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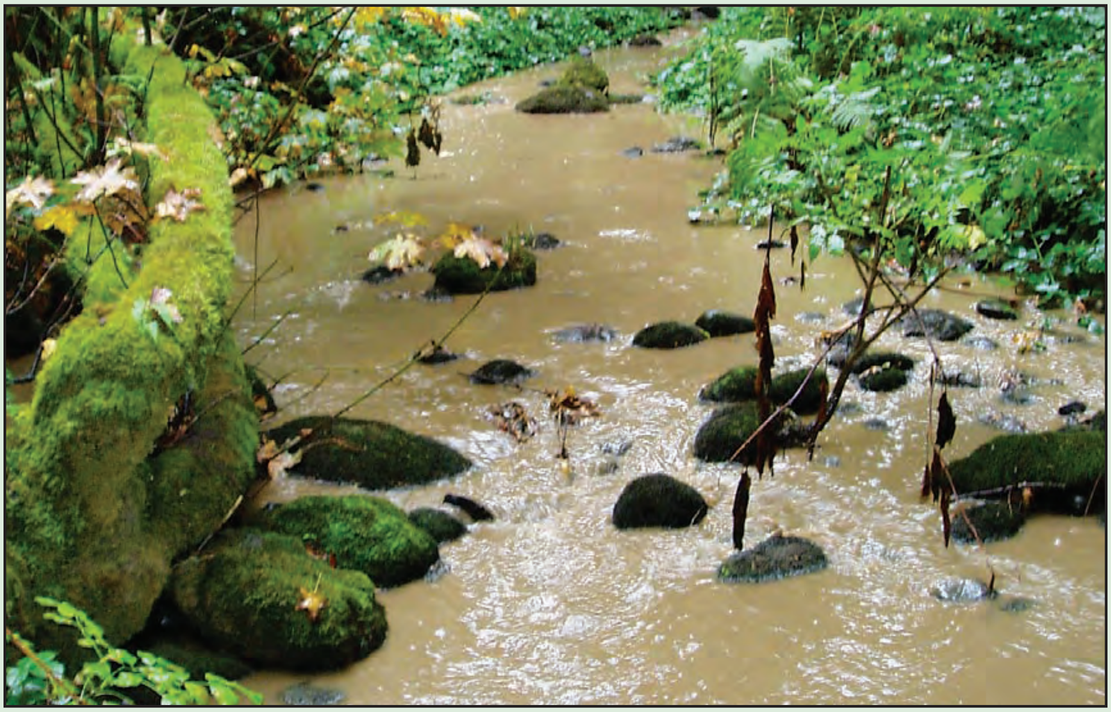
Pesticide Occurrence and Distribution in the Lower Clackamas River Basin, Oregon, 2000–2005



Scientific Investigations Report 2008–5027

U.S. Department of the Interior
U.S. Geological Survey

Cover:
Top left: Pesticides are sometimes used on urban landscaping (Rock Creek basin) (Photograph taken January 2, 2003.)
Top right: Arborvitae ornamental trees are grown at many of the Clackamas River basin nurseries (North Fork Deep Creek basin) (Photograph taken March 13, 2004.)
Bottom Noyer Creek, a tributary of lower Deep Creek, is highly turbid after stormwater runoff, September 2005. (Photograph taken September 30, 2005. All cover photographs taken by Kurt D. Carpenter, U.S. Geological Survey.)

Pesticide Occurrence and Distribution in the Lower Clackamas River Basin, Oregon, 2000–2005

By Kurt D. Carpenter, Steven Sobieszczyk, Andrew J. Arnsberg, and Frank A. Rinella

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U.S. Department of the Interior
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Foreword

The U.S. Geological Survey (USGS) is committed to providing the Nation with credible scientific information that helps to enhance and protect the overall quality of life and that facilitates effective management of water, biological, energy, and mineral resources (http://www.usgs.gov/). Information on the Nation's water resources is critical to ensuring long-term availability of water that is safe for drinking and recreation and is suitable for industry, irrigation, and fish and wildlife. Population growth and increasing demands for water make the availability of that water, now measured in terms of quantity and quality, even more essential to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to support national, regional, State, and local information needs and decisions related to water-quality management and policy (http://water.usgs.gov/nawqa). The NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. From 1991-2001, the NAWQA Program completed interdisciplinary assessments and established a baseline understanding of water-quality conditions in 51 of the Nation's river basins and aquifers, referred to as Study Units (http://water.usgs.gov/nawqa/studyu.html).

Multiple national and regional assessments are ongoing in the second decade (2001–2012) of the NAWQA Program as 42 of the 51 Study Units are reassessed. These assessments extend the findings in the Study Units by determining status and trends at sites that have been consistently monitored for more than a decade, and filling critical gaps in characterizing the quality of surface water and ground water. For example, increased emphasis has been placed on assessing the quality of source water and finished water associated with many of the Nation's largest community water systems. During the second decade, NAWQA is addressing five national priority topics that build an understanding of how natural features and human activities affect water quality, and establish links between sources of contaminants, the transport of those contaminants through the hydrologic system, and the potential effects of contaminants on humans and aquatic ecosystems. Included are topics on the fate of agricultural chemicals, effects of urbanization on stream ecosystems, bioaccumulation of mercury in stream ecosystems, effects of nutrient enrichment on aquatic ecosystems, and transport of contaminants to public-supply wells. These topical studies are conducted in those Study Units most affected by these issues; they comprise a set of multi-Study-Unit designs for systematic national assessment. In addition, national syntheses of information on pesticides, volatile organic compounds (VOCs), nutrients, selected trace elements, and aquatic ecology are continuing.

The USGS aims to disseminate credible, timely, and relevant science information to address practical and effective water-resource management and strategies that protect and restore water quality. We hope this NAWQA publication will provide you with insights and information to meet your needs, and will foster increased citizen awareness and involvement in the protection and restoration of our Nation's waters.

The USGS recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for cost-effective management, regulation, and conservation of our Nation's water resources. The NAWQA Program, therefore, depends on advice and information from other agencies—Federal, State, regional, interstate, Tribal, and local—as well as nongovernmental organizations, industry, academia, and other stakeholder groups. Your assistance and suggestions are greatly appreciated.

Robert M. Hirsch
Associate Director for Water

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Plate

[In pocket]

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Conversion Factors, Datum, and Abbreviations and Acronyms

Conversion Factors

Multiply	By	To obtain
	Length	
mile (mi)	1.609	kilometer (km)
inch (in)	2.54	centimeter (cm)
	Area	
acre (ac)	0.001562	square mile (mi^2)
square mile (mi^2)	2.59	square kilometer (km^2)
square mile (mi^2)	640	acre
	Volume	
liter (L)	0.264172051	gallon (gal)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second (ft^3/s)	646,316.88	gallon per day (gal/d)
	Mass	
microgram (µg)	0.000001	gram (g)
gram (g)	0.0352739619	ounce, avoirdupois (oz)
kilogram (kg)	2.20462262	pound (lb)

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations and Acronyms

Abbreviations and Acronyms	Meaning
2,4-D	2,4-dichlorophenoxyacetic acid
2,4-DP	2-(2,4-dichlorophenoxy) propionic acid
AMPA	amino-methyl-phosphonic acid (a glyphosate degradate)
AZM	azinphos-methyl (an orthophosphate insecticide)
BQ max	Maximum Benchmark Quotients
BMPs	best management practices
BT	Bacillus thuringiensis kurstaki (a bacteria used as a biocide)
CCME	Canadian Council of Ministers of the Environment
CAAT	2-chloro-4,6-diamino-1,3,5-s-triazine (desethyl-desisopropyl-atrazine) (an atrazine degradate)
CIAT	2-chloro-4-isopropylamino-6-amino-s-triazine (deethylatrazine)(an atrazine degradate)
CWMG	Clackamas Watershed Management Group
DCA	3,4-dichloroaniline (a diuron degradate)
DCPA	dimethyl-tetrachloroterephthalate (an herbicide also known as dacthal)
DDE	dichlorodiphenyl-dichloroethane (a degradate of the insecticide DDT)
DEET	N,N-diethyl-m-toluamide (an insect repellant)
DNOC	4,6-dinitro-o-cresol (an herbicide)

Conversion Factors, Datum, and Abbreviations and Acronyms—Continued

Abbreviations and Acronyms—Continued

Abbreviations and Acronyms	Meaning
EPTC	s-ethyl dipropyl-thiocarbamate (an herbicide)
ESUs	evolutionarily significant units
EUSE	Effects of Urbanization on Stream Ecosystems (USGS NAWQA study)
FNU	Formazin Nephelometric Unit (a measure of turbidity)
GC/MS	gas chromatography/mass spectrometry
GF	glass-fiber (filter material used during sample processing)
GIS	Geographic Information System
HA–L	Lifetime Health Advisory
HBSL	Health-Based Screening Level
IPM	integrated pest management program
Koc	organic carbon partition coefficient
LC_{50}	lethal concentration for 50 percent of the test population
LRL	laboratory reporting level
MCL	Maximum Contaminant Level
MCPA	2-methyl-4-chlorophenoxy acetic acid (a type of herbicide)
MCPB	2-methyl-4-chlorophenoxy butyric acid (a type of herbicide)
MDL	method detection level
MTC	median toxicity concentration
NAWQA	National Water-Quality Assessment
NLCD01	USGS National Land Cover Data (2001)
NTRU	Nephelometric Turbidity Ratio Unit (a measure of turbidity)
OIET	2-hydroxy-4-isopropylamino-6-ethylamino-s-triazine (hydroxyatrazine)(an atrazine degradate)
OPP	Office of Pesticide Programs (USEPA)
OSU	Oregon State University
OW	Office of Water (USEPA)
PAC	powdered activated carbon
PCODE	USGS parameter code
POCIS	polar organic chemical integrative sampler
PTI	Pesticide Toxicity Index
PURS	Oregon's Pesticide Use and Reporting System
QC	quality-control
SWCD	Soil and Water Conservation District
SWQA	Source Water-Quality Assessment (USGS NAWQA study)
SPMD	semipermeable membrane device
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

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Pesticide Occurrence and Distribution in the Lower Clackamas River Basin, Oregon, 2000–2005

By Kurt D. Carpenter, Steven Sobieszczyk, Andrew J. Arnsberg, and Frank A. Rinella

Abstract

Pesticide occurrence and distribution in the lower Clackamas River basin was evaluated in 2000–2005, when 119 water samples were analyzed for a suite of 86–198 dissolved pesticides. Sampling included the lower-basin tributaries and the Clackamas River mainstem, along with paired samples of pre- and post-treatment drinking water (source and finished water) from one of four drinking water-treatment plants that draw water from the lower river. Most of the sampling in the tributaries occurred during storms, whereas most of the source and finished water samples from the study drinking-water treatment plant were obtained at regular intervals, and targeted one storm event in 2005.

In all, 63 pesticide compounds were detected, including 33 herbicides, 15 insecticides, 6 fungicides, and 9 pesticide degradation products. Atrazine and simazine were detected in about half of samples, and atrazine and one of its degradates (deethylatrazine) were detected together in 30 percent of samples. Other high-use herbicides such as glyphosate, triclopyr, 2,4-D, and metolachlor also were frequently detected, particularly in the lower-basin tributaries. Pesticides were detected in all eight of the lower-basin tributaries sampled, and were also frequently detected in the lower Clackamas River.

Although pesticides were detected in all of the lower basin tributaries, the highest pesticide loads (amounts) were found in Deep and Rock Creeks. These medium-sized streams drain a mix of agricultural land (row crops and nurseries), pastureland, and rural residential areas. The highest pesticide loads were found in Rock Creek at 172nd Avenue and in two Deep Creek tributaries, North Fork Deep and Noyer Creeks, where 15–18 pesticides were detected. Pesticide yields (loads per unit area) were highest in Cow and Carli Creeks, two small streams that drain the highly urban and industrial northwestern part of the lower basin. Other sites having relatively high pesticide yields included middle Rock Creek and upper Noyer Creek, which drain basins having nurseries, pasture, and rural residential land.

Some concentrations of insecticides (diazinon, chlorpyrifos, azinphos-methyl, and *p,p'*-DDE) exceeded U.S. Environmental Protection Agency (USEPA) aquatic-life benchmarks in Carli, Sieben, Rock, Noyer, Doane, and North Fork Deep Creeks. One azinphos-methyl concentration in Doane Creek (0.21 microgram per liter [µg/L]) exceeded Federal and State of Oregon benchmarks for the protection of fish and benthic invertebrates. Concentrations of several other pesticide compounds exceeded non-USEPA benchmarks.

Twenty-six pesticides or degradates were detected in the Clackamas River mainstem, typically at much lower concentrations than those detected in the lower-basin tributaries. At least 1 pesticide was detected in 65 percent of 34 samples collected from the Clackamas River, with an average of 2–3 pesticides per sample. Pesticides were detected in 9 (or 60 percent) of the 15 finished water samples collected from the study water-treatment plant during 2003–2005. These included 10 herbicides, 1 insecticide, 1 fungicide, 1 insect repellent, and 2 pesticide degradates. The herbicides diuron and simazine were the most frequently detected (four times each during the study), at concentrations far below human-health benchmarks—USEPA Maximum Contaminant Levels or U.S. Geological Survey human Health-Based Screening Levels (HBSLs). The highest pesticide concentration in finished drinking water was 0.18 µg/L of diuron, which was 11 times lower than its low HBSL benchmark. Although 0–2 pesticides were detected in most finished water samples, 9 and 6 pesticides were detected in 2 storm-associated samples from May and September 2005, respectively. Three of the unregulated compounds detected in finished drinking water (diazinon-oxon, deethylatrazine [CIAT], and N, N-diethyl-m-toluamide [DEET]) do not have human-health benchmarks available for comparison.

Although most of the 51 current-use pesticides detected have multiple uses, 48 (or 94 percent) can be used on agricultural crops. Ninety-two percent can be used on nursery or floriculture crops; about one-half are commonly used on either lawns and landscaping in urban areas (57 percent), on golf courses (49 percent), along roads and right-of-ways (45 percent), and some can be used on forestland (7 percent).

Introduction

Background

In Oregon, more than 11,000 pesticide products are registered for use to control brush, weeds, insects, fungi, rodents, nematodes, and other pests. This includes 771 active ingredients (Janet Fults, Oregon Department of Agriculture, written commun., 2008). Much of the pesticide use is on agricultural crops, home gardens, lawns, landscaping in urban and industrial areas, golf courses, forestland, and along rights-of-way such as roads, railways, and utility lines. During the past 15–20 years, studies conducted by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program have documented widespread occurrence of pesticides and degradates in streams and ground water in the United States, especially in areas affected by human development. More than 90 percent of water samples from streams in agricultural, urban, or mixed-land-use settings contained 2 or more pesticide compounds, with 5 or more pesticide detections occurring in 70 percent of samples, and 10 or more compounds occurring in 20 percent of samples (Gilliom and others, 2006).

Previous studies conducted in Oregon indicate that a wide variety of pesticides and degradates are making their way into streams (Anderson and others, 1997; Rinella and Janet, 1998; Wentz and others, 1998; Wood, 2001; Grange, 2002; Sandahl and Jenkins, 2002) and ground water (Hinkle, 1997). Studies by Anderson and others (1997) and Rinella and Janet (1998) detected 36 and 50 pesticides, respectively, in Willamette Valley streams and discovered that the large diversity of crops grown in the northern Willamette Valley (for example, row crops, berries, nurseries, and vineyards) results in a wide variety of pesticides being applied and later detected in these streams. In the southern valley, however, the diversity of crops is small, consisting primarily of grass seed and other seed crops (Anderson and others, 1996), which reduced the types and variety of pesticides detected (Anderson and others, 1997).

The Clackamas River in northwestern Oregon originates on the western slope of the Cascade Mountains and enters the Willamette River south of Portland, downstream of the Tualatin River and Willamette Falls. The Clackamas River drains a diverse landscape of natural and developed areas, including forestland, agricultural areas, industrial land, rural residential areas, golf courses, and dense suburban developments (pl. 1). In 2000, the USGS began sampling for pesticides in the Clackamas River basin as part of a cooperative study with the Clackamas Watershed Management Group (CWMG). The first pesticide study included samplings during two storm events (May and October 2000). A total of 27 pesticides and degradates were detected in either the lower Clackamas River or in major lower-basin tributaries that discharge to the Clackamas River upstream of drinking-water intakes (Carpenter, 2004).

Pesticide concentrations during this first study were highest in Sieben and Rock Creeks—two relatively small streams on the northern side of the lower Clackamas River basin. These streams drain basins that are being urbanized from forested, agricultural, and rural residential land into suburban developments. The highest pesticide loads (or amounts) entering the Clackamas River were found in Deep Creek, a large tributary that drains the area southeast of Boring. Deep Creek and its tributaries drain large areas of nursery and greenhouse operations along with rural residential property and the city of Sandy and community of Boring (pl. 1).

The occurrence of pesticides in the Clackamas River and its tributaries is of concern to Federal, State, and local natural resource agencies and drinking water providers that use this valued resource. In addition to providing a source of drinking water for more than 300,000 residents, the Clackamas River is home to several species of anadromous salmon and steelhead, resident fish and other aquatic life, and some fish species are listed as threatened under the Endangered Species Act (National Marine Fisheries Service, 2006).

In 2001, the USGS NAWQA Program initiated a Source Water Quality Assessment (SWQA) study to characterize the water quality of major rivers and aquifers used as a source of water supply to community water systems in the United States. In 2002, the Clackamas River was selected to be one of nine community water systems to be sampled as part of the surface-water component of the SWQA study (Carter and others, 2007). This study built on the initial drinking-water pilot studies conducted by the USGS and USEPA, which examined the quality of pre- and post-treated (source and finished) drinking water from 12 water-supply reservoirs across the country (Blomquist and others, 2001; Coupe and Blomquist, 2004). These latter studies indicated that conventional water treatment did not completely remove pesticides and degradates during treatment, and although all concentrations were less than USEPA drinking-water standards, 9–30 pesticide compounds were detected in finished water from each of the 12 water-treatment plants (median number of pesticide compounds detected was 23).

These and other studies utilizing low-level (parts per billion, or lower) methods have detected pesticides and other contaminants in source and finished water, which raises concerns about the potential implications for human health and aquatic life in these rivers. Studies of the potential for cumulative effects from exposure to multiple pesticide compounds are needed to address such concerns because pesticides seldom occur in streams by themselves—they are nearly always found with other pesticides and degradates in multicompound mixtures (Gilliom and others, 2006).

Study Purpose and Report Scope

This report includes data from four USGS studies conducted between 2000 and 2005. The initial study included sampling of the mouths of the major lower-basin tributaries, plus a limited number of samples collected from the lower Clackamas River and of finished drinking water (Carpenter, 2004). Since then, three additional studies: the Source Water-Quality Assessment (SWQA) and Effects of Urbanization on Stream Ecosystems (EUSE) topical studies, and a USGS/Clackamas Watershed Management Group (CWMG) project in 2005 (repeat of 2000 study), have provided more information on the occurrence and distribution of pesticides in the lower Clackamas River basin. In all, about 119 pesticide samples were collected from 30 sites during the 6-year period (fig. 1; tables 1 and 2).

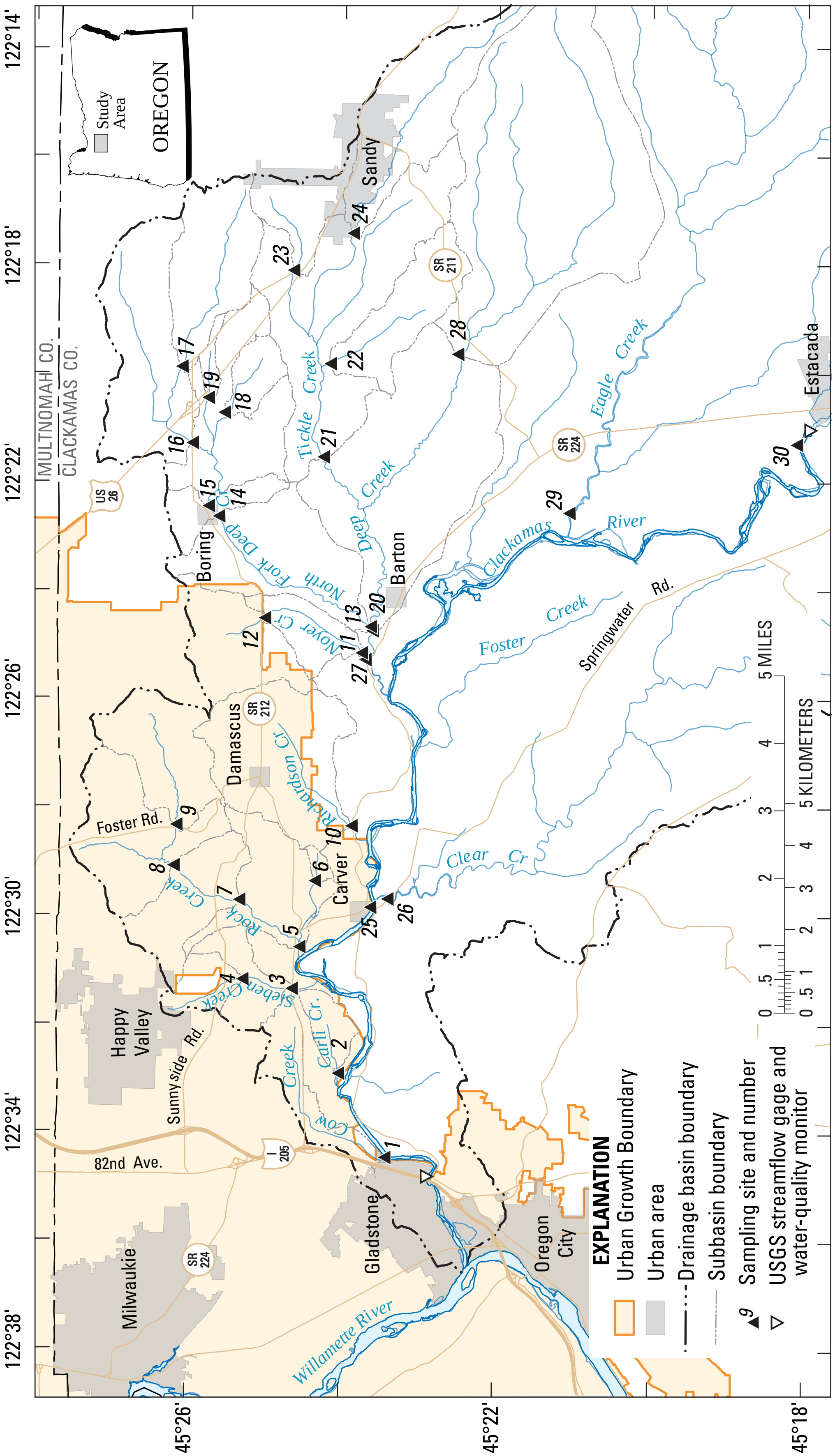
Two of the previously mentioned three additional studies were part of the USGS NAWQA Program. The SWQA drinking-water study examined the quality of source and finished water from the Clackamas River and eight other community water systems across the country (Carter and others, 2007). The EUSE study investigated the physical, chemical, and biological effects of urbanization on streams (Ian Waite, U.S. Geological Survey, written commun., 2007), with 3 sites in the Clackamas River basin included in the sampling along with 25 other streams. In 2005, a fourth pesticide study was conducted, another collaboration between the USGS and CWMG that included targeted sampling during one autumn and one spring storm. More details on each study are provided below.

Sampling of the Clackamas River for pesticides and other synthetic organic compounds as part of the SWQA study began in 2002. This two-phase study included sampling of source water (from a source water tap at the study water-treatment plant) in 2002–03 (Phase 1). During Phase 2 (2004–05), source and finished water samples from the same water-treatment plant were analyzed. During the SWQA and the USGS/CWMG repeat study in 2005, the treatment process at the water-treatment plant tested used direct filtration with multimedia rapid-sand filtration technology (anthracite coal, silica sand, and garnet sand). Coagulation chemicals and disinfectant (aluminum sulfate, aluminum chlorohydrate, and gaseous chlorine [Cl_2]) are injected near the beginning of the treatment process. A filter aid polymer is injected between sedimentation and filtration to enhance particle removal by the filter media. Occasionally, powdered activated carbon (PAC) was used at concentrations of between 2 and 5 mg/L as a final treatment step to reduce odors and improve taste, most often during summer months. Pesticide data collected during the SWQA are interpreted in this report, but the other data collected for the SWQA study, including information on other anthropogenic organic and wastewater-related compounds, are published in Carter and others (2007).

The 2003–04 EUSE study included three streams in the Clackamas River basin (all within the Deep Creek basin) that were sampled as part of a larger study in the Vancouver, Portland, Salem, and Eugene metropolitan areas (Ian Waite, U.S. Geological Survey, written commun., 2007). Three Clackamas River basin sites—North Fork Deep Creek, Tickle Creek, and upper Deep Creek—were sampled six times each for pesticides, nutrients, suspended sediment, and other water-quality constituents. Information on biological assemblages, including fish, benthic (bottom dwelling) invertebrates, and algae also were collected once from each stream during low-flow conditions in 2004. Contaminant data also were collected from semipermeable membrane devices (SPMDs), which were placed in the river to sequester pesticides and other organic compounds over a period of about 30 days. Data from this study are being used to characterize biological assemblages as they relate to urbanization and stream conditions, including pesticide occurrence during high- and low-flow conditions. Water sampling did not, however, target storm runoff during the EUSE study.

The most recent 2005 storm event sampling study, a repeat and expansion of the 2000 spring/autumn storm event study, included most of the initial sites plus additional sampling locations in the Sieben, Rock, and Deep Creek basins to further identify pesticide source areas. In 2005, Carli and Cow Creeks were added to the network of sampling sites to characterize storm-runoff conditions from these highly urbanized basins. These two streams drain the lower northwestern part the lower Clackamas River basin, where most of the commercial and industrial development is located. The most extensive storm event sampling occurred in September 2005, when 24 tributaries, the lower Clackamas River (source water), and finished water from the study drinking-water treatment plant were sampled for dissolved pesticides during a 1.5-inch rainfall event. During this storm, about a dozen sites in the Deep Creek basin were sampled, including multiple sites within the Noyer, North Fork Deep, and Tickle Creek basins, where much of the agricultural nursery land is concentrated.

This report summarizes data collected from the four USGS studies conducted between 2000 and 2005, and describes the spatial and temporal patterns in the occurrence of pesticides in the lower Clackamas River basin. This report also evaluates the potential for risks to aquatic life and human health by comparing pesticide concentrations to established benchmarks, when available, and concludes with potential directions for further study.



Base modified from U.S. Geological Survey and Metro RLIS data sets (1:24,000)
Oregon Lambert projection, North American Datum 1983

Figure 1. Locations of sampling sites in the lower Clackamas River basin, Oregon, 2000–2005.

Table 1. Sites sampled for pesticides in the lower Clackamas River basin, Oregon, 2000–2005.

[Map No. shown in figure 1. Land-cover data were derived from the 30-meter resolution USGS National Land Cover Data collected in 2001 (NLCD01) (U.S. Geological Survey, 2005). **Primary land cover: Open space** in urban areas includes greenways, lawns, parks, and other open areas. **Forest** includes evergreen, deciduous, and mixed forests (NLCD categories 41, 32, and ND 43) (Anderson and others, 1976). **Abbreviations**: NAWQA, National Water-Quality Assessment Program; EUSE, Effects of Urbanization on Stream Ecosystems (USGS NAWQA study); SWQA, Source Water-Quality Assessment (USGS NAWQA study); DWTP, drinking-water treatment plant; nd, no data; na, not applicable; mi², square mile; >, greater than]

Map No.	Drainage area (mi²)	Sampling site	Number of samples	Primary land cover (percent basin area): Agriculture: Cultivated crops	Agriculture: Pasture/hay	Urban land cover: Urban intensity: Low	Urban intensity: Medium	Urban intensity: High	Urban land cover: Open space	Forest	Study (years): Phase 1 (2000–01)	EUSE (2003–04)	SWQA (2002–05)	Phase 2 (2005)
–	–	Clackamas River at DWTP (finished drinking water)	18				na				X		X	X
–	–	Clackamas River at DWTP (source water)	34				nd				X		X	X
25	920	Clackamas River at Carver	1				74 percent forest/5 percent agriculture+urban[1]				X			
29	680	Clackamas River at Estacada	1				79 percent forest[1]				X			
1	1.3	Cow Creek at mouth, near Gladstone	2	0.0	2.7	16.5	35.0	30.6	9.8	2.5				X
2	0.6	Carli Creek upstream from mouth, near Clackamas	2	0.0	7.0	20.4	26.9	35.2	8.4	0.1				X
3	1.7	Sieben Creek at Highway 224	5	0.1	8.7	21.8	24.1	3.4	17.9	16.0	X			X
4	0.7	Sieben Creek downstream of Sunnyside Road	1	0.0	3.4	22.3	20.0	2.0	17.8	21.4				X
5	9.5	Rock Creek near mouth	3	3.8	27.6	11.4	2.7	0.3	15.6	26.2	X			X
6	0.1	Trillium Creek at Anderegg Parkway, near Damascus	2	0.0	0.5	31.6	18.6	1.9	19.4	13.0				X
7	7.3	Rock Creek at Stoneybrook Court downstream from 172nd Avenue	1	2.7	27.5	9.9	1.1	0.1	14.8	29.6				X
8	5.3	Rock Creek at 172nd Avenue	2	2.8	26.8	9.1	1.0	0.1	13.9	32.1				X
9	2.2	Rock Creek at Foster Road	1	1.2	26.4	8.0	0.8	0.0	14.4	33.1				X
10	3.9	Richardson Creek near Highway 224	3	4.9	26.3	15.3	2.4	1.0	19.5	20.1	X			X
26	87	Clear Creek at Carver	2				67 percent forest[1]				X			
27	59	Deep Creek at Highway 224	2				37 percent forest/28 percent agricultural+urban[1]				X			
11	3.1	Noyer Creek at mouth, near Barton	2	5.5	41.2	9.8	1.8	0.2	11.2	19.8				X
12	2.1	Noyer Creek downstream from Highway 212, near Damascus	2	7.3	39.1	12.4	2.2	0.3	14.7	15.0				X
20	32	Deep Creek at Camp Kuratli, near Barton	1	19.5	11.9	3.7	1.9	0.6	5.6	42.8				X
28	12.1	Deep Creek near Sandy	6	nd								X		
13	14.3	North Fork Deep Creek at Barton	8	21.8	25.3	10.8	3.4	1.1	11.8	12.4		X		X
14	10.9	North Fork Deep Creek upstream from weir, near Boring	1	27.0	22.0	11.8	3.9	1.3	13.1	7.7				X
15	10.1	North Fork Deep Creek at Boring	1	28.6	21.9	11.2	3.5	1.0	12.4	7.7				X
18	0.7	North Fork Deep Creek tributary at Church Road, near Boring	1	18.8	23.4	19.2	2.8	0.6	14.6	8.4				X
19	0.2	North Fork Deep Creek tributary at 312th Avenue, near Boring	1	56.3	13.2	10.0	9.1	1.4	3.7	1.2				X
16	6.5	Doane Creek downstream from Highway 212, near Boring	1	23.9	23.0	10.5	2.9	0.9	13.0	8.9				X
17	2.6	Dolan Creek downstream from Orient Road, near Boring	1	29.6	20.5	9.3	1.9	0.3	12.0	10.9				X
21	12.9	Tickle Creek near Boring	7	21.9	11.8	5.9	4.2	1.4	7.1	34.5		X		X
24	3.6	Tickle Creek at 362nd Avenue, near Sandy	1	31.4	1.7	8.8	7.8	2.1	7.1	34.0				X
23	1.3	Tickle Creek tributary at Orient Road, near Sandy	1	5.0	22.5	9.2	8.5	3.5	8.8	18.6				X
22	2.1	Tickle Creek tributary at Colorado Road, near Sandy	1	32.9	14.3	3.4	0.9	0.1	5.7	30.6				X
30	109	Eagle Creek at Bonnie Lure State Park	2				>80 percent forest[1]				X			

[1]Land cover data from Carpenter (2003).

Table 2. Pesticide data-collection activities in the lower Clackamas River basin, Oregon, 2000–2005.

[For a complete list of compounds analyzed in each schedule, refer to appendix table B1. **Number of samples:** Excludes quality-control samples. **Abbreviations**: CWMG, Clackamas Watershed Management Group; SWQA, Source Water-Quality Assessment (NAWQA study); EUSE, Effects of Urbanization on Stream Ecosystems (NAWQA study); NAWQA, National Water-Quality Assessment Program; USGS, U.S. Geological Survey]

Study	Years	Analytical schedules	Site types sampled			Storm events	Number of samples
			Tributaries	Clackamas River/source water	Finished drinking water		
Pesticide Study–Phase 1 (USGS/CWMG)	2000–2001	2010, 9060	X	X	X	X	21
SWQA–Phase 1 (NAWQA)	2002–2003	2003, 2060, 1433, 2020		X			18
EUSE (NAWQA)	2003–2004	2003, 2060	X				18
SWQA–Phase 2 (NAWQA)	2004–2005	2003, 2060, 1433, 2020		X	X		28
Pesticide Study–Phase 2 (USGS/CWMG)	2005	2001, 2060, 4024[1]	X	X	X	X	34

[1] Source and finished drinking-water samples (only) also were analyzed using schedules 2002 and 2003.

Methods

Field Data Collection

Sample Collection—Depth- and width-integrated water samples were collected at stream sites using a DH-81 hand sampler with cap and nozzle assembly attached to a 1–3 liter (L) Teflon® bottle (Edwards and Glysson, 1999), or if depths were shallow, by compositing width-integrated, hand-dipped samples into 1-L baked amber glass bottles, and composited into 3-L Teflon® bottles. During the 2005 storm synoptic samplings, width-integrated samples were sometimes collected in well-mixed streams using a large (15–18 L) glass carboy. Some of these samples were processed through a Teflon® churn splitter to produce split samples for the Oregon Department of Environmental Quality laboratory for analysis of select organophosphate, triazine, and pyrethroid pesticides in unfiltered water. These data are not included in this report.

Source and finished drinking-water samples were collected using trace-level (parts-per-billion) protocols developed by the NAWQA Program for dissolved pesticides (Wilde and others, 2004). Samples were collected from the drinking-water treatment plant taps into either a 14-L Teflon® churn splitter or 20-L glass carboy. With minor variation, finished samples were collected approximately 90 minutes after source water samples to approximate travel time through the water-treatment plant. Samples were placed into clean plastic cans, packed in ice, and transported to the Oregon Water Science Center laboratory in Portland, Oregon, for processing. Streamflow was measured according to standard USGS guidelines (Rantz and others, 1982), and continuous streamflow was obtained from the USGS streamflow-gaging stations in the lower Clackamas River at Estacada and near Oregon City.

Data Quality Control—About 20 percent of the water samples were submitted for quality control (QC). For pesticides, this included 15 field equipment blanks and 1 laboratory blank sample submitted to check for potential contamination in the sampling, processing, and laboratory analysis. Eleven replicate (split) samples were collected to check laboratory variability, and seven native stream and organic-free blank water samples were “spiked” with known additions of pesticides to measure the analytical accuracy of the reported concentrations, expressed as a percentage of individual compound recoveries. In addition, all pesticide samples (QC and regular samples) received synthetic tracer compounds (surrogate spikes) to track their recovery during analysis.

An evaluation of results for QC samples is presented in appendix A. In summary, all pesticide blank samples were free of pesticides, indicating a very low potential for false positives to occur for pesticides in the samples collected for the current study. Replicate QC samples showed good reproducibility in analytical results for concentrations in most cases. All pesticide concentration data used in this report can be obtained from the Clackamas River Basin Water-Quality Assessment Web page, http://or.water.usgs.gov/clackamas/. The source and finished water data from the SWQA study are published in Carter and others (2007).

Water Sample Processing and Laboratory Analysis

Water samples for pesticides were filtered through 0.7-µm baked glass-fiber (GF) filters into 1-L baked amber glass bottles. An ascorbic-acid based dechlorinating powder (quenching agent) was added to samples of finished drinking water in 2004 and 2005 to remove the chlorine from the samples (Mark Sandstrom, U.S. Geological Survey, oral commun., 2006). Water samples collected from the tributaries and the Clackamas River, including the source water samples collected at the water-treatment plant, were not chlorinated and did not receive the dechlorinating powder.

Water samples were shipped to the USGS National Water Quality Laboratory in Denver, Colorado, where they were analyzed for between 86 and 198 pesticides and degradates, depending on the individual study, using a C-18 solid phase extraction, gas chromatography/mass spectrometry (GC/MS) method (Zaugg and others, 1995; Lindley and others, 1996; Furlong and others, 2001). These laboratory methods are able to detect organic contaminants at trace concentrations (parts-per-billion, or lower), and are rigorously evaluated to establish detection limits based on statistical analysis of compound performance during analysis. When a pesticide is detected, there is a high degree of certainty (greater than 99 percent confidence) that the compound is present.

Pesticide detections occurring at concentrations less than assigned detection levels were quantified by the laboratory, but received an estimate code (remark code of "e") qualifying the concentration in the USGS database. Values were coded "e" by the laboratory when (1) certain compounds had poor recoveries or were particularly difficult to analyze, (2) sample matrix effects from chemical mixtures in storm runoff, for example, resulted in analytical difficulties, or (3) concentrations were less than the laboratory reporting level (LRL), but higher than the method detection level (MDL). Concentrations less than the LRL (also called the quantitation level) are difficult to quantify but considered to be nonzero. The accuracy of these estimated values are statistically less than values that were not coded "e," but the probability of a false positive is less than 1 percent whether values were coded "e" or not.

Differing suites (or schedules) of pesticides were analyzed in water samples collected during the different studies, depending on project goals, so interpretations regarding pesticide occurrence and distribution need to consider which pesticides were analyzed and when. Tributary samples collected during the four storm events in 2000 and 2005 were, for the most part, analyzed for a similar suite of pesticides and are relatively comparable. In 2000, storm samples were submitted for laboratory schedules 2010 and 2050, whereas schedules 2001 and 2060 (nearly identical suites of compounds) were used for the storm samples collected in 2005. These schedules cover 86 of the most commonly used pesticides in the United States. Samples collected for the USGS urbanization study were tested for a smaller subset of pesticides (about 65 pesticides and degradates) analyzed in schedule 2003. The SWQA samples were analyzed for about 130 pesticides in schedules 2003 and 2060. Pesticides and schedules in which they are included are presented in appendix B, table B1. During the May and September 2005 storm event samplings (only), glyphosate and two glyphosate degradates (AMPA and glufosinate) were analyzed. One herbicide (dichlobenil—the active ingredient in Casoron™) was detected at relatively high concentrations (8.0 and 16.8 µg/L) in Sieben Creek during 2000 (Carpenter, 2004), but laboratory analysis of dichlobenil was discontinued after 2001 because of difficulties associated with its analysis.

Turbidity data were collected from unfiltered grab samples collected during the May and September 2005 storm events, and from the continuous monitor operated by the USGS in the Clackamas River at river mile 1.3 near Oregon City. The grab samples were analyzed at the USGS Oregon Water Science Center laboratory with a Hach 2001N benchtop turbidity analyzer, which reports in Nephelometric Turbidity Ratio Units (NTRUs). The continuous water-quality monitor reports turbidity in Formazin Nephelometric Units (FNUs), which are comparable (not identical) to NTRUs. The continuous monitor data, related reports, and other data are available on the project Web page, http://or.water.usgs.gov/clackamas/.

Land-Cover Data Analyses

Land-cover data were derived for each sampling site from 30-meter resolution satellite data collected in 2001: USGS National Land Cover Data (NLCD01) (U.S. Geological Survey, 2005). The NLCD01 for Clackamas County was modified from the Coastal Change Analysis Program data (National Oceanic and Atmospheric Administration, 2005) by adjusting to match the USGS protocols and classification scheme to be consistent with NLCD01 datasets for other parts of the country. These land-cover data represent the Anderson Level II classification scheme (Anderson and others, 1976). Land-cover values for each site/basin (table 1) were tabulated using Geographic Information System (GIS) Spatial Analyst Tools extension software in Arc GIS, version 9.1, Environmental Systems Research Institute (ESRI).

Comparisons of Pesticide Concentrations to Aquatic-Life and Human-Health Benchmarks

A screening-level assessment was conducted to evaluate the concentrations of pesticides detected in the tributaries and mainstem Clackamas River, and in finished drinking water, to aquatic-life and human-health benchmarks, respectively. Pesticide concentrations in the tributaries and mainstem Clackamas River were compared with aquatic-life benchmarks from the USEPA Office of Water, USEPA Office of Pesticide Programs, State of Oregon Department of Environmental Quality, and other agencies, such as the National Academy of Sciences/National Academy of Engineering (NAS/NAE) and the Canadian Council of Ministers of the Environment (CCME). Pesticide concentrations in finished drinking water were compared to human-health benchmarks, such as USEPA Maximum Contaminant Levels (MCLs) or, for unregulated compounds, to newly established Health-Based Screening Levels (HBSLs), when available. These human-health benchmarks were developed to evaluate long-term concentrations, not the instantaneous pesticide concentrations measured during the study.

HBSLs are nonregulatory benchmarks that may indicate a potential concern for human health when concentrations exceed benchmarks (Toccalino and others, 2006). HBSLs were developed by the USGS in collaboration with the USEPA, the Oregon Health and Science University, and the New Jersey Department of Environmental Protection for compounds without USEPA drinking-water standards. HBSLs for unregulated contaminants are calculated using (a) standard USEPA Office of Water (OW) equations for establishing drinking-water guideline values (Lifetime Health Advisory (HA–L) and Cancer Risk Concentration values) for the protection of human health and (b) the most current USEPA peer-reviewed, publicly available human-health toxicity information (Toccalino and others, 2003; Toccalino, 2007). For noncarcinogens, the HBSL represents the contaminant concentration in drinking water that is not expected to cause adverse effects over a lifetime of exposure. For carcinogens, the HBSL range represents the contaminant concentration in drinking water that corresponds to an excess estimated lifetime cancer risk of 1 chance in 1 million (low HBSL) to 1 chance in 10,000 (high HBSL). HBSL calculations adopt USEPA assumptions for establishing drinking-water guidelines, namely, lifetime ingestion of 2 L of water per day by a 70-kilogram adult. For noncarcinogens, 20 percent of the total contaminant exposure is assumed to come from drinking-water sources, and 80 percent is assumed to come from other sources (for example, food and air). If data are available to quantify the percentage of contaminant exposure that comes from water, then a data-derived percentage is used instead of the default of 20 percent (Toccalino and others, 2006).

Because HBSLs are calculated using USEPA cancer classifications, USEPA toxicity data, and standard OW equations for establishing drinking-water guideline values, HBSLs are equivalent to existing USEPA Cancer Risk Concentration and HA–L values (when they exist), except for compounds for which more recent toxicity information has become available (Toccalino, 2007). The screening-level assessment used in this study was intended to identify pesticides that may be of potential concern or to prioritize needs for further investigation. Screening-level assessments are not designed to evaluate specific effects of contaminants on human health, and are not a substitute for comprehensive risk assessments, which generally include many additional factors, including multiple avenues of exposure (Toccalino and others, 2006). The USGS and its partners are continuing to refine the HBSL methodology—additional information about HBSLs and ongoing research is available at http://infotrek.er.usgs.gov/traverse/f?p=HBSL:HOME:3987754988573050.

In this report, contaminant concentrations were evaluated using maximum Benchmark Quotients (BQ max) values—ratios of the maximum measured contaminant concentrations detected to benchmark values, such as drinking water MCLs, HBSL, or aquatic-life benchmarks. The benchmark quotient ratios provide a way of evaluating the relative toxicity for each of the detections because it normalizes individual pesticide concentrations to their benchmarks. This approach does not, however, consider the potentially additive or synergistic effects of exposure to multiple compounds.

