GUIDANCE DOCUMENT

MONITORING REQUIREMENTS

FOR PERMITTED HAZARDOUS WASTE FACILITIES

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LIST OF ABBREVIATIONS

22 CCR	Title 22 of California Code of Regulations
23 CCR	Title 23 of California Code of Regulations
Appendix IX	Appendix IX to 22 CCR 66264 (Chapter 14)
Article 5	23 CCR
Article 6	22 CCR 66264.90 through 22 CCR 66264.100
Cal/EPA	California Environmental Protection Agency
CAP	corrective action program
CAMP	corrective action monitoring program
CCR	California Code of Regulations
CFR	Code of Federal Regulations
CMP	compliance monitoring program
CLGB	concentration limit greater than background
COC	constituents of concern
DMP	detection monitoring program
DTSC	Department of Toxic Substances Control
EMP	evaluation monitoring program
HERD	Human and Ecological Risk Division
HWF Permit	hazardous waste facility permit
MCL	maximum contaminant level
NAPL	non-aqueous phase liquid
O&M	operation and maintenance
POC	point of compliance
RWQCB	Regional Water Quality Control Board
SWRCB	State Water Resources Control Board
USCS	Unified Soil Classification System
VOC	volatile organic compound
WQPS	water quality protection standard
WQSAP	water quality sampling and analysis plan

1.0 INTRODUCTION

In California, the monitoring requirements for hazardous waste facilities are specified in Titles 22 and 23 of the California Code of Regulations (CCR) and are often referred to as Article 6 and Article 5, respectively. Title 22 is administered by the Department of Toxic Substances Control (DTSC) and Title 23 is administered by the State Water Resources Control Board (SWRCB). Although administered by different State agencies, the monitoring requirements specified in 22 CCR and 23 CCR are equivalent, with a minor exception [23 CCR 2550.7(e)(12)(B)]. The goals of 22 CCR and 23 CCR include the protection of human health and the environment from hazards posed by waste disposal and assurance that wastes are managed in a manner that is environmentally protective. Another 23 CCR goal is the protection of beneficial uses of water. Accomplishment of these goals for any waste management facility must be supported by monitoring programs that detect and assess releases to the environment.

1.1 REGULATORY MONITORING REQUIREMENTS

Article 6 (22 CCR 66264.90 through 66264.100) pertains to groundwater, surface water, and the unsaturated zone. This guidance is intended to assist facilities and regulators with development of monitoring programs that comply with the Article 6 (and Article 5) monitoring requirements. This guidance also addresses Article 17 (22 CCR 66264.700 through 66264.708) which pertains to environmental monitoring and response programs for air, soil and soil-pore gas for permitted facilities. This guidance is biased toward groundwater. However, it should assist the reader in establishing monitoring programs for other environmental media (e.g., surface water, unsaturated zone, air, soil, and soil-gas).

Although developed for permitted hazardous waste facilities, the concepts presented in this guidance document are also applicable to interim status facilities. The monitoring requirements for interim status facilities are found in 22 CCR, Division 4.5, Chapter 15, Article 6 (22 CCR 66265.90 through 66265.99). Appendix A summarizes the major differences between the Chapter 14 (permitted) and Chapter 15 (interim status) monitoring requirements.

1.2 INTENDED USE OF THIS GUIDANCE DOCUMENT

On a case-by-case basis, the information provided in this guidance may be applicable to permitted facilities and is provided for consideration during preparation of hazardous waste facility (HWF) permit conditions. Portions of this guidance may not be applicable to all facilities and should be used by DTSC staff according to need. The intent of this guidance is to provide the general approach to establishing, operating, and maintaining monitoring programs based on the experiences of DTSC staff in implementing 22 CCR. The actual monitoring program for a given facility must consider site-specific conditions and should be designed using site-specific information. The quantity and quality of site-specific data should be sufficient to support the design of the monitoring program.

This guidance should not be substituted for the requirements specified in the regulations. Always refer to the regulations when preparing HWF Permit language to satisfy monitoring requirements.

2.0 APPLICABILITY OF ARTICLE 6 [22 CCR 66264.90]

Article 6 is applicable to owners/operators of permitted surface impoundments, waste piles, land treatment units, or landfills that receive or have received hazardous waste after July 26, 1982 for the purpose of detecting, characterizing, and responding to releases to groundwater, surface water, or the unsaturated zone. Facilities that stopped receiving hazardous waste prior to July 26, 1982 may also be required to comply with Article 6 if DTSC determines that constituents in or derived from the waste pose a threat to human health or the environment. Article 6 is applicable to land disposal facilities that are active, undergoing closure, or that are not clean closed.

Miscellaneous units (as defined in 22 CCR 66260.10) are also subject to Article 6 as necessary to protect human health and the environment [22 CCR 66264.90(d)]. Aboveground and underground hazardous waste storage tanks are subject to Article 6 requirements during the post-closure care period if the facility cannot be clean closed (22 CCR 66264.197, 22 CCR 66265.197). As defined in 22 CCR 66260.10, sumps are treated as tanks for the purpose of assessing the applicability of Article 6.

2.1 CLEAN CLOSURE & POST-CLOSURE CARE REQUIREMENTS

Under 22 CCR 66264.117(a), clean closure requires removal of all hazardous wastes, waste residues, contaminated materials, and contaminated soils during closure below levels that are protective of human health and the environment. Concentrations of hazardous waste constituents in residual wastes and soils should be sufficiently low such that these concentrations will not impact groundwater, human health, or ecological receptors. Facilities having documented releases, or that cannot be clean closed, are subject to the post-closure care requirements (22 CCR 66264.117) and thus Article 6 monitoring requirements. Examples of facilities with documented releases that will require long-term monitoring include:

- Facilities with groundwater contamination exceeding maximum contaminant levels (MCLs) or Regional Water Quality Control Board (RWQCB) Basin Plan limits;

- Facilities with nonaqueous phase liquids (NAPLs) or other contamination requiring long-term cleanup;

- Facilitieswith soil contamination from mobile contaminants (e.g., volatile organic compounds (VOCs) or metal cyanides) that are likely to migrate and impact the beneficial use of groundwater.

Facilities expected to achieve clean closure within a short time frame may not be subject to post-closure care requirements, including groundwater monitoring. This determination must be made on a case-by-case basis and should be reevaluated during closure if new findings are made regarding the nature and extent of contamination or if it is determined that remediation cannot be completed. Examples of facilities expected to achieve clean closure within a short time frame include shallow soil contamination with immobile contaminants (e.g., some metals, polychlorinated biphenyls).

2.2 POST-CLOSURE CARE PERIOD

Post-closure HWF Permits are normally required for a minimum of 30 years after closure, unless a shorter post-closure period can be justified or all waste is removed and the facility was clean closed (see Section 2.1). The post-closure care period may be extended or reduced based on site-specific conditions [22 CCR 66264.117(b)(2)]. DTSC may extend the post-closure care period beyond the 30 year minimum to protect public health and the environment. Under 23 CCR 2580(a), the post-closure care period for Class I facilities "shall extend as long as the wastes pose a threat to water quality."

If the facility is clean closed, groundwater monitoring is required to demonstrate compliance with the water quality protection standard (WQPS) for a period of three consecutive years [22 CCR 66264.90(c)(1)]. This means the post-closure care period is extended each time the WQPS is exceeded.

3.0 MONITORING PROGRAMS [22 CCR 66264.91]

Article 6 provides for three types of monitoring programs, each having different monitoring objectives.

- **Detection Monitoring Program** (22 CCR 66264.98). The objectives of the detection monitoring program (DMP) are to determine whether a release has occurred and whether groundwater quality is being degraded.

- **Evaluation Monitoring Program** (22 CCR 66264.99). The objectives of an evaluation monitoring program (EMP) are to assess the nature and extent of a release and to design a corrective action program (CAP).

- **Corrective Action Monitoring Program** (22 CCR 66264.100). The objectives of a corrective action monitoring program (CAMP) are to demonstrate the effectiveness of the CAP, assess whether groundwater quality is improving, and to assess whether contamination is migrating away from the facility.

The monitoring system should be designed to support the monitoring objectives for the applicable program(s). For some sites, it may be appropriate to establish separate monitoring programs for different water-bearing units. For example, the facility may have impacted the water-bearing units closest to the ground surface, but has not impacted deeper water-bearing units. In this case, the upper units would fall under a CAMP and the deeper unit would fall under a DMP.

The HWF Permit specifies the type of monitoring program for each regulated unit and the elements of each monitoring program. The HWF Permit also outlines when the facility should move from one type of program to another. Examples of shifting from one monitoring program to another are as follows:

- **Detection Monitoring Program to Evaluation Monitoring Program**. A facility moves into an EMP when a statistically significant evidence of a release is verified under a DMP. The facility also moves into an EMP when physical evidence of a release is identified. Physical evidence of a release might include unexplained volume changes in a surface impoundment, visible signs of leachate migration, unexplained groundwater mounding beneath or adjacent to the regulated unit, and/or other appropriate evidence.

- **Evaluation Monitoring Program to Corrective Action Monitoring Program**. A facility moves from an EMP into a CAMP after the owner/operator has satisfactorily addressed (1) the nature and extent of a release, (2) collected sufficient data to support the remedy design, and (3) the corrective action design is complete.

- **Corrective Action Monitoring Program to Detection Monitoring Program**. Detection monitoring after completion of the corrective action is required under 22 CCR 66264.100(g). A facility moves into a DMP after the owner/operator has successfully demonstrated that the regulated unit is in compliance with the WQPS.

Moving from one monitoring program to another requires that the owner/operator submit an application for a HWF Permit modification and that DTSC approve the HWF Permit modification [22 CCR 66264.98(l)(2), 66264.99(f), 66264.99(d), 66264.100(g)(2)].

4.0 WATER QUALITY PROTECTION STANDARD [22 CCR 66264.92]

The monitoring program must include a WQPS comprised of the list of constituents of concern (COCs), concentration limits, monitoring points, and point of compliance (POC). Separate WQPS may be established for different monitoring programs.

4.1 CONSTITUENTS OF CONCERN [22 CCR 66264.93] AND MONITORING PARAMETERS

COCs are waste constituents, reaction products, and hazardous constituents that are reasonably expected to be in or derived from waste contained in the regulated unit. The selection of COCs should be based on the historical waste stream for the facility, the findings of site investigations, and expected derivatives of waste constituents.[1] The COC list should include many nonhazardous constituents and hazardous constituents.

Monitoring parameters are a set of parameters specified in the HWF Permit. A subset of COCs, monitoring parameters are measured more frequently than COCs and are used as surrogate indicators of water quality. Monitoring parameters include physical parameters, waste constituents, reaction products, and hazardous constituents that provide a reliable indication of a release from a regulated unit (22 CCR 66260.10).

4.2 CONCENTRATION LIMITS [22 CCR 66264.94]

Each COC identified in the HWF Permit must have a concentration limit.

4.2.1 Background Concentration Limits

For DMP and EMP, these concentration limits are the site-specific background data set. The background data set should be the same for each monitoring point unless:

- background differs for multiple surface water bodies, multiple aquifers, or geochemically distinct zones within the same aquifer; or

- the approved statistical method for a constituent includes intrawell comparison procedures (e.g., control charts).

For each regulated unit, the owner/operator is required to collect sufficient data for each COC and monitoring parameter to establish a background data set and to select the appropriate statistical methods for the applicable monitoring programs for all media. The statistical methods are used for determining statistically significant evidence of a release from a regulated unit and for determining compliance with the WQPS. The owner/operator is required to demonstrate that the proposed methods for determining the background data set and statistical protocol will be protective of human health and the environment and will comply with the performance standards outlined in 22 CCR 66264.97(e)(9).

The proposed methods for determining the background data set and protocol for statistical applications should be summarized in a Statistical Evaluation Plan. As discussed in Section

[1]From the perspective of the RWQCB, the COC list should include all constituents that could be mobilized from the waste at concentrations in excess of water quality objectives noted in the RWQCB Basin Plan.

13.2, the owner/operator must submit a Statistical Evaluation Plan to DTSC for review and approval. Developing a Statistical Evaluation Plan involves a multi-step process. First, the owner/operator must propose a method for determining and updating the background data set for each COC and monitoring parameter. Next, the owner/operator must select appropriate statistical methods for comparison of POC well data to the background values. The proposed statistical protocol should address all of the applicable performance standards outlined in Article 6. Refer to Section 13.2 and Appendix C for further details regarding development of a Statistical Evaluation Plan.

4.2.2 Concentration Limits Greater Than Background

For a CAMP, concentration limits greater than background (CLGB) may be proposed by the owner/operator and established with DTSC approval, after: (1) considering the criteria in 22 CCR 66264.94(d) and (e); (2) determining that it is technologically or economically infeasible to achieve background for that COC; and (3) determining that the COC will not pose a substantial present or potential hazard to human health or the environment as long as that concentration limit is not exceeded. CLGB cannot exceed the limits established by other applicable statutes or regulations (e.g., MCLs) and the lowest concentration that is technologically and economically achievable [22 CCR 66264.94(e)]. CLGB are applied within the plume area during corrective action and detection monitoring following corrective action. For DMP following the successful completion of a CAP, CLGB are reevaluated each time a new HWF Permit is issued to reflect natural decreases in concentration, if any.

The owner/operator should consult with the DTSC Human and Ecological Risk Division (HERD) when developing risk-based concentration limits. Contact the DTSC project manager for the appropriate contact person within HERD for a given facility.

4.3 MONITORING POINTS & POINT OF COMPLIANCE [22 CCR 66264.95]

The POC is defined as a vertical surface, located at the hydraulically downgradient limit of the regulated unit that extends through the uppermost aquifer underlying the unit (Figure 1). Each monitoring program must specify monitoring points at the POC and additional monitoring locations required under 22 CCR 66264.97 at which the WQPS applies and monitoring will be conducted. The POC and monitoring points can be specified for a single regulated unit or a contiguous group of regulated units. The POC may shift over time (seasonally, temporally, diurnally). The monitoring system needs to account for this shift.

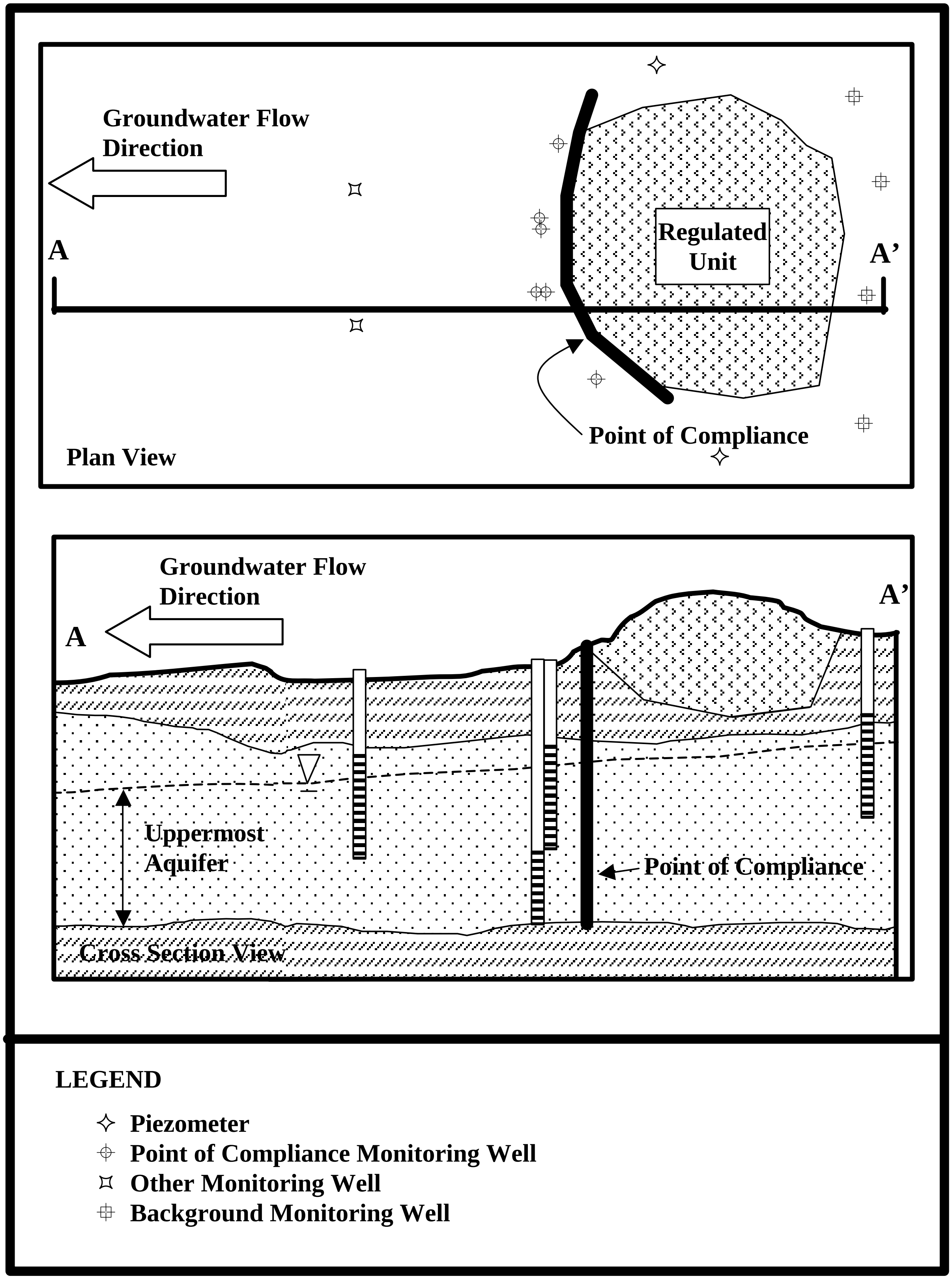

Figure 1a. Schematic Diagram of Point of Compliance for a DMP.

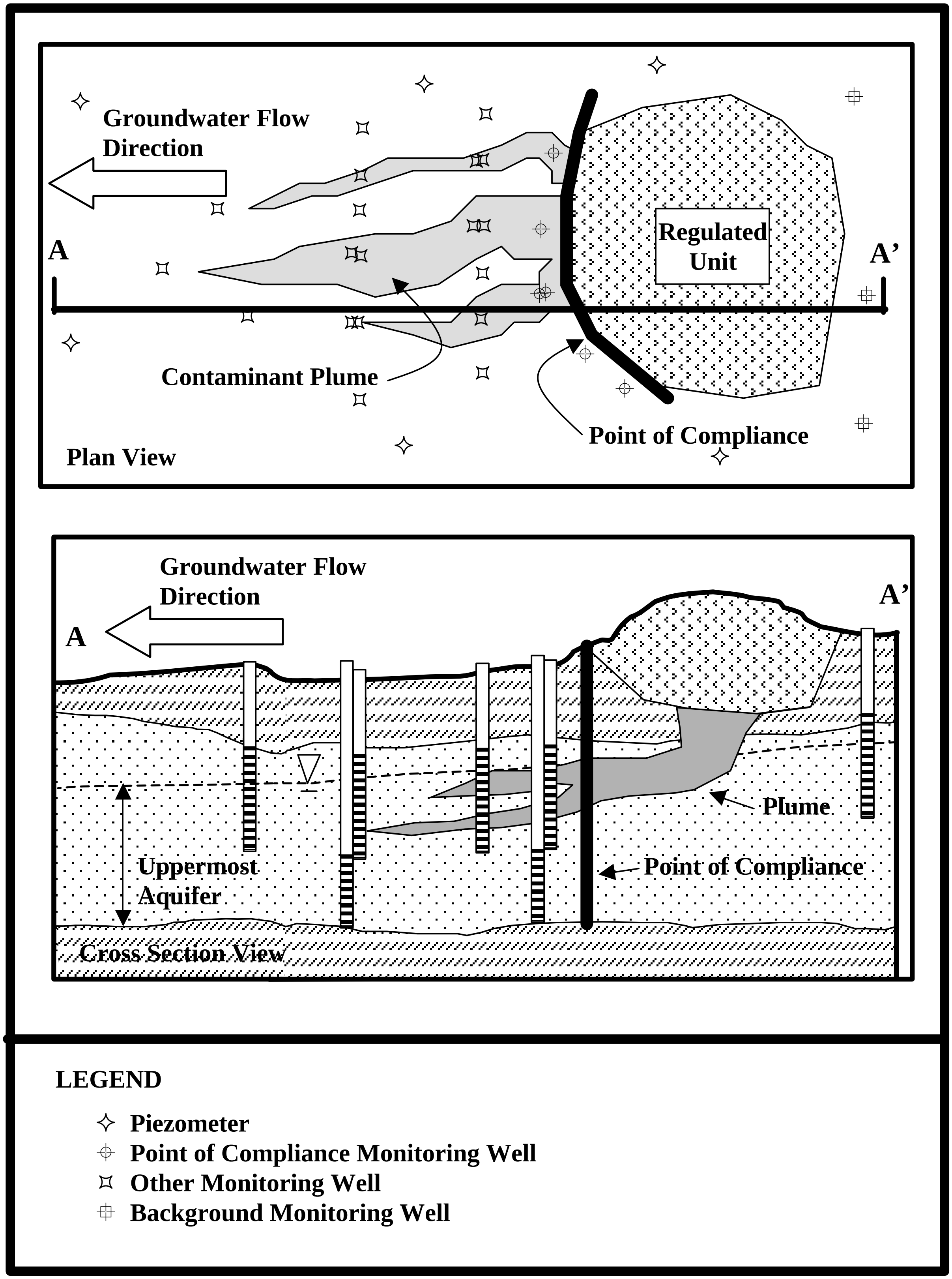

Figure 1b. Schematic Diagram of Point of Compliance for a CAMP.

5.0 COMPLIANCE PERIOD [22 CCR 66264.96]

The compliance period is the number of years equal to the active life[2] of the regulated unit and should only be of concern if it is appropriate to terminate Article 6 monitoring. The compliance period constitutes the minimum period of time during which the owner/operator must conduct a water quality monitoring program.

Unless a facility is clean closed, facilities are still subject to post-closure monitoring under Article 6 monitoring as specified in 22 CCR 66264.117. The post-closure monitoring period is a minimum of 30 years. DTSC may extend the post-closure monitoring period beyond the 30 year minimum to protect human health and the environment. Under 23 CCR 2580(a), the post-closure care monitoring period for Class I facilities "shall be extended for as long as wastes pose a threat to water quality."

If a facility is clean closed, the owner/operator must demonstrate compliance with the WQPS for three consecutive years before groundwater monitoring can cease and closure certification can be issued. For facilities under a CAMP, the compliance period is extended until the owner/operator demonstrates compliance with the WQPS for three consecutive years. The compliance period restarts each time the owner/operator initiates an EMP.

[2] The active life includes any waste management activity prior to permitting and the closure period.

6.0 FUNDAMENTAL QUESTIONS FOR GROUNDWATER MONITORING PROGRAM [22 CCR 66264.97]

The five fundamental questions associated with groundwater monitoring are an attempt to provide a framework for understanding the intent of a groundwater monitoring program and to promote a consistent statewide approach to groundwater monitoring. Among the benefits are a clearer understanding among regulators and the regulated community of the purpose of a groundwater monitoring program. The intent of addressing the five fundamental questions associated with a groundwater monitoring program is to focus more attention on the results of a comprehensive groundwater monitoring program rather than the methods of its implementation. The objective of a groundwater monitoring program is to detect releases or to define the rate and extent of contaminant migration from a regulated unit pursuant to Article 6.

6.1 WHAT IS THE UPPERMOST AQUIFER? [22 CCR 66264.97(b)(1)]

The uppermost aquifer is defined as the geologic formation nearest the ground surface that is an aquifer, as well as lower aquifers that are hydraulically connected to the uppermost aquifer (22 CCR 66260.10). The owner/operator must identify the uppermost aquifer (which includes any hydraulically interconnected underlying aquifers) beneath the facility. Surface water that is hydraulically connected to the uppermost aquifer must also be addressed by the groundwater monitoring program, regardless of whether the surface water is a gaining or losing water body. The underlying objective is to identify all likely flow paths for hazardous constituents that may leak from the facility. As such, many lines of evidence are available to determine whether aquifer interconnection is an issue for the facility. However, no single line of evidence may conclusively validate or invalidate aquifer interconnectivity. Hence, DTSC strongly recommends that the appropriate data, such as multiple lines of evidence, be obtained that yield compelling results. All hydrogeologic investigations should be designed, implemented, and reported by a qualified registered geologist, certified hydrogeologist, or licensed civil engineer.

Some lines of evidence that evaluate aquifer interconnection are as follows.

1) **Geochemistry**. Aquifers with differing geochemical signatures may be indicative of hydraulic isolation. Concentrations of common ions can be obtained and graphically displayed using trilinear, Stiff, Piper diagrams, etc. If geochemical patterns from two aquifers as presented on these diagrams show non-similar patterns, a lack of aquifer connection may be inferred.

2) **Tracer Tests**. Tracer tests can be used to evaluate aquifer interconnection under natural flow or pumping conditions. Common tracers include: naturally-occurring ions (e.g., chloride, bromide); environmental isotopes (e.g., deuterium, tritium, sulfate, boron, etc.); contaminants; and introduced compounds. Examples of introduced compounds include: radioisotopes, ionic species (e.g., halides), and organic compounds (e.g., rhodamine WT etc.).

3) **Radiometric Dating**. The radiometric dating of aquifer water may show hydraulic isolation. Two aquifers with differing radiometric ages suggest little interconnection. Common dating techniques are carbon-14 and tritium. Also, stable isotopic ratios, such as oxygen-16 and oxygen-18, can be used to identify individual water bearing units.

4) **Aquitard Character**. The character of the aquitard between two aquifers may suggest minimal hydraulic connection. Thick, homogeneous aquitards with hydraulic conductivity values that are significantly lower than the adjacent aquifers may suggest little aquifer interconnection. Aquitard thickness can be determined by drill core, boring logs and/or geophysics. Aquitard hydraulic conductivity can be determined by field or laboratory tests. Care must be taken to show that aquitards are not breached, either geologically or anthropomorphically, at a facility.

5) **Drawdown Test**. An aquifer pumping test while monitoring drawdown in the aquifer suspected of interconnection can be used to demonstrate aquifer interconnection. Pumping in one aquifer while showing that no drawdown occurs in adjacent aquifers is evidence for minimal interconnection. The drawdown test should be conducted for a sufficient duration, as determined by site-specific conditions, to ensure the validity of the test. Multiple wells should be monitored, both in the pumped aquifer and adjacent aquifers, during the drawdown test. Likewise, the pumping rate from the test well should be maximized to ensure that the aquifers are sufficiently stressed.

Additionally, the owner/operator should evaluate aquifer interconnection by preferential flow pathways. Preferential flow pathways that warrant evaluation, among others that are unique to site-specific conditions, are as follows.

- Abandoned wells (industrial, municipal, or agricultural)
- Improperly decommissioned wells
- Existing wells with poor annular seals
- Building caissons and pilings
- Sheetpiling
- Subsurface utility conduits and pipelines
- Faults in aquitard or aquifer
- Structural and desiccation fractures and joints in the aquitard
- Stratigraphic features (channels, high hydraulic conductivity unit within a low hydraulic conductivity aquifer)

6.2 WHAT IS THE GROUNDWATER FLOW RATE & DIRECTION?

The groundwater flow rate and direction, both the horizontal and vertical components, must be determined for each facility. By quantifying the groundwater flow rate and direction, POC wells can be properly located at a facility so that subsurface contamination can be detected at the earliest possible time and contaminant plumes can be monitored. To quantify the groundwater flow rate and direction, a sufficient number of groundwater monitoring wells must be installed at the facility. The wells must be sufficiently spaced and professionally surveyed to an appropriate datum so that the groundwater flow rate and direction can be accurately determined. Groundwater flow conditions beneath the facility must be identified and described in a report written by a qualified registered geologist, certified hydrogeologist, or licensed civil engineer. The report must be supported by field data and available professional literature.

Site-specific data necessary to determine the groundwater flow rate and direction are as follows.

1) **Hydrogeologic Properties**. The hydraulic conductivity, effective porosity, and hydraulic gradient should be determined at each facility so that the groundwater seepage velocity can

be quantified. This information will prove useful in understanding the rate and extent of any potential contamination at the facility. The hydraulic conductivity can be determined by aquifer pump tests, slug tests, packer tests, or laboratory permeameter tests. Effective porosity, which is the soil void space subject to groundwater flow, can be taken from literature values or specific yield can be used as the effective porosity for aquifers subject to unconfined conditions. The hydraulic gradient should be determined from static water levels in the groundwater monitoring well network by using a field sounding instrument capable of ±001 foot accuracy.

2) **Groundwater Flow Paths**. The owner/operator should determine whether the uppermost aquifer is subject to fractured or porous groundwater flow and design the groundwater monitoring network accordingly. Likewise, preferential groundwater flow paths should be determined, whether geologic or anthropomorphic, and the monitoring well locations should specifically target these areas.

3) **Reporting Requirements**. The potentiometric surface of the groundwater should be contoured and displayed on a facility site map. The hydraulic gradient should be quantified and presented within the associated reports. Additionally, hydrographs should be compiled for all the POC wells, and other wells, as appropriate, and presented in the reports. The hydrographs should have appropriate vertical and horizontal scales and should present all the data collected to date at the facility. To facilitate identification of local anomalies, the HWF Permit should require that hydrographs of *all related wells* be plotted on the same page [Note: This is only appropriate if the hydrograph is a useful depiction of hydraulic conditions and allows interpretation of hydraulic conditions]. It is also desirable that analytical data, including potentiometric data, be submitted to DTSC in an appropriate electronic format.

