

# **PART III, ATTACHMENT 5**

## **GROUNDWATER CHARACTERIZATION AND MONITORING**

**Temple Recycling & Disposal Facility**

**Temple, Bell County, Texas**

**TCEQ Permit MSW-692B**

**Owner/Site Operator/Permittee:**



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Temple, Texas 76501**

**Operator:**



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**INTENDED FOR PERMITTING  
PURPOSES ONLY**

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## **1.0 INTRODUCTION**

This document is the Groundwater Characterization and Monitoring Report for the Permit Amendment Application for the expansion of the Temple Recycling and Disposal Facility ("facility" or "site"), Municipal Solid Waste Permit No. MSW-692B and has been prepared in accordance with 30 Texas Administrative Code (TAC) §§330.63(f) and 330.403. The Temple Recycling and Disposal Facility is an existing 269 acre Type I permitted municipal solid waste facility owned by the City of Temple, Texas ("City") under Permit No. MSW-692A. The Temple Recycling and Disposal Facility is located at 706 Landfill Road, approximately 0.25 miles east of the intersection of Loop 363 and Little Flock Road in Bell County, Texas. The site location is shown on Figure III-5-1. By way of this application, the City of Temple proposes to add 191 acres and remove 17 acres from the permitted area of the facility, for a total permitted area of 443 acres.

This report summarizes available data related to the occurrence and distribution of groundwater in the area of the proposed site expansion, and establishes a groundwater monitoring system design and a groundwater sampling and analysis plan.

## 2.0 SITE HYDROGEOLOGY

To ensure a conservative approach to groundwater monitoring at the facility, and to ensure the detection of any contaminants that may be released, the facility has historically monitored the groundwater present at and above the interface of the Stratum II and Stratum III material. In this application, the facility proposes to continue monitoring groundwater in the saturated zone at and above the Stratum II/III interface. This section defines the uppermost aquifer and aquiclude units at the site and describes site hydrogeology.

30 TAC §330.3(8) defines an “aquifer” as “[a] geological formation, group of formations, or portion of a formation capable of yielding significant quantities of groundwater to wells or springs.” 30 TAC §330.3(168) defines the “uppermost aquifer” as “[t]he geologic formation nearest the natural ground surface that is an aquifer; includes lower aquifers that are hydraulically interconnected with this aquifer within the facility’s property boundary.”

Site groundwater conditions have been described previously by Rust (1994) and Tetra Tech (2010) in support of earlier permitting efforts. These studies were used as the basis for determining the “uppermost aquifer” and underlying confining unit (aquiclude). The following conclusions on the site hydrogeology are based on the literature and site hydrologic observations.

As described in Attachment III-4, Geology Report, the site sits on an outcrop of the Taylor Marl. The uppermost unit consists of residual clays (Stratum I) resulting from complete weathering of the Taylor Marl. Below the residual clays lies a weathered to highly weathered claystone (Stratum II), followed by an unweathered claystone (Stratum III). The saturated portion of the weathered claystone (Stratum II) represents the “uppermost aquifer” and the unweathered claystone (Stratum III) represents the underlying confining unit (aquiclude). The hydraulic conductivity of the unweathered Stratum III is approximately  $5 \times 10^{-10}$  cm/s (Rust, 1990). The Stratum II/III interface identifies the upper extent of the confining unit as described in Attachment III-4, Geology Report. Figure III-5-2 presents the approximate location of the Stratum II/III interface in relation to the proposed expansion area. Each of the facility’s proposed and current groundwater monitoring wells are screened at or near the interface pursuant to the requirements of 30 TAC §330.403(a).

Underlying the Taylor Group is the Austin Chalk, which consists of massive beds of chalk and marl with bentonitic seams, glauconite, and pyrite nodules (Brune and Duffin 1983). The Taylor Group is approximately 200 feet thick and the Austin Chalk is approximately 200 feet thick underlying the site. Below the Austin Chalk are the Eagle Ford Group, Buda Limestone, and Del Rio Clay, which have a combined thickness of approximately 150 feet. Underlying those units are the Edwards and associated limestones, which may extend beneath the site at a depth of approximately 1,000 feet. The northern extent of the Edwards Aquifer pinches out southwest of Temple and extends only to the Lampasas River in southern Bell County and does not extend beneath the site.

The next nearest geologic formation that would constitute an aquifer is the Trinity Aquifer. Generally groundwater is fresh, but total dissolved solids in the Trinity Aquifer increase from less than 1,000 milligrams per liter (mg/L), which is considered slightly saline, in the east and southeast, to between 1,000 and 5,000 mg/L, considered moderately saline, as the depth to the aquifer increases in the downdip portions of the aquifer. Sulfate and chloride concentrations also tend to increase with depth (Ridgeway and Petrini 1999). As discussed in Attachment III-4, the Trinity Aquifer is approximately 1,400 feet below the deepest excavation of the facility. Accordingly, per 30 TAC §330.63(e)(4)(B), the facility is not required to identify or characterize the Trinity Aquifer through soil borings. In its response to comments on the 2006 revisions to the agency's municipal solid waste rules in 30 TAC Chapter 330, Texas Commission on Environmental Quality (TCEQ) explained that "[i]f an aquifer is not required to be identified or characterized by commission rules, the commission believes it is clear that monitoring of the aquifer is not required." 31 Tex. Reg. 2502, 2575 (Mar. 24, 2006).

Furthermore, based on available drillers' logs, the two nearest public water supply wells (40-62-501 Acres WSC located approximately 1.75 miles to the southwest, and 40-62-401 VA Hospital located approximately 2 miles west) are completed in the Hosston member of the lower Trinity at depths of over 2,200 feet below ground surface (bgs). Drillers' logs indicate shale and limestone are present down to approximately 1,900 feet (bgs). The extent of the Edwards and Trinity Aquifers in Bell County is depicted on Figure III-5-3.

## **2.1 Hydraulic Characteristics**

Hydraulic properties of the uppermost aquifer on the western portion of the site are as follows:

- Average linear velocity: 0.08 ft/yr ( $7.33 \times 10^{-8}$  cm/s)
- Average horizontal hydraulic conductivity ( $K_H$ ):  $2.2 \times 10^{-7}$  cm/s
  - Calculated as the geometric mean of multiple slug tests (Rust 1994)
- Hydraulic conductivity of the unweathered Taylor Marl:  $5 \times 10^{-10}$  cm/s (Rust 1994)

Hydraulic properties of the uppermost aquifer on the eastern portion of the site are as follows:

- Average linear velocity: 0.08 ft/yr ( $7.57 \times 10^{-8}$  cm/s)
- Average horizontal hydraulic conductivity ( $K_H$ ):  $9.1 \times 10^{-7}$  cm/s
  - Calculated as the geometric mean of multiple slug tests

According to Texas Risk Reduction Program (TRRP) Groundwater Classification document TRRP-8, the above  $K_H$  values technically classify the uppermost aquifer (Stratum II) as a Saturated Soil ( $K_H < 10^{-5}$  cm/s). For purposes of permitting and engineering design, we are referring to Stratum II as the uppermost aquifer.

To characterize the horizontal hydraulic conductivity of the uppermost aquifer in the proposed expansion area, slug test were performed in select piezometers. These tests were conducted using the falling and rising head methods, whereby the water levels were displaced by introducing a “slug” into the water column and the fall of the water level measured over time (falling head test). The rise (following removal of the slug) in water level was also monitored with respect to time (rising head) by a pressure transducer. Raw data was analyzed by AqteSolv Pro® using the Bouwer and Rice (1976) method which is appropriate for unconfined aquifers. Table III-5-1 summarizes the results:

**Table III-5-1: Hydraulic Conductivity Values from Slug Tests**

Well ID	Stratum Tested	Screen Interval (ft-msl)	Round of Testing	Hydraulic Conductivity (cm/s)	
				Falling Head	Rising Head
GA-14	Stratum II	548.8 – 538.8	1	2.92 x 10 <sup>-6</sup>	1.55 x 10 <sup>-6</sup>
			2	1.46 x 10 <sup>-6</sup>	2.03 x 10 <sup>-6</sup>
GA-23	Stratum II	571.2 – 561.2	1	2.40 x 10 <sup>-7</sup>	1.37 x 10 <sup>-7</sup>
			2	9.33 x 10 <sup>-8</sup>	8.30 x 10 <sup>-8</sup>
GA-25	Stratum II	526.8 – 516.8	1	6.40 x 10 <sup>-6</sup>	3.01 x 10 <sup>-6</sup>
			2	2.21 x 10 <sup>-6</sup>	2.16 x 10 <sup>-6</sup>
Golder Geometric Mean (Eastern)				9.08 x10 <sup>-7</sup>	
Rust (1994) Geometric Mean (Western)				2.20 x 10 <sup>-7</sup>	

Note: ft-msl = feet above mean sea level

As shown in the table above, the recent Golder results are consistent with previously determined average horizontal hydraulic conductivities at the site. These values are consistent with clay materials (Fetter 1999). Furthermore, the previously documented hydraulic conductivity (Rust 1994) of the unweathered Taylor Marl (Stratum III) ( $5.0 \times 10^{-11}$  cm/s) is three orders of magnitude less than Stratum II, supporting that Stratum III serves as a confining layer.

Depth to groundwater at the site ranges from approximately 5 ft-bgs to 20 ft-bgs, depending on topography and season. The average hydraulic gradient in the western portion of the site as reported by Rust (1994) and as confirmed by Golder (2015) is 0.02 ft/ft. Golder calculated an average hydraulic gradient for the eastern portion of the site. In December 2014, March 2015, June 2015, October 2015, and May 2016, the gradient

on the eastern portion of the site is observed to flatten slightly, and the average hydraulic gradient potentiometric surface is approximately 0.005 ft/ft.

Hydraulic travel velocities were estimated for the saturated zones using the following formula:

$$V = (ki)/n_e$$

Where:

$V$  = travel velocity

$k$  = hydraulic conductivity of the aquifer

$i$  = hydraulic gradient (West = 0.02; East = 0.005)

$n_e$  = effective porosity (0.06)

Hydraulic properties of the uppermost aquifer on the western portion of the site are as follows:

- Average Linear Velocity: 0.08 ft/yr ( $7.33 \times 10^{-8}$  cm/s)
  - Calculated from: (  $2.20 \times 10^{-7} * 0.02$  ) / 0.06

Hydraulic properties of the uppermost aquifer on the eastern portion of the site are as follows:

- Average Linear Velocity: 0.08 ft/yr ( $7.57 \times 10^{-8}$  cm/s)
  - Calculated from (  $9.08 \times 10^{-7} * 0.005$  ) / 0.06



### **3.0 GROUNDWATER MONITORING SYSTEM**

This section presents information on the current and proposed groundwater monitoring programs.

#### **3.1 Existing Groundwater Monitoring System**

This facility is currently operating a groundwater monitoring program that was certified by a qualified groundwater scientist and approved by the TCEQ. The existing groundwater monitoring system consists of 19 groundwater monitoring wells, as shown on Figures III-5-5.1 through III-5-5.4. All existing monitoring wells are screened within the saturated zone at and above the Stratum II/III interface. These monitoring wells are sampled on a semiannual basis and are analyzed for the detection monitoring parameters listed in 30 TAC §330.419.

The original monitoring well network associated with the current facility included 2 upgradient sample points (MW-01 and MW-02) and 12 downgradient sample points (MW-03, MW-04, MW-05, MW-06, MW-07, MW-08, MW-09, MW-10, MW-11, MW-12, MW-13, and MW-14) installed at and above the Stratum II/III interface. These wells were installed in March through June 1996. In March 1998, MW-05 was plugged and abandoned and replaced with monitoring well MW-5R for construction of Tract 5B (later turned into a stormwater detention pond). In December 2010, the groundwater monitoring system was updated in accordance with rule changes in 30 TAC §330 Subchapter J, which resulted in the current monitoring well system. The December 2010 updates included the removal/plugging of three monitoring wells (MW-02, MW-11, and MW-14) and installation of eight new monitoring wells (MW-15, MW-16, MW-17, MW-18, MW-19, MW-20, MW-21, and MW-22).

As discussed in Section 6.2.1 of Attachment III-4, and below in Section 3.2.4 of this attachment, the local flow regime is radially outward from MW-01, mostly towards the east and southeast towards Little Elm Creek and Unnamed Tributary No. 1, a small tributary of Little Elm Creek. However, the flow direction begins to deviate in the eastern portion of the site as a result of the influence of the Stratum II/III interface. As presented on Figures III-5-5.1 through III-5-5.6, the groundwater flow direction begins to flow radially outward from the center of the expansion area, resulting from the topographic high in both the groundwater surface and the weathered/unweathered interface.

The 19 groundwater monitoring wells of the current program are screened at and above the Stratum II/III interface in the western and central portions of the site. One of these wells is located upgradient (MW-01) and 18 are located downgradient (MW-03, MW-04, MW-5R, MW-06, MW-07, MW-08, MW-09, MW-10, MW-12, MW-13, MW-15, MW-16, MW-17, MW-18, MW-19, MW-20, MW-21, and MW-22). These downgradient monitoring wells constitute the compliance monitoring network at the site. Table III-5-2 details the locations, ground elevation, and screened interval of the current monitoring well network.

**Table III-5-2: Current Groundwater Monitoring System**

Well ID	Northing	Easting	Ground Elevation	TOC	Depth of Screened Interval		Elevation of Screened Interval	
			ft-msl	ft-msl	ft-bgs		ft-msl	
					Top	Bottom	Top	Bottom
MW-01	525541.48	2946455.93	631.21	634.37	15.00	25.00	619.37	609.37
MW-03	523556.99	2946339.15	575.94	578.90	15.00	25.00	563.90	553.90
MW-04	523212.29	2946810.46	571.40	574.45	15.00	25.00	559.45	549.45
MW-5R	522887.45	2947423.35	570.60	573.92	12.00	22.00	561.92	551.92
MW-06	522944.89	2948020.33	568.37	571.47	25.00	35.00	546.47	536.47
MW-07	523438.52	2948815.15	572.49	574.97	25.00	35.00	549.97	539.97
MW-08	524148.50	2949348.22	589.73	597.71	28.00	38.00	569.71	559.71
MW-09	524723.53	2949559.73	585.70	588.83	20.00	30.00	568.83	558.83
MW-10	525310.06	2949734.40	578.32	581.19	19.00	29.00	562.19	552.19
MW-12	526659.39	2949344.99	559.54	562.59	10.00	20.00	552.59	542.59
MW-13	526676.48	2948737.91	571.61	574.59	18.00	28.00	556.59	546.59
MW-15	523080.62	2948482.24	568.40	571.00	24.00	34.00	547.00	537.00
MW-16	524003.95	2948989.50	587.40	591.40	26.00	36.00	565.40	555.40
MW-17	525901.88	2949877.27	571.20	574.40	27.00	37.00	547.38	537.38
MW-18	526377.79	2949582.43	570.20	573.90	19.00	29.00	554.94	544.94
MW-19	523042.05	2947199.15	573.50	576.40	22.00	32.00	554.44	544.44
MW-20	525818.50	2947750.00	622.10	623.50	29.00	39.00	594.52	584.52
MW-21	525971.25	2947213.46	616.60	619.30	28.00	38.00	591.30	581.30
MW-22	524040.29	2946044.59	593.00	594.80	29.50	39.50	565.29	555.29

## 3.2 Operational Concerns

### 3.2.1 Relationship of Excavation Bottom to Uppermost Aquifer

The elevation of the excavated base of the lined landfill cells of the Temple Landfill reportedly do not penetrate below the base of the uppermost aquifer, with the potential exception of the landfill in the vicinity of boring TE-2, which is located in the western portion of the site as shown on Figure III-4-11. A part of the east-central portion of the site is “pre-Subtitle D” vintage and consequently records of its construction are limited. Based on previous reporting, the elevation of the base of the “pre-Subtitle D” area is estimated at 570 ft-msl, which is above the Stratum II/III interface.

The excavation of the proposed expansion area is designed to be primarily within the weathered claystone. However, some limited portions may extend into the unweathered claystone (Stratum III), resulting from variable site geology. Figure III-5-4 presents the relationship between the Stratum II/III interface and the proposed elevation of the excavated base of the lined landfill cells.

### **3.2.2 Leachate Sump Design and Location**

The Temple Landfill containment system and excavation are designed to accommodate a Subtitle D Leachate Collection System (LCS). The base of the landfill will be lined with a composite liner (i.e., a geomembrane overlying compacted clay) and sloped to direct leachate flow to the sumps, where it is subsequently pumped out of the LCS. While a leak from the Subtitle D cell is unlikely, if one were to occur, it would most likely be at the lowest leachate collection points (i.e., the sumps). The sumps will be located near the Stratum II/III interface. As a result, the saturated zone at and above the Stratum II/III interface is included in the monitoring well network design. However, because of the low permeability and hydraulic conductivity of the unweathered claystone, migration rates will be extremely slow and thus monitoring the unweathered claystone below the Stratum II/III interface would not be necessary. Based on the sump locations, monitoring wells, and the radial direction of groundwater flow, each of the proposed monitoring wells will monitor the LCS sumps in the downgradient areas.

### **3.2.3 Critical Receptors**

Additional factors considered while designing the monitoring well network address downgradient critical receptors to groundwater flow. Critical receptors could include public drinking water wells, livestock wells, and surface water bodies used for drinking. A comprehensive water well search was conducted by Banks Environmental as a part of this permitting effort. The Banks study identified one water well record within 1 mile of the site and is reportedly screened in the Taylor formation at a depth of 57 feet bgs. Approximately 26 additional active water well records were identified from Clearwater Underground Water Conservation District (CUWCD) within approximately 1 mile of the site. Total depths of these water wells are listed between 15–57 feet; are reportedly screened in Alluvium, the Ozan formation (upper portion of Taylor), or Austin Chalk; and are used as domestic or livestock wells. Two of these well records were plotted within the permitted expansion boundary of the landfill. These wells were field located by CUWCD and Golder on July 9, 2015. The CUWCD did not have drilling report records pertaining to these two wells, but based on recollection of the previous owner, believe both to have been hand dug around the mid-1960s. Based on other well information in the area, these two wells are likely between 20 and 50 feet deep, unused, and will be proposed for plugging and abandonment prior to excavation for borrow or cell construction in the area. Based on the distance of remaining active wells from the site and the relatively low permeability of the lithology, these receptors are unlikely to be impacted by a release from the site. Furthermore, according to CUWCD district, East Bell Water Supply Corporation provides water for the area in the vicinity of the site, and public water supply lines are located along Little Flock Road, Bob White Road, and Highway 53.

Williamson Creek and Unnamed Tributary No. 1 of Little Elm Creek, considered critical receptors, are the closest surface water bodies to the site, with Williamson Creek being the closest. Current monitoring wells MW-12, MW-13, and MW-18 and proposed monitoring wells MW-23, MW-24, MW-25, and MW-26 will be between the landfill and Williamson Creek. Monitoring wells MW-5R, MW-6, and MW-15 and proposed

monitoring wells MW-33, MW-34, and MW-35 are located between the landfill and Unnamed Tributary No. 1 of Little Elm Creek.

### **3.2.4 Groundwater Flow**

The direction of groundwater flow is governed by the hydraulic gradient (from a higher to a lower groundwater elevation), which for this site is influenced by the elevation of the Stratum II/III interface, surface topography, and the low permeabilities of the subsurface soils. In some cases, groundwater flow is channeled through specific areas of the site due to the orientation of this interface. To aid in understanding groundwater flow at the site, seasonal potentiometric surfaces were created for December 2014, March 2015, June 2015, October 2015, December 2015, and May 2016 which may be found as Figures III-5-5.1, III-5-5.2, III-5-5.3, III-5-5.4, III-5-5.5, and III-5-5.6, respectively. As a result, groundwater wells placed in these areas can effectively monitor groundwater flow from large portions of the site and were also given high priority.

## **3.3 Proposed Groundwater Monitoring System**

The locations and depths of the monitoring wells are designed to determine the quality of groundwater passing the point of compliance and to ensure the detection of groundwater contamination in the saturated zone above the Stratum II/III interface (30 TAC §330.403(a)(2)). The potential pathways for contaminant movement, as discussed previously, are via groundwater in the saturated zone at and above the Stratum II/III interface.

### **3.3.1 Design Criteria**

Pursuant to §330.403(a) and (e)(1) “[A] groundwater monitoring system must be installed that consists of a sufficient number of monitoring wells, installed at appropriate locations and depths, to yield representative groundwater samples from the uppermost aquifer as defined in 330.3...” and “[t]he design of a monitoring system shall be based on site-specific technical information that must include a thorough characterization of: aquifer thickness; groundwater flow rate; groundwater flow direction, including seasonal and temporal fluctuations in flow; effect of site construction and operations on groundwater flow direction and rates; and thickness, stratigraphy, lithology, and hydraulic characteristics of saturated and unsaturated geologic units and fill materials overlying the uppermost aquifer, materials of the uppermost aquifer, and materials of the lower confining unit of the uppermost aquifer.”

The currently approved in-use monitoring well network at the site was designed and is in accordance with the above referenced applicable regulations. The current system monitors the saturated zone above the Stratum II/III interface within the Taylor Marl formation. Construction details of each of the existing monitoring wells may be found in Appendix III-5A. Where applicable, these criteria were evaluated for each of the wells proposed for the facility groundwater monitoring system.

