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Nine Total Maximum Daily Loads for Legacy Pollutants in Streams and a Reservoir in Dallas and Tarrant Counties

For Segments 0805, 0841, and 0841A

Prepared by the:
Field Operations Division, Region 4
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TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

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Introduction

Section 303(d) of the Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. For each listed water body that does not meet a standard, states must develop a total maximum daily load (TMDL) for each pollutant that has been identified as contributing to the impairment of water quality in that water body. The Texas Natural Resource Conservation Commission (TNRCC) is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

In simple terms, a TMDL is a quantitative plan that determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. In other words, TMDLs are the best possible estimates of the assimilative capacity of a water body for the pollutant under consideration. A TMDL is commonly expressed as a load, with units of mass per time period, but may also be expressed in other ways. TMDLs must also estimate how much the pollutant load needs to be reduced from current levels in order to achieve water quality standards.

The Total Maximum Daily Load Program, a major component of Texas' statewide watershed management approach, addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in or bordering the state of Texas. The primary objective of the TMDL Program is to restore and maintain the beneficial uses (such as drinking water, recreation, support of aquatic life, or fishing) of impaired or threatened water bodies.

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) implementing regulations (40 Code of Federal Regulations, Section 130) describe the statutory and regulatory requirements for acceptable TMDLs. The TNRCC guidance document, *Developing Total Maximum Daily Load Projects in Texas* (GI-250, 1999), further refines the process for Texas. This TMDL document has been prepared in accordance with these guidelines, and is composed of the following six elements:

- Problem Definition
- Endpoint Identification
- Source Analysis
- Linkage Between Sources and Receiving Waters
- Margin of Safety
- Pollutant Load Allocation

This TMDL document was prepared by:

- Region 4 of the Field Operations Division of the Office of Compliance and Enforcement of the Texas Natural Resource Conservation Commission, and
- the TMDL Team in the Strategic Assessment Division of the Office of Environmental Policy, Analysis, and Assessment of the Texas Natural Resource Conservation Commission.

It was adopted by the Texas Natural Resource Conservation Commission on December 20, 2000. Upon adoption, the TMDL became part of the state Water Quality Management Plan. The Texas Natural Resource Conservation Commission will use this document in reviewing and making determinations on applications for storm water permits and in its nonpoint source pollution abatement programs.

Background Information

These TMDLs address the contamination of fish tissue by several legacy pollutants in water bodies in Dallas and Tarrant Counties, north-central Texas:

- portions of two classified segments of the Trinity River, and
- Mountain Creek Lake, an unclassified reservoir.

Legacy pollutant is a collective term used to describe substances whose use has been banned or severely restricted by the U.S. Environmental Protection Agency (EPA). Because of their slow rate of decomposition, these substances frequently remain at elevated levels in the environment for many years after their widespread use has ended. No additional loading of legacy pollutants is allowed or expected due to the EPA restrictions. Gradual declines in environmental legacy pollutant concentrations occur as a result of natural attenuation processes.

EPA guidance (*Draft Guidance for Water Quality-based Decisions: The TMDL Process, Second Edition, EPA 841-D-99-001, 1999*) on the development of TMDLs offers flexibility in addressing particular situations and unusual circumstances, allowing States the discretion to adopt different approaches where appropriate. The guidance states that the allowable pollutant load "must be expressed in a manner ... that represents attainment and maintenance of water quality standards." The guidance allows for the use of a surrogate target for situations where "no .... quantifiable pollutant load can be used to .... express the TMDL."

In preparing these TMDLs for legacy pollutants, the TNRCC has modified the typical loading allocation approach of a TMDL, which limits the amount of a pollutant that can be added to an impaired water body. Because these legacy pollutants are already restricted, and no significant additional loading is expected, these TMDLs do not specifically attempt to quantify allowable loads for these contaminants. The ultimate goal of these TMDLs is the reduction of fish tissue contaminant concentrations to levels that constitute an acceptable risk to consumers, allowing

TDH to remove the bans on fish consumption and the beneficial use to be restored to these water bodies.

Problem Definition

The water bodies covered by this TMDL document were included on the State of Texas 1998, 1999, and 2000 §303(d) lists (see corresponding *State of Texas Clean Water Act Section 303(d) List and Schedule of Development of Total Maximum Daily Loads, SFR-58*) as a result of the issuance of Aquatic Life Orders by the Texas Department of Health (TDH), which prohibit the consumption of fish. Consumption bans were issued following determinations of unacceptable human health risk due to elevated concentrations of one or more legacy pollutants in fish tissue (Table 1). The impacted water bodies lie largely within Dallas County, in the upper portion of the Trinity River Basin (Figure 1).

Table 1. Dallas County water bodies on the Texas 303(d) list due to concentrations of legacy pollutants in fish tissue that have resulted in the issuance of a fish consumption ban by the Texas Department of Health.

Segment Number	Segment Name (Portion Covered by TDH Fish Consumption Ban)	Fish Tissue Contaminants on the 303(d) List	TDH Ban Issued
0841	Lower West Fork Trinity River (entire segment from the confluence with Village Creek to the end of the segment at the confluence with the Elm Fork Trinity River)	Chlordane	01/1990
0805	Upper Trinity River (lower 19 miles of the segment from the Elm Fork Trinity River confluence in west-central Dallas County to Interstate 20 in southeast Dallas County)	Chlordane	01/1990
0841A	Mountain Creek Lake (entire lake)	Chlordane DDT, DDD, and DDE Dieldrin Heptachlor epoxide PCBs	04/1996

All or part of four classified segments of the Trinity River in Tarrant and Dallas Counties do not support the fish consumption use. The impacted portions of these segments extend from the Clear Fork Trinity River at 7th Street in Fort Worth, downstream to the Trinity River at Interstate 20 in southeast Dallas County. TDH issued Aquatic Life Order 2 on January 4, 1990, declaring the entire length a "prohibited area for the taking of finfish" due to elevated levels of chlordane in fish tissue. Trinity River segments addressed in this document are:

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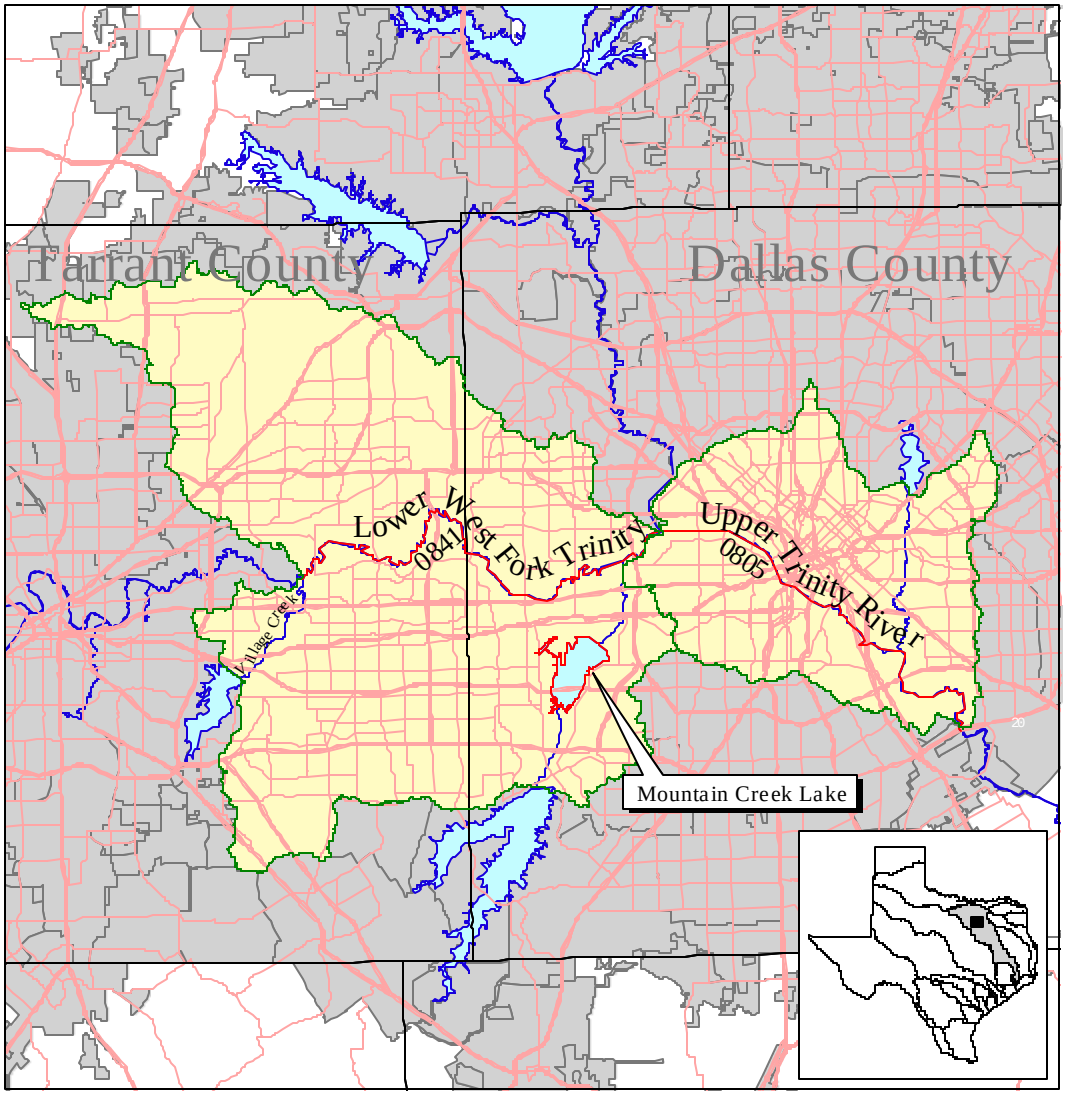

Figure 1. Location of Impaired Water Bodies

- Segment 0841 (Lower West Fork Trinity River) extends from a point immediately upstream of the confluence of Village Creek in east-central Tarrant County, downstream to a point immediately upstream of the confluence of the Elm Fork Trinity River in west-central Dallas County. The fish consumption use is not supported through the entire 27-mile segment.

- Segment 0805 (Upper Trinity River) extends from a point immediately upstream of the confluence of the Elm Fork Trinity River in west-central Dallas County, downstream to a point immediately upstream of the Cedar Creek Reservoir discharge canal in Henderson/Navarro County. The fish consumption use is not supported through the upper 19 miles of the segment, from the Elm Fork Trinity River confluence downstream to Interstate 20 in southeast Dallas County.

Segment 0841 and the impaired portion of Segment 0805 drain a combined watershed of 618,774 acres downstream from the dams on seven major reservoirs (Benbrook, Worth, Arlington, Mountain Creek, Grapevine, Lewisville, and White Rock). The watershed is approximately 71 percent urban and 24 percent agricultural/undeveloped land use (data compiled from *1999 Annual Water Quality Management Plan, North Central Texas Council of Governments, Arlington, Texas*). Three major regional wastewater treatment plants (WWTP) discharge into Segments 0841 and 0805 (City of Fort Worth Village Creek WWTP, Permit No. 10494-013; Trinity River Authority Central WWTP, Permit No. 10303-001; and City of Dallas Central WWTP, Permit No. 10060-001), with a current combined capacity of almost 500 million gallons per day. Flow in both segments is dominated by WWTP effluent during dry times of the year.

The fish consumption use is not supported in Mountain Creek Lake (Segment 0841A), a 2710-acre impoundment of Mountain Creek located in southwest Dallas County. Aquatic Life Order No. 12 was issued on 25 April 1996, declaring Mountain Creek Lake a "prohibited area for the possession of all fish species" due to elevated levels of chlordane, DDT, DDD, DDE, dieldrin, heptachlor epoxide, and PCBs in fish tissue.

Mountain Creek is a tributary of the West Fork Trinity River (Segment 0841). The lake was impounded in January 1937 as a cooling water reservoir for an adjacent power plant (Dowell and Breeding 1967). Heavy siltation reduced the lake storage capacity from the original 40,000 acre-feet to 25,720 acre-feet by 1963 (Dowell and Breeding 1967), and to a current capacity of approximately 20,200 acre-feet (Ulery *et al.* 1993). Mountain Creek Lake drains a 46,130-acre watershed downstream from the dam on Joe Pool Lake. Mountain Creek Lake received runoff predominately from undeveloped, rural, and agricultural areas between its impoundment in 1937 and the construction of Joe Pool Lake immediately upstream in 1985. Extensive development has occurred west of Mountain Creek Lake since 1985. The watershed is currently 60 percent urban and 35 percent agriculture/undeveloped land use. Three major industrial facilities are located adjacent to the lake:

- The Mountain Creek Steam Electric Station, currently owned by TXU Electric & Gas (TXU), is located on the northeast corner of the lake. The facility began operation in June 1938, when it was owned by the Dallas Power and Light Company. The plant is powered by natural gas, and uses the lake for cooling water, which is discharged back to the lake (Permit No. 01250).

- The U.S. Naval Weapons Industrial Reserve Plant (NWIRP) is located on 314 acres on the northwest corner of the lake. NWIRP was constructed in phases beginning in 1940. Ownership of NWIRP transferred to the U.S. Navy in 1947. Three-quarters of the site had been developed by the 1960s. The property is currently leased to the Northrop Grumman Corporation, which employs approximately 4000 people in the manufacture of commercial and military aircraft components and various weapons systems. Land cover at NWIRP is primarily industrial buildings and paved areas (Raines *et al.* 1997; EnSafe 2000b).

- The U.S. Naval Air Station Dallas (NASD) is located on 827 acres on the northwest corner of the lake, adjacent to NWIRP. Hensley Field was established at the site in 1929 as a training field for reserve pilots. The U.S. Navy established a naval reserve training base at the site in 1941. During World War II, the base also served as an aircraft engine repair station. In the early 1950s, a portion of Mountain Creek Lake was filled to extend the current NASD runway. The original discharge point of Cottonwood Creek, which was immediately southeast of NWIRP, was completely filled (EnSafe 2000b). A diversion channel was constructed to connect Mountain Creek Lake with Cottonwood Creek. NASD was officially closed in 1998, and is presently being redeveloped with various non-residential uses. The site is currently owned by the U.S. Navy (121 acres) and the City of Dallas (666 acres leased to the Navy and 40 acres leased to the Texas Army National Guard) (CH2M Hill 1999d). Land cover at NASD is primarily runways, hangers, office and commercial buildings, aircraft maintenance or automotive shops, barracks or high-density residential housing, and paved roads (Raines *et al.* 1997).

