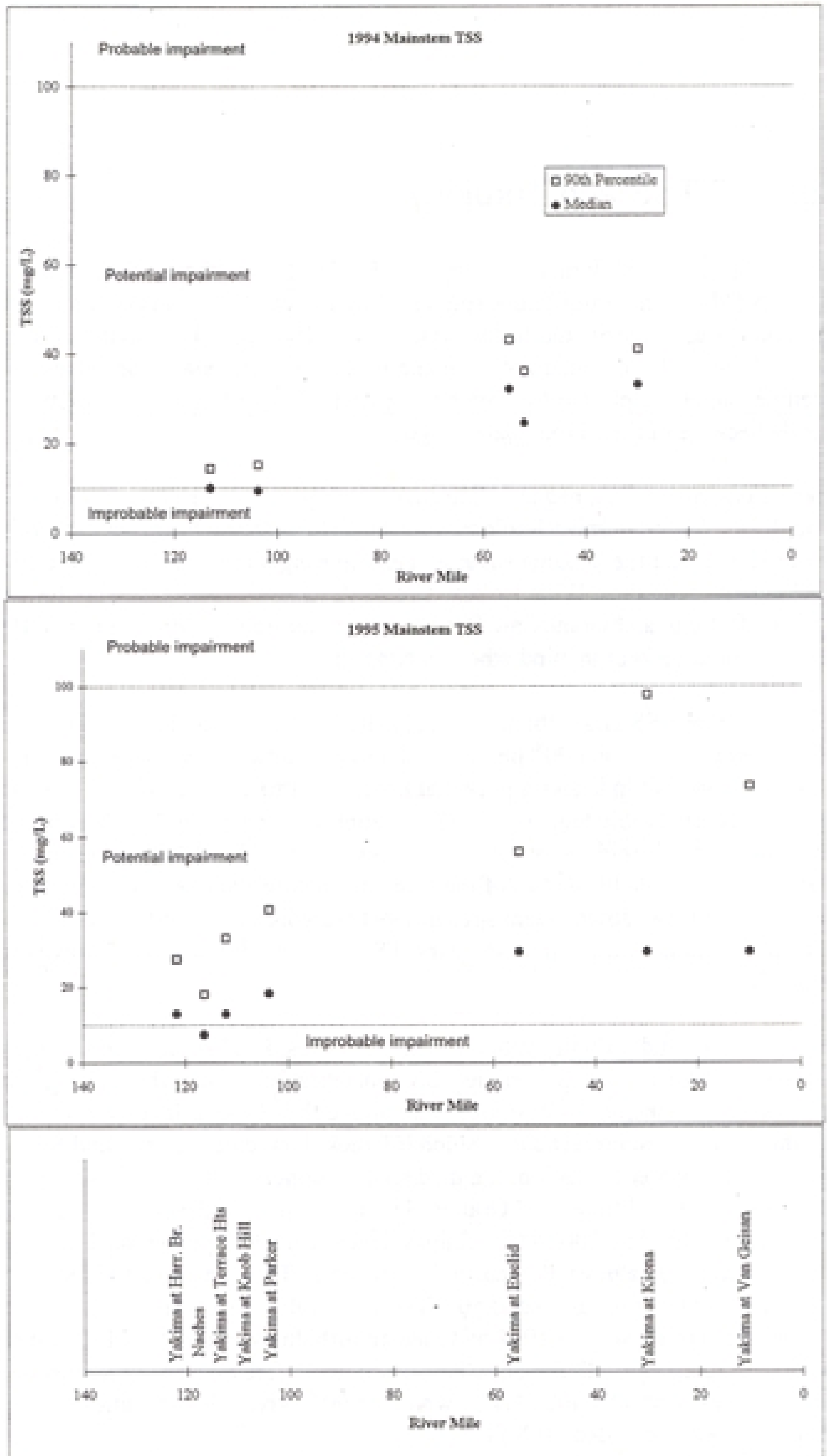


Figure 9. Comparison of 1994 and 1995 total suspended sediment data from the main stem Yakima River to 10 mg/L and 100 mg/L threshold concentrations for aquatic community effects.

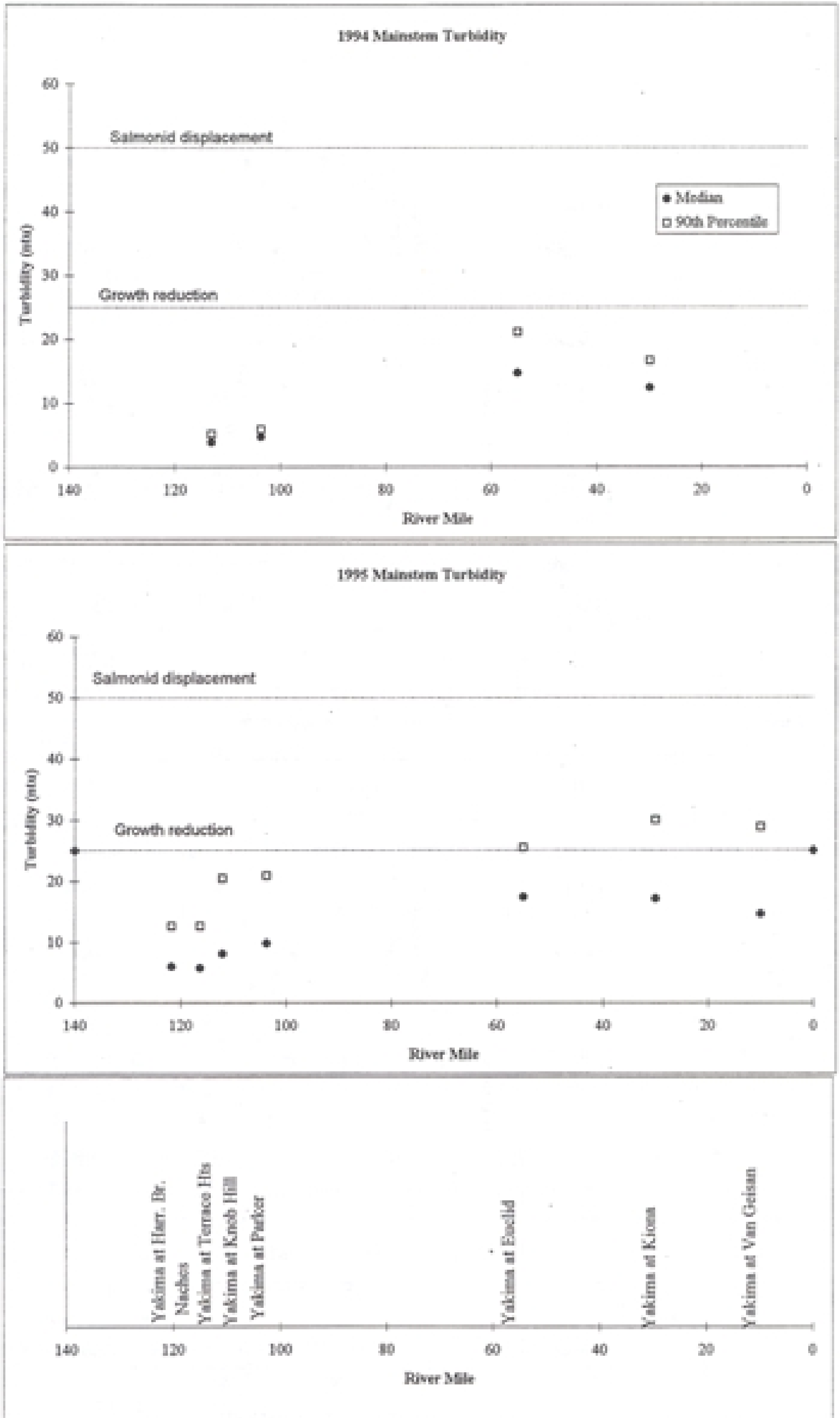


Figure 10. Comparison of 1994 and 1995 turbidity at main stem Yakima River sites to 50 NTU and 25 NTU salmonid response values.

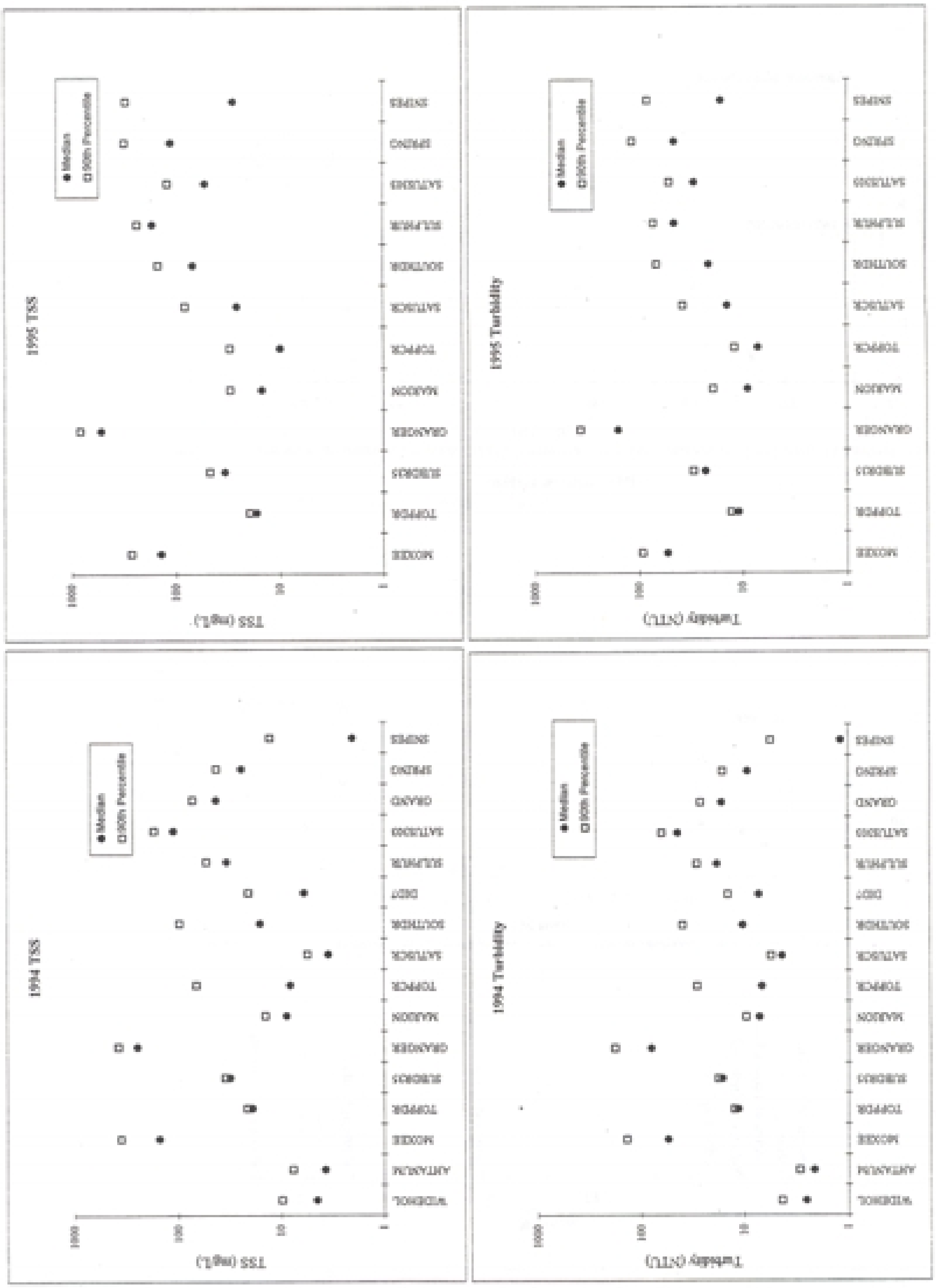


Figure 11. Yakima River tributary sites: 1994-1995 summary TSS and turbidity data (median and 90th percentile values) for project area and Yakama Reservation (YIR) sites.

Medians and 90th percentiles for data collected from Yakama Reservation drains and tributaries are shown for general comparisons to the project area data (Figure 11). TSS and turbidity values for 1994 YIN sites were estimated based on a regression of 1995 YIN turbidity to 1995 Ecology TSS (Appendix 2). In addition, 1994 YIN sites were only monitored from August through October and may not be comparable to the project sites that were monitored from June through October. In 1994, Reservation site TSS and turbidity data were within the range of values from project sites. In 1995, Reservation site 90th percentiles were generally lower, as a group, than the monitored project sites. Satus Drain 303 and South Drain had the highest turbidity and TSS concentrations among the Reservation sites.

Historical TSS and Turbidity Comparisons

The TMDL study area data followed a similar seasonal and spatial pattern as historical data. USGS (Rinella *et al.*, 1992a) reviewed turbidity and suspended sediment data collected from the Yakima River prior to 1985. They showed the highest concentrations of TSS and the highest turbidities in the lower Yakima River occurred from April to June. In those months, high streamflows with elevated TSS loads and turbidities from the upper Yakima River and Naches River basins are aggravated by erosion from unprotected fields, resuspended sediments in return drains, and other agricultural-related activities. Elevated TSS concentrations and turbidities continue in the lower basin even as upper basin levels decline because of the continued effect of irrigated agriculture. Prolonged elevated TSS and turbidity lead to impairment of aquatic habitat and other beneficial uses of the water.

Figure 12 shows a comparison of TSS concentrations from 1970 - 1995 at selected main stem Yakima River sites and the mouth of the Naches River during the irrigation season. Median TSS concentrations for the Yakima River at Parker, Euclid or Mabton, and Kiona have generally been above 10 mg/L, (*i.e.,* within the range of potential aquatic habitat impairment). The 90th percentile TSS concentrations exceeded 100 mg/L in one or more years at Harrison Bridge (2 years), Terrace Heights (1 year), and Kiona (6 years). At all sites, 1994 and 1995 TSS concentrations were similar to previous years.

TSS concentrations at tributary sites were usually considerably higher than in the main stem (Figure 13). Median TSS concentrations have been above 100 mg/L at project area drains in two or more years. At Granger and Moxee Drains, the 90th percentile TSS concentrations have never been below 100 mg/L. Tributary concentrations in 1994 and 1995, as expressed by the median and 90th percentile, were generally within the range of historical values for those sites.

Trend analyses have been conducted on Yakima River Basin water quality data by the USGS (1992). Statistical significance for trend analysis is usually determined by a probability (p) less than or equal to 0.10 (USGS, 1992). Unlike our analyses, which have focused only on irrigation season data, USGS analyses encompass year around data. The trends analysis included the period from 1974 to 1981. During this time period, there were significantly decreasing trends for

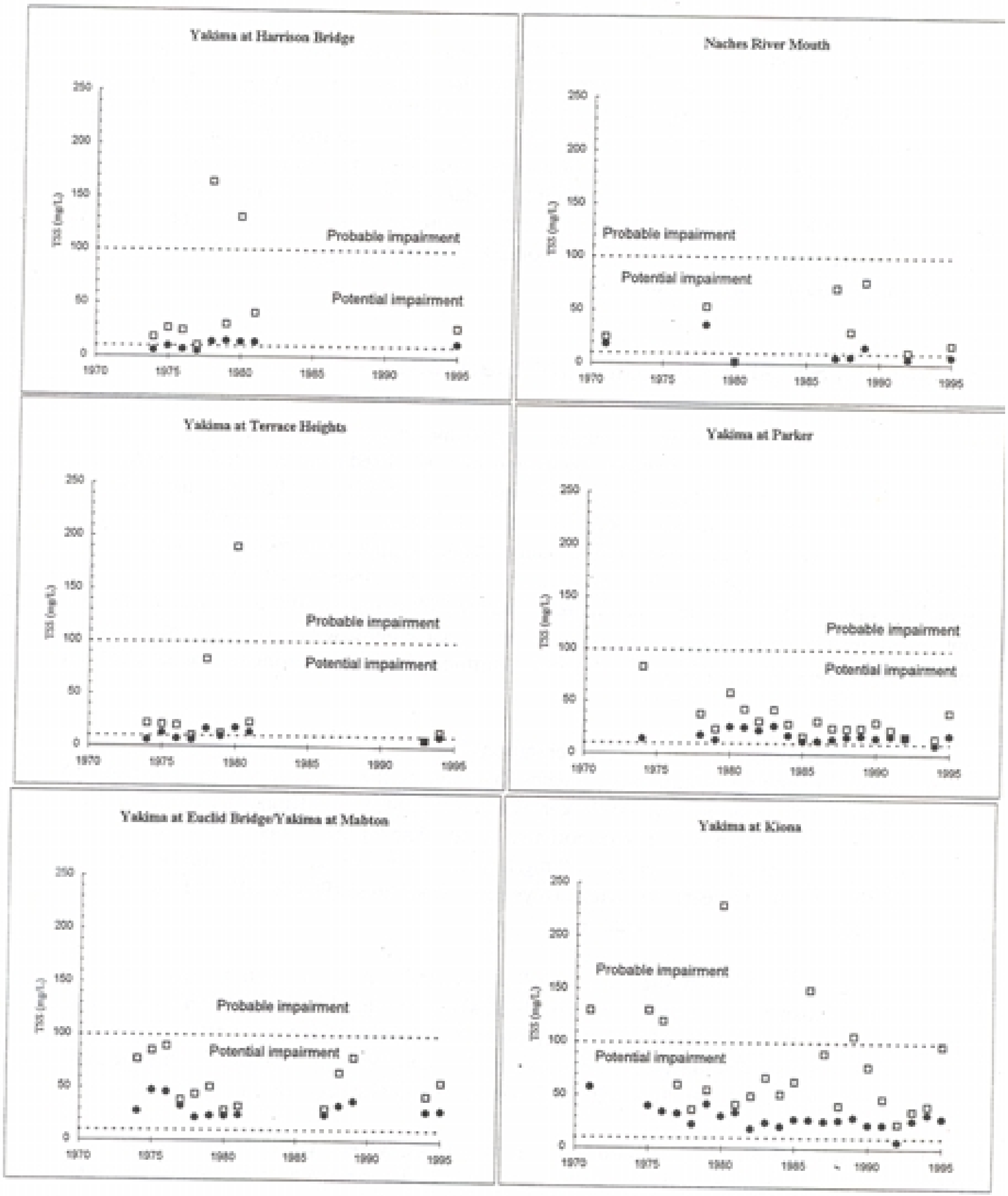


Figure 12. Total suspended solids median (•) and 90th percentile (□) concentrations collected at main stem sites on the Yakima River from 1970 to 1995. Threshold concentrations for aquatic community effects are also shown.

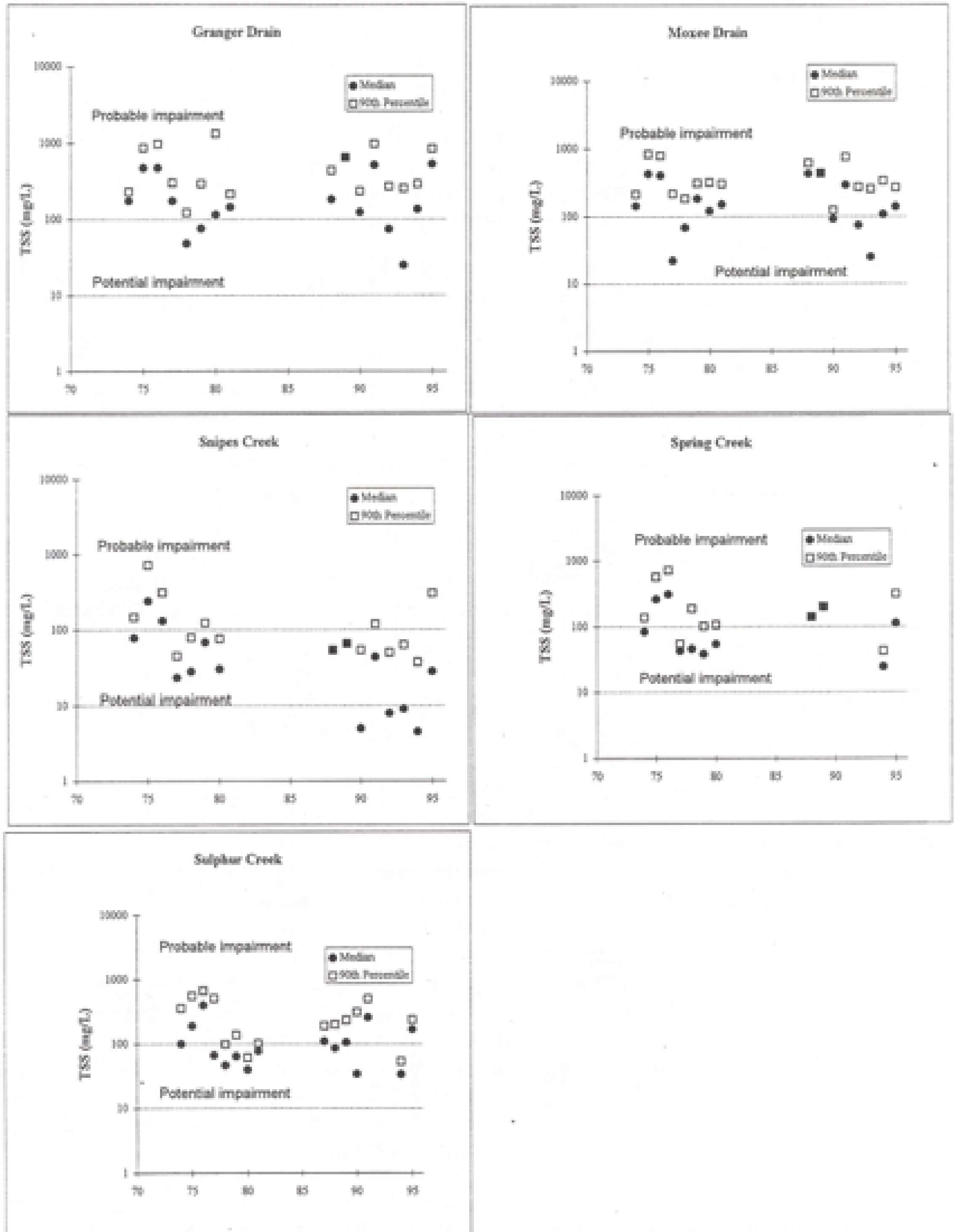


Figure 13. TMDL project area tributaries and drains: TSS data collected from 1970 to 1995. Threshold values suggest potential (>10 mg/L TSS) and probable (>100 mg/L TSS) impairment to aquatic communities are shown.

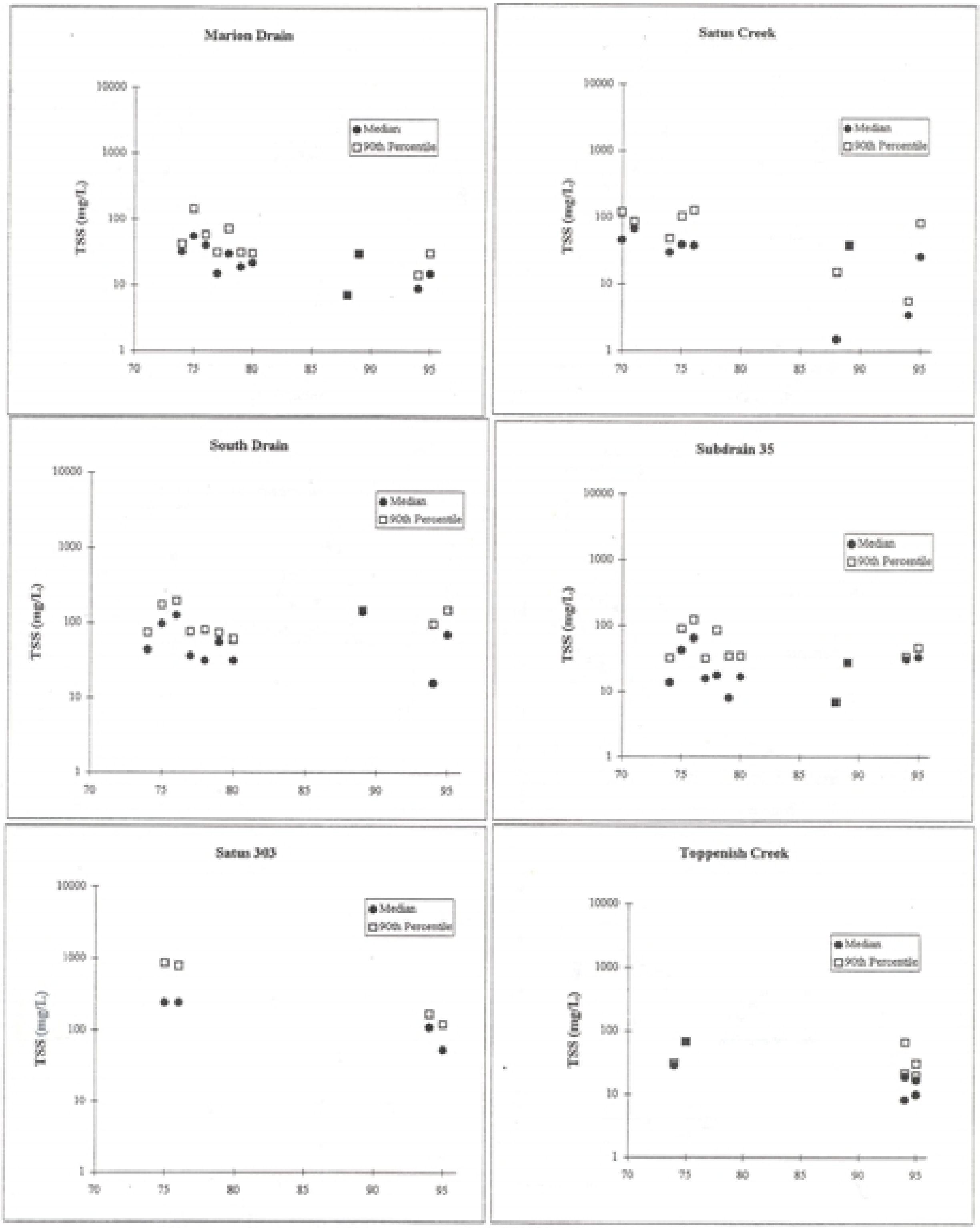


Figure 13. Continued. Yakama Indian Reservation tributaries.

turbidity and TSS at Sulphur Creek, Spring Creek, and Snipes Creek, and a significantly increasing trend for Yakima River at Granger. Additional decreasing turbidity trends within the project area were found at Wide Hollow Creek and Ahtanum Creek. Subdrain 35 and South Drain, on the Yakama Reservation bordering the project area, also showed decreasing trends in turbidity. The Naches River experienced an increasing TSS trend during this period.

