GENERAL WASTE DISCHARGE REQUIREMENTS
POST-CLOSURE MAINTENANCE OF INACTIVE
NONHAZARDOUS WASTE LANDFILLS
ORDER NO. R4-2002-022

FILE NO. 01-019

ATTACHMENT 1:
SWAT TECHNICAL GUIDANCE MANUAL

TECHNICAL GUIDANCE MANUAL

SOLID WASTE WATER QUALITY ASSESSMENT TEST (SWAT)

PROPOSALS AND REPORTS

SOLID WASTE DISPOSAL PROGRAM
HYDROGEOLOGY SECTION
LAND DISPOSAL BRANCH
DIVISION OF WATER QUALITY
STATE WATER RESOURCES CONTROL BOARD

August 1988

SOLID WASTE ASSESSMENT TEST (SWAT)
PROPOSALS AND REPORTS

TABLE OF CONTENTS

I. PREFACE 1

II. INTRODUCTION 2
A. BACKGROUND 2
B. PURPOSE 4
C. WAIVERS 4
D. INCORPORATION OF SUBCHAPTER 15 REQUIREMENTS 5

III. SWAT PROPOSALS 7
A. GENERAL SITE INFORMATION 8
1. SITE NAME 8
2. SITE LOCATION 8
3. OWNERS/OPERATORS 8
4. CURRENT PERMITS AND/OR REGULATORY ORDERS . . . 8
5. SITE HISTORY 8
6. WASTE DISPOSAL HISTORY 9
7. SITE CONSTRUCTION DETAILS 9
8. SITE CLOSURE DETAILS 9
9. CURRENT AND PROPOSED LAND USE 10
B. SITE ASSESSMENT 10
1. GEOLOGIC OVERVIEW 10
a. REGIONAL DATA 10
b. SITE-SPECIFIC DATA 11
2. HYDROGEOLOGIC OVERVIEW 11
a. REGIONAL DATA 11
b. SITE-SPECIFIC DATA 11
C. PROPOSED MONITORING/SAMPLING STATIONS 12
1. SURFACE WATER SAMPLING 12
2. VADOSE ZONE SAMPLING 12
3. GROUND WATER SAMPLING 12
D. PROPOSED SAMPLING PROCEDURES 12
E. PROPOSED CHEMICAL ANALYTICAL METHODS 12
F. PROPOSED QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) PROCEDURES 12

IV. SWAT REPORT 13
A. DOES THE REPORT CONTAIN AN EXECUTIVE SUMMARY OF THE KEY FINDINGS AND CONCLUSIONS? 13
B. IS THE PERSON CERTIFYING THE REPORT QUALIFIED? . . 13
C. IS ALL THE REQUIRED INFORMATION PROVIDED? 13
1. ARE YOU CONVINCED THAT THE MONITORING STATIONS PROVIDE RELIABLE DATA ON THE CHEMICAL CHARACTER OF THE WATER? 14
2. DOES THE REPORT PROVIDE ADEQUATE DATA FROM THE FOLLOWING LIST TO VALIDATE THE FINAL LOCATION AND AS-BUILT DESIGN FOR EACH MONITORING POINT? 14

3. DOES THE REPORT DESCRIBE ADEQUATE INSTALLATION QUALITY CONTROL AND QUALITY ASSURANCE MEASURES TO ENSURE THAT ALL MONITORING STATIONS WILL WORK PROPERLY? 15
4. WERE THE SAMPLING METHODS APPROPRIATE TO OBTAIN RELIABLE AND REPRESENTATIVE DATA? 15
5. WERE APPROPRIATE CHEMICAL, ANALYTICAL AND QUALITY CONTROL METHODS USED? 15
6. HAVE ENOUGH SAMPLES BEEN TAKEN TO PROVIDE INDICATION OF ANY SEASONAL VARIATIONS OF WATER QUALITY? 16
D. DOES THE REPORT CONTAIN A REASONABLE INTERPRETATION OF THE BASIC DATA INDICATING WHETHER HAZARDOUS WASTE IS LEAKING FROM THE SOLID WASTE DISPOSAL SITE? . . 16
1. DETERMINATION OF LEAKAGE 16
2. FINDING OF HAZARDOUS WASTE LEAKAGE 17
E. REJECTION OF INADEQUATE REPORTS 17

APPENDIX 1: APPLICABLE LAWS 19
A. GOVERNMENT CODE 19
B. WATER CODE 22
C. HEALTH AND SAFETY CODE 28

APPENDIX 2: SAMPLING AND ANALYSIS PROCEDURES 32
A. FREQUENCY OF SAMPLING 32
B. SAMPLING PLAN 32
C. GROUND WATER SAMPLE COLLECTION 32
1. WELL PURGING 32
2. SAMPLING DEVICES 33
a. BAILERS 33
b. SYRINGE BAILERS 33
c. BLADDER PUMPS 34
D. SURFACE WATER SAMPLE COLLECTION 34
E. SAMPLE STORAGE 34
1. METAL ANALYSES 34
2. ORGANIC CHEMICALS 35
3. OTHERS 35
F. SAMPLE PRESERVATION 35
G. METHODS OF ANALYSES 36
H. QUALITY ASSURANCE/QUALITY CONTROL 36

