Prepared in cooperation with the
U.S. Air Force Center for Engineering and the Environment–Restoration Program Management Office and the City of Tucson Water Department

# Results of the Analyses for 1,4-Dioxane of Groundwater Samples Collected in the Tucson Airport Remediation Project Area, South-Central Arizona, 2006-2009

Open-File Report 2009-1196

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

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

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KEN SALAZAR, Secretary

**U.S. Geological Survey**
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# Conversion Factors

Inch/Pound to SI

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| | Mass | |
| pound (lb) | 0.4536 | kilogram (kg) |
| | Pressure | |
| atmosphere, standard (atm) | 101.3 | kilopascal (kPa) |

SI to Inch/Pound

| Multiply | By | To obtain |
|---|---|---|
| | Volume | |
| liter (L) | 0.2642 | gallon (gal) |
| cubic meter ($m^3$) | 264.2 | gallon (gal) |
| | Mass | |
| gram (g) | 0.03527 | ounce, avoirdupois (oz) |

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F=(1.8×°C)+32
Vertical coordinate information is referenced to the insert datum name (and abbreviation) here for instance, "North American Vertical Datum of 1988 (NAVD 88)."
Horizontal coordinate information is referenced to the insert datum name (and abbreviation) here for instance, "North American Datum of 1983 (NAD 83)."
Altitude, as used in this report, refers to distance above the vertical datum.

# Results of the Analyses for 1,4-Dioxane of Groundwater Samples Collected in the Tucson Airport Remediation Project Area, South-Central Arizona, 2006-2009

By Fred D Tillman

## Abstract

Extensive groundwater contamination resulting from industrial activities led to the listing of the Tucson International Airport Area (TIAA) as a Superfund Site by the U.S. Environmental Protection Agency (USEPA) in 1983. Early investigations revealed elevated levels of volatile organic compounds (VOCs), including the chlorinated solvents trichloroethylene and perchloroethylene, in wells in the area. Several responsible parties were identified, and cleanup activities were initiated in the late 1980s using technology designed for removal of VOCs. In 2002, the compound 1,4-dioxane was discovered in wells in the TIAA area. Since then, 1,4-dioxane has been detected throughout the TIAA area at levels exceeding the USEPA Drinking Water Health Advisory value of 3 micrograms per liter (μg/L; U.S. Environmental Protection Agency, 2006). Chemical properties of 1,4-dioxane make it relatively unaffected by the treatment technologies employed in the TIAA area. In 2006, the U.S. Geological Survey (USGS) Arizona Water Science Center, in cooperation with the U.S. Air Force Center for Engineering and the Environment, began an investigation into the extent of groundwater contamination by 1,4-dioxane in the area. Five rounds of groundwater sampling in the TIAA area have been completed by the USGS since that time, yielding a total of 210 samples. Results from these analyses indicate less than reportable concentrations of 1,4-dioxane in 30 percent of the samples, with 46 percent of the samples having concentrations at or above the USEPA Drinking Water Health Advisory level.

## Introduction

Concerns over the quality of groundwater in southwest Tucson (fig.1) date back to the 1950s, when water from a municipal well was found to contain elevated concentrations of chromium (Graham and Monical, 1997). In 1981, the Arizona Department of Health Services (ADHS) and the U.S. Environmental Protection Agency (USEPA) identified organic contaminants including trichloroethylene (TCE) and perchloroethylene (PCE) in groundwater from the upper several hundred feet of the regional aquifer near the Tucson International Airport (TIA) (U.S. Environmental Protection Agency, 1988). Several potential sources were located near the TIA and adjacent industrial facilities. Improper disposal of liquid wastes going back to the early 1940s was determined to be the cause of the groundwater contamination (Graham and others, 2001). Natural groundwater gradients in the area trend in a northwesterly direction, transporting contaminated groundwater from source areas into residential communities in south Tucson (Leake and Hanson, 1987). Boundaries of the contaminated area were delineated in 1982 by USEPA, and the site was included on the National Priorities List in 1983. In 1987, a pump-and-treat facility began removing chlorinated solvents from groundwater at the Air Force Plant 44 location (AFP44) (fig. 1), reinjecting most of the treated water into the upper zone of the regional aquifer at the site (Graham and others, 2001). An additional water-treatment facility–Tucson Airport Remediation Project (TARP)–was completed in 1994 and began extracting groundwater from the northern portion of the plume of contaminated groundwater, using the treated water in the City of Tucson Water Department (Tucson Water) municipal supply system.