The U.S. Navy is conducting RCRA Facility Investigations at NWIRP and NASD to determine if waste management or disposal sites at either facility have released hazardous constituents to the environment. An associated study conducted by the U.S. Geological Survey (USGS) (Jones *et al.* 1997) detected the presence of several legacy pollutants in lake sediments and fish tissue. Evaluation of fish tissue data collected during the study led to issuance of the fish consumption ban.

The fish consumption use of a water body is not supported when TDH has issued an Aquatic Life Order prohibiting the consumption of aquatic life. The fish consumption bans on the water bodies addressed here are the result of contamination by one or more organochlorine insecticides, degradation products of organochlorine insecticides, and polychlorinated biphenyls (PCBs).

Organochlorine insecticides and PCBs were widely used in the U.S. prior to EPA restriction, and are common environmental contaminants (Moore and Ramamoorthy 1984; Schmitt *et al.* 1985, 1990; Smith *et al.* 1988; USGS 2000). These substances are a frequent cause of fish consumption advisories in the U.S. (EPA 1999b,c), and elevated concentrations of some of these contaminants are frequently found in game fish tissue (Kuehl *et al.* 1994). Fish consumption can be a primary route of human exposure to these contaminants (Schwartz *et al.* 1983; Humphrey 1987; Fiore *et al.* 1989), which can cause a variety of adverse health effects (Swain 1988; Longnecker *et al.* 1997). The Aquatic Life Orders for these water bodies were issued on the basis of an unacceptable carcinogenic risk of liver cancer and a noncarcinogenic risk of adverse liver effects due to fish tissue contaminant levels.

Endpoint Identification

The ultimate goal of these TMDLs is the reduction of fish tissue contaminant concentrations to levels that constitute an acceptable risk to fish consumers, allowing TDH to remove the bans on fish consumption. The allowable load of contaminant is based on fish tissue concentrations.

EPA (1997a) provides guidance for assessing contaminant data for risk assessment. This guidance and TDH assumptions were used to develop target values for tissue contaminant levels that result in an acceptable risk level. EPA (1997a) presents equations for calculating the maximum allowable fish consumption rate given consumer body weight, contaminant concentration, an acceptable cancer risk level, and the contaminant risk values for carcinogenic and noncarcinogenic risk. A cancer potency value (q_1*) is the risk value for carcinogens. The oral reference dose (RfD) is the risk value used to protect against chronic exposure by noncarcinogens.

The consumption rate and consumer body weight were set at the TDH constants of 30 grams of fish per day (0.03 kg/d) for a 70-kg adult, and at 15 grams of fish per day (0.015 kg/d) for a 15- and 35-kg child, both over a 30-year time period. TDH uses an acceptable cancer risk level of 1×10^{-4}, adjusted to 2.33×10^{-4} to account for the use of the 30-year time period. Cancer potency and chronic RfD values (Table 2) were obtained from EPA (1997a) and the EPA IRIS database.

Table 2. Maximum fish tissue concentrations (mg/kg) for individual contaminants that can be ingested by consumers of given body weights, within the acceptable cancer risk level (ARL) used by TDH, and without causing adverse noncarcinogenic health effects.

Carcinogenic (q_1*) and noncarcinogenic (RfD) risk values were obtained from EPA (1997a) and EPA IRIS database.

	Carcinogenic Risk ARL = 2.33 x 10^{-4}			**Noncarcinogenic Risk**		
	Maximum Fish Tissue Concentration (mg/kg)					
		Consumer Body Wt.			**Consumer Body Wt.**	
Contaminant	**q_1***	**15-kg**	**35-kg / 70-kg**	**RfD**	**15-kg**	**35-kg/70-kg**
Total Chlordane	0.35	0.67	1.55	5 x 10^{-4}	0.5	1.17
Total DDT[1]	0.34	0.68	1.6	5 x 10^{-4}	0.5	1.17
DDD	0.24	0.97	2.3	na	na	na
DDE	0.34	0.68	0.68	na	na	na
Dieldrin	16	0.015	0.034	5 x 10^{-5}	0.05	0.12
Heptachlor epoxide	9.1	0.03	0.06	1.3 x 10^{-5}	0.013	0.03
Total PCBs	2.0	0.12	0.27	2 x 10^{-5}	0.02	0.05

[1]Sum of 4,4'- and 2,4'- isomers of DDT, DDE, and DDD (EPA 1997a).
na = Separate RfDs not available for DDE and DDD.

Equations in EPA (1997a) were solved to calculate the maximum allowable concentration of contaminant in tissue (1) at a given cancer risk level, and (2) based on the noncarcinogenic health effects of a contaminant:

$$(1) \qquad C_m = (ARL)(BW) / (C_{lim})(q_1^*)$$

$$(2) \qquad C_m = (RfD)(BW) / (C_{lim})$$

where:

C_m = maximum allowable concentration of contaminant in tissue (mg/kg)
ARL = acceptable cancer risk level = 2.33 x 10^{-4}
BW = consumer body weight (kg)
C_{lim} = allowable fish consumption rate (kg/d)
q_1* = cancer slope factor for given contaminant (see Table 2)
RfD = oral reference dose for given contaminant (see Table 2).

Substituting adult and child consumption rates and body weights used by TDH, the maximum tissue contaminant concentrations that can be consumed within an acceptable level of risk were calculated (see Table 2).

The calculated contaminant concentrations are valid targets only for each contaminant individually. The chlordane target can be used for the Trinity River segments because the TDH risk assessment identified chlordane as the risk factor. The target concentration that will achieve an acceptable noncarcinogenic risk is less than that needed for an acceptable carcinogenic risk. The target concentration for a 15-kg child is less than that of a 35-kg child and 70-kg adult (see Table 2). The noncarcinogenic value for a 15-kg child is therefore most protective, and this value (0.5 mg/kg) becomes the endpoint target for chlordane in the Trinity River segments (Table 3).

Table 3. Most protective endpoint target for fish tissue contamination in each 303(d)-listed water body that will allow removal of the TDH fish consumption ban.

Segment	**Primary Endpoint Target**
Lower West Fork Trinity River (0841)	$\leq$ 1.17 mg/kg chlordane in fish tissue for adults $\leq$ 0.50 mg/kg chlordane in fish tissue for children
Upper Trinity River (0805)	$\leq$ 1.17 mg/kg chlordane in fish tissue for adults $\leq$ 0.50 mg/kg chlordane in fish tissue for children
Mountain Creek Lake (0841A)	additive cancer risk $\leq 2.33 \times 10^{-4}$ cumulative noncarcinogenic hazard index $\leq$ 1
All Water bodies	Removal of fish consumption bans

The situation is different in Mountain Creek Lake, where multiple contaminants were determined to be contributing to risk. TDH assumes that risk is additive when more than one contaminant is present at sufficient levels. The additive risk of all contaminants cannot exceed either the cancer risk level or a noncarcinogenic hazard index. When multiple contaminants are present, the concentration of one or more must be reduced so that the additive carcinogenic risk does not exceed 2.33×10^{-4}. The endpoint target for carcinogenic risk in this case is an additive risk that is no greater than the acceptable cancer risk level (Table 3).

The noncarcinogenic hazard index is the sum of the hazard ratios of each individual contaminant, and must be no greater than one for noncarcinogenic risk to be acceptable. The hazard ratio of a contaminant is the ratio of the actual noncarcinogenic exposure level to the oral reference dose (RfD). When multiple contaminants are present, the concentration of one or more must be reduced so that the additive hazard index does not exceed one. The endpoint target for noncarcinogenic risk is a hazard index that is no greater than one (Table 3).