APPENDIX 3: GEOLOGIC WELL LOG DESCRIPTION 41

APPENDIX 4: PHYSICAL ANALYSIS OF SOIL SAMPLES 43

APPENDIX 5: PIEZOMETER DESIGN AND PLACEMENT 45

APPENDIX 6: VADOSE ZONE MONITORING 47
A. INTRODUCTION 47
B. PRESSURE/VACUUM LYSIMETERS 47
1. DESCRIPTION 47
2. PRELIMINARY WORK 48

3. QUALITY CONTROL PROCEDURES 48
C. ALTERNATIVE DEVICES 48
D. REFERENCES 50

APPENDIX 7: MONITORING WELL DESIGN AND PLACEMENT 51
A. INTRODUCTION 51
B. DRILLING METHODS 51
1. HOLLOW STEM AUGER 51
2. CABLE TOOL 51
3. ROTARY DRILL 51
4. CASING HAMMER 52
C. WELL DESIGN 52
D. MATERIAL SELECTION 53
1. POLYVINYL CHLORIDE (PVC) 53
2. FLUOROCARBON RESINS (FR) 53
3. STAINLESS STEEL 53
E. WELL FILTER PACK DESIGN 54
F. SCREEN DESIGN 55
G. WELL DEVELOPMENT 55
H. WELL INTEGRITY 56
I. CEMENTING 57
J. WELL CONSTRUCTION 58
K. WELL PLACEMENT 58

APPENDIX 8: DETERMINATION OF SUBSURFACE HYDRAULIC CONDUCTIVITY 60

TECHNICAL GUIDANCE MANUAL
SOLID WASTE DISPOSAL PROGRAM

SOLID WASTE WATER QUALITY ASSESSMENT TESTS (SWATs) PROPOSALS AND REPORTS

I. PREFACE

It has long been known that solid waste disposal sites designed to receive only domestic or commercial waste also receive some hazardous waste. It is nearly impossible to prevent some hazardous wastes from entering these sites. For many years, most regulatory agency staff felt that only small quantities of hazardous wastes were received by ordinary solid waste disposal sites. Further, it was largely perceived that this hazardous waste would be diluted or adsorbed by the rubbish to the point where significant quantities, if any, would not reach ground water.

In recent years, however, we have seen scattered indications that hazardous wastes in ordinary disposal sites might be more of a problem than we had anti ipated. Solvents and pesticides have been found in ground water under disposal sites and in landfill gases emanating from the soil.

Based on these findings, legislation has been passed which requires all solid waste operators to demonstrate whether these indications of hazardous waste leakage are representative of a serious, widespread problem or are rare exceptions.

II. INTRODUCTION

A. BACKGROUND

In 1984, Section 13273 was added to the Water Code.[1] This Section required the State Water Resources Control Board (State Board) to rank all solid waste disposal sites throughout the State on the basis of the potential threat they may pose to water quality. Further, this Section mandates that these sites be tested to determine whether there is hazardous waste leakage from the site.

The State Board approved a ranked list of approximately 2,100 active and inactive solid waste disposal sites in December, 1985. Revised rankings were adopted by the State Board in October and December, 1986 and December, 1987. The most recently approved list contains over 2,200 sites, consisting of 14 ranks of 150 sites each, and a 15th partially filled rank.

Water Code Section 13273 requires the operators (and/or owners) of solid waste disposal sites to submit a Solid Waste Water Quality Assessment Test (SWAT) report to the appropriate California Regional Water Quality Control Board (Regional Board).[2] The SWAT reports are due the first day of July each year, depending on their ranking, with Rank 1 sites due July 1, 1987 (see Section II.C.).

---

[1]Chapter 1532, Statutes of 1984 (sometimes known as the Calderon Act after its author). This law added Sections 66795.53 and -.54 to the California Code of Regulations; Sections 40511, 41805.5, and 4231.5 to the Health and Safety Code; and Section 13273 to the Water Code. There were subsequent amendments to some of these Sections in 1986 and 1987. Copies of all relevant laws are contained in Appendix Number 1.

[2]Under Section 41805.5 of the Health and Safety Code, Air-SWAT reports are required to be submitted to the Air Resources Board. Only Water-SWATs are addressed in this document.

As per Subsection 13273(b), the SWAT report must contain:

1. An analysis of the surface and ground water on, under, and within one mile of a solid waste disposal site to provide a reliable indication of whether there is any leakage of hazardous waste; and

2. A chemical characterization of the soil-pore liquid in those areas which are likely to be affected if the solid waste disposal site is leaking, as compared to geologically similar areas near the solid waste disposal site which have not been affected by leakage of waste discharge.