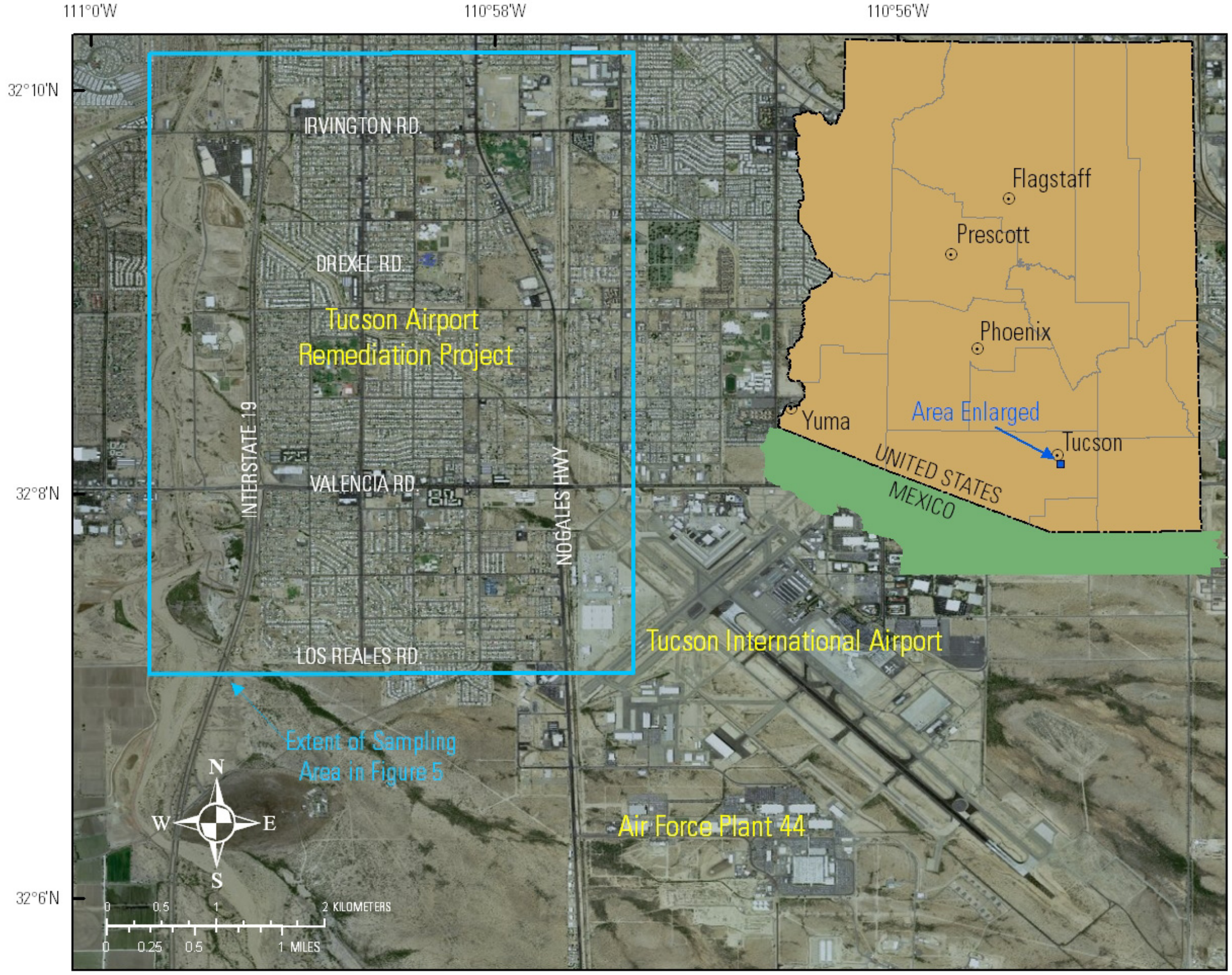


**Figure 1.** Study area showing general locations of the Tucson Airport Remediation Project, Tucson International Airport, and Air Force Plant 44.

In April 2002, the City of Tucson began analyzing samples from TARP groundwater extraction wells for 1,4-dioxane. That same year, 1,4-dioxane was discovered in influent and effluent groundwater at the AFP44 Groundwater Treatment Plant (AECOM, 2008). The 1,4-dioxane plume was ultimately found to extend more than 5 miles throughout the TARP area. USEPA issued an Administrative Order to the US Air Force in July 2007 under Section 1431 of the Safe Drinking Water Act, stating that 1,4-dioxane in the TIAA area posed an "imminent and substantial endangerment" to the public (U.S. Environmental Protection Agency, 2007). The Administrative Order required the installation of an advanced oxidation treatment system at AFP44 to remove 1,4-dioxane from water being recharged to the aquifer.

### 1,4-Dioxane

As recently as 1990, the total U.S. production volume of 1,4-dioxane was between 10,500,000 and 18,300,000 pounds, with as much as 90 percent of the compound used as a stabilizer for chlorinated solvents such as 1,1,1-trichloroethane (U.S. Environmental Protection Agency, 1995). USEPA has classified 1,4-dioxane as a "Probable Human Carcinogen"—the same classification given to TCE. Currently there are no Federal drinking water standards for 1,4-dioxane under the Safe Drinking Water Act. Groundwater cleanup guidelines vary by state and can range from 3 to 85 µg/L (U.S. Environmental Protection Agency, 2008). The City of Tucson has chosen the USEPA Office of Water Health Advisory value of 3 µg/L (U.S. Environmental Protection Agency, 2006) as the upper limit for water it will serve to the public and is using a blending strategy to dilute the 1,4-dioxane concentration in delivered water below this limit (U.S. Environmental Protection Agency, 2007). USEPA Region 9, covering the State of Arizona, has issued a Preliminary Remediation Goal (PRG) for 1,4-dioxane of 6.1 µg/L (U.S. Environmental Protection Agency, 2009).