It should be noted that separate monitoring points may be necessary to monitor the hydraulic versus water quality conditions in the uppermost aquifer.

Additional guidance in conducting hydrogeologic investigations can be found in *Guidance Manual for Ground Water Investigations* (Cal/EPA 1995) and *Guidelines for Hydrogeologic Characterization of Hazardous Substance Release Sites* (Cal/EPA 1995). Portions of these guidelines are included as Appendix F.

6.3 WHAT IS THE RATIONALE FOR WELL PLACEMENT? [22 CCR 66264.97(b)(1)]

A clear rationale for the placement of wells must be presented. Well placement should consider:

- Purpose for each well (e.g, background, evaluation, detection, hydraulic control, plume migration)
- Horizontal location with respect to regulated units or releases
- Well screen interval elevations
- Flow direction and rate with respect to regulated units or releases
- For EMP, the depth and thickness of impacted water-bearing zones
- For DMP, the depth and thickness of zones likely to be first impacted by a release
- Assessment of background or ambient locations
- Size of the regulated unit

- Conceptual site model including contaminant transport pathways in vadose zone and aquifer

The rationale for well placement should be reevaluated each time the type of groundwater monitoring program changes (e.g., change from CAMP to DMP) to ensure that the well placement supports the monitoring objectives of the new program.

The groundwater monitoring system should include both a sufficient number of background monitoring points and monitoring points representative of groundwater passing the POC and/or release area. The actual number of monitoring points depends on the requirements of an effective monitoring system and must support the monitoring objectives. Selection of appropriate well positions is contingent upon an accurate knowledge of the groundwater flow direction and rate. Therefore, the groundwater monitoring system should include a sufficient number of monitoring points to monitor the hydraulic conditions in the uppermost aquifer. These hydraulic monitoring points may or may not be redundant with monitoring points used to assess water quality.

The screened interval should monitor the aquifer zone where contaminants are most likely to occur and ideally should be no longer than ten feet (Cal/EPA 1995). The selected screen interval will depend upon the characteristics of the wastes, the configuration of the regulated unit or release point, and the aquifer characteristics. The screen length may also dictate the type of purging and sampling method appropriate for the well. For example, low-flow sampling methods should not be used for wells with screen length greater than 10 feet (Puls and Barcelona 1995) without prior approval of DTSC. Further rationale for the ten-foot screen requirement for low-flow methods is provided in the next paragraph.

Wells with screen lengths longer than ten feet should not be purged via low-flow methods even if a short interval of the screen is packed off for sampling purposes. It is not possible to pack off a portion of the screened interval completely, given the fact that the filter pack typically has a higher hydraulic conductivity than the surrounding formation. This means that the entire screened interval is in good hydraulic connection with the "packed-off" interval, so all portions of the well bore, in the screened interval, will respond to pumping in the "packed-off" interval. The highest hydraulic conductivity is in the vertical direction, within the well screen. Although fresh formation water will flow into the well bore from all portions of the screened interval, in the portions above and below the packed-off interval, it will tend to enter the screen and then flow up (or down) to the packed-off interval and then pass through the filter-pack to the packed-off interval. Given the small purge volume, the majority of this flow will consist of stagnant water that has resided in the well bore (or filter pack) for some time. Therefore, the longer the screened interval, the slower will be the inward radial flow rate, locally, and the greater the proportion of the sample that will consist of stagnant water drawn from above and below the packed-off interval. Under such conditions, stabilized field parameters can lead one to believe, incorrectly, that one is obtaining mainly fresh formation water. The same effect prevails in the absence of packers. Low-flow sampling is usually the method that produces the best data quality. The objective, therefore, is to build the well with a short screened interval to allow its use.

6.4 WHAT IS THE RATIONALE FOR WELL DESIGN? [22 CCR 66264.97(b)(3) through (7)]

The rationale for well design and construction should be described in the monitoring program work plan. Wells should be designed to assure collection of representative groundwater data and produce water with sufficient low turbidity (generally less than 5 nephelometric turbidity units). The rationale should explain the following design characteristics:

- Well material and casing schedule.
- Well materials compatible with subsurface conditions and contaminants.
- Well diameter and depth.
- Screened interval elevation and length should be based on identification of geologic intervals most likely to transport contamination (both dissolved and non-aqueous phase).
- Filter pack and screen slot dimensions should be based on sieve analyses of the targeted water-bearing zone.
- Screen lengths exceeding ten feet should be based on the need for securing non-depth-specific contaminant data (based on continuous coring logs) or other monitoring objective. Screens lengths should not exceed ten feet because of the dilution effects of long screen intervals (Cal/EPA 1995). Installation of nested or clustered wells is highly encouraged.

Table 1 provides a complete list of construction and design components necessary for monitoring well installation. A table with these data should be included in the Water Quality Sampling and Analysis Plan (WQSAP) and the Part B Permit Application.

Specific guidance for well design is presented in *Guidance Manual for Ground Water Investigations* (Cal/EPA 1995; see Appendix F) and any DTSC-approved updates. Specific well construction details that should be provided in a summary table for DTSC review include the information presented in Table 1. If not already submitted to DTSC, complete borehole logs, well completion logs, and any geophysical logs should be submitted with the monitoring program plan.

6.5 WHAT IS THE NATURE & EXTENT OF CONTAMINATION? [22 CCR 66264.99(a)/(b)]

The monitoring plan should describe the nature and extent of contamination. To develop a description of the nature and extent of contamination, subsurface characterization should be performed which identifies contaminated water-bearing zones or intervals. Such characterization may include depth-discrete sampling using direct push technology and data from properly designed monitoring wells.

Aquifer characteristics that must be determined include:

- Hydraulic conductivity and effective porosity (to calculate seepage velocity).
- Horizontal and vertical hydraulic gradients
- Preferential migration pathways
- Transmissivity and storativity
- Aquifer thickness
- Lithology based on continuous core soil borings logged by or supervised by a California registered geologist or California licensed civil engineer using the Unified Soil Classification System (USCS)

- Cross sections based on boring logs
- Groundwater analysis for the appropriate COCs

Sufficient data regarding the nature and extent of contamination should be gathered and presented to support the rationale for corrective action/evaluation monitoring well placement. Facilities preparing a HWF Permit application should consult *Guidance Manual for Ground Water Investigations* (Cal/EPA 1995; see Appendix F) and DTSC-approved updates.

TABLE 1
WELL COMPLETION INFORMATION

- Well number
- Monitored waste management unit
- Northing and easting coordinates
- Datum elevation (determined by a California licensed surveyor, to 0.01 feet vertical and 0.1 feet horizontal)
- Ground elevation (determined by a California licensed surveyor, to 0.01 feet vertical and 0.1 feet horizontal)
- Installation date
- Drilling contractor
- Drilling method
- Development method and report
- Total borehole depth
- Borehole diameter
- Total well depth at time of installation
- Most recent total well depth measurement & date of measurement
- Casing material and diameter
- Screen material, diameter, slot size, and interval elevations
- Filter pack type and interval
- Well seal material and interval and method of emplacement.
- Grout mixture recipe[1] (one or more may apply to given well)
- Centralizers (presence or absence) and intervals
- Deviation survey results (amount of deviation per 100 feet)
- Casing collar indicator results
- Maintenance history
- Rationale for well installation
- Other pertinent information

[1]Indicate the grout recipe used for the annular seal:

Example 1: One 94-pound sack of Portland cement (Type I-II; A-B) and 5.5 gallons of potable water.

Example 2: One 94-pound sack of Portland cement (Type I-II; A-B), 2 pounds of pure, non-beneficiated bentonite, and 6.8 gallons of water.

7.0 SURFACE WATER MONITORING PROGRAMS [22 CCR 66264.97(c)]

Article 6 requires that owners/operators of permitted hazardous waste land disposal facilities have a surface water monitoring system to monitor each surface water body that could be affected by a release from a regulated unit. The surface water monitoring system must include the following:

- A sufficient number of background monitoring points in areas not affected by a release in surface water that have a similar character to the surface water near the regulated units.

- For DMP, a sufficient number of monitoring points to provide the best assurance of the earliest possible detection of a release.

- For EMP, a sufficient number of monitoring points to provide data necessary to evaluate changes in water quality caused by a release and to support the assessment of the nature and extent of the release [22 CCR 666264.99(b)].

- For CAMP, a sufficient number of monitoring points to provide data necessary to evaluate compliance with the WQPS and to evaluate the effectiveness of the CAP.

Further requirements for surface water DMP, EMP, and CAMP are discussed in Sections 9.0, 10.0, and 11.0, respectively.

7.1 SURFACE WATER MONITORING LOCATIONS

The surface monitoring system should be developed from the facility's site-specific hydrologic conditions. The location of the surface water monitoring points should be based upon the run-off patterns from the land disposal units, areas of potential leachate generation, and the discharge and recharge of groundwater in the area. All appropriate surface water, such as streams, rivers, lakes, wetlands, and marine environments, should be sampled before significant dilution can occur. Ephemeral or intermittent streams should be sampled at the appropriate frequency based on precipitation distribution. Perennial streams and rivers are continually engaged in a dynamic relationship with groundwater, either receiving groundwater discharge or recharging the groundwater over any given stream reach. These characteristics should be considered in the selection of surface water monitoring points. Sampling locations in lakes, ponds, wetlands, bays, lagoons, and estuaries should be based upon the horizontal and vertical mixing character of the water body.

7.2 SURFACE WATER SAMPLE COLLECTION

The intent of the sample collection is to obtain a representative sample of the surface water body. It is critical that samples be collected using techniques that assure their chemical and physical integrity. Consistency in the sampling method is essential for facilitating comparison to background concentrations. Hence, the surface water sampling techniques should be included in the WQSAP. The sample type may be composite or discrete and may involve automated or manual collection systems, depending upon application, as follows:

- **Grab Samples.** This method is appropriate for sampling concentrations at a single point in time from small, relatively uniform flow. A typical application is sampling of small ephemeral streams.

- **Time Integrated Samples.** This type of sampling is useful for evaluating average concentrations during extended runoff events, where samples are taken periodically and composited to yield average concentration over the duration of sampling. Autosamplers are frequently used for time integrated sampling.

- **Depth and Width Integrated Sampling.** When samples are taken from large lakes or large streams, it may be necessary to obtain spatially integrated samples across a perpendicular transect of the water body. Submersible constant intake samplers can be used to obtain such samples.

Along with analysis of the surface water for the COCs, a basic suite of water quality measurements including ambient water temperature, pH, specific conductance, and dissolved oxygen should be collected at the time of sampling.

8.0 VADOSE ZONE MONITORING PROGRAMS [22 CCR 66264.97(d)]

Article 6 requires that owners/operators of permitted hazardous waste land disposal facilities have a vadose (unsaturated) zone monitoring system for all regulated units. 22 CCR 66264.97(d)(4) requires liquid recovery unsaturated zone monitoring devices (e.g., lysimeters), but allows for complementary or alternative non-liquid recovery methods to be utilized. These non-liquid recovery methods can be used provided that the owner/operator demonstrates that liquid recovery methods cannot provide an indication of a release from the regulated unit. Alternative methods include vadose zone monitoring with neutron probes or time domain reflectometry. If the regulated unit contained volatile constituents, DTSC believes that soil gas monitoring would also apply as an alternative method. As soil gas monitoring is a proven technology, it is a highly recommended alternative and may also be required by 22 CCR Article 17.

Additional vadose zone monitoring requirements for land treatment units are found in 22 CCR 66264.97(d)(6).

8.1 EXEMPTION FROM VADOSE ZONE MONITORING

For new regulated units, 22 CCR 66264.97(d)(5) provides exemption language that allows for the owner/operator to demonstrate to DTSC that "no method for unsaturated zone monitoring can provide any indication of a release from that regulated unit." Exemption language for existing units consists of the owner/operator demonstrating to DTSC that "either there is no unsaturated zone monitoring device or method designed to operate under the subsurface conditions existent at that waste management unit or the installation of unsaturated zone monitoring devices would require unreasonable dismantling or relocating of permanent structures."

If soil gas monitoring is not a viable vadose zone monitoring option (e.g., no volatile constituents), DTSC and the owner/operator should consider, as appropriate, obtaining a variance from the vadose zone monitoring regulations. It has been DTSC's experience that vadose zone monitoring data are often difficult to obtain with lysimeters, can provide limited liquids for analyses, can provide compromised analytical data (especially VOC data), and can be difficult to interpret. As no Federal regulations regarding vadose zone monitoring exist, the variance could entail complete or partial elimination of the vadose zone monitoring program.

8.2 VADOSE ZONE MONITORING

A vadose zone monitoring system must include the following:

- A sufficient number of background monitoring points in areas not affected by a release in soils that have a similar character to the soil under the regulated units.

- For DMP, a sufficient number of monitoring points to provide the best assurance of the earliest possible detection of a release.

- For EMP, a sufficient number of monitoring points to provide data necessary to evaluate changes in water quality due to a release and to evaluate the nature and extent of the release [22 CCR 66264.99(b)].

- For CAMP, a sufficient number of monitoring points to provide data necessary to evaluate compliance with the WQPS and to evaluate the effectiveness of the CAP.

Further requirements for vadose zone DMP, EMP, and CAMP are discussed in Sections 9.0, 10.0, and 11.0, respectively.

8.3 VADOSE ZONE LIQUID RECOVERY

Vadose zone monitoring systems where liquid samples are obtained, which is the required method of vadose zone monitoring [22 CCR 66264.97(d)(4)], must have the sampling points directly below the land disposal units. The frequency and timing of the vadose zone sampling events must be a function of the character of the waste and native soil permeability. DTSC recommends that the vadose zone sampling be conducted at the same frequency as the frequency of the groundwater monitoring. The owner/operator must develop consistent sampling and analysis procedures for the vadose zone liquid sampling, similar to the requirements for groundwater sampling. Hence, the procedures for vadose zone sampling should be documented in the WQSAP. At a minimum, the WQSAP should include procedures for sample collection, sample preservation and shipment, analytical procedures, and chain-of-custody control. The liquid samples must be analyzed for appropriate COCs including potential degradation and transformation products.

Background concentrations for the vadose zone must be established for each COC based on quarterly sampling for one year. During each vadose zone monitoring event, the owner/operator shall determine whether there has been a statistically significant change of the soil-pore liquid concentrations under the land disposal unit as compared to background concentrations for each COC. The statistical tests used to make this evaluation can be the same statistical tests used in evaluation of the groundwater monitoring data. The owner/operator shall complete the statistical evaluation of the vadose zone data in a reasonable time period and report any statistically significant increase in the concentration in the soil-pore liquid to DTSC within 72 hours [22 CCR 66264.278(i)]. If evidence exists that hazardous constituents have migrated out of an active land disposal unit, the owner/operator shall cease operating the land disposal unit until either appropriate remedial action has been implemented and the HWF Permit has been modified or the owner/operator has demonstrated that a source other than the land disposal unit caused the increase.

The following guidance is provided for lysimeter construction, installation, and sampling.

- **Lysimeter Construction.** The type of hydrophilic porous material to be used in all lysimeters should be a non-ceramic material, such as glass, nylon, or Teflon. Ceramic cup lysimeters should not be used because of the potential for sorption of metals on the ceramic material. All lysimeters should be constructed with two pressurization tubes: one for sample retrieval and one for chamber depressurization. The lysimeter sample chamber should be sufficiently large for the collection of the appropriate sample volume.

- **Lysimeter Installation**. The lysimeter should be placed into a borehole that is 4 to 8 inches in diameter. A 12 inch layer of bentonite should be placed at the bottom of the lysimeter upon which silica flour slurry is poured. A water to silica flour mixture of 150 ml of water to 0.45 kilogram of silica is recommended for the slurry. It is critical to center the lysimeter within the borehole so that the silica flour is uniformly distributed around the lysimeter. A centralizer should be used if needed. The slurry should extend at least 12 inches above the lysimeter upon which another layer of bentonite is placed. More than one lysimeter can be placed into a borehole, but care should be taken to seal between the nested lysimeters.

- **Lysimeter Sampling.** The time needed to transfer pore water from the soil into the lysimeter should be based on the hydraulic conductivity of the porous cup in the lysimeter and the soil hydraulic conductivity.

8.4 VADOSE ZONE INDIRECT MEASUREMENTS

Increases in soil moisture mass under a land disposal unit can be monitored to determine if a release of leachate to the vadose zone has occurred. Numerous techniques are available to monitor soil moisture without the retrieval of a water sample. Two such techniques are neutron probe logging and time domain reflectometry.

A vadose zone moisture increase that would represent a release would be an increase in percent soil moisture content by a specified percent by weight (e.g., ≤5 percent) as compared to (1) the data from the previous sampling quarter, (2) data from the previous calendar year, and/or (3) baseline conditions. These exceedances would trigger notification to DTSC within 72 hours [22 CCR 66264.278(i)].

Based on DTSC experience, a vadose monitoring system that uses indirect measurement of soil-pore moisture should contain the following items:

- **Equipment Calibration.** All equipment used to measure the soil moisture content of the vadose zone should be calibrated daily before use to ensure proper equipment operation. The results of the calibration should be recorded on the field logs and kept at the facility.

- **Calibration to Soil Moisture.** Site-specific instrument calibration to the native soil of the facility should be conducted. Numerous soil samples, retrieved from the boreholes which will be used for neutron or reflectometry monitoring, should be analyzed for soil moisture by a laboratory. These same soil samples should be measured for their neutron or reflectometry response so that a calibration curve can be fitted to the data. This site-specific calibration curve should be used by the owner/operator for all data acquisition. If the owner/operator, in the future, decides to change the brand or make of the field instrument, the generation of new field calibration curves may be warranted.

- **Sample Measurements.** For the sake of data comparison, neutron or reflectometry measurements should be taken at the same position for each sampling event so that an accurate comparison of soil moisture can be obtained. Accordingly, logging cables should be calibrated yearly to ensure that cable stretch has not occurred.

- **Data Presentation.** The soil moisture content data from the current sampling event, the prior four sampling events, and the baseline condition, should be presented to DTSC in graphical and table format. The data should be presented in tables such that easy comparison between the sampling events can be made. Likewise, graphs of the moisture data versus the depth of or distance along the sample borehole should be presented for the current data and prior four sampling events.

The procedures for the field operation of either the neutron probe logging or the time domain reflectometry should be described in the WQSAP, along with calibration procedures and sample measurement protocols. Additional items should be included, as necessary, to provide step-by-step procedures.

8.5 SOIL GAS MONITORING

Soil gas monitoring may also be vadose zone monitoring option for regulated units with volatile constituents. Soil gas monitoring is discussed further in Section 12.0.

9.0 DETECTION MONITORING PROGRAM [22 CCR 66264.98]

DMP are established to provide the best assurance of earliest detection of releases from a regulated unit to groundwater, surface water, and the unsaturated zone. The requirements discussed in this section are applicable to groundwater, surface water, and the unsaturated zone. Although this section is written in the context of groundwater, the concepts discussed in this section should also assist the reader in developing DMP for surface water and vadose zone monitoring programs (should monitoring of these media be appropriate for the facility).

Generally, groundwater analytical data from downgradient POC wells located adjacent to the regulated unit along the POC are statistically compared to background concentration limits. However, as specified in 22 CCR 66264.95(a), additional monitoring points at other appropriate non-POC locations can be specified in the HWF Permit to detect a release. 22 CCR 66264.98(l) provides a course of action if a significant physical evidence of a release (e.g., soil coloration, water table mounding) is detected. A DMP is also to be established after successful completion of a CAP (see Section 11.0) as stated in 22 CCR 66264.98(n).

9.1 MONITORING REQUIREMENTS

The monitoring system must comply with general provisions provided in 22 CCR 66264.97, including establishing a background concentration limit for all contaminants (monitoring parameters and COC). Monitoring parameters are a list of constituents that provide a reliable indication of a release from the regulated unit [22 CCR 66264.98(e)]. These are often mobile constituents associated with waste in the unit, such as VOCs, that would be detected early by the groundwater monitoring system if a release to groundwater occurs. COC, on the other hand, represent all waste constituents associated with the regulated unit (see Section 4.1).

DMP monitoring parameters, sampling frequencies, and statistical analyses are to be specified in the HWF Permit. According to 22 CCR 66264.98(f) and 66264.97(e)(12), monitoring parameter sampling frequency is either quarterly, semiannually, or more frequently (as specified by DTSC), and should include times of expected highest and lowest annual groundwater elevations. Periodic sampling for COC is also described for DMP monitoring [22 CCR 66264.98(g)] at a frequency of at least every five years. It is recommended that a reliable and sizable groundwater database consisting of quarterly sampling for COC be amassed prior to reducing sampling frequency. Infrequent sampling should also consider contaminant characteristics and site-specific conditions.

The water quality data collected during monitoring must be maintained in a report and in a form to allow evaluation of the statistical procedures utilized.

9.2 RESPONSE TO AN UNVERIFIED EXCEEDANCE

If a contaminant or waste constituent (monitoring parameter or COC) is detected above background, the owner/operator can either immediately resample to verify the detection according to 22 CCR 66264.98(j)(2) or not resample and assume the detection is valid. If confirmed, all groundwater monitoring points must be sampled for all COC and Appendix IX constituents. It is assumed that "all groundwater monitoring points" refers only to DMP/POC wells as suggested in the Federal equivalent of 22 CCR: Code of Federal Regulations (CFR), Title 40, Parts 260 to 299, 264.98(g)(2) and 264.99(g). Appendix IX (22 CCR, Chapter 14) is a large list of constituents designed to screen for and determine whether additional hazardous constituents are present in groundwater. If Appendix IX constituents not already listed as COC are detected during this sampling, then additional resampling may be conducted. If confirmed, the constituent becomes a COC and additional data shall be collected as necessary to establish its background concentration.

In summary, DMP groundwater sampling can follow the following sequence for newly detected contaminants:

1) Detect contaminant during a conventional sampling event;
2) Conduct resampling to verify this first detection;
3) Conduct Appendix IX/COC sampling if resampling verifies the detection;
4) Conduct resampling to verify the Appendix IX detection.

9.3 RESPONSE TO A CONFIRMED EXCEEDANCE

Once an exceedance is confirmed, the owner/operator must notify DTSC in writing and move into an EMP as described in 22 CCR 66264.98(k)(5). A feasibility study is also to be prepared as described in 22 CCR 66264.98(k)(6). At a minimum, the feasibility study shall contain a detailed description of the corrective action measures that could be taken to achieve background concentrations for all COCs. Guidance regarding feasibility studies/corrective measures studies can be found in Chapter 7, Corrective Measures Study, within DTSC's June 1994 Corrective Action Orientation Manual (see especially Section 7.3.2). Chapter 7 of the Corrective Action Orientation Manual is included as Appendix E of this guidance document.

The owner/operator may demonstrate, to the satisfaction of DTSC, that the regulated unit has not caused the detected release [22 CCR 66264.98(k)(7)]. Similar demonstration language is contained in 22 CCR 66264.99(k)(3) regarding Appendix IX detections. A demonstration under 22 CCR 66264.98(k)(7) is conducted after Task 3 (see Section 9.2) and should consider all available data for the regulated unit. Examples of information that might be included in the demonstration report are as follows:

- demonstration of an in-control concentration of the exceeding parameter and supporting interpretation;
- graphs of concentration versus time for indicator parameters that are reasonably expected to indicate a release from the monitored unit and supporting interpretation;
- trend analyses;
- discussion of whether exceedance correlates with seasonal changes, water level fluctuations, or off-site impacts;
- discussion of whether exceedance correlates with lithology of screened interval;
- detailed discussion of vadose zone and leachate monitoring findings for regulated unit and supporting interpretation;
- geochemical evaluations for naturally-occurring parameters;
- assessment of monitoring point contribution to observed exceedance(s);
- assessment of sampling and analysis procedure contribution to observed exceedance(s);
- discussion of inspection results and any physical evidence of a release;
- other methods judged necessary by DTSC or owner/operator to support the demonstration.

If the owner/operator or DTSC determines that the DMP does not satisfy the requirements in 22 CCR 66264.98, then the owner/operator shall apply for a HWF Permit modification to make appropriate changes to the monitoring program.

9.4 REPORTING & NOTIFICATION REQUIREMENTS, & STIPULATED SCHEDULES

The following time critical requirements contained in the DMP regulations are summarized below for convenient reference (appropriate citations are contained in parentheses):

1. Owner/operator shall determine if a statistically significant evidence of a release has occurred (see Appendix C, Statistical Evaluation Plan) within a "reasonable period of time" that is specified in the HWF Permit [22 CCR 66264.98(i)(2)].

2. Owner/operator shall notify DTSC by certified mail within seven days after detecting a statistically significant evidence of release from the unit [22 CCR 66264.98(j)(1), 66264.98(l)(1)]. Within 90 days of this determination, the owner/operator shall submit an application for HWF Permit modification to establish an EMP [22 CCR 66264.98(k)(5)].

3. Owner/operator may "immediately" resample a well to verify a release (i.e., a detection of a monitoring parameter or COC above background) [22 CCR 66264.98(j)(2)].

4. Owner/operator shall " immediately" sample all monitoring points for all COC and Appendix IX constituents if a contaminant detection is confirmed by resampling [22 CCR 66264.98(k)(1) and (2)].

5. If Appendix IX constituents not already listed as COC are detected during Appendix IX sampling, the owner/operator may again resample within one month to confirm the detection [22 CCR 66264.98(k)(3)].

6. Within 90 days of the determination or DTSC notification that the DMP does not satisfy 22 CCR 66264.98 standards, the owner/operator shall submit an application for a HWF Permit modification to make appropriate changes to the program [22 CCR 66264.98(l)(2) and 66264.98(m)].

7. If the owner/operator intends to make an alternative source demonstration, the owner/operator must notify DTSC by certified mail within seven days of determining a release. Within 90 days the owner/operator must submit an alternative source demonstration report [22 CCR 66264.98(k)(7)].

10.0 EVALUATION MONITORING PROGRAM [22 CCR 66264.99]

EMP are established to assess the nature and extent of a known release(s) from a regulated unit. The requirements discussed in this section are applicable to groundwater, surface water, and the unsaturated zone. Although this section is written in the context of groundwater, the concepts discussed in this section should also assist the reader in developing EMP for surface water and vadose zone monitoring programs (should monitoring of these media be appropriate for the facility).

At a minimum, the assessment of nature and extent of a release must include a determination of the spatial distribution and concentration of all potential contaminants throughout the zone affected by the release. Information gathered from this program is intended to assist in the design of a CAP (see Section 11.0). The EMP is intended to be a program that is quickly implemented and completed, however, this is often not the case. As a result, some EMP standards can become burdensome (see Appendix IX sampling below) and it is advised that this program be expeditiously, yet thoroughly, implemented and a CAP established.

While many facilities will know the spatial distribution and constituents of a release, additional contaminants may be identified in the future (e.g., less mobile contaminants) at DMP wells along the POC. Therefore, one should expect that an EMP will be conducted in conjunction with DMP and/or CAMP.

10.1 REMEDIAL ACTION/CORRECTIVE MEASURES

Soon after implementation of the EMP and delineation of the nature and extent of the release, the owner/operator is to ready for remedial action/corrective measures. This is done by updating the engineering feasibility study required by 22 CCR 66264.98(k)(6) and applying for a HWF Permit modification to establish a CAMP. Minimum requirements to be included in the application are discussed in 22 CCR 66264.99(d) and include, among other things, the proposed corrective action measures and justified clean up values (background concentrations and/or alternative concentration limits).

22 CCR 66264.99(g) provides specific authority enabling DTSC to require interim corrective measures where necessary to protect human health or the environment.

10.2 MONITORING REQUIREMENTS

During an EMP and transition to a CAMP, the owner/operator is required to monitor groundwater, surface water, and the unsaturated zone for changes in water quality resulting from the release as specified in 22 CCR 66264.99(e). EMP monitoring parameters, sampling frequencies, statistical analyses, and other appropriate data analysis methods are to be specified in the HWF Permit. The monitoring system must comply with general provisions provided in 22 CCR 66264.97. According to 22 CCR 66264.99(e)(3) and 66264.97(e)(12) sampling frequency is either quarterly or semiannually (as specified by DTSC) and should include times of expected highest and lowest annual groundwater elevations. Sampling for COC is also contained in EMP monitoring [22 CCR 66264.99(e)(4)]; the frequency of sampling for COC is to be determined by DTSC.

The data collected from this monitoring must be maintained in a form (e.g, database, trend graphs, etc.) to evaluate changes in water quality. In addition, the data should be evaluated with respect to the design criteria for the proposed CAP. If the data suggest that the planned corrective measure is insufficient, then 22 CCR 66264.99(e)(7) describes actions required by the owner/operator to remedy the plan.

In conjunction with establishment of an EMP and while monitoring groundwater for changes in water quality, Appendix IX sampling is required annually at all monitoring points. This requirement should encourage owner/operators to quickly and appropriately characterize groundwater releases and enact remedial measures. Details regarding detecting Appendix IX constituents in wells, optional resampling to confirm those detections, and owner/operator time line/notification requirements are specified in 22 CCR 66264.99(e)(6).

If the owner/operator or DTSC determines that the EMP does not satisfy the requirements in 22 CCR 66264.99, then the owner/operator shall apply for a HWF Permit modification to make appropriate changes to the program.