The proposed modifications to the monitoring well system are designed in accordance with the above stated regulations. Furthermore, spacing between all downgradient wells adheres to the provisions in 30 TAC §330.403(a)(2) that monitoring well spacing does not exceed 600 feet as measured along the Point of Compliance (POC). Each of the monitoring wells is also spaced along the POC (less than 500 feet from the proposed Solid Waste Management Unit [SWMU] pursuant to 30 TAC §330.3(106)) and are located respective of the previously discussed operation concerns and potential downgradient critical receptors. The groundwater monitoring system is designed to monitor downgradient of each sump. In summary, to design a monitoring well system to comply with 30 TAC §330.403, the following criteria listed in Table III-5-3 were followed:

**Table III-5-3: Groundwater Monitoring System Design Criteria**

Criterion	Location of information in the Report
Identify and Characterize the Uppermost Aquifer	Section 2.0 – Site Hydrogeology
Establish Groundwater Flow Direction and Rate	Section 2.1 – Hydraulic Characteristics
Evaluate Potential Impacts of Operation Attributes of the Facility on Groundwater Flow	Section 3.2.1 – Relationship of Excavation Bottom to Uppermost Aquifer
	Section 3.2.2 – Leachate Sump Design
Determine Impacts of Critical Receptors	Section 3.2.3 – Critical Receptors
Determine the Appropriate Locations and Screened Intervals of Groundwater Monitoring Wells	Section 3.3.3 – Monitoring Well Locations
	Section 3.3.4 – Monitoring Well Construction

Furthermore, it is understood that the Stratum II/III interface exerts some structural controls over the direction of groundwater flow. To this end, the Stratum II/III interface topography has also been taken into account in the monitoring well network design. Fortunately, the comprehensiveness of the above mentioned regulations ensure the monitoring well network will take into account different controls exerted on the groundwater flow regime.

### **3.3.2 Contaminant Pathway Analysis**

In the unlikely event of a leachate release (i.e., failure of multiple engineered containment systems), contaminants would likely move along the constructed liner/natural soil interface or downward into the unsaturated portion of the Taylor Marl. However, due to the low permeability of the material (determined in Attachment 4 Section 5.3 Soil Properties) and penetration into the unweathered unit being limited, contaminants are likely to move horizontally. If the contaminants were to reach the groundwater, the miscible contaminants would be diluted by the groundwater and would move laterally towards the perimeter monitoring system. Movement in the unweathered claystone (Stratum III) is unlikely due to the low

permeability. Any penetration of the unweathered interface will be limited in the aerial extent and therefore would not be expected to affect the groundwater flow regime.

### 3.3.3 Monitoring Well Locations

The uppermost aquifer beneath the Temple Landfill has been identified as the weathered Taylor Marl claystone or Stratum II. Stratum II at the site consists of weathered claystone materials. Stratum II is present and correlateable across the entire site, as shown in the cross-sections in Attachment III-4. Groundwater occurs on the site at approximately 6 to 20 ft-bgs, depending on topography and season.

The proposed monitoring well system will require modifications be made to the current system; these modifications are summarized in Table III-5-4. Details of the overall proposed monitoring well system are summarized in Table III-5-5 and shown on Figure III-5-6.

The new groundwater monitoring system will consist of 27 monitoring wells: 1 upgradient and 26 downgradient. A total of 15 new monitoring wells will be installed. The 15 new wells will be installed along the south, east, and north perimeter of the proposed expansion area. Monitoring wells MW-17R, MW-23, MW-24, MW-25, and MW-26 will be installed along the northern permit boundary between the landfill and Williamson Creek (a critical receptor); monitoring wells MW-27, MW-28, MW-29, MW-30, and MW-31 will be installed along the eastern permit boundary between the landfill and Bob White Road; and monitoring wells MW15R, MW-32, MW-33, MW-34, and MW-35 will be installed along the southern permit boundary between the landfill and Unnamed Tributary No. 1 of Little Elm Creek (a critical receptor). Since the flow path of groundwater at the site is observed to be radially outward from MW-1 and towards the east, each of the wells are considered downgradient. Seven existing monitoring wells will be properly plugged and abandoned as a direct result of their location within the proposed waste footprint. These wells are MW-7, MW-8, MW-9, MW-10, MW-15, MW-16, and MW-17.

The removal of existing monitoring wells and installation of the new wells will be sequenced to coincide with the construction schedule of the new cells.

**Table III-5-4: Changes to Current Monitoring Well System**

Well ID	Status
MW-1	Incorporated into New System
MW-3	Incorporated into New System
MW-4	Incorporated into New System
MW-5R	Incorporated into New System
MW-6	Incorporated into New System
MW-7	To Be Removed (Plugged & Abandoned)

Well ID	Status
MW-8	To Be Removed (Plugged & Abandoned)
MW-9	To Be Removed (Plugged & Abandoned)
MW-10	To Be Removed (Plugged & Abandoned)
MW-12	Incorporated into New System
MW-13	Incorporated into New System
MW-15	To Be Removed (Plugged & Abandoned)
MW-16	To Be Removed (Plugged & Abandoned)
MW-17	To Be Removed (Plugged & Abandoned)
MW-18	Incorporated into New System
MW-19	Incorporated into New System
MW-20	Incorporated into New System
MW-21	Incorporated into New System
MW-22	Incorporated into New System

**Table III-5-5: Proposed Additions to Monitoring Well System & Anticipated Construction Details**

Well ID	Northing	Easting	Ground Elevation	Depth of Screened Interval		Elevation of Screened Interval	
			ft-msl	ft-bgs		ft-msl	
				Top	Bottom	Top	Bottom
MW-15R	522769.7	2948413.8	564	26	36	538	528
MW-17R	526165.8	2949911.9	566	23	33	543	533
MW-23	526009.1	2950301.8	554	34	44	520	510
MW-24	525765.3	2950788.3	556	26	36	530	520
MW-25	525465.7	2951301.2	561	25	35	536	526
MW-26	525204.5	2951834.7	551	19	29	532	522
MW-27	524614.6	2951764.7	565	27	37	538	528
MW-28	524059.9	2951552.3	581	39	49	542	532
MW-29	523505.9	2951338.0	583	43	53	540	530
MW-30	522951.1	2951125.6	582	43	53	539	529
MW-31	522396.3	2950913.5	567	37	47	530	520
MW-32	521984.0	2950558.1	555	25	35	530	520
MW-33	522229.9	2950017.8	556	26	36	530	520
MW-34	522476.0	2949477.1	555	21	31	534	524
MW-35	522722.0	2948936.7	559	24	34	535	525

### **3.3.4 Monitoring Well Construction**

In accordance with 30 TAC §330.421, a licensed Texas driller will install the additional monitoring wells. Wells will be drilled by a method that will not introduce contaminants into the borehole or casing. A licensed professional geoscientist or engineer who is familiar with the geology of the area will supervise monitoring well installation and development and will provide a log of the boring. Equivalent alternatives to commission rules may be used if prior written approval is obtained from the TCEQ Executive Director.

If any fluid is required to drill the monitoring wells, clean, treated potable water will be used and a chemical analysis will be provided to the TCEQ Executive Director. No glue or solvents will be used in monitoring well construction. Wells will be installed according to the typical well construction diagram (Figure III-5-7). After installation, monitoring wells will be developed to remove sediment and open the water-bearing zone for maximum flow until all water used or affected during drilling is removed and field measurements of pH, specific conductance, and temperature are stabilized. Upon completion of the monitoring well, a registered professional land surveyor will survey the well location and elevation.

Within 30 days of completion of a monitoring well or any other part of a monitoring system, an installation report will be submitted to TCEQ. The report will include construction and installation details for each well on forms available from the commission, a site map (drawn to scale showing the location of all monitoring wells and the relevant point[s] of compliance), well elevations (to the nearest 0.01 ft-msl), latitude and longitude or landfill grid location of each well, copies of detailed geologic logs (including soil sample data), and copies of drillers reports, as required by other agencies.

Damaged monitoring wells that are no longer usable will be reported to the TCEQ Executive Director for a determination whether to replace or repair the well. In accordance with 30 TAC §305.70, if a compromised well requires replacement, a permit modification request will be submitted within 45 days of the discovery.

Plugging and abandoning of monitoring wells will be performed in accordance with 16 TAC §702 and 76.1004. No abandonment will be performed without prior written authorization.

All parts of the groundwater monitoring system will be operated and maintained so that they perform at least to design specifications throughout the life of the groundwater monitoring program.

The site must notify the TCEQ Executive Director if changes in site construction or operation, or changes in adjacent property, affect or are likely to affect the direction and rate of groundwater flow and the potential for detecting groundwater contamination from the facility.



#### 4.0 GROUNDWATER MONITORING DATA

Groundwater at the facility has been sampled and analyzed since the first quarter of 1996. Groundwater at the facility is currently monitored by 19 groundwater monitoring wells. These include one upgradient monitoring well, MW-01, and 18 downgradient monitoring wells.

Analytical results reported from the well (MW-01) located hydraulically upgradient from the Temple Recycling and Disposal Facility waste disposal area should be representative of natural background conditions or baseline conditions not affected by the Temple Recycling and Disposal Facility Municipal Solid Waste Landfill (MSWLF) units. Tabulated historical groundwater quality results from the ongoing monitoring program are included in Attachment III-4, Appendix E. This appendix presents the results of all semiannual and applicable quarterly groundwater monitoring events since 1996. Verification resamples, if collected as part of the laboratory analytical verification process, are also included in the appendix. Based on information provided by WMTX, none of the facility's groundwater monitoring wells are currently or have previously been in assessment monitoring or corrective action.

The groundwater quality data have been compared to the groundwater protection standards for the constituents listed in Appendix I of 40 CFR Part 258 and 30 TAC §330.419. The groundwater protection standards in Table 1 of 30 TAC §330.331 have also been included for comparison to provide a conservative analysis of these data. Both sets of protection standards are shown in Table III-5-6 below. On occasion, maximum contamination levels (MCLs) listed in Table 1 of 30 TAC §330.331 are less than those defined by 40 CFR Part 141. If a federally mandated primary MCL exists for a constituent listed in either table, it was used for comparative purposes. Additionally, if the MCL concentrations conflict, the lower of the two values was used for comparison. Those constituents exceeding a groundwater protection standard are listed in Table III-5-7. (A constituent's MCL is referred to as a groundwater protection standard in 30 TAC §330.409(h).) Note: only constituents with historic detections in exceedence of their respective MCLs are listed in Table III-5-7.

**Table III-5-6: TCEQ Maximum Contaminant Levels (MCLs)**

<b>Chemical</b>	<b>30 TAC §330.331 Table 1 MCL (mg/L)</b>	<b>40 CFR Part 258, Appendix I Chemical (Constituents with primary MCL and listed in 40 CFR Part 258, Appendix I) MCL (mg/L)</b>
Antimony		0.006
Arsenic	0.05	0.010
Cadmium	0.01	0.002
Lead	0.05	0.006
Selenium	0.01	0.002
Thallium		0.05

**Table III-5-7: Historical Detections above the MCL of Appendix I Constituents**

Well	Constituent	Filtered	Result (µg/L)	MCL (µg/L)	Date of Detection
MW-02	Cadmium	Yes	5.4	5	3/26/1997
MW-02	Selenium	Yes	21.8 J	10	10/9/1998
MW-02	Thallium	Yes	38.1	2	12/19/1997
MW-03	Antimony	Yes	27.4	6	10/9/1998
MW-03	Antimony	Yes	9.8	6	12/5/1998
MW-03	Cadmium	Yes	5.4	5	3/26/1997
MW-04	Antimony	Yes	15.8	6	12/5/1998
MW-04	Cadmium	Yes	13.4	5	3/26/1997
MW-04	Selenium	Yes	10.9	10	12/6/1996
MW-04	Selenium	Yes	13.9	10	9/16/1996
MW-04	Selenium	Yes	24.5	10	6/27/1996
MW-05R	Antimony	Yes	7.2	6	10/9/1998
MW-05R	Arsenic	Yes	10.8	10	10/9/1998
MW-06	Selenium	Yes	46.8	10	10/9/1998
MW-06	Selenium	Yes	10.2	10	12/19/1997
MW-06	Selenium	Yes	17.1	10	12/6/1996
MW-06	Selenium	Yes	22	10	9/16/1996
MW-07	Antimony	Yes	30.3	6	12/8/1998
MW-07	Selenium	Yes	10.8	10	6/8/2001
MW-07	Selenium	Yes	12.2	10	6/4/1998
MW-08	Antimony	Yes	54.2	6	12/8/1998
MW-08	Arsenic	No	11	10	12/18/2013
MW-08	Arsenic	No	13	10	7/19/2007
MW-08	Arsenic	Yes	17	10	10/28/2004
MW-08	Arsenic	Yes	13	10	7/13/2004
MW-08	Arsenic	Yes	11	10	12/12/2002
MW-08	Arsenic	Yes	11.6	10	5/2/2002
MW-08	Arsenic	No	14.2	10	1/9/2002
MW-08	Arsenic	Yes	15.2	10	6/7/2001
MW-08	Arsenic	Yes	17.8	10	6/7/2001 (duplicate)
MW-08	Arsenic	Yes	13.7	10	11/15/2000
MW-08	Arsenic	Yes	23 J	10	3/25/1998
MW-08	Arsenic	Yes	10.7	10	12/6/1996
MW-08	Arsenic	Yes	15.2	10	9/16/1996
MW-08	Lead	Yes	19.5 J	15	10/9/1998

Well	Constituent	Filtered	Result (µg/L)	MCL (µg/L)	Date of Detection
MW-08	Selenium	Yes	37.7	10	6/4/1998
MW-08	Selenium	Yes	28.5	10	3/25/1998
MW-08	Thallium	Yes	12.7	2	9/19/1997
MW-09	Antimony	Yes	10.7	6	10/9/1998
MW-09	Arsenic	Yes	11	10	10/28/2004
MW-09	Selenium	Yes	10.1	10	10/27/1999
MW-09	Selenium	Yes	15.4 J	10	3/25/1998
MW-09	Selenium	Yes	19.2	10	3/26/1997
MW-09	Selenium	Yes	45.9	10	12/6/1996
MW-09	Selenium	Yes	82.2	10	9/20/1996
MW-09	Selenium	Yes	104	10	7/1/1996
MW-10	Antimony	Yes	30.3	6	12/8/1998
MW-10	Selenium	Yes	18.1 J	10	10/9/1998
MW-10	Thallium	Yes	5.9	2	9/19/1997
MW-11	Antimony	Yes	17.7	6	10/9/1998
MW-12	Antimony	Yes	6.2	6	11/15/2000
MW-12	Antimony	Yes	31.7	6	12/10/1998
MW-12	Antimony	Yes	10.6 J	6	10/9/1998
MW-13	Cadmium	Yes	6	5	12/19/1997
MW-13	Selenium	Yes	10.1	10	10/9/1998
MW-14	Antimony	Yes	30.1	6	10/9/1998
MW-14	Cadmium	Yes	6	5	3/26/1997

Groundwater results prior to June 1999 from these wells represent values collected to establish the site background conditions prior to the facility starting the Detection Monitoring Program.

The facility began detection monitoring with the first semiannual sampling event of 1999. Analytical data prior to that was collected to establish background values before establishing the detection monitoring program. Per 30 TAC §330.407(b)(3), the occurrence of “a statistically significant increase over background of any tested constituent at any monitoring well” may be demonstrated to have been caused by “a source other than a landfill unit” or “from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality.”

The following sections discuss the exceedances in each of these wells.

#### MW-02

Groundwater samples collected from well MW-02 in 1997 and 1998 reported detections of cadmium, selenium, and thallium at concentrations slightly greater than the respective MCLs, as shown in Table III-5-7

above. However, these results were collected during background sampling from this well and represented natural spatial or temporal variability of groundwater quality un-impacted by the MSWLF unit.

#### *MW-03*

Groundwater samples collected from well MW-03 in 1997 and 1998 reported detections of antimony and cadmium at concentrations slightly greater than the respective MCLs, as shown in Table III-5-7 above. However, these results were collected during background sampling from this well and represented natural spatial or temporal variability of groundwater quality un-impacted by the MSWLF unit.

#### *MW-04*

Groundwater samples collected from well MW-04 in 1996, 1997, and 1998 reported detections of antimony, cadmium, and selenium at concentrations slightly greater than the respective MCLs, as shown in Table III-5-7 above. However, these results were collected during background sampling from this well and represented natural spatial or temporal variability of groundwater quality un-impacted by the MSWLF unit.

#### *MW-05R*

Groundwater samples collected from well MW-05R in 1998 reported detections of antimony and arsenic at concentrations slightly greater than the respective MCLs, as shown in Table III-5-7 above. However, these results were collected during background sampling from this well and represented natural spatial or temporal variability of groundwater quality un-impacted by the MSWLF unit.

#### *MW-06*

Groundwater samples collected from well MW-06 in 1996, 1997, and 1998 reported detections of selenium at concentrations slightly greater than the respective MCLs, as shown in Table III-5-7 above. However, these results were collected during background sampling from this well and represented natural spatial or temporal variability of groundwater quality un-impacted by the MSWLF unit.

#### *MW-07*

Groundwater samples collected from well MW-07 in 1998 and 2001 reported detections of antimony and selenium at concentrations slightly greater than the respective MCLs, as shown in Table III-5-7 above. However, the 1998 results were collected during background sampling from this well and represented natural spatial or temporal variability of groundwater quality un-impacted by the MSWLF unit. The 2001 detection of selenium is above the MCL from 30 TAC §330.331 Table 1, but below the recommended MCLs from 40 CFR 141 of 50 µg/L.

#### *MW-08*

Groundwater samples collected from well MW-08 in 1996, 1997, and 1998 reported detections of antimony, arsenic, lead, selenium, and thallium at concentrations slightly greater than the respective MCLs, as shown in Table III-5-7 above. However, these results were collected during background sampling from this well and represented natural spatial or temporal variability of groundwater quality un-impacted by the MSWLF unit.

Groundwater samples collected in 2000, 2001, 2002, 2004, 2007, and 2013 reported detections of arsenic above the MCL; however, none of these values exceeded the upper statistical control limit of 21.57 µg/L, as reported in the 2014 Background Update Report (Tetra Tech, 2014). As such, these detections are not a statistically significant increase and are not attributed to the MSWLF.

#### *MW-09*

Groundwater samples collected from well MW-09 in 1996, 1997, and 1998 reported detections of antimony and selenium at concentrations slightly greater than the respective MCLs, as shown in Table III-5-7 above. However, these results were collected during background sampling from this well and represented natural spatial or temporal variability of groundwater quality un-impacted by the MSWLF unit.

Groundwater samples collected in 1999 and 2004 reported detections of arsenic and selenium above the MCL; however, selenium did not exceed its upper statistical control limit of 50.00 µg/L, as reported in the 2014 Background Update Report (Tetra Tech, 2014), and as such, it is not a statistically significant increase and not attributed to the MSWLF. The detection of arsenic was a one-time detection in that well and was not verified in subsequent sampling events and is not attributed to be an impact by the MSWLF unit.

#### *MW-10*

Groundwater samples collected from well MW-10 in 1997 and 1998 reported detections of antimony, selenium, and thallium at concentrations slightly greater than the respective MCLs, as shown in Table III-5-7 above. However, these results were collected during background sampling from this well and represented natural spatial or temporal variability of groundwater quality un-impacted by the MSWLF unit.

#### *MW-11*

Groundwater samples collected from well MW-11 in 1998 reported detections of antimony at concentrations slightly greater than the respective MCLs, as shown in Table III-5-7 above. However, these results were collected during background sampling from this well and represented natural spatial or temporal variability of groundwater quality un-impacted by the MSWLF unit.

#### **MW-12**

Groundwater samples collected from well MW-12 in 1998 reported detections of antimony at concentrations slightly greater than the respective MCLs, as shown in Table III-5-7 above. However, these results were collected during background sampling from this well and represented natural spatial or temporal variability of groundwater quality un-impacted by the MSWLF unit.

Groundwater samples collected in 2000 reported detections of antimony at concentrations slightly greater than the respective MCLs. However, this was a one-time detection and was not verified in subsequent sampling and, as such, is not attributed to be an impact related to the MSWLF.

#### **MW-13**

Groundwater samples collected from well MW-13 in 1997 and 1998 reported detections of cadmium and selenium at concentrations slightly greater than the respective MCLs, as shown in Table III-5-7 above. However, these results were collected during background sampling from this well and represented natural spatial or temporal variability of groundwater quality un-impacted by the MSWLF unit.

#### **MW-14**

Groundwater samples collected from well MW-14 in 1997 and 1998 reported detections of antimony and cadmium at concentrations slightly greater than the respective MCLs, as shown in Table III-5-7 above. However, these results were collected during background sampling from this well and represented natural spatial or temporal variability of groundwater quality un-impacted by the MSWLF unit.

Based on the groundwater analytical results, comparisons to groundwater protection standards, and, when appropriate, detailed alternate source demonstrations and a review of these findings, Temple Recycling and Disposal Facility has reasonable cause to think that a source other than its landfill unit(s) caused the reported exceedances of the groundwater protection standards or that the results were due to errors in sampling, analysis, or natural variation in groundwater quality.

### **4.1 Comparison with Regional Groundwater Quality**

Chemical analysis data are available for various aquifers (lithostratigraphic units) in Bell County. Ranges of total dissolved solids (TDS) content for the aquifers are included in Attachment III-4 and are as follows: Hosston 696–5,267 mg/L, Hensell 335–4,274 mg/L, Lower Glen Rose 898–3,967 mg/L, Upper Glen Rose 358–5,431 mg/L, Edwards 277–3,582 mg/L, Austin Chalk 213–498 mg/L, and Taylor ~719 mg/L. In comparison, groundwater quality data from site monitoring wells and piezometers indicates that TDS content ranges from 71 mg/L–3,300 mg/L. Additionally, the regional and local groundwater is slightly saline (1,000–3,000 mg/L) to moderately saline (3,000–10,000 mg/L) (Brune and Duffin 1983).

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Submitted: June 2016  
Revised: December 2016

## 5.0 GROUNDWATER MONITORING SYSTEM CERTIFICATION

### General Site Information

Site: Temple Recycling and Disposal Facility

Site Location: Bell County, Texas

MSW Permit Application No. 692B

### Qualified Groundwater Scientist Statement

I, Christina M. Higginbotham, am a licensed professional geoscientist in the State of Texas and a qualified groundwater scientist as defined in 30 TAC §330.3. I have reviewed the groundwater monitoring system and supporting data contained herein. In my professional opinion, the groundwater monitoring system is in compliance with the groundwater monitoring requirements specified in 30 TAC §330.401 through 330.421. This system has been designed for specific application to the Temple Recycling and Disposal Facility (Permit Application No. MSW 692B). The only warranty made by me in connection with this document is that I have used that degree of care and skill ordinarily exercised under similar conditions by reputable members of my profession, practicing in the same or similar locality. No other warranty expressed or implied, is intended.