Calculation of Pesticide Toxicity Index—PTI Values

To address the issue of evaluating the potentially cumulative effects of multiple pesticide exposure on aquatic life, an additive model called the Pesticide Toxicity Index (PTI) developed by Munn and Gilliom (2001) and refined by Munn and others (2006) was used. The PTI provides an indication of the potential toxicity of a sample by adding individual toxicity quotients for pesticides detected in a sample, and although the PTI does not determine whether water in a sample is toxic, the values can be used to rank or compare the toxicity of samples on a relative basis. The PTI approach may be useful as a basis for comparing the significance of pesticides in different streams on a common basis, for evaluating relations between pesticide exposure and observed biological conditions, and for prioritizing future studies.

The PTI was calculated as the sum of the toxicity quotients for each pesticide detected in a sample, or the concentration divided by the median toxicity endpoint, typically an LC_{50} (the lethal concentration for 50 percent of a test population) for a 96-hour chemical exposure:

$$PTI = \sum_{i=1}^{n} E_i / MTC_{i,x} \quad , \qquad (1)$$

where

E_i is the concentration of pesticide i,
$MTC_{i,x}$ is the median toxicity concentration for the pesticide i for taxonomic group x,
n is the number of pesticides, and
E and MTC are expressed in micrograms per liter (µg/L).

Results

Streamflow and Turbidity Conditions

Water samples were collected during 2002–2005 over a range of streamflow conditions (fig. 2), although most samples were collected during storms. Some of the low-flow samples were collected from the mainstem Clackamas River in 2001 during winter base-flow conditions in January and during summer low-flow conditions in August (Carpenter, 2004). The three Deep Creek basin sites included in the USGS EUSE study were sampled for pesticides six times each between November 2002 and August 2004, including high- and low-flow conditions, but sampling did not target storm runoff (fig. 2).

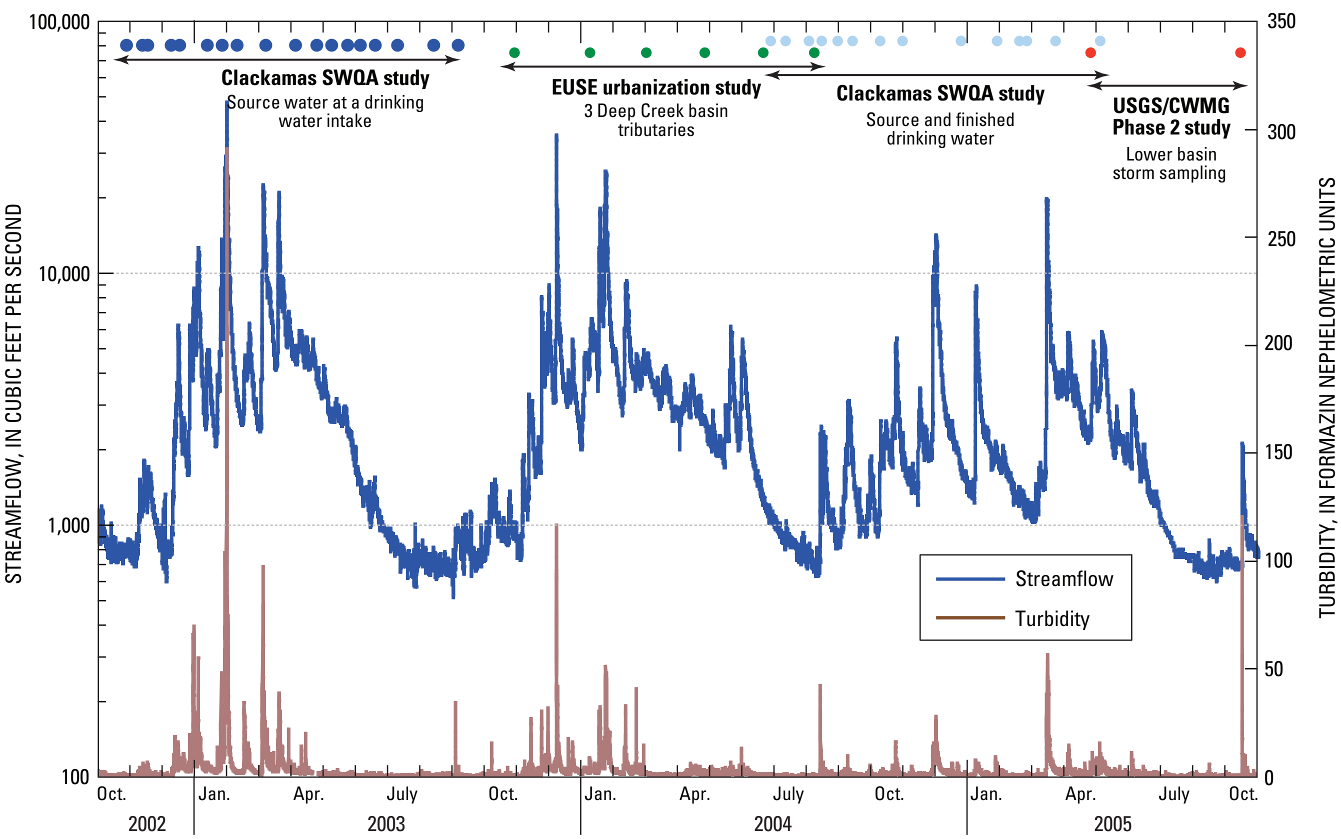


Figure 2. Distribution of data-collection activities and streamflow and turbidity conditions in the lower Clackamas River at Oregon City, Oregon, 2002–2005.

Water samples were collected from the Clackamas River during a range of streamflow conditions in 2002–2005 for the SWQA study, including low-flow (summer base flow), moderate, and high-flow conditions, but storms were purposely avoided by design. The SWQA study aimed to characterize the quality of source and finished drinking water supplies during representative conditions, not during periodic episodes of storm runoff. One set of source and finished water samples, however, was collected from the study water-treatment plant on May 18, 2005, during an elevated turbidity event in the mainstem Clackamas River (8.7 FNUs; appendix C, table C4). The mainstem Clackamas River (source water) was sampled during two storm events in May and September 2005, along with finished drinking water from the one treatment plant during the September 2005 storm.

Stormwater runoff produces high turbidity in lower Deep Creek. (Photograph taken October 2000.)

The storm samplings in May and September 2005 were designed to characterize pesticide concentrations during the spring high-use period and during the first major storm in autumn (fig. 3). In May, storm samples were collected from nine tributary sites plus source water from the water-treatment plant in the lower Clackamas River. In September, 24 tributary sites plus source and finished water from the water-treatment plant in the lower Clackamas River were sampled following several hours of heavy rainfall (fig. 4). In September, the storm came in two waves—the first arrived in the morning, when the urban streams—Sieben and Carli Creeks—were sampled, while other streams were sampled in the afternoon after a second front of rain (fig. 4). The turbidity levels in some of the lower Clackamas River tributaries were especially high during these two storms, especially upper Noyer Creek at Highway 212, where the turbidity was 670 NTRUs during the May 2005 storm, and 2,500 NTRUs during the September 2005 storm (appendix C, table C4; also, see cover photograph). Inputs of highly turbid water from the tributaries can produce elevated turbidity levels in the mainstem Clackamas River during or following rainfall (fig. 2). For example, turbidity in the lower Clackamas River increased from less than 1 to greater than 120 FNUs during the September 2005 storm (fig. 3), largely due to inputs from the lower-basin tributaries.

Samples collected from the different tributaries may not be directly comparable because of the patchy distribution of rainfall during storms, variations in the degree to which streams responded to rainfall, and where on the storm hydrograph samples were collected. In some instances, streams were sampled during peak runoff, producing relatively high instantaneous loads of pesticides. At other sites, samples were collected at the beginning of the storm before significant runoff had occurred. Streamflow conditions during the September 2005 storm show, for example, the effects of sample-collection timing at two of the Rock Creek sites. Rock Creek at Stoneybrook Court (the downstream site) was sampled in the morning, prior to the onset of the heavy rains and runoff that occurred later in the day. Although turbidity was elevated (15 NTRUs), this sample contained fewer compounds and had lower pesticide concentrations compared with the next upstream site (Rock Creek at 172nd Avenue). This site was sampled later in the day after heavy rainfall, when turbidity was considerably higher (40 NTRUs). This sample contained some of the highest pesticide concentrations detected during the study. Some of the streams (for example, Tickle, Noyer, Rock, and Sieben Creeks) were sampled during active runoff, and samples were highly turbid (200–2,500 FNUs) (appendix C, table C4).

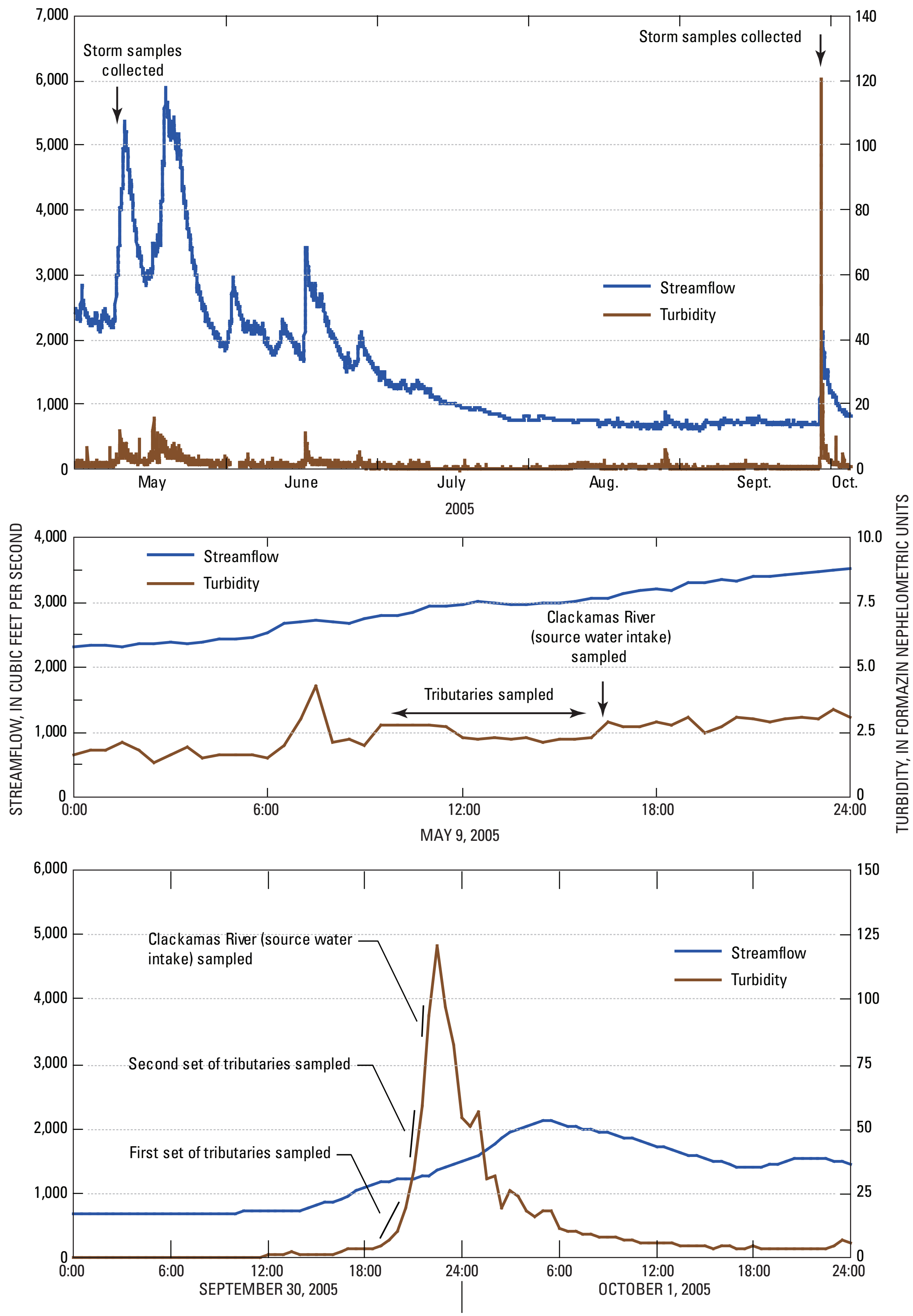


Figure 3. Streamflow and turbidity conditions in the lower Clackamas River at Oregon City, Oregon (USGS continuous water-quality monitor and streamflow-gaging station 14211010), during the May and September 2005 storm event samplings.

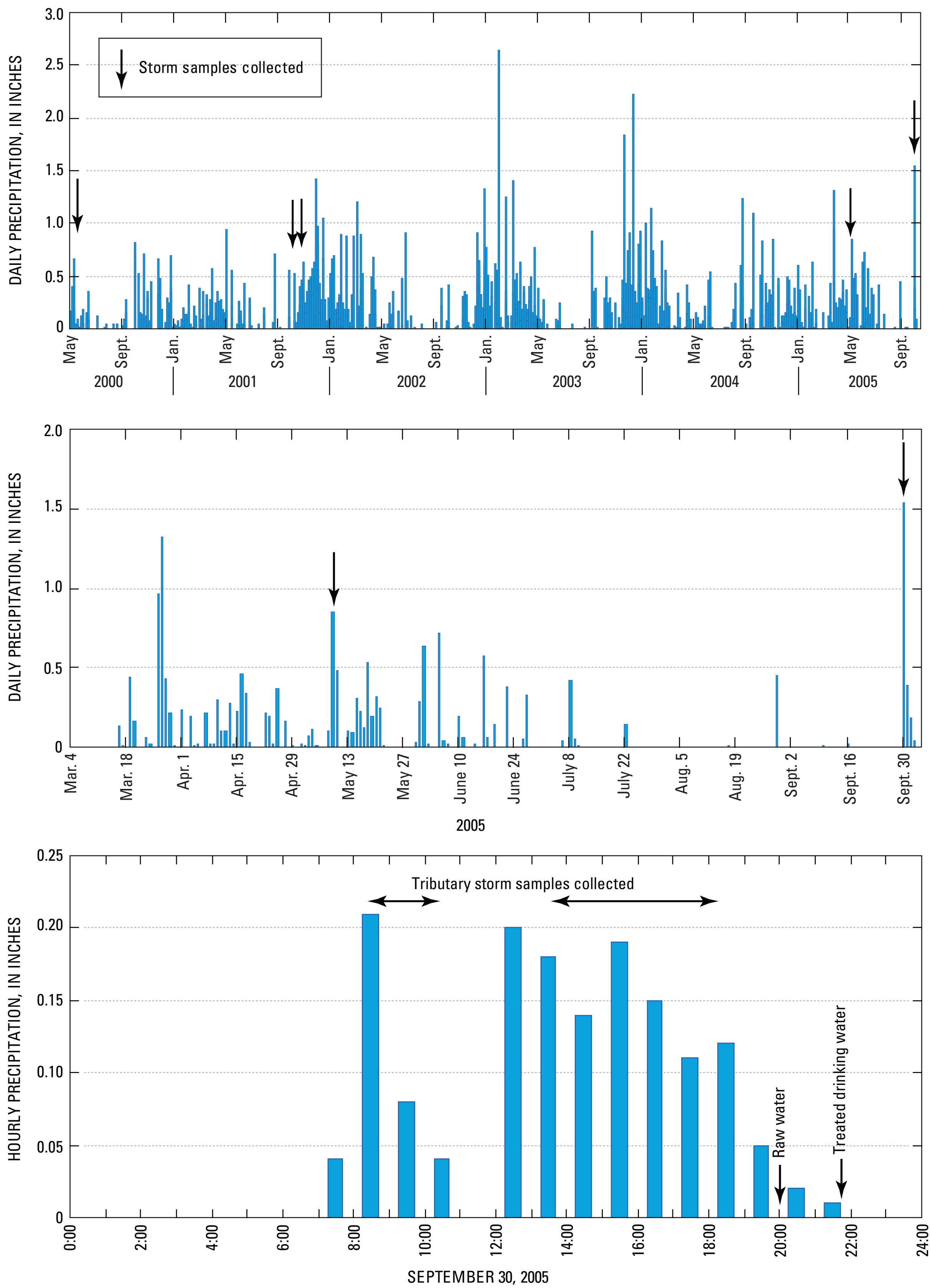


Figure 4. Daily and hourly precipitation at the Holgate Road rain gage and distribution of storm samples collected in the lower Clackamas River basin, Oregon, 2000–2005.

Confluence where Noyer Creek enters lower Deep Creek. (Photograph taken May 2005.)

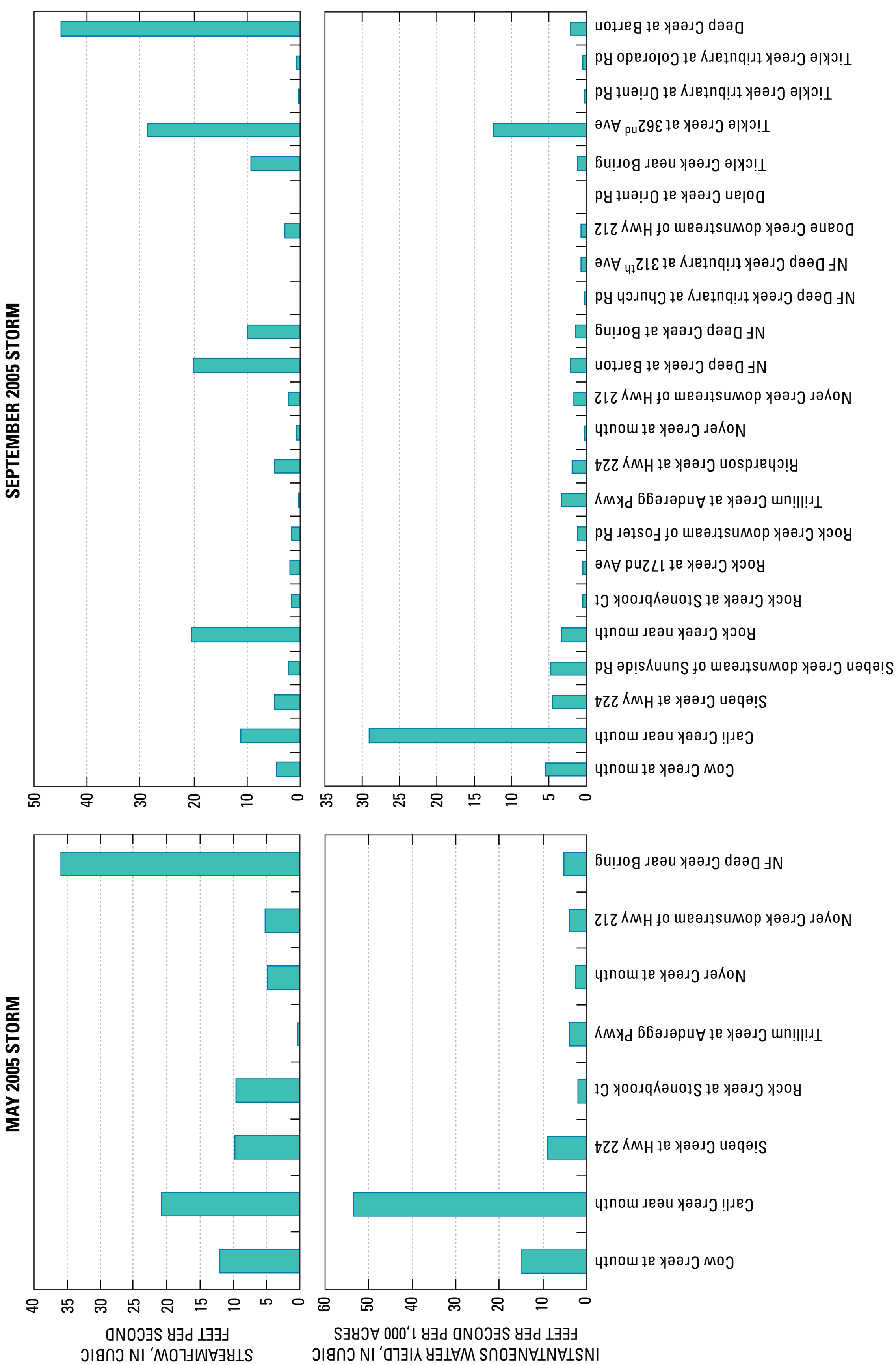
The water yield—the instantaneous streamflow (discharge) divided by the basin area—provides a measure of the amount of runoff per unit area for a basin or site, and can be used to gauge the response of a stream during periods of storm runoff. For this report, water yields were normalized to a 1,000-acre area. Water yields were highest for the urban-affected streams—Carli, Cow, Sieben, and upper Tickle Creeks (fig. 5*A*). Some of the small agricultural streams sampled during the September 2005 storm (for example, Dolan Creek, and the tributaries of upper North Fork Deep and Tickle Creeks) had relatively low streamflow (≥0.1–0.2 ft^3/s) and correspondingly low water yields (fig. 5*A*). The water yields calculated for the Rock Creek at Stoneybrook Court site in September 2005 were lower than for the two upstream locations on Rock Creek. The Rock Creek at Stoneybrook Court site was sampled in the morning prior to the onset of heavy rainfall, and may not have contained as much rainfall runoff as the two upstream sites (Rock Creek at 172nd Avenue and Rock Creek at Foster Road), which were sampled later in the day following heavy rainfall (fig. 4).

Pesticide Occurrence in the Lower Clackamas River Basin

Sixty-three pesticides and degradates were detected in 119 samples collected from the lower Clackamas River mainstem, tributaries, and source or finished drinking water (table 3). Individual pesticide concentration data from the 2000–2001 study (Carpenter, 2004) are available from the Clackamas River Basin Water-Quality Assessment Web page, http://or.water.usgs.gov/clackamas/. The recent 2003–2005 data are summarized in table 3 and individual concentrations are provided in appendix C grouped into three tables according to each study: appendix table C1 contains the May and September 2005 storm data, appendix table C2 contains the 2003–2004 EUSE study data, and appendix table C3 contains data from the 2002–2005 SWQA study. The data within each table are most comparable to each other because each study analyzed a specific subset of pesticide compounds and targeted either storm conditions (USGS/CWMG studies conducted in 2000 and 2005 only) or were collected routinely (during low, moderate, and high flows [but no targeted storm sampling]). In addition to these tables, the entire dataset from the NAWQA SWQA study, including data on pesticides, volatile organic, and other anthropogenic compounds in source and finished drinking water are provided in Carter and others (2007).

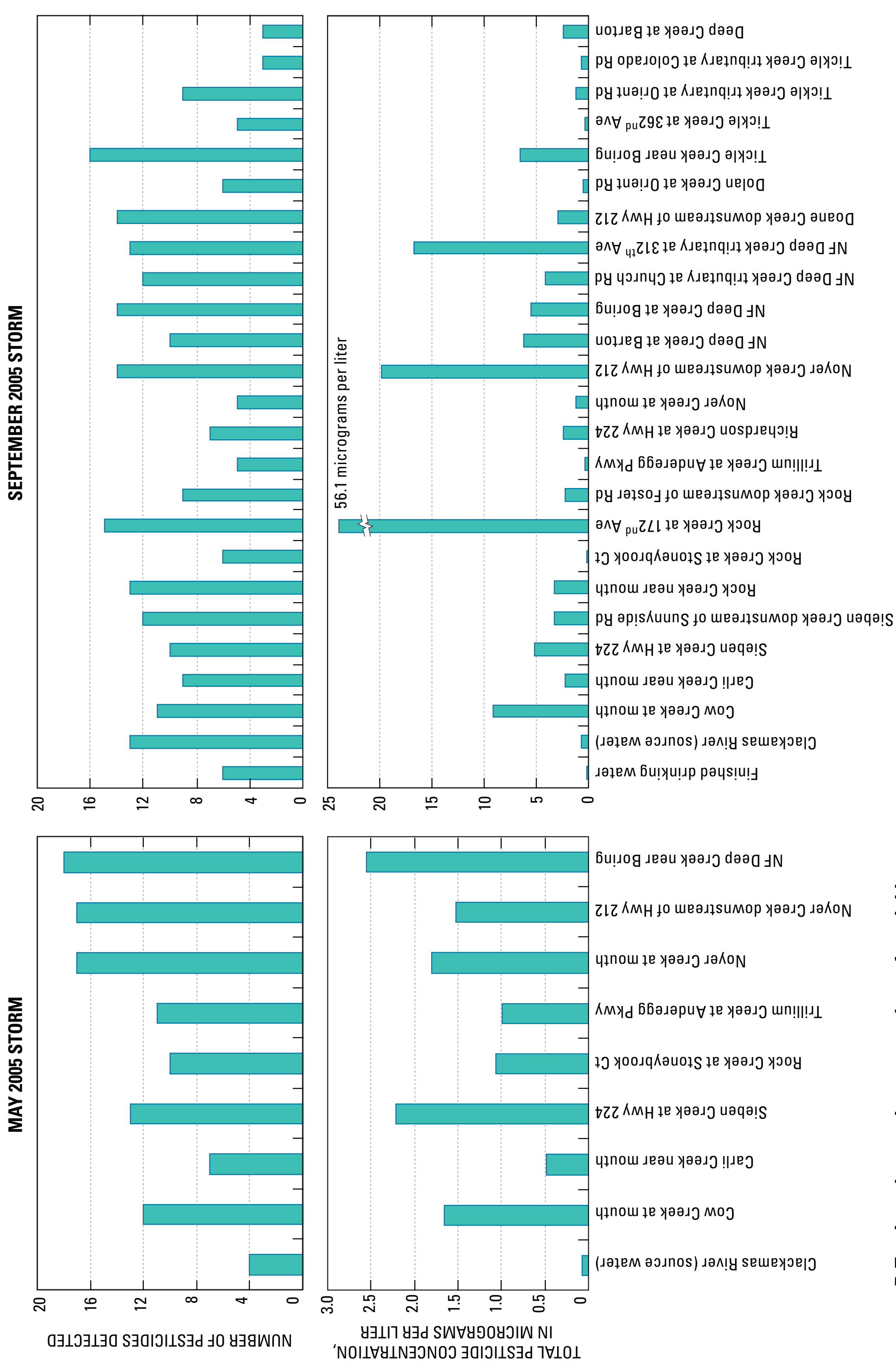
The greatest number of pesticides and the highest total pesticide concentrations were detected during storms, although most samples were collected during storms (nonstorm samples included only those collected for the EUSE urbanization study and the SWQA drinking-water study). Samples collected during storms—which represent most of the tributary samples plus a few of the mainstem samples—contained between 3 and 18 compounds each, averaging 11 pesticides per sample.

Pesticide occurrence was widespread in the tributaries that drain the northwestern area of the lower Clackamas River basin, including Deep, Richardson, Rock, Sieben, Carli, and Cow Creeks (fig. 5*B*). Pesticides were detected in all of 59 storm samples collected from these streams. Most of the samples containing the highest pesticide concentrations or greatest number of compounds also had relatively high turbidity values (appendix C, table C4).



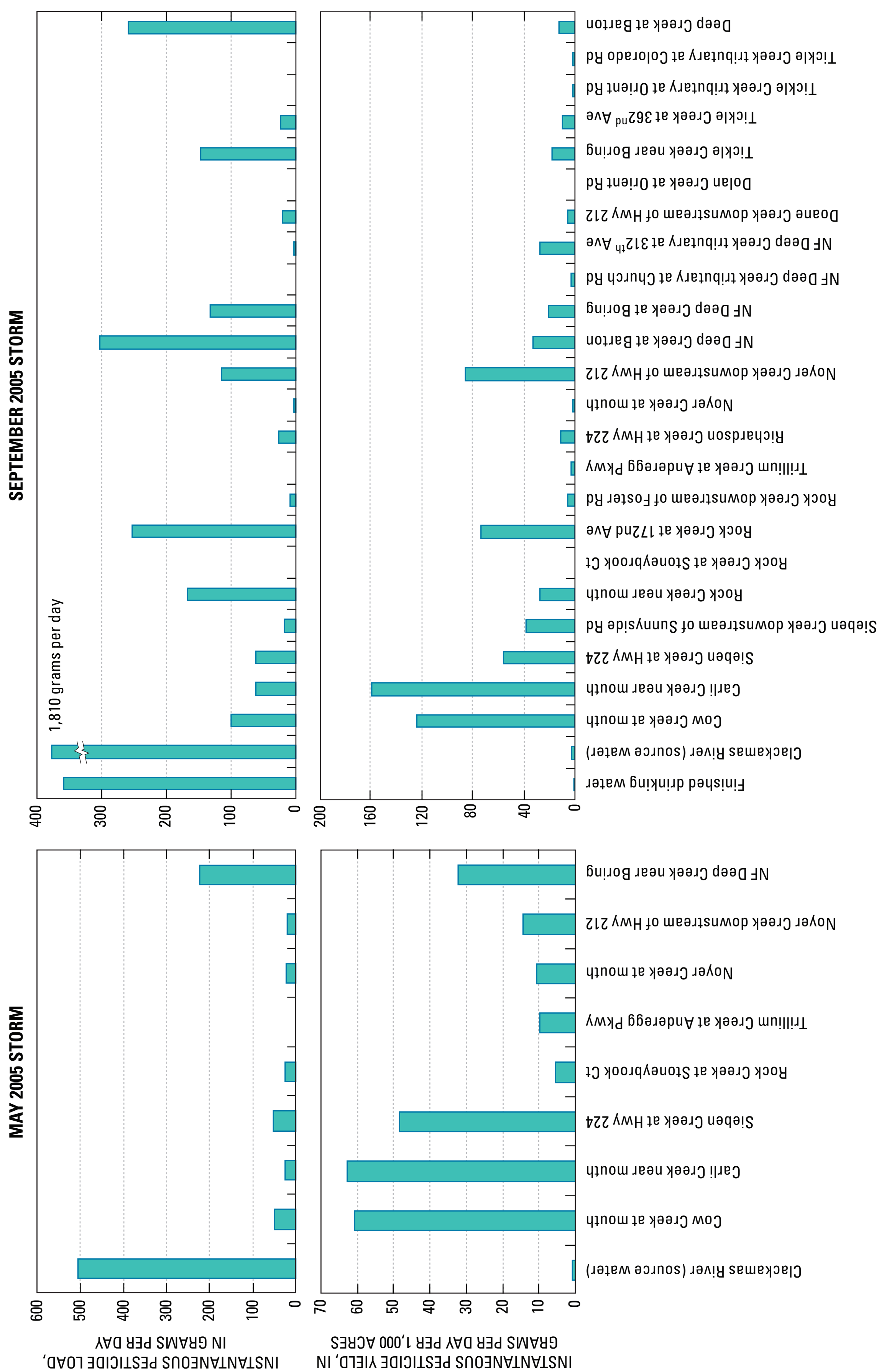
***A*. Streamflow and water yields**

Figure 5. Patterns in streamflow and water yield, pesticide numbers and total concentrations, and instantaneous pesticide load and yields during two storm event samplings in the lower Clackamas River basin, Oregon, May and September 2005.



***B.* Total numbers and concentrations of pesticides**

Figure 5.—Continued.



***C.* Pesticide loads and yields**

Figure 5.—Continued.

Table 3. Pesticide compounds detected in the lower Clackamas River basin, Oregon, 2000–2005.

[**Type:** H, herbicide; I, insecticide; F, fungicide; N, nematocide; M, molluscicide; HD, herbicide degradate; ID, insecticide degradate. **Symbols:** **, pesticide exceeded a U.S. Environmental Protection Agency (USEPA) aquatic-life benchmark; *, pesticide exceeded a non-USEPA aquatic-life benchmark; _, indicates a pesticide degradate; #, pesticide compound not detected since the 2000–2001 study]

Pesticide or degradate	Type	Commercial products/ common or trade name	Chemical class	Percent detection	Number of pesticide detections								
							Sample type			Study (years)			
					Parent compounds	Degradates	Tributaries	Clackamas River/ source water	Finished drinking water	Phase I (2000–2001)	SWQA (2002–2005)	EUSE (2003–2004)	Phase II (2005)
2,4-D methyl ester	H	Pestanal, Methyl (2,4-dichlorophenoxy) acetate	Chlorophenoxy acid	3	2		2	0	0	0	0	0	2
2,4-D*	H	Crossbow, Aqua-Kleen, Lawn-Keep, Weed-B-Gone, Fernesa	Chlorophenoxy acid	35	33		28	4	1	5	2	0	26
2,4-DP	H	Dichlorprop, Seritox 50, Kildip, Lentemul	Chlorophenoxy acid	1	1		1	0	0	0	0	0	1
Atrazine	H	AAtrex, Atrex, Atred, Gesaprim	Triazine	47	55		46	8	1	13	7	16	19
_Deethylatrazine (CIAT)	HD	Atrazine degradate, DEA, desethylatrazine	Triazine	31		36	31	4	1	7	5	18	6
_Hydroxyatrazine (OIET)	HD	Atrazine degradate	Triazine	8		6	5	1	0	0	1	0	5
Azinphos-methyl**	I	AZM, Carfene, Guthion, Gusathion M	Organothiophosphate	1	1		1	0	0	0	0	0	1
Benomyl	F	Benlate, Agrocit, Benex, Benosan, Fundazol	Carbamate	5	4		4	0	0	0	0	0	4
Bentazon	H	Basagran, Bentazone, Bendioxide	N heterocycle	1	1		1	0	0	0	0	0	1
Bromacil	H	Hyvar X, Urox B, Bromax	Uracil	3	3		2	1	0	1	1	0	1
Carbaryl*[1]	I	Carbamine, Denapon, Sevin, Savit	Carbamate	18	21		18	3	0	3	3	1	14
_1-Naphthol	HD/ID	Carbaryl/napropamide degradate, alpha-naphthol	Phenol	3		2	2	0	0	0	0	0	2
Chlorothalonil*	F	Bravo, Daconil 2787, Echo, Exotherm	Organochlorine	1	1		1	0	0	0	0	0	1
Chlorpyrifos**	I/N	Brodan, Dursban, Lorsban, Chlorpyrifos-ethyl	Organothiophosphate	21	25		23	2	0	4	2	8	11
Cycloate	H	Ro-Neet, Marathon	Thiocarbamate	3	2		1	1	0	0	0	0	2
Dacthal (DCPA)	H	Chlorthal-dimethyl	Chlorobenzoic acid ester	15	17		9	6	2	3	5	0	9
_*p,p'*-DDE** #	ID	DDT degradate	Organochlorine	2		1	1	0	0	1	0	0	0
DEET	I	Insect repellents (OFF, Cutter Outdoorsman, Skeeter skat)	N-diethyl toluamide	7	4		0	3	1	0	4	0	0
Diazinon**	I	Basudin, Diazatol, Neocidol, Knox Out	Organothiophosphate	25	29		23	6	0	10	3	5	11
_Diazinon-oxon	ID	Diazinon breakdown product, Diazinox	Organophosphate	2		1	0	0	1	0	0	0	1
Dichlobenil #[2]	H	Casoron, Barrier, Dyclomec, Norosac	Organochlorine	31	5		5	0	0	5	0	0	0
Dichlorvos	I/F	DDVP, Apavap, Devikol, Didivane, Duravos, Fly-Die	Organophosphate	2	1		0	1	0	0	1	0	0
Dieldrin*	I	Panoram D-31, Octalox, Compound 497, Aldrin epoxide	Organochlorine	7	8		8	0	0	2	0	2	4

Table 3. Pesticide compounds detected in the lower Clackamas River basin, Oregon, 2000–2005.—Continued

[**Type:** H, herbicide; I, insecticide; F, fungicide; N, nematocide; M, molluscicide; HD, herbicide degradate; ID, insecticide degradate. **Symbols:** **, pesticide exceeded a U.S. Environmental Protection Agency (USEPA) aquatic-life benchmark; *, pesticide exceeded a non-USEPA aquatic-life benchmark; _, indicates a pesticide degradate; #, pesticide compound not detected since the 2000–2001 study]

Pesticide or degradate	Type	Commercial products/ common or trade name	Chemical class	Percent detection	Number of pesticide detections								
							Sample type			Study (years)			
					Parent compounds	Degradates	Tributaries	Clackamas River/ source water	Finished drinking water	Phase I (2000–2001)	SWQA (2002–2005)	EUSE (2003–2004)	Phase II (2005)
Dimethenamid	H	Frontier, Guardsman, Optill, Pursuit	Amide	33	1		0	1	0	0	0	0	1
Dinoseb	H/I	DNPB, Dinosebe	Nitrophenol	1	1		1	0	0	0	0	0	1
Diuron*	H	Crisuron, Karmex, Direx, Diurex	Urea	44	41		22	15	4	7	16	0	18
_3,4-Dichloroaniline	HD	Diuron/iprodione degradate	Aniline	13		8	8	0	0	0	0	8	0
_3,4-Dichlorophenyl isocyanate[3]	HD	Diuron/linuron/neburon degradate	Urea	100		4	4	0	0	0	0	0	4
Endosulfan I*	I	alpha-Endosulfan, Endocel, Endocide, Endosol	Organochlorine	17	1		1	0	0	0	0	0	1
Endosulfan II*	I	beta-Endosulfan	Organochlorine	17	1		1	0	0	0	0	0	1
_Endosulfan sulfate	ID	Endosulfan I/II degradate	Organochlorine	33		2	2	0	0	0	0	0	2
Ethoprop	I/N	Ethoprophos, Mocap	Organothiophosphate	33	18		16	1	1	2	0	0	16
Fenuron	H	Beet-Klean, Dybar, Fenidim, Fenulon, Urab	Urea	3	3		3	0	0	0	0	0	3
Fonofos #	I	Dyfonate, Capfos, Cudgel, Tycap	Organothiophosphate	1	1		1	0	0	1	0	0	0
Glyphosate	H	Roundup, Rodeo	Amino acid derivative, organophosphate	71	24		23	1	0	0	0	0	24
_AMPA	HD	Glyphosate degradate	Organophosphate	24		8	8	0	0	0	0	0	8
Hexazinone	H	DPX 3674, Pronone, Velpar	Triazinone	42	22		16	4	2	0	6	16	0
Imazaquin #	H	Image 1.5LC, Scepter 1.5L	Imidazolinone	1	1		0	1	0	1	0	0	0
Imidacloprid	I	Admire, Gaucho, Merit	N heterocycle	3	2		2	0	0	0	0	0	2
Iprodione	F	Chipco, Kidan, Rovral, Verisan	Dicarboximide	2	1		1	0	0	0	0	0	1
Linuron #	H	Lorox, Linex, Sarclex, Linurex, Afalon	Urea	2	1		1	0	0	1	0	0	0
Malathion*	I	Cythion, Fyfanon	Organothiophosphate	2	2		2	0	0	1	0	0	1
MCPA	H	Rhomene, Rhonox, Chiptox	Chlorophenoxy acid	1	1		1	0	0	0	0	0	1
Metalaxyl	F	Apron, Delta-Coat AD, Ridomil, Subdue	Amino acid derivative	22	22		21	1	0	0	1	14	7
Methiocarb	I/M	Draza, Grandslam, Mesurol, Slug-Geta	Carbamate	3	3		3	0	0	0	0	0	3
Metolachlor	H	Dual, Pennant	Acetanilide	42	49		42	6	1	8	4	11	26
Metsulfuron-methyl	H	Escort, Gropper, Ally, Pasture	Sulfonylurea	1	1		0	0	1	0	1	0	0
Myclobutanil	F	Eagle, NOVA, Laredo EC, Fungicide m, Rally, Systhane	Triazole	10	6		6	0	0	0	0	6	0

Table 3. Pesticide compounds detected in the lower Clackamas River basin, Oregon, 2000–2005.—Continued

[**Type:** H, herbicide; I, insecticide; F, fungicide; N, nematocide; M, molluscicide; HD, herbicide degradate; ID, insecticide degradate. **Symbols:** **, pesticide exceeded a U.S. Environmental Protection Agency (USEPA) aquatic-life benchmark; *, pesticide exceeded a non-USEPA aquatic-life benchmark; _, indicates a pesticide degradate; #, pesticide compound not detected since the 2000–2001 study]

Pesticide or degradate	Type	Commercial products/ common or trade name	Chemical class	Percent detection	Number of pesticide detections								
							Sample type			Study (years)			
					Parent compounds	Degradates	Tributaries	Clackamas River/ source water	Finished drinking water	Phase I (2000–2001)	SWQA (2002–2005)	EUSE (2003–2004)	Phase II (2005)
Napropamide	H	Devrinol, Naproquard	Amide	44	24		22	2	0	8	0	0	16
Norflurazon	H	Evital, Predict, Solicam, Telok, Zorial	Amine	3	3		3	0	0	0	0	0	3
Oryzalin	H	Dirimal, Ryzelan, Surflan	Dinitroaniline	1	1		1	0	0	0	0	0	1
Oxyfluorfen	H	Goal, Koltar, RH-2915	Diphenyl ether	17	1		1	0	0	0	0	0	1
Pendimethalin	H	Pre-M, Prowl, Weedgrass Control, Stomp, Herbadox	Dinitroaniline	8	9		9	0	0	4	0	0	5
Prometon	H	Pramitol, Princep, Gesagram 50, Ontracic 80	Triazine	23	27		25	2	0	6	1	5	15
Pronamide	H	Propyzamid, Kerb	Amide	3	3		2	0	1	2	1	0	0
Propiconazole	F	Tilt, Orbit, Banner, Proconazole, Wocosin	Triazole	5	6		4	1	1	0	0	0	6
Propoxur	I	Baygon, Blattanex, Unden, Proprotox	Carbamate	1	1		1	0	0	0	0	0	1
Simazine	H	Princep, Caliber 90, Gesatop, Simazat	Triazine	52	60		44	12	4	9	13	13	25
Sulfometuron-methyl	H	Oust, DPX-T5648	Sulfonylurea	6	5		5	0	0	0	0	0	5
Tebuthiuron	H	Spike, Perflan, Tebusan	Urea	4	5		5	0	0	2	0	0	3
Terbacil #	H	Sinbar, Geonter	Uracil	2	1		1	0	0	1	0	0	0
Triclopyr	H	Crossbow, Garlon, Grandstand, Grazon, Redeem, Remedy	Organochlorine, N heterocycle	22	21		20	1	0	5	0	0	16
Trifluralin	H	Treflan, Elancolan, Gowan, Tri-4, Trific, Trilin	dinitroaniline	27	31		26	4	1	7	4	9	11

[1] Carbaryl recoveries in some QA spike samples were as high as 304 percent. For more details, see the quality-control discussion in appendix A.

[2] Although dichlobenil was detected at relatively high levels in 2000 (up to 17 µg/L), its analysis was discontinued in 2001.

[3] 3,4-Dichlorophenyl isocyanate data are provisional because the method was still under development at the time of analysis during this study. The occurrence of 3,4-Dichlorophenyl isocyanate (a degradate of diuron) is of significance due to the widespread use and the high detection frequency for diuron. 3,4-Dichlorophenyl isocyanate was detected in all 4 of 4 samples tested. For more details, see the quality-control discussion in appendix A.

The two most common pesticides were the triazine herbicides simazine and atrazine, which were detected in about one-half of samples collected during 2000–2005 (table 3). CIAT (deethylatrazine, a degradate of atrazine) was detected along with atrazine in about 30 percent of samples. The common household and forestry herbicides having active ingredients glyphosate, triclopyr, and 2,4-D (the active ingredients in the widely used herbicide products RoundUP™ and Crossbow™) were frequently detected together, often making up most of the total pesticide concentration for an individual sample (fig. 6).