Henry's Law Constant defines the ratio of a compound's saturated vapor pressure to its solubility in water. Larger values for Henry's Law Constant reflect a compound's affinity for air over water, while smaller values indicate an affinity for water over air. The low Henry's Law Constant for 1,4-dioxane, $6.92\times10^{-6}$ atm·m$^3$/mol compared to $9.09\times10^{-3}$ atm·m$^3$/mol for TCE (Montgomery, 2007), renders the traditional pump-and-treat air stripping technology for removing volatile organic compounds ineffective with 1,4-dioxane. The high solubility of 1,4-dioxane in water (miscible with water compared to 1,100 mg/L for TCE) and low sorption properties (log Koc of 0.54 versus 1.81 for TCE) (Montgomery, 2007) makes the transport of dissolved 1,4-dioxane in groundwater rapid in comparison to TCE.

### Purpose and Scope

In 2006, the USGS Arizona Water Science Center, in cooperation with the U.S. Air Force Aeronautical Systems Center and the City of Tucson Water Department, began sampling wells in the TARP Superfund area and analyzing the samples for 1,4-dioxane. Five sampling rounds have been completed by the USGS for a total of 210 samples. Sampled wells generally fall outside of known source areas and lie within the TARP area of the adjacent residential and commercial community (fig. 1). This report documents the 1,4-dioxane results from wells sampled in the area by USGS personnel.

### Acknowledgements

Rob Carruth, Hanna Coy, Kurt Schonauer, and Kimberly Beisner of the USGS assisted in sampling TARP wells during this project. The author would like to thank Joe Huerstel, Nagieb Mussa, Stephen Dean, and Michael Dew of the City of Tucson Water Department for their continued assistance in sampling wells in the TARP area.

## Methods

Sampling of TARP area wells by USGS personnel was performed during the summers of 2006 through 2009, with an additional spring round of sampling in 2008. This sampling was done to augment ongoing sampling in the area by Tucson Water. Tucson Water monitors all wells in the area for TCE and many wells for 1,4-dioxane. Four categories of wells were sampled: monitoring wells, supply wells, former supply wells, and one private well (table 1). Hydrologists from the USGS Arizona Water Science Center accompanied personnel from Tucson Water's Hydrology Division during their regular quarterly sampling of TARP monitoring wells and collected additional samples for 1,4-dioxane

**Table 1.** Well construction information for monitoring, supply, and private wells sampled in the TARP area.

[NWIS, National Water Information System]

| Well Name | NWIS Site Identification Number | Well Type | Depth to bottom of well (feet below land surface) | Depth to top of well opening (feet below land surface) | Depth to bottom of well opening (feet below land surface) |
|---|---|---|---|---|---|
| B-085 A | 321000110584901 | Supply | 520 | 93 | 500 |
| B-103 A | 320837110585001 | Former Supply | 522 | 65 | 522 |
| C-064 A | 320828110575201 | Former Supply | 189 | 75 | 165 |
| C-064 B | 320826110574801 | Former Supply | 900 | 107 | 900 |
| C-066 A | 320732110582601 | Former Supply | 743 | 68 | 388 |
| C-077 A | 320815110585201 | Former Supply | 150 | 57 | 150 |
| C-078 A | 320810110585001 | Former Supply | 229.6 | 31.8 | 229.6 |
| C-081 A | 320713110583101 | Former Supply | 518 | 79 | 298 |
| EPA 7 | 320750110574601 | Monitoring | 393 | 323 | 372 |
| EPA 10 | 320911110580601 | Monitoring | 235 | 166 | 214 |
| PK-010 A | 320837110584401 | Former Supply | 250 | 92 | 250 |
| PW-020 | 320755110583201 | Private | 140 | unknown | unknown |
| R-001 A | 320834110583301 | Supply | 160 | 105 | 145 |
| R-002 A | 320840110582701 | Supply | 155 | 110 | 150 |
| R-003 A | 320842110581901 | Supply | 165 | 115 | 150 |
| R-004 A | 320843110581301 | Supply | 170 | 125 | 160 |
| R-005 A | 320844110580801 | Supply | 150 | 100 | 140 |
| R-006 A | 320957110585101 | Supply | 415 | 175 | 395 |
| R-007 A | 320956110584901 | Supply | 415 | 175 | 395 |
| R-008 A | 320954110584201 | Supply | 415 | 155 | 395 |
| R-009 A | 320953110583501 | Supply | 415 | 175 | 395 |
| SS-001 A | 321003110592101 | Supply | 476 | unknown | unknown |
| SS-017 A | 320958110590201 | Supply | 255 | 41 | 250 |
| SS-021 A | 320921110592001 | Supply | 320 | 120 | 300 |
| SS-023 B | 320927110591001 | Supply | 420 | 260 | 400 |
| WR-055 B | 320803110572401 | Monitoring | 233 | 213 | 233 |
| WR-056 B | 320746110581101 | Monitoring | 178 | 158 | 178 |
| WR-056 C | 320746110581201 | Monitoring | 130 | 110 | 130 |
| WR-057 A | 320801110580201 | Monitoring | 160 | 130 | 160 |
| WR-058 A | 320835110580501 | Monitoring | 400 | 360 | 400 |