Firm/Address: Golder Associates Inc.  
500 Century Plaza Blvd, Suite 190  
Houston, TX 77073

Signature:   
Christina M. Higginbotham, PG No. 10527 – Texas

Date: 12-6-2016



GOLDER ASSOCIATES INC.  
Geoscience Firm Registration  
Certificate Number 50369

INTENDED FOR PERMITTING  
PURPOSES ONLY

## **6.0 GROUNDWATER SAMPLING AND ANALYSIS REQUIREMENTS**

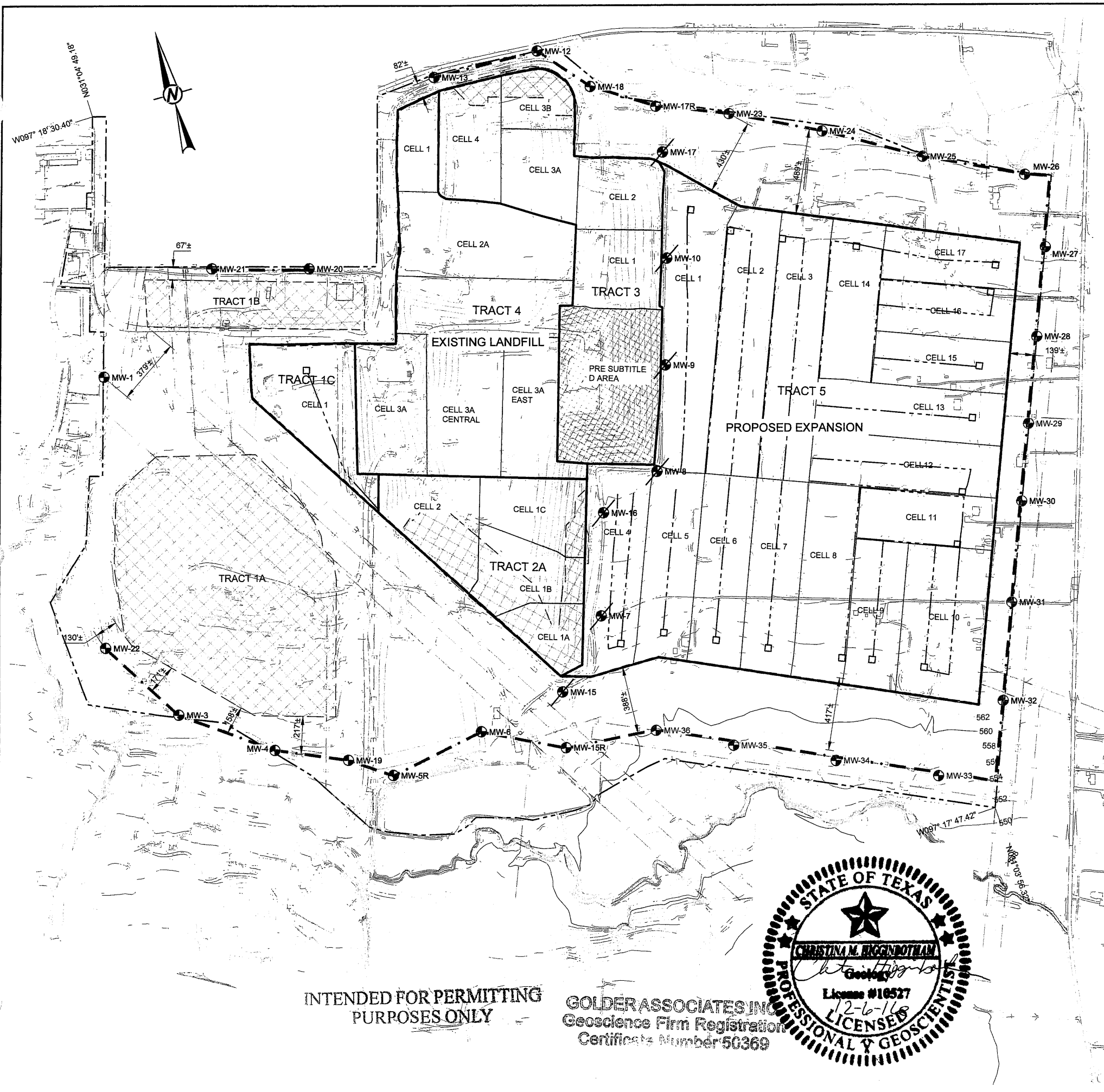
Groundwater sampling and analytical testing will be performed in accordance with the Groundwater Sampling and Analysis Plan (GWSAP), which may be found in Appendix III-5B.



## **7.0 REFERENCES**

- Bouwer, Herman and R.C. Rice. 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells. Water Resource Research. Vol. 12, No. 3, 6 pp.
- Brune, Gunnar and Gail L. Duffin. 1983. Occurrence, Availability, and Quality of Ground Water in Travis County, Texas. Texas Department of Water Resources Numbered Report 276, pp. 76.
- Fetter, C.W. 2001. Applied Hydrogeology. Fourth Ed. Prentice-Hall, Upper Saddle River, New Jersey
- Ridgeway, Cindy and Harald Petrini. 1999. Texas Water Development Board Report 350, Changes in Groundwater Conditions in the Edwards and Trinity Aquifers, 1987-1997, for Portions of Bastrop, Bell, Burnet, Lee, Milam, Travis, and Williamson Counties, Texas.
- Rust Environment & Infrastructure. 1994. Hydrogeology/Geotechnical Site Investigation, Temple Landfill, Temple, Texas.
- Tetra Tech Inc. 2010. Temple Recycling and Disposal Facility Permit Application No MSW-692A, Part III, Attachment 5 – Water Characterization Report Revision 4
- Tetra Tech, Inc. 2014. Background Population Pool Update Report – Temple Landfill, Bell County, Texas

**FIGURES**



## LEGEND

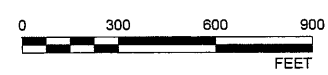
	PERMIT BOUNDARY
	LIMITS OF WASTE
	POINT OF COMPLIANCE
	EXISTING CONDITIONS CONTOUR
	CELL LAYOUT
	EASEMENTS
	CLOSED AREA OF LANDFILL
	LEACHATE COLLECTION SUMP AND PIPE
	AREAS WITH TCEQ APPROVED FINAL COVER

EXISTING	PROPOSED		
		MW-1	MONITORING WELL
		MW-2	MONITORING WELL TO BE ABANDONED

MONITORING WELL	INSTALL	ABANDONMENT
MW-7	Existing	ABANDON PRIOR TO TRACT 5 CELL 4 CONSTRUCTION
MW-8	Existing	ABANDON PRIOR TO TRACT 5 CELL 1 CONSTRUCTION
MW-9	Existing	ABANDON PRIOR TO TRACT 5 CELL 1 CONSTRUCTION
MW-10	Existing	ABANDON PRIOR TO TRACT 5 CELL 1 CONSTRUCTION
MW-15	Existing	ABANDON PRIOR TO TRACT 5 CELL 4 CONSTRUCTION
MW-15R	INSTALL PRIOR TO TRACT 5 CELL 1 CONSTRUCTION	-
MW-16	Existing	ABANDON PRIOR TO TRACT 5 CELL 4 CONSTRUCTION
MW-17	Existing	ABANDON PRIOR TO TRACT 5 CELL 1 CONSTRUCTION
MW-17R	INSTALL PRIOR TO TRACT 5 CELL 1 CONSTRUCTION	-
MW-23	INSTALL PRIOR TO TRACT 5 CELL 1 CONSTRUCTION	-
MW-24	INSTALL PRIOR TO TRACT 5 CELL 1 CONSTRUCTION	-
MW-25	INSTALL PRIOR TO TRACT 5 CELL 14 CONSTRUCTION	-
MW-26	INSTALL PRIOR TO TRACT 5 CELL 14 CONSTRUCTION	-
MW-27	INSTALL PRIOR TO TRACT 5 CELL 14 CONSTRUCTION	-
MW-28	INSTALL PRIOR TO TRACT 5 CELL 13 CONSTRUCTION	-
MW-29	INSTALL PRIOR TO TRACT 5 CELL 12 CONSTRUCTION	-
MW-30	INSTALL PRIOR TO TRACT 5 CELL 11 CONSTRUCTION	-
MW-31	INSTALL PRIOR TO TRACT 5 CELL 9 CONSTRUCTION	-
MW-32	INSTALL PRIOR TO TRACT 5 CELL 8 CONSTRUCTION	-
MW-33	INSTALL PRIOR TO TRACT 5 CELL 7 CONSTRUCTION	-
MW-34	INSTALL PRIOR TO TRACT 5 CELL 5 CONSTRUCTION	-
MW-35	INSTALL PRIOR TO TRACT 5 CELL 4 CONSTRUCTION	-
MW-36	INSTALL PRIOR TO TRACT 5 CELL 4 CONSTRUCTION	-

## NOTES

1. TOPOGRAPHY COMPILED BY PHOTOGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY DATED MARCH 6, 2015.



<b>PROJECT</b>	<b>PERMIT AMENDMENT APPLICATION MSW 692B TEMPLE RECYCLING AND DISPOSAL FACILITY BELL COUNTY, TEXAS</b>				
<b>REV.</b>	0				
	11 of 12				
	<div style="font-size: 2em; font-weight: bold; margin-bottom: 5px;">III</div> <div style="font-size: 2em; font-weight: bold;">5-6</div>				
<b>FIGURE</b>					

<b>PROJECT NO.</b>	<b>1400336</b>				
<b>APPLICATION SECTION</b>	<b>III Attachment 5</b>				

<b>CLIENT</b>	<div style="text-align: center;"> <p><b>CITY OF TEMPLE</b></p> </div>				
<b>CONSULTANT</b>	<div style="text-align: center;"> <p><b>Golder Associates</b></p> </div>				
	HOUSTON 500 CENTURY PLAZA DR., SUITE 180 HOUSTON, TX 77073 USA (281) 821-6868 www.golder.com				

REV.	DATE	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
1	2016-12	RESPONSE TO 1ST MOD MX	MX	TNB	MX	CGD
0	2016-06-10	INITIAL SUBMITTAL	DMW	TNB	JAW	CMH

**APPENDIX III-5B**

**GROUNDWATER SAMPLING AND ANALYSIS PLAN**

**TEMPLE RECYCLING AND DISPOSAL FACILITY  
PERMIT AMENDMENT APPLICATION  
TCEQ PERMIT MSW-692B  
BELL COUNTY, TEXAS  
GROUNDWATER SAMPLING AND ANALYSIS  
PLAN  
PART III, ATTACHMENT 5  
APPENDIX III-5B**

**Owner/Site Operator/Permittee:**



City of Temple  
201 North Main Street  
Temple, Texas 76501

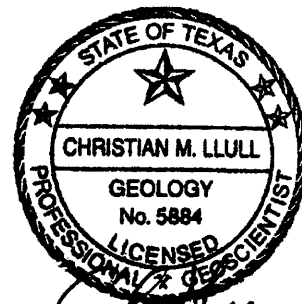
And

**Operator:**  
Waste Management  
9708 Giles Lane  
Austin, Texas 78781

**Submitted by:**

Tetra Tech, Inc.  
8911 North Capital of Texas Highway  
Building 2, Suite 2310  
Austin, Texas 78759

Professional Engineering Firm Registration Number F-3924



12-6-16

Submitted: June 2016  
Revised: December 2016

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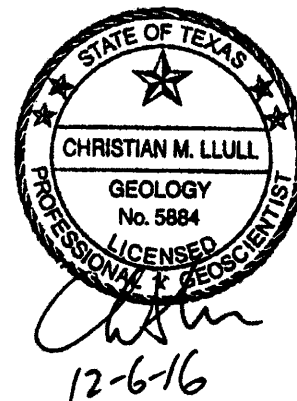
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### ATTACHMENTS

- Statistical Methodologies [Gibbon's Report]



## **1.0 INTRODUCTION**

On October 9, 1993, the State of Texas promulgated regulations governing all aspects of municipal solid waste management (30 Texas Administrative Code, Chapter 330). On March 27, 2006 the State of Texas revised the 30 TAC §330 regulations. In accordance with 30 TAC §330.401(f), groundwater monitoring must be conducted throughout the active life and any required post-closure care period. In accordance with 30 TAC §330.403(d), all parts of the groundwater monitoring system shall be operated and maintained so that they perform at least to design specifications. In accordance with 30 TAC §330.403(e)(3), the executive director and others shall be notified of any changes in facility construction or operation that affect or are likely to affect direction and rate of groundwater flow, and the potential for detecting contaminants from the waste management unit. Subchapter J, §330.405(b) requires that owners or operators of Municipal Solid Waste Landfills (MSWLFs) prepare and submit a Groundwater Sampling and Analysis Plan (GWSAP) to the Texas Commission on Environmental Quality (TCEQ) executive director for review and approval prior to commencement of sampling. Waste Management of Texas, Inc. (WMTX) shall maintain a current copy of the GWSAP in the Site Operating Records (SOR). The purpose of this document is to satisfy the requirements of these regulations as they pertain to the Temple Recycling and Disposal Facility (RDF).

## **2.0 GROUNDWATER SAMPLING PROCEDURES**

Prior to well purging and sampling, field set-up procedures should be in place to ensure 1) the collection of representative groundwater samples; 2) protection against the introduction of contamination into, or between wells; and, 3) the proper management and disposal of purge and rinsate fluids. The following subsections summarize specific tasks involved in sampling of the groundwater monitoring system.

### **2.1 Well Inspection**

Prior to performing any purging or sampling, each monitoring well will be inspected to assess its integrity. The condition of each well will be evaluated for any physical damage that may have been caused by the operation of site equipment or other vehicular traffic. The security of each well will be assessed in order to confirm that no outside source constituents have been introduced to the well. All inspection information, as well as the date and time, general weather conditions, and sampling personnel identification, will be documented on a Field Information Form. If it has been determined that the integrity of the well has, or may have been compromised, the necessary information will be documented and the executive director of the TCEQ (Executive Director) will be notified. No additional actions will be taken without the approval of the Executive Director.

### **2.2 Sample Collection**

For sample collection, each monitoring well in the groundwater monitoring system will have a dedicated sampling device (i.e. a QED Well Wizard (or equivalent bladder pump) or a teflon or stainless steel bailer). If a non-dedicated sampling device is used it will be decontaminated prior to use unless it is intended for single use (i.e. disposable). If a bailer is used for sampling, the bailer will be lowered gently into and through the water column to avoid turbulence that may affect sample results, particularly for volatile organic compounds (VOCs). When a bladder pump is used for sample collection, flow rates will not exceed the flow rate EPA recommends for low-flow sampling of 0.1 liters per minute.

If dedicated or disposable sampling devices (dedicated bladder pump or clean disposable bailer) are used, it will not be necessary to proceed from wells with higher water elevations to those with lower elevations as determined from the prior sampling event. If a non-dedicated



well sampling device (portable bladder pump) is used, then sampling will be conducted from wells with higher water elevations to those with lower water elevations. If dedicated or disposable sampling devices (dedicated bladder pump or clean disposable bailer) are used, it will not be necessary to sample non-contaminated wells prior to those wells which are known to be contaminated. If a non-dedicated well sampling device (portable bladder pump) is used, then non-contaminated wells will be sampled prior to those wells which are known to be contaminated.

### **2.2.1 Purging/Bailing**

Prior to sampling at each well location, water will be evacuated until a minimum of three well volumes has been purged, until the well has been pumped or bailed dry, or until an appropriate amount of water has been purged to achieve the collection of a representative sample. Groundwater will be considered representative once pH, specific conductance, temperature, and turbidity have stabilized. If low flow/minimal drawdown purging has been approved by the TCEQ, the procedures described in EPA/540/S-95/504 (Puls and Barcelona, 1996) will be followed. This will allow for samples to be drawn from the water bearing unit, not from stagnant water left in the screen between sampling events. If the well contains less than three well volumes, the well will be pumped or bailed dry, allowed to recover and immediately sampled. If sufficient water is not available for sampling within seven days of purging for slowly recovering wells, the well will be considered dry and the well will not be sampled during that sampling event. As discussed in Section 2.2, either a dedicated or a disposable sampling device (dedicated bladder pump or clean disposable bailer) may be utilized for this task. If a non-dedicated well sampling device (portable bladder pump) is utilized, it will be properly decontaminated as detailed in Section 2.2.2.

Purged groundwater will be containerized and held until laboratory analytical results are received. In accordance with TCEQ directive dated May 4, 2010, groundwater from a monitoring well is considered "contaminated" for the purposes of disposal only if the concentration of any monitored constituent is determined to be greater than the background concentration. Purged groundwater will be held until the analytical results are known, and only then discharged onto the ground if the water is determined to be uncontaminated. Purged groundwater determined to be contaminated will be managed as contaminated water in accordance with the May 4, 2010 TCEQ letter and approved Leachate and Contaminated Water Plan. Prior to sampling at each well location, water will be evacuated until a minimum

of three well volumes have been purged, until the well has been pumped or bailed dry, or until an appropriate amount of water has been purged to achieve the collection or a representative sample. To determine purge volume, the following equation will be used:

$$(DTB-DTW) \times \text{Vol/Ft} = \text{Purge Volume (in gallons)}$$

where:       DTB = Depth to bottom of well  
              DTW = Depth to water  
              Vol/Ft = As per the following chart

<u>Well Diameter</u>	<u>Vol/ft (gal)</u>
1"	0.04
2"	0.16
4"	0.65

## **2.2.2   Equipment Decontamination**

All equipment used for the collection of ground water samples will be decontaminated prior to use at each well location unless the equipment is dedicated to a specific well or disposable. An appropriate decontamination procedure consists of scrubbing all equipment with a solution of Alconox and de-ionized or distilled water and triple rinsing with de-ionized or distilled water. If a non-dedicated pump is used, sufficient deionized or distilled water should be run through the pump and hose to ensure the removal of all fluids, which may be present from previous sampling. Decontamination will be sufficient to avoid the introduction of any contaminant into a well and to not allow any contaminant to be transported between wells that will create false sample results or otherwise harm the environment. Decontamination water will be managed same as detailed in Section 2.2.1.

## **2.2.3   Water Level Measurements**

Prior to groundwater purging and sampling, water level measurements will be taken at each well location utilizing a portable water level indicator, fiberglass tape, or other suitable measuring device. Water level measurements will be collected over a period of time short enough to avoid temporal variations in water levels. Water level readings will be recorded to the nearest hundredth of a foot and will be taken from a surveyed reference datum (top of

PVC casing) that is clearly marked on the well. To prevent cross-contamination between sampling points, the measuring instrument will be decontaminated between well locations following the procedures previously discussed in Section 2.2.2.

#### **2.2.4 Calibration of Field Measurement Devices**

Before going to the field, all measuring devices will be cleaned and checked for any malfunctions. The sampling team must calibrate all meters, measuring devices, instruments, etc. before using them in the field. This is necessary to ensure the proper working order of these devices, and to ensure the integrity of the values measured.

All measuring devices will be calibrated daily in accordance with the manufacturer's specifications.

#### **2.3 Sample Preservation and Filtering**

In accordance with 30 TAC §330.405(c), groundwater samples collected as part of the monitoring program will not be filtered in the field or laboratory prior to laboratory analysis. Sample container and preservative requirements for each analyte are listed on Table 2-1. Pre-labeled containers will be supplied by the laboratory for each sampling event. The appropriate preservatives will be added to each sample container based on the required analytical method.

#### **2.4 Sample Shipment**

After collection and sample preservation, the sample bottles will be wiped clean, labeled and placed into an insulated, sealed cooler or other suitable container with ice or frozen ice packs. The temperature of the samples will be recorded when the shipping container (cooler) arrives at the analytical laboratory to assure that the appropriate sample temperature was maintained during shipment. All samples included in the shipping container will be packed in such a manner to minimize the potential for container breakage. A laboratory Chain of Custody Form (COC) will be sealed in a water resistant bag and placed with the appropriate sample bottle set. The shipping containers will then be sealed and sent to the appropriate laboratory or a designated analytical laboratory. All shipments will be scheduled for next day delivery. The Bill of Lading or receipt for sample container shipment will be attached to the COC form upon arrival at the Analytical Laboratory.

#### **2.4.1 Chain of Custody**

Appropriate Chain of Custody procedures for samples will be implemented to ensure sample integrity and to provide technically and legally defensible groundwater quality data. At the time each sample is collected, Chain of Custody and Field Information form will be completed and placed in the sealed container. The Field Information form will include general sampling event information including location, time, weather conditions, sampler identification, well integrity, any numerical field data values and well purging procedures. Upon arrival at the laboratory, the shipping container will be opened and the Chain of Custody forms will be signed and time/dated by the person taking custody of the environmental samples. If the shipping container is shipped, this person will affix the bill of lading or receipt to the Chain of Custody form.

### **3.0 GROUNDWATER ANALYSIS PROCEDURES**

#### **3.1 Analytical Methods/Procedures**

Table 2-2 presents the methodologies used by WMTX's designated laboratory for each parameter or group of parameters. All methods are USEPA approved.

#### **3.2 Quality Assurance/Quality Control**

Temple RDF has historically utilized a NELAC (National Environmental Laboratory Accreditation Council) certified laboratory for analysis of groundwater samples and will continue to use a NELAC certified laboratory for future groundwater analyses.

The laboratory evaluates and reports quality control information in a report with laboratory case narrative (LCN), with qualifiers and narrative detail where appropriate such that Temple RDF may ensure that all sample collection, preparation and analyses, and data management activities have been conducted in accordance with NELAC. The laboratory report (including the LCN) will report the number of samples, sampling parameters, and sample matrix, the name of the laboratory (including subcontract labs) involved in the analysis, an explanation of each failed precision and accuracy measurement determined to be outside the laboratory and/or method control limits and whether such a quality control excursion represents a positive or negative bias and the limitations these excursions have on data quality. Additionally exceedance of sample holding times and identification of matrix interferences shall be identified in the LCN. Any dilutions implemented due to sample matrix interference will be done to the smallest dilution possible to bring the sample into control for analysis.

