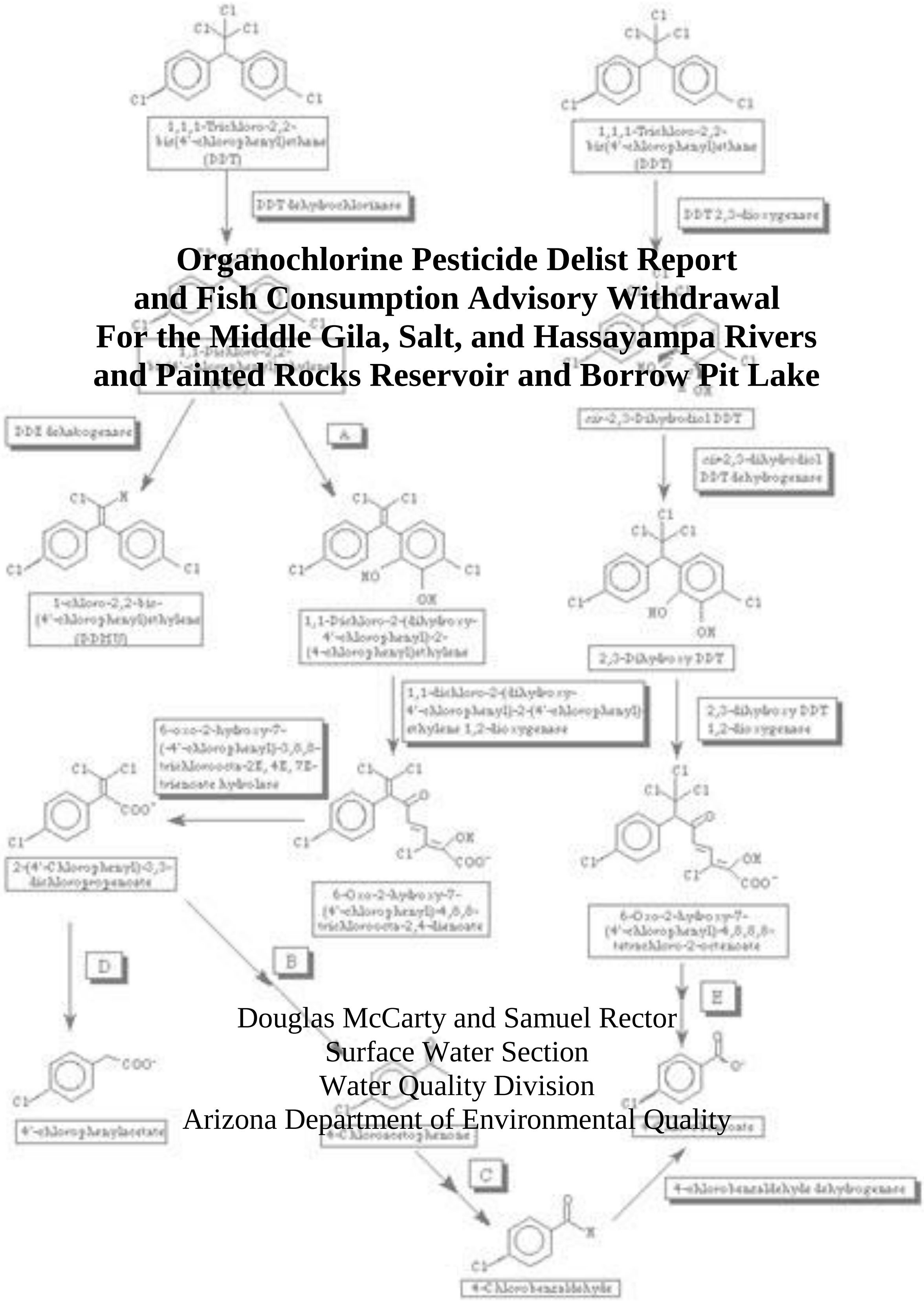

Organochlorine Pesticide Delist Report and Fish Consumption Advisory Withdrawal For the Middle Gila, Salt, and Hassayampa Rivers and Painted Rocks Reservoir and Borrow Pit Lake

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1.0 Executive Summary

Organochlorine pesticides such as DDT came into wide use in Arizona starting in the late 1940s. Because of DDT's low cost and relative effectiveness against the cotton bollworm infestation, almost 60 million pounds of DDT were applied to crops throughout the state. DDT was banned in Arizona in 1969 and nationally in 1972. Toxaphene came into wide use during the 1960s and early 1970s as a replacement for DDT. For a period of time it was one of the most heavily produced pesticides in the U.S. In 1982 it was banned for all but emergency use. Chlordane was first registered in the U.S. in 1948, and was widely used as a pesticide on agricultural crops, lawns, and gardens. In 1983, chlordane use was restricted to underground injection to control termites and in 1988, use was further limited to the control of fire ants in electrical transformers. The persistence and bioaccumulative potential of DDT, toxaphene, chlordane and their daughter products led to their subsequent build-up in fish and avian apex predators in the Middle Gila River drainage.

Beginning in the mid-1970s, sampling programs carried out by national and state agencies found concentrations of DDT residue (DDTr) that, along with other organochlorines and organophosphates, posed threats to human and ecosystem health. Because of the human health threat, a fish consumption advisory was issued for the Middle Gila and its tributaries in the early 1990s. This action was supplemented by EPA's 2002 listing of 12 reaches and water bodies in the Middle Gila watershed for harmful concentrations of DDT, chlordane and toxaphene residues in edible fish tissue. Since that time, tissue concentrations of organochlorines and other pesticides have shown a clear and steady decline, although data last gathered in 1999 still confirmed pesticide breakdown products at unhealthful concentrations.

Beginning in May 2012, ADEQ undertook pesticide sampling in fish tissue for the impaired segments of the Middle Gila watershed in support of an ongoing Total Maximum Daily Load investigation. A total of 54 fish tissue samples were taken by ADEQ personnel and combined with data from 13 samples taken in 2011 by the U.S. Fish and Wildlife Service (USFWS) at Painted Rock Borrow Pit Lake, for a total of 67. Toxaphene was not detected for any sample taken from an impaired reach or water body. Chlordane was not detected in any sample taken by ADEQ, but it was detected at low levels in six of 13 samples taken in the Painted Rock Borrow Pit Lake. DDTr was detected in 10 of the 54 samples taken by ADEQ from impaired segments and in the 13 samples taken in the Painted Rock Borrow Pit Lake by the USFWS. Geometric mean concentrations did not exceed current fish consumption screening values for any pesticide or pesticide residues analyzed for within the impaired reaches and water bodies. Geometric mean concentrations also met more stringent DDTr fish consumption screening values employed in a 1999 study for all locations.

Recommendations and actions: This report proposes the delisting of all listed reaches and water bodies in the Middle Gila watershed for legacy organochlorine pesticide impairments from Arizona's 2012/2014 CWA 303(d) Impaired Waters list, subject to final approval from EPA. ADEQ also proposes rescinding fish consumption advisories in place for all legacy pesticides in this watershed.

2.0 INTRODUCTION

Multiple reaches of the Gila, Salt, and Hassayampa rivers from the City of Phoenix 23rd Avenue Waste Water Treatment Plant (WWTP) to Painted Rock Dam were listed on Arizona's CWA 303(d) list of impaired waters in 2002 by EPA for excessive levels of DDT, DDD, DDE, chlordane, and toxaphene in fish tissue. Painted Rock Borrow Pit Lake below Painted Rock Dam and Painted Rock Reservoir were also listed for these pesticides. Periodic studies of varying extent and robustness dating to the early 1980s found high levels of DDT and its daughter products (DDD, DDE), chlordane, toxaphene, and dieldrin in fish tissue and soft-shell turtles, with a gradual decrease in fish tissue levels noted over time. Dieldrin was removed as a constituent of concern based on recommendations in the Priority Pollutant Program's 1999 study (Rector, 2000). Table 1 outlines the affected reaches and other pertinent descriptive information. The total length of all impaired reaches is 98.9 river miles. All listed reaches and water bodies share the same impairment analytes of DDTr, chlordane, and toxaphene. Figure 1 provides a location map of the affected reaches and water bodies.

Reach	Name	Terminus	Origin	Reach Length, mi.
AZL15070201-1010	Painted Rock Borrow Pit Lake	N.A.	N.A.	N.A.
AZL15070101-1020*	Painted Rock Reservoir	N.A.	N.A.	N.A.
AZ15070101-001*	Gila River/Painted Rock Reservoir	Painted Rock Reservoir	Sand Tank Wash	18.7
AZ15070101-005	Gila River/Painted Rock Reservoir	Sand Tank Wash	Rainbow Wash	16.9
AZ15070101-007	Gila River	Rainbow Wash	Gillespie Dam	5.1
AZ15070101-008	Gila River	Gillespie Dam	Centennial Wash	5.3
AZ15070101-009	Gila River	Centennial Wash	Hassayampa River	7.0
AZ15070103-001B	Hassayampa River	Gila River	Buckeye Canal	2.3
AZ15070101-010	Gila River	Hassayampa River	Waterman Wash	13.9
AZ15070101-014	Gila River	Waterman Wash	Agua Fria River	11.9
AZ15070101-015	Gila River	Agua Fria River	Salt River	3.7
AZ15060106B-001D	Salt River	Gila River	23rd Ave WWTP	14.1

*Painted Rock Reservoir co-located with Gila River Reach 001

Table 1. Pesticide-impaired reaches and water bodies, Middle Gila watershed

The purpose of this report is to convey the results of an extensive fish collection and analysis effort undertaken in 2012 and to present the rationale for the de-listing and withdrawal of fish consumption advisories of all segments of the Gila River and its tributaries outlined in Table 1. Pesticide-impaired reaches and water bodies, Middle Gila watershed
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2.1 Historic Watershed Research

Several studies and investigations of varying extent and robustness have been conducted on Middle Gila River organochlorine pesticide contamination since the late 1960s. Among others, these studies include data from the sample collection efforts of Clark-Krynitsky (1980), Kepner (1985), King (1994-95), and Rector (1999). Fish tissue data from the cited sampling efforts were used in this report (Section 6.0) for comparison of 2012 results against historic values. Kepner (1986) of USFWS summarized the findings of his 1985 data set:

Carp (Cyprinus carpio), channel catfish (Ictalurus punctatus), red-winged blackbird (Agelaius phoeniceus), Gambel' s quail (Callipepla gambelii), western whiptail lizard (Cnemidophorus tigris), and spiny softshell turtle (Trionyx spiniferus) were collected in triplicate whole body composites from each of ten stations located on the lower Gila River from Phoenix to Yuma… A total of 208 composite samples, which included 699 biological specimens, were submitted for analysis. All samples were scanned for 23 organochlorine pesticides, including dicofol…

The Gila River appeared to be the most DDT-burdened stream in the western United States based on 20 sampling stations (1966-68) operated by the U. S. Geological Survey Pesticides Monitoring Network (Manigold and Schulze 1969)…. DDE residue levels for channel catfish and replicate black crappie samples collected from Painted Rock Borrow Pit in December of the same year [1982] measured 18.0, 12.2 and 10.4 ppm, respectively. The national average (n=107) for whole body wet weight DDE in fish tissue is 0.20 ppm (Schmitt et al. 1985). All fish samples collected from Painted Rock had detectable amounts of DDD and toxaphene.

…The highest values of p,p'-DDE recorded for all species tested, except channel catfish, red-winged blackbird, and Gambel's quail, were collected at Station 5 where the Buckeye Canal empties into the Hassayampa River.

DDE residues were also elevated in carp, channel catfish, softshell turtles, and whiptail lizards. DDE values recorded for biota sampled in the lower Gila River clearly exceed the National Academy of Science and National Academy of Engineers 1.0 ppm criterion established for DDT and its metabolites for the protection of wildlife.

Toxaphene was detected in red-winged blackbird, carp, channel catfish, and softshell turtles. Previous studies have determined that toxaphene residues in fish tissue in excess of 0.4 to 0.6 ppm wet weight may be hazardous to fish health and presumptive evidence of significant environmental contamination…

Organochlorine residue trends were consistently elevated, particularly for those river reaches and irrigation conveyances between the Salt/Gila confluence and Painted Rock Borrow Pit.

Flood control and irrigation diversion dams, such as Painted Rock Reservoir and Gillespie Dam, appear to be acting as contaminant sinks for organochlorine pesticides. Contaminated sediments will continue to present a risk to fish and wildlife due to their ability to accumulate and biomagnify organochlorines. Collectively, the data presented in this report suggest that fish and wildlife are being exposed to a major source of DDE and toxaphene which present a threat of reduced viability and recruitment to wildlife resources of the lower Gila River drainage.

A fish consumption advisory was issued and has been in effect in the lower Gila River/Painted Rock Reservoir area since the early 1990s because of the high concentrations of DDT, chlordane, and toxaphene in fish and turtle tissues. In the course of subsequent sampling by the Priority Pollutant Sampling Program in 1994, several agricultural drains in the Phoenix area were sampled and showed high levels of pesticides in fish tissue. Very high levels of DDE (24 ppm) were found in carp tissue from the Dysart Drain in the northwest Phoenix metro area in 1994 (Rector, 1996). Carp from the Buckeye Canal had 5.5 ppm DDE with traces of DDD and DDT while bluegill taken at the western terminus of the Roosevelt Canal had tissue concentration of 3.4 ppm and also showed traces of DDD (Rector, 1996). A 1995 USFWS report, which repeated a study first done in 1985 (King et al, 1997), showed that there were still high levels of DDE and DDT in fish, soft-shell turtle and bird samples taken throughout the middle Gila River drainage southwest of Phoenix.

In November-December, 1999, the Arizona Priority Pollutant Sampling Program and the Water Quality Assurance Revolving Fund Program sampled three sites within the Gila River drainage for DDTr, dieldrin, and toxaphene. Sampling sites were located on the Gila River near Estrella Regional Park just below its confluence with the Agua Fria River, at the State Route 85 crossing, and at Gillespie Dam (Figure 1).

Arizona's state screening concentrations for the 1999-2000 study were derived from EPA fish consumption guidelines published in 2000 (EPA, 2000). While the 1999 study still showed concentrations of DDT residue (DDTr) in excess of the then-extant state screening concentrations for the initiation of a fish consumption advisory, fish tissues sampled at that time had considerably lower DDTr concentrations than found in previous studies of this area. Geometric mean concentrations for all 1999 samples of 0.12 mg/kg, a mean of 0.47 mg/kg, and a median value of 0.12 mg/kg was derived for DDTr. Each of these values was above the 1999 screening concentration of 0.065 mg/kg, as were 24 of the 33 individual samples (72.7 %). Dieldrin was not found above detection levels, leading to the dropping of fish consumption advisories for all reaches listed for this pesticide by 2002.

Toxaphene had historic fish tissue data associated only with the 1999 study. The data informing this study was a mix of quantitative analyses and presence/absence tests at various detection levels. Six quantified values were recorded with 11 "present" determinations; 16 values were non-detects. The value of the detection limit was used as the detected value for presence/absence tests for the purpose of historic analysis; other non-detects of quantitative data were evaluated using beta substitution methods (Appendix C). The geomean using beta substitution for all specimens (n = 33) for the 1999 study was 0.28 mg/kg. The 90th percentile for the set was 0.72 mg/kg. Toxaphene results from the 1999 study showed an increase in concentrations for sites considered successively downstream, ranging from 0.15 mg/kg at the Baseline/Meridian site to a high of 0.31 mg/kg at Gillespie Dam.

Historic data for chlordane was not available for consideration or comparison; chlordane was not analyzed for in the 1999 study due to interference from the other constituents. No chlordane data prior to 1999 was available for consideration.