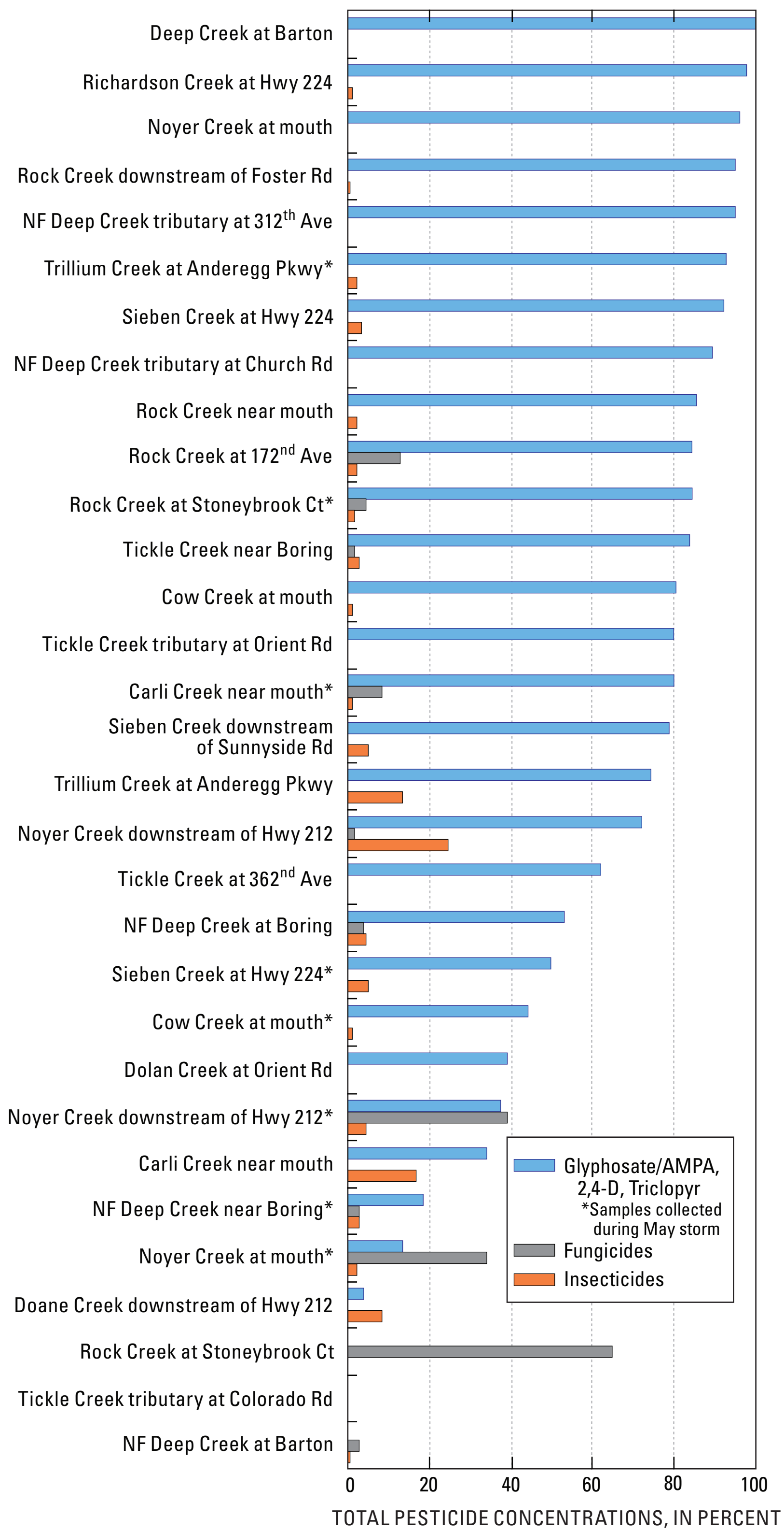


Figure 6. Percentage of total pesticide concentration from the common herbicide products RoundUP™ (glyphosate and its degradate AMPA) and Crossbow™ (2,4–D and triclopyr), fungicides, and insecticides for storm samples collected from tributaries, May and September 2005. (Samples are sorted by percentage of glyphosate/AMPA, 2,4-D, and triclopyr.)

Distribution of the total number of pesticide compounds detected in each of the major tributaries, the Clackamas River (or source water), and in finished drinking water is presented in figure 7. Not all streams were sampled with the same frequency, differing with the individual study objectives. Nevertheless, the greatest numbers of compounds were detected in the Rock Creek and Deep Creek basins, with 34 pesticides or pesticide degradates detected in North Fork Deep Creek alone (fig. 7). The relatively high number of pesticide compounds detected in this stream was due in part to the relatively high number of samples collected from this stream (*n* = 13).

Twelve compounds, including nine herbicides, two fungicides, and one insecticide, had maximum concentrations exceeding 1 µg/L (fig. 8). The maximum concentrations for most insecticides ranged from about 0.1 to 0.3 µg/L, and many of these higher concentrations exceeded aquatic-life benchmarks. Three samples containing the highest total pesticide concentrations (>15 µg/L) were all collected during the September 2005 storm sampling (fig. 5*B*). The sample from Rock Creek at 172nd Avenue contained relatively high concentrations of the herbicide glyphosate (45.8 µg/L) and the fungicide benomyl (5.7 µg/L). Rock Creek drains rural residential, agricultural (including nurseries), and forest lands. The total pesticide concentration in Noyer Creek downstream of Highway 212 was about 20 µg/L, mostly glyphosate (12.5 µg/L) and the insecticide imidacloprid (4.5 µg/L). The total pesticide concentration was about 15 µg/L in a small tributary of North Fork Deep Creek at 312th Avenue (site 19 in fig. 1), where three herbicides—glyphosate, 2,4-D, and triclopyr—were detected at concentrations ranging from 4.8 to 6 µg/L each. A wide variety of pesticide compounds (13–15 pesticides each) also were detected in these 3 samples (fig. 5*B*).

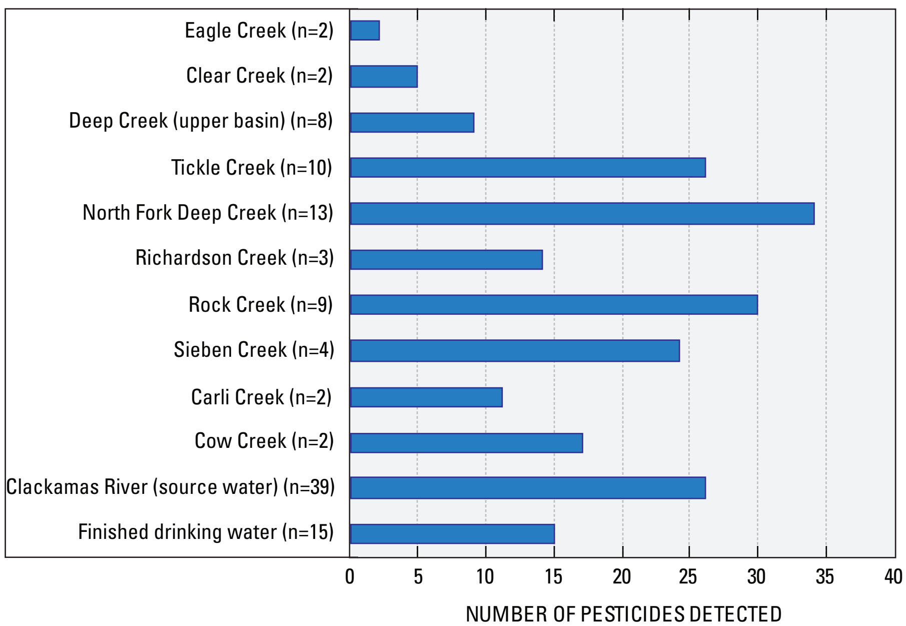


Figure 7. Number of pesticide compounds detected in samples collected from the lower Clackamas River basin tributaries and in source and finished drinking water from the study water-treatment plant on the lower Clackamas River, Oregon, 2000–2005.

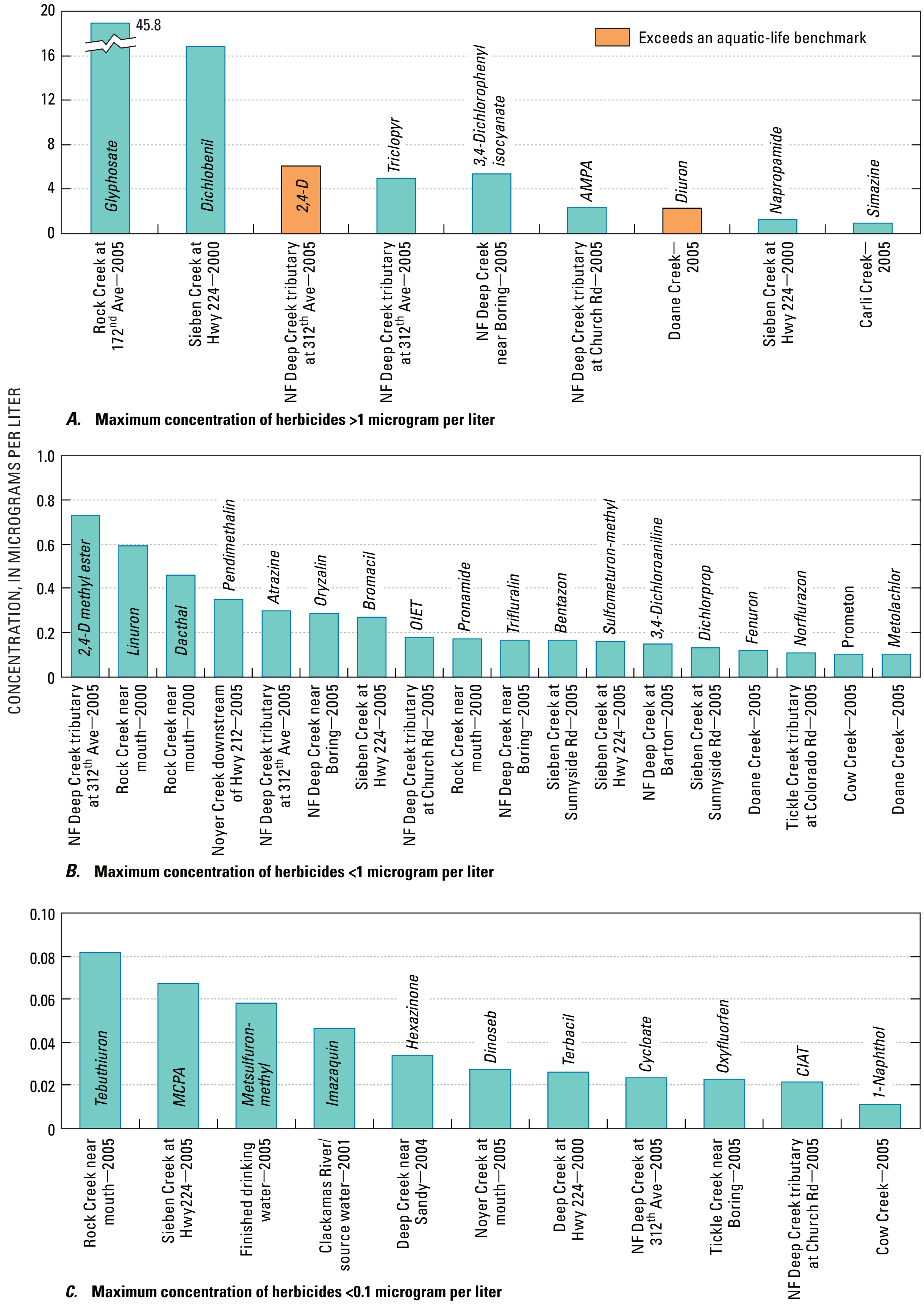


Figure 8. Maximum concentrations of herbicides, insecticides, and fungicides detected in samples collected from the lower Clackamas River basin, Oregon, 2000–2005.

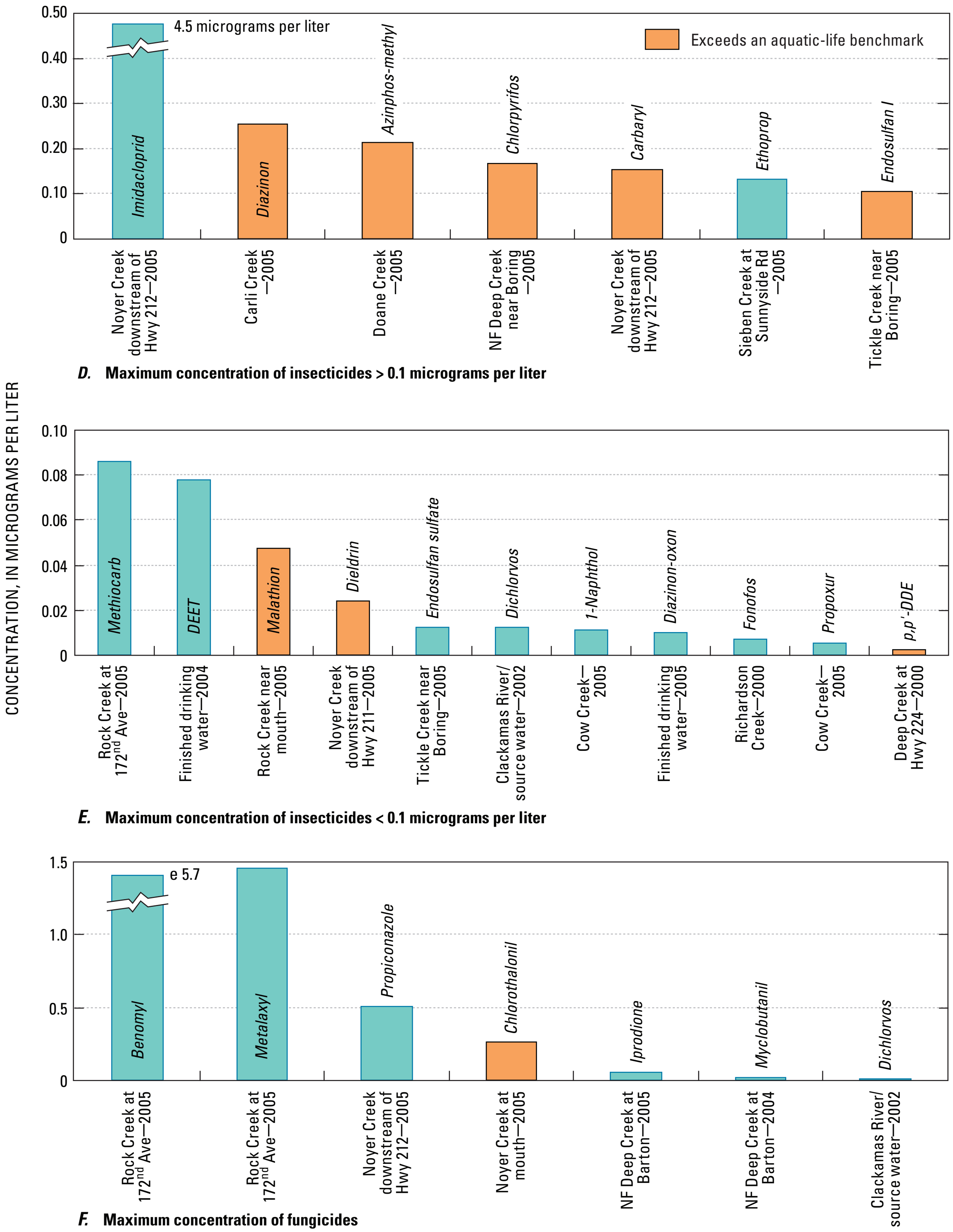


Figure 8.—Continued.

The highest instantaneous pesticide loads were found in Rock, Noyer, North Fork Deep Creek, Tickle, and upper Deep Creeks (fig. 5*C*). Tributaries draining nursery land such as Tickle, Noyer, Rock, and Sieben Creeks contained 24–30 pesticides each, with 17–18 compounds being detected in individual samples from upper Noyer and North Fork Deep Creeks during the May 2005 storm (fig. 5*B*).

The maximum chlorpyrifos concentrations in North Fork Deep Creek at Boring and Noyer Creek downstream from Highway 212 were 0.17 and 0.14 µg/L, respectively, during the September 2005 storm (appendix C, table C1). Azinphos-methyl, another organophosphate insecticide, was detected at an estimated concentration of 0.21 µg/L in Doane Creek, a tributary of North Fork Deep Creek that drains the agricultural and nursery land north of Highways 212 and 26 (fig. 1; pl. 1).

Pesticides were detected in all 18 samples collected from the 3 Deep Creek basin streams sampled for the EUSE study, with between 3 and 13 pesticides detected in each sample. Six sets of pesticide samples collected during nonstorm conditions from Deep, Tickle, and North Fork Deep Creeks identified North Fork Deep Creek as a major pesticide contributor to Deep Creek during nonstorm periods (fig. 9). The total pesticide load in North Fork Deep Creek was on average three times greater than Tickle Creek and eight times greater than upper Deep Creek.

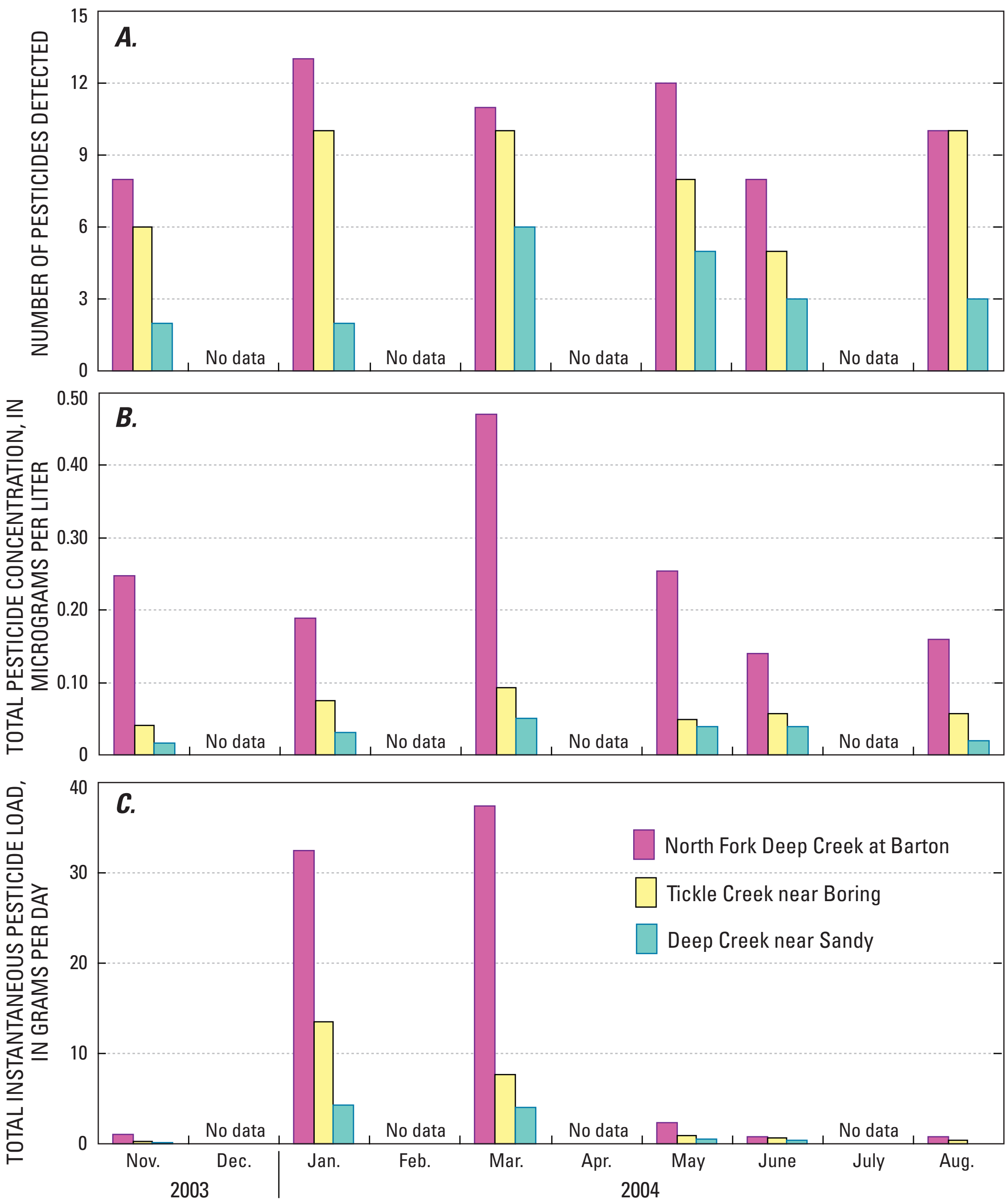


Figure 9. Number, total concentration, and total instantaneous load of pesticides for samples collected during the EUSE urbanization study from three streams in the Deep Creek basin, Oregon, 2003–2004.

North Fork Deep Creek near Boring, Oregon. (Photograph taken April 2006.)

Twenty-six pesticides and degradates were detected in 39 samples collected from the mainstem Clackamas River or from the source-water tap at a direct filtration treatment plant on the lower river (fig. 2; table 3). Of the 34 samples of source water analyzed, at least 1 pesticide was detected in 22 samples (65 percent) with an average of 2–3 pesticides per sample. Pesticide concentrations in the mainstem Clackamas River generally were much lower than those in the tributaries owing to dilution from streamflow originating in the forested upper Clackamas River basin.

The most frequently detected pesticides in the mainstem Clackamas River included the herbicides simazine, diuron, and atrazine, which were detected in 8–15 samples, followed by the insecticide diazinon and the herbicide metolachlor, which were each detected 6 times (table 3). Following the pattern observed for tributaries, the greatest number and highest concentrations of pesticides were detected in the mainstem Clackamas River following storms (fig. 10). One sample of the mainstem Clackamas River collected during the September 2005 storm event contained 13 compounds—2,4-D, cycloate, dacthal (DCPA), diazinon, dimethanamid, diuron, ethoprop, glyphosate, metolachlor, prometon, propiconazole, simazine, and triclopyr (appendix C, table C3).

Pesticide Concentrations in Finished Drinking Water

Fifteen pesticide compounds were detected in at least 1 sample of finished drinking water from the study water-treatment plant in the lower Clackamas River sampled during 2004–2005, including 10 herbicides, 1 insecticide, 1 insect repellent, 1 fungicide, and 2 pesticide degradates (tables 3 and 4; fig. 7). All told, there were 23 individual detections of a pesticide in finished drinking water, with at least 1 pesticide occurring in 9 of 15 (or 60 percent) of samples. About 98 percent of the 1,790 individual pesticide analyses in finished drinking water were below laboratory method detection levels. All of the concentrations for regulated pesticide compounds in finished water were far below their respective USEPA drinking-water standard, and for unregulated compounds, none of the available human Health-Based Screening Level (HBSL) benchmarks were exceeded. About one-half of the finished water detections were "e" coded (table 4), and although relatively low, they appear reliable because nearly all of the individual detections in finished drinking water had corresponding detections in source water.

In most cases, pesticide concentrations in finished water were somewhat lower than those in the source water. In addition to actual removal during treatment, small concentration differences between source and finished drinking water samples could represent variability in the analytical method at these sub-parts-per-billion concentrations. Also, the timing of sample collection can be especially important during storms, when streamflow and pesticide runoff are dynamic (fig. 3). At such times, contaminant concentration may be different in source and finished water if the timing of sample collection of the source and finished water varies significantly from the actual travel time through the treatment plant.

The four most common pesticides detected in finished drinking water were the herbicides diuron, simazine, dacthal (DCPA), and hexazinone, which occurred in two to four samples each. Simazine and diuron were each detected four times (table 3). Pesticide compounds detected once in finished water included the herbicides 2,4-D, atrazine, CIAT (an atrazine degradate), metolachlor, trifluralin, pronamide, and metsulfuron-methyl; the insecticide ethoprop, diazinon-oxon (the degradate of the insecticide diazinon), and DEET (an insect repellent).

The greatest numbers and highest concentrations of pesticides in finished drinking water were detected in samples collected after storms (fig. 10), with finished drinking water results typically following the pattern observed in the mainstem Clackamas River and lower-basin tributaries. The highest concentration of total pesticides in finished drinking water (0.28 µg/L from nine pesticide compounds) occurred in the May 18, 2005, sample collected 9 days following a storm (table 4, figs. 11 and 12). About one-third (or 38 percent) of the finished water samples contained no detectable pesticides, with a maximum of two pesticides being detected in finished water samples minimally affected by storm runoff.

Powdered activated carbon (PAC) appeared to be effective in removing some pesticide compounds present in source water samples such as OIET, cycloate, dacthal, trifluralin, and triclopyr (table 5). In most cases, however, concentrations in the source water were low (often close to the detection level), such that observed reductions during treatment may not be statistically significant for individual compounds. Nevertheless, the overall number and concentrations of pesticides in finished water decreased on the two occasions when PAC was in use. For comparison, 9 of 10 compounds detected in source water also were detected in finished drinking water on May 18, 2005, when PAC was not in use, with a marginal decrease in the total pesticide concentration (fig. 10).

Table 4. Pesticide concentrations in source and finished drinking water from the study water-treatment plant on the lower Clackamas River, Oregon, 2004–2005.

[Pesticide concentrations in micrograms per liter. See p. 3 for more information on the study plant's water treatment process. **Abbreviation**: e, estimated value (see Glossary). Symbol: <, less than]

Date	Pesticide or degradate	Source water		Finished drinking water	
		Remark	Value	Remark	Value
07-21-04	Dacthal (DCPA)		0.005		0.005
09-23-04	Diuron		0.02		0.02
08-25-04	DEET	e	0.007	e	0.008
10-20-04	Diuron		0.06		0.04
02-09-05	Diuron		0.06		0.06
	Simazine	<	.005		.006
03-09-05	Simazine	<	0.005	e	0.003
04-06-05	Hexazinone	e	0.01	e	0.01
05-18-05	Diuron		0.22		0.18
	Metsulfuron-methyl	<	.025	e	.06
	Hexazinone		.022		.02
	Atrazine		.007	e	.006
	Deethylatrazine (CIAT)	e	.005	e	.005
	Pronamide	<	.004		.005
	Trifluralin	e	.005	e	.005
	Simazine		.005	e	.004
	Dacthal (DCPA)	e	.002	e	.002
09-30-05	2,4-D		0.18		0.08
	Propiconazole (*cis*)	e	.003	e	.001
	Propiconazole (*trans*)	e	.006	e	.005
	Diazinon		.016	<	.005
	Diazinon-oxon	<	.006	e	.01
	Simazine		.018		.02
	Ethoprop		.009		.006
	Metolachlor	e	.005	e	.002

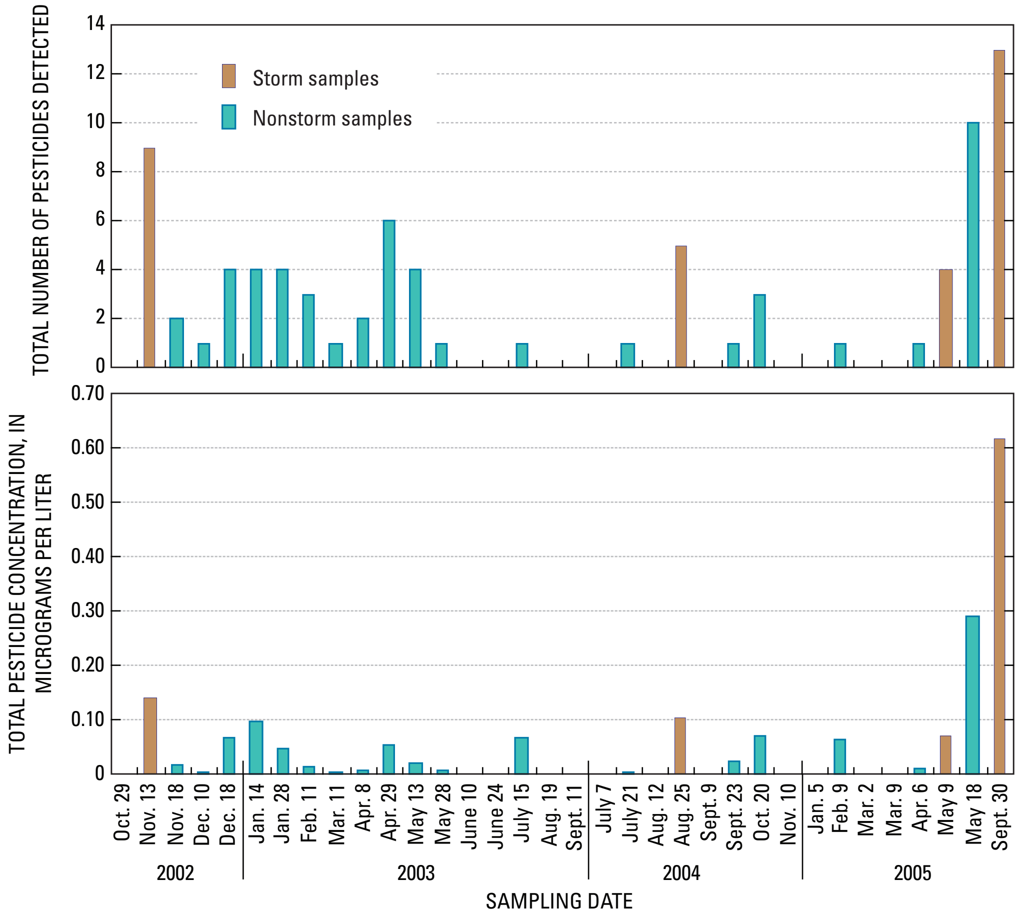


Figure 10. Total number of pesticides detected and total pesticide concentrations for storm and nonstorm samples of source water collected from the study water-treatment plant on the lower Clackamas River, Oregon, 2002–2005.

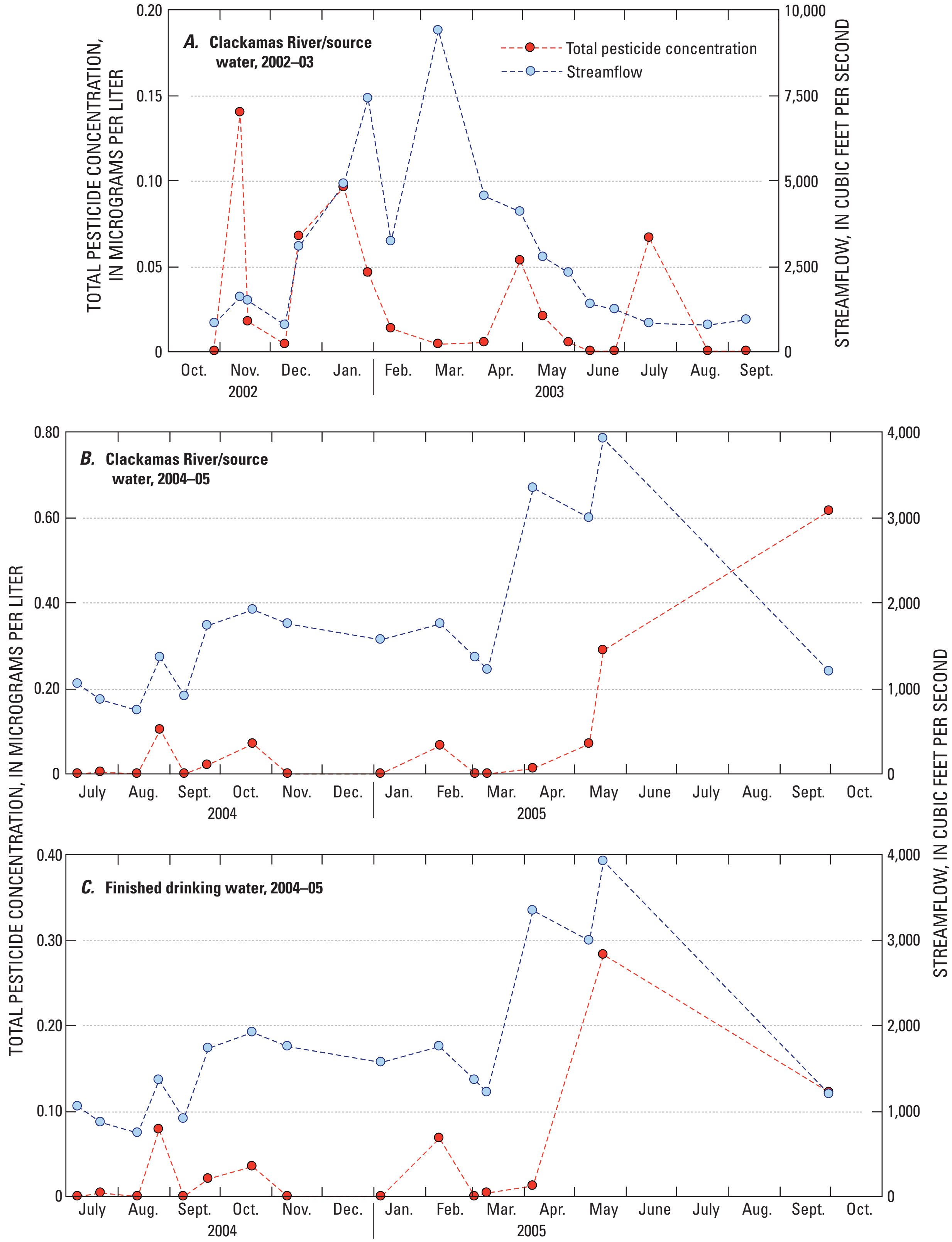


Figure 11. Total pesticide concentrations in source and finished drinking water samples collected from the study water-treatment plant on the lower Clackamas River, Oregon, 2002–2005.

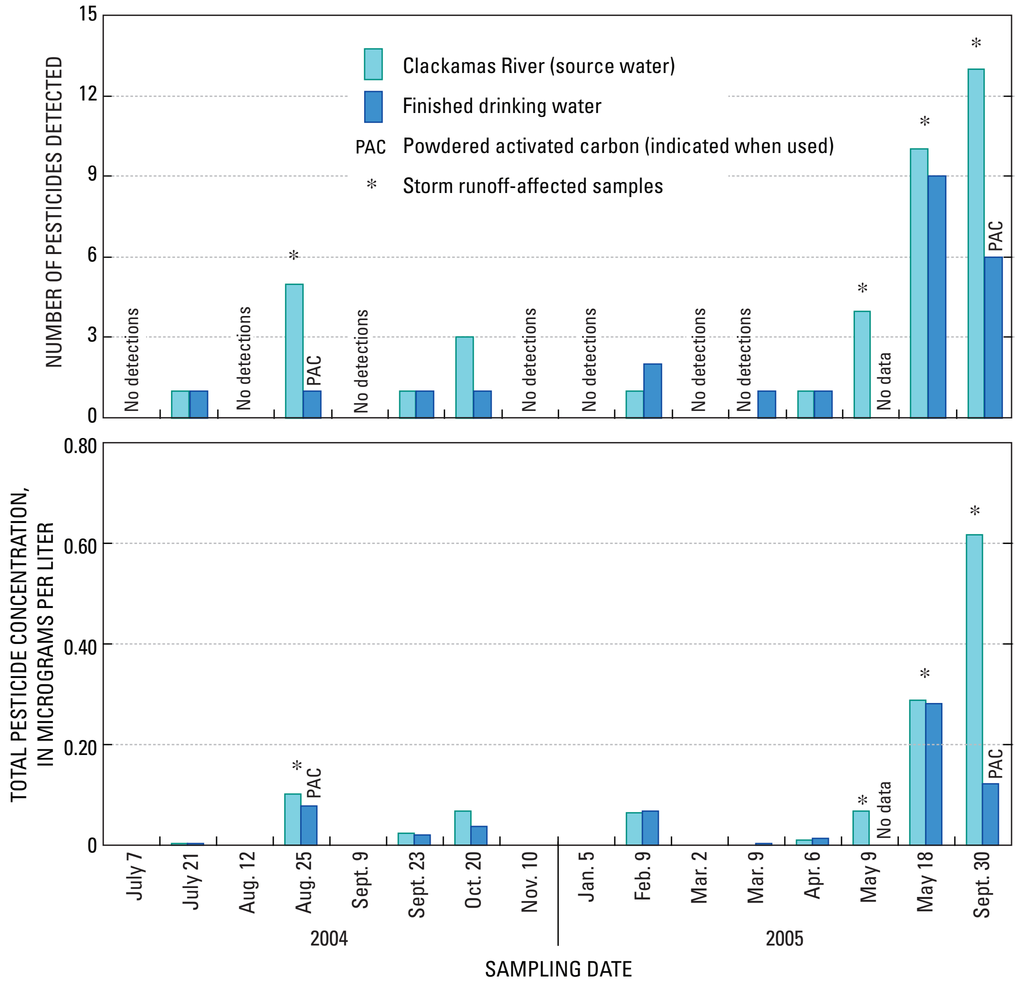


Figure 12. Number of pesticides detected and total pesticide concentrations in source and finished drinking water samples collected from the study water-treatment plant on the lower Clackamas River, Oregon, 2004–2005.

Table 5. Potential effect of powdered activated carbon on concentrations of pesticides and degradates in finished water samples collected from the study water-treatment plant on the lower Clackamas River, Oregon, 2004–2005.

[Pesticide and degradate concentrations in micrograms per liter. Shading indicates PAC use. See p. 3 for information on the study plant's water treatment process. **Abbreviations:** PAC, powdered activated carbon addition (2–5 milligrams per liter); e, estimated value (see Glossary); Rep, replicate sample; na, not analyzed]

PAC treatment (Yes-No)	Pesticide or degradate	Date	Sample	Source water		Finished drinking water	
				Remark	Value	Remark	Value
No	Dacthal (DCPA)	07-21-04		e	0.005	e	0.005
Yes	Hydroxyatrazine (OIET)	08-25-04		e	.014	<	.008
Yes	Dacthal (DCPA)	08-25-04		e	.003	<	.003
Yes	Diazinon	08-25-04		e	.007	<	.005
Yes	Trifluralin	08-25-04		e	.006	<	.009
Yes	DEET	08-25-04		e	.074	e	.078
No	Atrazine	05-18-05			.007	e	.006
No	Deethylatrazine (CIAT)	05-18-05		e	.004	e	.002
No	Dacthal (DCPA)	05-18-05		e	.002	e	.002
No	Diuron	05-18-05			.22		.181
No	Hexazinone	05-18-05			.022		.017
No	Metsulfuron-methyl	05-18-05		<	.03		.058
No	Pronamide	05-18-05		<	.004		.005
No	Trifluralin	05-18-05		e	.005	e	.005
No	Simazine	05-18-05			.005	e	.004
No	2,4-D	05-18-05		e	.014	<	.038
No	Chlorpyrifos	05-18-05			.006	<	.005
No	Metolachlor	05-18-05		e	.005	<	.006
Yes	Cycloate	09-30-05	Rep 1		.016	<	.005
Yes	Cycloate	09-30-05	Rep 2		.019	<	.005
Yes	Dacthal (DCPA)	09-30-05	Rep 1		.004	<	.003
Yes	Dacthal (DCPA)	09-30-05	Rep 2		.005	<	.003
Yes	Dimethenamid	09-30-05	Rep 1	e	.005	<	.006
Yes	Dimethenamid	09-30-05	Rep 2	e	.005	<	.006
Yes	Diuron	09-30-05	Rep 1		.015	<	.015
Yes	Diuron	09-30-05	Rep 2		.019	<	.015
Yes	Glyphosate	09-30-05	Rep 1	e	.12	<	.15
Yes	Glyphosate	09-30-05	Rep 2	e	.1	<	.15
Yes	Prometon	09-30-05	Rep 1	e	.003	<	.01
Yes	Prometon	09-30-05	Rep 2	e	.004	<	.01
Yes	Pronamide	09-30-05	Rep 1		.005	<	.005
Yes	Pronamide	09-30-05	Rep 2	<	.005	<	.005
Yes	Triclopyr	09-30-05	Rep 1		.23	<	.11
Yes	Triclopyr	09-30-05	Rep 2		.23	<	.11
Yes	2,4-D	09-30-05	Rep 1		.18		.081
Yes	2,4-D	09-30-05	Rep 2		.18		.075
Yes	Propiconazole (*cis*)	09-30-05	Rep 1	e	.003	e	.001
Yes	Propiconazole (*cis*)	09-30-05	Rep 2	e	.003	e	.001
Yes	Propiconazole (*trans*)	09-30-05	Rep 1	e	.006	e	.005
Yes	Propiconazole (*trans*)	09-30-05	Rep 2	e	.006	e	.005
Yes	Diazinon[1]	09-30-05	Rep 1		.016	<	.005
Yes	Diazinon[1]	09-30-05	Rep 2		.013	<	.005
Yes	Diazinon-oxon[1]	09-30-05	Rep 1	<	.006	e	.010
Yes	Diazinon-oxon[1]	09-30-05	Rep 2	<	.006	e	.010
Yes	Simazine	09-30-05	Rep 1		.018		.021
Yes	Simazine	09-30-05	Rep 2		.018		.020
Yes	Ethoprop	09-30-05	Rep 1		.009		.006
Yes	Ethoprop	09-30-05	Rep 2		.009		.006
Yes	Metolachlor	09-30-05	Rep 1	e	.005	e	.002
Yes	Metolachlor	09-30-05	Rep 2	e	.003	<	.006

[1]Diazinon is oxidized to diazinon-oxon during treatment.

Comparison of Pesticide Concentrations to Aquatic-Life Benchmarks

Many of the pesticide concentrations in the lower-basin tributaries exceeded aquatic-life benchmarks on at least one occasion, sometimes for multiple pesticides in one sample. Four insecticides, including azinphos-methyl (AZM), chlorpyrifos, diazinon, and *p,p'*-DDE were detected at concentrations that exceeded USEPA aquatic-life benchmarks (table 6). AZM was detected once during the study, at a concentration of 0.21 µg/L in Doane Creek, a tributary of North Fork Deep Creek. This AZM detection exceeded the USEPA benchmark concentration for fish (0.18 µg/L for acute exposure), and for benthic invertebrates (0.08 µg/L for acute exposure) and the State of Oregon water-quality criteria (0.01 µg/L for chronic exposure).

The highest chlorpyrifos concentration (0.56 µg/L) was detected in a storm sample collected in October 2000 from Rock Creek near its mouth (Carpenter, 2004). Since then, chlorpyrifos concentrations have been highest in samples from the North Fork Deep Creek basin, where concentrations were 0.17 µg/L in North Fork Deep Creek at Boring (in September 2005) and 0.14 µg/L in Noyer Creek downstream of Highway 212 (in May 2005). These chlorpyrifos detections exceed the USEPA aquatic-life benchmark for benthic invertebrates (0.05 µg/L for acute exposure) and the State of Oregon water-quality criterion (0.043 µg/L for chronic exposure) (table 6). Chlorpyrifos concentrations in several other post-2000 samples were greater than the nonregulatory aquatic-life guideline suggested by the NAS/NAE of 0.001 µg/L, including those from North Fork Deep Creek (at Barton) and upstream tributaries—Doane Creek and NF Deep Creek tributaries (at 312th Avenue and at Church Road)—Tickle Creek (near Boring), and Trillium Creek (a tributary of Rock Creek), where concentrations ranged from 0.004 to 0.021 µg/L (appendix C table C1). The highest chlorpyrifos concentration detected in the Clackamas River (0.006 µg/L in May 2005) exceeded aquatic-life benchmarks from the NAS/NAE and Canada (table 6). Some of the chlorpyrifos concentrations that were greater than the NAS/NAE benchmarks, however, were only slightly greater than the reporting level of 0.004 µg/L for chlorpyrifos (appendix B, table B1).

Diazinon concentrations exceeded the USEPA aquatic-life benchmark for benthic invertebrates (0.1 µg/L for acute exposure) in three streams—Carli Creek near the mouth (September 2005), Rock Creek at 172nd Avenue (September 2005), and Sieben Creek (May 2000) (Carpenter, 2004)—where the diazinon concentrations ranged from 0.16 to 0.25 µg/L. Although the sale of diazinon has been banned, regulations allow the use of existing supplies. Other streams with diazinon concentrations exceeding the NAS/NAE benchmark of 0.008 µg/L included North Fork Deep, Doane, Tickle, and Trillium Creeks (in May 2005), and the mainstem Clackamas River (source water sample from the study water-treatment plant in September 2005, when the concentration was 0.014 µg/L).