**Table 1.** Well construction information for monitoring, supply, and private wells sampled in the TARP area—Continued.

| Well Name | NWIS Site Identification Number | Well Type | Depth to bottom of well (feet below land surface) | Depth to top of well opening (feet below land surface) | Depth to bottom of well opening (feet below land surface) |
|---|---|---|---|---|---|
| WR-058 B | 320834110580401 | Monitoring | 144.5 | 124.5 | 144.5 |
| WR-059 A | 320846110583801 | Monitoring | 401 | 361 | 401 |
| WR-059 B | 320845110583801 | Monitoring | 141 | 121 | 141 |
| WR-075 S | 320708110573601 | Monitoring | 190 | 150 | 190 |
| WR-076 S | 320944110583901 | Monitoring | 400 | 300 | 400 |
| WR-077 S | 320737110581001 | Monitoring | 130 | 100 | 130 |
| WR-078 S | 320803110581701 | Monitoring | 160 | 110 | 160 |
| WR-079 S | 320723110581701 | Monitoring | 145 | 95 | 145 |
| WR-080 S | 320821110580701 | Monitoring | 150 | 100 | 150 |
| WR-081 S | 320819110583601 | Monitoring | 175 | 95 | 175 |
| WR-082 S | 320833110582701 | Monitoring | 158 | 108 | 158 |
| WR-084 S | 320858110580201 | Monitoring | 160 | 130 | 160 |
| WR-085 S | 320909110582101 | Monitoring | 190 | 110 | 190 |
| WR-086 S | 320728110580101 | Monitoring | 140 | 100 | 140 |
| WR-087 S | 320927110590001 | Monitoring | 240 | 140 | 240 |
| WR-089 S | 320933110583201 | Monitoring | 405 | 300 | 400 |
| WR-091 S | 320907110582801 | Monitoring | 175 | 125 | 175 |
| WR-163 A | 320902110583801 | Monitoring | 350 | 300 | 350 |
| WR-165 A | 320934110584701 | Monitoring | 350 | 300 | 350 |
| WR-236 A | 320946110591701 | Monitoring | 250 | 150 | 250 |
| WR-237 A | 320956110590101 | Monitoring | 400 | 150 | 400 |
| WR-238 A | 321000110585601 | Monitoring | 380 | 150 | 280 |
| WR-239 A | 320958110583301 | Monitoring | 400 | 150 | 400 |
| WR-240 A | 320940110582501 | Monitoring | 400 | 150 | 400 |
| WR-241 A | 320914110585201 | Monitoring | 402 | 152 | 402 |
| WR-700 A | 320851114582301 | Monitoring | 177 | 100 | 170 |

analysis. All monitoring wells were pumped for a minimum of five well-casing volumes prior to sample collection at the wellhead (figs. 2 and 3). Supply wells were sampled with personnel from Tucson Water's Water Quality Division. The pumps at these supply wells were running at the time of sample collection at the wellhead. Former supply wells in the study area were sampled using disposable polyethylene bailers (fig. 4). These wells were not purged prior to sample collection, and multiple bails were required to fill larger volume sample bottles. Samples were generally collected from these wells at a depth within the reported screened interval of the wells (table 2). Water from a private well in the area was sampled from a wall tap closest to the well location. Neither the well nor the water line were purged prior to sample collection. All samples were packed on ice in the field, refrigerated at < 5 °C, and shipped on ice to the contract laboratory before the expiration of sample holding times. Raw groundwater samples were collected directly into sample bottles; therefore, no equipment blanks were collected or analyzed during sampling rounds.


**Figure 2.** Purging of a TARP-area monitoring well by City of Tucson Water Department personnel prior to groundwater sample collection.

**Figure 3.** Groundwater sample being collected at monitoring-well head by U.S. Geological Survey employee.


**Figure 4.** Sample bottles being filled by U.S. Geological Survey employee with groundwater sample taken from a former supply well by a polyethylene bailer.

**Table 2.** Depth sampled by bailer in feet below land surface for former supply wells for sampling periods indicated.

| Well Name | 2006 | 2007 | Spring 2008 | Summer 2008 | 2009 |
|---|---|---|---|---|---|
| B-103 A | 155 | 180 | 150 | 150 | 150 |
| C-064 A | not sampled | 114 | 120 | 120 | 120 |
| C-064 B | not sampled | 118 | 120 | 120 | 120 |
| C-066 A | not sampled | 84 | 100 | 100 | 100 |
| C-077 A | 90 | 75 | 75 | 75 | 75 |
| C-078 A | 175 | 170 | 170 | 170 | 170 |
| C-081 A | 275 | 99 | 185 | not sampled | 185 |
| PK-010 A | 155 | 188 | 190 | 190 | 190 |

Two contract laboratories were used for sample analyses during this project. TestAmerica in Phoenix, Arizona, performed all of the 2006 and 2007 sample analyses. TestAmerica is certified by the National Environmental Laboratory Accreditation Program (NELAP # 01109CA) and ADHS (DHS#AZ0426). TestAmerica used USEPA Method 5030B/8260B for 1,4-dioxane quantification, requiring 40-mL sample volumes in clear glass vials preserved with 1:1 hydrochloric acid. The analytical method and procedures used by TestAmerica resulted in a method detection limit of 0.65 µg/L and a reporting limit of 1.0 µg/L. Weck Laboratories in City of Industry, California, was awarded the analysis contract for samples in 2008 and 2009. Weck Laboratories is certified by the National Environmental Laboratory Accreditation Program (NELAP # 04229CA) and the California Department of Public Health (ELAP#1132). Weck Laboratories was also certified for this project through the USGS Branch of Quality Systems Laboratory Evaluation Program (LEP) in both 2008 and 2009. Three blind Performance Test Samples (PTS) were sent along with field samples as part of the LEP program. Analyses of the PTS samples resulted in standard errors ranging from 8 to 22 percent. Weck Laboratories used USEPA Method 8270M, requiring 1 L unpreserved samples in amber glass bottles. The analytical method and procedures used by Weck Laboratories resulted in a method detection limit of 0.13 µg/L and a reporting limit of 0.5 µg/L.