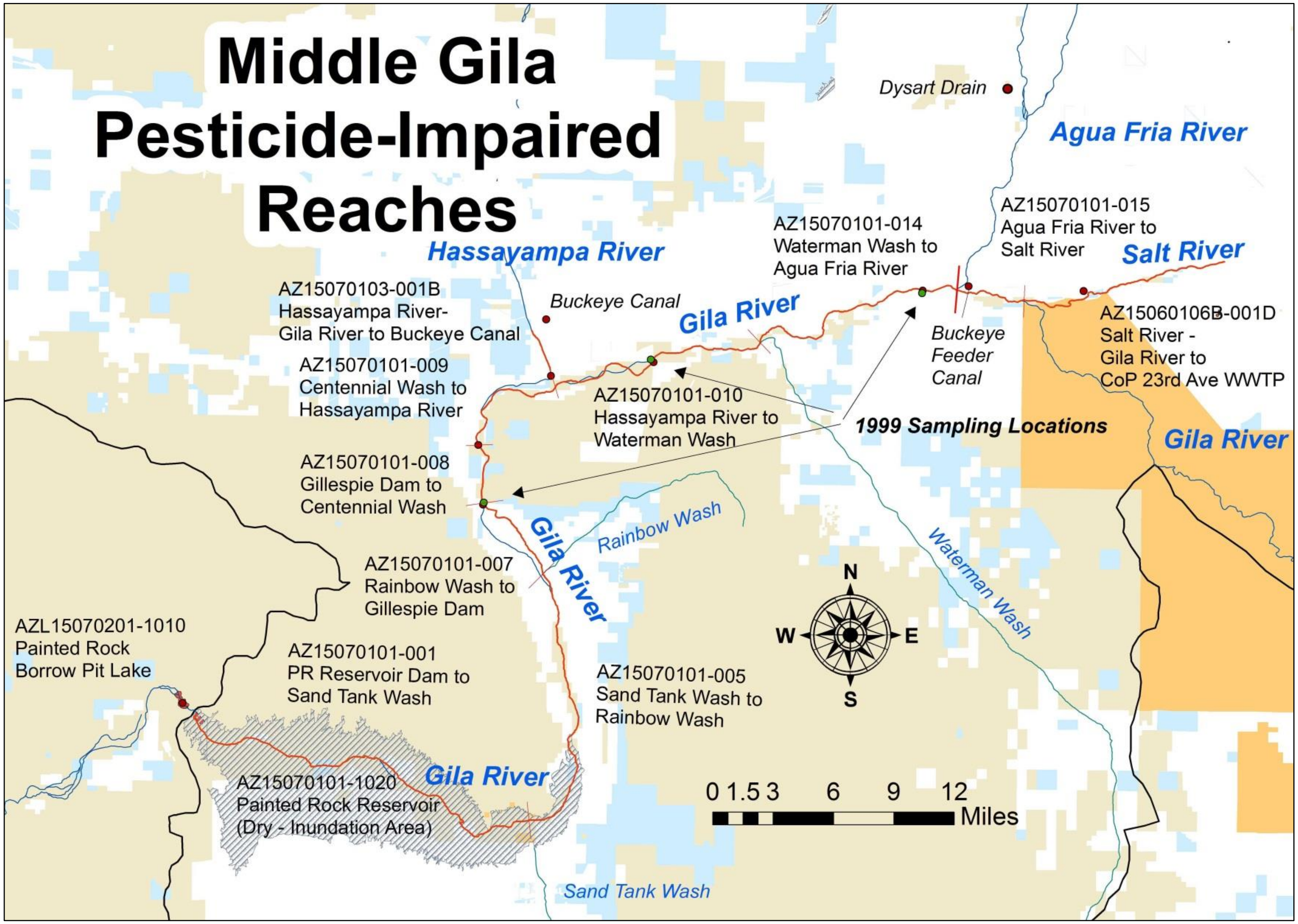

Figure 1. Pesticide-impaired reaches and water bodies
Fish collection sites denoted with red markers. Green markers indicate 1999 sample collection locations.
Red cross hatches indicate reach divisions.

3.0 PESTICIDES

3.1 DDT, DDD, and DDE

DDT (1,1,1-trichloro-2,2-bis (p-chlorophenyl)ethane) has a long and varied history. The graduate student who first synthesized the chemical in 1873 discarded it as useless but Dr. Paul Müller, a Swiss researcher for the Geigy Chemical Company, won the Nobel Prize for Medicine in 1948 for the discovery of its insecticidal properties. Its use to control mosquitoes and agricultural pests was responsible, in part, for the control of malaria and a sharp increase in agricultural productivity. However, its use was also responsible, in part, for a sharp decline in the populations of peregrine falcons, osprey and bald eagles.

DDT was first applied experimentally in Arizona in 1943 and commercial use began in 1945. Within a year, DDT was in general use against the cotton bollworm. Because of its low cost two cents per pound) and efficacy as an insecticide, almost 60 million pounds of DDT were applied to crops in Arizona at an application rate approaching one to three pounds per acre. As a result of milk contamination, use of DDT in Arizona was banned in 1969. In 1972, DDT was banned from use in the United States and remains banned barring a public health emergency (e.g., outbreak of malaria); however, it is still used in other, primarily tropical, countries. Historically, many pesticide companies have been involved with DDT production. By 1991, only Enichem Synthesis (Italy), Hindustan Insecticides (India) and P.T. Montrose Pesticido Nusantara (Indonesia) were listed by UN Environment Program (UNEP) as basic producers (UNEP, 1991). DDT is also produced in Mexico (Lopez-Carillo, et al. 1996) and possibly entered the environment through the application of dicofol which is marketed under the trade name Kelthane. Dicofol is synthesized from DDE (containing small amounts of DDT) which is reacted with chlorine to form chlorinated DDE. This compound is then refined further to give dicofol. The final product therefore can contain low levels of DDT and chlorinated DDE. Dicofol itself does not breakdown to DDT. However, there is evidence that the chlorinated DDE species will dechlorinate in the environment, the resultant degradation product being DDE (see Mischke et al, 1985).

In the environment, DDT degrades rapidly to DDD (1,1-dichloro-2,2-bis (p-chlorophenyl)ethane) then to DDE (1,1-dichloro-2,2-bis(p-dichlorodiphenyl)ethylene), a stable form that has been reported to persist for long periods (30 years or more) in the environment. DDT is immobile in most soils and is effectively insoluble in water. Because of this, where heavy applications have been made annually, it may accumulate in the top layer of soil. Routes of loss and degradation in soils include runoff, volatilization, photolysis and biodegradation (aerobic and anaerobic). These processes generally occur very slowly. The main pathways for loss in the aquatic environment are volatilization, photodegradation, adsorption to water-borne particulates, bioaccumulation and sedimentation.

DDT and its metabolites DDD and DDE (hereafter referred to as DDTr) are particularly hazardous in the environment in that DDTr has a bioconcentration factor (BCF, a measure of its probable propensity to build up in animal tissues) of 53,600 (the highest of any priority pollutant) (USEPA, 1992). Bioconcentration may cause almost undetectable amounts of DDTr in the sediments and water of aquatic ecosystems to be concentrated to extreme levels in top predators such as cormorants (*Phalacrocorax* spp.), and popular sport fish such as largemouth bass (*Micropterus salmoides*) and black crappie (*Promoxis nigromaculatius*). While an average human would have to consume 32 grams of DDTr for it to be acutely toxic, a BCF of 53,600 can cause excessive concentrations in edible fish tissue (Rector, 2000).

3.1.1 Human Health Effects

DDTr has been classified as a B2, or probable, human carcinogen (USEPA, 1996) on the strength of animal trials on DDT. DDT is moderately to slightly toxic to mammals via oral intake. Reported oral LD50s (lethal dose to 50 percent of test organisms) range from 113 to 800 mg/kg in rats (ATSDR, 1994, Wasserman et al., 1982); 150-300 mg/kg in mice (Wasserman et al., 1982); 300 mg/kg in guinea pigs (ATSDR, 1994); 400 mg/kg in rabbits (ATSDR, 1994); 500-750 mg/kg in dogs (Wasserman et al., 1982) and more than 1,000 mg/kg in sheep and goats (Wasserman et al., 1982). Upon ingestion, DDT is readily absorbed through the gastrointestinal tract, with increased absorption in the presence of fats (ATSDR, 1994). With low to moderate exposure, acute effects in humans may include nausea, diarrhea, increased liver enzyme activity, irritation (of the eyes, nose or throat), disturbed gait, malaise and excitability. At higher doses, tremors and convulsions are possible (ATSDR, 1994, Van Ert and Sullivan, 1992). Moderate to high ingested doses of up to 280 mg/kg, may be tolerated by adults, although one ounce of 5 percent DDT in a kerosene solution was reported to have caused a fatal poisoning in a child (ATSDR, 1994).

Teratogenic effects (causing fetal malformations) have been reported in test animals as well. In mice, maternal doses of 26 mg/kg/day DDT from gestation through lactation resulted in impaired learning performance in maze tests (ATSDR, 1994). In a two-generational study of rats, 10 mg/kg/day resulted in abnormal tail development (ATSDR, 1994). Epidemiological evidence regarding the occurrence of teratogenic effects as a result of DDT exposure is unavailable (ATSDR, 1994). It seems unlikely that teratogenic effects will occur in humans because of DDT at likely exposure levels.

3.1.2 Decay

Transformation of DDT to its metabolites DDD, DDE and DDA (bis (dichlorodiphenyl) acetic acid) occurs at a very slow rate in humans and animals. Initially, in mammalian systems, DDT degrades to DDD then to DDE, all of which are very readily stored in fatty tissues (ATSDR, 1994). These compounds in turn are ultimately transformed into DDA at a very slow rate (ATSDR, 1994). DDA is readily excreted via the urine (ATSDR, 1994). Analysis of human blood and fat tissue samples collected in the early 1970s showed detectable levels of DDT and its metabolites in all samples, but a downward trend in the levels over time (ATSDR, 1994). DDT or metabolites may also be eliminated via mother’s milk by lactating women (ATSDR, 1994).

3.1.3 Environmental toxicity

While DDTr may be only slightly toxic to birds, (LD50s greater than 2,240 mg/kg for mallard, 841 mg/kg in Japanese quail and 1,334 mg/kg in pheasant (Hudson et al., 1984)) chronic exposure of bird species to DDT has led to effects on reproduction, especially eggshell thinning and embryo deaths (WHO, 1989).

3.2 Toxaphene

Produced by the chlorination of camphene, toxaphene is a complex mixture of at least 177 chlorinated bornanes and a total of more than 670 chemicals. Commercial production of toxaphene in the U.S. began in 1947 and an estimated 233,688 metric tons (approximately 514 millionpounds) were produced in the U.S. between 1964 and 1982 (Rector, 2004). Four major companies produced toxaphene in the U.S.: Hercules, Inc., at Brunswick, Georgia; Tenneco Chemical, Inc., at Ford, New Jersey; Riverside Chemical Company at Groves, Texas; and Vicksburg Chemical Company at Vicksburg, Mississippi (Rector, 2004). The largest single use of toxaphene was as a pesticide on cotton crops (National Toxicology Program, 2002). Other major uses are on livestock and other food crops. Since its ban by the EPA in 1982, existing stocks of toxaphene can only be used for emergency situations on corn, cotton and small grain for specific insect infestation; pineapples and bananas for specific insects in Puerto Rico and the Virgin Islands only; and scabies treatment of cattle and sheep (Rector, 2004).

3.2.1 Human health effects

Toxaphene is considered a B2, or probable human carcinogen based on the incidence of hepatocellular tumors in mice and thyroid tumors in rats (Rector, 2004). Acute toxicity can be characterized by reflex hyperexcitability, evidenced by tremor, salivation, and vomiting. Generalized epileptiform convulsions of variable duration also may occur with death occurring due to exhaustion respiratory failure (Gosselin, et al, 1984). The toxicity of two of the major metabolites of toxaphene have been found to have even greater toxicity than the parent material (Casida et al. 1974)

3.2.2 Decay

When released into water, toxaphene will adsorb to suspended solids and sediment possibly attenuating volatilization from water surfaces. Toxaphene is persistent under aerobic conditions; an oligotrophic lake was still toxic to fish five years following the application of toxaphene (Rector, 2004). Once sequestered in sediment, toxaphene is susceptible to anaerobic biodegradation, however, bioconcentration values ranging from 3,100 to 69,000 in fish suggest the possibility of accumulation to elevated concentrations in aquatic organisms is very high.

3.2.3 Environmental toxicity

Toxaphene was widely released to the environment mainly as a result of its past use as an insecticide. Toxaphene strongly adsorbs to particles and is relatively immobile in soils. In water, toxaphene is strongly adsorbed to suspended particulates and sediments and is bioconcentrated by aquatic organisms to fairly high levels, with bioconcentration factors (BCFs) on the order of 4,200–60,000. Toxaphene also appears to be biomagnified in aquatic food chains, although not to the extent of PCBs or other chlorinated insecticides, such as DDT. Toxaphene is resistant to chemical and biological transformation in aerobic surface waters. It is not expected to undergo direct photolysis or photo-oxidation. Hydrolysis is also not an important fate process (ATSDR, 2013).

Toxaphene is especially hazardous to nontarget marine and freshwater organisms, with death recorded at ambient water concentrations substantially below 10 μg/l, and adverse effects observed on growth, reproduction, and metabolism at water concentrations between 0.05 and 0.3 μg/l (Eisler 1985).

Toxaphene is highly toxic, with 96-hour LC50 values in the range of 1.8 μg/L in rainbow trout to 22 μg/L in bluegill. Brook trout exposed to toxaphene for 90 days experienced a 46 percent reduction in weight at 0.039 μg/L, the lowest concentration tested. Egg viability in female trout was significantly reduced upon exposure to a concentration of 0.075 μg/L or more. Long term exposure to 0.5 μg/L reduced egg viability to zero. Female ring-necked pheasants exposed to 300 mg toxaphene/kg diet experienced reductions in egg laying and hatchability (UNEP, 2013).
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3.3 Chlordane

Chlordane is a chlorinated cyclodiene that is a mixture of more than 50 compounds, but is mainly comprised of closely related chemicals such as chlordane, cis-chlordane, trans-chlordane, heptachlor and nonachlor. Used mainly for termite control, chlordane was also used on food and nonfood crops and residential lawns. First registered in the U.S. in 1948, all uses for the insecticide chlordane were cancelled in 1988 except for its use for fire ant control in power transformers. Chlordane can still be legally manufactured in the U.S. although it can only be sold in foreign countries (Rector, 2004).

3.3.1. Human health effects

Chlordane is classified as a B2, or probable human carcinogen, based on studies in animals (Rector, 2004). While the following doses would be impossible to consume from contaminated fish, it has been estimated that a fatal oral dose for an adult lies between six and 60 grams, with onset of symptoms within 45 minutes to several hours after ingestion (Gosselin et al. 1984) and convulsive symptoms have occurred with as little as 2.25 grams. Topical skin application of about 30 grams to an adult resulted in death in 40 minutes (American Conference of Governmental Industrial Hygienists, 2001). Effects of overexposure may include shaking, blurred vision, irritability, confusion, delirium, and staggering, cough, vomiting, ataxia, and diarrhea (Mackison et al. 1981).

3.3.2 Decay

If released into water, chlordane is expected to adsorb to suspended solids and sediments. Biodegradation (the breakdown of a substance’s chemical constituents in the environment attributable to the action of microbiological agents) is not an important fate process in water as indicated by no biodegradation after 28 days incubation with a sludge inoculum. Volatilization from water surfaces is expected to be an important fate process based upon this compound's Henry's Law constant. Estimated volatilization half-lives for a model river and model lake are 42 hours and 19 days, respectively. However, volatilization from water surfaces is expected to be attenuated by adsorption to suspended solids and sediment in the water column (Rector, 2004).