In addition to the exceptions listed above, the LCN report for all problems and anomalies observed will be included in the laboratory report for each sampling event. The LCN will report, at a minimum, the following information:

1. The exact number of samples, testing parameters and sample matrix.
2. The name of the laboratory involved in the analysis. If more than one laboratory is used,

all laboratories shall be identified in the case narrative.

3. The test objective regarding samples.
4. Explanation of each failed precision and accuracy measurement determined to be outside of the laboratory and/or method control limits
5. Explanation if the effect of the failed precision and accuracy measurements on the results induces a positive or negative bias.
6. Identification and explanation of problems associated with the sample results, along with the limitations these problems have on data usability. The facility will explain any problems encountered in the laboratory analysis, either by adding additional explanations to the laboratory checklist or by extending the laboratory case narrative.
7. A statement on the estimated uncertainty of analytical results of the samples when appropriate and/or when requested.
8. A statement of compliance and/or noncompliance with the requirements and specifications. Exceedance of holding times and identification of matrix interferences must be identified. Dilutions shall be identified and if dilutions are necessary, they must be done to the smallest dilution possible to effectively minimize matrix interferences and bring the sample into control for analysis.
9. Identification of any and all applicable quality assurance and quality control samples that will require special attention by the reviewer.
10. A statement on the quality control of the analytical method of the permit and the analytical recoveries information shall be provided when appropriate and/or when requested.

The analytical laboratory report for each sampling event will document the results and methods for each sample and analyte along with the quantification limits. The report will also include a copy of the chain-of-custody and an understandable correlation between the chain-

of-custody and the sample results reported to the TCEQ. The analytical laboratory report will be submitted either electronically or in hard copy upon TCEQ request.

Temple RDF shall ensure that a data reviewer consider the project data quality objectives as appropriate to determine if the results meet the project needs with respect to completeness, representativeness, and accuracy. Prior to submittal of the data to the Commission the data will be reviewed, including the laboratory quality control results, the relative percent difference (RPD) of the monitor well results and its duplicate analysis (DUP) as a measure of accuracy. The reviewer will also evaluate other potential impacts such as bias. These results will be identified using qualifiers in the test reports tied to footnotes and the laboratory case narrative. Additionally, the data reviewer will look for transcription errors in the analyses and compare the contemporary data and historical data to assess excursions from trends. The data review will include a statement assessing data usability by a certified groundwater scientist with respect to the project data quality objectives (primarily a statistical evaluation of the groundwater analytical data) and, when necessary, provide comment to further explain or supplement the quality control data on the laboratory report.

A record of the Chain of custody, laboratory sample receipt, storage and analysis procedures will be kept for each sample received. A summary of this record will be part of the laboratory analysis report. The facility will submit, along with the laboratory case narrative (LCN), either (1) a laboratory checklist; or (2) the laboratory quality assurance and quality control data and laboratory analytical data (in hard-copy or electronic format). Any information required in the laboratory case narrative that cannot be completed by the laboratory will be completed by the permittee.

### ***Field Sampling QA/QC***

**Field Procedures.** As quality assurance procedures are an integral part of each segment of field sampling methodology, the quality assurance procedures associated with each step of the field sampling routine (e.g., proper well purging, field sampling and preservation methodologies) have been directly incorporated into each respective field sampling subsection of this GWSAP.

**Field and Trip Blanks.** Trip and field blanks will be used during each semi-annual sampling event conducted at the site. The trip blank, containing laboratory-grade distilled water, will

be will remain unopened and be packaged and sent from and to the laboratory in the same manner as the site environmental samples. The trip blank will be provided by the analytical laboratory supplying the sample containers. A trip blank will accompany each shipping cooler that contains samples for VOCs and will be analyzed for VOCs only. The trip blank will only be analyzed if VOCs are included in the sampling event. A minimum of one (1) field blank will be prepared in the field by pouring the supplied laboratory grade deionized or distilled water into one of the clean sample containers opened in the field. The field blank will then be sealed and shipped in the same manner as the environmental samples. Field blanks will be analyzed for the constituents listed in Table 5-1.

**Duplicate Samples.** Sample duplicates are collected to assure the precision of the sampling and analytical processes. For sampling events that involve the collection of five or more samples, a minimum of one duplicate will be obtained during the sample event and submitted to the laboratory under a different sample identification number. This sample will be collected and analyzed to provide a check on the precision of the laboratory techniques.

**Laboratory Practical Quantitation Limit.** The practical quantitation limit (PQL) is defined as the lowest concentration reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions and is analogous to the limit of quantitation (LOQ) definition in the most recent available NELAC Standard. The PQL is method, instrument, and analyte specific and may be updated as more data becomes available. The PQL must be below the groundwater protection standard established for that analyte as defined by 30 TAC §330.409(h) unless approved otherwise by the TCEQ. The precision and accuracy of the PQL shall be initially determined from the PQLs reported over the course of a minimum of eight groundwater monitoring events. The results obtained from these events shall be used to demonstrate that the PQLs meet the specified precision and accuracy as shown in the table below. The PQL will be supported by the analysis of a PQL check sample, which is a laboratory reagent grade sample matrix spiked with chemicals of concern at concentrations equal to or less than the PQL. At a minimum, a PQL check sample will be performed quarterly during the calendar year to demonstrate that the PQL continues to meet the specified limits for precision and accuracy as defined in the table below.



Constituent of Concern (COC)	Precision (% Relative Standard Deviation [RSD])	Accuracy (% Recovery)
Metals	10	70-130
Volatiles	20	50-150
Semi-Volatiles	30	50-150

For analytes that the established PQL cannot meet the precision and accuracy requirements in the table above, the owner/operator will ensure the laboratory will submit sufficient documentation and information to the TCEQ for alternate precision and accuracy limits on a case by case basis. Non-detected results will be reported as less than the established PQL limit that meets these precision and accuracy requirements.

#### **4.0 ESTABLISHMENT OF BACKGROUND GROUNDWATER QUALITY - 330.407(a)(1)**

Background groundwater quality will be established for all upgradient and downgradient wells in the groundwater monitoring system.

Constituents to be monitored for the establishment of background are listed in Table 5-1. This background constituent list consists of all constituents listed in 40 Code of Federal Regulations (CFR) Part 258, Appendix I (30 TAC §330.419) and any additional indicator parameters chosen by WMTX.

In order to establish background concentrations for each constituent listed in Table 5-1, a minimum of eight (8) statistically independent samples will be collected from each monitoring well (upgradient and downgradient) in the groundwater monitoring system (the number of samples may vary depending on the statistical method used).

The statistical independence of samples will be achieved through the assignment of a proper sampling interval. Pursuant to the TCEQ guidance document, the appropriate time interval between sampling events can be estimated through the use of site-specific groundwater velocities to determine what time "fresh" formation groundwater will be found in the monitoring well after initial sampling. These calculated groundwater velocities can be calculated for the water bearing unit beneath the site using the standard average linear velocity formula (Freeze and Cherry, 1979):

$$V = \frac{K}{n_e} i$$

where: V = horizontal groundwater velocity  
K = average hydraulic conductivity for the aquifer monitored  
i = average horizontal gradient  
n<sub>e</sub> = estimated effective porosity (Freeze & Cherry, 1979)

The horizontal hydraulic gradient, i is calculated using the formula:

$$i = d_h/d_l$$

where:

$i$  = horizontal hydraulic gradient (ft/ft)

$d_h$  = difference in hydraulic head (feet)

$d_l$  = distance between wells

At the Temple Landfill site, the average horizontal hydraulic gradient in the shallow flow system was calculated to be 0.03 to 0.05. Using these horizontal hydraulic gradients, an average hydraulic conductivity of  $2.2 \times 10^{-7}$  cm/sec ( $6 \times 10^{-4}$  ft/day), and an effective porosity of 0.1, the average linear velocity within the shallow flow system is estimated to be 2 to 3  $10^{-4}$  ft/day (approximately 0.1 ft/yr).

Using a groundwater velocity of 0.1 ft/year and a monitoring well casing diameter of 0.17 ft indicates that 2 year intervals may be required to ensure that samples are independent. However, since there is some variation of hydraulic gradient, hydraulic conductivity, and groundwater flow rates in the shallow flow system at the site, and to prevent an extended background sampling schedule, background samples will be collected and analyzed on a quarterly basis for each new or replacement monitoring well. Background monitoring will be initiated for new and replacement monitoring wells within 90 days of installation after being properly developed in order to collect a representative groundwater sample. To compensate for the short sample intervals and to ensure statistical independence, a minimum of eight sets of background samples will be collected over a 2 year period.

Background constituent concentrations for each parameter listed in Table 5-1 will be derived from the analytical results using the statistical methods described in Attachment 1. The statistical methods were provided to the TCEQ in a document prepared by Robert Gibbons entitled *"Statistical Methods for Ground-Water Monitoring at the Temple RDF"* dated August 3, 1998. For the constituents that are in control, the background data set will be updated no more frequently than once every two (2) years with TCEQ approval. Upon completion of background monitoring and during background updates, the owner or operator will evaluate the background data to ensure that the data are representative of background groundwater constituent concentrations unaffected by waste management activities or other sources of contamination, and that the evaluation will be documented in a report and submitted to the executive director for review and approval before the next subsequent

groundwater monitoring event following the updated (or initial) background period in accordance with 30 TAC §330.407(a)(1).

Groundwater monitoring results from new wells at facilities where waste has already been placed shall be evaluated after each sampling event during the background data collection period, for evidence of releases from the facility. Examples of a release from the facility include detection of VOC in concentrations greater than MSW PQLs or detection of MSW leachate indicator(s) in significant concentrations, either of which may require notification and/or investigation.

## **5.0 DETECTION MONITORING**

The Detection Monitoring Program is discussed in the following subsections.

### **5.1 Groundwater Detection Monitoring Parameters**

Parameters that will be monitored during Detection Monitoring consist of inorganic and organic constituents found in 40 Code of Federal Regulations (CFR) Part 258, Appendix I. The detection monitoring list has been included as Table 5-1, which was compiled pursuant to 30 TAC §330.419(a). In addition to the constituents found in 40 CFR Part 258, Appendix I, other groundwater quality indicator parameters (i.e. calcium, chloride) may be collected and analyzed as part of a Detection Monitoring event but will not be evaluated in accordance with the statistical methods described in Section 5.4.

### **5.2 Groundwater Detection Monitoring Frequency**

After the establishment of background groundwater quality (refer to Section 4.0), the detection monitoring frequency for all constituents previously identified in Section 5.1 will be semi-annual during the active life, closure, and post-closure care periods of the site and as required in accordance with §330.407(a)(2).

### **5.3 Reporting Requirements - §330.407(b) and (c)**

Not later than 60 days after each sampling event, WMTX shall determine whether there has been a statistically significant increase (SSI) over background of any tested constituent at any monitoring well. In accordance with the statistical procedures outlined by Dr. Robert Gibbons for this site and supported by ASTM D6312-98, an increase is not statistically significant unless it has been verified (see Section 5.4.1). If a single detection without the use of verification re-sampling is used as a trigger for SSI, much higher control limits would be required to maintain the performance standards prescribed by USEPA for multiple statistical comparisons. If there has been a SSI, WMTX shall notify the TCEQ, and any local pollution agency with jurisdiction that has requested to be notified, in writing within 14 days of this determination.

If a SSI over background of any tested constituent at any monitoring well has occurred, WMTX shall immediately place a notice in the operating record describing the increase and shall establish an assessment monitoring program meeting the requirements of 30 TAC

§330.409 within 90 days of the date of the SSI determination notice to the TCEQ, except as provided for in the following two paragraphs:

(1) If an initial exceedance over background of any tested constituent at any monitoring well has occurred, WMTX may submit the results of up to two (2) verification resamples (not closer than 30 days apart) within 60 days of determining the SSI. The resample data may be used to statistically confirm or disprove the SSI determination. Verification samples from the re-sampling event must be completed before the next groundwater monitoring event.

(2) If a SSI over background of any tested constituent at any monitoring well has occurred and WMTX has reasonable cause to think that a source other than a landfill unit caused the contamination or that the SSI resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality, then WMTX may submit a report providing documentation to this effect. In making this alternate source demonstration (ASD), WMTX will notify the TCEQ, and any local pollution agency with jurisdiction that has requested to be notified, in writing within 14 days of determining a SSI over background at the compliance point that WMTX intends to prepare and submit an ASD. Within 90 days of determining a SSI, WMTX will submit an ASD to the TCEQ, and any local pollution agency with jurisdiction that has requested to be notified, that demonstrates that a source other than a monitored landfill unit caused the contamination or that the SSI resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality. The ASD must be prepared and certified by a qualified groundwater scientist. WMTX will not filter the groundwater sample for constituents addressed by the ASD prior to laboratory analysis. Per 30 TAC §330.407(b)(3)(C) the executive director may require that WMTX provide landfill leachate analyses to support an alternate source demonstration if one is submitted. WMTX will continue to monitor after the review and approval of the alternate source demonstration (ASD) by the TCEQ in accordance with the detection monitoring program established under 30 TAC §330.407.

If WMTX does not make a demonstration satisfactory to the executive director within 90 days after the date of the notice to the TCEQ required under this subsection, WMTX shall initiate an assessment monitoring program as required in 30 TAC §330.407(b)(1). WMTX may install additional wells at the point of compliance to further characterize the release.

WMTX shall submit an annual detection monitoring report within 90 days after the facility's last groundwater monitoring event in a calendar year. The annual report will include the results of all analytical data in hard-copy format on form TCEQ-0312, Groundwater Sampling Report, and in any other format requested by the TCEQ, for example, electronic format. The LCN is described in detail in Section 3.2.

The annual report will include the following information determined since the previously submitted annual report:

- (1) a statement regarding whether a SSI has occurred over background values in any well during the previous calendar year period and the status of any SSI events;
- (2) the results of all groundwater monitoring, testing, and analytical work obtained or prepared under the requirements of this permit, including a summary of background groundwater quality values, groundwater monitoring analyses, statistical calculations, graphs, and drawings;
- (3) the groundwater flow rate and direction in the uppermost aquifer. The groundwater flow rate and direction of groundwater flow shall be established using the data collected during the preceding calendar year's sampling events from the monitoring wells of the detection monitoring program. WMTX shall also include in the report all documentation used to determine the groundwater flow rate and direction of groundwater flow;
- (4) a contour map of piezometric water levels in the uppermost aquifer based at a minimum upon concurrent measurement in all monitoring wells. All data or documentation used to establish the contour map should be included in the report;
- (5) recommendation for any changes; and
- (6) any other items requested by the TCEQ.

#### **5.4 Statistical Analysis - §330.405(e) and (f)**

The statistical method used to evaluate the groundwater data was prepared in accordance with the facility's statistical plan in this section, the EPA statistical guidance document *"Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance"*, March 2009) (Unified Guidance), and ASTM standard D6312-98 (*"Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs"*).

Attachment 1, Statistical Methodologies, provides the initial statistical design of the Detection Monitoring program, prior to routine implementation. Updates to this program have been and will be provided to TCEQ in routine submittals such as Background Evaluation Reports (or BERs). The Detection Monitoring program complies with the program elements presented in Chapter 6 of the March 2009 EPA Unified Guidance document. The site-specific Detection Monitoring program has been approved by TCEQ via multiple regulatory rule revisions including a November 23, 2010 approval of Chapter 330, Subchapter J revisions confirming regulatory approval that the routine process of detection monitoring meets the objective of the regulations: using statistical testing to accurately evaluate whether or not there is a release to groundwater at one or more compliance wells. Any changes to current conditions will be outlined in the submittals to TCEQ.

The inorganic parameters listed in Table 5-1 will be compared to historical background data using intrawell statistics. Intrawell statistics compare new measurements to the historical data at each groundwater monitoring well independently. The statistical analysis used for this facility will be in accordance with §330.405(e) and §330.405(f)(1-6), as appropriate, and will include control charts, prediction limits, confidence limit, or other methods approved for use in Detection or Assessment Monitoring. For Detection Monitoring, the methodology will employ the use of combined Shewhart-CUSUM control chart method in accordance with §330.405(e)(4) or prediction limit (normal, log-normal, or non-parametric) in accordance with §330.405(e)(3) depending on the detection frequency and distribution of the data set. Combined Shewhart-CUSUM control charts will detect releases both in terms of the constituent concentration and cumulative increases. These methods are to be utilized on Table 5-1 metals only since many of these constituents may be found naturally in soils and groundwater samples.

The statistical method for evaluating VOCs is a nonparametric prediction limit, in which the statistical limit corresponds to the quantitation limit, or detection limit, if a quantitation limit exceeds a GWPS, for each compound. Table 5-1 organic constituents will be evaluated based upon a verified detection of a concentration greater than their respective PQLs since many, if not all, of these constituents are not expected to be found naturally in groundwater. Details on verification procedures are provided in Section 5.4.1.



To remove the possibility of historical outliers and trends creating false statistical limits, the data for each well and each constituent will be tested for the existence of outliers. The DUMPStat® program uses the method described by W. J. Dixon ("Processing Data for Outliers": *Biometrics*, 1953, 9, 74-89) to define outliers in the background data set. If a sample collected during background is found to be above the critical value for the sample of size  $(n-1)$ , then the value is not used in the establishment of the statistical limit from the background data set. Outliers may be removed from consideration during the establishment of all statistical limits. The statistical outlier and trend detection procedure will be performed for those wells that have had at least 5 measurements for a given constituent. Once the background database is established, the outlier procedure described above may be applied and appropriate statistical limits set.

#### **5.4.1 Detection Verification Procedure - §330.407(b)(2)**

Once groundwater analysis results have been collected, checked for QA/QC consistency and determined to be above the appropriate statistical level, the results must be verified before the next groundwater monitoring event in accordance with the objectives of 40 CFR Part 258.53. Verification re-sampling is an integral part of the statistical methodology described by EPA's March 2009 Unified Guidance Document. Without verification re-sampling, much larger statistical limits would be required to achieve site-wide false positive rates of 5% or less. Furthermore, the resulting false negative rate would be greatly increased. The following procedure will be performed for each compound determined to be initially above its statistical limit. Only compounds that initially exceed their statistical limit will be sampled for verification purposes. The use of a "pass 1 of 2" verification option will be implemented based on an evaluation by Dr. Robert Gibbons to manage the site wide false positive and false negative rates in the accordance with the March 2009 EPA statistical guidance document. In a "pass 1 of 2" re-sampling scheme, the second resample does not need to be collected if the first re-sample passes (that is, if the first sample is below the statistical limit). The re-samples should not be taken at the same time, but rather spread out over a period between the initial SSI that triggered the re-sampling, and the time by which re-sampling results must be submitted (that is, within 60 days of the initial SSI determination). Regardless of the re-sampling scheme, all re-samples must be obtained within the period between the initial SSI that triggered the re-sampling and the time by which the results must be submitted.

#### **5.4.1.1 Volatile Organic Compounds**

If one or more VOCs are detected above their statistical limit (i.e., PQL), up to two verification resamples will be scheduled. A SSI will be recorded if any single VOC is verified in any of the scheduled resampling events if a concentration is greater than the statistical limit.

#### **5.4.1.2 Inorganic Constituents**

If one or more of the inorganic parameters are detected above their statistical limit, up to two verification re-samples will be collected with the re-sampling event. A SSI will be recorded if verification of one elevated parameter is confirmed in a concentration greater than the control/prediction limit for each of the discrete verification re-samples. If the re-sampling program confirms that the initial sample represented a laboratory or sampling-induced outlier, the verification sample will replace the original reported value to eliminate bias from the statistical calculation which considers all data points collected at the site.

## **6.0 ASSESSMENT MONITORING PLAN - §330.409 through §330.415**

### **6.1 Assessment Monitoring**

Assessment monitoring will be performed on a site-specific basis pursuant to this Assessment Monitoring Plan (AMP) whenever it is determined that there has been a SSI over background for one or more of the constituents listed in Table 5-1. The purpose of this AMP is to provide the procedures and a statistical methodology to evaluate inorganic and/or organic compound detections in groundwater against background and against health-based groundwater protection standards. This AMP is designed to meet the requirements of the §330.409 through §330.411 and federal Subtitle D (40 CFR Part 258) regulations.

In accordance with 30 TAC §330.409(b), within 90 days of determining that a SSI has occurred (i.e., after verification of the SSI and completion of any alternate source demonstrations, if conducted), and not less than annually thereafter, the groundwater monitoring system will be sampled and analyzed for the full set of constituents in Appendix II to 40 CFR Part 258. Groundwater samples collected as part of assessment monitoring will not be filtered in the field or the laboratory prior to laboratory analysis. If a SSI is verified, assessment monitoring will be initiated at the well(s) exhibiting the SSI and at the immediately adjacent wells on each side of the well(s) exhibiting the SSI, unless an alternative subset of wells is designated by the executive director. For any new constituent(s) detected in the point of compliance wells as a result of the complete Appendix II analysis, a minimum of four statistically independent samples from each background well shall be collected and analyzed to establish background levels for the additional constituent(s). After sampling point of compliance wells for Appendix II constituents, the TCEQ may specify an appropriate subset of wells to be sampled and analyzed for the Appendix II constituents during assessment monitoring and may delete any of the Appendix II constituents if WMTX can document that the removed constituents are not reasonably expected to be in or derived from the waste contained in the unit. All other groundwater wells will continue to be monitored in accordance with the existing detection monitoring protocols and statistical program.