The USGS (Rinella *et al.,* 1992a) suggested that decreasing trends may have been the result of an agricultural change. Highly erosive row crops have been replaced by orchards that use less erosive irrigation and cultivation techniques. Improvements may also have come from sediment control measures installed during the 1970s "Section 208" implementation period. Although these trends are encouraging for this time period, 1995 TSS concentrations were very similar to historical concentrations and may indicate that many of the changes have occurred outside of the irrigation season.

Ecology's trend analyses by the Ecology Ambient Monitoring Program (B. Ehinger, personal communication) covered the subsequent period from 1981-1993. During this time there was a significant increasing trend for TSS concentrations adjusted for flow at the Yakima River at Kiona. For the same period at the Yakima River at Parker, the TSS trend adjusted for flow was significantly decreasing during the irrigation season (the trend for year around data is slightly significant at p=0.127).

Main Stem TSS Mass Balance

Although TSS concentrations are essential measurements to assess water quality effects and compare to criteria, loading calculations are necessary to evaluate TSS sources, transport mechanisms, and fate in the river system. Loads are estimates of masses of material being added to a water body, and are calculated as the product of the discharge and concentration. They are usually expressed as mass per time (e.g., pounds/day, kilograms/season, tons/year, etc.). When TSS loads are tracked through a river system, a mass balance, much like a check book balance, is calculated as source loads are added or as instream loads are diverted from the river. If source and diversion TSS loads are closely quantified, instream areas of sediment release (erosion) and storage (sedimentation) can be defined. Instream erosion processes can originate from banks or from bed sediments, and can result from a naturally or anthropogenically caused activity. Sedimentation areas can be important for seasonal storage of sediment to reduce water column TSS concentrations, or they can indicate a possible area of fish habitat degradation. Within a year, some reaches can exhibit sediment release or storage characteristics, depending upon the seasonal changes in hydrological characteristics.

Suspended sediment concentrations and water discharge volumes were measured at several sites through the lower basin in 1995. The Beales ratio estimator formula was used to calculate TSS loads for the irrigation season at sites with continuously monitored discharge records (Thomann and Mueller, 1987). Discharge weighted TSS loads were calculated when only instantaneous discharge measurements were available at some TSS sampling sites. Estimates of the TSS concentrations and loads from unmonitored sites were calculated from data provided in the references noted for the same sources in the water balance (Corps of Army Engineers, 1978; U.S. Department of Interior, 1974). No attempt was made to perform more advanced loading calculations by partitioning loads by particle size, or by separating wash load from suspended and bed load transport. USGS particle size data suggest 90% of the suspended sediment in most study area main stem sites during the late irrigation season are less than 0.062 mm. that separates fine sands from coarse silts. Tributary and irrigation return drain particle sizes appeared to be more variable, with 50% to 95% of the suspended sediments in individual samples being less than 0.062 mm.

Data from a canal wash-out event observed in 1995 were not included in the seasonal TSS load calculation. On April 24, 1995, the Kittitas Reclamation District (KRD) canal wall in the upper Yakima River basin broke, causing a large slug of sediment to reach the lower Yakima River on April 26. Because of our site sampling order on the April 25-26, only samples collected at some of the main stem sites and the Roza Canal site were affected by the sediment passing through. The effect of the spill data on the seasonal TSS load calculations was to increase the daily average load by 3 to 4 tons/day.

As with the water balance described earlier, TSS load sources and transport are described in two sets of pie charts for two calculation periods: for the 1995 irrigation season, and for the July-October period (Figure 14 and 15). The pie charts summarize the sources and fates of TSS loads for two reaches: Confluence to Parker, and Parker to Kiona. Data are also presented in Table 7.

Between the confluence and Parker, approximately 50% of the 330 tons/day TSS load during the irrigation season was generated by the three large sources of water: the upper Yakima River (50 tons/day), the Naches River (90 tons/day) and the Roza Power Return (30 tons/day). Most of the load was generated earlier in the season. In the months of July to October, 140 tons/day were generated in the reach. The same three sources contributed 70% (98 tons/day) of the TSS load. Moxee Drain's average TSS load during the irrigation season was equal to the Roza Power Return's even though the former has only 10% of the latter's daily average flow. In the later part of the season, Moxee's TSS load (35 tons/day) exceeded both Roza Return's (21 tons/day) and the Naches River's (27 tons/day). Approximately 1% of the irrigation season TSS load (5 tons/day) came from the combination of other return drains, small tributaries, and municipal/industrial sources. Between July and October, these sources accounted for 3% of the TSS load. A large portion of the average load calculated over the entire season, 36%, was from unknown sources and may represent instream bed deposit releases created by high spring run-off flows during the early part of the irrigation season. In contrast, the months of July to October shows a loss of TSS (32 tons/day). Sedimentation may be one cause for the loss as flows and velocities dropped, but averaging and measuring errors are also possibilities.

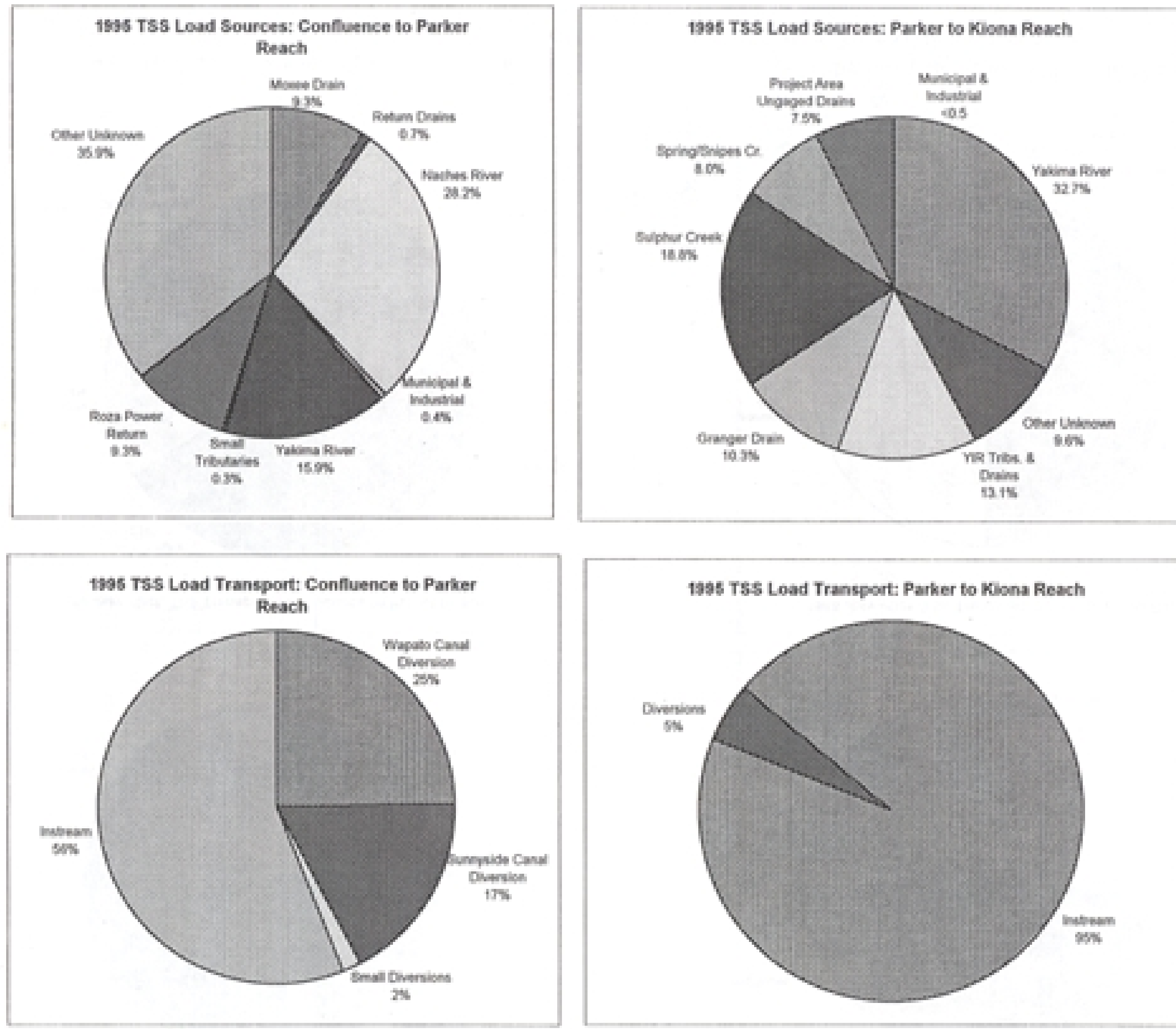


Figure 14. 1995 lower Yakima River TSS load balance (sources and transport) during the irrigation season (March to October). Yakama Indian Reservation (YIR) tributaries are not included in the TMDL project area.

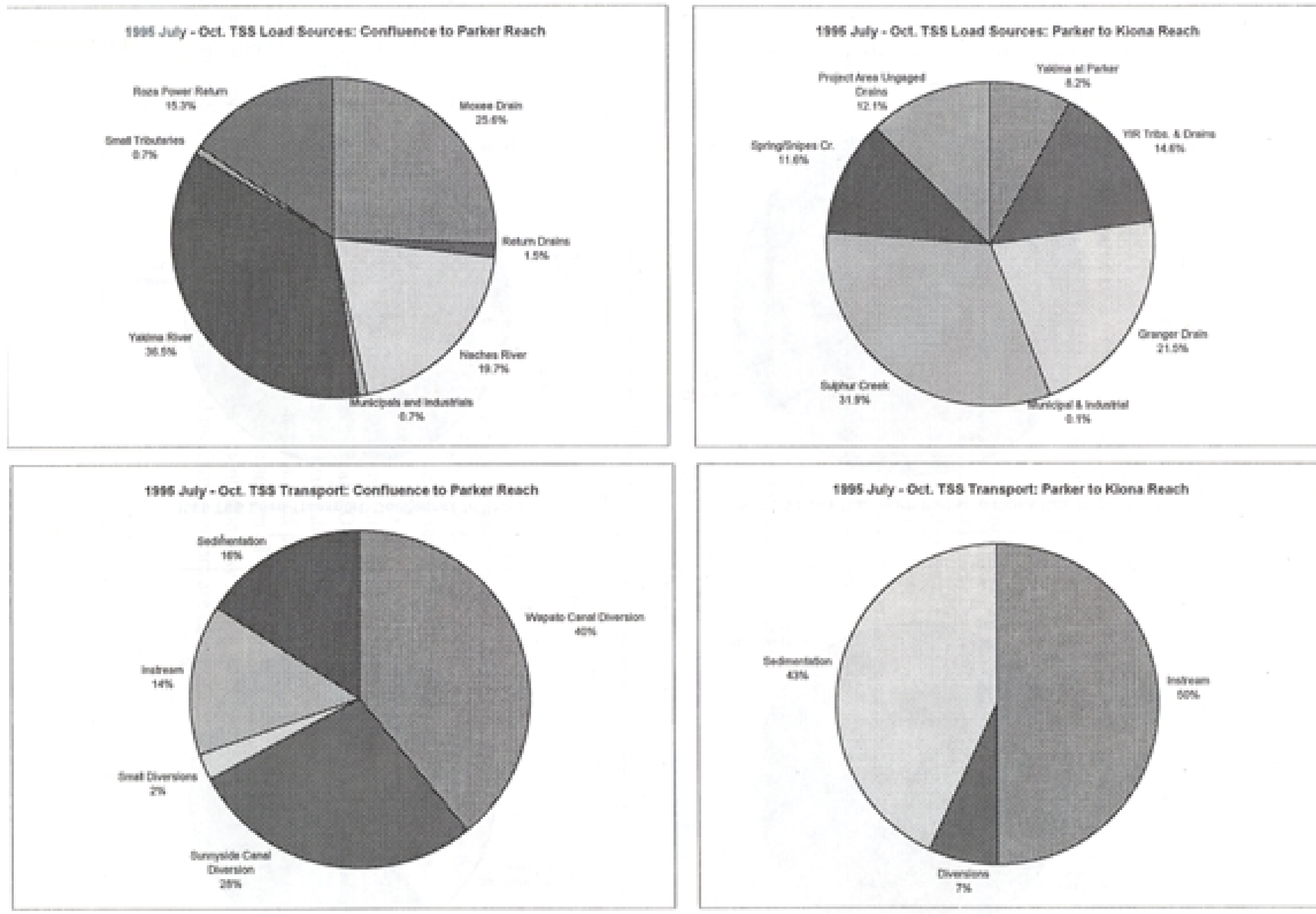


Figure 15. 1995 lower Yakima River TSS load balance (sources and transport) for the last part of the irrigation season (July to October). Yakama Indian Reservation (YIR) tributaries not included in the TMDL project area.

Table 7. Total supended sediment (TSS) sources and transport for two reaches of the lower Yakima River during the 1995 irrigation season: average TSS load (tons/day) over the entire season, and the last part (July - October) are compared.

Confluence to Parker Reach

TSS Load Sources	Yakima River	Naches River	Roza Power Return	Small Tributaries	Municipal & Industrial	Return Drains	Moxee Drain	Other
March to October	53	94	31	1.1	1.4	2.3	31	120
July to October	50	27	21	1.1	1.4	2.3	35	

TSS Load Transport	Wapato Canal	Sunnyside Canal	Small Diversions	Instream	Sedimentation
March to October	83	58	5.3	188	
July to October	79	57	5.3	29	32

Parker to Kiona Reach

TSS Load Sources	Yakima River	YIR Tribs.* & Drains	Project Area Gaged Drains	Project Area Ungaged Drains	Municipal & Industrial	Other
March to October	188	75	213	43	0.2	55
July to October	29	52	230	43	0.2	

TSS Load Transport	Instream	Irrigation Diversions	Sedimentation
March to October	546	28	
July to October	177	24	153

* Yakama Indian Reservation tributaries and drains are not within the TMDL project area, but contribute to the reach.

More than half of the TSS load (190 tons/day) calculated over the irrigation season in the reach above Parker passed into the Parker to Kiona reach. However, this comprised only a third of the TSS load generated in the lower reach. During the months of July to October, 30 tons/day TSS passed from the upper reach to the lower reach. A greater portion of the TSS load was diverted to the Wapato and SVID canals. Larger TSS loads were also generated by tributaries and return drains, so the 30 tons/day contribution from the upper reach constituted only 8% of TSS load generated below Parker. For example, Granger Drain's contribution to the reach doubled from 10% to 21% as its average TSS load increased from 60 tons/day over the entire season to 76 tons/day during the later period. The TSS load from Sulphur Creek, the largest tributary loading source, remained fairly stable at 110 tons/day for both the whole season, and the July to October period. Sulphur Creek's average load over the entire season accounted for 19% of the total, but it was a third of the TSS load in the reach when calculated for the later portion of the irrigation season. Spring and Snipes Creeks' TSS loads remained near 10% of the reach-wide contribution over both calculation periods.

Tributaries and return drains out of the project area, the Yakama Indian Reservation (YIR), were unusual in that, in most cases, their average TSS loads were higher when calculated over the entire irrigation season (75 tons/day) than during the later part of the season (50 tons/day). Therefore, YIR drains and tributaries TSS loading remained under 15% for both calculation periods. This was consistent with historical data that indicated YIR tributaries contributed far less sediment loading to the river than project area tributaries (Rinella *et al.*, 1992a; USGS unpublished data).

Ungaged tributaries contributed an estimated 7.5% of the load (43 tons/day) over the irrigation season, which was less than that from unknown sources (55 tons/day). Approximately 95% of the TSS load over the irrigation season was passed downstream of Kiona. However, in the later part of the irrigation season, much more TSS was added to the lower reach than passed downstream of the Kiona gage. An estimated 43% of the Yakima River's load (150 tons/day) was thought to have settled in the reach, primarily between Granger and Prosser. Estimated average channel velocities were 0.5 to 1.5 feet per second (fps) in some parts of the reach under the flow conditions observed in the discharge record, which are slow enough to increase settling rates.

Pesticides

Nonionic pesticides have been used extensively on the agricultural crops of the Yakima Valley since at least the 1950s. In general, the organochlorine compounds, such as DDT, dieldrin, and endosulfan, have been the most frequently detected in basin waters, sediments, and biota due to their persistence in the environment. These compounds are transported to water and biota via soil erosion. Because of their persistence, they pose greater chronic risks to aquatic organisms, and are more likely to bioaccumulate in fish and predator species. Organophosphate pesticides, such as parathion, chlorpyrifos, azinphos-methyl, and diazinon, are generally not as persistent, but they are more acutely toxic to terrestrial and aquatic organisms than the organochlorines. The use of organophosphates has increased since many of the organochlorines have been banned. For example, DDT was banned in 1972, and dieldrin was banned in 1987 because of damage to the environment based on their bioaccumulative properties. More recently, some organophosphates such as parathion in 1991, have been banned because of their direct toxicity to humans.

Criteria and Guidelines

Washington State criteria and screening values, and USEPA guidelines have been developed for pesticides in water and fish for the protection of aquatic biota and human health. Criteria and guidelines are summarized in Table 8 for those pesticides that have been detected in Yakima River Basin water and fish samples. The Food and Drug Administration (FDA) also has some pesticide standards for commercially sold fish tissue. Since some pesticides do not have state criteria, other USEPA guidelines, FDA standards, National Academy of Science (1973), or New York State (Newell *et al.*, 1987) guidelines are also provided.

Washington State human health screening values for fish tissue are based on carcinogenic and non-carcinogenic health risks (Davis and Johnson, 1994b). The screening values for organochlorine tissue are calculated from USEPA's National Toxics Rule (NTR) water quality criteria (40 CFR part 131.36). Other screening guidelines are calculated with oral dosage factors and an average consumption rate of 6.5 grams/day of edible fish (muscle tissue) by a 70 kg adult (USEPA, 1993). A carcinogenic risk factor of one in one million (10^{-6}) for a lifetime exposure is used for suspected or known carcinogens. In addition, the calculated values are used by Washington to assess a water body's ability to support fish safe for human consumption. If contaminants in one or more samples exceed criteria at a site (based on a five fish composite sample of edible tissue), the site is eligible for addition to the 303 (d) list of waters not meeting state water quality criteria (State Water Quality Policy 1-11, 1993). The list is used to establish priority for waters in need of pollutant control.

The Washington NTR criteria and the screening values to protect human health are calculated from a set of assumptions about the amount of fish consumed by the average U.S. citizen, and about what is eaten. The consumption rate is low for some people in the U.S., which was one key factor in the Washington State Department of Health fish consumption advisory for the Yakima River (Department of Health, 1993). A consumption rate of 59.9 grams/day has been derived from a recent survey of native people by the Columbia River Inter-Tribal Fish Commission under a cooperative agreement with the USEPA (CRITFC, 1994). Whole fish tissue sample concentrations may be more appropriate for health risk assessment to some ethnic populations that consume a wider variety of fish parts and organs than the general U.S. population. Concentrations of some pesticides are generally higher in samples of whole fish than in muscle tissues. Fish tissue criteria calculated with the higher consumption rate, or with the whole fish contaminant concentrations would be more stringent than are currently used to assess national and state waters.

Table 8. Criteria and guidelines for pesticides in water and fish established or recommended by Washington State (WA), USEPA, National Academy of Sciences (NAS), Food and Drug Administration (FDA), and New York. Fish tissue values are to protect human health and whole fish values are to protect wildlife.

	Water Quality (ug/L)				Fish Tissue (ug/kg, wet weight)		Whole Fish (ug/kg, wet weight)		
	WA and/or EPA							New York - Niagara	
Pesticide	Chronic	Acute	HH NTR*	NAS Guidelines	WA Screening Level	FDA	NAS Guidelines	Non-carcin.	Carcinogen
organochlorines									
4,4'-DDD	0.001	1.1	0.00084	-	45	-	1000	200	270
4,4'-DDE	0.001	1.1	0.00059	-	32	-	1000	200	270
4,4'-DDT	0.001	1.1	0.00059	-	32	-	1000	200	270
total DDT	0.001	1.1	-	0.002	32	5000	1000	200	270
total chlordane	0.0043	2.4	0.00057	-	8.3	300	100	500	370
dieldrin/aldrin	0.0019	2.5	0.00014	0.005	0.7	300	100	120	22
endosulfan	0.056	0.22	2	0.003	540	20,000	100	-	-
lindane	0.08	2	0.063	0.02	8.3	-	100	-	-
heptachlor epoxide	0.0038	0.52	0.00011	-	1.2	300	100	200	210
toxaphene	0.0002	0.73	0.00075	0.01	9.8	5000	-	-	-
endrin	0.0023	0.18	0.81		3231				
organophosphates									
azinphos-methyl	0.01	-	-	0.001					
chlorpyrifos	0.041	0.083	-	0.001	30,000				
parathion	0.013	0.065	-	0.0004					
malathion	0.1	-	-	0.008					
diazinon	-	-	-	0.009	900				
disulfonton	-	-	-	0.05	500				
ethion	-	-	-	0.02	5000				
Herbicides									
2,4-D	-	-	-	4					
dicamba	-	-	-	200					
simazine	-	-	-	10					

* Human health criteria assuming 10^{-6} carcinogenic risk from consumption of fish taken from waters with listed concentration.
References: NAS, 1973; USEPA, 1986; Newell et al., 1987; National Toxics Rule (NTR) 40 CFR part 131

When the pesticide bioconcentration potentials and either fish consumption rate are used, water quality guidelines for human health protection are far more stringent than aquatic life protection criteria. However, most of the water quality criteria developed from these calculations would be below current detection limits for these contaminants in water samples. In cases such as this, fish tissue concentrations are better media for environmental monitoring since tissue burdens are more likely to be within analytical detection limits.

Criteria for pesticides in whole fish have not yet been adopted for the protection of pisciverous wildlife. However, the National Academy of Sciences (1973) established guidelines for whole fish tissue (not just muscle tissue portions) that are designed to protect predators (Table 8). A more recent study conducted on the Niagara River established guidelines based on carcinogenic and non-carcinogenic effects (Newell *et al.*, 1987). The carcinogenic risk to wildlife was set at one in 100 (10^{-2}) to avoid any population reduction. The non-carcinogenic guidelines were calculated from toxicity data using the no-observed-effect-level (NOEL).

Historical Pesticide Data (Water column)

In the 1970s and early 1980s the USGS and USEPA analyzed water samples from sites in the Yakima Basin. During this period, the USGS analytical reporting limits were higher than USEPA's, and higher than current reporting limits. This resulted in fewer reported detections (Rinella *et al.*, 1992a). In both sample sets, total DDT or t-DDT (DDT + DDD + DDE) and dieldrin were the organochlorine pesticides most frequently detected at concentrations above the chronic aquatic toxicity criteria. One USGS sample collected at Kiona in 1982 also contained total chlordane, endrin, and toxaphene. Concentrations of chlordane and toxaphene exceeded human health and aquatic toxicity criteria. The endrin concentration exceeded chronic aquatic toxicity criteria. Diazinon, an organophosphate, was frequently detected in USGS samples collected at Kiona at concentrations above the NAS guideline. A parathion concentration above the chronic and acute criteria was detected in a sample collected at the same site in 1973.