The degradate of the banned pesticide DDT (*p,p'*-DDE) was detected in Deep Creek at Highway 224 in October 2000 at a concentration of 0.002 µg/L (Carpenter, 2004), which exceeded the USEPA aquatic-life benchmark of 0.001 µg/L. Seven other pesticides (2,4-D, carbaryl, chlorthalonil, dieldrin, diuron, endosulfan, and malathion) exceeded aquatic-life benchmarks established by the State of Oregon, the NAS/NAE or the CCME (table 6). Although concentrations of these pesticides did not exceed benchmarks established by the USEPA, some of the compounds such as the organochlorine insecticide endosulfan have no USEPA aquatic-life benchmark. Endosulfan was detected at a concentration of 0.11 µg/L in Tickle Creek near Boring in September 2005, which is about twice the value of the State of Oregon chronic benchmark for benthic invertebrates (0.056 µg/L) and about one-third the median 96-hour LC_{50}, the lethal concentration dosage for one-half of the test population for fish exposed to endosulfan (0.33 µg/L) (Munn and others, 2006). The malathion concentration in Rock Creek (0.047 µg/L) was well below the USEPA aquatic-life acute exposure benchmark for benthic invertebrates (0.25 µg/L), but exceeded the NAS/NAE aquatic-life benchmark of 0.008 µg/L.

Glyphosate was detected in 71 percent of samples collected during the May and September 2005 storms (table 3), with the highest concentration found in Rock Creek at 172nd Avenue (45.8 µg/L). Although this glyphosate concentration was the highest pesticide concentration detected during the study, it was still less than the USEPA aquatic life benchmark for vascular plants (850 µg/L) or the Canadian aquatic-life benchmark of 65 µg/L (table 6). None of the potentially toxic surfactants commonly included in glyphosate-containing products, however, were analyzed during this study. Some of the pesticides detected do not have benchmarks for evaluation, including benomyl, metalaxyl, imidacloprid, 3,4-dichloroaniline (a diuron degradate) and AMPA (a glyphosate degradate); these pesticides were occasionally detected at maximum concentrations ranging from 1.5 to 5.7 µg/L.

Table 6. Aquatic-life benchmarks for pesticides and degradates detected in the lower Clackamas River basin, Oregon, 2000–2005.

[Pesticide concentrations in micrograms per liter (µg/L). Shaded values represent benchmark exceedances. **USEPA OPP references** available at http://www.epa.gov/oppefed1/ecorisk_ders/aquatic_life_benchmark.htm. **Canada:** CCME, Canadian Council of Ministers of the Environment (2003). **NAS/NAE:** National Academy of Sciences/ National Academy of Engineering (1973). **Abbreviations:** USEPA, U.S. Environmental Protection Agency; OPP, USEPA Office of Pesticide Programs; NAS/NAE, National Academy of Sciences/National Academy of Engineering; USGS, U.S. Geological Survey; HBSL, Health-Based Screening Levels; Sept., September; Oct., October; na, no benchmark available for these compounds; ds, downstream]

Pesticide or degradate	Sites and sample dates of aquatic-life benchmark exceedance	Maximum concen-trations	Benchmark quotient (BQ)		Aquatic-life benchmark derived from USEPA Office of Water		Aquatic-life benchmark derived from USEPA OPP reregistration eligibility decisions and ecological risk assessments						Aquatic-life benchmark from other agencies				USEPA OPP references
							Fish		Benthic invertebrates		Non-vascular plants (algae) acute-each sample	Vascular plants acute-each sample	Oregon DEQ		NAS/NAE	Canada	
			USEPA	Other agency	Acute-each sample	Chronic-4-day average	Acute-each sample	Chronic-60-day average	Acute-each sample	Chronic-21-day average			Acute	Chronic	(Maximum concentration-each sample)		
							Exceedance of USEPA aquatic-life benchmark										
Azinphos-methyl	Doane Creek ds Hwy 212 (Sept. 2005)	0.21	21	214		0.01	0.18	[2]0.36	0.08	[2]0.16				0.01	0.001		USEPA (2005b)
Chlorpyrifos	NF Deep Creek at Boring (Sept. 2005)	.17	3.4	167	.083	.041	.9	.57	.05	.04	140		0.083	.041	.001	0.004	USEPA (2000a, 2002)
	Noyer Creek ds Hwy 212 (May/ Sept. 2005)	.14	2.8	140													
	Rock Creek near mouth (Oct. 2000)	.056	1.1	56													
Diazinon	Carli Creek near mouth (Sept. 2005)	.25	2.5	28	.17	.17	45	[3].55	[4,5]0.1	[4].17	3,700		[10].08	[10].05	.009		USEPA (2000b, 2004c)
	Rock Creek at 172nd Ave (Sept. 2005)	.17	1.7	19													
	Sieben Creek at Hwy 224 (May 2000)	.16	1.6	18													
p,p'-DDE[8]	Deep Creek at Hwy 224 (Oct. 2000)	.002	2.4		1.1	0.001							1.1	.001			–

Table 6. Aquatic-life benchmarks for pesticides and degradates detected in the lower Clackamas River Basin, Oregon, 2000–2005.—Continued

[Pesticide concentrations in micrograms per liter (µg/L). Shaded values represent benchmark exceedances. **USEPA OPP references** available at http://www.epa.gov/oppefed1/ecorisk_ders/aquatic_life_benchmark.htm. **Canada:** CCME, Canadian Council of Ministers of the Environment (2003). **NAS/NAE:** National Academy of Sciences/ National Academy of Engineering (1973). **Abbreviations:** USEPA, U.S. Environmental Protection Agency; OPP, USEPA Office of Pesticide Programs; NAS/NAE, National Academy of Sciences/National Academy of Engineering; USGS, U.S. Geological Survey; HBSL, Health-Based Screening Levels; Sept., September; Oct., October; na, no benchmark available for these compounds; ds, downstream]

Pesticide or degradate	Sites and sample dates of aquatic-life benchmark exceedance	Maximum concen-trations	Benchmark quotient (BQ)		Aquatic-life benchmark derived from USEPA Office of Water		Aquatic-life benchmark derived from USEPA OPP reregistration eligibility decisions and ecological risk assessments						Aquatic-life benchmark from other agencies				USEPA OPP references
			USEPA	Other agency	Acute-each sample	Chronic-4-day average	Fish: Acute-each sample	Fish: Chronic-60-day average	Benthic invertebrates: Acute-each sample	Benthic invertebrates: Chronic-21-day average	Non-vascular plants (algae) acute-each sample	Vascular plants acute-each sample	Oregon DEQ: Acute	Oregon DEQ: Chronic	NAS/NAE (Maximum concentration-each sample)	Canada (Maximum concentration-each sample)	
Exceedance of non-USEPA aquatic-life benchmark																	
2,4-D	NF Deep C trib at 312th Ave (Sept. 2005)	6.1	0.02	2.0			[6]50,500	[6]14,200	[6]12,500	[6]16,400	[6]3,880	[6]299			3	4	USEPA (2004a)
Carbaryl[9]	Noyer Creek ds Hwy 212 (Sept. 2005)	.15	.1	7.7			[4]125	[4]210	2.55	1.5	1,100				.02	.2	USEPA (2003a)
	Sieben Creek at Hwy 224 (May 2005)	.094	.06	4.7													
	Rock Creek at 172nd Ave (Sept. 2005)	.052	.03	2.6													
	Sieben Creek ds Sunnyside Rd (Sept. 2005)	.026	.02	1.3													
Chlorpyrifos	Clackamas River (source water) (Nov 2002/ May2005)	.006	.12	6.0	0.83	0.41	.9	.57	.05	.04	140		0.083	0.41	.001	.004	USEPA (2002a, 2002)
Chloro-thalonil	Noyer Creek at mouth (May 2005)	.26	.09	1.4			11.5	3	34	39	190					.18	USEPA (1999a)
Dieldrin	Noyer Creek ds Hwy 212 (May/ Sept. 2005)	.024	.43	4.8	0.24	0.056							0.24	0.019	.005		–
	NF Deep C trib at 312th Ave (Sept. 2005)	.01	.04	2													
	Rock Creek near mouth (Oct. 2000)	.008	.03	1.6													

Table 6. Aquatic-life benchmarks for pesticides and degradates detected in the lower Clackamas River Basin, Oregon, 2000–2005.—Continued

[Pesticide concentrations in micrograms per liter (µg/L). Shaded values represent benchmark exceedances. **USEPA OPP references** available at http://www.epa.gov/oppefed1/ecorisk_ders/aquatic_life_benchmark.htm. **Canada:** CCME, Canadian Council of Ministers of the Environment (2003). **NAS/NAE:** National Academy of Sciences/ National Academy of Engineering (1973). **Abbreviations:** USEPA, U.S. Environmental Protection Agency; OPP, USEPA Office of Pesticide Programs; NAS/NAE, National Academy of Sciences/National Academy of Engineering; USGS, U.S. Geological Survey; HBSL, Health-Based Screening Levels; Sept., September; Oct., October; na, no benchmark available for these compounds; ds, downstream]

Pesticide or degradate	Sites and sample dates of aquatic-life benchmark exceedance	Maximum concen-trations	Benchmark quotient (BQ)		Aquatic-life benchmark derived from USEPA Office of Water		Aquatic-life benchmark derived from USEPA OPP reregistration eligibility decisions and ecological risk assessments						Aquatic-life benchmark from other agencies				USEPA OPP references
							Fish		Benthic invertebrates		Non-vascular plants (algae) acute-each sample	Vascular plants acute-each sample	Oregon DEQ		NAS/NAE	Canada	
			USEPA	Other agency	Acute-each sample	Chronic-4-day average	Acute-each sample	Chronic-60-day average	Acute-each sample	Chronic-21-day average			Acute	Chronic	(Maximum concentration-each sample)		
Exceedance of non-USEPA aquatic-life benchmark—Continued																	
Diuron	Doane Creek at Hwy 212 (Sept. 2005)	2.3	0.94	1.4			355	26	80	[2]160	2.4				1.6		USEPA (2003d)
	NF Deep Creek at Boring (Sept 2005)	1.9	.8	1.2													
Endosulfan[1]	Tickle Creek near Boring (Sept. 2005)	.11	.51	35.2									0.22	0.056	0.003	0.02	
Malathion	Rock Creek near mouth (Sept. 2005)	.05	.79	5.9		0.1	2	[2]4	0.25	0.06				.1	.008		USEPA (2000c)
	Sieben Creek at Hwy 224 (May 2000)	.025	.1	3.1													
No exceedances of aquatic-life benchmark (sorted by descending maximum benchmark quotient)																	
Methiocarb		0.09	0.86				218	50	3.5	0.1							USEPA (1994b)
Dichlobenil		17	.56	0.46			2,465	[3]330	1,850	560	1,000	30			37		USEPA (1998b)
Ethoprop		.13	.16				150	24	22	.8	8,400						USEPA (1999b)
Trifluralin		.17	.15	.83			20.5	1.14	280	2.4	7.52	43.5				0.2	USEPA (1996a)
Pendimethalin		.35	.07				69	6.3	140	14.5	5.4	12.5					USEPA (1997b)
Glyphosate		45.8	.05	.70			42,450	>25,700	27,500	>50,000	850	21,500				65	USEPA 1993
Triclopyr		5.0	.05				180	104,000	850	80,700	100	880					USEPA (1998c)
Bromacil		.27	.04	.05			18,000		60,500		6.8					5	USEPA (1996c)
Simazine		.96	.03	.10			3,200	960	500	[2]1,000	36	140			10	10	USEPA (2005c, 2005d)
Oryzalin		.29	.02				1,440	220	700		42	15.4					USEPA (1994c)
Atrazine		.30	.02	.16			2,650	62	360	62	32	18				1.8	USEPA (2003b, 2003c)
Linuron		.59	.01	.08			1,500	[3]42	60	[2]120	67					7	USEPA (1995b)
2,4-D methyl ester		.73	.01	.18												4	
Norflurazon		.11	.01				4,050	770	7,500	1,000	13	86					USEPA (1996b)

Table 6. Aquatic-life benchmarks for pesticides and degradates detected in the lower Clackamas River Basin, Oregon, 2000–2005.—Continued

[Pesticide concentrations in micrograms per liter (µg/L). Shaded values represent benchmark exceedances. **USEPA OPP references** available at http://www.epa.gov/oppefed1/ecorisk_ders/aquatic_life_benchmark.htm. **Canada:** CCME, Canadian Council of Ministers of the Environment (2003). **NAS/NAE:** National Academy of Sciences/ National Academy of Engineering (1973). **Abbreviations:** USEPA, U.S. Environmental Protection Agency; OPP, USEPA Office of Pesticide Programs; NAS/NAE, National Academy of Sciences/National Academy of Engineering; USGS, U.S. Geological Survey; HBSL, Health-Based Screening Levels; Sept., September; Oct., October; na, no benchmark available for these compounds; ds, downstream]

Pesticide or degradate	Sites and sample dates of aquatic-life benchmark exceedance	Maximum concen-trations	Benchmark quotient (BQ)		Aquatic-life benchmark derived from USEPA Office of Water		Aquatic-life benchmark derived from USEPA OPP reregistration eligibility decisions and ecological risk assessments						Aquatic-life benchmark from other agencies				USEPA OPP references
							Fish		Benthic invertebrates		Non-vascular plants (algae) acute-each sample	Vascular plants acute-each sample	Oregon DEQ		NAS/NAE	Canada	
			USEPA	Other agency	Acute-each sample	Chronic-4-day average	Acute-each sample	Chronic-60-day average	Acute-each sample	Chronic-21-day average			Acute	Chronic	(Maximum concentration-each sample)		
No exceedances of aquatic-life benchmark (sorted by descending maximum benchmark quotient)—Continued																	
MCPA		0.07	0.003	0.03			[6]380	[6]12,000	[6]90	[6]11,000	[6]160	[6]20				2.6	USEPA (2004b)
Dinoseb		.03	.003	.55												.05	
Terbacil		.03	.002				23,100		31,500		11	140					USEPA (1998d)
Tebuthiuron		.08	.002	.05			53,000	9,300	148,500	21,800	50	135				1.6	USEPA (1994e)
Propoxur		.01	.001				1,850		5.5								USEPA (1997a)
Napropamide		1.3	.0004				3,200		7,150		3,400						USEPA (2005a)
Pronamide		.17	.0002				36,000		[7]2,800		760						USEPA (1994a)
Metolachlor		.11	.0001	.01			1,950	780	12,550							7.8	USEPA (1995a)
Dacthal		.46	.00004				15,000		13,500		[7]11,000	[7]11,000					USEPA (1998a)
Bentazon		.16	.00004				50,000		50,000		4,500	5,350					USEPA (1994d)

[1] Endosulfan includes endosulfan I and endosulfan II.

[2] The chronic benchmark is based on the acute toxicity value (which was lower than the lowest available chronic toxicity value), and therefore may underestimate chronic toxicity.

[3] Because the underlying toxicity value is a "less-than" value (such as <1,500), this benchmark may underestimate toxicity.

[4] Although the underlying acute toxicity value is greater than or equal to the chronic toxicity value, the acute benchmark is lower than the chronic benchmark because acute and chronic toxicity values were multiplied by LOC values of 0.5 and 1, respectively.

[5] During public comment on draft ambient water-quality criteria that are under development by USEPA, public comment noted an atypical distribution of the acute toxicity data for diazinon. If data from the second most sensitive study were used (U.S. Environmental Protection Agency, 2000b risk assessment), rather than the most sensitive study, then the benchmark would change from 0.1 to 0.4 µg/L.

[6] Original toxicity values are in micrograms of acid equivalents per liter. For 2,4-D and 2,4-DB, the toxicity values selected were the lowest available values for the acid or salt forms. For MCPA, acute toxicity values were the lowest for the acid, salt or ester forms, and chronic toxicity values were the lowest of the acid and salt forms. Selection was consistent with risk quotients in the cited USEPA references.

[7] Because the underlying toxicity value is a "greater-than" value (such as >265,000), this benchmark may overestimate toxicity.

[8] Benchmark applies to total DDT, so comparison with measured *p,p´*-DDE concentration may underestimate potential effects.

[9] Carbaryl recoveries in some QA spike samples were as high as 304 percent. For more details, see the quality-control discussion in appendix A.

[10] The diazinon benchmark concentrations are DEQ guidance values, rather than water-quality criteria. DEQ can, however, use these values in the application of Oregon's Narrative Toxics Criteria (State of Oregon Administrative Rule 340-0033[1]).

Pesticide Toxicity Index—PTI Values

Pesticide Toxicity Index (PTI) values for samples collected in the Clackamas River basin were calculated separately for benthic invertebrates and fish (table 7). The individual toxicity values for each of the pesticide compounds detected are listed in appendix D, table D1, and samples with the highest PTI values are shown in figure 13. With the exception of one sample from Tickle Creek, which had a relatively high PTI value from the insecticide endosulfan, the PTI values generally were higher for benthic invertebrates than for fish, indicating a greater risk to these organisms. Most of the highest PTI values were for samples collected during the September 2005 storm, with the highest PTI values in samples collected from the Deep Creek basin, including North Fork Deep Creek, Tickle Creek, and Noyer Creek. Due to a lack in toxicity values for two compounds, the PTI value for the Rock Creek at 172nd Avenue sample may underestimate the potential toxicity because it did not include the fungicide benomyl and the herbicide glyphosate, which were detected at relatively high concentrations (5.7 and 45.8 µg/L, respectively).

Table 7. Pesticide Toxicity Index values for benthic invertebrates and fish for stormwater samples collected in the lower Clackamas River basin, May and September 2005.

Sample	Date	Pesticide Toxicity Index	
		Benthic invertebrates	Fish
Carli Creek near mouth	05-09-05	4.06E-04	1.31E-05
	09-30-05	1.42E-02	5.75E-04
Cow Creek at mouth	05-09-05	1.26E-03	1.17E-04
	09-30-05	1.65E-03	1.04E-03
Clackamas River (source water)	05-09-05	6.20E-05	1.15E-05
	09-30-05	6.30E-04	2.16E-04
Deep Creek at Barton	09-30-05	1.16E-05	9.36E-04
Doane Creek downstream of Highway 212	09-30-05	1.96E-01	1.01E-02
Dolan Creek at Orient Road	09-30-05	8.54E-07	1.51E-04
North Fork Deep Creek tributary at Church Road	09-30-05	7.68E-03	1.37E-04
North Fork Deep Creek tributary at 312th Avenue	09-30-05	1.04E-02	5.15E-03
North Fork Deep Creek at Boring	05-09-05	5.79E-02	3.09E-03
North Fork Deep Creek at Barton	09-30-05	3.24E-02	6.05E-04
North Fork Deep Creek near Boring	09-30-05	2.97E-01	5.51E-03
Noyer Creek at mouth	05-09-05	5.27E-02	6.90E-03
	09-30-05	8.06E-05	3.16E-04
Noyer Creek downstream of Highway 212	05-09-05	7.50E-02	2.73E-03
	09-30-05	2.48E-01	6.53E-03
Richardson Creek at Highway 224	09-30-05	1.33E-04	5.48E-04
Rock Creek at 172nd Avenue	05-09-05	1.25E-03	1.87E-04
Rock Creek at Stoneybrook Court	09-30-05	1.62E-06	2.03E-06
	09-30-05	1.14E-02	1.06E-03
Rock Creek downstream of Foster Road	09-30-05	1.57E-04	6.79E-04
Rock Creek near mouth	09-30-05	5.01E-03	1.10E-03
Sieben Creek at Highway 224	05-09-05	6.66E-03	1.68E-04
	09-30-05	4.99E-03	8.26E-04
Sieben Creek downstream of Sunnyside Road	09-30-05	1.87E-03	7.48E-04
Tickle Creek at 362nd Avenue	09-30-05	1.39E-04	2.61E-05
Tickle Creek near Boring	09-30-05	3.89E-02	3.22E-01
Tickle Creek tributary at Colorado Road	09-30-05	6.02E-04	1.17E-04
Tickle Creek tributary at Orient Road	09-30-05	2.40E-05	8.56E-06
Trillium Creek at Anderegg Parkway	05-09-05	9.91E-03	3.64E-04
	09-30-05	2.79E-05	2.94E-05

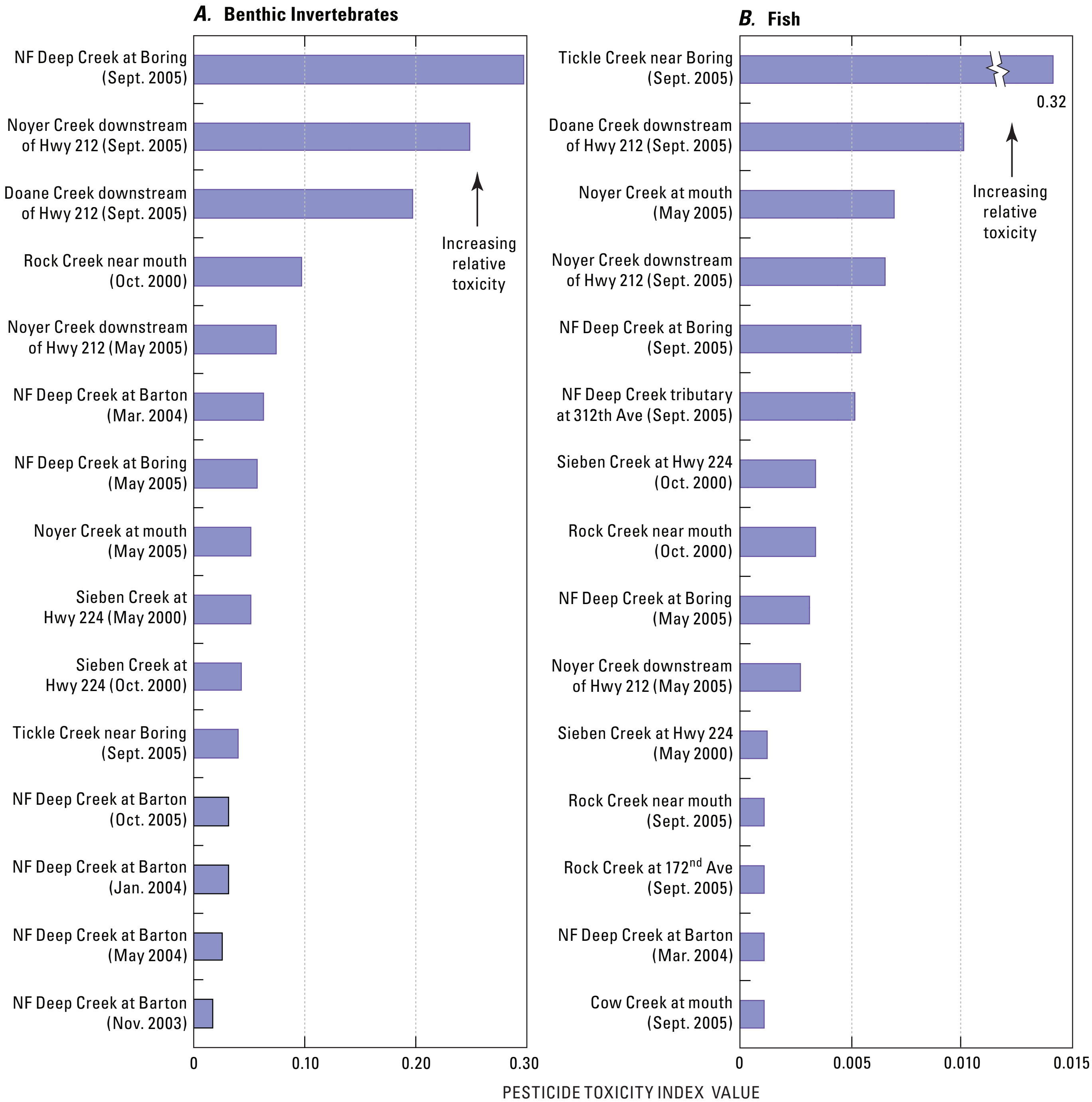


Figure 13. Highest Pesticide Toxicity Index values for benthic invertebrates and fish for samples collected from the lower Clackamas River basin tributaries, Oregon, 2000–2005.

Comparison of Pesticide Concentrations to Drinking-Water Standards and Human-Health Benchmarks

All pesticide concentrations in finished drinking water were far below applicable USEPA Maximum Concentration Level (MCLs) for regulated contaminants and USGS Health-Based Screening Levels (HBSLs) for unregulated contaminants. HBSLs were available for nine of the pesticide compounds detected in finished drinking water (table 8). Three of the unregulated contaminants—diazinon-oxon (a degradate of the insecticide diazinon), deethylatrazine (CIAT, a degradate of the herbicide atrazine), and the insect repellent DEET—do not, however, have human-health benchmarks available for comparison because toxicity data are currently lacking. The maximum Benchmark Quotient (BQ max)—the ratio of the highest measured concentration of a detected compound in finished water to human-health benchmark—ranged from 0.09 for diuron to 0.000003 for metolachlor (table 8; fig. 14). These BQ max values for pesticides detected in finished water were 11 and more than 300,000 times lower than their respective human-health benchmarks.

Table 8. Maximum benchmark quotients for pesticide concentrations in finished drinking-water samples from the study water-treatment plant on the lower Clackamas River, Oregon, 2004–2005.

[The maximum Benchmark Quotient (BQ max) is the ratio of the highest measured concentration of a detected compound in finished water to its benchmark. BQ values close to 1 indicate a potential concern and higher levels indicate greater potential risk. Human-health benchmarks: Low and high HBSL values correspond to 10-6 and 10-4 cancer risk, respectively, for unregulated carcinogens. HBSLs from Toccalino and others (2006), and MCLs from USEPA (2006). Abbreviations: e, estimated value (see Glossary); USEPA, U.S. Environmental Protection Agency; USGS, U.S. Geological Survey; HBSL, Heath-Based Screening Level; µg/L, microgram per liter; MCL, Maximum Contaminant Level; na, no benchmark available for these compounds]

Pesticide or degradate	Compound type	Remark	Maximum concentration in finished water (µg/L)	BQ max	Date	Pesticide concentrations (µg/L) — Human-health benchmarks: USGS HBSL (Low)	USGS HBSL (High)	USEPA MCL
Diuron	Herbicide		0.18	0.091	05-18-05	2	200	na
Ethoprop	Insecticide/Nematocide		.006	.006	09-30-05	1	100	na
Simazine	Herbicide		.021	.005	09-30-05			4
Pronamide	Herbicide		.005	.005	05-18-05	1	100	na
Atrazine	Herbicide	e	.006	.002	05-18-05			3
2,4-D	Herbicide		.08	.001	09-30-05			70
Trifluralin	Herbicide		.005	.0002	05-18-05	20	20	na
Propiconazole (*trans*)[1]	Fungicide	e	.005	.0001	09-30-05	70	70	na
Dacthal (DCPA)	Herbicide		.005	.00007	07-21-04	70	70	na
Hexazinone	Herbicide		.017	.00004	05-18-05	400	400	na
Metsulfuron-methyl	Herbicide	e	.060	.00003	05-18-05	2,000	2,000	na
Metolachlor	Herbicide	e	.002	.000003	09-30-05	700	700	na
Diazinon-oxon	Degradate of the insecticide diazinon	e	.01	na	09-30-05	na	na	na
DEET	Insect repellent	e	.008	na	08-25-04	na	na	na
Deethylatrazine (CIAT)	Degradate of the herbicide atrazine	e	.005	na	05-18-05	na	na	na

[1]HBSL for propiconazole was used for propiconazole (*trans*).

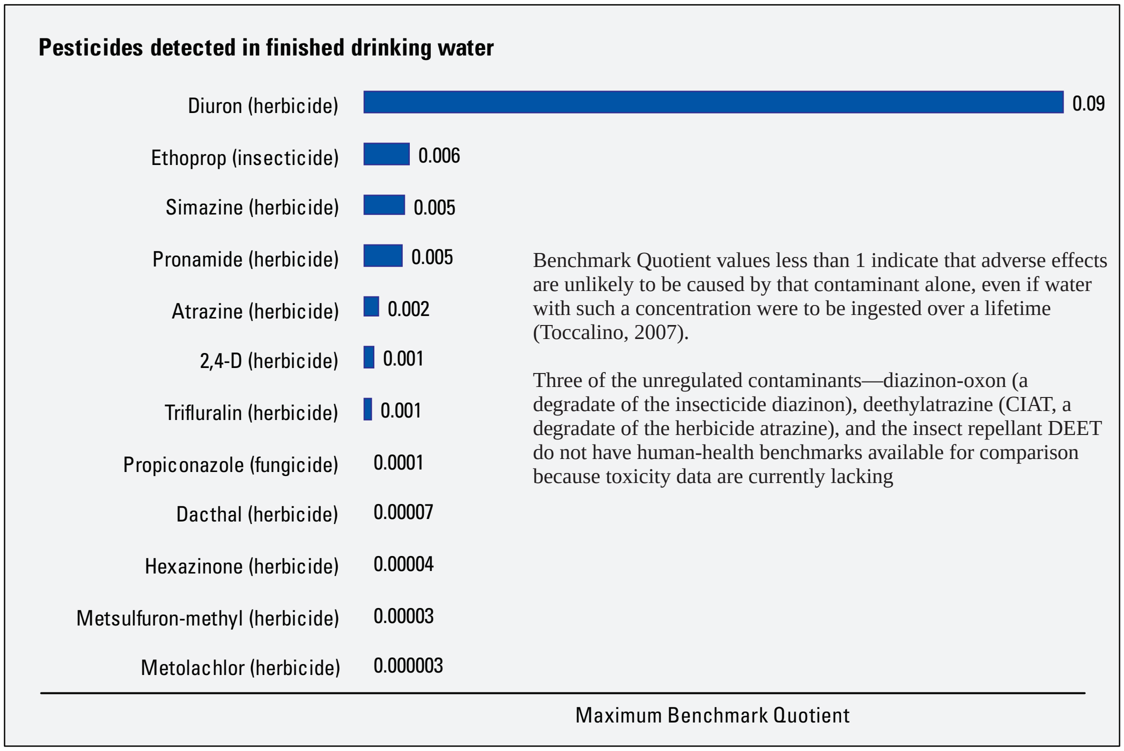


Figure 14. Maximum benchmark quotients for pesticide concentrations in finished drinking-water samples from the study water-treatment plant on the lower Clackamas River, Oregon, 2004–2005.

Discussion

Pesticide Occurrence in the Lower Clackamas River Basin

Pesticide occurrence in the lower Clackamas River basin was widespread, particularly in the tributaries, but also in the mainstem Clackamas River. Analyses of samples from four storm events identified some of the tributaries (Rock and North Fork Deep Creeks, for example) that contributed relatively high quantities (or loads) of pesticides to the Clackamas River upstream of drinking-water intakes. In some streams, pesticide concentrations exceeded aquatic-life benchmarks, and these findings can be used to focus and prioritize current and future efforts related to pesticide and land management, stream restoration, and salmon recovery.

The occurrence of pesticides in the Clackamas River basin is not unexpected given the large amount of urban and agricultural land in the drainage basin, where pesticides are frequently applied, and these results are similar to those from other studies. The most frequently detected pesticides in the Clackamas River basin—atrazine, simazine, metolachlor, diuron, and the organophosphate insecticides diazinon and chlorpyrifos—also were the most frequently detected pesticides in the Willamette River basin in Oregon (Rinella and Janet, 1998) and in other rivers across the United States (Gilliom and others, 2006). Several of the pesticides detected in the Clackamas River basin also were detected downstream in the Willamette River at Portland (21 pesticides during 2004–2005), and 5 have been detected downstream in the Columbia River (Jennifer Morace, U.S. Geological Survey, oral commun., 2006), but it is unclear how much the Clackamas River contributes compared with other major rivers in the Willamette River basin, such as the Molalla and Tualatin Rivers.

Pesticide occurrence in the Clackamas River is influenced by runoff from the tributaries and antecedent streamflow conditions in the mainstem prior to rainfall events. Streamflow in the lower Clackamas River is dynamic during the rainy season (fall to spring), responding to water releases from upstream dams, patterns and intensity of rainfall, snowmelt, and rain-on-snow events. Winter or spring storms can deliver precipitation to the lower basin during cold periods when moisture in the upper basin remains as snow. During such times, freezing levels may be low enough to reduce streamflow from the upper basin, which can result in less dilution water for the lower mainstem. At such times, and after heavy rainfall, pesticide concentrations in the lower Clackamas River can be elevated from tributary inputs in the lower basin.

The significance of these mostly trace-level concentrations of pesticides, however, is not yet known, but future studies could examine potential effects on aquatic life and human health. Identifying which compounds are present, when, and at what concentrations is a first step towards understanding the contamination potential posed by pesticides, and this information can be used to guide future pesticide reduction strategies to improve water quality in affected areas.

Potential Effects of Pesticides on Aquatic Life

Many pesticides have the potential to harm nontarget organisms, especially benthic invertebrates, fish, amphibians, and various stream microbes (Nowell and others, 1999). Biota in the lower Clackamas River and the lower-basin tributaries are exposed to pesticides, sometimes at concentrations high enough to exceed aquatic-life benchmarks. Aquatic life in the Clackamas River and some of its tributaries include various anadromous and resident fish species, amphibians, plants, and other organisms. Declines in some fish populations, including winter steelhead, spring chinook, and coho salmon have resulted in their being included on the Endangered Species List (National Marine Fisheries Service, 2006). Potential explanations for such declines have included overharvesting of fish, hydroelectric dams, poor-quality stream habitat, and degraded water quality from pesticides and other contaminants. Understanding the potential cumulative effects of the combined influences on aquatic life is challenging, and the understanding of the effects of pesticides alone, for example, is not complete because most toxicity research focuses on single compounds, not mixtures. The chemical and (or) physical conditions in streams may affect aquatic life through mechanisms related to stress (and sometimes-resulting disease), feeding, and reproduction, but such cumulative effects are not yet well understood.

There also exists potential for sediment-bound pesticides to affect benthic organisms. This study examined the occurrence of pesticides dissolved in water, not those associated with streambed sediments. Some pesticides such as pyrethroid insecticides, for example, may adhere to sediments and cause toxicity to benthic invertebrates (Amweg and others, 2006). In some places, pyrethroids are being used as an alternative to organophosphate insecticides, which are more toxic to humans than pyrethroids. Because the pyrethroids insecticides accumulate in sediments, benthic organisms may be exposed to elevated concentrations in low gradient pools and riffles affected by sedimentation. Sediment and turbidity levels were high in many of the Clackamas River basin tributaries during the storm sampling in 2005 (appendix C, table C4) due to erosion of stream banks, resuspension of sediment from the streambed, and nonpoint source runoff from the drainage basin. It is not known whether such sedimentation causes sorption of pesticides that tend to adhere to sediment particles, but such a hypothesis could be examined with further study.

Previous studies found invertebrate assemblages in upper Noyer and North Fork Deep Creeks to be severely impaired (Cole and Hennings, 2004). The invertebrate assemblage quality was poorest in the headwaters, and improved somewhat at the downstream sites in the lower forested canyon reaches of these and other streams, including Rock and Richardson Creeks. Specific conductance also was lower at the downstream sites, indicating fewer dissolved ions in water compared with the upstream sites and, potentially, improved water quality (Cole and Hennings, 2004). The water quality at sites in these lower reaches may be affected by low-ion content ground water, which might help decrease contaminant concentrations (and lower water temperatures), but improved physical habitat quality probably also benefited benthic invertebrate assemblages. Headwater streams in the Noyer

The Clackamas River supports the last remaining wild coho salmon stock in the Columbia River basin. (Photograph by Tim Shibahara, Portland General Electric.)

Creek and North Fork Deep Creek basins have less intact and narrower riparian zones, with some concentrated agricultural and rural residential areas (Cole and Hennings, 2004). Downstream reaches in forested canyons have greater amounts of intact riparian vegetation and contain cobble-substrate riffles that are more suitable for benthic invertebrates (for example, see cover photograph of Noyer Creek). Dewberry and others (1999) found the diversity of aquatic insect assemblages in Rock and Sieben Creeks to be suppressed by factors including habitat impairment, and in light of the current study findings, pesticides also may affect benthic invertebrates and other aquatic life in these streams.

Pesticides occasionally exceeding their respective USEPA aquatic-life benchmarks in this study included the insecticides diazinon, chlorpyrifos, endosulfan, and azinphos-methyl. The diazinon concentrations in storm samples collected from Carli, Sieben, and Rock Creeks, for example, exceeded the USEPA aquatic-life criterion for benthic invertebrates of 0.1 µg/L by a factor of as much as 2.5. Diazinon and other organophosphate insecticides are designed to impair nervous system function through inhibition of the enzyme acetylcholinesterase (Nowell and others, 1999). Exposure to these compounds may inhibit the activity of this enzyme in organisms such as benthic invertebrates, amphibians, and fish. Diazinon impairs predator avoidance behavior and homing ability in Chinook salmon at concentrations of 1 and 10 µg/L, respectively (Scholz and others, 2000). Although these concentrations are much higher than those detected in the Clackamas River basin, the effects of sustained or multiple exposures to diazinon are not well understood. Diazinon was detected in the lower Clackamas River on six occasions (fig. 15), and peak concentrations may not have been measured by this study, given the small number of samples collected during storms. Although diazinon sales for residential usage ended on December 31, 2004, diazinon in storage likely has been used since then; diazinon continued to be detected into 2005.

Another compound that exceeded its criterion was the organophosphate insecticide chlorpyrifos. Chlorpyrifos concentrations in Noyer and North Fork Deep Creeks were 0.14 and 0.17 µg/L, respectively, and exceeded the USEPA chronic and acute aquatic-life benchmarks of 0.041 and 0.083 µg/L (table 6). The chlorpyrifos concentration in extract from an SPMD deployed in North Fork Deep Creek was the highest among all 28 sites sampled for the EUSE study (Ian Waite, U.S. Geological Survey, written commun., 2007) and highest among all sites nationally (Bryant and others, 2007). Because the SPMDs were deployed for an extended period (30 days), the high value suggests a relatively high average concentration over time in North Fork Deep Creek compared with the other sites. This is consistent with the results from the 2005 pesticide storm event samplings, when chlorpyrifos was detected in two-thirds of the sites in the Deep Creek basin (appendix C, table C1). In 2005, the chlorpyrifos concentrations in North Fork and Noyer Creeks (up to 0.17 and 0.14 µg/L, respectively) were substantially greater than the highest value in 2000 (0.056 µg/L in Rock Creek; Carpenter, 2004). In 2005, chlorpyrifos was detected in only one other tributary, Trillium Creek at a concentration of 0.005 µg/L. Chlorpyrifos also exceeded non-USEPA benchmarks in the mainstem Clackamas River on two occasions (table 6).

The prevalence of pesticide mixtures in Clackamas River basin streams presents challenges for understanding how aquatic life in these streams might be affected. Some stocks of salmon, winter steelhead, and sea-run cutthroat trout continue to use tributaries, including Eagle, Clear, Deep, and Rock Creeks to spawn and rear, and are sometimes exposed to multiple pesticides. Some of the tributaries, such as Rock and Tickle Creek, still support coho salmon populations despite threats from a variety of potential contaminants, including pesticides.

One of the complicating factors in determining safe exposure levels for aquatic life for pesticides is that laboratory studies typically involve only a single compound and do not consider additive or possibly synergistic effects of multiple pesticide exposure. Although it might be logical to assume that two pesticides with the same mode of action (such as the orthophosphate insecticides chlorpyrifos and diazinon, which inhibit the same acetylcholinesterase enzyme) would act in an additive fashion, certain pesticides may affect the toxicity of others through various physiological mechanisms that are just beginning to be understood. For example, the toxicity of orthophosphate insecticides was shown to increase markedly by simultaneous exposure to the herbicide atrazine (Pape-Lindstrom and Lydy, 1997). Other studies (Kao and others, 1995) have found a potential mechanism for this: atrazine exposure stimulates Cytochrome P450 and general esterase activity in insects that increases production of oxon degradates such as diazinon-oxon and malathion-oxon from the parent compounds. Ironically, the degradation to oxon compounds produces a more toxic degradation compound. A recent study of frog tadpoles found that oxon derivatives such as diazinon-oxon, chloroxon, and maloxon (degradates of diazinon, chlorpyrifos, and malathion, respectively) were between 10 and 100 times more toxic than the parent insecticide compounds (Sparling and Fellers, 2007).

The PTI values suggest that benthic invertebrates were more at risk than fish at most sites, and it is unclear how other aquatic life may be affected. Benthic invertebrate assemblages were highly degraded in lower Tickle Creek during the EUSE study (Ian Waite, U.S. Geological Survey, written commun., 2007). Good habitat quality was found in the lower mainstem of Tickle Creek during the EUSE biological and habitat

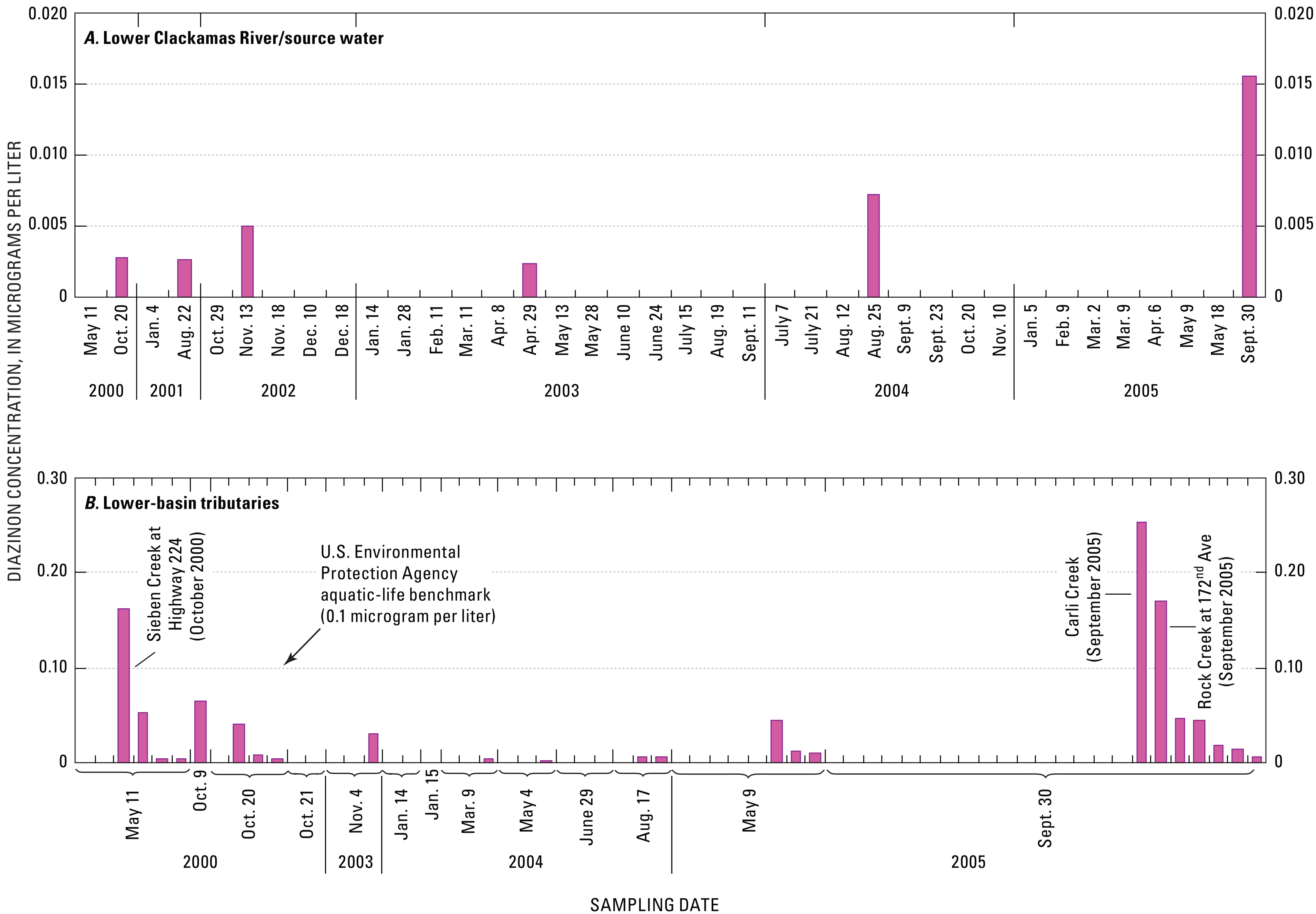


Figure 15. Diazinon concentrations in source water samples collected from the study drinking-water treatment plant on the lower Clackamas River, Oregon, and in the lower-basin tributaries, 2000–2005. (Aquatic-life benchmarks are provided in table 6.)

survey, and included cobble riffles in a mostly forested canyon with abundant riparian vegetation, so some other factor, possibly exposure to pesticides, wastewater-treatment plant effluents, or other contaminants may be affecting benthic invertebrates in lower Tickle Creek.