10.3 DEMONSTRATION REPORT FOR RELEASES NOT CAUSED BY REGULATED UNIT

The owner/operator may demonstrate, to the satisfaction of DTSC, that the regulated unit has not caused the detected release and modify the HWF Permit to revert back to a DMP [22 CCR 66264.99(f)]. Similar demonstration language is contained in 22 CCR 66264.99(e)(6) regarding Appendix IX detections. The owner/operator shall continue to conduct an EMP until the HWF Permit is modified.

10.4 REPORTING & NOTIFICATION REQUIREMENTS, & STIPULATED SCHEDULES

The following time critical requirements contained in the EMP regulations are summarized below for convenient reference (appropriate citations are contained in parentheses). As noted below, a large amount of work is required within a small time frame (within 90 days of establishing an EMP). The owner/operator should be quickly reminded of this upcoming time constraint and aggressively assess the nature and extent of contamination, appropriately update the engineering feasibility study, and develop the CAMP plan while awaiting for inclusion of the EMP into the HWF Permit. This hiatus (prior to officially beginning the EMP) is a valuable time for doing assessment work. It should not be wasted.

1. Owner/operator shall complete and submit an assessment report on the nature and extent of contamination to DTSC within 90 days of establishing an EMP [22 CCR 66264.99(b)].

2. Owner/operator shall update the engineering feasibility study and submit it to DTSC within 90 days of establishing an EMP [22 CCR 66264.99(c)].

3. Owner/operator shall submit an application for a HWF Permit modification to establish a CAMP to DTSC within 90 days of establishing an EMP [22 CCR 66264.99(d)].

4. Owner/operator shall report the concentration of non-COC Appendix IX detections to DTSC by certified mail within seven days after analysis [22 CCR 66264.99(e)(6)].

5. Owner/operator may resample to confirm non-COC identified Appendix IX detections within one month after receipt of analyses [22 CCR 66264.99(e)(6)].

6. Owner/operator shall notify DTSC by certified mail within seven days after determining that water quality data indicate that the plan for corrective action is insufficient. Within 90 days of this determination, the owner/operator shall submit an application for a HWF Permit modification to make appropriate changes to the program [22 CCR 66264.99(e)(7)].

7. If the owner/operator intends to make an alternative source demonstration, owner/operator must notify DTSC by certified mail within seven days of determining a release [22 CCR 66264.99(f)(1)].

8. Within 90 days of the determination or DTSC notification that the EMP does not satisfy 22 CCR 66264.99 standards, the owner/operator shall submit an application for a HWF Permit modification to make appropriate changes to the program [22 CCR 66264.99(h) and 66264.99(f)].

11.0 CORRECTIVE ACTION MONITORING PROGRAM [22 CCR 66264.100]

CAMPs are established to monitor the progress of the CAP and to ensure compliance with the WQPS. The requirements discussed in this section are applicable to groundwater, surface water, and the unsaturated zone. Although this section is written in the context of groundwater, the concepts discussed in this section should also assist the reader in developing CAMP for surface water and vadose zone monitoring programs (should monitoring of these media be appropriate for the facility).

Of importance in the WQPS are concentration limits which cannot be exceeded. The concentration limits are therefore cleanup values and discussed in detail in Section 4.0 of this guidance document. Of special note from 22 CCR 66264.94, concentration limits cannot exceed MCLs at and beyond the POC as discussed in 22 CCR 66264.94(e). Also, CLGB can only be applied within the plume area during a CAMP or DMP that follows corrective action.

11.1 MONITORING REQUIREMENTS

In conjunction with corrective measures, a monitoring program must be established to demonstrate the effectiveness of the CAP. While an owner/operator may base a monitoring program on EMP requirements, the regulations do not require this and provide for greater flexibility in establishing a CAMP. This greater flexibility is exemplified by the brevity of standards set out in 22 CCR 66264.100. Reports addressing the effectiveness of the CAP are to be submitted to DTSC at least semiannually and more often if necessary.

As specified in 22 CCR 66264.100(c), the owner/operator shall take other actions specified by DTSC to prevent exceeding established groundwater concentration limits including, but not limited to, source control. These additional measures are to be specified in the HWF Permit.

If the owner/operator or DTSC determines that the CAMP does not satisfy the requirements in 22 CCR 66264.100, then the owner/operator shall apply for a HWF Permit modification to make appropriate changes to the program.

11.2 TERMINATION OF CORRECTIVE MEASURES

Corrective measures may be terminated when contaminant concentrations fall below established concentration limits. However, the CAMP remains until sampling data indicate that concentration limits have not been exceeded for a one year period and the owner/operator has applied for a HWF Permit modification to establish a DMP for all COC. For some facilities, this one-year period should be extended until sufficient data are collected to demonstrate compliance with the WQPS. For example, after cessation of groundwater recovery, at least a year of quarterly monitoring is necessary to evaluate whether the concentrations will rebound. Additional data collection may be necessary to assess whether the facility is ready to move from a CAMP to a DMP.

11.3 REPORTING & NOTIFICATION REQUIREMENTS, & STIPULATED SCHEDULES

The following time critical requirements contained in the CAP regulations are summarized below for convenient reference (appropriate citations are contained in parentheses):

1. Corrective action measures shall be initiated and completed by the owner/operator within a time period specified in the HWF Permit [22 CCR 66264.100(e)].

2. Owner/operator shall submit reports to DTSC addressing the effectiveness of corrective measures at least semiannually and more often if necessary [22 CCR 66264.100(h)].

3. Within 90 days of determination or notification that the CAMP does not satisfy 22 CCR 66264.100 standards, the owner/operator shall submit an application for a HWF Permit modification to make appropriate changes to the program [22 CCR 66264.100(i) and 66264.100(j)].

12.0 ARTICLE 17 ENVIRONMENTAL MONITORING & RESPONSE PROGRAMS FOR AIR, SOIL, AND SOIL-PORE GAS FOR PERMITTED FACILITIES

Article 17 provides nonrestrictive standards for implementation of a monitoring and response program for ambient air, soil-pore gas, and soil matrix. Article 17 is based on old original 22 CCR, Article 22. As part of efforts for DTSC to obtain RCRA authorization in the early 1990s, water quality monitoring requirements within old 22 CCR, Article 22 were extracted and incorporated into current Article 6 requirements paralleling SWRCB requirements. Because the SWRCB did not have equivalent requirements for monitoring soil, air, and soil-pore gas, the residual requirements of old 22 CCR, Article 22 were included in Article 17.

12.1 APPLICABILITY TO PERMITTED FACILITIES [22 CCR 66264.700]

The regulations in this article apply to owners/operators of permitted facilities that treated, stored, recycled or disposed of hazardous waste after February 2, 1985 in a surface impoundment, waste pile, land treatment unit or landfill. [Note: This section of 22 CCR is not explicit because the section does not specifically reference surface impoundments, waste piles, land treatment units and landfills as originally intended in old 22 CCR, Article 22 and as clearly indicated in Article 18, the Interim Status equivalent of Article 17.] The article applies during the active life, closure period, and post-closure care period of the regulated unit. The article also applies during any compliance period required under 22 CCR 66264.96. After closure, the article does not apply if the site is clean closed. This section also applies to aboveground and underground hazardous waste storage tanks during the post-closure period only if the units cannot be clean closed.

22 CCR 66264.700(b) provides an exemption to the article for land treatment units provided certain criteria are met: 1) hazardous constituents are determined statistically to not be above background concentrations by an amount that is statistically significant and 2) unsaturated zone monitoring has not shown a statistically significant increase in hazardous constituents. This exemption does not apply during the post-closure care period.

22 CCR 66264.700(c) provides another exemption to the article for all units provided the owner/operator demonstrates that hazardous waste will not migrate from a unit during the active life of the unit and the post-closure care period. Certification requirements for the demonstration are outlined in the section.

12.2 REQUIRED PROGRAMS [22 CCR 66264.701]

This section mandates conducting an environmental monitoring and response program. If a statistically significant increase for any hazardous constituent is detected at any monitoring point, then a compliance monitoring program (CMP) should be instituted. Whenever the environmental protection standard or specified concentration limit is exceeded, a CAP should be instituted. Otherwise a DMP shall be in place. However, the HWF Permit may specify one or more of these programs to protect human health and the environment. In deciding whether to require the owner/operator to be prepared to institute a particular program, DTSC should consider the potential adverse effects on human health or the environment that might occur before final administrative action could be taken on a HWF Permit modification application to incorporate such a program.

12.3 ENVIRONMENTAL PROTECTION STANDARD [22 CCR 66264.702]

This standard states that the owner/operator shall comply with HWF Permit conditions to ensure hazardous constituents outside a regulated unit or entering soil or air from a regulated unit should not exceed established concentration limits expressed as maximum acceptable concentrations in soil, soil-pore gas, air, or on the land surface.

12.4 HAZARDOUS CONSTITUENTS [22 CCR 66264.703]

The HWF Permit shall specify the hazardous constituents to which the environmental protection standard applies. Hazardous constituent is defined as a constituent identified in Appendix VIII to Chapter 11 of Division, 4.5, 22 CCR or any other element, chemical compound, or mixture of compounds which is a component of a hazardous waste or leachate and which has a physical or chemical property that causes the waste or leachate to be identified as a hazardous waste. This definition is different and less encompassing than the COC term used in Article 6 groundwater monitoring. The constituents specified in the HWF Permit will be limited to those reasonably expected to be in or derived from waste contained in a regulated unit and should not include those constituents considered not capable of posing a substantial present or potential hazard to human health or the environment and that are not useful as an indicator of migration of hazardous waste.

This section lists factors to evaluate when considering which constituents to cite in the HWF Permit and are categorized into the following: 1) potential effects on human health or the environment, 2) potential to adversely affect surface and groundwater quality, and 3) usefulness as an indicator of the possible presence of a hazardous constituent.

12.5 CONCENTRATION LIMITS [22 CCR 66264.704]

The HWF Permit shall specify concentration limits for soil, soil-pore gas, and open-air downwind from the regulated unit, for hazardous constituents established under 22 CCR 66264.703. The concentration limit for a hazardous constituent in soil and soil-pore gas outside the regulated unit shall not exceed the background concentration of that constituent unless an alternate concentration limit greater than background is established by DTSC. The concentration limit for a hazardous constituent in open-air immediately downwind from the regulated unit shall not exceed an ambient air quality standard established by the California Air Resources Board and shall not exceed a concentration limit established by DTSC to protect human health or the environment.

DTSC shall establish an alternate concentration limit for a hazardous constituent if it is found that the constituent will not pose a substantial present or potential hazard to human health or the environment as long as the alternate concentration limit is not exceeded. In establishing alternate concentration limits, DTSC shall consider factors listed under 22 CCR 66264.703(b).

12.6 MONITORING POINTS [22 CCR 66264.705]

Monitoring points, at which the environmental protection standard of 22 CCR 66264.702 applies, shall be specified in the HWF Permit. These points shall be located close enough to the regulated unit to provide an early indication of contaminant migration.

12.7 DETECTION MONITORING PROGRAM [22 CCR 66264.706]

The DMP monitors for air and soil-pore gas releases from a regulated unit. Provided the regulated unit contained hazardous waste that either contained a volatile toxic substance or one that could be degraded to a volatile toxic substance, or any toxic substance that could become airborne, the HWF Permit should describe methods for representative sampling and analysis of air upwind and at the disposal area, and at soil-pore gas at monitoring points. Samples are analyzed for those substances specified in the HWF Permit. If parameters and constituents are not specifically cited in the HWF Permit (this is not recommended), then the owner/operator shall analyze the samples to determine the concentration of all constituents that caused waste at the regulated unit to be hazardous waste [22 CCR 66264.706(c)]. The HWF Permit will specify the location and frequency of monitoring and the type of statistical analysis. The details of sampling program design requirements are not constrictive and allow for appropriate, yet flexible, DMP. As sampling details are not discussed in the regulations, the details must be documented in detail within the monitoring section of the HWF Permit. Results of sampling are submitted to DTSC.

Some requirements for vapor well construction are discussed in 22 CCR 66264.706(b). While limited and somewhat dated, it does mention that instrumentation providing continuous recording of concentrations of substances in open air and from vapor wells may be required if specified by DTSC.

12.7.1 Reporting & Notification Requirements, & Stipulated Schedules

The following time critical requirements contained in the DMP regulations are summarized below for convenient reference (appropriate citations are contained in parentheses):

1. The owner/operator shall submit a report to DTSC presenting the results of analyses for air and soil-pore gas samples. The report shall be submitted to DTSC within 30 days of the date analyses are completed [22 CCR 66264.706(c)].

2. If the owner/operator determines that there is an increase of hazardous constituents at any monitoring point, then the owner/operator must notify DTSC of this finding in writing within seven days of the determination (including which constituents have shown statistically significant increases). Within 90 days of the determination, the owner/operator must apply for a HWF Permit modification to make appropriate changes to modify the facility or operating practices [22 CCR 66264.706(d)(2)].

3. If the owner/operator intends to make an alternative source demonstration indicating that the regulated unit has not caused the detected release, the owner/operator must notify DTSC in writing within seven days of determining an increase at any monitoring point [22 CCR 66264.706(e)(1)] . Within 90 days of the determination, the owner/operator must submit an alternative source demonstration report [22 CCR 66264.706(e)(2)] and apply for a HWF Permit modification to make any appropriate changes to the monitoring program [22 CCR 66264.706(e)(3)].

4. Within 90 days of determining that the DMP does not satisfy 22 CCR 66264.706 standards, the owner/operator shall submit an application for a HWF Permit modification to make appropriate changes to the program [22 CCR 66264.706(f)].

12.8 COMPLIANCE MONITORING PROGRAM [22 CCR 66264.707]

CMP are established to assess the nature and extent of a known release(s) to ambient air, soil-pore gas, or soil from a regulated unit to ultimately ensure compliance with the environmental protection standard.

12.8.1 Determine Nature & Extent of Contamination

Once it is confirmed that a constituent of hazardous waste has migrated from a regulated unit in air or soil-pore gas, the owner/operator shall obtain soil samples, as necessary, from specified depths and locations for chemical analyses to determine the lateral and vertical extent of contamination [22 CCR 66264.707(g)]. The owner/operator shall report the concentration at each sampling station in a form necessary for the determination of contaminant increases.

12.8.2 Reporting & Notification Requirements, & Stipulated Schedules

The following time critical requirements contained in the CMP regulations are summarized below for convenient reference (appropriate citations are contained in parentheses):

1. If specified in the HWF Permit, the owner/operator shall determine the concentration of hazardous constituents in the unsaturated zone or in the air and submit these data to DTSC within 30 days after it is obtained [22 CCR 66264.707(b)].

2. If the owner/operator determines that the environmental protection standard is being exceeded at any monitoring point, then the owner/operator must notify DTSC of this finding in writing within seven days of the determination including which concentration limits have been exceeded [22 CCR 66264.707(c)(1)]. Within 180 days of the determination, the owner/operator must apply for a HWF Permit modification to establish a CAP, or within 90 days, if an engineering feasibility study has been previously submitted to DTSC. The application shall, at a minimum, include a detailed description of corrective actions and a plan for an environmental monitoring program to demonstrate the effectiveness of the corrective action [22 CCR 66264.707(c)(2)].

3. If the owner/operator intends to make an alternative source demonstration indicating that the regulated unit has not caused the exceedance, the owner/operator must notify DTSC in writing within seven days of the determination [22 CCR 66264.707(d)(1)]. Within 90 days of the determination, the owner/operator must submit an alternative source demonstration report [22 CCR 66264.707(d)(2)] and apply for a HWF Permit modification to make any appropriate changes to the monitoring program [22 CCR 66264.707(d)(3)].

4. Within 90 days of determining that the CMP does not satisfy 22 CCR 66264.707 standards, the owner/operator shall submit an application for a HWF Permit modification to make appropriate changes to the program [22 CCR 66264.707(e)].

12.9 CORRECTIVE ACTION PROGRAM [22 CCR 66264.708]

The owner/operator shall implement a CAP that prevents hazardous constituents from exceeding their respective concentration limits at monitoring points by removing the hazardous waste constituents, treating them in place, or providing other effective measures. Remedial measures must also address hazardous waste constituents remaining at the regulated unit that could cause the environmental protection standard to be exceeded in the future. The HWF Permit will specify the specific measures that will be taken.

12.9.1 Monitoring Requirements

In conjunction with corrective measures, a monitoring program must be established to demonstrate the effectiveness of the CAP. Reports addressing the effectiveness of the measures are to be submitted to DTSC.

12.9.2 Termination of Corrective Measures

Corrective action measures may be terminated once compliance is achieved with the environmental protection standard, contaminant concentrations fall below established concentration limits, and it is not likely that residual contamination at the regulated unit will cause a concentration limit to eventually be exceeded. Furthermore, termination requires that the environmental protection standard not have been exceeded during the last three consecutive years of monitoring [22 CCR 264.708(f)].

12.9.3 Reporting & Notification Requirements, & Stipulated Schedules

The following time critical requirements contained in the CAP regulations are summarized below for convenient reference (appropriate citations are contained in parentheses):

1. Corrective action measures shall be initiated and completed within a reasonable time period after the environmental protection standard is exceeded and after considering the extent of contamination [22 CCR 66264.708(c) and 66264.708(e)(1)].

2. The owner/operator shall submit reports to DTSC addressing the effectiveness of corrective measures semiannually [22 CCR 66264.708(g)].

3. Within 90 days of determination that the CAP does not satisfy 22 CCR 66264.708 standards, the owner/operator shall submit an application for a HWF Permit modification to make appropriate changes to the program [22 CCR 66264.708(h)].

13.0 DOCUMENTS NECESSARY FOR ARTICLE 6 MONITORING PROGRAMS

Effective implementation of an Article 6 monitoring program requires that the program be described in procedural documents. The HWF Permit should always identify the approved documents under which the monitoring program is to be conducted.

Before a HWF Permit is issued, the owner/operator must have a DTSC-approved WQSAP, statistical evaluation plan, and a monitoring system operation and maintenance (O&M) plan. The owner/operator should submit these documents to DTSC with the Part B Permit Application. Once approved, the procedures outlined in these documents are incorporated by reference in the HWF Permit. Alternatively, the HWF Permit can enumerate portions of these documents as approved by DTSC. The remainder of this section provides a brief discussion of these necessary documents. More detailed discussions of these documents are provided in Appendices B and C.

13.1 WATER QUALITY SAMPLING & ANALYSIS PLAN

Monitoring programs conducted to address Article 6 requirements must be conducted under a DTSC-approved WQSAP. The WQSAP provides consistent sampling and analysis procedures designed to ensure that all monitoring results provide a reliable indication of water quality at all monitoring points. The minimum WQSAP content includes a detailed (e.g., step-by-step) description of procedures for [22 CCR 66264.97(e)(4)]:

- sample collection (e.g., purging techniques, sampling equipment, decontamination of sampling equipment);
- sample preservation and shipment;
- analytical procedures; and
- chain of custody control.

The WQSAP must include sampling and analytical methods appropriate for the environmental media being sampled so that the data accurately reflect the concentration of each analytical parameter (e.g., monitoring parameter, COC, Appendix IX constituent). The WQSAP must require that pH, specific conductance, temperature, and turbidity are measured in the field each time that a groundwater well is sampled [22 CCR 66264.97(e)(13)]. Further guidance in developing a WQSAP is provided in Appendix B.

It is to be expected that the WQSAP must be periodically updated as standard industry practice changes and the monitoring program is modified. DTSC must approve all WQSAP modifications prior to implementation. Concurrently, DTSC will determine what class of permit modification is appropriate for the WQSAP modification.

13.2 STATISTICAL EVALUATION PLAN

Article 6 requires use of statistical methods to evaluate water quality monitoring data. The type of data analysis methods used depends on the monitoring program objective(s). For DMP and EMP, the objective of the analysis is to evaluate whether a release has occurred from the unit and for determining compliance with the WQPS. For a CAMP, the objective is to demonstrate the effectiveness of the CAP, assess whether water quality is improving, and to determine compliance with the WQPS. Different data analysis methods are used to support these different objectives.

The owner/operator must develop a Statistical Evaluation Plan that provides the step-by-step procedure that will be used to evaluate the water quality monitoring data. The Statistical Evaluation Plan should include the following items:

1. Tabulated summary of historical analytical data for all monitoring parameters and COC for all media sampled.

2. Map and tabulated summary showing all monitoring points and associated construction details. Summary should delineate which monitoring points are upgradient monitoring points, POC monitoring points, and cross-gradient monitoring points for all media. For the groundwater monitoring network, this information should be provided for all monitored aquifers for each regulated unit.

3. Tabulated summary of historical water levels for all monitoring points.

4. Map showing most recent groundwater elevation contours and flow direction.

5. Time series plots for all monitoring parameters and detected COC for the entire monitoring network. For example, each plot should illustrate historical concentrations of a given monitoring parameter for all wells within the monitoring network (i.e., a multi-well, single constituent plot).

6. Box and whisker plots for all monitoring parameters and detected COC for the entire monitoring network. For example, a box and whisker plot should show the concentrations of a given monitoring parameter for all wells within the monitoring network (i.e., a multi-well, single constituent plot).

7. Flow chart showing proposed methods for determining background values for each monitoring parameter and COC for all monitoring points.

8. Flow chart showing proposed statistical protocol for each monitoring program for each regulated unit for all media.

9. Tabulated summary of all statistical methods proposed. Include references for each proposed method and proposed statistical software (if applicable).

10. Text describing the proposed methods for determining background values and proposed statistical applications. Include a demonstration that the proposed methods will be protective of human health and the environment and will comply with the performance standards outlined in 22 CCR 66264.97(e)(9).

The proposed statistical protocol should address all of the applicable performance standards outlined in Article 6. Refer to Appendix C for further details regarding development of a Statistical Evaluation Plan.

13.3 OPERATION & MAINTENANCE PLAN

As with any type of equipment, every monitoring system requires operation and maintenance during its operating life. The owner/operator must provide an O&M Plan for all monitoring system components. The plan should address routine, short-term, and long-term O&M

procedures. The plan should also provide a schedule for responding to items identified during routine inspections [22 CCR 66264.15(c)]. The O&M Plan can be developed as a stand-alone document or included as part of the WQSAP. Further guidance in developing an O&M plan is included in Appendix B.

14.0 MONITORING REPORTS

Under 22 CCR 66264.75, facilities are required to submit annual monitoring reports by March 1 each year. In addition, DTSC usually requires more frequent reporting of monitoring data in the form of quarterly or semi-annual monitoring reports. Annual and quarterly or semi-annual monitoring reports are not a substitute for other Article 6 notification requirements (see Sections 9.4, 10.4, 11.3).

The annual report should cover the monitoring activities for the previous reporting year. An annual report may be combined with the quarterly report for the fourth quarter provided that it is submitted by March 1. Quarterly or semi-annual monitoring reports should cover data collected during the reporting period and are typically submitted within 60 to 90 days following the last field activity addressed by these reports.

The remainder of this section discusses the required content for monitoring reports. Appendix D provides suggested content for monitoring report. Suggested content should be evaluated on a site-specific basis.

14.1 SIGNATURE REQUIREMENTS FOR ALL MONITORING REPORTS

Because monitoring reports must contain interpretations of hydrogeologic and geochemical data, each report must be signed by a qualified geologist or professional civil engineer, registered/licensed in the state of California, who takes responsibility for the technical content of the report. Signature of an appropriate licensed professional is required by California Business and Professions Code, Geologists and Geophysicists Act, Section 7835 and 16 CCR 3003(f)(2) and 16 CCR 3003(h). Reports must indicate the license number of the geologist or engineer.

14.2 MINIMUM REPORTING REQUIREMENTS FOR ANNUAL REPORTS

22 CCR 66264.97(e)(14),(15), and (16) specify minimum ground water quality annual report content. These regulations require, in short, that facilities supply graphical depiction of concentration trends, groundwater flow rate and direction, and records maintenance. Specific minimum reporting requirements are summarized as follows:

1. **22 CCR 66264.97(e)(14)**: The owner/operator must graph all analytical data from each monitoring point and background monitoring point and submit these graphs to DTSC at least annually. Graphs shall be at a scale appropriate to show trends or variations in water quality. All graphs for a given constituent shall be plotted at the same scale to facilitate visual inspection of monitoring data. Further guidance on graph preparation is provided in Appendix D.

2 **22 CCR 66264.97(e)(15)**: In addition to the water quality sampling conducted pursuant to the requirements of this article, the owner/operator shall measure the water level in each well and determine groundwater flow rate and direction in the uppermost aquifer and in any zones of perched water and in any additional aquifers monitored pursuant to 22 CCR 66264.97(b)(1) at least quarterly, including the times of expected highest and lowest elevations of the water levels in the wells.

3. **22 CCR 66264.97(e)(16)**: Water quality monitoring data collected in accordance with this article, including actual values of constituents and parameters, must be maintained in the

facility operating record. The frequency for submitting these data to DTSC is specified in the HWF Permit.

14.3 SITE-SPECIFIC REPORTING REQUIREMENTS

Monitoring reports that address only the minimum content required by 22 CCR are likely to be of limited use to the reader. Site-specific reporting requirements should be specified in the HWF Permit. Appendix D provides the suggested content for monitoring reports; the suggested content should be evaluated on a site-specific basis.

14.4 DATA REPORTING [22 CCR 66264.97(e)(16)]

The HWF Permit should specify (1) the frequency, (2) format, and (3) content for submitting water quality monitoring data to DTSC. These data include analytical data as well as water-level monitoring data. A historical summary of monitoring data up through the reporting year should be included in the annual report.

14.4.1 Format

Monitoring data for the facility should be submitted in tabular and graphical formats. If appropriate, the owner/operator should also submit data electronically with the annual report. Electronic data submittals should be used cautiously because the data may be lost unless a hard copy is included in the report. The specific electronic format for the database should be discussed with the DTSC project manager to ensure that the database will be in a form that is efficiently utilized by DTSC.

Common database fields for water-level data include:

- Date (D/M/Y)
- Monitoring Point (e.g., well number, surface water station number, etc.)
- Monitoring Point Coordinates (northing, easting)
- Datum Elevation
- Water Level
- Water Elevation
- Units
- Comments

Common database fields for analytical data include:

- Date (D/M/Y)
- Monitoring Point (e.g., well number, surface water station number, etc.)
- Parameter
- Concentration
- Detection Limit
- Data Qualifier
- Concentration Units
- Comments

14.4.2 Content

Quarterly or semi-annual monitoring reports should include the data for the reporting period. Annual reports should include a summary of historical data. If the historical database has already been submitted to DTSC, submittal of the data set for the reporting year only may be appropriate. However, it is requested that the entire historical data set be submitted in the annual report in an appropriate electronic format.

15.0 REFERENCES

Cal/EPA. 1995. *Guidance Manual for Groundwater Investigations*.

Monitoring Well Design and Construction for Hydrogeologic Characterization.
www.dtsc.ca.gov/SiteCleanup/SMP_Monitoring_Well_Design.pdf

Drilling, Coring, Sampling and Logging at Hazardous Substance Release Sites.
www.dtsc.ca.gov/SiteCleanup/SMP_Drilling_Coring_Sampling_Logging.pdf

Representative Sampling of Ground Water for Hazardous Substances.
www.dtsc.ca.gov/SiteCleanup/SMP_Representative_Sampling_GroundWater.pdf

Application of Borehole Geophysics at Hazardous Substance Release Sites.
www.dtsc.ca.gov/SiteCleanup/SMP_Brownfields_Application-Borehole_Geophysics_2.pdf

Aquifer Testing for Hydrogeologic Characterization.
www.dtsc.ca.gov/SiteCleanup/SMP_Aquifer_Testing.pdf

Ground Water Modeling for Hydrogeologic Characterization.
www.dtsc.ca.gov/SiteCleanup/SMP_Groundwater_Modeling.pdf

Reporting Hydrogeologic Characterization Data at Hazardous Substance Release Sites.
www.dtsc.ca.gov/SiteCleanup/SMP_Report-Hydrogeologic_Char_Data.pdf

Application of Surface Geophysics at Hazardous Substance Release Sites.
www.dtsc.ca.gov/SiteCleanup/SMP_Application_Surface_Geophysics.pdf

Cal/EPA. 1995. *Guidelines for Hydrogeologic Characterization of Hazardous Substance Release Sites*.

Volume 1: Field Investigation Manual.
(www.dtsc.ca.gov/SiteCleanup/SMP_Guidelines_Hydrogeologic_Characterization_Vol1.pdf)

Volume 2: Project Management Manual.
www.dtsc.ca.gov/SiteCleanup/SMP_Guideline_Hydrogeologic_Character_Part1_Vol2.pdf
www.dtsc.ca.gov/SiteCleanup/SMP_Guidelines_Hydrogeologic_Character_Part2_Vol2.pdf

Puls, R.W. and Barcelona, M.J. 1995. Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures. *U.S. EPA Ground Water Issue*. EPA/540/S-95/504. December.