In 1985, Ecology collected samples throughout the basin (Johnson *et al.*, 1986). DDT and dieldrin concentrations exceeded human health and aquatic life protection criteria for chronic exposure. Endosulfan was detected in three samples and diazinon was detected in one sample from Birchfield (Moxee) Drain. One endosulphan concentration exceeded the USEPA chronic toxicity criterion, and the other two exceeded the NAS criterion. The diazinon concentration exceeded the NAS criterion. No other pesticides (including organophosphates) were detected in any samples, although only screening procedures with high detection limits were used.

The USGS NAWQA study in 1988-89 also analyzed samples for pesticides throughout the basin (Rinella *et al.*, 1992b). Total DDT was detected in 79%, endosulfan in 70%, and dieldrin in 78% of the samples collected from main stem and tributaries; detection rates were especially high in the lower basin. Although none of these pesticide concentrations exceeded acute toxicity criteria, most t-DDT and dieldrin concentrations exceeded the chronic toxicity criteria, and most endosulphan concentrations exceeded the NAS guidelines. All detected DDT and dieldrin concentrations exceeded human health criteria.

This was also the first study to detect widespread contamination of water by organophosphates and herbicides. Diazinon was the most frequently detected organophosphate compound; all concentrations exceeded the NAS guideline. Parathion was detected in 13 samples; all detected concentrations exceeded the NAS guideline. Parathion concentrations exceeded the chronic toxicity criterion at five sites, including one sample from Moxee Drain that was also above the acute toxicity criterion. Disulfonton, ethion, and malathion were detected above the NAS recommended levels in one to five samples. Malathion was detected in five different tributaries, while ethion was detected five times and only in Moxee Drain samples. Several herbicide compounds were also detected in samples: 2,4-D, dicamba, and picloram (Rinella *et al.*, 1992b). There are no state criteria or USEPA guidelines for most herbicides. None of the samples collected in the lower Yakima River basin exceeded NAS guidelines.

Concentrations of total DDT in the water were highest in the early 1970s (Figure 16). 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. Samples collected by USGS during the NAWQA survey indicate that DDT is still present in the main stem at concentrations above criteria.

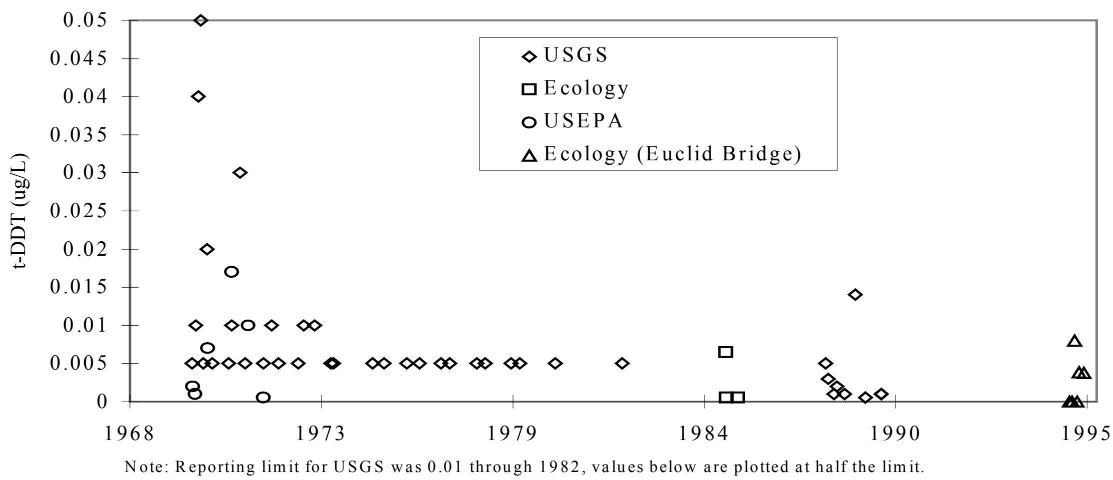


Figure 16. Comparison of t-DDT concentrations in water collected from lower Yakima River sites between 1968 and 1995.

1995 Pesticides Data Summary (Water Column)

In 1995, whole water samples were analyzed for 46 pesticides at Granger Drain, Spring Creek, Sulphur Creek, and the Yakima River at Euclid Bridge (Figure 4). Table 9 summarizes the frequency of detected pesticides at each site grouped by pesticide class. The organochlorine, organophosphate, and nitrogen containing pesticides were those most frequently detected at all sites. Organochlorines other than t-DDT, particularly dieldrin and endosulfan, may not have been detected in 1995 sampling because of high detection limits. Future pesticide analysis should establish detection limits that would allow comparisons of results to criteria. Granger Drain had the highest number of pesticides detected, followed by the Yakima River at Euclid, Sulphur Creek, and Spring Creek.

Table 9. Detection frequency: number of detections in six samples collected from four sites in 1995 in the lower Yakima project area.

(shaded) = Criteria or guidelines available

Class	CAS Description	GRANGER	SPRING	SULPHUR	YAKEUC
Organochlorine Pesticides					
	4,4'-DDD	**4**	**1**	**1**	**-**
	4,4'-DDE	**6**	**5**	**6**	**3**
	4,4'-DDT	**5**	**2**	**3**	**-**
	Methoxychlor	1	-	-	
Organophosphate Pesticides		-	-	-	-
	Azinphos (Guthion)	**4**	**5**	**5**	**5**
	Chlorpyriphos	**-**	**2**	**1**	**1**
	Diazinon	**-**	**2**	**2**	
	Dimethoate	-	-	1	1
	Disulfoton (Di-Syston)	1	-	1	1
	Disulfoton Sulfone	3	1	1	3
	Malathion	**1**	**1**	**-**	**1**
Nitrogen-containing Pesticides					
	Alachlor	1	-	-	-
	Atrazine	4	-	1	4
	Bromacil	2	2	2	-
	Ethalfluralin (Sonalan)	1	-	-	-
	Norflurazon	-	1	-	-
	Simazine	**5**	**1**	**2**	**3**
	Terbacil	1	1	3	3
	Treflan (Trifluralin)	2	-	-	-
Chlorinated Herbicides					
	2,4-D	**-**	**-**	**-**	**3**
	3,5-Dichlorobenzoic Acid	-	-	-	1
	Bentazon	-	-	-	2
Carbamates					
	Carbaryl	1	-	-	-
Urea Pesticides					
	Cyanazine	1	-	-	-
Other					
	1,3-Dimethyl-2-nitrobenzene	-	-	-	1
	1h-Benzimidazole, 2-(4-Thiazolyl)	-	-	-	1
	2,4,6-Tribromophenol	-	-	-	1
	Decachlorobiphenyl	1	1	1	1
	Hexazinone	1	-	-	-
	Propargite	**2**	**-**	**1**	**2**
	Triphenyl Phosphate	1	1	1	1

Sites were: Granger Drain, Spring Creek, Sulphur Creek Wasteway, and the Yakima River at Euclid Bridge

Total DDT was detected above the human health and aquatic life chronic toxicity criteria at all sites on three or more sampling dates (Figure 17). Twenty of the 24 t-DDT samples analyzed had concentrations from 0.004 µg/L to 0.357 µg/L, and a median of 0.0083 µg/L. Total DDT was not detected at the Yakima River at Euclid site in April, May, or July, nor at the Spring Creek site in April. The median concentration, and most sample results, were similar to what has been reported over the past years for these sites.Concentrations were highest at Granger Drain, including a sample collected on June 19 that contained 0.357 µg/L t-DDT. This concentration was more than 300 times the USEPA chronic toxicity criterion to protect aquatic life, although it was still below the acute toxicity criterion of 1.1 µg/L. It was 40 times the median concentration of the samples taken in 1995, and twice the previously highest concentration of t-DDT detected since 1968 (*i.e.* 0.15 µg/L at DID #18 as reported by Rinella *et al.* (1992a), and 0.122 µg/L reported at Granger Drain by Rinella *et al.* (1992b)). The single concentration was also unusual since it was primarily 4,4'-DDT, rather than DDE or DDD metabolites that normally comprise the largest fraction of the t-DDT result.

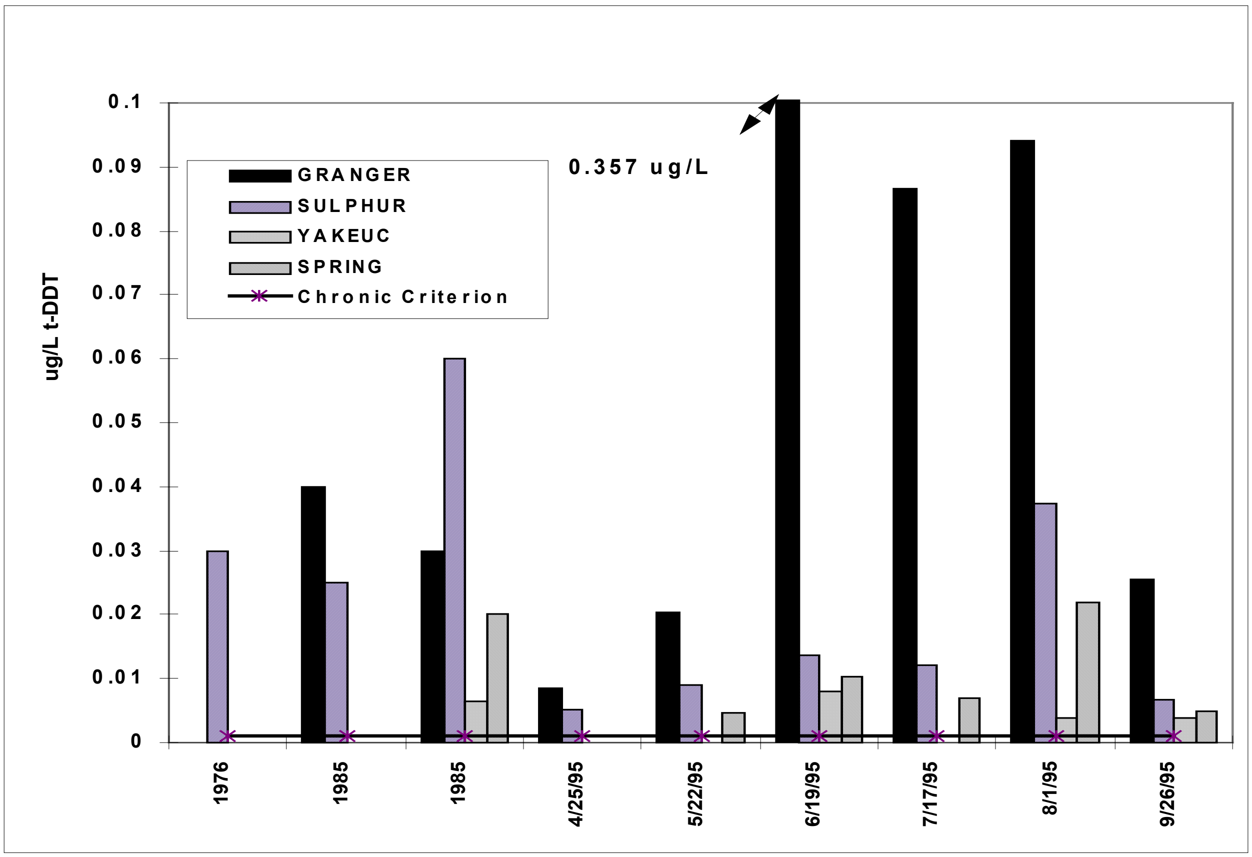


Figure 17. Total DDT (t-DDT) concentrations in water samples collected in 1995 and some previous years from sites in the lower Yakima basin: Granger Drain, Sulphur Creek, Yakima River at Euclid Br., and Spring Creek.

Additional pesticides detected in water at concentrations above criteria or guidelines are summarized in Table 10. Azinphos-methyl was detected from May through September at every site (with the exception of Granger in September). Concentrations were highest in May and June and lower in August and September. Most likely, concentrations in the water correspond with pesticide application patterns. Chlorpyrifos was detected above acute criteria one time each at the Yakima River at Euclid Bridge, and at Spring Creek. Concentrations of these insecticides did not correlate well with TSS concentrations. Both azinphos-methyl and chlorpyrifos are highly toxic insecticides used on many fruit and vegetable crops. These insecticides may have replaced parathion, which was discontinued in 1991. This could explain why parathion was frequently detected by USGS in 1988-89, but not detected in the Ecology sampling effort in 1995.

Table 10. Pesticides other than DDT metabolites detected in 1995 water samples, and were above criteria or guidelines.

Pesticide	Site	Date	Concentration	Criterion	Reference
Azinphos-methyl	GRANGER	5/22/95	0.07 NJ	0.01	EPA Chronic aquatic toxicity
		6/19/95	0.1 J		
		7/17/95	0.0395 J		
		8/1/95	0.04 J		
	SPRING	5/22/95	0.13 J		
		6/19/95	0.074 J		
		7/17/95	0.041 J		
		8/1/95	0.0044 J	0.001	NAS, 1973
		9/26/95	0.014 J		
	SULPHUR	5/22/95	0.1 J		
		6/19/95	0.13 J	0.11 - 6.4	Johnson & Findley, 1980 Acute aquatic toxicity
		7/17/95	0.048 J		
		9/26/95	0.026 J		
	YAKEUC	5/22/95	0.028 NJ		
		6/19/95	0.036 J		
		7/17/95	0.028 J		
		8/1/95	0.021 J		
		9/26/95	0.0105 NJ		
Chlorpyriphos	YAKEUC	6/19/95	0.12	0.083	EPA/WA Acute aquatic toxicity
	SPRING	3/20/95	0.445	0.041	EPA/WA Chronic aquatic toxicity
Diazinon	SPRING	7/17/95	0.013 J	0.009	NAS, 1973
Malathion	GRANGER	8/1/95	0.051 J	0.008	NAS. 1973
	YAKEUC	8/1/95	0.010 J		
Propargite	GRANGER	7/17/95	0.215	0.2	Norris & Dost, 1991 -Chronic toxicity to fish

Qualifiers: NJ= analyte is likely present, and numerical result is an estimate
J= analyte is positively identified, and the numerical result is an estimate

Summary of Pesticides in Fish Tissue

Historical fish muscle tissue data for t-DDT and dieldrin collected from 1984 - 1994 are compared to human health criteria and guidelines in Table 11. Also included are results from samples taken by Ecology staff in 1995 in cooperation with this study (Davis, in preparation). As previously discussed, human health criteria and guidelines are compared to composite samples of muscle tissue. As part of the NAWQA study in the Yakima Basin, the USGS collected fish tissue samples. However, the data do not represent composite samples. Rather, USGS collected 10 fish and reported the concentration in the muscle for *each* fish. The mean concentration of these values was used for comparison to the human health measures; tissue values below the analytical reporting limit were estimated at half of the limit to calculate the mean concentration.

Table 11. Comparison of fish muscle tissue data collected from 1985 - 1994 to EPA and Washington screening levels for human health effects from t-DDT and dieldrin

	t-DDT (ug/kg)								Dieldrin (ug/kg)					
Human Health Criteria				**32**						**0.7**				
Fish Species	MWF	LSS	BLS	NS	SMB	C	CC	RT	MWF	LSS	SMB	NS	C	CC
Davis, 1996 unpublished (Ecology)														
Yakima at Euclid Bridge					**213**	**917**							**8.8**	
Davis and Johnson, 1994 (DOE)														
Yakima at Horn Rapids					**48**						**3.3J**			
Rinella et al., 1992 (USGS)														
Yakima at Umtanum	**65**	17.8							<u>**3.1**</u>	<u>**2.7**</u>				
Yakima at Parker	**280**	**47**							ND	ND				
Yakima at Kiona	**542**	**231**							<u>**14**</u>	<u>**8.6**</u>				
EPA, 1987														
Yakima nr Horn Rapids					**63.6**						**5.3**			
Johnson et al, 1986 (DOE)														
Yakima at Cle Elum	**90**								ND					
Yakima at Wymer (RM 135)	**150**	**60**		**190**				30	ND			ND		
Yakima at Buena	**865**	**150**		**200**					<u>**15**</u>	ND		ND		
Yakima at Kiona		**130**		**250**	**40**		**1500**			**80**	ND	**30**		**120**
Hopkins, 1985 (DOE)														
Yakima at Birchfield Dr.	**1400**		**610**	**2700**										
Yakima blw Kiona			**2000**	**2200**										

ND - Median of group of samples was calculated and found to below detection limit
<u>Underline</u> Mean includes values that are one half the quantitation limit
Bold Exceeds criteria
Fish Species Key: MWF= Mountain whitefish; LSS=Largescale sucker; BLS= Bridgelip sucker; NS= Northern squawfish; C=Carp; SMB= Smallmouth bass
CC= Channel catfish; RT= Rainbow trout

There is some indication that t-DDT burdens in fish tissues are declining, although there are not enough data to confirm this trend. Concentrations of t-DDT were highest in the 1984 Ecology study (Hopkins *et al.*, 1985) where none of the results exceeded FDA standards, but all were far above the Washington screening value of 32 µg/kg. Samples analyzed by Ecology, USEPA, and USGS from 1986 to 1990 contained about ten times less t-DDT than the 1984 samples. However, no further reductions have been observed, and most samples continue to exceed the Washington human health screening level. The t-DDT concentrations in the small mouth bass and carp samples collected in 1995 from the Yakima River at Euclid exceeded the screening guideline by an order of magnitude. The bass sample had a higher concentration than bass previously analyzed in the lower basin, and the carp sample was at the higher end of the range of values observed.

Dieldrin concentrations in muscle tissues also continue to exceed human health guidelines, although it is less frequently detected than t-DDT (Table 11). Dieldrin was detected in the bass and carp samples collected in 1995 at concentrations similar to Kiona and Horn Rapids samples collected in the 1990s. All of these concentrations exceeded the 0.7 µg/kg screening guideline by an order of magnitude.

In the USGS NAWQA study, heptachlor epoxide and total chlordane were also detected above human health guidelines in samples from the Yakima River at Kiona. Hexachlorbenzene was also detected but was below the criterion. Total chlordane was detected below the guideline in a sample from the Yakima River at Parker. In the 1995 carp sample, the 15 µg/kg total chlordane concentration exceeded the human health screening level of 8.3 µg/kg. Total PCBs (polychlorinated biphenyls) in both the carp and bass also exceeded the screening guideline for human health risk. Other pesticides detected, but below guideline concentrations were: heptachlor expoxide, hexachlorobenzene, and trifluralin.

Continued presence of DDT and other pesticides in fish at concentrations exceeding human health guidelines reinforce the need for limiting transport of pesticides into the aquatic environment. Once pesticides are in the biotic community, all that can be done is to issue health advisories to prevent consumption of contaminated fish. The 1993 Washington State Department of Health advisory to limit consumption of bottom fish is a direct result of DDT contamination in the basin (Department of Health, 1993).

Summary of Pesticides in Whole Fish

Whole fish from the Yakima River Basin have been analyzed for pesticides since the early 1970s (Appendix 3). Contaminant tissue burdens from whole fish are commonly used to compare to guidelines for protecting wildlife. As previously mentioned, guidelines for concentrations of organochlorine pesticides in whole fish for the protection of fish predators are summarized in Table 8. Concentrations of t-DDT and dieldrin have been the most frequently detected. Concentrations of t-DDT and dieldrin generally increase from upstream to downstream (Figure 18). Resident species tended to have higher tissue burdens than anadromous species (Johnson *et al.*, 1986).

From 1970 to 1984, the USFWS analyzed pesticides in whole fish from the Yakima River at Granger. Based on these data, the USGS (Rinella *et al.,* 1992a) reported that concentrations of total DDT in fish were decreasing. Concentrations appeared to be consistently below the NAS guideline of 1,000 µg/kg. However, t-DDT in fish collected in 1989-90 by USGS, and fish collected by Ecology in 1990, 1992, and 1995 found that fish from many reaches of the project area still have tissue burdens exceeding the NAS guideline (Figure 19). The three largescale sucker composite samples collected from the Yakima River at Euclid in 1995 contained from 2,276 µg/kg to 3,728 µg/kg t-DDT (Davis, in preparation). Nearly all concentrations observed to

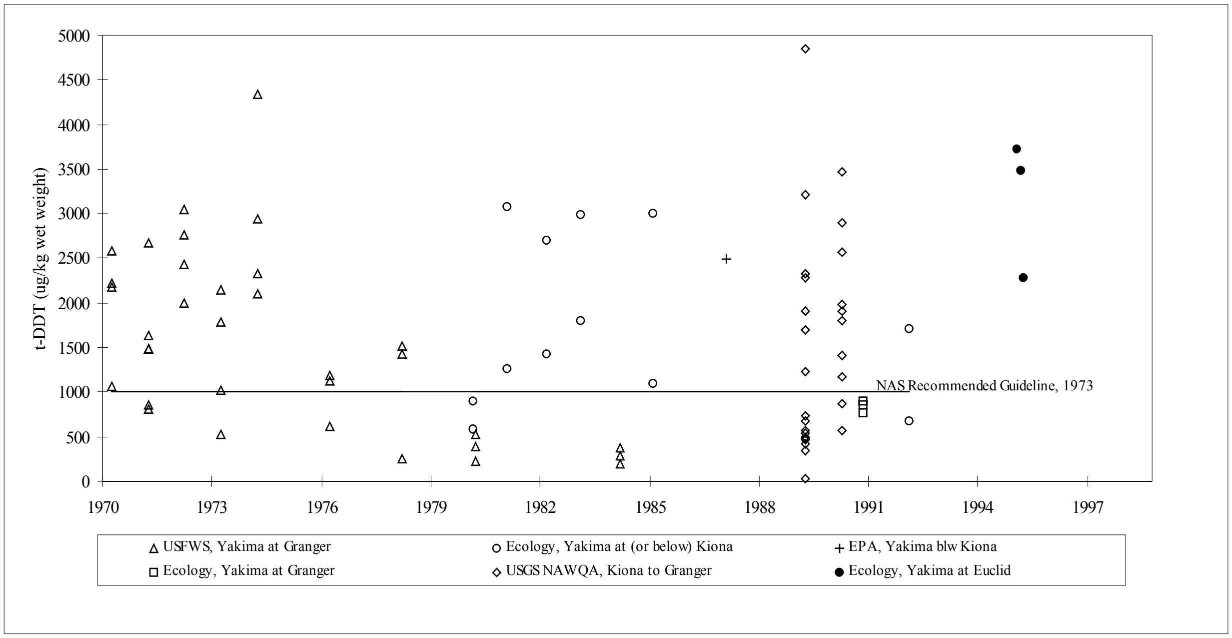


Figure 18. T-DDT in whole fish in the lower main stem Yakima River, 1970 - 1995.

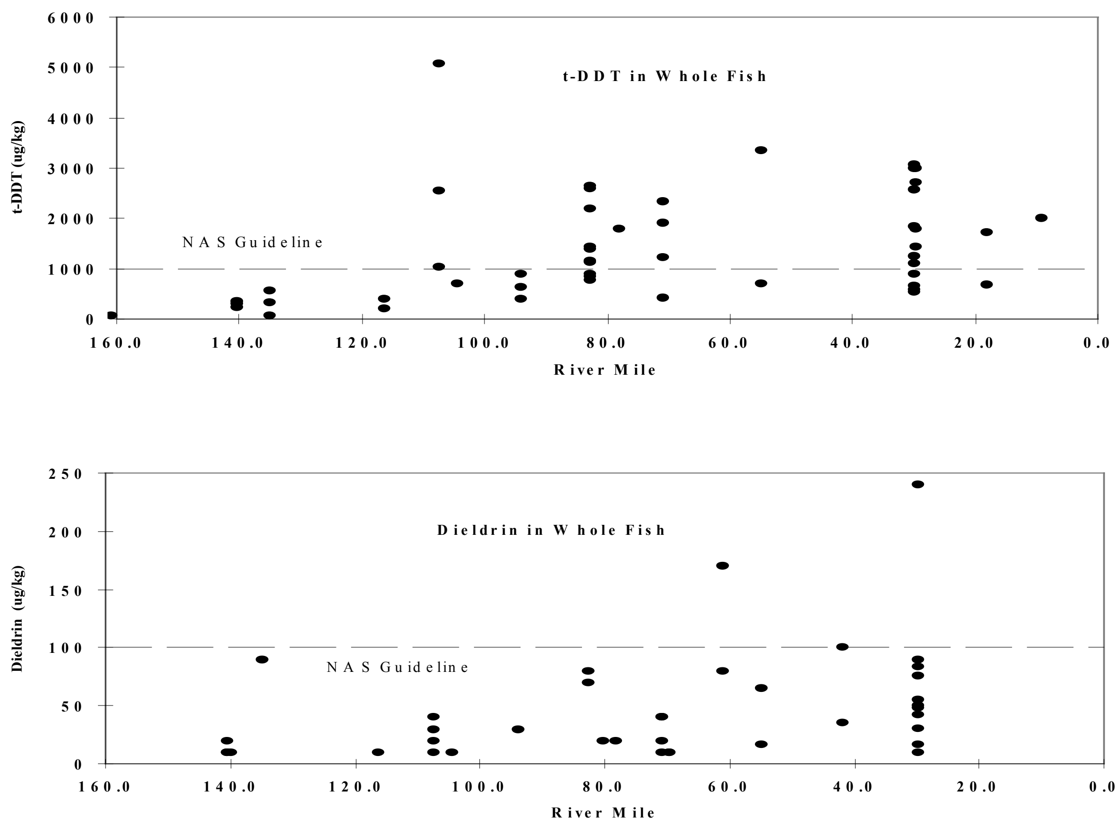


Figure 19. Concentrations of t-DDT and dieldrin (ug/kg) in whole fish samples collected from the lower Yakima River basin, 1970 - 1992

date have exceeded the New York guidelines of 200 µg/kg to 270 µg/kg. Dieldrin and total PCB concentrations in the 1995 samples also exceeded the New York guidelines to protect wildlife populations from carcinogenic risks. These data indicate that pisciverous wildlife are still likely at risk from exposure to t-DDT, dieldrin and other pesticides. Therefore periodic monitoring of whole fish tissue should continue.