The calculated target values are valid only under the assumed conditions. TDH has the authority and jurisdiction for the decision to issue or remove fish consumption bans. Subsequent risk assessments by TDH may result in no change to a ban, removal of the ban, or a shift to an advisory for certain groups at greater risk. The ultimate endpoint goal for the affected water bodies is the protection of all groups and complete removal of the fish consumption bans.

Source Analysis

Production and use of legacy pollutants has been banned or severely restricted by the EPA. Because of their past heavy and widespread use, strong affinities for sorption to sediment organic matter and tissue, and slow rates of decomposition, these substances and/or their degradation products frequently remain at elevated levels in the environment for many years after widespread use has ended (Moore and Ramamoorthy 1984; Smith *et al.* 1988; Jones and de Voogt 1999; USGS 2000).

- Chlordane was introduced in 1948, and was used extensively as a broad spectrum insecticide to control soil insects on agricultural crops, as a home lawn and garden insecticide, as a fumigating agent, and for termite control (EPA 1980b; Dick 1982; Dearth and Hites 1991). EPA suspended use of chlordane on food crops in 1978, and phased out other above-ground uses over the following five years (EPA 1997b; Mattina *et al.* 1999). All uses except underground application for termite control were banned in 1983 (Mattina *et al.* 1999). Manufacture and domestic sales were halted in 1987, and use of existing stores was allowed until April 1988 when sale and use were terminated (Dearth and Hites 1991; EPA 1997b; Mattina *et al.* 1999).

- DDT was initially used in World War II for control of disease-carrying insects, and was used extensively as a broad spectrum insecticide for the control of almost all agricultural and disease-carrying insects (EPA 1980c; NPTN 1999). It was used extensively in the 1950s and 1960s for mosquito control in urban areas. DDD is a metabolite of DDT, and was itself manufactured as a pesticide for several years. Most uses of DDT, and all uses of DDD, were banned by EPA in December 1972 (EPA 1980c). DDE is the major degradation product of DDT and DDD, and is among the most widely occurring pesticide residues (Schmitt *et al.* 1990; Kuehl *et al.* 1994).

- Dieldrin was used as a pesticide, and is a degradation product of the pesticide aldrin. Although aldrin was used in greater quantity, it is rapidly converted to the more persistent dieldrin in the environment (EPA 1980a; Dick 1982). Both pesticides were used primarily for the control of corn rootworm and cutworm, with some use in the citrus industry and for mosquito larvae and termite control (EPA 1980a; Dick 1982). All food crop uses of both compounds were canceled in May 1975, and only subsurface injection for termite control was allowed after that time. All remaining uses were canceled in 1987.

- Heptachlor epoxide is the principal metabolite of the pesticide heptachlor. Heptachlor was used as a broad spectrum insecticide for the control of insects on corn and other crops, cotton insects, alfalfa weevils, termites, and for fire ant control prior to the introduction of mirex in the 1950s (EPA 1980d; Dick 1982). Heptachlor was isolated from chlordane, and typically included various chlordane components (EPA 1980d). Chlordane residues may be present in locations where heptachlor was used. Both heptachlor and the hepatachlor component of chlordane are frequently converted to heptachlor epoxide in the environment (see Schmitt *et al*. 1985). EPA suspended the registration for all food crop and home use of heptachlor as of August 1976 (EPA 1980d). Commercial use on nonfood plants continued until July 1983, after which the only approved use was for underground application for termite control. Remaining uses were canceled in 1988 as part of the ban on chlordane and chlordane-containing products.

- Polychlorinated biphenyls (PCBs) are a group of synthetic organic chemicals containing 209 possible individual compounds, which vary in chemical and physical properties, toxicity, environmental persistence, and degree of bioaccumulation (EPA 1980e, 1999b). PCBs were manufactured as mixtures of different congeners, and generally sold under the trade name Aroclor. PCBs were most widely used as coolants and lubricants in transformers, capacitors, and other electrical equipment. In 1976 the Toxic Substances Control Act banned, with limited exceptions, the manufacture, processing, distribution in commerce, and use of PCBs (EPA 1994). TSCA also required the EPA to promulgate regulations for proper use, cleanup, and disposal. TSCA and subsequent EPA rules did not require PCB-containing materials to be removed from service, and many are still in use (EPA 1999b). A substantial portion of the PCBs manufactured before 1977 remain in service, although these are being phased out as equipment is replaced or decontaminated.

Organochlorine insecticides have entered aquatic systems as a result of direct application to a water body, drift from aerial spraying, urban and agricultural runoff, spills, industrial and municipal wastewater discharges, and erosion of contaminated soils (Dick 1982; Smith *et al*. 1988; Van Metre *et al*. 1998). PCBs can enter the environment via spills and leaks from sites where they are used, improper disposal methods, and leaching from landfills (Tanabe 1988).

Studies that have examined the relationship between land use and contamination by legacy pollutants suggest that problems can originate from both urban and agricultural land uses, although determination of a specific source can be very difficult (Tate and Heiny 1996; Munn and Gruber 1997; Webster *et al*. 1998). Numerous studies have associated organochlorine pesticide and PCB residues in tissue and sediment with urban land uses (Stamer *et al*. 1985; Arruda *et al*. 1987; Smith *et al*. 1988; Pereira *et al*. 1996; Mattina *et al*. 1999; Black *et al*. 2000).

Chlordane contamination in the Trinity River segments appears to have originated from urban areas, as the watershed for these segments is highly urbanized. Erosion as a result of extensive urban development over the past 10 to 15 years may have contributed contaminants attached to source soils. Ulery and Brown (1995) evaluated a number of available data sets from the Trinity River Basin, and found a significant correlation between sediment chlordane presence and urban land use. Irwin (1988) found concentrations of total chlordane in mosquitofish to be strongly associated with residential runoff from the area. Kleinsasser and Linam (1989) found elevated chlordane levels in fish collected within the area covered by TDH consumption ban, and suggested urban or suburban runoff as the source.

Recent household hazardous wastes received at the City of Fort Worth Environmental Collection Center have included chlordane, suggesting some recent or possible continued use in the area. Urban residents may have continued using existing stocks of chlordane since it was in use longer than some of the other legacy insecticides. Van Metre and Callender (1997) found the chlordane peak in sediment cores from White Rock Lake in Dallas to have occurred around 1990, reflecting its relatively recent urban use. Extensive sampling of storm water outfalls in the seven Phase I storm water cities in the Dallas-Fort Worth area in 1992-1993 (Baldys *et al*. 1998) detected low levels of chlordane (0.1-1.2 Fg/L) in 22 percent of samples from residential areas, 21 percent from commercial areas, and ten percent from industrial areas.

Legacy pollutant contamination in Mountain Creek Lake probably originated from a variety of land use sources. Much of the current lake watershed is urban land use, and the above discussion concerning chlordane association with urban areas also applies to the Mountain Creek Lake watershed. The storm water outfall sampling performed in 1992-1993 (Baldys *et al.* 1998) also detected dieldrin and heptachlor in a small ($\leq$12 percent) number of samples draining residential areas. Agricultural runoff was a dominant contributor to Mountain Creek Lake prior to the construction of Joe Pool Lake and the subsequent extensive urbanization in the area. The past use of pesticides on cropland may also be a factor in the pesticide residues in Mountain Creek Lake. Subsequent erosion as a result of recent urban development west of the lake may have contributed contaminants attached to the source soils.