In accordance with 30 TAC §330.409(d), WMTX will submit the results from the initial and subsequent sampling events (if applicable) to the executive director of the TCEQ and also place them in the operating record within 60 days of the sampling event. Within 90 days of

submittal of the results and on at least a semiannual basis thereafter, WMTX will collect samples from the wells specified by 30 TAC §330.403(a) and conduct analyses for the constituents listed in Table 5-1 and any additional constituents in 40 CFR Part 258, Appendix II that are detected in response to assessment monitoring. Results will be submitted to the TCEQ not later than 60 days after the sampling event and also placed in the site's operating record. At least one sample will be collected and analyzed from each background and point of compliance well during each sampling event. However, the TCEQ may specify an alternative monitoring frequency (not less than annual) during the active life and the closure and post-closure care period for the assessment monitoring constituents. The TCEQ will base the alternative frequency on the facility lithology and hydraulic conductivity, groundwater flow rate, travel distance from the waste nearest to a point of compliance monitoring well, resource value of the uppermost aquifer; and fate and transport of the constituent(s) detected.

Background concentrations will be established if any additional Appendix II constituents are detected. WMTX will also establish groundwater protection standards for the additional Appendix II constituents detected in a point of compliance well, in accordance with §330.409(h) or (i). WMTX will evaluate the results and determine whether any 40 CFR Part 258, Appendix II constituents were detected at statistically significant levels above the groundwater protection standard (GWPS) within 60 days of the sampling event. If the concentrations of all 40 CFR Part 258, Appendix II constituents are shown to be at or below background values, in accordance with the Facility's statistical procedures, for two consecutive sampling events, WMTX will notify the TCEQ in writing and return to detection monitoring, if approved. In accordance with 30 TAC §330.409(f), if the concentrations of any 40 CFR Part 258, Appendix II constituents are above background values, but all concentrations are below the GWPS, WMTX shall continue assessment monitoring. If the GWPS has been exceeded, the executive director and appropriate local government officials will be notified in writing within seven days of this determination.

If the GWPS has been exceeded, in accordance with 30 TAC §330.409(g)(1), WMTX will characterize the nature and extent of the potential release by installing additional monitoring wells as necessary, and will install at least one additional monitoring well between the affected monitoring well and the next adjacent wells along the point of compliance before the next sampling event and sample the well(s), in accordance with this GWSAP. If contaminants have been shown to have migrated off-site, WMTX will notify in writing all

persons that own or occupy the land that directly overlies any part of the affected area. WMTX may demonstrate that a source other than the monitored municipal solid waste management unit(s) caused the contamination or that the statistically significant level resulted from an error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality, in accordance with 30 TAC §330.409(g)(2). If a demonstration is to be made under this provision, WMTX will notify the TCEQ in writing within 14 days of determining a statistically significant level above the GWPS at the point of compliance and submit a report, certified by a qualified groundwater scientist, to the TCEQ that demonstrates that a source other than the monitored solid waste management unit(s) caused the impact or that the statistically significant level resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality within 90 days. Groundwater samples shall not be filtered for constituents addressed by the demonstration prior to laboratory analysis. The TCEQ may also require WMTX to provide analysis of landfill leachate to support the demonstration; and continue to monitor in accordance with the AMP. In accordance with 30 TAC §330.409(g)(3), if a successful demonstration is made, WMTX will continue monitoring in accordance with the AMP and may return to detection monitoring if the 40 CFR Part 258, Appendix II constituents are at or below background levels for two consecutive sampling events. In accordance with 30 TAC §330.409(g)(4), if WMTX determines that the AMP no longer satisfies the requirements of §330.409, WMTX will submit a permit amendment or modification to make appropriate changes to the AMP within 90 days.

## 6.2 Assessment Statistics

Statistical analysis of the assessment monitoring constituents detected above background is based on the 2009 EPA *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities*. The statistical methodology will closely follow the methods presented in ASTM D-7048-04, *Standard Guide for Applying Statistical Methods for Assessment and Corrective Action Environmental Monitoring Programs*, 2004 and includes the following methods:

- A) For each constituent, set background to the upper 95% confidence prediction limit as described in ASTM D-7048-04 and Gibbons (1994). The prediction limits are computed from all available data collected from upgradient wells only. The data are first screened for outliers and then tested for normality and log normality.

- 1) If the test of normality cannot be rejected, background is equal to the 95% confidence normal prediction limit.
- 2) If the test of normality is rejected but the test of log normality cannot be rejected, background is equal to the 95% confidence lognormal prediction limit.
- 3) If the data are neither normal nor lognormal, or the detection frequency is less than 50%, background is the nonparametric prediction limit, which is computed as the maximum number of upgradient measurements.

Data evaluation during assessment monitoring will consist of the establishment of 95% Lower Confidence Limits (LCLs) for any Appendix II constituent detected in concentrations greater than the PQL, assuming that a minimum of four (4) background samples exist for each parameter detected during the assessment monitoring program. If inadequate background data exists, sufficient background data will be collected to provide adequate sample size for statistical analysis. According to USEPA technical guidance, if the 95% Lower Confidence Limit (LCL) of one parameter exceeds action levels defined as Maximum Contaminant Level (MCLs), if applicable, or a health-based alternate GWPS the facility is to initiate an assessment of corrective measures.

The use of LCLs for assessment monitoring is stipulated by USEPA in the 2009 statistical guidance document and supported by Dr. Kirk Cameron (statistical consultant to USEPA), Jim Brown (EPA), and Dr. Robert Gibbons. In accordance with the USEPA document entitled "*Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance*" dated March 2009, Chapter 21,

"Confidence intervals are the recommended general statistical strategy in compliance/assessment or corrective action monitoring. Groundwater monitoring data must typically be compared to a fixed numerical limit set as a GWPS. In compliance/assessment, the comparison is made to determine whether groundwater concentrations have increased above the compliance standard. In corrective action, the test determines whether concentrations have decreased below a clean-up criterion or compliance level. In compliance/assessment monitoring, the lower confidence limit [LCL] is of primary interest, while the upper confidence limit [UCL] is most important in corrective action."

### **6.3 Assessment of Corrective Measures**

An assessment of corrective measures (30 TAC §330.411) will be initiated within 90 days of finding that any of the assessment constituents have been detected at a statistically significant level exceeding the GWPS defined under 30 TAC §330.409(h), (i), or (j). Such an assessment will be completed within 180 days of initiating the assessment. WMTX will continue to monitor in accordance with the assessment monitoring program as specified in 30 TAC §330.409. The assessment shall include an analysis of the effectiveness of potential corrective measures in meeting all of the requirements and objectives of the remedy in accordance with 30 TAC §330.413 (Selection of Remedy). The assessment shall address the requirements outlined in 30 TAC §330.411(c). WMTX will also provide information concerning the costs of remedy implementation; and any institutional requirements that may substantially affect implementation of the remedy or remedies. Once the assessment report is completed, WMTX will arrange a public meeting and provide notice in accordance with 30 TAC §39.501(e)(3) to discuss the results of the corrective measures assessment, prior to the selection of a remedy, with interested and affected parties.

If statistically significant levels of constituents are detected greater than the groundwater protection standards established in §330.409(h), (i), or (j) and are related to a release from the landfill unit, WMTX will specify a schedule for initiating and evaluating the goals and performance standards of the remedial activities in accordance with §330.415(a) through (h).

## 7.0 REFERENCES

Gibbons, R. D., 1994, *Statistical Methods for Groundwater Monitoring*, Wiley, New York, NY

ASTM D-7048-04, *Standard Guide for Applying Statistical Methods for Assessment and Corrective Action Environmental Monitoring Programs*, published June 2004

Puls, R.W. and M.J. Barcelona, 1996, Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedure, EPA/540/S-95/504, 12 pp.

U.S. Environmental Protection Agency (USEPA). 2009. Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Unified Guidance. March 2009



## **TABLES**

**Table 2-1**  
**Temple Recycling and Disposal Facility**  
**Sample Collection, Preservation, and Holding Times**

<b>PARAMETER<sup>1</sup></b>	<b>SAMPLE COLLECTION<sup>2</sup> AND CONTAINER</b>	<b>SAMPLE<sup>3,4</sup> PRESERVATION</b>	<b>RECOMMENDED<sup>5</sup> HOLDING TIME</b>
Acid Extractables	1000 ml Glass only (Amber) w/Teflon liner	Cool, 4°C	Extract within 7 days; analyze within 40 days
Alkalinity	100 ml P,G	Cool, 4°C	14 days
Ammonia	125 ml P,G	Cool, 4°C H <sub>2</sub> SO <sub>4</sub> to pH <2	28 days
Base/Neutral Extractables (priority pollutants)	1000 ml Glass only (Amber) w/Teflon liner	Cool, 4°C	Extract within 7 days; analyze within 40 days
Biochemical Oxygen demand, 5 day (HODS)	1000 ml P,G	Cool, 4°C	48 hours
Calcium	500 ml P	HNO <sub>3</sub> to pH <2	6 months
Chemical Oxygen demand (COD)	125 ml P,G	Cool, 4°C H <sub>2</sub> SO <sub>4</sub> to pH <2	28 days
Chloride	250 ml P,G	None required	28 days
Coliform, fecal and total	100 ml P,G sterilized	Cool, 4°C	24 hours
Cyanide	1000 ml P,G	Cool, 4°C NaOH to pH >12 0.6g ascorbic acid <sup>6</sup>	14 days
Fluoride	250 ml P	None required	28 days
Hardness	100 ml P,G	HNO <sub>3</sub> to pH <2	6 months
<b><u>Metals</u></b>			
Chromium (hexavalent)	200 ml P,G	Cool, 4°C	24 hours
Mercury (total)	1000 ml P,G	HNO <sub>3</sub> to pH <2	28 days

**Table 2-1 (Cont'd)**  
**Temple Recycling and Disposal Facility**  
**Sample Collection, Preservation, and Holding Times**

<b>PARAMETER<sup>1</sup></b>	<b>SAMPLE COLLECTION<sup>2</sup> AND CONTAINER</b>	<b>SAMPLE<sup>3,4</sup> PRESERVATION</b>	<b>RECOMMENDED<sup>5</sup> HOLDING TIME</b>
Other metals, (totals) (Antimony, Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Nickel, Potassium, Selenium, Silver, Sodium, Thallium, Vanadium, Zinc)	1000 ml P,G	HNO <sub>3</sub> to pH <2	6 months
Nitrate <sup>5</sup>	125 ml P,G	Cool, 4°C	48 hours
Nitrite	125 ml P,G	Cool, 4°C	48 hours
Oil and Grease	1000 ml, G only	Cool, 4°C	28 days
PCB (priority pollutant)	1000 ml, Glass only (Amber w/ Teflon liner	H <sub>2</sub> SO <sub>4</sub> to pH <2 Cool, 4°C	Extract within 7 days; analyze within 40 days
Pesticides Endrin Lindane Toxaphene Methoxychlor	1000 ml, Glass only (Amber) w/ Teflon liner	Cool, 4°C pH 5 - 9	Extract within 7 days; analyze within 40 days
pH (field)	25 ml P,G	None required	Analyze immediately
Phenols	500 ml G only	Cool, 4°C H <sub>2</sub> SO <sub>4</sub> to pH <2	28 days
Phosphorous (total)	125 ml P,G	Cool 4°C H <sub>2</sub> SO <sub>4</sub> to pH <2	28 days

**Table 2-1 (Cont'd)**  
**Temple Recycling and Disposal Facility**  
**Sample Collection, Preservation, and Holding Times**

<b>PARAMETER<sup>1</sup></b>	<b>SAMPLE COLLECTION<sup>2</sup> AND CONTAINER</b>	<b>SAMPLE<sup>3,4</sup> PRESERVATION</b>	<b>RECOMMENDED<sup>5</sup> HOLDING TIME</b>
Semi-volatile Organics	1000 ml, G	Cool, 4°C	Extract within 7 days; Analyze within 40 days
Specific Conductance (field)	100 ml P,G	None required	Analyze immediately
Sulfate	50 ml P,G	Cool, 4°C	28 days
Temperature (field)	1000 ml P,G	None required	Analyze immediately
Total Dissolved Solids residue on evaporation (TDS/ROE) 180° C	1000 ml P	Cool, 4°C	7 days
Total Organic Carbon (TOC)	2-40 ml P	Cool, 4°C H <sub>2</sub> SO <sub>4</sub> to pH <2	28 days
Total Suspended Solids (TSS)	1000 ml P	Cool, 4°C	7 days
Volatile Organic Acids, priority pollutants	4-40 ml glass vial w/septum caps	Cool, 4°C HCl to pH < 2	14 days
Volatile Organics	4-40 ml glass vial w/septum caps	Cool, 4°C HCl to pH < 2	14 days

1. Table may include more parameters than required for groundwater sampling. A general discussion on sampling water and industrial waste water may be found in ASTM, Part 31, pages 72-81 (1976) Method D-3370.
2. Plastic (P) or Glass (G). For metals, polyethylene with a polypropylene cup (no liner) is preferred.
3. Sample preservation should be performed immediately upon sample collection. For composite samples, each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then samples may be preserved by maintaining at 4°C until compositing and sample splitting is completed.
4. When any sample is to be shipped by common carrier or sent through the United States mail, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirements of Table 5-4, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater); Nitric acid (HNO<sub>3</sub>) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080 % by weight or less (pH about 12.30 or less).
5. Samples should be analyzed as soon as possible after collection. The times listed are the maximum time that samples may be held before analysis and still considered within hold time. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that the specific types of sample under study are stable for the longer time, and has received a variance from the Regional Administrator. Some samples may not be stable for the maximum time period given in the table. A permittee or monitoring laboratory is obligated to hold the sample for a shorter time if knowledge exists to show this is necessary to maintain sample stability.
6. Should only be used in the presence of residual chlorine. Maximum holding time is 24 hours when sulfide is present. Optionally, all samples may be tested with lead acetate paper helium the pH adjustment in order to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.
7. In accordance with 30 TAC §330.405, sample preservation, handling, and analysis will meet the specifications described by "Test Methods for Evaluating Solid Waste Physical/Chemical Methods, third edition" (EPA Publication Number SW-846, 1986, as revised) or an equivalent substitute as approved by the administrative authority.

**Note:** Many tests can be combined in bottles. For example, Alkalinity, Chloride, Fluoride, Nitrate, Nitrite, pH, Sulfate, TDS, TSS will be collected in a 1 liter poly bottle.

**Table 2-2**  
**Temple Recycling and Disposal Facility**  
**Methodologies for Testing and Analysis**

<b><u>PARAMETER</u></b>	<b><u>METHOD DESCRIPTION</u></b>	<b><u>METHOD</u></b>
Acid Extractables (priority pollutants)	GC/MS	EPA 625/8270C(D)
Alkalinity	Titrametric/Potentiometric	(A)310.1
Ammonia	Colorimetric; Automated Phenate	(A)350.1
Base/Neutral Extractables (priority pollutants)	GC/MS	EPA 625/8270C(D)
Biochemical Oxygen demand, 5 day (GODS)	BOD (5 day, 20°C)	(A)405.1
Calcium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Chemical Oxygen demand (COD)	Colorimetric	(A)410.4
Chloride	Manual Titration Or Ion Chromatography	(A)325.3 or 300.0
Coliform (fecal)	Delayed Incubation Procedure	(B)909C
Coliform (total)	Standard Membrane Filter Procedure	(B)909A
Cyanide (total)	Colorimetric, Automated UV	(A)335.3/9012A(D)
Fluoride	Potentiometric, Ion Selective Electrode Or Ion Chromatography	(A)340.2 or 300.0
Hardness	Calculation	(C)2340B
<b><u>Metals, dissolved</u></b>		
Antimony	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Arsenic	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Barium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Beryllium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Boron	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Cadmium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Chromium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Chromium (hexavalent)	Atomic Absorption, Chelation, extraction	(A)7196A
Cobalt	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Copper	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Iron	Atomic Emission Spectrometric	(A)200.7/ 6010B(D)

**Table 2-2 (Cont'd)**  
**Temple Recycling and Disposal Facility**  
**Methodologies for Testing and Analysis**

<b><u>PARAMETER</u></b>	<b><u>METHOD DESCRIPTION</u></b>	<b><u>METHOD .</u></b>
Lead	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Magnesium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Manganese	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Mercury	Atomic Absorption, cold vapor technique	(A)245.2/7470(D)
Nickel	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Potassium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Selenium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Silver	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Sodium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Thallium	Atomic Emission/Mass Spectrometric	(A)200.8/6020(D)
Vanadium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Zinc	Atomic Emission Spectrometric	(A)200.7/6010B(D)
<b><u>Metals. total</u></b>		
Antimony	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Arsenic	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Barium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Beryllium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Boron	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Cadmium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Chromium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Cobalt	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Copper	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Iron	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Lead	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Magnesium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Manganese	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Mercury	Atomic Absorption, cold vapor technique	(A)2452/7470(D)
Nickel	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Potassium	Atomic Emission Spectrometric	(A)258,1/6010B(D)
Selenium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Silver	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Sodium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Thallium	Atomic Emission/Mass Spectrometric	(A)200.8/6020 (D)
Vanadium	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Zinc	Atomic Emission Spectrometric	(A)200.7/6010B(D)
Nitrate	Colorimetric, Automated, Cadmium Reduction Or Ion Chromatography	(A)353.2 300.0
Nitrite	Colorimetric, Automated, Cadmium Reduction	(A)3532

**Table 2-2 (Cont'd)**  
**Temple Recycling and Disposal Facility**  
**Methodologies for Testing and Analysis**

<u>PARAMETER</u>	<u>METHOD DESCRIPTION</u>	<u>METHOD</u>
Oil and Grease	Ion Chromatography	300.0
	Gravimetric, Separatory Funnel Extraction or Spectrometric, Infrared	(A)413.1/9070(D) OR (A)413.2
PCB (priority pollutants)	Gas Chromatograph	EPA608(A)or 8082(D)
Pesticides (Endrin, Lindane, Toxaphene, Methoxychlor)	Gas Chromatograph	EPA608(A)or8081A(D)
pH (field)	Electrometric	(A)150.1
Phenols	Colorimetric, Automated 4-AAP with Distillation	(A)420.2/9066(D)
Phosphorous	Colorimetric, Automated Ascorbic Acid	(A)365.3
Semi-volatile Organics	GC/MS Acids & Base Neutrals	EPA 625/8270C(D)
Specific Conductance (field)	Wheatstone bridge	(A)120.1
Sulfate	Turbidimetric or Ion Chromatography	(A)375.4 or 300.0
Temperature (field)	Reversing Thermometer	(B)212
Total dissolved solids residue on evaporation (TDS/ROE)	Gravimetric, Dried at 180°C	(A)160.1
Total Organic Carbon (TOC)	Combustion or Oxidation	(A)415.1
Total Suspended Solids (TSS)	Gravimetric, Dried at 103-105°C	(A)160.2
Volatile Organic Acids (PP/VOA), priority pollutants	Purge and Trap/GC/MS	EPA 624//8260B(D)
Volatile Organics	Purge and Trap/GC/MS	EPA 624/(D) /8260B(D)/524.2
DBCP, EDB	Microextraction	EPA 504.1/ 8011(D)

*\*NOTE: Analytical methods listed above may be substituted for as deemed necessary provided that the alternate methods provide adequate analytical data to fulfill monitoring requirements and meet regulatory standards.*

**References:**

- A: Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-0920, EMSL, Cincinnati, Revision (March 1983)
- B: Standard Methods for the Examination of Water and Wastewaters: 15th Edition, APHA-AQWQA-WPCF, 1980
- C\*: Standard Methods for the Examination of Water and Wastewaters: 18th Edition, APHA-AWWA-WEF, 1992
- D: Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-84<sup>6</sup>, 3rd Edition, Final Update 3, May 1997.

- \* 2340B is the same in the 18th Edition as in the 17th Edition.

**Table 5-1**  
**Temple Recycling and Disposal Facility**  
**Background and Detection Monitoring Parameter List**

COMMON NAME	CAS RN
<i>Inorganic Constituents (Totals):</i>	
(1) Antimony	(Total)
(2) Arsenic	(Total)
(3) Barium	(Total)
(4) Beryllium	(Total)
(5) Cadmium	(Total)
(6) Chromium	(Total)
(7) Cobalt	(Total)
(8) Copper	(Total)
(9) Lead	(Total)
(10) Nickel	(Total)
(11) Selenium	(Total)
(12) Silver	(Total)
(13) Thallium	(Total)
(14) Vanadium	(Total)
(15) Zinc	(Total)
<i>Organic Constituents:</i>	
(16) Acetone	67-64-1
(17) Acrylonitrile	107-13-1
(18) Benzene	71-43-2
(19) Bromochloromethane	74-97-5
(20) Bromodichloromethane	75-27-4
(21) Bromoform (tribromomethane)	75-25-2
(22) Carbon disulfide	75-15-0
(23) Carbon tetrachloride	56-23-5
(24) Chlorobenzene	108-90-7
(25) Chloroethane (ethyl chloride)	75-00-3
(26) Chloroform (trichloromethane)	67-66-3
(27) Dibromochloromethane (chlorodibromomethane)	124-48-1
(28) 1,2-Dibromo-3-chloropropane (DBCP)	96-12-8
(29) 1,2-Dibromoethane (ethylene dibromide, EDB)	106-93-4
(30) o-Dichlorobenzene (1,2-dichlorobenzene)	95-50-1
COMMON NAME	CAS RN
(31) p-Dichlorobenzene (1,4-dichlorobenzene)	106-46-7
(32) trans-1,4-Dichloro-2-butene	110-57-6
(33) 1,1-Dichloroethane (ethyldiene chloride)	75-34-3
(34) 1,2-Dichloroethane (ethylene dichloride)	107-06-2
(35) 1,1-Dichloroethylene (1,1-dichloroethene, vinylidene chloride)	75-35-4
(36) cis-1,2-Dichloroethylene (cis-1,2-dichloroethene)	156-59-2
(37) trans-1,2-Dichloroethylene (trans-1,2-dichloroethene)	156-60-5
(38) 1,2-Dichloropropane (Propylene dichloride)	78-87-5
(39) cis-1,3-Dichloropropene	10061-01-5



**Table 5-1**  
**Temple Recycling and Disposal Facility**  
**Background and Detection Monitoring Parameter List**

(40)	trans-1,3-Dichloropropene	10061-02-6
(41)	Ethylbenzene	100-41-4
(42)	2-Hexanone (methyl butyl ketone)	591-78-6
(43)	Methyl bromide (bromomethane)	74-83-9
(44)	Methyl chloride (chloromethane)	74-87-3
(45)	Methylene bromide (dibromomethane)	74-95-3
(46)	Methylene chloride (dichloromethane)	75-09-2
(47)	Methyl ethyl ketone (MEK, 2-butanone)	78-93-3
(48)	Methyl iodide (iodomethane)	74-88-4
(49)	4-Methyl-2-pentanone (methyl isobutyl ketone)	108-10-1
(50)	Styrene	100-42-5
(51)	1,1,1,2-Tetrachloroethane	630-20-6
(52)	1,1,2,2-Tetrachloroethane	79-34-5
(53)	Tetrachloroethylene (tetrachloroethane, perchloroethylene)	127-18-4
(54)	Toluene	108-88-3
(55)	1,1,1-Trichloroethane (methylchloroform)	71-55-6
(56)	1,1,2-Trichloroethane	79-00-5
(57)	Trichloroethylene (trichloroethene)	79-01-6
(58)	Trichlorofluoromethane (CFC-11)	75-69-4
(59)	1,2,3-Trichloropropane	96-18-4
(60)	Vinyl acetate	108-05-4
(61)	Vinyl chloride	75-01-4
(62)	Xylenes (total)	1330-20-7

# **ATTACHMENT 1**

Statistical Methodologies

**Statistical Methods for Ground-Water  
Monitoring at  
the Temple RDF**

Prepared

by

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August 3, 1998

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## Executive Summary

This report has two specific aims. First to describe a general statistical strategy for ground-water detection monitoring that is applicable at the Temple RDF and second, to apply this methodology to existing data at the facility. The methodology is first described in considerable detail, appropriately referenced to both the scientific literature and USEPA regulation and guidance and then applied to existing data at the facility. For completeness we describe appropriate statistical methodologies for both inter-well (*i.e.*, upgradient versus downgradient) and intra-well comparisons.