APPENDIX A

SUMMARY OF MAJOR DIFFERENCES BETWEEN 22 CCR CHAPTER 14 & CHAPTER 15 MONITORING REQUIREMENTS

SUMMARY OF MAJOR DIFFERENCES[1] BETWEEN 22 CCR CHAPTER 14 & 15 MONITORING REQUIREMENTS

Item	Chapter 14 (Permitted Facility)	Chapter 15 (Interim Status Facility)
Applicability	22 CCR 66264.90: ** Regulated units[2] that received waste after July 26, 1982. ** Regulated units[2] that ceased receiving waste before July 26, 1982 if the Department determines that constituents derived in or from waste may pose a threat to human health or environment.	22 CCR 66265.90: ** Regulated units[2] that received waste after November 19, 1980. ** Regulated units[2] that ceased receiving waste before November 19, 1980 if the Department determines that constituents derived in or from waste may pose a threat to human health or environment.
Required Programs	22 CCR 66264.91(a)(4): ** Provides for corrective action programs.	Corrective action programs are implemented through a Corrective Action Consent Agreement or Order.
Water Quality Sampling & Analysis Plan (WQSAP)	Chapter 14 does not contain a citation equivalent to 22 CCR 66265.91(b). WQSAP-type items are to be cited in the facility permit.	22 CCR 66265.91(b): ** Develop a WQSAP that satisfies the requirements of Chapter 15, Article 6.
Water Quality Protection Standard (WQPS)	22 CCR 66264.92: ** Department establishes the WQPS in the facility permit.	22 CCR 66265.92: ** Owner/operator establishes the WQPS in the WQSAP.
Constituents of Concern (COC)	22 CCR 66264.93: ** Department specifies COCs in the facility permit.	22 CCR 66265.93: ** Owner/operator establishes COC in WQSAP.
Concentration Limits	22 CCR 66264.94: ** Owner/operator proposes concentration limits. ** Department approves proposed concentration limits. ** For corrective action programs, specific criteria for establishing Concentration Limits Greater Than Background, if appropriate.	22 CCR 66265.94: ** Specify concentration limits for each COC in the WQSAP.
Monitoring Points & Point of Compliance (POC)	22 CCR 66264.95: ** Department specifies the POC in permit.	22 CCR 66265.95: ** Owner/operator specifies POC in WQSAP.

TABLE 1 (CONTINUED)
SUMMARY OF MAJOR DIFFERENCES[1] BETWEEN
22 CCR CHAPTER 15 & CHAPTER 14 MONITORING REQUIREMENTS

Item	Chapter 14 (Permitted Facility)	Chapter 15 (Interim Status Facility)
Compliance Period	22 CCR 66264.96: ** Department specifies the compliance period in the facility permit. ** Extended compliance period if facility under corrective action program.	22 CCR 66265.96: ** Owner/operator specifies compliance period in WQSAP.
Groundwater Monitoring System	22 CCR 66264.97: ** Sufficient number of background monitoring points. ** For detection, evaluation, or corrective action monitoring program, sufficient number of monitoring points	22 CCR 66265.97: ** Sufficient number (at least one) of background monitoring points ** For detection or evaluation monitoring program, sufficient number of monitoring points (at least three)
Surface Water Monitoring System	22 CCR 66264.97(c): ** Includes requirements for corrective action programs.	Corrective action programs are implemented through a Corrective Action Consent Agreement or Order.
Unsaturated Zone Monitoring System	22 CCR 66264.97(d): ** Includes requirements for corrective action programs.	Corrective action programs are implemented through a Corrective Action Consent Agreement or Order.
Statistical Analysis	22 CCR 66264.97(e): ** Owner/operator proposes statistical method for evaluating water quality monitoring data. ** Department approves statistical method and specifies statistical method in permit. ** If practical quantitation limits (PQL) are used in the statistical method, the owner/operator proposes the PQL and the Department approves the PQL.	22 CCR 66265.97(e): ** Owner/operator selects statistical method for evaluating water quality monitoring data and specifies in WQSAP.

TABLE 1 (CONTINUED)
SUMMARY OF MAJOR DIFFERENCES[1] BETWEEN
22 CCR CHAPTER 15 & CHAPTER 14 MONITORING REQUIREMENTS

Item	Chapter 14 (Permitted Facility)	Chapter 15 (Interim Status Facility)
Groundwater Flow Rate & Direction	22 CCR 66264.97(e)(15): ** Chapter 14 does not explicitly include a requirement for annual review of monitoring network adequacy.	22 CCR 66265.97(e)(15): ** Requires the owner/operator to determine, at least annually, whether the requirements of 22 CCR 66265.97(b)(1) are satisfied. If the requirements are not satisfied, as soon as technically feasible, the owner/operator must modify the groundwater monitoring network to bring the system into compliance with Chapter 15, Article 6.
Background Water Quality Parameters	Chapter 14 does not contain a citation equivalent to 22 CCR 66265.97(e)(16).	22 CCR 66265.97(e)(16): ** Unless previously established, by June 30, 1992, the owner/operator must establish background concentrations/values for the listed Background Water Quality Parameters by sampling quarterly for one year.
Detection Monitoring Program	22 CCR 66264.98: ** Owner/operator proposes list of monitoring parameters. Department approves and specifies list in permit with consideration of identified factors. ** Includes provision for establishing a detection monitoring program after successful completion of a corrective action program.	22 CCR 66265.98: ** Owner/operator specifies monitoring parameter list in WQSAP, with consideration of identified factors. Except as provided, include identified Groundwater Monitoring Parameters in list of monitoring parameters.

TABLE 1 (CONTINUED)
SUMMARY OF MAJOR DIFFERENCES[1] BETWEEN
22 CCR CHAPTER 15 & CHAPTER 14 MONITORING REQUIREMENTS

Item	Chapter 14 (Permitted Facility)	Chapter 15 (Interim Status Facility)
Evaluation Monitoring Program	22 CCR 66264.99: ** Within 90 days of establishing an evaluation monitoring program, submit an assessment of the nature and extent of the release. ** Within 90 days of establishing an evaluation monitoring program, submit an updated engineering feasibility study. ** Within 90 days of establishing an evaluation monitoring program, submit an application for a permit modification. ** The owner/operator proposes a list of monitoring parameters for evaluating changes in water quality. Department approves list.	22 CCR 66265.99: ** As soon as technically feasible, assess the nature and extent of a release. Submit assessment within 15 days of completion. ** As soon as technically feasible, submit an engineering feasibility study. ** If required to obtain a permit, submit a Part B permit application. ** Explicitly states: on a quarterly basis, determine the rate and extent of contaminant migration and describe the nature of changes in the geometry and geochemistry of the volume affected by the release. ** Owner/operator selects list of monitoring parameters for evaluating changes in water quality.
Corrective Action Monitoring Program	22 CCR 66264.100: ** Requirements for corrective action programs.	Chapter does not address corrective action. Corrective action programs are implemented through a Corrective Action Consent Agreement or Order.

1 This table is not intended to outline every difference between 22 CCR Chapters 14 and 15. Always refer to the regulations when preparing HWF Permit language to satisfy monitoring requirements.
2 Regulated unit is a surface impoundment, waste pile, land treatment unit, or landfill.

APPENDIX B

SUGGESTED CONTENT FOR MONITORING REPORTS

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LIST OF ABBREVIATIONS

22 CCR	Title 22 of California Code of Regulations
Article 6	22 CCR 66264.90 through 22 CCR 66264.100
ASTM	American Society of Testing and Materials
Cal/EPA	California Environmental Protection Agency
CAMP	corrective action monitoring program
CCR	California Code of Regulations
DMP	detection monitoring program
DNAPL	dense nonaqueous phase liquid
DOT	U.S. Department of Transportation
DTSC	Department of Toxic Substances Control
EMP	evaluation monitoring program
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
FSP	field sampling plan
HWF	hazardous waste facility
LNAPL	light nonaqueous phase liquid
MDL	method detection limit
NTU	nephelometric turbidity unit
ORP	oxidation-reduction potential
PQL	practical quantitation limit
PVC	polyvinyl chloride
QA	quality assurance
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
QC	quality control
VOC	volatile organic compound
WQSAP	water quality sampling and analysis plan

1.0 INTRODUCTION

Monitoring procedures should be conducted using a water quality sampling and analysis plan (WQSAP) that has been approved by the Department of Toxic Substances Control (DTSC). The WQSP must address the physical process of obtaining field information, measurements, and environmental samples. The WQSAP is required by California Code of Regulations (CCR), Title 22 for interim status facilities, but for permitted facilities, regulations specify this information be placed in the Hazardous Waste Facility (HWF) Permit. All HWF Permits should reference a WQSAP. Deviations from the procedures described in the WQSAP/HWF Permit are subject to enforcement by DTSC.

The WQSAP must be written to unambiguously describe exactly what steps will be taken to ensure representative groundwater samples are collected. The WQSAP must contain sufficient detail for a sampler with limited experience to understand and follow and to ensure that sampling will be conducted in the same manner by different samplers.

The WQSAP should consist of two parts: a Field Sampling Plan (FSP) and a Quality Assurance Project Plan (QAPP). The FSP completely describes the following: site background and environmental setting, regional and site hydrogeology, sampling objectives, rationale for sampling and analysis, presampling activities, sample collection, analytes and analytical methods, and guidance for all fieldwork describing, in detail, sampling and data gathering methods. The QAPP describes the quality assurance and quality control (QA/QC) protocols necessary to achieve the objectives dictated by the intended use of the data. Control protocols include the procedures for sample collection, preservation, chain-of-custody, and transport, calibration and maintenance of instruments, processing verification, storage, and reporting of data, and other relevant QA/QC procedures required to maintain precision and accuracy of the data.

The recommendations contained herein represent minimum criteria judged necessary to obtain quality data and assure reasonable and independently verifiable interpretations.

2.0 WQSAP MODIFICATIONS

2.1 WQSAP DOES NOT MEET ARTICLE 6 REQUIREMENTS

If the owner/operator or DTSC determines that the WQSAP no longer satisfies the requirements of 22 CCR, Division 4.5, Chapter 14, Article 6, the owner/operator must, within a reasonable amount of time (i.e., 90 days), submit a revised WQSAP to DTSC for review and approval. DTSC will either approve or require additional information/modification to the revised SAP. Upon approval by DTSC, the owner/operator shall implement the WQSAP with any modifications required by DTSC. Concurrently, DTSC will determine which class of permit modification is appropriate.

2.2 OTHER WQSAP MODIFICATIONS

Future modifications to the WQSAP must be submitted in writing to DTSC for approval within a reasonable amount of time (e.g., at least 60 days) prior to the planned implementation of the new WQSAP. Concurrently, DTSC will determine which class of permit modification is appropriate.

3.0 SUGGESTED CONTENT

The following checklist may be applicable to a given facility on a case by case basis. The suggested content is largely biased toward groundwater sampling and is based on recommendations in EPA (1986), Cal/EPA (1995a,b), and DTSC experience with Article 6 monitoring programs. Similar or analogous content would be appropriate for surface water, pore water, etc. This document discusses broad categories of methods and devices used in the sampling and analysis of groundwater. The document does not define specific operating procedures for sampling and analysis, nor does this document propose guidelines for every available sampling device or analytical method. The qualified professional in charge of the field investigation should specify the methods, equipment and operating procedures in an appropriate work plan and document any significant departures from the work plan that were necessary during the course of the investigation. Although activities such as well drilling and installation, monitoring network (e.g. well construction details, survey coordinates, etc.), development, etc. may be included in the FSP, they are not discussed in detail in this guidance document.

This document does not supersede existing statutes and regulations. Federal, state and local regulations, statutes, and ordinances should be identified when required by law, and site characterization activities should be performed in accordance with the most stringent of these requirements where applicable, relevant, and appropriate.

4.0 ELEMENTS OF SAMPLING & ANALYSIS PROGRAMS

The WQSAP consists of a FSP and a QAPP. At a minimum, the WQSAP should include information on:

** Sampling objectives;
** Pre-sampling activities;
** Sample collection;
** In-situ or field analyses;
** Sample preservation and handling;
** Chain-of-custody control and records management;
** Analytical procedures and quantitation limits for both laboratory and field methods;
** Field and laboratory quality assurance/quality control;
** Evaluation of data quality; and
** Health and Safety Plan.

The WQSAP should also include procedures for installing and developing groundwater monitoring wells, and implementing other monitoring programs (e.g., vadose zone, surface water and spring monitoring).

5.0 PRE-SAMPLING ACTIVITIES

5.1 WELL-HEAD INSPECTION

Well-head conditions (condition of well casing, well lock, markings, standing water at surface, condition of surface pad and annular seal) and any suggested maintenance should be recorded in the field notes. The WQSAP must describe procedures and schedules for performing routine well maintenance. Incidental maintenance should be recorded in the field notes and conducted in a timely manner. A well head maintenance checklist form should be included in the WQSAP.

5.2 MONITORING FOR GASES OR IMMISCIBLE LAYERS

Discuss the need to monitor for wellhead gases and immiscible layers. If necessary, the WQSAP must describe equipment and procedures for testing wellhead gases and for testing the water surface for immiscible layers (e.g., nonaqueous phase liquids). Measuring immiscible layers should be conducted prior to conventional sampling.

5.3 WATER LEVEL MEASUREMENT

1. The WQSAP should include provisions for measuring the static water elevation in each well to the nearest 0.01 feet prior to each sampling event. Measurement of water level elevations on a continuing basis is important to determine whether horizontal and vertical components of groundwater flow change over time. A change in groundwater flow may necessitate modification to the monitoring system;

2. Describe equipment and procedures for depth to water measurement. The WQSAP must specifically state that (1) water levels will be measured in all wells and piezometers at least quarterly for the calculation of groundwater flow rate and direction; (2) all water levels will be measured in the shortest possible time; and (3) water levels in all wells will be measured before any well is purged. Also, when determining depth to water in the field, two consecutive water level readings should be obtained that are within 0.01 feet of each other before recording a value;

3. Regardless of the method or device chosen to measure the water level elevation in a monitoring well or piezometer, after well construction and development, water levels in piezometers and wells should be allowed to stabilize prior to measurement. A 12 to 24 hour stabilization period is recommended; however, in low yield aquifers, recovery may take longer, and several water level measurements should be made over a period of several days to ensure recovery has occurred. Well development or well maintenance should be scheduled well ahead of monitoring events to avoid potential adverse effects on data quality;

4. Specify that water levels for the calculation of groundwater flow rate and direction will be measured during times of expected seasonal maximum and minimum water levels. The WQSAP should specify when the seasonal maximum and minimum water levels are expected (by month) and should provide documentation (hydrographs) to support the conclusions;

5. The location of all wells should be surveyed by a California Registered Civil Engineer or licensed professional land surveyor. All well locations should be recorded using the California State Plane coordinate system. The height of the reference survey datum, permanently marked on the inner well casing, should be determined within ±0.01 foot in relation to mean sea level, which in turn is established by reference to an established National Geodetic Vertical Datum (Cal/EPA 1995b). The reference point should be resurveyed once every five years unless anomalous groundwater head data are recorded or damage to the protective completion or well casing are noted;

6. The depth to water should be measured with reference to a marked point, surveyed by a licensed surveyor, at the top of well casing. The water level probe must be capable of obtaining reliable measurements to ±0.01 foot;

7. Indicate the order in which wells will be visited for water level monitoring, sampling, and maintenance. Include the rationale for the selected order in terms of minimizing the possibility of cross-contaminating the wells and/or samples;

8. Water level measurements from boreholes, piezometers, or monitoring wells used to define the water table or a single potentiometric surface should be collected within less than 24 hours. This practice is adequate if the magnitude of elevation change over that period of time is small relative to the gradient. In certain situations, water level measurements should be made within a shorter time interval (i.e., tidally influenced aquifers; aquifers with very flat gradients, aquifers affected by river stage, bank storage, impoundments, and/or unlined ditches; aquifers stressed by any type of pumping; aquifers being actively recharged naturally or artificially; confined or semi-confined aquifers significantly affected by barometric pressure (Cal/EPA 1995a);

9. Water level and well depth measurement equipment should be decontaminated between wells to prevent cross-contamination and ensure sample integrity;

10. Measuring tapes and marked cables used to measure water levels and well depths should be periodically (annually) calibrated. All field equipment calibration and maintenance data should be recorded in a logbook kept with each piece of equipment and a copy included in the groundwater monitoring report.

5.4 TOTAL WELL DEPTH MEASUREMENT

Describe the procedures, frequency, and record keeping for the total well depth sounding measurement. Total well depth should be measured to the nearest ±0.1 foot from a reference point, surveyed by a licensed surveyor, marked at the top of well casing. This measurement is necessary to determine whether sediment is accumulating in the well screen, suggesting the need for well redevelopment, and whether there is a blockage in the well casing. Less frequent total well depth measurements may be appropriate for sites where sediment is not accumulating or where dedicated pumps are used. The use of dedicated pumps does not necessarily eliminate the need for total well depth measurement. Total well depth measurement may also be based on water quality data (i.e., excessive turbidity or anomalous metals readings). At a minimum, well depths should be gauged each time the dedicated pump is removed from the well for maintenance.

5.5 PURGING

1. Specify the purge method and equipment for each well. Conventional purge methods are described in EPA (1986). Low-flow purge methods are described in Puls and Barcelona (1996). The screen length restriction for low-flow purge methods is discussed in Section 6.3 of this guidance document. Use of dedicated equipment is preferred to minimize the risk of contaminant introduction into the well and reduce the number of equipment blanks;

2. Describe the procedure for calculation of well casing volumes. Well casing volumes should include the filter-pack volume. Where references are made to total well depth, it must be clear the total well depth was measured from the surveyed permanent mark on the top of well casing. Depending on the frequency of total well depth measurement, the date of the total well depth measurement used for purge volume calculation must also be recorded. The as-built total well depth should be included in the WQSAP;

3. Specify the maximum purge rate for each well. Whenever possible, purge rates should not exceed recharge rates determined from appropriate well testing. Wells should be purged at rates below those used to develop the well to prevent further development of the well and agitation of sediment, to prevent damage to the well, and to avoid disturbing accumulated corrosion or reaction products in the well (Puls et al., 1990; Puls and Barcelona, 1989; Puls and Barcelona, 1995; Barcelona and Helfrich, 1986). A low purge rate will also reduce the possibility of stripping volatile organic compounds (VOCs) from the water, and will reduce the likelihood of mobilizing solids in the subsurface that are immobile under natural flow conditions. Withdrawal rates should minimize drawdown while satisfying time constraints. Excessive drawdown distorts the natural flow patterns around a well and can cause contaminants not present originally to be drawn into the well. Due to such effects, low flow sampling should be compared to large volume purge sampling methods to determine which one is more appropriate at a particular well. If contaminants are only detected by the large volume sampling method, this may suggest the well is not appropriately located for low flow sampling. Historical purge rates and volumes should be reviewed by the field team during each sampling event. Changes in historical purge volumes or times should be included in the monitoring report;

4. The actual volume of water purged should be based on stabilization of field parameters. DTSC believes field parameter stability is the best indication the water being sampled is representative of groundwater in the aquifer. All measurements of field parameters are to be recorded in the field log. The final, stable value for each field parameter must be recorded and graphed through time for each well;

5. Describe procedures for purging with little or no drawdown. Sampling must proceed as soon as field parameters stabilize. Describe the procedures for measuring and recording water levels during purging to ensure excessive drawdown is not occurring;

6. For all purging, specify the pump intake placement, allowable drawdown, and volume of water to be removed from each well. The use borehole flow meters or other borehole flow devices may be used in longer screened wells (i.e., greater than 10 feet) to determine pump placement within the well intake area; however, DTSC recommends the saturated well intake length be ten feet or less. The actual volume of water purged should be based on field parameter stabilization;

7. Sampling low yielding wells is problematic. Low yielding wells are defined as wells that can not sustain a static water level during groundwater extraction at the rate of 100 milliliters per minute. Excessive purging, or exposure of the well intake, may cause volatilization or chemical reactions to occur providing non-representative samples. Comparative side-by-side sampling is strongly recommended for low yielding wells. For example, in the case of VOC sampling, comparisons could be made between no purge (i.e., diffusion bags, no purge micropurge), low flow techniques, and one to three well volume purging. Evacuation methods should be evaluated and approved by DTSC to determine which technique provides the most representative sample for each site and the constituents sampled;

8. Sampling should be conducted as soon as possible after purging is complete. The WQSAP must specify, based on measured recharge rates, the approximate time period after purging that sampling will occur. Alternatively, the WQSAP must describe the procedures for measuring and recording water levels after purging and before sampling and must specify the criteria for recharge;

9. Describe the equipment and procedures for measuring field indicator parameters during purging. 22 CCR 66264.97(e)(13) requires that pH, specific conductance, temperature, and turbidity be measured each time groundwater is sampled. Turbidity must be measured with a turbidity meter; visual turbidity estimates are not sufficient. Other field indicator parameters (e.g., oxidation-reduction potential (ORP), dissolved oxygen) should also be measured during purging. Parameters used to determine stabilization are a function of the type of purge method. For example, the one to three well volume purging method typically use pH, specific conductance, and temperature as field stabilization parameters. Low-flow purge methods typically use pH, specific conductance, temperature, ORP, dissolved oxygen, and turbidity as field stabilization parameters. A flow-through cell or downhole meters should be used for the analysis of temperature, specific conductance, pH, ORP, and dissolved oxygen. Turbidity measurements may be used to evaluate the need to redevelop monitoring wells and interpreting metals data. The WQSAP must state the minimum purge volume between tests to determine whether field parameters have stabilized (e.g., one-half casing volume);

10. Specify the criteria for determining that field parameters have stabilized before sampling. Common acceptance criteria are as follows: pH (±0.1); specific conductance (±3%); temperature (±1°C); ORP (±10 mV); dissolved oxygen (±10%); turbidity (±10%);

11. Describe procedures for recording flow rates, volumes of water purged, and for disposing of purge water. Field notes must include the appearance of the purge water (e.g., color, nonaqueous phase liquids, obvious odor, etc.). If the purged water is contaminated, based on prior test results, the water should be stored in appropriate containers until analytical results are available, at which time proper arrangements for disposal or treatment should be made (i.e., contaminated purge water may be a hazardous waste). Purge water from new wells, for which there are no prior chemical data, should be containerized and assumed potentially contaminated until sample analytical results prove otherwise;

12. Discuss well conditions that indicate the well should not be sampled or the data from the well should be flagged. For example, wells with turbidity greater than 5 to 50 nephelometric turbidity units (NTU) are not in acceptable condition for sampling; however, site data should be evaluated on a case-by-case basis;

13. In wells with floating product, a sample of the product should be collected and analyzed prior to sampling groundwater for dissolved constituents. A sampling methodology should be devised to allow pump placement through the immiscible layer with minimal disturbance. For example, a small conduit, temporarily sealed at one end, should be inserted in the well past the product layer. The sampling device should be lowered into the conduit, through (breaking) the temporary seal, and into groundwater for sample collection. During purging, drawdown should be minimized impact from the free product.

6.0 COLLECTING GROUNDWATER SAMPLES

1. Sampling frequency should be based on the site-specific hydrogeologic conditions as well as regulatory requirements. Groundwater analytical results should be reviewed periodically, and sampling frequency modified according to data needs, historical water quality trends and regulatory goals. At a minimum, a quarterly sampling frequency is required to conduct statistical evaluations pursuant to 22 CCR Section 66264.97(e)(12). To track potential seasonal changes in concentration, at least two sampling rounds should coincide with annual maximum and minimum water table or potentiometric surface elevations;

2. Describe the equipment and procedures for collecting samples. Sampling equipment must be constructed of inert materials. Sampling procedures must be designed to minimize sample disturbance resulting in changes in water chemistry. Dedicated equipment should be used whenever possible. If equipment must be used at more than one well, the WQSAP must describe, in detail, equipment decontamination procedures and equipment blank collection procedures. Wells should be sampled from least to most contaminated;

   NOTE: To encourage innovation, Cal/EPA may allow the use of other devices if the facility demonstrates the device will yield representative groundwater samples.

3. The following requirements should apply to the selection of sampling equipment:

   i. Sampling equipment should be chosen based on the analytes of interest and the characteristics and depth of the saturated zone from which the sample is withdrawn. For example, the choice of sampling equipment should reflect consideration of the potential for light non-aqueous-phase liquids (LNAPLs) and dense non-aqueous phase liquids (DNAPLs);

   ii. Sampling equipment should be constructed of inert material. Sample collection equipment should not alter analyte concentrations, cause loss of analytes via sorption, or cause gain of analytes via desorption, degradation, or corrosion;

   iii. Sampling equipment should cause minimal sample agitation and should be selected to reduce/eliminate sample contact with the atmosphere during sample transfer. Sampling equipment should not allow volatilization or aeration of samples to the extent that analyte concentrations are altered.

4. Clean gloves (as specified in the site health and safety plan) shall be worn by sampling personnel. If surgical gloves are worn, the gloves should be powderless. The WQSAP should indicate the frequency with which gloves will be changed (i.e., frequently, between wells, etc.);

5. A chemical analytical table should be included in the WQSAP which lists the following: analytical parameters, container types and sizes (i.e., glass, plastic, amber, etc.), methods of preservation, holding times, number of samples, and minimum volume requirements. The table should also indicate what order the containers will be filled at the wellhead. Samples should be collected and containerized according to the volatility of the target analytes;

6. Describe the numbering protocol for samples. Identify each sample with a unique identification number. Duplicate or split samples should be numbered in sequence with the general samples. Duplicate sample numbers should be noted in the field log;

7. Describe the labeling of the sample containers. A sample copy of a label should be included. At a minimum, labels should contain the following: sample identification number; name and signature of collector; date and time of collection; place of collection; requested analysis; and preservative used;

8. Describe the preservation techniques necessary for each type of sample. State that bottles prepared with preservatives should not be overfilled;

9. Describe the procedures for determining the amount of preservative necessary to achieve the required chemical stability (e.g., amount of acid necessary to ensure pH<2 for metals analysis);

10. Describe the procedures for checking and documenting the results of preservation. For example, checking whether temperature is maintained at 4°C during shipping and handling or that a sample for metals analysis were acidified to pH<2;

11. Present the rationale for deciding whether samples for metals analysis will be filtered or not. The decision must include a consideration of the purpose of sampling. The following recommendations are provided as a guide to sampling groundwater for the analysis of trace metals:

    i. Filtered samples for dissolved metals analysis should be used whenever groundwater is excessively turbid or to reduce statistical outliers. Poorly designed or developed wells yielding high turbidity should be replaced. If turbidity is less than 5 NTU, filtering is not necessary (Cal/EPA. 1995a);

    ii. Samples should never be filtered when a water supply well is sampled (Cal/EPA. 1995a);

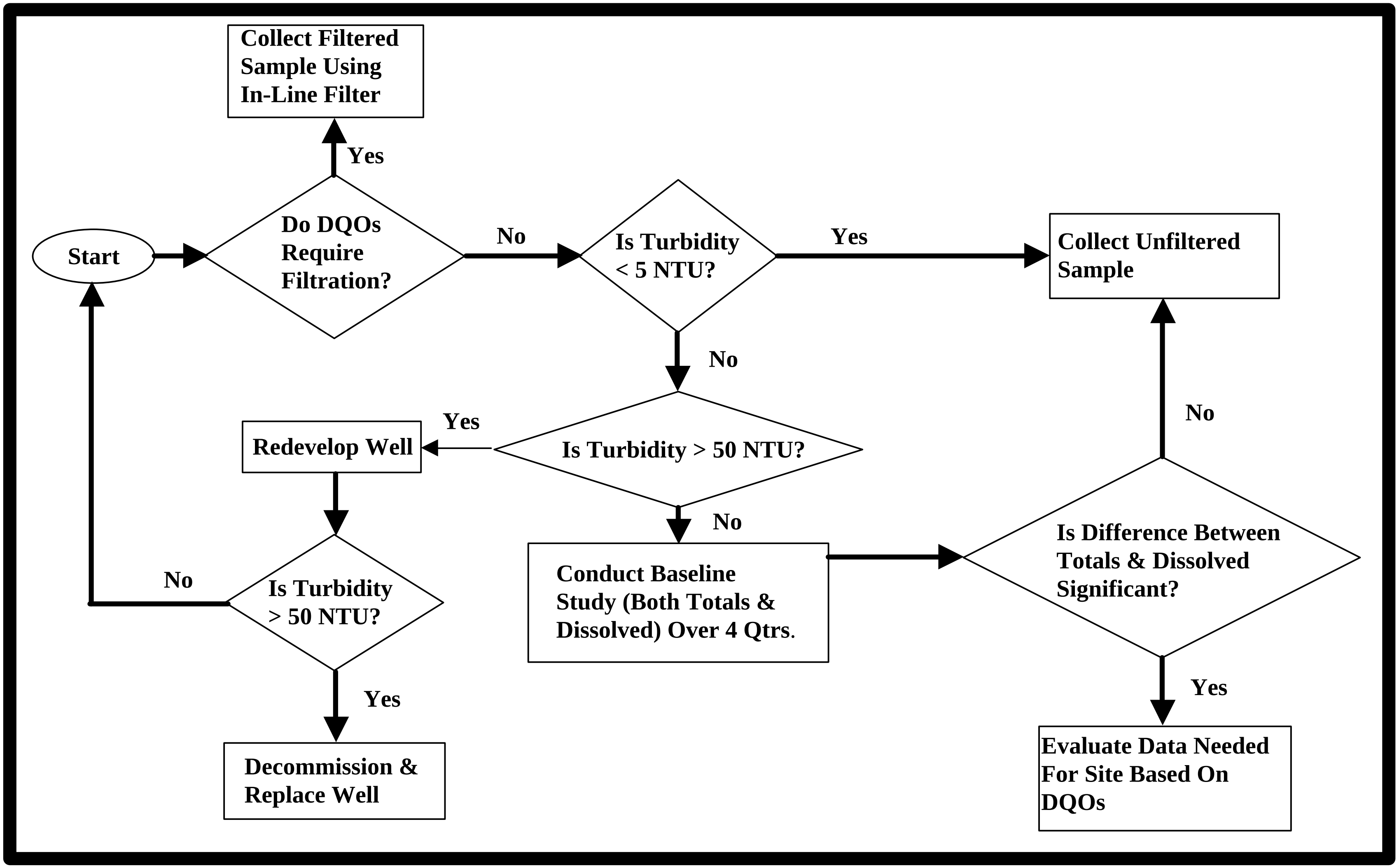
    iii. For risk assessment purposes and to assess facility impacts to groundwater, unfiltered samples should also be considered if significant colloidal transport is suspected; filtered samples may also be collected at the same time for comparison. A recommended approach to sample filtration is included as Figure B-1 (Puls 1990, Cal/EPA. 1995a).

