Arizona Phase 1 MS4 Discharge Monitoring Data Characterization 2011-2020

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1 Introduction

Arizona's Department of Environmental Quality (ADEQ) is the delegated authority for administering the Arizona Pollutant Discharge Elimination System (AZPDES) program and issuing AZPDES permits within the State, including permits for stormwater discharges. Under the Clean Water Act (CWA), municipal separate stormwater systems (MS4s) are required to apply for permit coverage under the AZPDES program for discharges of stormwater to surface waters that meet the definition of a Water of the United States.

The U.S. Environmental Protection Agency (EPA) developed the MS4 permit program in two phases:

- Phase I: Medium and large communities and select industrial facilities were required to obtain permit coverage starting in 1990.
- Phase II: Small communities in urbanized areas, as defined by the U.S. Census Bureau, and select non-municipal organizations which operated large campuses (e.g., military bases, schools and universities) were required to obtain permit coverage starting in 1999.

ADEQ issues AZPDES permits for eight Phase I MS4s within the state (Table 1-1). These include the Arizona Department of Transportation (ADOT), which maintains and operates roads and highways throughout the state, and six medium and large municipalities concentrated in Arizona's two largest metropolitan areas around Phoenix and Tucson, and the unincorporated areas of Pima County (Figure 1-1). The municipalities with Phase I MS4s include the Cities of Glendale, Mesa, Phoenix, Scottsdale, Tempe, Tucson (Figure 1-1). AZPDES permits are issued, in part, to ensure that stormwater discharged to surface waters comply with Arizona's Water Quality Standards listed in Arizona Administrative Code (AAC) Title 18, Chapter 11 (AAC R18-11).

Table 1-1. Phase I MS4 Permittees and AZPDES Permit Administrative Information

Permittee Name	APDES No.	Permit Effective Date
ADOT	AZS0000018	July 1, 2021 – June 30, 2026
City of Glendale	AZS000019	July 1, 2021 – June 30, 2026
City of Mesa	AZS000004	July 1, 2021 – June 30, 2026
City of Phoenix	AZS000003	July 1, 2021 – June 30, 2026
City of Scottsdale	AZS000020	July 1, 2021 – June 30, 2026
City of Tempe	AZS000005	July 1, 2021 – June 30, 2026
City of Tucson	AZS000001	July 1, 2021 – June 30, 2026
Pima County	AZS000002	July 1, 2021 – June 30, 2026

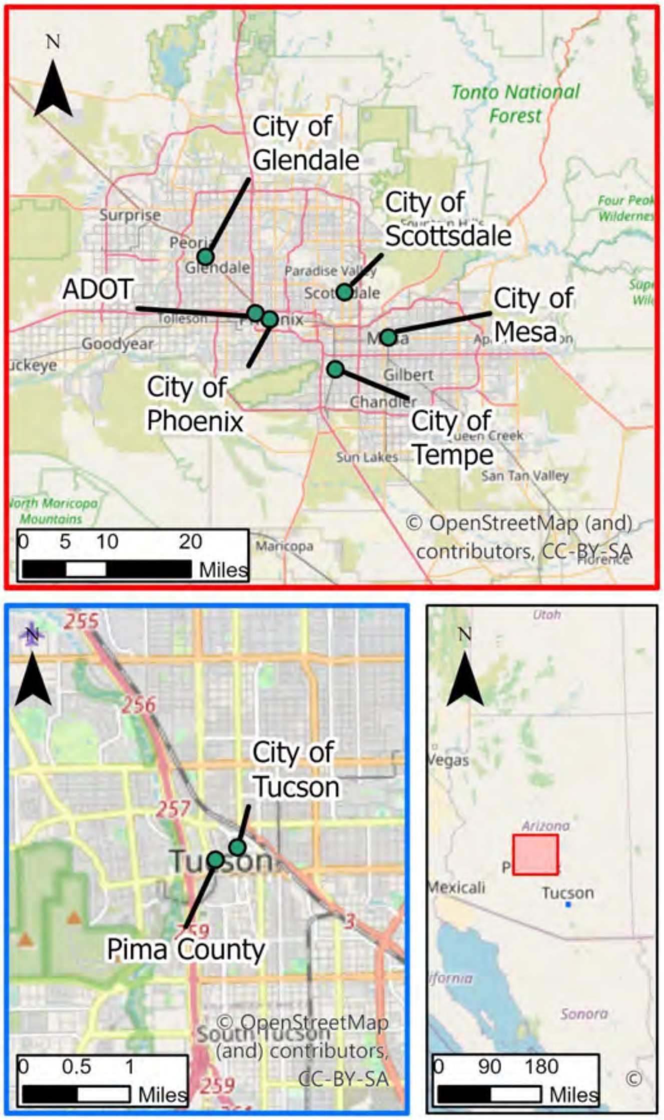

Figure 1-1. Approximate Locations of Phase I MS4 Permittees in the Phoenix and Tucson Metropolitan Areas.

Note: ADOT's regulated area is distributed throughout the state and is not limited to either metropolitan area.

Municipalities and other entities regulated under Phase I MS4 AZPDES permits collect and discharge stormwater runoff arising from precipitation events which occur within the defined MS4 service area. As stormwater flows over the land within the regulated service area, it has the potential to entrain pollutants which may deleteriously impact receiving waters. Stormwater is generated when rain or snowmelt falls on impervious surfaces like buildings and pavement which prevent infiltration of the precipitation. Urban land uses, such as commercial, industrial, and residential (low, medium, and high density) areas, tend to be less pervious than other types of land cover and may contribute greater pollutant loads to receiving waters.

Similar to other regulated sources under the AZPDES regulatory program, MS4s have the potential to discharge pollutants at high levels that could adversely affect receiving waters. However, while effluent from wastewater treatment plants and industrial discharges are required to undergo physical and chemical treatment processes prior to discharge, stormwater is largely discharged to protected surface waters without treatment. For some pollutants of concern, discharge monitoring data reviewed in this study showed that Phase I systems are, on average, discharging pollutants at levels greater than in discharges from individually permitted Publicly Owned Treatment Plants (POTWs) and industrial wastewater plants (Table 1-2). Parameters compared in Table 1-2 are bacteria and metals that are frequently detected in stormwater discharges at concentrations that exceed applicable water quality standards. As discussed in Section 4.3.2, the discharge monitoring and reporting (DMR) data reviewed as part of this study illustrates that during the period 2011 – 2020 Phase I MS4 discharges routinely exceeded applicable surface water quality standards for bacteria and frequently exceeded standards for multiple metals.

Table 1-2. Comparison of Mean and Maximum Pollutant Discharge Levels for Pollutant of Concern

Parameter	Units	MS4 Discharge[1]		POTWs & Industrial Wastewater[2]	
		Mean	Maximum	Mean	Maximum
E. coli	CFU/100 mL	7,100	1,100,000	15.2	26,100
Copper	µg/L	36.8	1,110	5.59	4,500
Lead	µg/L	9.38	299	0.619	950
Zinc	µg/L	138	1,970	42.3	3,610

1. See Sections 3.3 and 4.3 of this report for methods and results.
2. Arithmetic mean and maximum values computed from ADEQ's DMR reporting data dating from 2016 – 2020. Non-detect values were treated as zero for purposes of computing averages. Means were computed from average monthly reported concentrations, and maximums were computed from maximum daily reported values.

According to the National Research Council's 2009 report, *Urban Stormwater Management in the United States*, microorganisms are a pollutant of concern associated with typical urban land uses but particularly so with residential areas. In addition, toxic parameters (e.g., metals) have a moderate propensity to be discharged from commercial land uses and a high propensity to be discharged from industrial land uses found in urban areas.

Where discharges are identified as demonstrating a high-risk of adversely impacting receiving waters, stormwater system managers develop and implement management measures to protect the biological integrity of the waterbody and the health of the communities that use and recreate in them. Management measures may include non-structural Best Management Practices (BMPs), like community education programs and pet waste control ordinances, or structural BMPs, like retrofits to retention basins. For example, the American Society of Civil Engineers report, *Pathogens in Urban Stormwater* (Clary, *et al.*, 2014), states that BMPs that reduce runoff volumes, retention ponds, and media filtration BMPs may decrease pathogen loading to receiving waters. Improving and implementing programs to eliminate illicit discharges and sanitary sewer system cross-connections can decrease the discharge of pathogens from MS4s (Center for Watershed Protection, 2004).

The purpose of this report is to review and summarize discharge monitoring data from each of Arizona's Phase I MS4 permittees collected over approximately the past decade (2011-2020). Outcomes include characterization of pollutant discharge concentration and mass loading trends for the MS4s collectively and individually, evaluation of sources of variability in discharge quality, and identification of pollutants of concern in municipal stormwater discharges.

The report is organized into the following sections:

Section 1: An introduction to AZPDES permitting for point source surface water discharge of stormwater from Phase 1 MS4s and the objectives of this discharge characterization report.

Section 2: A summary of the Phase I MS4 monitoring and reporting requirements in existing permits.

Section 3: A description of the methods employed to compile the data set and the statistical methods applied in this study.

Section 4: A presentation of results and discussion about the statistical analyses performed.

Section 5: A summary of conclusions derived from the study and a list of recommendations for future AZPDES permit reissuances.

Section 6: A table of references cited in the report.

2 Permit Monitoring and Reporting Conditions

Discharge monitoring data was collected by the Phase I MS4 permittees under monitoring and reporting requirements specified in their respective AZPDES permits. Discharge monitoring data used in this study was collected under existing and previous permits in effect from 2011 – 2020. Sections 2.1 — 2.3 outline the permit requirements for monitoring and reporting of MS4 discharges and describe the pollutants of interest for this study.

2.1 Monitored Sites for Stormwater Characterization

Under ADEQ's MS4 program, each permittee was required to select 5 – 7 outfalls for representative discharge monitoring. These monitoring locations were selected from among all outfalls within the system to collect data representative of the whole MS4 drainage area based on land use and stormwater discharge quality. Attachment A lists the representative monitoring locations established by each permittee, their associated receiving water, and the Designated Use assigned to the receiving water under AAC R18-11, Appendix B, and R18-11-105 which establishes rules for identifying Designated Uses for waterbodies that are not explicitly listed in Appendix B of the Water Quality Standards.

The purpose of stormwater monitoring under the permits is:

1. To characterize stormwater quality and identify stormwater pollutants;
2. To detect and eliminate illicit discharges; and
3. To evaluate the effectiveness of control measures listed in the Storm Water Management Program (SWMP) to decrease the discharge of pollutants to the maximum extent practicable.

For the discharge monitoring data collected from 2011-2020, permit holders were required to monitor stormwater discharge from qualifying storm events during each of the two wet seasons[1]. A qualifying storm event is rainfall in the amount of 0.1 or 0.2 inches or more that results in a discharge. During each monitored storm event, the permittee was required to design their sampling procedures such that they captured the "first flush" (i.e., approximately the first 30 minutes) of the qualifying storm event. Each permit specified the frequency at which the samples were to be collected, the pollutant parameters to be analyzed, and the type of sample to be collected (i.e., flow-weighted composite, or discrete grab sample). Results were self-reported to ADEQ.

When a qualifying storm event occurred, a permittee was required to record the date of the qualifying storm event, the amount of rainfall, and indicate whether a discharge occurred. Each permittee monitored and collected samples for at least one qualifying event per wet season or more until all required samples had been collected. This meant collecting and analyzing a sample for each required parameter at each discharge monitoring outfall that met quality assurance and quality control (QA/QC) acceptance criteria.

Table 2-1 summarizes the monitoring requirements contained in the existing Phase I MS4 permits. The data used in this study was collected over multiple permit terms and requirements in previous permits may have differed in some respects from the requirements summarized from the existing permits.

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[1] The summer wet season runs from June 1 – October 31, and the winter wet season from November 1 – May 31.

Table 2-1. Summary of Monitoring Requirements from Existing AZPDES Permit

Permittee	No. of Representative Monitoring Locations[1]	Qualifying Storm Event	Monitoring Frequency
ADOT	5[2]	0.1 inches of rainfall and discharge occurs	Once per wet season (summer and winter) during one or more years of the permit term
City of Glendale	5	0.2 inches of rainfall and discharge occurs	Once per wet season (summer and winter) during one or more years of the permit term
City of Mesa	5	0.1 inches of rainfall and discharge occurs	Once per wet season (summer and winter) during one or more years of the permit term
City of Phoenix	5	0.1 inches of rainfall and discharge occurs	Once per wet season (summer and winter) during one or more years of the permit term
City of Scottsdale	5	0.1 inches of rainfall and discharge occurs	Once per wet season (summer and winter) during one or more years of the permit term
City of Tempe	5	0.1 inches of rainfall and discharge occurs	Once per wet season (summer and winter) during one or more years of the permit term
City of Tucson	5	0.2 inches of rainfall and discharge occurs	Once per wet season (summer and winter) during one or more years of the permit term
Pima County	5	0.2 inches of rainfall and discharge occurs	Once per wet season (summer and winter) during one or more years of the permit term

1. The number of representative monitoring locations required under the existing permit. However, the number of monitoring locations with available data for this study exceeds this number for some permittees due to: (a) designated representative monitoring locations having been changed over the period of record, and/or (b) changes in the number of representative monitoring locations required under previous permits relative to the existing permit. This study uses all available data, including data from monitoring locations established under previous permit terms from 2011-2020 which are no longer in use.
2. In previous permits, the required number of monitoring locations was seven which were entirely replaced with 5 new locations at the start of the existing permit term.

2.2 Parameters of Interest

Each AZPDES permit defined the set of pollutant parameters a permittee was required to monitor. In general, the permittees were required to monitor for pollutant parameters with numeric water quality criteria defined in the Water Quality Standards (AAC R18-11), hardness, and parameters that are pollutants of concern in municipal stormwater (e.g., total suspended solids, nutrients, and total oil and grease). The following list summarizes the set of parameters for which monitoring data was typically reported in the Annual Reports for the Phase I MS4s.

Bacteria

- ESCHERICHIA COLI

Conventional Pollutants and Other Parameters of Concern (i.e., Conventionals)

- BIOCHEMICAL OXYGEN DEMAND (BOD)
- CHEMICAL OXYGEN DEMAND
- OIL & GREASE
- pH
- TOTAL DISSOLVED SOLIDS
- TOTAL SUSPENDED SOLIDS

Hydrocarbons

- 2,4-DINITROTOLUENE
- 2,6-DINITROTOLUENE
- ACENAPHTHENE
- ANTHRACENE
- BENZ[A]ANTHRACENE
- BENZO[A]PYRENE
- BENZO[K]FLUORANTHENE
- CHRYSENE
- CIS-1,2-DICHLOROETHYLENE
- DIBENZ[A,H]ANTHRACENE
- DICHLOROBROMOMETHANE
- ETHYLBENZENE
- FLUORANTHENE
- FLUORENE
- INDENO[1,2,3-CD]PYRENE
- NAPHTHALENE
- PHENANTHRENE
- PYRENE
- TOLUENE
- TOTAL PETROLEUM HYDROCARBONS
- TRICHLOROETHYLENE
- XYLENE

Metals

- ANTIMONY
- ARSENIC
- BARIUM
- BERYLLIUM
- CADMIUM
- CHROMIUM (III)
- CHROMIUM (VI)
- COPPER

Metals (continued)

- LEAD
- MERCURY
- NICKEL
- SELENIUM
- SILVER
- THALLIUM
- ZINC

Other Inorganic Parameters (i.e., Inorganics)

- CYANIDE

Nutrients

- NITRATE
- NITRITE
- INORGANIC NITROGEN (NITRATE + NITRITE)
- AMMONIA

Organics

- ALPHA-ENDOSULFAN
- ALPHA-HEXACHLOROCYCLOHEXANE
- BETA-HEXACHLOROCYCLOHEXANE
- DELTA-HEXACHLOROCYCLOHEXANE
- 1,1,1-TRICHLOROETHANE
- 1,1,2,2-TETRACHLOROETHANE
- 1,1,2-TRICHLOROETHANE
- 1,1-DICHLOROETHYLENE
- 1,2,4-TRICHLOROBENZENE
- 1,2-DICHLOROETHANE
- 1,2-DICHLOROPROPANE
- 1,2-DIPHENYLHYDRAZINE
- 1,3-DICHLOROPROPENE
- 2,4,6-TRICHLOROPHENOL
- 2,4-DICHLOROPHENOL
- 2,4-DIMETHYLPHENOL
- 2,4-DINITROPHENOL
- 2-CHLOROETHYL VINYL ETHER
- 2-CHLORONAPHTHALENE
- 3,3'-DICHLOROBENZIDINE
- 4,6-DINITRO-O-CRESOL
- ACROLEIN
- ACRYLONITRILE
- BENZENE
- BENZIDINE
- BIS(2-CHLOROETHYL) ETHER
- BIS(2-CHLOROISOPROPYL) ETHER

Organics (continued)

- CARBON TETRACHLORIDE
- CHLOROBENZENE
- CHLOROFORM
- CHLOROMETHANE
- HEXACHLOROBENZENE
- HEXACHLOROBUTADIENE
- HEXACHLOROCYCLOPENTADIENE
- HEXACHLOROETHANE
- ISOPHORONE
- LINDANE
- M-DICHLOROBENZENE
- METHYL BROMIDE
- METHYLENE CHLORIDE
- NITROBENZENE
- N-NITROSODIMETHYLAMINE
- N-NITROSODI-N-PROPYLAMINE
- N-NITROSODIPHENYLAMINE
- P-CHLORO-M-CRESOL
- P-DICHLOROBENZENE
- PENTACHLOROPHENOL
- PHENOL
- P-NITROPHENOL
- STYRENE
- TETRACHLOROETHYLENE
- TRANS-1,2-DICHLOROETHYLENE
- TRIBROMOMETHANE
- VINYL CHLORIDE

PCBs

- TOTAL PCBs

Pesticides

- ALDRIN
- CHLORDANE
- DIELDRIN
- ENDOSULFAN SULFATE
- ENDRIN
- ENDRIN ALDEHYDE
- HEPTACHLOR
- HEPTACHLOR EPOXIDE
- METHOXYCHLOR
- P,P'-DDD
- P,P'-DDE
- P,P'-DDT
- TOXAPHENE
- DI(2-ETHYLHEXYL) PHTHALATE
- DIBUTYL PHTHALATE
- DIETHYL PHTHALATE
- DIMETHYL PHTHALATE
- DI-N-OCTYL PHTHALATE

Phthalates

- BUTYLBENZYL PHTHALATE
- DI(2-ETHYLHEXYL) PHTHALATE
- DI-N-OCTYL PHTHALATE
- DIBUTYL PHTHALATE
- DIETHYL PHTHALATE
- DIMETHYL PHTHALATE

2.3 Sample Collection and Analytical Methods

Under the AZPDES permit conditions, permittees were responsible for assuring the quality and accuracy of all data collection efforts required by the permit. Permittees were required to create and implement a Quality Assurance (QA) Manual which describes the means and methods used by the permittee to ensure the quality of data collection. Typical topics discussed in the QA Manual include but are not limited to:

- An identification of the personnel responsible for monitoring and their qualifications,
- The parameters or analytes to be quantified,
- Sample collection procedures,
- Selected analytical methods,
- Instrument calibration standards, and
- Corrective actions to be taken when problems were identified.

Permittees were required to use approved analytical methods listed in 40 CFR 136, or alternative methods approved under AAC R9-14-610(C). In addition, the permits generally required the use of an approved analytical method with method detection limits (MDLs) or Reporting Limits (RLs, i.e., the limit of quantitation) at or below the applicable water quality criteria. If all MDLs or RLs for the approved methods are greater than the applicable criteria, then the permittee must use the approved analytical method with the lowest published MDL.

3 Methods

This section describes the methods used to compile data for this characterization report and discusses the approach for evaluation of data quality and usability.

3.1 Data Compilation and Management

As discussed in Section 2, each Phase I MS4 permittee is required under their AZPDES permit to monitor stormwater discharge at a set of representative monitoring locations during qualifying storm events at set intervals throughout each permit term. This data was reported to ADEQ at a frequency of once per year in the required Annual Report.

The contractor (PG Environmental or PG) was provided with the Annual Reports which were stored in ADEQ's records management system. Source documents were provided in a number of formats including Microsoft Word documents, Portable Document Formats (PDFs), and Excel sheets (.csv or .xlsx). PG extracted the reported data for the monitoring locations from each Annual Report using a combination of automated data extraction tools (e.g., using Adobe Acrobat's Export tool to convert PDF tables to spreadsheet tables) and manual data entry where application of automated tools was infeasible. When a record was ambiguous and analytical laboratory sheets were provided in the Annual Report, PG referred to the analytical laboratory sheets for the monitoring event to clarify the result. Where a gap was identified in the records maintained by ADEQ, PG and ADEQ directly requested data from the permittee.

In some cases, non-detect data reported in permittee Annual Reports were reported as "<Value" (e.g., <10 µg/L) without indicating whether the value was an MDL or RL. When the type of limit reported was ambiguous, PG defaulted to assuming the value represented an MDL.

A small number of reported values were reported at high levels that appeared to be due to unit transcription errors (i.e., at concentrations 1000 times a typical expected value). These values were adjusted based on the assumption that their units had been misreported, resulting in an erroneously high value. All data were converted to a consistent set of units (e.g., by converting mg/L to µg/L).

Some results were reported as having been sampled on a range of dates rather than on a single date. In these cases, a single date from the range was selected to record in the database's sample date field.

Where both dissolved and total recoverable metal concentrations were reported by a permittee, both were recorded in the database. If it was infeasible to determine whether a reported value in an Annual Report referred to dissolved or total recoverable metal, the value was assumed to be in the total recoverable metal form.

The extracted data was compiled in a Microsoft Excel workbook format composed of three separate sheets or tables:

1. DMR Table: A table of all discharge monitoring and reporting data compiled by PG Environmental.
2. PRECIP Table: A table of precipitation events.
3. Monitoring Location Table: A table with location and receiving water identifying information associated with each representative monitoring location for which data is available.

These three Excel workbook tables constitute the database and were used to develop the analyses described in this report. Attachment B includes a data dictionary for the database.

In addition to compiling discharge monitoring data, PG compiled Geographic Information System (GIS) watershed boundary data for the monitored outfall locations. ADEQ and PG contacted permittees and requested watershed boundary data for each representative monitoring location. GIS data was not available for all monitoring locations—in instances where watershed boundary GIS data was not available, spatial analyses were not performed for the location. The watershed boundary files were stored in an ESRI Shapefile format. Table 3-1 catalogs the monitored watersheds for which GIS boundary data was available and those monitored watersheds for which data was unavailable.

Table 3-1. Inventory of Representative Monitoring Locations with Watershed Boundary GIS Data

Permittee	Watershed GIS Data Present	No Data Available
ADOT	Flagstaff2, Nogales, Phoenix, Sedona, Tucson	Flagstaff (Decommissioned), Nogales Maintenance Yard, Roosevelt Maintenance Yard, Spring Creek Maintenance Yard, Superior Storage and Fuel Yard
City of Glendale	ACDC10, ARROW, CITRUS, INDPK, OLIVE	–
City of Mesa	54-EMF, AS-US60, SS-US50, UN-EMF	FF-ACES
City of Phoenix	AC033, IB008, SC046, SR003, SR030, SR045, SR049	–
City of Scottsdale	–	080710, 080610, 130570, 130820, 250940
City of Tempe	KP-01, SR-05, SR-08, TD-01, TD-03	–
City of Tucson	Sampling Site 1, Sampling Site 2, Sampling Site 3, Sampling Site 4, Sampling Site 5	–
Pima County	–	Site 1, Site 2, Site 3, Site 4, Site 5

PG compiled summaries of land use data and Environmental Justice Indicator data for each monitored MS4 watershed for which watershed boundary data was available. Land use data for each monitored watershed was extracted from the 2019 National Land Cover Database (NLCD; Dewitz and U.S. Geological Survey, 2021). Environmental Justice Indicator values were extracted from each monitored watershed using EPA's EJScreen Tool[2] and are further discussed in Section 3.3.4 (EPA, 2022a). Environmental Justice indicators were selected in consultation with ADEQ to encompass an array of environmental, economic, and demographic factors. The selected indicators included the following:

(1) Particulate Matter 2.5 µm diameter levels (PM 2.5),
(2) Ozone,
(3) Air toxic cancer risk,
(4) Superfund proximity,
(5) Demographics,
(6) Percent of households where household income is less than or equal to twice the federal poverty level,

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[2] https://ejscreen.epa.gov/mapper/

(7) Percent of people with less than high school education, and
(8) Unemployment rate.

3.2 Data Qualification

This section reviews the methods employed to quantify the sensitivity (i.e., MDLs and RLs) of the compiled Phase I MS4 data reported for 2011-2020.

3.2.1 Detection and Quantitation Limits

Discharge monitoring data can be reported with varying detection and quantification status conditions:

- Non-detect: The pollutant parameter is either absent entirely, or is present at levels below which it can be accurately measured and reported with 99% confidence that the analyte concentration is greater than zero (i.e., at or below the MDL). Non-detect results were reported as "non-detect", "ND" or with a "<" flag. These results are assumed to have a concentration or level ranging from zero to the reported MDL.
- Detected but Not Quantified: The pollutant parameter was definitively detected above the MDL and is present in the discharge. However, it is present below the level at which it can be accurately quantified. Therefore, this result is qualified as "DNQ" (Did Not Quantify) and is known to be present at levels ranging between the MDL and RL (i.e., the level at which accurate quantification is possible with the analytical method). State certified laboratories may report an estimated level or concentration for a DNQ result.
- Detected: The pollutant parameter was definitively detected at levels above the applicable RL and was successfully quantified.
- Over Maximum Quantitation Limit: Present at levels higher than can be quantified with methods employed and flagged with ">" symbol. Typically, these results occur during bacteria monitoring when levels are high.

MDLs and RLs depend on the analytical methods and procedures employed by the laboratory performing the analysis. As discussed in Section 2.3, the Phase I MS4 AZPDES permits required permittees to use analytical methods which were sensitive at levels below the applicable water quality criteria (i.e., MDL < Criterion) or the most sensitive method available.

3.2.2 Non-detect Data Handling

Unlike detected results, which are point estimates of a concentration, a non-detect result is reported as a range of possible concentrations ranging from zero to the analytical method MDL. Consequently, non-detect results can be challenging to summarize. In this study, substitution methods based on one-half of the MDL concentration are used for non-detect results to permit calculation of summary statistics. For example, a result reported as non-detect with an MDL of 10 µg/L will be substituted with a result set at one-half of the MDL (i.e., 5 µg/L) when computing summary statistics that require a point estimate of the concentration. This method was selected since it is the method most routinely used for non-detect data handling by most CWA permitting authorities, including ADEQ.

3.2.3 Sensitivity of Methods Employed

Method sensitivity was evaluated by comparing the MDL (or an RL if an MDL was not reported) of non-detect results to the applicable water quality criteria for the receiving water (refer to Section 4.1.1 for results of the analysis). The proportion of non-detect samples utilizing methods with MDLs or RLs adequate to definitively confirm an exceedance of the standard were reported (i.e., the percentage of non-detect values at or below the applicable criteria). Note that this analysis did not include an assessment to determine if the most sensitive approved method available was used in instances where the MDL exceeded the criteria, and is limited to an assessment of whether the methods employed were capable of definitively confirming non-detects were below the applicable standard.

3.3 Numerical Analysis

This section provides a general description of the methods employed to analyze discharge monitoring data, land use data, and environmental justice indicators.

3.3.1 Distributional Analysis

In AZPDES permitting analyses, pollutant discharges are frequently assumed to fit a lognormal distribution to determine reasonable potential for a discharge to exceed a surface water quality standard (e.g., using a Reasonable Potential Analysis), and to compute effluent limitations or benchmarks. To test whether this is a reasonable assumption for Arizona urban stormwater discharges, each Phase I MS4 pollutant parameter data set was evaluated for goodness-of-fit under a lognormal distribution model. The suitability of a data set was assessed using the following data quality objectives:

- A minimum of 35 observation records available, and
- Fewer than 20% of observations are censored (i.e., concentrations below the lower limit of quantification and above the upper limit of quantification were considered censored)

These data quality objectives ensure that a sufficient number of representative and accurate data points are available to support the model parameterization for a pollutant distribution. The testing statistic (the Shapiro-Wilk Test W, discussed in further detail below) requires the use of detected data, which limits this procedure to parameters with a high detection rate (≥ 80%). During distribution modeling, the data which met the objectives was evaluated at two levels: (1) pooling all available data for a given parameter, and (2) pooling all available data for a given parameter from all outfalls for a single permittee.

Goodness-of-fit under a lognormal distribution model was tested using the Shapiro-Wilk Test (Helsel, *et al.*, 2020) under a hypothesis testing framework. The test takes as a null hypothesis that the data is lognormally distributed which will be rejected at test statistic p-values < 0.05 (i.e., a 95% significance level). Tests were conducted on detected data using analytical tools contained in the R programming language (R Core Team, 2023). Fit was confirmed via visual inspection of a probability plot of the observed data and the lognormal distribution. Lognormal model fit results are reported in Attachment C Table B-1 and are described further in Section 4.1.3.

3.3.2 Descriptive Statistics

Summary statistics were computed for all pollutant and precipitation data compiled in the database. These included:

- N: The number of records captured in the database for the parameter.
- Minimum and Maximum: Minimum and maximum reported concentrations. If non-detects were reported, the minimum reported MDL of the non-detect results is assumed to be the minimum. If all values were non-detect, the minimum and maximum MDLs were reported.

- Percent Non-Detect: The percentage of the data set which was reported as below the detection limit.
- Mean and standard deviation: The mean and standard deviation of the data set. Non-detect values were assumed to be equal to one-half (1/2) the MDL.
- For storm event precipitation data, empirical minimum, maximum, and median storm levels were reported in Section 4.2.

In addition to the summary statistics described above, all available pollutant concentration data were plotted as time series (see Attachment E), and storm event data were plotted as histograms (Attachment D).

3.3.3 Water Quality Analysis

3.3.3.1 Water Quality Criteria

Arizona's Surface Water Quality Standards (SWQS) (AAC R18-11) define Designated Uses for Arizona's surface waters subject to Clean Water Act protections, numeric, and narrative criteria protective of those uses, and an antidegradation policy to preserve existing water quality. Table 3-2 describes the Designated Uses of surface waters defined in the Water Quality Standards. This study used the numeric water quality criteria adopted for toxics approved by EPA and effective as of December 23, 2016 (see AAC R18-11, and AAC R18-11 Appendices B and C[3]).

Table 3-2. Water Quality Standard Designated Uses

Designated Use	Description
Agricultural Irrigation (AgI)	The use of surface water for crop irrigation.
Agricultural Livestock Watering (AgL)	The use of surface water as a water supply for consumption by livestock.
Aquatic Life and Wildlife (cold water) (A&W$_c$)	The use of a surface water by animals, plants, or other cold-water organisms, generally occurring at an elevation greater than 5,000 feet, for habitation, growth, or propagation.
Aquatic Life and Wildlife (warm water) (A&W$_w$)	The use of a surface water by animals, plants, or other warm-water organisms, generally occurring at an elevation less than 5,000 feet, for habitation, growth, or propagation.
Aquatic Life and Wildlife (ephemeral) (A&W$_e$)	The use of an ephemeral water by animals, plants, or other organisms, excluding fish, for habitation, growth, or propagation.
Aquatic Life and Wildlife (effluent-dependent water) (A&W$_{edw}$)	The use of an effluent-dependent water by animals, plants or other organisms for habitation, growth, or propagation.
Full-Body Contact (FBC)	The use of a surface water for swimming or other recreational activity that causes the human body to come into direct contact with the water to the point of complete submergence. The use is such that ingestion of the water is likely and sensitive body organs, such as the eyes, ears, or nose, may be exposed to direct contact with the water.
Partial-Body Contact (PBC)	The recreational use of a surface water that may cause the human body to come into direct contact with the water, but normally not to the point of complete submergence (for example, wading or boating). The use is such that ingestion of the water is not likely and sensitive body organs, such as the eyes, ears, or nose, will not normally be exposed to direct contact with the water.
Fish Consumption (FC)	The use of a surface water by humans for harvesting aquatic organisms for

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[3] See: https://static.azdeq.gov/wqd/SW_Standards_12_31_16.pdf

Designated Use	Description
	consumption. Harvestable aquatic organisms include, but are not limited to, fish, clams, turtles, crayfish, and frogs.

Aquatic and Wildlife Criteria for pentachlorophenol, ammonia, and some metals (see Tables 2 through 12 of AAC R18-11, Appendix B) vary based on secondary parameters present in the discharge or the receiving water. This is because the toxicity of these pollutants changes based on the availability of the secondary parameter—for example, divalent metal ions, like copper, compete with dissolved water hardness ions for binding sites on fish gills and high hardness concentrations decrease the bioavailability of the dissolved copper. To estimate applicable criteria at a given discharge location for these parameters, the following strategy was used:

1. Effluent pH, and hardness values were used to compute applicable criteria for receiving waters with A&W$_{e}$ and A&W$_{edw}$ Designated Use since the instream flow will be largely composed of the effluent.
2. Ecoregional default pH, temperature, and hardness values were used for receiving water with A&W$_{c}$ and A&W$_{w}$ Designated Uses. Default values were based on the 10th percentile pH or hardness values, and the 90th percentile for temperature values reported for monitored surface waters in the EPA Level III Ecoregion (2023) as reported by the EPA (2022b). Refer to Table 3-3 for default values associated with each Arizona ecoregion.

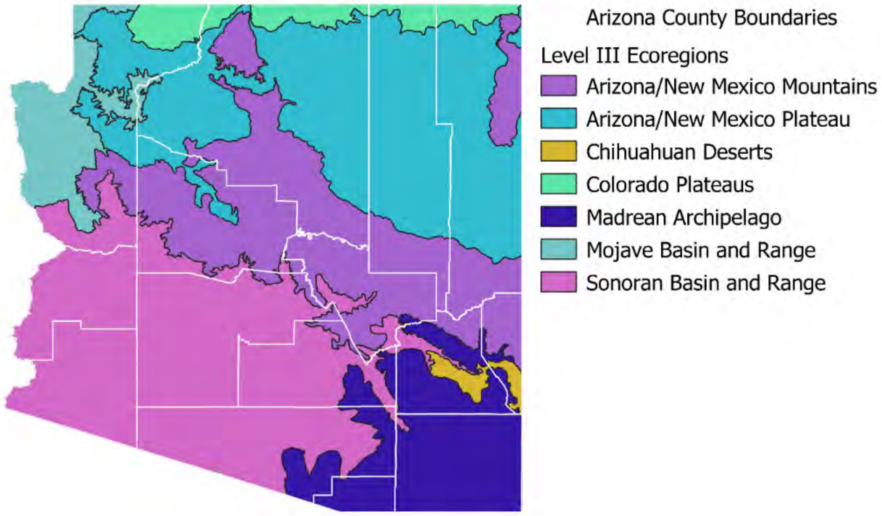

Figure 3-1. Level III Ecoregions of Arizona

Table 3-3. Ecoregional Default Water Quality Parameters

Ecoregion Name	Hardness (mg/L CaCO$_3$)	pH (Standard Units)	Water Temperature (deg. F)
Mojave Basin and Range	249.0	7.6	23.5
Colorado Plateaus	138.0	7.9	20.1
Arizona/New Mexico Mountains	115.4	8.0	23.3
Madrean Archipelago	131.0	7.8	27.5
Sonoran Basin and Range	143.0	7.7	28.4

For *E. coli* bacteria standards, only the single sample maximum value criteria were used in the exceedance analysis. No comparison was made between the MS4 discharges and the geometric mean bacteria criteria because the geomean criteria require a minimum of four samples in a 30 day period for assessment and this condition is not met by the reported monitoring data for a qualifying storm event. For A&W standards, both chronic and acute criteria values were compared to reported MS4 discharge quality data.

3.3.3.2 Exceedances of Water Quality Criteria

All discharge monitoring values that were both (1) detected in the discharge, and (2) present at levels that exceeded a minimum applicable numeric criterion (human health, acute A&W, or chronic A&W) were categorized as an exceedance. Non-detect values were always categorized as a non-exceedance. In situations where no applicable criteria were available, the monitoring record was removed from the water quality exceedance analysis and was not counted for either category. Overall criterion exceedance rates were computed at the following levels:

- The pooled rate for all Phase I MS4s, and
- The permittee-level exceedance rates

This analysis was performed using discharge monitoring data collected from outfalls that discharge to protected surface waters with an associated water quality criterion for a pollutant of concern. Exceedances of water quality criteria were plotted by year to illustrate trends in discharge quality over time. The results of this analysis are reported in Section 4.3.2 Figure 4-8.

Note that this analysis is based on Water Quality Standards described in Section 3.3.3.1 which were adopted in 2016. The applicable standards prior to 2016 may have been different than the values used in this study. Exceedances of the 2016 water quality criteria, as discussed in this report, may not reflect exceedances of water quality for discharges occurring prior to the adoption of the 2016 standards and approval by EPA.