## Results

Samples were collected from 56 different wells in the TARP area by USGS personnel from 2006 to 2009 for a total of 210 samples, including replicates (table 3, fig. 5). During the 2006 sampling round, samples were collected from 34 wells. Concentrations ranged from less than reporting limits (<1.0 µg/L for this time period) in 10 wells to a maximum of 11 µg/L in 2 wells. There were 19 wells with concentrations at or above USEPA Drinking Water Health Advisory value of 3 µg/L, with 14 wells at or above the USEPA Region 9 PRG of 6.1 µg/L.

Of the 45 wells sampled in 2007, 15 had concentrations less than reporting limits (<1.0 µg/L for TestAmerica). A maximum concentration of 16 µg/L was found in monitoring well WR-075 S in the southeast corner of the study area (fig. 5). This well was not sampled during the 2006 sampling round. Two wells with the 2006 maximum concentration of 11 µg/L either remained the same (WR-056 B) or declined to 8.5 µg/L (WR-057 A) in 2007. There were 22 wells at or above the USEPA Drinking Water Health Advisory value of 3 µg/L, with 16 wells at or above the USEPA Region 9 PRG of 6.1 µg/L.

**Table 3.** Analytical results for 1,4-dioxane analyses from wells sampled in the TARP area, 2006-2009.

[μg/L, micrograms per liter; multiple results on same sample date indicate replicate analyses]

| Well Name | 2006 | | 2007 | | 2008 | | | | 2009 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sample Date | 1,4-Dioxane (μg/L) | Sample Date | 1,4-Dioxane (μg/L) | Sample Date | 1,4-Dioxane (μg/L) | Sample Date | 1,4-Dioxane (μg/L) | Sample Date | 1,4-Dioxane (μg/L) |
| B-085 A | not sampled | | not sampled | | not sampled | | 08/25/2008 | <0.5 | not sampled | |
| B-103 A | 09/18/2006 | <1.0 | 08/14/2007 | <1.0 | 05/15/2008 | <0.5 | 08/29/2008 | <0.5 | 07/28/2009 | <0.5 |
| C-064 A | not sampled | | 08/15/2007 | 1.7 | 05/15/2008 | 1.7 | 08/29/2008 | 1.4 | 07/28/2009 | 1.5 |
| C-064 B | not sampled | | 08/15/2007 | 1.6 | 05/15/2008 | 1.7 | 08/29/2008 | 1.5 | 07/28/2009 | 2.0 |
| C-066 A | not sampled | | 08/15/2007 | 4 | 05/15/2008 | 3.6 | 08/29/2008 | 2.7 | 07/28/2009 | 1.9 |
| C-077 A | 09/18/2006 | <1.0 | 08/14/2007 | <1.0 | 05/15/2008 | 0.77 | 08/29/2008 | <0.5 | 07/28/2009 | 0.53 |
| C-078 A | 09/18/2006 | <1.0 | 08/14/2007 | <1.0 | 05/15/2008 | 0.61 | 08/29/2008 | 0.52 | 07/28/2009 | 0.58 |
| C-081 A | 09/18/2006 | <1.0 | 08/15/2007 | <1.0 | 05/15/2008 | <0.5 | not sampled | | 07/28/2009 | <0.5 |
| EPA 7 | 08/17/2006 | 5.8 | 08/09/2007 | 4.8 | not sampled | | not sampled | | not sampled | |
| EPA 10 | not sampled | | 08/06/2007 | <1.0 | 01/30/2008 | 0.76 | not sampled | | 08/05/2009 | 0.63, <0.5 |
| PK-010 A | 09/18/2006 | 2 | 08/14/2007 | 1.9 | 05/15/2008 | 1.8 | 08/29/2008 | 1.5 | 07/28/2009 | 1.6 |
| PW-020 | 09/11/2006 | 6.8 | 08/7/2007 | 5.3 | 02/20/2008 | 4.3 | 08/29/2008 | 3.8, 3.8 | 08/10/2009 | 3.0 |
| R-001 A | 08/09/2006 | 7.8 | 08/14/2007 | 6.2 | 02/19/2008 | 7.1 | 08/25/2008 | 7.4 | 08/10/2009 | 6.4 |
| R-002 A | 08/09/2006 | 8.6 | 08/14/2007 | 7.3 | 02/19/2008 | 7.7 | 08/25/2008 | 8.2 | 08/10/2009 | 6.6 |
| R-003 A | not sampled | | not sampled | | not sampled | | 08/25/2008 | 9.3 | 08/10/2009 | 7.5 |
| R-004 A | not sampled | | not sampled | | not sampled | | 08/25/2008 | 8.1, 8.3 | 08/10/2009 | 7.1 |
| R-005 A | not sampled | | not sampled | | 02/19/2008 | 6.7 | 08/25/2008 | 7.4 | not sampled | |
| R-006 A | not sampled | | not sampled | | not sampled | | 08/25/2008 | <0.5, <0.5 | not sampled | |
| R-007 A | not sampled | | not sampled | | not sampled | | 08/25/2008 | 1.5 | not sampled | |
| R-008 A | not sampled | | not sampled | | not sampled | | 08/25/2008 | <0.5 | not sampled | |
| R-009 A | not sampled | | not sampled | | not sampled | | 08/25/2008 | 0.58 | not sampled | |
| SS-001 A | not sampled | | not sampled | | not sampled | | 08/26/2008 | <0.5 | not sampled | |