According to the PTI (fig. 13), fish assemblages in Tickle Creek were most at risk from the organochlorine insecticide endosulfan, which was detected at a total concentration of 0.11 µg/L, which included 0.067 µg/L endosulfan I (*alpha* endosulfan) and 0.039 µg/L endosulfan II (*beta* endosulfan). Note that these two compounds were not distinguished in toxicity tests used for the PTI (appendix D, Table D1). Although the total endosulfan (I + II) concentration in Tickle Creek (0.11 µg/L) was less than the Oregon DEQ benchmark for acute exposure (0.22 µg/L), it is greater than the Oregon DEQ chronic benchmark of 0.056 µg/L and benchmarks suggested by NAS/NAE and Canada (table 6). Although the storm-runoff samples collected for this study probably reflect short duration exposure (making acute benchmarks more appropriate than chronic benchmarks), it is not clear whether peak concentrations were captured during sampling or how long such high concentration pulses persist. The endosulfan concentration in Tickle Creek might be more indicative of chronic exposure levels during periods of active runoff. If this were true, the lower chronic benchmark would be more appropriate. Repeated or prolonged exposures to elevated concentrations of endosulfan (or other contaminants) might have contributed to the lackluster condition of juvenile coho salmon and quality of benthic invertebrates in Tickle Creek found during the 2004 EUSE study (Ian Waite, USGS, oral commun., 2004), but more study would be needed before specific conclusions regarding connections to pesticides can be made.

Doane Creek, a tributary of North Fork Deep Creek, had the second highest PTI for fish (fig. 13), largely due to the occurrence of the potent orthophosphate insecticide azinphos-methyl (AZM), which was detected at a concentration of 0.21 µg/L. AZM is highly toxic to freshwater fish and invertebrates—the risk assessment for AZM (U.S. Environmental Protection Agency, 2001) states that

> "…if [AZM] enters a water body in sufficient quantities, it can result in death and reproductive effects in aquatic organisms, and there is also potential exposure and risk to birds, mammals, and bees from direct spray, drift, and surface AZM residues."

Although the AZM QA spike results in the current Clackamas River basin study suggested a positive bias for AZM of about 17 percent (from four QA blank water spikes), the AZM concentration in Doane Creek, when corrected for this bias, would be reduced 17 percent to 0.179 µg/L. This value—the only AZM detection during the study—exceeded the USEPA aquatic-life acute benchmark for benthic invertebrates (0.06 µg/L) and approximates the USEPA aquatic-life acute benchmark for fish (0.18 µg/L) (table 6).

Although not examined during this study, exposure to pesticides or other contaminants may cause sublethal effects on aquatic life, such as deformities during early developmental stages or diminished reproductive success from disruption of endocrine system function. Developmental deformities in frog gonads, for example, have been documented in laboratory experiments by Hayes and others (2002a) from exposure to the herbicide atrazine. Twenty percent of male frogs studied developed deformities at atrazine concentrations as low as 0.10 µg/L. This concentration is lower than the USEPA MCL allowable in drinking water (3 µg/L) by a factor of 30. Atrazine is the most widely used pesticide in the world and is the most frequently detected pesticide in streams nationwide (U.S. Geological Survey, 1999); it was the second most frequently detected pesticide in the Clackamas River basin—detected in nearly one-half of the samples collected (table 3). Sublethal effects on aquatic life, such as impaired reproduction and development from exposure to pesticides have been documented by numerous laboratory and field studies. Cope and others (1970) reported delayed fish spawning (in bluegill) from exposure to 2,4-D; Von Westernhagen and others (1989) showed reduced fish fertilization from exposure to dieldrin; Choudhury and others (1993) and Baatrup and Junge (2001) demonstrated reproductive system disruption in fish from exposure to carbaryl and *p,p'*-DDE, respectively; Hayes and others (2002b) found developmental irregularities in frogs from low-level exposure to atrazine. Hayes and others (2006) also found that a nine-pesticide mixture had profound effects on the development of frog larvae by delaying metamorphosis. Because frogs took longer to reach maturity, they were smaller as adults, presumably because they used more of their energy reserves before reaching a feeding age than the control group. Colborn and others (1993) reported endocrine system disruption in wildlife and humans from exposure to pesticides. Pesticides also may affect fish behaviors, including predator avoidance and homing (Scholz and others, 2000), swimming (Matton and Laham, 1969), and feeding (Bull, 1974). One of the challenges in understanding toxicity is that in the past, most studies were designed to detect effects on growth or survival (LC_{50} tests, for example)—not on sublethal effects such as those described above. Determining such effects on aquatic life is complicated by the multiple-compound exposures, by variations in concentrations (including high-level pulses that occasionally occur), and by interactions with streambed sediment where pesticide residues may accumulate over time in areas affected by erosion.

Pesticides in Source and Finished Drinking Water

Of the 57 pesticides or degradates detected in tributary streams draining into the Clackamas River upstream of the treatment plant intakes, 26 were detected in the mainstem Clackamas River or in samples of source water from the study water treatment plant on the lower Clackamas River. Of these, 15 pesticides and degradates—11 herbicides, 3 insecticides, and 1 fungicide—were detected in samples of finished drinking water from the study drinking water-treatment plant (table 3).

Only one of the four water-treatment plants on the lower Clackamas River was examined during the SWQA drinking water study. Consequently, these results characterize just a portion of the water supply derived from the Clackamas River, from a water treatment plant that uses direct filtration, one of four treatment technologies used by the municipal water providers, along with sand filtration, membrane filtration, and conventional water treatment.

The finding of pesticides in finished drinking water derived from the Clackamas River is consistent with other studies of medium to large sized integrator-type rivers and reservoirs conducted in other parts of the United States. A recent pilot study by the USGS and USEPA examined raw and finished drinking water from 12 water-supply reservoirs across the country found that conventional water treatment did not completely remove pesticides and degradates, and that 9–30 compounds were detected in finished water in each area (median number of pesticide compounds detected was 23) (Blomquist and others, 2001; Coupe and Blomquist, 2004).

Although concentrations of pesticides in finished drinking water derived from the lower Clackamas River were all well below USEPA standards and other human-health benchmarks, current benchmarks do not account for multiple compound exposures. In addition, some of the compounds are likely or possible carcinogens, endocrine disruptors, and (or) acetylcholinesterase inhibitors (table 9), and may warrant further study and monitoring.

The pesticides having the highest human health Benchmark Quotients (BQs) in this study were diuron, ethoprop, simazine, and pronamide (table 8). Maximum concentrations of pesticides in finished drinking water were less than their respective human-health benchmarks by a factor of between 11 and 350,000 (fig. 14). Three of the compounds detected in finished water—diazinon-oxon (a degradate of diazinon), CIAT (deethylatrazine, a degradate of atrazine), and the insect repellent DEET—have no established MCL or HBSL benchmark for which to compare (table 4) because the toxicity data needed to calculate HBSL values are lacking. CIAT was frequently detected in tributary and mainstem samples, occurring in 31 percent of samples overall (table 3). CIAT is formed in the environment from the degradation of atrazine, a commonly used herbicide. In the USEPA OPP Human-Health Risk Assessment for atrazine, the toxicity

Table 9. Potential human-health effects of select pesticides detected in the lower Clackamas River basin, Oregon, 2000–2005.

Type: H, herbicide; I, insecticide; F, fungicide; N, nematocide; M, molluscicide. **Carcinogen group:** carcinogen classification from USEPA (2006) as follows: B2, Sufficient evidence in animals and inadequate or no evidence in humans to classify as a probable human carcinogen; C, Possible human carcinogen; D, Not classifiable as to human carcinogenicity; E, Evidence of noncarcinogenicity for humans; L, Likely to be carcinogenic to humans; N, Not likely to be carcinogenic to humans. **Endocrine disruptor:** Draft List of Initial Pesticide Active Ingredients and Pesticide Inerts to be Considered for Screening under the Federal Food, Drug, and Cosmetic Act (U.S. Environmental Protection Agency, 2007). **Cholinesterase inhibitor:** Extoxnet (1993). **Symbol:** #, pesticide not detected since 2000–2001]

Pesticide	Type	Carcinogen group	Endocrine disruptor	Cholinesterase inhibitor
2,4-D	H	D	Potential	
Atrazine	H	N	Potential	
Azinphos-methyl	I		Potential	Yes
Bromacil	H	C		
Carbaryl	I	L	Potential	Yes
Chlorothalonil	F	B2	Potential	
Chlorpyrifos	I/N	D	Potential	Yes
Cycloate	H			Yes
Dacthal (DCPA)	H	C	Potential	
Diazinon	I	E	Potential	Yes
Dichlobenil#	H		Potential	
Dichlorvos	I		Potential	Yes
Dieldrin	I	B2		
Diuron	H	L		
Endosulfan	I		Potential	
Ethoprop	I/N	[1]L	Potential	Yes
Fonofos	I	N		Yes
Glyphosate	H	D	Potential	
Hexazinone	H	D		
Imidacloprid	I		Potential	
Iprodione	F		Potential	
Linuron#	H		Potential	
Malathion	I	D	Potential	Yes
MCPA	H	N		
Metalaxyl	F		Potential	
Methiocarb	I/M		Potential	Yes
Metolachlor	H	C		
Myclobutanil	F		Potential	
Norflurazon	H		Potential	
Prometon	H	D		
Pronamide	H	B2	Potential	
Propiconazole	F	[2]C	Potential	
Propoxur	I			Yes
Simazine	H	N	Potential	
Tebuthiuron	H	D		
Terbacil#	H	E		
Trifluralin	H	C	Potential	

[1] Ethoprop is a likely carcinogen (USEPA, http://www.epa.gov/oppsrrd1/REDs/ethoprop_ired.pdf, accessed July 10, 2007), U.S. Environmental Protection Agency (1999b).

[2] USEPA (http://www.epa.gov/oppsrrd1/REDs/propiconazole_red.pdf, accessed July 10, 2007).

of CIAT was considered as equivalent to that of the parent compound atrazine (U.S. Environmental Protection Agency, 2003b). The consensus-based protocol for HBSL development (Toccalino and others, 2003), however, does not currently permit the use of toxicity data from a parent compound to calculate a HBSL for a degradate. The MCL for atrazine is 3 µg/L, which is 600 times higher than the CIAT concentration (0.005 µg/L) detected in the one sample of finished water.

Detections of pesticides in finished water samples collected in 2004 and 2005 differ from previous results from 2000–2001 (Carpenter, 2004) and from the routine compliance monitoring by the water providers over the past several years that has detected no pesticides in finished water. One of the possible explanations for this difference is that prior to 2004, all of the USGS samples were processed without the use of a dechlorinating agent to stop the chlorine activity and subsequent degradation of pesticides (see "Methods"). This quenching procedure was added in 2004 for the second phase of the SWQA study (Carter and others, 2007). Because previously collected finished-water samples did not receive a dechlorinating agent, pesticides that may have been present in the samples could have been oxidized by residual chlorine prior to being analyzed at the laboratory. In addition, laboratory methods used during the USGS studies had considerably lower detection limits for pesticides compared with the routine compliance monitoring.

A comparison of pesticide concentrations in a limited number of samples with and without the dechlorinating agent provides some indication of the potential effects of chlorine on many pesticides, with fewer compounds being detected and at lower concentrations in the unquenched samples than in the quenched samples (appendix A, tables A2 and A3). Many of the percent recoveries for quality control spiked samples were zero for unquenched drinking-water samples, indicating oxidation of these pesticide compounds. Based on these data, chlorination may be effective at decreasing concentrations of certain pesticides in finished water, although more analyses are needed to verify these results. Many pesticides, however, transform into degradates through oxidation by chlorine in public distribution lines and in chlorinated drinking-water samples prior to analysis. The degradation of pesticides into degradates forms new compounds that are generally less toxic, but in some cases, such as for diazinon-oxon (degradate of the orthophosphate insecticide diazinon) and 3,4-dichloroaniline (degradate of the herbicide diuron), the degradates have greater toxicity than the parent compounds. Although some pesticide degradates were examined during this study, the full suite of pesticide degradates that could form from the 63 pesticides detected were not characterized.

The occurrence of simazine and diuron in finished drinking water is consistent with their high rates of detection in the lower-basin tributaries and in the lower Clackamas River mainstem. These two herbicides occurred in 50–70 percent of tributary samples, sometimes at elevated concentrations (1–2 µg/L). Simazine is a selective herbicide used to control broadleaf weeds and annual grasses on nursery and field crops, including Christmas trees, hazelnuts, and cane berries. Simazine also may be used to control aquatic plant growth in farm ponds, swimming pools, and fish hatchery ponds (Extension Toxicological Network, 1996).

Diuron was detected in finished drinking water on four occasions at a maximum concentration of 0.18 µg/L, which was 11 times less than the low HBSL value (table 8). Diuron also was frequently detected during the study, occurring in 44 percent of samples. Diuron was first registered for use in 1967. It is applied as a pre- and post-emergent herbicide, with approximately two-thirds of its use on agricultural crops and the remaining third on noncrop areas such as along roads and other right-of-ways (table 10). It is also used to control mildew, as a preservative in paints and stains, and to control algae in commercial fish production, residential ponds and aquariums (U.S. Environmental Protection Agency, 2003d).

One of the primary degradates of diuron, 3,4-dichloroaniline (DCA), may warrant further study given the frequent occurrence of diuron and the relative lack of data for DCA because it was analyzed for in a small number of samples (18 samples analyzed compared with 93 for diuron) (table 3). DCA was frequently detected during the EUSE study, occurring in two-thirds of samples collected from Tickle and North Fork Deep Creeks (appendix C, table C2). A recent review of the environmental toxicity and degradation of diuron by Giacomazzi and Cochet (2004) indicated a greater toxicity from DCA compared with diuron. The USEPA has completed an "Effects Determination" for diuron to evaluate exposure of endangered and threatened salmon and steelhead species to diuron and the potential for indirect effects on these fish from damage to their aquatic plant cover in water bodies in California and the Pacific Northwest. The USEPA concluded that agricultural crop uses of diuron will not have effects on Pacific salmon and steelhead, except at certain high-use rates on walnuts, filberts, and peaches, and that noncrop uses may affect 25 salmon and steelhead evolutionarily significant units (ESUs). For those ESUs that may be affected by diuron use, the USEPA will consult with the National Marine Fisheries Service to determine what protective measures are needed (U.S. Environmental Protection Agency, 2003d).

Another pesticide detected in finished drinking water during the September 2005 storm event was the insecticide/nematocide ethoprop, at a concentration of 0.006 µg/L, which was 175 times less than the low HBSL value of 1 µg/L (table 8). Ethoprop is classified by USEPA as a likely human carcinogen (table 9). This low HBSL corresponds to a 1-in-1 million cancer risk for ethoprop, which at higher concentrations is a likely human carcinogen (table 9). This insecticide was detected in 18 or one-third of storm samples, with nearly all of the detections in the lower-basin tributaries (table 3). Although ethoprop was detected in the Clackamas River and in finished drinking water (once), its occurrence in the mainstem Clackamas River was not fully characterized by this study as it was analyzed only during the four storms sampled for the USGS/CWMG studies, not during the routine sampling for the SWQA study.

Table 10. Potential uses for pesticides detected in the lower Clackamas River basin, Oregon, 2000–2005.

[**Type:** H, herbicide; I, insecticide; F, fungicide; N, nematocide; M, molluscicide; ID, insecticide degradate. **Agriculture:** uses estimated from average pesticide application rates for crops in the Pacific Northwest (Oregon State University, 2001a; 2001b), from estimated crop acreage during 1999–2000 for Clackamas County (Oregon Department of Agriculture, 1997), and from the National Agricultural Statistics Service (2004). **Urban:** Anderson and others (1996); Kratzer (1998); Panshin and others (1998); U.S. Geological Survey (1999). **Golf courses:** pesticides used on and detected in ground water beneath golf courses, Jack Barbash, U.S. Geological Survey, http://ca.water.usgs.gov/pnsp/golf.html, accessed July 9, 2002. **Right-of-ways:** Will Lackey, Oregon Department of Transportation, written commun., 2006; Ronald Buck, Clackamas County Department of Public Works, written commun., 2002. **State and private forestland:** Cramer (1974); Glyphosate is the only herbicide approved for use on Federal land within the Mt. Hood National Forest in the Clackamas River Basin. **Restrictions:** Oregon State University (2001a; 2001b). ***p,p´*-DDE** is one of several degradation products of *p,p'*-DDT, an organochlorine insecticide that is restricted in all states. **Norflurazon** use information from the California pesticide use database, http://www.pesticideinfo.org/Detail_ChemUse.jsp?Rec_Id=PC36413, accessed October 5, 2006. **Symbols:** **, pesticide exceeded a U.S. Environmental Protection Agency (USEPA) aquatic-life benchmark; *, pesticide exceeded a non-USEPA aquatic-life benchmark; #, pesticide not detected since 2000–2001 study]

Pesticide or degradate	Type	Commercial product/ common or trade name	Chemical class	Potential use or application area: Agri-culture	Nursery and floriculture crops	Urban	Golf courses	Right-of-ways	State and private forestland	Potential agricultural (or other) uses	Restrictions
Current use pesticides											
		Number of current use pesticides		48	47	29	25	23	7		
		Percentage of current use pesticides		94	92	57	49	45	14		
2,4-D*	H	Aqua-Kleen, Lawn-Keep, Weed-B-Gone, DMA 4, Fernesa	Chlorophenoxy acid	X	X	X	X	X	X	Pastureland, hay, grass seed, hazelnuts, wheat	
2,4-DP	H	Dichlorprop, Seritox 50, Kildip, Lentemul, Tordon 101	Chlorophenoxy acid	X	X			X		(Along right-of-ways)	All states
2,4-D methyl ester	H	Pestanal, Methyl (2,4-dichlorophenoxy) acetate	Chlorophenoxy acid							No uses were found for this herbicide	
Atrazine	H	AAtrex, Atrex, Atred, Gesaprim, Conifer 90	Triazine	X	X	X	X		X	Christmas trees, sweet corn	All states
Azinphos-methyl**	I	Carfene, Guthion, Gusathion M	Organothio-phosphate	X	X					Fruit, vegetable, nut, and field crops; ornamentals	All states
Benomyl	F	Benlate, Agrocit, Benex, Benosan, Fundazol	Carbamate	X	X					Field crops, fruits, nuts, ornamemtals, mushrooms, and turf	
Bentazon	H	Basagran, Bentazone, Bendioxide	N heterocycle	X	X		X			Beans, rice, corn, peanuts, mint	
Bromacil	H	Hyvar X, Urox B, Bromax	Uracil	X	X	X		X		(Landscaping, structural pest control)	Washington
Carbaryl*	I	Carbamine, Denapon, Sevin, Savit	Carbamate	X	X	X	X			Pastureland, hay, cane berries, wheat, sweet corn	
Chlorothalonil*	F	Bravo, Daconil 2787, Echo, Exotherm	Organochlorine	X	X		X			Vegetables, small fruits, ornamentals, turf	
Chlorpyrifos**	I/N	Brodan, Dursban, Lorsban, Chlorpyrifos-ethyl	Organothio-phosphate	X	X	X	X			Hazelnuts, sweet corn, Christmas trees, strawberries	Most uses
Cycloate	H	Ro-Neet, Marathon	Thiocarbamate	X	X			X		Spinach, leaf lettuce, beets, squash	
Dacthal (DCPA)	H	Chlorthal-dimethyl	Chlorobenzoic acid ester	X	X	X	X			Cucumbers and pickles, strawberries, squash, snap beans	Washington
DEET	I	Insect repellents (OFF!, Cutter Outdoorsman, Skeeter skat)	N-diethyl toluamide			X				(Insect repellent)	

Table 10. Potential uses for pesticides detected in the lower Clackamas River basin, Oregon, 2000–2005.—Continued

[**Type:** H, herbicide; I, insecticide; F, fungicide; N, nematocide; M, molluscicide; ID, insecticide degradate. **Agriculture:** uses estimated from average pesticide application rates for crops in the Pacific Northwest (Oregon State University, 2001a; 2001b), from estimated crop acreage during 1999–2000 for Clackamas County (Oregon Department of Agriculture, 1997), and from the National Agricultural Statistics Service (2004). **Urban:** Anderson and others (1996); Kratzer (1998); Panshin and others (1998); U.S. Geological Survey (1999). **Golf courses:** pesticides used on and detected in ground water beneath golf courses, Jack Barbash, U.S. Geological Survey, http://ca.water.usgs.gov/pnsp/golf.html, accessed July 9, 2002. **Right-of-ways:** Will Lackey, Oregon Department of Transportation, written commun., 2006; Ronald Buck, Clackamas County Department of Public Works, written commun., 2002. **State and private forestland:** Cramer (1974); Glyphosate is the only herbicide approved for use on Federal land within the Mt. Hood National Forest in the Clackamas River Basin. **Restrictions:** Oregon State University (2001a; 2001b). ***p,p´*-DDE** is one of several degradation products of *p,p*'-DDT, an organochlorine insecticide that is restricted in all states. **Norflurazon** use information from the California pesticide use database, http://www.pesticideinfo.org/Detail_ChemUse.jsp?Rec_Id=PC36413, accessed October 5, 2006. **Symbols:** **, pesticide exceeded a U.S. Environmental Protection Agency (USEPA) aquatic-life benchmark; *, pesticide exceeded a non-USEPA aquatic-life benchmark; #, pesticide not detected since 2000–2001 study]

Pesticide or degradate	Type	Commercial product/ common or trade name	Chemical class	Potential use or application area: Agri-culture	Nursery and floriculture crops	Urban	Golf courses	Right-of-ways	State and private forestland	Potential agricultural (or other) uses	Restrictions
Current use pesticides—Continued											
Diazinon**	I	Basudin, Diazatol, Neocidol, Knox Out	Organothio-phosphate	X	X	X	X			Grass seed, cane berries, fescue seed, nurseries, squash	Most uses
Dichlobenil #	H	Barrier, Casoron, Dyclomec, Norosac	Organochlorine	X	X	X	X	X		Hazelnuts, cane berries, cauliflower, blueberries	
Dichlorvos	I/F	DDVP, Apavap, Devikol, Didivane, Duravos, Fly-Die	Organo-phosphate	X	X		X			Vegetables, fruits, and greenhouse crops	
Dimethenamid	H	Outlook, Frontier, Guardsman, Optill, Pursuit	Amide	X						Dry bulb onions and non-bearing grape vines	
Diuron*	H	Crisuron, Karmex, Direx, Diurex	Urea	X	X	X		X		Grass seed, hay, hazelnuts, fescue seed, cane berries	Washington
Endosulfan I/II*	I	alpha/beta Endosulfan, Endocel, Endocide, Endosol	Organochlorine	X	X					Numerous fruits (blueberries), nuts, and vegetable crops (broccoli, cabbage, celery)	
Ethoprop	I/N	Ethoprophos, Mocap	Organothio-phosphate	X	X	X	X			Sweet corn, snap beans	Most uses
Fenuron	H	Beet-Klean, Dybar, Fenidim, Fenulon, Urab	Urea							No uses were found for this herbicide	
Fonofos #	I	Dyfonate, Capfos, Cudgel, Tycap	Organothio-phosphate	X	X	X	X			Sweet corn, snap beans, broccoli, strawberries	Most uses
Glyphosate	H	Roundup, Rodeo, Accord, Honcho, Kill Zall, Roundup Biactive	Amino acid derivative, organo-phosphate	X	X	X	X	X	X	Numerous crops, fruits, and vegetables	
Hexazinone	H	DPX 3674, Pronone, Velpar	Triazine	X	X	X		X	X	Christmas trees, alfalfa, forage grasses	
Imazaquin #	H	Image 1.5LC, Scepter 1.5L	Imidazolinone	X	X	X				Cottonwood trees grown for pulp, ornamentals, and grass turf	
Imidacloprid	I	Admire, Gaucho, Merit	N heterocycle	X	X					(Used for the control of sucking insects in a variety of crops)	

Table 10. Potential uses for pesticides detected in the lower Clackamas River basin, Oregon, 2000–2005.—Continued

[**Type:** H, herbicide; I, insecticide; F, fungicide; N, nematocide; M, molluscicide; ID, insecticide degradate. **Agriculture:** uses estimated from average pesticide application rates for crops in the Pacific Northwest (Oregon State University, 2001a; 2001b), from estimated crop acreage during 1999–2000 for Clackamas County (Oregon Department of Agriculture, 1997), and from the National Agricultural Statistics Service (2004). **Urban:** Anderson and others (1996); Kratzer (1998); Panshin and others (1998); U.S. Geological Survey (1999). **Golf courses:** pesticides used on and detected in ground water beneath golf courses, Jack Barbash, U.S. Geological Survey, http://ca.water.usgs.gov/pnsp/golf.html, accessed July 9, 2002. **Right-of-ways:** Will Lackey, Oregon Department of Transportation, written commun., 2006; Ronald Buck, Clackamas County Department of Public Works, written commun., 2002. **State and private forestland:** Cramer (1974); Glyphosate is the only herbicide approved for use on Federal land within the Mt. Hood National Forest in the Clackamas River Basin. **Restrictions:** Oregon State University (2001a; 2001b). ***p,p*´-DDE** is one of several degradation products of *p,p*'-DDT, an organochlorine insecticide that is restricted in all states. **Norflurazon** use information from the California pesticide use database, http://www.pesticideinfo.org/Detail_ChemUse.jsp?Rec_Id=PC36413, accessed October 5, 2006. **Symbols:** **, pesticide exceeded a U.S. Environmental Protection Agency (USEPA) aquatic-life benchmark; *, pesticide exceeded a non-USEPA aquatic-life benchmark; #, pesticide not detected since 2000–2001 study]

Pesticide or degradate	Type	Commercial product/ common or trade name	Chemical class	Potential use or application area: Agri-culture	Nursery and floriculture crops	Urban	Golf courses	Right-of-ways	State and private forestland	Potential agricultural (or other) uses	Restrictions
Current use pesticides—Continued											
Iprodione	F	Chipco, Kidan, Rovral, Verisan	Dicarboximide	X	X		X			(Used to control a wide variety of crop diseases on vegetables and ornamentals)	
Linuron #	H	Lorox, Linex, Sarclex, Linurex, Afalon	Urea	X	X					Garden crops such as corn, potatoes, fruit trees, wheat, oats, and barley	
Malathion*	I	Cythion, Fyfanon	Organothio-phosphate	X	X	X	X		X	Pastureland, hay, cane berries, hazelnuts, wheat	
MCPA	H	Rhomene, Rhonox, Chiptox	Chlorophenoxy acid	X	X		X			(Used on landscaping)	
Metalaxyl	F	Apron, Delta-Coat AD, Ridomil, Subdue	Amino acid derivative	X	X					Used on food crops, including tobacco, ornamentals, conifers, and grass turf	
Methiocarb	I/M	Draza, Grandslam, Mesurol, Slug-Geta	Carbamate	X	X					Used on a wide variety of nursery and greenhouse crops	
Metolachlor	H	Dual, Pennant	Acetanilide	X	X	X	X	X		Grass seed, sweet corn, snap beans, green peas	Washington
Metsulfuron-methyl	H	Escort, Gropper, Ally	Sulfonylurea	X	X			X	X	(Used along roadsides and right-of-ways)	
Myclobutanil	F	Eagle, NOVA, Laredo EC, Fungicide m, Rally, Systhane	Triazole	X	X		X			Strawberries, tomatoes, landscaping	
Napropamide	H	Devrinol, Naproquard	Amide	X	X	X		X		Hazelnuts, cane berries, strawberries, rhubarb	
Norflurazon	H	Evital, Predict, Solicam, Telok, Zorial	Amine	X	X			X		Alfalfa, blueberries	
Oryzalin	H	Dirimal, Ryzelan, Surflan	Dinitroaniline	X	X	X	X	X		Crabgrass, (landscaping)	
Oxyfluorfen	H	Goal, Koltar, RH-2915	Diphenyl ether	X	X	X		X		Wide variety of fruit, vegetable, and nut crops, landscaping	
Pendimethalin	H	Pre-M, Prowl, Weedgrass Control, Stomp, Herbadox	Dinitroaniline	X	X	X	X	X		Christmas trees, grass seed, snap beans, grapes	

Table 10. Potential uses for pesticides detected in the lower Clackamas River basin, Oregon, 2000–2005.—Continued

[[**Type:** H, herbicide; I, insecticide; F, fungicide; N, nematocide; M, molluscicide; ID, insecticide degradate. **Agriculture:** uses estimated from average pesticide application rates for crops in the Pacific Northwest (Oregon State University, 2001a; 2001b), from estimated crop acreage during 1999–2000 for Clackamas County (Oregon Department of Agriculture, 1997), and from the National Agricultural Statistics Service (2004). **Urban:** Anderson and others (1996); Kratzer (1998); Panshin and others (1998); U.S. Geological Survey (1999). **Golf courses:** pesticides used on and detected in ground water beneath golf courses, Jack Barbash, U.S. Geological Survey, http://ca.water.usgs.gov/pnsp/golf.html, accessed July 9, 2002. **Right-of-ways:** Will Lackey, Oregon Department of Transportation, written commun., 2006; Ronald Buck, Clackamas County Department of Public Works, written commun., 2002. **State and private forestland:** Cramer (1974); Glyphosate is the only herbicide approved for use on Federal land within the Mt. Hood National Forest in the Clackamas River Basin. **Restrictions:** Oregon State University (2001a; 2001b). ***p,p´*-DDE** is one of several degradation products of *p,p*'-DDT, an organochlorine insecticide that is restricted in all states. **Norflurazon** use information from the California pesticide use database, http://www.pesticideinfo.org/Detail_ChemUse.jsp?Rec_Id=PC36413, accessed October 5, 2006. **Symbols:** **, pesticide exceeded a U.S. Environmental Protection Agency (USEPA) aquatic-life benchmark; *, pesticide exceeded a non-USEPA aquatic-life benchmark; #, pesticide not detected since 2000–2001 study]

Pesticide or degradate	Type	Commercial product/ common or trade name	Chemical class	Potential use or application area: Agri-culture	Nursery and floriculture crops	Urban	Golf courses	Right-of-ways	State and private forestland	Potential agricultural (or other) uses	Restrictions
Current use pesticides—Continued											
Prometon	H	Pramitol, Princep, Gesagram 50, Ontracic 80	Triazine	X	X	X		X		Wine grapes, (landscaping)	All states
Pronamide	H	Propyzamid, Kerb	Amide	X	X	X	X			Christmas trees, cane berries, grass seed, alfalfa	All states
Propiconazole	F	Tilt, Orbit, Banner, Proconazole, Wocosin	Triazole	X	X	X	X	X		Celery, plumbs, (turf and landscaping, wood treatment)	
Propoxur	I	Baygon, Blattanex, Unden, Proprotox	Carbamate	X	X	X		X		(Structural pest control, public health pest control)	
Simazine	H	Princep, Caliber 90, Gesatop, Simazat	Triazine	X	X	X	X	X		Christmas trees, hazelnuts, cane berries, blueberries	
Sulfometuron-methyl	H	Oust, Landmark MP, DPX-T5648	Sulfonylurea	X	X			X		(Along right-of-ways)	
Tebuthiuron	H	Spike, Perflan, Tebusan	Urea	X	X	X		X		Pastureland	
Terbacil #	H	Sinbar, Geonter	Uracil	X	X					Grass seed, cane berries, alfalfa, apples, peaches	
Triclopyr	H	Crossbow, Garlon, Grandstand, Grazon, Redeem, Remedy	Organochlorine, N heterocycle	X	X	X	X	X	X	Pastureland, hay, Christmas trees, clearing heavy brush	
Trifluralin	H	Treflan, Elancolan, Gowan, Tri-4, Trific, Trilin	Dinitroaniline	X	X	X	X	X		Wheat, alfalfa, cucumbers and pickles, cauliflower	
Banned by the USEPA											
p,p´-DDE** #	ID	*p,p´*-DDT degradate	Organochlorine							All uses cancelled in the U.S.	Banned in all states
Dieldrin*	I	Panoram D-31, Octalox, Compound 497, Aldrin epoxide	Organochlorine							All uses cancelled in the U.S.	Banned in all states
Dinoseb	H/I	DNPB, Dinosebe	Nitrophenol							All uses cancelled in the U.S.	Banned in all states

The low-level detections of pesticides and degradates inform watershed managers about their presence and gives some idea of their respective levels in source and finished drinking water from one of the four treatment plants on the lower Clackamas River. The presence of pesticides and degradates raises questions regarding the potential for effects on aquatic life in the lower-basin tributaries and the lower Clackamas River, and on human health from exposure to low-level concentrations of pesticides. It is uncertain, for example, what the cumulative effects might be on human health from simultaneous exposure to multiple pesticide compounds, and current regulations do not yet consider the spectrum of interactions that may occur among pesticides and other contaminants that may be present.

Potential Pesticide Sources

The pesticides detected in the Clackamas River basin come from a wide variety of sources. The diverse land use in the study area and unpredictable water management (pumping, irrigation, collection, and release) make it challenging to identify sources. Pesticide applications are made along roads and on agricultural fields, harvested forests and urban landscaping, especially in the lower Clackamas River basin where agricultural and urban land is concentrated. One survey estimated that at least 116 have been used in the Clackamas River basin (Hassanein and Peters, 1998), but the actual numbers may be much higher given that there are approximately 11,000 pesticide products registered for use in Oregon.

A more recent report on pesticide occurrence in the Clackamas River basin estimated that as much as one-half of the agricultural pesticide use could be on nursery and greenhouse crops, with lesser amounts applied to pastureland, Christmas trees, alfalfa and hay fields, hazelnut orchards, and grass seed fields (Carpenter, 2004). Findings from the current study also suggest that nursery, floriculture, and greenhouse operations continue to be a significant source of pesticides in the Clackamas River basin.

A Source Water Assessment was conducted in 2003 by the Oregon Department of Environmental Quality and the Oregon Department of Human Services (2003) with guidance from the Clackamas River Water Providers identified 961 individual or area-wide potential contaminant sources upstream of the drinking-water intakes in the lower Clackamas River, with 445 sources posing a moderate-to-high risk. Specific sources include 55 high density housing areas, 33 high maintenance lawn areas, 6 golf courses, 3 wastewater-treatment plants, 173 irrigated and 200 nonirrigated agricultural operations, 22 pesticide/fertilizer storage areas, and 35 ponds, some of which collect irrigation tail water from agricultural land.

The collective influence of land use, topography, drainage network, and patchy nature of storms contributes to producing variable runoff of water, sediment, and pollutants from these basins during storms. Drainage basins affected by urbanization—Carli, Cow, and Sieben Creek basins, and other streams around Estacada, Boring, and Sandy—collect and transfer stormwater to streams through drains, culverts, and other engineering conveyance systems. Large amounts of overland runoff with high levels of suspended sediment also may transport dissolved and sediment-bound contaminants to the lower Clackamas River upstream of drinking-water intakes. Basins with relatively steep topography and large amounts of impervious areas—Sieben, Rock, and Richardson Creek basins, for example—respond quickly to rainfall and are often highly turbid after storms (appendix C, table C4).

The sources of pesticides detected in the Clackamas River basin are difficult to identify because most have multiple uses (table 10). Furthermore, data collected for Oregon's Pesticide Use and Reporting System (PURS) will be at a relatively coarse scale, and not specific enough to locate sources. Pesticide applications in the Clackamas River basin will likely be incorporated into a larger report for the entire Willamette River basin. The PURS data will be useful, however, for identifying potentially important chemicals not currently being analyzed. Only a small fraction of the 11,000 pesticide products registered for use in Oregon were tested during this study, which makes pesticide use data especially helpful for designing pesticide monitoring plans.

The transport of pesticides from their target areas to waterways occurs from several sources, including: (1) surface runoff from urban and rural areas, agricultural fields, roadside ditches and culverts (which are sprayed directly for vegetation control), greenhouses and nurseries, and other source areas, (2) erosion of soils treated with chemicals, especially pesticides with high K_{oc} values (appendix E) that tend to adhere to sediment, (3) atmospheric drift, and (4) ground water, whereby pesticides travel into aquifers or move through shallow flow paths to streams.

Pesticides used on the landscape may be transported into streams, exposing aquatic life to pulses of toxic runoff and also may travel to drinking-water intakes as was demonstrated in this study. Although highly soluble compounds—those with high water solubility or low K_{oc} values in appendix E—tend to move from the land at relatively high rates, additional factors also may explain the fate of pesticides in the environment. These include the chemical half life (rate of breakdown in water or soil), pattern and extent of chemical use, and physical or hydrologic characteristics of the drainage basin.

Many studies have shown that while streams and rivers are most vulnerable to pesticide contamination and tend to have higher pesticide concentrations, ground water also may contain pesticides. This source of pesticides merits careful attention because ground water contamination is difficult to reverse. The importance of ground water as a pesticide source for surface waters in the Clackamas River basin is not, however, known but may be important in certain areas where surface runoff containing pesticides recharges ground water. Future studies examining the surficial geology and ground-water quality beneath nurseries, golf courses, and urban areas could begin to characterize pesticide concentrations in some of the high-risk areas identified during the Source Water Assessment (Oregon Department of Environmental Quality and the Oregon Department of Human Services, 2003).

Concentrations of some compounds, including CIAT (deethylatrazine), metalaxyl, and simazine were somewhat elevated in samples collected during low-flow conditions in the Deep Creek basin during the EUSE study, particularly in North Fork Deep and Tickle Creeks. The pesticide detections in these streams during nonstorm conditions indicate a continuous non-storm-derived source such as ground-water inflows, irrigation return flows, or wastewater-treatment plant effluent. Both North Fork Deep and Tickle Creeks receive effluent from the community of Boring and the city of Sandy, respectively. Currently, Sandy's wastewater is used to irrigate nursery stock during the dry months, and although wastewater inputs to surface water are reduced, some amount may enter ground water.

One of the most commonly detected pesticides in the Clackamas River basin was the herbicide glyphosate, the active ingredient in many household, agricultural, and forestry herbicide products such as RoundUP™, Rodeo™, and Accord™ (table 10). The average glyphosate concentration in tributary samples was 3.5 µg/L, and the highest concentration was 45.6 µg/L in middle Rock Creek at 172nd Avenue during the September 2005 storm. Glyphosate has a relatively high water solubility (900,000 mg/L) and moderate half life in soil (47 days) (appendix E). Most glyphosate products contain surfactants that are designed to make the chemical spread and stick to surfaces, and therefore, have a low tendency to runoff or enter ground water despite its high water solubility. Although surfactants may retard movement of glyphosate, it may be transported to streams on sediment particles. Although sediment-associated transport of glyphosate to streams may explain its frequent occurrence during storms—71 percent of samples contained glyphosate (table 3), it is also one of the most widely used herbicides.

Tractor and boom sprayers are used to apply pesticides on a variety of agricultural crops in the Clackamas River basin. (Photograph taken May 2, 2003.)

Landscaping ornamentals are grown in a Rock Creek basin nursery. (Photograph taken January 2, 2003.)

Agriculture—About 100,000 acres of land are used for agriculture in Clackamas County. In the Clackamas River basin, agricultural land is concentrated on the high plateau between the Clackamas and Sandy Rivers (pl. 1). Some agricultural land also is located adjacent to or within the floodplain of the Clackamas River. Although diverse crops are grown, pastureland, hay fields (mostly alfalfa), nurseries, and greenhouses make up about 65 percent of the agricultural land in the basin. Clackamas County also is one of the top Christmas tree producing counties in the country. According to the National Agricultural Statistics Service (2002), 18 herbicides, 12 insecticides, and 4 fungicides are used on Christmas trees in Oregon. Several of these pesticides (including atrazine, hexazinone, simazine, triclopyr, and chlorpyrifos) were detected in the Clackamas River basin during this study, but the individual contribution from each of the types of agriculture was not part of the study design.

Irrigated container nursery in the Sieben Creek basin. (Photograph taken July 10, 2003.)

The greatest amount of agricultural land is located in the Deep Creek basin, which is drained by tributaries including Noyer, North Fork Deep, and Tickle Creeks. These streams drain basins containing the highest percentage of agricultural land—approximately 33 to 47 percent of the total basin area was agricultural land (table 1). Rock and Richardson Creek basins also contain substantial amounts of agricultural land (about 31% each), along with some rural residential and urban land. Deep, Noyer, Richardson, and Rock Creeks have cut into a large plateau in the northern part of the lower Clackamas River basin, forming drainages that are relatively flat in the headwaters and descend through steep forested canyons before joining the mainstem Clackamas River to the south. Streams draining this part of the basin contribute sediment, nutrients, and pesticides to the Clackamas River, particularly during storms.

Herbicides are used for weed control in Christmas tree plantations. (Photograph taken July 10, 2003.)

Nursery, floriculture, and greenhouse crops—In 2003, there were 12,700 acres of nursery land in Clackamas County (Oregon Department of Agriculture, 2005), with much of the acreage located within the Clackamas River basin (pl. 1). In 2000, the top agricultural commodity in Oregon was production from nurseries and greenhouses and sales in Oregon have increased from $347 million in 1993 to $844 million in 2004 (Oregon Department of Agriculture, 2005). The results of this study show that Deep Creek and its tributaries, including Noyer, North Fork Deep, Tickle, and Rock Creeks are among the largest contributors of pesticides to the Clackamas River during storms. All these streams have potential to be impacted from various sources, including large nursery operations. The contributions from nursery operations relative to other types of agriculture, or from rural residential use in these areas were not, however, specifically examined during this study.

A 2003 survey of nursery and floriculture operations (National Agricultural Statistics Service, 2004) reported about 275 herbicides, insecticides, and fungicides applied to nursery and floriculture crops in program States during 2003. The

Cane berries are an important agricultural commodity in Clackamas County. (Photograph taken July 10, 2003.)

Herbicides are applied for vegetation control along roads in the Clackamas River basin. (Photograph taken July 10, 2003.)

survey reported aggregated data on the types and amount of chemicals used in Oregon and four other states—California, Michigan, Pennsylvania, and Florida. Some data in the National Agricultural Statistics Service survey were reported by State, including the number of operations, total number of pesticides used, and qualitative information on patterns in pesticide use. Applications of pesticides occurred in open areas and inside greenhouses to control various pests. Most pesticides were applied manually in 2003 (80 percent) using backpack or power hydraulic sprayers, and about 20 percent of applications for all States were made using a tractor and boom sprayer. There were more than 25,000 reports of chemical usage from about 900 nursery and floriculture operations in Oregon during 2003, some of which are in the Clackamas River basin. Nearly 600,000 lbs of active ingredient were applied in Oregon for agricultural purposes, with 40 percent of nursery and floriculture operations applying pesticides based mostly on a preventative schedule (National Agricultural Statistics Service [NASS], 2004), and not in response to an active threat. The 2003 NASS survey determined that 51 percent of operators in the program States actively surveyed for pests, and that in Oregon, 11 percent of operators use pheromone traps as part of an integrated pest management program (IPM) to monitor for pests. IPM potentially allows for early detection and treatment of pest infestations, which can prevent loss of crops. Early detection also may reduce the amount of chemical required to treat the spread of a particular infestation, which over the long term, may reduce the need for preventative applications in the future.

Ninety-two percent of current-use pesticides detected in the Clackamas River basin (table 10) were on the National Agricultural Statistics Service list of pesticides applied to nursery, greenhouse, and floriculture crops. Given the potential for extensive pesticide use on nursery and greenhouse crops in the Clackamas River basin, the results presented in this report may underestimate the relative contribution from nursery operations because many of the compounds used at nurseries were not analyzed. Acephate, for example, was the most commonly used insecticide for nursery operations (National Agricultural Statistics Service, 2004), yet it was not tested during this study.