3.3.3 Environmental toxicity

Chlordane is persistent and bioaccumulative in the tissues of organisms comprising the food chain in the environment. It does not readily break down by photolysis, hydrolysis, or oxidization. The half-life of chlordane in soil is estimated at 350 days with a possible range from 37 to 3,500 days. It is moderately toxic to birds (LD50 83 mg/l) and highly toxic to fish (LC50 0.07-0.09 mg/l). Chlordane has also been determined as toxic to bees (Rector, 2004).

4.0 FISH CONSUMPTION RISK

State screening concentrations were taken from EPA recommended screening levels for recreational fishers for total DDT, toxaphene, and chlordane (USEPA, 2000). Adult screening concentrations for comparison were established at 0.117 mg/kg for total DDT, 0.114 mg/kg for chlordane, and 0.036 mg/kg for toxaphene. The health risk concerns for fish consumption are based on the EPA equation for the calculation of risk-based limits for the consumption of contaminated fish tissue for recreational fishers (USEPA, 2000):

$$SV = [(RL/CSF)*BW]/CR$$

Where SV = screening value for a carcinogen in mg/kg or ppm;
RL = maximum acceptable risk level (dimensionless)
CSF = oral cancer slope factor $(mg/kg\text{-}day)^{-1}$
BW = body weight in kg
and CR = consumption rate in kg/day.

Default values for some of these variables were employed. Body weight was established at an average of 70 kg (154 lbs.) / adult. A risk level of 10^{-5} was employed, consistent with the EPA default value. A consumption rate of 17.5 g/day was used to establish screening values. Oral cancer slope factors of 0.34, 0.35, and 1.10 $mg/kg\text{-}day^{-1}$ for DDTr, chlordane, and toxaphene respectively were employed.

DDTr levels were also compared to the 1999 screening value of 0.065 mg/kg, where a higher default consumption rate of 32.4 grams of fish per day was assumed. Discussion follows in Section 6.0.

5.0 STUDY LOCALE AND METHODS

With the exception of significant precipitation events, the flows within the Gila and Salt River channels between Phoenix and Gillespie Dam are primarily composed of treated effluent discharged from the City of Phoenix and City of Tolleson wastewater treatment plants, along with agricultural drainage water. Additional inflow originating from groundwater recharge and upwelling off the eastern slopes of the Estrella Mountains is contributed by the Gila River upstream of its confluence with the Salt River. The majority of flow below the Salt River confluence is diverted to the Buckeye Canal on a seasonal basis for use in irrigation. Buckeye

Canal drains to the Hassayampa River, where flow returns to the Gila River channel within a few miles (Figure 1). The canal also serves as a conveyance for agricultural drain water. The Agua Fria River joins the Gila River upstream of the Buckeye Canal diversion, but it is ephemeral in character. Rare discharges from the Avondale and Goodyear wastewater treatment plants as well as storm water flows from multiple sources also enter the Gila River in this segment. Discharges from agricultural or other drains enter the Gila River drainage at several points on a seasonal or episodic basis. Of these, the Extension, St. John's, Buckeye Feeder, Roosevelt, and Arlington Canals and the Dysart Drain have drains connecting to the Gila River or its tributaries. Dysart Drain tail water would reach the Gila River in only the most extreme hydrological events. Roosevelt Canal drain water is discharged to the Hassayampa River bed and typically infiltrates before joining Buckeye Canal tail water (also discharged to the Hassayampa River bed) or the larger Gila River system hydrologic network. Because of this, Roosevelt Canal was not sampled.

In November-December, 1999, the Arizona Priority Pollutant Sampling Program and the Water Quality Assurance Revolving Fund Program sampled three sites within the Gila River drainage for organochlorine pesticides. Sampling sites in 1999 were located on the Gila River near Estrella Regional Park just below its confluence with the Agua Fria River, at the State Route 85 crossing, and at Gillespie Dam (Figure 1, green markers). All three sites were revisited and sampled for the current study. For the 2012 study, fish were collected at Gillespie Dam and the State Route 85 Crossing; the Estrella Park site was visited on two different occasions in 2012, but no fish were taken in either sampling event. The Estrella Park site has been reduced to ephemeral conditions with occasional standing pools in 2012, in contrast to its healthier water supply condition in 1999. All sampling sites for the current study are shown in Figure 1 (red markers) and cataloged in Table 2.

5.1 Methods

Methods employed can be subdivided into four groups of activities, including sampling design, field sampling and lab subsampling activities, laboratory analyses, and data analysis and treatment.

5.1.1 Sampling Design

ADEQ selected representative locations on several stream and canal reaches in the impaired water network (Figure 1, point locations). The network was designed to attempt to collect one site in each reach where water availability and public access permitted. Due largely to the spatially intermittent character of the Gila River system, ADEQ was unable to sample all listed reaches in the study area. Two reaches visited in the sampling effort did not yield samples; one reach with flowing perennial water (Hassayampa River Reach 001B) yielded no fish in the collection effort; the second reach (Gila River Reach 015) was visited two times in an attempt to collect from the only pooled water available for sampling in the reach with no success. Generally, other reaches not sampled were due to ephemeral character and lack of aquatic habitat. Sampling locations were more extensive than in the 1999 study (Figure 1, Table 2), and USFWS supplemented the data set with samples from Painted Rock Borrow Pit Lake. Bracketing of unsampled reaches with sampled reaches occurred throughout the study area. Table 3 catalogs numbers of specimens from each reach, and Figure 1 shows sampling locations including canal and drain locations.

Reach/Water Body ID	Water Body Name	Sampling Site Description	Site/Reach status	Sample status	# Fish Collected	Collected in 1999 Study
AZL15070201-1010	Painted Rock Borrow Pit Lake	Painted Rock Borrow Pit Lake	Wet	Fish collected	13	--
AZL15070101-1020	Painted Rock Reservoir	N.A.	Dry	Not sampled	--	--
AZ15070101-001	Gila River/P Rock Reservoir	N.A.	Dry	Not sampled	--	--
AZ15070101-005	Gila River/P Rock Reservoir	N.A.	Dry	Not sampled	--	--
AZ15070101-007	Gila River	N.A.	Dry	Not sampled	--	--
AZ15070101-008	Gila River	Gila River at Gillespie Dam	Wet	Fish collected	17*	Yes
AZ15070101-009	Gila River	Gila River at Centennial Wash	Wet	Fish collected	1*	--
AZ15070103-001B	Hassayampa River	Hassayampa River at Arlington Canal	Wet	Unsuccessful collection	--	--
AZ15070103-090	Buckeye Canal	Buckeye Canal near Terminus	Wet	Fish collected	5	--
AZ15070101-010	Gila River	Gila River at SR 85	Wet	Fish collected	13	Yes
AZ15070101-014	Gila River	Gila River at Estrella Park	Wet	Unsuccessful collection	--	Yes
AZ15070101-064	Buckeye Feeder Canal	Buckeye Feeder Canal	Wet	Fish collected	7	--
AZ15070102-460	Unnamed Trib to Agua Fria River	Dysart Drain	Wet	Fish collected	1**	--
AZ15070101-015	Gila River	N.A.	Wet	Not sampled	--	--
AZ15060106B-001D	Salt River	Salt River at 91st Ave. WWTP	Wet	Fish collected	10	--

* Samples from Centennial Wash site and Gillespie Dam grouped together for analysis
** Composited sample

Table 2. Sample site description and sample information

Analyte Test Numbers by Reach		Analyte		
WBID (Abbrev.) Reach	Impaired Reach/Water Body Name	Chlordane	Total DDTr	Toxaphene
0201-1010	Painted Rock Borrow Pit Lake	13	13	13
0101-1020	Painted Rock Reservoir	0	0	0
0101-001	Gila - PR Dam to Sand Tank Wash	0	0	0
0101-005	Gila - Sand Tank Wash to Rainbow Wash	0	0	0
0101-007	Gila-Rainbow Wash to Gillespie Dam	0	0	0
0101-008	Gila - Gillespie Dam to Centennial Wash	18	18	18
0101-009	Gila - Centennial Wash to Hassayampa	0	0	0
0103-001B	Hassayampa - Buckeye Canal to Gila River	0	0	0
0101-010	Gila - Hassayampa to Waterman Wash	13	13	13
0101-014	Gila - Waterman Wash to Agua Fria River	0	0	0
0101-015	Gila – Agua Fria River to Salt River	0	0	0
0106B-001D	Salt - Gila River to CoP 23rd Ave WWTP	10	10	10
	Total Analyte Tests, Impaired Reaches and Water Bodies:	*54*	*54*	*54*
WBID (Abbrev.) Canals/Drains	Name	Chlordane	Total DDTr	Toxaphene
0103-090	Buckeye Canal	5	5	5
0101-064	Buckeye Feeder Canal	7	7	7
0102-460	Dysart Drain	1	1	1
	Total Analyte Tests, Canals and Drains:	*13*	*13*	*13*
	Grand Total, all locations:	**67**	**67**	**67**

Table 3. Analyte test numbers by reach

5.1.2 Field Sampling and Laboratory Subsampling

Field samples were taken by ADEQ personnel using gill and cast nets. Fish were left whole, placed on water ice, and transported to the ADEQ laboratory where they were weighed, measured, identified by species and location collected, wrapped individually in aluminum foil or Zip-Loc bags, and frozen in a consumer-grade deep freezer. Samples were later processed for analysis by removing the skin and scales from the fillet portion and using a 6.0mm Fray® Biopunch to subsample tissue from above the lateral line (Cizdziel, et al. 2002). Once a total of six grams of tissue were removed from each sample, the material was placed in a laboratory mortar and pestle, homogenized, then decanted into a precleaned, 60ml, wide-mouth HDPE bottle and returned to the freezer. One sample (Dysart Drain – Reach 460 in Table 3 was processed by compositing a group of small fish into one submission.

A total of 54 discrete samples representing six reaches of the Gila River hydrologic system were collected. Additionally, USFWS contributed data to the set from sampling occurring in 2011 at Painted Rock Borrow Pit Lake (Reach/Lake 1010, 1020, Table 1). The FWS dataset comprised an additional 13 specimens including carp, crappie, green sunfish, and largemouth bass analyzed for DDT isomers, DDD, DDE, chlordane isomers, toxaphene, and other constituents of concern. Altogether, these 67 specimens represented an increase in numbers over the previous years' studies: Rector 2000 (33 specimens), King 1994 (52 specimens), King 1985 (24 specimens), and the 1980 Clark-Krynitsky study (two specimens).

5.1.3 Laboratory Analyses

The Arizona Department of Health Services (ADHS) analyzed samples collected by ADEQ. ADHS analyzed only for the 4,-4' isomers of DDT and its byproducts as this isomer constituted the bulk of commercial DDT. The omission of the 2,-4' isomer values (constituting only a fraction of commercial DDT) is considered inconsequential given the low levels identified in the study. The primary method used for determining concentrations for chlordane, toxaphene, 4, 4'-DDT, 4, 4'-DDD and 4, 4'-DDE was gas chromatography with an electron capture detector. These analytes were confirmed with a second confirmatory column where necessary.

USFWS samples were analyzed by the Geochemical & Environmental Research Group (GERG) of College Station, Texas, a group under long-term contract with USFWS (Marr, 2013a). The quantitative analyses were performed by capillary gas chromatography (CGC) with electron capture detector for pesticides. There were specific cases where analytes requested for the pesticides are known to co-elute with other analytes in the normal CGC with electron capture. In these cases, the samples were analyzed by CGC/mass spectrometry with a mass spectrometer detector in the SIM mode. Confirmatory analyses for selected samples were performed by gas chromatography/mass spectrometry where doubt about the original analysis existed (Marr, 2013b).

Detections for pesticide residues were found more frequently in USFWS data from Painted Rock Borrow Pit Lake than elsewhere in the project study area. This higher detection rate is likely a function both of the lake's properties as a terminal sink for the entire study area (where more pesticide residues would be expected to be found) and of the more robust and discriminating analysis conducted by the GERG lab in fulfillment of USFWS needs. USFWS objectives in its collection were informed by its mission to assess risks to wildlife and aquatic life, which requires a finer resolution and lower detection levels in analysis than assessment for human health designated uses require. Wildlife risks are greater than human risks, given the probabilities of continuous exposure, higher metabolisms, lesser lifespans, smaller body masses, and differences in uptake/excretion kinetics as compared to humans. Consequently, samples sent to the GERG laboratory were analyzed more comprehensively for pesticide isomers and at lower detection limits than the ADHS analyses conducted for locations elsewhere in the study area. However, ADHS detection limits were adequate for all pesticides examined to determine whether fish consumption risks for people remain in the ecosystem. This methodological sufficiency permitted the re-censoring of all USFWS data to ADHS detection limits for statistical consideration. The minor differences in laboratory treatment do not appreciably affect the analysis of the data or alter the conclusions of this study.

5.1.4 Data Analysis and Treatment

Because DDTr has a BCF of 53,600 and has been previously detected at all sites in this study, the probability that tissue taken from this system would have a DDTr concentration of zero is low. Samples with DDE, DDT, or DDD concentrations below the ADHS laboratory detection level (0.02 mg/kg) were assigned a concentration based on the method of beta substitution (Ganser and Hewett, 2010). The substitution method is further outlined in Appendix C. Chlordane was treated in a similar fashion. Isomers of DDT or chlordane, where analyzed separately, were summed after substitution to yield a total DDT or chlordane value. The geometric mean (geomean) value was determined from total values, and a 90th percentile value was determined for all data groupings of interest, including pooled impaired reaches/water bodies and by individual reach. Toxaphene, as a single constituent, did not require the same data treatment as chlordane and DDTr. Detection levels varied by specimen for toxaphene, but in all cases they were less than the toxaphene screening level. Toxaphene data was re-censored to the highest detection level and subsequently analyzed. For all three pesticides, where no detections existed in the data set after treatment, geomeans and 90th percentile values were reported as "< PQL" where PQL indicates the practical quantitation limit for each considered pesticide. Where subsets of data by reach had insufficient detections to calculate a 90th percentile, the benchmark was reported as "<PQL." However, beta substitution geomeans derived from a beta factor applied to the entire set of data were still employed in these subsets of data with limited detections, due to the robust character of beta substitution and its reduced bias and standard error attributable to mean values as opposed to percentile values.

6.0 RESULTS AND DISCUSSION

Pesticide residues in fish tissues, while present in some instances, have decreased substantially since the 1999 survey for all pesticides previously found to have caused impairment. The majority of pesticides analyzed for in this study were not detected at detection limits of 0.02 mg/kg (DDTr, chlordane) or a conservative 0.034 mg/kg (toxaphene, MDL varied by specimen). Appendix A catalogs ADEQ individual specimen results. Appendix B presents USFWS results from Painted Rock Borrow Pit Lake. See Table 4 and Table 5 for presentations of geometric means and 90th percentile values for all pesticides (Note: 90th percentile values are included solely for reference purposes to indicate the range of dispersion of concentrations. Original listings were made only on the basis of geometric mean calculations, and consistent with original listings, delisting proposals are made based on geometric means alone). Table 4 presents summary values for data from impaired 303(d)-listed reaches and water bodies. Table 5 breaks down the dataset for summaries by individual impaired reaches/water bodies. Supporting data summaries from canals and drains have been presented in Table 6. Screening values are presented only for comparative purposes in Table 6; it is here noted that canals and agricultural drains do not carry fish consumption designated uses in Arizona.