3.3.4 Land Use and Environmental Justice Indicator Statistics

Descriptive statistics were developed for the watersheds associated with each representative monitoring location or outfall. The 2019 NLCD (Dewitz and U.S. Geological Survey, 2021) was used to compute the following:

1. Percent impervious surface cover (i.e., developed land cover surfaces which are not permeable to water, like roofs and pavement) and pervious surface cover for the watershed associated with each monitored outfall, and

2. Land cover quantities as a percentage of total watershed area for each monitored outfall.

These were computed using publicly available GIS software (ESRI ArcGIS), the 2019 NLCD raster images, and vector-based boundary files for the monitoring locations provided by the permittees (i.e., six out of eight of the permittees produced GIS boundary files for the monitored watersheds as described in Section 3.1). For outfalls where GIS watershed boundary data was unavailable (see Table 3-1), it was infeasible to calculate land use estimates. Results of this analysis are presented in Section 4.4.

For Environmental Justice (EJ) indicators, EPA's Environmental Justice Screening & Mapping Tool (EJScreen; EPA, 2022a) was used to develop descriptive statistics for each of the permittee's representative monitored drainage basins (again, limited to the watersheds for which GIS boundary data was available). ADEQ selected eight EJ indicators for this analysis—four indicators based on pollutant conditions and four related to socioeconomic indicators of general interest to ADEQ and the public. Table 3-4 describes the eight selected indicators. EPA's EJScreen tool was used to identify the relative level of an indicator (i.e., the percentile in the distribution of indicator results for all locations in the area of interest). Metrics were reported as a percentile relative to the population of (1) Arizona, and (2) the United States. This reporting approach tells the reader roughly what percent of the Arizona population or U.S. population lives in a census block group that has a higher indicator value than that of the monitored watershed. As stated in EPA's EJScreen Technical Support Document (2022c), the percentile "indicates how uncommon" an indicator value is within Arizona or the United States. Results of this analysis are presented in Section 4.5. In some cases, monitored watersheds were too small to register a result when input into the EJScreen tool; therefore, a 0.25-mile buffer was added to each monitored watershed boundary file when input in order to generate a reading within the tool.

Table 3-4. Description of EJ Indicators

Indicator Name	Description
Pollutant Indicators	
PM 2.5	Particulate matter (PM 2.5) levels in air, micrograms per cubic meter (µg/m3) annual average.
Ozone	Ozone summer seasonal avg. of daily maximum 8-hour concentration in air in parts per billion.
Air Toxics Cancer Risk	Lifetime cancer risk from inhalation of air toxics, as risk per lifetime per million people.
Superfund Proximity	Count of proposed and listed NPL sites within 5 km (or nearest one beyond 5 km), each divided by distance in km. Count excludes deleted sites.
Socioeconomic Indicators	
Demographics	The demographic index in EJScreen is a combination of percent low-income and percent minority, the two socioeconomic factors that were explicitly named in *Executive Order 12898 on Environmental Justice*. For each Census block group, these two numbers are simply averaged together. The formula is as follows: demographic index = (% people of color + % low-income) / 2.
Low Income	Percent of individuals whose ratio of household income to poverty level in the past 12 months was less than 2 (as a fraction of individuals for whom ratio was determined).
Less Than High School Education	Percent of individuals age 25 and over with less than high school degree.
Unemployment	All those who did not have a job at all during the reporting period, made at least one specific active effort to find a job during the prior 4 weeks, and were available for work (unless temporarily ill).

3.3.5 Seasonality

The effects of seasonal conditions on the discharge were investigated by comparing the relative levels of select metals and *E. coli* in the Phase I MS4 discharges between the two wet seasons[4] defined in the AZPDES Phase I MS4 permits. The metals selected were antimony, arsenic, barium, chromium, copper,

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[4] The summer wet season runs from June 1 – October 31, and the winter wet season from November 1 – May 31.

lead, nickel, and zinc. These metals and *E. coli* were included in the analysis because (1) monitoring data were available for most monitoring locations, (2) discharges of these pollutants frequently result in water quality exceedances, and (3) they were detected in the discharges at high rates. Other metals were excluded from the analysis because low detection rates rendered the test methods employed here either ambiguous or infeasible to implement.

The Wilcoxon rank sum test (Helsel, 2020) was used to compare seasonal median concentrations. Data from all permittees were pooled for this comparison (i.e., all copper observations from all permittees were grouped and seasonal medians compared). The Wilcoxon rank sum test is a nonparametric test that does not rely on the assumption of an underlying distribution for the data (e.g., that the data are lognormally distributed). Pollutant data may display different data distributions or no distribution at all, therefore this approach provides a consistent and robust approach to compare seasonal patterns in the data across the universe of pollutant parameters in the database. All data for the time period of interest (2011-2020) for all eight permittees was used in the analysis. See Section 4.6 for a discussion of the results of this analysis.

3.3.6 Pollutant Loads

Pollutant loading rates to receiving waters were calculated for the monitored watersheds. Loading rates were calculated using the Simple Method, as described in EPA's *Guidance Manual for the Preparation of Part 2 of the NPDES Permit Applications for Discharges from Municipal Separate Storm Sewer Systems* (1992). The total area of the majority of the Phase I MS4 service areas were not available, therefore pollutant loading rate calculations were limited to the representative monitored watersheds.

The Simple Method is described by the following formula:

$$L_i = (P)(R_i)(EMC)(Ai)$$

Where,

L_i = Annual pollutant load for outfall i
P = Total annual precipitation which produces runoff
R_i = Runoff coefficient for the watershed draining to the ith monitored outfall
EMC = Even mean concentration of pollutant
A_i = Catchment area for the ith monitored outfall

Watershed precipitation data reported by the permittees was used compute the total annual rainfall in each watershed. As discussed in Section 2.1, permittees are required to report on qualifying storm events which meet a minimum rainfall threshold likely to result in runoff (either 0.1 or 0.2 inches depending on the permittee). Therefore, it was assumed that all reported rainfall totals were associated with storms that had the potential to produce runoff. For some permittees, this total precipitation quantitation method is likely to result in an underestimate of total rainfall since not all qualifying storm events were reported due to rain gauge failures or other issues.

The runoff coefficient (R_i) is a function of the imperviousness of the catchment area and indicates the fraction of precipitation which will runoff in a runoff-producing storm event. Runoff coefficients may be computed through direct measurement, or estimated based on the amount of impervious cover in the watershed. The 2019 NLCD (Dewitz and U.S. Geological Survey, 2021) was used to characterize impervious cover present in each monitored watershed. This study estimated runoff coefficients based on Equation 3 from EPA (1992), as follows:

$$R_i = 0.05 + 0.9 \times I_i$$

Where,

I_i = The impervious cover fraction of the i^{th} catchment area

Pollutant event mean concentrations (EMC) were based on the annual average discharge concentration at each location. When computing mean values, non-detects were treated as one-half (1/2) the MDL. In years where pollutant concentrations were not measured at an outfall by the permittee, the overall average concentration at the location was substituted for purposes of calculating a load value for the year with missing data.

Monitored outfall catchment areas were computed from GIS watershed boundary data provided by the permittees identified in Table 3-1 and described in greater detail in Section 3.1.

Monitored outfall pollutant loading rates were also normalized and reported on a unit-area rate basis. These normalized values were computed by dividing each watershed's loading rate by its respective watershed catchment area. Overall average unit loading rates were computed by computing the average unit loading rate for each permittee over the period of record, then by averaging the resulting values such that each MS4 permittee is given equal weight in the overall average.

4 Results and Discussion

This section describes the results of data and analyses for Arizona's Phase I MS4 permittees.

4.1 Database Description

As discussed in Section 3.1, the database compiled for this study included three tables which contained (1) discharge monitoring data reported by Arizona's Phase I MS4s at their representative discharge monitoring locations, (2) precipitation data for recorded storm events, and (3) information on monitoring locations and their associated receiving waters.

The discharge monitoring table included approximately 74,400 records reported by the eight Phase I MS4 permittees. Table 4-1 summarizes the number of monitoring locations, monitoring events reported, and the date range recorded for each permittee. Table 4-2 expands this description by summarizing similar information at the level of each monitoring year included in the database.

Table 4-1. Discharge Monitoring Data Summary by Permittee

Permittee	Count of Monitoring Events[1]	Count of Monitoring Locations	Date Range
ADOT	70	11	2011 - 2020
Glendale	47	5	2011 - 2020
Mesa	47	5	2011 - 2019
Phoenix	53	7	2011 - 2020
Pima County	46	5	2011 - 2019
Scottsdale	70	5	2011 - 2019
Tempe	67	5	2011 - 2020
Tucson	51	5	2011 - 2020

1. The count of unique sample dates reported at each monitoring location.

Table 4-2. Number of Reported Sampling Events by Year

Permittee	Count of Monitoring Events[1] by Year									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
ADOT	2	4	7	6	11	9	3	11	13	4
Glendale	4	6	4	4	4	8	4	7	5	1
Mesa	6	9	9	2	5	6	2	7	1	NA
Phoenix	5	5	7	4	3	10	4	6	8	1
Pima County	4	5	4	5	6	7	2	6	7	NA
Scottsdale	6	8	10	5	9	10	5	5	12	NA
Tempe	5	10	11	7	5	8	6	8	6	1
Tucson	3	6	7	8	6	6	3	4	3	5

1. The count of unique sample dates reported at each monitoring location.

4.1.1 Data Quality

Generally, the sensitivity of the methods employed by the permittees over the period of record were adequate to definitively determine whether pollutants in the discharge are present at levels exceeding the applicable water quality standards. Figure 4-1 displays the percentage of non-detect monitoring results utilizing analytical methods suitable for definitively confirming whether a measurement was below the applicable water quality criterion. Pollutant categories with low method sensitivity attainment rates are associated with parameters with low water quality criteria. Approved analytical methods at or below these levels may be unavailable (e.g., PCBs and some pesticides).

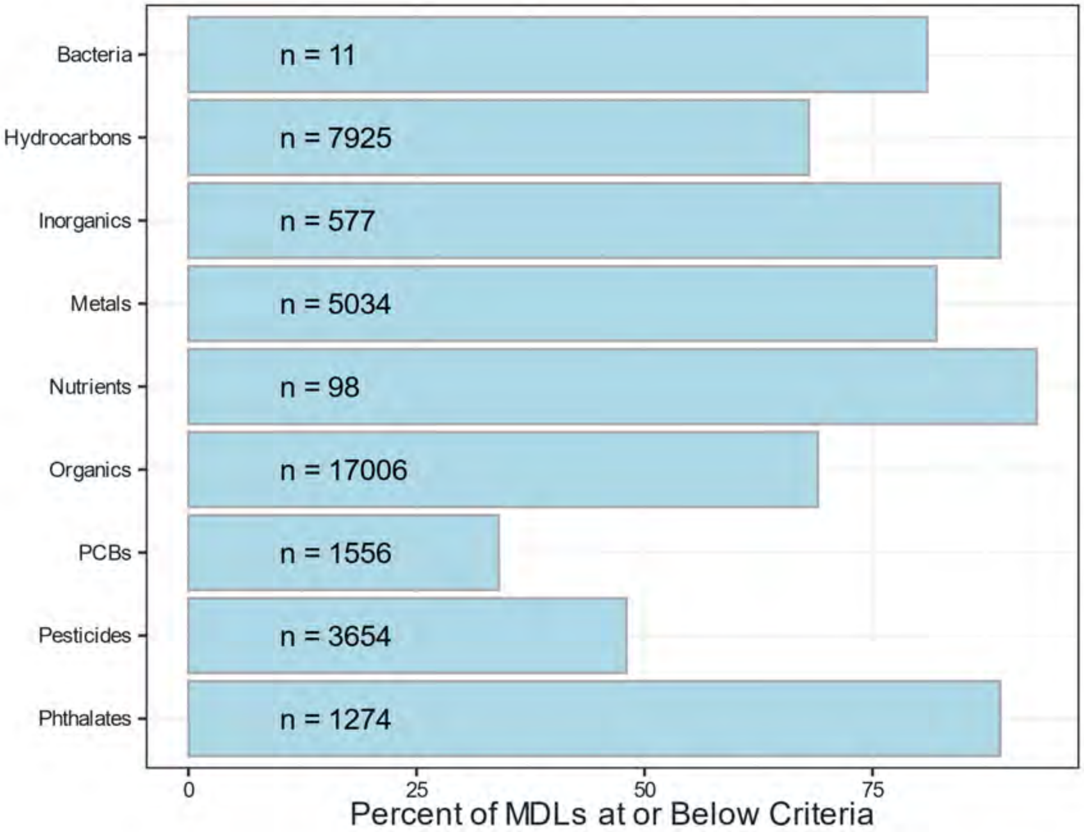


Figure 4-1. Percent of Non-Detect Samples Using MDLs at or Below the Applicable Criteria
Note: n-value indicates the number of samples in the category included in the calculation.

Table 4-3 summarizes method sensitivity results by Phase I MS4 permittee. It reports the percentage of non-detect results which were below the applicable criterion for pollutant categories, the overall percentage for the permittee, and number of non-detect samples with an applicable criterion for each permittee.

Table 4-3. Method Sensitivity by Permittee

Permittee	Category	Non-Detects at or Below Applicable Criteria (%)	Non-Detects at or Below Applicable Criteria (%)	Count of Non-Detect Samples with an Associated Criterion
ADOT	Bacteria	77	63	1182
	Conventionals	NA[1]		
	Hydrocarbons	56		
	Inorganics	92		
	Metals	72		
	Nutrients	83		
	Organics	100		
	PCBs	NA[2]		

Permittee	**Category**	**Non-Detects at or Below Applicable Criteria (%)**	**Non-Detects at or Below Applicable Criteria (%)**	**Count of Non-Detect Samples with an Associated Criterion**
	Pesticides	NA[2]		
	Phthalates	NA[2]		
Glendale	Bacteria	100	86	5397
	Conventionals	NA[1]		
	Hydrocarbons	87		
	Inorganics	100		
	Metals	87		
	Nutrients	NA[1]		
	Organics	91		
	PCBs	42		
	Pesticides	80		
	Phthalates	100		
Mesa	Bacteria	NA[1]	82	3231
	Conventionals	NA[1]		
	Hydrocarbons	91		
	Inorganics	100		
	Metals	90		
	Nutrients	100		
	Organics	82		
	PCBs	0		
	Pesticides	66		
	Phthalates	100		
Phoenix	Bacteria	NA[1]	74	10536
	Conventionals	NA[1]		
	Hydrocarbons	75		
	Inorganics	97		
	Metals	83		
	Nutrients	100		
	Organics	77		
	PCBs	43		
	Pesticides	61		
	Phthalates	95		
Pima County	Bacteria	NA[1]	9	4108
	Conventionals	NA[1]		
	Hydrocarbons	3		
	Inorganics	11		
	Metals	10		
	Nutrients	NA[1]		
	Organics	4		
	PCBs	29		
	Pesticides	30		
	Phthalates	12		
Scottsdale	Bacteria	NA[1]	73	4306

Permittee	Category	Non-Detects at or Below Applicable Criteria (%)	Non-Detects at or Below Applicable Criteria (%)	Count of Non-Detect Samples with an Associated Criterion
	Conventionals	NA[1]		
	Hydrocarbons	71		
	Inorganics	100		
	Metals	90		
	Nutrients	100		
	Organics	70		
	PCBs	37		
	Pesticides	51		
	Phthalates	98		
Tempe	Bacteria	NA[1]	62	6031
	Conventionals	NA[1]		
	Hydrocarbons	70		
	Inorganics	100		
	Metals	92		
	Nutrients	NA[1]		
	Organics	63		
	PCBs	0		
	Pesticides	0		
	Phthalates	100		
Tucson	Bacteria	NA[1]	89	2344
	Conventionals	NA[1]		
	Hydrocarbons	89		
	Inorganics	63		
	Metals	95		
	Nutrients	NA[1]		
	Organics	94		
	PCBs	1		
	Pesticides	78		
	Phthalates	100		

1. Not applicable. All samples for waterbodies with applicable criteria were detected in the discharge.
2. Not applicable. No discharge monitoring samples were reported for the period of interest.

4.1.2 High Frequency Non-Detected Parameters

Figure 4-2 depicts the total rates of non-detection by pollutant category and total number of sample records for each category. Hydrocarbons, organic pollutants, PCBs, and pesticides were reported as non-detect in more than 98% of samples. Outside of these categories, the following individual parameters had non-detect rates in excess of 90%:

- DI-N-OCTYL PHTHALATE (98%)
- DI (2-ETHYLHEXYL) PHTHALATE (100%)
- DIMETHYL PHTHALATE (98%)
- DIETHYL PHTHALATE (93%)
- DIBUTYL PHTHALATE (94%)
- CYANIDE (93%)

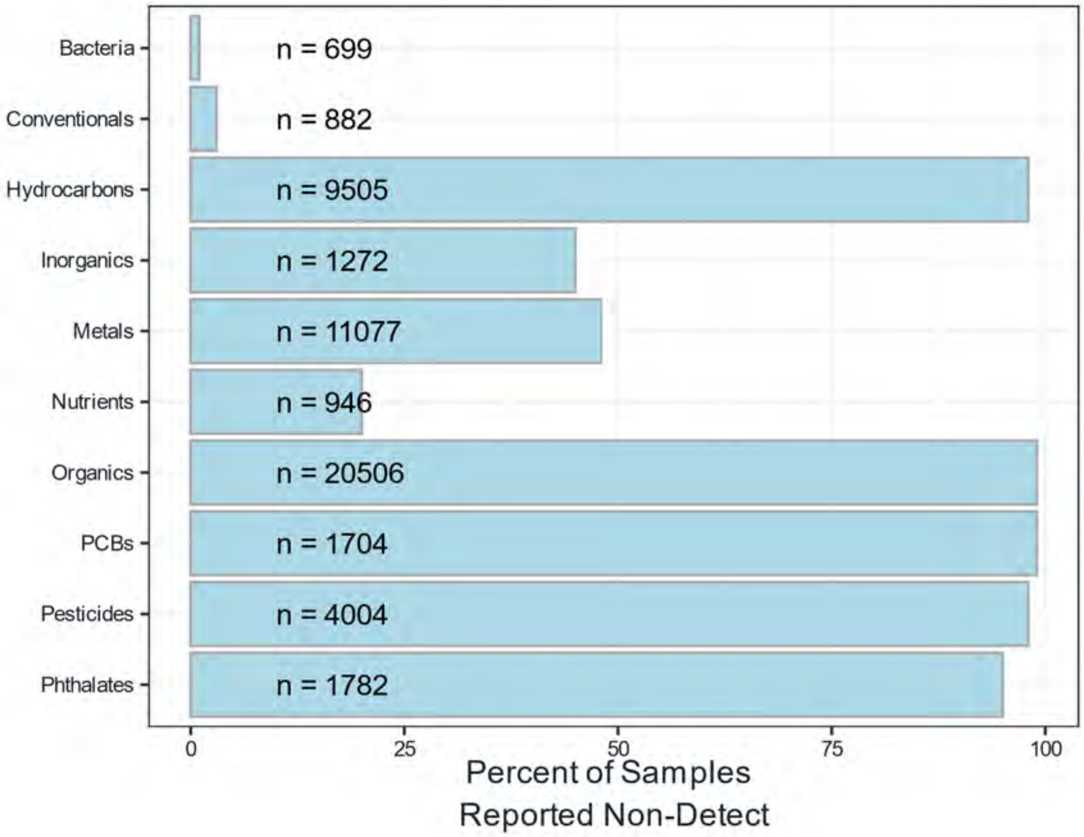


Figure 4-2. Parameter Categories with High Frequency of Non-Detects
Note: n-value indicates the number of samples in the category included in the calculation.

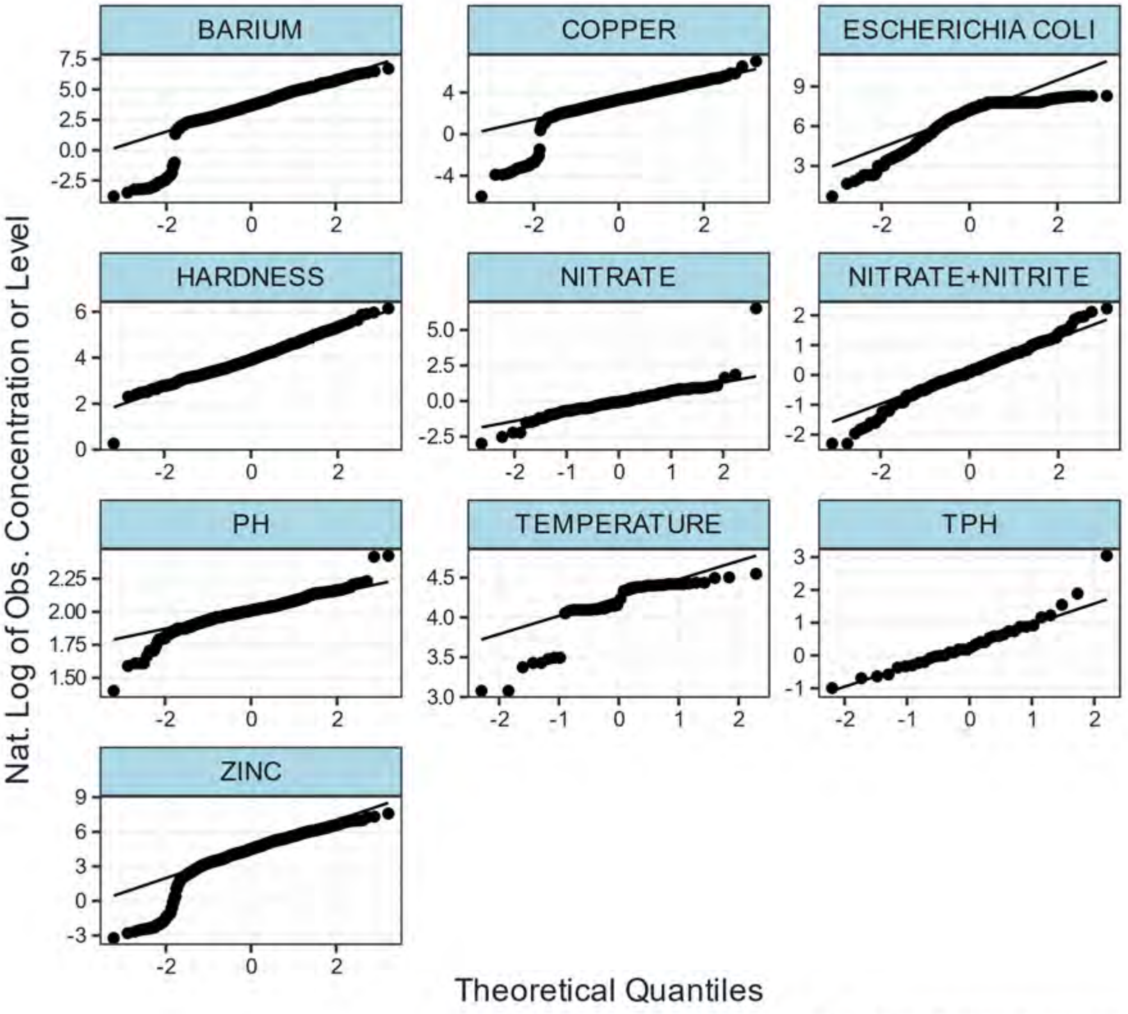
The high percent (89%) of phthalate samples measured usings methods capable of definitively confirming an exceedance of the applicable criteria, combined with a high percent of those samples being measured as non-detect, indicate that phthalates are either absent or present at low levels. In the case of hydrocarbons (68%), organics (69%), PCBs (34%) and pesticides (48%), the analytical methods employed by the permittees were not consistently sensitive enough to definitively confirm compliance with criteria. When analytical methods with MDLs or RLs that exceed the water quality criterion are used, it is infeasible to determine definitively whether these parameters are of low or limited risk to water quality in the MS4 discharges.

4.1.3 Data Distributions

Distributional modeling was performed on monitoring data from permittees' representative outfalls to determine if the effluent data displayed reasonable conformance with a lognormal distribution model. Lognormal distributions are a common statistical model for pollutant concentrations in effluent discharges and in the natural environment (Helsel, et al., 2020; EPA, 1991). Lognormal model goodness-of-fit was evaluated at two levels: (1) by pollutant parameter for all Phase I MS4s combined, and (2) by pollutant for individual MS4 permittees.

In the first case, lognormal model fit was evaluated based on pooled data sets which combined the data from all permittees. At this level of analysis, none of the parameters displayed a statistically significant fit with a lognormal model at the 95% significance level. Figure 4-3 shows lognormal model quantile-

quantile plots for each parameter that met the data quality objectives for inclusion in the analysis. Quantile plots provide a visual indication of the level of fit between the observed data (points) and the theoretical distribution (lines). The better the match between the points and lines in the displayed figure, the better the fit with a theoretical lognormal model. Table 4-4 reports the test statistic results and p-values associated with each test.



Points = observed values
Solid line = line of the theoretical lognoral distribution
Note: Plot excludes two outlier hardness values to improve the legibiity of the figure.

Figure 4-3. Lognormal quantile-quantile plots for parameters with suitable data for performing distribution modeling.

Table 4-4. Lognormal Model Fit Results

Parameter	W Test Statistic[1]	P-Value[2]	Decision
BARIUM	0.81	<<0.01	Poor Fit
COPPER	0.78	<<0.01	Poor Fit
ESCHERICHIA COLI	0.96	<<0.01	Poor Fit
HARDNESS	0.99	<<0.01	Poor Fit
NITRATE	0.82	<<0.01	Poor Fit
NITRITE + NITRATE	0.99	<<0.01	Poor Fit
PH	0.93	<<0.01	Poor Fit
TEMPERATURE	0.93	<<0.01	Poor Fit
TOTAL PETROLEUM HYDROCARBONS (TPH)	0.93	0.030	Poor Fit
ZINC	0.85	<<0.01	Poor Fit

1. The Shapiro–Wilk test statistic
2. A significant test result ($P < 0.05$) means that the test hypothesis (i.e., the data is lognormally distributed) is false or should be rejected.

At this level of analysis, the results suggest that a lognormal model is generally a poor assumption for Arizona Phase I MS4s taken as a group. The poor fit of the model may have been influenced by the use of the one-half MDL substitution method for non-detects, as this can cause deformation of the lower tail of the distribution that otherwise might not occur if the true concentrations of the non-detect sample records were known. Other non-detect handling methods, like use of robust regression-on-order statistical imputation methods (Helsel, 2012; and Helsel, et al., 2020), may produce different results, as these methods were designed to overcome the limited information content of censored data (i.e., that only a range of potential concentrations is known, rather than a point concentration estimate). As discussed in Section 3.2.2, this analysis uses the ½ MDL substitution method to be consistent with best practices employed by most NPDES permitting authorities when developing permit conditions.

This analysis was repeated at the permittee level (i.e., model fit was assessed for each parameter for each permittee individually; see Attachment C for detailed results). At this level of analysis, the model fit results were mixed with a lognormal model showing an acceptable goodness-of-fit in approximately 52% (34 out of 65) of permittee-pollutant parameter groupings. This suggests that the application of a lognormal model may be reasonable for MS4 stormwater modeling at the individual system level, but may not be universally applicable.

Figure 4-4 illustrates the results for copper for the permittees with data suitable for the analysis. Among this group, Mesa, Phoenix, Tempe, Tucson, and Pima County show acceptable fit with a lognormal model at the 95% significance level. ADOT, and Scottsdale copper data do not fit a lognormal model at the 95% significance level.

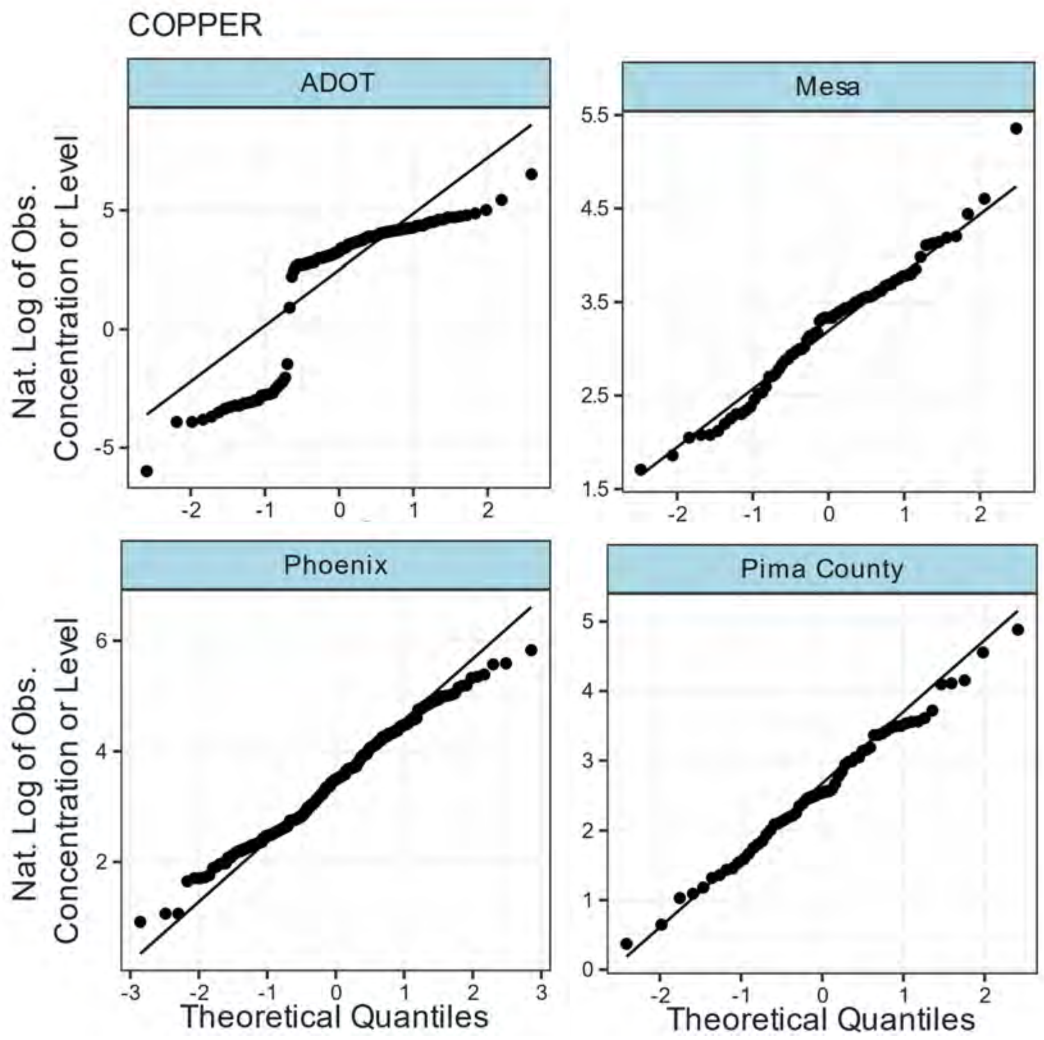


Figure 4-4. Copper lognormal quantile-quantile plots for permittees with suitable data for performing distribution modeling.

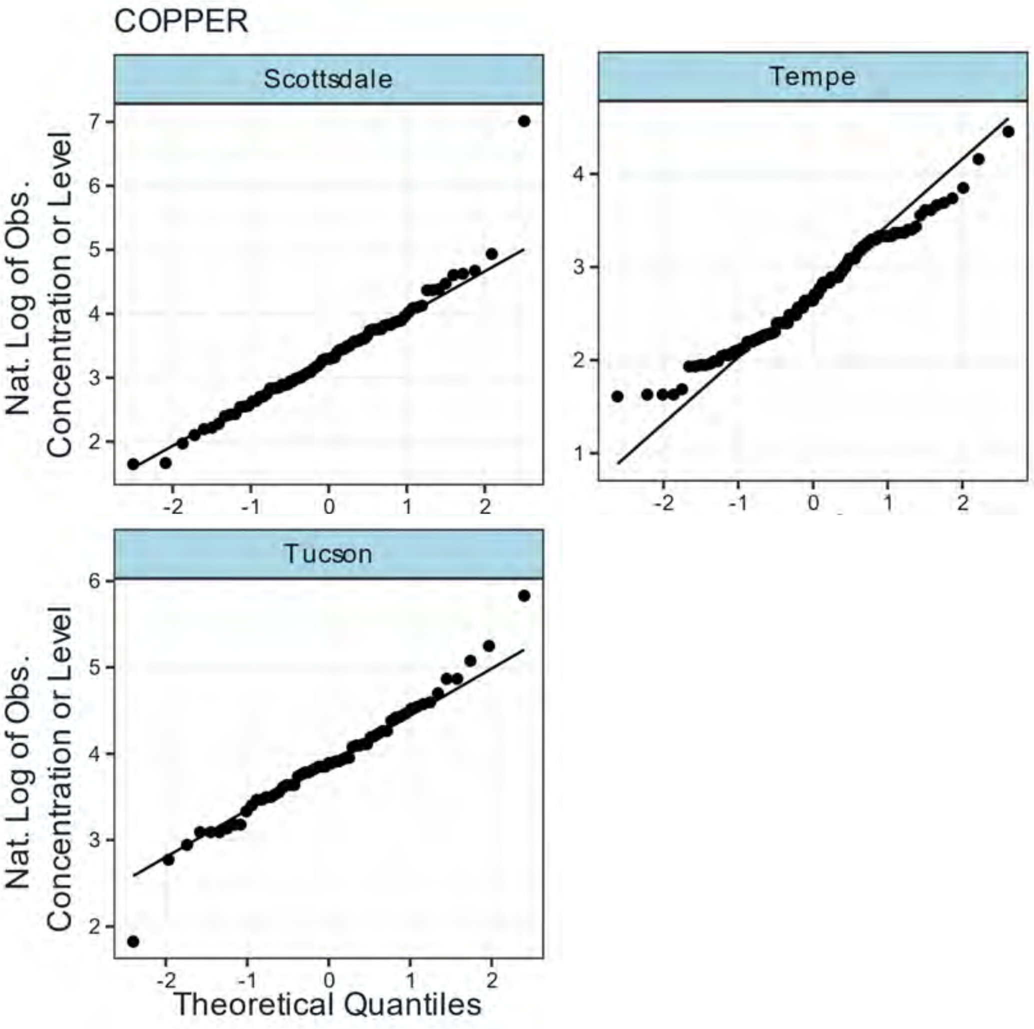


Figure 4-4 (Continued). Copper lognormal quantile-quantile plots for permittees with suitable data for performing distribution modeling.

In addition to the limitations of substitution methods for non-detect data, additional uncontrolled factors which may confound this analysis are changes in pollution control measures adopted over the period of record by the permittees. Improvements (or the opposite) in pollution control measures may result in systemic shifts in discharge quality which would interfere with model fitting. If the analysis was performed on data distributions for sample dates preceding and following pollution control implementation activities separately, it is possible that distribution fit results would be found to be different than those that have been reported here.

4.2 Storm Event Precipitation Totals

Reported storm event precipitation for the period 2011 – 2020 was summarized and reported as minimum, median, and maximum storm event precipitation levels (Table 4-5). Histograms of reported precipitation in inches were plotted against the number of recorded qualifying precipitation events for each monitoring location and are presented in Attachment D.

The largest reported precipitation event in the database was reported at ADOT's Nogales station on July 20, 2018 (approximately 5 inches over a week). The second largest reported precipitation event was reported at a large number of stations throughout the Phoenix metropolitan area on September 8, 2014 (total value ranging from 1.0 – 4.5 inches depending on the station over two days).