Total Maximum Daily Load Component

Total Maximum Daily Loads (TMDLs)

Section 303(d) of the federal Clean Water Act requires states to identify water bodies where technology based controls have been insufficient to meet, or are not expected to meet, applicable water quality standards or support beneficial uses. The TMDL is a mechanism for establishing water quality-based controls on all point and nonpoint sources of pollutants within these water bodies. The TMDL evaluation uses monitoring data and water quality models to estimate the pollutant load that a water body can receive and continue to meet water quality standards. This loading capacity is then apportioned among all point sources through waste load allocations (WLAs), and among nonpoint and background sources through load allocations (LAs). The TMDL and allocations can be expressed in units of mass per time, as toxicity, or other appropriate measures [40 CFR 130.2(I)]. The TMDL is defined by USEPA as the sum of all WLAs, LAs, and any margin of safety. The margin of safety can incorporate future growth options, or data and modeling uncertainty.

The WLAs and LAs are achieved through discharge permits, and by implementing control and education activities outlined in watershed or subbasin management plans. Where a large nonpoint source load allocation is included in the TMDL, as in the lower Yakima River study area, or where data contain a high degree of uncertainty, a phased TMDL approach is appropriate (USEPA, 1991). Ecology plans to refine the LA targets and schedules of the phased TMDL at five-year intervals as:

- control measures are implemented, and the effectiveness of those measures are monitored and evaluated, and
- more data are evaluated that lead to decreasing the level of uncertainty about the sources and extent of the pollution problem.

All aspects of the TMDL evaluation, including the WLA and LA assumptions and recommendations, involve participation from dischargers and the public. Local initiative and participation in the TMDL process are especially important when decisions on management plans and control measures are made.

In summary, Ecology has determined the key points of a phased TMDL as:

1. Defining the beneficial uses affected
2. Determining the factor/causes of use impairment
3. Determining the pollutant reduction targets and source control priorities
4. Developing the most effective pollution controls and identifying resources
5. Monitoring the results of implementation
6. Adjusting the controls
7. Involving the public in all steps of the TMDL process

The following discussion addresses the first three points of the lower Yakima River TMDL, and also contains recommendations for point five, TMDL implementation monitoring.

Beneficial Uses Affected

Suspended sediment, turbidity, and pesticides were mentioned as causing impairments to domestic water supply, primary and secondary contact recreation, aesthetic enjoyment, and fish and wildlife support in the Yakima Valley Conference of Governments' (1995) *Yakima River Basin Water Quality Plan*. The 1993 Washington State Department of Health advisory to limit consumption of bottom fish is a direct result of DDT contamination in the basin. This TMDL report compared USEPA and fishery resource literature citations to suspended sediments and turbidity levels in Yakima River study area to document likely impairments of aquatic communities, especially salmonid health and habitat. Excessive TSS and turbidity caused by poor irrigation practices upstream can also impair the use of water for irrigation downstream.

Spawning, migration, rearing of salmonids

The spawning, migration, and rearing of salmonids is a beneficial use that shall be supported by water quality of the lower Yakima River and the tributaries in the study area. As mentioned earlier in this report, many Yakima salmon runs are now threatened or extinct, in part, from agricultural development and agriculture-related pollution. However, the Yakima River basin also has the greatest potential for reviving Columbia River salmon stocks. Salmon are important cultural resources for Yakama and lower Columbia tribes, and are of great value to northwest economies and fishers.

General information on life-cycle schedules for each salmon species is outlined in Table 12. Figure 20 shows the distribution of spring and fall chinook in the basin (a reach is highlighted if the species occupies that segment during any stage of their life history). Spawning spring chinook are found as far down as Union Gap, but most spawning occurs in the upper basins (Yakima Valley Council of Governments, 1995; Confederated Tribes and Bands of the Yakama Indian Nation *et al.*, 1990). Emergent and juvenile spring chinook that do not smolt as sub-yearlings, over-winter along the main stem of the mid- and lower basin, and migrate out in the spring (Confederated Tribes and Bands of the Yakama Indian Nation *et al.*, 1990).. Fall chinook enter the basin in September, and are present exclusively in the lower basin from the Sunnyside

Valley Diversion Dam to the mouth of the river (Confederated Tribes and Bands of the Yakama Indian
Nation *et al.*, 1990). Summer steelhead utilize much of the Yakima Basin. Juvenile steelhead occupy the Naches River and the lower Yakima tributaries year around (Figure 21). Summer chinook were once present in the lower river during the irrigation season.

Table 12. Activity schedule for salmon found in the lower Yakima River basin.

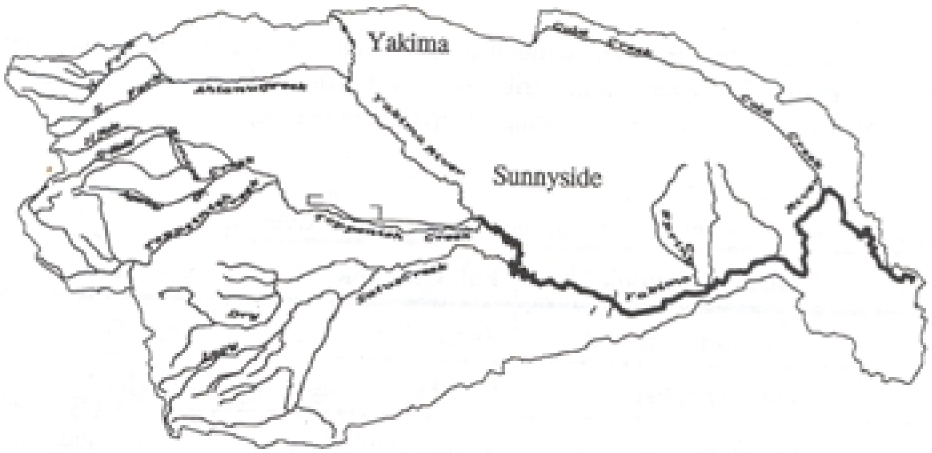
Activity	Spring Chinook	Fall Chinook	Steelhead
Migration	late April - late July	September -November	Sept.-Dec; Feb -June
Spawning	July - October	October - November	March - May
Rearing	rear in main stem all year	spring, smolt as sub-yearlings	rear in tributaries for 1+ years
Out-migration	March - late June	February - June	April - mid June

Elevated TSS reduce water quality by affecting salmon stocks in many ways. For example, adult salmon returning to the upper Yakima River and Naches River need lower turbidities and suspended sediment concentrations in the lower Yakima River to pass to spawning areas early in the irrigation season. Juvenile spring chinook require good water clarity for proper feeding, growth, and establishing territory in rearing areas late in the irrigation season, and early in the season as they out-migrate. If TSS concentrations and turbidities are too high, juveniles will avoid those areas and crowd into areas with better water quality. Fall chinook and summer steelhead require clean spawning gravel in the lower main stem, or in lower basin tributaries. Juvenile summer steelhead need good water clarity in the main stem and tributaries for the same reasons as the chinook. If stocks of summer chinook are reintroduced into the lower Yakima, their health and survival will depend, in part, on lower turbidities and sedimentation.

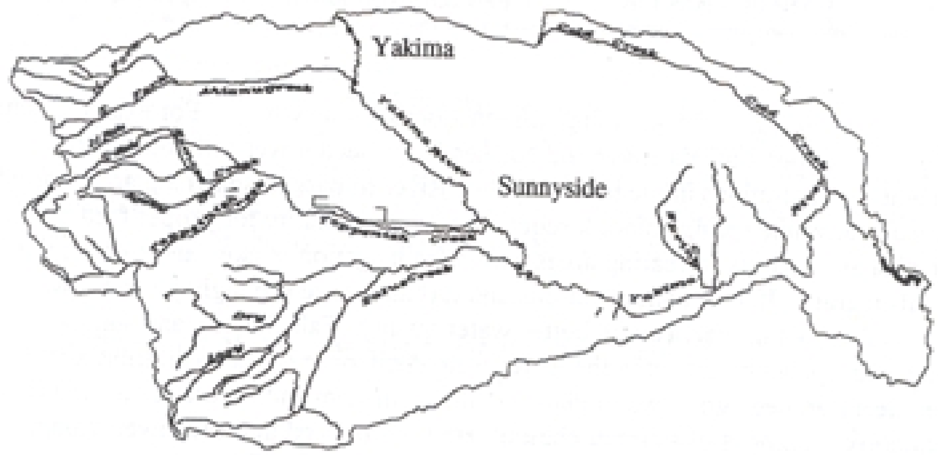
Recreation

Sport fishing is another beneficial use that occurs in the lower main stem Yakima River that has been affected by poor water quality. Highly turbid water interferes with the effectiveness of fishing lures, and reduces the populations of many fish species. As mentioned earlier, turbidities as low as 10 NTU over extended periods can reduce sport fishing and fish growth. Due to high DDT levels found in Yakima River bottom fish, the Washington State Department of Health issued an advisory recommending that people eat fewer bottom fish, including mountain whitefish, bridgelip sucker, and common carp (Washington State Department of Health, 1993). As was earlier discussed, the area of concern was identified as the Yakima River mouth at the Columbia River upstream to the city of Yakima. A potential warm water fishery is also limited by poor habitat and poor water quality in rearing areas caused by excessive turbidities and TSS concentrations.

Fall Chinook



Spring Chinook



Chinook (Species Unknown)

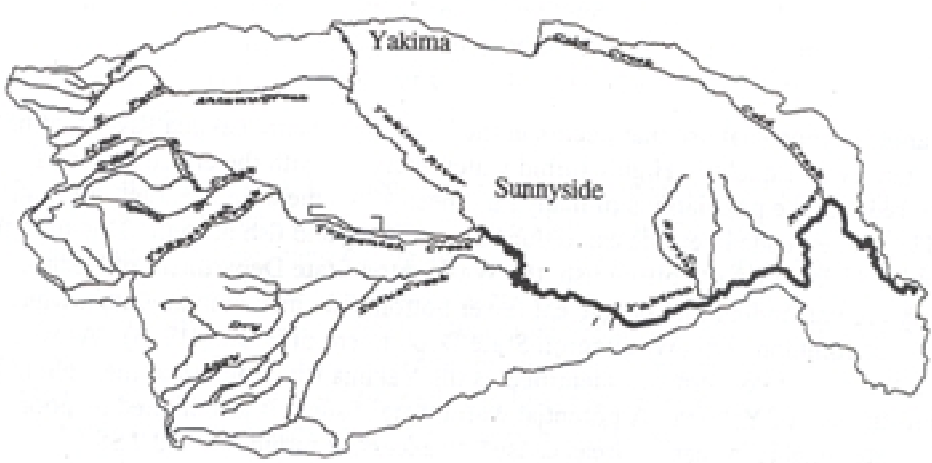


Figure 20. Distribution of chinook salmon in the lower Yakima River basin.

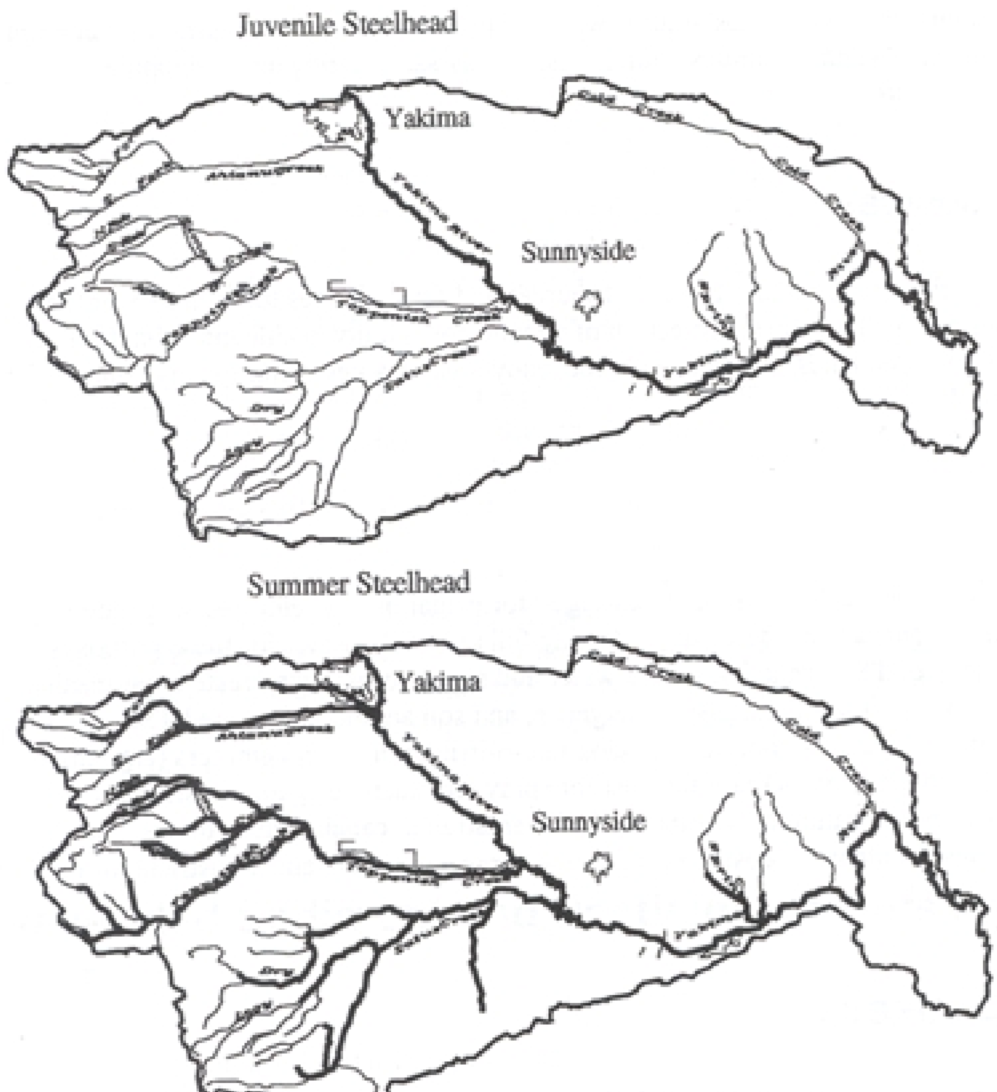


Figure 21. Distribution of steelhead in the lower Yakima River basin.

Boating and swimming opportunities in the lower Yakima River and its tributaries also are limited by poor water quality. High turbidities reduce visibility for safe boating and swimming, and reduce the water's aesthetic appeal.

Cultural resources

Salmon and other fish are important cultural resources and food sources for members of the Yakama Indian Nation. Therefore, protection of aquatic community health and habitat on the reservation and on ceded lands, which include the study area, is a key water quality concern for the Yakama People.

Irrigation

Although the lower Yakima River is highly managed for irrigation use, elevated suspended sediment concentrations can interfere with obtaining full use of the water for these purposes. High concentrations of TSS carried in source water and supply canals can create impermeable crusts that reduce water infiltration, plant emergence, and soil aeration. Elevated TSS concentration can damage spray nozzles and clog micro-irrigation system emitters (e.g., drip, trickle, sprayer, or fogger), or increase the cost for spray and micro-irrigation systems by requiring extensive pre-filtration or treatment. Sedimentation in canals, return drains, and reservoirs increases maintenance costs to irrigation or drainage improvement districts for dredging and vegetation control.

Factors/Causes

During the irrigation season, 50% to 75% of the incoming water into the lower valley is diverted for irrigation and power generation. The water in many irrigation return drains and tributaries is highly turbid, and quickly degrades the portion of the Yakima River running at reduced flows. Eroded soils from surface irrigated agricultural areas adsorb elevated concentrations of DDT and other organochlorine pesticides, nutrients, and bacteria. Erosion also occurs along banks or in riparian areas with heavy livestock use. Some soil particles settle in the return drains, but others are transported by return drains and field drains, raising the turbidity of the river. The portion of sediments carried downstream in the water column, characterized by elevated TSS and turbidity measurements, interferes with aquatic organism's feeding, oxygen exchange, homing, mating, and other behaviors. The portion of sediments that settle allows adsorbed pesticides like DDT to be available for uptake into the food chain, eventually posing a health risk to aquatic and terrestrial organisms including humans. Sedimentation where salmon spawn directly interferes with emergence and survival of fry by blocking water circulation in redds and reducing the oxygen available to developing eggs.

Erosive soils under intense cultivation, past pesticide application practices, and inadequate soil and water management practices have contributed to the TSS and DDT problems in the lower Yakima Valley. Tooley (1995) used a geographical information system (GIS) land use analysis to demonstrate that large portions of the agricultural regions of the lower Yakima study area were susceptible to soil erosion. Rinella *et al.* (1993) have documented the history and lingering problem of DDT in the Yakima River Valley. Several reports by NRCS, CD, and Cooperative Extension have demonstrated the advantages of improved water and soil conservation techniques for Yakima Valley conditions (SCS, 1978; South Yakima Conservation District, 1982; King *et al.*, 1984; North Yakima Conservation District, 1993).

Economic factors and water policy also have played a role in reducing incentives to practice better soil and water conservation techniques (Pfeiffer and Whittlesey, 1976; Dawson and Domka, 1987; Meuer, 1992). Lack of regulatory standards and a low agricultural community recognition of the TSS problems have delayed implementation of solutions.

Point sources and non-agricultural nonpoint sources appear to have insignificant roles in the TSS and DDT water quality problems during the irrigation season. Data evaluations in this TMDL study suggest that municipal wastewater treatment plants and industrial discharges are not significant sources of turbidity, TSS, and DDT. Timber and range activities, urban run-off and other nonpoint sources may be more significant sources of TSS and turbidity during other seasons when precipitation is a driver.

Suspended Sediment and Pesticide Targets and Goals

Since suspended sediment and DDT are two of the most significant pollutants in the Yakima River Basin, it is necessary to set nonpoint source reduction targets through load allocations in the study area. Data from this TMDL evaluation have demonstrated that reduction targets for TSS can be established based on Washington State water quality criteria despite the lack of a specific TSS criterion. Three approaches are used to determine TSS and DDT targets and nonpoint source load allocations for the Yakima River and its tributaries in the study area:

1. ***Turbidity criterion*** -Using the correlation of TSS concentrations to turbidity values, TSS targets on the main stem Yakima River will be based on the turbidity standard of 5 NTU above background.
2. ***Fisheries (aquatic biota) support*** - Using the narrative criteria to protect aquatic life, a 25 NTU turbidity or 56 mg/L TSS target will apply 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 t-DDT, long-term TSS reduction goals will be 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 to the aquatic life criterion is made.

Each of these approaches and their application are discussed in detail below.

Turibidity Criterion

Suspended sediment can be addressed through the state turbidity criterion because of a strong correlation found between turbidity and TSS in the lower Yakima River Basin. Using 1994 and 1995 monitoring data generated in this TMDL evaluation, a regression was developed of turbidity as a function of TSS (Figure 22). The details of the relationship are discussed in Appendix 2. Briefly, the best 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:

$$\log_{10} \text{Turbidity} = 0.871 * \log_{10} \text{TSS} - 0.145$$

The equation had a coefficient of determination (r^2) of 0.956, which means 96% of the data variability is explained by the TSS data. Data from various source water (e.g., main stem, canals, return drains, and tributaries) were not significantly different enough to exclude from grouping. A better TSS to turbidity relationship may have been obtained than previous research because a ratio turbidimeter was used, and because the geographic and seasonal scope of the data was more focused.

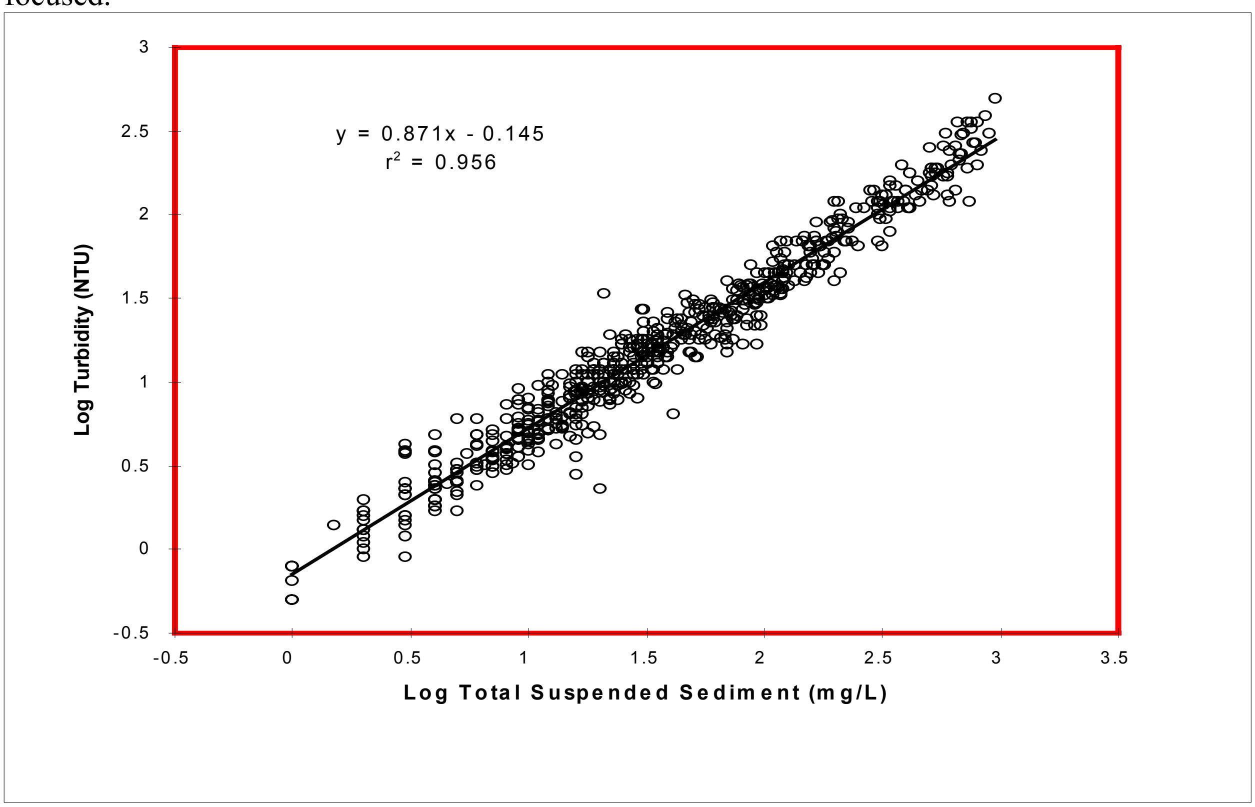


Figure 22. TSS and turbidity regression developed using TMDL data collected 1994 and 1995.

As stated earlier, Washington's turbidity water quality criteria for Class A waters [WAC 173-201A-030(2)(vi)] are:

> "turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background is more than 50 NTU."

Under the TMDL recommendation, the 5 NTU criterion will be applied to the main stem Yakima River between the confluence of the Naches and Yakima Rivers (RM 116.3) and the Kiona gage at Benton City (RM 29.9) during the irrigation season. In a sense, most of the lower Yakima River basin irrigation project will then be treated as a single source of turbidity and TSS. The application of the state turbidity criterion in this way addresses the cumulative effect from multiple irrigation return discharges. Water quality under the Clean Water Act should be met if the cumulative effect of suspended sediment loads are limited to less than a 5 NTU turbidity increase. The state narrative criteria for protection of sensitive biota is also relevant. It is fairly obvious that water quality would be degraded and beneficial uses would be lost if background were defined as upgradient from each discharge, and if a 5 NTU increase were allowed for each irrigation return in the study area.