Baldys *et al*. (1998) detected small amounts (0.1-0.8 Fg/L) of PCBs in storm water outfalls draining industrial land uses. No PCBs were detected in drainage from residential and commercial land uses. There have been no known PCB-oil spills or releases of PCBs to Mountain Creek Lake from the TXU power plant. TXU has replaced all PCB transformers at the facility as a part of an overall company phase-out of PCB-containing equipment. The RCRA Facility Investigations at the NASD and NWIRP facilities have discovered legacy pollutant contamination at some of the waste management units at these sites. Most of the storm water runoff from both facilities discharges to the lake (Raines *et al*. 1997; EnSafe 2000a); however, recent sampling of runoff from NWIRP and NASD did not detect any of 27 organochlorine insecticides and PCBs analyzed (Raines *et al*. 1997). Cleanup of legacy pollutant contamination at NWIRP and NASD is being addressed through the TNRCC Defense and State Memorandum of Agreement Program.

Naval Weapons Industrial Reserve Plant (NWIRP)

Storm water drainage, water from building foundation French drains, and groundwater infiltration enters storm sewers that discharge into two drainage lagoons at NWIRP. The lagoons discharge directly to the lake (EnSafe 2000b). The baseline environmental survey for the site (EnSafe 2000b) concluded that records concerning pesticide application are not known in sufficient detail to characterize historical usage; however, pesticides are not expected to be a problem requiring any significant remediation.

PCB-containing equipment used at NWIRP has included transformers, light ballasts, and machines with PCB oils. The only documented PCB release occurred in summer 1993, adjacent to a transformer station. The affected area was subsequently remediated (EnSafe 2000b). PCBs were also detected in a drainage ditch adjacent to a plant salvage yard that has been in use since 1986. The baseline survey concluded that the contaminated drainage ditch was adequately remediated (EnSafe 2000b). U.S. Navy policy was to eliminate PCB transformers, capacitors, and PCB-containing equipment from its facilities by 1998. NWIRP began a removal program in 1991, and Northrop Grumman reports that all PCB-containing equipment has since been removed from the site (EnSafe 2000b).

U.S. Naval Air Station Dallas (NASD)

Cleanup activities at NASD were initiated to comply with the requirements of the TNRCC Industrial Solid Waste Part B Permit (HW-50276) for the site, and the 1993 Defense Base Realignment and Closure Act (CH2M Hill 1999d). The permit requires that a RCRA Facility Investigation be conducted to characterize and remediate any past contamination from base solid waste management units (SWMU). Remediation must meet the TNRCC Risk Reduction Standards contained in Title 30 Texas Administrative Code, Chapter 335, Subchapter S.

Soil sampling at NASD detected the presence of chlordane isomers, DDT, DDE, dieldrin, heptachlor epoxide, and PCBs (Tetra Tech 1999, 2000). Corrective actions (soil excavation and removal and site restoration) have been implemented to address soil contamination (see Ch2M Hill 1999c). Pesticide residues were most commonly detected in former container storage areas, and do not appear to be a major problem.

The NASD facility investigation detected one significant site of PCB contamination, at SWMU 85 located west of the crash/rescue boat dock in the south-central portion of the facility. PCB transformers and capacitors were stored in this area between 1975 and 1982 (CH2M Hill 1999a,b,d). PCBs were found in a number of the transformer oils sampled in 1982, and soil sampling around leaking transformers found PCB levels of up to 151,500 mg/kg in a contaminated area of approximately 500 square feet (CH2M Hill 1999d). A total of 40 cubic yards of soil was removed from the area (CH2M Hill 1999b,d). Follow-up sampling revealed residual PCB contamination in two small areas of SWMU 85 (CH2M Hill 1999d). Further recommendations were made to excavate the contaminated soils, and to conduct sampling in an adjacent ditch and outside the SWMU 85 fence in the northwest corner to evaluate any lateral distribution (CH2M Hill 1999a). A work plan for the excavation and removal of remaining PCB-contaminated soils was developed (CH2M Hill 1999d), and the site has since been remediated.

Linkage Between Sources and Receiving Waters

The time required for the reduction of legacy pollutant tissue concentrations to endpoint levels is a function of their persistence and fate in the environment. Organochlorine insecticides and PCBs are extremely hydrophobic, and their affinity for sorption to soil and sediment, along with their tendency to partition into the lipid of aquatic organisms, determine their transport, fate, and distribution (Smith *et al.* 1988).

Numerous studies have documented the long-term persistence of organochlorine pesticides and their degradation products in soil. Pesticide residue concentrations in soils can span several orders of magnitude, and are a reflection of application history and loss rates (Lichtenstein *et al.* 1971; Harner *et al.* 1999). Heavily used pesticides will be present in higher concentrations years later. Degradation rates of organochlorine residues are highly variable, and soil half-lives of as much as 20 to 35 years have been reported (Nash and Woolson 1967; Dimond and Owen 1996; Mattina *et al.* 1999).

The primary method of transport of legacy pollutants into aquatic systems is by erosion of soil and attached contaminants (Munn and Gruber 1997). Sedimentation has been observed to be a major cause of legacy pollutant loss from the water column, particularly in lakes (Hamelink and Waybrant 1976; Schnoor 1981; Bierman and Swain 1982). Aquatic sediments act as a reservoir for hydrophobic pesticides and PCBs (Moore and Ramamoorthy 1984). Contaminants may be present in sediment at concentrations that are orders of magnitude higher than in the water column, where they are typically very low or undetectable (see Smith *et al.* 1988).

These contaminants degrade slowly, and may be present for long periods of time (Oliver *et al.* 1989; EPA 1999b). Van Metre *et al*. (1998) analyzed sediment core samples from 11 reservoirs, including White Rock Lake in Dallas, and determined mean sediment half-lives of 7.7 to 17 years for chlordane, 13 $\pm$ 5.8 years for total DDT, and 9.5 $\pm$ 2.2 years for PCBs. Field and laboratory studies of contaminated sediments have found that the greatest amount of PCB dechlorination occurs during a relatively short and rapid initial phase after contaminant input, but then slows or effectively ceases (Rhee *et al.* 1993; Sokol *et al.* 1998).

Sediments may act as long-term sources of contamination through desorption of contaminants, and as a result of the resuspension of sediment particles by disturbances (Oliver *et al.* 1989; Baker *et al.* 1991; Zaranko *et al.* 1997; Maher *et al.* 1999). Sediment-associated contaminants can be a long-term source of chronic toxicity to organisms that live or feed in contact with the sediments, and provide a source for the introduction of contaminants into the food web (Reynoldson 1987; Farrington 1991; Larsson 1986).

Organochlorine insecticides and PCBs are highly lipophilic and rapidly accumulate in the tissue of aquatic organisms. Contaminant concentrations are found in fish tissue at levels considerably higher than that of the water column and sediments (Smith *et al.* 1988; Rinella *et al.* 1993; EPA 1997a, 1999b). Fish tissue contaminant concentrations can vary within the same water body (Stow *et al*. 1995; Lamon and Stow 1999), and among different fish species, size classes

within a fish species, and various tissues within a fish (Swackhamer and Hites 1988; EPA 1997a).