Table 4-5. Summary of Precipitation Events

Permittee	Monitoring Location	No. of Reported Storm Events	Total Precipitation (inches)		
			Minimum	Median	Maximum
ADOT	Flagstaff	96	0.1	0.39	2.21
ADOT	Nogales	83	0.1	0.36	4.97
ADOT	Phoenix	52	0.1	0.325	2.05
ADOT	Sedona	67	0.1	0.3	3.09
ADOT	Tucson	89	0.1	0.28	2.28
Glendale	ACDC10	57	0	0.32	3.72
Glendale	Arrow	57	0	0.27	3.27
Glendale	Citrus	56	0	0.3	3.51
Glendale	INDPK	39	0	0.25	3.15
Glendale	Indpk	18	0	0.315	1.54
Glendale	Olive	57	0	0.26	3.07
Mesa	54-EMF	69	0.01	0.16	1.31
Mesa	AS-US60	66	0.01	0.15	1.17
Mesa	FF-ACES	98	0.01	0.09	2.07
Mesa	SS-US60	88	0.01	0.115	2.61
Mesa	UN-EMF	76	0	0.11	1.83
Phoenix	AC33	111	0	0.28	1.2
Phoenix	IB08	128	0	0.315	2.88
Phoenix	SC046	130	0	0.23	1.57
Phoenix	SR003	105	0	0.32	1.75
Phoenix	SR030	110	0	0.3	2.4
Phoenix	SR045	127	0	0.25	2.42
Phoenix	SR049	117	0	0.25	4.5
Pima County	Site #1	336	0	0.16	1.88
Pima County	Site #2	325	0	0.15	2.09
Pima County	Site #3	336	0	0.16	1.88
Pima County	Site #4	336	0	0.16	1.88
Pima County	Site #5	331	0	0.16	2.56
Scottsdale	130570	130	0	0.05	2.77
Scottsdale	130820	131	0	0.05	2.91
Scottsdale	250940	132	0	0.09	2.32
Scottsdale	80610	133	0	0.085	3.49
Scottsdale	80710	132	0	0.065	3.35
Tempe	KP-01	309	0	0.03	3.58
Tempe	SR-05	315	0	0.04	2.85
Tempe	SR-08	313	0	0.04	1.8
Tempe	TD-01	313	0	0.04	4.14
Tempe	TD-03	317	0	0.04	3.98

Permittee	Monitoring Location	No. of Reported Storm Events	Total Precipitation (inches)		
			Minimum	Median	Maximum
Tucson	Sampling Site #1	72	0.02	0.205	2.81
Tucson	Sampling Site #2	58	0.08	0.28	1.54
Tucson	Sampling Site #3	90	0.04	0.255	1.73
Tucson	Sampling Site #4	89	0.02	0.29	1.59
Tucson	Sampling Site #5	70	0	0.21	1.98

4.3 Water Quality Analysis

This section describes the descriptive and statistical analyses performed on the Phase I MS4 effluent discharge monitoring data.

4.3.1 Descriptive Statistics

Descriptive summary statistics were computed for each parameter with data reported in the database for the period 2011-2020 (Table 4-6). Values reported include the number of records in the database for the period of record (N), the fraction of N which were reported as non-detect (Percent Non-Detect), the minimum and maximum values reported, and the mean and standard deviation. The mean and standard deviation were calculated assuming non-detect values were equal to one-half (1/2) the MDL. Attachment E includes full-time series plots grouped by pollutant and monitoring station displaying the results of all discharge monitoring events in the database. Refer to Section 3.3.2 for a description of methods used in this analysis.

Table 4-6. Discharge Monitoring Data Descriptive Statistics

Category	Parameter	Units	N	Percent Non-Detect	Minimum Value	Maximum Value	Mean	Standard Deviation	Minimum Criterion[1]	Exceedance[2]
Bacteria	ESCHERICHIA COLI	MPN/100mL	699	1.9	<1	1100000	7100	49200	235	Exceedance
Conventionals	BIOCHEMICAL OXYGEN DEMAND	mg/L	34	8.8	<5	156	25.9	28.4	NA	NA
Conventionals	CHEMICAL OXYGEN DEMAND	mg/L	34	0	29	1500	189	251	NA	NA
Conventionals	OIL & GREASE	mg/L	36	72.2	<5	32	4.62	5.12	NA	NA
Conventionals	pH	Standard Units	710	0	4.06	11.3	7.45	0.661	4.5	Exceedance
Conventionals	TEMPERATURE	deg. F	46	0	21.7	94.5	49.1	20	NA	NA
Conventionals	TOTAL DISSOLVED SOLIDS	mg/L	34	0	46	744	169	139	NA	NA
Conventionals	TOTAL SUSPENDED SOLIDS	mg/L	34	0	20	1200	220	222	NA	NA
Hydrocarbons	2,4-DINITROTOLUENE	ug/L	437	100	<0.00306	<2100	8.78	54.7	14	No Exceedance
Hydrocarbons	2,6-DINITROTOLUENE	ug/L	437	100	<0.000768	<2100	8.68	55.2	0.05	No Exceedance
Hydrocarbons	ACENAPHTHENE	ug/L	690	99.6	<5e-05	20	5.27	19.4	198	No Exceedance
Hydrocarbons	ANTHRACENE	ug/L	504	99.8	<5e-05	0.07	5.37	22.4	74	No Exceedance
Hydrocarbons	BENZO[A]PYRENE	ug/L	504	97.6	<5e-05	0.36	4.61	24.5	0.02	Exceedance
Hydrocarbons	BENZO[B]PYRENE	ug/L	20	100	<0.57	<8.4	1.29	1.28	NA	NA
Hydrocarbons	BENZO[GHI]PERYLENE	ug/L	20	100	<0.26	<24	3.07	3.9	NA	NA
Hydrocarbons	BENZO[K]FLUORANTHENE	ug/L	503	98.8	<5e-05	0.41	5.09	21.7	0.005	Exceedance
Hydrocarbons	BENZ[A]ANTHRACENE	ug/L	20	100	<0.34	<8.9	1.21	1.38	0.005	No Exceedance
Hydrocarbons	CHRYSENE	ug/L	502	98	<5e-05	0.78	3.86	22.1	0.005	Exceedance
Hydrocarbons	CIS-1,2-DICHLOROETHYLENE	ug/L	2	100	<0.2	<0.2	0.100	0	70	No Exceedance
Hydrocarbons	CARBAZOLE	ug/L	2	100	<2.67	<2.67	1.34	0	NA	NA
Hydrocarbons	DIBENZ[A,H]ANTHRACENE	ug/L	505	99.2	<5e-05	0.48	5.65	28.8	0.005	Exceedance
Hydrocarbons	DICHLOROBROMOMETHANE	ug/L	437	99.8	<0.15	2.2	1.46	2.73	17	No Exceedance
Hydrocarbons	ETHYLBENZENE	ug/L	461	99.8	<0.09	0.19	63.6	34.8	700	No Exceedance
Hydrocarbons	FLUORANTHENE	ug/L	509	99.2	<5e-05	0.3	5.52	22.7	28	No Exceedance
Hydrocarbons	FLUORENE	ug/L	504	100	<5e-05	<840	5.47	23.1	280	No Exceedance
Hydrocarbons	INDENO[1,2,3-CD]PYRENE	ug/L	500	97.4	<5e-05	4.89	5.82	27.5	0.05	Exceedance
Hydrocarbons	NAPHTHALENE	ug/L	506	99.8	<5e-05	0.6	5.18	21.5	140	No Exceedance
Hydrocarbons	ORO (C22-C32)	mg/L	3	0	0.52	2.4	1.27	0.994	NA	NA
Hydrocarbons	PHENANTHRENE	ug/L	505	100	<5e-05	<840	4.71	22.1	6.3	No Exceedance
Hydrocarbons	PYRENE	ug/L	505	99	<5e-05	20	6.95	52	210	No Exceedance
Hydrocarbons	TOLUENE	ug/L	458	98	<0.11	1.13	63.6	34.8	180	No Exceedance
Hydrocarbons	TRICHLOROETHYLENE	ug/L	459	99.8	<0.13	0.28	1.26	2.21	5	No Exceedance
Hydrocarbons	TOTAL (C10-C32)	mg/L	36	0	0.37	21	1.89	3.46	NA	NA
Hydrocarbons	TOTAL PETROLEUM HYDROCARBONS	mg/L	1	0	7.29	7.29	7.29	NA	NA	NA
Hydrocarbons	XYLENE	ug/L	475	99.2	<0.08	92	97.0	51.9	10000	No Exceedance
Inorganics	CYANIDE	ug/L	618	93.4	<0.005	96	6.92	13.1	9.7	Exceedance
Inorganics	CALCIUM	mg/L	4	0	17.4	45.6	31.0	14.4	NA	NA

Category	Parameter	Units	N	Percent Non-Detect	Minimum Value	Maximum Value	Mean	Standard Deviation	Minimum Criterion[1]	Exceedance[2]
Inorganics	HARDNESS	mg/L	646	0.2	<16.6	466	66.5	51.6	NA	NA
Inorganics	MAGNESIUM	mg/L	4	0	1.63	6.07	3.87	2.43	NA	NA
Metals	ANTIMONY	ug/L	735	46.4	<5e-04	42	2.87	3.74	6	Exceedance
Metals	ARSENIC	ug/L	774	38.8	<1e-04	120	4.23	6.14	10	Exceedance
Metals	BARIUM	ug/L	884	2.9	<0.36	831	65.9	85.4	2000	No Exceedance
Metals	BERYLLIUM	ug/L	715	83.9	<0.001	4.07	0.746	0.868	4	Exceedance
Metals	CADMIUM	ug/L	765	80.7	<1e-04	15.8	1.14	1.26	0.51	Exceedance
Metals	CHROMIUM	ug/L	751	42.2	<0.004	111	5.81	8.96	100	Exceedance
Metals	CHROMIUM(III)	ug/L	32	62.5	<10	26	6.32	4.72	75000	No Exceedance
Metals	COPPER	ug/L	886	7.8	<0.01	1110	36.8	58.2	0.405	Exceedance
Metals	LEAD	ug/L	822	29	<0.001	299	9.38	20.4	0.685	Exceedance
Metals	MERCURY	ug/L	784	82.1	<2e-04	5	0.141	0.425	0.01	Exceedance
Metals	NICKEL	ug/L	806	37.1	<0.01	110	7.17	10.8	20.1	Exceedance
Metals	SELENIUM	ug/L	782	74.3	<0.002	6.4	1.18	2.33	2	Exceedance
Metals	SILVER	ug/L	766	81.5	<2.1e-05	43.1	1.87	4.57	0.00216	Exceedance
Metals	THALLIUM	ug/L	694	84.4	<0.0036	2.5	0.523	0.685	1	Exceedance
Metals	ZINC	ug/L	881	9.6	<0.3	1970	138	194	28.7	Exceedance
Nutrients	AMMONIA	mg/L	34	14.7	<0.5	4.28	0.955	0.904	1.3	Exceedance
Nutrients	NITRATE	mg/L	120	1.7	<0.02	672	3.92	61.2	10	Exceedance
Nutrients	NITRITE	mg/L	122	71.3	<0.02	0.92	0.0986	0.138	1	No Exceedance
Nutrients	NITROGEN (NITRATE AND NITRITE), INORGANIC	mg/L	570	12.8	<0.0015	9.3	1.26	0.984	10	No Exceedance
Nutrients	ORTHOPHOSPHATE	mg/L	34	64.7	<0.2	0.68	0.295	0.174	NA	NA
Nutrients	TOTAL KJELDAHL NITROGEN	mg/L	34	11.8	<1	23	3.46	4.38	NA	NA
Nutrients	TOTAL PHOSPHOROUS	mg/L	32	0	0.1957	34	2.53	6.60	NA	NA
Organics	.ALPHA.-ENDOSULFAN	ug/L	434	92.4	<5e-05	0.7	0.0729	0.118	0.06	Exceedance
Organics	.ALPHA.-HEXACHLOROCYCLOHEXANE	ug/L	435	98.2	<5e-05	0.065	0.0696	0.110	0.005	Exceedance
Organics	.BETA.-HEXACHLOROCYCLOHEXANE	ug/L	435	97.7	<5e-05	2.6	0.0932	0.172	0.02	Exceedance
Organics	.DELTA.-HEXACHLOROCYCLOHEXANE	ug/L	437	98.4	<5e-05	1.3	0.0791	0.135	130	No Exceedance
Organics	1,1,1-TRICHLOROETHANE	ug/L	460	100	<0.14	<50	1.24	2.21	200	No Exceedance
Organics	1,1,2,2-TETRACHLOROETHANE	ug/L	460	100	<0.06	<50	1.24	2.19	0.2	No Exceedance
Organics	1,1,2-TRICHLOROETHANE	ug/L	460	100	<0.09	<50	1.21	2.21	5	No Exceedance
Organics	1,1-DICHLOROETHYLENE	ug/L	459	100	<0.11	<50	1.64	3.44	7	No Exceedance
Organics	1,1-DICHLOROETHANE	ug/L	22	100	<0.17	<20	0.918	2.69	NA	NA
Organics	1,2,4-TRICHLOROBENZENE	ug/L	439	99.3	<0.002	0.12	6.12	23.2	70	No Exceedance
Organics	1,2,4-TRIMETHYLBENZENE	ug/L	20	100	<2	<20	1.75	2.77	NA	NA
Organics	1,2-DIBROMO-3-CHLOROPROPANE	ug/L	2	100	<0.09	<0.09	0.0450	0	NA	NA
Organics	1,2-DICHLOROBENZENE	ug/L	22	100	<0.08	<20	0.895	2.69	NA	NA

Category	Parameter	Units	N	Percent Non-Detect	Minimum Value	Maximum Value	Mean	Standard Deviation	Minimum Criterion[1]	Exceedance[2]
Organics	1,2-DICHLOROETHANE	ug/L	460	100	<0.09	<50	1.19	2.21	5	No Exceedance
Organics	1,2-DICHLOROPROPANE	ug/L	460	100	<0	<50	1.27	2.21	5	No Exceedance
Organics	1,2-DIPHENYLHYDRAZINE	ug/L	435	100	<0.00306	<2100	7.73	56.8	0.04	No Exceedance
Organics	1,2-DIBROMOETHANE	ug/L	2	100	<0.24	<0.24	0.12	0	NA	NA
Organics	1,3,5-TRIMETHYLBENZENE	ug/L	20	100	<2	<20	1.75	2.77	NA	NA
Organics	1,3-DICHLOROBENZENE	ug/L	22	100	<0.08	<20	0.895	2.69	NA	NA
Organics	1,3-DICHLOROPROPENE	ug/L	545	100	<0.09	<75	2.02	4.42	0.7	No Exceedance
Organics	1,4-DICHLOROBENZENE	ug/L	22	100	<0.17	<20	0.918	2.69	NA	NA
Organics	2,3-DICHLOROANILINE	ug/L	2	100	<2.14	<2.14	1.07	0	NA	NA
Organics	2,4,6-TRICHLOROPHENOL	ug/L	443	100	<0.00153	<2100	10.2	58	2	No Exceedance
Organics	2,4-DICHLOROPHENOL	ug/L	443	100	<0.00141	<2100	8.76	56.3	21	No Exceedance
Organics	2,4-DIMETHYLPHENOL	ug/L	443	100	<0.00299	<2100	8.67	56.5	140	No Exceedance
Organics	2,4-DINITROPHENOL	ug/L	443	98.9	<0.00208	9.2	24.4	162	9.2	No Exceedance
Organics	2-CHLOROETHYL VINYL ETHER	ug/L	460	100	<0.173999999999999	<50	3.63	8.63	9800	No Exceedance
Organics	2-CHLORONAPHTHALENE	ug/L	2	100	<1.47	<1.47	0.735	0	74700	No Exceedance
Organics	2-CHLOROPHENOL	ug/L	20	100	<0.42	<24	2.78	3.97	NA	NA
Organics	2-METHYLPHENOL	ug/L	2	100	<1.15	<1.15	0.575	0	NA	NA
Organics	2-METHYL-4,6-DINITROPHENOL	ug/L	2	100	<5.37	<5.37	2.68	0	NA	NA
Organics	3,3'-DICHLOROBENZIDINE	ug/L	436	100	<0.00323	<11000	30.7	300	0.03	No Exceedance
Organics	4,6-DINITRO-O-CRESOL	ug/L	423	99.8	<0.00277	9.5	29.3	281	24	No Exceedance
Organics	4-BROMOPHENYL PHENYL ETHER	ug/L	2	100	<1.19	<1.19	0.595	0	NA	NA
Organics	4-METHYLPHENOL	ug/L	2	100	<1.71	<1.71	0.855	0	NA	NA
Organics	ACROLEIN	ug/L	455	96.9	<0	7.5	13.4	29.3	1.9	Exceedance
Organics	ACRYLONITRILE	ug/L	460	100	<0.14	<50	7.94	10.2	0.06	No Exceedance
Organics	BENZENE	ug/L	461	98.7	<0.11	11	32.7	17.4	5	Exceedance
Organics	BENZIDINE	ug/L	2	100	<6.52	<6.52	3.26	0	2800	No Exceedance
Organics	CARBON TETRACHLORIDE	ug/L	460	100	<0.18	<50	1.59	2.94	2	No Exceedance
Organics	CHLOROBENZENE	ug/L	460	100	<0.06	<50	1.21	2.21	100	No Exceedance
Organics	CHLOROFORM	ug/L	456	99.3	<0.14	0.92	1.2	2.22	230	No Exceedance
Organics	CHLOROMETHANE	ug/L	22	100	<0.2	<50	2.24	6.73	15000	No Exceedance
Organics	CHLOROETHANE	ug/L	22	100	<0.18	<50	2.23	6.73	NA	NA
Organics	DIBROMOCHLOROMETHANE	ug/L	460	99.8	<0.06	2.6	1.28	2.46	NA	NA
Organics	HEXACHLOROBENZENE	ug/L	435	100	<0.000587	<2100	7.16	54.3	3.00E-04	No Exceedance
Organics	HEXACHLOROBUTADIENE	ug/L	437	100	<0.003	<2100	7.31	53.8	0.4	No Exceedance
Organics	HEXACHLOROCYCLOPENTADIENE	ug/L	437	100	<0.00317	<11000	17.7	281	0.3	No Exceedance
Organics	HEXACHLOROETHANE	ug/L	437	100	<0.00306	<2100	7.78	53.7	2.5	No Exceedance
Organics	ISOPHORONE	ug/L	437	100	<0.00072	<2100	7.65	54.1	37	No Exceedance
Organics	LINDANE	ug/L	21	95.2	<0.011	0.09	0.0402	0.034	0.2	No Exceedance

Category	Parameter	Units	N	Percent Non-Detect	Minimum Value	Maximum Value	Mean	Standard Deviation	Minimum Criterion[1]	Exceedance[2]
Organics	M-DICHLOROBENZENE	ug/L	444	99.5	<0.00244	0.11	2.20	8.9	970	No Exceedance
Organics	METHYL BROMIDE	ug/L	459	99.3	<0.13	0.39	1.99	3.97	9.8	No Exceedance
Organics	METHYLENE CHLORIDE	ug/L	456	96.3	<0.2	15	2.45	3.93	5	Exceedance
Organics	N-NITROSODI-N-PROPYLAMINE	ug/L	437	100	<0.00074	<2100	8.02	54.1	0.005	No Exceedance
Organics	N-NITROSODIMETHYLAMINE	ug/L	436	100	<0.00222	<2100	8.03	52	0.001	No Exceedance
Organics	N-NITROSODIPHENYLAMINE	ug/L	439	100	<0.00331	<2100	8.37	54.8	6	No Exceedance
Organics	NITROBENZENE	ug/L	437	100	<0.000733	<2100	7.99	54	3.5	No Exceedance
Organics	P-BROMOPHENYL PHENYL ETHER	ug/L	2	100	<1.24	<1.24	0.62	0	NA	NA
Organics	P-CHLORO-M-CRESOL	ug/L	423	99.8	<0.00127	36	8.32	56.3	4.7	Exceedance
Organics	P-DICHLOROBENZENE	ug/L	444	100	<0.00279	<106.5	2.51	8.23	75	No Exceedance
Organics	P-NITROPHENOL	ug/L	40	97.5	<0.35	4.1	5.87	7.97	3000	No Exceedance
Organics	PENTACHLOROPHENOL	ug/L	443	97.5	<0.00305	96	25.6	281	1	Exceedance
Organics	PHENOL	ug/L	445	93	<0.000709	25	7.48	18.0	37	No Exceedance
Organics	STYRENE	ug/L	2	100	<0.08	<0.08	0.0400	0	187000	No Exceedance
Organics	TETRACHLOROETHYLENE	ug/L	455	100	<0.13	<50	1.19	2.22	5	No Exceedance
Organics	TRANS-1,2-DICHLOROETHYLENE	ug/L	22	100	<0.14	<20	0.91	2.69	100	No Exceedance
Organics	TRIBROMOMETHANE	ug/L	22	100	<0.3	<50	2.26	6.72	133	No Exceedance
Organics	TOTAL TRIHALOMETHANES	ug/L	2	100	<0.3	<0.3	0.150	0	NA	NA
Organics	TRICHLOROFLUOROMETHANE	ug/L	2	100	<0.27	<0.27	0.135	0	NA	NA
Organics	VINYL CHLORIDE	ug/L	460	100	<0.19	<100	1.43	3.54	2	No Exceedance
PCBs	PCB-1016	ug/L	21	100	<0.05	<5	0.292	0.475	NA	NA
PCBs	PCB-1221	ug/L	21	100	<0.09	<5	0.306	0.471	NA	NA
PCBs	PCB-1232	ug/L	21	100	<0.07	<5	0.300	0.480	NA	NA
PCBs	PCB-1242	ug/L	21	100	<0.13	<5	0.325	0.488	NA	NA
PCBs	PCB-1248	ug/L	21	100	<0.1	<5	0.309	0.471	NA	NA
PCBs	PCB-1254	ug/L	21	100	<0.07	<5	0.308	0.474	NA	NA
PCBs	PCB-1260	ug/L	21	100	<0.08	<5	0.295	0.473	NA	NA
PCBs	PCBS	ug/L	1557	99.9	<5e-04	4.3	0.586	0.761	6.00E-05	Exceedance
Pesticides	.BETA.-ENDOSULFAN	ug/L	21	100	<0.021	<0.25	0.0306	0.0307	NA	NA
Pesticides	ALDRIN	ug/L	435	97	<0	0.207	0.0727	0.108	5.00E-05	Exceedance
Pesticides	CHLORDANE	ug/L	436	99.8	<0	0.0068	0.279	0.437	8.00E-04	Exceedance
Pesticides	DIELDRIN	ug/L	434	97.2	<0.0037	0.08	0.0711	0.107	5.00E-05	Exceedance
Pesticides	ENDOSULFAN SULFATE	ug/L	437	97.7	<5e-05	0.08	0.0679	0.109	0.06	Exceedance
Pesticides	ENDRIN	ug/L	434	99.8	<0.00046	0.004	0.0726	0.0995	0.004	No Exceedance
Pesticides	ENDRIN ALDEHYDE	ug/L	436	99.3	<0.003	0.34	0.0974	0.107	0.04	Exceedance
Pesticides	HEPTACHLOR	ug/L	435	93.6	<0.00286	1.57	0.0802	0.13	8.00E-05	Exceedance
Pesticides	HEPTACHLOR EPOXIDE	ug/L	434	99.5	<0.0015	0.939	0.0736	0.113	4.00E-05	Exceedance
Pesticides	METHOXYCHLOR	ug/L	2	100	<0.04	<0.05	0.0225	0.00354	4670	No Exceedance

Category	Parameter	Units	N	Percent Non-Detect	Minimum Value	Maximum Value	Mean	Standard Deviation	Minimum Criterion[1]	Exceedance[2]
Pesticides	P,P'-DDD	ug/L	21	100	<0.013	<0.25	0.0283	0.0307	2.00E-04	No Exceedance
Pesticides	P,P'-DDE	ug/L	21	100	<0.014	<0.25	0.0318	0.0309	2.00E-04	No Exceedance
Pesticides	P,P'-DDT	ug/L	21	100	<0.013	<0.25	0.0293	0.0310	2.00E-04	No Exceedance
Pesticides	TOXAPHENE	ug/L	437	100	<5e-04	<22	0.886	1.23	2.00E-04	No Exceedance
Phthalates	BUTYLBENZYL PHTHALATE	ug/L	2	100	<1.9	<1.9	0.950	0	NA	NA
Phthalates	DI(2-ETHYLHEXYL) PHTHALATE	ug/L	30	100	<0.24	<20	1.32	2.31	3	No Exceedance
Phthalates	DI-N-OCTYL PHTHALATE	ug/L	440	98.2	<0.00137	6.2	8.77	34	2800	No Exceedance
Phthalates	DIBUTYL PHTHALATE	ug/L	437	93.8	<0.00105	88.44	11.1	26.7	35	Exceedance
Phthalates	DIETHYL PHTHALATE	ug/L	437	92.9	<0.000793	22	8.04	24	1600	No Exceedance
Phthalates	DIMETHYL PHTHALATE	ug/L	436	97.9	<0.000812	8.7	8.31	23.8	1000	No Exceedance

1. The minimum criterion value identified for the receiving waters associated with the representative outfalls. NA indicates that no criterion was applicable to the receiving waters.
2. Comparison between the maximum concentration in the dataset and the minimum identified criterion from all monitored outfall receiving waters was included to provide an indication of the relative magnitude of the maximum discharge concentration. Maximum discharge may not be to the receiving water with the minimum criterion. NA indicates a comparison was infeasible to complete.

4.3.2 Exceedance Analysis

As discussed in Section 3.3.3.2, the potential for discharges to exceed water quality standards was evaluated at (1) the permittee level, and (2) for all permittees collectively. Discharge quality from the monitored outfalls was compared to the applicable criteria (see Section 3.3.3.1) based on the assigned Designated Uses of each receiving water.

The discharges from the Phase I MS4s displayed a high level of attainment with criteria for hydrocarbons, inorganics, nutrients, organics, PCBs, pesticides, and phthalates with criteria exceedance rates generally below one percent as shown in Figure 4-5 and Table 4-7). Bacteria, metals, and pH exhibited higher rates of exceedance. *E. coli* discharges for all permittees exceeded the applicable single sample maximum criterion 74 percent of the time, with no single permittee reporting less than a 50 percent exceedance rate for this criterion. Refer to Attachment F for detailed plots comparing reported discharge values to applicable criteria at each monitoring location. As described in 3.3.3.2, this analysis was based on comparisons to the applicable criteria associated with a given monitored discharge location (i.e., a discharge concentration at an outfall was compared to the criteria specifically applicable to that outfall's receiving water and not to any other standards).

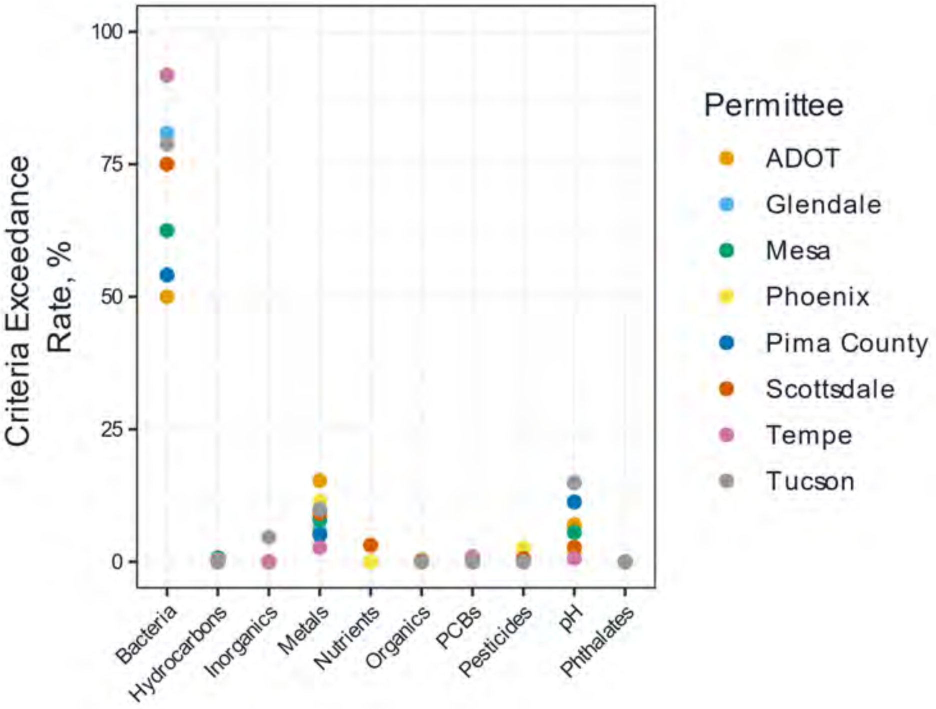


Figure 4-5. Rates of water quality criteria exceedance by pollutant category and permittee
Note: In this plot, the Conventionals category has been relabeled as pH since this is the only conventional pollutant parameter with applicable water quality criteria.

Table 4-7. Rates of Water Quality Criteria Exceedance by Pollutant Category

Category	Exceedance Rate (Percent of Records)
Bacteria	74
Hydrocarbons	0.2
Inorganics	0.5
Metals	8.7
Nutrients	1.3
Organics	0.3
PCBs	0.1
Pesticides	0.9
pH (Conventionals)	4.6
Phthalates	0

In the case of metals, the criteria exceedances were driven largely by high levels of copper, lead and zinc. Discharge of other metal parameters rarely resulted in criteria exceedances (Figure 4-6). When metal exceedances occurred, they were due to exceedance of the applicable A&W standards for discharge from outfalls to receiving waters with A&W designated uses. Refer to Section 3.3.3.1 for discussion on how hardness-based metal criteria were calculated.

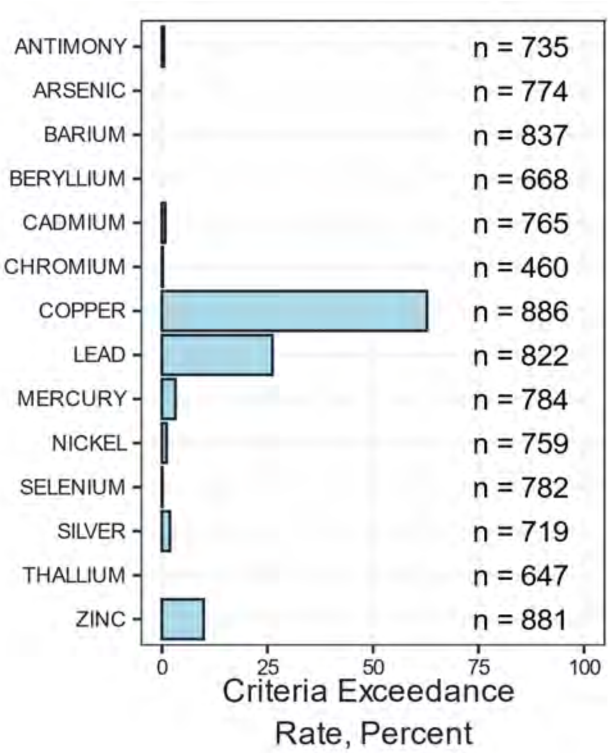


Figure 4-6. Exceedance rate by metal pollutant parameters for all permittees

When pH exceedances occurred, they were generally due to discharges occurring below the minimum applicable criterion. Figure 4-7 (below) displays boxplots of pH discharge levels by year at each monitored location. Excursions above or below the criteria were relatively localized to a small number of monitoring locations.

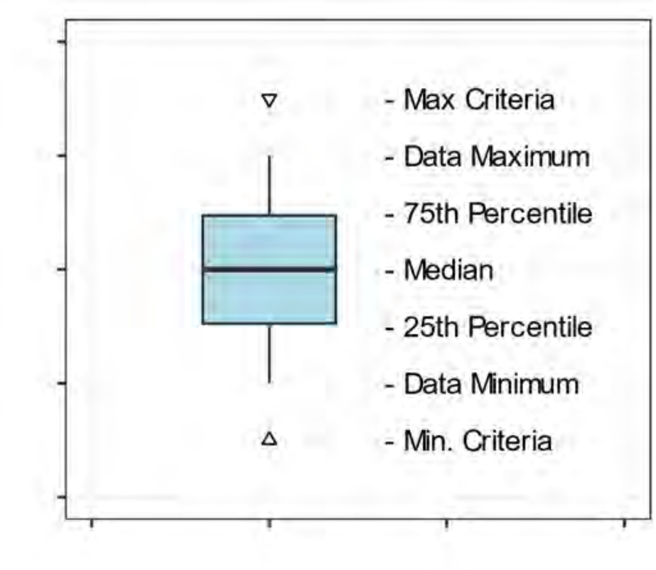


Figure 4-7. Key for interpreting boxplots included in this report.

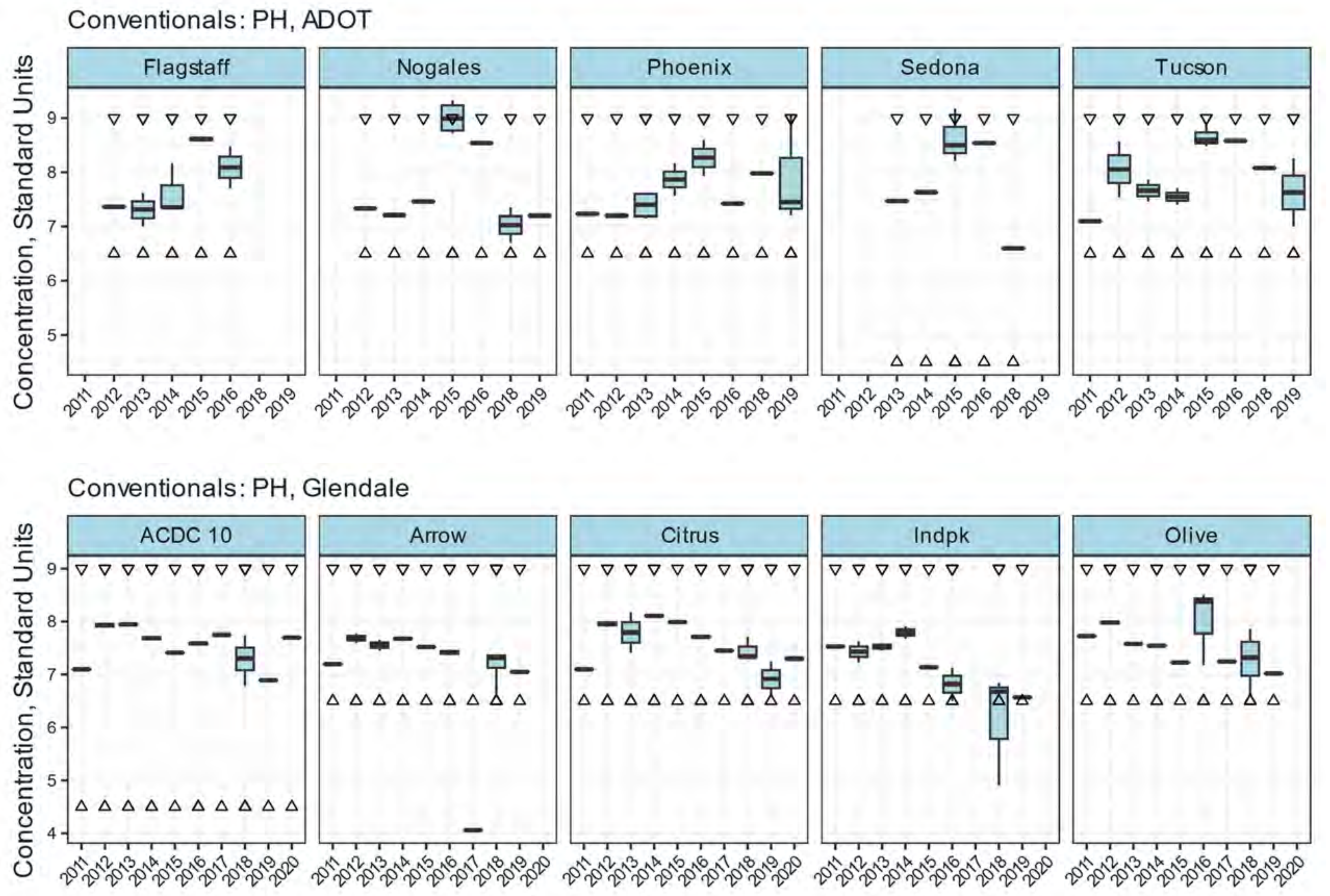


Figure 4-8. Time series of pH discharges by permittee and monitoring location. Triangles indicate level of applicable water quality criteria

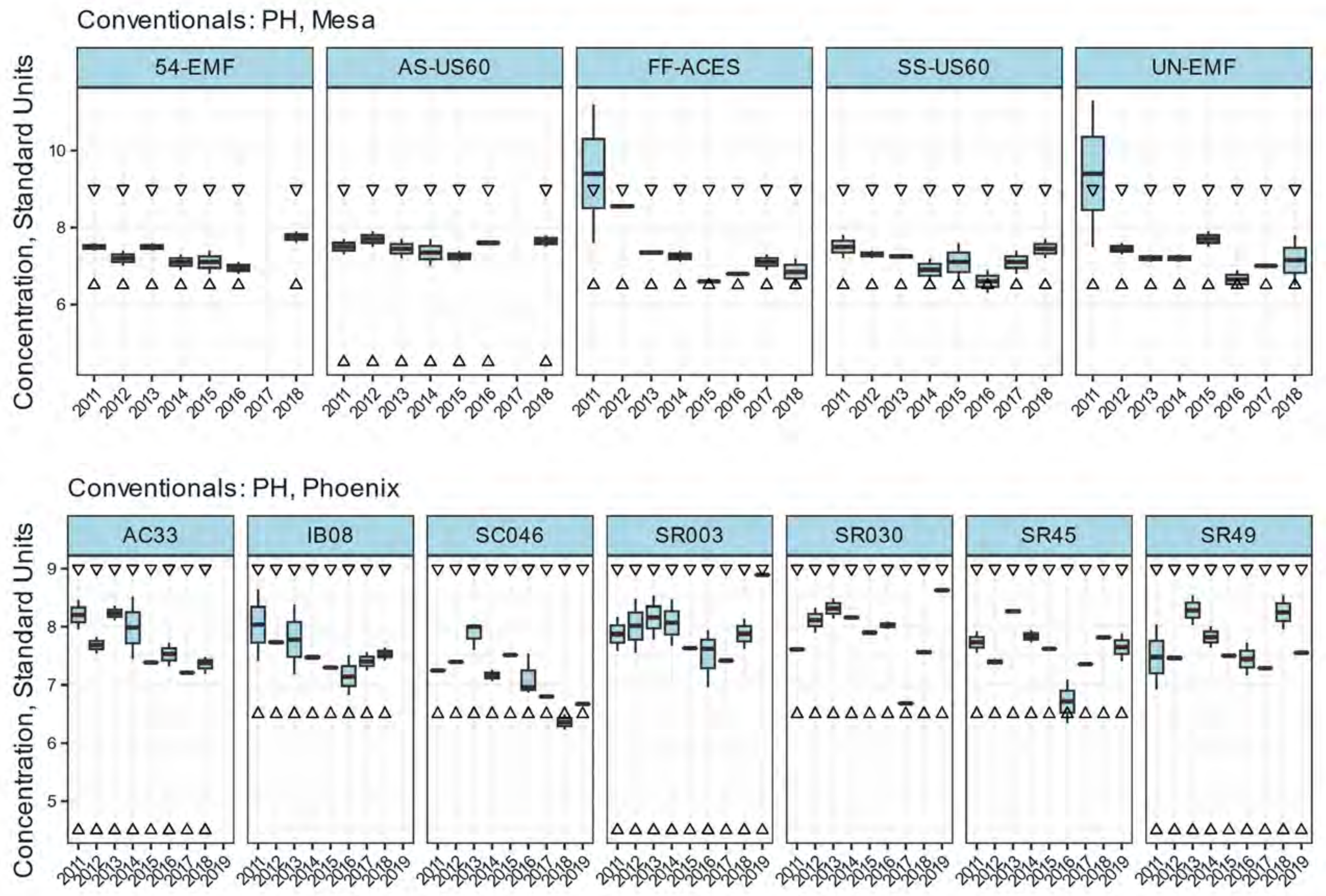


Figure 4-8 (continued). Time series of pH discharges by permittee and monitoring location. Triangles indicate level of applicable water quality criteria.