The confluence is the most logical control site for measuring the effect of irrigation return drains in the study area because few return drains or sources of consequence enter the lower basin above that point. Although the TSS and turbidity effects in the lower valley occur with greatest intensity between the SVID diversion at Parker (RM 103.7) and Kiona (RM 29.9), diversions, tributaries, return drains, and point sources between the confluence and Parker have a measurable effect during the irrigation season and require control. The Kiona gage is a logical compliance point at this time because it is positioned below a majority of the irrigation returns, and because it continues to be a significant monitoring site for several agencies and programs. Detailed recommendations for other monitoring points between these two sites, and general monitoring guidelines are provided later (see Monitoring Results/Adjusting Controls).

Table 13 outlines the results of this approach for 1994 and 1995 data. As the table indicates, the TSS concentrations in both years would have required reductions of approximately 50% at Kiona.

Table 13. TSS targets for the mainstem Yakima River at Kiona based on the Washington State turbidity criterion, and a regression equation relating turbidity to TSS. Background established at confluence of Naches and Yakima Rivers.

Year	Background Turbidity	Background + 5 NTU	TSS Goal Yakima at Kiona*	90th% TSS Yakima at Kiona	Percent TSS Reduction Needed
1994	5 NTU	10 NTU	20 mg/L	39 mg/L	49%
1995	9 NTU	14 NTU	29 mg/L	62 mg/L	53%

* Calculated as $\log_{10}$ turbidity= 0.871($\log_{10}$ TSS) - 0.145

There was a slight variation between years. In years of low water availability and use, like 1994, storm-generated background values, and agriculture-generated turbidity and suspended sediment concentrations tend to be lower. Under these conditions, the TSS reductions needed to meet the turbidity target in the river in some subbasins may be also lower. However, as 1994 data suggested, main stem turbidity levels may peak upstream of the Kiona gage during lower flow years (Figure 10). The 5 NTU criterion would apply to all points in the main stem between the control and compliance sites.

The irrigation season 90th percentile turbidity value calculated for the confluence of the Naches and Yakima River was used as the background control value. The 90 th percentile turbidity was used because it allows for background seasonal variability while still fully supporting uses under USEPA policy (USEPA, 1995), and it is adequate for background definition under Ecology policy (Ecology, 1994c; Ecology, 1996). Background turbidity was based on data from Yakima at Terrace Heights for 1994 (5 NTU) and the flow-weighted average data from Yakima at Harrison Bridge and the Naches River for 1995 (9 NTU). The TSS concentrations at these 90th percentile turbidity values are 9 mg/L and 18 mg/L, respectively. The background values for 1994 and 1995 are below the 25 NTU criterion suggested earlier, and at the lower end of the range that could potentially harm aquatic life (see *Turbidity and TSS Criteria*).

As previously shown in Figure 12, the 1994 and 1995 TSS concentrations were not unusually low compared to past years. However, years that had high water events in March through May (or catastrophic events like the May 1980 eruption of Mt. St. Helens), and six or less sampling points yielded 90th percentile TSS concentrations unacceptably high as background controls. The TSS concentrations at the higher end of this range are usually still reasonably protective for most aquatic life uses since they are from short duration events during the early part of the season. To avoid this type of problem, future monitoring at control and target sites should be performed at the frequency and interval described later (see Monitoring Results/Adjusting Controls).

Fisheries (Aquatic Biota) Support

Tributaries in the study area provide habitat for fish, especially salmon species: Spring Creek and Snipes Creek. Other tributaries, such as Ahtanum Creek, Moxee Drain, Granger Drain and Sulphur Creek, have historically supported fisheries, and require varying levels of restoration. They also discharge to reaches of the main stem with important fish habitat (Figure 20 & 21). Since TSS and turbidities at many return drains and tributaries are constantly discharged at elevated concentrations over the entire 200 days of the irrigation season, TSS reduction targets shall be established in the TMDL to protect aquatic organisms from the chronic effects (*i.e.,* injury or death from long periods of exposure) of suspended sediment.

As discussed earlier, the scientific literature has documented that turbidities and TSS concentrations become detrimental, or lethal, to aquatic life at varying concentrations, depending upon the species of organism, and the duration of exposure (see *Turbidity and TSS Criteria*). A TMDL target of 25 NTU (or 56 mg/L TSS based on the turbidity/TSS regression) for the mouths of tributaries and return drains was chosen as the most appropriate initial action for the following reasons:

- avoids most chronic effects of suspended sediment to aquatic organisms, (e.g., reduced fish growth from poor sight feeding, habitat avoidance, and effects on territorial behavior),
- located at the mid-point of the turbidity range for achieving a moderate fishery that sustains most habitat requirements,
- consistent with technical data used to develop a Idaho's cold water fishery criterion,
- will substantially reduce sediment loading from key tributaries to salmon spawning and aquatic habitat areas on the main stem Yakima River
- will assist in compliance with the main stem turbidity target of not more than a 5 NTU increase over background,
- evidence that it will be an achievable target using conventional soil and water conservation practices for irrigated agriculture, and
- practical for compliance monitoring.

Total suspended solids load targets were not set for project area tributaries and drains because water availability is so variable. A critical discharge condition on which a load could be calculated could not be confidently established. Tributary loading targets may be an optional TMDL compliance measure as soil and water conservation practices are implemented, and the effectiveness of the practices is observed. It may be that a tributary where implementation has reduced overall TSS loads substantially will be allowed an allowance for more frequent excursions of the concentration target.

The 25 NTU target will be applied to the 90th percentile turbidity value of the irrigation season to measure compliance with the TMDL. In this way, only ten percent of the turbidities should exceed the target over the irrigation season, and the average turbidity should be below 25 NTU, which would provide better protection to aquatic life.

In Table 14, estimated TSS reductions for each tributary in the TMDL project area are shown using the 1994 and 1995 data sets. The percent TSS reduction required to meet the TMDL was calculated by comparing the 25 NTU target to the 90th percentile TSS concentrations for each year. Those tributaries which would have required TSS reduction, and are likely candidates for future TMDL compliance monitoring, are highlighted. Tributaries and drains with 1994 or 1995 turbidities lower than 25 NTUs will be monitored as part of the TMDL, and will be expected to remain lower than 25 NTUs.

Most tributaries generally would have required less TSS reduction in 1994 than in 1995 to meet the TMDL target. It may be because of the lower water availability and better water conservation practices in 1994. However, Moxee Drain appeared to have responded to different influences. At Moxee, the lower TSS reduction required for 1995 may have been related to efforts by NYCD and hop growers to convert from furrow to drip irrigation. The next few years of monitoring by NYCD should indicate whether the conversions make significant water quality improvements, or if the difference between the two years was just a reflection of data variability.

Table 14. TSS targets for the tributaries and drains of the Yakima River project area based on support of fisheries compared to data collected in 1994 and 1995. Highlighted sources failed to meet target, and estimated reductions have been calculated.

			90th % TSS		Percent Reduction Needed	
Tributary	Turbidity Goal	TSS Goal	1994	1995	1994	1995
WideHollow Cr.	25 NTU	56	10		0%	
Ahtanum Cr.	25 NTU	56	6		0%	
Moxee Drain	25 NTU	56	343	285	84%	80%
Granger Drain	25 NTU	56	408	748	86%	93%
DID #7	25 NTU	56	23		0%	
Sulphur Creek	25 NTU	56	57	215	2%	74%
Grandview Drain	25 NTU	56	75		25%	
Spring Creek	25 NTU	56	45	299	0%	81%
Snipes Creek	25 NTU	56	10	64	0%	13%

The TSS reductions required for Spring Creek and Sulphur Creek to meet the TMDL target changed dramatically from 1994 to 1995. In 1994, Spring Creek was in compliance with the target, and Sulphur Creek would have been only about 2% over the target. Both subbasins are heavily influenced by returns from the Roza Irrigation District that received less than half of its normal water allocation in 1994. In response, all districts urged their growers to exercise extra water conservation efforts. In contrast, both subbasins would have needed over 70% in TSS reductions to meet the turbidity target in 1995, an average year for water availability when conservation measures were relaxed. Moxee and Granger were the only two subbasins monitored in both years that would have required at least an 80% TSS reduction in each year. Consequently, both should be given a high priority for implementing erosion controls.

TSS load reductions stated in Table 14 may be underestimated. The average turbidity of individual drains may need to be in the range of 6 to 14 NTU to meet the 25 NTU target value. The daily variability, calculated on the lognormal distribution of TSS and turbidities collected at individual sites in 1995, can be expressed as a coefficient of variation (CV). For example, a site with a high CV will require a lower seasonal average turbidity to ensure the 90th percentile turbidity meets the 25 NTU target value. As measures are introduced by growers in subbasins to reduced TSS concentrations, the variability in seasonal turbidities may drop (*i.e.,* the data may yield a lower CV). Subbasin drain TSS concentrations with a lower CV may then be able to maintain a higher average turbidity value with less risk of the 90th percentile exceeding the TMDL target.

The 1995 TSS mass balance for the study area was recalculated after reducing the TSS loads from the five “overloaded” tributaries identified in Table 14 to meet the target concentration. The cumulative effect of the load reductions on the river would have been substantial. Had the five tributaries met the 25 NTU turbidity target, the TSS load to the Yakima River would have been reduced by approximately 207 tons/day. For example, the daily average load from Moxee Drain would have been reduced from 31 tons/day to 5 tons/day. In the reach from Parker to Kiona, the cumulative contribution to the river from Granger Drain, Sulphur Creek, Spring Creek and Snipes Creek would have been reduced from 213 tons/day to 32 tons/day (Figure 23). These four tributaries would have accounted for 9% of the TSS load to the reach instead of 37%.

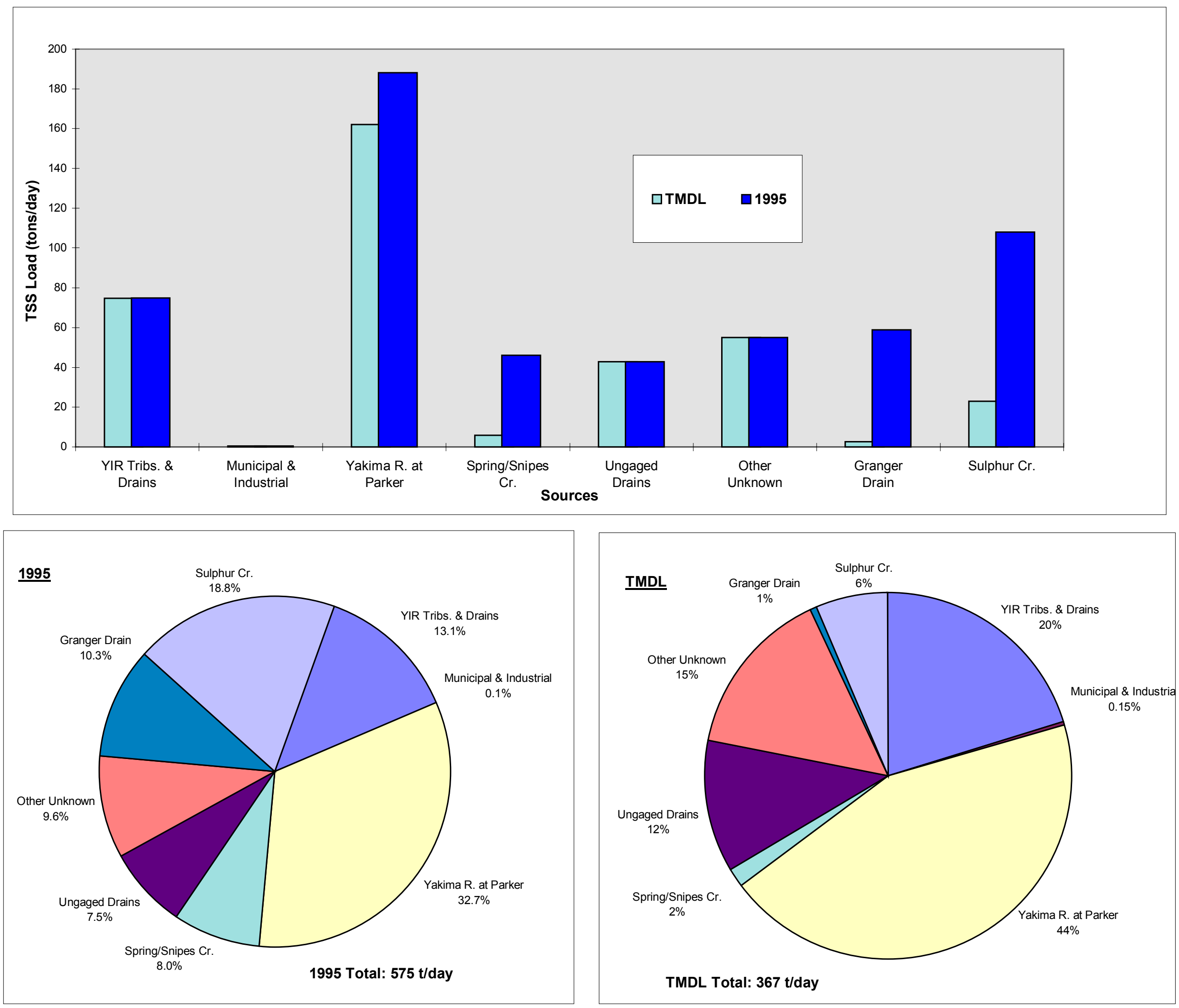


Figure 23. 1995 TSS loads from tributaries in the Parker to Kiona reach of the lower Yakima River compared to loads with TMDL project area tributaries at recommended targets of 25 NTU turbidity or 56 mg/L TSS.

A series of simple computer modeling simulations was performed as another measure of the potential effect of the tributary and drain TMDL targets on main stem turbidities and TSS concentrations. Twelve tributary TSS loads to the Yakima River between East Toppenish Drain (RM 86) and Prosser (RM 47) were used in the model. Simulations were run using the USEPA model, SMPTOX3, with qualitative sedimentation rates estimated from 1988 and 1995 data. A variety of instream flow and sedimentation conditions were used to assess main stem response while tributary loads were set at 90th percentile critical loading situations (Appendix 4, Table 4A; Appendix 4, Figures 4A-4B).

Base simulations were run for the following conditions:

1. May - June high flow (3320 cfs) in the river at Parker, low river sedimentation rates, and 90th percentile TSS loading from gaged and Reservation tributaries.
2. July - October low flow (420 cfs) in the river at Parker, high sedimentation rates, and 90th percentile TSS loading from gaged and Reservation tributaries.
3. July - October low flow (420 cfs) in the river at Parker, low sedimentation rates, and 90th percentile TSS loading from gaged and Reservation tributaries.

For each of these base simulations, another simulation was run with the 25 NTU target imposed on Granger Drain and Sulphur Creek (Appendix 4, Figures 4C-4E). These two drains represented 64% of the combined tributary TSS load in the May-June period and, 77% of the July-October loading period. TSS loads from eight tributaries from the Yakama Reservation were not changed. Two tributaries from the TMDL project area with 90th percentile TSS concentrations below the 56 mg/L (25 NTU) target in 1995 were not changed either. Also, the background TSS concentration in the river (22- 23 mg/L) was kept consistent with 1995 data.

The simulations suggest the 25 NTU target at the mouths of Granger Drain and Sulphur Creek is adequate to maintain the main stem TMDL turbidity target below 5 NTU over background under most, but not all, irrigation season conditions represented in 1995 (e.g., a main stem turbidity in 1995 less than 14 NTU or 29 mg/L TSS). The combined TSS tributary load was reduced by 50% in the May-June scenario, and 64% in the July-October scenario. Under lower river flow conditions with normal sedimentation rates, the turbidity target will be met. This appears to be the most common hydrologic condition in the river in July through October.

However, if sedimentation rates are too low, then instream turbidities may rise to unacceptable levels. Other sources will need limits to meet the main stem turbidity target during this type of critical condition. For example, the river under high flow conditions in April to June may have enough dilution to assimilate the reduced tributary loads from Granger Drain. But, the cumulative loading from all drains and tributaries upstream of Sulphur Creek, combined with high retention of sediments in the water column, will cause main stem turbidities to exceed the target (Appendix 4, Figure 4C). This situation could also happen at lower flow conditions. If fine silts and clays dominated the suspended sediment discharged by the drains and tributaries, they could resist settling (Appendix 4, Figure 4E).

The model simulations reveal that TSS load reductions will be necessary in most return drains below Union Gap to meet the main stem TMDL target during some critical conditions, especially. in the reach upstream of Sulphur Creek. An agreement will need to be negotiated with the Yakama Indian Nation and USEPA to provide for adequate protection of the main stem through Reservation tributary load reductions. If project area and reservation loads can be reduced, simulations suggest that main stem target turbidities will be met more often during the higher flow periods of the irrigation season (Figure 24a). In addition, fewer areas may exceed the target during lower flow periods with low sedimentation rates (Figure 24b)

Other controls will be needed. The ungaged and unknown sources in the critical reach between Parker and Prosser during higher flow conditions, which were not modeled in the simulation, could also periodically bring turbidities over the target. Moxee Drain and other upstream sources will need to be controlled so background TSS concentrations for the Parker to Prosser reach are kept at a minimum. Return drains and tributaries that had low turbidities in 1994 and 1995 will be expected to remain below the target. Lower instream turbidities, and a better margin of safety against exceeding the turbidity criterion may be possible when TSS loads from ungaged drains on both sides of the river are placed under control. Unknown sources of TSS will need identification and reduction. However, complete reduction during higher flows may not be feasible if the TSS source is instream resuspension.

Once suspended sediment transport to the main stem Yakima River is controlled, it will be necessary to protect water quality within the subbasins. tributaries will be expected to meet the 25 NTU target at all points within their system to protect aquatic resources. An implementation strategy for each subbasin will be established through coordination with local resource agencies and the Yakima River Enhancement Project.

Pesticides Criteria

State water quality standards and USEPA guidelines provide chronic and acute criteria for DDT and other toxic substances to protect aquatic life (Chapter 173-201A-040 WAC; USEPA, 1986). The USGS demonstrated that DDT and suspended sediment concentrations in the Yakima River basin were highly related (Rinella *et al.* 1992a; Rinella *et al.*, 1993). Using 1995 monitoring data generated in this TMDL evaluation and previous USGS and Ecology data, a regression was developed of t-DDT (t-DDT = DDD+DDE+DDT) as a function of TSS (Figure 25).

The details of the relationship are discussed in Appendix 2. Briefly, the best linear regression equation based on 71 data pairs from river and tributary sites with detectable t-DDT concentrations (expressed as nanograms per liter, or ng/L) was obtained after logarithmic transformation (base 10) of the data:

$$\log_{10} \text{t-DDT} = 0.953 * \log_{10} \text{TSS} - 0.820$$

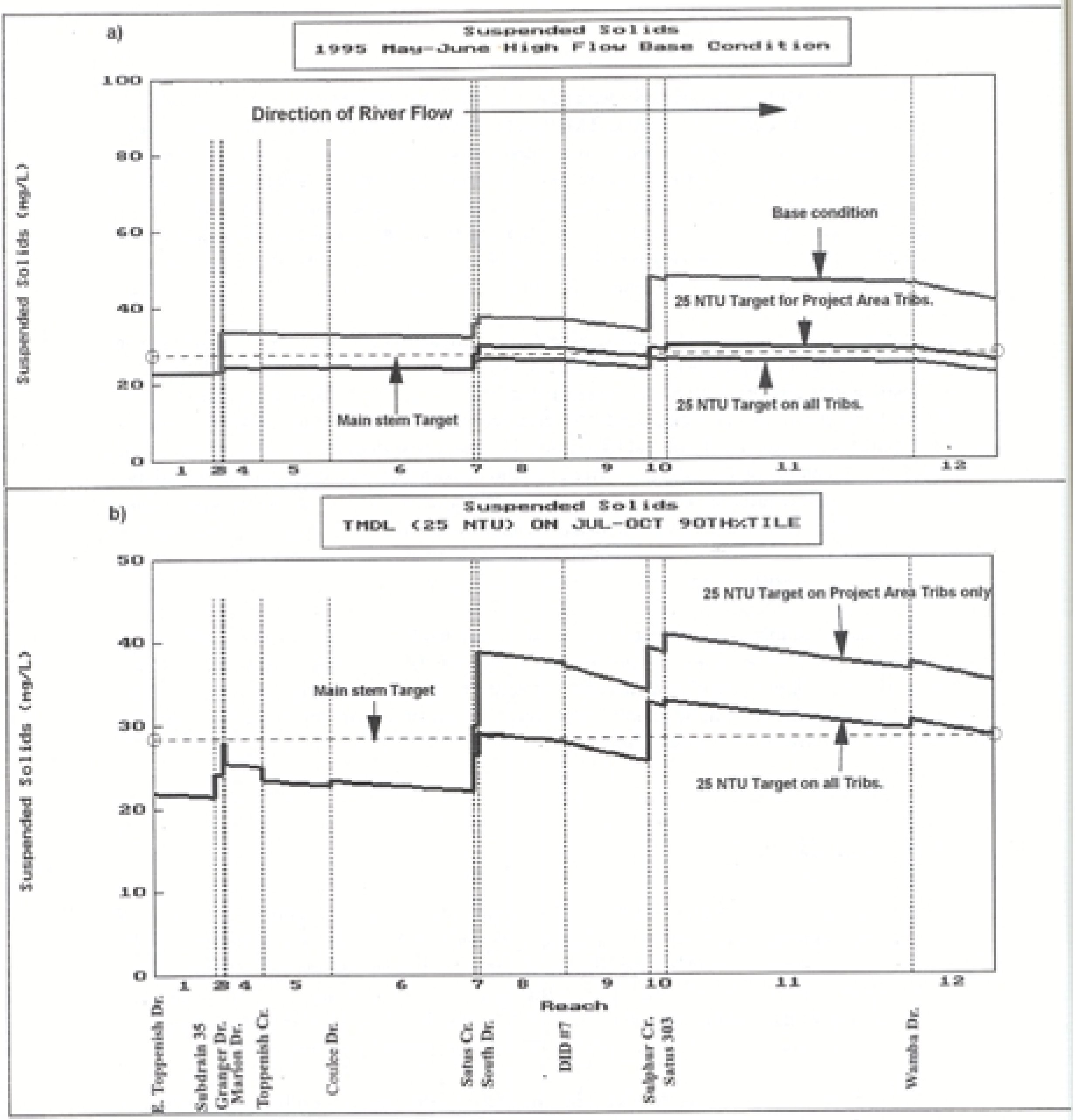


Figure 24. SMPTOX3 model simulations of TSS concentrations in the lower Yakima River main stem: a) May-June high base flow conditions, comparing main stem effects of TMDL targets placed on project tributaries and placed on all tributaries; b) July-October low sedimentation and low main stem flow conditions, comparing same implementation alternatives as example a.

The equation had a coefficient of determination (r^2) of 0.747. Data collected in 1995 were not significantly different from previously collected data (Appendix 2, Table 2A), and tributary data were not significantly different from main stem data, so all data were grouped.

Given the strong association between t-DDT and TSS concentrations, it is possible to establish TSS limits in the TMDL to prevent the further transport and presence of t-DDT in the lower Yakima River basin. TSS concentrations and loads in Yakima basin waters can be reduced by controlling erosion of agricultural soils, some of which still contain high concentrations of t-DDT (Rinella *et al.*, 1993). As difficult as erosion control may seem, the DDT already in the water, benthic sediment, and aquatic biota cannot be controlled as easily.

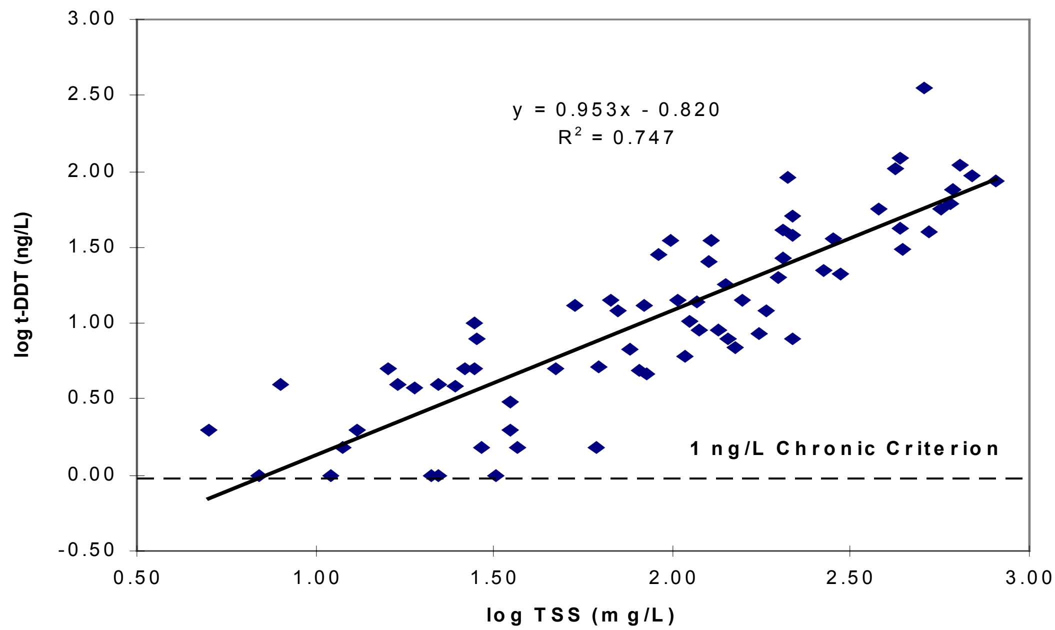


Figure 25. Regression of t-DDT as a function of TSS for water samples collected from the lower Yakima River basin canals, tributaries, drains and main stem river.