The methods described here are based on the new ASTM standard PS 64-96 *Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs* written by Dr. Robert Gibbons (University of Illinois), Dr. Kirk Cameron (statistical consultant to USEPA) and Jim Brown (USEPA).

The absence of detected VOCs and any clear increasing trends support the general use of intra-well comparisons using combined Shewhart-CUSUM control charts for routine monitoring at this facility.

Application of this methodology revealed no statistically significant exceedances of control limits at any downgradient well. Despite the appropriateness of the statistical methodology at the site, the overall site-wide false positive rate was still high (approximately 20% for intra-well comparisons). This rate can be reduced to the intended 5% level with the addition of approximately four more samples in each well. From the available leachate data, only antimony, arsenic, barium, iron, manganese, nitrogen ammonia, TKN, and potassium provide a clear contrast with upgradient ground-water quality.

In light of these results we propose to perform intra-well comparisons using combined Shewhart-CUSUM control charts for routine detection monitoring at this facility. In addition, we will monitor VOCs and a verified quantification of a VOC will be used as a trigger level. For the next four monitoring events we will continue to update background in an effort to reduce the site-wide false positive rate to 5%. At that time, background will be fixed for a period of two years and reupdated at that time for all wells that have not exhibited a verified exceedance. This process will continue for the life of the facility. Statistical analysis will be restricted to the 8 leachate indicator constituents and Appendix I VOCs.

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## Overview

In the context of ground-water monitoring at waste disposal facilities, legislation has required statistical methods as the basis for investigating potential environmental impact due to waste disposal facility operation. Owner/Operators must perform a statistical analysis on a quarterly or semi-annual basis. A statistical test is performed on each of many constituents (*i.e.*, 10 to 50) for each of many wells (5 to 100 or more). The result is potentially hundreds, and in some cases, a thousand or more statistical comparisons performed on each monitoring event. Even if the false positive rate for a single test is small (*e.g.*, 1%), the possibility of failing at least one test on any monitoring event is virtually guaranteed. This assumes you have done the correct statistic in the first place.

In the following sections, a statistical plan is developed that includes: an effective verification resampling plan, and selection of appropriate statistical methods (*e.g.*, parametric and nonparametric prediction limits or control charts for intra-well comparison) that detect contamination when it is present and do not falsely conclude that the site is contaminated. Statistical significance of contamination detection cannot be properly determined without verification resampling. It is noted from the information presented herein that the final statistical detection monitoring plan cannot be fully specified until background samples for the required list of indicator constituents are available. In general, it is unwise to perform statistical computations on any less than eight background samples. This may be four quarterly samples in each of two upgradient wells, or eight samples taken in each well where intra-well comparisons are to be performed. To take any fewer samples will lead to high false negative rates due to the large size of the prediction limit (*i.e.*, with four samples and three degrees of freedom, the uncertainty in the true mean and standard deviation ( $\mu$  and  $\sigma$ ) given the sample based estimates ( $\bar{x}$  and  $s$ ) is enormous, resulting in extremely high prediction limits). Conversely, with only a few background measurements, our knowledge of the true sampling variability, distributional form and detection frequency may be completely inaccurate leading to a high false positive rate.

Yet another major concern is whether the upgradient wells accurately characterize the natural spatial variability that is observed in the downgradient wells. The alternative is to perform intra-well comparisons which are gen-

erally preferable, however, we must first demonstrate that the well has not been impacted by the site. To this end, we will first test the appropriateness of upgradient versus downgradient comparisons for each well and constituent, and in those cases where intra-well comparisons are applicable, demonstrate (1) the absence of any significant trend in that well and constituent and (2) demonstrate the absence of any constituents of concern (*e.g.*, volatile organic priority pollutant list compounds or other constituents that characterize the leachate from the facility and would not be expected in the natural ground water).

It is noted that when justified, intra-well comparisons are always more powerful than their inter-well counterparts because they completely eliminate the spatial component of variability. Due to the absence of spatial variability, the uncertainty in measured concentrations is decreased making intra-well comparisons more sensitive to real releases (*i.e.*, false negatives) and false positive results due to spatial variability are completely eliminated.

The following provides an outline of the general statistical procedure for ground-water monitoring under the Subtitle D regulation, which is also described in the flowchart at the end of this report.

#### A. Detection Monitoring

##### 1. Upgradient Versus Downgradient Comparisons

- (a) Detection frequency > 50%
  - i. If normal, compute normal prediction limit (40CFR 258.53(h)(4)), selecting false positive rate based on number of wells, constituents and verification resamples (40CFR 258.53(h)(2)), adjusting estimates of sample mean and variance for nondetects.
  - ii. If lognormal, compute a lognormal prediction limit (40CFR 258.53(h)(1)).
  - iii. If neither normal nor lognormal, compute nonparametric prediction limit (40CFR 258.53(h)(1)) unless background is insufficient to achieve a 5% site-wide false positive rate. In this case, use a normal distribution (40CFR 258.53(h)(1)).



- (b) If the background detection frequency is greater than zero but less than 50%, compute a nonparametric prediction limit and determine if the background sample size will provide adequate protection from false positives. If insufficient data exist to provide a site-wide false positive rate of 5%, more background data must be collected (40CFR 258.53(h)(1)).
- (c) If the background detection frequency equals zero, use the laboratory specific PQL (recommended) or limits required by applicable regulatory agency (40CFR 258.53(h)(5)). This only applies for those wells and constituents that have at least 13 background samples. Thirteen samples provides a 99% confidence nonparametric prediction limit with one resample (see Table 1). If less than 13 samples are available more background data must be collected.
- (d) As an alternative to (c), use a Poisson prediction limit which can be computed from only 4 background measurements regardless of the detection frequency (USEPA, 1992 section 2.2.4).
- (e) If downgradient wells fail, determine cause.
  - i. If the downgradient wells fail because of natural or off-site causes, select constituents for intra-well comparisons (40CFR 258.53(h)(3)).
  - ii. If site impacts are found, a site plan for assessment monitoring and detection monitoring (at unaffected wells) may be necessary (40CFR 258.55).

## 2. Intra-well Comparisons

- (a) For those facilities that either
  - i. Have no definable gradient,
  - ii. Have no existing contamination from an on-site-off-site landfill or other source,
  - iii. Have too few upgradient wells to meaningfully characterize spatial variability (*e.g.*, a site with one upgradient well or a facility in which upgradient water quality is not representative of downgradient water quality),

- iv. Satisfy specific hydrogeological criteria (*e.g.*, slow moving ground-water zones, no access to upgradient ground water, inappropriate ground-water migration pathways) as defined by a ground-water professional,

compute intra-well comparisons using combined Shewhart-CUSUM control charts (40CFR 258.53(h)(3)).

- (b) For those wells and constituents that fail upgradient versus down-gradient comparisons, compute combined Shewhart-CUSUM control charts. If no VOCs or hazardous metals are detected and no trend is detected in other indicator constituents, use intra-well comparisons for detection monitoring of those wells and constituents.
- (c) If data are all non-detects after 13 quarterly sampling events, use PQL as statistical decision limit (40CFR 258.53(h)(5)). Thirteen samples provides a 99% confidence nonparametric prediction limit with one resample (40CFR 258.53(h)(1) and USEPA 1992 section 5.2.3). Note that 99% confidence is equivalent to a 1% false positive rate, and pertains to a single comparison (*i.e.*, well and constituent) and not the site-wide error rate (*i.e.*, all wells and constituents) that is set to 5%.
- (d) If detection frequency is greater than zero (*i.e.*, the constituent is detected in at least one background sample) but less than 25% set control limit to the largest of at least 13 background samples.
- (e) As an alternative to (c) and (d) compute a Poisson prediction limit following collection of at least 4 background samples (USEPA 1992 section 2.2.4). Since the mean and variance of the Poisson distribution are the same, the Poisson prediction limit is defined even there is no variability (*e.g.*, even if then constituent is never detected in background). In this case, the reporting limits are used in place of the measurements and the Poisson prediction limit can be computed directly.

### 3. Verification Resampling

- (a) Verification resampling is an integral part of the statistical methodology (USEPA 1992 section 5).

- (b) Without verification resampling much larger prediction limits would be required to obtain a site-wide false positive rate of 5%. The resulting false negative rate would be dramatically increased.
- (c) Verification resampling allows sequential application of a much smaller prediction limit, therefore minimizing both false positive and false negative rates.
- (d) A statistically significant exceedance is not declared and should not be reported until the results of the verification resample are known. The probability of an initial exceedance is much higher than 5% for the site as a whole.
- (e) Note that requiring passage of two verification resamples (*e.g.*, in the state of California regulation) will lead to higher false negative rates because larger prediction limits are required to achieve a site-wide false positive rate of 5% than for a single verification resample; hence, the preferred method is one verification resample. Also note that for nonparametric limits, requiring passage of two verification resamples may result in need for a larger number of background samples than are typically available (see Gibbons, 1994).

#### 4. False Positives and False Negative Rates

- (a) Conduct simulation study based on current monitoring network, constituents, detection frequencies, and distributional form of each monitoring constituent (USEPA 1992 Appendix B).
- (b) Project frequency of verification resamples and false assessments for site as a whole for each monitoring event based on the results of the simulation study.
- (c) As a general guideline, we require a site-wide false positive rate of 5% and a false negative rate of approximately 5% for differences on the order of 3 to 4 standard deviation units (see USEPA 1992 Appendix B). Note that following USEPA we simulate the most conservative case of a release that effects a single constituent in a single downgradient well. In practice, multiple constituents in multiple wells will be impacted, therefore, the actual false negative rates will be considerably smaller than estimates obtained via simulation.

## 5. Use of MDLs and PQLs in Ground-Water Monitoring

- (a) MDLs indicate that the analyte is present in the sample with confidence.
- (b) PQLs indicate that the true quantitative value of the analyte is close to the measured value.
- (c) For analytes with estimated concentration exceeding the MDL but not the PQL, it can only be concluded that the true concentration is greater than zero - there is no way of knowing the actual concentration.
- (d) If the laboratory-specific MDL for a given compound is  $3\text{ }\mu\text{g/l}$ , and the PQL for the same compound is  $6\text{ }\mu\text{g/l}$ , then a detection of that compound at  $4\text{ }\mu\text{g/l}$  could actually represent a true concentration of anywhere between 0 and  $6\text{ }\mu\text{g/l}$ . The true concentration may well be *less than* the MDL (see Currie 1968, Hubaux and Vos, 1970 and Gibbons 1994).
- (e) Comparison of such a value to a maximum contaminant level (MCL), or any other concentration limit, is not meaningful unless the concentration is larger than the PQL.
- (f) Verification resampling applies to this case as well.

## B. Assessment or Corrective Action Monitoring

### 1. Comparison to Background

- (a) Define background for any Appendix II compounds detected (*i.e.*, a minimum of four background samples 40CFR 258.55(b)).
- (b) Compute appropriate prediction limit based on distributional tests and detection frequency as previously described, based on upgradient data or historical data from each well (40CFR 258.55(e)).
- (c) Compare any Appendix II constituent concentrations found to the background prediction limit. If all values are below the prediction limit for two consecutive sampling events return to detection monitoring (40CFR 258.55(e)).

- (d) In Corrective Action (required if background is exceeded) use same statistic until background is achieved for three years. (40CFR 258.58(e)(2)). Use Sen's test to evaluate trends (declining) to demonstrate effectiveness of corrective action.

## 2. Comparison to a Standard

- (a) If a maximum contaminant level (MCL) or alternate concentration limit (ACL) is used, and the ACL or MCL is greater than the background prediction limit, then new concentrations in the assessment or corrective action wells should be compared to the standard (*i.e.*, ACL or MCL) using the upper 95% normal confidence limit computed from the last four independent samples (USEPA 1992).
- (b) In the case of anthropogenic compounds such as VOCs, if the standard is less than the PQL, then the standard becomes the PQL, since no smaller value can be quantified.
- (c) Use Sen's test to evaluate trends (both increasing and decreasing) to demonstrate the effectiveness of corrective action.

## C. Implementation

1. The computer program used to implement the detection monitoring plan will encompass all aspects of the previously presented statistical decision tree.
2. The program will be automatic with respect to selection of statistical methods based on the decision tree and all wells and analytes will be input as a complete file and analyzed on the basis of a single instruction. Cumbersome programs such as GRITS/STAT which require extensive user input for analysis of each well and constituent individually will be avoided.
3. Once the program is configured no further statistical decisions, choices or selections will be made so that it can be run by someone with or without adequate statistical background to make these decisions.

4. The program will have a graphical user interface that allows the user to communicate the data format and to add new data to an existing database rather than requiring a complete new database each quarter.
5. The computer program DUMPStat (Downgradient Upgradient Monitoring Program Statistics) distributed by Discerning Systems, Vancouver CA is the only existing program that provides these features.

#### D. Technical Details

The purpose of this section is to provide a description of the specific statistical methods used in DUMPStat, which is the computer program that will be used in performing the routine statistical analysis of detection monitoring data at the facility. Please note, however, that specific recommendations for any given facility require an interdisciplinary site-specific study that encompasses knowledge of the facility, its hydrogeology, geochemistry, and study of the false positive and false negative error rates that will result. In general, the appropriate statistical methods are available in DUMPStat, however the program must be properly configured for each site to insure that the methods are properly implemented. Performing a correct statistical analysis, such as nonparametric prediction limits, in the wrong situation (*e.g.*, when there are too few background measurements) can lead to disaster. It is for this reason that DUMPStat's simulation capabilities are so important. In the following, the general DUMPStat algorithm is described.

##### 1. Upgradient Versus Downgradient Comparisons

For those wells and constituents that show similar variability in upgradient and downgradient monitoring zones inter-well comparisons can be performed by computing limits based on historical upgradient data to which individual new downgradient monitoring measurements can be compared. In the following, the decision rules by which various prediction limits can be computed is outlined. The decision points are based on detection frequency and distributional form of the upgradient data.

## (a) Case 1: Compounds Quantified in All Background Samples

- i. Test normality of distribution using the multiple group version of the Shapiro-Wilk test (Wilk and Shapiro, 1968) applied to  $n$  background measurements. The multiple group version of the original Shapiro-Wilk test (Shapiro and Wilk, 1965) takes into consideration that upgradient measurements are nested within different upgradient monitoring wells, hence the original Shapiro-Wilk test does not apply (USEPA, 1992 section 1.1.4).
- ii. If normality is not rejected, compute the 95% prediction limit as:

$$\bar{x} + t_{[n-1, \alpha]} s \sqrt{1 + \frac{1}{n}}$$

where

$$\bar{x} = \sum_{i=1}^n \frac{x_i}{n}$$

$$s = \sqrt{\sum_{i=1}^n \frac{(x_i - \bar{x})^2}{n - 1}}$$

$\alpha$  is the false positive rate for each individual test,

$t_{[n-1, \alpha]}$  is the one-sided  $(1 - \alpha)100\%$  point of Student's  $t$  distribution on  $n - 1$  degrees of freedom,

and  $n$  is the number of background measurements.

- iii. Select  $\alpha$  as the minimum of .01 or one of the following:

A. Pass the first or one of one verification resample

$$\alpha = (1 - .95^{1/k})^{1/2}$$

B. Pass the first or one of two verification resamples

$$\alpha = (1 - .95^{1/k})^{1/3}$$

C. Pass the first or two of two verification resamples

$$\alpha = \sqrt{1 - .95^{1/k}} \sqrt{1/2}$$

where  $k$  is the number of comparisons (*i.e.*, monitoring wells times constituents - see USEPA 1992 section 5.2.2).

- iv. If normality is rejected, take natural logarithms of the  $n$  background measurements and recompute the multiple group Shapiro-Wilk test.
- v. If the transformation results in a nonsignificant  $G$  statistic (*i.e.*, the values  $\log_e(x)$  are normally distributed - see USEPA 1992 section 1.1), compute the lognormal prediction limit as:

$$\exp \left( \bar{y} + t_{[n-1, \alpha]} s_y \sqrt{1 + \frac{1}{n}} \right)$$

where

$$\bar{y} = \sum_{i=1}^n \frac{\log_e(x_i)}{n}$$

and

$$s_y = \sqrt{\sum_{i=1}^n \frac{(\log_e(x_i) - \bar{y})^2}{n-1}}$$

- vi. If log transformation does not bring about normality (*i.e.*, the probability of  $G$  is less than 0.01), compute nonparametric prediction limits as in section 3 (USEPA 1992 section 5.2.3). (Option - compute Poisson prediction limits as in section 3.4 - see USEPA 1992 section 2.2.4).

(b) Case 2: Compounds Quantified in at Least 50% of All Background Samples

- i. Apply the multiple group Shapiro-Wilk test to the  $n_1$  quantified measurements only.
- ii. If the data are normally distributed compute the mean of the  $n$  background samples as:

$$\bar{x} = \left( 1 - \frac{n_0}{n} \right) \bar{x}'$$

where  $\bar{x}'$  is the average of the  $n_1$  detected values, and  $n_0$  is the number of samples in which the compound is not detected or is below the method detection limit. The standard deviation is:

$$s = \sqrt{\left( 1 - \frac{n_0}{n} \right) s'^2 + \frac{n_0}{n} \left( 1 - \frac{n_0 - 1}{n - 1} \right) \bar{x}'^2}$$



where  $s'$  is the standard deviation of the  $n_1$  detected measurements. The normal prediction limit can then be computed as previously described. This method is due to Aitchison (1955) - (see USEPA 1992 section 2.2.2).

- iii. If the multiple group Shapiro-Wilk test reveals that the data are lognormally distributed, replace  $\bar{x}'$  with  $\bar{y}'$  and  $s'$  with  $s'_y$  in the equations for  $\bar{x}$  and  $s$ .
  - iv. The lognormal prediction limit may then be computed as previously described.
  - v. Note that this adjustment only applies to positive random variables. The natural logarithm of concentrations less than 1 are negative and therefore the adjustment does not apply. For this reason we add 1 to each value (*i.e.*,  $\log_e(x_i + 1) \geq 0$ ), compute the prediction limit on a log scale and then subtract one from the antilog of the prediction limit.
  - vi. If the data are neither normally or lognormally distributed, compute a nonparametric prediction limit. (Option - compute normal prediction limit).
- (c) Case 3: Compounds Quantified in less than 50% of All Background Samples
- i. In this application, the nonparametric prediction limit is the largest concentration found in  $n$  upgradient measurements (USEPA 1992 section 4.2.1).
  - ii. Gibbons (1990, 1991) has shown that the confidence associated with this decision rule, following one or more verification resamples, is a function of the multivariate extension of the hypergeometric distribution (USEPA 1992 section 5.2.3).

- iii. Complete tabulations of confidence levels for  $n = 4, \dots, 100$ ,  $k = 1, \dots, 100$  future comparisons (*e.g.*, monitoring wells), and a variety of verification resampling plans are presented in Gibbons (1994). For example with 5 monitoring wells and 10 constituents (*i.e.*, 50 comparisons), we would require 40 background measurements to provide 95% confidence (USEPA 1992 section 5.2.3). Table 1 displays confidence levels for a single verification resample.
- iv. Note that from time to time samples may need to be diluted and the resulting reporting limit may be increased by an order of magnitude or more. In these cases, DUMPStat substitutes the median reporting limit for all nondetects so that the nonparametric prediction limit will not be artificially set to an elevated reporting limit.
- v. As an option to the nonparametric prediction limits, DUMPStat can compute Poisson prediction limits. Poisson prediction limits are useful for those cases in which there are too few background measurements to achieve an adequate site-wide false positive rate using the nonparametric approach. Gibbons (1987) derived the Poisson prediction limit as

$$\text{Poisson PL} = y/n + \frac{t^2}{2n} + t/n\sqrt{y(1+n) + t^2/4}.$$

where  $y$  is the sum of the detected measurements or reporting limit for those samples in which the constituent was not detected and  $t$  is the  $(1 - \alpha)100$  upper percentage point of Student's  $t$ -distribution (USEPA 1992 section 2.2.4). More recent work in this area suggests that a more conservative approach is to substitute the normal multiplier  $z$  for  $t$  using a value of  $\alpha$  as previously described. The normal multiplier is now used in DUMPStat.