Screening values used for comparison in this study were drafted directly from EPA guidance for recreational fishers (EPA, 2000). Subsistence fishing in the Gila River is considered to be of low incidence; consequently, standard EPA values as outlined in the *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* were employed for consumption rates. The risk level for comparison was established at 10^{-5}, correlating to one cancer death per 100,000 population exposed daily over a 70 year lifetime. The 1999 study considered DDT values against a screening value of 0.065 mg/kg derived from different consumption rate criteria, though the 2012 study and the 1999 study used the same formula in calculating carcinogenic risk for DDT (Section 4.0). The difference in screening values between 2000 and 2012 can be entirely attributed to differences in the consumption rate used in the formula; the assumed consumption rate of 32.4 grams per day in 2000 exceeded the EPA default value of 17.5 g/day used in the screening value in 2012. The more stringent screening value used in 2000 did not reflect any substantive difference in the toxicity rates or other factors from the current study; instead, the use of the 2000 criteria was a pragmatic one designed and adopted to make fish consumption risks more readily understandable to the general public. The 2000 study sought to present all consumption data in rounded unit meal portion sizes expressed in a frequency of consumption by the week or month. The consumption rate adopted in 2000 corresponded to a weekly consumption of one 8-ounce serving (227 g) of fish. Even when compared to the stricter 2000 screening value, DDT geomean values in the 2012 study meet the screening value for DDTr in all instances as shown in Tables 4 and 5.

The breakdown of values by reach reveals spatial patterns in the data for DDTr. Impaired reaches are sorted from downstream to upstream in Table 5. Geomean concentrations are highest at the furthest downstream impaired segment (Painted Rock Borrow Pit Lake), with concentrations steadily decreasing as ones moves upstream. These data suggest that flushing and attenuation of sediment reservoirs of DDT has proceeded since 1999, with the highest remaining concentrations in the Gila River main-stem at the furthest downstream point in the series of reaches listed by EPA. This result is in accordance with expectations; the spatial pattern is similar to that determined in 1999, with downstream sampling locations showing higher concentrations than upstream locations (Rector, 2000).

Pesticide Concentrations in Fish Tissue, mg/Kg
Impaired Reaches and Lakes, Pooled

	DDTr	Chlordane	Toxaphene
Screening Value	0.117	0.114	0.0363
Geomean	0.007	<0.02	<0.034
90th Pctl	0.077	<0.02	<0.034
Number specimens	54	54	54
Number detections	23	0*	0

* FWS data re-censored to ADHS PQL

Table 4. Summary Fish Tissue Concentrations, pooled impaired segments
13 samples from canals and drains not included

Total DDT				
Reach	Reach Name	Screening Value, mg/kg	Geomean, mg/kg	90th P-tile, mg/kg
0201-1010	Painted Rock Borrow Pit Lake	0.117	0.064	0.158
0101-1020	Painted Rock Reservoir	0.117	--	--
0101-001	Gila - PR Dam to Sand Tank Wash	0.117	--	--
0101-005	Gila - Sand Tank Wash to Rainbow Wash	0.117	--	--
0101-007	Gila-Rainbow Wash to Gillespie Dam	0.117	--	--
0101-008	Gila - Gillespie Dam to Centennial Wash	0.117	0.006	0.034
0101-009	Gila - Centennial Wash to Hassayampa	0.117	--	--
0103-001B	Hassayampa - Buckeye Canal to Gila River	0.117	--	--
0101-010	Gila - Hassayampa to Waterman Wash	0.117	0.005	<0.02
0101-014	Gila - Waterman Wash to Agua Fria River	0.117	--	--
0101-015	Gila - Agua Fria River to Salt River	0.117	--	--
0106B-001D	Salt - Gila River to CoP 23rd Ave WWTP	0.117	0.001	<0.02
Chlordane				
Reach	Reach Name	Screening Value, mg/kg	Geomean, mg/kg	90th P-tile, mg/kg
0201-1010	Painted Rock Borrow Pit Lake	0.114	<0.02	<0.02
0101-1020	Painted Rock Reservoir	0.114	--	--
0101-001	Gila - PR Dam to Sand Tank Wash	0.114	--	--
0101-005	Gila - Sand Tank Wash to Rainbow Wash	0.114	--	--
0101-007	Gila-Rainbow Wash to Gillespie Dam	0.114	--	--
0101-008	Gila - Gillespie Dam to Centennial Wash	0.114	<0.02	<0.02
0101-009	Gila - Centennial Wash to Hassayampa	0.114	--	--
0103-001B	Hassayampa - Buckeye Canal to Gila River	0.114	--	--
0101-010	Gila - Hassayampa to Waterman Wash	0.114	<0.02	<0.02
0101-014	Gila - Waterman Wash to Agua Fria River	0.114	--	--
0101-015	Gila - Agua Fria River to Salt River	0.114	--	--
0106B-001D	Salt - Gila River to CoP 23rd Ave WWTP	0.114	<0.02	<0.02
Toxaphene				
Reach	Reach Name	Screening Value, mg/kg	Geomean, mg/kg	90th P-tile, mg/kg
0201-1010	Painted Rock Borrow Pit Lake	0.0363	<0.034	<0.034
0101-1020	Painted Rock Reservoir	0.0363	--	--
0101-001	Gila - PR Dam to Sand Tank Wash	0.0363	--	--
0101-005	Gila - Sand Tank Wash to Rainbow Wash	0.0363	--	--
0101-007	Gila-Rainbow Wash to Gillespie Dam	0.0363	--	--
0101-008	Gila - Gillespie Dam to Centennial Wash	0.0363	<0.034	<0.034
0101-009	Gila - Centennial Wash to Hassayampa	0.0363	--	--
0103-001B	Hassayampa - Buckeye Canal to Gila River	0.0363	--	--
0101-010	Gila - Hassayampa to Waterman Wash	0.0363	<0.034	<0.034
0101-014	Gila - Waterman Wash to Agua Fria River	0.0363	--	--
0101-015	Gila - Agua Fria River to Salt River	0.0363	--	--
0106B-001D	Salt - Gila River to CoP 23rd Ave WWTP	0.0363	<0.034	<0.034

Table 5. Summary Fish Tissue Concentrations by impaired reach/water body
Dataset comprised of 54 specimens including FWS data

Total DDT				
WBID/Reach	Name	Screening Value,* mg/kg	Geomean, mg/kg	90th P-tile, mg/kg
0103-090	Buckeye Canal	0.117*	0.021	0.043
0101-064	Buckeye Feeder Canal	0.117*	0.030	1.075
0102-460	Dysart Drain	0.117*	**4.107**	N.A.
Chlordane				
WBID/Reach	Name	Screening Value,* mg/kg	Geomean, mg/kg	90th P-tile, mg/kg
0103-090	Buckeye Canal	0.114*	<0.02	<0.02
0101-064	Buckeye Feeder Canal	0.114*	<0.02	<0.02
0102-460	Dysart Drain	0.114*	<0.02	N.A.
Toxaphene				
WBID/Reach	Name	Screening Value,* mg/kg	Geomean, mg/kg	90th P-tile, mg/kg
0103-090	Buckeye Canal	0.0363*	<0.034	<0.034
0101-064	Buckeye Feeder Canal	0.0363*	0.005	0.264
0102-460	Dysart Drain	0.0363*	**3.110**	N.A.

Table 6. Summary Fish Tissue Concentrations for canals/drains by water body ID
*- Screening values not applicable where Fish consumption designated uses not applied. Shown for comparative purposes only

DDTr, where it exists at detectable levels, still shows at the highest levels in the study area in the canals and agricultural drains that originate from and/or eventually return to the Gila River system (Table 6). The Buckeye Feeder Canal (Reach 15070101-064), which drains the southwestern region of the Phoenix metro area northeast of the Agua Fria River confluence, shows high values of pesticide residues for both toxaphene and DDTr when the 90th percentile value of the dataset is considered. These results suggest the possibility that the accelerated construction and development activities with their associated soil disturbances because of rapid growth in the southwest Phoenix metro area since 2000 may have liberated some remaining soil reservoirs of these legacy pesticides, which may have subsequently found their way into the canal system. Immediately below the Buckeye Feeder Canal's confluence with the Gila, all Gila River water is diverted into the Buckeye Canal. Data from the Buckeye Canal near its terminus (Reach 15070103-090, Table 6) demonstrate that attenuation of DDT fish tissue concentrations occurs between the two sites if temporal flow continuity and spatial hydrologic contiguity is assumed. Buckeye Canal has historically demonstrated the highest levels of DDTr among the listed reaches and water bodies with a site history of consistent sampling as shown in Table 7. It can be considered as a historical worst-case bellwether in the hydrologic network. Even here, DDTr geometric mean values have decreased below the screening value by more than a five-fold factor, with the 90th percentile exhibiting a value well below one-half the screening value. As noted earlier, canals in Arizona do not carry fish consumption designated uses.

The highest pesticide fish tissue values observed for all collection efforts (bolded values, Table 5) were recorded in a composited sample taken from the Dysart Drain (Reach 0102-460), a small persistent terminal pond/sink at the end of a concrete runoff channel near Luke Air Force Base

(AFB). The drain is a second-order tributary to the Agua Fria River located about eight miles north of the Gila River (Figure 1). It is not considered a water of the U.S., nor does it carry a fish consumption designated use. Thus, Dysart Drain was not formally listed by EPA in 2002. The Agua Fria River and the tributaries to the Agua Fria below the pond are ephemeral, and the system flows continuously to the Gila River in only the most extreme hydrologic events. Runoff from agricultural fields north of Luke AFB supplies the pond much of its inflow, and a reproductive population of carp permanently reside in the pond. Historic research has determined that roses were grown in the fields north of Luke AFB during the period of pesticide usage and these fields received some of the highest application rates of these legacy pesticides in Maricopa County (Rector, 2000). Effects are seen to be persisting at high levels at this location decades after the pesticides were banned. Collectively, these canal and agricultural drain data show that certain pesticide residues are still present in the environment at measurable and comparatively high levels in fish tissue for selected specimens.

Temporally, it is evident that DDTr breakdown and disappearance continue at an accelerated pace in recent years. Please refer to Figure 2 and Table 7. Results were compiled from several previous studies dating to 1980, including Clark-Krynitsky (1980), Kepner (1985), King et al. (1994-95), Rector (2000), and this 2012 study. Geomeans were grouped by site/reach and ordered from oldest to most recent. Impaired reaches were arranged from downstream (left) to upstream (right) on the chart. In the graph, the screening value for the 2012 study is shown as a transiting line. The table and chart show a clear temporal decrease at any site selected for consideration. Additionally, the spatial pattern of decreasing concentrations upstream previously noted is evident upon inspection.

DDTr Geomean Values, mg/Kg

Sampling Location	Reach/WBID	1980	1985	1994-95	1999	2012
Painted Rock Borrow Pit Lake	0201-1010	--	--	--	--	0.064 *
Painted Rock Reservoir	0101-1020	--	2.36	1.31	--	--
N.A.	0101-001	--	--	--	--	--
N.A.	0101-005	--	--	--	--	--
N.A.	0101-007	--	--	--	--	--
Gila - Gillespie Dam	0101-008	--	4.61	1.49	0.22	0.006 *
N.A.	0101-009	--	--	--	--	--
N.A.	0103-001B	--	--	--	--	--
Gila - SR85	0101-010	6.21	4.52	2.78	0.15	0.005 *
Gila - Estrella Parkway	0101-014	--	2.46	0.81	--	--
Gila - Baseline Meridian	0101-015	--	--	--	0.003	--
Salt River 59th/91st Ave	0106B-001D	--	0.86	0.29	--	0.001 *
Buckeye Canal	0103-090	--	19.37	11.97	--	0.021 *

*Beta substitution used

Table 7. Temporal DDTr trends at selected sites, 1980-2012

Chlordane was not detected in any sample collected by ADEQ in this study. Chlordane was detected by USFWS at Painted Rock Borrow Pit Lake at very low levels (maximum value 3.8 ppb) in six of 13 specimens. All USFWS chlordane data was re-censored to the highest detection level (0.02 ppm, below the screening value of 0.114 ppm) and subsequently analyzed.

Toxaphene was detected in only three samples of the 54 collected by ADEQ. Two detections were recorded in specimens from the Buckeye Feeder Canal; one detection was observed in the composited sample from Dysart Drain. As previously mentioned, these locations do not carry fish consumption designated uses and consequently are not listed as impaired. USFWS recorded no detections of toxaphene in the 13 specimens taken from Painted Rock Borrow Pit Lake. Considered in total, toxaphene was not detected in any sample in this study for the impaired and 303(d)-listed stream reaches and water bodies of the Gila River hydrologic network.

6.1 Painted Rock Borrow Pit Lake

Because of Painted Rock Borrow Pit Lake's former status as a recreational area and fishing destination, and since it is the location in the study area most susceptible to exhibiting continued impacts from legacy pesticide use, special discussion focused on the lake is presented below. Painted Rock Dam was built by the U.S. Army Corps of Engineers between 1957 and 1960 as an earthenwork flood retention structure on the Gila River northwest of Gila Bend. The dam's excavation created a depression footprint below the dam that has since filled with water from runoff years. The impoundment created above the dam (Painted Rock Reservoir) is generally dry except in exceptional runoff years. The Painted Rock Borrow Pit Lake, a much smaller water body below the dam (190 surface acres [ETC, 1993]), holds water on an intermittent basis and is largely dependent upon releases from the reservoir for its persistence. The lake below the dam was a popular fishing area in the 1970s and 1980s. At one point, the lake and its surrounding area was an Arizona State Park. Visitor surveys conducted by the Arizona State Parks Department in 1987 and 1988 found that about 5,200 visitors, or 22 percent of total visitors, participated in fishing over the two-year period (ETC, 1993). Rising concern about pesticide contamination eventually led to the lake being closed as a recreational area in 1989 with fishing prohibited and public access denied, and the State of Arizona relinquished its lease on the park and transferred stewardship of the area back to the Corps of Engineers in the 1990s.

Hydrologically, the lake is ephemeral, typically isolated from surface water inputs, and subject to complete replenishment only in large runoff years when the dam releases water from the reservoir upstream. There are no known springs replenishing the lake. Groundwater movement and groundwater hydrologic budget additions are unknown and have only been estimated (ETC, 1993). A 1992 survey by ADEQ determined that the lake volume and average depth had diminished since construction, with an average water depth of 13 feet and a maximum depth of 15 feet at that time. Lake volume in 1992 was calculated to be 2,470 acre-feet. Evaporation rates are high, calculated at 1,760 acre-feet annually (AFA) by the ETC study, with a calculated annual hydrologic budget loss of 1,490 AFA. A theoretical residence time of 14.23 years for water in the lake was determined by the Earth Technology Corporation study, but this value was based on precipitation and discharge data from 1960 to 1991; it does not account for conditions in the current extended drought Arizona is experiencing. A review of Google Earth imagery dating to 1996 shows cyclical periods where the lake holds water from a release event for a duration of up to a few years, gradually reducing in size between major events as hydrologic losses exceeded gains. This cycle has been repeated multiple times since the original fish consumption advisory was issued in the early 1990s. As of summer 2014, the lake was dry, exhibiting the same status it showed in aerial photography for the years 2002-2004 and 2013. More recent lake outflow data is not available for consideration, but it is reasonable to conclude that actual residence time generously appears to be in the five- to seven- year range currently. This duration is subject to considerable variability from year to year depending upon climatic and hydrologic conditions. Table 8 illustrates the sporadic and generally low-level hydrologic inputs (with occasional large influxes) the lake receives. The last column in the table summarizes total annual inflow to the lake based on USGS summary data.

As Painted Rock Borrow Pit Lake is immediately below the Painted Rock Reservoir Dam and in the Gila River channel proper, the settling of sediments carrying DDT residue or traces of other pesticides and their uptake into the food web would be expected to occur at this last hydrologic sink before the Gila River becomes truly ephemeral in character beyond its last impoundment. Sediments holding these residues were likely flushed in the exceptional water years of 1980, 1993, 2005, and most recently in 2010. Notably, however, the 1993 ETC study found only trace levels of DDE below the method reporting limit for two of 50 sediment samples at 22 different locations in the lakebed. Since the lower listed reaches of the Gila River, Painted Rock Reservoir, and Painted Rock Borrow Pit Lake are dry for extended periods, photolysis of any remaining DDTr in sediments due to ultraviolet radiation exposure proceeds during any period where the lake bed is exposed.