Glyphosate, oxyflurfen, and oryzalin were the most commonly applied herbicides, and the fungicide of choice was chlorthalonil. Chlorthalonil was detected just once, at the mouth of Noyer Creek in May 2005, at a concentration of 0.26 µg/L. The insecticide imidacloprid was detected in Noyer Creek downstream from Highway 212 (September 2005) at a concentration of 4.5 µg/L (appendix C, table C1). According to the NASS survey, this compound was used by 20 percent of nursery operations in all program States (National Agricultural Statistics Service, 2004). Imidacloprid is used as a less toxic alternative to orthophosphate insecticides to control sucking insects such as aphids in various nursery and floriculture crops (National Agricultural Statistics Service, 2004). Scholz and Spiteller (1992) reported that imidacloprid breaks down faster in soils with plant ground cover compared to fallow soils, although there is potential for imidacloprid to move through sensitive or porous soil types with large amounts of gravel or cobble. Because of its moderate water solubility (10 mg/L) and relatively long half life in soil (48–190 days; appendix E), imidacloprid can be transported in irrigation runoff, especially from steep slopes.

Many nurseries collect irrigation tail-water in ponds, and re-use of water during the summer irrigation season is a common practice. In many cases, nursery and farm ponds are formed from small impoundments on small streams, and unlined ponds may lose some water to the surrounding area, recharging the shallow ground-water system. This water may enter streams through springs or in upwelling areas downstream. Ponds typically are drained in the autumn, before the onset of heavy rains. Releases from these ponds could be an important source of pesticides to Clackamas River basin tributaries and the mainstem Clackamas River, but more information is needed to quantify their contributions. Determining the factors influencing breakdown rates for certain compounds, including high-use compounds or those with relatively high toxicity—including endosulfan, diazinon, and chlorpyrifos, for example, could improve management of this potential pesticide source.

Forestry—The use of pesticides on forestland includes selective control of insect pests and invasive plant species in problem areas, and broad scale herbicide applications during site preparation following harvest on private timberland to control under story vegetation during the early stages of regeneration. Applications of herbicides also are used to control noxious nonnative plant species such as Himalayan Blackberry, Scotch Broom, English Ivy, Purple Loosestrife, and Japanese Knotweed. These invasive plants have the potential to displace native vegetation, reduce replanted tree growth, alter habitat, reduce forage for grazing animals, and cause economic damage and other effects.

Efforts to remove Japanese Knotweed from riparian areas in the Deep Creek and other Clackamas River basin streams have included plant stem injection with Rodeo™, a formulation of glyphosate that does not contain surfactants present in RoundUP™ that are more toxic to some aquatic life than glyphosate itself (Pesticide Action Network, 1996). In addition, there are an estimated 420,000 acres of National Forest System lands in the Pacific Northwest Region Six that are currently infested with invasive plants. The official Record of Decision, which includes Federal lands within the Clackamas River basin, includes provisions for using herbicides to control invasive plants (U.S. Forest Service, 2005).

The amount of pesticides applied in the Clackamas River basin on private, State, and Federal forestland is not readily available, but pesticide use on the Mount Hood National Forest, which comprises most of the Federal land in the upper Clackamas River basin, is relatively insignificant. The herbicide glyphosate is used sparingly to control invasive plants—in 2006, 2 acres were treated with 0.25 gal of glyphosate (Rodeo™) to control spotted knapweed along USFS Road 46 in the upper Clackamas River basin (Mark Kreiter, U.S. Forest Service, written commun., 2007). Pesticides also may be used to control insect pests on the forest, and in 1989, an outbreak of western spruce budworms (*Choristoneura occidentalis*) in the upper Clackamas River basin was treated with the biological insecticide *Bacillus thuringiensis kurstaki* (BT), which was aerially applied to more than 7,595 acres (Sheehan, 1996). This insecticide was not among those analyzed during the USGS study. No other pesticides are applied in the Clackamas River basin on the Mount Hood National Forest at this time (Jennie O’Connor, U.S. Forest Service, written commun., 2007).

Private forestland in the Clackamas River basin occurs primarily in the lower basin, especially in the Eagle and Clear Creek basins, but also in other basins (for example, upper Deep Creek and in other localized areas). Pesticide use on private forestland in the Clackamas River basin is unknown, but data from a nearby drainage basin, the McKenzie River basin (south of the Clackamas River basin), indicates that pesticide uses on private forestland may be significant. For example, about 97,650 acres of forestland in the McKenzie River basin was projected to be treated with the herbicides 2,4-D, glyphosate, hexazinone, metsulfuron, triclopyr, and imazapyr in 2006 (Morgenstern, 2006).

In the Clackamas River basin study, sampling did not focus specifically on forestland, but forestland was a large component of the basin land cover for a few of the streams sampled, which can provide some insights into pesticide concentrations and loadings from these largely forested basins.

Overall, fewer pesticide compounds were detected in storm-runoff samples collected from Eagle and Clear Creeks in May and October 2000 (2 and 5 pesticides each, respectively) compared with streams draining agricultural or urban land. Because of their higher streamflows, however, Clear and Eagle Creeks contributed 19 and 12 percent of the total measured atrazine load in the lower Clackamas River in May 2000 (Carpenter, 2004). Although atrazine can be used on conifer trees on forestland or Christmas tree plantations—plentiful in Clear and Eagle Creek basins—atrazine also is used for agricultural purposes. The nonstorm-runoff samples collected from the mostly forested upper Deep Creek basin during the 2003–04 EUSE study contained six pesticide compounds, with the forestry and Christmas tree herbicide hexazinone being detected in all six samples (appendix C, table C2). Detection of hexazinone is consistent with the high amount of forestland in the upper Deep Creek basin (53 percent). Despite the large amount of forestland, pesticide use on rural residential areas, pasturelands, or along right-of-ways also may contribute to detections in these streams, so specific studies focused on forestland are needed to fully evaluate this potential source.

Urban uses—Pesticides are used in urban areas to control weeds and insect pests on lawns, gardens, and ornamental trees and plants, and in homes to control pests such as ants and fleas. During the past 20 years, about one-half of homes in the United States were treated with pesticides for nonstructural pests (Templeton and others, 1998). About 55 percent of the pesticides detected in the Clackamas River basin have urban uses, and several herbicides are applied along fences, utility lines, roads and other right-of-ways in urban areas (table 10). Many urban-use pesticides were detected in the Clackamas River basin, including atrazine, metolachlor, simazine, prometon, diuron, and 2,4-D. These were the most common herbicides detected in urban streams nationwide (U.S. Geological Survey, 1999; Gilliom and others, 2006).

The two most highly urbanized streams in the Clackamas River basin—Cow and Carli Creeks—have about 90 percent urban land, and drain large amounts of impervious area such as buildings, roads, and parking lots that convey rainfall runoff to the Clackamas River. These streams had between 7 and 12 pesticides detected during the 2 storms, with some occurring at relatively high concentrations (appendix C, table C1). The diazinon concentration in Carli Creek, for example, was 0.25 µg/L, which exceeded the USEPA aquatic-life criterion of 0.1 µg/L (fig. 8*D*). Streamflow in each of these urban creeks was relatively high for their drainage area during the May and September 2005 storms, resulting in higher water yields compared with other less developed basins (fig. 5*A*). Pesticide yields (mass per unit area) in these basins also were the highest of all basins sampled during the May and September 2005 storms (fig. 5*C*).

Wastewater effluents—Although the quality of wastewater in the Clackamas River basin was not examined during this study, treated effluent from the city of Estacada is discharged to the Clackamas River upstream of River Mill Dam, and North Fork Deep and Tickle Creeks receive treated effluent from the community of Boring and the city of Sandy, respectively. Effluent from Sandy is routed to a nearby nursery to irrigate ornamental nursery stock from about May through October. Leakage from failed or failing septic systems, which can be a source of many different kinds of contaminants, including pesticides, also may introduce wastewater into the surrounding soils and aquifers connected to the Clackamas River and some of its tributaries.

In addition, the Source Water Assessment study identified 194 areas with septic systems and 27 large capacity septic systems in the basin that have potential to release wastewater to ground water flowing into the Clackamas River upstream of drinking-water intakes (Oregon Department of Environmental Quality and the Oregon Department of Human Services, 2003). Basinwide, however, there may be thousands of individual septic systems.

Golf courses—The extent of pesticide use on golf courses in the Clackamas River basin is unknown. There are six golf courses located within the drainage basin, and considering that many golf courses in Oregon treat turf for various fungal, insect, and weed pests, golf courses are another potential pesticide source. About 50 percent of the pesticides detected in the Clackamas River basin have reported use on golf courses (Barbash, 1998) (table 10). More specific information on golf course applications in the basin could help quantify this potential source, and may become available through existing or future Pesticide Use Reporting surveys.

Atmospheric deposition—Pesticides and other chemicals also may be transported through the air and later deposited on land and into waterways. For example, orthophosphate insecticides in two Oregon streams, Hood River and Mill Creek (tributaries of the Columbia River), were detected following periods of chemical applications on orchard crops, and may be related to atmospheric drift, mixing operations, or other aspects of their use (Gene Foster, Oregon Department of Environmental Quality, oral commun., 2006). In another study, chlorpyrifos, diazinon, trifluralin, and other pesticides were detected in air samples collected in Sacramento, California (Majewski and Baston, 2002). Pesticides were detected in wet deposition (rain) (Capel and Wotzka, 1998), and in snow samples from Mount Rainier National Park, Washington (Hageman and others, 2006). Three of the four most frequently detected pesticides in the Mount Rainier snow (dacthal, chlorpyrifos, and endosulfan) also were detected in the Clackamas River basin during 2000–2005.

Potential Future Studies

Additional monitoring could track contaminants that may pose a future threat, for pesticides identified during this study, or from other compounds that may be identified through the PURS, which began in 2007. Candidate streams for follow-up studies include Tickle, North Fork Deep, and Noyer Creeks (all Deep Creek tributaries), and Rock Creek, where some of the highest loads and concentrations of pesticides were measured during this study. Future studies might also focus on Cow and Carli Creeks, which had the highest pesticide yields during the May and September 2005 storms.

The seasonal contributions from select streams also could be evaluated with monthly sampling, for example, to better understand the relations between the timing of pesticide applications and detections in streams. Such monitoring could better quantify contaminant contributions from potential sources identified in this study, such as urban developments or certain types of agriculture, including, for example, nursery operations or Christmas tree plantations.

Future studies may utilize autosampling devices that could collect water during periodic storm-runoff events, for example, to provide more detailed information on the temporal occurrence and transport of contaminants including pesticides. Passive sampling equipment such as semipermeable membrane devices (SPMDs) and polar organic chemical integrative samplers (POCIS) could provide time-weighted concentrations for certain hydrophilic compounds present in streams or the mainstem Clackamas River. Some SPMD data were collected for three Deep Creek basin streams during the EUSE study in 2004 (Ian Waite, U.S. Geological Survey, written commun., 2007), and results from future studies could be compared to results of the 2004 study. Alvarez and others (2004) used POCIS samplers to identify the presence of select pesticides, including diuron, in surface water. Diuron was among the most frequently detected pesticides in the Clackamas River basin during the present study—occurring in the tributaries, mainstem Clackamas River, and in samples of source and finished drinking water—making POCIS a viable option for future monitoring of this herbicide.

Detailed time-series data collected over the course of a storm hydrograph could provide insights into the dynamic nature of pesticide transport within these basins, and could better quantify their overall contributions during storms. Such data would provide much needed information about the duration of pesticide occurrence in the Clackamas River and at the downstream drinking-water supply intakes during storms. Time-series data also could determine the concentrations and duration of exposure for aquatic life in the Clackamas River and its tributaries.

Future studies could examine the cumulative effects of nursery and farm pond drawdown on the Clackamas River in autumn, when the combination of released pond water and storm runoff may produce spikes in pesticide concentrations during this susceptible period, when dilution water is in shorter supply. If warranted, future studies could analyze pesticides in fish tissue and conduct physiological studies to determine potential impairment to biological functions.

Reductions in the offsite transport of pesticides to streams may be achieved by developing and implementing best management practices (BMPs) to reduce erosion or reducing chemical application rates. The Oregon Department of Environmental Quality (DEQ) is working on a pesticide Stewardship Partnership in the Clackamas River basin, for example, with the objective of identifying streams with elevated levels of pesticides (orthophosphate insecticides and triazine herbicides—atrazine and simazine) and helping to implement BMPs. DEQ and other agencies, including Oregon Departments of Environmental Quality, Agriculture, Human Services, and Forestry, and the Clackamas County Soil and Water Conservation District (SWCD) have formed a water quality working group and are working collaboratively on this issue. Targeted monitoring before and after implementation of specific projects initiated by the working group might identify BMPs that can identify mechanisms involved in offsite transport from sources such as pond discharges or runoff of irrigation water. In addition, educational programs aimed at reducing pesticide contamination are currently being developed by the Clackamas River Basin Council in cooperation with Clackamas Watershed Management Group, USGS, Portland METRO, and Clackamas County SWCD.

Additional monitoring of source and finished drinking water could verify the results presented here, and examine treatment options for the various types of water treatment plants that utilize the river. Additional monitoring of the source water could provide information on the seasonal patterns in pesticide occurrence in the basin, and identify trends in concentrations over time that may occur. Continued monitoring for pesticides is especially important for the lower Clackamas River and its tributaries because of the encroaching development from Portland, which has expanded its urban growth boundary into parts of the lower basin near Damascus, including parts of Rock and Richardson Creeks (fig. 1). Population growth in this area is expected to be considerable in the coming years, which poses additional threats to water quality.

Pesticide concentrations in finished drinking water reported herein may be higher than concentrations farther along in the distribution system (for example, at the customers' taps) because finished water samples were preserved with a dechlorinating agent to stop chlorine activity (see Water Sample Processing and Laboratory Analysis section), whereas pesticides in the distribution system continue to be exposed to residual chlorine. Continued oxidation of pesticide compounds by chlorine would be expected to occur in the distribution system, resulting in lower concentrations at customers' taps. Even with relatively short contact time (about 90 min), chlorination did appear to oxidize many of the organic compounds in this study, in one case transforming the insecticide diazinon in source water to its degradate diazinon-oxon in finished drinking water. A small number of split samples with and without the dechlorinating agent showed significant differences for some compounds (appendix A, table A3; appendix B, table B2). Although this study was not designed to fully characterize water treatment, comparisons between pesticide concentrations in source and finished water can provide some indications about the removal of pesticides by the process of direct filtration.

Future studies could evaluate treatment options for the different types of compounds, if concentrations should increase to levels approaching human-health benchmarks. Such studies would benefit from more precise estimates of travel time through the water-treatment plant (for example, time from source to finished water) to ensure comparability between the two samples. Tracer studies, for example, could ensure that accurate comparisons are made. Accurate travel times are especially important during storms because pesticide concentrations may change rapidly as runoff from different areas of the basin reaches source-water intakes.

In the current study, PAC (powdered activated carbon) appeared to be somewhat effective at decreasing concentrations of some pesticides. In most cases, however, concentrations in the source water were so low (often close to the detection level) that measured decreases in finished water may not be statistically significant. Although PAC has been shown to be effective at decreasing concentrations of pesticides and other organic contaminants elsewhere (Westerhoff and others, 2005), additional studies could determine the potential effectiveness of PAC in these waters. PAC appeared to be less effective at decreasing or removing pesticides during storms, possibly because of interference by high concentrations of suspended sediment in source water. The September 2005 sample of PAC-treated finished water, for example, contained several pesticides, including diazinon-oxon, simazine, ethoprop, metolachlor, 2,4-D and propiconazole, among others (table 5). Higher doses of PAC may be required to remove the pesticides from highly turbid water, in this case about 100 NTRU (appendix C, table C4). There was no apparent association between the physical properties of the pesticides, such as the organic carbon partitioning coefficient (K_{oc}) or water solubility (appendix E), that determined the likelihood of a pesticide being removed through treatment with PAC or chlorine, although future studies could evaluate removal efficiencies at varying levels of PAC or evaluate other treatment options using controlled laboratory experiments.

Summary

During 2000–2005, ultra low detection level analyses for 86–198 pesticides in 119 water samples collected from sites in the lower mainstem Clackamas River, its tributaries, and in pre- and post-treatment (source and finished) drinking-water from the study water-treatment plant—one of four drinking-water treatment plants that draw from the lower Clackamas River. In all, 63 pesticide compounds: 33 herbicides, 15 insecticides, 6 fungicides, and 9 pesticide degradates were detected in samples collected during storm and nonstorm conditions. Fifty-seven pesticides or degradates were detected in the tributaries (mostly during storms), whereas fewer compounds (26) were detected in samples of source water from the lower mainstem Clackamas River, with fewest (15) occurring in drinking water.

The two most commonly detected pesticides were the triazine herbicides simazine and atrazine, which occurred in about one-half of samples. Deethylatrazine (a degradate of atrazine) commonly was detected along with atrazine in about 30 percent of samples. The active ingredients in the common household herbicides RoundUP™ (glyphosate) and Crossbow™ (triclopyr and 2,4-D) also were frequently detected together. These three herbicides often made up most of the total pesticide concentration in tributaries throughout the study area.

Pesticides were most prevalent in the Clackamas River during storms, and were present in all storm-runoff samples (collected from Deep, Richardson, Rock, Sieben, Carli, and Cow Creeks)—averaging 10 pesticides per sample from these streams. Two tributaries of Deep Creek (North Fork Deep and Noyer Creeks) contained 17–18 pesticides each during a storm in May 2005. Streams draining predominantly forested basins such as Eagle and Clear Creeks contained fewer pesticides (2–5 pesticides), and were not sampled after 2000.

Many of the highest insecticide concentrations in the tributaries exceeded U.S. Environmental Protection Agency (USEPA) aquatic-life benchmarks, including diazinon, chlorpyrifos, *p,p′*-DDE, and azinphos-methyl. Nearly one-quarter of the tributary samples had at least one pesticide that exceeded an aquatic-life benchmark. Azinphos-methyl was detected only once during the study (in Doane Creek) at a concentration of 0.21 µg/L, which exceeded the State of Oregon and USEPA aquatic-life benchmarks (0.01 µg/L) by a factor of about 20. Doane Creek drains high density nursery land in the North Fork Deep Creek basin, and was highly turbid (120 Nephelometric Turbidity Ratio Units) during sampling.

Concentrations of pesticides in the Clackamas River were much lower than those in the tributaries owing to greater dilution (higher streamflow) derived from the mostly forested upper drainage basin. In all, 26 pesticides and degradates were detected in the Clackamas River mainstem or in source water from the study water treatment plant intake. At least

1 pesticide was detected in 22 of 34 (65 percent) source water samples, with an average of 2–3 pesticides per sample (1 source water sample collected during a September 2005 storm contained 13 pesticides). Although none of the USEPA aquatic-life benchmarks were exceeded in the mainstem, concentrations of the insecticide chlorpyrifos exceeded non-USEPA benchmarks from the NAS/NAE and Canada.

In all, 15 pesticides were variously detected in the 18 samples of finished drinking water from the selected water-treatment plant on the lower river, although concentrations of some pesticides in finished drinking water reported here may differ from other treatment plants in the lower Clackamas River because differing treatment processes were not investigated during the study. Although 98 percent of the 1,790 individual pesticide analyses of drinking water were below detection, one or more pesticides were detected in 60 percent of finished water samples. The four most common were herbicides, diuron, simazine, dacthal, and hexazinone, which occurred in 2–4 samples each. Other detected compounds included 2,4-D, atrazine, deethylatrazine, metolachlor, trifluralin, pronamide, and metsulfuron-methyl (all herbicides), the insect repellent DEET, plus three others. During the September 2005 storm, diazinon-oxon (a degradate of the organophosphate insecticide diazinon), ethoprop (another orthophosphate insecticide), propiconazole (a fungicide), and three other pesticides were detected in finished drinking water. As many as nine pesticide compounds occurred in a single sample, 9 days following a storm in May 2005.

All pesticide concentrations in finished water occurred at trace levels far below USEPA Maximum Contaminant Levels (MCLs) for regulated contaminants, and USGS human Health Based Screening Levels (HBSLs) for unregulated contaminants. Three compounds (diazinon-oxon, deethylatrazine [CIAT], and DEET [an insect repellent]), however, do not have human-health benchmarks available for comparison and were not included in this screening-level assessment.

The highest measured pesticide concentration in finished drinking water (0.18 micrograms per liter of the herbicide diuron) occurred 9 days following a storm in May 2005. This value is 11 and 1,100 times lower than the low-HBSL and high-HBLS benchmark, respectively, for diuron and would not be expected to cause adverse effects if water with such a concentration were to be ingested over a lifetime. Pesticide concentrations in finished drinking water may be higher than actual concentrations in the distribution system because finished water samples were preserved with a dechlorinating agent to stop the breakdown of pesticides by chlorine prior to laboratory analysis. Concentrations of readily degradable compounds could be less at customers' taps, depending on the amount of time water is in contact with chlorine in the distribution system. Further study on the water treatment processes and their ability to remove pesticides could help evaluate potential treatment options.

The aquatic-life and human-health benchmarks currently do not account for simultaneous exposure to multiple pesticides and degradates. Benchmarks are derived from toxicological experiments on individual compounds and do not reflect the totality of exposure that organisms in these streams experience. In this study, as many as 18 pesticides were detected in a single sample (from upper Noyer Creek), and it is difficult to determine the cumulative effect of such a mixture. Future studies could examine the potential for physiological interactions that may occur among pesticides and other organic or inorganic chemicals that may be present in the river or in finished drinking water.

Of the 51 current-use pesticides detected in the basin, 47 have uses associated with nursery and floriculture crops (29 herbicides, 12 insecticides, and 6 fungicides). About one-half of the pesticides detected in the Clackamas River basin also are commonly used on lawns and landscaping in urban areas (57 percent), on golf courses (49 percent), applied along fences, roads, and other right-of-ways (45 percent). Although not specifically examined in this study, 14 percent of the pesticides may be used on forestland, and considering the large amount of forest acreage in the basin, applications to State or private forestland also may be important. Pesticide use on Federal land in the basin is rare, although applications have been done in the past.

In a previous report on pesticides in the Clackamas River basin, it was estimated that as much as one-half of the agricultural pesticide use could be on nursery, floriculture, and greenhouse crops, with lesser amounts applied to pastureland, Christmas trees, alfalfa and hay fields, hazelnut orchards, and grass seed fields. Findings from the current study also suggest that nursery and greenhouse operations could be a significant source of pesticides to the lower Clackamas River. Future studies could develop source reduction strategies and best management practices in the Deep Creek and Rock Creek drainage basins, for example, to minimize pesticide transport from nurseries in these basins.

The diverse land use in the study area and unpredictable water management (pumping, irrigation, collection, and release) make it challenging to identify pesticide sources. Data collected for Oregon's Pesticide Use and Reporting System (PURS) will be at a coarse scale, making it difficult, if not impossible, to locate sources within the Clackamas River basin. Pesticide applications in the Clackamas River basin, for example, will likely be incorporated into a larger report for the entire Willamette River basin. The PURS data will be useful, however, for identifying potentially important chemicals not currently being analyzed. Only a small fraction of the approximately 11,000 pesticide products registered for use in Oregon were analyzed during this study, which makes pesticide-use data especially helpful for developing monitoring plans. Urban-use surveys conducted as part of the PURS also may provide data on the types and amounts of pesticides used in urban areas. Urban use could be significant considering that the 3 streams draining the highly urbanized and industrial northwestern part of the basin (Cow, Carli, and Sieben Creeks) contained 11–24 pesticides each.

Given their frequent and widespread occurrence, especially during storms, pesticides have the potential to affect aquatic life and the quality of drinking water derived from the lower river. The dynamic nature of pesticide runoff, and potentially highly variable concentrations of pesticides during storms, makes it difficult to determine the chronic and acute exposure levels in the tributaries and mainstem Clackamas River. Future studies could include multiple samples collected during and after a storm to determine how long concentrations are elevated. Future studies also could examine the transport and fate of pesticides from application areas to waterways, evaluate trends in concentrations over time, evaluate the potential cumulative effects of pesticide mixtures on aquatic life, and evaluate water-treatment options that might reduce pesticide concentrations in finished drinking water.

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Glossary

Aquatic-life Benchmark Pesticide concentrations in water that, if exceeded, may be of potential concern for aquatic life. In this report, benchmarks are given for fish, benthic invertebrates, and vascular plants, for both acute and chronic exposure.

Benchmark Quotient (BQ) The ratio of a measured concentration of a detected contaminant to its benchmark, and in this report, to a USEPA drinking water standard Maximum Contaminant Level (MCL) value (for regulated compounds); Health-Based Screening Level (HBSL) value (for unregulated compounds); and Aquatic-life benchmarks when available.

Cancer Risk Concentration The drinking-water concentration associated with a specified cancer risk level (typically 1 in 10,000, 1 in 100,000, or 1 in 1,000,000), under certain exposure conditions: consumption of 2 liters of drinking water per day by a 70-kilogram body weight individual over a lifetime (70 years) (U.S. Environmental Protection Agency, 2006).

Clackamas Watershed Management Group (CWMG) A group of public agencies including Clackamas County Water Environment Services (WES) and the Clackamas River Water Providers (CRWP)—a consortium of local water agencies including the Cities of Estacada and Lake Oswego, Clackamas River Water, North Clackamas County Water Commission, South Fork Water Board, and Sunrise Water Authority—that manage or utilize water resources in the Clackamas River Watershed.

"e" coded data Pesticide concentration values that are "e" coded indicate values estimated by the laboratory because (1) certain compounds had poor recoveries or are particularly difficult to analyze, (2) sample matrix effects (highly turbid water, for example) interfered with laboratory analyses, or (3) concentrations were less than laboratory reporting levels (LRLs), resulting in reduced statistical certainty for reported concentrations. The probability of a false positive result for a pesticide detection in this study was less than 1 percent, whether the value was "e" coded or not.

Formazin Nephelometric Unit (FNU) The measurement unit for turbidity data collected by the continuous water-quality monitors in the Clackamas River. FNUs are similar to Nephelometric Turbidity Units (NTUs), the difference being the wavelength of light used to make the measurement (infrared light type instruments report in FNUs, whereas white light instruments report in NTUs). Due to the fact that suspended particles scatter light of different wavelengths with varying efficiency, FNU data often are not directly comparable to NTU data. *See* http://or.water.usgs.gov/grapher/fnu.html for more information.

Health-Based Screening Level (HBSL) HBSLs are benchmark concentrations of contaminants in water that, if exceeded, may be of potential concern for human health. HBSLs are nonenforceable benchmarks that were developed by the USGS in collaboration with the U.S. Environmental Protection Agency (USEPA) and others using (1) USEPA methodologies for establishing drinking-water guidelines, and (2) the most recent, USEPA peer-reviewed, publicly available human-health toxicity information (Toccalino and others, 2003; Toccalino, 2007).

Human-Health Benchmarks Benchmark concentrations used in this report to evaluate observed concentrations in finished drinking water. These include USEPA MCL values for regulated contaminants and USGS HBSL values for unregulated contaminants.

Maximum Contaminant Level (MCL) A legally enforceable drinking-water standard that sets a maximum allowable level of a particular contaminant in public water systems. MCLs are set as close as feasible to the maximum level of a contaminant at which no known or anticipated adverse effects on human health would occur, taking into account the best available technology, treatment techniques, cost considerations, expert judgment, and public comments (U.S. Environmental Protection Agency, 2006).

Nephelometric Turbidity Ratio Unit (NTRU) The measurement of turbidity reported by benchtop instruments used in this study to measure the turbidity of storm samples. This method uses a light source with a wavelength of 400-680 nanometers (nm), 90 degree detection angle, and multiple detectors with ratio compensation. See Formazin Nephelometric Unit (FNU).

Pesticide Toxicity Index (PTI) PTI values were calculated for each sample to estimate its relative toxicity by summing the toxicity quotients for each pesticide detected in a sample (or the concentration divided by the median toxicity endpoint, typically an LC_{50} [the lethal concentration for 50 percent of the test population] for a 96-hour chemical exposure). The PTI does not, however, determine whether water in a sample is toxic (Munn and Gilliom, 2001).

Storm Event (Synoptic) Sampling A data collection effort occurring over a short period of time at a number of sites to characterize spatial conditions or provide a snapshot of conditions during target periods such as the spring pesticide application season or the first flush event in autumn. In this study, pesticide synoptic samplings occurred during spring and fall storms in 2000 and 2005.

Unregulated Pesticide Compounds As used in this report, pesticide compounds without Federal and (or) State drinking-water standards.

Appendix A. Evaluation of Quality-Control Results for Pesticides and Degradates, 2000–2005

QC blank samples—Fifteen quality-control blank samples were analyzed in 2000–2005 for up to 190 pesticides. No pesticides or degradates were detected.

QC spike samples—Some compounds—CIAT [deethylatrazine], benomyl, bromacil, propiconazole and others—had low or 0 percent recovery in one or more spike samples (appendix D, table D1), so concentrations for these compounds may be underestimated in this report. Some compounds had relatively high recoveries, including azinphos-methyl, imazaquin, terbacil, and carbaryl, ranging from 150 to about 300 percent (appendix table A2), which indicates a high bias.

Although the high recoveries for carbaryl in spike samples suggests a positive bias, it was not detected in any of the 15 equipment blank samples, which suggests that contamination at the lab is not an issue. Carbaryl is widely used, and its moderately high detection frequency (18 percent) is not unexpected, but the concentrations in this report could be higher than actual concentrations. Carbaryl was often analyzed by two schedules 2010/2001 and 2060, with the latter having a more reliable (or preferred) method. When both methods were used, schedule 2001 data were on average 500 percent higher than 2060 data (ranged from 250–800 percent). Schedule 2060 detections of carbaryl (PCODE 49310), therefore, superseded the schedule 2001 (PCODE P82680) values in the carbaryl data compilation and analyses. Six samples had carbaryl concentrations exceeding an aquatic-life benchmark, four of which had detections of carbaryl by both methods. In two cases where carbaryl concentrations exceeded the NAS/NAE aquatic-life benchmark (table 6), 2060 data were either not available (mainstem Clackamas River in November 2002) or carbaryl was not detected using the preferred schedule (for September 2005 sample from Cow Creek). Carbaryl was, however, detected in Cow Creek with both methods in May 2005, so its detection by the nonpreferred method alone in September 2005 does not appear to be a false positive. Correcting for the apparent positive bias in carbaryl concentrations (for POCODE 82680 values), however, could result concentrations that would not have exceeded the aquatic-life benchmark.

QC surrogate pesticide compounds—Surrogate pesticide compound percent recoveries were within an acceptable range of between 60 and 140 percent, with a few exceptions (appendix A, table A3). The surrogates 2,4,5-T and barban had some exceedingly high percent recovery values—up to 318 percent and 245 percent, respectively, in some of the tributary samples collected during the September 2005 storm. These same surrogates had 0 percent recoveries for some of the other samples collected during this storm: Carli Creek, for example, had a 0 percent recovery for the 2,4,5-T surrogate, but a 318 percent recovery for the barban surrogate—and the alpha-HCH-d6 and diazinon d-10 surrogates were 80 percent and 106 percent, respectively, in this same sample. These results from Carli Creek show the sample matrix difficulties and range of surrogate recoveries possible when samples contain multiple pesticides, in this case at least nine pesticides. Zero percent recoveries were also obtained for the pesticide surrogates barban and 2,4,5-T in spiked samples from Sieben and Trillium Creeks during the September 2005 storm. On a few occasions, diazinon d-10 surrogate recoveries were also zero for spiked samples of raw and finished drinking water. Note that in general, the finished drinking water samples collected during 2000–2001 that were not quenched with the dechlorinating agent had lower recoveries for the diazinon d-10, barban, and 2,4,5-T surrogates. The continuing action of chlorine in those samples could have resulted in the oxidation of those compounds into degradates that were not analyzed for, such as the diazinon degradate diazinon-oxon. In the above samples, where the percent recoveries were zero, the possibility of false negatives for certain compounds increases, and where detections occurred, it is possible that the actual concentrations were higher than those reported in this report. Conversely, samples showing unusually high recoveries may produce results that have a high bias, which are discussed individually in the report.

In addition, four pesticide samples for schedule 2001 collected from Cow, Dolan, Tickle, and North Fork Deep Creeks during the September 2005 storm were extracted onto the resin columns after a delay of about 12 days. These storm-runoff samples probably contained high levels of dissolved organic carbon that may have enhanced bacterial activity and degradation of some compounds. Therefore, the parent compound results for these 4 samples may be lower than actual concentrations due to degradation during holding. These four samples were specially tested for a additional pesticide degradates. One compound (3,4-dichlorophenyl isocyanate)—a degradate of diuron—was identified in each of the four affected samples (table 3). At the time, the analysis for 3,4-dichlorophenyl isocyanate was not an approved method, so its presence as reported by the lab chemist is preliminary, but noteworthy because diuron was frequently detected during this study, and 3,4-dichlorophenyl isocyanate was found at relatively high levels (5.4 µg/L in North Fork Deep Creek, for example). Some degradation of certain chemicals such as endosulfan to endosulfan sulfate may have occurred in these four samples during holding despite being filtered and refrigerated. A carbaryl degradate (1-naphthol) was detected in two of the affected samples from Cow and Dolan Creeks (appendix table C1), possibly from the decay of carbaryl—but other degradates, such as malaoxon and azinphos-methyl-oxon were examined but not detected.

Table A1. Quality-control results for pesticides and degradates in field blank samples, 2000–2005.

[Includes 15 blank samples. Abbreviations: USGS, U.S. Geological Survey; PCODE, USGS parameter code]

Pesticide or degradate	USGS PCODE	Number of analyses	Number of detections
1,4-Naphthoquinone	61611	1	0
1-Naphthol	49295	8	0
2-(2-Ethyl-6-methylphenyl)-amino-1-propanol	61615	5	0
2-(4-tert-butylphenoxy)-cyclohexanol	61637	1	0
2,4,5-T	39742	2	0
2,4-D	39732	8	0
2,4-D methyl ester	50470	6	0
2,4-DB	38746	8	0
2,5-Dichloroaniline	61614	1	0
2,6-Diethylaniline	82660	11	0
2-Amino-N-isopropylbenzamide	61617	1	0
2-Chloro-2,6-diethylacetanilide	61618	8	0
2-Ethyl-6-methylaniline	61620	8	0
3-(4-Chlorophenyl)-1-methyl urea	61692	6	0
3,4-Dichloroaniline	61625	8	0
3,5-Dichloroaniline	61627	1	0
3-Hydroxycarbofuran	49308	8	0
3-Ketocarbofuran	50295	6	0
3-Trifluoromethylaniline	61630	1	0
4,4´-Dichlorobenzophenone	61631	1	0
4-Chloro-2-methylphenol	61633	8	0
4-Chlorobenzylmethyl sulfone	61634	1	0
Acetochlor	49260	11	0
Acifluorfen	49315	8	0
Alachlor	46342	11	0
Aldicarb	49312	8	0
Aldicarb sulfone	49313	8	0
Aldicarb sulfoxide	49314	8	0
alpha-HCH	34253	4	0
AMPA	62649	1	0
Atrazine	39632	11	0
Azinphos-methyl	82686	11	0
Azinphos-methyl-oxon	61635	8	0
Bendiocarb	50299	6	0
Benfluralin	82673	11	0
Benomyl	50300	6	0
Bensulfuron-methyl	61693	6	0
Bentazon	38711	8	0
Bifenthrin	61580	1	0
Bromacil	4029	12	0
Bromoxynil	49311	8	0
Butylate	4028	4	0
CAAT	4039	6	0
Carbaryl	82680	15	0
Carbaryl1	49310	8	0
Carbofuran	49309	8	0
Carbofuran	82674	4	0
CEAT	4038	6	0
Chloramben methyl ester	61188	8	0
Chlorimuron-ethyl	50306	6	0
Chlorothalonil	49306	8	0
Chlorpyrifos	38933	15	0
Chlorpyrofos-oxon	61636	8	0
CIAT	4040	11	0
cis-Permethrin	82687	11	0
Clopyralid	49305	8	0
Cyanazine	4041	4	0
Cycloate	4031	6	0
Cyfluthrin	61585	8	0
Cyhalothrin (*lambda*)	61595	1	0
Cypermethrin	61586	8	0
Dacthal (DCPA)	82682	11	0
Dacthal monoacid	49304	8	0
DEET	62082	8	0
Desulfinylfipronil	62170	8	0
Desulfinylfipronil amide	62169	8	0
Diazinon	39572	15	0
Diazinon-oxon	61638	8	0
Dicamba	38442	8	0
Dichlobenil	49303	2	0
Dichlorprop	49302	8	0
Dichlorvos	38775	12	0
Dicofol	61587	1	0
Dicrotophos	38454	8	0
Dieldrin	39381	11	0
Dimethenamid	61588	1	0
Dimethoate	82662	8	0
Dimethomorph (*e*)	79844	1	0
Dimethomorph (*z*)	79845	1	0
Dinoseb	49301	8	0
Diphenamid	4033	6	0
Disulfoton	82677	4	0
Disulfoton sulfone	61640	1	0
Disulfoton sulfoxide	61641	1	0
Diuron	49300	8	0
DNOC	49299	2	0
Endosulfan I	34362	1	0
Endosulfan II	34357	1	0
Endosulfan ether	61642	1	0
Endosulfan sulfate	61590	1	0
EPTC	82668	4	0
Ethalfluralin	82663	4	0
Ethion	82346	8	0
Ethion-monoxon	61644	8	0
Ethoprop	82672	4	0
Fenamiphos	61591	8	0
Fenamiphos sulfone	61645	8	0
Fenamiphos sulfoxide	61646	8	0
Fenthion	38801	1	0
Fenthion sulfone-oxon	62851	1	0
Fenthion sulfoxide	61647	1	0
Fenthion-sulfone	61648	1	0
Fenuron	49297	8	0
Fipronil	62166	8	0
Fipronil sulfide	62167	8	0
Fipronil sulfone	62168	8	0
Flumetralin	61592	1	0
Flumetsulam	61694	6	0
Fluometuron	38811	8	0
Fonofos	4095	11	0
Fonofos-oxon	61649	7	0
Glufosinate	62721	1	0
Glyphosate	62722	1	0
Hexazinone	4025	5	0
Imazaquin	50356	6	0
Imazethapyr	50407	6	0

Table A1. Quality-control results for pesticides and degradates in field blank samples, 2000–2005.—Continued

[Includes 15 blank samples. Abbreviations: USGS, U.S. Geological Survey; PCODE, USGS parameter code]

Pesticide or degradate	USGS PCODE	Number of analyses	Number of detections
Imidacloprid	61695	6	0
Iprodione	61593	8	0
Isofenphos	61594	8	0
Lindane	39341	4	0
Linuron[1]	38478	8	0
Linuron	82666	4	0
Malathion	39532	11	0
Malathion-oxon	61652	8	0
MCPA	38482	8	0
MCPB	38487	8	0
Metalaxyl	50359	10	0
Metalaxyl[1]	61596	8	0
Methidathion	61598	8	0
Methiocarb	38501	8	0
Methomyl	49296	8	0
Methyl 3-(2,2-dichlorovinyl)-2,2-dim (*cis*)	79842	1	0
Methyl 3-(2,2-dichlorovinyl)-2,2-dim (*trans*)	79843	1	0
Metolachlor	39415	15	0
Metribuzin	82630	11	0
Metsulfuron methyl	61697	6	0
Molinate	82671	4	0
Myclobutanil	61599	8	0
Naled	38856	1	0
Napropamide	82684	4	0
Neburon	49294	8	0
Nicosulfuron	50364	6	0
Norflurazon	49293	8	0
O-Ethyl-O-methyl-S-propylphosphorothioate	61660	1	0
OIET	50355	6	0
Oryzalin	49292	8	0
Oxamyl	38866	8	0
Oxyfluorfen	61600	1	0
p,p´-DDE	34653	4	0
Paraoxon-ethyl	61663	1	0
Paraoxon-methyl	61664	8	0
Parathion	39542	4	0
Parathion-methyl	82667	11	0
Pebulate	82669	4	0
Pendimethalin	82683	11	0
Phorate	82664	11	0
Phorate-oxon	61666	8	0
Phosmet	61601	8	0
Phosmet-oxon	61668	7	0
Picloram	49291	8	0
Profenofos	61603	1	0
Prometon	4037	15	0
Prometryn	4036	8	0
Pronamide	82676	11	0
Propachlor	4024	4	0
Propanil	82679	4	0
Propargite	82685	4	0
Propetamphos	61604	1	0
Propham	49236	8	0
Propiconazole	50471	6	0
Propiconazole (*cis*)	79846	1	0
Propiconazole (*trans*)	79847	1	0
Propoxur	38538	8	0
Siduron	38548	6	0
Silvex	39762	2	0
Simazine	4035	11	0
Sulfometuron-methyl	50337	6	0
Sulfotepp	61605	1	0
Sulprofos	38716	1	0
Tebuconazole	62852	1	0
Tebupirimphos	61602	1	0
Tebupirimphos-oxon	61669	1	0
Tebuthiuron	82670	11	0
Tefluthrin	61606	1	0
Temephos	61607	1	0
Terbacil[1]	4032	6	0
Terbacil	82665	4	0
Terbufos	82675	11	0
Terbufos sulfone	63773	1	0
Terbufos sulfone-oxon	61674	8	0
Terbuthylazine	4022	8	0
Thiobencarb	82681	4	0
Triallate	82678	4	0
Tribufos	61610	1	0
Triclopyr	49235	8	0
Trifluralin	82661	11	0

[1]These PCODES are the preferred method code (shown for compounds that were analyzed by more than one schedule).

Table A2. Quality-control results for spike samples receiving known additions of pesticides and degradates, 2000–2005.