A large number of factors have been found to influence contaminant uptake, accumulation, and elimination in fish and other aquatic organisms. Characteristics of fish species and their environments are very important to uptake and elimination processes (Swackhamer and Hites 1988). Fish characteristics include lipid content, age, length, weight, diet and feeding habits, reproductive status, contaminant transfer from females to young, growth dilution, metabolism, and other species-specific physiological factors. Environmental factors include contaminant levels in food items, trophic position and length of the food chain, habitat use and movement, seasonal variation in contaminant availability, water column contaminant concentration, and sediment contaminant concentration and bioavailability. The relative importance of these factors is much debated, and research has found the effects of many of them to be interrelated (Smith *et al.* 1988; Farrington 1991; Pritchard 1993; Jones and de Voogt 1999; Gobas and Morrison 2000; Sijm *et al.* 2000).

Characteristics of the contaminants also affect their tissue concentrations. These factors include differences in isomer and residue bioavailability, equilibrium time, and susceptibility to uptake, biotransformation, and elimination. Schmitt *et al.* (1985) found that changes in tissue concentrations over time vary with differences in chlordane and PCB isomers. Significant differences have been found in the accumulation rates of different PCB congeners, and in the degree of accumulation within different fish body tissues (Gruger *et al.* 1975; van der Oost *et al.* 1988; Zhou and Wong 2000).

The time necessary for a contaminant to reach equilibrium in tissue is variable, hard to determine, and generally very long. Stable organic compounds with low aqueous solubility, such as many legacy pollutants, generally exhibit the longest equilibrium times. Time to equilibrium is also a function of fish size, with larger fish accumulating contaminants at a slower rate (Smith *et al.* 1988).

Once equilibrium is reached, the time necessary for a contaminant to be eliminated from tissue is also long, often on the order of years, and variable, generally increasing with the hydrophobicity and lipophilicity of the compound (Larsson 1986). Contaminant elimination may occur through respiration, metabolism, egestion, growth dilution, and transfer to eggs or young (Sharpe and Mackay 2000). Elimination rates can also be affected by the form of the contaminant (Niimi and Oliver 1983; Sijm *et al.* 1992; de Boer *et al.* 1994), especially in the case of PCBs. Schnoor (1981) calculated a dieldrin decrease of 15 percent per year in reservoir fish tissue. Half-lives for DDT, DDE, and PCBs in lake trout have been estimated at 9 to 10 years (see Borgmann and Whittle 1992; Van Metre *et al.* 1998). Delorme *et al.* (1999) suggest that hydrophobic contaminants may not remobilize from fish tissue unless severe nutritional stress occurs.

In addition to generally excluding the effects of contaminated sediment and food, most studies of contaminant uptake and elimination are relatively short-term laboratory experiments (de Boer

et al. 1994; Sijm *et al*. 2000). Long-term field studies have generally found that elimination rates are considerably longer than in those measured in laboratory studies (de Boer *et al*. 1994; Delorme *et al*. 1999). The interval between bioconcentration and elimination may be too short in laboratory studies to allow equilibrium within all tissues, allowing elimination to proceed much faster than in a field situation. Published uptake and elimination rates derived from laboratory studies may not reflect field conditions, limiting their use for the prediction of contaminant behavior (Swackhamer and Hites 1988; de Boer *et al*. 1994).

Trinity River

Available Trinity River sediment and fish tissue data indicate that chlordane concentrations are decreasing as a result of natural attenuation processes. Davis and Bastian (1990) found evidence that sediment chlordane levels were decreasing in samples collected between 1974 and 1989 (Table 4). Declines were noted at three locations on Segments 0806 and 0841. A decrease was not evident in samples from the downstream third of the impaired portion of Segment 0805 in southeast Dallas. Subsequent data collected in 1992-1993 by Moring (1997) suggests that reductions have occurred in this area. The data suggest that sediment chlordane levels are decreasing in the affected area, thus removing a significant source of potentially bioavailable contamination.

Table 4. Chlordane concentrations (mg/kg) in Trinity River sediment.
Data for 1974 through 1989 are mean values reported by Davis and Bastian (1990). Data for 1992-1993 are the sum of five chlordane isomers and metabolites reported by Moring (1997).

Segment	Sample Location	1974-1979	1980-1985	1986-1989	1992-1993
0806	West Fork Trinity at Beach Street (Fort Worth)	0.050	0.018	0.006	0.013
0841	West Fork Trinity at Belt Line Road (Grand Prairie)	0.266	0.014	0.005	---
	West Fork Trinity at West Loop 12 (Dallas)	0.174	---	0.010	---
0805	Trinity River at South Loop 12 and Interstate 20 (Dallas)	0.098	---	0.150	0.011

Fish tissue data are available for several sample dates. Samples frequently consisted of a relatively small number of fish, and most often included largemouth bass and/or one or more of the bottom-feeding common carp, smallmouth buffalo, and blue catfish. Mean contaminant levels for each sample date and location were calculated using available fish fillet data, to see if any changes were apparent in tissue concentrations (see Table 5). The Segment 0806 location was included to provide additional data because it is in the downstream end of the segment, near the upstream end of Segment 0841.

There is some evidence of a decline in chlordane tissue concentrations along the Trinity River. Sample collections near Loop 820 in Segment 0806 in 1990 and 1996 show a decline in both the mean and maximum chlordane level. The only data available for Segment 0841 is the 1998 sample collected downstream from Belt Line Road, near the downstream end of the segment. The mean and maximum chlordane concentrations in Segment 0841 are similar to those of the 1996 sample collected at Loop 820 in Segment 0806, suggesting a general decline in tissue chlordane through both segments.

TABLE 5. Fish tissue chlordane means and ranges in Trinity River segments.
N = number of fish. na = not applicable. nd = less than detection limit.

Sample Month and Year		**08/1987**	**01-04/1988**	**10/1990**	**07/1996**	**11/1998**
Segment/Sample Location		**Fish Tissue (Fillets) Concentration (mg/kg)**				
0806 - West Fork Trinity at Loop 820 (Fort Worth)	N Mean Range	---	---	5 0.13 nd-0.28	3 0.03 nd-0.06	---
0841 - West Fork Trinity two miles downstream Belt Line Road (Grand Prairie)	N Mean Range	---	---	---	---	10 0.04 nd-0.13
0805 - Trinity River at Elm Fork Trinity (Irving/Dallas)	N Mean Range	---	---	---	---	10 0.24 nd-0.84
0805 - Trinity River at Sylvan Avenue (Dallas)	N Mean Range	---	---	4 0.39 nd-0.98	---	---
0805 - Trinity River at Commerce Street (Dallas)	N Mean Range	---	4 0.71 0.50-0.84	---	3 0.14 0.02-0.29	---
0805 - Trinity River at South Loop 12 (Dallas)	N Mean Range	1 0.50 na	---	---	3 0.18 0.04-0.26	---

Sources of Data:

Kleinsasser and Linam (1989)
Texas Department of Health (*Fish Tissue Sampling Data 1970-1997* and unpublished 11/1998 data)
Texas Parks & Wildlife Department (unpublished 10/1990 and 07/1996 data)

Samples were collected at the upstream end of Segment 0805, at the confluence with the Elm Fork Trinity River, in late 1998. Earlier samples were collected just downstream at Sylvan Avenue in 1990, and at Commerce Street in 1988 and 1996. These locations are relatively close, and taken together, the data suggest a general decline in tissue chlordane concentrations through time (see Table 5). Fish were collected downstream at South Loop 12 in 1987 and

1996. A decline is also suggested; however, sample sizes in this area of the segment were very small.

Mountain Creek Lake

Sediment and fish tissue samples were collected in Mountain Creek Lake in 1994-1996 as part of a two-phase USGS study (Jones *et al.* 1997) conducted for the U.S. Navy in conjuction with the facility investigations at NWIRP and NASD. Phase I sediment samples were collected from a variety of locations in the lake (see Table 6). Pesticide residue levels were generally less than 0.01 mg/kg. Surface sediment PCB concentrations were greater in Cottonwood Bay (up to 0.8 mg/kg) and adjacent to NASD (up to 0.099 mg/kg) relative to other locations. Sediment core samples collected in Cottonwood Bay contained PCB concentrations of up to 4.0 mg/kg. Sediment samples collected from drainage areas on NASD property contained low levels of some pesticide residues, and PCB concentrations as high as 3.2 mg/kg at one location.