12. If filtering is required, describe the equipment (including filter size) and procedures for filtering samples. Use of in-line filters is strongly recommended. Filters must be discarded after each well. Poor filtration methods can introduce variability into the analytical results. If in-line filtration is not possible, filtering should be done as quickly as possible (immediately) using positive pressure filtering equipment. Laboratory filtration or filtration by vacuum methods is not acceptable. The WQSAP should discuss the appropriate filter size. DTSC recommends the use of 1 to 5 micron filters to allow passage of colloids and filtration of particles greater than clay size;

13. The WQSAP should specify the filter will be pre-washed with well water and the filtrate discarded before the samples are collected. The filter manufacturer's instructions must be consulted for filter medium specific preconditioning specifications (Nielsen 2000). Filtration should not be used to compensate for unacceptable well performance (e.g., excessive turbidity) or poor sampling practice;

14. The type, manufacturer, and composition of filters should be recorded in the field logs. Changes in filter type, manufacturer, or composition can introduce variability into the analytical database.

Figure B-1. Example Criteria for Sample Filtration.



7.0 SAMPLE HANDLING

1. Describe the equipment and procedures for storing samples prior to and during transport. Sample containers should be decontaminated before shipment to the laboratory. Packaging and labeling requirements must comply with U.S. Department of Transportation (DOT) and Federal Aviation Administration (FAA) regulations. Ensure sample containers are properly packed to prevent breakage (i.e., use of vermiculite, foam packing blocks, sawdust, bubble pack, plastic netting sleeves, and secondary containers) (Nielsen 2000);

2. Describe the forms and procedures for sample transport, the custody of pre-preserved sample containers sent from the laboratory prior to use (i.e., storage in secure and clean area), and chain-of-custody control. Specify the procedures to be followed to assure strict custody of samples is maintained during sample collection, storage, and transport. Samples should not be left unattended, but must be secured areas. Include copies of chain-of-custody and sample analysis request forms in the WQSAP;

3. Describe the method used to cool the samples and determine whether the recommended preservation temperature is achieved. A maximum/minimum thermometer or temperature blank in each cooler should be used to demonstrate proper temperature preservation. Upon receipt, the laboratory should record the temperature of each cooler on the chain-of-custody record.

8.0 DECONTAMINATION\EQUIPMENT HANDLING

1. Describe equipment, procedures, and record keeping for decontamination of all sampling equipment and protective gear. Equipment should not be used if visual signs, such as discoloration, indicate decontamination was insufficient;

2. Include a decontamination procedure for the water level indicator meter. DTSC recommends decontaminating the portion of the water level indicator and tape lowered into the well. A typical decontamination procedure for water level probes is as follows: (1) hand wash meter with phosphate-free detergent and a scrubber; (2) thoroughly rinse with distilled water;

3. Include a decontamination procedure for field parameter instrument sensors. A typical procedure is to rinse the probe with distilled water between readings at one well. After the sampling event at one well, the field parameter instruments should be cleaned by washing with phosphate-free detergent and rinsing with distilled water. After the sampling event, the field parameter instruments should be cleaned and maintained per manufacturer's instructions;

4. Include a decontamination procedure for sampling pumps between monitoring wells. The pump, discharge line, and other lines (e.g., support cable, electrical wires) in contact with groundwater in the well casing must be decontaminated. A typical decontamination procedure for pumps is as follows: (1) prepare bucket (or short PVC casing with one end capped) filled with tap (potable) water and a small amount of phosphate-free detergent; (2) place pump in bucket until completely submerged; (3) remove pump from bucket and scrub outside of the pump housing and cable; (4) place pump and discharge line in bucket, start pump and recirculate soapy water for two minutes (wash); (5) re-direct discharge line to 55-gallon drum, continue to add 5 gallons of tap water; (6) turn off pump and place pump in a second bucket containing tap water and continue to add 5 gallons of tap water (rinse) with pump on; (7) turn pump off and place pump into third bucket containing distilled/deionized water; (8) continue to add three to five gallons of distilled/deionized water (final rinse);

5. Include a decontamination procedure for non-dedicated equipment (i.e., bailers). The line used to lower equipment into the well should also be decontaminated if not discarded.

9.0 LABORATORY & FIELD QA/QC

9.1 LABORATORY ANALYSIS

1. Describe the analytical method to be performed for each sample;

2. Laboratory analyses should be performed by a laboratory certified by the State of California (http://www.dhs.ca.gov/ps/ls/elap/elapindex.htm).

9.2 QUALITY ASSURANCE/QUALITY CONTROL

1. Discuss the purpose of quality control (QC) samples (EPA 1995);

2. Discuss areas of concern for quality assurance (QA) in the collection of representative groundwater samples: (1) obtain sample representative of the zone of interest; (2) verify field water quality stabilization during purging; (3) ensure purging and sampling devices are made of inert materials and utilized in a manner that will not interact with or alter sample quality; (4) ensure results generated by WQSAP procedures are reproducible; (5) prevent cross-contamination; and (6) properly preserve, package, and ship samples. Discuss how these areas of concern are documented in the sampling and analytical process;

3. Include or reference a QA/QC plan describing the data quality objectives for the monitoring system. The QA/QC plan should include data quality objectives (precision, accuracy, and completeness), analytical data acceptance criteria, and QA/QC program format for reporting results;

4. Discuss the purpose, frequency of collection, labeling, and handling of QC samples collected during monitoring events. Examples of QC samples are summarized in Table B-1.

5. Field duplicate, equipment blank, and field blank samples should be labeled in the same manner as other samples collected. The laboratory should not be able to identify the QA/QC samples;

6. Describe the well selection rationale for QC sample collection. In general, QC samples should not be collected from the same monitoring points during each sampling event and should not be collected from background or non-detect monitoring points.

TABLE B-1
QUALITY CONTROL SAMPLES

Type	Typical Frequency	Purpose
Field duplicate	1 per 10 samples	Evaluate precision of sampling and analysis procedures.
Matrix spike	1 per 20 samples or 1 per analytical batch	Evaluate accuracy of analytical procedures.
Matrix spike duplicate	1 per 20 samples or 1 per analytical batch	Evaluate accuracy of analytical procedures.
Equipment blank	1 per set of equipment cleaned. Collect one sample at the beginning of sampling and one each day after decontamination.	Evaluate cross-contamination caused by non-dedicated equipment.
Field blank	1 per day	Evaluate whether contaminants introduced by ambient air during sample collection.
Trip blank	1 per sample cooler containing VOCs	Evaluate whether VOC contamination introduced during sampling, storage, or shipment.
Temperature blank	1 per sample cooler	Evaluate whether sample preservation requirements are achieved.

10.0 EQUIPMENT CALIBRATION

1. Describe calibration procedures, frequency, and record keeping for all instruments, probes, and meters used during sampling. Any deviations noted during the day (e.g., meter drift) must also be recorded. If meter drift requires an adjustment to any final values for field parameters, the results must be flagged in the database. The standard solution expiration date used for calibration should be recorded in the field log;

2. All calibration data will be recorded in a log book and a copy included in the monitoring report.

11.0 MONITORING SYSTEM

11.1 OPERATION & MAINTENANCE

1. Describe the routine and long-term operation and maintenance requirements for the monitoring system. These requirements should include: performance criteria for system components; procedures; and decision criteria that necessitate a given response. Inclusion of these elements in the WQSAP will allow these procedures to be implemented without preparation and review of an additional plan;

2. Include specific criteria that can be used to evaluate the performance of the monitoring system components. For example, a monitoring well producing water of unacceptable turbidity or accumulating sediment in the screened interval would not meet performance standards and a response action, such as well redevelopment, would be warranted;

3. Include the procedures necessary for system operation and maintenance. Examples of procedures that should be included in the WQSAP include procedures for inspection, maintenance, redevelopment, decommissioning, and installation. Installation procedures should also incorporate methods to determine whether a monitoring system component was properly installed. For example, downhole geophysical methods (e.g., deviation surveys, cement-bond logs, casing collar indicator surveys, etc.) may be used to assess proper well installation. Other procedures may be appropriate for a given monitoring system component. The procedures should address tasks that will be conducted at different frequencies. For example, the surface completion of a monitoring well may be inspected quarterly whereas a downhole camera survey to assess well condition may be conducted less frequently (i.e., every 3 to 5 years depending on site conditions);

4. Include decision criteria for responding to a system component not meeting performance standards. Figure B-2 is an example decision flow chart for determining whether a well should be decommissioned.

11.2 RESPONDING TO EXCEEDANCES

1. Reference the statistical evaluation plan for evaluating the data (see following Appendix). A determination of a statistical exceedance under a Detection Monitoring Program (DMP) or an exceedance of the maximum allowable concentration under a Corrective Action Monitoring Program (CAMP) necessitates further action. The WQSAP should address the logistical considerations for responding to exceedances. For example, for a site with a statistical exceedance under a DMP, the WQSAP should discuss when the verification sample will be obtained. If the exceedance is verified, the WQSAP should discuss when Appendix IX sampling will be performed;

2. For compounds not naturally occurring and/or those compounds not detected in background samples, verification (retest) procedures should always be required under the following conditions under a DMP or Evaluation Monitoring Program (EMP) (Cal/EPA 1993):

   i. compound is detected above the Practical Quantitation Limit (PQL) in a downgradient monitoring point;

   ii. compound detected above Method Detection Limit (MDL), but below PQL in two successive samples or more than once in a 12-month period;

iii. more than one compound is detected above the MDL, but below the PQL at a single monitoring point during a single monitoring event;

iv. a compound is detected above the MDL, but below the PQL, and a review of available data shows trends or other indications a release may have occurred. Such a review of available data, including graphical and spatial analysis, must be documented by the discharger/owner or operator in the next scheduled monitoring report, or sooner, as required by regulation, HWF Permit, waste discharge requirements, or monitoring and reporting program.

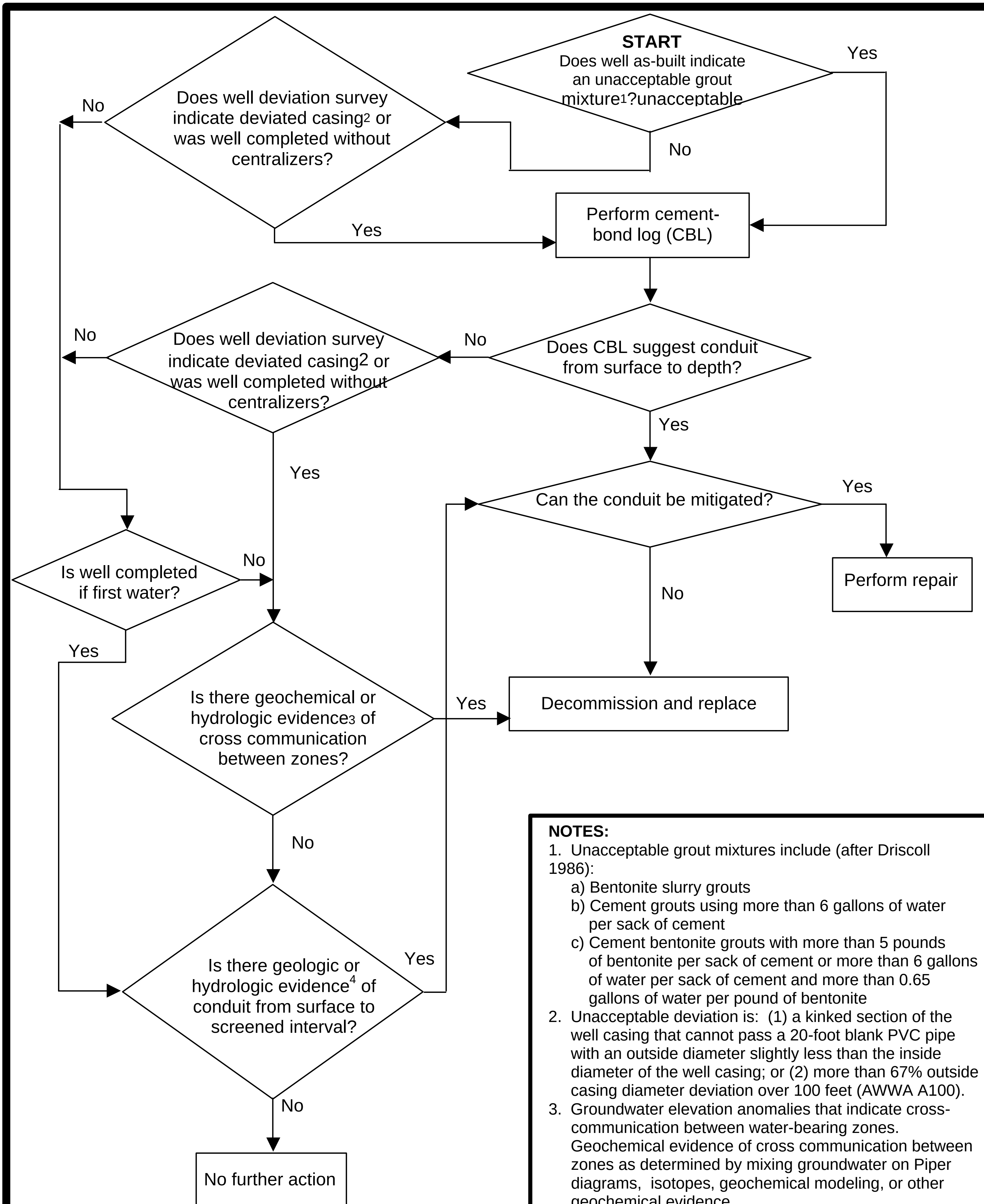


Figure B-2
Example Criteria for
Well Decommissioning Decision

NOTES:

1. Unacceptable grout mixtures include (after Driscoll 1986):
   a) Bentonite slurry grouts
   b) Cement grouts using more than 6 gallons of water per sack of cement
   c) Cement bentonite grouts with more than 5 pounds of bentonite per sack of cement or more than 6 gallons of water per sack of cement and more than 0.65 gallons of water per pound of bentonite
2. Unacceptable deviation is: (1) a kinked section of the well casing that cannot pass a 20-foot blank PVC pipe with an outside diameter slightly less than the inside diameter of the well casing; or (2) more than 67% outside casing diameter deviation over 100 feet (AWWA A100).
3. Groundwater elevation anomalies that indicate cross-communication between water-bearing zones. Geochemical evidence of cross communication between zones as determined by mixing groundwater on Piper diagrams, isotopes, geochemical modeling, or other geochemical evidence.
4. Hydrologic evidence of a surface conduit as indicated by correlation with surface releases, etc. Geochemical evidence of a surface conduit as indicated by intermittent water quality changes, increased TDS, or difference from nearest neighbor.

12.0 DOCUMENTATION

1. Before each sampling event (e.g., quarterly, semi-annual, annual), each member of the field team must sign a document stating he/she has read and understands the current version of the WQSAP. A copy of this document must be submitted to DTSC with the report of analytical results;

2. The monitoring report must document whether all field measurements and samples were collected in accordance with the procedures described in the WQSAP. Following each sampling event, each member of the field team must sign a document detailing any deviations from the WQSAP necessitated by field conditions. A copy of this document must be submitted to DTSC with the report of analytical results;

3. Describe or include copies of example field data sheets, sample labels, chain-of-custody records, etc.;

4. Indicate the information that should be recorded by the laboratory on the chain-of-custody record and in the laboratory narrative. For example, the laboratory should record and report the temperature at which the samples were received.;

5. Hard-covered, bound notebooks should be used to record all field observations and measurements. All entries should be made in black, indelible ink. Good laboratory practices should be followed when correcting entries in the field log (i.e., single line cross-out corrections, etc.). Entries should be accurate, unbiased, detailed, legible, and understandable. Legal advice should be sought for high-profile cases (Nielsen 2000). For field log content, refer to ASTM 6089-97.

13.0 REPORTING

Describe in detail the content and submittal dates for monitoring reports. Reporting is discussed further under Appendix D of this guidance document.

14.0 HEALTH AND SAFETY

Reference the site-specific health and safety plan. The WQSAP should state that standard operating procedures should be followed, such as minimizing contact with potential contaminants in liquid and vapor phases through appropriate use of personal protective equipment.

15.0 REFERENCES

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APPENDIX C

SUGGESTED CONTENT FOR STATISTICAL EVALUATION PLANS

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LIST OF ABBREVIATIONS

$1-\beta$	power
22 CCR	Title 22 of California Code of Regulations
α	Type I error rate, significance level
β	Type II error rate
ANOVA	analysis of variance
Appendix IX	Appendix IX to 22 CCR Chapter 14
Article 6	22 CCR 66264.90 through 22 CCR 66264.100
ASTM	American Society of Testing and Materials
Cal/EPA	California Environmental Protection Agency
CAMP	corrective action monitoring program
CAP	corrective action program
CLGB	concentration limits greater than background
COC	constituent of concern
CCR	California Code of Regulations
DMP	detection monitoring program
DNAPL	dense non-aqueous phase liquid
DTSC	Department of Toxic Substances Control
EMP	evaluation monitoring program
EPA	U.S. Environmental Protection Agency
H_o	null hypothesis
H_a	alternate hypothesis
HWF	hazardous waste facility
MCL	maximum contaminant level
MDL	method detection limit
n	number of samples in data set
ND	not detected, nondetect
p value	measure of strength of the evidence
P	proportion of population
POC	point of compliance
PQL	practical quantitation limit
QA	quality assurance
QC	quality control
SWRCB	State Water Resources Control Board
TR	trace
UTL	upper tolerance limit
VOC	volatile organic compound
WQPS	water quality protection standard
Y	specified confidence coefficient

1.0 INTRODUCTION

Water quality monitoring and response programs for permitted hazardous waste facilities require use of statistical methods for determining compliance with the water quality protection standard (WQPS) associated with each type of monitoring program. The statistical applications should be designed to meet the needs of the facility's specific monitoring program, whether it be detection monitoring program (DMP), evaluation monitoring program (EMP), or corrective action monitoring program (CAMP). A well-designed water quality monitoring program requires a well thought out WQPS for each regulated unit. Development and monitoring of concentration limits (an element of the WQPS), requires an appropriate statistical approach which generally utilizes a sequence of various statistical methods. When used properly and applied with common sense, statistical applications can be a powerful tool in developing and evaluating compliance with the monitoring program WQPS. When used improperly, statistical results can be misleading, and can drive the direction of a monitoring program away from its original intent: to detect, characterize, and respond to releases to groundwater. It is critical to remember that results of statistical applications be kept in perspective with an understanding of overall hydrogeological conditions, operational facility conditions, and analytical limitations.

Article 6 [California Code of Regulations (CCR), title 22, sections 66264.90 through 66264.100] allows facility owner/operators to propose a wide variety of statistical methods for use with monitoring programs. This guidance primarily focuses on explanation of statistical applications, rather than specific statistical methods. Details regarding specific statistical methods are not included herein, however, numerous resources are cited for reference.

1.1 RECOMMENDED RESOURCES FOR PREPARING STATISTICAL EVALUATION PLAN

This guidance references the following text books and guidance documents that address statistical applications for groundwater monitoring:

- *Standard Guide for Developing Appropriate Statistical Approaches for Groundwater Detection Monitoring Programs* (ASTM 1998)
- *Statistical Methods for Groundwater Monitoring* (Gibbons 1994)
- *Statistical Methods in Water Resources* (Helsel and Hirsch 1992)
- *Statistical Methods for Environmental Pollution Monitoring* (Gilbert 1987)
- *Addendum to Interim Final Guidance, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (EPA 1992)
- *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (EPA 1989)

Additional information can be accessed through recent articles, statistical software, and ongoing workshops. A good starting point is the *Standard Guide for Developing Appropriate Statistical Approaches for Groundwater Detection Monitoring Programs* (ASTM 1998). It is important to note that Article 6 requires no specific recipe for statistical applications in groundwater monitoring. Most available references focus on application of specific statistical methods, rather than overall approach. The ASTM document, however, provides detailed guidance on developing a statistical monitoring plan, and is well illustrated with flow charts depicting the various decision points at which the general comparative strategy is selected, and how the statistical methods are to be selected based on site-specific considerations.

Other good resources include commercially available statistical software programs for groundwater monitoring applications that offer artificial intelligence algorithms that incorporate and/or expand upon the approaches proposed by references cited herein. The EPA Groundwater Information Tracking System/Statistic Software *GRITS/STAT* is available at no charge through the EPA web site. However, EPA no longer supports or updates the software. It is critical that the user of any statistical software program should obtain appropriate documentation regarding the program's calculations and methodology. This is a necessary step, because the owner/operator needs to demonstrate an understanding of the statistical methods (i.e., the software should not be used as a " black box"), and provide a demonstration that the proposed methods meet the performance standards listed in Article 6 and are protective of human health and the environment.

1.2 TYPES OF STATISTICAL APPROACHES

In general, there are four statistical approaches used in monitoring programs: descriptive statistics, interwell comparisons (i.e., upgradient background well to point of compliance (POC) well comparisons), intrawell comparisons (i.e., comparison of recent data to historical background data within a single POC well), and comparison of POC well data with fixed limits (i.e., comparison of POC well data to applicable corrective action threshold concentrations). The owner/operator is required to demonstrate that the proposed statistical approach is protective of human health and the environment and meets the applicable performance standards listed in 22 CCR 66264.97(e)(9). The next section provides a brief summary of the performance standards followed with a description of selected statistical methods.

2.0 APPLICABLE PERFORMANCE STANDARDS [22 CCR 66264.97(E)(9) & 66265.97(E)(9)]

The statistical methods proposed by the owner/operator are required to comply with the following performance standards for each six-month period:

2.1 DATA DISTRIBUTION

The statistical method used to evaluate water quality monitoring data should be appropriate for the distribution of the constituent of concern (COC) or monitoring parameter to which it is applied, and should be the least likely of the appropriate methods to fail to identify a release from the regulated unit. If the distribution of a COC or monitoring parameter is shown by the owner/operator to be inappropriate for a normal theory test (i.e., parametric tests), then the data should either be transformed so that the distribution of the transformed data is appropriate for a normal theory test, or a distribution-free theory test (i.e., nonparametric test) should be used. If the distributions for the COC or monitoring parameters differ, more than one statistical method may be needed. Some common tests for departure from normality include the Shapiro-Wilk test (when $n<50$), and the Shapiro-Francia Test and D'Agostino's Test (when $n>50$), probability plot correlation coefficient, skewness test, and kurtosis test. Various graphic approaches may also be used (Gibbons, 1994 and EPA 1992). Note that use of the Coefficient of Variation test is no longer recommended (EPA, 1992).

2.2 TYPE I ERROR RATES

Hypothesis tests are used to evaluate and compare groups of data. Statistical tests are the most quantitative ways to determine whether hypotheses can be substantiated, or whether they must be rejected outright. Use of hypothesis tests is intended to provide greater advantage over educated opinion, in that they provide a standardized approach for arriving at the same result, and they present a measure of strength of the evidence (p value). The decision to reject a hypothesis is augmented by the risk of that decision being incorrect. Hypothesis testing utilizes the following structure (from Helsel and Hirsch, 1992):

1. Choose the appropriate test
2. Establish the null and alternate hypothesis (H_o and H_a, respectively)
3. Decide on an acceptable Type I error rate α
4. Compute the test statistic from the data
5. Compute the p-value
6. Reject the null hypothesis if p is less than or equal to α

The choice of test can be based on a prior test of normality for the data set. If normality is rejected, then a nonparametric test is chosen. The null hypothesis usually states the situation that is assumed to be true until the data indicate that it is likely to be false. The alternative hypothesis is the situation anticipated to be true if the evidence shows the null hypothesis (H_o) is unlikely. For example, for detection monitoring, H_o could be the assumption of " no contamination" (i.e., no significant exceedance of background concentration limit). If the computed test statistic equals or exceeds the critical value, then H_o would be rejected, then the alternative hypothesis would assume that contamination (i.e., a significant exceedance of background concentration limit) does exist. The α-value, or significance level, is the probability of incorrectly rejecting H_o (i.e., when H_o is true) and is referred to as a Type I error. A higher Type I error could result in greater chances for false positive detects. If the null hypothesis is actually true, the probability of correctly not rejecting H_o is thus $1-\alpha$. Power $(1 - \beta)$ is referred to as the probability of correctly rejecting H_o if it is false. Type II error (β) occurs when failing to reject H_o when it is false (i.e., false negative results). Situations with low power may result in failure to recognize significant differences in water quality (i.e., potential release) when they do occur.

If an individual monitoring point comparison procedure is used to compare an individual monitoring point COC or monitoring parameter value with a background monitoring parameter value, the test should be done at a Type I error level no less than 0.01. If a multiple comparisons procedure is used, the Type I experiment-wise error rate should be no less than 0.05; however, the Type I error of no less than 0.01 for individual monitoring point comparison should be maintained. This performance standard does not apply to tolerance intervals, prediction intervals, or control charts.

2.2.1 Control Chart

If a control chart approach is used to evaluate water quality monitoring data, the specific type of control chart and its associated statistical parameter values (e.g., the upper control limit) should be proposed by the owner/operator and approved by the Department of Toxic Substances Control (DTSC) if DTSC finds it to be protective of human health and the environment. Any control charting procedure must have a false-positive rate of no less than one percent for each monitoring point charted (e.g., upper control limits on X-bar or R-charts, used only once every six months, must be set at no more than 2.327 standard deviations of the statistic plotted for one-sided statistical comparison, or at no more than 2.576 standard deviations of the statistic plotted for two-sided statistical comparison).

2.2.2 Tolerance Interval or Prediction Interval

If a tolerance interval or a prediction interval is used to evaluate water quality monitoring data, the levels of confidence and, for tolerance intervals, the percentage of the population that the interval must contain should be proposed by the owner/operator and approved by the DTSC if the DTSC finds these statistical parameters to be protective of human health and the environment. These statistical parameters should be determined after considering the number of samples in the background database, the data distribution, and the range of the concentrations or values for each constituent of concern or monitoring parameter. The coverage of any tolerance interval used must be no more than 95 percent and the confidence coefficient must be no more than 95 percent for a six-month period. Prediction intervals should be constructed with an experiment-wise error rate of no less than five percent and an individual monitoring point error rate of no less than one percent.

2.3 USE OF DATA THAT IS LESS THAN THE PRACTICAL QUANTITATION LIMIT

The statistical method should account for data below the practical quantitation limit (PQL) with one or more statistical procedures that are protective of human health and the environment. Non-numerical determinations (non-detect or trace values) are referred to as *censored data*. Various opinions exist regarding dealing with censored data issues. There is some debate regarding definition of the "censoring point". Cal/EPA (1993) recommends that the method detection limit (MDL) be the censoring point, and that trace or estimated values (i.e., values between MDL and PQL) be reported for DMP and EMP. Gibbons (1994) indicates that the PQL and not the MDL should be the censoring mechanism since values above the MDL and below the PQL are detected but not quantifiable. Controversy also exists regarding the appropriate method or methods for incorporating the censored data in computing summary statistics, testing hypotheses, and computing interval estimates. Selection of the appropriate method can be complex, as it depends on both the degree of censoring and the type of application. Further discussions on treatment of censored data are presented in Gilbert (1987), Gibbons (1994), Helsel and Hirsch (1992), and Akritas et al, (1994).

It is quite common to have COC and monitoring parameters that have a high proportion of nondetects. These may include non-naturally occurring COC and monitoring parameters and other constituents that are present at concentrations below the PQL. One of the most difficult problems in the analysis of groundwater monitoring data involves incorporation of these "nondetects" into statistical applications. Several questions arise when dealing with nondetects, such as what is the minimum detection frequency required for statistical applications? What are the best methods for estimating summary statistics for data that include nondetects? There is no single answer, and various resources provide differing guidance.

In addressing this issue, it is important to recognize that many nondetected COC and monitoring parameters are anthropogenic and are not naturally occurring, and any detected concentration of such should warrant further attention. For example, volatile organic compounds (VOCs) are generally not expected in background water quality, and their concentration limit should be their respective MDL, which should be established with due care. A MDL (trace) indication provides roughly a 99 percent certainty that the analyte is present at some concentration between zero and the PQL.

The California Nonstatistical Method provides a viable "measurably significant" indication of a release. One trigger from this method that may be indicative of a release occurs when at least two trace values for a monitoring parameter or COC (not, or rarely, detected in background) are detected in a single well's data, for a given reporting period. This method's other trigger occurs when one or more such COC is detected at or above its respective PQL. Under this scenario, the MDL is still the concentration limit; the trigger indicates an exceedance of the MDL by a single COC exceeding the PQL. Preliminary indications using this method are subject to verification by retest, to minimize the false-positive rate. If the nonparametric prediction interval is used, then the concentration limit should be the PQL.