As the data from this investigation shows, DDTr levels in fish tissue persist here at levels that are the highest for any impaired segment of the listed water bodies and stream segments. However, with a DDTr geomean value of 0.064 ppm, the lake not only meets the EPA recreational fishing screening value of 0.117 ppm recommended for DDTr, but it also complies with the more stringent value of 0.065 ppm used for comparison in 1999. The 1999 threshold was based on a more conservative recommendation intended to protect subsistence fishermen, i.e. those who relied upon fishing on a daily basis, or multiple times in a week, to meet their family's dietary needs. Painted Rock Borrow Pit Lake is geographically isolated, located 31 road miles (45 minutes) from the small town of Gila Bend (population 1,977, 2013) and 100 miles (1 hour, 45 minutes) from Phoenix. Access to the lake is restricted to one road. Painted Rocks Lake Road is accessed 13 miles west of Gila Bend off Interstate 8 in open desert and irrigated agricultural country. Given the remote nature of the lake and the sparsely populated nature of western Maricopa County, the proximity of the mean DDTr level and the 1999 screening criteria is not a reasonable concern warranting additional caution for subsistence fishing activity. Recreational fisher screening levels are the appropriate benchmark for comparison for the lake, as they are for other reaches in the study area. DDTr levels in fish tissue meet the screening criteria at the lake, are trending down, and are expected to go lower in the future.

It is acknowledged that the lake is the most sensitive barometer for legacy pesticide contamination in the Gila River system. ADEQ is committed to continued fish tissue monitoring for legacy pesticides of all segments of the Gila River system, including Painted Rock Borrow Pit Lake, as circumstances warrant in coming years. If additional major hydrologic events having the potential to escalate DDTr levels occur, such as central Arizona's 1993 flood events, ADEQ will continue to work with FWS and endeavor to collect follow-up fish tissue data from the lake to ensure public health is protected. Fish consumption advisories will again be issued if threats to human health through elevated fish tissue pesticide levels become evident.

Year	*Date*	*Annual peak streamflow, cfs*	*Water Year inflow, acre-ft annually*
2000	Mar. 07, 2000	4.7	Records unavailable
2001	Mar. 08, 2001	1.9	Records unavailable
2002	2002	0	0*
2003	2003	0	0*
2004	2004	0	0*
2005	Mar. 01, 2005	2,770	Records unavailable
2006	Mar. 11, 2006	23	4,420
2007	Aug. 02, 2007	35	1,550
2008	Jan. 29, 2008	10	1,370
2009	Mar. 26, 2009	2.4	73
2010	Mar. 17, 2010	2,790	287,000
2011	Jun. 06, 2011	7.8	1,240
2012	Mar. 19, 2012	3.4	129
2013	Mar. 10, 2013	7.3	289

Table 8. Annual peak streamflows, Gila River below Painted Rock Dam. Source: USGS
*** Records not available; surmised based on no positive peak flow reported for the year**

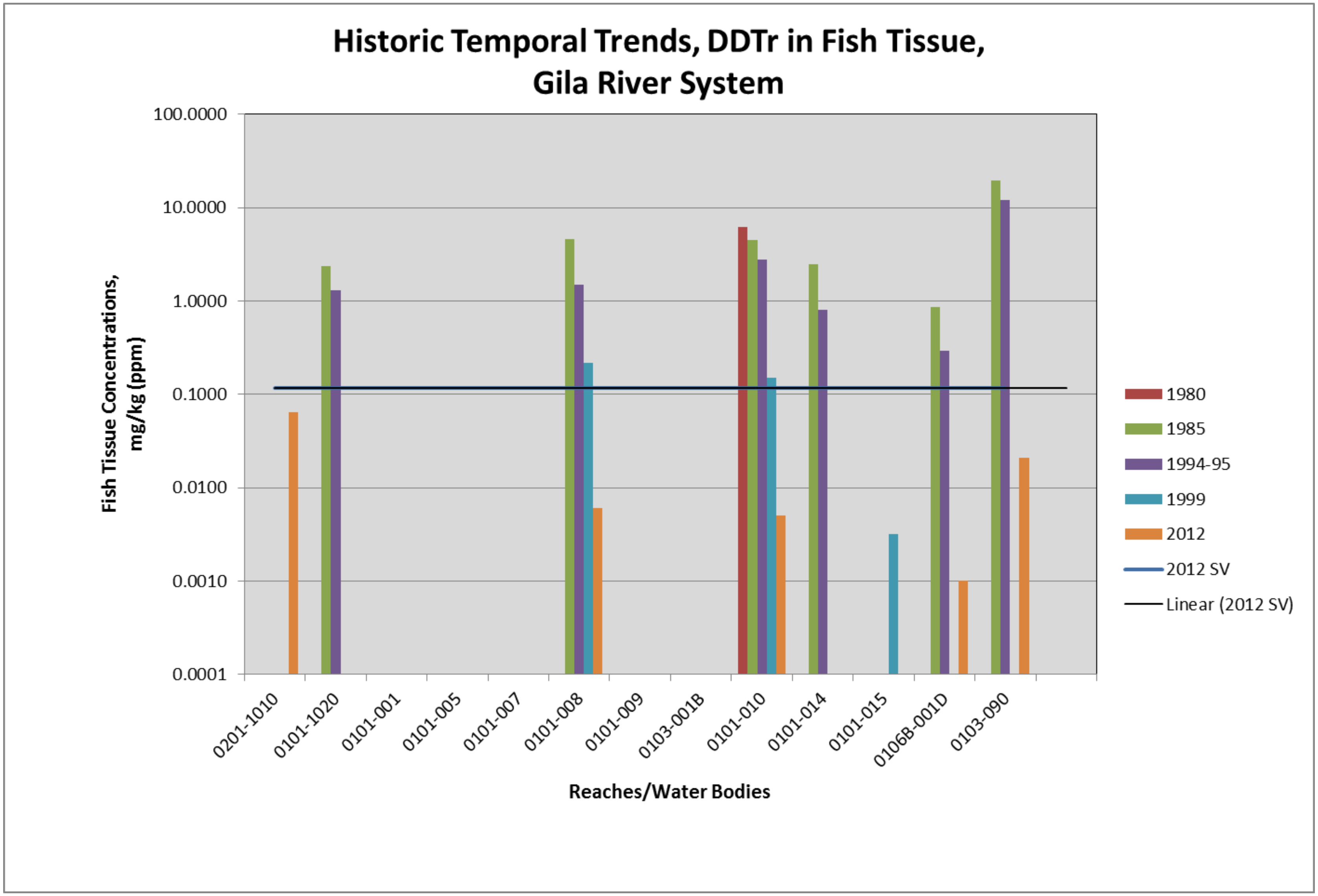

Figure 2. Temporal trends by site, DDTr concentrations

7.0 ACTIONS

ADEQ initially intended to evaluate and act only on data collected upstream of Gillespie Dam (Gila River Reach 008). Water below the lower end of Reach 008 at Gillespie Dam persists only for two or three miles, beyond which the Gila River is ephemeral for almost 40 river miles downstream to the Painted Rock Borrow Pit Lake (refer to Figure 1). However, USFWS supplied fish tissue data collected in 2011 from the Painted Rock Borrow Pit Lake, which permitted bracketing of the reaches downstream of Reach 008 and allowed for determinations of the status by either supported inference or direct data for each of the 12 listed reaches or lakes EPA originally listed as impaired in 2002. Because of this added support and the bracketed sample design, ADEQ is able to assess all listed reaches and water bodies and make proposals regarding the fish consumption advisories and 303(d) listings for each segment and analyte.

When evaluated by site, some canal and agricultural drain data indicate that pesticides are still present in the environment. If extreme runoff for the reaches and lakes addressed in this report is recorded in future years, ADEQ will initiate another fish collection and data analysis effort to ascertain whether fish consumption advisories are again warranted as a protective measure for the Arizona population. However, as this study clearly demonstrates, the reasons for the original listings and pesticide advisories have abated to a significant degree for the listed reaches and water bodies. The geomean value for all impaired segments for DDTr in this study is approximately one-tenth of the most stringent screening value applied in 1999 (Table 4), while chlordane and toxaphene geomeans did not register above the fish tissue detection limit (re-censored in certain cases to ADHS MDLs) for these pooled impaired segments' assessments. Absent major perturbations of the hydrologic system, such as those experienced in Arizona's 1993 floods, ADEQ concludes that risk from exposure to these pesticides is no longer sufficient to warrant advisories and impaired water listings.
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Based on 2012 data collected by ADEQ and 2011 data collected by USFWS, ADEQ is recommending the withdrawal of fish consumption advisories for legacy organochlorine pesticides for all listed reaches and water bodies of the Gila River system detailed in Table 9 and the delisting of all previous 303(d) listed segments in the 2012/2014 CWA 303(d) impaired waters list of the waterways for the legacy pesticides outlined in this report. Table 9 details the proposals and recommendations with regard to each pesticide and reach. All recommendations are subject to final approval by EPA.

In evaluating a surface water for delisting, ADEQ in accordance with Arizona Administrative Code R18-11-605(E).2.a "shall remove a pollutant from a surface water or segment from the 303(d) List based on one or more of the following criteria." The pertinent and applicable criteria subsequently listed (R18-11-605(E).2.a.ii., R18-11-605(E).2.a.v.) state:

- *"The data used for previously listing the surface water or segment under R18-11-605(D) is superseded by more recent credible and scientifically defensible data meeting the requirements of R18-11-602, showing that the* *surface water or segment meets the applicable numeric or narrative surface water quality standard. When evaluating data to remove a pollutant from the 303(d) List, the monitoring entity shall collect the more recent data under similar hydrologic or climatic conditions as occurred when the samples were taken that indicated impairment, if those conditions still exist."*

The more recent and scientifically credible data for the reaches and water bodies listed in Table 9 demonstrate to ADEQ's satisfaction that all segments meet the requirements necessary for a water body to be considered attaining the fish consumption designated use for these constituents. Though numeric fish tissue standards for individual pesticides are not encoded in the Arizona Water Quality Standards, ADEQ has adopted and used standard federal numeric criteria as recommended by EPA as the benchmark values for comparison, and ADEQ has supplemented those values with a secondary comparison to more stringent criteria for DDTr developed by the agency for use in the 1999 study. In all cases, summary geomean data for impaired segments conformed to screening concentration benchmarks. Based upon these criteria, all reaches and water bodies listed in Table 9 are assessed by ADEQ as meeting the state's fish consumption designated use criteria for organochlorine pesticides, and these reaches and water bodies are officially proposed for removal from the Arizona 303(d) impaired waters list subject to EPA final approval. Concomitantly with the proposed delisting actions, fish consumption advisories for organochlorine pesticides for the reaches and water bodies listed in Table 9 are also proposed for rescission.

Reach	Stream/Lake Name	Administrative hydrography changes since 2002 listing	Recommendations and Proposals DDTr	Chlordane	Toxaphene
AZL15070201-1010	Painted Rock Borrow Pit Lake		Delist/ FCA Withdrawal	Delist/ FCA Withdrawal	Delist/ FCA Withdrawal
AZL15070101-1020*	Painted Rock Reservoir		Delist/ FCA Withdrawal	Delist/ FCA Withdrawal	Delist/ FCA Withdrawal
AZ15070101-001*	Gila River/Painted Rock Reservoir		Delist/ FCA Withdrawal	Delist/ FCA Withdrawal	Delist/ FCA Withdrawal
AZ15070101-005	Gila River/Painted Rock Reservoir		Delist/ FCA Withdrawal	Delist/ FCA Withdrawal	Delist/ FCA Withdrawal
AZ15070101-007	Gila River	Merged into Reach 005	Delist w/ Rch 005	Delist w/ Rch 005	Delist w/ Rch 005
AZ15070101-008	Gila River		Delist/ FCA Withdrawal	Delist/ FCA Withdrawal	Delist/ FCA Withdrawal
AZ15070101-009	Gila River	Merged into Reach 008	Delist w/ Rch 008	Delist w/ Rch 008	Delist w/ Rch 008
AZ15070103-001B	Hassayampa River		Delist/ FCA Withdrawal	Delist/ FCA Withdrawal	Delist/ FCA Withdrawal
AZ15070101-010	Gila River		Delist/ FCA Withdrawal	Delist/ FCA Withdrawal	Delist/ FCA Withdrawal
AZ15070101-014	Gila River		Delist/ FCA Withdrawal	Delist/ FCA Withdrawal	Delist/ FCA Withdrawal
AZ15070101-015	Gila River		Delist/ FCA Withdrawal	Delist/ FCA Withdrawal	Delist/ FCA Withdrawal
AZ15060106B-001D	Salt River		Delist/ FCA Withdrawal	Delist/ FCA Withdrawal	Delist/ FCA Withdrawal

*Painted Rock Reservoir co-located with Gila River Reach 001
FCA - Fish Consumption Advisory
All recommendations and proposals subject to EPA final approval

Table 9. Actions by Reach and Pesticide

8.0 REFERENCES

Agency for Toxic Substances and Diseases Registry (ATSDR)/US Public Health Service, Toxicological Profile for 4,4'-DDT, 4,4'-DDE, 4, 4'-DDD (Update). 1994. ATSDR. Atlanta, GA.

Agency for Toxic Substances and Diseases Registry (ATSDR)/US Public Health Service, Toxicological Profile for Toxaphene. 2013. ATSDR. Atlanta, GA. http://www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=548&tid=99

American Conference of Governmental Industrial Hygienists. Documentation of Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 2001. Cincinnati, OH. 2001., p. 2

Augustijn-Beckers, P.W.M., Hornsby, A.G. and Wauchope, R.D. 1994. SCS/ARS/CES Pesticide Properties Database for Environmental Decisionmaking II. Additional Properties Reviews of Environmental Contamination and Toxicology, Vol.137.

Casida JE, Holmstead RL, Khalifa S, et al. 1974. Toxaphene insecticide: A complex biodegradable mixture. Science 183:520-521.

Clark, D. and A. Krynitsky, 1983. DDT Recent contamination in New Mexico and Arizona? Environment, 25-5.

Cizdziel, J. V., T. A. Hinners, and E. M. Heithmar. 2002. *Determination of Total Mercury in Fish Tissue Using Combustion Atomic Absorption Spectrometry with Gold Amalgamation*. Water, Air and Soil Pollution 135: 355-370.

Earth Technology Corporation (ETC). 1993. *Lower/Middle Gila River Study and Painted Rocks Lake Phase I Diagnostic/Feasibility Study, Maricopa County, Arizona*. Volume 1. Tempe, Arizona. August 1993.

Edwards, C.A. 1966. Insecticide Residues in Soils. Residue Reviews 1383. Springer Verlag, New York.

Eisler, R. and J. Jacknow. 1985. Toxaphene hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85(1.4).

Ganser, G.H. and Paul Hewett, 2007. *A Comparison of Several Methods for Analyzing Censored Data*, Ann. Occup. Hyg., Vol.51, No.7, pp 611-632, 2007.

Ganser, G.H. and Paul Hewett, 2010. *An accurate substitution method for analyzing censored data*. J Occup Environ Hyg. 2010 Apr; 7(4):233-44., 2010.

Gosselin, R.E., R.P. Smith, H.C. Hodge. Clinical Toxicology of Commercial Products. 5th ed. Baltimore: Williams and Wilkins, 1984.III-387

Hudson, R.H., Tucker, R.K. and Haegele, K. 1984. Handbook of Acute Toxicity of Pesticides to Wildlife. Resource Publication 153. U.S. Dept. of Interior, Fish and Wildlife Service, Washington, DC.