Phase II sediment sampling (Jones *et al.* 1997) focused on Cottonwood Bay and the lake adjacent to NASD (Table 6). Pesticide residues were again relatively low. PCBs were analyzed as three separate congeners. The greatest concentrations, 0.680 mg/kg near NASD and 0.420 mg/kg in Cottonwood Bay, were the Aroclor 1260 form.

Table 6. Summary of Legacy Pollutant Concentrations (Mg/kg) in Mountain Creek Lake surface sediment.
Data summarized from Jones *et al.* (1997). nd = less than detection limit.

	Range of Sediment Concentrations (mg/kg)						
Sample Location Phase I	**Chlordane**	**DDT**	**DDD**	**DDE**	**Dieldrin**	**Heptachlor epoxide**	**PCBs**
Upstream end of lake	nd	nd	0.0003	0.0008	nd	nd	0.002
Mid-lake	nd	nd	nd	0.0004	nd	nd	0.003
Downstream end of lake	nd	nd	nd	0.0004	nd	nd	0.002
Adjacent to TXU plant	0.001	nd	nd	0.0004	nd	nd	0.003
Inlet to lake from Cottonwood Bay	0.005	nd	0.0005 - 0.0017	0.0004	0.0005	nd nd	0.006 - 0.007
Adjacent to NASD and NWIRP	nd - 0.007	nd	nd - 0.0056	0.0004 - 0.0023	nd - 0.0002	nd	0.007 - 0.099
Cottonwood Bay	0.003 - 0.016	nd - 0.0001	0.0005 - 0.0018	0.0003 - 0.0017	nd - 0.0024	nd	0.006 - 0.800
Phase II							
Cottonwood Bay and lake adjacent to NASD	nd - 0.022	nd - 0.0035	0.0002 - 0.011	0.0002- 0.0064	nd - 0.0006	nd	**nd - 0.680

**Analyzed as three separate congeners (Aroclor 1242, 1254, and 1260).

The greatest legacy pollutant concentrations in Mountain Creek Lake surface sediments are PCBs in Cottonwood Bay and adjacent to NASD. No subsequent sediment data is currently available to determine if any changes have occurred in PCB concentrations. Remediation of the NASD should eliminate any significant remaining PCB sources to Mountain Creek Lake. Natural attenuation will continue to reduce contaminant concentrations, while on-going sedimentation will continue to bury any remaining contaminated sediment. This appears to be occurring in three small urban lakes in Fort Worth that are also on the §303(d) list for legacy pollutants in fish tissue. Samples of recent sediment deposits were collected from these lakes in May 1999 by the Trinity River Authority and the City of Fort Worth. Pesticide residue and PCB concentrations were less than the detection limits (0.0007 mg/kg and 0.02 mg/kg, respectively) in all three lakes, suggesting that there have been no recent contaminant inputs to the lakes, and that any remaining contaminated sediments are being buried, thus reducing their bioavailability.

Phase I fish samples were collected at the upstream end of the lake, in the northwest corner adjacent to NASD, and in Cottonwood Bay (see Table 7). Contaminants were more commonly found in whole fish, and concentrations in whole fish were greater than those in fillets, as would be expected. PCBs and DDE were detected in both whole fish and fillets at all three locations. PCB concentrations were generally elevated at the NASD and Cottonwood Bay sites relative to the upstream lake location. Chlordane was detected in both whole fish and fillets near NASD. Dieldrin, DDT, and heptachlor epoxide were not detected in any of the samples.

Table 7. Concentrations of legacy pollutants (mg/kg) detected in Mountain Creek Lake fish tissue (Phase I samples).
Data summarized from Jones *et al.* (1997). All results are composites of 4-5 fish (whole-body common carp or largemouth bass fillets). nd = less than detection limit.

	Sample Location					
	Upstream end of lake		**Adjacent to NASD**		**Cottonwood Bay**	
Pollutant	whole carp	bass fillets	whole carp	bass fillets	whole carp	bass fillets
Chlordane[1]	0.11	nd	0.068	0.024	0.076	nd
DDD	0.013-0.018	nd	0.006-0.011	nd	0.065-0.070	nd
DDE	0.140	0.009-0.014	0.029-0.034	0.009-0.014	0.088	0.014-0.02
PCBs	0.590	0.063	1.60	0.580	4.20	0.30

[1]Sum of *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane concentrations.

Phase II fish samples consisted of fillets (both skin-on and skin-off) from individual largemouth bass, channel catfish, and common carp, and eviscerated whole-body channel catfish (Jones *et*

al. 1997). Fish from Mountain Creek Lake are cooked and consumed in all of these conditions (TDH 1996). Samples were collected in the same general areas sampled in Phase I, as well as along the northeast lake shoreline. Chlordane, DDE, and PCBs (Aroclors 1254 and 1260) were the most commonly detected legacy pollutants. The other pesticide residues were generally at concentrations less than the detection limit, and at very low concentrations when detected. TDH assessment of the data determined that there was no significant difference in carcinogenic risk between fillets with the skin on and those with the skin off. Carcinogenic risk was determined to be significantly higher for eviscerated whole fish (TDH 1996).

Tissue concentration ranges were compiled for the most commonly detected Phase II contaminants using data from Jones *et al.* (1997) (see Table 8). The greatest fillet values for chlordane and DDE were found at the upstream end of the lake. The greatest fillet values for PCBs were found adjacent to NASD, in Cottonwood Bay, and at the upstream end of the lake. The greatest whole fish values for chlordane, DDE, and PCBs were from the upstream location, Cottonwood Bay, and the northeast portion of the lake.

Table 8. Phase II concentrations ranges (mg/kg) of most common legacy pollutants in Mountain Creek Lake fish tissue.
Data summarized from Jones *et al.* (1997). Fillet data includes individual fish of three species (largemouth bass, channel catfish, and common carp), with both skin on and skin off. Whole fish are eviscerated channel catfish. N = number of fish. nd = less than detection limit.