Subsection 13273(b) states that a qualified professional must certify that the report contains all of the information required above as well as any additional information required by the Regional Board. This certification must be made by a professional meeting the following qualifications:

1. Must be registered or certified as:

   a. A Registered Geologist registered pursuant to Business and Professions (B&P) Code Section 7850, or

   b. A Certified Engineering Geologist certified pursuant to B&P Code Section 7842, or

   c. A Registered Civil Engineer registered pursuant to B&P Code Section 6762, and,

2. Must have at least five years experience in ground water hydrology.

Based on the Regional Board's prior experience with similar investigations and reports, it was recognized that the site operator's preparation of a SWAT investigation proposal was a necessary first step. Although Water Code Section 13273 makes no mention of a proposal, Section 13267 of the same code authorizes Regional Boards to require submittal of technical reports. Thus, a SWAT investigation proposal, containing detailed plans for the work required for this program, should be prepared at least a year before the SWAT report due date. Further, the Regional Boards are urged to require that the proposal be prepared by a person having the same qualifications as required for the certification of a SWAT report.

B. PURPOSE

This Technical Guidance Manual (Manual) addresses the contents of the SWAT proposals and reports. It draws upon two draft technical guidance documents, dated March and October, 1986, as well as various guidance memoranda, literature, and other relevant sources.

The Manual provides guidance for:

1. The preparation of adequate SWAT proposals and SWAT reports to meet the requirements set forth in Water Code Section 13273, and

2. The review of SWAT proposals and reports by Regional Board staff.

The Manual's contents are not regulations; thus site specific considerations should dictate how closely the Manual's procedures are followed. However, the Regional Boards may wish to ask the site owner/operator to justify any omissions on the basis that local circumstances make them unnecessary and that the final results will not be compromised. (For example, a site having average ground water levels above most of the refuse will not need unsaturated zone monitoring since there is no unsaturated zone.)

Use of procedures different than those suggested in this Manual should also be justified on the basis that the proposed substitute procedure will provide data that is equally or more reliable than that discussed in the Manual. For example, a newly developed lysimeter design might be substituted for the current procedures if it is more suitable for the soils underlying the site.

It is intended that this Manual be a dynamic document. As significant advances in the fields of ground, vadose zone, and surface water sampling and other germane subjects are developed, addenda or corrections to this Manual will be prepared and distributed.

C. WAIVERS

The SWAT law contains one clause for which waivers for the SWAT work may be granted. Water Code Subsection 13273(c) states, "If the regional board determines that the information specified in paragraph (1) [surface and ground

water sampling] or (2) [soil-pore liquid sampling] is not needed because other information demonstrates that hazardous wastes are migrating into the water, the regional board may waive the requirement to submit this information specified in paragraphs (1) and (2) of subdivision (b)." Thus, for those sites where existing monitoring systems or other available data indicate that there is hazardous waste leakage, the Regional Board may grant a waiver.

In those cases where hazardous waste is leaking from the site, ongoing investigations should be capable of determining the extent of the leakage and whether there are any additional leakage areas. These investigations are covered under Subchapter 15 and Water Code Sections 13301 and 13304.

If a waiver is granted, the Regional Board must notify the California Department of Health Services (DHS) and must take remedial action pursuant to Chapter 5 (Section 13300 et. seq.).

D. INCORPORATION OF SUBCHAPTER 15 REQUIREMENTS

The technical requirements of the SWAT program and Subchapter 15[3] have a substantial overlap. Owners of active solid waste disposal sites were required to submit to the Regional Board by mid-1985 a proposed monitoring program that would meet the requirements of Articles 5 and 9 of Subchapter 15. Wherever such a program was implemented, it should have met all or most of the SWAT requirements. There are, however, some important differences between the two programs:

1. Water Code Section 13273 is written in language that can be interpreted as requiring only a single sample per sampling point. Since almost all of California has distinctly wet and dry seasons, water quality may likewise have a seasonal variation. During and immediately following the wet season, infiltrating rainfall may dilute and reduce the mineral concentrations of existing vadose zone and ground water. On the other hand, following the infiltration of precipitation from a major storm through waste, a distinct "slug" of degraded water may be found moving toward or within the zone of

[3]California Code of Regulations, Title 23, Chapter 3, Subchapter 15, "Disposal of Waste to Land".

saturation. A further complication is that a "slug" of leachate may take many months to move from the site to a particular monitoring well. Therefore, the general rule should be that a reliable indication of ground water quality can only be obtained from a suite of at least four quarterly samples. Any site operator submitting sample data that does not meet the above criteria must demonstrate that his site is different from the general rule stated above.

2. Subchapter 15 only mandates water quality monitoring of active sites. The SWAT law makes no distinction between active and inactive sites.

3. Subchapter 15's requirements for unsaturated (vadose) zone sampling apply only "if feasible". The SWAT law contains no such exception.