2.4 SEASONAL AND SPATIAL VARIABILITY AND TEMPORAL CORRELATION

Certain descriptive statistical methods such as time series plots and box and whisker plots are excellent tools for use in evaluating site-wide water quality. These methods can be used to evaluate temporal and seasonal variations (through time series plots) and spatial variability (through box and whisker plots) in water quality. Time series plots are a graphical analysis that display select constituent concentrations (y-axis) for one or more well through time (x-axis). These plots allow one to graphically identify temporal variations such as trends, seasonality, and outliers. Multi-well time series plots can also be used for evaluating spatial variability for a given parameter. Box and whisker plots graphically depict distribution and spatial variability of data for the site. The box plot graphically locates the median, 25^{th} percentile and 75^{th} percentile of the constituent data set for a given well and the whiskers extend to the minimum and maximum values of the data set. The range between the ends of the box represents the interquartile range (along y-axis), which can be used as a quick estimate of spread or variability. Typically, each box and whisker represents the range of historical data for a given constituent at a given well. The series of boxes and whiskers thus graphically depicts historical data for a given constituent for all wells within the monitoring network. At a glance, one can quickly compare the median concentrations for a given constituent across the facility's monitoring network. This chart is an excellent tool for quickly identifying site-wide spatial variability. Examples and instructions for generating box and whisker plots are included in Helsel and Hirsch (1992). Use of time series and box and whisker plots is highly recommended when evaluating whether to use interwell versus intrawell approach for DMP.

A variety of statistical tests are available for testing and adjusting for significant seasonal variability in water quality data. Various statistical methods are also available to test for the presence of outliers, trends, and temporal correlation. The owner/operator should clearly state which tests are utilized and clearly document and provide rationale for any adjustments performed to deseasonalize, remove outliers, or detrend any data.

Appropriate definition of "background" water quality requires ca reful consideration of the presence of spatial variability. If significant spatial variability is determined to be present that precludes the use of upgradient wells as background wells for interwell comparisons, then intrawell comparisons (i.e., within well comparisons) should be considered. If intrawell comparisons are proposed, the owner/operator should demonstrate that the data selected for the background historical period does not show evidence of prior impacts.

2.5 DATA QUALITY CONTROL

Any quality control procedure that is approved by the DTSC for application to compliance water quality data for a monitored medium should also be applied to all newly-acquired background data from that medium. Any newly-acquired background monitoring datum that is rejected by an approved quality control procedure should be maintained in the facility record but should be excluded from use in statistical comparisons with compliance water quality data.

3.0 DEFINITION OF STATISTICAL TERMS

3.1 COMBINED SHEWHART-CUSUM CONTROL CHART

The Shewhart-CUSUM control chart allows for detection of recent and cumulative releases. This control chart is one of the more commonly used intrawell methods currently used, and is described in EPA (1989), ASTM (1998), and Gibbons (1994). It assumes that data are independent and normally distributed with a fixed mean and constant variance.

3.2 ANOVA

EPA (1989) describes the parametric and nonparametric one way analysis of variance (ANOVA) as the preferred statistical test method for interwell background to POC well comparisons. ANOVA consists of a variety of procedures that compare the means of different groups of observations to determine whether there are any significant differences among the groups. If significant differences exist, contrast procedures may be used to determine where the differences lie. It is important to note that although the US EPA has strongly supported the use of ANOVA methods, these methods have more recently been recognized to be insensitive to releases. The ANOVA methods are among the least useful and most expensive (due to their large required sample size) for a DMP. The best use of ANOVA is to evaluate spatial variation between upgradient wells, in support of using intrawell comparisons. The general consensus in recent literature also appears to be in disfavor of ANOVA. One concern pertains to the minimum sample size requirements. An effort to meet the minimum of four samples per well per sampling event creates logistical, technical, and cost effective challenges. Gibbons (1994) summarizes the following concerns regarding use of ANOVA:

- ANOVA procedures do not adjust for multiple comparisons due to multiple constituents which can be devastating to the site-wide false positive rate;
- ANOVA is more sensitive to spatial variability than contamination;
- nonparametric and parametric ANOVA assumes homogeneity of variance, which generally is not a valid assumption;
- ANOVA sampling requirements can maximize false positive and false negative rates and double the cost of monitoring.
- Even if equal variance exists at all wells, prior to a release, it will increase greatly at a downgradient well as soon as the plume arrives there. This exploding variance blinds the method to detecting the release.

3.3 RANK SUM

The rank sum test is a nonparametric procedure that can be used for determining whether two different groups (such as POC and background) differ. The rank sum test is described in EPA (1992) and Helsel and Hirsch (1992). Helsel and Hirsch demonstrate use of this test when comparing groups of sample size less than 10 (exact test) and greater than 10 (large-sample approximation test). EPA recommends use of the Wilcoxon rank sum test when the proportion of nondetects in the combined data set exceeds 15 percent. The Wilcoxon rank sum is not recommended for use unless the POC well and background data groups both contain at least four samples each.

3.4 PREDICTION INTERVAL/LIMIT

EPA (1989) and ASTM (1998) describe use of the prediction interval for interwell background to POC well comparisons. The most comprehensive summary of normal and nonparametric prediction intervals is provided in Gibbons (1994). A prediction interval is a statistical interval calculated to include one or more future observations from the same population with a specified confidence. The concentrations of a COC in background are used to establish an interval within which k future observations from the same population are expected to lie with a specified confidence. Each of the k future POC well observations is then compared to the prediction interval. The interval is constructed to contain all of k future observations with the stated confidence. Exceedance of the prediction interval by future observation may indicate statistically significant evidence of contamination. It is very important to maintain a low "k"; otherwise the power of the method decreases drastically. Typically, a prediction interval based on k-value of more than 10 will be able to detect only an overwhelming indication of a release. Therefore, for a prediction interval applied to a number of downgradient wells, in order to keep the power up, one recalculates the prediction interval anew for each reporting period. A Prediction Interval is calculated only for a two-tailed constituent (e.g., pH), with each tail using half the Type I error rate. An Upper Prediction Limit is calculated for a one-tailed test, where all of the Type I error rate is placed into the upper tail.

3.5 TOLERANCE INTERVAL/LIMIT

EPA (1989) describes use of the tolerance interval for interwell background to POC well comparisons. The most comprehensive summary of normal and nonparametric tolerance limits is provided in Gibbons (1994). A tolerance interval establishes a concentration range that is constructed to contain a specified proportion (P%) of the population with a specified confidence coefficient (Y). The proportion of the population included, P, is referred to as the coverage. The probability with which the tolerance interval includes the proportion P% of the population is referred to as the tolerance coefficient. EPA recommends a coverage and tolerance coefficient of 95%. A tolerance interval is calculated only for a two-tailed constituent (e.g., pH), with each tail using half the Type I error rate. An upper tolerance limit (UTL) is calculated for a one-tailed test, where all of the Type I error rate is placed into the upper tail.

4.0 DETECTION MONITORING PROGRAM (DMP)

The intent of the DMP is to detect the earliest possible release from a regulated unit. The DMP utilizes statistical applications to analyze the background and POC well data on a periodic basis to produce a "critical value" and a "test statistic" . These two values may not be in units of concentration, but will always be in the same scale. The results indicate significant exceedance of the background concentration limit (i.e., the detection of a release) if the test statistic equals or exceeds the critical value. Except in the case of intrawell comparisons, the background data set usually includes new background data obtained during that reporting period; therefore, the critical value typically changes from one reporting period to the next. Most data analysis methods have one critical/test-statistic couplet, but some produce two such couplets, either of which can indicate a release. Statistically significant deviations of a single downgradient well' s data from its respective concentration limit (background) for a single monitoring parameter or COC may be indicative of a release from the regulated unit. Note, however, that, if the method includes a retest, then it has not indicated a release until the preliminary indication is verified by a retest.

Article 6 allows for a variety of statistical methods to be used in the monitoring programs. These methods include, but are not limited to, parametric ANOVA, ANOVA based on ranks, tolerance or prediction interval procedures, control chart, or other DTSC-approved statistical test methods that include a procedure to verify that there is statistically significant evidence of a release from the regulated unit.

4.1 DETERMINING BACKGROUND WATER QUALITY

For all media monitored, the owner/operator is required to propose and justify the use of a procedure for determining a background value for each COC and monitoring parameter specified in the HWF Permit. The owner/operator is to propose a procedure for determining the background value for each constituent or parameter that does not display appreciable variation, or a procedure for establishing and updating background value for a constituent or parameter to reflect changes in water quality if the use of contemporaneous or pooled data provides the greatest power to the statistical method for that constituent or parameter.

Upon approval of the procedures for determining background values, the DTSC will specify in the HWF Permit either the background value or a detailed description of the procedure for establishing and updating the background value for each COC and monitoring parameter. Rather than include the actual background values in the HWF Permit and run the risk of modifying the HWF Permit every time background values are updated, it is generally more beneficial to include a detailed description of the procedure for establishing and updating the background values. This approach is recommended as it does not require HWF Permit modifications every time the background values are updated.

The general success of the DMP lies in how appropriately "background" water quality is defined. Recent references indicate that the traditional method of upgradient versus downgradient well comparisons (i.e., interwell comparisons) is often not appropriate, due to commonly-recognized naturally-occurring site-wide spatial variability in background water quality (ASTM, 1998; Gibbons, 1994; and Davis, 1994). The over-simplistic concept of adding additional upgradient wells to accommodate for spatial variation creates a statistical dilemma in that it can result in an erroneous variance component estimate that often is too small (Davis, 1994). Ideally, site-wide spatial variability in background can be addressed through comparison of recent data to historical data within a given well (i.e., intrawell comparison). This approach obviously has its limitations, in that it requires a demonstration that the historical "background" data are not contaminated. This demonstration can be more of a challenge for many facilities whose wells were installed after the regulated unit started operation, compared to those facilities whose wells were installed prior to start up of operations. Typically, the owner/operator will perform upgradient versus downgradient comparisons (if review of site conditions support interwell approach), identify which downgradient wells exceed background values for which constituents, provide evidence that these exceedances are not due to a release from the regulated unit, and use an intrawell strategy for these cases. If the monitoring well network is younger than the regulated unit, then additional screening of its historical data can be performed to demonstrate applicability for intrawell comparisons. For example, based on an evaluation of outliers, seasonality, and trends, the owner/operator may demonstrate a sufficient window of time for use of intrawell historical background data for each well in the monitoring network.

Definition of "background" for anthropogenic constituents (i.e., non-naturally occurring) and other constituents having low detection frequencies should be carefully defined as well. It is important to note whether nearby sources are present that affect background but are not affiliated with the regulated unit. In this case, although the constituents are not naturally occurring, they may be considered to be present in "background" water quality. Another problematic scenario may occur when VOCs are present in upgradient wells as a result of having migrated through the unsaturated zone. In this situation, a VOC that is released from the unit can reach and enter water in the upgradient wells, thereby producing elevated background values that will mask the detection of a release at the downgradient wells. Because of this problem, it is recommended to monitor for increased frequency of VOC detection (trace level or higher) in upgradient wells. The results of this monitoring may be handled as "physical evidence of a release" rather than based on the usual statistical testing. Investigation of VOC detections in this scenario can be through installation of a series of soil gas sampling wells (in permeable horizons in the unsaturated zone) in a line extending from the Unit to a point well beyond the indicating upgradient well. If the concentration of the indicating VOC becomes less as one moves away from the Unit, then this may indicate the Unit is the source. Otherwise, there may be another upgradient source and the elevated background value is valid.

The following steps are recommended for establishing background values at each regulated unit under the DMP.

1. Define “background” water quality for all COCs by evaluating the entire existing monitoring network. Definition should be based on understanding of site hydrogeology, site conditions, and past and present operations of site and vicinity. Compile and evaluate historical data for groundwater, leachate, surface water, soil, soil gas, etc. Create a groundwater database. Select either interwell or intrawell approach for establishing background values. The background values for the interwell approach will utilize upgradient wells. The background values for the intrawell approach will utilize historical data for each well. If the interwell approach appears feasible based on review hydrogeologic conditions and graphical descriptive statistics (such as time series and box and whisker plots), conduct statistical comparison to determine the significant exceedance of the background concentration limit. If the results indicate significant exceedance of the background concentration limit and the

regulated unit is new, consider an intrawell approach. In this situation for an existing unit, the owner/operator must demonstrate that the results are not attributed to a previous release, before proposing to use intrawell approach. If intrawell approach is selected, screen the historical data to test trends, outliers, seasonality, etc. Define a window of time for the historical background data, and propose method for updating background data (if naturally-occurring temporal variability warrants this).

2. Compute detection frequencies for COCs and develop an approach for dealing with censored data (i.e., trace and nondetect determinations). Select appropriate methods for determining concentration limits for low detection frequency COCs. The selected method should be able to accommodate possible future EMP and CAMP monitoring requirements.

3. Propose a statistical approach for future periodic statistical testing. The proposed approach may incorporate graphic descriptive statistics, summary statistics and their corresponding hypothesis tests, and interval estimates, as necessary. For DMP, groundwater sampling and statistical analysis of COCs is required at a minimum, once every five years (22 CCR 66264.98(g) to ensure that the monitoring parameter list is acting as an acceptable surrogate for the full COC list. Groundwater sampling and statistical analysis of monitoring parameters is required at the frequencies required by 22 CCR 66264.97(e)(12). Provide written summary of proposed methods and demonstration that the following issues are addressed: testing and adjustments for sample size, data distribution, censored data, outliers, natural spatial variability, natural temporal variability (i.e., seasonality and trends), data independence, etc. Also, each statistical method requires a minimum percentage of detected values in order to apply the test. The owner/operator should demonstrate that the minimum detection frequency requirements are identified and attained prior to use of the proposed statistical method. The following statistical methods have been typically utilized: classical ANOVA, ANOVA based on ranks (nonparametric), tolerance or prediction interval procedures (parametric and nonparametric), control charts (parametric), and other statistical test methods.

4. Evaluate and demonstrate correlation between COCs and propose a subset list of monitoring parameters for use in periodic statistical testing.

5. Conduct the statistical testing and tabulate the results for all COCs . The purpose is to show which tests resulted in statistically significant exceedances of the concentration limit for all COCs. If any statistical exceedances are observed, evaluate data to determine likely cause of exceedance (i.e, from other potential source, false positive, result of a release, etc.).

6. If statistically significant evidence of a release is determined to occur, the owner/operator is to notify DTSC of the finding by certified mail within seven days of the determination. The notification should identify for each effected monitoring point the monitoring parameters and COCs that have indicated statistically significant evidence of a release from the regulated unit. If the statistically significant results are not demonstrated to be attributed to anything other than a release from the regulated unit, the owner/operator may immediately initiate a verification procedure for the parameter or constituent that indicated a statistically significant release at a monitoring point, per specifications in the HWF Permit.

7. If resampling confirms that there is statistically significant evidence of a release from the regulated unit, or the owner/operator chooses not to resample, all groundwater monitoring wells must be sampled for analysis of all COCs, as wells as all constituents in Appendix IX to 22 CCR Chapter 14. Verification of any detected Appendix IX constituents that were not previously included on the COC list may be conducted through resampling within one month. If new Appendix IX constituents are to be added to the list of COCs, additional data shall be collected as necessary to establish their respective background concentrations.

4.2 INTERWELL COMPARISONS

The following modified approach from ASTM (1998) may be used for interwell comparisons:

1. If the background detection frequency is equal to or exceeds 50%, proceed with computing the prediction limit. If the data are normally distributed, compute a normal prediction limit selecting the false positive rate based on the number of wells, constituents, verification resamples, and adjusting estimates of sample mean and variance for nondetects. ASTM does not specify the method for adjusting for nondetects. The EPA (1992) recommends 1) if the detection frequency is greater than 75%, replace each nondetect by half its MDL or PQL and proceed with a parametric analysis; and 2) if the detection frequency is between 50% and 75%, either use Cohen's adjustment to the sample mean and variance in order to proceed with a parametric analysis, or employ a nonparametric procedure by using the ranks of the observations and by treating all nondetects as tied values

2. 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. ASTM also suggests use of an alternative Poisson prediction limit that can be computed from "any available set of background measurements regardless of the detection frequency". Procedures that have been recommended by others for dealing with large numbers of nondetects, include, but are not limited to Poisson prediction limits and Poisson tolerance limits (EPA, 1992). Loftis and others (1999) found the use of Poisson-based tolerance and prediction limits to lead to erroneous results when applied to data having a large proportion of nondetects, and proposed the use of nonparametric tolerance and prediction limits and a test of proportions based on the binomial distribution. The owner/operator should learn and be aware of how various available groundwater monitoring software programs utilize procedures for dealing with censored data. The EPA (1992) recommends use of the nonparametric Wilcoxon Rank-Sum procedure for all two-group comparisons that involve more than 15 percent nondetects.

3. If the background detection frequency equals zero, use the laboratory-specific PQL if applying the nonparametric prediction limit. This only applies for wells and constituents that have at least 13 background samples. Thirteen samples provide a 99% confidence nonparametric prediction limit with one resample for a single well and constituent. If less than 13 samples are available, more background data must be collected to use the nonparametric prediction limit.

   Another method that can apply under these conditions is the standard California Nonstatistical Method. The scope of analysis addresses all COCs (or monitoring parameters) that exceed their MDL in less than 10 percent of applicable background samples and that also are in detection-mode at a given POC well being tested (i.e., not yet shown a measurably significant indication of a release at that POC well). Under this method verification procedures are triggered at a given POC well if a sample exhibits a “preliminary indication of a release” by having either:

(1) one such compound that exceeds its PQL; or

(2) two or more compounds that show a trace, or stronger indication of a release.

Under this method, one conducts a retest on two new samples. The procedure for the retest is the same as for the initial test, but the scope of COCs addressed is limited to those that exhibited a preliminary indication of a release. If either or both retest samples reconfirms for either or both of the above triggering conditions, then that constitutes a measurably significant evidence of a release for the COC(s) in the retest sample(s). The logic behind the two standard triggers for the California Nonstatistical Method is that conditions meeting either or both triggers should occur seldom by chance alone, and that retesting should eliminate detections attributable to chance. Therefore, when used with a retest on rarely-detected anthropogenic constituents, these two triggers make good use of trace value determinations for detection a release. Yet, they will rarely provide a false-positive indication.

Depending on the site-specific situation, two additional triggers for this method might include (for any given POC well):

(3) one such compound that is detected at a trace level or higher in two successive samples, or more than once during a 12-month period; and/or

(4) one such compound that is detected above its MDL but below its PQL, and review of data shows trends or other indications that a release may have occurred.

Although this test’s two standard triggers make sense, they cannot encompass all possible release scenarios. For example, consider a case where a single constituent (rarely detectable in background) keeps showing up at trace levels at a given POC well (or at several POC wells). Given such an occurrence, in conjunction with other indicators, DTSC can make a determination that this constitutes physical evidence of a release pursuant to 22 CCR 66264.91(a)(3), thereby forcing the onset of an EMP.

4. Although this example implies use of an interwell approach, it also illustrates how the MDL effectively serves as the applicable concentration limit for certain constituents that have an inordinate proportion of nondetects. For this situation, it is important to understand how the laboratory utilizes statistical methods and analytical procedures to generate MDLs and PQLs. A good discussion of statistical approaches for deriving MDLs and PQLs is included in Gibbons (1994).

4.3 INTRAWELL COMPARISONS

ASTM (1998) suggests the following approach for intrawell comparisons :

1. Compute intrawell comparisons using combined Shewhart-CUSUM control charts following procedures described in EPA (1992). Verify use of intrawell comparison by demonstrating that no VOCs or hazardous metals are detected and no significant trend is observed for other indicator constituents.

2. If detection frequency is zero for at least 13 previous quarterly sampling events, use PQL as the nonparametric limit. Thirteen samples provide a 99% confidence nonparametric prediction limit with one resample. Note that 99% confidence is equivalent to a 1% false positive rate, and pertains to a single comparison and not the site-wide error rate, which is set to 5%.

3. If the detection frequency is greater than zero but less than 25%, use the nonparametric prediction limit that is the largest (or second largest) of at least 13 historical background samples. Alternatively, compute a Poisson prediction limit following collection of at least four background samples. Since the mean and variance of the Poisson distribution are the same, the Poisson prediction limit is used in place of the measurements, and the Poisson prediction limit can be computed directly. Refer to the above comments regarding limits of Poisson-based statistics for low detection frequencies, and use of California's Nonstatistical Method for composite parameters.

4.4 VERIFICATION RESAMPLING

Article 6 requires a procedure for verification of statistically significant evidence of a release from a regulated unit. The procedure is to consist of either a single composite retest (i.e., a statistical analysis of the original data combined with newly-acquired data from the monitoring point at which evidence of the release has been indicated) or shall consist of at least two discrete retests (i.e., statistical analyses which analyze only newly-acquired data from the monitoring point at which evidence of a release has been indicated). The statistical test method used in verification composite retest should be the same as the method used in the initial statistical comparison, except that the composite verification test should be conducted at a Type I error level of no less than 0.05 for both experiment wise analysis and the individual monitoring point comparisons.

If the verification procedure consists of discrete retests, rejection of the null hypothesis for any one of the retests will be considered confirmation of statistically significant evidence of a release. The statistical test method used in verification discrete retests should be the same as the method used in the initial statistical comparison. The Type I error rate for all individual monitoring point comparisons should be the same, whether for an initial test or a retest. Refer to Article 6 for the formula used in calculating the Type I error rate.

5.0 EVALUATION MONITORING PROGRAM (EMP)

The purpose of the EMP is to assess nature and extent of a release from a regulated unit to allow appropriate design of a CAP. During the EMP and CAMP, each COC at a given well (well/COC pair) falls into one of two modes:

1. If the COC has been verified at that well, then it is in the " tracking mode" and is monitored for changes in water quality through time. For tracking mode well/COC pairs, during a CAMP, a decreasing trend is proof that the corrective measures are working. Once a well/COC pair enters tracking mode, it remains there until the beginning of the proof period, at the end of a successful CAMP; or

2. If the COC has not been verified at that well, then the well is in "detection mode" even if the entire Unit is under an EMP or CAMP. DMP-type testing continues unabated for detection mode well/COC pairs throughout the EMP and CAMP. If a well/COC pair in detection mode subsequently verifies a detection of that COC, then the plume for that COC has enlarged. If the triggered well/COC pair indicates an expansion of the overall plume, then interim corrective measures (in EMP) or a corrective measures revision (in CAMP) is in order.

Statistical analyses for EMP's tracking mode well/COC pairs are typically are used to evaluate changes in water quality due to a release from the regulated unit. In many cases, providing graphical time series plots (i.e., concentration versus time) for well/COC pairs that are within the release is sufficient for purposes of evaluating changes in water quality through time. Trend analysis is also suited for the purpose of EMP, and can be used to determine the significance of an apparent trend and estimate the magnitude of the trend. Other temporal effects on trend should also be considered, such as distribution, missing values, seasonality, serial correlation, censored data, and outliers. Some of the more common trend tests used for EMP are:

5.1 SEN’S TEST

This nonparametric estimator of trend requires no distributional assumptions and allows missing data or irregularly spaced measurement periods. This method is robust to outliers, missing data, and nondetects. Computation of Sen's trend estimator is described in Gilbert (1987) and Gibbons (1994).

5.2 MANN-KENDALL TEST

A version of the Mann-Kendall nonparametric trend test recommended for 40 or fewer measurements is summarized in Gilbert (1987) and Gibbons (1994).

5.3 SEASONAL KENDALL TEST

Seasonal effects on data may bias trend estimator results. In this case, a trend estimator may be required that is adjustable for seasonal variation. The test accounts for seasonality by computing the Mann-Kendall test on each of the seasons separately, and then combines the results. Available literature provides comprehensive discussion of nonparametric test for trend on Y (Gilbert, 1987; Gibbons, 1994; and Helsel and Hirsch, 1992), and mixed nonparametric/parametric applications of this test on residuals from regression of Y on X (Helsel and Hirsch, 1992)

6.0 CORRECTIVE ACTION MONITORING PROGRAM (CAMP)

The purpose of the CAMP is to evaluate compliance of water quality as a result of corrective measures. Statistical applications during CAMP are useful mainly during the proof period at the end of a successful CAMP; prior to that, the tracking and detection-modes (see discussion in above EMP section) will prevail. Statistics conducted during the proof period should be carried out under a clean-water H_o, based upon a visual determination that the data appears to be appropriate regarding each respective concentration limit: cleanup value [concentration limit greater than background (CLGB), MDL, or PQL]; or background. Based on the visual estimate, the owner/operator should proceed to conduct the DMP-type testing: for elevated cleanup values; for background concentration limits, the test is typical for a DMP.

Proof period statistical applications are often used for comparison of POC well data with concentration limit threshold values specified in CAMP. The most common types of methods utilize statistical comparisons with fixed concentration limits, such as tolerance, prediction, and confidence intervals. EPA (1989 and 1992) describes the use of tolerance limits and parametric or nonparametric confidence limits for CAMP statistical evaluation. A valuable critique of these applications is presented in Gibbons (1994), in which the use of confidence limits for CAMP statistical evaluation appears to be more favored.

7.0 REFERENCES

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APPENDIX D

SUGGESTED CONTENT FOR MONITORING REPORTS

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1.2 Annual Reports D-3
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Attachment D-1: Example Graphs

LIST OF ABBREVIATIONS

22 CCR	Title 22 of California Code of Regulations
Article 6	22 CCR 66264.90 through 22 CCR 66264.100
CCR	California Code of Regulations
COC	constituent of concern
DTSC	Department of Toxic Substances Control
HWF	hazardous waste facility
MDL	method detection limit
ND	not detected, nondetect
PQL	practical quantitation limit
QA/QC	quality assurance/quality control
TR	trace
WQSAP	water quality sampling and analysis plan

1.0 INTRODUCTION

On a case-by-case basis, the following suggestions for monitoring report content may be applicable. As stated in Section 14.0 of this guidance document, reporting requirements for all monitoring reports should be specified in the water quality sampling and analysis plan (WQSAP) and/or the hazardous waste facility (HWF) permit.

1.1 ALL MONITORING REPORTS

The following suggestions are applicable to all monitoring reports. Monitoring reports should:

* Be presented in a professional report format including a table of contents and sequentially numbered pages.

* Include an executive summary of the sampling events that identifies the type of monitoring program for each regulated unit (detection, evaluation, and/or corrective action) and describes significant findings.

* Reference the current WQSAP and state that, with only the exceptions listed in the report, all sampling and analysis was conducted in accordance with the current WQSAP.

* Include a detailed description of any deviations from the current WQSAP, an explanation of the conditions that necessitated those deviations, and a description of any corrective measures being taken to avoid future deviations from the WQSAP.

* Include description of recent changes to the monitoring program that are allowed by the conditions of the current WQSAP. For example, minor changes in sampling or analytical equipment or protocol, addition of new or replacement wells to the monitoring system, and the use of updated concentration limits.

* Provide a narrative summarizing and interpreting/evaluating the results of the monitoring event, including, but not limited to a(n):

  - Analysis of water level data and potentiometric maps, including a quantitative determination of groundwater flow rate and direction in each hydrologic zone monitored at the facility;

  - An analysis of water level data, hydrographs[3], and potentiometric maps to determine if the water quality monitoring system is in compliance with the requirements of California Code of Regulations (CCR), Title 22, Section 66264.97(b)(1). If the system is not adequate, the facility should specify in the report the steps to be taken to achieve compliance with those requirements.

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[3]Hydrographs should be compiled for all point of compliance wells, and other wells, as appropriate. The hydrographs should have appropriate vertical and horizontal scales and should present all data collected to-date at the facility. To facilitate identification of local anomalies, the HWF Permit should require that all related wells be plotted on the same page (as long as the depicted data are still interpretable and the hydrograph is still useful).

- A report on the results of quality assurance/quality control (QA/QC) sampling and analysis. The report must state whether or not data quality objectives of accuracy, precision and completeness have been met. In the event that the facility cannot attain the objectives, describe the corrective measures being implemented by the facility and/or the laboratory.

- Interpretation of soil moisture data;

- A summary of the results of the facility maintenance inspections of the monitored units and their monitoring systems.

- Statement of the objectives of the monitoring program and discussion of monitoring data in the context of these objectives.

* Include a section that tracks outstanding facility issues and/or outstanding follow-up work (e.g., verification sampling of apparently significant evidence of a release, repair or replacement of wells or equipment). Any item included in this section should be addressed in every subsequent monitoring report until the outstanding issue is resolved.

* Include graphs that are presented in the following format. Example graphs are provided in Attachment D-1.

  - Every monitoring parameter or constituent of concern (COC) should be shown on a separate graph with the data from as many wells as can be legibly displayed. As much historic data as possible should be included on each graph so that long-term and/or recurring trends can be distinguished.

  - When a concentration is reported as below the method detection limit (MDL), it must be displayed on the graph to clearly indicate that the analyte was not detected. The value of the MDL must be evident. If the MDL remains constant, it is sufficient to simply state the limit and to plot the data at a constant value (i.e., the value of the MDL). If the MDL varies or has varied through time, the facility must depict that information on the graph.

  - When a concentration is reported below the reporting limit [or practical quantitation limit (PQL)], but above the MDL, these data are frequently referred to as "censored" or "trace" data. These concentrations must be displayed on the graph at the estimated concentration reported by the laboratory, but in such a way that it clearly indicates that the concentration was estimated to be below the reporting limit (or PQL). The values of the reporting limit (or PQL) and the MDL must be evident. Suggested methods in use by other facilities include: substituting the letters ND (not detected) or TR (trace) for the well symbol on the graph, altering the well symbol in some standard way (e.g., circling the well symbol, using alternate colors), and plotting detection limits on overlays.

  - The spread of the y-axis should be selected to best display the variability of the data and should be no more than three times the range of the data.