	Fillet Tissue Concentration (mg/kg)			
Sample Area (Size)	**Chlordane**	**DDE**	**PCB 1254**	**PCB 1260**
Upstream end of lake (N = 8)	nd - 0.580	0.0089 - 0.150	nd - 0.410	0.005 - 1.7
Northeast shoreline (N = 11)	nd - 0.029	nd - 0.081	nd - 0.021	nd - 0.073
Cottonwood Bay (N = 13)	nd - 0.087	nd - 0.030	0.015 - 0.110	0.053 - 0.420
Adjacent to NASD (N = 21)	nd - 0.120	nd - 0.065	nd - 0.470	0.022 - 1.67
	Whole-body Tissue Concentration (mg/kg)			
	Chlordane	**DDE**	**PCB 1254**	**PCB 1260**
Upstream end of lake (N = 1)	0.220	0.160	0.074	1.0
Northeast shoreline (N = 2)	0.031 - 0.207	0.022 - 0.134	0.027 - 0.140	0.081 - 0.860
Cottonwood Bay (N = 5)	0.074 - 0.290	0.025 - 0.110	0.064 - 0.420	0.180 - 2.2
Adjacent to NASD (N = 1)	0.017	0.023	0.044	0.091

The presence of the larger contaminant concentrations in several areas of the lake is probably a reflection of both the widespread use of legacy substances and the movement of fish throughout the lake. Higher contaminant levels are generally more apparent in fish collected in Cotton-

wood Bay and adjacent to NASD. No subsequent fish tissue data is currently available, so no evaluation of any changes can be made at this time. With the exception of PCBs in one lake, fish tissue collected from the three Fort Worth urban lakes between 1988 and 1990 exhibited an average decline in maximum legacy pollutant concentrations of 75 percent. This suggests that contaminant levels will also decline in Mountain Creek Lake fish as a result of remediation of pollutant sources at NASD and natural attenuation processes in the lake.

Margin of Safety

A margin of safety is required in a TMDL in order to account for any uncertainty about the pollutant load and its association with water quality. The margin of safety may be an explicit component that leaves a portion of the potential assimilative capacity of a water body unallocated, or an implicit component established through the use of conservative analytical assumptions (EPA 1999a).

These TMDLs use an implicit margin of safety. EPA (1997a) guidance on the assessment of contaminant data for use in fish advisories contains an extensive discussion of the assumptions and uncertainties present in the calculation of fish consumption limits. Conservative assumptions and calculations are used throughout the guidance to provide a margin of safety for the various uncertainties. Strict criteria exist concerning the types of studies and the data required to support assumptions and calculations. Numeric adjustments are made for the extrapolation of study results from animals or humans to the general population, and to provide a conservative upper bound on cancer risk values and a conservative RfD for noncarcinogens. Adjustments are designed to provide a safe margin between observed toxicity and potential toxicity in a sensitive human.

EPA assumes no safe threshold for exposure to carcinogens. Any exposure is assumed to pose some cancer risk. Noncarcinogenic effects occur with chronic exposure over a significant period of time. The oral reference dose (RfD) is defined in EPA (1997a) as "an estimate (with uncertainty perhaps spanning an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime." Calculated RfDs reflect the assumption that, for noncarcinogens, a threshold exists below which exposure does not cause adverse health effects. RfD calculations use modifying and uncertainty factors to account for variables such as the variability of responses in human populations, differences in responses between animal study species and humans, and gaps in available data. The RfD is calculated so there is little probability of an adverse health effect due to chronic exposure to concentrations below the RfD (EPA 1997a).

The flexibility provided by having numerous combinations of contaminants and concentration reductions that can produce acceptable carcinogenic and noncarcinogenic risk when multiple contaminants are present provides an inherent margin of safety that the goal of acceptable risk will be met. Use of the most protective target concentration for single contaminants provides additional assurance that protection from both carcinogenic and noncarcinogenic effects will be achieved. Because the goal of this TMDL is removal of fish consumption bans through

reduction of the consumption risk, the margin of safety inherent in the EPA guidance, combined with the conservative use of endpoint targets, will provide an adequate margin of safety for the protection of human health. The decline of tissue contaminant concentrations to within an acceptable level of risk will allow TDH to remove the fish consumption bans, which will effectively restore the fish consumption use to these water bodies.

Pollutant Load Allocation

Restrictions on the use of legacy pollutants generally have resulted in a slow but steady decline in environmental residues (Smith *et al.* 1988). Contaminant levels in lake sediment cores have shown good agreement with production and usage histories of the parent compounds, with peak concentrations appearing at the times of peak use (Ricci *et al.* 1983; Oliver *et al.* 1989; Van Meter and Callender 1997; Van Metre *et al.* 1998). Higher concentrations generally appeared deeper in the cores, indicating that input and accumulation were decreasing with time. Although residues continue to persist in deeper parts of the cores, burial by more recently deposited sediments may result in effective exclusion of the contaminants from bioavailability to aquatic life (Ricci *et al.* 1983).

Decreases in fish and human tissue concentrations of organochlorine insecticides and PCBs have been observed where no major additional inputs are occurring (see Moore and Ramamoorthy 1984; Brown *et al.* 1985; Hovinga *et al.* 1992; Bremle and Larsson 1998). Reviews of tissue data collected from a variety of water bodies in northern Europe between 1967 and 1995 have found a significant decrease in organochlorine concentrations over time (Skåre *et al.* 1985; Bignert *et al.* 1998). Fish tissue concentrations of total DDT, chlordane, and dieldrin have declined across the U.S. since uses of these substances were discontinued (Schmitt *et al.* 1990; USGS 2000). The DDE component of total DDT has increased as a result of continued degradation. Declining tissue DDT and PCB concentrations have been reported in various locations and fish species in the Great Lakes (Scheider *et al.* 1998). Less consistent trends in tissue PCB levels may be a reflection of the congener-specific nature of PCB metabolism and degradation. In addition, strong oscillations in PCB levels influenced by food web interactions can be superimposed over a gradual declining trend (see Borgmann and Whittle 1992).

Continuing decreases in environmental legacy pollutant levels are expected, although the necessary time frame is subject to debate. Within the context of these TMDLs, legacy pollutants are considered background sources that reflect the site-specific application history and loss rates of the subject area. Continuing sources of pollutant loadings occur from nonpoint source runoff , leaching, or erosion of the various sinks that may exist within the watersheds. Any residual contamination at the NASD may be a source to Mountain Creek Lake while site remediation continues. No authorized point source discharges of these pollutants are allowed by law. Therefore, any contribution from point source discharges would be the result of illegal disposal of these contaminants by customers of the treatment systems.

Available evidence suggests that chlordane is generally declining in both the surface sediments and the fish tissue of the Trinity River. Continuing natural attenuation is expected via degradation and metabolism of the contaminant, and scouring and redistribution of sediments. Remediation of any remaining contamination at the NWIRP and NASD facilities through the TNRCC Defense and State Memorandum of Agreement Program will eliminate a significant source of PCBs to Mountain Creek Lake. Continuing natural attenuation in the lake is

expected via degradation and metabolism of pesticide residues and PCBs, and the burial of contaminated sediments.

Natural attenuation is generally a preferred option for the elimination of legacy pollutants. More drastic alternatives, such as sediment removal by dredging, can result in considerable habitat disturbance and destruction, and sediments resuspended during dredging further expose aquatic life to contaminants and the potential for additional uptake, cause abrasive damage to gills and sensory organs of fish and invertebrates, and interfere with fish prey selection (O'Brien 1990; Waters 1995). Alternatives such as dredging or eradication of contaminated fish communities and restocking (O'Meara *et al.* 2000) are generally better justified at sites heavily contaminated by point source discharges and major spills.

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