**Table 3.** Analytical results for 1,4-dioxane analyses from wells sampled in the TARP area, 2006-2009—Continued.

| | 2006 | | 2007 | | 2008 | | | | 2009 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Well Name | Sample Date | 1,4-Dioxane (μg/L) | Sample Date | 1,4-Dioxane (μg/L) | Sample Date | 1,4-Dioxane (μg/L) | Sample Date | 1,4-Dioxane (μg/L) | Sample Date | 1,4-Dioxane (μg/L) |
| SS-017 A | not sampled | | not sampled | | not sampled | | 08/26/2008 | <0.5 | not sampled | |
| SS-021 A | 08/08/2006 | <1.0 | 08/14/2007 | <1.0 | 02/20/2008 | <0.5 | 08/26/2008 | <0.5 | not sampled | |
| SS-023 B | 08/08/2006 | <1.0 | 08/14/2007 | <1.0 | 02/20/2008 | <0.5 | 08/26/2008 | <0.5 | not sampled | |
| WR-055 B | 08/15/2006 | <1.0 | 08/14/2007 | <1.0 | 02/22/2008 | <0.5 | not sampled | | 08/10/2009 | <0.5 |
| WR-056 B | 08/22/2006 | 11 | 08/09/2007 | 11 | 02/22/2008 | 8.3 | not sampled | | 08/05/2009 | 7.6 |
| WR-056 C | not sampled | | 08/09/2007 | 9.4 | not sampled | | 08/26/2008 | 8.6, 8.6 | 08/05/2009 | 7.6 |
| WR-057 A | 08/15/2006 | 11 | 08/07/2007 | 8.5 | 01/31/2008 | 9.6 | not sampled | | 08/03/2009 | 8.3 |
| WR-058 A | 08/14/2006 | <1.0 | 08/14/2007 | <1.0 | 01/31/2008 | <0.5 | not sampled | | 08/10/2009 | <0.5, <0.5 |
| WR-058 B | 08/14/2006 | 7.6 | 08/28/2007 | 6.5 | 01/31/2008 | 8.2 | not sampled | | 08/05/2009 | 6.7 |
| WR-059 A | 08/14/2006 | <1.0 | 08/14/2007 | <1.0 | not sampled | | 08/26/2008 | <0.5 | 08/10/2009 | <0.5 |
| WR-059 B | 08/14/2006 | 8.5 | 08/07/2007 | 7.6 | 02/27/2008 | 7.8 | not sampled | | 08/05/2009 | 7.0 |
| WR-075 S | not sampled | | 08/08/2007 | 16 | 02/21/2008 | 7.5 | not sampled | | 08/05/2009 | 16 |
| WR-076 S | not sampled | | 08/08/2007 | 1.1 | 02/27/2008 | 1.2 | 08/04/2008 | 0.84 | 08/03/2009 | 1.3 |
| WR-077 S | 08/23/2006 | 9.3 | 08/09/2007 | 8.9 | 02/22/2008 | 8.6 | not sampled | | 08/06/2009 | 7.3 |
| WR-078 S | 08/15/2006 | 9.6 | 08/09/2007 | 8.6 | not sampled | | 08/26/2008 | 9.8, 10 | 08/06/2009 | 9.0 |
| WR-079 S | 08/17/2006 | 6.9 | 08/06/2007 | 6.2 | 02/22/2008 | 4.8 | not sampled | | 08/10/2009 | 3.3 |
| WR-080 S | 08/14/2006 | 7.4 | 08/07/2007 | 6.2 | 01/31/2008 | 6.8 | 08/06/2008 | 5.5 | 08/03/2009 | 6.2 |
| WR-081 S | 08/14/2006 | 5 | 08/07/2007 | 5.3 | 02/25/2008 | 5.8 | not sampled | | 08/10/2009 | 4.1 |
| WR-082 S | 08/15/2006 | 9 | 08/28/2007 | 7.2 | 02/27/2008 | 8.8 | not sampled | | 08/03/2009 | 7.2 |
| WR-084 S | 08/17/2006 | <1.0 | 08/13/2007 | <1.0 | 02/28/2008 | <0.5 | 08/06/2008 | <0.5 | 08/04/2009 | <0.5 |
| WR-085 S | 08/22/2006 | 7.6 | 08/06/2007 | 7.2 | 01/30/2008 | 8.1 | not sampled | | 08/03/2009 | 7.0 |
| WR-086 S | 08/23/2006 | 8.6 | 08/08/2007 | 9.3 | 02/21/2008 | 7.8 | not sampled | | 08/06/2009 | 7.7 |
| WR-087 S | 08/22/2006 | 1.4 | 08/08/2007 | 2.6 | 02/27/2008 | 1.9 | 08/04/2008 | 1.5 | 08/06/2009 | 1.7, 1.7 |