Disposal site operators with active sites on the State Board's ranked SWAT list should comply with the monitoring requirements in Subchapter 15 at the same time they complete the SWAT report. Disposal site operators should contact their Regional Boards for site specific information on Subchapter 15 compliance. Disposal site operators in the process of implementing Subchapter 15 requirements may find that many of their SWAT Program requirements will have been satisfied with their Subchapter 15 efforts. In these cases, the required SWAT will summarize the ongoing Subchapter 15 efforts and report on the specific hazardous waste test results required by the Regional Board. Hence, for all references contained in this guidance, unless otherwise noted, refer to code sections found in Title 23, Chapter 3, Subchapter 15 of the California Code of Regulations.

III. SWAT PROPOSALS

The purpose of a SWAT proposal is threefold:

- Provide to the Regional Board all relevant background information and supporting data for the proposed SWAT investigation.
- Provide to the Regional Board an outline of the investigation plan, including the location, design, and rationale for all monitoring and sampling stations.
- Provide the site operator an early opportunity to adjust the SWAT investigation plans in order to meet the mandates of the law and the requirements of the Regional Board.

In most cases, a preliminary (pre-proposal) hydrogeologic assessment of the site will be necessary. This should include a thorough inventory of all available site and regional data, such as existing maps and literature, well data, water quality analyses, etc. If additional background information is needed, the operator may wish to install piezometers or exploratory boreholes, do site specific geologic mapping, or take other measures to establish hydraulic gradients, aquifer characteristics, etc. The Regional Board staff may wish to confer with the site operator at this stage to ensure that the necessary preliminary assessment work is being done.

The following sections (III.A through III.F) provide an outline of the items which should be addressed in the SWAT proposal. It is expected that much of the requested data will not be available for older and/or smaller sites. In such cases, the Regional Boards should determine whether any of the omitted data are critical for successful completion of the SWAT report. In such cases, they should require that these data or equivalent alternative data be obtained by the site operator.

Site data previously submitted to the Regional Board under another program need not be resubmitted; however, it must be clearly and accurately referenced.

A. GENERAL SITE INFORMATION

This section is designed to give all relevant background data concerning the disposal site.

1. SITE NAME: Include the preferred name and all previous names used for the facility.

2. SITE LOCATION: Data submitted should include both general information necessary for determining where the site is located and, also, data showing where on the site property waste has been placed. All of the following should be submitted:

   a. A scaled map showing the relationship of the site to highways, communities and other cultural features.

   b. A street address, if available, or general location.

   c. Township, range, section, and fractional section, if available.

   d. County Assessor's parcel map showing site boundaries.

   e. Other types of maps or descriptive matter that provide equivalent information useful for specifying the site and waste location.

3. OWNERS/OPERATORS: Include current property owner(s) and site operator(s) of the facility. Include names, current mailing addresses and telephone numbers.

4. CURRENT PERMITS AND/OR REGULATORY ORDERS: Reference all relevant permits and orders (copies need not be submitted unless specifically requested by the Regional Board).

5. SITE HISTORY:

   a. Identify names and current addresses, and duration of involvement for all past site owners and operators.

   b. Describe past and present modes of operation used at the site.

6. WASTE DISPOSAL HISTORY:

   a. Include a description of the types, quantities, physical states; concentrations, and disposal locations of wastes contained in the site. This should include information for all previous operations. Wastes and waste constituents should be specifically identified according to the most descriptive nomenclature. This should include, if possible, reference numbers for listings established by DHS in Section 66680, Title 22, California Code of Regulations.

   b. Include a description of waste disposal methods specifying waste mixing and management practices.

7. SITE CONSTRUCTION DETAILS (Section 2596(a)(1)):

   a. Include detailed information on liners including:

      (1) Liner material specifications and testing.

      (2) Method of placement and other construction details.

      (3) Quality assurance/quality control procedures.

      (4) Subsequent inspections, repairs, etc.

   b. If a leachate collection and removal system pursuant to Section 2557 is present, include construction details and specifications along with a representative analysis of leachate. Include a summary of all previous analyses.

8. SITE CLOSURE DETAILS:

   a. Date operations ceased.

   b. Date closure plan was approved. (If site closure was phased, provide map showing closure dates for each portion of the site.)

   c. Details on final treatment processes (mixing, chemical treatment, burial, removal, etc.).

   d. Quantity and quality of all waste left in place.

e. Cover specifications (same details as for liners, 7a. above). Specify if cover is final cover.

f. Description of landfill gas collection system and gas condensate disposal method.

g. Description of occurrences of settlement or cracking.

9. CURRENT AND PROPOSED LAND USE:

Describe the present and proposed (if known) land use of the disposal site property and the present and proposed land use patterns existing within 0.5 mile of the disposal site.