**TABLE 1**  
**PROBABILITY THAT THE FIRST SAMPLE OR THE VERIFICATION RESAMPLE**  
**WILL BE BELOW THE MAXIMUM OF n BACKGROUND MEASUREMENTS**  
**AT EACH OF k MONITORING WELLS FOR A SINGLE CONSTITUENT**

Previous n	Number of Monitoring Wells (k)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4	.933	.881	.838	.802	.771	.744	.720	.698	.679	.661	.645	.630	.617	.604	.592
5	.952	.913	.879	.849	.823	.800	.779	.760	.742	.726	.711	.697	.684	.672	.661
6	.964	.933	.906	.882	.860	.840	.822	.805	.789	.774	.761	.748	.736	.725	.714
7	.972	.947	.925	.905	.886	.869	.853	.838	.825	.812	.799	.788	.777	.766	.757
8	.978	.958	.939	.922	.906	.891	.878	.864	.852	.841	.830	.819	.809	.800	.791
9	.982	.965	.949	.935	.921	.908	.896	.885	.874	.864	.854	.844	.835	.827	.818
10	.985	.971	.957	.945	.933	.922	.911	.901	.891	.882	.873	.865	.857	.849	.841
11	.987	.975	.964	.953	.942	.933	.923	.914	.906	.897	.889	.882	.874	.867	.860
12	.989	.979	.969	.959	.950	.941	.933	.925	.917	.910	.902	.896	.889	.882	.876
13	.990	.981	.973	.964	.956	.948	.941	.934	.927	.920	.914	.907	.901	.895	.889
14	.992	.984	.976	.969	.961	.954	.948	.941	.935	.929	.923	.917	.912	.906	.901
15	.993	.986	.979	.972	.966	.959	.953	.947	.942	.936	.931	.926	.920	.915	.910
16	.993	.987	.981	.975	.969	.964	.958	.953	.948	.943	.938	.933	.928	.923	.919
17	.994	.988	.983	.978	.972	.967	.962	.957	.953	.948	.943	.939	.935	.930	.926
18	.995	.990	.985	.980	.975	.970	.966	.961	.957	.953	.949	.944	.940	.937	.933
19	.995	.991	.986	.982	.977	.973	.969	.965	.961	.957	.953	.949	.946	.942	.938
20	.996	.991	.987	.983	.979	.975	.972	.968	.964	.960	.957	.953	.950	.947	.943
25	.997	.994	.992	.989	.986	.984	.981	.978	.976	.973	.971	.968	.966	.964	.961
30	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.974	.972
35	.998	.997	.996	.994	.993	.991	.990	.988	.987	.986	.984	.983	.981	.980	.979
40	.999	.998	.997	.995	.994	.993	.992	.991	.990	.989	.988	.987	.985	.984	.983
45	.999	.998	.997	.996	.995	.995	.994	.993	.992	.991	.990	.989	.988	.987	.987
50	.999	.998	.998	.997	.996	.996	.995	.994	.993	.993	.992	.991	.990	.990	.989
60	.999	.999	.998	.998	.997	.997	.996	.996	.995	.995	.994	.994	.993	.993	.992
70	1.00	.999	.999	.998	.998	.998	.997	.997	.997	.996	.996	.995	.995	.995	.994
80	1.00	.999	.999	.999	.998	.998	.998	.998	.997	.997	.997	.996	.996	.996	.996
90	1.00	1.00	.999	.999	.999	.999	.998	.998	.998	.998	.997	.997	.997	.997	.996
100	1.00	1.00	.999	.999	.999	.999	.999	.998	.998	.998	.998	.998	.997	.997	.997

Previous n	Number of Monitoring Wells (k)														
	20	25	30	35	40	45	50	55	60	65	70	75	80	90	100
4	.542	.504	.474	.449	.428	.410	.394	.380	.367	.356	.345	.336	.327	.312	.299
5	.612	.574	.543	.517	.495	.476	.459	.443	.430	.417	.406	.396	.386	.369	.355
6	.668	.631	.600	.574	.552	.532	.514	.499	.484	.472	.460	.449	.439	.420	.405
7	.713	.678	.648	.623	.600	.580	.563	.547	.532	.519	.507	.496	.485	.466	.450
8	.750	.717	.688	.664	.642	.622	.605	.589	.574	.561	.549	.537	.527	.507	.490
9	.781	.750	.723	.699	.678	.659	.642	.626	.612	.598	.586	.574	.564	.544	.527
10	.807	.777	.752	.729	.709	.691	.674	.659	.644	.631	.619	.608	.597	.578	.560
11	.828	.801	.777	.755	.736	.718	.702	.687	.674	.661	.649	.638	.627	.608	.590
12	.847	.821	.799	.778	.760	.743	.727	.713	.700	.687	.675	.664	.654	.635	.618
13	.862	.839	.817	.798	.781	.764	.750	.736	.723	.711	.699	.689	.678	.660	.643
14	.876	.854	.834	.816	.799	.784	.769	.756	.744	.732	.721	.710	.701	.682	.666
15	.888	.867	.848	.831	.815	.801	.787	.774	.762	.751	.740	.730	.721	.703	.686
16	.898	.879	.861	.845	.830	.816	.803	.791	.779	.768	.758	.748	.739	.722	.706
17	.907	.889	.872	.857	.843	.830	.817	.806	.794	.784	.774	.765	.756	.739	.723
18	.914	.898	.882	.868	.855	.842	.830	.819	.808	.798	.789	.780	.771	.754	.739
19	.921	.906	.891	.878	.865	.853	.842	.831	.821	.811	.802	.793	.785	.769	.754
20	.928	.913	.899	.886	.874	.863	.852	.842	.832	.823	.814	.806	.798	.782	.768
25	.950	.939	.929	.919	.910	.901	.892	.884	.876	.869	.862	.855	.848	.835	.823
30	.963	.955	.947	.940	.932	.925	.919	.912	.906	.900	.894	.888	.882	.872	.861
35	.972	.966	.959	.954	.948	.942	.937	.931	.926	.921	.916	.911	.907	.898	.889
40	.978	.973	.968	.963	.958	.954	.949	.945	.941	.936	.932	.928	.924	.917	.909
45	.982	.978	.974	.970	.966	.962	.959	.955	.951	.948	.944	.941	.938	.931	.925
50	.985	.982	.979	.975	.972	.969	.966	.963	.959	.956	.954	.951	.948	.942	.937
60	.990	.987	.985	.982	.980	.978	.975	.973	.971	.968	.966	.964	.962	.958	.954
70	.992	.990	.989	.987	.985	.983	.981	.980	.978	.976	.974	.973	.971	.968	.965
80	.994	.993	.991	.990	.988	.987	.986	.984	.983	.981	.980	.979	.977	.975	.972
90	.995	.994	.993	.992	.991	.990	.988	.987	.986	.985	.984	.983	.982	.980	.978
100	.996	.995	.994	.993	.992	.991	.991	.990	.989	.988	.987	.986	.985	.983	.982

## 2. Intra-Well Comparisons

One particularly good method for computing intra-well comparisons is the combined Shewhart-CUSUM control chart (USEPA 1992 section

6.1). The method is sensitive to both gradual and rapid releases and is also useful as a method of detecting “trends” in data. Note that this method should be used on wells unaffected by the landfill. There are several approaches to implementing the method and in the following one useful way is described as well as discussion of some statistical properties.

(a) Assumptions

The combined Shewhart-CUSUM control chart procedure assumes that the data are *independent* and *normally* distributed with a *fixed* mean  $\mu$  and constant variance  $\sigma^2$ . The most important assumption is independence, and as a result wells should be sampled *no more* frequently than quarterly. In some cases, where ground-water moves relatively quickly, it may be possible to accelerate background sampling to eight samples in a single year; however, this should only be done to establish background and not for routine monitoring. The assumption of normality is somewhat less of a concern, and if problematic, natural log or square root transformation of the observed data should be adequate for most practical applications. For this method, nondetects can be replaced by the method detection limit without serious consequence. This procedure should *only* be applied to those constituents that are detected at least in 25% of all samples, otherwise,  $\sigma^2$  is not adequately defined.

(b) Nondetects

- i. For those well and constituent combinations in which the detection frequency is less than 25%, we will provide graphical display of these data until a sufficient number of measurements are available to provide 99% confidence (*i.e.*, 1% false positive rate) for an individual well and constituent using a nonparametric prediction limit, which in this context is the maximum detected value out of the  $n$  historical measurements. As previously discussed this amounts to 13 background samples for 1 resample, 8 background samples for pass 1 of 2 resamples and 18 background samples for pass 2 of 2 resamples. It should be obvious that if nonparametric prediction limits are to be used for intra-well comparisons of rarely detected constituents, two verification resamples will often be required and failure will

only be indicated if *both* measurements exceed the limit (*i.e.*, the maximum of the first 8 samples).

- ii. For those cases in which the detection frequency is greater than 25%, DUMPStat substitutes the median reporting limit for the nondetects. In this way, changes in reporting limits do not appear to be significant trends.
- iii. If nothing is detected in 8, 13 or 18 independent samples (depending on resampling strategy), DUMPStat uses the reporting limit as the control limit.
- iv. As in the previously described inter-well comparisons, DUMPStat provides optional use of Poisson prediction limits as an alternative to nonparametric prediction limits for rarely detected constituents (*i.e.*, less than 25% detects). Poisson prediction limits can be computed after 8 background measurements regardless of detection frequency.

(c) Procedure

- i. DUMPStat requires that at least 8 historical independent samples are available to provide reliable estimates of the mean  $\mu$  and standard deviation  $\sigma$ , of the constituent's concentration in each well.
- ii. DUMPStat selects the three Shewhart-CUSUM parameters  $h$  (the value against which the cumulative sum will be compared),  $k$  (a parameter related to the displacement that should be quickly detected), and  $SCL$  (the upper Shewhart limit which is the number of standard deviation units for an immediate release). Lucas (1982) and Starks (1988) suggest that  $k = 1$ ,  $h = 5$ , and  $SCL = 4.5$  are most appropriate for ground-water monitoring applications. This sentiment is echoed by USEPA in their interim final guidance document *Statistical analysis of ground-water monitoring data at RCRA facilities* (April, 1989). Also see USEPA 1992 section 6.1. For ease of application, however, we have selected  $h = SCL = 4.5$ , which is slightly more conservative than the value of  $h = 5$  suggested by USEPA.
- iii. Denote the new measurement at time-point  $t_i$  as  $x_i$ .

- iv. Compute the standardized value  $z_i$

$$z_i = \frac{x_i - \bar{x}}{s}$$

where  $\bar{x}$  and  $s$  are the mean and standard deviation of the at least 8 historical measurements for that well and constituent (collected in a period of no less than one year).

- v. At each time period,  $t_i$ , compute the cumulative sum  $S_i$ , as

$$S_i = \max[0, (z_i - k) + S_{i-1}]$$

where  $\max[A, B]$  is the maximum of A and B, starting with  $S_0 = 0$ .

- vi. Plot the values of  $S_i$  (y-axis) versus  $t_i$  (x-axis) on a time chart. Declare an “out-of-control” situation on sampling period  $t_i$  if for the first time,  $S_i \geq h$  or  $z_i \geq SCL$ . Any such designation, however, must be verified on the next round of sampling, before further investigation is indicated.
- vii. The reader should note that unlike prediction limits which provide a fixed confidence level (*e.g.*, 95%) for a given number of future comparisons, control charts do not provide explicit confidence levels, and do not adjust for the number of future comparisons. The selection of  $h = SCL = 4.5$  and  $k = 1$  is based on USEPA’s own review of the literature and simulations (see Lucas, 1982; Starks, 1988; and USEPA, 1989). USEPA indicates that these values “allow a displacement of two standard deviations to be detected quickly.” Since 1.96 standard deviation units corresponds to 95% confidence on a normal distribution, we can have approximately 95% confidence for this method as well.
- viii. In terms of plotting the results, it is more intuitive to plot values in their original metric (*e.g.*,  $\mu\text{g/l}$ ) rather than in standard deviation units. In this case  $h = SCL = \bar{x} + 4.5s$  and the  $S_i$  are converted to the concentration metric by the transformation  $S_i * s + \bar{x}$ , noting that when normalized (*i.e.*, in standard deviation units)  $\bar{x} = 0$  and  $s = 1$  so that  $h = SCL = 4.5$  and  $S_i * 1 + 0 = S_i$ .
- ix. When  $n \geq 12$  Starks (1988) and USEPA (1992) suggest that  $k = .75$ , and  $h = SCL = 4.0$  provide more conservative control

limits and this approach is now used in DUMPStat.

(d) Outliers

- i. From time to time, inconsistently large or small values (outliers) can be observed due to sampling, laboratory, transportation, transcription errors, or even by chance alone. The verification resampling procedure that we have proposed will tremendously reduce the probability of concluding that an impact has occurred if such an anomalous value is obtained for any of these reasons. However, nothing has eliminated the chance that such errors might be included in the historical measurements for a particular well and constituent. If such erroneous values (either too high or too low) are included in the historical database, the result would be an artificial increase in the magnitude of the control limit, and a corresponding increase in the false negative rate of the statistical test (*i.e.*, conclude that there is no site impact when in fact there is).
- ii. To remove the possibility of this type of error, the historical data are screened for each well and constituent for the existence of outliers (USEPA 1992 section 6.2) using the well known method described by Dixon (*Biometrics*, 1953, **9**, 74-89). These outlying data points are indicated on the control charts (using a different symbol), but are excluded from the measurements that are used to compute the background mean and standard deviation. In the future, new measurements that turn out to be outliers, in that they exceed the control limit, will be dealt with by verification resampling in downgradient wells only.
- iii. This same outlier detection algorithm is applied to each up-gradient well and constituent to screen outliers for inter-well comparisons as well.

(e) Existing Trends

If contamination is pre-existing, trends will often be observed in the background database from which the mean and variance are computed. This will lead to upward biased estimates and grossly inflated control limits. To remove this possibility, we first screen the background data for each well and constituent for trend using Sen's

(1986) nonparametric estimate of trend. Confidence limits for this trend estimate are given by Gilbert (1987). A significant trend is one in which the 99% lower confidence bound is greater than zero. In this way, even pre-existing trends in the background dataset will be detected.

(f) A Note on Verification Sampling

- i. It should be noted that when a new monitoring value is an outlier, perhaps due to a transcription error, sampling error, or analytical error, the Shewhart and CUSUM portions of the control chart are affected quite differently. The Shewhart portion of the control chart compares each individual new measurement to the control limit, therefore, the next monitoring event measurement constitutes an independent verification of the original result. In contrast, however, the CUSUM procedure incorporates *all* historical values in the computation, therefore, the effect of the outlier will be present for both the initial and verification sample; hence the statistical test will be invalid.
- ii. For example, assume  $\bar{x} = 50$ , and  $s = 10$ . On quarter 1 the new monitoring value is 50, so  $z = (50 - 50)/10 = 0$  and  $S_i = \max[0, (z - 1) + 0] = 0$ . On quarter 2, a sampling error occurs and the reported value is 200, yielding  $z = (200 - 50)/10 = 15$  and  $S_i = \max[0, (15 - 1) + 0] = 14$ , which is considerably larger than 4.5; hence an initial exceedance is recorded. On the next round of sampling, the previous result is not confirmed, because the result is back to 50. Inspection of the CUSUM, however, yields  $z = (50 - 50)/10 = 0$  and  $S_i = \max[0, (0 - 1) + 14] = 13$ , which would be taken as a confirmation of the exceedance, when in fact, no such confirmation was observed. For this reason, the verification must *replace* the suspected result in order to have an unbiased confirmation.

(g) Updating the Control Chart

- i. As monitoring continues and the process is shown to be in control, the background mean and variance should be updated periodically to incorporate these new data. Every year or two, all new data that are *in control* should be pooled with the



initial samples and  $\bar{x}$  and  $s$  recomputed. These new values of  $\bar{x}$  and  $s$  will then be used in constructing future control charts. This updating process should continue for the life of the facility and/or monitoring program (USEPA 1992 section 6.2).

- ii. DUMPStat allows the user to update background by changing the time window menu option. This option sets a window of time for which background summary statistics are computed. Changing the maximum date will incorporate new data into the background limit estimate. Note that this time window applies to computing background for both inter-well and intra-well comparisons.

(h) An Alternative Based on Prediction Limits

- i. An alternative approach to intra-well comparisons involves computation of well-specific prediction limits. Prediction limits are somewhat more sensitive to immediate releases but less sensitive to gradual releases than the combined Shewhart-CUSUM control charts. Prediction limits are also less robust to deviations from distributional assumptions.
- ii. As an alternative to combined Shewhart-CUSUM control charts DUMPStat can compute normal prediction limits as described in the previous section on inter-well comparisons.
- iii. For detection frequencies greater than 25%, nondetects are replaced with the median reporting limit. For detection frequencies less than 25%, either nonparametric or Poisson prediction limits are computed depending on what option the user has selected (*i.e.*, rare-event statistic window).

3. Comparison to a Standard

- (a) For assessment or corrective action, it is often required that samples from a potentially impacted well be compared to a ground-water quality protection standard such as an MCL or ACL. DUMPStat's assessment monitoring module provides tabular and graphical display of this comparison based on tests of increasing and decreasing trend and comparison of the standard to the upper 95% normal confidence limit applied to the last four independent samples.

- (b) The 95% confidence limit for the mean of the last four measurements is computed as

$$\bar{x} + t_{[3, .05]} \frac{s}{2} .$$

- (c) Nondetects are replaced by one-half of the reporting limit since with only four measurements, more sophisticated statistical adjustments are not appropriate.

#### E. Some Methods to be Avoided

In the following sections some statistical methods that should be avoided are described.

##### 1. Analysis of Variance - ANOVA

Application of ANOVA procedures to ground-water detection monitoring programs, both parametric and nonparametric is inadvisable for the following reasons.

- (a) Univariate ANOVA procedures do not adjust for multiple comparisons due to multiple constituents which can be devastating to the site-wide false positive rate) As such, a site with 10 indicator constituents will have a 40% chance of failing at least one on every monitoring event (USEPA 1992 section 5.2.1).
- (b) ANOVA is more sensitive to spatial variability than contamination. Spatial variability effects mean concentrations but typically not the variance, hence small yet consistent differences will achieve statistical significance. In contrast, contamination effects both variability and mean concentration, therefore a much larger effect is required to achieve statistical significance. In fact, application of ANOVA methods to pre-disposal ground-water monitoring data can result in statistically significant differences between upgradient and downgradient wells, despite the fact that there is no waste in between. The reasons for this are: (a) The overall F-statistic tests the null hypothesis of no differences among any of the wells regardless of gradient (*i.e.*, it will be significant if two downgradient wells are

different), and (b) The distribution of the mean of 4 measurements (*i.e.*, four measurements collected from the same well within a six month period) is normal with mean  $\mu$  and variance  $\sigma^2/4$  whereas the distribution of each of the individual measurements is normal with mean  $\mu$  and variance  $\sigma^2$ . This means that the standard deviation of the mean of four measurements is one-half the size of the standard deviation of the individual measurements themselves. As a result, small but consistent geochemical differences that are invariably observed naturally across a waste disposal facility will be attributed to contamination. To make matters worse, since there are far more downgradient than upgradient wells at these facilities, spatial variation has a far greater chance of occurrence downgradient than upgradient further increasing the likelihood of falsely concluding that contamination is present. While spatial variation is also a problem for prediction limits and tolerance limits for single future measurements, it is not nearly as severe a problem as for ANOVA since the distribution of the individual measurement is considered and not the more restrictive distribution of the sample mean.

- (c) Nonparametric ANOVA is often presented by USEPA as if it protects the user from all of the weaknesses of its parametric counterpart. This is *not* the case. Both methods assume identical distributions for the analyte in *all* monitoring wells. The only difference is that the parametric ANOVA assumes that the distribution is normal and the nonparametric ANOVA is indifferent to what the distribution is. Both parametric and nonparametric ANOVA assume homogeneity of variance, a condition that almost never occurs in practice. This is not a weakness of methods for single future samples (*i.e.*, prediction and tolerance limits) since the variance estimates rely solely on the background data. Why would anyone want to use downgradient data from an existing site (which could be affected by the site) to characterize natural variability? Yet this is exactly what the ANOVA does. Furthermore, ANOVA is not a good statistical technique for detecting a narrow plume that might effect only one of 10 or 20 monitoring wells (USEPA 1992 section 5.2.1).

- (d) ANOVA requires the pooling of downgradient data. Specifically, USEPA has suggested that four samples per semi-annual monitoring event be collected (*i.e.*, eight samples per year). As such, on average, it will never most rapidly detect a release, since only a subset of the required four semi-annual samples will be affected by a site impact. This heterogeneity will decrease the mean concentration and dramatically increase the variance for the affected well thereby limiting the ability of the statistical test to detect contamination when it occurs. This is not true for tolerance limits, prediction limits and control charts, which can and *should* be applied to individual measurements. USEPA may like ANOVA because it will appear to be more powerful than prediction and tolerance limits for single future values. The increased power, however, is only realized when all four measurements from a single well are equally affected by the site impact which on average will only occur 25% of the time (*i.e.*, if four semi-annual sampling events are evenly spaced, all four will be impacted by a new release only one in four times). For these reasons, when applied to ground-water detection monitoring, ANOVA will maximize both false positive and false negative rates, and double the cost of monitoring (*i.e.*, ANOVA requires four samples per semi-annual event or eight per year versus a maximum of four quarterly samples per year for prediction or tolerance limits that test each new individual measurement).

To illustrate, consider the data in Table 2 which were obtained from a facility in which no disposal of waste has yet occurred (see Gibbons, 1994 *NSWMA WasteTech Conference Proceedings*, Charleston SC, 1/14/94).