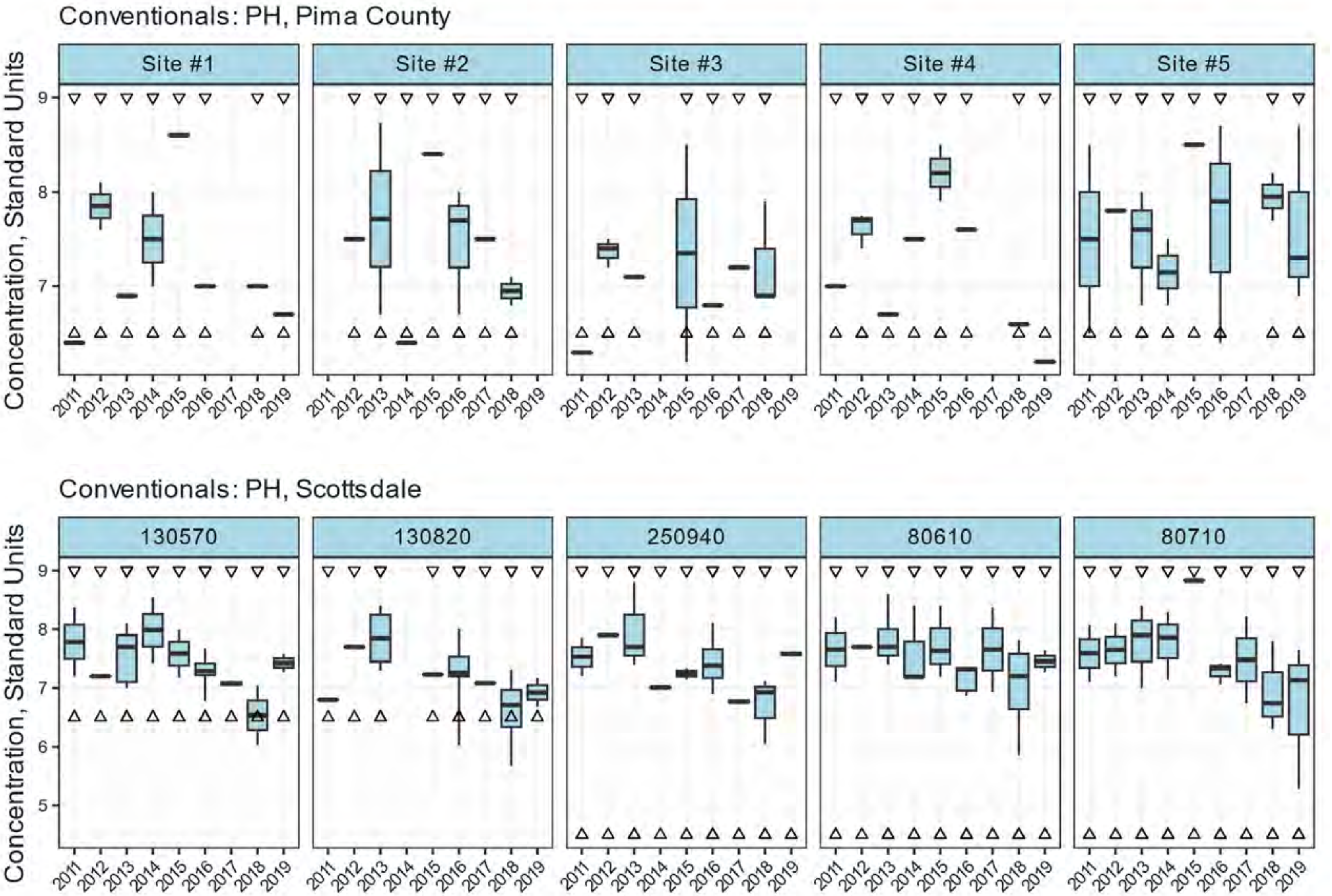


Figure 4-8 (continued). Time series of pH discharges by permittee and monitoring location. Triangles indicate level of applicable water quality criteria.

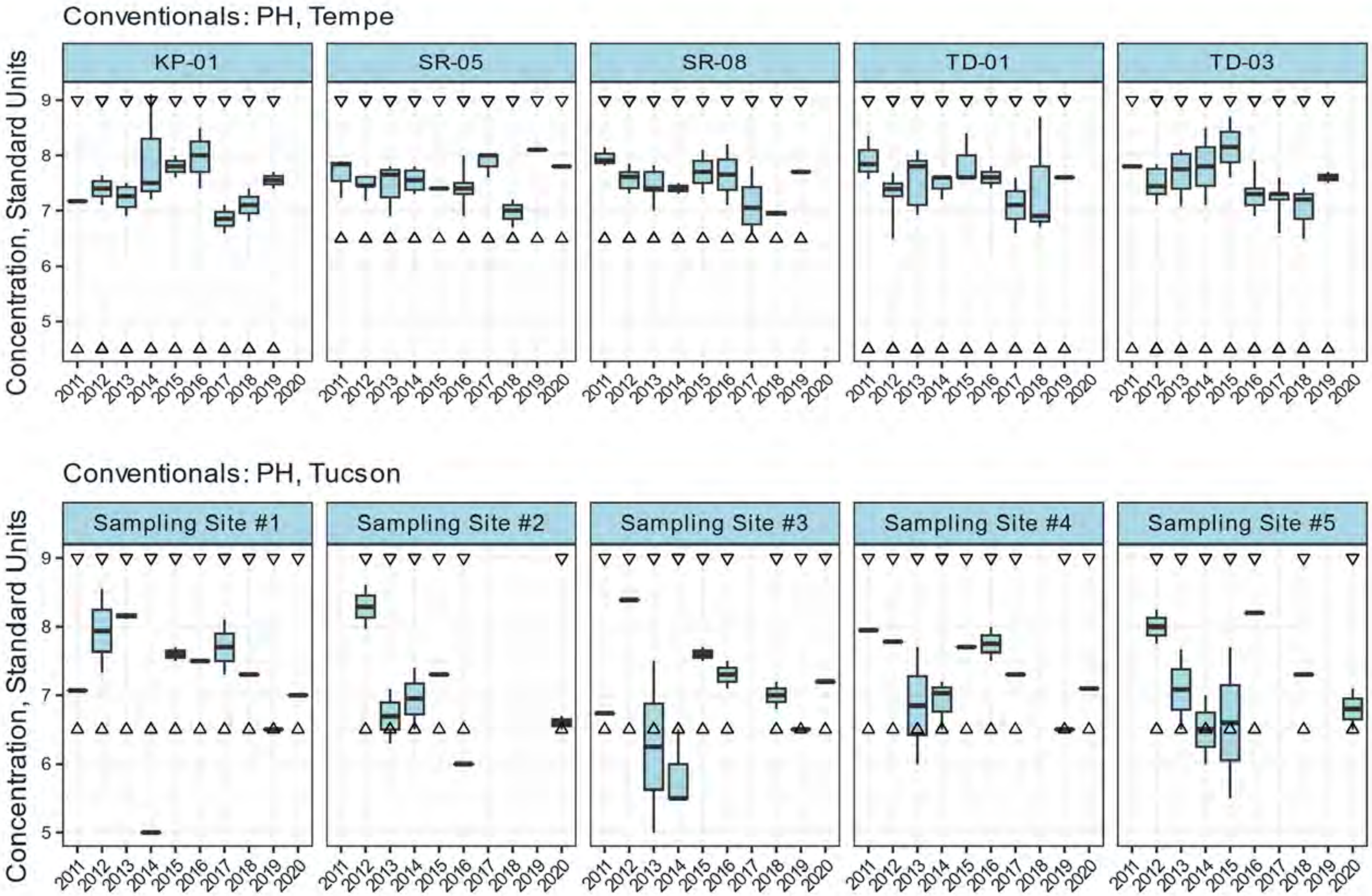


Figure 4-8 (continued). Time series of pH discharges by permittee and monitoring location. Triangles indicate level of applicable water quality criteria.

4.4 Land Use Patterns

Patterns of impervious cover and land use, as measured in the 2019 NLCD, were computed for each representative monitoring location where GIS watershed boundary data was available. Figure 4-9 illustrates patterns of impervious cover associated with each watershed. As one might expect for storm sewer systems associated with large urban areas, the watersheds are predominantly composed of impervious surfaces with most watersheds ranging from 50% - 80% impervious surface.

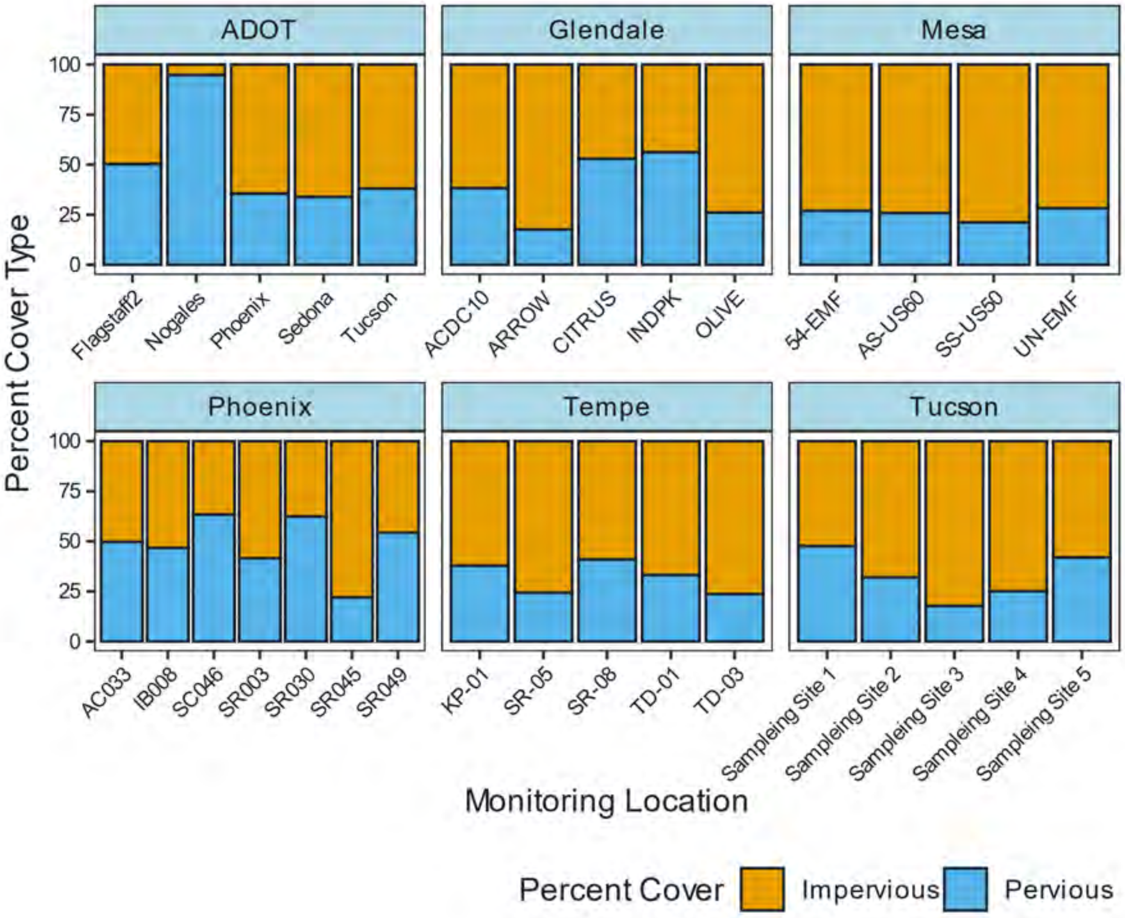


Figure 4-9. Impervious cover computed for monitored watersheds

The relationship between exceedance rates for select metals (copper, lead, and zinc) and *E. coli* and impervious cover was investigated to determine if impervious cover in the MS4s might be a useful indicator of threat to water quality. Exceedance rates associated with individual representative outfalls were plotted as a function of the impervious cover associated with the outfall's drainage watershed. These parameters were selected since monitoring data and criteria were available for most monitoring locations, and they were detected in the discharges at high rates. Figure 4-10 plots the rate of exceedance of criteria at each monitoring location as a function of the monitored watersheds' impervious cover. Neither of the regressions for copper nor *E. coli* were statistically significant at the 95% significance level (copper slope = 0.12, p-value = 0.7; *E. coli* slope = -0.10, p-value = 0.7) and indicated that impervious cover alone was not a significant indicator for the threat to water quality for discharge of these pollutants. Regression relationships for lead and zinc were statistically significant at the 95% confidence level (lead slope = -0.52, p-value = 0.04; zinc slope = -0.44, p-value = 0.02) and indicate that watersheds with lower percent impervious cover were correlated with a higher propensity to discharge at levels that exceed applicable water quality standards.

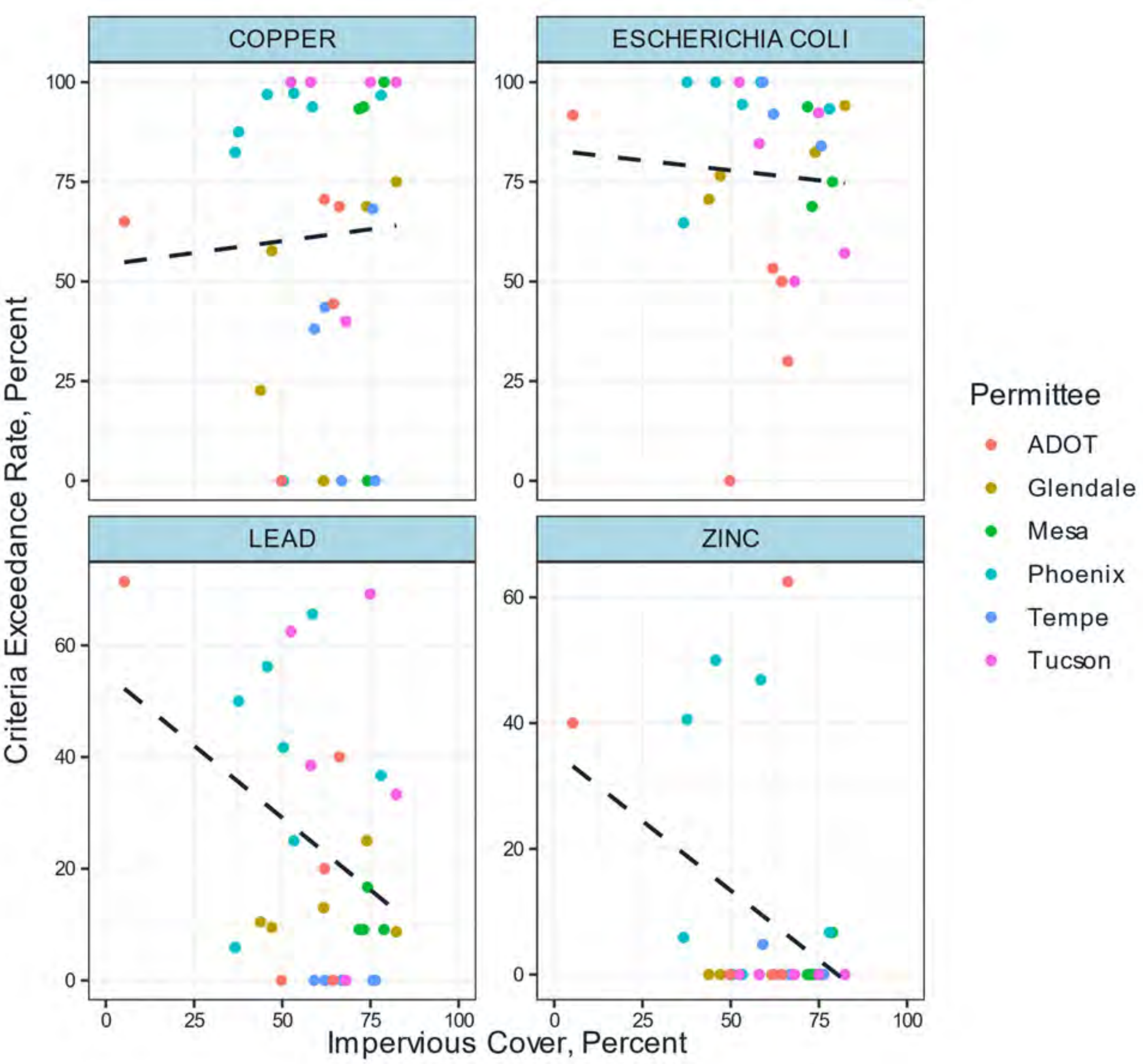


Figure 4-10. Copper, *E. coli*, lead, and zinc criteria exceedance rate at individual monitoring locations as a function of watershed percent impervious cover

The 2019 NLCD also includes general land cover information which was used to characterize the watersheds. The 2019 NLCD was used to provide a consistent basis for describing land cover patterns across all MS4s. This data may be less detailed than locally derived land use/land cover data available to the permittees; however, these data sets may also be mutually inconsistent in the categorical definitions and methods used to generate the data. The land cover categories identified in the MS4s are defined in Table 4-8.

Table 4-8. Land Cover Categories

Land Cover Category	Description
Developed, Open Space	Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
Developed, Low Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
Developed, Medium Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
Developed, High Intensity	Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
Shrub/Scrub	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
Woody Wetlands	Areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Cultivated Crops	Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
Grassland/Herbaceous	Areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
Open Water	Areas of open water, generally with less than 25% cover of vegetation or soil.

The most common single land cover was for high imperviousness, single-family residential uses (i.e., the Developed, Medium Intensity category). However, there were a number of watersheds dominated by high-density urban and/or industrial land uses (the Developed, High Intensity category). Table 4-9 reports the acreage of each land cover class and the percent imperviousness for each monitored outfall watershed where analysis was feasible. See Attachment G for detailed plots of land cover patterns for each permittee where watershed boundary GIS data was available. Figure 4-11 is a representative example of the patterns in land use for the MS4s, and displays the fraction of each land cover category present in each of the five monitored watersheds in the City of Glendale.

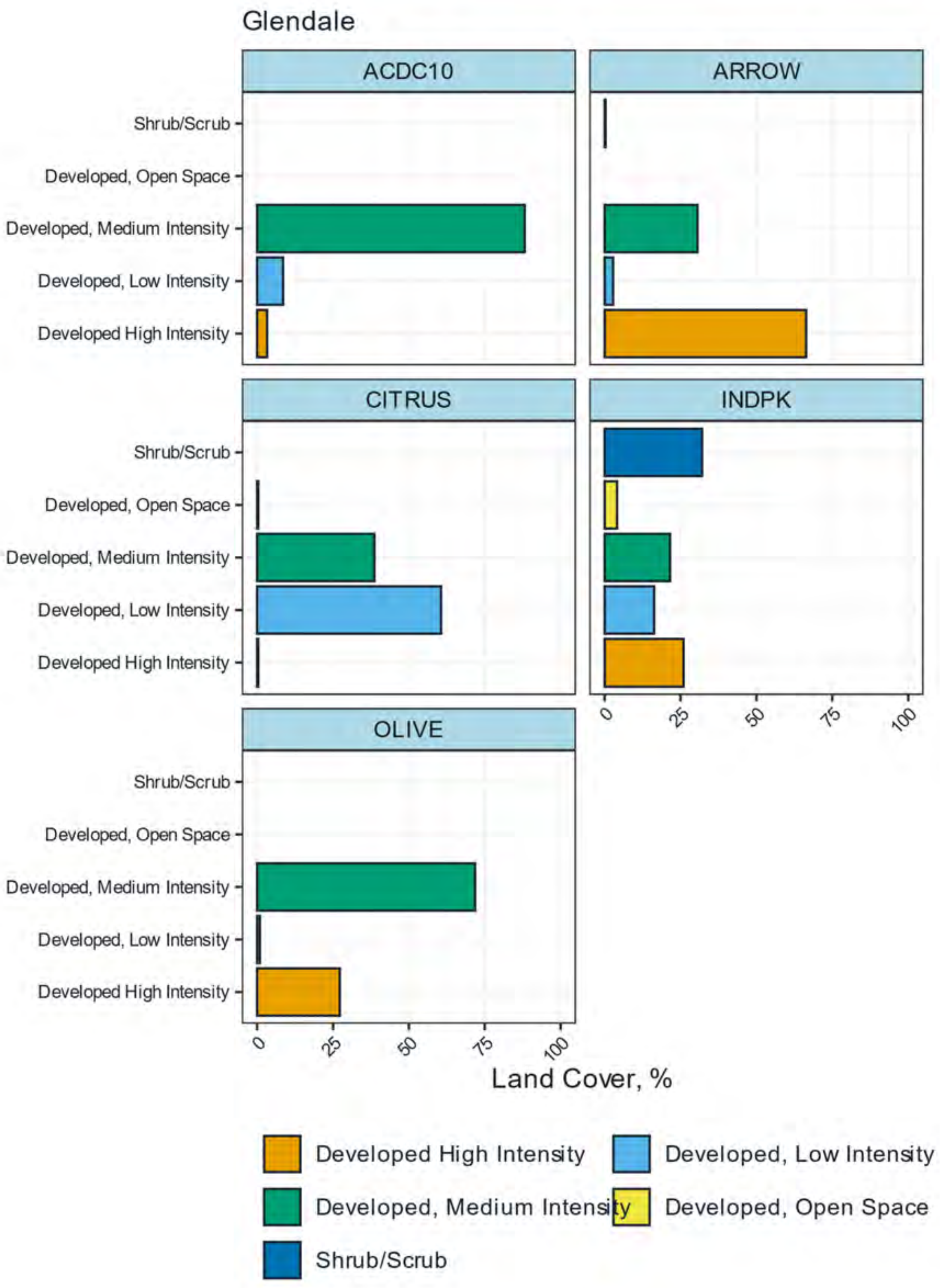


Figure 4-11. City of Glendale land cover summary

Table 4-9. Land Cover Area, Total Watershed Area, and Watershed Percent Impervious Cover

Permittee	Outfall	Area (Acres)									Total Watershed Area (Acres)	Impervious Cover (%)
		Developed, Open Space	Developed, Low Intensity	Developed, Medium Intensity	Developed High Intensity	Shrub or Scrub	Woody Wetlands	Cultivated Crops	Grassland or Herbaceous	Open Water		
ADOT	Flagstaff2	2.9	2.5	1.6	3.4	0	0	0	0	0	10.3	49.8
ADOT	Nogales	1.1	0.7	0.2	0	6.3	0	0	0	0	8.3	5.2
ADOT	Phoenix	0	7.7	15.8	10.3	1.1	0	0	0	0	34.8	64.5
ADOT	Sedona	0	0.5	1.4	0.7	0	0	0	0	0	2.6	66.2
ADOT	Tucson	6.7	54.9	85.2	50.3	0.2	0	0	0	0	197.3	62
Glendale	INDPK	7.1	28.5	37.6	45.4	56	0	0	0	0	174.6	43.8
Glendale	ACDC10	0	5.8	59.7	2.2	0	0	0	0	0	67.7	61.7
Glendale	CITRUS	0.2	36	22.9	0.2	0	0	0	0	0	59.3	47.1
Glendale	ARROW	0	6.9	76	165	0.7	0	0	0	0	248.6	82.4
Glendale	OLIVE	0	0.2	17.5	6.6	0	0	0	0	0	24.3	73.9
Mesa	SS-US50	0	0.7	7.1	9.9	0	0	0	0	0	17.6	78.9
Mesa	UN-EMF	0.9	22.2	362.7	130	0.2	0	0	0	0	515.9	71.8
Mesa	AS-US60	0	8.8	76.1	68.1	0	0	0	0	0	153.1	74.2
Mesa	54-EMF	0	1.3	21.3	10.4	0	0	0	0	0	33	73.1
Phoenix	IB008	83.8	440.8	669.3	134	1.1	0	0	0	0	1329	53.3
Phoenix	AC033	1.6	17.7	60.4	14.3	19.4	0	0	0	0	113.3	50.3
Phoenix	SC046	6.5	20.7	10.6	0.2	3.4	0	0	0	0	41.4	36.7
Phoenix	SR003	74.7	506.5	863.7	445.5	61.8	2.2	0	0	0	1954.5	58.5
Phoenix	SR030	147.7	286.5	311.6	85.1	43.4	0	141.5	0	0	1015.8	37.6
Phoenix	SR045	0	4.5	28	57	2.5	0	0	0	0	91.9	78
Phoenix	SR049	227.7	637.6	543.8	343.2	136.8	0	85.2	0.4	0	1974.6	45.8
Tempe	SR-08	52.3	162.4	573.8	132.4	0	0	3.1	0	0	924	59.1
Tempe	TD-03	0.2	1.3	16.6	20.1	0	0	0	0	0	38.2	76.4
Tempe	TD-01	44	64.2	172.6	291.7	28	0	0	0	0.2	600.7	66.8
Tempe	SR-05	3.6	7.6	53.8	80.7	3.1	0	0	0	0	148.8	75.7
Tempe	KP-01	0.9	29.4	207.5	11.6	0	0	0	0	0	249.4	62.1
Tucson	Sampling Site	2.7	47.1	46.2	9.2	0	0	0	0	0	105.3	52.4

Permittee	Outfall	Area (Acres)									Total Watershed Area (Acres)	Impervious Cover (%)
		Developed, Open Space	Developed, Low Intensity	Developed, Medium Intensity	Developed High Intensity	Shrub or Scrub	Woody Wetlands	Cultivated Crops	Grassland or Herbaceous	Open Water		
	1											
Tucson	Sampling Site 2	0	2.9	37.2	8.5	0.2	0	0	0	0	48.8	68.1
Tucson	Sampling Site 3	0	0.9	12.6	24.6	0	0	0	0	0	38.1	82.3
Tucson	Sampling Site 4	0	9.8	39.4	41.4	0	0	0	0	0	90.5	74.9
Tucson	Sampling Site 5	4	86.2	114.1	44	0	0	0	0	0	248.3	58.1

4.5 Environmental Justice

As discussed in Section 3.1, ADEQ and PG requested GIS data describing the watershed boundaries associated with each representative monitored discharge location. The provided GIS files were input into EPA's EJScreen tool to generate indicator summary results. Tables 4-10 to 4-16[5] display these results by monitoring location. The results describe the relative condition of the EJ indicator in the monitored watershed relative to (1) all of Arizona, and (2) all of the United States. For example, the PM2.5 indicator for ADOT's Tucson watershed was lower than most sites in Arizona at the 27th percentile, and near the bottom of the distribution of all sites in the United States at the 4th percentile—this indicates the residents in this watershed enjoy lower PM 2.5 concentrations in their air than do the majority of residents in both Arizona and the United States as a whole.

Table 4-10. ADOT Watershed EJ Indicator Results

Outfall Name	Tucson		Nogales		Phoenix		Sedona		Flagstaff2	
Indicator (as Percentile)	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**
PM 2.5	27	4	35	9	53	29	9	1	7	0
Ozone	18	90	4	87	68	94	39	91	39	91
Air Toxics Cancer Risk	56	80-90	29	<50	96	95-100	29	<50	29	<50
Superfund Proximity	52	49	11	7	31	37	13	14	10	5
Demographics	88	90	93	94	35	43	26	34	62	66
Low Income	92	93	88	90	43	46	56	59	63	67
Less Than High School Education	78	81	85	88	38	34	40	35	55	52
Unemployment	82	83	73	75	36	37	38	39	38	39

Table 4-11. Glendale Watershed EJ Indicator Results

Outfall Name	ACDC10		Arrow		Citrus		INDPK		Olive	
Indicator (as Percentile)	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**
PM 2.5	57	32	51	26	51	26	76	46	70	42
Ozone	75	94	72	94	75	94	50	92	68	94
Air Toxics Cancer Risk	96	95-100	96	95-100	96	95-100	96	95-100	96	95-100
Superfund Proximity	28	35	27	34	26	33	62	53	37	41
Demographics	48	55	50	57	16	23	56	61	80	82
Low Income	56	59	41	44	12	14	49	51	87	89
Less Than High School Education	54	52	36	32	53	51	69	70	67	67
Unemployment	55	57	34	35	31	31	25	25	94	95

Table 4-12. Mesa Watershed EJ Indicator Results

Outfall Name	AS-US60		SS-US60		UN-EMF		54-EMF		FF-ACES[1]	
Indicator (as Percentile)	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**

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[5] Note: Results reported as a range (e.g., 95-100, or <50) reflect the level of precision of the estimate generated by the EJScreen tool. See: https://www.epa.gov/ejscreen/limitations-and-caveats-using-ejscreen#sl-indicators

Outfall Name	**AS-US60**		**SS-US60**		**UN-EMF**		**54-EMF**		**FF-ACES[1]**	
Indicator (as Percentile)	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**
PM 2.5	67	40	53	29	51	26	52	28	--	--
Ozone	75	94	84	95	90	95	87	95	--	--
Air Toxics Cancer Risk	96	95-100	96	95-100	96	95-100	96	95-100	--	--
Superfund Proximity	84	70	78	63	65	55	71	58	--	--
Demographics	82	84	6	11	34	42	63	67	--	--
Low Income	78	81	33	36	47	50	77	80	--	--
Less Than High School Education	77	79	32	28	48	44	46	42	--	--
Unemployment	87	88	58	60	65	68	75	77	--	--

1. GIS boundary data was unavailable for this outfall.

Table 4-13. Phoenix Watershed EJ Indicator Results (Part 1)

Outfall Name	**SR49**		**SR030**		**SR003**		**SR45[1]**	
Indicator (as Percentile)	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**US**
PM 2.5	98	68	99	70	99	71	--	--
Ozone	46	92	44	91	57	93	--	--
Air Toxics Cancer Risk	96	95-100	96	95-100	96	95-100	--	--
Superfund Proximity	60	52	64	54	62	53	--	--
Demographics	89	90	82	84	90	92	--	--
Low Income	78	81	63	67	90	91	--	--
Less Than High School Education	88	91	84	87	95	96	--	--
Unemployment	53	55	48	50	59	61	--	--

1. The EJScreen tool was unable to compute results for this watershed after inclusion of the 0.25 mi buffer.

Table 4-14. Phoenix Watershed EJ Indicator Results (Part 2)

Outfall Name	**AC33**		**IB08**		**SC046**	
Indicator (as Percentile)	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**
PM 2.5	64	37	46	22	34	7
Ozone	90	95	96	96	84	95
Air Toxics Cancer Risk	96	95-100	92	95-100	56	80-90
Superfund Proximity	57	51	46	46	18	23
Demographics	77	79	40	47	4	7
Low Income	75	79	41	44	0	3
Less Than High School Education	75	77	51	48	0	0
Unemployment	84	85	61	63	58	60

Table 4-15. Tempe Watershed EJ Indicator Results

Outfall Name	**KP-01**		**SR-05**		**SR-08**		**TD-01**		**TD-03**	
Indicator (as Percentile)	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**
PM 2.5	81	49	72	44	74	44	87	54	82	49
Ozone	53	92	64	93	64	93	51	92	57	93
Air Toxics Cancer Risk	97	95-100	96	95-100	96	95-100	97	95-100	96	95-100
Superfund Proximity	81	66	96	87	86	72	87	74	94	84

Outfall Name	KP-01		SR-05		SR-08		TD-01		TD-03	
Indicator (as Percentile)	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**
Demographics	57	62	62	66	41	48	77	79	67	71
Low Income	48	50	77	80	48	51	69	73	52	55
Less Than High School Education	41	36	46	42	34	30	71	73	57	55
Unemployment	72	74	49	51	45	46	68	70	25	25

Table 4-16. Tucson Watershed EJ Indicator Results

Outfall Name	Site 1		Site 2		Site 3		Site 4		Site 5	
Indicator (as Percentile)	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**	**AZ**	**USA**
PM 2.5	26	4	22	3	29	5	31	5	23	3
Ozone	21	90	27	90	21	90	17	90	21	90
Air Toxics Cancer Risk	56	80-90	56	80-90	56	80-90	56	80-90	56	80-90
Superfund Proximity	59	52	48	47	70	57	75	61	47	46
Demographics	39	47	64	68	32	40	75	78	78	81
Low Income	48	50	65	68	42	45	78	81	83	85
Less Than High School Education	35	31	33	28	22	19	66	66	70	71
Unemployment	45	47	67	70	31	31	57	59	75	76

4.6 Seasonality

The effects of seasonal conditions on the discharge were investigated by comparing the relative levels of select metals and *E. coli* in the Phase I MS4 discharges in the two wet seasons[6] defined in the Phase I MS4 AZPDES permits. The metals selected were antimony, arsenic, barium, chromium, copper, lead, nickel, and zinc. Refer to Section 3.3.5 for a discussion of the rationale for pollutant parameters included in the analysis and for the statistical methods employed.

For all pollutants included in the seasonality analysis, summer median concentrations were higher than winter wet season concentrations at the 95% statistical significance level (see Table 4-17, Figure 4-12, and Figure 4-13; p-values less than 0.05 indicate a significant difference in seasonal median concentrations). For example, the copper summer wet season median concentration was 29 µg/L vs 22 µg/L in the winter.

Table 4-17. Wet Season Median Concentrations of Select Metals and E. Coli

Pollutant Parameter	Summer Median	Winter Median	Units	p-value
ANTIMONY	0.52	0.054	ug/L	0.012
ARSENIC	1.5	1.0	ug/L	<0.010
BARIUM	48	33	ug/L	<0.010
CHROMIUM	1.4	1	ug/L	<0.010
COPPER	29	22	ug/L	<0.010
LEAD	2.2	1.2	ug/L	0.013
NICKEL	3.8	1.5	ug/L	<0.010
ZINC	80	67	ug/L	<0.010
E. coli	2130	1627	CFU/100 mL	0.015

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[6] The summer wet season runs from June 1 – October 31, and the winter wet season from November 1 – May 31.

For *E. coli*, the summer wet season median concentration was 2130 CFU/100 mL vs 1627 CFU/100 mL in the winter.