Table 15 outlines necessary reductions in TSS at various drain, tributary, and main stem sites to meet the freshwater chronic toxicity t-DDT criterion of 1 ng/L for the TMDL. The estimated TSS target of 7 mg/L was calculated from the previously mentioned regression equation for 1 ng/L t-DDT. Estimated tributary and drain TSS reductions are calculated from the ratio of the 7 mg/L goal to the 1994 and 1995 90th percentile TSS concentrations. Nearly all sites monitored in 1994 or 1995 will require a substantial reduction of TSS to meet the target.

Table 15. Estimated TSS reductions at tributary and main stem sites based on 1994 and 1995 TSS data collected during the TMDL evaluation. Reductions are based on meeting the 7 mg/L TSS goal that relates to the t-DDT chronic criterion to protect aquatic life.

Tributary	Chronic t-DDT Criterion	TSS Goal*	90th % TSS 1994	90th % TSS 1995	Percent Reduction Needed 1994	Percent Reduction Needed 1995
WideHollow	1 ng/L	7	10		30%	
Ahtanum	1 ng/L	7	6		0%	
Moxee	1 ng/L	7	343	285	98%	98%
Granger	1 ng/L	7	408	748	98%	99%
DID7	1 ng/L	7	23		69%	
Sulphur	1 ng/L	7	57	215	88%	97%
Grandview	1 ng/L	7	75		91%	
Spring	1 ng/L	7	45	299	84%	98%
Snipes	1 ng/L	7	10	64	30%	89%
Yakima R. at Kior	1 ng/L	7	39	62	82%	89%
Yakima R. at Eucl	1 ng/L	7	43	62	84%	89%

* $\log_{10}$ t-DDT = 0.953 ($\log_{10}$ TSS) - 0.820

SMPTOX3 was used to estimate the effect reduced tributary DDT loads would have on main stem DDT concentrations if the TMDL were in place (Figure 26). Simulations were calibrated to data from a June 1989 USGS monitoring survey (Rinella *et al.*, 1992b). As with the turbidity TMDL simulations, TSS and DDT concentrations in Granger Drain and Sulphur Creek were reduced to meet the TMDL targets. The two drains represented approximately 75% of the DDT load delivered to the modeled river reach.

Main stem t-DDT concentrations should experience significant reductions as tributaries comply with the 25 NTU turbidity TMDL target. Based on the regression equation, the turbidity-related TMDL target of 56 mg/L TSS at mouths of drains could reduce t-DDT concentrations to 7 ng/L. That would substantially (66%) reduce t-DDT loading to the Yakima River from Granger Drain and Sulphur Creek (Figure 26).

However, the simulation results suggest the 1 ng/L DDT chronic aquatic toxicity criterion target might not be attained in the river, even if the TSS concentrations in the two drains were reduced to the 7 mg/L TSS TMDL goal (Figure 26). Some additional progress toward the TMDL goal would be made if the USEPA and Yakama Indian Nation also implemented controls for Yakama Reservation tributary and drain loads. Ungaged sources on both sides of the river would also require control. However, as all tributary and drain loads are reduced, the simulation data suggest that background t-DDT residuals carried in the river from upstream or in resuspended sediment become the dominant sources of t-DDT in the lower Yakima River. These sources are more difficult to predict and control, and could likely prevent complete TMDL compliance in the main stem.

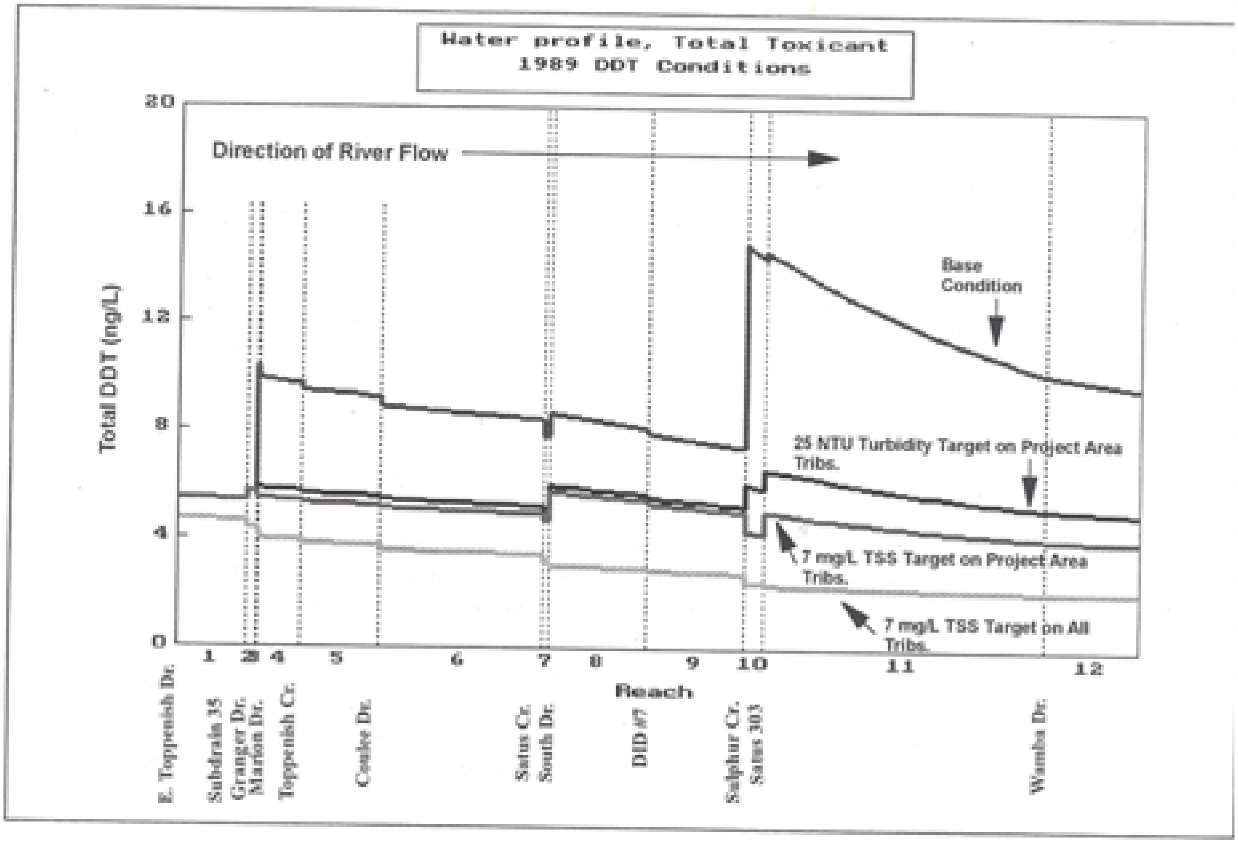


Figure 26. SMPTOX3 model simulation results for total DDT concentrations in the lower Yakima River. Water column DDT reductions from various total maximum daily load (TMDL) scenarios are compared to base conditions. Scenarios include: Project area tributaries meeting 25 NTU target compliance to protect aquatic organisms from the effects of TSS; Project area or all tributaries meeting a 7 mg/L TSS target to meet the chonic aquatic toxicity criterion for DDT based on a TMDL regression equation (see text).

On the other hand, the SMPTOX model simulations do not account for some important factors. First, the 95% confidence interval around the regression estimate for the TSS/DDT concentration goal is fairly broad: 3 mg/L to 41 mg/L TSS at 1 ng/L t-DDT. The TSS to t-DDT regression developed from data collected to date shows a greater variability in the lower region of the regression where TSS concentrations are less than 70 mg/L (Figure 25). DDT data are lacking for the lower TSS concentration range. Therefore, as more DDT samples are collected from return drains and tributaries as they approach compliance with the interim turbidity TMDL target of 25 NTU (56 mg/L TSS), the regression can be re-calculated. A more definitive relationship between relatively low levels of TSS and t-DDT may then be available. The TMDL goal can be evaluated along with the new data to better set the long-term TSS goals for eliminating DDT contamination in the basin.

Second, the additional DDT data from tributaries will also help to better define the coefficient of variability in order to estimate acceptable mean TSS targets with a low risk of their 90^{th} percentile concentrations exceeding the DDT criterion. Evaluating land use and other factors related to past use of DDT may also increase the understanding of the transport and fate of DDT in the lower Yakima basin, and bring about a more selective criterion for DDT reduction in some subbasins. For example, some soil types, pesticide application practices, crops, and cultivation practices may influence the amount of t-DDT archived in subbasin soils.

Finally, the rate at which DDT is lost from the Yakima basin once it is in the aquatic system is not well understood. As water-eroded soil is eliminated as a source of DDT to the canals, tributaries, and river, the DDT in the aquatic sediments may be flushed at a rate that reduces instream background concentrations. On the other hand, DDT may continue to be transported to the river by wind erosion, or it may continue to be recycled through the biological community with little net improvement in instream background concentrations.

When the relationship of t-DDT to lower concentrations of TSS is better understood, the ultimate goal for the basin is to achieve the DDT human health criterion, the most stringent among the DDT criteria. Using the Washington State human health DDT criterion under the National Toxics Rule of 0.59 ng/L, and the regression relationship of t-DDT and TSS from present data, the TSS goal would be 4 mg/L. A human health criterion for DDT calculated on CRITFC (1994) fish consumption rates of native peoples (0.064 ng/L DDT) would yield a TSS goal of less than 1 mg/L. Developing a TMDL to these levels of protection will require better definition of t-DDT movement through the physical (e.g., soil, sediment, and water) and biological (e.g., producer, consumer, and decomposer) systems of the Yakima River basin. Although successful implementation of this TMDL will drastically reduce t-DDT transport to the river, controls other than TSS alone may be necessary to reduce fish tissue concentrations to acceptable levels.

TMDL Priorities and Schedule

Evaluations of historical and TMDL study data have identified specific targets for suspended sediment and t-DDT reductions in the lower Yakima River basin. The ability to reduce these contaminants to acceptable levels depends upon the implementation of control measures. Resources for implementation are limited and so sources must be placed in some priority order.

To some degree, the problem areas in the lower Yakima River project are have also been the highest priorities in the past:

- **Moxee Drain**,
- **Granger Drain**, and
- **Sulphur Creek** subbasins.

The North and South Yakima Conservation Districts, the Cooperative Extension Service, and NRCS (formerly the SCS) have targeted monitoring, education, and assistance programs to growers and/or dairies in these areas over the last 25 years. Some of their efforts have improved water quality, but not to the degree necessary to protect aquatic life and human health. Ecology will need to support further on-farm control and education efforts to accelerate TSS reductions in these subbasins by working with growers, irrigation districts, and resource conservation agencies through local basin committees. In addition, Benton Conservation District has initiated work in **Spring Creek**, which should be further supported.

Ecology will need to negotiate an agreement with the Yakama Indian Nation and USEPA to reach a load allocation for Yakama Reservation (YIR) subbasins. As was demonstrated in the model simulations, YIR tributaries and drains will need TSS load reductions to ensure water quality in the main stem is improved between Parker and Kiona. An extension of the cooperative monitoring agreement between the Yakama Nation and Ecology in 1995 would also lay the foundation for assessing TSS from ungaged drains on both sides of the river. An agreement between all parties is necessary for effective water quality management in the Yakima basin.

The TMDL process allows a phased-approach to occur with scheduling of target load or concentration reductions over several years. The effectiveness of subbasin water quality management groups will be assessed at regular intervals. Targets can be adjusted through the TMDL public process if changes are recommended from the data assessment. The scheduling of targets and TMDL-related activities are proposed as follows:

5 years (2002)

- Yakima River main stem 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 gage at Benton City (RM 30).
- All drains and tributaries within the project area will comply with the 90^{th} percentile turbidity target of 25 NTU at their mouths, especially Moxee Drain, Granger Drain, Sulphur Creek, and Spring Creek.
- The efficacy of using TSS load targets for tributaries and drains where the 25 NTU target is not representative of total load reductions will be evaluated.
- Agreements between the State of Washington, Yakama Indian Nation, and the U.S. Environmental Protection Agency that sets load allocations for the Yakama Reservation, and management of basin water quality will be completed.

10 years (2007)

- The mouths of all tributaries and drains, and all points within all basin tributaries and drains will comply with the 90^{th} 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 to meet the DDT human health criteria in fish and water will be developed.
- Yakima River main stem will comply with the turbidity target of not more than a 5 NTU increase between the confluence of the Yakima and Naches Rivers and the Van Geisan Road bridge at West Richland (RM 8.4).

15 years (2012)

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

20 years (2017)

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

The TMDL-related activities include re-evaluation work and further target development. These are necessary components of the phased TMDL approach. The effectiveness of control measures implemented to reduce soil erosion in irrigated agricultural areas is fairly well understood. However, the availability of grant or loan resources, local economic factors related to crop production, and legal/political factors concerning water rights and jurisdiction will determine the actual rate at which the public will implement control measures. Ecology will need to commit resources to work closely with the public to ensure targets are accomplished through a balance of education, loans/grants, coordination, and enforcement.

Monitoring

Monitoring is a required component of the TMDL process. Monitoring allows direct evidence of target compliance or control measure effectiveness. It also can provide the data necessary to modify or adjust targets in specific situations. The TMDL schedule contains elements requiring monitoring for both compliance, and target re-evaluation and development

Turbidity and TSS monitoring will be necessary to check progress with the turbidity criterion compliance along the main stem Yakima River. Compliance monitoring will require establishing a background turbidity site, and at least one compliance check point at the Kiona gage at Benton City (RM 29.9). We recommend establishment of three more sites to ensure turbidity compliance within the reach: 1) the abandoned Parker railroad trestle below the Sunnyside Dam (RM 103.7); 2) a site between the mouths of Granger Drain and Toppenish Creek (approximately RM 81), and 3) Euclid bridge (RM 55). Monitoring at the first two of the three should be done in cooperation with the Yakama Indian Nation.

Monitoring can be done in either of two ways to establish the background value:

1. Monitor the Yakima River at Harrison bridge and the Naches River at Twin Bridges, and calculate the theoretical mixed TSS and turbidity
2. Monitor the Yakima River below the confluence at the Terrace Heights bridge (RM 113.2).

The first solution provides an estimate of the turbidity and TSS above most return drains and TSS sources in the study area. It requires two sets of samples, and a calculation based on conservative assumptions (*i.e.,* the TSS and turbidity measured at these two points does not appreciably change to the confluence). The second solution includes bias from the Roza Power Return on the left bank, and a few small industrial and irrigation returns between the confluence and the Terrace Heights bridge.

The TMDL monitoring and evaluation concluded that most TSS effects from irrigated agriculture are observed by RM 29.9, the Kiona gage at Benton City. However, West Richland at Van Giesan bridge (RM 8.4) could be an alternative compliance site since it would place controls on the entire lower main stem except for the Kennewick Irrigation District return via the Amon Wasteway (RM 2.1). Sampling at West Richland is recommended as progress is made upstream of Benton City. Data can be used to ensure the water quality improvement are transferred downstream by the year 2006. Amon Wasteway should be monitored as part of the assessment. If it is considered a significant TSS input, it should be placed under the same reduction schedule as the returns and tributaries upstream.

Drains and tributaries should be monitored at locations used for the TMDL evaluation unless more appropriate sites are chosen. Tributaries and drains should be sampled for TSS and turbidity at the same time as main stem sites. Continuous discharge monitoring stations should be established at the water quality monitoring sites. If not, instantaneous discharge measurements should be obtained at the time samples are collected.

Monitoring should be conducted every two weeks during the irrigation season (*i.e.,* usually between March 20 and October 20). This would normally provide 15 data points per site to calculate 90th percentile values for control and compliance checks. Sampling order should follow upstream to downstream. Sample timing should be roughly synchronized with discrete blocks of water by evaluating gage data or calculating river time of travel (Hubbard *et al.*, 1982).

A depth integrating sampler should be employed for sampling at main stem sites at three or more points along the cross-section. Sulphur Creek, Spring Creek, Granger Drain and Moxee Drain should also be sampled at multiple points along the site cross-section. The smaller drains require only one depth integrated grab sample. A ratio turbidimeter should be used to continue to check the TSS to turbidity relationship.

Pesticide samples should continue to be collected in conjunction with turbidity and TSS samples, especially in the priority drains and tributaries as turbidity and TSS levels are reduced. Main stem sample collection should continue as well. Historically, the peak concentrations of t-DDT and other organochlorine pesticides occur in June and July, so samples should be collected at that time. Analytical quantification limits must be at or below the chronic aquatic life criteria for the DDT metabolites and dieldrin.

Monitoring of organophosphorus pesticides detected in this report should continue to document any further water quality problems related to their use. Sampling periods should occur during periods of application to crops.

Several agencies conduct water quality and land use monitoring in the lower Yakima basin. Monitoring resources need to be coordinated so that data collected by other agencies and groups are useful to the TMDL effort and vice versa. Ecology should support efforts to coordinate monitoring, and be a key participant in developing data quality standards, data storage and exchanges, geographical information system (GIS) coverages, and cooperative monitoring agreements.

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Appendix 1: Methods and Quality Assurance Measures

In order to compare collection methods for turbidity and TSS, additional replicates were collected at 10% of the sites during 1994. This was done to determine if Ecology data could be compared to historical data. Samples can be collected as subsurface grabs in the center of the stream, the method most commonly used by Ecology, or by using a DH48 or DH76 sampler which collects an isokinetic sample that is both depth and width integrated. This latter method has been used by USGS. There has been some indication that grab samples result in significantly lower concentrations than integrated samples (Martin *et al.*, 1992).

There are also two analysis methods for determination of TSS; total non-filterable residue (EPA Method 160.2, SM 2540D, STORET parameter code 530) used by Ecology and USBR, and suspended sediment concentration determined by evaporation at 110°, used by USGS (STORET code 80154). In the EPA method, an aliquot of the total sample is analyzed; the total sample is analyzed in the USGS method. In order to determine if historical TSS data were comparable, two samples were collected at 10% of the sites with the DH48 (or DH76) sampler and glass bottles. One sample was sent to the USGS lab in Vancouver, Washington, and the other to Ecology's Manchester Lab.

Uncertainties and discrepancies in turbidity measurements have confounded inter-laboratory agreement of turbidity results from standard turbidimeters (APHA, AWWA, WEF, 1992). The Ecology Manchester Environmental Laboratory began using a ratio turbidimeter in September 1993. It was necessary to determine if Ecology turbidity results with the ratio meter could be compared to historical turbidity data.

In addition, when suspended sediment concentrations were regressed against turbidity values from a standard turbidimeter, there was a "flattening" of the curve at higher values because of excessive scattering. The end result was a poor relationship between suspended sediment concentrations and turbidity values over the range usually found in irrigation return waters.

Ratio turbidimeter appears to have a significant effect on reducing the scattering effect experienced by standard turbidimeters at higher NTUs.

Table 1A. Yakima River Phase I and II monitoring parameter methods

Parameter	Precision Limit (for field measurements) or Detection Limit (all others)	Method[1]
Field Measurements		
Velocity	± 0.05 f/s	Magnetic or propeller current meter
Temperature	± 0.2° C	Red liquid thermometer
Specific Conductivity	± 20 µmhos/cm	Conductivity bridge
pH	± 0.05 pH units	pH probe
Lab Measurements		
Total suspended solids	1 mg/L	EPA 160.2
Turbidity*	± 1 NTU	EPA 180.1
Chlorinated Pesticides or Pesticides Screen	0.01-0.1 µg/L	EPA 1618 - AED

[1]Method References:
EPA: U.S. EPA, 1983
SM: APHA, AWWA, WEF 1992
*Ratio turbidimeter

Table 1B. Summary of QA replicate pairs for 1994 and 1995

Parameter	% of Replicate Pairs with CV < 20% 1994	1995
TSS	83%	98%
Turbidity	95%	93%
Pesticides		74%

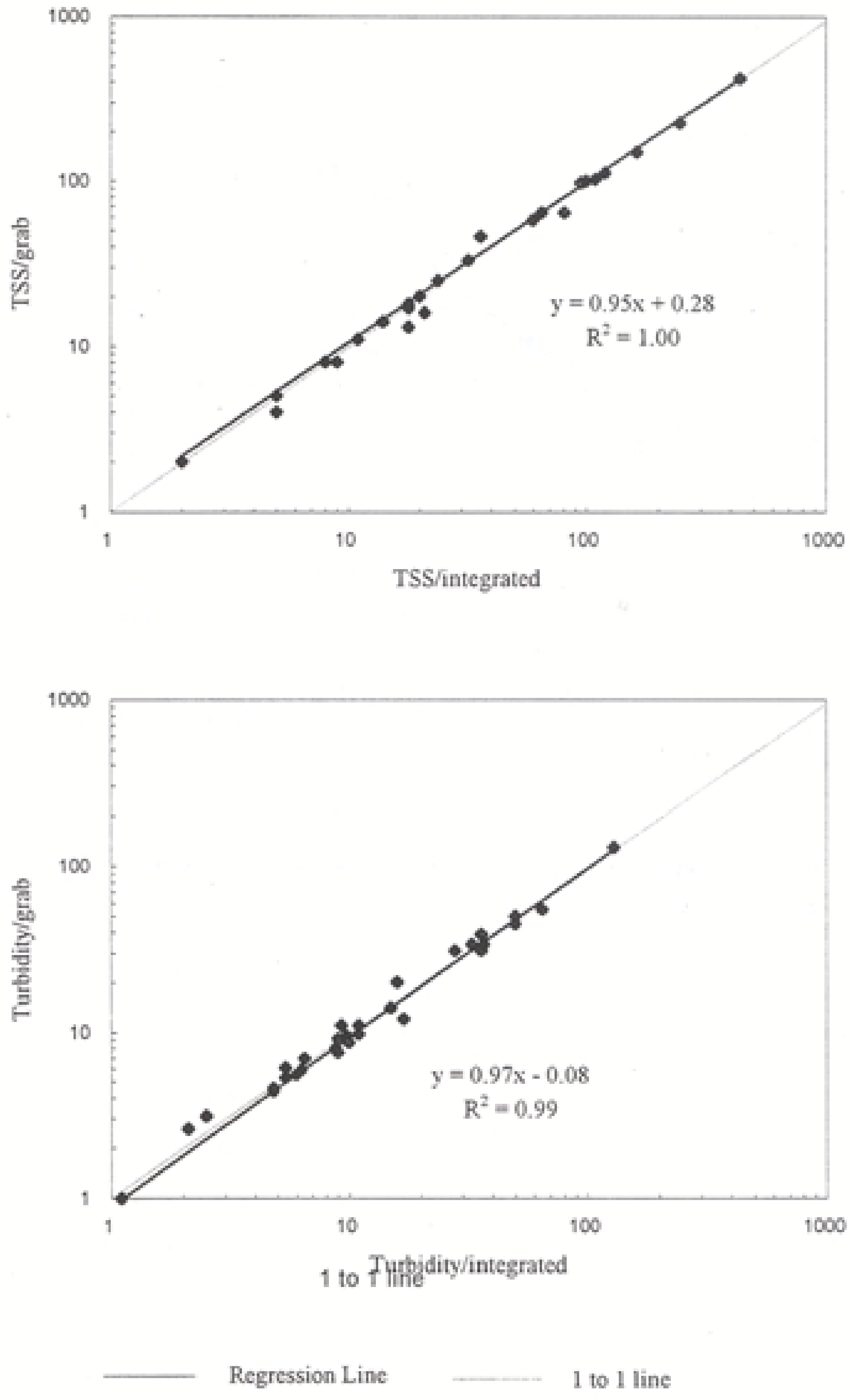

Figure 1A. Comparison of grab and integrated sampling techniques for TSS and turbidity.