Kepner, W.G. 1986. Lower Gila River contaminant study. Pages 251-258 *in* Toxic substances in agricultural water supply and drainage: defining the problem. J.B. Summers and S.S. Anderson (eds.). 1986 Regional Meetings Proceedings: U.S. Committee on Irrigation and Drainage, Denver.

Kepner, W.G. 1987. Organochlorine contaminant investigation of the lower Gila River, Arizona. Arizona Ecological Services State Office report. Phoenix. 18 p.

King, K., B. Andrews, C. Martinez and W. Kepner. 1997. Environmental contaminants in fish and wildlife of the lower Gila River, Arizona. U.S. Fish and Wildlife Services Region 2 Contaminants Program report.

López-Carrillo, L., L. Torres-Arreola, L. Torres-Sánchez, F. Espinosa-Torres, C. Jiménez, Mariano Cebrián, S. Waliszewski, and O. Saldate , 1996. Is DDT Use a Public Health Problem in Mexico? DDT Exposure in Mexico, Environmental Health Perspectives, 1046,

Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981., p. 1

Marr, Carrie, 2013a. Personal communication, Carrie Marr, U.S. Fish and Wildlife Service, Phoenix, Az. 2013.

Marr, Carrie, 2013b. Unpublished lab report, GERG, College Station, Texas via U.S. Fish and Wildlife Service, Phoenix, Az. 2013.

Mischke T., K. Brunetti, V. Acosta, D. Weaver and M. Brown, 1985. Agricultural sources of DDT residues in California's environment. A Report Prepared in Response to House Resolution No. 53 (1984) Environmental hazards assessment program, California Department of Food and Agriculture

NPIC, 2001. National Pesticide Information Center Chlordane Technical Fact Sheet. Oregon State Univerity, Corvallis Oregon. http//npic.orst.edu/factsheets/chlordanetech.pdf. 2001.

Rector, 1996. Arizona Priority Pollutant Sampling Program 1994 Report. Arizona Department of Environmental Quality, Phoenix, Arizona. 44 p.

Rector, 2000. *Priority Pollutant Sampling Program 1999 Report a fish consumption advisory investigation for the Middle Gila River; patterns and trends.* Arizona Department of Environmental Quality, Phoenix, Arizona. 10 p.

Rector, 2004. *Fish consumption risk analysis for the Salt River through the Phoenix metropolitan area.* Draft, unpublished. Arizona Department of Environmental Quality, Phoenix, Arizona. 14 pp. 2004.

Report on Carcinogens, Tenth Edition; U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program, December 2002.

Wasserman, M., Ron, M., Bercovici, B., Wasserman, D., Cucos, S. and Pines, A. 1982. Premature delivery and organochlorine compounds polychlorinated biphenyls and some organochlorine insecticides, Environ Res 28106-112.

World Health Organization (WHO). 1979. Environmental Health Criteria 9, DDT and its Derivatives. World Health Organization, Geneva.

World Health Organization (WHO). 1989. Environmental health Criteria 83, DDT and its Derivatives, Environmental Effects. World Health Organization, Geneva

UNEP, 1991. Decision Guidance Document, DDT, Joint FAO/UNEP program for the operation of Prior Informed Consent, 1991.

UNEP, 2013. United Nations Environment Program, Chemical Branch. Substance Profiles for Persistent Organic Pollutants: 6.11 Toxaphene. Accessed June 13, 2013. http://www.chem.unep.ch/pops/indxhtms/asses6.html#TOXA

USEPA. 1989. Environmental Fate and Effects Division, Pesticide Environmental Fate One Line Summary DDT (p, p'). U. S. Environmental Protection Agency, Washington, DC.

USEPA, 1992. TSC1292 Criteria Chart. U.S.E.P.A. Region IV Water Management Division.

USEPA, 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories: Volume 1 Fish Sampling and Analysis. Third Edition. pp 5-0 to 5-22. November, 2000.

USFDA, 1998. U. S. Food and Drug Administration Industry Activities Staff Booklet March 1998. Action levels for poisonous or deleterious substances in human food and animal feed

Van Ert, M. and Sullivan, J. 1992. Organochlorine Pesticides, In Sullivan, J. and Krieger, G., Hazardous Materials Toxicology, Clinical Principles of Environmental Health. Williams & Wilkins, Baltimore, MD.

Appendix A. ADEQ Data

ADEQ ID	Species	Reach	Analyte	Results	MRL (mg/kg)	Units
Gillespie 320-542	Carp	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0206	mg/Kg
Gillespie 390-465	Tilapia	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0225	mg/Kg
Gillespie 300-455	Largemouth Bass	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0202	mg/Kg
Gillespie 330-513	Carp	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0338	mg/Kg
Gillespie 275-460	UID	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0294	mg/Kg
Gillespie 320-633	Carp	0101-008	Toxaphene	N.D., <PQL	0.2	mg/Kg
Gillespie 335-576	Carp	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0288	mg/Kg
Gillespie 320-522	Carp	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0201	mg/Kg
Gillespie 315-493	Carp	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0337	mg/Kg
Gillespie 260-377	Carp	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0336	mg/Kg
Gillespie 330-478	Carp	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0170	mg/Kg
Gillespie 350-590	Carp	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0254	mg/Kg
Gillespie 340-602	Carp	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0203	mg/Kg
Gillespie 500-1526	UID	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0315	mg/Kg
Centennial 365-752	Carp	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0290	mg/Kg
Gillespie 490-1575 (Pool)	Channel Catfish	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0281	mg/Kg
Gillespie 540-1968 (Pool)	Channel Catfish	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0254	mg/Kg
Gillespie 560-2089 (Pool)	Channel Catfish	0101-008	Toxaphene	N.D., <PQL	0.2 / 0.0266	mg/Kg
SR85 445-923	UID	0101-014	Toxaphene	N.D., <PQL	0.2 / 0.0254	mg/Kg
SR85 475-1492	Carp	0101-014	Toxaphene	N.D., <PQL	0.2 / 0.0202	mg/Kg
SR85 320-542	Carp	0101-014	Toxaphene	N.D., <PQL	0.2 / 0.0336	mg/Kg
SR85 330-453	Carp	0101-014	Toxaphene	N.D., <PQL	0.2 / 0.0338	mg/Kg
SR85 370-480	Channel Catfish	0101-014	Toxaphene	N.D., <PQL	0.2 / 0.0310	mg/Kg
SR85 330-490	Carp	0101-014	Toxaphene	N.D., <PQL	0.2 / 0.0299	mg/Kg
SR85 365-585	Carp	0101-014	Toxaphene	N.D., <PQL	0.2 / 0.0319	mg/Kg
SR85 400-815	Carp	0101-014	Toxaphene	N.D., <PQL	0.2 / 0.0288	mg/Kg
SR85 320-442	Carp	0101-014	Toxaphene	N.D., <PQL	0.2 / 0.0292	mg/Kg
SR85 360-657	Carp	0101-014	Toxaphene	N.D., <PQL	0.2 / 0.0319	mg/Kg
SR85 455-989	Carp	0101-014	Toxaphene	N.D., <PQL	0.2 / 0.0171	mg/Kg
SR85 330-462	Carp	0101-014	Toxaphene	N.D., <PQL	0.2 / 0.0340	mg/Kg
SR85 540-1721	UID	0101-014	Toxaphene	N.D., <PQL	0.2 / 0.0299	mg/Kg
*St Johns 242-203	Small mouth Bass	0101-065	Toxaphene	0.23	0.2	mg/Kg
*St Johns 320-531	Tilapia	0101-065	Toxaphene	N.D., <PQL	0.2 / 0.0251	mg/Kg
*St Johns 400-1036	Carp	0101-065	Toxaphene	0.316	0.2	mg/Kg
*St Johns 295-481	Tilapia	0101-065	Toxaphene	N.D., <PQL	0.2 / 0.0254	mg/Kg
*St Johns 448-1354	Carp	0101-065	Toxaphene	N.D., <PQL	0.2 / 0.0206	mg/Kg
*St Johns 242-277	Tilapia	0101-065	Toxaphene	N.D., <PQL	0.2 / 0.0242	mg/Kg
*St Johns 492-1513	Carp	0101-065	Toxaphene	N.D., <PQL	0.2 / 0.0239	mg/Kg
Dysart Drain Composite	Mix	0102-460	Toxaphene	3.11	0.2	mg/Kg
Buckeye Canal 252-230	Carp	0103-090	Toxaphene	N.D., <PQL	0.2 / 0.0213	mg/Kg

ADEQ ID	Species	Reach	Analyte	Results	MRL (mg/kg)	Units
Buckeye Canal 260-247	Carp	0103-090	Toxaphene	N.D., <PQL	0.2 / 0.0293	mg/Kg
Buckeye Canal 285-403	Tilapia	0103-090	Toxaphene	N.D., <PQL	0.2 / 0.0229	mg/Kg
Buckeye Canal 275-297	Carp	0103-090	Toxaphene	N.D., <PQL	0.2 / 0.0342	mg/Kg
Buckeye Canal 290-358	Carp	0103-090	Toxaphene	N.D., <PQL	0.2 / 0.0321	mg/Kg
Salt 91st 192-156	Tilapia	0106B-001D	Toxaphene	N.D., <PQL	0.2 / 0.0256	mg/Kg
Salt 91st 210-207	Tilapia	0106B-001D	Toxaphene	N.D., <PQL	0.2 / 0.0258	mg/Kg
Salt 91st 235-257	Tilapia	0106B-001D	Toxaphene	N.D., <PQL	0.2 / 0.0254	mg/Kg
Salt 91st 210-197	Tilapia	0106B-001D	Toxaphene	N.D., <PQL	0.2 / 0.0253	mg/Kg
Salt 91st 218-212	Tilapia	0106B-001D	Toxaphene	N.D., <PQL	0.2 / 0.0254	mg/Kg
Salt 91st 355-384	Plecostomus	0106B-001D	Toxaphene	N.D., <PQL	0.2 / 0.0255	mg/Kg
Salt 91st 415-519	Plecostomus	0106B-001D	Toxaphene	N.D., <PQL	0.2 / 0.0255	mg/Kg
Salt 91st 355-372	Plecostomus	0106B-001D	Toxaphene	N.D., <PQL	0.2 / 0.0253	mg/Kg
Salt 91st 280-215	Plecostomus	0106B-001D	Toxaphene	N.D., <PQL	0.2 / 0.0256	mg/Kg
Salt 91st 425-601	Plecostomus	0106B-001D	Toxaphene	N.D., <PQL	0.2 / 0.0257	mg/Kg
Gillespie 350-590	Carp	0101-008	Total DDTr	0.0154	0.02	mg/Kg
Gillespie 320-522	Carp	0101-008	Total DDTr	0.0204	0.02	mg/Kg
Gillespie 330-513	Carp	0101-008	Total DDTr	0.0279	0.02	mg/Kg
Centennial 365-752	Carp	0101-008	Total DDTr	0.0286	0.02	mg/Kg
Gillespie 275-460	UID	0101-008	Total DDTr	0.0286	0.02	mg/Kg
Gillespie 490-1575 (Pool)	Channel Catfish	0101-008	Total DDTr	0.0331	0.02	mg/Kg
Gillespie 560-2089 (Pool)	Channel Catfish	0101-008	Total DDTr	0.0331		mg/Kg
Gillespie 540-1968 (Pool)	Channel Catfish	0101-008	Total DDTr	0.0346		mg/Kg
Gillespie 340-602	Carp	0101-008	Total DDTr	0.3163	0.02	mg/Kg
Gillespie 260-377	Carp	0101-008	Total DDTr	N.D., <PQL	0.02	mg/Kg
Gillespie 300-455	Largemouth Bass	0101-008	Total DDTr	N.D., <PQL	0.02	mg/Kg
Gillespie 315-493	Carp	0101-008	Total DDTr	N.D., <PQL	0.02	mg/Kg
Gillespie 320-542	Carp	0101-008	Total DDTr	N.D., <PQL	0.02	mg/Kg
Gillespie 320-633	Carp	0101-008	Total DDTr	N.D., <PQL	0.02	mg/Kg
Gillespie 330-478	Carp	0101-008	Total DDTr	N.D., <PQL	0.02	mg/Kg
Gillespie 335-576	Carp	0101-008	Total DDTr	N.D., <PQL	0.02	mg/Kg
Gillespie 390-465	Tilapia	0101-008	Total DDTr	N.D., <PQL	0.02	mg/Kg
Gillespie 500-1526	UID	0101-008	Total DDTr	N.D., <PQL	0.02	mg/Kg
SR85 365-585	Carp	0101-014	Total DDTr	0.0204	0.02	mg/Kg
SR85 320-442	Carp	0101-014	Total DDTr	N.D., <PQL	0.02	mg/Kg
SR85 320-542	Carp	0101-014	Total DDTr	N.D., <PQL	0.02	mg/Kg
SR85 330-453	Carp	0101-014	Total DDTr	N.D., <PQL	0.02	mg/Kg
SR85 330-462	Carp	0101-014	Total DDTr	N.D., <PQL	0.02	mg/Kg
SR85 330-490	Carp	0101-014	Total DDTr	N.D., <PQL	0.02	mg/Kg
SR85 360-657	Carp	0101-014	Total DDTr	N.D., <PQL	0.02	mg/Kg
SR85 370-480	Channel Catfish	0101-014	Total DDTr	N.D., <PQL	0.02	mg/Kg
SR85 400-815	Carp	0101-014	Total DDTr	N.D., <PQL	0.02	mg/Kg
SR85 445-923	UID	0101-014	Total DDTr	N.D., <PQL	0.02	mg/Kg

ADEQ ID	Species	Reach	Analyte	Results	MRL (mg/kg)	Units
SR85 455-989	Carp	0101-014	Total DDTr	N.D., <PQL	0.02	mg/Kg
SR85 475-1492	Carp	0101-014	Total DDTr	N.D., <PQL	0.02	mg/Kg
SR85 540-1721	UID	0101-014	Total DDTr	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 260-247	Carp	0103-090	Total DDTr	0.0114	0.02	mg/Kg
*St Johns 448-1354	Carp	0101-065	Total DDTr	0.0367	0.02	mg/Kg
Buckeye Canal 252-230	Carp	0103-090	Total DDTr	0.04	0.02	mg/Kg
*St Johns 242-203	Small mouth Bass	0101-065	Total DDTr	0.586	0.02	mg/Kg
*St Johns 400-1036	Carp	0101-065	Total DDTr	1.808	0.02	mg/Kg
*St Johns 242-277	Tilapia	0101-065	Total DDTr	N.D., <PQL	0.02	mg/Kg
*St Johns 295-481	Tilapia	0101-065	Total DDTr	N.D., <PQL	0.02	mg/Kg
*St Johns 320-531	Tilapia	0101-065	Total DDTr	N.D., <PQL	0.02	mg/Kg
*St Johns 492-1513	Carp	0101-065	Total DDTr	N.D., <PQL	0.02	mg/Kg
Dysart Drain Composite	Mix	0102-460	Total DDTr	4.1065		mg/Kg
Buckeye Canal 285-403	Tilapia	0103-090	Total DDTr	0.0088	0.02	mg/Kg
Buckeye Canal 275-297	Carp	0103-090	Total DDTr	0.02114	0.02	mg/Kg
Buckeye Canal 290-358	Carp	0103-090	Total DDTr	0.0456	0.02	mg/Kg
Salt 91st 192-156	Tilapia	0106B-001D	Total DDTr	N.D., <PQL	0.02	mg/Kg
Salt 91st 210-197	Tilapia	0106B-001D	Total DDTr	N.D., <PQL	0.02	mg/Kg
Salt 91st 210-207	Tilapia	0106B-001D	Total DDTr	N.D., <PQL	0.02	mg/Kg
Salt 91st 218-212	Tilapia	0106B-001D	Total DDTr	N.D., <PQL	0.02	mg/Kg
Salt 91st 235-257	Tilapia	0106B-001D	Total DDTr	N.D., <PQL	0.02	mg/Kg
Salt 91st 280-215	Plecostomus	0106B-001D	Total DDTr	N.D., <PQL	0.02	mg/Kg
Salt 91st 355-372	Plecostomus	0106B-001D	Total DDTr	N.D., <PQL	0.02	mg/Kg
Salt 91st 355-384	Plecostomus	0106B-001D	Total DDTr	N.D., <PQL	0.02	mg/Kg
Salt 91st 415-519	Plecostomus	0106B-001D	Total DDTr	N.D., <PQL	0.02	mg/Kg
Salt 91st 425-601	Plecostomus	0106B-001D	Total DDTr	N.D., <PQL	0.02	mg/Kg
Gillespie 320-542	Carp	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 390-465	Tilapia	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 300-455	Largemouth Bass	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 330-513	Carp	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 275-460	UID	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 320-633	Carp	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 335-576	Carp	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 320-522	Carp	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 315-493	Carp	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 260-377	Carp	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 330-478	Carp	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 350-590	Carp	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 340-602	Carp	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 500-1526	UID	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Centennial 365-752	Carp	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 490-1575 (Pool)	Channel Catfish	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg

ADEQ ID	Species	Reach	Analyte	Results	MRL (mg/kg)	Units
Gillespie 540-1968 (Pool)	Channel Catfish	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 560-2089 (Pool)	Channel Catfish	0101-008	Chlordane	N.D., <PQL	0.02	mg/Kg
SR85 445-923	UID	0101-014	Chlordane	N.D., <PQL	0.02	mg/Kg
SR85 475-1492	Carp	0101-014	Chlordane	N.D., <PQL	0.02	mg/Kg
SR85 320-542	Carp	0101-014	Chlordane	N.D., <PQL	0.02	mg/Kg
SR85 330-453	Carp	0101-014	Chlordane	N.D., <PQL	0.02	mg/Kg
SR85 370-480	Channel Catfish	0101-014	Chlordane	N.D., <PQL	0.02	mg/Kg
SR85 330-490	Carp	0101-014	Chlordane	N.D., <PQL	0.02	mg/Kg
SR85 365-585	Carp	0101-014	Chlordane	N.D., <PQL	0.02	mg/Kg
SR85 400-815	Carp	0101-014	Chlordane	N.D., <PQL	0.02	mg/Kg
SR85 320-442	Carp	0101-014	Chlordane	N.D., <PQL	0.02	mg/Kg
SR85 360-657	Carp	0101-014	Chlordane	N.D., <PQL	0.02	mg/Kg
SR85 455-989	Carp	0101-014	Chlordane	N.D., <PQL	0.02	mg/Kg
SR85 330-462	Carp	0101-014	Chlordane	N.D., <PQL	0.02	mg/Kg
SR85 540-1721	UID	0101-014	Chlordane	N.D., <PQL	0.02	mg/Kg
*St Johns 242-203	Small mouth Bass	0101-065	Chlordane	N.D., <PQL	0.02	mg/Kg
*St Johns 320-531	Tilapia	0101-065	Chlordane	N.D., <PQL	0.02	mg/Kg
*St Johns 400-1036	Carp	0101-065	Chlordane	N.D., <PQL	0.02	mg/Kg
*St Johns 295-481	Tilapia	0101-065	Chlordane	N.D., <PQL	0.02	mg/Kg
*St Johns 448-1354	Carp	0101-065	Chlordane	N.D., <PQL	0.02	mg/Kg
*St Johns 242-277	Tilapia	0101-065	Chlordane	N.D., <PQL	0.02	mg/Kg
*St Johns 492-1513	Carp	0101-065	Chlordane	N.D., <PQL	0.02	mg/Kg
Dysart Drain Composite	Mix	0102-460	Chlordane	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 252-230	Carp	0103-090	Chlordane	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 260-247	Carp	0103-090	Chlordane	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 285-403	Tilapia	0103-090	Chlordane	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 275-297	Carp	0103-090	Chlordane	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 290-358	Carp	0103-090	Chlordane	N.D., <PQL	0.02	mg/Kg
Salt 91st 192-156	Tilapia	0106B-001D	Chlordane	N.D., <PQL	0.02	mg/Kg
Salt 91st 210-207	Tilapia	0106B-001D	Chlordane	N.D., <PQL	0.02	mg/Kg
Salt 91st 235-257	Tilapia	0106B-001D	Chlordane	N.D., <PQL	0.02	mg/Kg
Salt 91st 210-197	Tilapia	0106B-001D	Chlordane	N.D., <PQL	0.02	mg/Kg
Salt 91st 218-212	Tilapia	0106B-001D	Chlordane	N.D., <PQL	0.02	mg/Kg
Salt 91st 355-384	Plecostomus	0106B-001D	Chlordane	N.D., <PQL	0.02	mg/Kg
Salt 91st 415-519	Plecostomus	0106B-001D	Chlordane	N.D., <PQL	0.02	mg/Kg
Salt 91st 355-372	Plecostomus	0106B-001D	Chlordane	N.D., <PQL	0.02	mg/Kg
Salt 91st 280-215	Plecostomus	0106B-001D	Chlordane	N.D., <PQL	0.02	mg/Kg
Salt 91st 425-601	Plecostomus	0106B-001D	Chlordane	N.D., <PQL	0.02	mg/Kg
Gillespie 320-542	Carp	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 390-465	Tilapia	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 300-455	Largemouth Bass	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 330-513	Carp	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg

ADEQ ID	Species	Reach	Analyte	Results	MRL (mg/kg)	Units
Gillespie 275-460	UID	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 320-633	Carp	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 335-576	Carp	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 320-522	Carp	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 315-493	Carp	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 260-377	Carp	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 330-478	Carp	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 350-590	Carp	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 340-602	Carp	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 500-1526	UID	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Centennial 365-752	Carp	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 490-1575 (Pool)	Channel Catfish	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 540-1968 (Pool)	Channel Catfish	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 560-2089 (Pool)	Channel Catfish	0101-008	4,4-DDT	N.D., <PQL	0.02	mg/Kg
SR85 445-923	UID	0101-014	4,4-DDT	N.D., <PQL	0.02	mg/Kg
SR85 475-1492	Carp	0101-014	4,4-DDT	N.D., <PQL	0.02	mg/Kg
SR85 320-542	Carp	0101-014	4,4-DDT	N.D., <PQL	0.02	mg/Kg
SR85 330-453	Carp	0101-014	4,4-DDT	N.D., <PQL	0.02	mg/Kg
SR85 370-480	Channel Catfish	0101-014	4,4-DDT	N.D., <PQL	0.02	mg/Kg
SR85 330-490	Carp	0101-014	4,4-DDT	N.D., <PQL	0.02	mg/Kg
SR85 365-585	Carp	0101-014	4,4-DDT	N.D., <PQL	0.02	mg/Kg
SR85 400-815	Carp	0101-014	4,4-DDT	N.D., <PQL	0.02	mg/Kg
SR85 320-442	Carp	0101-014	4,4-DDT	N.D., <PQL	0.02	mg/Kg
SR85 360-657	Carp	0101-014	4,4-DDT	N.D., <PQL	0.02	mg/Kg
SR85 455-989	Carp	0101-014	4,4-DDT	N.D., <PQL	0.02	mg/Kg
SR85 330-462	Carp	0101-014	4,4-DDT	N.D., <PQL	0.02	mg/Kg
SR85 540-1721	UID	0101-014	4,4-DDT	N.D., <PQL	0.02	mg/Kg
*St Johns 242-203	Small mouth Bass	0101-065	4,4-DDT	N.D., <PQL	0.02	mg/Kg
*St Johns 320-531	Tilapia	0101-065	4,4-DDT	N.D., <PQL	0.02	mg/Kg
*St Johns 400-1036	Carp	0101-065	4,4-DDT	N.D., <PQL	0.02	mg/Kg
*St Johns 295-481	Tilapia	0101-065	4,4-DDT	N.D., <PQL	0.02	mg/Kg
*St Johns 448-1354	Carp	0101-065	4,4-DDT	N.D., <PQL	0.02	mg/Kg
*St Johns 242-277	Tilapia	0101-065	4,4-DDT	N.D., <PQL	0.02	mg/Kg
*St Johns 492-1513	Carp	0101-065	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Dysart Drain Composite	Mix	0102-460	4,4-DDT	0.0771	0.02	mg/Kg
Buckeye Canal 252-230	Carp	0103-090	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 260-247	Carp	0103-090	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 285-403	Tilapia	0103-090	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 275-297	Carp	0103-090	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 290-358	Carp	0103-090	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Salt 91st 192-156	Tilapia	0106B-001D	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Salt 91st 210-207	Tilapia	0106B-001D	4,4-DDT	N.D., <PQL	0.02	mg/Kg

ADEQ ID	Species	Reach	Analyte	Results	MRL (mg/kg)	Units
Salt 91st 235-257	Tilapia	0106B-001D	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Salt 91st 210-197	Tilapia	0106B-001D	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Salt 91st 218-212	Tilapia	0106B-001D	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Salt 91st 355-384	Plecostomus	0106B-001D	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Salt 91st 415-519	Plecostomus	0106B-001D	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Salt 91st 355-372	Plecostomus	0106B-001D	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Salt 91st 280-215	Plecostomus	0106B-001D	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Salt 91st 425-601	Plecostomus	0106B-001D	4,4-DDT	N.D., <PQL	0.02	mg/Kg
Gillespie 320-542	Carp	0101-008	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Gillespie 390-465	Tilapia	0101-008	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Gillespie 300-455	Largemouth Bass	0101-008	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Gillespie 330-513	Carp	0101-008	4,4-DDE	0.0279	0.02	mg/Kg
Gillespie 275-460	UID	0101-008	4,4-DDE	0.0286	0.02	mg/Kg
Gillespie 320-633	Carp	0101-008	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Gillespie 335-576	Carp	0101-008	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Gillespie 320-522	Carp	0101-008	4,4-DDE	0.0204	0.02	mg/Kg
Gillespie 315-493	Carp	0101-008	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Gillespie 260-377	Carp	0101-008	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Gillespie 330-478	Carp	0101-008	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Gillespie 350-590	Carp	0101-008	4,4-DDE	0.0154	0.02	mg/Kg
Gillespie 340-602	Carp	0101-008	4,4-DDE	0.3163	0.02	mg/Kg
Gillespie 500-1526	UID	0101-008	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Centennial 365-752	Carp	0101-008	4,4-DDE	0.0286	0.02	mg/Kg
Gillespie 490-1575 (Pool)	Channel Catfish	0101-008	4,4-DDE	0.0331	0.02	mg/Kg
Gillespie 540-1968 (Pool)	Channel Catfish	0101-008	4,4-DDE	0.0346	0.02	mg/Kg
Gillespie 560-2089 (Pool)	Channel Catfish	0101-008	4,4-DDE	0.0331	0.02	mg/Kg
SR85 445-923	UID	0101-014	4,4-DDE	N.D., <PQL	0.02	mg/Kg
SR85 475-1492	Carp	0101-014	4,4-DDE	N.D., <PQL	0.02	mg/Kg
SR85 320-542	Carp	0101-014	4,4-DDE	N.D., <PQL	0.02	mg/Kg
SR85 330-453	Carp	0101-014	4,4-DDE	N.D., <PQL	0.02	mg/Kg
SR85 370-480	Channel Catfish	0101-014	4,4-DDE	N.D., <PQL	0.02	mg/Kg
SR85 330-490	Carp	0101-014	4,4-DDE	N.D., <PQL	0.02	mg/Kg
SR85 365-585	Carp	0101-014	4,4-DDE	0.0204	0.02	mg/Kg
SR85 400-815	Carp	0101-014	4,4-DDE	N.D., <PQL	0.02	mg/Kg
SR85 320-442	Carp	0101-014	4,4-DDE	N.D., <PQL	0.02	mg/Kg
SR85 360-657	Carp	0101-014	4,4-DDE	N.D., <PQL	0.02	mg/Kg
SR85 455-989	Carp	0101-014	4,4-DDE	N.D., <PQL	0.02	mg/Kg
SR85 330-462	Carp	0101-014	4,4-DDE	N.D., <PQL	0.02	mg/Kg
SR85 540-1721	UID	0101-014	4,4-DDE	N.D., <PQL	0.02	mg/Kg
*St Johns 242-203	Small mouth Bass	0101-065	4,4-DDE	0.586	0.02	mg/Kg
*St Johns 320-531	Tilapia	0101-065	4,4-DDE	N.D., <PQL	0.02	mg/Kg
*St Johns 400-1036	Carp	0101-065	4,4-DDE	1.808	0.02	mg/Kg

ADEQ ID	**Species**	**Reach**	**Analyte**	**Results**	**MRL (mg/kg)**	**Units**
*St Johns 295-481	Tilapia	0101-065	4,4-DDE	N.D., <PQL	0.02	mg/Kg
*St Johns 448-1354	Carp	0101-065	4,4-DDE	0.0367	0.02	mg/Kg
*St Johns 242-277	Tilapia	0101-065	4,4-DDE	N.D., <PQL	0.02	mg/Kg
*St Johns 492-1513	Carp	0101-065	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Dysart Drain Composite	Mix	0102-460	4,4-DDE	3.967	0.02	mg/Kg
Buckeye Canal 252-230	Carp	0103-090	4,4-DDE	0.04	0.02	mg/Kg
Buckeye Canal 260-247	Carp	0103-090	4,4-DDE	0.0114	0.02	mg/Kg
Buckeye Canal 285-403	Tilapia	0103-090	4,4-DDE	0.0088	0.02	mg/Kg
Buckeye Canal 275-297	Carp	0103-090	4,4-DDE	0.02114	0.02	mg/Kg
Buckeye Canal 290-358	Carp	0103-090	4,4-DDE	0.0456	0.02	mg/Kg
Salt 91st 192-156	Tilapia	0106B-001D	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Salt 91st 210-207	Tilapia	0106B-001D	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Salt 91st 235-257	Tilapia	0106B-001D	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Salt 91st 210-197	Tilapia	0106B-001D	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Salt 91st 218-212	Tilapia	0106B-001D	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Salt 91st 355-384	Plecostomus	0106B-001D	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Salt 91st 415-519	Plecostomus	0106B-001D	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Salt 91st 355-372	Plecostomus	0106B-001D	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Salt 91st 280-215	Plecostomus	0106B-001D	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Salt 91st 425-601	Plecostomus	0106B-001D	4,4-DDE	N.D., <PQL	0.02	mg/Kg
Gillespie 320-542	Carp	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 390-465	Tilapia	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 300-455	Largemouth Bass	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 330-513	Carp	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 275-460	UID	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 320-633	Carp	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 335-576	Carp	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 320-522	Carp	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 315-493	Carp	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 260-377	Carp	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 330-478	Carp	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 350-590	Carp	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 340-602	Carp	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 500-1526	UID	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Centennial 365-752	Carp	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 490-1575 (Pool)	Channel Catfish	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 540-1968 (Pool)	Channel Catfish	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Gillespie 560-2089 (Pool)	Channel Catfish	0101-008	4,4-DDD	N.D., <PQL	0.02	mg/Kg
SR85 445-923	UID	0101-014	4,4-DDD	N.D., <PQL	0.02	mg/Kg
SR85 475-1492	Carp	0101-014	4,4-DDD	N.D., <PQL	0.02	mg/Kg
SR85 320-542	Carp	0101-014	4,4-DDD	N.D., <PQL	0.02	mg/Kg
SR85 330-453	Carp	0101-014	4,4-DDD	N.D., <PQL	0.02	mg/Kg