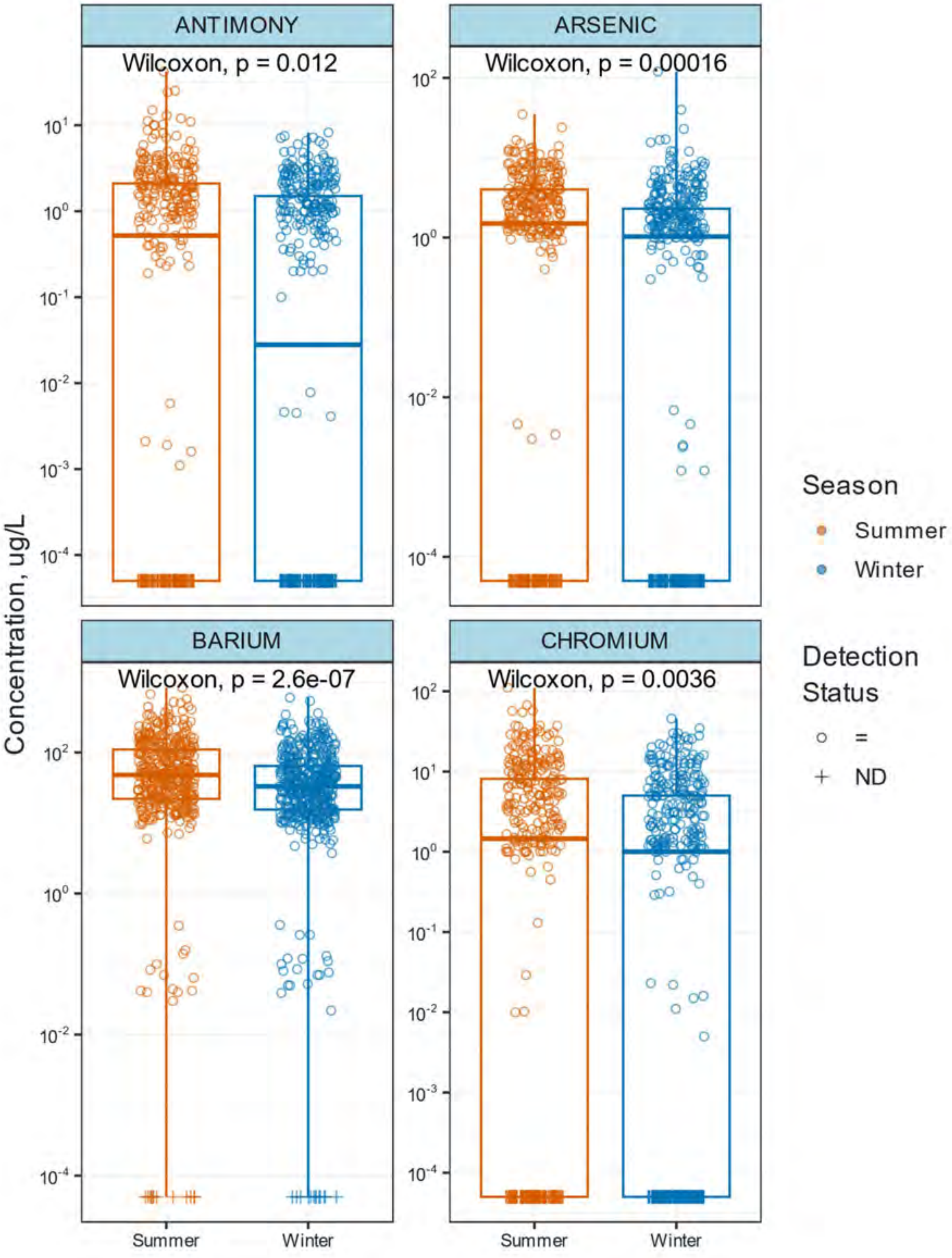

Figure 4-12. Comparison of summer and winter wet season metal parameter concentrations
Note: Figure displays boxplots of concentration distribution and points/pluses indicating concentration and detection status of each observation

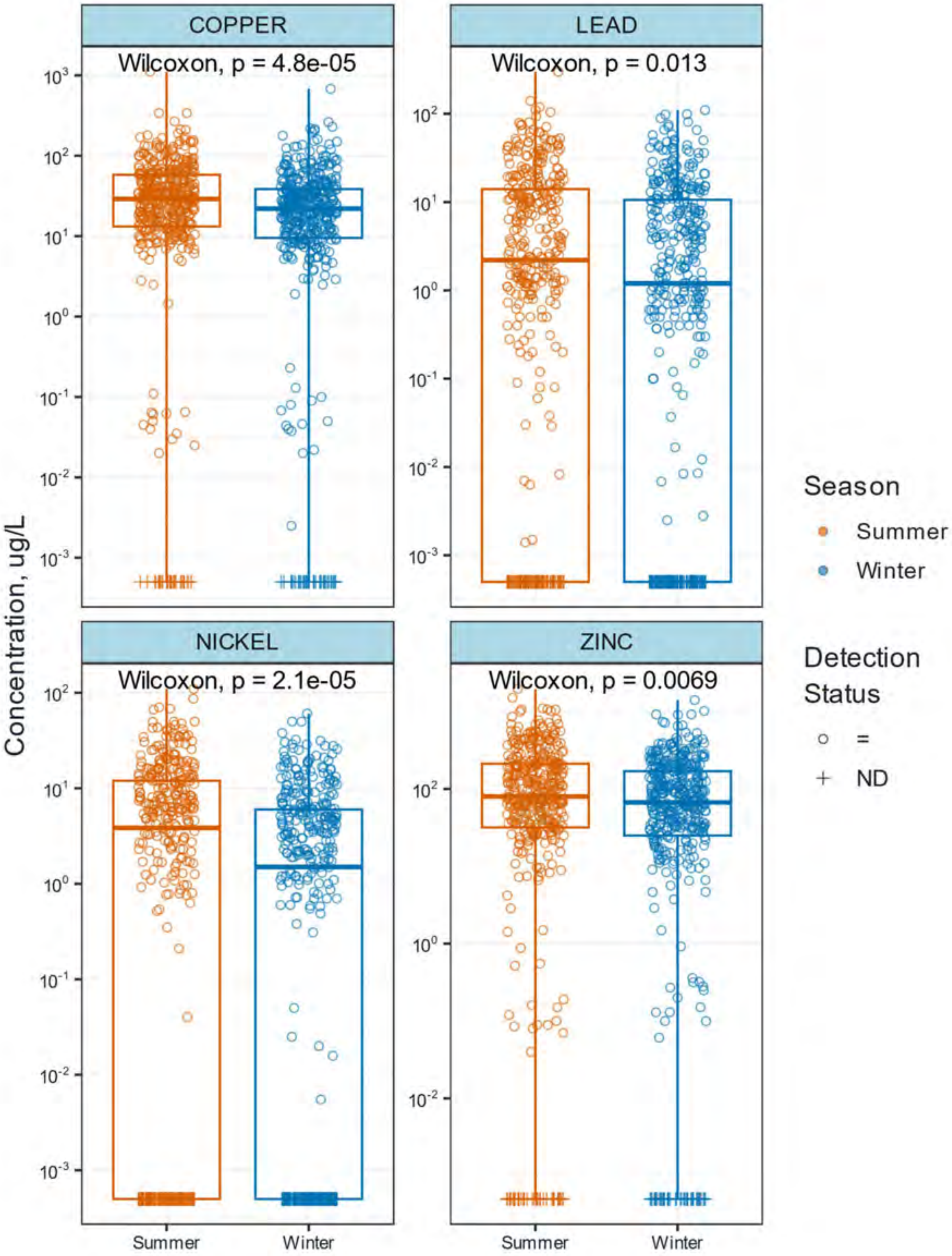

Figure 4-12 (continued). Comparison of summer and winter wet season metal parameter concentrations

Note: Figure displays boxplots of concentration distribution and points/pluses indicating concentration and detection status of each observation.

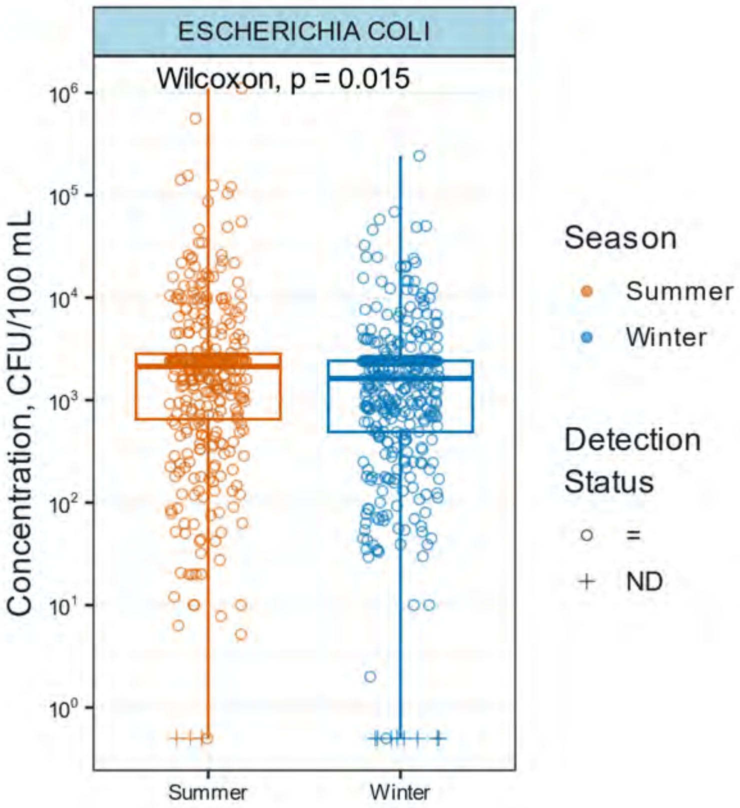

Figure 4-13. Comparison of summer and winter wet season *E. coli* concentrations
Note: Figure displays boxplots of concentration distribution and points/pluses indicating concentration and detection status of each observation.

In addition to the above pollutant parameters, seasonal storm event precipitation patterns were also compared. For precipitation, the pattern is reversed from the pattern observed above. The median winter wet season storm event total rainfall (0.17 inches) was greater than the summer median (0.13 inches) at the 95% statistical significance level. However, the scale of this difference is relatively small in magnitude and, as can be seen from Figure 4-14, the largest summer storms over the period of record were larger than the largest winter storms.

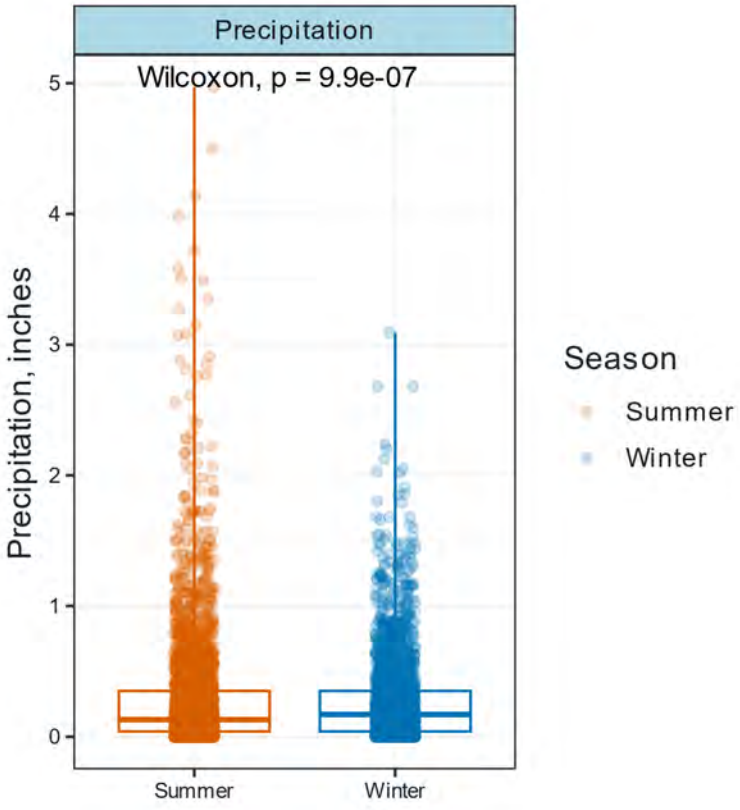

Figure 4-14. Comparison of summer and winter wet season storm event rainfall totals
Note: Figure displays boxplots of storm event total rainfall distribution.

4.7 Pollutant Loads

Annual pollutant mass discharge quantities were calculated for each of the monitored watersheds according to the methods described in Section 3.3.6. Total annual loads for each year were divided by the size of the corresponding monitored watersheds to produce a unit pollutant loading rate (i.e., total pollutant discharge per unit area) to facilitate cross-watershed comparisons since the watersheds vary in size (Figure 4-15). The modeled total annual pollutant mass discharged from an outfall generally increased in proportion with the amount of impervious area present in the outfall's catchment area (Figure 4-16).

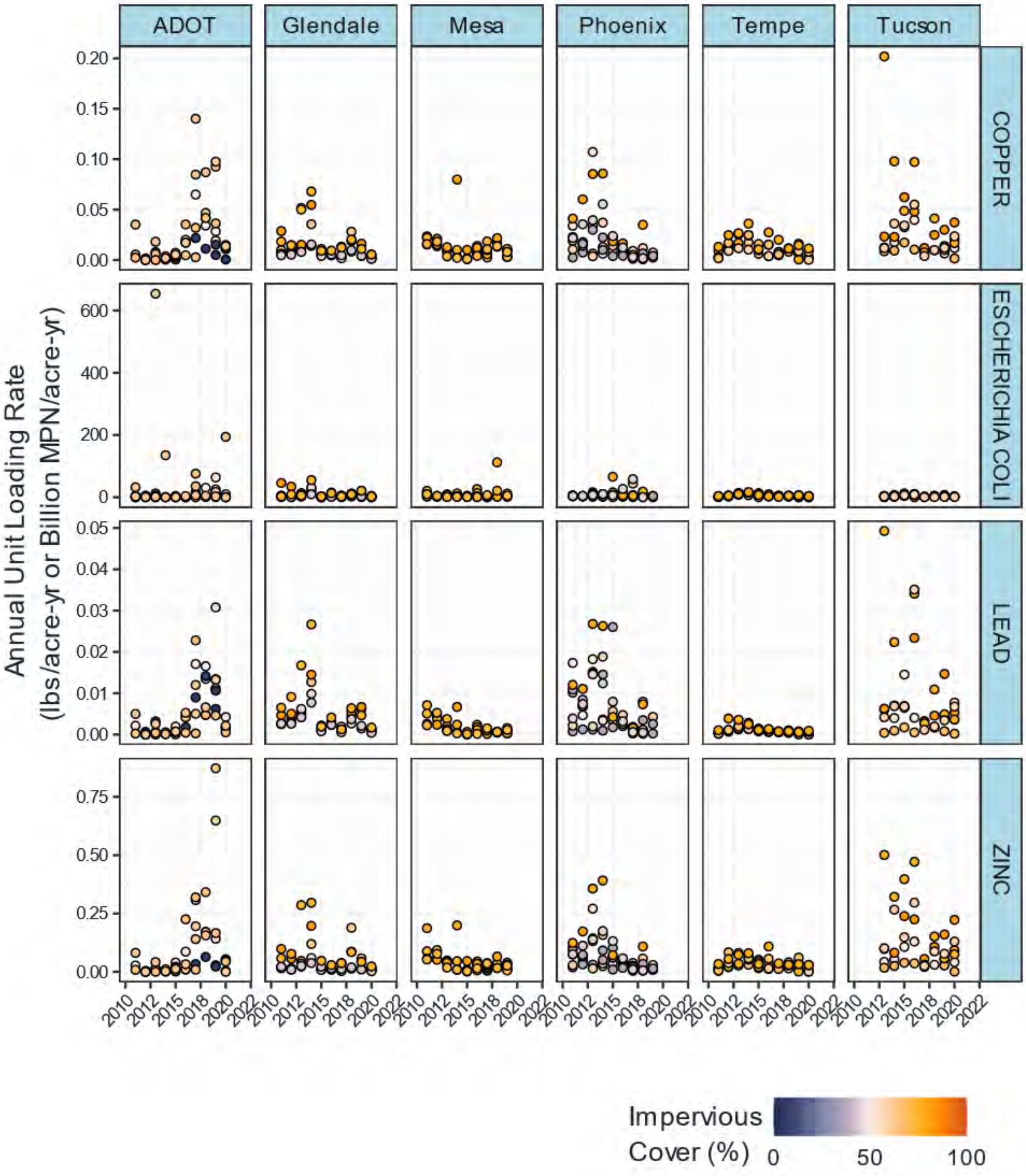

Figure 4-15. Annual pollutant discharge rates on a per-unit area basis for monitored watersheds. Note: Each point depicts the annual unit pollutant load discharged from a single monitoring location in a given year during the period 2011-2020.

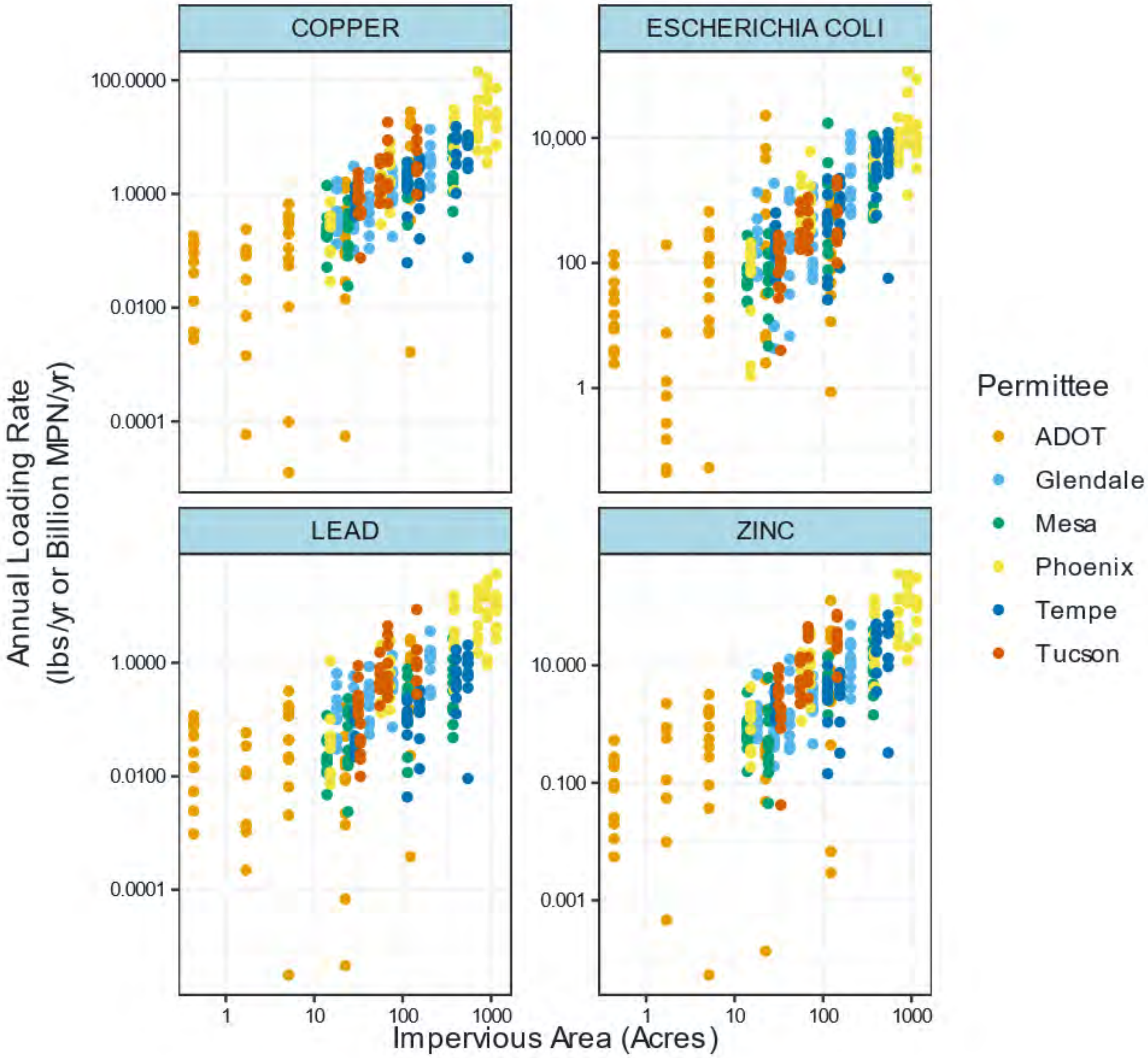

Figure 4-16. Annual pollutant mass discharged as a function of watershed impervious area.
Note: Each point depicts the annual total pollutant load discharged from a single monitoring location each year during the period 2011-2020.

The average unit mass discharge rates, averaged across all the Phase I MS4s for the years 2011-2020, were as follows:

- Copper: 0.0182 lbs/acre/year
- Lead: 0.00455 lbs /acre/year
- Zinc: 0.0691 lbs /acre/year
- E. coli: 9,927 Million MPN/acre/year

5 Summary of Key Findings and Recommendations

This section summarizes several key findings of this study and associated recommendations for AZPDES permitting authority consideration during future permit reissuances.

5.1 Monitoring

The results of the analysis in Section 4.1.1 suggest that the permittees are generally employing analytical methods which are capable of definitively identifying whether a discharge was occurring above or below the applicable water quality criteria. In parameter groups where approved analytical method MDLs exceeded the lowest water quality criteria, such as PCBs and some pesticides, there is no approved method available capable of definitively confirming a discharge is consistent with the applicable criteria.

The analysis of seasonality in discharge quality in Section 4.6 suggests that there is a marginal benefit in monitoring during the summer wet season over the winter wet season. To the extent that ADEQ considers decreasing total monitoring events or the frequency of events, it is recommended that summer wet season monitoring be retained, or that monitoring during both seasons be retained.

For future permit reissuances, it is recommended that ADEQ consider EJ factors when directing permittees to identify representative monitoring locations. While representative monitoring locations should broadly reflect the land uses of the MS4, a secondary factor to consider are the EJ attributes of communities present within the regulated MS4 and ensuring all segments of the community are protected from the adverse consequences of unsafe pollution levels.

5.2 Pollutants of Concern

The analysis of surface water quality criteria attainment in the discharges, described in Section 4.3.2, suggests that bacteria, copper, lead, zinc, and pH are pollutants of particular concern for urban stormwater. The MS4 discharges exceeded the applicable criteria for these pollutants regularly, particularly copper and *E. coli* which displayed criteria exceedances in over half of all discharge records and at most monitoring locations.

During future permit reissuances, it is recommended that ADEQ review Storm Water Management Program (SWMP) permit conditions to ensure that these pollutants are being controlled to the maximum extent possible. Common sources of metals in urban storm water include automobiles, industrial activity, soil erosion, corrosion of metal surfaces, combustion processes, and atmospheric deposition. Metals are often bound up in particulate matter such that control practices that reduce the discharge of sediments may have co-benefits in terms of metal removal.

High levels of bacteria in urban stormwater may be due to human sanitary sources (e.g., sanitary sewer overflows, inflow and infiltration from damaged sewers, illicit discharges from unsewered communities, leaky septic systems), domestic animal sources (e.g., loose pet waste in dog parks, sidewalks, and residential areas), or wildlife (e.g., congregations of geese or ducks in parks or golf courses). Many of these bacteria sources can be reduced or eliminated through the application of public education and outreach, detection and elimination of illicit discharges, targeted deployment of best management practices (BMP), or retrofit of existing BMPs. Development of monitoring plans to identify hot spots and sources of bacteria in the regulated MS4 area may allow the MS4 to develop more targeted communication and outreach, and BMP deployment/retrofit strategies.

6 References

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Attachment A – MS4 Monitoring Locations

Representative locations for discharge monitoring for each of the eight Phase I MS4 permittees, the associated receiving water, and Designated Uses of the receiving waters according to AAC R18-11.

Table A-1. ADOT Monitoring Locations

Monitoring Location Name	Outfall Latitude and Longitude	Receiving Water	Designated Uses
Phoenix	33.62194°, -112.2392°	Unnamed Tributary of New River	A&We, PBC
Tucson	32.25472°, -110.9969°	Santa Cruz River	A&We, PBC, AgL
Sedona	34.86194°, -111.2392°	Oak Creek	A&Ww, FBC, FC, DWS, AgI, AgL
Nogales	31.35056°, -110.9233°	Nogales Wash	A&Ww, PBC, FC
Flagstaff (Decommissioned Monitoring Site)	35.19814°, -111.6515°	Flagstaff Wastewater Treatment Plant to confluence with San Francisco Wash	A&Wedw, PBC
Nogales Maintenance Yard	31.356°, 110.927°	Nogales Wash	AWw, PBC, FC
Roosevelt Maintenance Yard	33.663° 111.134°	Roosevelt Lake	AWw, FBC, DWS, FC, AgL, AgI
Spring Creek Maintenance Yard	34.800° 111.923°	Spring Creek	AWw, FBC, FC, AgI, AgL
Superior Maintenance Yard	33.287° 111.111°	Queen Creek	AWw, PBC, AgL
Superior Storage and Fuel Yard	33.288° 111.112°	Queen Creek	AWw, PBC, AgL
Flagstaff2	35.17194°, -111.6656°	Rio De Flag	A&Wedw, PBC

Table A-2. City of Glendale Monitoring Locations

Monitoring Location Name	Outfall Latitude and Longitude	Receiving Water	Designated Uses
ACDC10	33.61611°, -112.1922°	Phoenix Area Canals	DWS, AgL, AgI
CITRUS	33.64556°, -112.2114°	Unnamed Tributary of the New River	A&We, PBC
OLIVE	33.56833°, -112.2028°	New River	A&We, PBC, AgL
ARROW	33.63194°, -112.2269°	Skunk Creek	A&We, PBC

Monitoring Location Name	Outfall Latitude and Longitude	Receiving Water	Designated Uses
INDPK	33.54389°, -112.2828°	New River	A&We, PBC, AgL

Table A-3. City of Mesa Monitoring Locations

Monitoring Location Name	Outfall Latitude and Longitude	Receiving Water	Designated Uses
SS-US50	33.38689°, -111.6937°	East Maricopa Floodway	A&We, PBC, AgL
AS-US60	33.38689°, -111.8577°	Phoenix Area Canals	DWS, AgL, AGI
UN-EMF	33.42264°, -111.7246°	East Maricopa Floodway	A&We, PBS, AgL
54-EMF	33.41125°, -111.7149°	East Maricopa Floodway	A&We, PBS, AgL
FF-ACES	33.45458°, -111.7292°	East Maricopa Floodway	A&We, PBS, AgL

Table A-4. City of Phoenix Monitoring Locations

Monitoring Location Name	Outfall Latitude and Longitude	Receiving Water	Designated Uses
AC033	33.56889°, -112.0829°	Phoenix Area Canals	AgL, AgI, DWS
IB008	33.59951°, -111.9956°	Indian Bend Wash	PBC, A&We
SR003	33.41195°, -112.1347°	Salt River	A&Wedw, PBC, FC, AgL, AgI
SR030	33.40874°, -112.1164°	Salt River	A&Ww, PBC, FC
SR045	33.42613°, -111.9956°	Salt River	A&We, PBC
SR049	33.40014°, -112.2042°	Salt River	A&Wedw, PBC, FC, AgI, AgL
SR046	33.8031°, -112.1187°	Unnamed Tributary to the New River	A&We, PBC

Table A-5. City of Scottsdale Monitoring Locations

Monitoring Location Name	Outfall Latitude and Longitude	Receiving Water	Designated Uses
080710	33.45167°, -111.9128°	McKellips Park Lake	A&Ww, PBC, FC, AgI
080610	33.45444°, -111.9117°	McKellips Park Lake	A&Ww, PBC, FC, AgI

Monitoring Location Name	Outfall Latitude and Longitude	Receiving Water	Designated Uses
130570	33.50194°, -111.9072°	Indian Bend Wash	A&We, PBC
130820	33.50583°, -111.9094°	Indian Bend Wash	A&We, PBC
250940	33.61111°, -111.9228°	Phoenix Area Canals	DWS, AgL, AGI

Table A-6. City of Tempe Monitoring Locations

Monitoring Location Name	Outfall Latitude and Longitude	Receiving Water	Designated Uses
KP-01	33.37439°, -111.9386°	Kiwanis Park Lake	A&Ww, PBC, FC, AgI
TD-01	33.41667°, -111.9779°	Phoenix Area Canals	AgI, AgL
TD-03	33.41683°, -111.9777°	Phoenix Area Canals	AgI, AgL
SR-05	33.43208°, -111.9431°	Tempe Town Lake	A&Ww, FBC, FC
SR-08	33.43048°, -111.9223°	Tempe Town Lake	A&Ww, FBC, FC

Table A-7. City of Tucson Monitoring Locations

Monitoring Location Name	Outfall Latitude and Longitude	Receiving Water	Designated Uses
Sampling Site #1	32.25079° -110.9376°	Santa Cruz River	A&We, PBC, AgL
Sampling Site #2	32.27081°, -110.8991°	Rillito Creek	A&We, PBC, AgL
Sampling Site #3	32.22116°, -110.918°	Santa Cruz River	A&We, PBC, AgL
Sampling Site #4	32.21343°, -110.9534°	Santa Cruz River	A&We, PBC, AgL
Sampling Site #5	32.28286°, -110.9612°	Rillito Creek	A&We, PBC, AgL

Table A-8. Pima County Monitoring Locations

Monitoring Location Name	Outfall Latitude and Longitude	Receiving Water	Designated Uses
Site #1	32.29614°, -110.9085°	Rillito Creek	A&We, PBC, AgL
Site #2	32.29239°, -111.0118°	Rillito Creek	A&We, PBC, AgL
Site #3	32.30636°,	Rillito Creek	A&We, PBC, AgL

Monitoring Location Name	Outfall Latitude and Longitude	Receiving Water	Designated Uses
	-110.9108°		
Site #4	32.30639°. -110.9108°	Rillito Creek	A&We, PBC, AgL
Site #5	32.17431°, -110.9261°	Julian Wash	A&We, PBC

Attachment B – Phase I MS4 Database Data Dictionary

This attachment provides descriptions and metadata for all fields included in the database of compiled monitoring data.

Field	Description
DMR Table	
ID	Unique identifier code assigned by PG Environmental for each monitoring record.
Permittee	Permittee name.
Monitoring.Location	Monitoring location name or ID.
Original.Parameter	Parameter name originally recorded during compilation.
New.Parameter	Normalized parameter name designed to provide a consistent naming convention for monitoring records.
Type	Modifier for the parameter—for example, “dissolved” or “total recoverable” for some metals, “cis-“ or “trans-“ for some organic pollutants.
CAS No	Chemical Abstract Service ID (CAS) code for the pollutant.
Standard.RID	Identifier code assigned by PG Environmental to assist with linking monitoring records with numeric criteria.
Category	Pollutant category.
Qualifier	Code qualifying the status of the monitoring result--e.g., detected (=), non-detect (<), detected but not quantified (DNQ), or above maximum quantitation level (>)
Result	Reported detected concentration.
Units	Units of the Result/MDL/RL measurement.
Sample.Date	Date on which the sample was collected.
MDL	Method detection limit (MDL) reported for the observation. Not reported for all records.
RL	Reporting Limit (RL; also known as Minimum Level [ML]) or limit of quantitation for the measurement. Note reported for all records.
Comments	Other information contained in original reporting document which was recorded to provide context for the result.
PRECIP Table	
Permittee	Permittee name.
Location	Monitoring location name or ID.
Start Date	Start date of the qualifying storm event. Not recorded in all instances.
Date	Date of storm event.
Precipitation	Quantity of precipitation measured for the storm event.
Units	Units for the Precipitation measurement.
Status	Status code reported by Permittee.
Comments	Other information contained in original reporting document which was recorded to provide context for the result.
MONITORING LOCATIONS Table	
Permittee	Permittee name.

Field	Description
Monitoring Location	Monitoring location name or ID.
Latitude	Latitude coordinate of the monitoring location.
Longitude	Longitude coordinate of the monitoring location.
Other Location Information	Other location information (e.g., nearby street address) associated with the monitoring location.
Other Names/Labels	Alternate names or labels attached to the location in reporting materials.
Receiving Water	Identifying information associated with the receiving water for the discharge point.
Designated Uses	Designated uses identified as applicable to the receiving water by ADEQ and PG Environmental.
Site-Specific Criterion	Information on any site-specific criteria applicable to the receiving water.
Level III Ecoregion	EPA Level III Ecoregion which the monitoring location is located within.
Permittee Comments	Other information relevant to the monitoring location and its associated MS4 watershed as reported by the permittee.