**Table 3.** Analytical results for 1,4-dioxane analyses from wells sampled in the TARP area, 2006-2009—Continued.

| | 2006 | | 2007 | | 2008 | | | | 2009 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Well Name** | **Sample Date** | **1,4-Dioxane (µg/L)** | **Sample Date** | **1,4-Dioxane (µg/L)** | **Sample Date** | **1,4-Dioxane (µg/L)** | **Sample Date** | **1,4-Dioxane (µg/L)** | **Sample Date** | **1,4-Dioxane (µg/L)** |
| WR-089 S | 08/23/2006 | 1 | 08/06/2007 | 2.1 | 01/30/2008 | 2.1 | not sampled | | 08/06/2009 | 2.6 |
| WR-091 S | 08/17/2006 | 4.8 | 08/13/2007 | 4.6 | 02/28/2008 | 5.1 | not sampled | | 08/04/2009 | 4.1 |
| WR-163 A | 08/23/2006 | 3 | 08/06/2007 | 2.7 | 01/30/2008 | 2.5 | 08/05/2008 | 2.0 | 08/03/2009 | 2.0 |
| WR-165 A | 08/23/2006 | 4.9 | 08/08/2007 | 6.1 | 02/27/2008 | 5.9 | not sampled | | 08/03/2009 | 5.6 |
| WR-236 A | not sampled | | 08/28/2007 | <1.0 | 02/25/2008 | 1.5 | not sampled | | 05/28/2009<br>08/10/2009 | <0.5, <0.5<br><0.5 |
| WR-237 A | not sampled | | 08/13/2007 | <1.0 | 02/25/2008 | <0.5 | 08/07/2008 | <0.5 | 08/04/2009 | <0.5 |
| WR-238 A | not sampled | | 08/13/2007 | <1.0 | 02/25/2008 | <0.5 | 08/07/2008 | <0.5 | 08/04/2009 | <0.5 |
| WR-239 A | not sampled | | 08/13/2007 | <1.0 | 02/25/2008 | <0.5 | 08/07/2008 | <0.5 | 08/04/2009 | <0.5 |
| WR-240 A | 08/23/2006 | 1.7 | 08/06/2007 | 2.8 | not sampled | | 08/04/2008 | 2.8 | 08/06/2009 | 3.0 |
| WR-241 A | 08/22/2006 | 2.9 | 08/08/2007 | 3.4 | 02/21/2008 | 2.3 | 08/04/2008 | 1.9 | 08/06/2009 | 1.7 |
| WR-700 A | not sampled | | not sampled | | not sampled | | not sampled | | 08/04/2009 | 6.0 |