B. SITE ASSESSMENT

This section is designed to describe the geology and hydrogeology of the site as necessary to justify all monitoring station locations and designs (Section 2596(a)).

1. GEOLOGIC OVERVIEW

a. REGIONAL DATA:

(1) Excerpts of all relevant published geologic information that is referenced in the SWAT proposal.

(2) Topographic maps, geologic maps, and air photos (if available) of the disposal site area. Include locations of all springs, seeps, and surface flows within one mile of the facility boundaries.

(3) Regional geologic cross sections.

(4) Regional soil surveys (available through the U.S. Soil Conservation Service) within one mile of the facility boundaries.

(5) All available well logs within one mile of the facility boundaries, along with a map showing locations and functions of all wells (i.e., monitoring, production, etc.).

b. SITE-SPECIFIC DATA:

(1) Surface and subsurface geologic maps, and a description of the geologic structure of the waste site, including the lithology, thickness, strike, and dip of bedding; the location, attitude, and condition (tight, open, clay- or gypsum-filled, etc.) of any fractures or faults; the nature, type (anticlinal, synclinal, etc.), and orientation of any folds; and all other structural data relevant to ground water and pollutant movement.

(2) Logs and a location map of all monitoring and other wells drilled for this facility (see Appendix 3: Geologic Well Log Description).

(3) Trench logs (if available).

(4) Geologic cross-sections: These sections should be both perpendicular to, and along the regional structure.

2. HYDROGEOLOGIC OVERVIEW

a. REGIONAL DATA: Include a summary of all relevant published regional hydrologic and hydrogeologic information. If referenced reports are not readily available, copies of the appropriate data should be submitted (Section 2595(c)).

b. SITE-SPECIFIC DATA: Include the following:

(1) Well logs and completion reports from pilot holes, wells, or any prior piezometer construction (see Appendix 3: Geologic Well Log Description).

(2) All prior water level measurement data (see Appendix 5: Piezometer Design and Placement).

(3) All prior analytical data from surface waters, ground waters or vadose zone soil pore liquids under or adjacent to the landfill (see Appendix 5: Physical Analysis of Soil Samples).

C. PROPOSED MONITORING/SAMPLING STATIONS

1. SURFACE WATER SAMPLING: Proposed locations and sampling methodology together with supporting rationale for each.

2. VADOSE ZONE SAMPLING: Proposed locations and vadose zone sampling methodology together with supporting rationale for each (see Appendix 6: Vadose Zone Monitoring) (Section 2559).

3. GROUND WATER SAMPLING: Proposed locations and ground water monitoring well design, along with supporting rationale for each (see Appendix 7: Monitoring Well Design and Placement) [Section 2555(c),(d),(e),(f),(g) & Section 2596(a)].

D. PROPOSED SAMPLING PROCEDURES

Full details should be provided on all proposed surface, vadose, and ground water sampling methods (see Appendix 2: Sampling Procedures) (Section 2855).

E. PROPOSED CHEMICAL ANALYTICAL METHODS

An important consideration in implementing the SWAT program is the assumption that solid waste disposal sites will contain some wastes that were not expected to be present. It is easy to picture circumstances where site users have brought in hazardous wastes, knowingly or unknowingly, for disposal at a site intended for common domestic waste only. Therefore, the chemical analytical methods used must be aimed not at the determination of what is known to be present, but rather, what might be present (see Appendix 2, Section G: Methods of Analyses).

F. PROPOSED QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) PROCEDURES

One of the responsibilities of the operator is to ensure the reliability and validity of field and analytical laboratory data gathered as part of the overall ground water monitoring program.

The operator's sampling and analysis plan must explicitly describe the QA/QC program that will be used in the field and laboratory. (see Appendix 2, Section H: Quality Assurance/Quality Control).

IV. SWAT REPORT

All SWAT reports will be thoroughly reviewed to determine whether they fully comply with the law and provide adequate data to support the required findings. Matters of special importance include:

A. DOES THE REPORT CONTAIN AN EXECUTIVE SUMMARY OF THE KEY FINDINGS AND CONCLUSIONS? The SWAT report's executive summary should contain the following:

1. For each type of sampling (monitoring) method (surface, vadose zone, and ground water):

   - Number of monitoring points.
   - Number of sampling events per monitoring point.
   - Evidence of waste leakage (hazardous, non-hazardous, or none).

2. Is there evidence of hazardous waste in the waste disposal site?

B. IS THE PERSON CERTIFYING THE REPORT QUALIFIED? Water Code Subsection 13273(b) states:

> "(b)...a registered geologist, ...a certified engineering geologist, ...or a civil engineer, ...who has at least five years' experience in groundwater hydrology, shall certify that the report contains all of the following information ...."

The report must contain clear evidence that the person certifying the report fully meets the above requirements. The person's license number and expiration date should be given together with a thorough description of their qualifying experience.