**TABLE 2**

Raw Data for All Detection Monitoring  
Wells and Constituents (mg/l)  
This Landfill has no Garbage in it

Well	Event	TOC	TKN	COD	ALK
MW01	1	5.2000	.8000	44.0000	58.0000
MW01	2	6.8500	.9000	13.0000	49.0000
MW01	3	4.1500	.5000	13.0000	40.0000
MW01	4	15.1500	.5000	40.0000	42.0000
MW02	1	1.6000	1.6000	11.0000	59.0000
MW02	2	6.2500	.3000	10.0000	82.0000
MW02	3	1.4500	.7000	10.0000	54.0000
MW02	4	1.0000	.2000	13.0000	51.0000
MW03	1	1.0000	1.8000	28.0000	39.0000
MW03	2	1.9500	.4000	10.0000	70.0000
MW03	3	1.5000	.3000	11.0000	42.0000
MW03	4	4.8000	.5000	26.0000	42.0000
MW04	1	4.1500	1.5000	41.0000	54.0000
MW04	2	1.0000	.3000	10.0000	40.0000
MW04	3	1.9500	.3000	24.0000	32.0000
MW04	4	1.2500	.4000	45.0000	28.0000
MW05	1	2.1500	.6000	39.0000	51.0000
MW05	2	1.0000	.4000	26.0000	55.0000
MW05	3	19.6000	.3000	31.0000	60.0000
MW05	4	1.0000	.2000	48.0000	52.0000
MW06	1	1.4000	.8000	22.0000	118.0000
MW06	2	1.0000	.2000	23.0000	66.0000
MW06	3	1.5000	.5000	25.0000	59.0000
MW06	4	20.5500	.4000	28.0000	63.0000
P14	1	2.0500	.2000	10.0000	79.0000
P14	2	1.0500	.3000	10.0000	96.0000
P14	3	5.1000	.5000	10.0000	89.0000

Results of applying both parametric and nonparametric ANOVA to these predisposal data yielded an effect that approached significance for Chemical Oxygen Demand (COD) ( $p < .072$  parametric and  $p < .066$  nonparametric) and a significant difference for Alkalinity (ALK) ( $p < .002$  parametric and  $p < .009$  nonparametric). In terms of individual comparisons, significantly increased COD levels were found for well MW05 ( $p < .026$ ) and significantly increased ALK was found for wells MW06 ( $p < .026$ ) and P14 ( $p < .003$ ) relative to upgradient wells. Of course, these

results represent false positives due to spatial variability, since there is no garbage. What is perhaps most remarkable, however, is the absence of any significant results for TOC, where some of the values are as much as 20 times higher than the others. The reason, of course, is that these extreme values tremendously increase the within-well variance estimate, rendering the ANOVA powerless to detect any differences regardless of magnitude. This is yet another testimonial to why it is environmentally negligent to average measurements from downgradient monitoring wells, a problem that is inherent to ANOVA-type analyses when applied to dynamic ground-water quality measurements. The elevated TOC data are clearly inconsistent with chance expectations and should be investigated. In this case, however, they are likely due to insects getting into the wells since this greenfield facility is in the middle of the Mohave desert.

## 2. Cochran's Approximation to the Behrens Fisher $t$ -test

Although no longer required, for years the USEPA RCRA regulation was based on application of the Cochran's approximation to the Behrens Fisher (CABF)  $t$ -test. The test was incorrectly implemented by requiring that four quarterly upgradient samples from a single well and single samples from a minimum of three downgradient wells each be divided into four aliquots and treated as if there were  $4n$  independent measurements. The net result was that every hazardous waste disposal facility regulated under RCRA was declared "leaking." As an illustration consider the data in Table 3.

**TABLE 3**  
 Illustration of pH Data Used in Computing  
 the CABF  $t$ -test

the GABP t-test					
Date	Replicate				Average
	1	2	3	4	
Background					
11/81	7.77	7.76	7.78	7.78	7.77
2/82	7.74	7.80	7.82	7.85	7.80
5/82	7.40	7.40	7.40	7.40	7.40
8/82	7.50	7.50	7.50	7.50	7.50
$\bar{X}_B$		7.62			7.62
$SD_B$		0.18			0.20
$N_B$		16			4
Monitoring					
9/83	7.39	7.40	7.38	7.42	7.40
$\bar{X}_B$		7.40			7.40
$SD_B$		0.02			
$N_B$		4			1

Note that the aliquots are almost perfectly correlated and add virtually no independent information yet they are assumed to be completely independent by the statistic. The CABF  $t$ -test is computed as

$$t = \frac{\bar{X}_B - \bar{X}_M}{\sqrt{\frac{S_B^2}{N_B} + \frac{S_M^2}{N_M}}} = \frac{7.62 - 7.40}{\sqrt{\frac{.032}{16} + \frac{.0004}{4}}} = \frac{.22}{.05} = 4.82 .$$

The associated probability of this test statistic is 1 in 10,000 indicating that the chance that the new monitoring measurement came from the same population as the background measurements is 1 in 10,000. Note that in fact, the mean concentration of the four aliquots for the new monitoring measurement is identical to one of the four mean values for background, suggesting that intuitively the probability is closer to 1 in

4 rather than 1 in 10,000. Averaging the aliquots, which should have never been split in the first place, yields the statistic

$$t = \frac{\bar{X}_B - \bar{X}_M}{S_B \sqrt{\frac{1}{N_B} + 1}} = \frac{7.62 - 7.40}{.20 \sqrt{\frac{1}{4} + 1}} = \frac{.22}{.22} = 1.0$$

which has an associated probability of 1 in 2. Had the sample size been increased to  $N_B = 20$  the probability would have decreased to 1 in 3. It took U.S. EPA six years to recognize this flaw and to change this regulation (see USEPA 1988).

### 3. Control of False Positive Rate by Constituent

Site-wide false positive and false negative rates are more important than choice of statistic, nonetheless, certain statistics make it impossible to control the site-wide false positive rate because the rate is controlled separately for each constituent (*e.g.*, parametric and nonparametric ANOVA - see USEPA 1992 section 5.2.1). The only important false positive rate is the one which includes all monitoring wells and all constituents, since any single exceedance can trigger an assessment. This criterion impacts greatly on the selection of statistical method. These error rates are dependent on the number of wells, number of constituents, number of background measurements, type of comparison (*i.e.*, intra-well versus inter-well), distributional form of the constituents, detection frequency of the constituents and the individual comparison false positive rate of the statistic being used. Invariably, this leads to a problem in interval estimation the solution of which is typically a prediction limit that incorporates the effects of verification resampling as well as multiple comparisons introduced by both multiple monitoring wells and multiple monitoring constituents.

### 4. Restriction of Background Samples

Certain states have interpreted the Subtitle D regulation as indicating that background be confined to the first four samples collected in a day or a semi-annual monitoring event or a year. The first approach (*i.e.*, four samples in a day violates the assumption of independence and confounds day to day temporal and seasonal variability with potential contamination. As an analogy, consider setting limits on yearly ambient



temperatures in Chicago by taking four temperature readings on July 4th. Say the temperature varied between 75 and 85 degrees on that day yielding a prediction interval from 70 to 90 degrees. As I write this, the temperature in Chicago is -20 degrees. Something is clearly amiss. In the second example of restricting background to the first four events taken in 6 months, the measurements may be independent if ground water flows fast enough, but seasonal variability is confounded with contamination. The net result is that comparisons of background water quality in the summer may not be representative of point of compliance water quality in the winter (*e.g.*, disposal of road salts increasing conductivity in the winter). In the third example in which background is restricted to the first four quarterly measurements, independence is typically not an issue and background versus point of compliance monitoring well comparisons are not confounded with season. However, as previously pointed out in the site-specific illustration, restriction of background to only four samples dramatically increases the size of the statistical prediction limit thereby increasing the false negative rate of the test (*i.e.*, the prediction limit is over five standard deviation units above the background mean concentration). The reason for this is that the uncertainty in the true mean concentration covers the majority of the normal distribution. As such we could obtain virtually any mean and standard deviation by chance alone. If by chance the values are low, false positive results will occur. If by chance the values are high, false negative results will occur. By increasing the background sample size, uncertainty in the sample based mean and standard deviation decrease as does the size of the prediction limit, therefore both false positive and false negative rates are minimized. Furthermore, use of statistical outlier detection procedures applied to the background data will remove the possibility of spurious background results falsely inflating the size of the prediction limit.

## F. Results of Application at the Temple RDF

In the following, results of site-specific analysis of the existing monitoring program are described.

### 1. Monitoring Well Network

A list of upgradient and downgradient monitoring wells are provided in the following Table.

Current Upgradient and Downgradient Monitoring Wells

Upgradient	Downgradient
MW01	MW03
MW02	MW04
	MW05R
	MW06
	MW07
	MW08
	MW09
	MW10
	MW11
	MW12
	MW13
	MW14

A list of the constituents used in the analysis is provided in the following Table.

Constituents used in the Analysis

<u>Constituent</u>
Alkalinity (as $\text{CaCO}_3$ )
Antimony-dissolved
Arsenic-dissolved
Barium-dissolved
Beryllium-dissolved
Cadmium-dissolved
Calcium-dissolved
Chloride
Chromium-dissolved
Cobalt-dissolved
Iron-dissolved
Lead-dissolved
Magnesium-dissolved
Manganese-dissolved
Nickel-dissolved
Nitrogen, ammonia
Nitrogen, nitrate
Nitrogen, total kjeldahl
Potassium-dissolved
Selenium-dissolved
Silver-dissolved
Sodium-dissolved
Solids, total dissolved
Sulfate
Thallium-dissolved
Total organic carbon
Vanadium-dissolved
Zinc-dissolved
<u>Appendix I VOCs</u>

## 2. Comparison to Leachate

In an effort to obtain the most relevant site-specific list of monitoring constituents, concentrations of monitoring constituents in leachate were compared to the upgradient prediction limits in the following Table.

Most Current Leachate Monitoring Data					
Constituent	Units	Well	Date	Result	Pred. Limit
Alkalinity (as $\text{CaCO}_3$ )	mg/L	LCS01	03/30/1995	788.0000	688.9567
Alkalinity (as $\text{CaCO}_3$ )	mg/L	TANK	06/09/1998	884.0000	688.9567
Antimony-total	ug/L	LCS01	03/30/1995	2.2000	3.0000
Antimony-total	ug/L	TANK	06/09/1998	60.0000	3.0000
Arsenic-total	ug/L	LCS01	03/30/1995	50.7000	10.0000
Arsenic-total	ug/L	TANK	06/09/1998	34.5000	10.0000
Barium-total	ug/L	LCS01	03/30/1995	2120.0000	280.1689
Barium-total	ug/L	TANK	06/09/1998	2480.0000	280.1689
Beryllium-total	ug/L	LCS01	03/30/1995	0.6000	2.0000
Beryllium-total	ug/L	TANK	06/09/1998	5.0000	2.0000
Cadmium-total	ug/L	LCS01	03/30/1995	5.0000	5.4000
Cadmium-total	ug/L	TANK	06/09/1998	5.0000	5.4000
Calcium-total	ug/L	LCS01	03/30/1995	222000.0000	301683.0257
Calcium-total	ug/L	TANK	06/09/1998	174000.0000	301683.0257
Chloride	mg/L	LCS01	03/30/1995	159.0000	228.2979
Chloride	mg/L	TANK	06/09/1998	373.0000	228.2979
Chromium-total	ug/L	LCS01	03/30/1995	10.0000	10.0000
Chromium-total	ug/L	TANK	06/09/1998	10.0000	10.0000
Cobalt-total	ug/L	LCS01	03/30/1995	50.0000	50.0000
Cobalt-total	ug/L	TANK	06/09/1998	50.0000	50.0000
Iron-total	ug/L	LCS01	03/30/1995	41700.0000	100.0000
Iron-total	ug/L	TANK	06/09/1998	4580.0000	100.0000
Lead-total	ug/L	LCS01	03/30/1995	5.0000	5.0000
Lead-total	ug/L	TANK	06/09/1998	5.0000	5.0000
Magnesium-total	ug/L	LCS01	03/30/1995	19800.0000	15448.3601
Magnesium-total	ug/L	TANK	06/09/1998	24000.0000	15448.3601
Manganese-total	ug/L	LCS01	03/30/1995	2330.0000	90.8487
Manganese-total	ug/L	TANK	06/09/1998	423.0000	90.8487
Nickel-total	ug/L	LCS01	03/30/1995	40.0000	40.0000
Nickel-total	ug/L	TANK	06/09/1998	50.5000	40.0000
Nitrogen, ammonia	mg/L	LCS01	03/30/1995	20.0000	0.8300
Nitrogen, ammonia	mg/L	TANK	06/09/1998	42.6000	0.8300
Nitrogen, nitrate	mg/L	LCS01	03/30/1995	0.0500	12.5689
Nitrogen, nitrate	mg/L	TANK	06/09/1998	0.0500	12.5689
Nitrogen, total kjeldahl	mg/L	LCS01	03/30/1995	23.9000	3.5000
Nitrogen, total kjeldahl	mg/L	TANK	06/09/1998	80.0000	3.5000
Potassium-total	ug/L	LCS01	03/30/1995	17200.0000	3328.9153
Potassium-total	ug/L	TANK	06/09/1998	21500.0000	3328.9153
Selenium-total	ug/L	LCS01	03/30/1995	5.0000	5.0000
Selenium-total	ug/L	TANK	06/09/1998	5.0000	5.0000
Silver-total	ug/L	LCS01	03/30/1995	25.0000	25.0000
Silver-total	ug/L	TANK	06/09/1998	25.0000	25.0000
Sodium-total	ug/L	LCS01	03/30/1995	129000.0000	116826.1018
Sodium-total	ug/L	TANK	06/09/1998	277000.0000	116826.1018
Solids, total dissolved	mg/L	LCS01	03/30/1995	1070.0000	1208.8797
Solids, total dissolved	mg/L	TANK	06/09/1998	1500.0000	1208.8797
Sulfate	mg/L	LCS01	03/30/1995	22.4000	246.3714
Sulfate	mg/L	TANK	06/09/1998	15.0000	246.3714
Thallium-total	ug/L	LCS01	03/30/1995	2.0000	38.1000
Thallium-total	ug/L	TANK	06/09/1998	2.0000	38.1000
Total organic carbon	mg/L	LCS01	03/30/1995	74.1000	27.6000
Total organic carbon	mg/L	TANK	06/09/1998	65.3000	27.6000
Vanadium-total	ug/L	LCS01	03/30/1995	50.0000	50.1000
Vanadium-total	ug/L	TANK	06/09/1998	50.0000	50.1000
Zinc-total	ug/L	LCS01	03/30/1995	22.5000	20.0000
Zinc-total	ug/L	TANK	06/09/1998	47.6000	20.0000

Among these constituents, only antimony, arsenic, barium, iron, manganese, nitrogen ammonia, TKN, and potassium provide a clear contrast

with upgradient ground-water quality. In the following sections, analysis is restricted to this subset of leachate indicator constituents and Appendix I list VOCs.

### 3. Upgradient versus Downgradient Comparisons

Results of upgradient versus downgradient comparisons are presented in Appendix A. All historical data for each downgradient well and constituent is displayed graphically along with the upgradient prediction limit (*i.e.*, horizontal line). All historical upgradient data were used in computing the prediction limits, hence the shaded background time line covers the entire x-axis. Raw upgradient data with outliers indicated are displayed in Table 1 for all constituents. Current downgradient monitoring results with statistical exceedances noted are displayed in Table 2. Comparison of detection frequencies in upgradient and downgradient wells is presented in Table 3. Tests of distributional form and corresponding type of prediction limit selected are displayed in Table 4. Computed prediction limit values and intermediate statistics for normal and lognormal prediction limits and confidence levels for nonparametric prediction limits are displayed in Table 5. Historical data for those downgradient monitoring wells that exceeded an upgradient prediction limit (whether they were verified or not) are displayed in Table 6.

Inspection of Table 2 of Appendix A revealed verified exceedances of upgradient limits for iron and manganese in MW08 and potassium in MW09. Inspection of Table 6 in Appendix A and associated graphs reveals that these wells and constituents have historically been at similar levels. Initial exceedances for antimony (MW04 and MW07) and potassium (MW08) were noted and are awaiting verification.

### 4. Intra-well Comparisons

In general, given (1) the presence of spatial variability, (2) the absence of any detected volatile organic compounds (which are present in large concentrations in the facility's leachate) and (3) the absence of any significant trend in historical concentrations, intra-well comparisons are the method of choice. Combined Shewhart-CUSUM control charts are displayed graphically for all wells and constituents in Appendix B. Summary statistics and intermediate computations are displayed in Table 1 of Appendix B.

All wells and constituents were automatically tested for trend using Sen's nonparametric test prior to analysis and none were found. No exceedances of control limits were found.

## 5. Statistical Power

Statistical power curves for the facility-wide false positive and false negative rates are presented at the end of each Appendix. For upgradient versus downgradient comparisons the false positive rate is 10% and the test becomes sensitive to 5 standard deviation unit increases over background. For intra-well comparisons the false positive rate is 20% and the test becomes sensitive to 2.5 to 3 standard deviation unit increases over background. These false positive rate for intra-well comparisons will be reduced to the 5% level with additional sampling.

## 6. VOCs

Historical detections of all Appendix I VOCs are displayed in Appendix C. Inspection of Table 1 in Appendix C reveals that the only verified detection of a VOC was 11-DCA in upgradient well MW02. This finding further questions the usefulness of inter-well comparisons at this site.

## 7. Summary

The absence of detected VOCs and any clear increasing trends support the general use of intra-well comparisons using combined Shewhart-CUSUM control charts for routine monitoring at this facility.

Application of this methodology revealed no statistically significant exceedances of control limits at any downgradient well. Despite the appropriateness of the statistical methodology at the site, the overall site-wide false positive rate was still high (approximately 20% for intra-well comparisons). This rate can be reduced to the intended 5% level with the addition of approximately four more samples in each well. From the available leachate data, only antimony, arsenic, barium, iron, manganese, nitrogen ammonia, TKN, and potassium provide a clear contrast with upgradient ground-water quality.

In light of these results we propose to perform intra-well comparisons using combined Shewhart-CUSUM control charts for routine detection monitoring at this facility. In addition, we will monitor VOCs and a

verified quantification of a VOC will be used as a trigger level. For the next four monitoring events we will continue to update background in an effort to reduce the site-wide false positive rate to 5%. At that time, background will be fixed for a period of two years and reupdated at that time for all wells that have not exhibited a verified exceedance. This process will continue for the life of the facility. Statistical analysis will be restricted to the 8 leachate indicator constituents and Appendix I VOCs.

## Some Relevant Literature

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**APPENDIX III-5C**

**MONITORING WELL SURVEY DATA FROM SURVEYING AND MAPPING, LLC (SAM)**

**TEMPLE RECYCLING & DISPOSAL FACILITY  
TCEQ PERMIT NO. MSW 692B  
MONITORING WELL AND PIEZOMETER LOCATIONS**

<b>NORTHING</b>	<b>EASTING</b>	<b>ELEVATION</b>	<b>DESCRIPTION</b>
521791.4560	2950687.4290	555.6600	PZ GA14 CONCRETE
522436.9720	2949849.4810	562.2500	PZ GA26 CONCRETE
522814.4360	2951366.2100	574.8100	PZ GA25 CONCRETE
523900.6760	2950848.6320	601.7500	PZ GA24 CONCRETE
524541.7070	2951930.4730	569.7700	PZ GA23 CONCRETE
525519.4280	2950919.7820	571.0000	PZ GA22 CONCRETE
526529.0770	2947762.8350	598.2900	PZ GA4 CONCRETE
526653.9250	2949382.6810	562.2700	PVC TOP GMP-5
523211.8640	2946809.9020	574.2100	MW-4 CONCRETE
523556.7850	2946338.7520	578.6500	MW-3 CONCRETE
522769.6430	2948413.8020	563.4100	MW-15R CONCRETE
526093.0360	2946700.5070	633.2800	GMP-1 CONCRETE
525971.5140	2947222.3280	619.3000	PVC TOP MW-21
525977.0210	2947205.3900	617.2400	GMP-2 CONCRETE
525713.7450	2948109.7100	609.6000	GMP-3 CONCRETE
525817.6070	2947761.7500	623.5200	MW-20 CONCRETE
523041.3110	2947195.0630	576.4400	PVC TOP MW-19
522886.3880	2947423.0750	571.1500	MW-5R CONCRETE
522759.4070	2948615.7880	563.9500	GMP-10 CONCRETE
523078.9990	2948483.8180	570.8400	PVC TOP MW-15
522944.2800	2948020.7120	569.0100	MW-06 CONCRETE
522956.0140	2948029.5480	568.7400	GMP-11 CONCRETE
524039.6330	2946034.0580	594.7900	PVC TOP MW-22
525541.1450	2946457.3800	633.9600	PVC TOP MW-1
523438.1540	2948815.3910	572.9600	MW-07 CONCRETE
523592.9410	2948872.9340	576.1400	GMP-9 CONCRETE
524003.5760	2949001.0820	591.4000	PVC TOP MW-16
524148.2210	2949348.5110	589.8800	MW-08 CONCRETE
524153.8060	2949364.7420	589.9300	GMP-8 CONCRETE
526637.4160	2948399.3610	586.1400	GMP-4 CONCRETE
524724.0250	2949558.7270	586.2400	MW-09 CONCRETE
525048.3750	2949652.5420	583.0000	GMP-7 CONCRETE
525310.1150	2949734.3810	578.1600	MW-10 CONCRETE
525919.5830	2949918.1370	568.0300	GMP-6 CONCRETE
525901.6020	2949883.7010	574.3800	PVC TOP MW-17
526374.8320	2949579.7070	573.9300	PVC TOP MW-18
526658.8510	2949345.1670	562.3800	MW-12 CONCRETE
526675.2450	2948738.2240	571.6900	MW-13 CONCRETE

**NOTE:** COORDINATES AND ELEVATIONS ARE BASED ON THE SITE SURVEY CONTROL SYSTEM