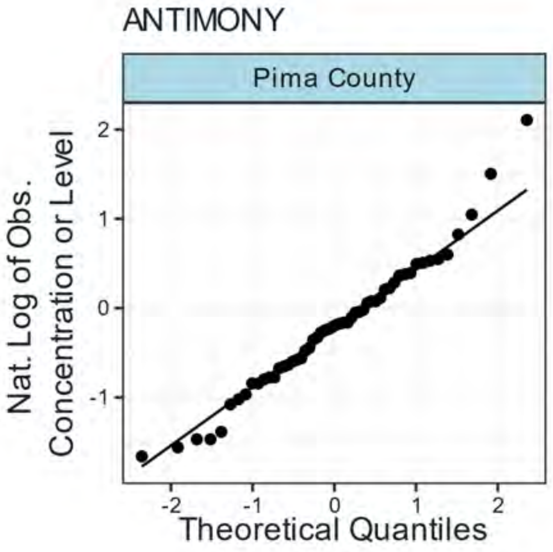
Attachment C – Permittee Lognormal Distribution Analysis

Table C-1. Lognormal Model Fit Results

Parameter	Permittee	W Test Statistic	P-Value	Decision
ANTIMONY	Pima County	0.976	3.36E-01	Lognormal Model Accepted
ANTIMONY	Tucson	0.916	4.87E-04	Poor Fit
ARSENIC	Pima County	0.882	3.50E-05	Poor Fit
ARSENIC	Scottsdale	0.951	8.11E-03	Poor Fit
BARIUM	ADOT	0.786	1.01E-09	Poor Fit
BARIUM	Glendale	0.945	8.01E-06	Poor Fit
BARIUM	Mesa	0.978	1.98E-01	Lognormal Model Accepted
BARIUM	Phoenix	0.975	3.73E-04	Poor Fit
BARIUM	Pima County	0.984	6.02E-01	Lognormal Model Accepted
BARIUM	Scottsdale	0.982	3.19E-01	Lognormal Model Accepted
BARIUM	Tempe	0.972	1.69E-02	Poor Fit
BARIUM	Tucson	0.934	4.00E-03	Poor Fit
CHROMIUM	Pima County	0.985	7.31E-01	Lognormal Model Accepted
CHROMIUM	Scottsdale	0.977	4.24E-01	Lognormal Model Accepted
COPPER	ADOT	0.773	1.92E-11	Poor Fit
COPPER	Mesa	0.981	3.08E-01	Lognormal Model Accepted
COPPER	Phoenix	0.99	1.30E-01	Lognormal Model Accepted
COPPER	Pima County	0.993	9.84E-01	Lognormal Model Accepted
COPPER	Scottsdale	0.942	1.08E-03	Poor Fit
COPPER	Tempe	0.979	7.68E-02	Lognormal Model Accepted
COPPER	Tucson	0.977	3.16E-01	Lognormal Model Accepted
ESCHERICHIA COLI	ADOT	0.971	9.22E-02	Lognormal Model Accepted
ESCHERICHIA COLI	Glendale	0.989	7.27E-01	Lognormal Model Accepted
ESCHERICHIA COLI	Mesa	0.981	2.73E-01	Lognormal Model Accepted
ESCHERICHIA	Pima	0.955	2.55E-02	Poor Fit

Parameter	Permittee	W Test Statistic	P-Value	Decision
COLI	County			
ESCHERICHIA COLI	Scottsdale	0.988	5.95E-01	Lognormal Model Accepted
HARDNESS	ADOT	0.976	4.29E-01	Lognormal Model Accepted
HARDNESS	Glendale	0.97	4.50E-02	Poor Fit
HARDNESS	Mesa	0.972	1.01E-01	Lognormal Model Accepted
HARDNESS	Phoenix	0.985	2.10E-01	Lognormal Model Accepted
HARDNESS	Pima County	0.986	7.02E-01	Lognormal Model Accepted
HARDNESS	Scottsdale	0.993	9.42E-01	Lognormal Model Accepted
HARDNESS	Tempe	0.966	5.25E-03	Poor Fit
HARDNESS	Tucson	0.951	1.05E-02	Poor Fit
LEAD	ADOT	0.837	9.58E-08	Poor Fit
LEAD	Phoenix	0.944	5.23E-07	Poor Fit
LEAD	Scottsdale	0.989	7.45E-01	Lognormal Model Accepted
LEAD	Tucson	0.92	4.50E-04	Poor Fit
NICKEL	Mesa	0.982	3.84E-01	Lognormal Model Accepted
NICKEL	Phoenix	0.985	4.15E-02	Poor Fit
NICKEL	Pima County	0.964	8.32E-02	Lognormal Model Accepted
NITRATE	ADOT	0.747	3.70E-09	Poor Fit
NITRATE	Scottsdale	0.967	2.18E-01	Lognormal Model Accepted
NITRATE+NITRITE	Glendale	0.981	2.51E-01	Lognormal Model Accepted
NITRATE+NITRITE	Phoenix	0.981	1.36E-01	Lognormal Model Accepted
NITRATE+NITRITE	Pima County	0.966	9.79E-02	Lognormal Model Accepted
NITRATE+NITRITE	Scottsdale	0.981	3.52E-01	Lognormal Model Accepted
NITRATE+NITRITE	Tempe	0.96	1.84E-03	Poor Fit
PH	ADOT	0.952	2.55E-02	Poor Fit
PH	Glendale	0.693	8.28E-12	Poor Fit
PH	Mesa	0.768	2.60E-09	Poor Fit
PH	Phoenix	0.981	1.27E-01	Lognormal Model Accepted
PH	Pima	0.964	6.77E-02	Lognormal Model

Parameter	Permittee	W Test Statistic	P-Value	Decision
	County			Accepted
PH	Scottsdale	0.953	6.35E-04	Poor Fit
PH	Tempe	0.986	1.17E-01	Lognormal Model Accepted
PH	Tucson	0.919	3.34E-04	Poor Fit
TEMPERATURE	Scottsdale	0.778	2.46E-06	Poor Fit
TPH	Scottsdale	0.933	3.09E-02	Poor Fit
ZINC	ADOT	0.781	1.23E-09	Poor Fit
ZINC	Mesa	0.972	9.48E-02	Lognormal Model Accepted
ZINC	Phoenix	0.975	4.27E-04	Poor Fit
ZINC	Pima County	0.972	1.53E-01	Lognormal Model Accepted
ZINC	Scottsdale	0.976	1.29E-01	Lognormal Model Accepted
ZINC	Tempe	0.949	1.33E-03	Poor Fit
ZINC	Tucson	0.881	1.89E-05	Poor Fit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Pima County
Nat. Log of Obs. Concentration or Level
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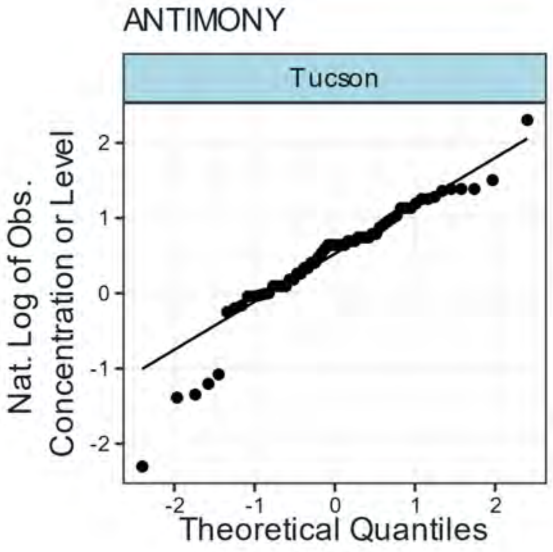
-2
-1
0
1
2
Theoretical Quantiles


ANTIMONY
Tucson
Nat. Log of Obs. Concentration or Level
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-1
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-2
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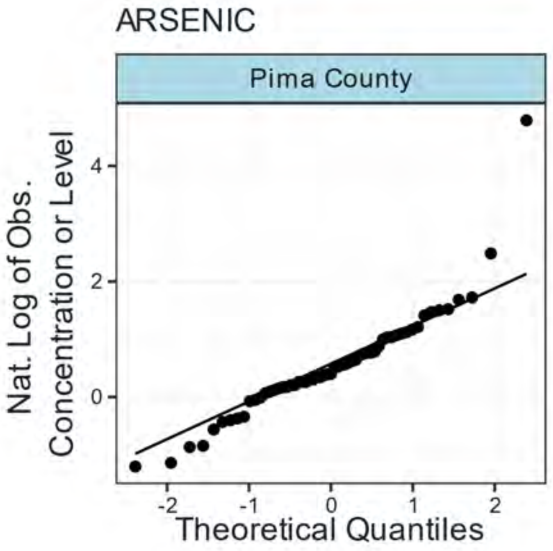
0
1
2
Theoretical Quantiles


ARSENIC
Pima County
Nat. Log of Obs. Concentration or Level
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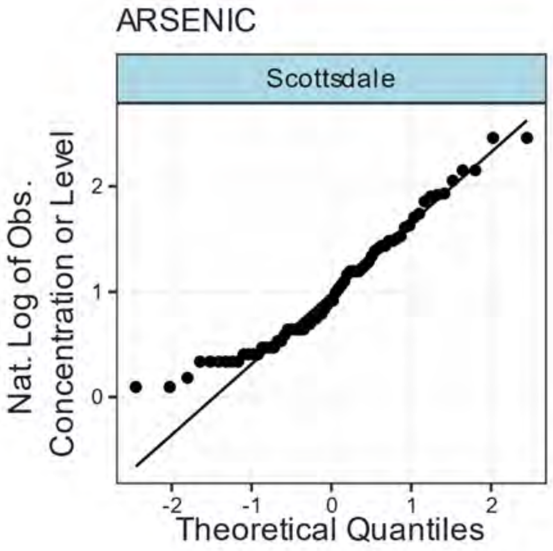
0
1
2
Theoretical Quantiles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Scottsdale
Nat. Log of Obs. Concentration or Level
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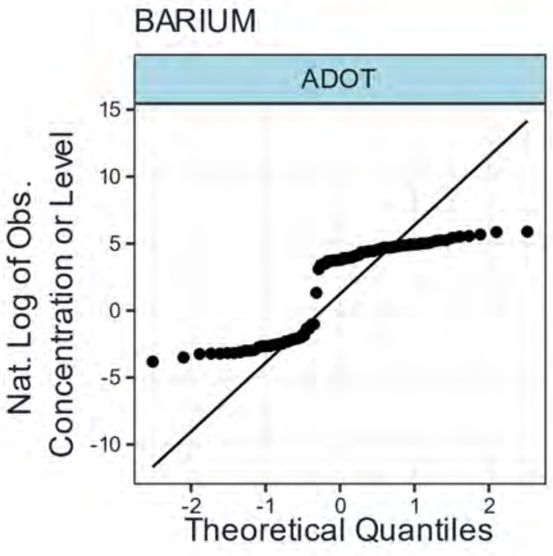
1
2
Theoretical Quantiles


BARIUM
ADOT
Nat. Log of Obs. Concentration or Level
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-2
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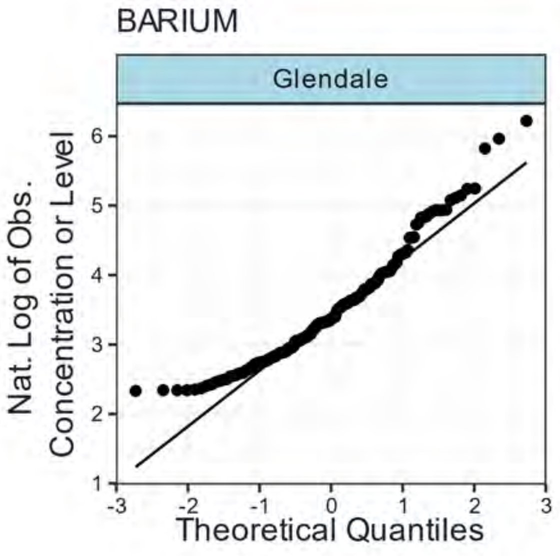
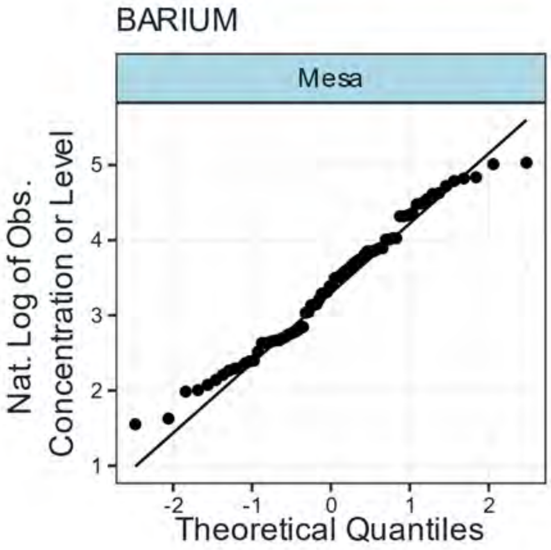
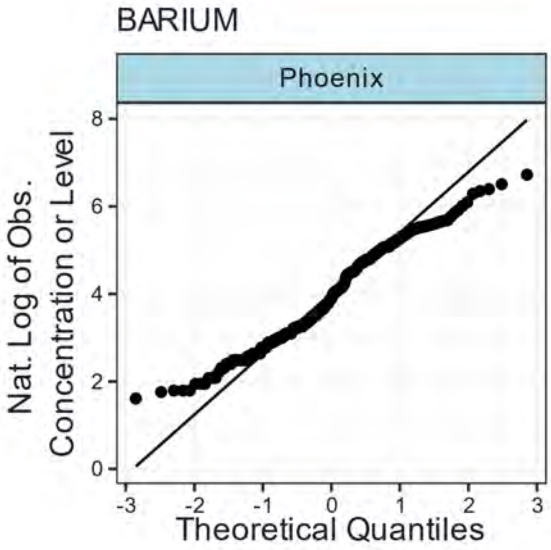
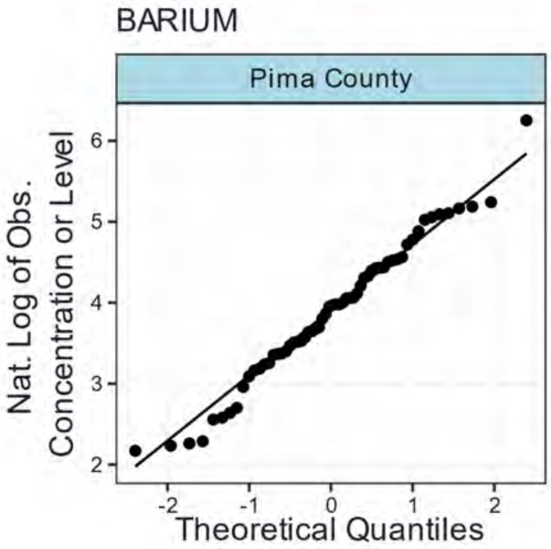
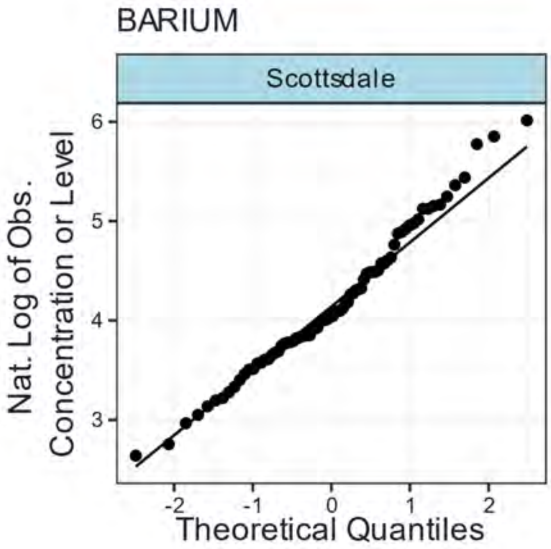
0
1
2
Theoretical Quantiles

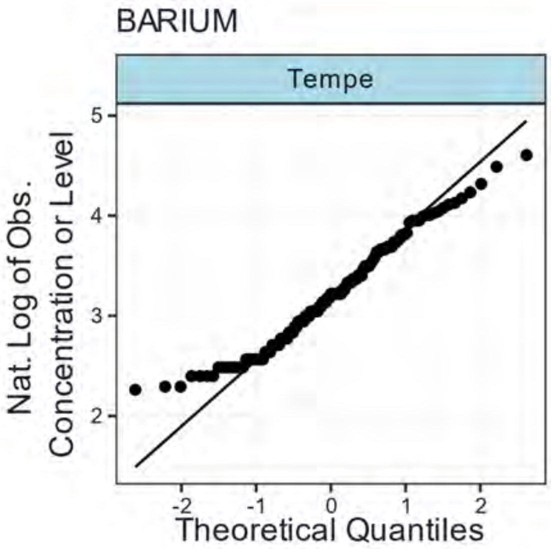

BARIUM
Glendale
Nat. Log of Obs. Concentration or Level
6
5
4
3
2
1
-3
-2
-1
0
1
2
3
Theoretical Quantiles

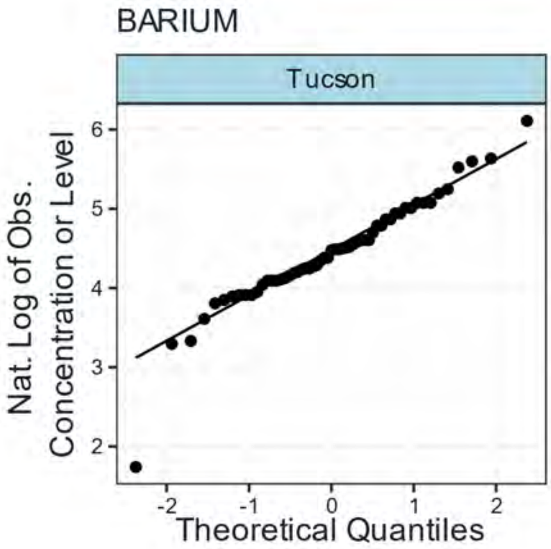

BARIUM
Mesa
Nat. Log of Obs. Concentration or Level
1
2
3
4
5
-2
-1
0
1
2
Theoretical Quantiles

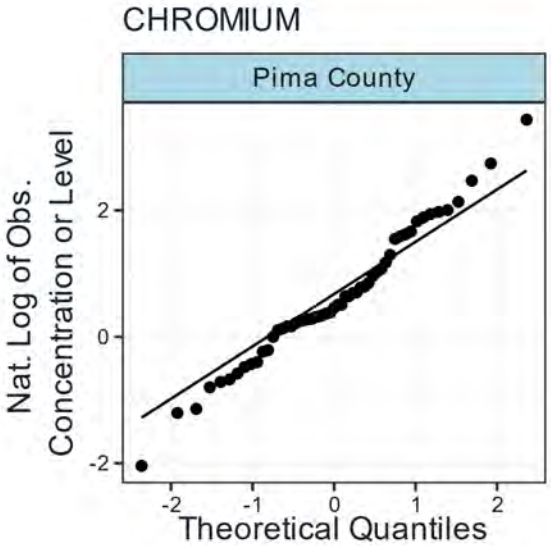

BARIUM
Phoenix
Nat. Log of Obs. Concentration or Level
0
2
4
6
8
-3
-2
-1
0
1
2
3
Theoretical Quantiles

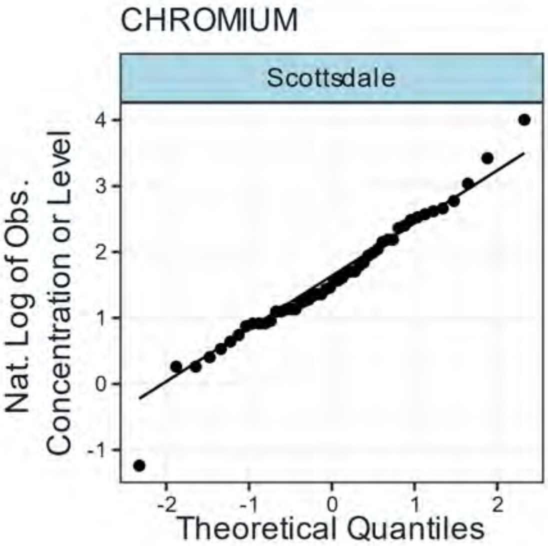

BARIUM
Pima County
Nat. Log of Obs. Concentration or Level
2
3
4
5
6
-2
-1
0
1
2
Theoretical Quantiles

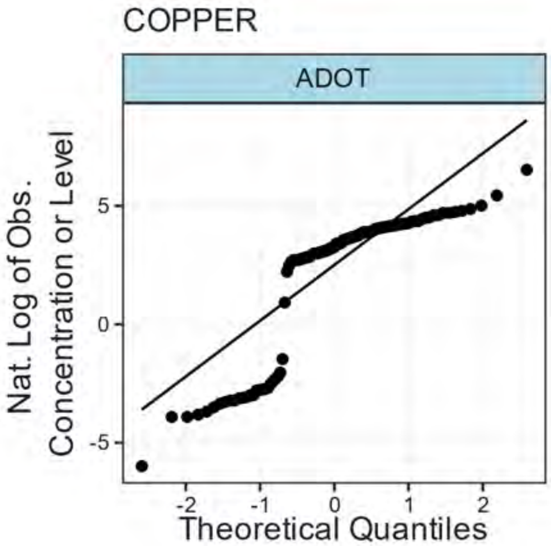

BARIUM
Scottsdale
Nat. Log of Obs. Concentration or Level
3
4
5
6
-2
-1
0
1
2
Theoretical Quantiles

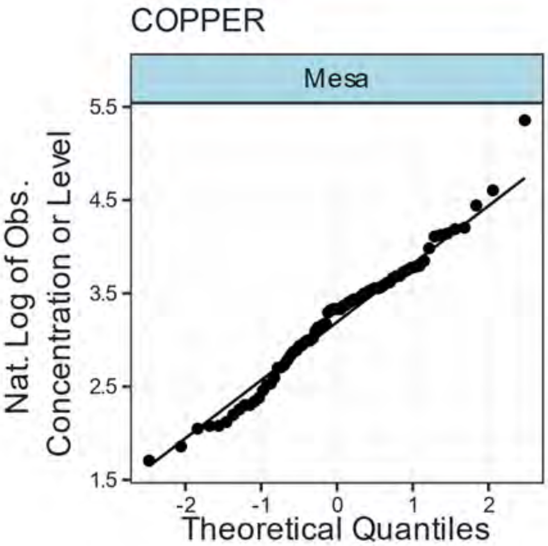

BARIUM
Tempe
Nat. Log of Obs. Concentration or Level
2
3
4
5
-2
-1
0
1
2
Theoretical Quantiles

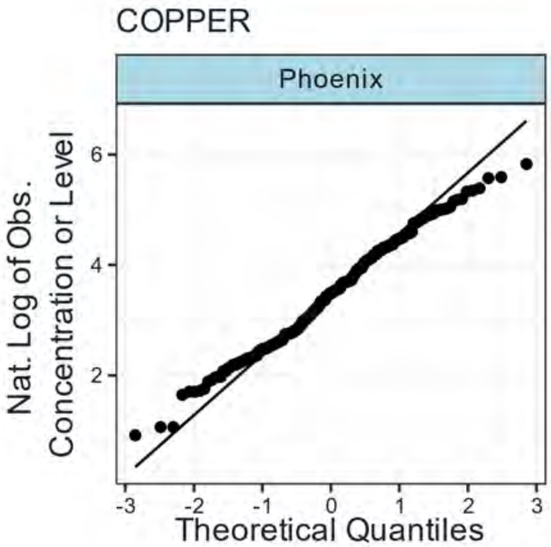

BARIUM
Tucson
Nat. Log of Obs. Concentration or Level
2
3
4
5
6
-2
-1
0
1
2
Theoretical Quantiles

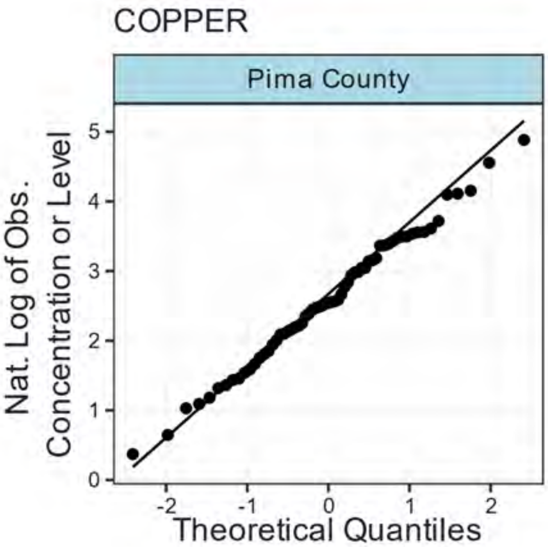

CHROMIUM
Pima County
Nat. Log of Obs. Concentration or Level
Theoretical Quantiles
-2
0
2
-2
-1
0
1
2

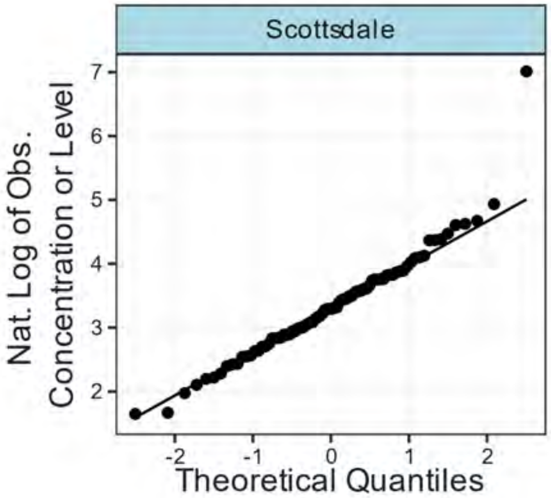

CHROMIUM
Scottsdale
Nat. Log of Obs. Concentration or Level
Theoretical Quantiles
-1
0
1
2
3
4
-2
-1
0
1
2

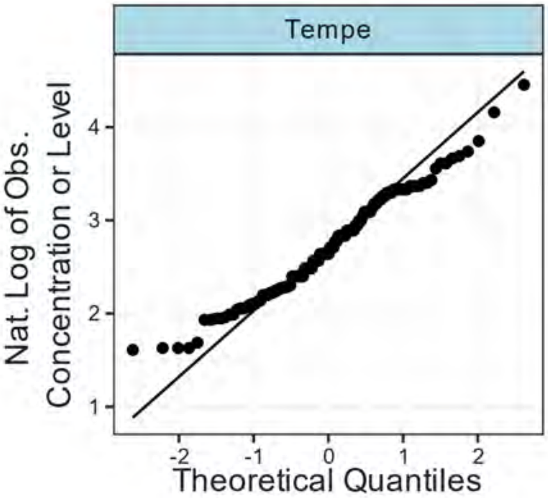

COPPER
ADOT
Nat. Log of Obs. Concentration or Level
Theoretical Quantiles
-5
0
5
-2
-1
0
1
2

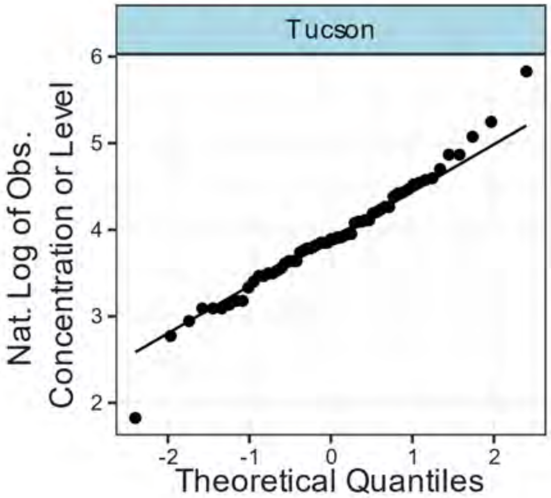

COPPER
Mesa
Nat. Log of Obs. Concentration or Level
Theoretical Quantiles
1.5
2.5
3.5
4.5
5.5
-2
-1
0
1
2

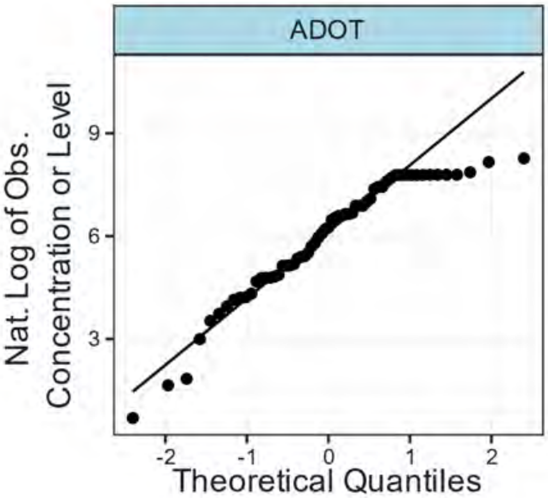

COPPER
Phoenix
Nat. Log of Obs. Concentration or Level
Theoretical Quantiles
2
4
6
-3
-2
-1
0
1
2
3

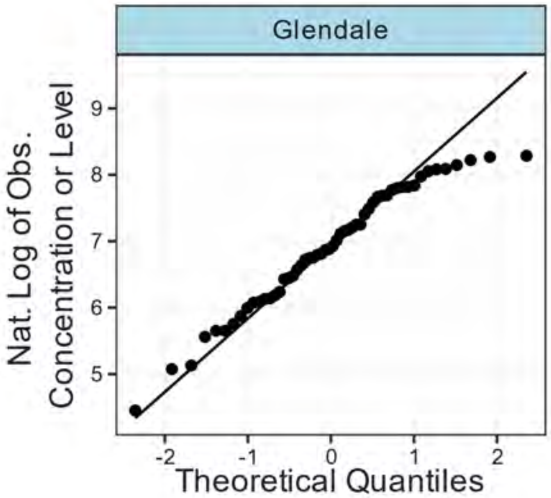

COPPER
Pima County
Nat. Log of Obs. Concentration or Level
Theoretical Quantiles
0
1
2
3
4
5
-2
-1
0
1
2

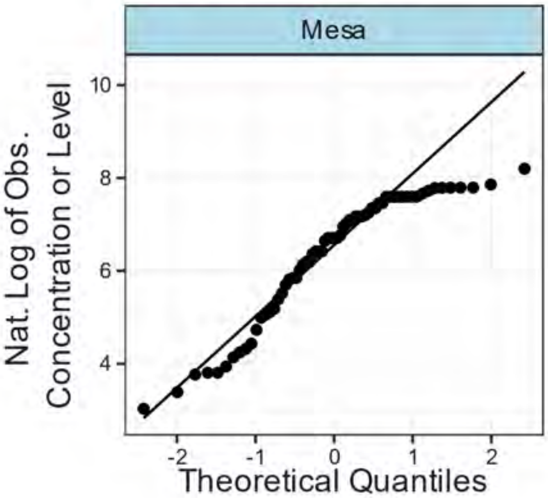

COPPER

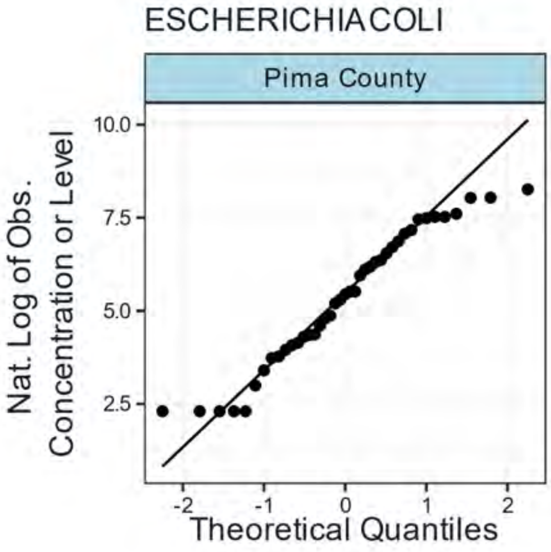

COPPER

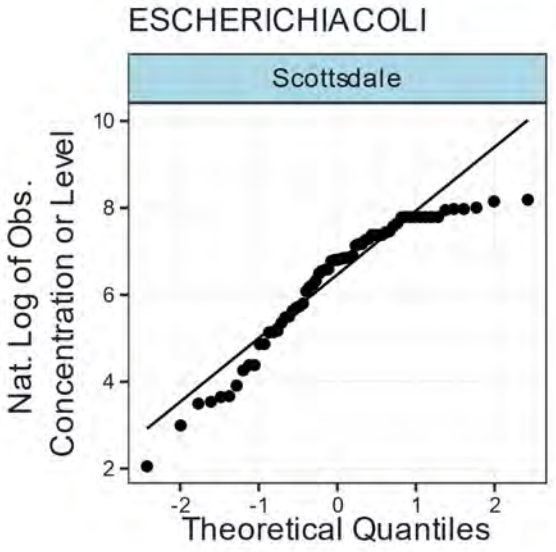

COPPER

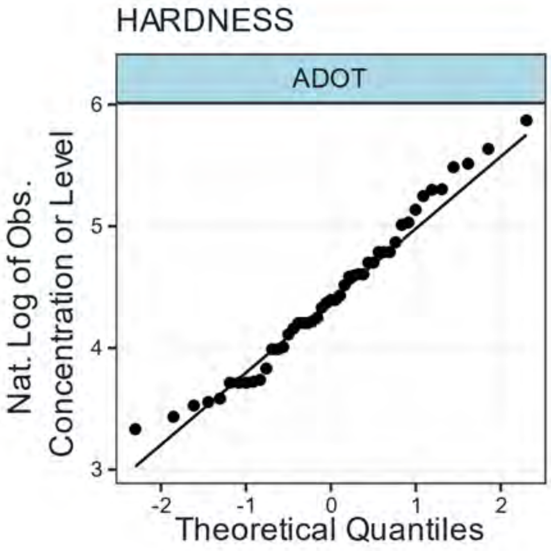

ESCHERICHIACOLI

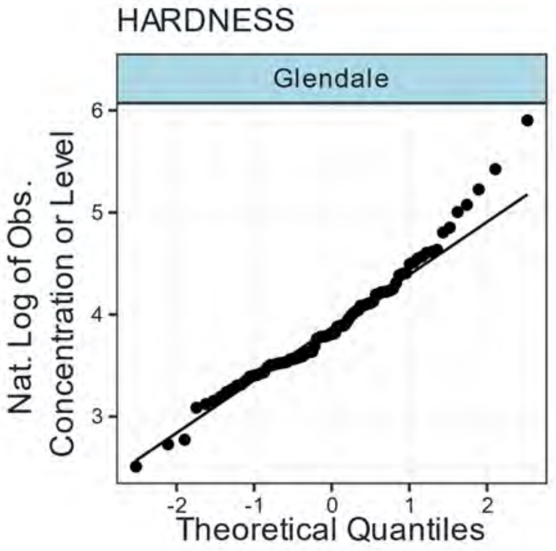

ESCHERICHIACOLI

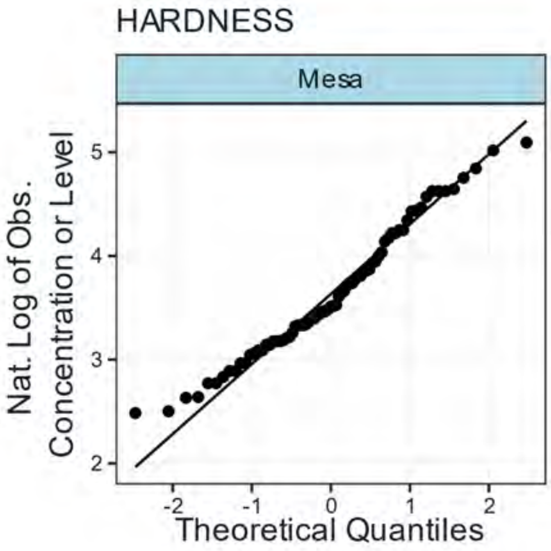

ESCHERICHIACOLI

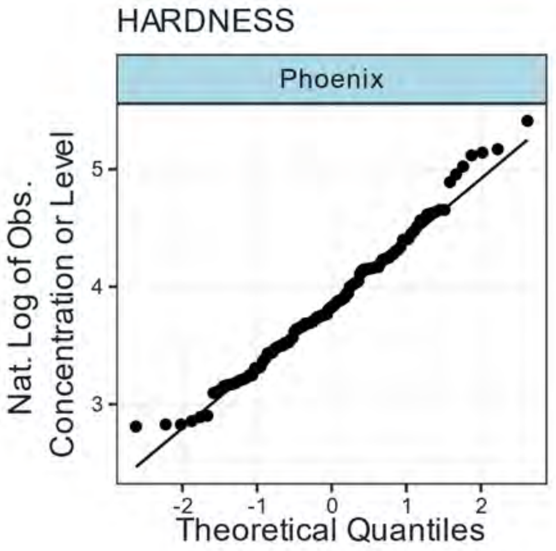

ESCHERICHIACOLI
Pima County
Nat. Log of Obs. Concentration or Level
10.0
7.5
5.0
2.5
-2
-1
0
1
2
Theoretical Quantiles

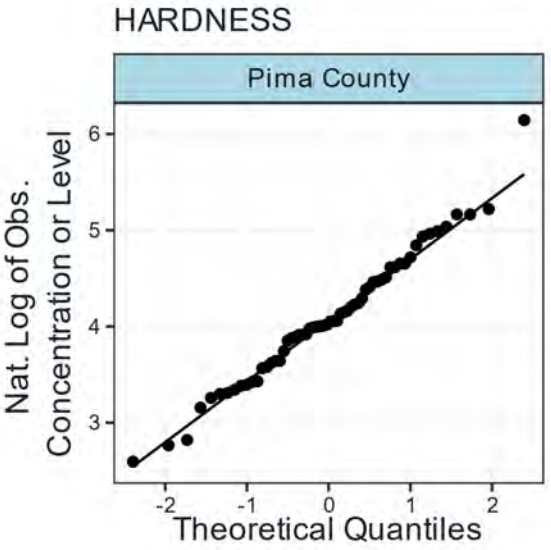

ESCHERICHIACOLI
Scottsdale
Nat. Log of Obs. Concentration or Level
10
8
6
4
2
-2
-1
0
1
2
Theoretical Quantiles

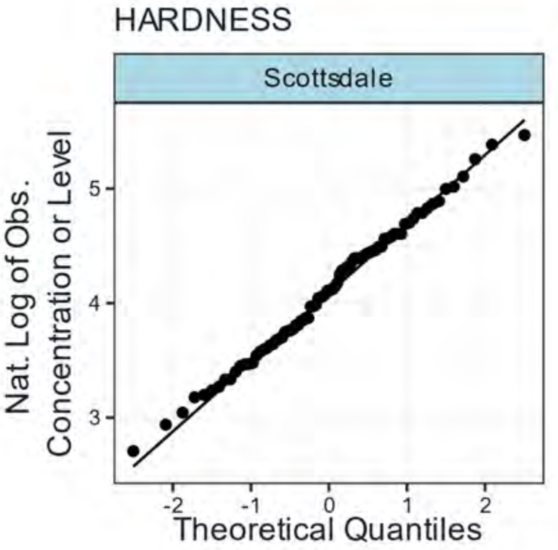

HARDNESS
ADOT
Nat. Log of Obs. Concentration or Level
6
5
4
3
-2
-1
0
1
2
Theoretical Quantiles

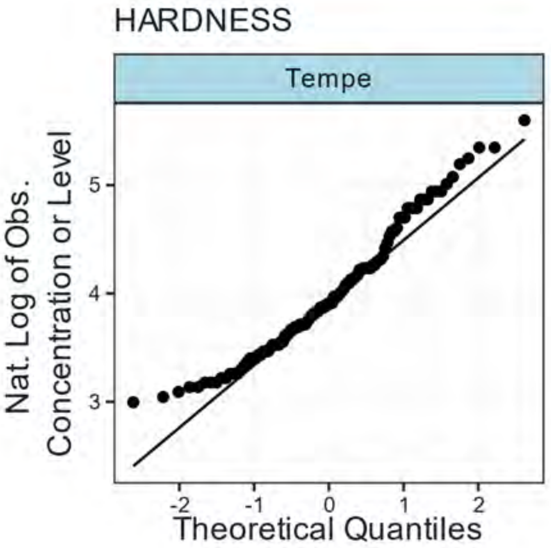

HARDNESS
Glendale
Nat. Log of Obs. Concentration or Level
6
5
4
3
-2
-1
0
1
2
Theoretical Quantiles

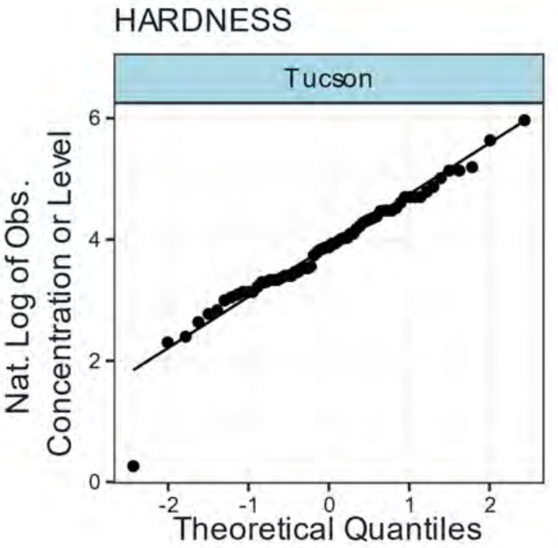

HARDNESS
Mesa
Nat. Log of Obs. Concentration or Level
5
4
3
2
-2
-1
0
1
2
Theoretical Quantiles