C. IS ALL THE REQUIRED INFORMATION PROVIDED? Water Code Subsection 13273(b) continues with a description of required data:

"(1) An analysis of the surface and groundwater on, under, and within one mile of the solid waste disposal

site to provide a reliable indication whether there is any leakage of hazardous waste."

"(2) A chemical characterization of the soil-pore liquid in those areas which are likely to be affected if the solid waste disposal site is leaking, as compared to geologically similar areas near the solid waste disposal site which have not been affected by leakage or waste discharge."

Emphasis should be placed on the following considerations:

1. ARE YOU CONVINCED THAT THE MONITORING STATIONS PROVIDE RELIABLE DATA ON THE CHEMICAL CHARACTER OF THE WATER?

   Do all monitoring stations comply with Subchapter 15, Articles 5 and 9? Does the sampling program provide representative samples of ground water, surface water (if appropriate), and unsaturated zone water from all significant potential pollutant escape routes? Are the sampling points capable of intercepting pollutant movement that occurs for only a short period each year (i.e., after a heavy rainfall or as a result of nearby seasonal heavy pumping)?

2. DOES THE REPORT PROVIDE ADEQUATE DATA FROM THE FOLLOWING LIST TO VALIDATE THE FINAL LOCATION AND AS-BUILT DESIGN FOR EACH MONITORING POINT?

   - Site improvements and locations of waste.
   - Site geology.
   - Site hydrogeology.
   - Site soils data.
   - Other relevant information.

   Enough data should be provided so that the reviewer, given the same information, would select the same monitoring network locations and designs as those constructed. The report should include geologic cross-sections, ground water gradient data, and other supporting rationale for the location, depth, and

methods for each sampling point. This discussion also should support the numbers of monitoring points relative to the size, shape, and location of each significant potential escape route.

Much of this information may have been included in the proposal; however, initial assessment of site conditions may prove to be significantly different than actual subsurface conditions discovered during drilling and exploration. If actual conditions are similar to those initially described, a brief discussion here with reference to the proposal would be appropriate.

3. DOES THE REPORT DESCRIBE ADEQUATE INSTALLATION QUALITY CONTROL AND QUALITY ASSURANCE MEASURES TO ENSURE THAT ALL MONITORING STATIONS WILL WORK PROPERLY?

Improperly installed stations can be a vehicle for movement of pollutants into heretofore clean aquifers. In addition, if they produce non-representative samples (i.e., diluted or de-gassed) they can lead to erroneous data and a false sense of security. An incorrectly installed lysimeter that cannot obtain a water sample gives false data on the presence of water in the formation and prevents one from obtaining data on its quality. The SWAT report should contain as-built details and rationale for locations and construction designs for all sampling (monitoring) stations.

4. WERE THE SAMPLING METHODS APPROPRIATE TO OBTAIN RELIABLE AND REPRESENTATIVE DATA?

The sampling procedures should have been capable of obtaining fresh, representative samples of the water with no significant loss of volatile organic chemicals or undue dilution of the samples.

5. WERE APPROPRIATE CHEMICAL ANALYTICAL AND QUALITY CONTROL METHODS USED?

The analytical methods used should have been capable of providing data on any significant quantities of hazardous substances that could be leaking from the disposal site. Have standard quality control procedures (blanks, spikes, etc.) been employed?

Did the analytical laboratory have the appropriate certifications?

6. HAVE ENOUGH SAMPLES BEEN TAKEN TO PROVIDE INDICATION OF ANY SEASONAL VARIATIONS OF WATER QUALITY?

This is especially important where pollutant movement is related to periods of heavy rainfall. Unless exceptional circumstances are demonstrated, quarterly samples should be required.

D. DOES THE REPORT CONTAIN A REASONABLE INTERPRETATION OF THE BASIC DATA INDICATING WHETHER HAZARDOUS WASTE IS LEAKING FROM THE SOLID WASTE DISPOSAL SITE?

- There should be a full description of the chemical quality of surface, vadose zone, and ground water under and adjacent to the waste disposal site.
- The report must contain all relevant analytical data, not just a summary of results.
- Chemical data should be accompanied by a description of the analytical methods used and a discussion of all quality control measures, including chain-of-custody documents, spikes, blanks, etc.
- Are the SWAT report conclusions consistent with the findings and conclusions of the Air-SWAT report?

1. DETERMINATION OF LEAKAGE

As discussed above, chemical analytical work must be aimed at a determination of what constituents might be present. If a chemical constituent is found that is not naturally occurring in water (e.g., vinyl chloride) and is absent from upgradient waters, these facts alone indicate the heavy probability of site leakage. In some cases, a positive determination of whether leakage has occurred may require a statistical analysis of data from upgradient and downgradient wells.

2. FINDING OF HAZARDOUS WASTE LEAKAGE

Water Code Subsection 13273(e) requires the Regional Board to make a finding whether any hazardous waste has migrated into the water. The question of whether a water sample from one of the site's monitoring (sampling) points is hazardous can be answered by referring to the California Code of Regulations, Title 22, Article 11, Sections 66693 et seq.