[Data include only those compounds detected during the study. **No dechlorinating agent:** pertains to 2–5 samples of finished drinking water. **Abbreviations:** USGS, U.S. Geological Survey; PCODE, USGS parameter code; µg/L, microgram per liter; nd, no data]

Pesticide or degradate	USGS PCODE	Amount of spike (µg/L)	Number of samples spiked	Percent recovery			
				Minimum	Maximum	Average	No dechlorinating reagent
1-Naphthol	49295	0.1	3	14	21	18	9
2(2-Ethyl-6-methylphenyl)-amino-1-pro	61615	.1	2	85	92	88	nd
2,4,5-T (surrogate)	99958	.25	2	71	120	96	83
2,4-D	39732	.25	2	112	120	116	109
2,4-D methyl ester	50470	.25	1	63	63	63	72
2,4-DB	38746	.25	2	61	229	145	77
2,6-Diethylaniline	82660	.1	5	89	152	107	0
2-Chloro-2,6-diethylacetanilide	61618	.1	3	96	116	107	41
2-Ethyl-6-methylaniline	61620	.1	3	86	103	95	0
3(4-Chlorophenyl)-1-methyl urea	61692	.25	2	74	90	82	0
3,4-Dichloroaniline	61625	.1	3	65	76	72	0
3-Hydroxycarbofuran	49308	.25	2	74	94	84	91
3-Ketocarbofuran	50295	.1	1	120	120	120	49
4-Chloro-2-methylphenol	61633	.1	3	50	70	60	0
Acetochlor	49260	.1	5	83	116	102	114
Acifluorfen	49315	.25	2	61	126	93	84
Alachlor	46342	.1	5	87	116	101	107
Aldicarb	49312	.25	2	0	38	19	0
Aldicarb sulfone	49313	.25	2	44	58	51	20
Aldicarb sulfoxide	49314	.25	2	74	105	89	0
alpha-HCH	34253	.1	2	97	102	99	nd
alpha-HCH-d6 (surrogate)	91065	.1	2	87	107	97	nd
alpha-HCH-d6 (surrogate)	99995	.1	3	80	100	91	87
Atrazine	39632	.1	5	100	124	111	113
Azinphos-methyl	82686	.1	5	87	159	118	0
Azinphos-methyl-oxon	61635	.1	3	50	91	77	119
Barban (surrogate)	90640	.25	2	70	112	91	112
BDMC (surrogate)	99835	.1	1	79	79	79	nd
Bendiocarb	50299	.25	2	72	72	72	79
Benfluralin	82673	.1	5	58	93	75	88
Benomyl	50300	.25	1	69	69	69	0
Bensulfuron-methyl	61693	.25	2	105	182	144	0
Bentazon	38711	.25	2	52	121	87	37
Bromacil	4029	.25	2	50	71	60	0
Bromoxynil	49311	.25	2	65	68	67	64
Butylate	4028	.1	2	102	106	104	nd
CAAT	4039	.25	2	0	0	0	0
Carbaryl	82680	.1	5	90	304	164	121
Carbaryl[1]	49310	.25	2	84	94	89	91
Carbofuran	82674	.1	2	111	275	193	nd
Carbofuran	49309	.25	2	79	92	85	97
CEAT	4038	.25	2	40	57	49	122
Chloramben methyl ester	61188	.25	2	23	41	32	0
Chlorimuron-ethyl	50306	.25	2	70	246	158	33
Chlorothalonil	49306	.1	1	63	63	63	175
Chlorpyrifos	38933	.1	5	86	110	98	0
Chlorpyrofos-oxon	61636	.1	3	13	52	32	113
CIAT	4040	.25	5	14	33	23	21
cis-Permethrin	82687	.1	5	29	63	51	73
Clopyralid	49305	.25	2	70	100	85	62
Cyanazine	4041	.1	2	103	115	109	nd
Cycloate	4031	.25	2	80	96	88	0

Table A2. Quality-control results for spike samples receiving known additions of pesticides and degradates, 2000–2005.—Continued

[Data include only those compounds detected during the study. **No dechlorinating agent:** pertains to 2–5 samples of finished drinking water. **Abbreviations:** USGS, U.S. Geological Survey; PCODE, USGS parameter code; µg/L, microgram per liter; nd, no data]

Pesticide or degradate	USGS PCODE	Amount of spike (µg/L)	Number of samples spiked	Percent recovery			
				Minimum	Maximum	Average	No dechlorinating reagent
Cyfluthrin	61585	0.1	3	49	66	60	81
Cypermethrin	61586	.1	3	50	62	55	78
Dacthal (DCPA)	82682	.1	5	104	118	109	108
Dacthal monoacid	49304	.25	1	75	75	75	91
DEET	62082	.8	1	252	252	252	13
Desulfinylfipronil	62170	.2	4	52	58	56	24
Desulfinylfipronil amide	62169	.2	4	48	63	55	37
Diazinon	39572	.1	5	89	111	101	0
Diazinon-d10 (surrogate)	91063	.1	2	101	113	107	nd
Diazinon-d10 (surrogate)	99994	.1	3	94	109	100	0
Diazinon-oxon	61638	.1	3	68	95	83	157
Dicamba	38442	.25	1	73	73	73	100
Dichlorprop	49302	.25	2	73	100	86	91
Dichlorvos	38775	.1	3	30	44	39	73
Dicrotophos	38454	.1	3	24	31	26	29
Dieldrin	39381	.1	5	70	125	95	97
Dimethoate	82662	.1	3	21	38	29	0
Dinoseb	49301	.25	2	65	116	90	61
Diphenamid	4033	.25	2	88	98	93	97
Disulfoton	82677	.1	2	56	86	71	nd
Diuron	49300	.25	2	85	99	92	48
EPTC	82668	.1	2	96	128	112	nd
Ethalfluralin	82663	.1	2	67	90	78	nd
Ethion	82346	.1	3	79	101	92	0
Ethion-monoxon	61644	.1	3	78	96	86	0
Ethoprop	82672	.1	2	99	104	102	nd
Fenamiphos	61591	.1	3	80	103	95	0
Fenamiphos sulfone	61645	.1	3	68	124	100	243
Fenamiphos sulfoxide	61646	.1	3	49	98	70	0
Fenuron	49297	.25	2	75	96	85	80
Fipronil	62166	.1	4	83	136	111	0
Fipronil sulfide	62167	.2	4	47	55	53	2
Fipronil sulfone	62168	.2	4	45	49	47	0
Flumetsulam	61694	.25	2	152	166	159	148
Fluometuron	38811	.25	2	86	100	93	96
Fonofos	4095	.1	5	85	108	97	8
Fonofos-oxon	61649	.1	3	73	89	83	170
Hexazinone	4025	.1	2	83	95	89	106
Imazaquin	50356	.25	2	165	428	297	37
Imazethapyr	50407	.25	2	125	129	127	115
Imidacloprid	61695	.25	2	127	142	134	133
Iprodione	61593	.1	3	11	81	51	15
Isofenphos	61594	.1	3	94	116	105	0
Lindane	39341	.1	2	94	102	98	nd
Linuron	82666	.1	2	52	164	108	nd
Linuron[1]	38478	.25	2	87	100	94	100
Malathion	39532	.1	5	82	122	106	0
Malathion-oxon	61652	.1	3	64	105	86	177
MCPA	38482	.25	2	70	89	79	89
MCPB	38487	.25	2	61	79	70	79
Metalaxyl	50359	.25	2	87	106	96	98
Metalaxyl[1]	61596	.1	3	97	101	99	105

Table A2. Quality-control results for spike samples receiving known additions of pesticides and degradates, 2000–2005.—Continued

[Data include only those compounds detected during the study. **No dechlorinating agent:** pertains to 2–5 samples of finished drinking water. **Abbreviations:** USGS, U.S. Geological Survey; PCODE, USGS parameter code; µg/L, microgram per liter; nd, no data]

Pesticide or degradate	USGS PCODE	Amount of spike (µg/L)	Number of samples spiked	Percent recovery			
				Minimum	Maximum	Average	No dechlorinating reagent
Methidathion	61598	0.1	3	87	102	97	0
Methiocarb	38501	.25	2	87	90	89	0
Methomyl	49296	.25	2	74	94	84	0
Metolachlor	39415	.1	5	102	119	109	111
Metribuzin	82630	.1	5	80	119	89	5
Metsulfuron-methyl	61697	.25	2	41	78	60	0
Molinate	82671	.1	2	99	106	103	nd
Myclobutanil	61599	.1	3	82	102	94	108
Napropamide	82684	.1	2	110	120	115	nd
Neburon	49294	.25	2	85	102	94	64
Nicosulfuron	50364	.25	2	153	247	200	2
Norflurazon	49293	.25	2	88	104	96	81
OIET	50355	.25	1	5	5	5	4
Oryzalin	49292	.25	2	75	100	87	50
Oxamyl	38866	.25	2	71	86	78	74
p,p´-DDE	34653	.1	2	31	61	46	nd
Paraoxon-methyl	61664	.1	3	57	88	72	167
Parathion	39542	.1	2	110	129	120	nd
Parathion-methyl	82667	.1	5	72	103	93	0
Pebulate	82669	.1	2	103	106	104	nd
Pendimethalin	82683	.1	5	77	119	98	100
Phorate	82664	.1	5	57	82	72	0
Phorate oxon	61666	.1	3	57	81	71	0
Phosmet	61601	.1	3	0	26	11	0
Phosmet oxon	61668	.1	2	8	27	17	0
Picloram	49291	.25	1	73	73	73	41
Prometon	4037	.1	5	99	112	103	108
Prometryn	4036	.1	3	105	119	113	0
Pronamide	82676	.1	5	93	109	101	98
Propachlor	4024	.1	2	118	119	118	nd
Propanil	82679	.1	2	117	118	117	nd
Propargite	82685	.1	2	100	130	115	nd
Propham	49236	.25	2	90	102	96	96
Propiconazole	50471	.25	2	84	104	94	109
Propoxur	38538	.25	2	78	91	84	95
Siduron	38548	.25	2	100	110	105	82
Simazine	4035	.1	5	95	117	107	116
Sulfometuron-methyl	50337	.25	2	112	157	135	35
Tebuthiuron	82670	.1	5	77	123	106	121
Terbacil	82665	.1	2	86	311	198	nd
Terbacil[1]	4032	.25	1	61	61	61	0
Terbufos	82675	.1	5	72	92	82	0
Terbufos oxygen analog sulfone	61674	.1	3	65	115	96	109
Terbuthylazine	4022	.1	3	105	124	114	118
Thiobencarb	82681	.1	2	111	118	115	nd
Triallate	82678	.1	2	99	101	100	nd
Triclopyr	49235	.25	2	66	102	84	97
Trifluralin	82661	.1	5	64	93	78	95

[1]These PCODES are the preferred method code (shown for compounds that were analyzed by more than one schedule).

Table A3. Comparison of quality-control results for pesticide surrogate compounds in samples of spiked blank water, native water from tributaries and the lower Clackamas River/source water, and chlorinated drinking water, 2000–2005.

[Abbreviations: UNQ, unquenched drinking-water samples]

Sample	Sample type	Pesticide surrogate	Number of samples	Percent recovery		
				Minimum	Maximum	Median
Finished drinking water-UNQ	QA-replicate	Diazinon-d10	5	0	112	0
Finished drinking water	QA-blank	Diazinon-d10	1	139	139	139
Stream sample	QA-blank	Diazinon-d10	10	85	127	94
Finished drinking water	QA-replicate	Diazinon-d10	18	67	122	93
Finished drinking water	QA-spike	Diazinon-d10	2	0	96	48
Stream sample	QA-spike	Diazinon-d10	5	94	113	101
Stream sample	Regular	Diazinon-d10	108	0	129	98
Stream sample	QA-blank	BDMC	2	74	81	77
Stream sample	QA-spike	BDMC	1	79	79	79
Stream sample	Regular	BDMC	17	72	102	80
Finished drinking water-UNQ	Regular	Barban	3	27	89	71
Finished drinking water	QA-blank	Barban	1	88	88	88
Stream sample	QA-blank	Barban	5	85	114	93
Finished drinking water	QA-replicate	Barban	16	82	127	101
Finished drinking water	QA-spike	Barban	2	99	112	105
Stream sample	QA-spike	Barban	2	70	112	91
Stream sample	Regular	Barban	66	0	318	88
Finished drinking water-UNQ	QA-replicate	alpha-HCH-d6	5	81	112	105
Finished drinking water	QA-blank	alpha-HCH-d6	1	94	94	94
Stream sample	QA-blank	alpha-HCH-d6	10	80	104	93
Stream sample	QA-blank	alpha-HCH-d6	8	74	114	91
Finished drinking water	QA-spike	alpha-HCH-d6	2	87	90	89
Stream sample	QA-spike	alpha-HCH-d6	5	80	107	92
Stream sample	Regular	alpha-HCH-d6	107	72	122	88
Finished drinking water	Regular	alpha-HCH-d6	19	76	117	92
Finished drinking water-UNQ	Regular	2,4,5-T	2	62	72	67
Finished drinking water	QA-blank	2,4,5-T	1	80	80	80
Stream sample	QA-blank	2,4,5-T	5	71	126	96
Finished drinking water	QA-replicate	2,4,5-T	16	62	124	100
Finished drinking water	QA-spike	2,4,5-T	2	83	92	87
Stream sample	QA-spike	2,4,5-T	2	71	120	96
Stream sample	Regular	2,4,5-T	66	0	245	90

Table A4. Quality-control results for pesticides and degradates detected in replicate water samples, 2000–2005.

[Unrounded pesticide concentrations in micrograms per liter (µg/L). Data include only those compounds detected during the study. **Abbreviations:** PCODE, USGS parameter code; Percent diff, percent relative difference between replicate samples. **Symbols:** _, pesticide degradate; <, less than]

Pesticide or degradate	Maximum percent difference	Replicate samples											
		Clackamas River (source water)			Clackamas River (source water)			North Fork Deep Creek at Barton			Deep Creek near Sandy (upper)		
		12-10-02			04-29-03			01-14-04			08-17-04		
		Rep 1	Rep 2	Percent diff	Rep 1	Rep 2	Percent diff	Rep 1	Rep 2	Percent diff	Rep 1	Rep 2	Percent diff
2,4-D	7	<	<										
_3,4-Dichloroaniline	19	<	<					0.0613	0.0508	19	<	<	
Atrazine	[1]100	<	<					.0297	.0273	8.4	<0.007	0.0023	100
Carbaryl	7	<	<					.0068	.0073	7.1	<	<	
Chlorpyrifos	6	<	<		<	<		.0134	.0126	6.2	<	<	
_CIAT	35	<	<					.004	.0035	13	.001	.0007	35
Cycloate	18	<	<										
Dacthal	29	<	<					<	<		<	<	
Diazinon	17	<	<					<	<		<	<	
_Diazinon-oxon	6	<	<					<	<		<	<	
Dieldrin	26	<	<					.0023	.003	26	<	<	
Dimethenamid	0												
Diuron	46	0.005	0.003	46									
Ethoprop	4												
Fenuron	2	<	<										
Glyphosate	18												
Hexazinone	16							.0159	.0149	6.5	.0172	.0147	16
Metalaxyl	8	<	<		<	<		.0045	.0045	0	<	<	
Methiocarb	29	<	<										
Metolachlor	[1]100	<	<		<	<		.0288	.0253	13	<	<	
Myclobutanil	1	<	<					.013	.0131	.8	<	<	
Napropamide	8												
Prometon	46	<	<		<	<		.0023	.0019	19	<	<	
Pronamide	[1]100	<	<					<	<		<	<	
Propiconazole (*cis*)	21												
Propiconazole (*trans*)	9												
Simazine	9	<	<					.0113	.0105	7.3	<	<	
Triclopyr	1	<	<										
Trifluralin	1	<	<					.005	.005	0	<	<	

Table A4. Quality-control results for pesticides and degradates detected in replicate water samples, 2002–2005.—Continued

[Unrounded pesticide concentrations in micrograms per liter (µg/L). Data include only those compounds detected during the study. **Abbreviations:** PCODE, USGS parameter code; Percent diff, percent relative difference between replicate samples. **Symbols:** _, pesticide degradate; <, less than]

Pesticide or degradate	Maximum percent difference	Replicate samples											
		Finished drinking water			NF Deep Creek at Boring			Clackamas River (source water)			Finished drinking water		
		09-23-04			09-30-05			09-30-05			09-30-05		
		Rep 1	Rep 2	Percent diff	Rep 1	Rep 2	Percent diff	Rep 1	Rep 2	Percent diff	Rep 1	Rep 2	Percent diff
2,4-D	7	<	<		0.8403	0.8529	1.5	0.1768	0.1799	1.7	0.0751	0.0809	7.4
_3,4-Dichloroaniline	19	<	<					<	<		<	<	
Atrazine	[1]100	<	<		.0088	.0078	12	<	<		<	<	
Carbaryl	7	<	<		<	<		<	<		<	<	
Chlorpyrifos	6	<	<		.171	.162	5.4	<	<		<	<	
_CIAT	35	<	<		<	<		<	<		<	<	
Cycloate	18	<	<		<	<		.0186	.0155	18	<	<	
Dacthal	29	<	<		<	<		.0052	.0039	29	<	<	
Diazinon	17	<	<		.045	.0465	3.3	.0156	.0132	17	<	<	
_Diazinon-oxon	6	<	<					<	<		.0103	.0097	6.0
Dieldrin	26	<	<		<	<		<	<		<	<	
Dimethenamid	0							.0054	.0054	0.0	<		
Diuron	46	0.0205	0.0204	0.5	1.8616	2.0079	7.6	.0187	.0153	20	<	<	
Ethoprop	4				.0162	.0159	1.9	.0087	.0086	1.2	.0055	.0057	3.6
Fenuron	2	<	<		.0661	.0648	2.0	<	<		<	<	
Glyphosate	18				1.56	1.5	3.9	.1	.12	18	<	<	
Hexazinone	16	<	<					<	<		<	<	
Metalaxyl	8	<	<		.2189	.203	7.5	<	<		<	<	
Methiocarb	29	<	<		.0311	.0232	29	<	<		<	<	
Metolachlor	[1]100	<	<		.0464	.0458	1.3	.0048	.0032	40	.0022	<.006	100
Myclobutanil	1	<	<					<	<		<	<	
Napropamide	8				.0139	.0128	8.2	<	<		<	<	
Prometon	46	<	<		<	<		.0043	.0027	46	<	<	
Pronamide	[1]100	<	<		<	<		<.005	.0046	100	<	<	
Propiconazole (*cis*)	21							.0032	.0026	21	.0014	.0013	7.4
Propiconazole (*trans*)	9							.0061	.0056	8.5	.0047	.0045	4.3
Simazine	9	<	<		<	<		.0178	.0162	9.4	.0204	.0211	3.4
Triclopyr	1	<	<		.5337	.5311	.5	.2289	.2265	1.1	<	<	
Trifluralin	1	<	<		.0194	.0193	.5	<	<		<	<	

[1]In all three cases where a pesticide was detected in just one of the replicate samples, the detection was at or below the reporting level, at concentrations having a 50 percent chance of being detected.

Appendix B. List of Pesticide Compounds Analyzed, Schedules and Detection Levels, and Compounds Not Detected During 2000–2005

Table B1. Pesticides and degradates analyzed in water samples collected from the lower Clackamas River basin, Oregon, 2000–2005.

[**Abbreviations:** USGS, U.S. Geological Survey; NWQL, National Water-Quality Laboratory; µg/L, microgram per liter]

Pesticide compound	2000–2005 laboratory method detection limit range (µg/L)	USGS NWQL schedule
1,4-Naphthoquinone	0.005	2002
1-Naphthol	0.09	2002; 2003
2-(4-tert-butylphenoxy)-cyclohexanol	0.01	2002
2,4-D	0.04 – 0.09	2060
2,4-D methyl ester	0.016 – 0.009	2060
2,4-DB	0.02 – 0.1	2060
2,5-Dichloroaniline	0.01	2002
2,6-Diethylaniline	0.002 – 0.006	2001; 2003
2-[(2-Ethyl-6-methylphenyl)-amino]-1-propanol	0.1	2002
2-Amino-N-isopropylbenzamide	0.005	2002
2-Chloro-2,6-diethylacetanilide	0.005	2002; 2003
2-Ethyl-6-methylaniline	0.004	2002; 2003
3(4-Chlorophenyl)-1-methyl urea	0.02 – 0.04	2060
3,4-Dichloroaniline	0.004	2002; 2003
3,4-Dichlorophenyl isocyanate	–	–
3,5-Dichloroaniline	0.004	2002
3-Hydroxycarbofuran	0.008 – 0.11	2060
3-Ketocarbofuran	0.01 – 0.02	2060
3-Trifluoromethylaniline	0.01	2002
4,4’-Dichlorobenzophenone	0.007	2002
4-Chloro-2-methylphenol	0.006	2002; 2003
4-Chlorobenzylmethyl sulfone	0.01	2002
Acetochlor	0.002 – 0.006	2001; 2003
Acifluorfen	0.007 – 0.09	2060
Alachlor	0.002 – 0.005	2001; 2003; 2060
Aldicarb	0.04 – 0.21	2060
Aldicarb sulfone	0.02 – 0.2	2060
Aldicarb sulfoxide	0.008 – 0.022	2060
alpha-HCH	0.002 – 0.005	2001
AMPA	0.31	2052
Atrazine	0.001 – 0.007	2001; 2003; 2060
Azinphos-methyl	0.001 – 0.05	2001; 2003
Azinphos-methyl-oxon	0.02 – 0.07	2002; 2003
Bendiocarb	0.02 – 0.03	2060
Benfluralin	0.002 – 0.01	2001; 2003
Benomyl	0.004 – 0.022	2060
Bensulfuron-methyl	0.02	2060
Bentazon	0.04 – 0.01	2060
Bifenthrin	0.005	2002
Bromacil	0.03 – 0.5	2060
Bromoxynil	0.02 – 0.07	2060
Butylate	0.002 – 0.004	2001
CAAT	0.04	2003
Carbaryl	0.003 –1	2001; 2003
Carbofuran	0.003 – 0.29	2001
CEAT	0.01 – 0.08	2003
Chloramben methyl ester	0.02 – 0.14	2060
Chlorimuron-ethyl	0.01 – 0.032	2060
Chlorothalonil	0.04 – 0.48	2060
Chlorpyrifos	0.004 – 0.5	2001; 2003
Chlorpyrofos-oxon	0.06	2002; 2003
CIAT	0.002 – 0.006	2001; 2003; 2060
Clopyralid	0.01 – 0.42	2060
Cyanazine	0.004 – 0.018	2001
Cycloate	0.005 – 0.01	2002; 2060
Cyfluthrin	0.008 – 0.027	2002; 2003
Cyhalothrin (*lambda*)	0.009	2002
Cypermethrin	0.009	2002; 2003
Dacthal (DCPA)	0.002 – 0.003	2001; 2003
Dacthal monoacid	0.01 – 0.07	2060
DEET	0.5	1433
Desulfinylfipronil amide	0.009 – 0.031	2001; 2003
Diazinon	0.002 – 0.5	2001; 2003
Diazinon-oxon	0.01 – 0.04	2002; 2003
Dicamba	0.01 – 0.04	2060
Dichlobenil	0.05 – 0.07	2050
Dichlorprop	0.01 – 0.05	2060
Dichlorvos	0.01 – 1	2002; 2003
Dicofol	0.02	2002
Dicrotophos	0.08	2002; 2003
Dieldrin	0.001 – 0.009	2001; 2003
Dimethenamid	0.01	2002
Dimethoate	0.006	2002; 2003
Dimethomorph (*e*)	0.02	2002
Dimethomorph (*z*)	0.05	2002
Dinoseb	0.01 – 0.09	2060
Diphenamid	0.01 – 0.03	2060
Disulfoton	0.02	2001
Disulfoton sulfone	0.01	2002
Disulfoton sulfoxide	0.036 – 0.01	2002
Diuron	0.01 – 0.06	2060
DNOC	0.25 – 0.42	2050
Endosulfan I	0.005	2002
Endosulfan II	0.01	2002
Endosulfan ether	0.007	2002
Endosulfan sulfate	0.014	2002
EPTC	0.002 – 0.004	2001
Ethalfluralin	0.004 – 0.009	2001
Ethion	0.004	2002; 2003
Ethion-monoxon	0.002 – 0.03	2002; 2003
Ethoprop	0.003 – 0.005	2001
Fenamiphos	0.03	2002; 2003
Fenamiphos sulfone	0.008 – 0.049	2002; 2003
Fenamiphos sulfoxide	0.03 – 0.04	2002; 2003
Fenthion	0.02	2002
Fenthion sulfone	0.01	2002
Fenthion sulfone-oxon	0.01	2002

Table B1. Pesticides and degradates analyzed in water samples collected from the lower Clackamas River basin, Oregon, 2000–2005.—Continued

[**Abbreviations:** USGS, U.S. Geological Survey; NWQL, National Water-Quality Laboratory; µg/L, microgram per liter]

Pesticide compound	2000–2005 laboratory method detection limit range (µg/L)	USGS NWQL schedule
Fenthion sulfoxide	0.008	2002
Fenuron	0.02 – 0.07	2060
Fipronil	0.007 – 0.016	2001; 2003
Fipronil sulfide	0.005 – 0.013	2001; 2003
Fipronil sulfone	0.005 – 0.024	2001; 2003
Flumetralin	0.003	2002
Flumetsulam	0.01 – 0.04	2060
Fluometuron	0.02 – 0.06	2060
Fonofos	0.003	2001; 2003
Fonofos-oxon	0.002 – 0.003	2002
Glufosinate	0.14	2052
Glyphosate	0.15	2052
Hexazinone	0.013	2002; 2003
Imazaquin	0.02 – 0.04	2060
Imazethapyr	0.02 – 0.04	2060
Imidacloprid	0.007 – 0.02	2060
Iprodione	0.387 -1	2002; 2003
Isofenphos	0.003	2002; 2003
Lindane	0.004	2001
Linuron	0.002 – 0.09	2001
Malathion	0.005 –0.027	2002; 2003
Malathion-oxon	0.008 – 0.03	2001; 2003
MCPA	0.02 –0.17	2060
MCPB	0.01 – 0.13	2060
Metalaxyl	0.005 – 0.5	2002; 2003
Methidathion	0.006	2002; 2003
Methiocarb	0.008 – 0.07	2060
Methomyl	0.004 – 0.02	2060
Methomyl oxime - removed from schedule 9060		9060
Methyl *cis*-3-(2,2-dichlorovinyl)-2,2-dim	0.02	2002
Methyl *trans*-3-(2,2-dichlorovinyl)-2,2-d	0.01 – 0.02	2002
Metolachlor	0.002 – 0.5	2001; 2003
Metribuzin	0.004 – 0.006	2001; 2003
Metsulfuron-methyl	0.03	2060
Molinate	0.002 – 0.004	2001
Myclobutanil	0.008	2002; 2003
Naled	0.4	2002
Napropamide	0.003 – 0.007	2001
Neburon	0.01 – 0.07	2060
Nicosulfuron	0.01 – 0.04	2060
Norflurazon	0.02 – 0.04	2060
O-Ethyl-O-methyl-S-propylphosphorothioate	0.005	2002
OIET	0.008 – 0.032	2060
Oryzalin	0.01 – 0.31	2060
Oxamyl	0.01 – 0.03	2060
Oxyfluorfen	0.007	2002
p,p´-DDE	0.003 – 0.006	2001
Paraoxon-ethyl	0.016	2002
Paraoxon-methyl	0.03	2002; 2003
Parathion	0.004 – 0.01	2001
Parathion-methyl	0.006 –0.015	2001
Pebulate	0.002 – 0.004	2001
Pendimethalin	0.004 – 0.022	2001; 2003
cis-Permethrin	0.005 – 0.006	2001; 2003
Phorate	0.002 – 0.011	2001; 2003
Phorate-oxon	0.1	2002; 2003
Phosmet	0.008	2002; 2003
Phosmet oxon	0.05 – 0.06	2002; 2003
Picloram	0.02 – 0.09	2060
Profenofos	0.006	2002
Prometon	0.01 – 0.5	2001; 2003
Prometryn	0.005	2002; 2003
Pronamide	0.003 – 0.004	2001; 2003
Propachlor	0.007 – 0.025	2001
Propanil	0.004 – 0.011	2001
Propargite	0.01 – 0.02	2001
Propetamphos	0.004	2002
Propham	0.01 – 0.09	2060
Propiconazole	0.01 – 0.02	2060
cis-Propiconazole	0.008	2002
trans-Propiconazole	0.01	2002
Propoxur	0.008 – 0.12	2060
Siduron	0.02	2060
Silvex	0.03 – 0.06	2050
Simazine	0.005 – 0.011	2001; 2003
Sulfometuron-methyl	0.009 – 0.038	2060
Sulfotepp	0.003	2002
Sulprofos	0.02	2002
Tebuconazole	0.01	2002
Tebupirimphos	0.005	2002
Tebupirimphos-oxon	0.006	2002
Tebuthiuron	0.01 – 0.02	2001; 2003; 2060
Tefluthrin	0.008	2002
Temephos	0.3	2002
Terbacil	0.007 – 0.034	2001
Terbufos	0.01 – 0.02	2001; 2003
Terbufos sulfone	0.02	2003
Terbufos sulfone-oxon	0.07	2002
Terbuthylazine	0.01	2002; 2003
Thiobencarb	0.002 – 0.01	2001
Triallate	0.001 – 0.006	2001
Tribufos	0.004	2002
Triclopyr	0.02 – 0.25	2060
Trifluralin	0.002 – 0.009	2001; 2003

Table B2. Pesticides and degradates not detected in the lower Clackamas River basin, Oregon, 2000–2005.

Pesticide or degradate	Number of analyses
1,4-Naphthoquinone	3
2-(2-Ethyl-6-methylphenyl)-amino-1-propanol	21
2-(4-tert-butylphenoxy)-cyclohexanol	3
2,4,5-T	16
2,4-DB	94
2,5-Dichloroaniline	3
2,6-Diethylaniline	113
2-Amino-N-isopropylbenzamide	3
2-Chloro-2,6-diethylacetanilide	61
2-Ethyl-6-methylaniline	61
3(4-Chlorophenyl)-1-methyl urea	78
3,5-Dichloroaniline	3
3-Hydroxycarbofuran	95
3-Ketocarbofuran	78
3-Trifluoromethylaniline	3
4,4’-Dichlorobenzophenone	3
4-Chloro-2-methylphenol	61
4-Chlorobenzylmethyl sulfone	3
Acetochlor	113
Acifluorfen	94
Alachlor	113
Aldicarb	94
Aldicarb sulfone	95
Aldicarb sulfoxide	94
alpha-HCH	55
Azinphos-methyl-oxon	61
Bendiocarb	78
Benfluralin	113
Bensulfuron-methyl	78
Bifenthrin	3
Bromoxynil	94
Butylate	55
CAAT	78
Carbofuran	94
Carbofuran	55
CEAT	78
Chloramben methyl ester	94
Chlorimuron-ethyl	78
Chlorpyrofos-oxon	62
cis-Permethrin	114
Clopyralid	94
Cyanazine	55
Cyfluthrin	62
Cyhalothrin (*lambda*)	3
Cypermethrin	62
Dacthal monoacid	94
Desulfinylfipronil	93
Desulfinylfipronil amide	93
Dicamba	93
Dicofol	3
Dicrotophos	62
Dimethoate	62
Dimethomorph (*e*)	3
Dimethomorph (*z*)	3
Diphenamid	78
Disulfoton	55
Disulfoton sulfone	3
Disulfoton sulfoxide	3
DNOC	16
Endosulfan ether	3
EPTC	55
Ethalfluralin	55
Ethion	62
Ethion-monoxon	62
Fenamiphos	62
Fenamiphos sulfone	62
Fenamiphos sulfoxide	60
Fenthion	3
Fenthion sulfone-oxon	3
Fenthion sulfoxide	3
Fenthion-sulfone	3
Fipronil	93
Fipronil sulfide	93
Fipronil sulfone	93
Flumetralin	3
Flumetsulam	78
Fluometuron	94
Fonofos-oxon	53
Glufosinate	34
Imazethapyr	78
Isofenphos	62
Lindane	55
Linuron	94
Malathion-oxon	62
MCPB	94
Methidathion	62
Methomyl	94
Methomyl oxime	1
Methyl *cis*-3-(2,2-dichlorovinyl)-2,2-dim	3
Methyl *trans*-3-(2,2-dichlorovinyl)-2,2-dim	3
Metribuzin	114
Molinate	55
Naled	3
Neburon	94
Nicosulfuron	78
O-Ethyl-O-methyl-S-propylphosphorothioate	3
Oxamyl	94
Oxamyl oxime	1
Paraoxon-ethyl	3
Paraoxon-methyl	62
Parathion	55
Parathion-methyl	114
Pebulate	55
Phorate	114
Phorate-oxon	62
Phosmet	57
Phosmet-oxon	52
Picloram	94

Table B2. Pesticides and degradates not detected in the lower Clackamas River basin, Oregon, 2000–2005.—Continued

Pesticide or degradate	Number of analyses	Pesticide or degradate	Number of analyses
Profenofos	3	Tebupirimphos	3
Prometryn	62	Tebupirimphos-oxon	3
Propachlor	55	Tefluthrin	3
Propanil	55	Temephos	3
Propargite	55	Terbufos	114
Propetamphos	3	Terbufos sulfone	3
Propham	94	Terbufos sulfone-oxon	62
Siduron	78	Terbuthylazine	62
Silvex	16	Thiobencarb	55
Sulfotepp	3	Triallate	55
Sulprofos	3	Tribenuron-methyl	2
Tebuconazole	3	Tribufos	3

Appendix C. Pesticide, Turbidity, and Streamflow Data for Sites Sampled in the Lower Clackamas River Basin, Oregon, 2002–2005

Table C1. Concentrations of pesticides and degradates in the lower Clackamas River basin, Oregon, May and September 2005.

[Pesticide concentrations in micrograms per liter (µg/L). May 2005 data are shaded. **Abbreviations:** e, estimated value (see Glossary); Ct, Court; ds, downstream; Hwy, highway; Rd, road; Pkwy, parkway; trib, tributary; ft^3/s, cubic foot per second; g/d, gram per day; mi^2, square mile; nd, no data. **Symbols:** _, pesticide degradate; <, less than laboratory method detection limit]

Pesticide or degradate	Number of detections	Maximum concentrations	Finished drinking water	Clackamas River (source water)		Tributary sites, in upstream order: Cow Creek at mouth		Carli Creek near mouth		Sieben Creek near Hwy 224		Sieben Creek ds Sunnyside Rd	Rock Creek near mouth	Trillium Creek at Anderegg Pkwy		Rock Creek at Stoneybrook Ct		Rock Creek at 172nd Ave	Rock Creek ds Foster Rd
			09-30-05	05-09-05	09-30-05	05-09-05	09-30-05	05-09-05	09-30-05	05-09-05	09-30-05	09-30-05	09-30-05	05-09-05	09-30-05	05-09-05	09-30-05	09-30-05	09-30-05
2,4-D	26	6.1	0.08	<	0.18	0.36	e1.9	0.09	<	0.52	e2.4	e0.92	1.3	0.52	0.23	0.34	<	e0.04	e1.09
2,4-D methyl ester	2	.73	<	<	<	<	<	<	<	<	<	<	<	<	<	.043	<	<	<
2,4-DP	1	.13	<	<	<	<	<	<	<	<	<	e.13	<	<	<	<	<	<	<
Atrazine	19	.08	<	e 0.003	<	.023	<	.021	e.014	e.007	<	<	e.006	e.005	<	e.004	0.007	e.005	<
_CIAT	6	.012	<	<	<	<	<	<	<	<	<	<	<	<	<	<	e.003	<	<
_OIET	5	.18	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Azinphos-methyl	1	.21	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Benomyl	4	5.7	<	<	<	<	<	<	<	<	<	<	<	<	<	.05	.063	e5.7	<
Bentazon	1	.164	<	<	<	<	<	<	<	<	<	.164	<	<	<	<	<	<	<
Bromacil	1	.12	<	<	<	<	<	<	<	.12	<	<	<	<	<	<	<	<	<
Carbaryl	14	.15	<	<	<	e.009	e.023	e.01	e.064	.094	e.074	e.026	e.01	e.004	<	e.019	<	e.052	<
_1-Naphthol	2	.01	<	nd	<	nd	.01	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Chlorothalonil	1	.26	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Chlorpyrifos	11	.17	<	<	<	<	<	<	<	<	<	<	<	.005	<	<	<	<	<
Cycloate	2	.024	<	<	.017	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Dacthal (DCPA)	9	.02	<	.004	e.005	.003	<	.008	.004	e.003	<	<	.02	e.003	.003	<	<	<	<
Diazinon	11	.25	<	<	.014	<	<	<	.25	.012	<	<	<	.01	<	<	<	.17	<
_Diazinon-oxon	1	.01	e .01	nd	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dieldrin	4	.024	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Dimethenamid	1	.005	<	nd	.005	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dinoseb	1	.03	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Diuron	18	2.26	<	.06	.017	.5	<	<	<	.19	e.10	e.12	.26	.03	<	.03	<	<	.03
_3,4-Dichlorophenyl isocyanate	4	5.4	nd	nd	nd	nd	e1.52	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Endosulfan I	1	.067	<	nd	<	nd	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Endosulfan II	1	.04	<	nd	<	nd	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
_Endosulfan sulfate	2	.036	<	nd	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ethoprop	16	.13	.006	<	.009	<	e.093	<	e.055	<	e.087	e.13	e.017	<	.043	<	<	.014	e.012
Fenuron	3	.12	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Glyphosate	24	45.8	<	<	e.12	.38	e3.9	.29	.76	.58	1.5	1.1	.54	.18	<	.34	<	45.8	.23
_AMPA	8	2.4	<	<	<	<	.32	<	<	<	<	<	<	<	<	<	<	e1.7	<
Imidacloprid	2	4.5	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	e1	<
Iprodione	1	.056	<	nd	<	nd	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Malathion	1	.047	<	<	<	<	<	<	<	<	<	<	.047	<	<	<	<	<	<
MCPA	1	.067	<	<	<	<	<	<	<	.067	<	<	<	<	<	<	<	<	<
Metalaxyl	7	1.5	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	e1.5	<
Methiocarb	3	.086	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	.086	<
Metolachlor	26	.11	.002	<	.004	.04	.03	<	.056	<	.058	.07	.007	<	.027	<	.009	.007	e.006
Napropamide	16	.40	<	.004	<	<	<	<	<	.40	.022	.016	<	<	<	<	<	<	<
Norflurazon	3	.11	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Oryzalin	1	.29	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<

Table C1. Concentrations of pesticides and degradates in the lower Clackamas River basin, Oregon, May and September 2005.—Continued

[Pesticide concentrations in micrograms per liter (µg/L). May 2005 data are shaded. **Abbreviations:** e, estimated value (see Glossary); Ct, Court; ds, downstream; Hwy, highway; Rd, road; Pkwy, parkway; trib, tributary; ft^3/s, cubic foot per second; g/d, gram per day; mi^2, square mile; nd, no data. **Symbols:** _, pesticide degradate; <, less than laboratory method detection limit]

Pesticide or degradate	Number of detections	Maximum concen-trations	Finished drinking water	Clackamas River (source water)		Tributary sites, in upstream order: Cow Creek at mouth		Carli Creek near mouth		Sieben Creek near Hwy 224		Sieben Creek ds Sunnyside Rd	Rock Creek near mouth	Trillium Creek at Anderegg Pkwy		Rock Creek at Stoneybrook Ct		Rock Creek at 172nd Ave	Rock Creek ds Foster Rd
			09-30-05	05-09-05	09-30-05	05-09-05	09-30-05	05-09-05	09-30-05	05-09-05	09-30-05	09-30-05	09-30-05	05-09-05	09-30-05	05-09-05	09-30-05	09-30-05	09-30-05
Oxyfluorfen	1	0.023	<	nd	<	nd	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pendimethalin	5	.35	<	<	<	<	<	<	0.08	<	0.046	0.033	<	<	<	<	<	<	<
Prometon	15	.11	<	<	e0.004	0.06	0.11	<	<	<	<	<	0.02	0.01	<	e0.007	e0.005	0.02	0.01
Propiconazole	6	.51	e0.006	<	e.009	<	<	0.04	<	<	<	<	<	<	<	<	<	<	<
Propoxur	1	.005	<	<	<	e.005	<	<	<	<	<	<	<	<	<	<	<	<	<
Simazine	25	.96	.02	<	.017	.11	<	.021	.96	0.054	.019	<	.007	<	0.007	.016	.01	.023	.016
Sulfometuron-methyl	5	.2	<	<	<	.10	<	<	<	0.2	<	<	<	<	<	<	<	<	.043
Tebuthiuron	3	.08	<	<	<	.08	e.024	<	<	<	<	<	.08	<	<	<	<	<	<
Triclopyr	16	5	<	<	.23	<	e1.2	<	<	<	e.83	e.59	1.0	e.21	<	.22	<	<	e.83
Trifluralin	11	.17	<	<	<	<	<	<	<	e.004	<	e.004	<	e.003	<	<	<	.056	<
Number of pesticides detected			6	4	13	12	11	7	9	13	10	12	13	11	5	10	6	15	9
Total pesticide concentration (µg/L)			.12	.07	.62	1.7	9.1	.48	2.2	2.2	5.1	3.3	3.3	1.0	.3	1.1	.1	56.1	2.3
Streamflow (ft^3/s)			1,200	3,000	1,200	12	4.4	21	11	10	4.8	2.3	20	.3	.3	10	1.7	1.8	1.5
Instantaneous pesticide load (g/d)			360	506	1,810	49	99	24	62	53	60	18	167	1	.2	25	.4	253	9
Basin area (mi^2)			942	942	942	1.3	1.3	.6	0.6	1.7	1.7	.7	9.5	.1	.1	7.3	7.3	5.3	2.2
Instantaneous pesticide yield (g/d/1,000 acres)			.6	.8	3.0	60.9	123.8	62.8	159.5	48.4	55.3	37.7	27.5	9.7	2.5	5.3	.1	74.1	6.0
Instantaneous water yield (ft^3/s/1,000 acres)			2.0	5.0	2.0	15.0	5.5	53.6	29.0	8.9	4.4	4.7	3.4	4.0	3.3	2.0	.4	.5	1.1

Table C1. Concentrations of pesticides and degradates in the lower Clackamas River basin, Oregon, May and September 2005.—Continued

[Pesticide concentrations in micrograms per liter (µg/L). May 2005 data are shaded. **Abbreviations:** e, estimated value (see Glossary); Ct, Court; ds, downstream; Hwy, highway; Rd, road; Pkwy, parkway; trib, tributary; ft³/s, cubic foot per second; g/d, gram per day; mi², square mile; nd, no data. **Symbols:** _, pesticide degradate; <, less than laboratory method detection limit]

Pesticide or degradate	Number of detections	Maximum concen-trations	Tributary sites, in upstream order: Richardson Creek at Hwy 224	Noyer Creek at mouth		Noyer Creek ds Hwy 212		Deep Creek at Barton	NF Deep Creek at Barton	NF Deep Creek nr Boring (ds weir)	NF Deep Creek at Boring	NF Deep Creek trib at 312th Ave	NF Deep Creek trib at Church Rd	Dolan creek at Orient Rd	Doane Creek ds Hwy 212	Tickle Creek near Boring	Tickle Creek trib at Orient Rd	Tickle Creek trib at Colorado Rd	Tickle Creek at 362nd Ave
			09-30-05	05-09-05	09-30-05	05-09-05	09-30-05	09-30-05	09-30-05	05-09-05	09-30-05	09-30-05	09-30-05	09-30-05	09-30-05	09-30-05	09-30-05	09-30-05	09-30-05
2,4-D	26	6.1	e1.1	<	e0.7	<	e0.14	e0.1	<	0.13	e0.85	e6.1	e0.20	<	e0.11	0.07	e0.17	<	e0.2
2,4-D methyl ester	2	.73	<	<	<	<	<	<	<	<	<	0.73	<	<	<	<	<	<	<
2,4-DP	1	.13	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Atrazine	19	.08	<	e0.004	<	0.017	<	<	<	.013	.008	e.003	.08	<	.008	<	.035	<	e.003
_CIAT	6	.012	<	e.003	<	e.004	<	<	<	e.008	<	<	e.012	<	<	<	e.007	<	<
_OIET	5	.18	<	<	<	<	<	<	<	e.028	<	<	.18	<	.07	.06	.15	<	<
Azinphos-methyl	1	.21	<	<	<	<	<	<	<	<	<	<	<	<	e.21	<	<	<	<
Benomyl	4	5.7	<	<	<	<	<	<	<	.04	<	<	<	<	<	<	<	<	<
Bentazon	1	.164	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Bromacil	1	.12	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Carbaryl	14	.15	<	e.004	<	e.01	.15	<	<	<	<	<	<	<	<	<	<	<	<
_1-Naphthol	2	0.01	nd	nd	nd	nd	nd	nd	<	nd	nd	nd	nd	e0.004	nd	<	nd	nd	nd
Chlorothalonil	1	.26	<	e.26	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Chlorpyrifos	11	.17	<	.03	<	.042	.14	<	0.018	.03	.17	.005	e.004	<	.008	.021	<	<	<
Cycloate	2	.024	<	<	<	<	<	<	<	<	<	.024	<	<	<	<	<	<	<
Dacthal (DCPA)	9	.02	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Diazinon	11	.25	<	<	<	<	<	<	.015	.044	.05	<	.007	<	.02	.046	<	<	<
_Diazinon-oxon	1	.01	nd	nd	nd	nd	nd	nd	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dieldrin	4	.024	<	e.005	<	.012	.024	<	<	<	<	.01	<	<	<	<	<	<	<
Dimethenamid	1	.005	nd	nd	nd	nd	nd	nd	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dinoseb	1	.03	<	e.03	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Diuron	18	2.26	<	.82	<	<	<	<	.52	e1.16	e1.9	.04	<	<	e2.26	<	<	0.57	.11
_3,4-Dichlorophenyl isocyanate	4	5.4	nd	nd	nd	nd	nd	nd	e5.4	nd	nd	nd	nd	.26	nd	.60	nd	nd	nd
Endosulfan I	1	.067	nd	nd	nd	nd	nd	nd	<	nd	nd	nd	nd	<	nd	.067	nd	nd	nd
Endosulfan II	1	.04	nd	nd	nd	nd	nd	nd	<	nd	nd	nd	nd	<	nd	e0.04	nd	nd	nd
_Endosulfan sulfate	2	.036	nd	nd	nd	nd	nd	nd	e.012	nd	nd	nd	nd	nd	nd	.036	nd	nd	nd
Ethoprop	16	.13	0.028	<	<	.01	e.021	<	<	<	e.016	e.014	<	<	e.016	<	<	<	<
Fenuron	3	.12	<	<	<	<	<	<	.032	<	.07	<	<	<	.12	<	<	<	<
Glyphosate	24	45.8	.5	.07	<	.18	12.5	1	<	.16	1.5	4.8	e1.2	<	<	3.2	e.13	<	<
_AMPA	8	2.4	<	.17	<	.39	1.7	<	<	<	<	<	2.4	<	<	.44	.62	<	<
Imidacloprid	2	4.5	<	<	<	<	4.5	<	<	<	<	<	<	<	<	<	<	<	<
Iprodione	1	.056	nd	nd	nd	nd	nd	nd	e.056	nd	nd	nd	nd	<	nd	<	nd	nd	nd
Malathion	1	.047	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
MCPA	1	.067	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Metalaxyl	7	1.5	<	.02	<	.09	<	<	.11	.03	.21	<	<	<	<	.11	<	<	<
Methiocarb	3	.086	<	<	<	<	<	<	<	<	.027	<	<	<	<	.027	<	<	<
Metolachlor	26	.11	.011	.005	e.005	e.005	.02	<	.006	.11	.05	.013	e.005	.008	.10	<	.006	<	e.006
Napropamide	16	.40	<	.016	<	.09	.031	<	.008	.05	.013	.015	.02	.009	.02	.017	.02	<	<
Norflurazon	3	.11	<	.018	.03	<	<	<	<	<	<	<	<	<	<	<	<	.11	<
Oryzalin	1	.29	<	<	<	<	<	<	<	0.29	<	<	<	<	<	<	<	<	<

Table C1. Concentrations of pesticides and degradates in the lower Clackamas River basin, Oregon, May and September 2005.—Continued

[Pesticide concentrations in micrograms per liter (µg/L). May 2005 data are shaded. **Abbreviations:** e, estimated value (see Glossary); Ct, Court; ds, downstream; Hwy, highway; Rd, road; Pkwy, parkway; trib, tributary; ft^3/s, cubic foot per second; g/d, gram per day; mi^2, square mile; nd, no data. **Symbols:** _, pesticide degradate; <, less than laboratory method detection limit]

Pesticide or degradate	Number of detections	Maximum concen-trations	Tributary sites, in upstream order																
			Richardson Creek at Hwy 224	Noyer Creek at mouth		Noyer Creek ds Hwy 212		Deep Creek at Barton	NF Deep Creek at Barton	NF Deep Creek nr Boring (ds weir)	NF Deep Creek at Boring	NF Deep Creek trib at 312th Ave	NF Deep Creek trib at Church Rd	Dolan creek at Orient Rd	Doane Creek ds Hwy 212	Tickle Creek near Boring	Tickle Creek trib at Orient Rd	Tickle Creek trib at Colorado Rd	Tickle Creek at 362nd Ave
			09-30-05	05-09-05	09-30-05	05-09-05	09-30-05	09-30-05	09-30-05	05-09-05	09-30-05	09-30-05	09-30-05	09-30-05	09-30-05	09-30-05	09-30-05	09-30-05	09-30-05
Oxyfluorfen	1	0.023	nd	nd	nd	nd	nd	nd	<	nd	nd	nd	nd	<	nd	e0.023	nd	nd	nd
Pendimethalin	5	.35	<	<	<	0.041	0.35	<	<	<	<	<	<	<	<	<	<	<	<
Prometon	15	.11	e0.006	<	<	e.004	<	<	<	e.004	<	<	e0.003	<	e0.01	<	<	<	0.006
Propiconazole	6	.51	<	0.34	<	.51	.32	<	<	<	<	<	<	<	<	<	<	<	<
Propoxur	1	.005	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Simazine	25	.96	.007	.01	0.01	.013	.023	<	<	.034	<	0.015	.141	0.011	.022	<	0.01	0.013	<
Sulfometuron-methyl	5	.2	<	<	<	.09	<	<	<	.07	<	<	<	<	<	<	<	<	<
Tebuthiuron	3	.08	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Triclopyr	16	5	e.66	<	e.39	<	<	e1.2	<	e.19	e0.53	e5.0	<	.19	<	e1.8	<	<	<
Trifluralin	11	.17	<	e.002	<	.03	.011	<	<	.17	.02	<	<	<	e.003	.026	<	<	<
Number of pesticides detected			7	17	5	17	14	3	10	18	14	13	12	6	14	16	9	3	5
Total pesticide concentration (µg/L)			2.4	1.8	1.1	1.5	19.9	2.4	6.2	2.6	5.5	16.7	4.2	0.5	3.0	6.5	1.1	.7	.33
Streamflow (ft^3/s)			4.7	5	.7	5	2.4	45	20	36	10	.1	0.1	0.1	2.9	9.2	.2	.6	29
Instantaneous pesticide load (g/d)			27	21	1.8	20	116	259	303	224	131	4.0	1.1	0.1	21	146	.6	1.1	23
Basin area (mi^2)			3.9	3.1	3.1	2.1	2.1	32	14	11	10	.2	.7	2.6	6.5	13	1.3	2.1	3.6
Instantaneous pesticide yield (g/d/1,000 acres)			10.6	10.6	.9	14.5	85.9	12.5	33.2	32.1	20.3	27.5	2.5	.07	5.1	17.7	.7	.8	10.0
Instantaneous water yield (ft^3/s/1,000 acres)			1.8	2.4	.3	3.9	1.8	2.2	2.2	5.1	1.5	.7	.2	.06	.7	1.1	.2	.5	12.4

Table C2. Pesticides and degradates detected in the Deep Creek basin during the EUSE urbanization study, 2003–2004.