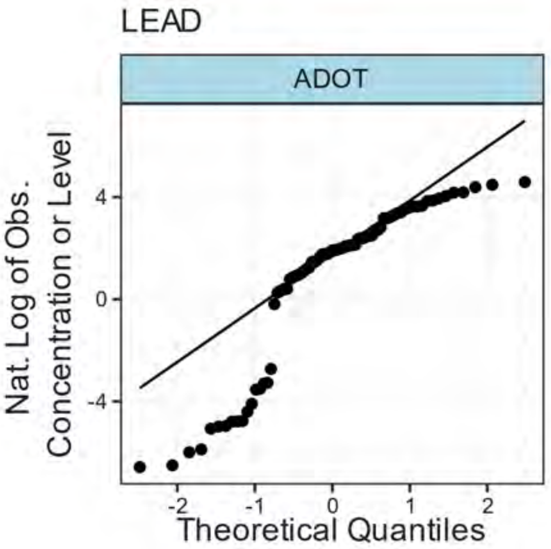

HARDNESS
Phoenix
Nat. Log of Obs. Concentration or Level
5
4
3
-2
-1
0
1
2
Theoretical Quantiles

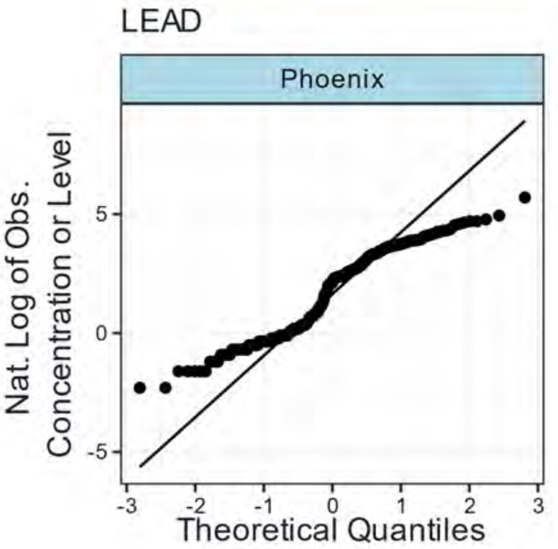

HARDNESS
Pima County
Nat. Log of Obs. Concentration or Level
6
5
4
3
-2
-1
0
1
2
Theoretical Quantiles

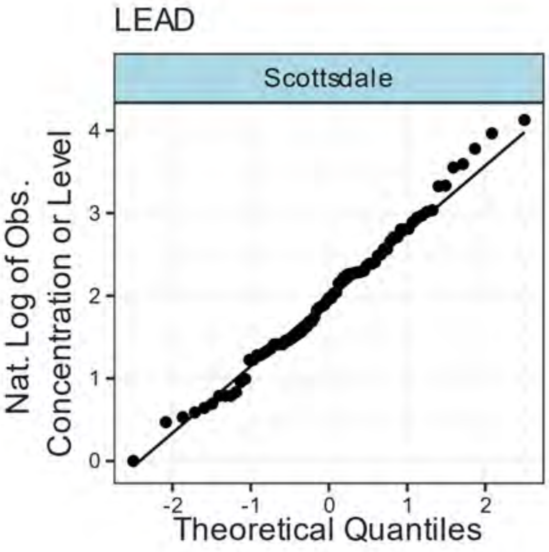

HARDNESS
Scottsdale
Nat. Log of Obs. Concentration or Level
5
4
3
-2
-1
0
1
2
Theoretical Quantiles

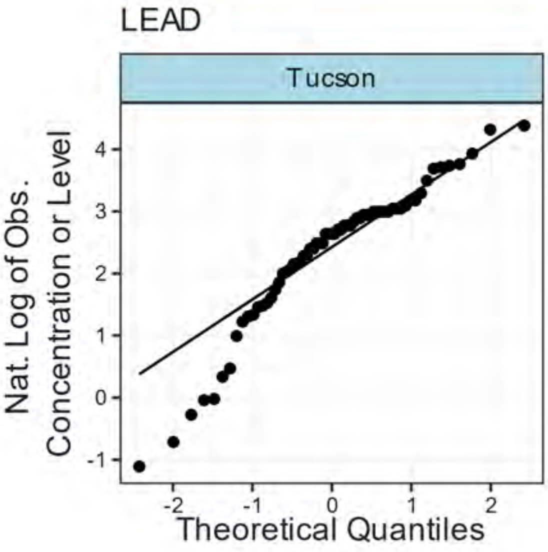

HARDNESS
Tempe
Nat. Log of Obs. Concentration or Level
5
4
3
-2
-1
0
1
2
Theoretical Quantiles

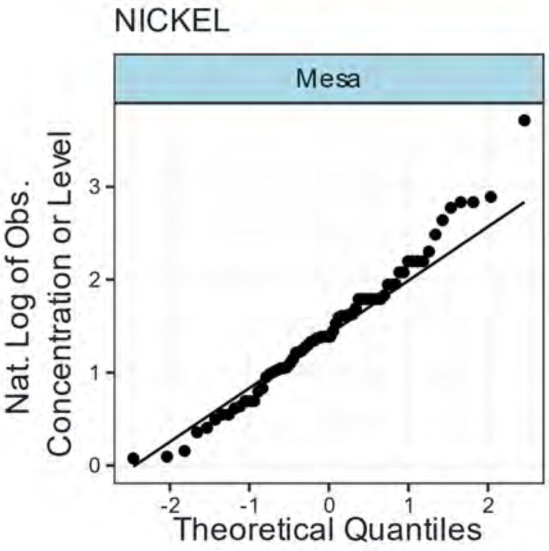

HARDNESS
Tucson
Nat. Log of Obs. Concentration or Level
6
4
2
0
-2
-1
0
1
2
Theoretical Quantiles

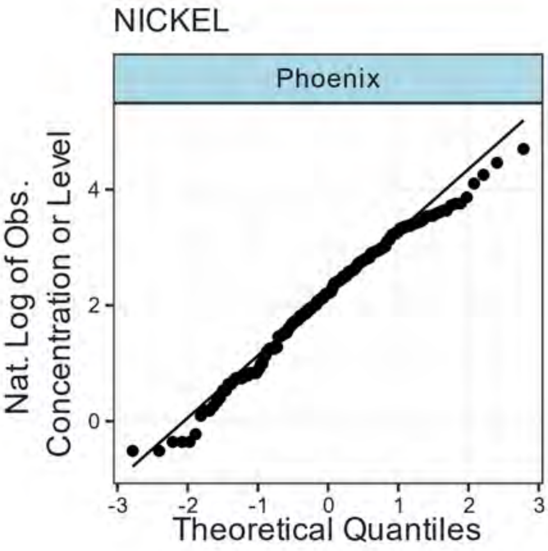

LEAD
ADOT
Nat. Log of Obs. Concentration or Level
4
0
-4
-2
-1
0
1
2
Theoretical Quantiles

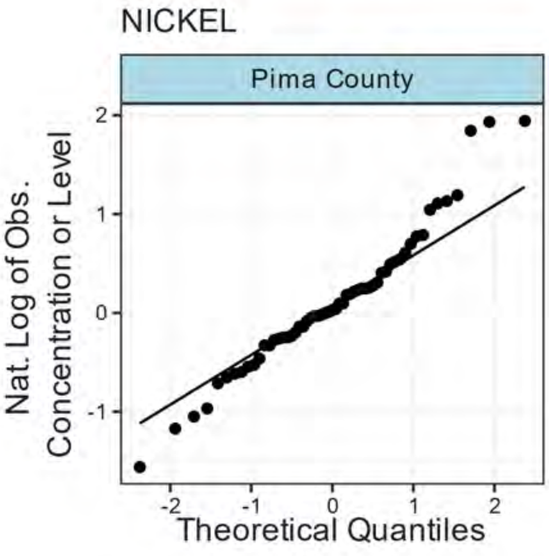

LEAD
Phoenix
Nat. Log of Obs. Concentration or Level
5
0
-5
-3
-2
-1
0
1
2
3
Theoretical Quantiles

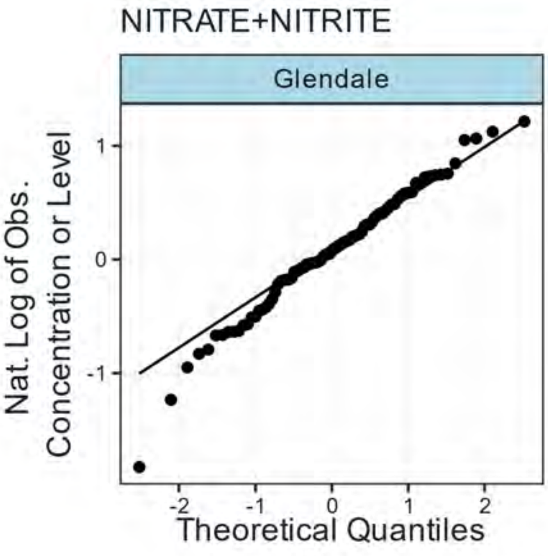

LEAD
Scottsdale
Nat. Log of Obs. Concentration or Level
0
1
2
3
4
-2
-1
0
1
2
Theoretical Quantiles

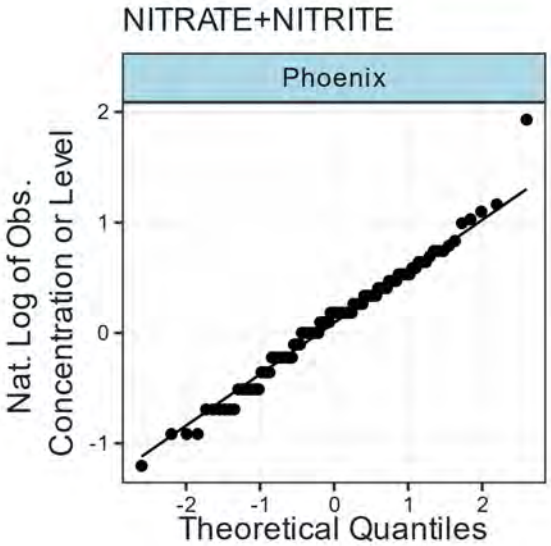

LEAD
Tucson
Nat. Log of Obs. Concentration or Level
-1
0
1
2
3
4
-2
-1
0
1
2
Theoretical Quantiles

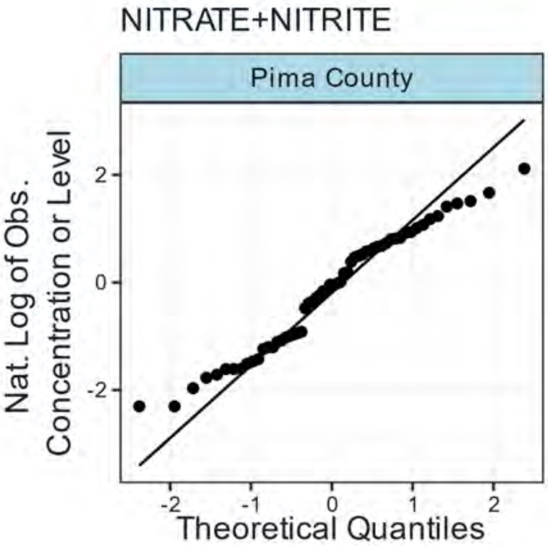

NICKEL
Mesa
Nat. Log of Obs. Concentration or Level
0
1
2
3
-2
-1
0
1
2
Theoretical Quantiles

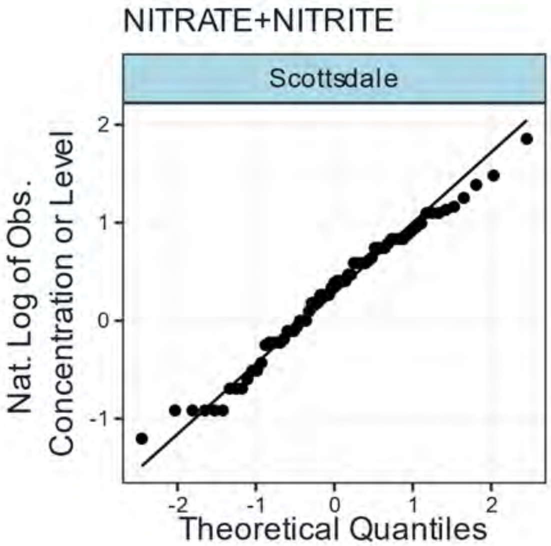

NICKEL
Phoenix
Nat. Log of Obs. Concentration or Level
0
2
4
-3
-2
-1
0
1
2
3
Theoretical Quantiles

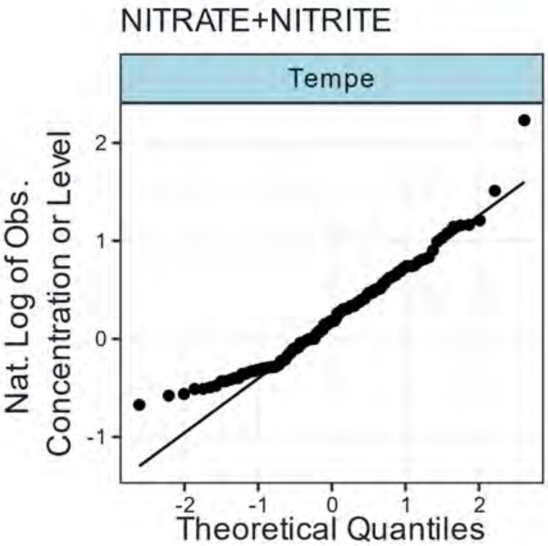

NICKEL
Pima County
Nat. Log of Obs. Concentration or Level
-1
0
1
2
-2
-1
0
1
2
Theoretical Quantiles

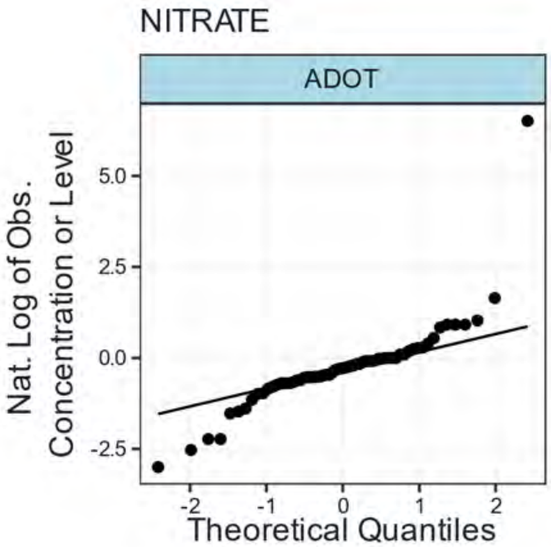

NITRATE+NITRITE
Glendale
Nat. Log of Obs. Concentration or Level
-1
0
1
-2
-1
0
1
2
Theoretical Quantiles

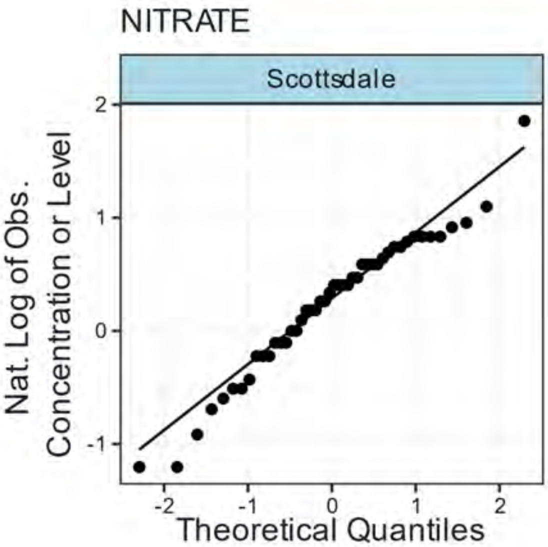

NITRATE+NITRITE
Phoenix
Nat. Log of Obs. Concentration or Level
2
1
0
-1
-2
-1
0
1
2
Theoretical Quantiles

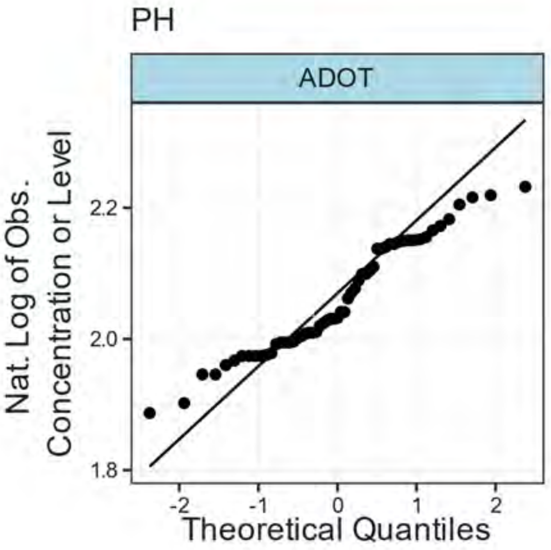

NITRATE+NITRITE
Pima County
Nat. Log of Obs. Concentration or Level
2
0
-2
-2
-1
0
1
2
Theoretical Quantiles

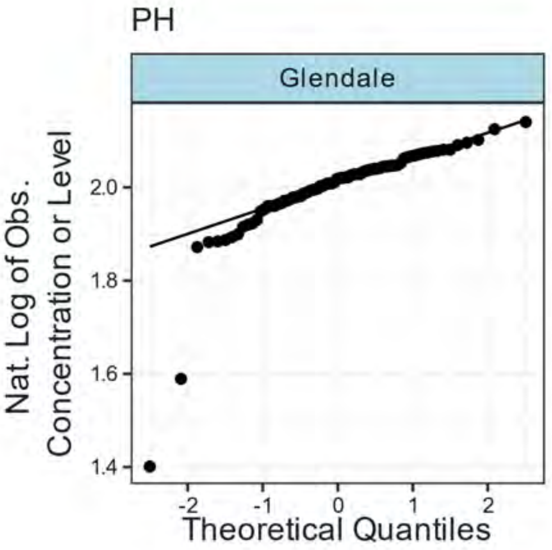

NITRATE+NITRITE
Scottsdale
Nat. Log of Obs. Concentration or Level
2
1
0
-1
-2
-1
0
1
2
Theoretical Quantiles

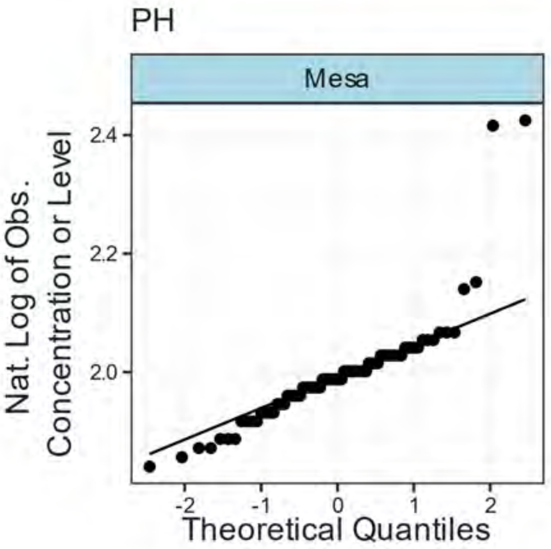

NITRATE+NITRITE
Tempe
Nat. Log of Obs. Concentration or Level
2
1
0
-1
-2
-1
0
1
2
Theoretical Quantiles

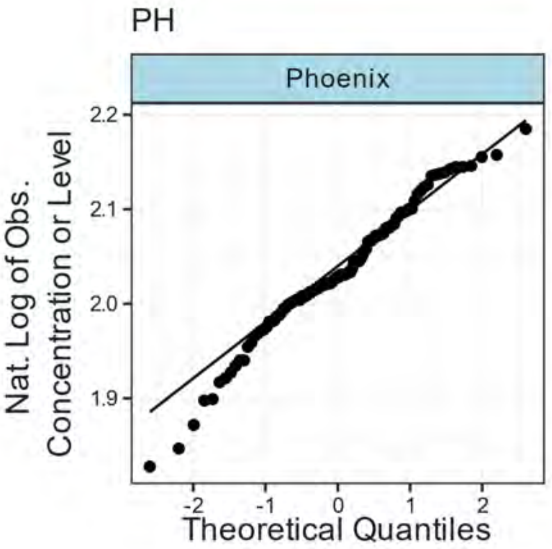

NITRATE
ADOT
Nat. Log of Obs. Concentration or Level
5.0
2.5
0.0
-2.5
-2
-1
0
1
2
Theoretical Quantiles

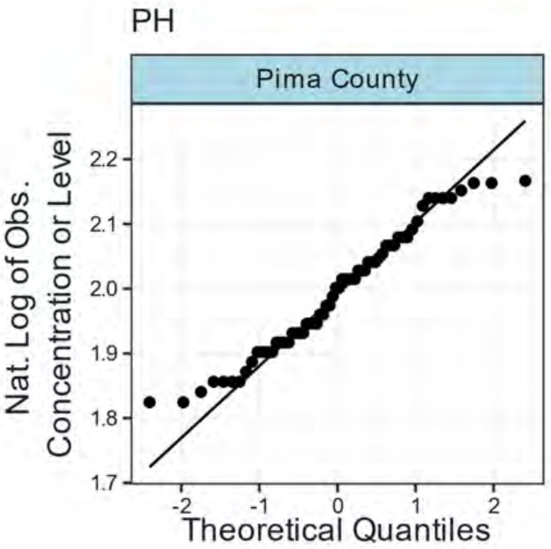

NITRATE
Scottsdale
Nat. Log of Obs. Concentration or Level
2
1
0
-1
-2
-1
0
1
2
Theoretical Quantiles

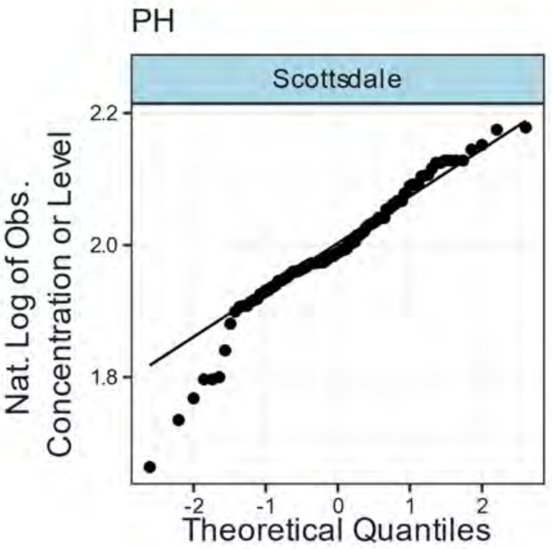

PH
ADOT
Nat. Log of Obs. Concentration or Level
2.2
2.0
1.8
-2
-1
0
1
2
Theoretical Quantiles

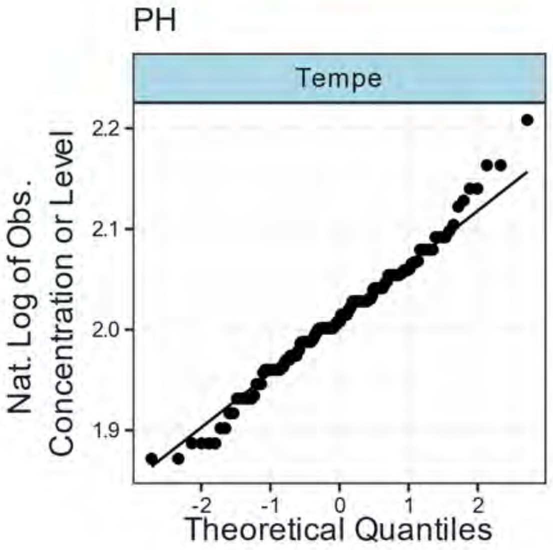

PH
Glendale
Nat. Log of Obs. Concentration or Level
2.0
1.8
1.6
1.4
-2
-1
0
1
2
Theoretical Quantiles

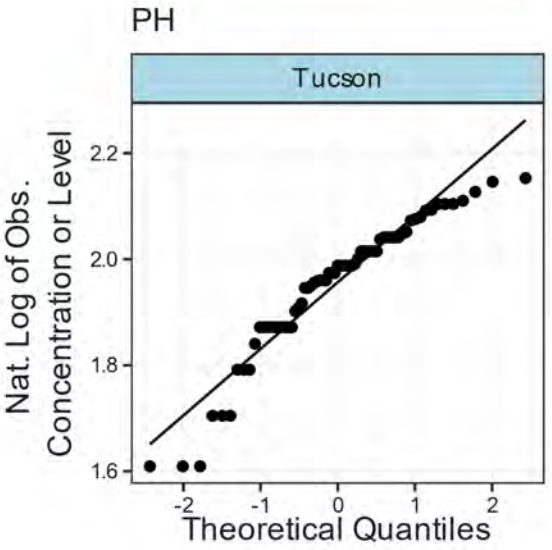

PH
Mesa
Nat. Log of Obs. Concentration or Level
2.4
2.2
2.0
-2
-1
0
1
2
Theoretical Quantiles

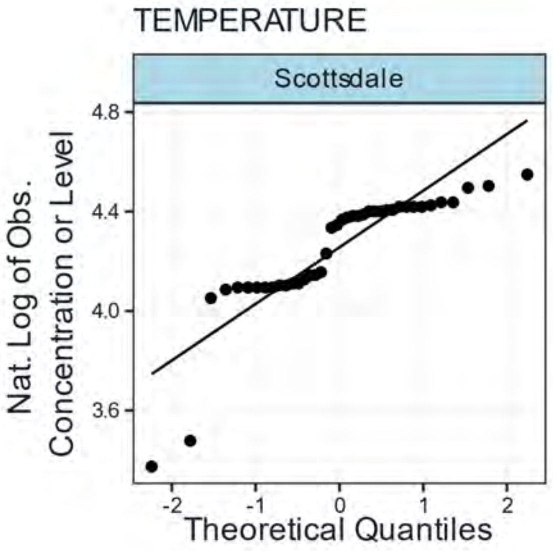

PH
Phoenix
Nat. Log of Obs. Concentration or Level
2.2
2.1
2.0
1.9
-2
-1
0
1
2
Theoretical Quantiles

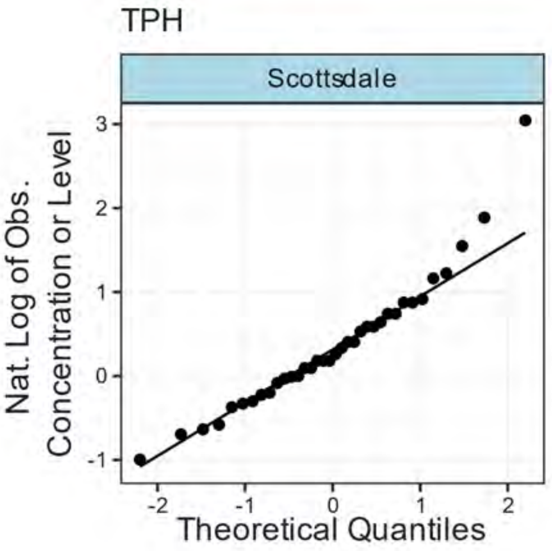

PH
Pima County
Nat. Log of Obs. Concentration or Level
2.2
2.1
2.0
1.9
1.8
1.7
-2
-1
0
1
2
Theoretical Quantiles

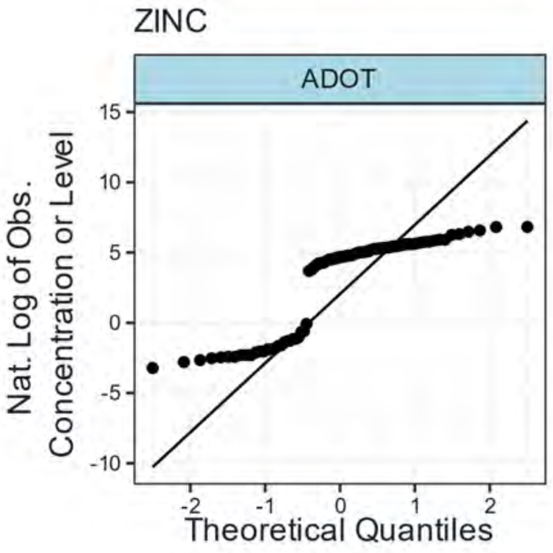

PH
Scottsdale
Nat. Log of Obs. Concentration or Level
2.2
2.0
1.8
-2
-1
0
1
2
Theoretical Quantiles

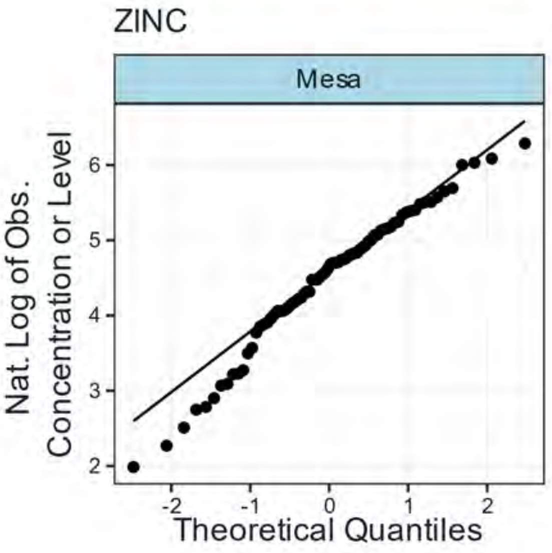

PH
Tempe
2.2
2.1
2.0
1.9
-2
-1
0
1
2
Nat. Log of Obs. Concentration or Level
Theoretical Quantiles

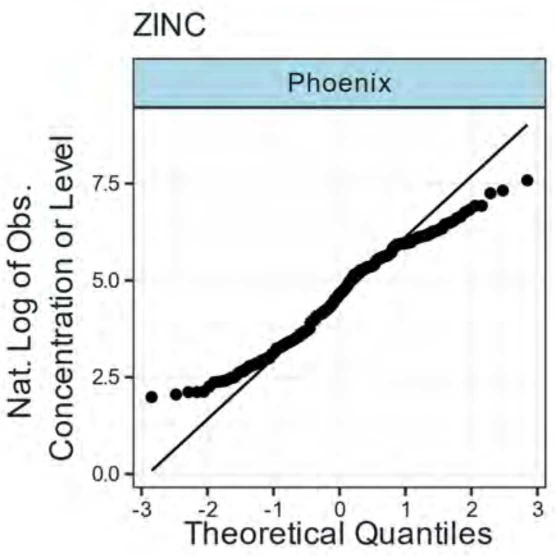

PH
Tucson
2.2
2.0
1.8
1.6
-2
-1
0
1
2
Nat. Log of Obs. Concentration or Level
Theoretical Quantiles

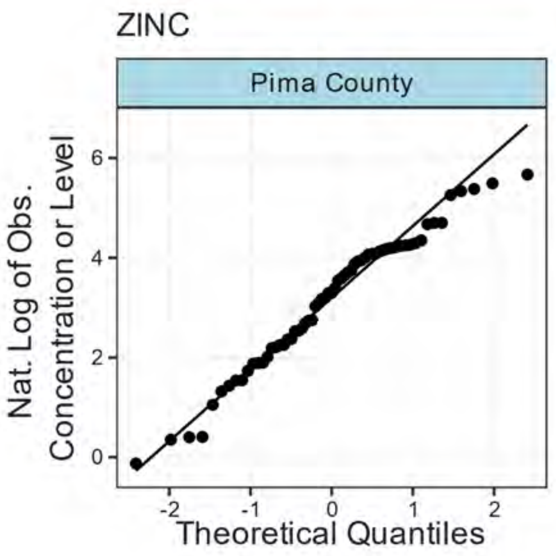

TEMPERATURE
Scottsdale
4.8
4.4
4.0
3.6
-2
-1
0
1
2
Nat. Log of Obs. Concentration or Level
Theoretical Quantiles

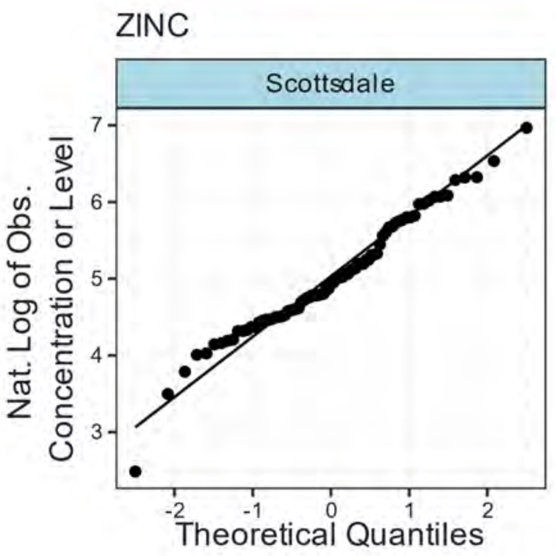

TPH
Scottsdale
3
2
1
0
-1
-2
-1
0
1
2
Nat. Log of Obs. Concentration or Level
Theoretical Quantiles

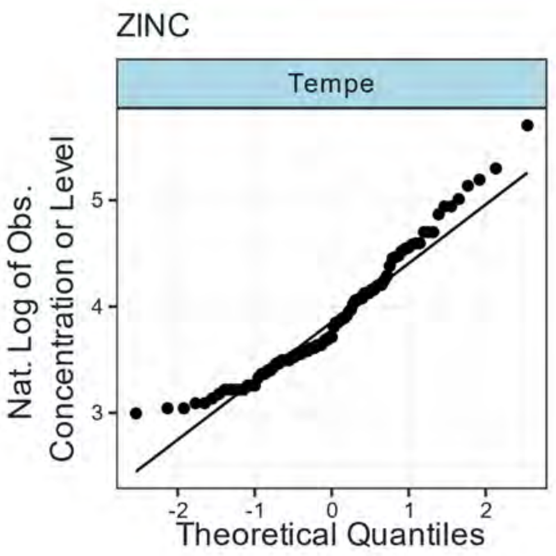

ZINC
ADOT
15
10
5
0
-5
-10
-2
-1
0
1
2
Nat. Log of Obs. Concentration or Level
Theoretical Quantiles

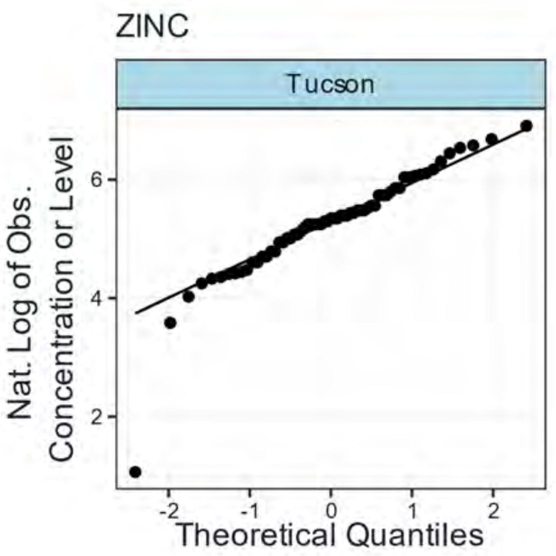

ZINC
Mesa
6
5
4
3
2
-2
-1
0
1
2
Nat. Log of Obs. Concentration or Level
Theoretical Quantiles


ZINC
Phoenix
Nat. Log of Obs. Concentration or Level
0.0
2.5
5.0
7.5
-3
-2
-1
0
1
2
3
Theoretical Quantiles


ZINC
Pima County
Nat. Log of Obs. Concentration or Level
0
2
4
6
-2
-1
0
1
2
Theoretical Quantiles

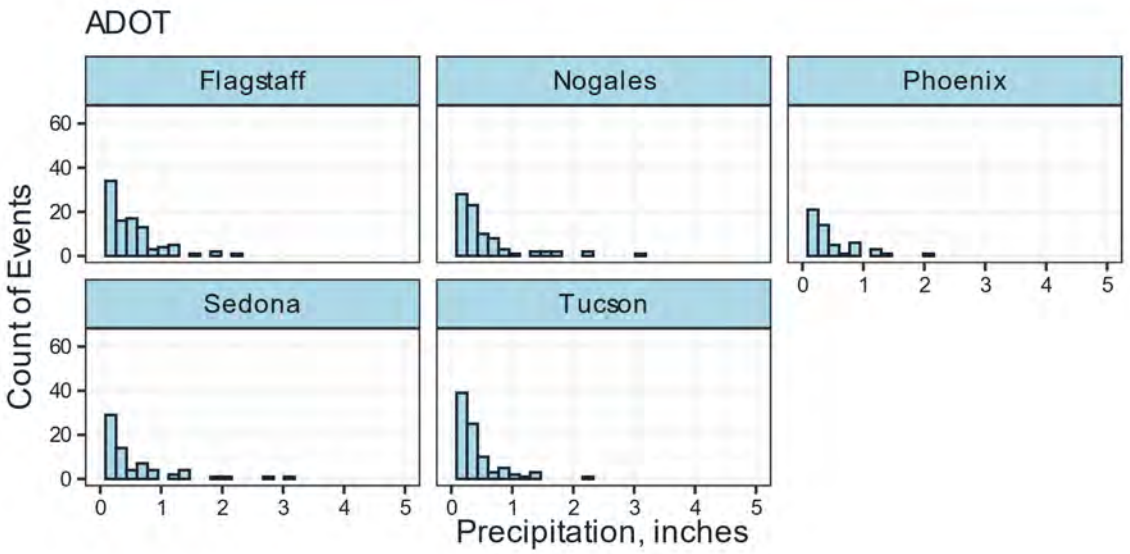

ZINC
Scottsdale
Nat. Log of Obs. Concentration or Level
3
4
5
6
7
-2
-1
0
1
2
Theoretical Quantiles