More frequently, however, sample analyses will indicate the presence of hazardous constituents listed in Title 22, Article 9, Section 66680 rather than hazardous waste, per se. Most of the constituents will be at concentrations below the Soluble Threshold Limit Concentration (STLC) or equivalent levels. When this occurs, all the circumstances of the determination must be examined. Certainly, any finding of a hazardous waste constituent at levels above background concentrations is a cause of concern.

In some cases, hazardous waste will be the source of the pollutants found at the monitoring point. Preferring to err on the safe side, assume that significant dilution and/or attenuation of the hazardous waste constituent has occurred.

In those cases where it is questionable that the pollutant source is hazardous waste in the disposal site, continued monitoring is critical. It must be determined whether the given chemical concentrations are indicative of a hazardous waste source which will continue to degrade the water, or are temporal or naturally occurring constituents which do not indicate a problem.

E. REJECTION OF INADEQUATE REPORTS

Water Code Section 13273 states:

"(d) The regional board shall examine the report submitted pursuant to subdivision (b) and determine whether the number, location, and design of the wells and the soiling (sic) testing could detect any leachate buildup, leachate migration, or hazardous waste migration. If the regional board determines that the monitoring program could detect the leachate

and hazardous waste, the regional board shall take the action specified in subdivision (e). If the regional board determines that the monitoring program was inadequate, the regional board shall require the solid waste disposal site to correct the monitoring program and resubmit the solid waste assessment test based on the results from the corrected program."

The SWAT report must meet all the criteria set forth in Section 13273. A SWAT report should be returned for modifications if:

- The report fails to fulfill any of the law's requirements.
- It lacks the required professional certification, as per Subsection 13273(b).
- It is not complete in its sampling of ground water, surface water (if applicable), and unsaturated zone water, as required by Subsections 13273(b)(1) and (2); both with regard to space (consider three-dimensions!) and time.
- It does not provide adequate rationale for the location and design of each monitoring station to allow the Regional Board to make the determination specified in Subsection 13273(d).
- It does not provide convincing evidence that supports its conclusions regarding hazardous waste leakage and does not allow the Regional Board to make the determination specified in Subsection 13273(e).

APPENDIX 1: APPLICABLE LAWS
A. GOVERNMENT CODE

TITLE 7.3. Solid Waste Management, Resource Recovery, and Recycling
CHAPTER 3. Enforcement Program
ARTICLE 4. Administrative Enforcement and Remedies Available to an Enforcement Agency

Section
66796.53. Enforcement order or action; explanatory and justifying statement to other agencies; time; inspection of site; receipt of complaint by wrong agency; action by agency or written explanation required

(a) At least 10 days before issuing an enforcement order which is not for an emergency, within 5 days after issuing an enforcement order for an emergency, and within 15 days after discovering a violation of a state law, regulation, or permit, or a local ordinance, rule, regulation, license, or permit, for a solid waste disposal site which is likely to result in an enforcement action, the following agencies shall provide a written statement providing an explanation of, and justification for, the enforcement order or a description of the violation in the following manner:

(1) The enforcement agency shall provide the statement to the local California regional water quality control board, the local air pollution control district or air quality management district, and the State Department of Health Services.

(2) A California regional water quality control board shall provide the statement to the enforcement agency, the local air pollution control district or air quality management district, and the State Department of Health Services.

(3) An air pollution control district or an air quality management district shall provide the statement to the enforcement agency, the California regional water quality control board, and the State Department of Health Services.

(4) The State Department of Health Services shall provide the statement to the enforcement agency, the local California regional water quality control board, and the local air pollution control district or air quality management district.

(b) Within 10 days after receiving a notice of the issuance of, or the proposal to issue, an enforcement order, pursuant to subdivision (a), the local California regional water quality control board, the enforcement agency, the local air pollution control district or the air quality management district, and the State Department of Health Services shall inspect the solid waste disposal site to determine whether any state law, regulation, or permit, which that board or agency is authorized to enforce, is being violated.

(c) If any board or agency specified in subdivision (a) receives a complaint concerning a solid waste disposal site and the board or agency determines that it is not authorized to take action concerning the complaint, the board or agency shall refer the complaint within 10 days of receipt to another state agency which it determines is authorized to take action.

(d) If any agency or board specified in subdivision (a) receives a complaint concerning a solid waste disposal site which the agency or board does not refer to another state agency pursuant to subdivision (c), or if such an agency or board receives a complaint referred to it by another agency or board pursuant to subdivision (c), the agency or board shall either take enforcement action concerning that facility or provide the person who filed the complaint with a written statement within 10 days explaining why an enforcement action would not be appropriate.

HISTORY:

+Added Stats. 1984, ch. 1532, Section 1.