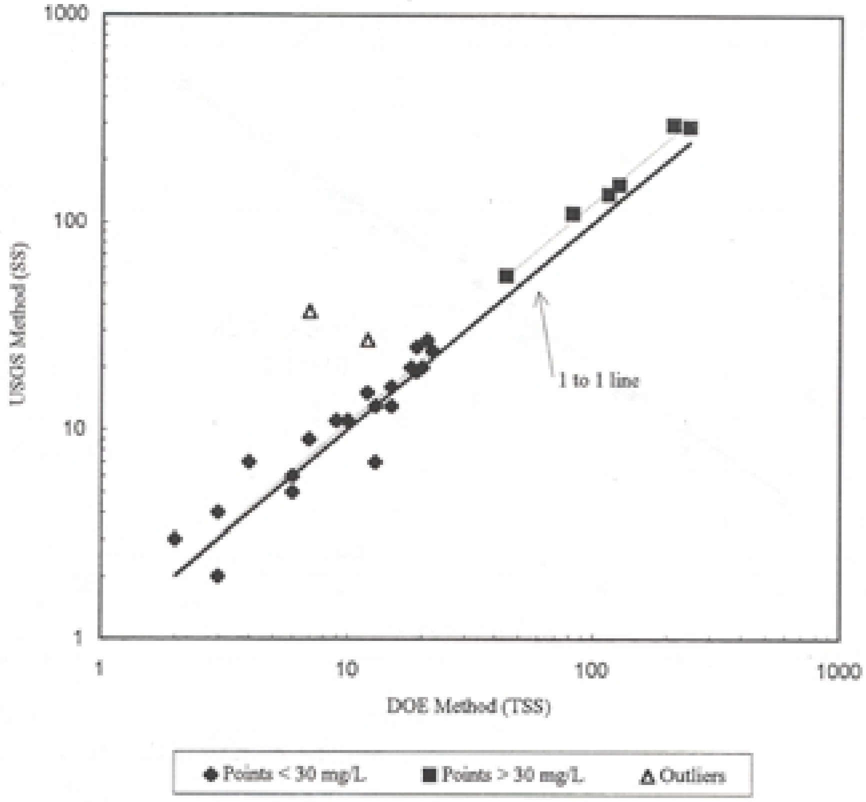

Figure 1B. Comparison of USGS suspended sediment analysis method to Ecology TSS analysis method.

Appendix 2: TSS-Turbidity Regression

In this section, the rationale and process of developing the regression equation for turbidity as a function of TSS is outlined. Table 2A provides a summary of each of the regressions discussed with their r^2 values, standard errors, and p-values.

Several studies have been conducted to establish the relationship between suspended sediment and turbidity, although each has cautioned against using the relationship outside the watershed or data set for which it was developed (Kunkle and Comer, 1971; Lloyd *et al.*, 1987). Using all 1994 and 1995 Ecology data, a regression was established of turbidity as a function of TSS specific for the Yakima Basin. The regression was analyzed with turbidity as the dependent (Y) variable since TSS influences water clarity and light scatter, turbidity. The relationship that has been established is specific to analysis methods used by Ecology. With additional data from other basins, it would be possible to determine if this relationship differed. As discussed under QA/QC, the correlation of turbidity to TSS has improved with the use of the HACH ratio turbidity meter.

To address some of the concerns expressed in the literature, regressions were developed and compared for 1994 and 1995 data, and for main stem/canal sites and drain sites. In both cases, groups were made comparable by limiting the analysis so that the maximum values of both groups were similar. All data were log transformed to satisfy assumptions of homogeneity and normality.

For the comparison of 1994 to 1995, the analysis was limited to TSS less than 600 mg/L (the maximum value in 1994). The regression lines for the two groups are significantly different (Table 2A). However, the magnitude of that difference is small (Figure 2A). For example, if the background turbidity of 9 NTU from the Yakima/Naches confluence were used, then the TSS goal would be 20 mg/L for 1994 and 17 mg/L for 1995. At 25 NTU, the 1994 TSS goal would be 61 mg/L and the 1995 goal would be 59 mg/L. The coefficients of variation of each of these pairs are 11% and 5%, respectively. These values are within the coefficient of variation range for TSS replicates.

The regression for main stem and canal sites was compared to that for drain sites. The analysis was limited to less than the maximum main stem/canal TSS value (200 mg/L). The regression lines for the two groups of data were not significantly different (Table 2A and Figure 2B).

Given the results of the above analyses, we determined that all data could be grouped to establish one regression equation. In order to satisfy assumptions of homogeneity of variance and normality, data were log transformed. To improve the linearity of the relationship, the regression analysis was limited to turbidity less than 1000 NTU and TSS less than 1000 mg/L. One 1994 site, DID #7, was eliminated from the analysis due to difficulty in establishing an appropriate sampling area and turbidity TSS pairs showing up as outliers. An additional outlier from Satus 303 was removed from the analysis because of possible laboratory or field sampling error. That TSS value corresponded poorly with both Ecology's turbidity result and the YIN turbidity result.

Table 2A. Summary of TSS and turbidity regression development.

Analysis	Transformation/ Data Subset	N	Adjusted R^2	Std Error	Coefficient p-value	Constant p-value
Turbidity/TSS	Log_{10}	682	0.946	0.147	0	0
	Log_{10}, turbidity < 1000 ntu, tss < 1000 mg/L	663	0.942	0.138	0	0
	Log_{10}, turbidity < 1000 ntu, tss < 1000 mg/L, Satus outlier and DID7 removed	646	0.956	0.120	0	0
Turbidity/TSS - 1994 vs 1995	Log_{10}, TSS < 600	622	0.952	0.117	TSS - 0 TSS*YrGrp 0.001	TSS - 0 YrGrp - 0
Turbidity/TSS - Mainstem-Canals vs Drains	Log_{10}, TSS < 200	553	0.928	0.120	0 - 1994 0.277 - 1995	0 - 1994 0.93 - 1995
YIN Turbidity/Ecology TSS	Log_{10}	96	0.698	0.274	0	0.569
	Square Root	96	0.783	1.184	0	0.002
	Square Root, w/out Satus 303 outlier	95	0.845	0.997	0	0.008

Table 2B. Summary of TSS and t-DDT regression development.

Analysis	Transformation/ Data Subset	N	Adjusted R^2	Std Error	Coefficient p-value	Constant p-value
t-DDT/TSS	Log_{10} Transformed	75	0.701	0.365	0	0
	Log_{10} Transformed, at or above DDT detection	71	0.743	0.309	0	0
t-DDT/TSS - 1995 vs previous year	Log_{10} Transformed, at or above DDT detection	71	0.754	0.302	TSS - 0 TSS*YrGrp- 0.473	TSS - 0 YrGrp - 0.350

The final regression equation was:

$$\text{Log Turbidity} = 0.871 * \text{Log TSS} - 0.145$$

In 1994, YIN drains were monitored independently by the YIN water quality staff. In 1995, YIN and Ecology monitored YIN streams side by side. A regression was analyzed of 1995 YIN turbidity to Ecology TSS (since YIN uses a different turbidimeter) so that TSS values for 1994 could be estimated for YIN sites. Although YIN and Ecology turbidity results were not one to one, a strong correlation exists between both the turbidity values and the YIN turbidity and Ecology TSS (Figure 2C & 2D). YIN turbidity and Ecology TSS data were transformed by taking the square root rather than the logarithmic values. The square root transformation provided a better linear fit to the data. One outlier from Satus 303 was removed for reasons described above. The following regression had a significant relationship ($r^2 = 0.85$):

$$\text{Sq. Root YIN Turbidity} = 0.765 * \text{Sq.Root TSS} + 0.605$$

TSS-DDT REGRESSION

Concentrations (in water) of some pesticides are highly correlated with total suspended sediment. The USGS found a strong correlation of DDT and dieldrin to suspended sediment from historical samples collected throughout the Yakima basin (Rinella *et al.* 1992a). In our 1995 sampling, DDT was again frequently detected and associated with high concentrations of suspended sediment. Dieldrin was not detected by Ecology in 1995 at the detection limit of 0.05 µg/L. Its use was gradually phased-out from 1974-1987. It appears that dieldrin may degrade more rapidly, and therefore, would not be suitable for establishing a TSS goal.

Using the USGS NAWQA data, data collected in 1993 for the Ecology's Washington State Pesticide Monitoring Program, and Ecology 1995 pesticide monitoring data from this study, a regression was developed for total DDT (t-DDT) as a function of TSS. Only detected DDT analytes were included in the sum of t-DDT. Data were log (base 10) transformed to satisfy assumptions for normality and homogeneity. The final regression equation was:

$$\log_{10} \text{t-DDT} = 0.953 * \log_{10} \text{TSS} - 0.820$$

As with the turbidity/TSS analysis, the regression equations were compared for 1995 data to data collected in previous years. The regressions were not significantly different (Table 2B & Figure 2E). Regressions were not established for individual sites because of insufficient data.

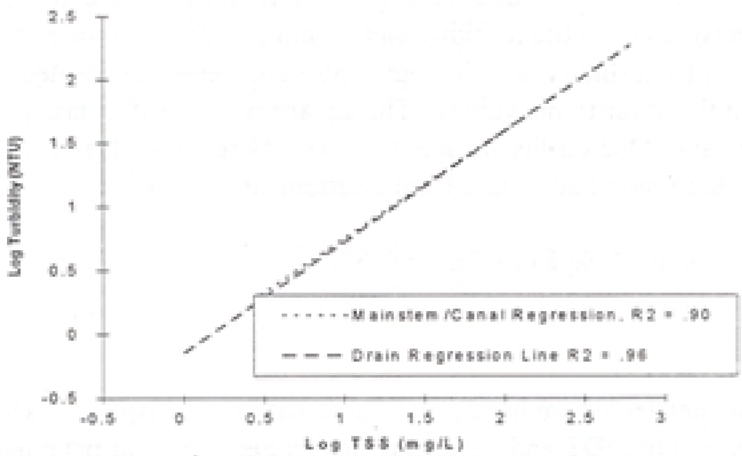

Figure 2A. Comparison of turbidity/TSS regression for main stem and canal sites t

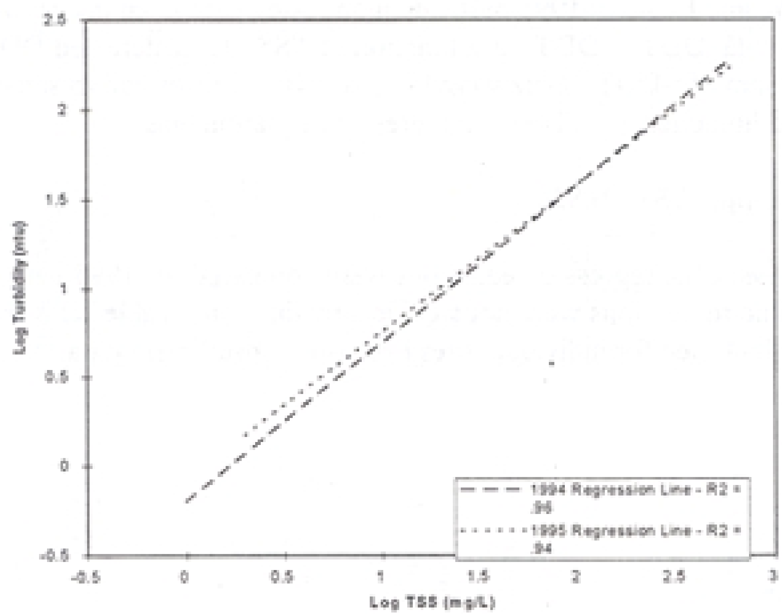

Figure 2B. Comparison of 1994 and 1995 regression lines for turbidity versus TSS.

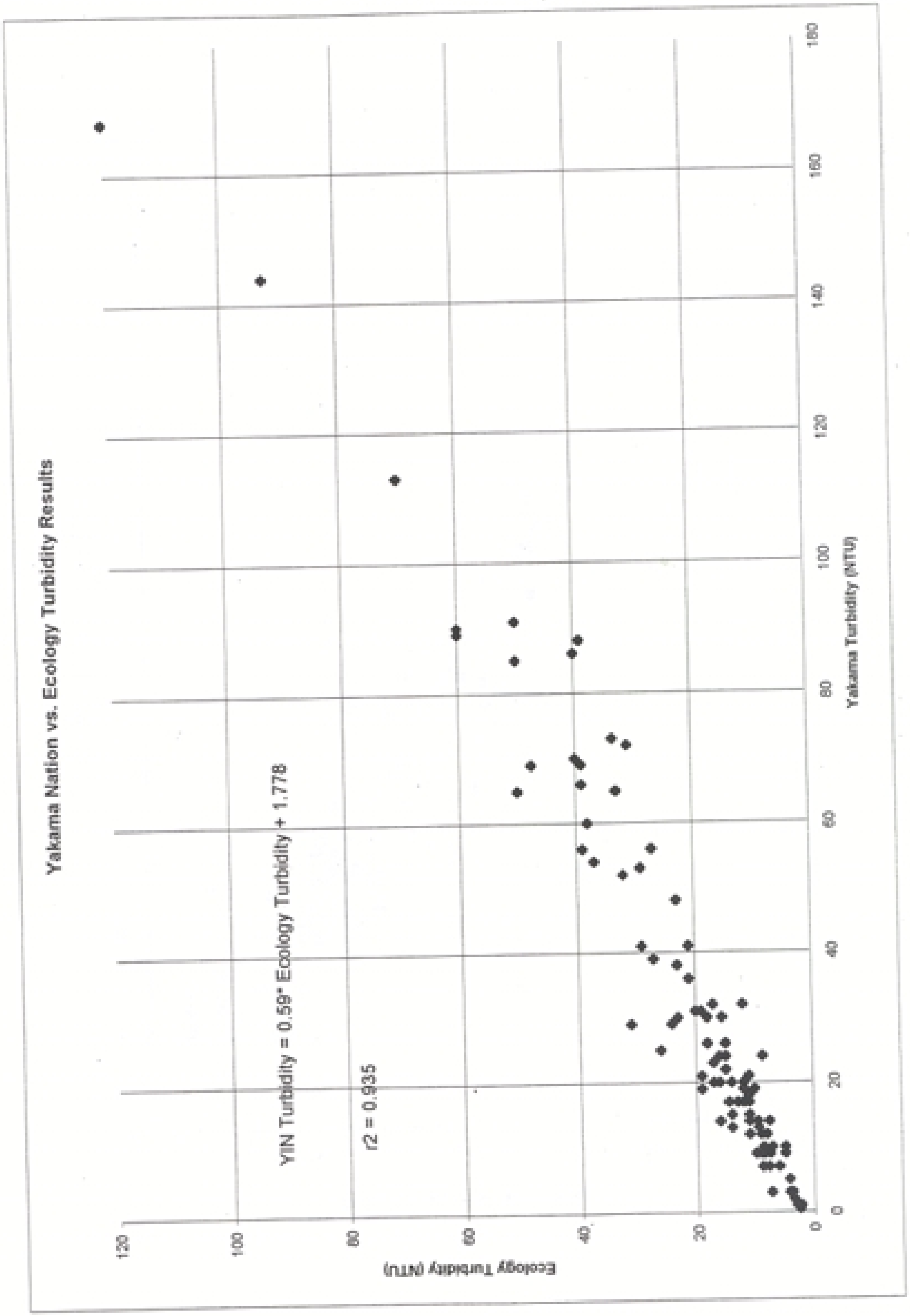

Figure 2C. Regression showing the relationship between Washington State Department of Ecology laboratory turbidity measurements (ratio turbidimeter) and Yakama Indian Nation Environmental Protection Program turbidity measurements (field turbidimeter), 1995.

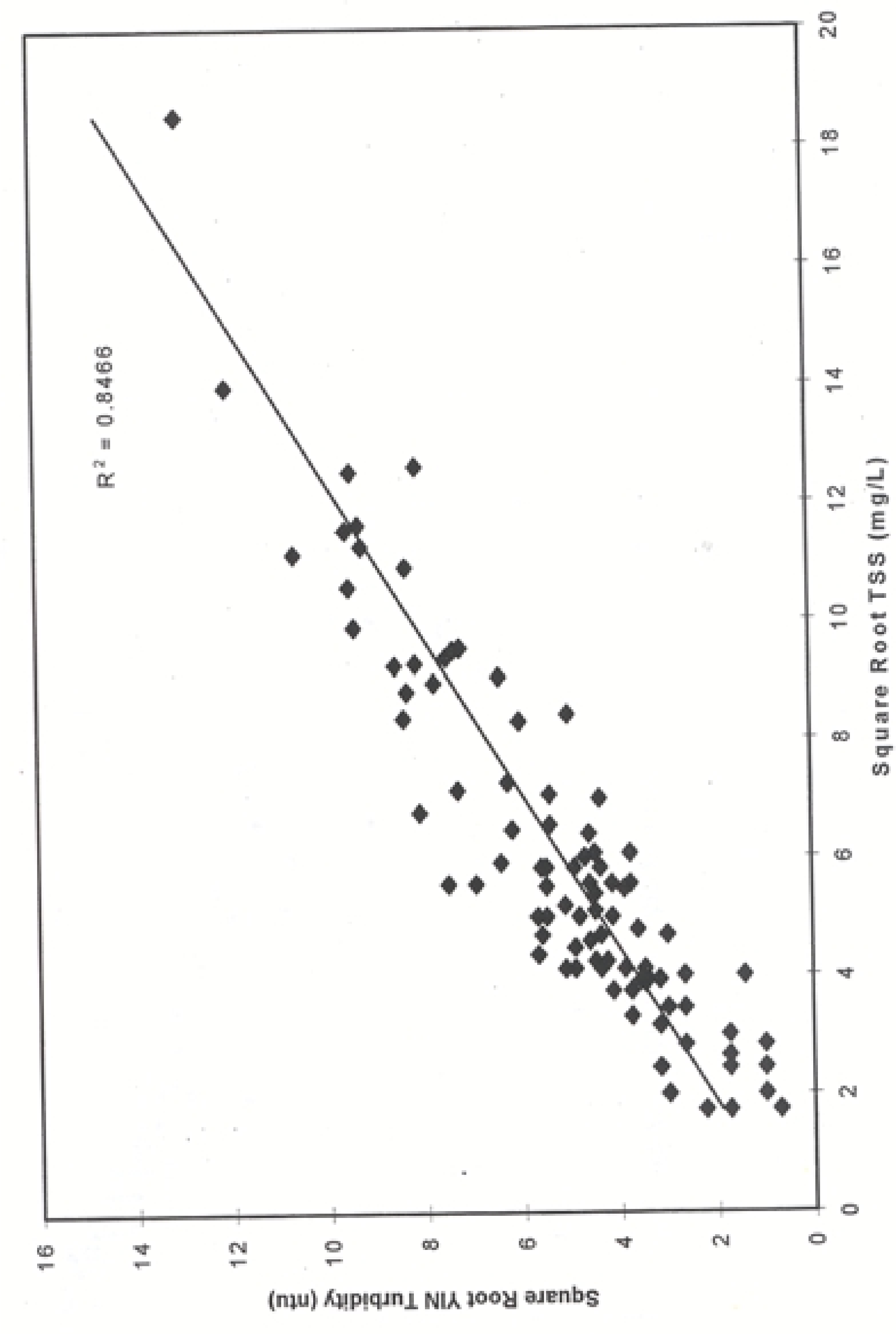

Figure 2D. Regression of YIN turbidity to Ecology TSS, 1995 data.

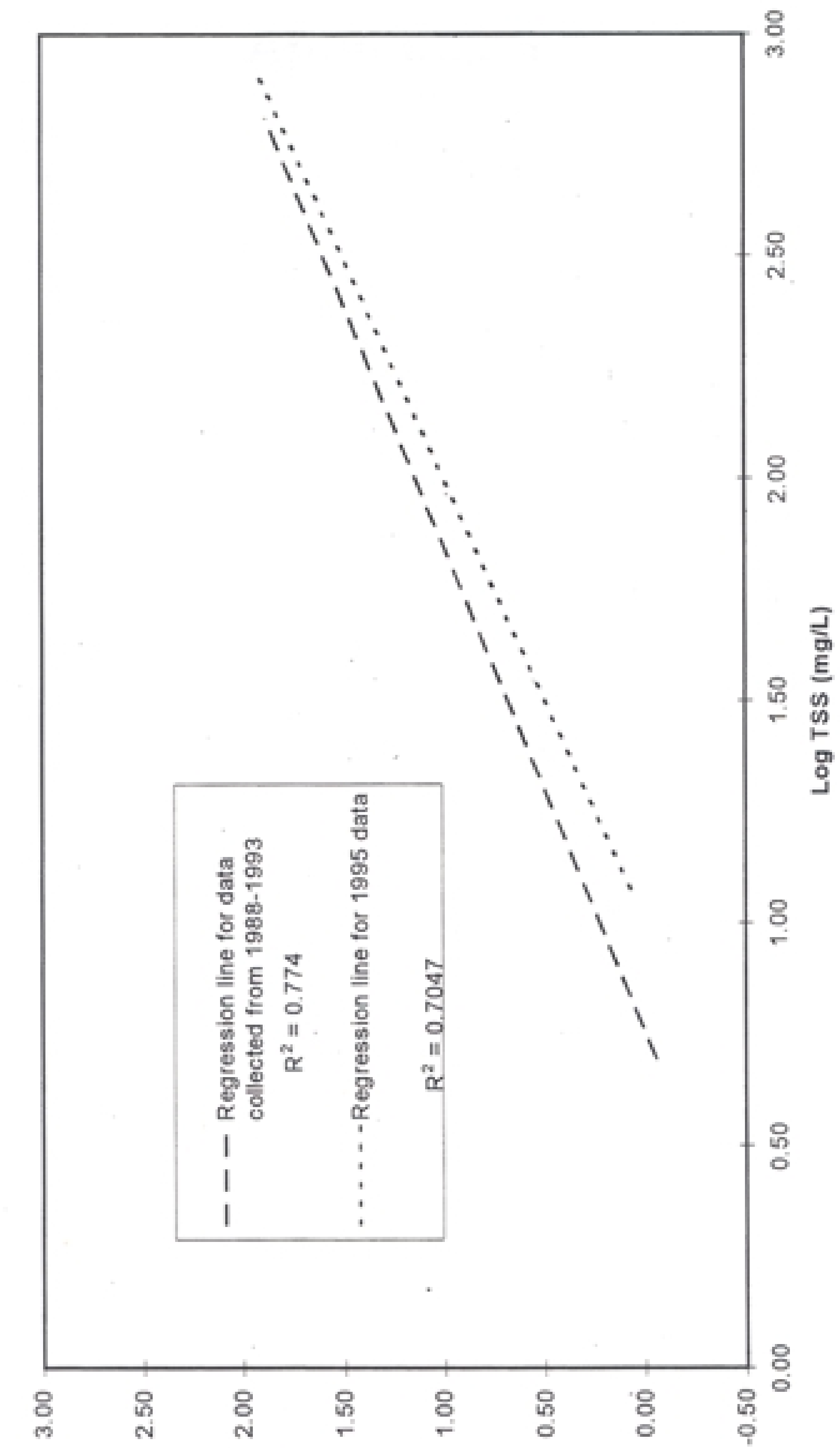

Figure 2E. Regression of t-DDT as a function of TSS.

Appendix 3:

Pesticide Analytical Results from whole fish samples collected in the lower Yakima River basin by USFWS, USGS, Ecology, and USEPA from 1970 to 1992

Table 3A. Pesticides in whole fish from the Yakima River basin (all concentrations in ug/kg wet weight).