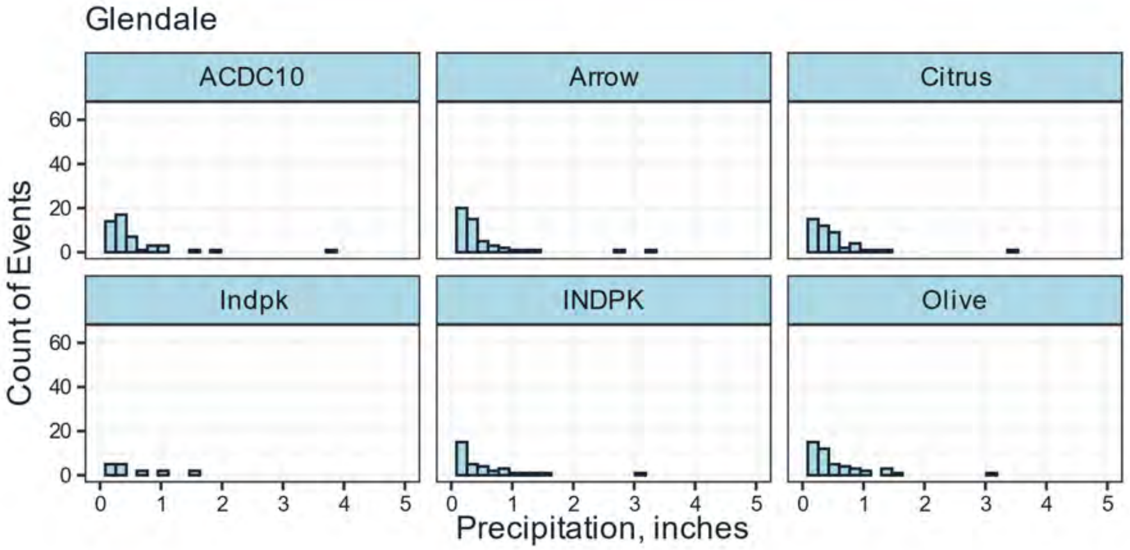

ZINC
Tempe
Nat. Log of Obs. Concentration or Level
3
4
5
-2
-1
0
1
2
Theoretical Quantiles

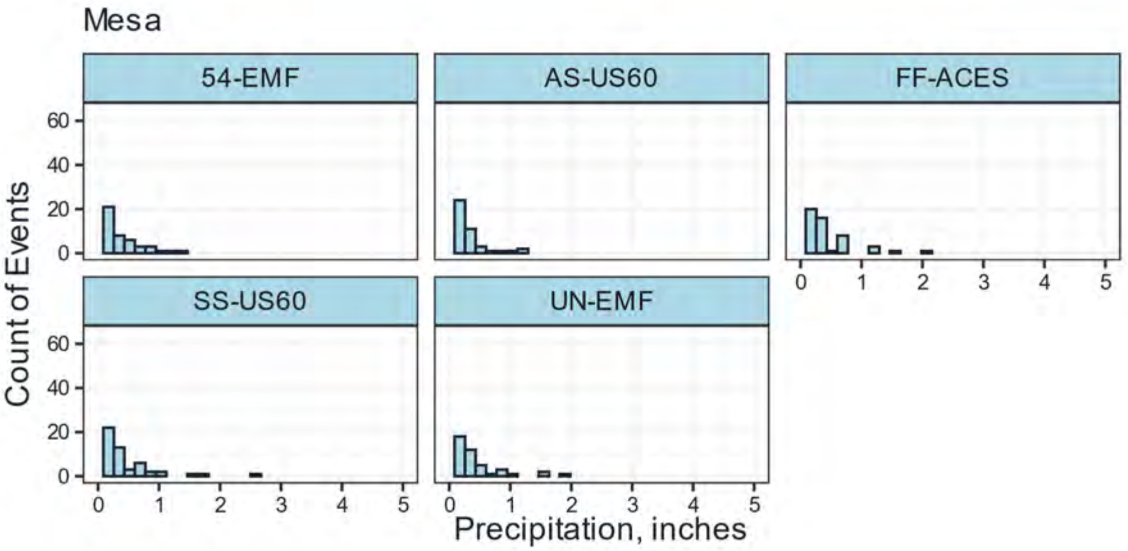

ZINC
Tucson
Nat. Log of Obs. Concentration or Level
2
4
6
-2
-1
0
1
2
Theoretical Quantiles

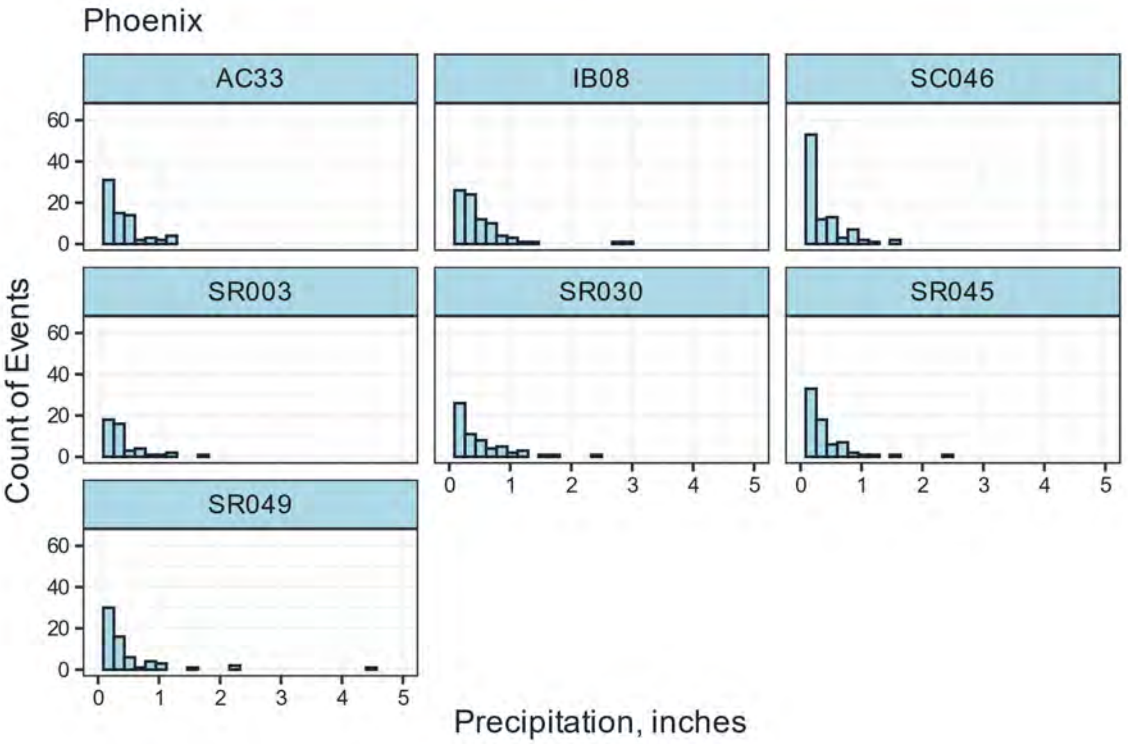
Attachment D – Storm Event Measurements

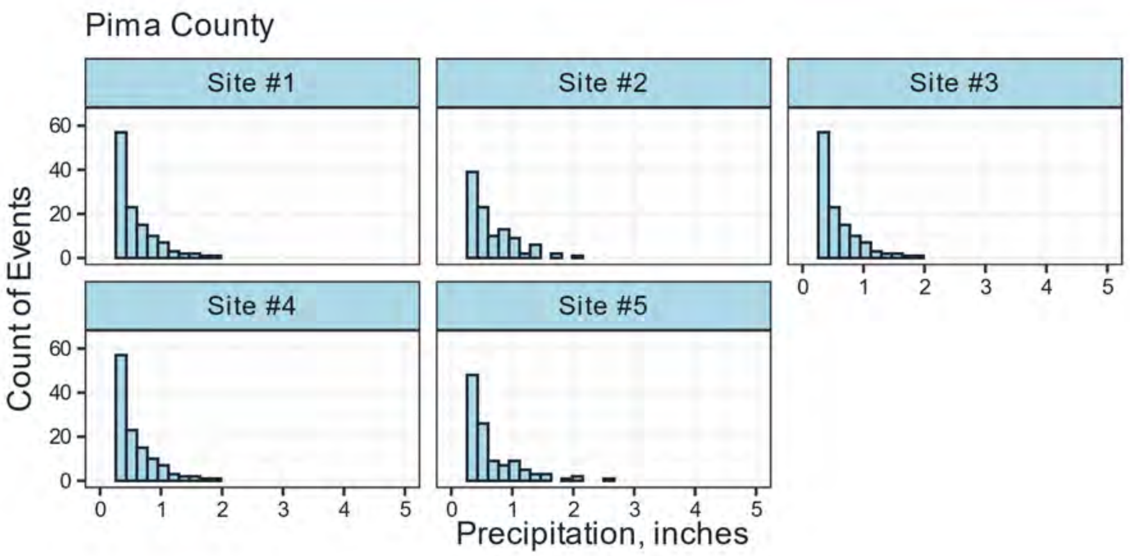
Storm Event Histograms (2011-2020)

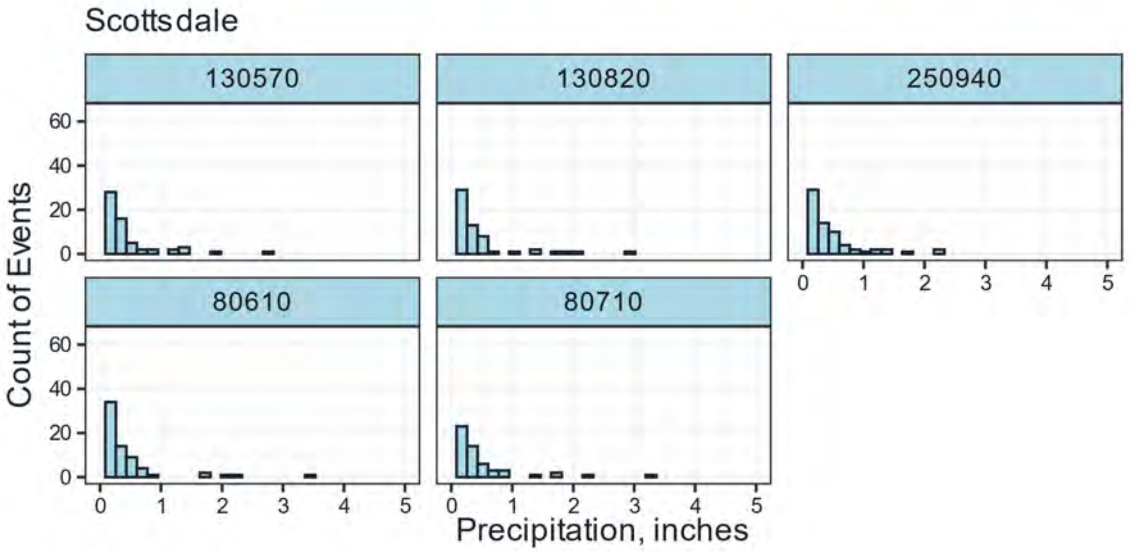


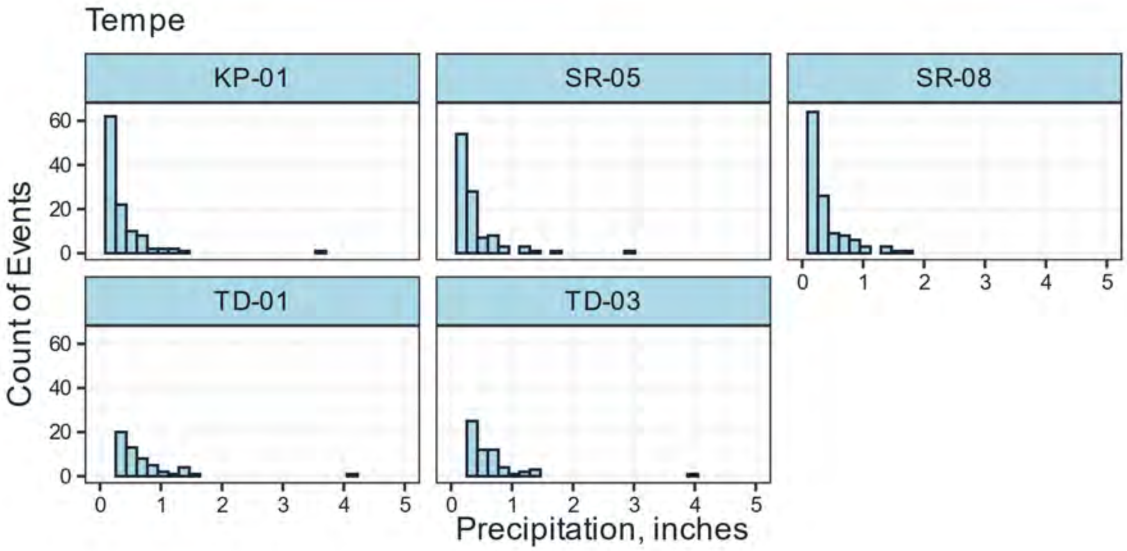


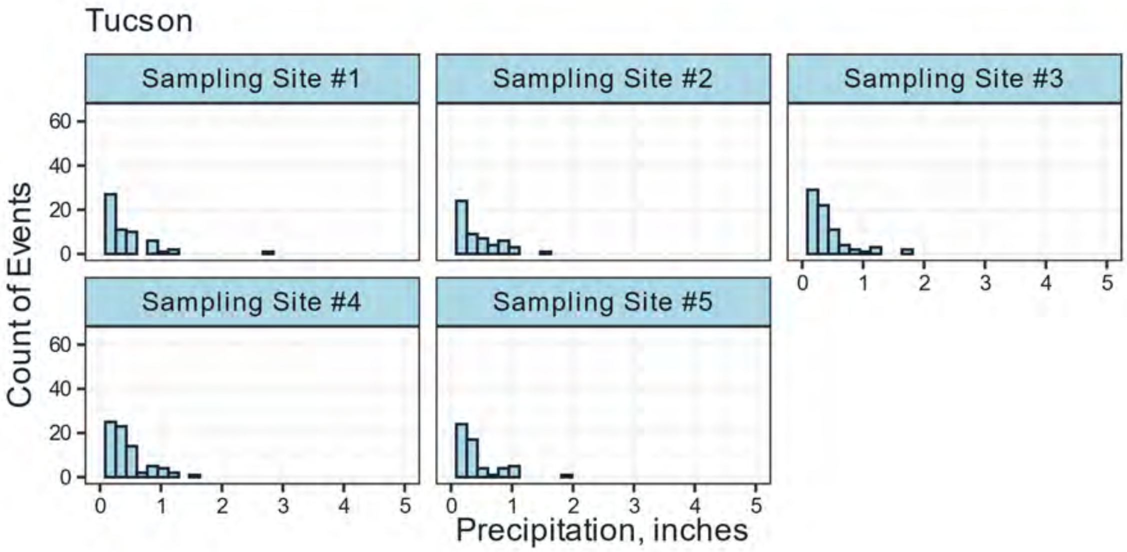

Mesa
54-EMF
AS-US60
FF-ACES
SS-US60
UN-EMF
Count of Events
0
20
40
60
0
1
2
3
4
5
Precipitation, inches


Phoenix
AC33
IB08
SC046
SR003
SR030
SR045
SR049
Count of Events
0
20
40
60
0
1
2
3
4
5
Precipitation, inches


Pima County
Site #1
Site #2
Site #3
Site #4
Site #5
Count of Events
0
20
40
60
0
1
2
3
4
5
Precipitation, inches


Scottsdale
130570
130820
250940
80610
80710
Count of Events
0
20
40
60
0
1
2
3
4
5
Precipitation, inches


Tempe


Tucson

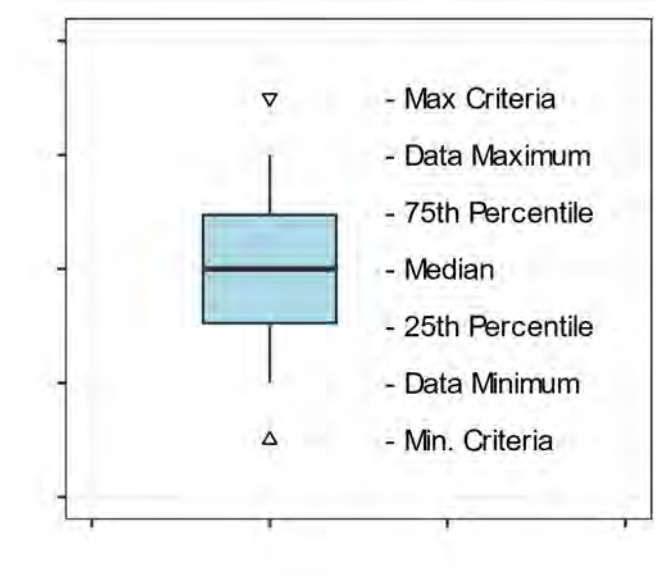
Attachment E – Time Series Plots

Refer to separately attached archive of figures displaying summary plots reported concentrations for detected values and MDL/RL for non-detect values. Circles represent detected concentrations (○), while plus signs indicate the MDL or RL for observations reported with a non-detect status (+).

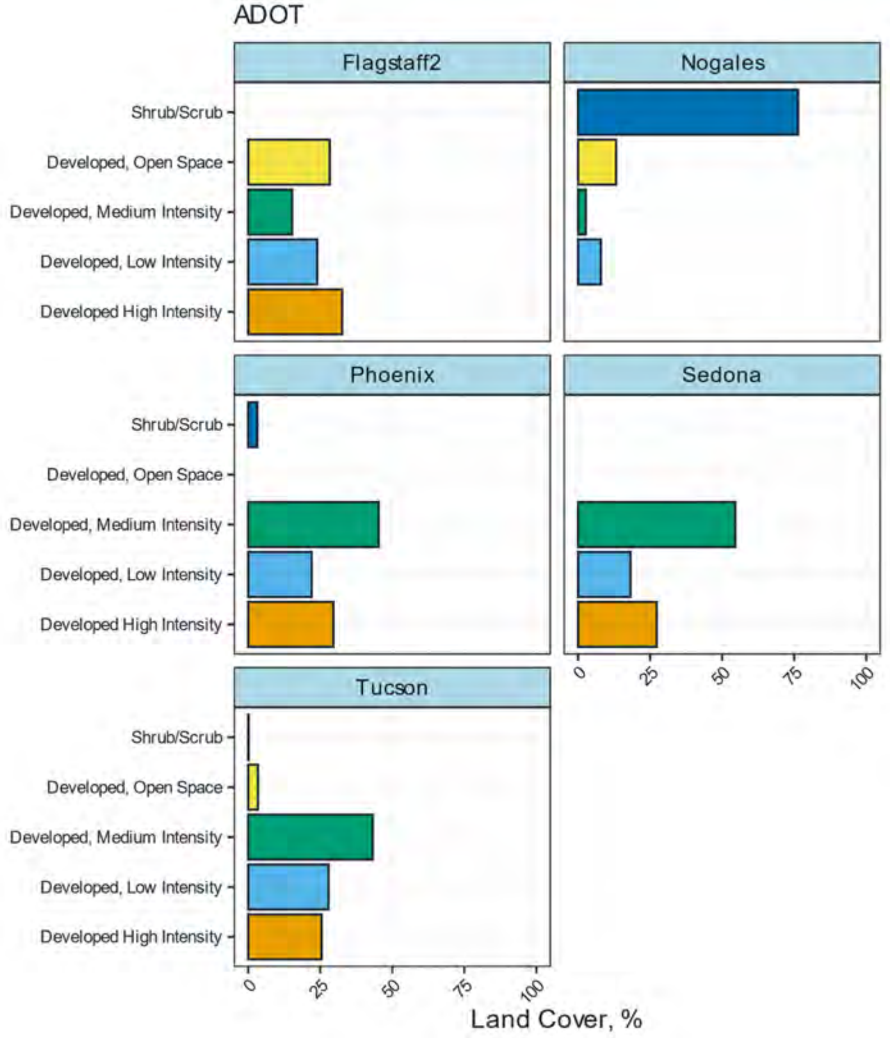
Attachment F – Exceedance Reports

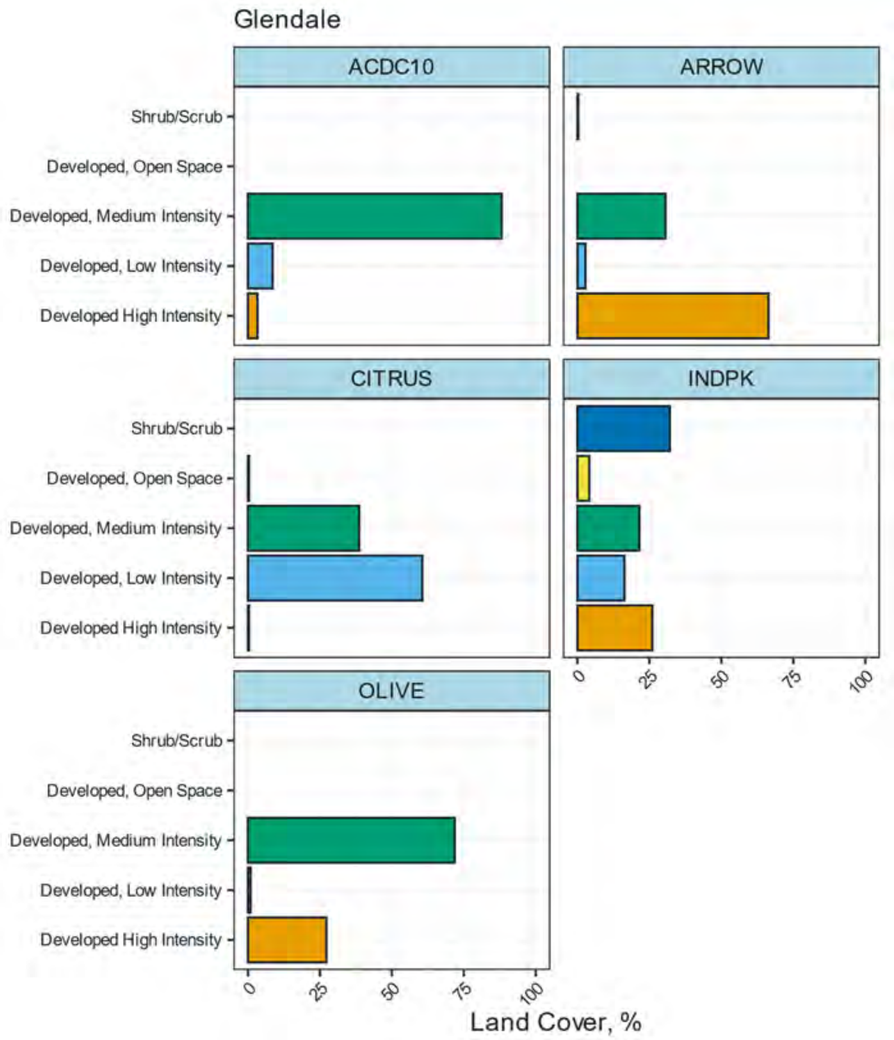
Refer to separately attached archive of figures displaying summary plots comparing reported discharge concentrations and applicable criteria. Note that plots were produced only in cases where there was an applicable water quality criterion. Circles represent detected concentrations (○), while plus signs indicate the MDL or RL for observations reported with a non-detect status (+).

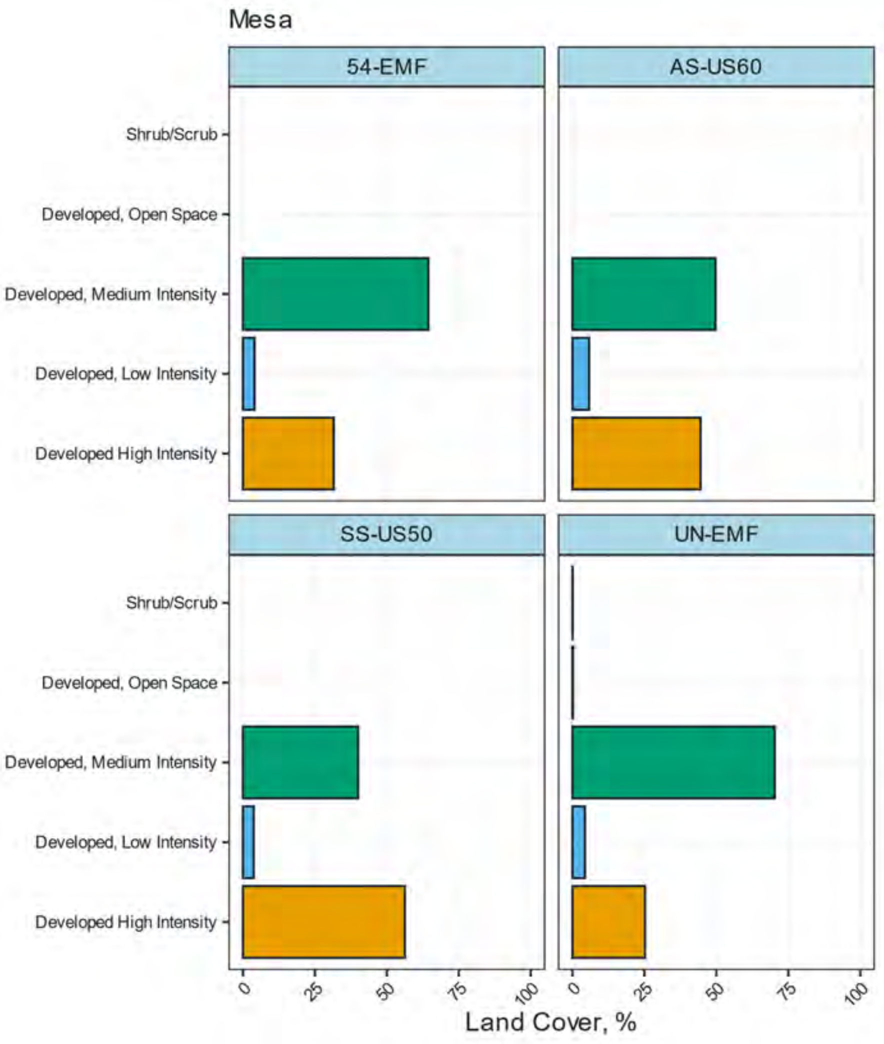
In addition, boxplots of annual discharge data were produced comparing discharge quality to applicable criteria at each individual monitored outfall's receiving water. The figure below provides a key or legend to the symbology used in the boxplots.

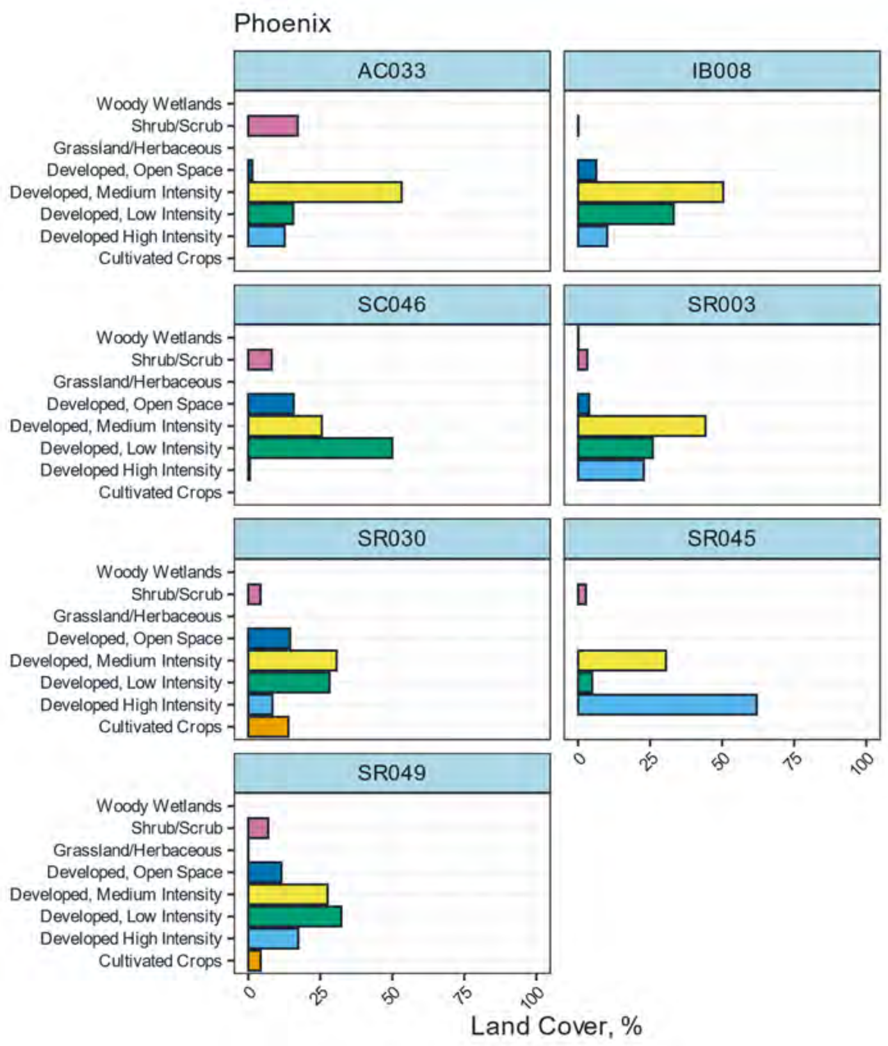


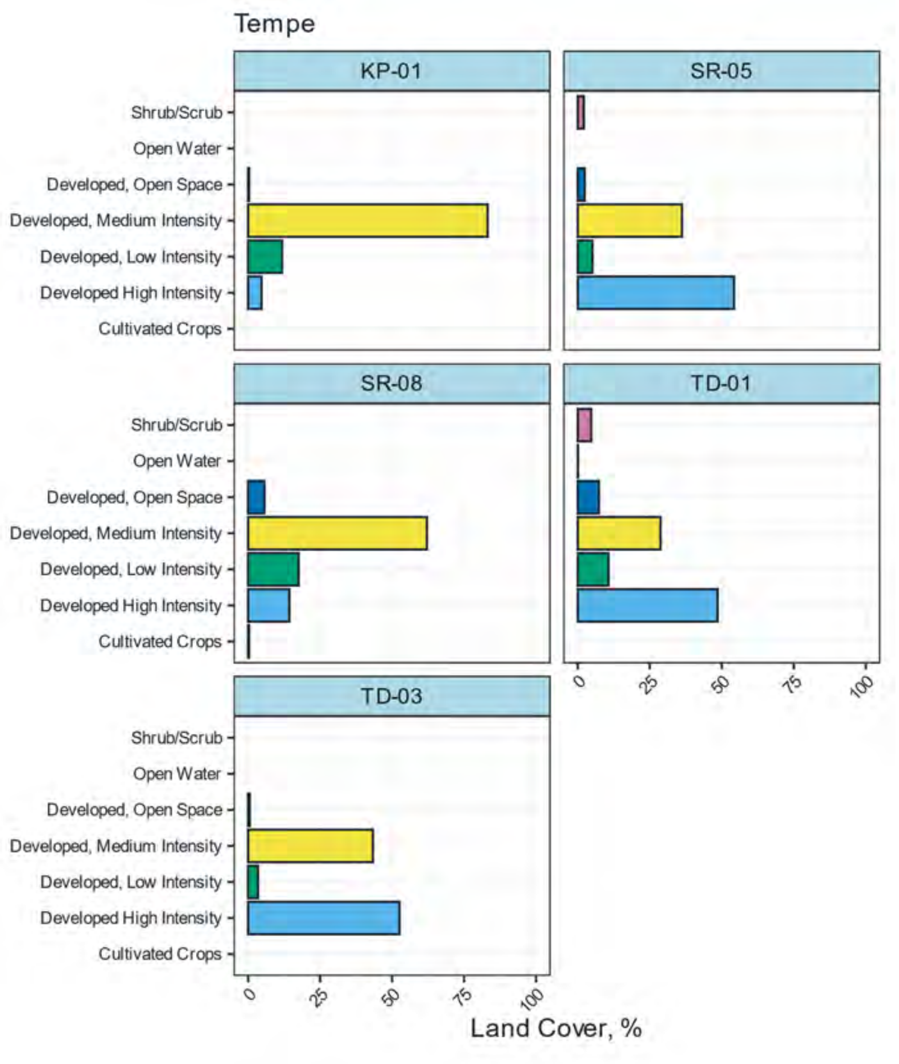
Attachment G – Land Cover Summary

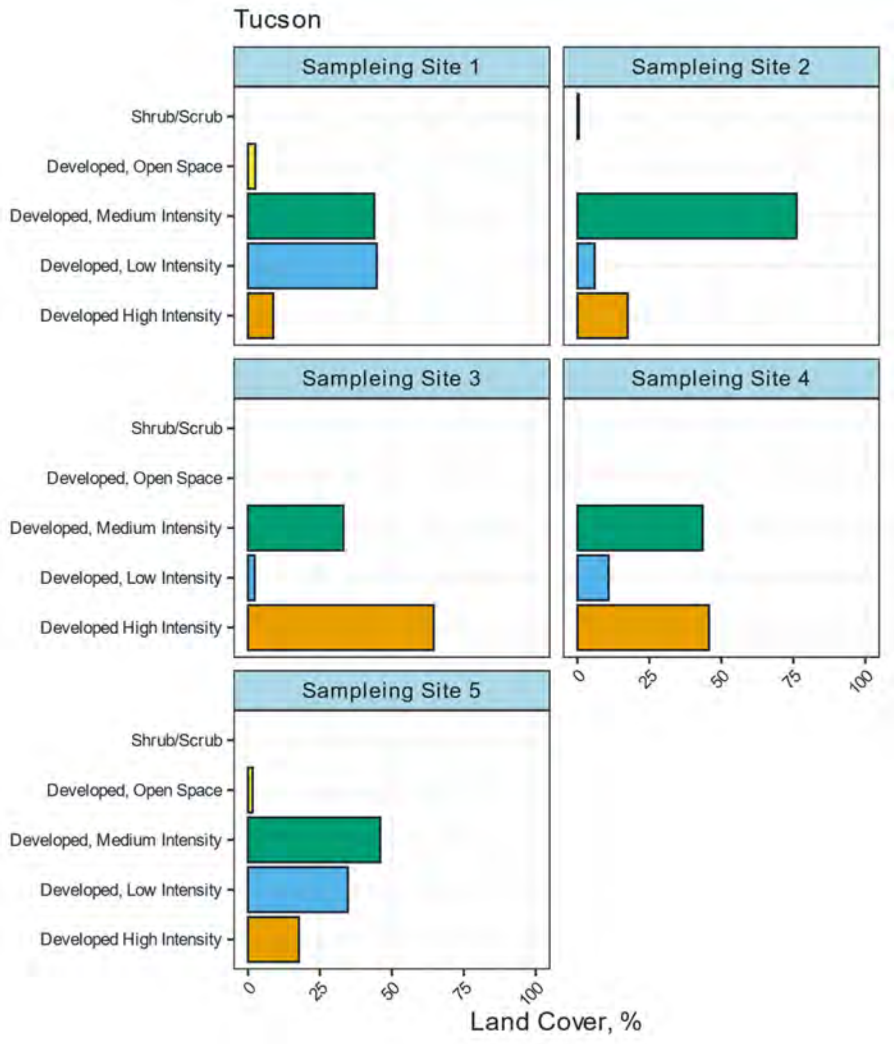



Glendale
ACDC10
ARROW
CITRUS
INDPK
OLIVE
Shrub/Scrub
Developed, Open Space
Developed, Medium Intensity
Developed, Low Intensity
Developed High Intensity
0
25
50
75
100
Land Cover, %


Mesa
54-EMF
AS-US60
SS-US50
UN-EMF
Shrub/Scrub
Developed, Open Space
Developed, Medium Intensity
Developed, Low Intensity
Developed High Intensity
0
25
50
75
100
Land Cover, %


Phoenix
AC033
IB008
SC046
SR003
SR030
SR045
SR049
Woody Wetlands
Shrub/Scrub
Grassland/Herbaceous
Developed, Open Space
Developed, Medium Intensity
Developed, Low Intensity
Developed High Intensity
Cultivated Crops
0
25
50
75
100
Land Cover, %


Tempe
KP-01
SR-05
SR-08
TD-01
TD-03
Shrub/Scrub
Open Water
Developed, Open Space
Developed, Medium Intensity
Developed, Low Intensity
Developed High Intensity
Cultivated Crops
0
25
50
75
100
Land Cover, %


Tucson
Sampleing Site 1
Sampleing Site 2
Sampleing Site 3
Sampleing Site 4
Sampleing Site 5
Shrub/Scrub
Developed, Open Space
Developed, Medium Intensity
Developed, Low Intensity
Developed High Intensity
0
25
50
75
100
Land Cover, %