ADEQ ID	Species	Reach	Analyte	Results	MRL (mg/kg)	Units
SR85 370-480	Channel Catfish	0101-014	4,4-DDD	N.D., <PQL	0.02	mg/Kg
SR85 330-490	Carp	0101-014	4,4-DDD	N.D., <PQL	0.02	mg/Kg
SR85 365-585	Carp	0101-014	4,4-DDD	N.D., <PQL	0.02	mg/Kg
SR85 400-815	Carp	0101-014	4,4-DDD	N.D., <PQL	0.02	mg/Kg
SR85 320-442	Carp	0101-014	4,4-DDD	N.D., <PQL	0.02	mg/Kg
SR85 360-657	Carp	0101-014	4,4-DDD	N.D., <PQL	0.02	mg/Kg
SR85 455-989	Carp	0101-014	4,4-DDD	N.D., <PQL	0.02	mg/Kg
SR85 330-462	Carp	0101-014	4,4-DDD	N.D., <PQL	0.02	mg/Kg
SR85 540-1721	UID1	0101-014	4,4-DDD	N.D., <PQL	0.02	mg/Kg
*St Johns 242-203	Small mouth Bass	0101-065	4,4-DDD	N.D., <PQL	0.02	mg/Kg
*St Johns 320-531	Tilapia	0101-065	4,4-DDD	N.D., <PQL	0.02	mg/Kg
*St Johns 400-1036	Carp	0101-065	4,4-DDD	N.D., <PQL	0.02	mg/Kg
*St Johns 295-481	Tilapia	0101-065	4,4-DDD	N.D., <PQL	0.02	mg/Kg
*St Johns 448-1354	Carp	0101-065	4,4-DDD	N.D., <PQL	0.02	mg/Kg
*St Johns 242-277	Tilapia	0101-065	4,4-DDD	N.D., <PQL	0.02	mg/Kg
*St Johns 492-1513	Carp	0101-065	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Dysart Drain Composite	Mix	0102-460	4,4-DDD	0.0624	0.02	mg/Kg
Buckeye Canal 252-230	Carp	0103-090	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 260-247	Carp	0103-090	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 285-403	Tilapia	0103-090	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 275-297	Carp	0103-090	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Buckeye Canal 290-358	Carp	0103-090	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Salt 91st 192-156	Tilapia	0106B-001D	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Salt 91st 210-207	Tilapia	0106B-001D	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Salt 91st 235-257	Tilapia	0106B-001D	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Salt 91st 210-197	Tilapia	0106B-001D	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Salt 91st 218-212	Tilapia	0106B-001D	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Salt 91st 355-384	Plecostomus	0106B-001D	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Salt 91st 415-519	Plecostomus	0106B-001D	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Salt 91st 355-372	Plecostomus	0106B-001D	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Salt 91st 280-215	Plecostomus	0106B-001D	4,4-DDD	N.D., <PQL	0.02	mg/Kg
Salt 91st 425-601	Plecostomus	0106B-001D	4,4-DDD	N.D., <PQL	0.02	mg/Kg

1 UID – Unidentified *Samples marked with an asterisk retain field identification to correlate with lab results. Canal later determined to be Buckeye Feeder Canal.

Appendix B. USFWS Data, Painted Rock Borrow Pit Lake

Sample ID	Species	WBID	Analyte	Results	MRL (mg/kg)	Units
CARP01	Carp	0201-1010	Total DDTr	0.011641	Varies by specimen	
CARP02	Carp	0201-1010	Total DDTr	0.033213	Varies by specimen	
CRAPPIE01	Crappie	0201-1010	Total DDTr	0.12915	Varies by specimen	
CRAPPIE02	Crappie	0201-1010	Total DDTr	0.16283	Varies by specimen	
CRAPPIE03	Crappie	0201-1010	Total DDTr	0.0796	Varies by specimen	
CRAPPIE04	Crappie	0201-1010	Total DDTr	0.141	Varies by specimen	
LECY01	Green Sunfish	0201-1010	Total DDTr	0.0105	Varies by specimen	
LECY02	Green Sunfish	0201-1010	Total DDTr	0.0373	Varies by specimen	
LECY03	Green Sunfish	0201-1010	Total DDTr	0.0659	Varies by specimen	
LECY04	Green Sunfish	0201-1010	Total DDTr	0.0678	Varies by specimen	
LECY05	Green Sunfish	0201-1010	Total DDTr	0.071	Varies by specimen	
LECY06	Green Sunfish	0201-1010	Total DDTr	0.0643	Varies by specimen	
LMBASS01	LM Bass	0201-1010	Total DDTr	0.37307	Varies by specimen	
CARP01	Carp	0201-1010	DDT	N.D., <PQL	0.000122*	mg/Kg
CARP02	Carp	0201-1010	DDT	0.0002	Varies by specimen	
CRAPPIE01	Crappie	0201-1010	DDT	N.D., <PQL	0.000122*	mg/Kg
CRAPPIE02	Crappie	0201-1010	DDT	0.00021	Varies by specimen	
CRAPPIE03	Crappie	0201-1010	DDT	N.D., <PQL	0.000122*	mg/Kg
CRAPPIE04	Crappie	0201-1010	DDT	N.D., <PQL	0.000122*	mg/Kg
LECY01	Green Sunfish	0201-1010	DDT	N.D., <PQL	0.000122*	mg/Kg
LECY02	Green Sunfish	0201-1010	DDT	N.D., <PQL	0.000122*	mg/Kg
LECY03	Green Sunfish	0201-1010	DDT	N.D., <PQL	0.000122*	mg/Kg
LECY04	Green Sunfish	0201-1010	DDT	N.D., <PQL	0.000122*	mg/Kg
LECY05	Green Sunfish	0201-1010	DDT	N.D., <PQL	0.000122*	mg/Kg
LECY06	Green Sunfish	0201-1010	DDT	N.D., <PQL	0.000122*	mg/Kg
LMBASS01	LM Bass	0201-1010	DDT	0.00066	Varies by specimen	
CARP01	Carp	0201-1010	DDE	0.0115	Varies by specimen	
CARP02	Carp	0201-1010	DDE	0.03295	Varies by specimen	
CRAPPIE01	Crappie	0201-1010	DDE	0.127	Varies by specimen	
CRAPPIE02	Crappie	0201-1010	DDE	0.16	Varies by specimen	
CRAPPIE03	Crappie	0201-1010	DDE	0.0796	Varies by specimen	
CRAPPIE04	Crappie	0201-1010	DDE	0.141	Varies by specimen	
LECY01	Green Sunfish	0201-1010	DDE	0.0105	Varies by specimen	
LECY02	Green Sunfish	0201-1010	DDE	0.0373	Varies by specimen	
LECY03	Green Sunfish	0201-1010	DDE	0.0659	Varies by specimen	
LECY04	Green Sunfish	0201-1010	DDE	0.0678	Varies by specimen	
LECY05	Green Sunfish	0201-1010	DDE	0.071	Varies by specimen	
LECY06	Green Sunfish	0201-1010	DDE	0.0643	Varies by specimen	
LMBASS01	LM Bass	0201-1010	DDE	0.36642	Varies by specimen	
CARP01	Carp	0201-1010	DDD	0.000141	Varies by specimen	

Sample ID	Species	WBID	Analyte	Results	MRL (mg/kg)	Units
CARP02	Carp	0201-1010	DDD	0.000063	Varies by specimen	
CRAPPIE01	Crappie	0201-1010	DDD	0.00215	Varies by specimen	
CRAPPIE02	Crappie	0201-1010	DDD	0.00262	Varies by specimen	
CRAPPIE03	Crappie	0201-1010	DDD	N.D., <PQL	0.000122*	mg/Kg
CRAPPIE04	Crappie	0201-1010	DDD	N.D., <PQL	0.000122*	mg/Kg
LECY01	Green Sunfish	0201-1010	DDD	N.D., <PQL	0.000122*	mg/Kg
LECY02	Green Sunfish	0201-1010	DDD	N.D., <PQL	0.000122*	mg/Kg
LECY03	Green Sunfish	0201-1010	DDD	N.D., <PQL	0.000122*	mg/Kg
LECY04	Green Sunfish	0201-1010	DDD	N.D., <PQL	0.000122*	mg/Kg
LECY05	Green Sunfish	0201-1010	DDD	N.D., <PQL	0.000122*	mg/Kg
LECY06	Green Sunfish	0201-1010	DDD	N.D., <PQL	0.000122*	mg/Kg
LMBASS01	LM Bass	0201-1010	DDD	0.00599	Varies by specimen	
CARP01	Carp	0201-1010	Chlordane	0.000439605	Varies by specimen	
CARP02	Carp	0201-1010	Chlordane	0.000485365	Varies by specimen	
CRAPPIE01	Crappie	0201-1010	Chlordane	0.001081869	Varies by specimen	
CRAPPIE02	Crappie	0201-1010	Chlordane	0.001418	Varies by specimen	
CRAPPIE03	Crappie	0201-1010	Chlordane	N.D., <PQL	0.000122*	mg/Kg
CRAPPIE04	Crappie	0201-1010	Chlordane	0.000741605	Varies by specimen	
LECY01	Green Sunfish	0201-1010	Chlordane	N.D., <PQL	0.000122*	mg/Kg
LECY02	Green Sunfish	0201-1010	Chlordane	N.D., <PQL	0.000122*	mg/Kg
LECY03	Green Sunfish	0201-1010	Chlordane	N.D., <PQL	0.000122*	mg/Kg
LECY04	Green Sunfish	0201-1010	Chlordane	N.D., <PQL	0.000122*	mg/Kg
LECY05	Green Sunfish	0201-1010	Chlordane	N.D., <PQL	0.000122*	mg/Kg
LECY06	Green Sunfish	0201-1010	Chlordane	N.D., <PQL	0.000122*	mg/Kg
LMBASS01	LM Bass	0201-1010	Chlordane	0.003803	Varies by specimen	
CARP01	Carp	0201-1010	Toxaphene	N.D., <PQL	0.000904	mg/Kg
CARP02	Carp	0201-1010	Toxaphene	N.D., <PQL	0.000966	mg/Kg
CRAPPIE01	Crappie	0201-1010	Toxaphene	N.D., <PQL	0.000923	mg/Kg
CRAPPIE02	Crappie	0201-1010	Toxaphene	N.D., <PQL	0.000993	mg/Kg
CRAPPIE03	Crappie	0201-1010	Toxaphene	N.D., <PQL	0.000973	mg/Kg
CRAPPIE04	Crappie	0201-1010	Toxaphene	N.D., <PQL	0.000962	mg/Kg
LECY01	Green Sunfish	0201-1010	Toxaphene	N.D., <PQL	0.00119	mg/Kg
LECY02	Green Sunfish	0201-1010	Toxaphene	N.D., <PQL	0.00244	mg/Kg
LECY03	Green Sunfish	0201-1010	Toxaphene	N.D., <PQL	0.00227	mg/Kg
LECY04	Green Sunfish	0201-1010	Toxaphene	N.D., <PQL	0.00211	mg/Kg
LECY05	Green Sunfish	0201-1010	Toxaphene	N.D., <PQL	0.00221	mg/Kg
LECY06	Green Sunfish	0201-1010	Toxaphene	N.D., <PQL	0.00238	mg/Kg
LMBASS01	LM Bass	0201-1010	Toxaphene	N.D., <PQL	0.000935	mg/Kg

* Data for isomer totals was re-censored to highest detection limit of the set.

Appendix C. Censored Data Treatment - Beta Substitution Method

The treatment of left-censored environmental data in any analysis where non-detect data is a possibility can make a significant difference in the determination of means and other summary statistics used to evaluate a dataset. Methods commonly used include substituting one-half the detection limit for non-detect values, substituting LOD/$\sqrt{2}$, Maximum Likelihood Estimation (MLE), Kaplan Meier survival analysis method (nonparametric empiric cumulative distribution analysis), Robust Order Statistics (ROS), and others. The choice of method can make a significant difference in the reporting of final results, as some methods demonstrate inherently more bias than others. Common substitution methods generally fared the worst in comparisons of introduced bias among methods of treatment of censored data for moderate to large datasets (Ganser and Hewett, 2007).

A common drawback for all of the better-performing methods other than substitution methods is that they do not permit for the summation of constituent parts of a total analysis. Focus is entirely given to the summary statistics a researcher may be interested in, such as a mean or geomean, and individual data points are disregarded except for their aggregate characteristics, such as counts or percentages, or the magnitude of common detection limits. This limited one-array approach is adequate for most cases of censored data analysis, but it is unusable when a set of related analyses or observations with embedded individual non-detect values must be summed to arrive at a total value prior to the generation of any necessary summary statistics. For example, in this analysis, the sum of several different isomers of DDT and chlordane is necessary to arrive at a total value for the parent analytes, and the sum of DDT, DDD, and DDE is necessary to determine total DDTr. Only after such summations are made can meaningful summary statistics be validly determined. The common substitution methods, though inferior when bias and precision are evaluated, do allow for the summation of totals prior to the generation of summary statistics in a manner that recommended methods do not.

Ganser and Hewett (2010) have developed a new substitution method called beta substitution which retains the advantages of the common substitution methods, yet performs comparably to MLE, the so-called "gold standard" of censored data analysis methods, in terms of accuracy and precision. The method is applicable to lognormal datasets. The method differs from common substitution methods in that bias is reduced to near zero as sample size increases, whereas the common substitution methods demonstrate increasing bias as sample size increases. The abstract of the paper follows:

> *When analyzing censored datasets, where one or more measurements are below the limit of detection (LOD), the maximum likelihood estimation (MLE) method is often considered the gold standard for estimating the GM and GSD of the underlying exposure profile. A new and relatively simple substitution method, called β -substitution, is presented and compared with the MLE method and the common substitution methods (LOD/2 and LOD/$\sqrt{2}$ substitution) when analyzing a left-censored dataset with either single or multiple censoring points. A computer program was used to generate censored exposure datasets for various combinations of true*

geometric standard deviation (1.2 to 4), percent censoring (1% to 50%), and sample size (5 to 19 and 20 to 100). Each method was used to estimate four parameters of the lognormal distribution: (1) the geometric mean, GM; (2) geometric standard deviation, GSD; (3) 95th percentile, and (4) Mean for the censored datasets. When estimating the GM and GSD, the bias and root mean square error (rMSE) for the β -substitution method closely matched those for the MLE method, differing by only a small amount, which decreased with increasing sample size. When estimating the Mean and 95th percentile the β -substitution method bias results closely matched or bettered those for the MLE method. In addition, the overall imprecision, as indicated by the rMSE, was similar to that of the MLE method when estimating the GM, GSD, 95th percentile, and Mean. The bias for the common substitution methods was highly variable, depending strongly on the range of GSD values. The β-substitution method produced results comparable to the MLE method and is considerably easier to calculate, making it an attractive alternative. In terms of bias it is clearly superior to the commonly used LOD/2 and LOD/√2 substitution methods. The rMSE results for the two substitution methods were often comparable to rMSE results for the MLE method, but the substitution methods were often considerably biased.

Beta substitution was selected as the method for the treatment of non-detect data in this project. The steps to applying beta substitution are briefly outlined below.

1. An array of the uncensored data in the set is created.

2. Four input values are calculated, including the log mean of the uncensored dataset, the inverse normal function of the ratio of non-detects to the total size of the dataset (z), a ratio of the probability density function to the complement of the cumulative distribution function for variable z (f(z)), and a final input variable (s_y), denoted as the difference between the log mean and the Ln(LOD) divided by the difference between f(z) and z.

3. The beta value for the geomean is then calculated as

$$\beta_{GM} = exp[-s_y * (z + \frac{(n-k)}{k} * f(z))]$$

Where n = sample size and
k = number of non-detected values in the array

4. The beta value is multiplied by the level of detection (LOD).

5. The result is substituted into the array wherever a non-detect value exists.

6. Summary calculations are then determined following project objectives. In this project, summations across isomers or metabolite breakdown products occur as the subsequent step using substituted values in the summation. Summary statistics are then calculated.

For mathematical details and derivation, refer to Ganser and Hewett (2010).