  - The spread of the x-axis should be presented on a proportional scale that represents the relative amount of time between samples.

- When plotting concentration data for multiple wells, it is expected that much of the data will overplot for values near the mean of the data set. This still provides useful information and should not be a problem as long as the graphs are submitted at an appropriate scale and well symbols are clearly legible in areas where the concentration deviates from normal.

- If more than one graph is needed for each parameter then:
  * each graph should show data from the background monitoring points.
  * downgradient wells should be grouped by location or by other significant characteristics; and
  * all graphs for a parameter should be at the same scale, provided that the concentration ranges depicted by the graphs are the same order of magnitude.

- Include maps and cross-sections of contaminant plumes to visualize the nature and extent of contamination.

1.2 ANNUAL REPORTS

In addition to the general monitoring report content described in Section 1.1, the following annual report elements may be applicable to facilities on a case-by-case basis.

* Comprehensive summary tables of all historical analytical data related to water quality monitoring (groundwater, surface water, and soil-pore liquid) at each regulated unit.

* Time series plots of water level, laboratory analytical data, and the final, stable value of field parameters.

* Describe recent changes to the monitoring program that are allowed by the conditions of the current WQSAP. For example, minor changes in sampling or analytical equipment or protocol, addition of new or replacement wells to the monitoring system, and the use of updated concentration limits.

* Narrative report summarizing and interpreting the results of statistical analysis on water chemistry data.

* Summary tables of current water level data, analytical data, and the results of the statistical analysis.

1.3 QUARTERLY OR SEMI-ANNUAL REPORTS

In addition to the general monitoring report content described in Section 1.1, the following quarterly or semi-annual report elements may be applicable to facilities on a case-by-case basis.

* Summary tables of current water level data, analytical data, and statistical analyses.
* Well completion data summary table.
* Supporting documentation related to the sampling event, including, but not limited to: copies of field logs and activity sheets; copies of calibration logs; depth to water data; total depth measurement data; well head data; immiscible layer data; field parameter results; purge volume data; on-scene observations; chain-of custody forms; and laboratory data sheets (analytical reports).

ATTACHMENT D-1

EXAMPLE GRAPHS

EXAMPLE 1

- Illustrates multiple wells plotted on the same graph for a single constituent (nickel, benzene).
- Separate graphs are provided for wells monitoring different units (Landfarm No. 1, Landfarm No. 4).
- Reporting limit clearly depicted relative to reported value. Changes in reporting limit over time also depicted.
- Logarithmic scale for the y-axis is not preferred, but graph does achieve goal of depicting long-term trends.
- X-axis scale is proportional (i.e., reflects actual gap in time between measurements).
- Symbols are legible where values overplot.

EXAMPLE 2

- Illustrates multiple wells plotted on same graph for a single constituent (PCE, TCE).
- All historical data depicted. Graph shows long-term trends.
- Plotted wells are meaningfully grouped on the graphs. For example, corrective action monitoring program wells are shown here on one graph. Detection monitoring program wells are shown on separate graphs.
- Inclusion of the concentration limit on the graph is helpful.
- Y-axis scale is appropriate for concentration range.
- X-axis scale is proportional (i.e., reflects actual gap in time between measurements).
- Symbols are legible where values overplot.

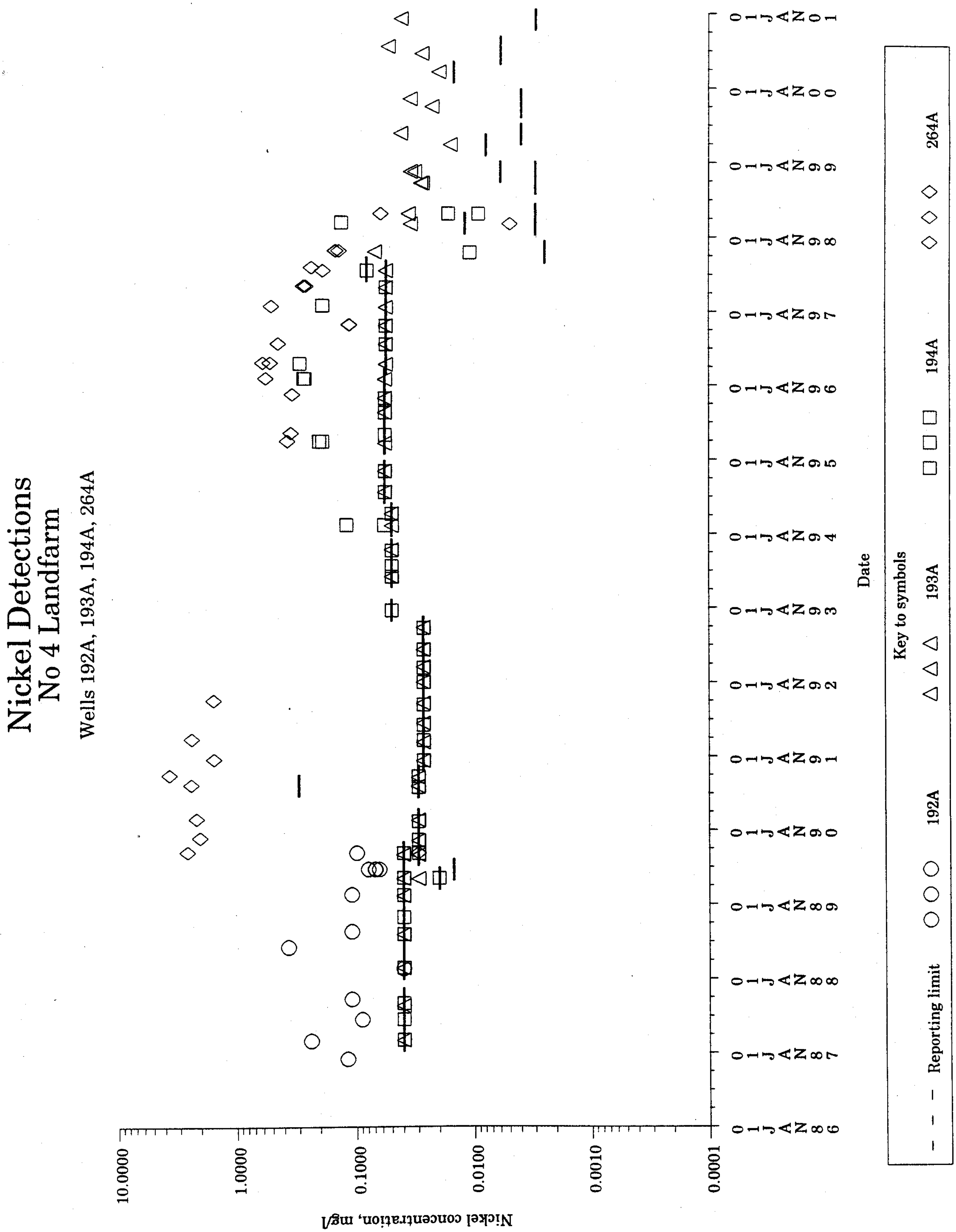
EXAMPLE 3

- Illustrates multiple single well plots for individual constituents. Although presentation is facilitated by multiple constituent graphs on a single page, presentation would be improved by plotting multiple wells in meaningful groupings (e.g., all weathered bedrock wells monitoring a given regulated unit).
- All historical data is depicted. Graphs show long-term trends.
- Graphs clearly depict detected, trace, and non-detected values.
- Y-axis scale is appropriate for concentration range.
- X-axis scale is proportional (i.e., reflects actual gap in time between measurements).

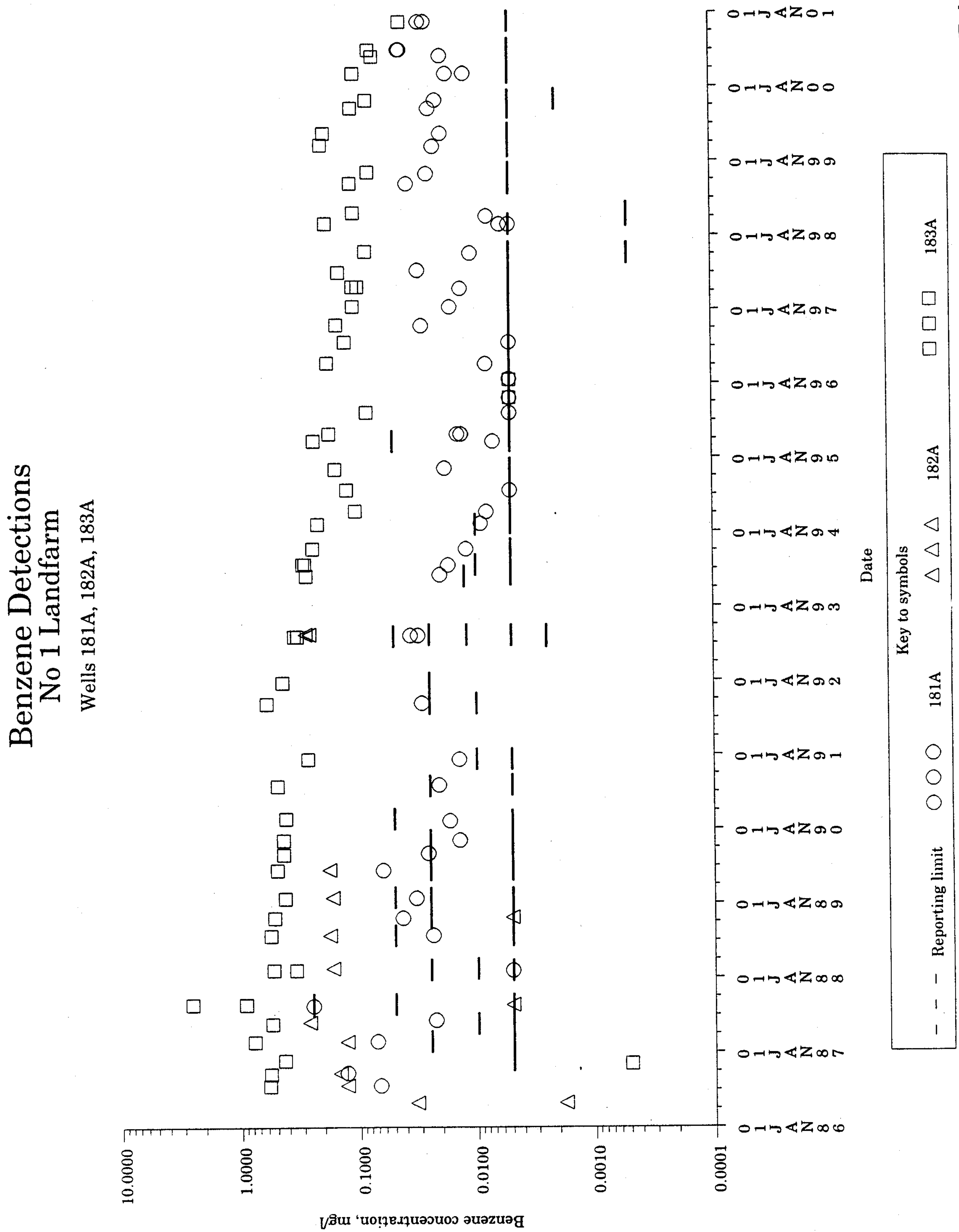
EXAMPLE 4

- This graph style is not recommended for the following reasons:
  - Multiple constituents are plotted on the same graph for a given well.
  - The Y-axis scale is too large for the data range.
  - Long-term trends are difficult to interpret.
- Inclusion of the concentration limit on the graph is helpful.

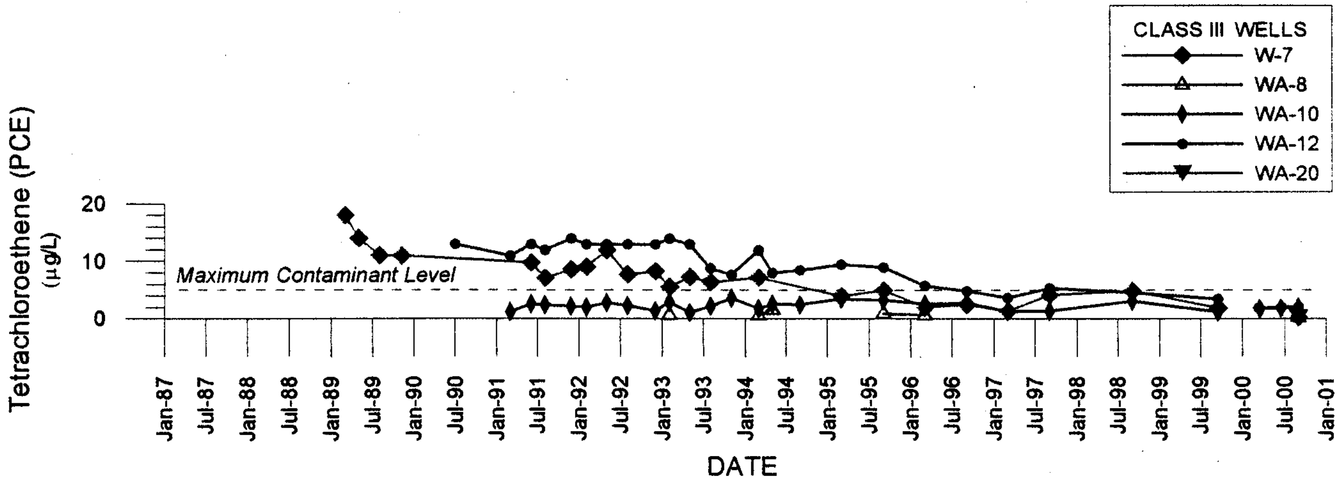
EXAMPLE 1

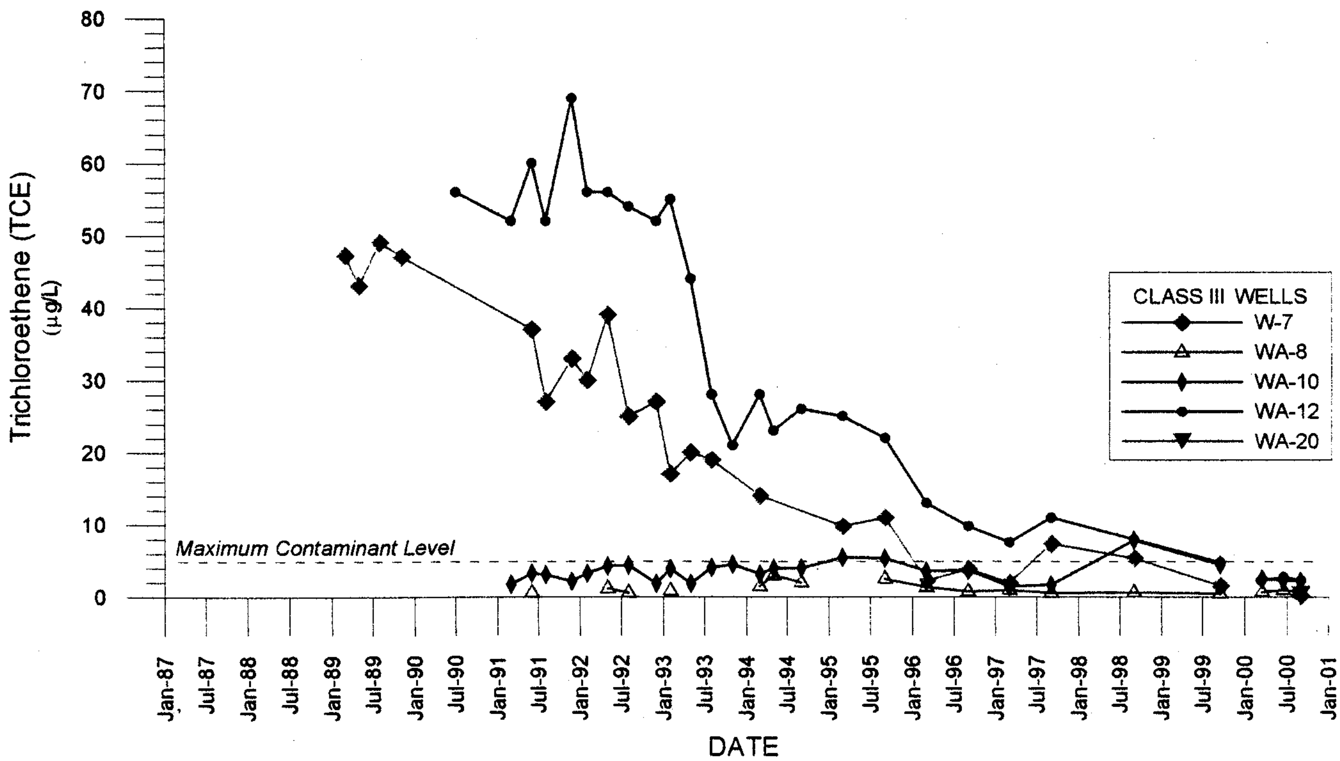

Nickel Detections
No 4 Landfarm
Wells 192A, 193A, 194A, 264A
Nickel concentration, mg/l
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
01JAN86
01JAN87
01JAN88
01JAN89
01JAN90
01JAN91
01JAN92
01JAN93
01JAN94
01JAN95
01JAN96
01JAN97
01JAN98
01JAN99
01JAN00
01JAN01
Date
Key to symbols
Reporting limit
192A
193A
194A
264A

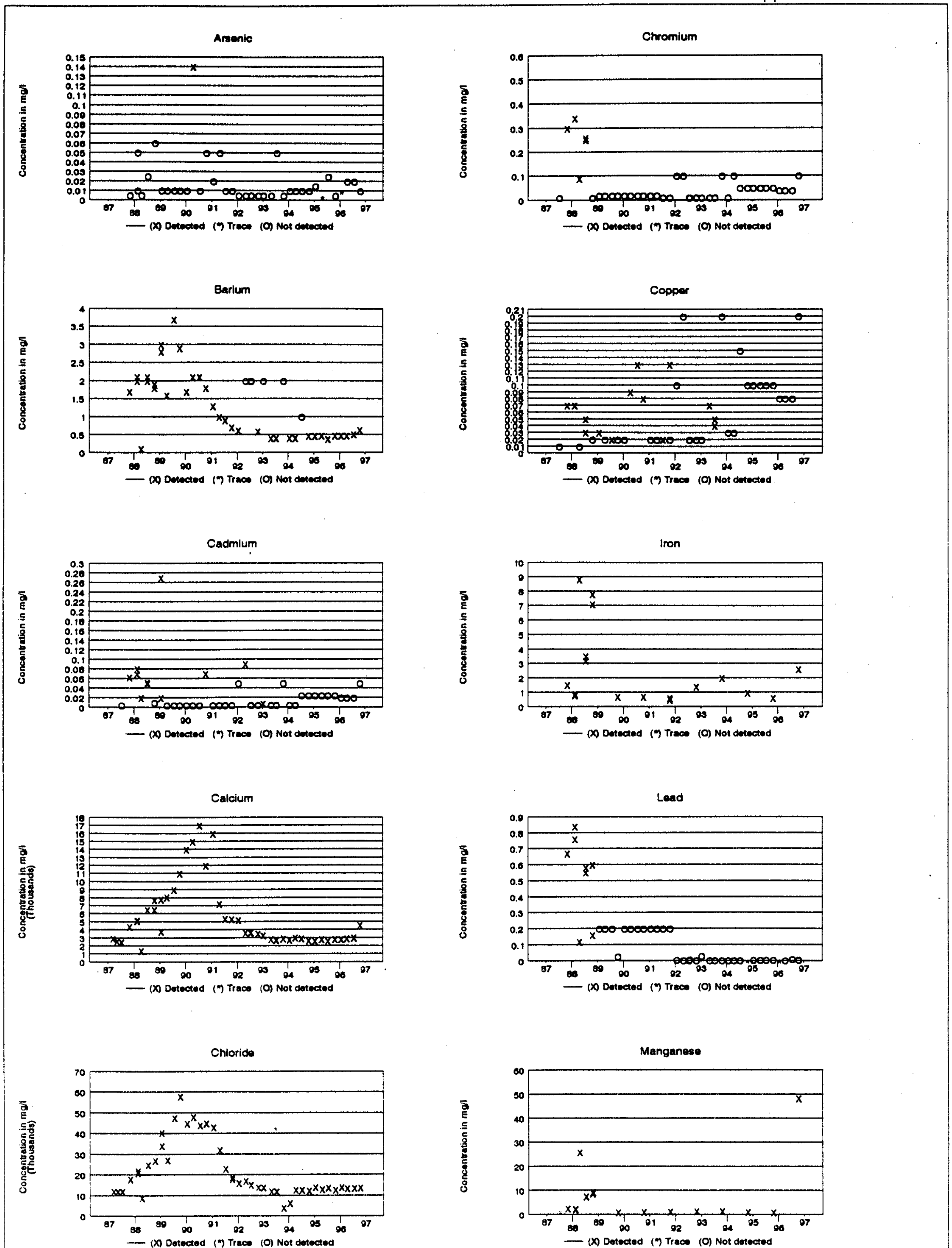
EXAMPLE 1


Benzene Detections
No 1 Landfarm
Wells 181A, 182A, 183A
Benzene concentration, mg/l
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
Date
01JAN86
01JAN87
01JAN88
01JAN89
01JAN90
01JAN91
01JAN92
01JAN93
01JAN94
01JAN95
01JAN96
01JAN97
01JAN98
01JAN99
01JAN00
01JAN01
Key to symbols
Reporting limit
181A
182A
183A

Time-Series Plots
VOC Concentrations
Class III Area Corrective Action Assessment Monitoring Program