USFWS Data

Station	Date	t-DDT	Dieldrin	Species
Yakima at Granger	Oct-70	2170	60	BLS
	Oct-70	1070	30	C
	Oct-70	2220	20	C
	Oct-70	2590	80	LMB
	Oct-71	810	10	BC
	Oct-71	850	30	BC
	Oct-71	1490	10	C
	Oct-71	1480	20	C
	Oct-71	2680	10	LSS
	Oct-71	1640	20	LSS
	Oct-72	2760	nd	C
	Oct-72	2000	nd	LSS
	Oct-72	2430	nd	LSS
	Oct-72	3050	nd	NS
	Oct-73	520	nd	C
	Oct-73	1780	nd	LSS
	Oct-73	2140	160	LSS
	Oct-73	1020	nd	LMB
	Oct-74	4340	170	C
	Oct-74	2940	120	C
	Oct-74	2330	80	LSS
	Oct-74	2100	80	SMB
	Oct-76	1180	30	BC
	Oct-76	1130	30	LSS
	Oct-76	610	30	LSS
	Oct-78	1520	10	C
	Oct-78	1430	10	C
	Oct-78	260	10	WC
	Oct-80	390	nd	BC
	Oct-80	530	nd	LSS
	Oct-80	230	nd	LSS
	Oct-84	380	20	BC
	Oct-84	280	10	LSS
	Oct-84	190	10	LSS

Ecology (Hopkins, 1985)

Station	Date	t-DDT	Dieldrin	Species
Yakima at Kiona	Sep-80	580		SMB
	Sep-80	900		BLS
	Aug-81	1260	48	NS
	Aug-81	3080	76	LSS
Yakima blw Kiona	Sep-82	2710		BLS
	Sep-82	1430		MWF
	Sep-83	1798		BLS
	Sep-83	2989		CC
Yakima blw Birchfield Drain	Sep-83	5071		BLS
	Sep-83	1033		MWF
	Sep-83	2540		NS

Ecology (Johnson et al, 1986)

Station	Date	t-DDT	Dieldrin	Species
Yakima at Kiona	Aug-85	1100	240	LSS
	Aug-85	3000	90	NS
Yakima at Buena (RM 94)	Aug-85	640		MWF
	Aug-85	390	30	*LSS
	Aug-85	890		NS
Yakima at Wymer (RM 135)	Aug-85	330	90	MWF
	Aug-85	80		BLS
	Aug-85	560		NS
Yakima at Cle Elum	Aug-85	50		MWF

EPA(a)

Station	Date	t-DDT	Species
Yakima nr Richland RM9.3	Jul-80	2012	na
Naches RM9.7	Jul-80	407	na
Naches at mouth	Jul-80	202	na
Yakima at Ellensburg RM161	Apr-78	81	na

(a) median values reported
* mean of replicate samples

Species Codes	
AC	Asiatic Clam
BC	Black Crappie
BS	Bridelip Sucker
C	Carp
CM	Chiselmouth
LSS	Largescale Sucker
MW	Mountain Whitefish
RT	Rainbow Trout
S	Sculpin
SB	Smallmouth Bass
NS	Northern Squawfish
WC	White Crappie
na	species information not available

Table 3B. Concentrations of organochlorine pesticides in whole fish from the Yakima River basin.

USGS NAWQA (Rinella, etal., 1992)

Site	Date	t-DDT	dieldrin*	total chlordane*	heptachlor epoxide*	Sum of Marked Compounds	Species
Ahtanum Creek at Union Gap	Nov-90	130					S
Granger Drain at mouth nr Granger	Nov-89		70			70	LSS
	Nov-89	1950					LSS
	Nov-90		80			80	BLS
	Nov-90	1165		60	20	80	BLS
Moxee Drain at Thorp Rd nr Union Gap	Nov-89		10			10	LSS
			20			20	MW
	Nov-89	775					LSS
		1075		30		30	MW
	Oct-90	455		40	10	50	CM
Naches River nr North Yakima	Nov-90	550		25		25	MW
		755	10	30	10	50	RT
Satus Cr abv Wilson-Charley Canyon nr Toppenish	Nov-89	35					RT
Satus Creek at gage at Satus	Nov-89		10			10	MW
	Nov-89	145					MW
	Nov-90		10			10	S
	Nov-90	95			10	10	S
Satus Creek below Dry Cr nr Toppenish	Nov-90	35					S
Spring Creek at mouth at Whitstran	May-89		100			100	CM
	Oct-89	505					CM
		65					CR
	Oct-89	1890					AC
	Nov-89		40			40	AC
	Nov-90	1910		30		30	AC
	Nov-90		30			30	AC
Sulphur Cr Wasteway nr Sunnyside	Oct-89		170			170	LSS
	Nov-89	4850		80		80	CM
	Nov-90	1415	80	30		110	RT
Toppenish Cr at Indian Church Rd nr Granger	Nov-89		20			20	S
	Nov-89	1290					RT
Wide Hollow Cr at Old STP at Union Gap	Nov-89		40			40	BLS
	Nov-89	365		30		30	BLS
	Nov-90	405		30		30	LSS
Wide Hollow Cr at W. Valley School nr Ahtanum	May-89	1050	30	45		75	BLS
		135					CR
Yakima R at Euclid Br at RM 55 nr Grandview	Oct-89	637.5	20			20	AC
		3220	80	50		130	LSS
	Nov-90	865	10			10	AC
	Nov-90	3475	50	60	10	120	LSS
Yakima R at Parker	Nov-89	580	10			10	LSS
	Nov-90	820					LSS
Yakima R blw Toppenish Cr at RM 79.6 nr Grange	Nov-90	1795	20	30		50	LSS
Yakima River at Kiona	Oct-89	527.5	10			10	AC
	Oct-89	2280	100	50		150	LSS
		1690	60	60		120	MW
		670	50			50	SMB
	Nov-90	565	10	30		40	AC
	Nov-90	2730	75	85	15	175	LSS
		1975	50	50	10	110	MW
Yakima River at RM 72 ab Satus Cr nr Sunnyside	Nov-89	432.5	10			10	AC
		1910	20	30		50	C
		2330	40	30		70	LSS
		1230	40	30		70	MW
Yakima River at Umtanum	May-89	360	10	25		35	BLS
	Nov-89	225	20			20	MW
	Nov-90	315	10	35	10	55	LSS
		170					MW

Ecology (Johnson and Serdar, 1991)

Yakima at Granger	6/4/91	770					LSS
		901					LSS
		856	17				NS

Ecology (Davis and Johnson, 1994)

Yakima below Kiona	Oct-92	1717	42	84		126	na
		678	31	35		66	na

Appendix 4:

This section reviews simulation results from modeling the main stem of the lower Yakima River from E. Toppenish Drain (RM 86) to Chandler Diversion at Prosser (RM 47.5) using the USEPA model, SMPTOX3.

Table 4A describes site locations, TSS and flow conditions, and reach data used in the SMPTOX3 model simulations. Early (1) and late (2) irrigation season hydrological conditions were simulated for TSS critical condition analyses based on 1995 data. A separate simulation for t-DDT analysis was performed using June 1989 conditions observed by the USGS (Rinella *et al.*, 1992b). Reach numbers in all Table 4A scenarios correspond to **Reach** numbers in simulation Figures 4A - 4H.

Table 4A. Variables used in SMPTOX3 modeling on the Yakima River between Zillah and Prosser.

(1) May-June Conditions

TRIBUTARY/DRAIN	FLOW	TSS	Reach	LENGTH	VELOCITY	SETTLING
	mgd	mg/L		mi	fps	1/day
E. Toppenish Drain	34	24	1	3	4	0.2
Subdrain 35	32.3	49	2	0.4	4	0.2
Granger Drain	32.3	759	3	0.1	4	0.2
Marion Drain	219.7	33	4	1.8	4	0.2
Toppenish Creek	122.8	30	5	3.4	4	0.2
Coulee Drain	43.9	31	6	7	4	0.2
Satus Creek	172.6	87	7	0.3	3	0.2
South Drain	54.9	134	8	4.2	3	0.2
DID #7	20	15	9	4.1	2	0.7
Sulphur Creek	266	200	10	0.8	2	0.7
Satus #303	31.6	158	11	12	3.2	0.2
Wamba	6.4	120	12	4	2	0.9

(2) July-October Conditions

TRIBUTARY/DRAIN	FLOW	TSS	Reach	LENGTH	VELOCITY	SETTLING
	mgd	mg/L		mi	fps	1/day
E. Toppenish Drain	32.3	21	1	3	2	0.9
Subdrain 35	32.3	49	2	0.4	2	0.9
Granger Drain	44.6	868	3	0.1	2	0.9
Marion Drain	98.9	16	4	1.8	1.5	2.4
Toppenish Creek	171.3	19	5	3.4	1.5	2.4
Coulee Drain	23.3	39	6	7	1.5	1.9
Satus Creek	99.5	83	7	0.3	1.5	0.9
South Drain	72.3	134	8	4.2	1.5	0.9
DID #7	19.4	20	9	4.1	0.6	0.9
Sulphur Creek	265.6	244	10	0.8	0.6	1.9
Satus #303	30.4	120	11	12	1.3	1.9
Wamba	13	120	12	4	0.8	1.9

Table 4A. Continued

(3) 1989 DDT Conditions

TRIBUTARY/DRAIN	FLOW	DDT	TSS	Reach	LENGTH	VELOCITY	SETTLING	PAR.COEF
	mgd	ng/L	mg/L		mi	fps	1/day	L/mg
E. Toppenish Drain	34	12	52	1	3	2.5	0.6	0.02
Subdrain 35	36	10	28	2	0.4	2.5	0.6	0.02
Granger Drain	24	110	643	3	0.1	2.5	0.4	0.04
Marion Drain	46	5	29	4	1.8	2.5	0.6	0.05
Toppenish Creek	25	4	32	5	3.4	2.2	0.4	0.05
Coulee Drain	43.9	4	31	6	7	2.2	0.4	0.05
Satus Creek	80	3	38	7	0.3	1.7	0.4	0.05
South Drain	53	20	145	8	4.2	1.7	0.6	0.05
DID #7	20	2	15	9	4.1	1.5	0.6	0.05
Sulphur Creek	171	51	230	10	0.8	1.5	2	0.02
Satus #303	53	20	145	11	12	2	2	0.02
Wamba	6.4	7	56	12	4	1.5	0.8	0.02

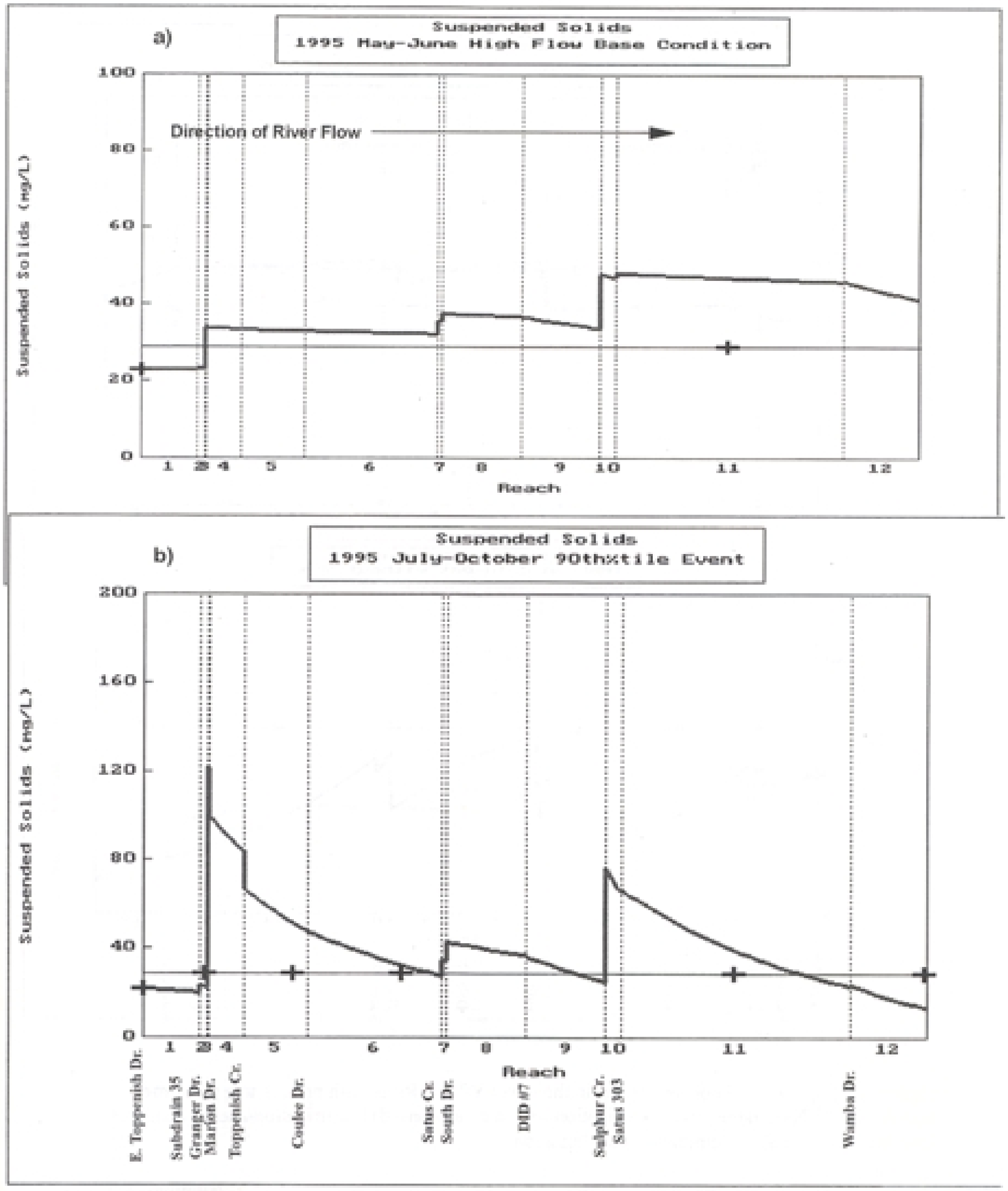

Figure 4. a) 1995 early irrigation season base conditions in the lower Yakima River SMPTOX3 simulation of TSS with main stem TMDL target indicated by line. b) 1995 late irrigation season base condition.

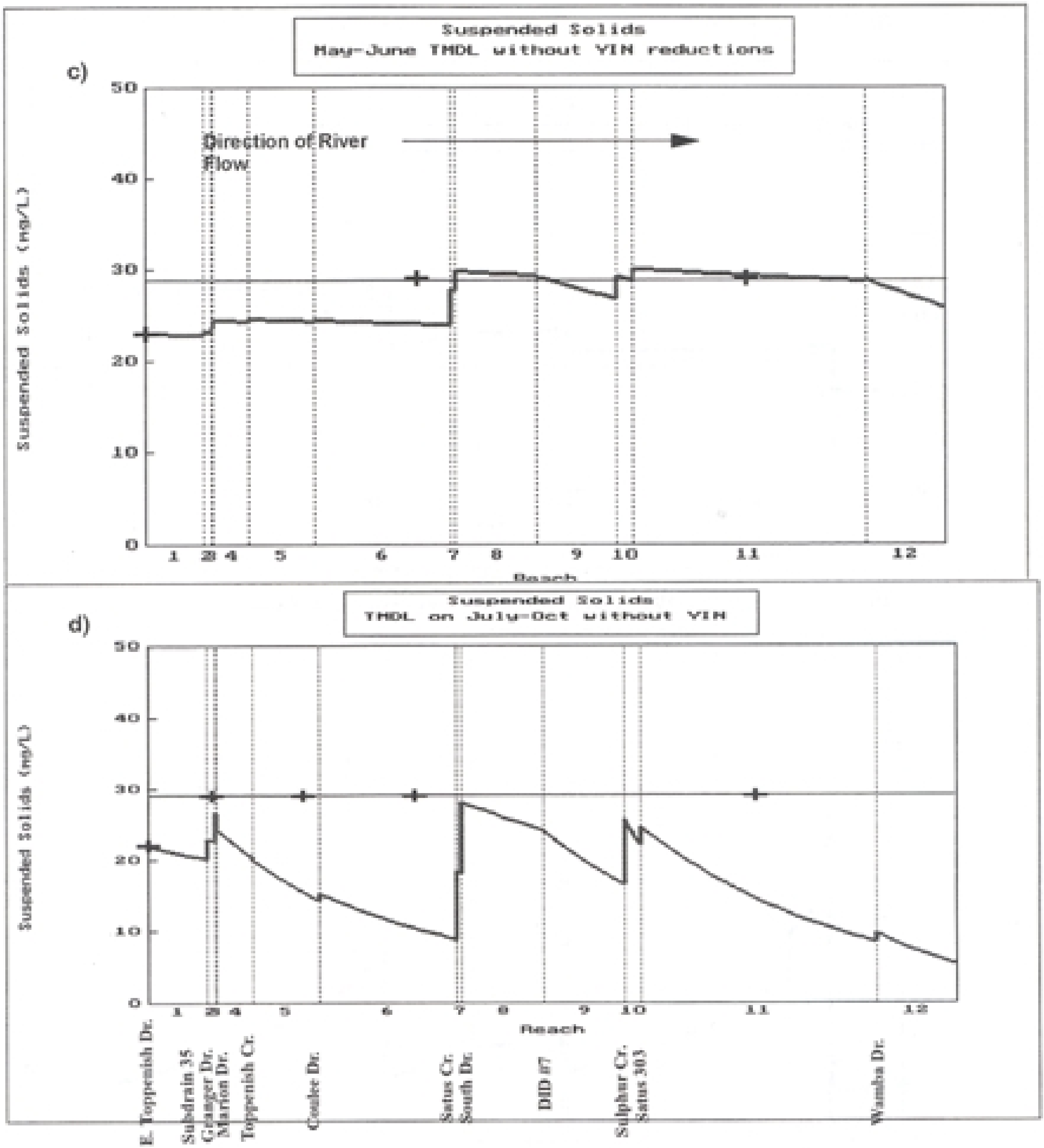

Figure 4 continued. TSS concentrations in the lower Yakima River with project area tributaries meeting the 25 NTU target: c) early irrigation season conditions, d) late irrigation season conditions. Line denotes main stem compliance concentration.

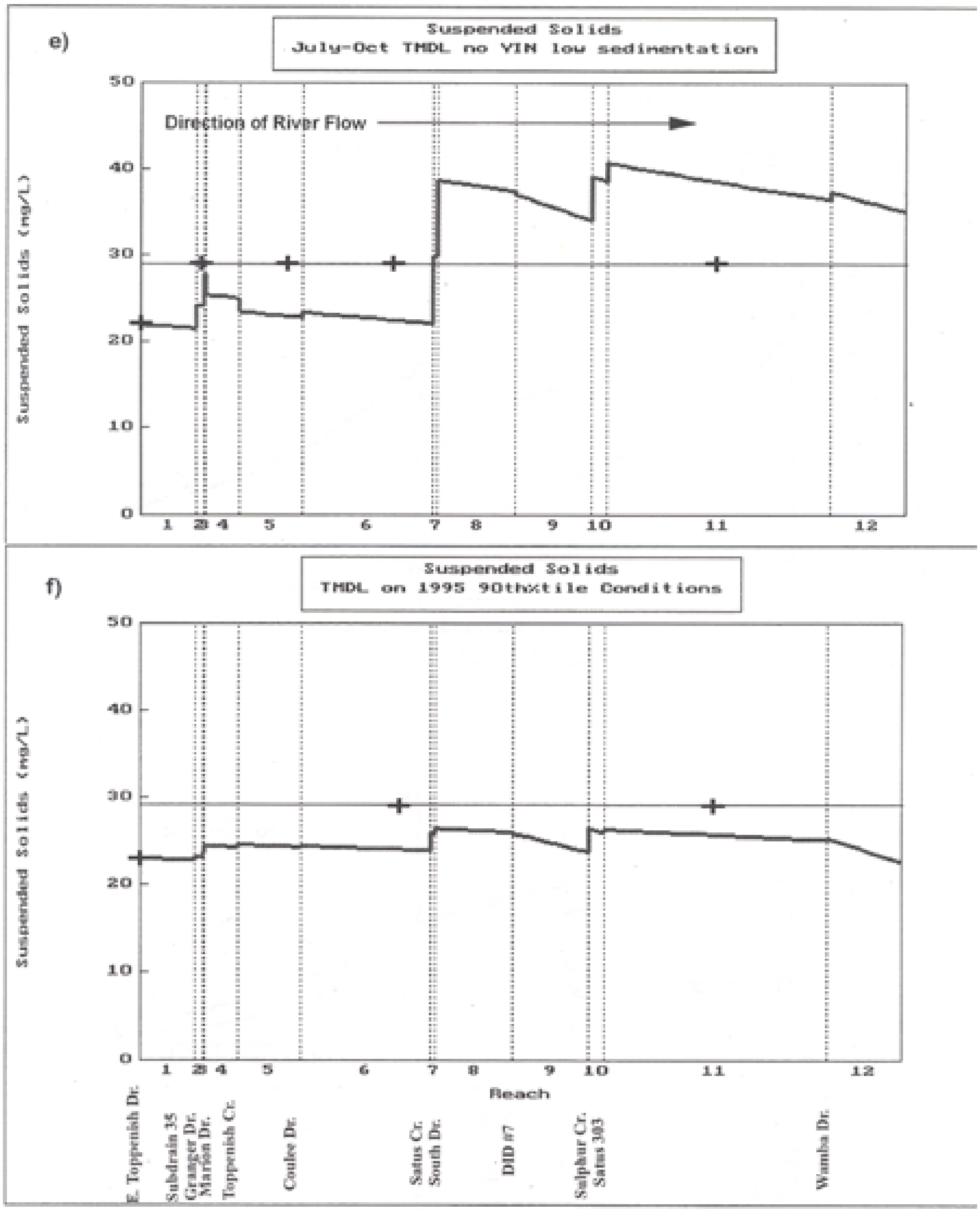

Figure 4 continued. TSS concentrations in the lower Yakima River with project area tributaries meeting the 25 NTU target: e) late irrigation season with low sedimentation rate, f) irrigation season 90th percentile TSS event with project area and Yakama Reservation tributaries meeting 25 NTU target.

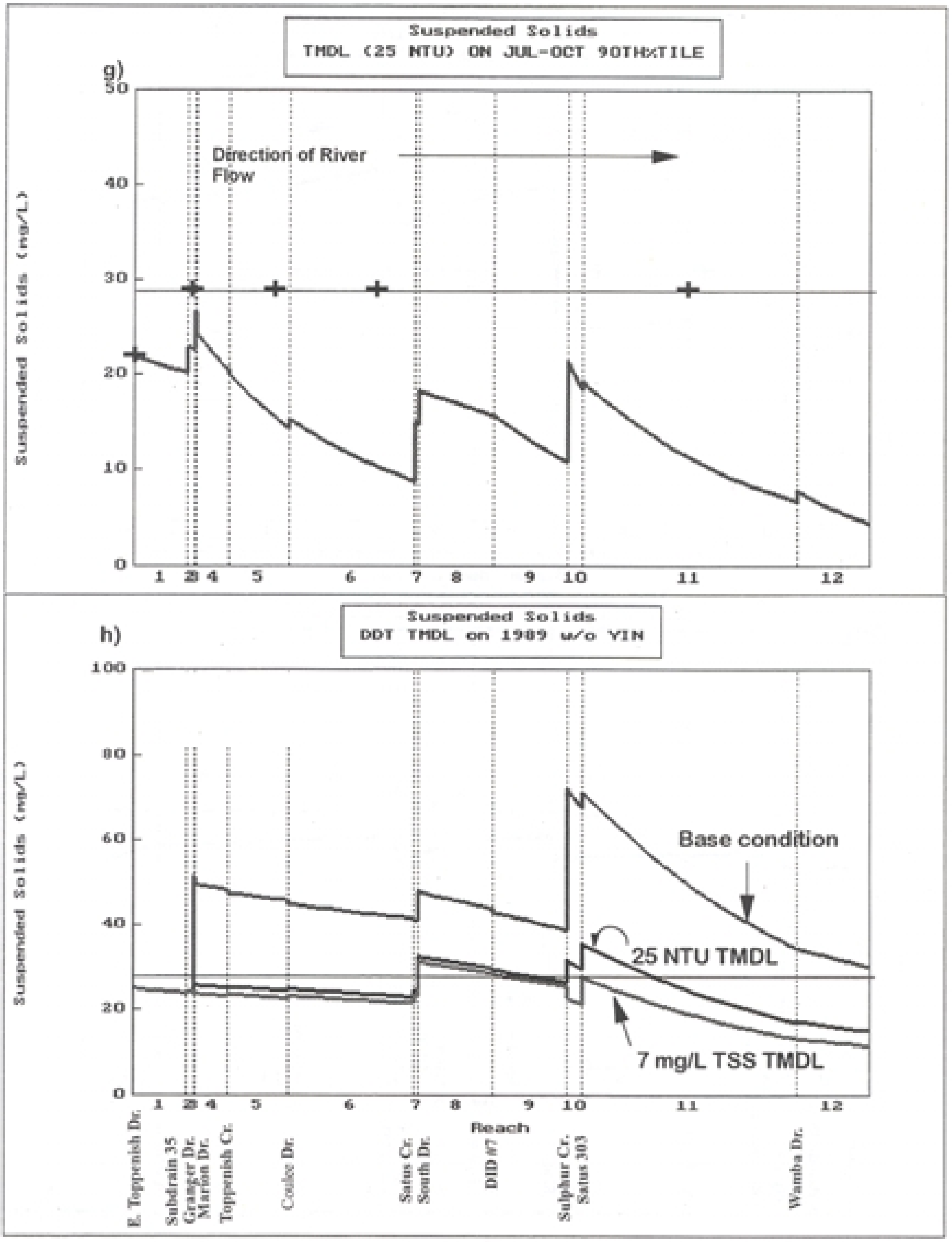

Figure 4 continued. TSS concentrations in the lower Yakima River. g) Project area and Yakama Reservation tributaries meeting the 25 NTU target during late irrigation season conditions, h) comparisons of 1989 base condition to conditions with 25 NTU compliance of project area tributaries, and 7 mg/L TSS compliance of project area tributaries. See text for details.