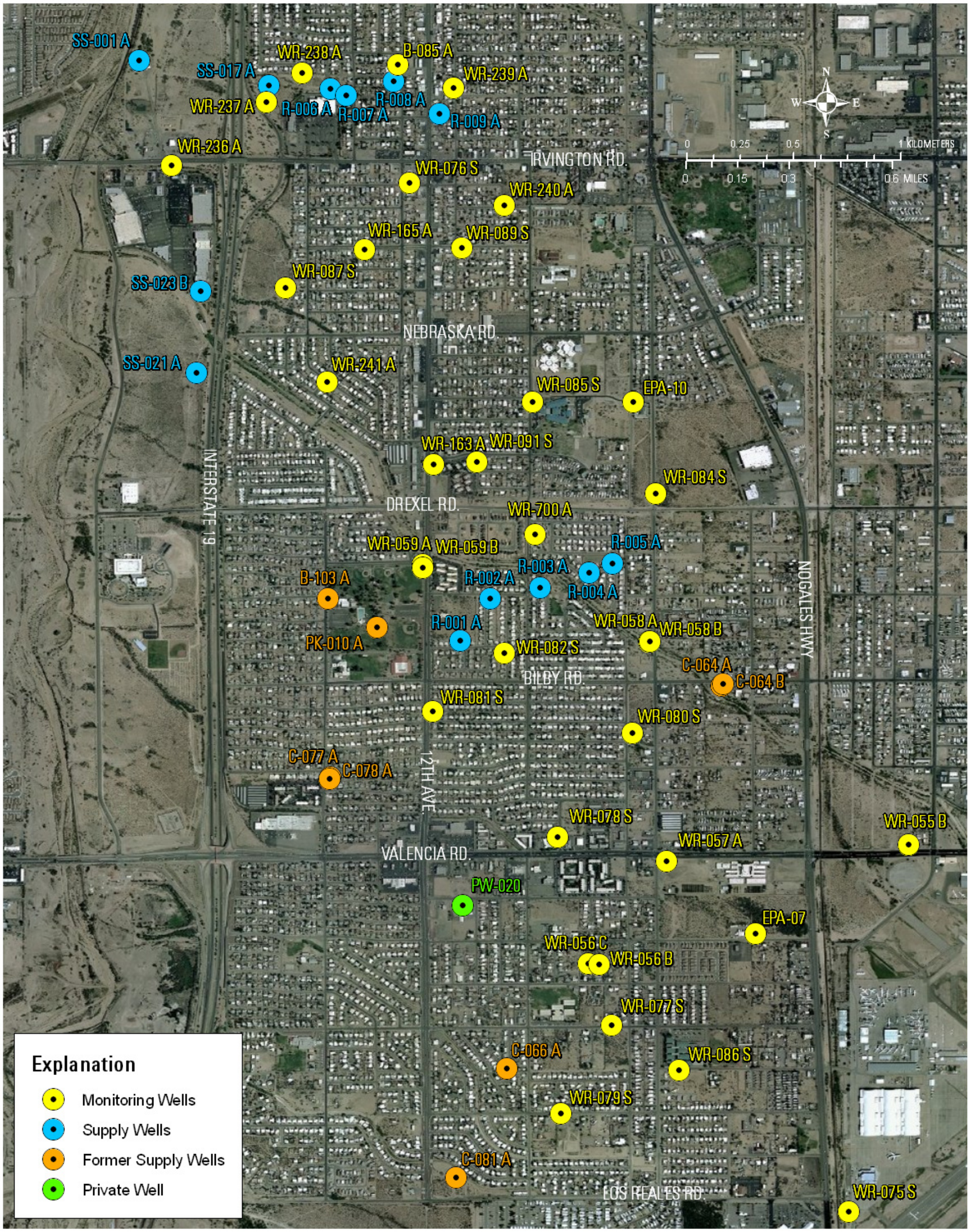


**Figure 5.** Location and type of wells sampled for 1,4-dioxane by U.S. Geological Survey personnel in the Tucson Airport Remediation Project area. See figure 1 for location.

In 2008, two sampling rounds occurred, with 41 wells sampled in the spring and 35 wells sampled in late summer. Of the 41 samples collected in the spring of 2008, 10 were below reporting limits (<0.5 µg/L for Weck Laboratories) and the maximum concentration of 9.6 µg/L was reported in WR-057 A—a well with one of the higher reported concentrations in both 2006 and 2007. The 2007 high concentration of 16 µg/L in monitoring well WR-075 S decreased to 7.5 µg/L in 2008. Nineteen of the spring 2008 wells had concentrations at or above the USEPA Drinking Water Health Advisory value of 3 µg/L, with 13 wells having concentrations at or above the USEPA Region 9 PRG of 6.1 µg/L. Summer 2008 sampling identified 13 wells with less than reporting limit concentrations (<0.5 µg/L for Weck Laboratories), with a maximum concentration of 9.8 µg/L (with a replicate concentration of 10 µg/L) in monitoring well WR-078 S (WR-057 A was not sampled). Nine wells had concentrations at or above the USEPA Drinking Water Health Advisory value of 3 µg/L, with 7 wells at or above the USEPA Region 9 PRG of 6.1 µg/L. Replicate samples from five wells were all within a relative percent difference of 2.5 percent of the original sample concentration.

Samples were collected from 45 wells in 2009, including newly installed monitoring well WR-700 A. Of the 45 wells sampled, 10 had concentrations less than reporting limits (<0.5 µg/L for Weck Laboratories), 23 were at or above the USEPA Drinking Water Health Advisory value of 3 µg/L, and 16 wells had concentrations at or above the USEPA Region 9 PRG of 6.1 µg/L. The maximum concentration for wells in 2009 was 16 µg/L and was found in WR-075 S where the same maximum concentration was detected in 2007. Three of four replicate samples in 2009 produced identical results as the original sample, with the fourth replicate and original samples reported as 0.63 µg/L and <0.5 µg/L, respectively.

Although the wells sampled were screened over differing depths and aquifer units, the overall trend in observed 1,4-dioxane concentrations is from higher values in the southeast part of the TARP area to lower concentrations towards the northwest. This trend follows the general direction of groundwater flow in the area. Higher concentrations are noted along the central axis of this southeast-northwest trend, with lower concentrations generally along the margins. Concentrations in supply wells sampled from the northern part of the study area were low, ranging from less than reporting values to a high of 1.5 µg/L in R-007 A. Higher concentrations were found in supply wells in the central portion of the study area, with concentrations ranging from 6.2 to 9.3 µg/L in sampled wells. Concentrations in former supply wells were low, ranging from less than reporting values to a high of 4 µg/L in well C-066 A. Although significant mass of dissolved 1,4-dioxane is not likely to volatilize out of water under natural conditions, results from bailed former supply wells should be viewed as indicative only of the concentration of 1,4-dioxane in the borehole water at the sampling depth at the time of sampling, and not necessarily representative of the surrounding aquifer or comparable to pumped-well samples.

## Summary

In order to assist in investigating the extent of groundwater contamination in the TARP area, 210 samples from 56 individual wells were collected by USGS personnel and analyzed for 1,4-dioxane from 2006 through 2009. Nearly one-third of these samples were determined to contain 1,4-dioxane concentrations below reporting limits. Maximum concentrations for all sampling rounds for each well indicate 28 wells with concentrations at or above the USEPA Drinking Water Health Advisory value of 3 µg/L and 20 wells at or above the USEPA Region 9 PRG of 6.1 µg/L. Of the 20 wells at or above the PRG, 5 are City of Tucson production wells used for municipal water supply and 1 is a private well serving a church in the area.

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