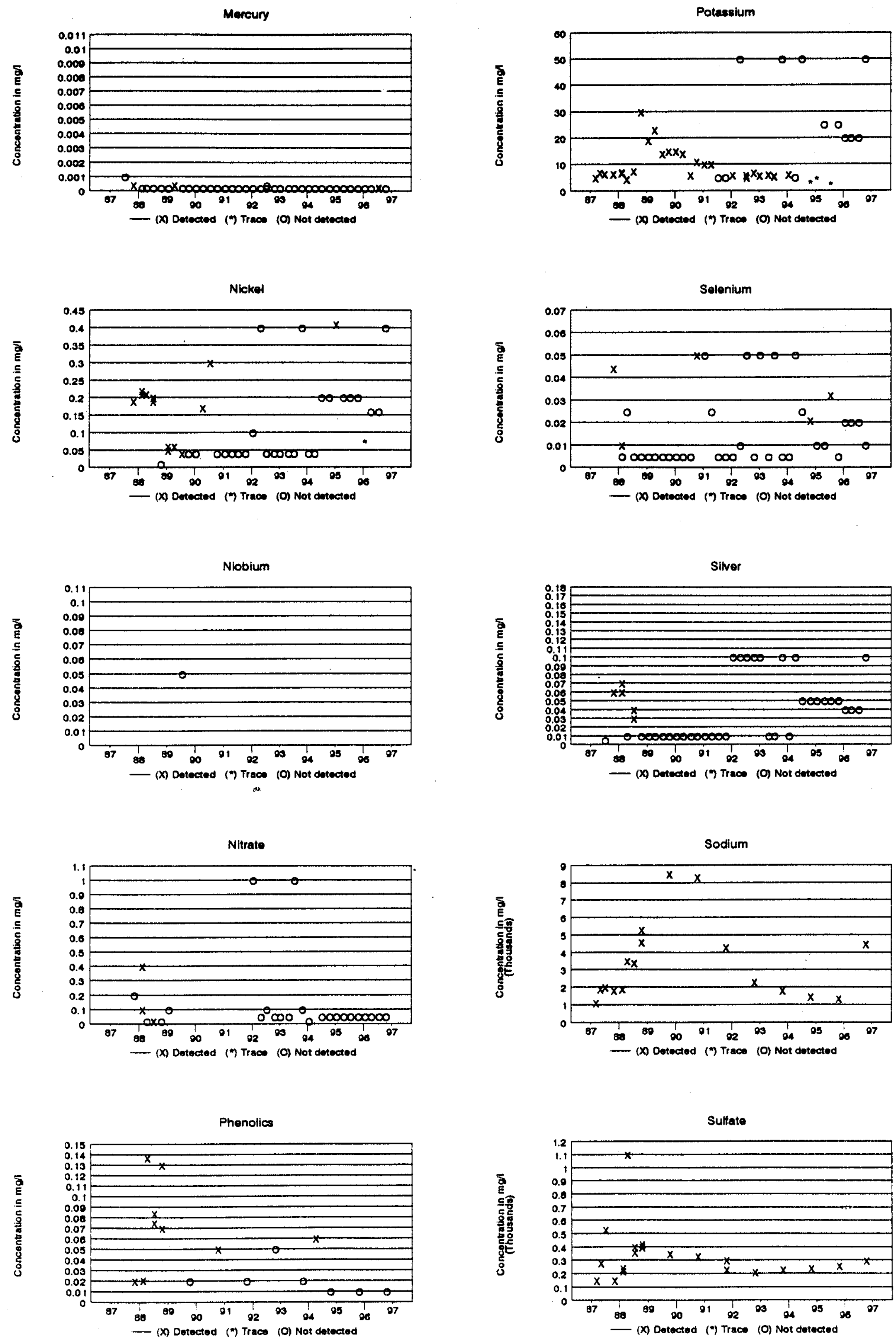




MW–046

Weathered Bedrock

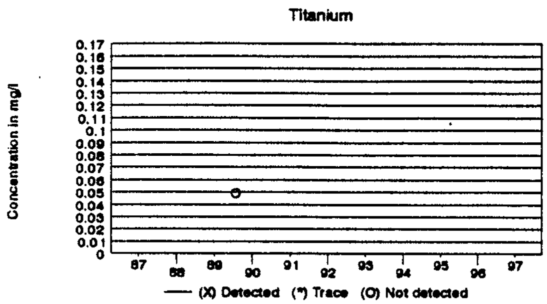
EXAMPLE 3

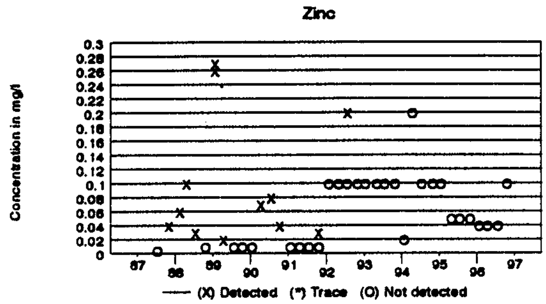


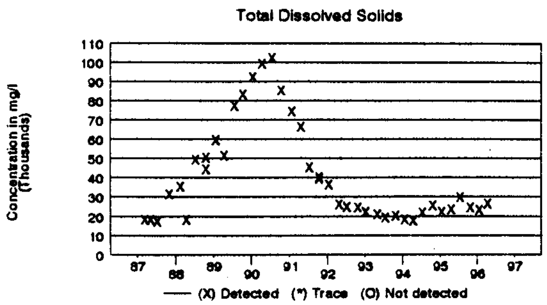
MW–046

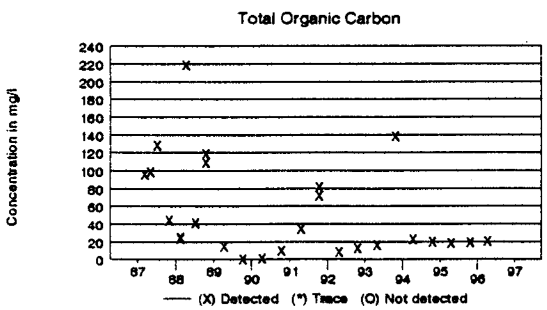
Weathered Bedrock

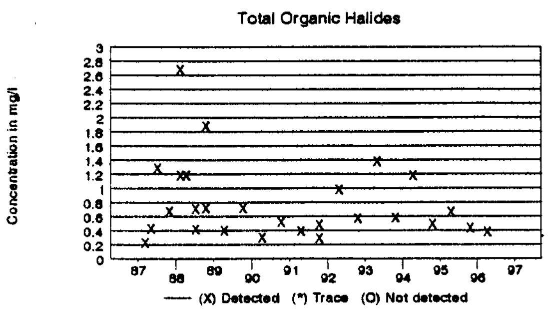
EXAMPLE 3

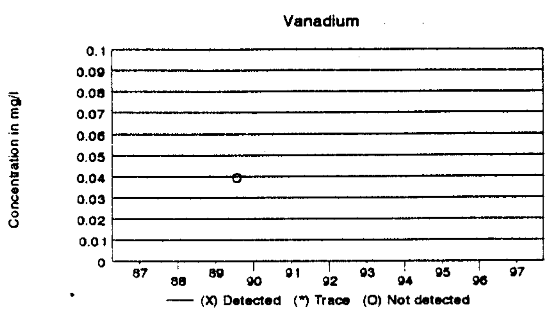










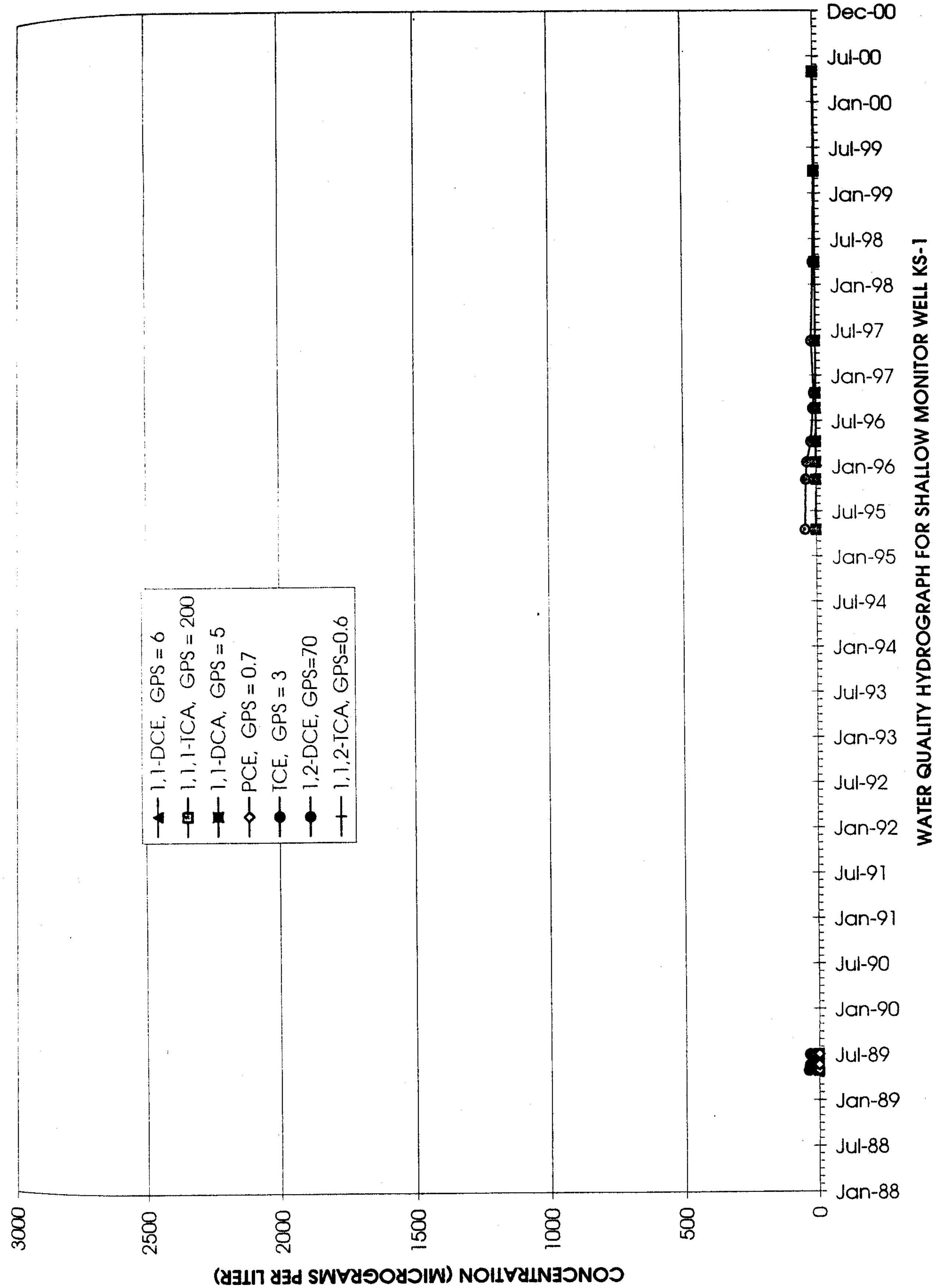


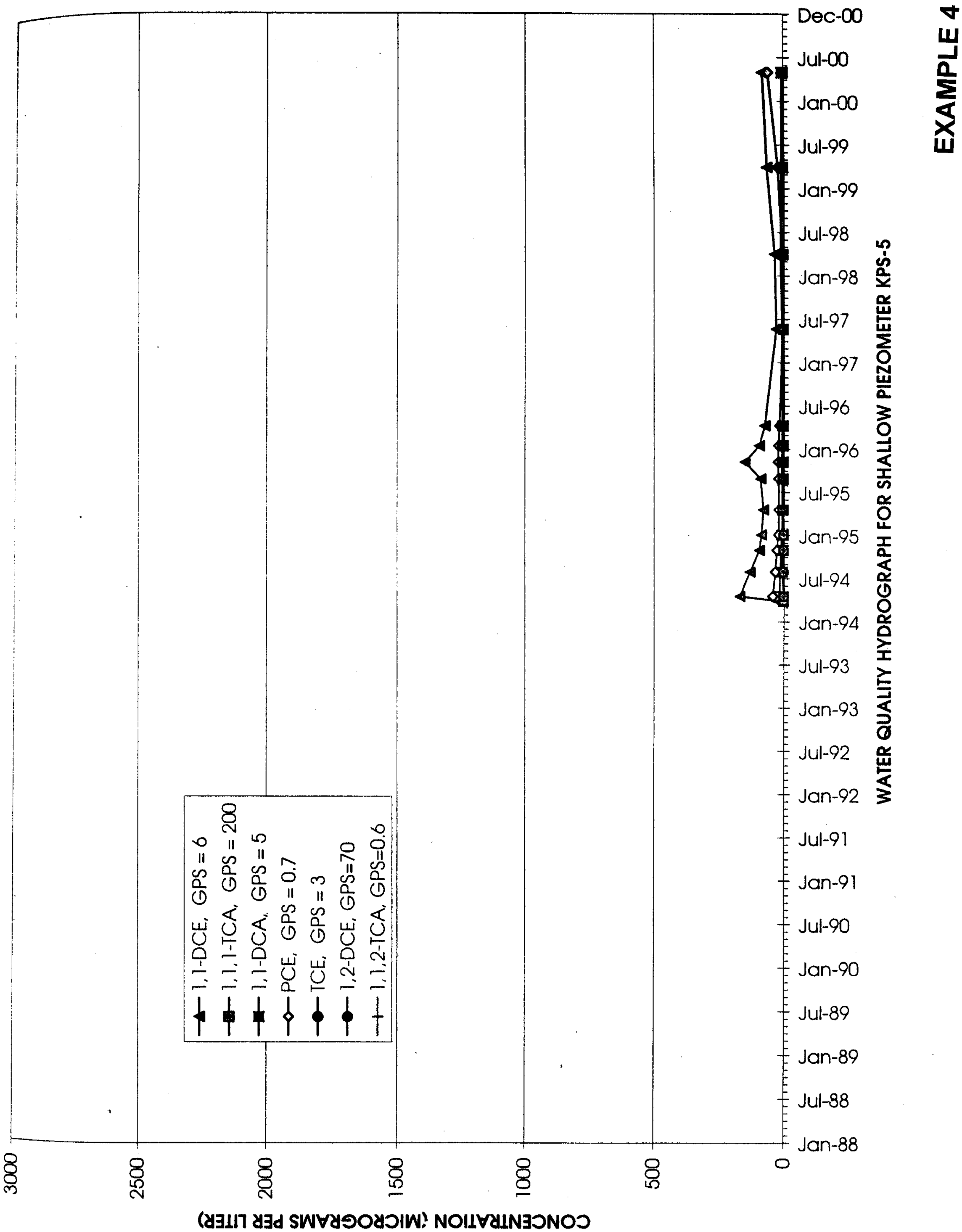
MW-046

Weathered Bedrock

EXAMPLE 3

EXAMPLE 4


WATER QUALITY HYDROGRAPH FOR SHALLOW MONITOR WELL KS-1
CONCENTRATION (MICROGRAMS PER LITER)
0
500
1000
1500
2000
2500
3000
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Dec-00
1,1-DCE, GPS = 6
1,1,1-TCA, GPS = 200
1,1-DCA, GPS = 5
PCE, GPS = 0.7
TCE, GPS = 3
1,2-DCE, GPS=70
1,1,2-TCA, GPS=0.6


EXAMPLE 4
WATER QUALITY HYDROGRAPH FOR SHALLOW PIEZOMETER KPS-5
CONCENTRATION (MICROGRAMS PER LITER)
0
500
1000
1500
2000
2500
3000
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
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Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Dec-00
1,1-DCE, GPS = 6
1,1,1-TCA, GPS = 200
1,1-DCA, GPS = 5
PCE, GPS = 0.7
TCE, GPS = 3
1,2-DCE, GPS=70
1,1,2-TCA, GPS=0.6

APPENDIX E

CHAPTER 7 CORRECTIVE MEASURES STUDY
DTSC CORRECTIVE ACTION ORIENTATION MANUAL
JUNE 1994 DRAFT WORKING COPY

CORRECTIVE ACTION ORIENTATION MANUAL

State of California
Environmental Protection Agency

Department of Toxic Substances Control

Prepared by
Corrective Action Program Improvement Workgroup
Mohinder S. Sandhu, P.E., Chairperson

DRAFT WORKING COPY
June 1994

NOTICE

The policies set out in this document by the Department of Toxic Substances Control (Department) are intended solely as guidance. They are not intended, nor can they be relied upon, to create any rights enforceable by any party in litigation with the State of California or the United States. Any or all parts of this document shall not constitute grounds for legal actions against the State of California or the Department. The Department staff and management may decide to follow the guidance provided in this document, or to act at variance with the guidance, based on an analysis of specific site circumstances. The Department also reserves the right to revise this document at any time without public notice.

CHAPTER 7

CORRECTIVE MEASURES STUDY

7.1 Introduction

The general objective of the Corrective Measures Study (CMS) is to develop and evaluate corrective measure alternative(s) that may be utilized at the facility to address releases of hazardous wastes or constituents from SWMUs, areas of concern, and other source areas at the facility. The information collected during the RFA, RFI, and CMS phases will be used to determine which technologies to use during the Corrective Measures Implementation. With adequate forethought during the RFI, certain technologies may be adequately screened or eliminated from the CMS decision process with a minimum outlay of time and expense.

The CMS Scope of Work (SOW) in Section 7.3 of this chapter is intended to provided guidance for developing the CMS Workplan and CMS Report. The SOW is intended to be a flexible document capable of addressing both simple and complex site situations. Keep in mind that certain sections of a plan and/or report may not be necessary for every facility. The SOW also references essential technical documents needed for a successful study.

Each corrective action alternative must meet four corrective action standards (Sections 7.3.2.6.1 through 7.3.2.6.4) and be evaluated using five remedy selection decision factors (Sections 7.3.2.6.5 through 7.3.2.6.9). Based on these results, a final remedy or remedies must be chosen that will address all of the concerns of the facility. The permit writer is encouraged to refer to Chapter 11 of this manual for a discussion of corrective action management units and temporary units during CMS.

7.2 General Guidelines

The CMS process consists of preparation of the CMS Workplan and CMS Report. The permit or order that requires the corrective action for the facility triggers the CMS, based on the results from the RFI. The permit writer assigned with a CMS project generally follows the guidelines below:

- Learn about the facility problems -- review facility file, read RFA and RFI, study the permit or order, highlight schedule of compliance, etc.

- Learn about corrective measures that are appropriate for the circumstances of the facility. Request technology guidance documents from USEPA, talk to other staff, etc.

- Study the CMS SOW, Section 7.3 of this chapter, and identify relevant guidance documents. Each regional Facility Permitting Branch has a complete set of corrective action guidance documents in the Branch library. A list of corrective action guidance documents is summarized in Section 7.5 of this chapter.

- Plan ahead to get specialized technical assistance to review documents and for field oversight visits (e.g., hydrogeologists, etc.).

- Require interim measures if there is an immediate threat to human health and/or the environment, to prevent or minimize the spread of contaminants and to control sources of contaminant releases. If feasible, require interim measures as soon as possible for all facilities that have a medium or high NCAPS ranking. Refer to Chapter 4 of the Corrective Action Orientation Manual.

- Consult with the Public Participation Branch and plan community involvement strategy.

- Prepare project action plan -- identify tasks leading to completion of milestones, assign responsibilities, estimate start and completion dates, etc.

- Receive CMS Workplan. For larger or more complex sites, the CMS investigation may be divided into phases with more than one workplan being submitted. In general, the phases containing the highest priority unit should be investigated in the first phase of a project.

- Review the CMS Workplan and workplan for treatability studies, or justification for not proposing a treatability study.

- Request technical support, if necessary, for various sections of the CMS.

- Use the permit's/order's CMS SOW in reviewing the CMS Workplan.

- Minimize workplan revisions - workplans do not have to be perfect, they need to get the job done.

- Initiate roundtable discussions and peer review meetings to discuss facility issues, strategy for action, corrective action objectives, possible remedies, etc.

- Prepare written comments that clearly specify what is needed and why. Meet with the facility to clarify requirements, if necessary.

- Review the revised CMS Workplan and/or treatability studies workplan. Approve these workplans if they are adequate. Complete a RCRIS form.

- Oversee the study progress and observe any procedures deviated from the approved CMS Workplan.

- Visit the facility during treatability studies.

- Receive CMS Report by the due date specified in the permit or order.

- Use the permit's/order's CMS SOW in reviewing the CMS Report.

- Prepare written comments that clearly specify what is needed and why. Meet with the facility to clarify requirements, if necessary.

- Review the revised CMS Report. Approve the CMS Report. Complete a RCRIS form.

7.3 Scope of Work for a Corrective Measures Study

A CMS Workplan and a CMS Report are, unless otherwise specified by the Department, the required elements of a CMS. The scope of work (SOW) for the CMS Workplan and Report describe what should be included in each document. The SOWs are intended to be flexible documents capable of addressing both simple and complex site situations. If the facility owner or operator can justify, to the satisfaction of the Department, that sections of a plan and/or report are not needed in the given site specific situation, then the Department may waive that requirement.

The scope and substance of the CMS should be focused to fit the complexity of the site-specific situation. It is anticipated that the facility owner or operator with complex environmental problems may need to evaluate a number of technologies and corrective measure alternatives. For other facilities, however, it may be appropriate to evaluate a single corrective measure alternative.

The Department may require the facility owner or operator to conduct additional studies beyond what is discussed in the SOWs in order to support the CMS. The facility owner or operator will furnish all personnel, materials and services necessary to conduct the additional tasks. The SOW for the CMS Workplan and Report are specified in Sections 7.3.1 through 7.3.2.7.

7.3.1 Corrective Measures Study Workplan

The CMS Workplan shall, at a minimum, include the following elements:

- A brief project summary;
- A site-specific description of the overall purpose of the CMS;
- A description of the proposed media cleanup standards and points of compliance that will be used in the corrective measures study report. Include the justification and supporting rationale for the proposed media cleanup standards and points of compliance. The proposed media cleanup standards must be based on available promulgated federal and state cleanup standards, risk based analysis, data and information gathered during the corrective action process (e.g., from RCRA Facility Investigation, etc.), and/or information from other applicable guidance documents. The Department may require that the Owner/Operator or Respondent conduct a risk assessment to gather information for establishing cleanup standards. Based on the CMS Report and other information including public comments, the Department will establish final cleanup standards and points of compliance as part of the remedy selection process.
- A description of the specific corrective measure technologies and/or corrective measure alternatives which will be studied;

- A description of the general approach to investigating and evaluating potential corrective measures;

- A detailed description of any proposed treatability, pilot, laboratory and/or bench scale studies. Proposed studies must be further detailed in either the CMS Workplan or in separate workplans. Submittal times for separate workplans must be included in the CMS Workplan project schedule;

- A proposed outline for the CMS Report including a description of how information will be presented;

- A description of overall project management including overall approach, levels of authority (include organization chart), lines of communication, budget and personnel. Include a description of qualifications for personnel directing or performing the work; and

- A project schedule that specifies all significant steps in the process and when key documents (e.g., CMS Report) are to be submitted to the Department.

7.3.2 Corrective Measures Study Report

The CMS Report shall, at a minimum, include the following elements:

7.3.2.1 Introduction/Purpose

Describe the purpose and intent of the document.

7.3.2.2 Description of Current Conditions

The facility owner or operator shall include a brief discussion of any new information that has been developed since the RCRA Facility Investigation Report was finalized. This discussion should concentrate on those issues which could significantly affect the evaluation and selection of the corrective measure alternative(s).

7.3.2.3 Proposed Media Cleanup Standards

The facility owner or operator shall describe and justify the proposed media cleanup standards and points of compliance.

7.3.2.4 Identification and Screening of Corrective Measure Technologies

- Identification:

  List and briefly describe potentially applicable technologies for each affected media that may be used to achieve the media cleanup standards. The facility owner or operator should consider including a table that summarizes the available technologies.

  The facility owner or operator should consider innovative treatment technologies, especially in situations where there are a limited number of applicable corrective measure technologies. Innovative technologies are defined as those technologies for source control other than incineration, solidification/stabilization and pumping with conventional treatment for contaminated ground water. Innovative treatment technologies may require extra initial effort to gather information, analyze options and to adapt the technology to site specific situations. However, in the long run, innovative treatment technologies could be more cost effective. Treatability studies and on-site pilot scale studies may be necessary for evaluating innovative treatment technologies.

- Screening:

  Technologies must be screened to eliminate those that may prove unfeasible to implement given the existing set of waste and site-specific conditions. The screening is accomplished by evaluating technology limitations (e.g., for volume, area, contaminant concentrations, interferences, etc.) and using contaminant and site characterization information from the RCRA Facility Investigation to screen out technologies that cannot be fully implemented at the facility. The screening process must focus on eliminating those technologies which have severe limitations for a given set of waste and site-specific conditions (e.g., depth to ground water and aquitards).

  As with all decisions during the CMS, the screening of technologies must be fully documented. This is especially true if the screening step indicates that only one corrective action technology should proceed to the next step and be evaluated in detail. List the corrective action technologies selected for further evaluation. Also document the reasons for excluding any corrective action technologies. The facility owner or operator should consider including a table that summarizes the findings.

7.3.2.5 Corrective Measure Alternative Development

Assemble the technologies that pass the screening step into specific alternatives that have potential to meet the corrective action objectives. Options for addressing less complex sites could be relatively straightforward and may only require evaluation of a single or limited number of alternatives.

Each alternative may consist of an individual technology or a combination of technologies used in sequence (e.g., treatment train). Depending on the site specific situation, different alternatives may be considered for separate areas of the facility. List and briefly describe each corrective measure alternative.

7.3.2.6 Evaluation of Corrective Measure Alternatives

The four corrective action standards and five remedy selection decision factors described below shall be used to evaluate the corrective measure alternatives. All alternatives must meet the corrective action standards before the remedy selection decision factors are used for further evaluation.

The corrective action standards are as follows:

- Be protective of human health and the environment;

- Attain media cleanup standards;

- Control the source(s) of releases in order to reduce or eliminate, to the extent practicable, further releases of hazardous wastes (including hazardous constituents) that may pose a threat to human health and the environment; and

- Comply with any applicable federal, state, and local standards for management of wastes.

The remedy selection decision factors are as follows:

- Short- and Long-Term Effectiveness;
- Reduction of Toxicity, Mobility and/or Volume;
- Long-Term Reliability;
- Implementability; and
- Cost.

The corrective action standards and decision factors are described in further detail below.

7.3.2.6.1 Be Protective of Human Health and the Environment

Describe in detail how each corrective measure alternative is protective of human health and the environment.

This standard for protection of human health and the environment is a general mandate of the RCRA statute. The standard requires that remedies include any measures that are needed to be protective. These measures may or may not be directly related to media cleanup, source control, or management of wastes. An example would be a requirement to provide alternative drinking water supplies in order to prevent exposures to a contaminated drinking water supply.

7.3.2.6.2 Attain Media Cleanup Standards

Describe in detail each corrective measure alternatives ability to meet the proposed media cleanup standards.

7.3.2.6.3 Control the Sources of Releases

Describe in detail each corrective measure alternatives ability to control the sources of releases.

A critical objective of any remedy must be to stop further environmental degradation by controlling or eliminating further releases that may pose a threat to human health and the environment. Unless source control measures are taken, efforts to cleanup releases may be ineffective or, at best, will essentially involve a perpetual cleanup. Therefore, an effective source control program is essential to ensure the long-term effectiveness and protectiveness of the corrective action effort.

The source control standard is not intended to mandate a specific remedy or class of remedies. Instead, the facility owner or operator is encouraged to examine a wide range of options. This standard should not be interpreted to preclude the equal consideration of using other protective remedies to control the source, such as partial waste removal, capping, slurry walls, in-situ treatment/stabilization and consolidation.

7.3.2.6.4 Comply With Any Applicable Standards for Management of Wastes

Discuss how any specific waste management activities will be conducted in compliance with all applicable state or federal regulations (e.g., CAMU closure requirements, land disposal restrictions).

7.3.2.6.5 Short- and Long-Term Effectiveness

Each corrective measure alternative must be evaluated with regard to its effectiveness in protecting human health and the environment and meeting the proposed media cleanup standards. Both short- and long-term components of effectiveness must be evaluated; short-term referring to the construction and implementation period, and long-term referring to the period after the remedial action is complete. Estimate approximately how much time it will take to implement each corrective measure alternative, the length of time before initial beneficial results are obtained, and the length of time required to achieve the proposed media cleanup standards.

The evaluation of short-term effectiveness must include possible threats to the safety of nearby communities, workers, and environmentally sensitive areas (e.g., oceans, wetlands) during construction of the corrective measure alternative. Factors to consider are fire, explosion, exposure to hazardous substances and potential threats associated with treatment, excavation, transportation and re-disposal or containment of waste material. Laboratory and/or field studies are extremely useful in estimating the effectiveness of corrective measures and should be used whenever possible.

The evaluation of long-term effectiveness must include possible threats to the safety of nearby communities workers, and environmentally sensitive areas (e.g., oceans, wetlands) during operation of the corrective measure alternative.

7.3.2.6.6 Reduction of Toxicity, Mobility and/or Volume

Each corrective measure alternative must be evaluated for its ability to reduce the toxicity, mobility, and/or volume of the contaminated media. Reduction in toxicity, mobility, and/or volume refers to changes in one or more characteristics of the contaminated media by the use of corrective measures that decrease the inherent threats associated with the media.

Estimate how much the corrective measure alternative will reduce the waste toxicity, volume and/or mobility (compare initial site conditions to post-corrective measure conditions). In general, the Department strongly prefers corrective measures that have a high degree of permanence and reduce the contaminant toxicity, mobility and volume through treatment.

7.3.2.6.7 Long-Term Reliability

Each corrective measure alternative must be evaluated with regards to its long-term reliability. This evaluation includes consideration of operation and maintenance requirements.

Demonstrated and expected reliability is a way of assessing the risk and effect of failure. Discuss whether the technology or combination of technologies have been used effectively together under analogous site conditions, whether failure of any one technology in the alternative has an impact on receptors or contaminant migration, and whether the alternative would have the flexibility to deal with uncontrollable changes at the site (e.g., heavy rain storms, earthquakes, etc).

Operation and maintenance requirements include the frequency and complexity of necessary operation and maintenance. Technologies requiring frequent or complex operation and maintenance activities should be regarded as less reliable than technologies requiring little or straightforward operation and maintenance. The availability of labor and materials to meet these requirements must also be considered.

Most corrective measure technologies, with the exception of destruction, deteriorate with time. Often, deterioration can be slowed through proper system operation and maintenance, but the technology eventually may require replacement. Each corrective measure alternative shall be evaluated in terms of the projected useful life of the overall alternative and of its component technologies. Useful life is defined as the length of time the necessary or required level of effectiveness can be maintained.

7.3.2.6.8 Implementability of Corrective Measure Alternatives

The implementability criterion addresses the technical and administrative feasibility of implementing a corrective measure alternative and the availability of various services and materials needed during implementation. Each corrective measure alternative must be evaluated using the following criteria:

- Construction and Operation: Corrective measure alternatives must be feasible to implement given the existing set of waste and site-specific conditions. This evaluation was initially done for specific technologies during the screening process and is addressed again in this detailed analysis of the alternative as a whole. It is not intended that the screening process be repeated here, but instead to highlight key differences and/or changes from the screening analysis that may result from combining technologies.

- Administrative Feasibility: Discuss the administrative activities needed to implement the corrective measure alternative (e.g., permits, public acceptance, rights of way, off-site approvals, etc.).

- Availability of Services and Materials: Discuss the availability of adequate off-site treatment, storage capacity, disposal services, needed technical services and materials, and the availability of prospective technologies for each corrective measure alternative.

7.3.2.6.9 Cost

Develop a preliminary cost estimate for each corrective measure alternative (and for each phase or segment of the alternative). The cost estimate shall include both capital and operation and maintenance costs. Include a description of how the costs were estimated and what assumptions were used.

- The preliminary capital cost estimate must consider all key costs including, at a minimum, costs for engineering, mobilization, demobilization, site preparation, construction, materials, labor, equipment purchase and rental, sampling, analysis, waste disposal, permitting and health and safety measures.

- The preliminary operation and maintenance cost estimate must consider all key costs including, at a minimum, costs for labor, training, sampling, analysis, maintenance materials, utilities, waste disposal, waste treatment, permitting and health and safety measures.

- Calculate the net present value of preliminary capital and operation and maintenance costs for each corrective measure alternative.

7.3.2.7 Facility Owner or Operator's Recommended Corrective Measure Alternative

The facility owner or operator may recommend a preferred corrective measure alternative for consideration by the Department. Such a recommendation should include a description and supporting rationale for the preferred alternative that is consistent with the corrective action standards and remedy selection decision factors discussed above.

Based on the CMS Report and other information including public comments, the Department will establish final cleanup standards, points of compliance and will select a final remedy for the facility.

7.4 Questions and Answers

The following questions represent frequently asked questions regarding the CMS portion of the corrective action program. This is meant to be an interactive system, and if additional questions need to be addressed, please forward them to the Corrective Action

Workgroup.

1. Q: What is the primary goal of the CMS?

   A: The primary elements of the CMS include: 1) identification and development of corrective measure alternatives, 2) evaluation of alternatives; and 3) selection of a corrective measure(s) for implementation. This process ensures that all appropriate technologies are identified and evaluated on an equal basis.

2. Q: Can more than one cleanup alternative be used for a single medium?

   A: Yes. This is especially viable if one remedy will remediate the medium in the short-term while another remedy will remediate the medium for the long-term or if removal of contaminants is necessary prior to destruction. This may also be considered an interim measure.

3. Q: How much characterization is necessary for the CMS?

   A: Many tradeoffs make the decision of remedy selection difficult. The characterization of the sites must be complete enough in order to select a cleanup strategy.

4. Q: What are the steps necessary to identify and develop the corrective measures alternatives?

   A: The permit writer should first define the problem in terms of the site conditions found during the RFI. Thereafter, site-specific objectives for the corrective action are established to serve as a basis for technology assessment and to establish the end point for cleanup activities.

5. Q: What are the objectives when selecting corrective measures?

   A: The objectives of the corrective measures should: 1) be protective of human health and the environment; 2) attain media cleanup standards; 3) control the sources of releases so as to reduce or eliminate, to the extent practicable, further releases that may pose a threat to human health and the environment; and 4) comply with standards for management of wastes.

6. Q: What conditions are grounds for eliminating various treatment alternatives?

A: Alternatives are judged to be poor when they are: 1) difficult or infeasible to implement, 2) associated with technologies unlikely to perform satisfactorily or reliably, 3) those that are unlikely to achieve the corrective measure objective within a reasonable time period, or 4) those that are unlikely to be cost effective.

7. Q: The cost effectiveness of each alternative is very important. What costs should be included?

A: The following costs should be considered: 1) direct capital costs (e.g., construction, land and site-development, building and service costs); 2) indirect capital costs (e.g., engineering and geological expenses, legal fees, start-up); 3) operation and maintenance costs including, operating labor, maintenance materials, energy, disposal and treatment costs, administrative and insurance taxes and licensing costs.

8. Q: Does the Department have flexibility to modify remedies presented in the CMS Workplan?

A: The CMS Workplan is subject to the Department's review and approval or modification. The Department may modify the CMS Workplan to include a study of different remedies to eliminate the need for further iterations of the submission and approval process.

9. Q: When should treatability studies be conducted?

A: Treatability studies provide valuable site-specific data necessary to evaluate the performance of a remedial technology. These studies indicate whether a given technology can meet the expected cleanup goals for the facility, and establish the design and operating parameters for optimization of technology performance. Treatability studies should be conducted after the Department approves the workplan for such studies. Generally, a facility would submit the workplan for the proposed treatability studies concurrent with the submittal of the CMS Workplan.

7.5 References

"Basics of Pump-and-Treat Ground-Water Remediation Technology," USEPA, EPA/600/8-89/003, March 1990.

"Corrective Measures for Releases to Ground Water from Solid Waste Management Units," Draft Final, USEPA, EPA/530/SW-88/020, PB 88-185251, August 1985.

"Corrective Measures for Releases to Soil from Solid Waste Management Units," Draft Final, USEPA, EPA/530/SW-88/022, PB 88-185277, August 1985.

"Corrective Measures for Releases to Surface Water," Draft Final, USEPA, EPA/530/SW-90/085, PB 91-102046, August 1985.

"Guide for Conducting Treatability Studies Under CERCLA," Interim Final, USEPA, EPA/540/2-89/058, PB 90-249772, December 1989.

"Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites," USEPA, EPA/540/G-88/003, December 1988.

"Handbook, Approaches for the Remediation of Federal Facility Sites Contaminated with Explosive or Radioactive Wastes," USEPA, EPA/625/R-93/013, September 1993.

"The Superfund Innovative Technology Evaluation Program: Technology Profiles," USEPA, EPA/540/5-89/013, PB 90-249756, November 1989.

APPENDIX F

CAL/EPA GUIDANCE MANUAL FOR GROUNDWATER INVESTIGATIONS & GUIDELINES FOR HYDROGEOLOGIC CHARACTERIZATION OF HAZARDOUS SUBSTANCE RELEASE SITES

(Note: These documents can be downloaded from the DTSC Web-site. Refer to the Reference section (Section 15.0) of this Guidance Document for the web address.)