[Pesticide concentrations in micrograms per liter (µg/L). **Abbreviations:** EUSE, Effects of Urbanization on Stream Ecosystems (USGS NAWQA study); NAWQA, National Water-Quality Assessment Program; USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; g/d, gram per day. **Symbols:** _, pesticide degradate; <, less than laboratory method detection limit]

Pesticide or degradate	Number of detections	Maximum concen-trations	Sample and date																	
			North Fork Deep Creek at Barton						Tickle Creek near Boring						(upper) Deep Creek near Sandy					
			11-04-03	01-14-04	03-09-04	05-04-04	06-29-04	08-17-04	11-04-03	01-15-04	03-09-04	05-04-04	06-29-04	08-17-04	11-04-03	01-14-04	03-09-04	05-04-04	06-29-04	08-17-04
Atrazine	12	0.03	0.01	0.03	0.017	0.026	0.018	0.014	e0.005	e0.003	e0.004	e0.0004	e0.004	e0.004	<	<	e0.003	e.005	e0.003	e0.002
_CIAT	12	.01	e.004	e.004	e.004	e.005	.01	e.005	e.004	e.003	e.003	e.003	e.006	e.003	e.002	e.003	e.002	e.002	e.005	e.001
Hexazinone	10	.03	<	.015	.026	.02	.017	e.008	<	.03	.03	e.011	.02	e.006	.015	.03	.034	.028	.03	.016
Metalaxyl	12	.02	.02	e.005	.007	.006	.017	.02	.01	e.006	.009	e.007	.02	.02	<	<	e.005	e.003	<	<
Simazine	12	.18	.05	.01	.18	.068	.032	.04	.014	.008	.007	e.016	.012	.008	<	<	e.003	<	<	<
Metolachlor	9	.03	.022	.027	.028	.025	.02	e.007	e.002	<	<	e.002	<	e.002	<	<	e.004	e.002	<	<
Trifluralin	9	.02	.009	e.005	.02	e.005	<	<	e.006	.006	e.008	e.004	<	e.005	<	<	<	<	<	<
Chlorpyrifos	8	.022	<	.013	.022	.009	0.006	<	<	e.003	e.005	e.002	<	e.003	<	<	<	<	<	<
_3,4-Dichloroaniline	8	.15	.10	.056	.15	.07	0.02	.05	<	.007	.012	<	<	<	<	<	<	<	<	<
Myclobutanil	6	.016	<	.013	.016	e.014	<	e.01	<	.01	.012	<	<	<	<	<	<	<	<	<
Prometon	5	.005	<	e.002	<	.005	<	e.004	<	e.003	<	<	<	e.003	<	<	<	<	<	<
Diazinon	5	.03	.03	<	<	e.003	<	.007	<	<	e.004	<	<	.006	<	<	<	<	<	<
Dieldrin	2	.003	<	e.003	.002	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Carbaryl	1	.007	<	e.007	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Number of pesticides detected			8	13	11	12	8	10	6	10	10	8	5	10	2	2	6	5	3	3
Total pesticide concentration (µg/L)			0.25	.189	.470	.253	.140	.160	.041	.075	.093	.049	.057	.057	.017	.031	.050	.039	.039	.019
Streamflow (ft^3/s)			1.7	70.2	32.5	3.7	2.4	2.0	3.1	73.5	33.8	7.2	4.9	2.9	2.3	56.4	33.4	5.1	4.0	1.3
Instantaneous pesticide load (g/d)			1.0	32.5	37.4	2.3	.8	.8	.3	13.5	7.7	.9	.7	.4	.1	4.3	4.1	.5	0.4	.06
Instantaneous pesticide yield (g/d/1,000 acres)			.11	3.6	4.1	.3	.1	.1	.0	1.6	.9	.1	.08	.05	.00	.21	.20	.02	.02	.00
Instantaneous water yield (ft^3/s/1,000 acres)			.0002	.0077	.0036	.0004	.0003	.0002	.0004	.0089	.0041	.0009	.0006	.0004	.0001	.0027	.0016	.0002	.0002	.0001

Table C3. Concentrations of pesticides and degradates in source water (2002–2005) and finished drinking water (2004–2005) from the study water treatment plant on the lower Clackamas River, Oregon.

[Pesticide concentrations in micrograms per liter (µg/L). See p. 3 for more information on the study plant's water-treatment process. **Abbreviations:** FNU, Formazin Nephelometric Unit; e, estimated value (see Glossary); ft³/s, cubic foot per second; g/d, gram per day; nd, no data; **Symbols:** _, pesticide degradate; <, less than laboratory method detection limit]

Pesticide or degradate	Number of detections		Maximum concentration		Source water																	
					2002					2003												
	Source water	Finished drinking water	Source water	Finished drinking water	10-29	11-13	11-18	12-10	12-18	01-14	01-28	02-11	03-11	04-08	04-29	05-13	05-28	06-10	06-24	07-15	08-19	09-11
Diuron	14	4	0.22	0.18	<	<	e0.012	e0.004	0.06	0.09	0.034	e0.008	e0.004	<	nd	e0.006	<	<	<	<	nd	<
Simazine	11	4	.017	.021	<	0.005	e.005	<	e.003	e.003	.007	e.003	<	e0.003	e0.003	e.003	<	<	<	<	nd	<
Dacthal	5	2	.005	.005	<	<	<	<	<	<	<	<	<	<	nd	<	<	<	<	<	nd	<
Hexazinone	4	2	.022	.017	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	e.008	e0.005	<	<	<	nd	<
Atrazine	7	1	.023	.006	<	<	<	<	<	e.002	e.003	e0.002	<	<	.023	e.004	<	<	<	<	nd	<
_CIAT	4	1	.005	.005	<	<	<	<	<	e.002	e.002	<	<	<	e.002	<	<	<	<	<	nd	<
Metolachlor	5	1	.005	.002	<	e.003	<	<	e.002	<	<	<	<	e.003	nd	<	<	<	<	<	<	<
2,4-D	3	1	.18	.08	<	<	<	<	<	<	<	<	<	<	e.018	<	<	<	<	<	nd	<
Trifluralin	3	1	.006	.005	<	<	<	<	<	<	<	<	<	<	nd	<	<	<	<	<	nd	<
DEET	3	1	.074	.078	<		<	<	<	<	<	<	<	<	nd	<	<	<	<	e0.066	<	<
Ethoprop	1	1	.009	.006	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Propiconazole	1	1	.009	.006	<	<	<	<	<	<	<	<	<	<	nd	<	<	<	<	<		<
Diazinon	4	0	.014	<	<	.005	<	<	<	<	<	<	<	<	e.002	<	<	<	<	<	<	<
_Diazinon-oxon	0	1	<	.010	<	<	<	<	<	<	<	<	<	<	nd	<	<	<	<	<	nd	<
Metsulfuron methyl	0	1	<	.06	<	<	<	<	<	<	<	<	<	<	nd	<	<	<	<	<	nd	<
Pronamide	0	1	<	.005	<	<	<	<	<	<	<	<	<	<	nd	<	<	<	<	<	nd	<
Carbaryl	3	0	.041	<	<	.041	<	<	e.004	<	<	<	<	<	e.004	<	<	<	<	<	<	<
Chlorpyrifos	2	0	.006	<	<	.005	<	<	<	<	<	<	<	<	nd	<	<	<	<	<	<	<
Prometon	2	0	.015	<	<	.015	<	<	<	<	<	<	<	<	nd	<	<	<	<	<	<	<
Bromacil	1	0	.033	<	<	.033	<	<	<	<	<	<	<	<	nd	<	<	<	<	<	<	<
_OIET	1	0	.014	<	<	<	<	<	<	<	<	<	<	<	nd	<	<	<	<	<	nd	<
Cycloate	1	0	.017	<	<	<	<	<	<	<	<	<	<	<	nd	<	<	<	<	<	nd	<
Dichlorvos	1	0	.012	<	<	.012	<	<	<	<	<	<	<	<	nd	<	<	<	<	<	<	<
Dimethenamid	1	0	.005	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Glyphosate	1	0	.11	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Metalaxyl	1	0	.02	<	<	.02	<	<	<	<	<	<	<	<		<	<	<	<	<	<	<
Napropamide	1	0	.004	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Triclopyr	1	0	.23	<	<	<	<	<	<	<	<	<	<	<		<	<	<	<	<	nd	<
Number of pesticides detected					0	9	2	1	4	4	4	3	1	2	6	4	1	0	0	1	0	0
Total pesticide concentration (µg/L)					0	0.139	0.017	0.004	0.067	0.096	0.046	0.013	0.004	0.006	0.053	0.020	0.005	0	0	0.066	0	0
Streamflow (ft³/s)					831	1,600	1,465	788	3,080	4,912	7,400	3,220	9,370	4,523	4,057	2,750	2,287	1,390	1,230	818	758	901
Turbidity (FNU)					0.7	1.7	1.6	0.4	6.4	4.7	16.3	2.3	7.4	2.3	1.8	1.0	11.3	0.6	0.4	0.3	0.2	0.2
Instantaneous pesticide load (g/d)					0	546	61.3	8.0	506	1,153	835	105	98.6	60.9	527	137	29.7	0	0	132	0	0

Table C3. Concentrations of pesticides and degradates in source water (2002–2005) and finished drinking water (2004–2005) from the study water treatment plant on the lower Clackamas River, Oregon.—Continued

[Pesticide concentrations in micrograms per liter (µg/L). See p. 3 for more information on the study plant's water-treatment process. **Abbreviations:** FNU, Formazin Nephelometric Unit; e, estimated value (see Glossary); ft³/s, cubic foot per second; g/d, gram per day; nd, no data; **Symbols:** _, pesticide degradate; <, less than laboratory method detection limit]

Pesticide or degradate	Number of detections		Maximum concentration		07-07-04		07-21-04		08-12-04		08-25-04		09-09-04		09-23-04		10-20-04		11-10-04	
	Source water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water
Diuron	14	4	0.22	0.18	<	<	<	<	<	<	<	<	<	<	0.023	0.020	0.06	0.04	<	<
Simazine	11	4	.017	.021	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Dacthal	5	2	.005	.005	<	<	0.005	0.005	<	<	0.003	<	<	<	<	<	<	<	<	<
Hexazinone	4	2	.022	.017	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Atrazine	7	1	.023	.006	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
_CIAT	4	1	.005	.005	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Metolachlor	5	1	.005	.002	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
2,4-D	3	1	.18	.08	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Trifluralin	3	1	.006	.005	<	<	<	<	<	<	e.005	<	<	<	<	<	e.004	<	<	<
DEET	3	1	.074	.078	<	<	<	<	<	<	e0.1	0.078	<	<	<	<	e.010	<	<	<
Ethoprop	1	1	.009	.006	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Propiconazole	1	1	.009	.006	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Diazinon	4	0	.014	<	<	<	<	<	<	<	.007	<	<	<	<	<	<	<	<	<
_Diazinon-oxon	0	1	<	.010	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Metsulfuron methyl	0	1	<	.06	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Pronamide	0	1	<	.005	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Carbaryl	3	0	.041	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Chlorpyrifos	2	0	.006	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Prometon	2	0	.015	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Bromacil	1	0	.033	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
_OIET	1	0	.014	<	<	<	<	<	<	<	e.013	<	<	<	<	<	<	<	<	<
Cycloate	1	0	.017	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Dichlorvos	1	0	.012	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Dimethenamid	1	0	.005	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Glyphosate	1	0	.11	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Metalaxyl	1	0	.02	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Napropamide	1	0	.004	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Triclopyr	1	0	.23	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Number of pesticides detected					0	0	1	1	0	0	5	1	0	0	1	1	3	1	0	0
Total pesticide concentration (µg/L)					0	0	0.005	0.005	0	0	0.103	0.078	0	0	0.023	0.020	0.069	0.036	0	0
Streamflow (ft³/s)					1,050	nd	861	nd	748	nd	1,363	nd	912	nd	1,729	nd	1,920	nd	1,750	nd
Turbidity (FNU)					0.8	0.8	0.5	0.4	0.7	0.7	4.2	nd	0.7	nd	0.9	nd	1.1	nd	1.2	nd
Instantaneous pesticide load (g/d)					0	nd	10	nd	0	nd	345	nd	0	nd	96	nd	326	nd	0	nd

Table C3. Concentrations of pesticides and degradates in source water (2002–2005) and finished drinking water (2004–2005) from the study water treatment plant on the lower Clackamas River, Oregon.—Continued

[Pesticide concentrations in micrograms per liter (μg/L). See p. 3 for more information on the study plant's water-treatment process. **Abbreviations:** FNU, Formazin Nephelometric Unit; e, estimated value (see Glossary); ft^3/s, cubic foot per second; g/d, gram per day; nd, no data; **Symbols:** _, pesticide degradate; <, less than laboratory method detection limit]

Pesticide or degradate	Number of detections		Maximum concentration		01-05-05		02-09-05		03-02-05		03-09-05		04-06-05		05-09-05		05-18-05		09-30-05	
	Source water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water	Raw water	Finished drinking water	Source water	Finished drinking water	Source water	Finished drinking water
Diuron	14	4	0.22	0.18	<	<	0.06	0.06	nd	nd	<	<	<	<	0.06	nd	0.22	0.18	0.017	<
Simazine	11	4	.017	.021	<	<	<	.005	nd	nd	<	e0.003	<	<	<	nd	.005	e.004	.017	0.021
Dacthal	5	2	.005	.005	<	<	<	<	nd	nd	<	<	<	<	e.004	nd	e.002	e.002	.005	<
Hexazinone	4	2	.022	.017	<	<	<	<	nd	nd	<	<	e0.011	e0.012	nd	nd	.022	.017	<	<
Atrazine	7	1	.023	.006	<	<	<	<	nd	nd	<	<	<	<	e.003	nd	.007	e.006	<	<
_CIAT	4	1	.005	.005	<	<	<	<	nd	nd	<	<	<	<	<	nd	e.005	e.005	<	<
Metolachlor	5	1	.005	.002	<	<	<	<	<	<	<	<	<	<	<	nd	e.005	<	e.004	e.002
2,4-D	3	1	.18	.08	<	<	<	<	nd	nd	<	<	<	<	<	nd	e0.01	<	.178	.08
Trifluralin	3	1	.006	.005	<	<	<	<	nd	nd	<	<	<	<	<	nd	e.005	e.005	<	<
DEET	3	1	.074	.078	<	<	<	<	<	<	<	<	<	<	nd	nd	<	<	nd	nd
Ethoprop	1	1	.009	.006	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<	nd	nd	nd	e.009	.006
Propiconazole	1	1	.009	.006	<	<	<	<	nd	nd	<	<	<	<	<	nd	<	<	.009	e.01
Diazinon	4	0	.014	<	<	<	<	<	<	<	<	<	<	<	<	nd	<	<	.014	<
_Diazinon-oxon	0	1	<	.010	<	<	<	<	nd		<	<	<	<	nd	nd	<	<	<	e.01
Metsulfuron methyl	0	1	<	.06	<	<	<	<	nd	nd	<	<	<	<	<	nd	<	e.06	<	<
Pronamide	0	1	<	.005	<	<	<	<	nd	nd	<	<	<	<	<	nd	<	.005	nd	<
Carbaryl	3	0	.041	<	<	<	<	<	<	<	<	<	<	<	<	nd	<	<	<	<
Chlorpyrifos	2	0	.006	<	<	<	<	<	<	<	<	<	<	<	<	nd	.006	<	<	<
Prometon	2	0	.015	<	<	<	<	<	<	<	<	<	<	<	<	nd	<	<	e.004	<
Bromacil	1	0	.033	<	<	<	<	<	<	<	<	<	<	<	<	nd	<	<	<	<
_OIET	1	0	.014	<	<	<	<	<	nd	nd	<	<	<	<	<	nd	<	<	<	<
Cycloate	1	0	.017	<	<	<	<	<	nd	nd	<	<	<	<	<	nd	<	<	.017	<
Dichlorvos	1	0	.012	<	<	<	<	<	nd	nd	<	<	<	<	nd	nd	<	<	<	<
Dimethenamid	1	0	.005	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	e.005	<
Glyphosate	1	0	.11	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<	nd	nd	nd	e.110	<
Metalaxyl	1	0	.02	<	<	<	<	<	<	<	<	<	<	<	<	nd	<	<	<	<
Napropamide	1	0	.004	<	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.004	nd	nd	nd	<	<
Triclopyr	1	0	.23	<	<	<	<	<			<	<	<	<	<	nd	<	<	0.228	<
Number of pesticides detected					0	0	1	2	0	0	0	1	1	1	4	nd	10	9	13	6
Total pesticide concentration (μg/L)					0	0	0.064	0.067	0	0	0	0.003	0.011	0.012	0.069	nd	0.289	0.282	0.616	0.123
Streamflow (ft^3/s)					1,570	nd	1,743	nd	1,370	nd	1,217	nd	3,340	nd	3,000	nd	3,926	nd	1,200	nd
Turbidity (FNU)					1.1	nd	1.3	nd	.5	nd	0.4	nd	2.0	nd	2.5	nd	8.7	nd	97	nd
Instantaneous pesticide load (g/d)					0	nd	273	nd	0	nd	0	nd	93	nd	506	nd	2,773	nd	1,810	nd

Table C4. Instantaneous streamflow and turbidity values for samples collected in the lower Clackamas River basin, Oregon, 2002–2005.

[Discharge in cubic feet per second. Turbidity values (in Formazin Nephelometric Units, [FNRUs]) for the Clackamas River obtained from the continuous monitor in the Clackamas River near Oregon City. Turbidity values for May and September 2005 samples obtained with a Hach 2001 N benchtop turbidity analyzer. See Glossary for more details. **Abbreviation:** ft^3/s, cubic foot per second]

Site name	Sampling date	Time	Discharge (ft^3/s)	Turbidity (FNRU)
2002–2005 SWQA sampling				
Clackamas River near Oregon City (at the water-quality monitor)	10-29-2002	1050	830	0.7
	11-13-2002	1200	1,600	1.7
	11-18-2002	1220	1,465	1.6
	12-10-2002	1110	790	.4
	12-18-2002	1100	3,080	6.4
	01-14-2003	1140	4,910	4.7
	01-28-2003	1200	7,400	16
	02-11-2003	1130	3,220	2.3
	03-11-2003	1130	9,370	7.4
	04-08-2003	1140	4,520	2.3
	04-29-2003	1210	4,060	1.8
	05-13-2003	1230	2,750	1.0
	05-28-2003	1140	2,290	11
	06-10-2003	1400	1,390	.6
	06-24-2003	1150	1,230	.4
	07-15-2003	1140	820	.3
	08-19-2003	1220	760	.2
	09-11-2003	1230	900	.2
	07-07-2004	1050	1,050	.8
	07-21-2004	1130	860	.5
	08-12-2004	1100	750	.7
	08-25-2004	1050	1,360	4.2
	09-09-2004	1410	910	.7
	09-23-2004	1100	1,730	.9
	10-20-2004	1100	1,920	1.1
	11-10-2004	1110	1,750	1.2
	01-05-2005	1100	1,570	1.1
	02-09-2005	1140	1,740	1.3
	03-02-2005	1100	1,370	.5
	03-09-2005	1100	1,220	.4
	04-06-2005	1100	3,340	2.0
	05-09-2005	1220	3,000	2.5
	05-18-2005	1100	3,930	8.7

Table C4. Instantaneous streamflow and turbidity values for samples collected in the lower Clackamas River basin, Oregon, 2002–2005.—Continued

[Discharge in cubic feet per second. Turbidity values (in Formazin Nephelometric Units, [FNRUs]) for the Clackamas River obtained from the continuous monitor in the Clackamas River near Oregon City. Turbidity values for May and September 2005 samples obtained with a Hach 2001 N benchtop turbidity analyzer. See Glossary for more details. **Abbreviation:** ft^3/s, cubic foot per second]

Site name	Time	Discharge (ft^3/s)	Turbidity (FNRU)
May 9, 2005 storm event sampling			
Carli Creek upstream of mouth, near Clackamas	1200	21	19
Cow Creek at mouth, near Gladstone	1230	12	43
North Fork Deep Creek upstream of weir, near Boring	1300	36	50
Noyer Creek at mouth, near Barton	1340	4.8	140
Noyer Creek downstream of Highway 212, near Damascus	1040	5.2	670
Rock Creek at Stoneybrook Court downstream of 172nd Avenue	920	10	23
Sieben Creek at Highway 224	1110	10	50
Trillium Creek at Anderegg Parkway, near Damascus	1010	.3	29
September 30, 2005 storm event sampling			
Carli Creek upstream from mouth, near Clackamas	1130	11	25
Clackamas River at DWTP (source water)	2000	1,200	100
Cow Creek at mouth, near Gladstone	1520	4.4	58
Deep Creek at Camp Kuratli, near Barton	1640	45	90
Doane Creek downstream from Highway 212, near Boring	1510	3	120
Dolan Creek downstream of Orient Road, near Boring	1415	.1	11
North Fork Deep Creek at Barton	1700	20	110
North Fork Deep Creek at Boring	1700	10	72
North Fork Deep Creek tributary at 312th Avenue, near Boring	1130	.1	44
North Fork Deep Creek tributary at Church Road, near Boring	1240	.1	75
Noyer Creek at mouth, near Barton	1630	.7	55
Noyer Creek downstream of Highway 212, near Damascus	1110	2.4	2,500
Richardson Creek near Highway 224	1710	5	150
Rock Creek at 172nd Avenue	1820	1.8	40
Rock Creek at Foster Road	1850	1.5	36
Rock Creek at Stoneybrook Court, downstream from 172nd Avenue	1130	1.7	15
Rock Creek near mouth	1750	20	230
Sieben Creek at Highway 224	1240	4.8	260
Sieben Creek downstream of Sunnyside Road	1120	2.3	270
Tickle Creek at 362nd Avenue, near Sandy	1210	29	330
Tickle Creek near Boring	1320	9	36
Tickle Creek tributary at Colorado Road, near Sandy	1420	.6	18
Tickle Creek tributary at Orient Road, near Sandy	1110	.2	28
Trillium Creek at Anderegg Parkway, near Damascus	1115	.3	82

Appendix D. Toxicity Values Used in the Pesticide Toxicity Index (PTI) and Maximum Benchmark Quotients for Pesticides Detected in the Lower Clackamas River Basin, Oregon, 2000–2005

Table D1. Toxicity values used for the Pesticide Toxicity Index (PTI) and maximum benchmark quotients for pesticides detected in the lower Clackamas River basin, 2000–2005.

[PTI values from Munn and Gilliom (2006). Pesticide toxicity values (96-hour LC_{50}) given in micrograms per liter (µg/L). Max benchmark quotient is the ratio of the maximum concentration detected divided by the minimum toxicity value. **Abbreviations;** N, number of laboratory tests; Min, minimum; Max, maximum; Med, median. **Symbols:** _, pesticide degradate; –, no data]

Pesticide or degradate	Maximum concentration	Maximum benchmark quotient	Minimum value (all taxa)	Benthic invertebrates N	Benthic invertebrates Toxicity values Min	Benthic invertebrates Toxicity values Median	Benthic invertebrates Toxicity values Max	Fish N	Fish Toxicity values Min	Fish Toxicity values Median	Fish Toxicity values Max	Cladocerans N	Cladocerans Toxicity values Min	Cladocerans Toxicity values Median	Cladocerans Toxicity values Max
2,4-D	6.1	0.004	1,400	4	1,600	8,700	144,100	43	1,400	44,500	358,000	3	3,200	4,900	25,000
2,4-D methyl ester	.73	.005	145	–	–	–	–	–	–	–	–	2	145	1,423	2,700
2,4-DP	.13	.0003	500	–	–	–	–	18	500	1,450	6,100	2	5,400	5,825	6,250
Atrazine	.30	.003	94	9	94	9,000	14,900	33	2,000	15,000	69,000	4	6,900	41,500	115,000
_CIAT	.021	–	–	–	–	–	–	–	–	–	–	–	–	–	–
_OIET	.18	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Azinphos-methyl	.21	2.1	0.1	31	.10	1	56	107	.36	23	4,270	4	1.10	1.55	4.40
Benomyl	5.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Bentazon	.16	.0000002	978,000	–	–	–	–	2	978,000	2,426,000	3,874,000	–	–	–	–
Bromacil	.27	.00001	36,000	–	–	–	–	5	36,000	127,000	186,000	1	–	121,000	–
Carbaryl	.15	.09	1.7	51	1.70	16	6,933	165	140	4,330	290,000	16	2.77	6.93	7,100
_1-Naphthol	.011	.00001	1,460	–	–	–	–	7	1,460	3,570	4,630	–	–	–	–
Chlorothalonil	.26	8	7.6	–	–	–	–	25	7.6	51	430	4	70	97	172
Chlorpyrifos	.17	4.2	0.04	31	.04	0.57	83	53	.58	38	806	3	.10	.40	1.70
Cycloate	.024	.00001	2,600	4	2,600	2,600	2,600	11	4,500	6,000	10,000	2	24,000	24,000	24,000
Dacthal (DCPA)	.46	.00007	6,200	1	–	6,200	–	2	6,600	18,300	30,000	2	27,000	82,500	138,000
DEET	.074	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Diazinon	.25	8.4	0.03	19	.03	25	6,160	79	22	602	10,300	17	.50	1.22	1.80
_Diazinon-oxon	.010	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Dichlobenil	17	.005	3,700	10	6,600	10,500	35,000	20	4,930	8,850	6,200,000	6	3,700	5,800	6,200
Dichlorvos	.012	.56	0.02	16	.02	37	400,000	32	2.50	1,145	180,000	5	.07	.26	1,000
Dieldrin	.024	.05	0.5	30	0.50	24	6,710	83	.62	10	10,000	7	130	240	251
Dimethenamid	.005	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Dinoseb	.028	.001	28	1	–	1,800	–	42	28	97	1,400	–	–	–	–
Diuron	2.3	.014	160	8	160	950	15,500	30	500	5,400	84,000	7	1,400	2,000	8,400
_3,4-Dichloroaniline	.15	.045	3.4	8	3.40	6.40	7,400	13	53	7,700	9,960	10	54	709	2,254
_3,4-Dichlorophenyl isocyanate	5.4	.002	2,700	–	–	–	–	–	–	–	–	1	–	2,700	–
Endosulfan I[1]	.11	.6875	.16	–	–	–	–	3	.16	.33	1	–	–	–	–
Endosulfan II[1]	.11	.6875	.16	–	–	–	–	3	.16	.33	1	–	–	–	–
_Endosulfan sulfate	.012	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ethoprop	.13	.003	43.9	–	–	–	–	13	180	2,070	13,800	3	43.9	93	690,000
Fenuron	.12	.000001	204,000	–	–	–	–	1	–	204,000	–	–	–	–	–
Fonofos	.007	.003	2.0	–	–	–	–	16	5	20	2,800	3	2	8.37	15.50
Glyphosate	46	–	–	–	–	–	–	–	–	–	–	–	–	–	–
_AMPA	2.4	.0003	7,200	–	–	–	–	–	–	–	–	3	7,200	8,200	14,000
Hexazinone	.034	.0000004	85,000	–	–	–	–	25	100,000	317,000	1,964,000	2	85,000	118,300	151,600
Imazaquin	.047	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table D1. Toxicity values used for the Pesticide Toxicity Index (PTI) and maximum benchmark quotients for pesticides detected in the lower Clackamas River basin, 2000–2005.—Continued

[PTI values from Munn and Gilliom (2006). Pesticide toxicity values (96-hour LC_{50}) given in micrograms per liter (µg/L). Max benchmark quotient is the ratio of the maximum concentration detected divided by the minimum toxicity value. **Abbreviations;** N, number of laboratory tests; Min, minimum; Max, maximum; Med, median. **Symbols:** _, pesticide degradate; –, no data]

Pesticide or degradate	Maximum concentration	Maximum benchmark quotient	Minimum value (all taxa)	Benthic invertebrates N	Benthic invertebrates Toxicity values Min	Benthic invertebrates Toxicity values Median	Benthic invertebrates Toxicity values Max	Fish N	Fish Toxicity values Min	Fish Toxicity values Median	Fish Toxicity values Max	Cladocerans N	Cladocerans Toxicity values Min	Cladocerans Toxicity values Median	Cladocerans Toxicity values Max
Imidacloprid	4.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Iprodione	.06	0.00002	3,060	–	–	–	–	6	3,060	3,950	7,800	–	–	–	–
Linuron	.6	.005	120	–	–	–	–	8	890	6,100	16,400	4	120	240	1,100
Malathion	.047	.25	.19	68	0.50	12	50,000	146	.19	200	52,200	15	.59	1.80	100
MCPA	.067	.000003	25,000	–	–	–	–	6	25,000	75,000	97,000	–	–	–	–
Metalaxyl	1.5	.0001	12,500	–	–	–	–	9	18,400	100,000	150,000	3	12,500	29,300	121,000
Methiocarb	.086	.11	.75	12	5	62	8,800	12	.75	538	4,700	1	–	19	–
Metolachlor	.11	.00003	3,900	–	–	–	–	8	3,900	8,200	10,000	3	23,500	25,100	26,000
Metsulfuron-methyl	.058	.000001	100,000	–	–	–	–	6	100,000	150,000	150,000	–	–	–	–
Myclobutanil	.016	.00001	2,400	–	–	–	–	2	2,400	3,300	4,200	1	–	11,000	–
Napropamide	1.3	.0001	9,400	–	–	–	–	6	9,400	12,650	14,000	2	14,300	19,500	24,700
Norflurazon	.11	.00001	8,100	–	–	–	–	3	8,100	9,580	16,300	–	–	–	–
Oryzalin	.3	.002	190	2	190	295	400	3	2,880	3,260	3,450	1	–	1,500	–
Oxyfluorfen	.023	.0001	200	–	–	–	–	3	200	400	410	–	–	–	–
_*p,p'*-DDE	.002	.00008	32	1	–	1,050	–	3	32	96	240	–	–	–	–
Pendimethalin	.35	.003	138	–	–	–	–	12	138	960	90,400	2	280	2,690	5,100
Prometon	.11	.00001	12,000	–	–	–	–	13	12,000	19,600	47,300	3	25,700	38,000	59,800
Pronamide	.17	.000002	72,000	–	–	–	–	3	72,000	150,000	350,000	–	–	–	–
Propiconazole	.5	.001	830	11	900	1,200	49,000	27	830	5,500	506,000	3	3,200	4,800	11,300
Propoxur	.005	.0005	11	13	13	50	146,000	34	1,300	6,970	180,000	2	11	19	27
Simazine	1.0	.011	90	3	1,900	13,000	13,000	32	90	56,000	822,000	2	1,100	1,100	1,100
Sulfometuron-methyl	.16	.00001	12,500	1	–	12,174,000	–	4	12,500	80,250	150,000	3	12,500	150,000	1,000,000
Tebuthiuron	.082	.000001	106,000	–	–	–	–	2	106,000	124,500	143,000	1	–	297,000	–
Terbacil	.026	.000001	46,200	–	–	–	–	6	46,200	90,950	112,000	1	–	65,000	–
Triclopyr	5.0	.019	260	–	–	–	–	19	260	1,300	9,700	–	–	–	–
Trifluralin	.17	.020	8.4	13	37	2,800	26,000	28	8.4	96	12,000	7	240	625	900

[1]Toxicity tests for endosulfan did not distinguish between endosulfan I and endosulfan II.

Appendix E. Physical Properties of Pesticides and Degradates Detected in the Lower Clackamas River Basin, Oregon, 2000–2005

Table E1. Physical properties of pesticides and degradates detected in the lower Clackamas River basin, Oregon, 2000–2005.

[Pesticide movement rating is derived from empirical data on pesticide half-life and soil Koc from the Oregon State University Extension Pesticide Properties Database (Vogue and others, 1994). Pesticide properties data from Hornsby, Wauchope, and Herner (1996). Soil Koc: Organic carbon adsorption coefficients. Compounds with higher values have relatively greater affinity to adhere to sediment than those with lower values. **Abbreviations:** CAS, Chemical Abstracts Service; F, fungicide; H, herbicide; I, insecticide; HD, herbicide degradate; ID, insecticide degradate; N, nematocide; USGS, U.S. Geological Survey; PCODE, USGS parameter code. **Symbols:** _, pesticide degradate; –, no data]

Pesticide or degradate	Type	USGS PCODE	CAS No.	Water solubility (mg/L)	Soil Koc	Soil half-life (days)	Pesticide movement rating
_1-Naphthol	HD/ID	49295	–	–	–	–	–
2,4-D	H	39732	94-75-7	890	20	10	Moderate
2,4-D methyl ester	H	50470	1928-38-7	100	100	10	Moderate
2,4-DP	H	49302	120-36-5	50	1,000	10	Low
_3,4-Dichloroaniline	HD	61625	–	–	–	–	–
_3,4-Dichlorophenyl isocyanate	HD	63145	–	–	–	–	–
_AMPA	HD	62649	–	–	–	–	–
Atrazine	H	39632	1912-24-9	33	100	60	High
Azinphos-methyl	I	82686	86-50-0	29	1,000	10	Low
Benomyl	F	50300	17804-35-2	2	1,900	67	Low
Bentazon[1]	H	38711	25057-89-0	500	–	<14	–
Bromacil	H	4029	314-40-9	700	32	60	Very high
Carbaryl	I	49310	63-25-2	120	300	10	Low
Chlorothalonil	F	49306	1897-45-6	.6	1,380	30	–
Chlorpyrifos	I	38933	2921-88-2	.4	6,070	30	Very low
_CIAT	HD	4040	–	–	–	–	–
Cycloate	H	4031	1134-23-2	95	430	30	Moderate
Dacthal	H	82682	1861-32-1	.5	5,000	100	Very low
DEET	I	62082	–	–	–	–	–
Diazinon	I	39572	333-41-5	60	1,000	40	Low
_Diazinon-oxon	ID	61638	–	–	–	–	–
Dichlobenil	H	49303	1194-65-6	21	400	60	Moderate
Dichlorvos	I/F	38775	62-73-7	10,000	30	0.5	Extremely low
_*p,p´*-DDE	ID	34653	72-55-9	.1	50,000	1,000	Extremely low
Dieldrin	I	39381	60-57-1	0	12,000	1,000	Extremely low
Dimethenamid	H	61588	87674-68-8	1,174	160	20	–
Dinoseb	H	49301	88-85-7	52	30	30	High
Diuron	H	49300	330-54-1	42	480	90	Moderate
Endosulfan	I	34362	959-98-8	.32	12,400	50	Extremely low
_Endosulfan sulfate	ID	61590	–	–	–	–	–
Ethoprop	I/N	82672	13194-48-4	750	70	25	High
Fenuron	H	49297	101-42-8	3,850	42	60	Very high
Fonofos	I	4095	944-22-9	17	870	40	Low
Glyphosate	H	62722	1071-83-6	900,000	24,000	47	Extremely low
Hexazinone	H	4025	51235-04-2	33,000	54	90	Very high
Imazaquin	H	50356	81335-37-7	60	20	60	Very high
Imidacloprid[1]	I	61695	13826-41-3	510	–	48-190	–
Iprodione	F	61593	36734-19-7	13.9	700	14	Low
Linuron	H	82666	330-55-2	75	400	60	Moderate
Malathion	I	39532	121-75-5	130	1,800	1.0	Extremely low

Table E1. Physical properties of pesticides and degradates detected in the lower Clackamas River basin, Oregon, 2000–2005.—Continued

[Pesticide movement rating is derived from empirical data on pesticide half-life and soil Koc from the Oregon State University Extension Pesticide Properties Database (Vogue and others, 1994). Pesticide properties data from Hornsby, Wauchope, and Herner (1996). Soil Koc: Organic carbon adsorption coefficients. Compounds with higher values have relatively greater affinity to adhere to sediment than those with lower values. **Abbreviations:** CAS, Chemical Abstracts Service; F, fungicide; H, herbicide; I, insecticide; HD, herbicide degradate; ID, insecticide degradate; N, nematocide; USGS, U.S. Geological Survey; PCODE, USGS parameter code. **Symbols:** _, pesticide degradate; –, no data]

Pesticide or degradate	Type	USGS PCODE	CAS No.	Water solubility (mg/L)	Soil Koc	Soil half-life (days)	Pesticide movement rating
MCPA	H	38482	94-74-6	866,000	20	25	High
Metalaxyl	F	61596	57837-19-1	8,400	50	70	Very high
Methiocarb	I	38501	2032-65-7	24	3000	30	Very low
Metolachlor	H	39415	51218-45-2	530	200	90	High
Metsulfuron methyl	H	61697	74223-64-6	9,500	35	30	High
Myclobutanil	F	61599	88671-89-0	142	500	66	Moderate
Napropamide	H	82684	15299-99-7	74	400	70	Moderate
Norflurazon	H	49293	27314-13-2	28	700	30	Low
_OIET	HD	50355	–	–	–	–	–
Oryzalin	H	49292	19044-88-3	2.5	600	20	Low
Oxyfluorfen	H	61600	42874-03-3	0.1	100,000	35	Extremely low
Pendimethalin	H	82683	40487-42-1	.3	5,000	90	Very low
Prometon	H	4037	1610-18-0	720	150	500	Very high
Pronamide	H	82676	23950-58-5	15	200	60	Low
Propiconazole	F	50471	60207-90-1	110	650	110	Moderate
Propoxur	I	38538	114-26-1	1,800	30	30	High
Simazine	H	4035	122-34-9	6.2	130	60	High
Sulfometuron-methyl	H	50337	74222-97-2	70	78	20	Moderate
Tebuthiuron	H	82670	34014-18-1	2,500	80	360	Very high
Terbacil	H	82665	5902-51-2	710	55	120	Very high
Triclopyr	H	49235	55335-06-3	435	27	155	Very high
Trifluralin	H	82661	1582-09-8	.3	8,000	60	Very low

[1]Extension Toxicological Network (Extoxnet) (1996).

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