GOVERNMENT CODE

Section
66796.54. Report to the legislature; extent of hazardous wastes; potential effects on water quality; accuracy of tests

(a) On or before January 1, 1989, January 1, 1990, and January 1, 1991, the State Water Resources Control Board shall submit a report to the Legislature summarizing the extent of hazardous waste in solid waste disposal sites and the potential effects these hazardous wastes may have upon the quality of waters of the state, and recommending actions needed to protect the quality of water. Each report shall summarize the data from those solid waste water quality assessment test reports which have been submitted during the preceding year to California regional water quality control boards pursuant to Section 13273 of the Water Code, and shall evaluate the accuracy of the solid waste water quality assessment tests conducted.

(b) On or before July 1, 1988, and July 1, 1989, the State Air Resources Board shall submit a report to the Legislature summarizing the extent of hazardous waste in solid waste disposal sites and the potential effects these hazardous wastes may have upon the ambient air quality of the state, and recommending actions needed to protect the quality of air. The reports submitted on July 1, 1988, and July 1, 1989, shall summarize the data from the solid waste air quality assessment test reports submitted to air quality maintenance districts and air pollution control districts on or before July 1, 1987, and January 1, 1988, respectively, pursuant to Section 41805.5 of the Health and Safety Code, and shall evaluate the accuracy of the solid waste assessment tests conducted.

HISTORY:

+Added Stats. 1986, ch. 1055, Section 3, effective September 24, 1986, operative January 1, 1987.

+Former Section: Former Section 66796.54, similar to the present section was added by Stats. 1984, ch. 1532, Section 2, amended by Stats. 1986, ch. 971, Section 1, and repealed by Stats. 1986, ch. 1055, Section 1, effective September 24, 1986.

B. WATER CODE

DIVISION 7. Water Quality
CHAPTER 4. Regional Water Quality Control
ARTICLE 4. Waste Discharge Requirements

Section
13273. Solid waste disposal sites; ranking based on threat to water quality; submission of water quality assessment test reports by rank; waiver; evaluation; procedure upon discovery of inadequate monitoring or contamination of the water; revision of discharge requirements

(a) The state board shall, on or before January 1, 1986, rank all solid waste disposal sites, as defined in Section 66714.1 of the Government Code, based upon the threat which they may pose to water quality. On or before July 1, 1987, the operators of the first 150 solid waste disposal sites ranked on the list shall submit a solid waste water quality assessment test to the appropriate Regional Board for its examination pursuant to subdivision (d). On or before July 1 of each succeeding year, the operators of the next 150 solid waste disposal sites ranked on the list shall submit a solid waste water quality assessment test to the appropriate regional board for its examination pursuant to subdivision (d).

(b) Before a solid waste water quality assessmenttest report may be submitted to the regional board, a registered geologist, registered pursuant to Section 7850 of the Business and Professions Code, a certified engineering geologist, certified pursuant to Section 7842 of the Business and Professions Code, or a civil engineer registered pursuant to Section 6762 of the Business and Professions Code, who has at least five years' experience in groundwater hydrology, shall certify that the report contains all of the following information and any other information which the state board may, by regulation, require:

(1) An analysis of the surface and groundwater on, under, and within one mile of the solid waste disposal site to provide a reliable indication whether there is any leakage of hazardous waste.

(2) A chemical characterization of the soil-pore liquid in those areas which are likely to be affected if the solid waste

disposal site is leaking, as compared to geologically similar areas near the solid waste disposal site which have not been affected by leakage or waste discharge.

(c) If the regional board determines that the information specified in paragraph (1) or (2) is not needed because other information demonstrates that hazardous wastes are migrating into the water, the regional board may waive the requirement to submit this information specified in paragraphs (1) and (2) of subdivision (b). The regional board shall also notify the State Department of Health Services, and shall take appropriate remedial action pursuant to Chapter 5 (commencing with Section 13300).

(d) The regional board shall examine the report submitted pursuant to subdivision (b) and determine whether the number, location, and design of the wells and the soiling testing could detect any leachate buildup, leachate migration, or hazardous waste migration. If the regional board determines that the monitoring program could detect the leachate and hazardous waste, the regional board shall take the action specified in subdivision (e). If the regional board determines that the monitoring program was inadequate, the regional board shall require the solid waste disposal site to correct the monitoring program and resubmit the solid waste assessment test based upon the results from the corrected monitoring program.

(e) The regional board shall examine the approved solid waste assessment test report and determine whether any hazardous waste migrated into the water. If the regional board determines that hazardous waste has migrated into the water, it shall notify the State Department of Health Services and the California Waste Management Board and shall take appropriate remedial action pursuant to Chapter 5 (commencing with Section 13300).

(f) When a regional board revises the waste discharge requirements for a solid waste disposal site, the regional board shall consider the information provided in the solid waste assessment test report and any other relevant site-specific engineering data provided by the site operator for that solid waste disposal site as part of a report of waste discharge.

HISTORY:

+Added Stats. 1984, ch. 1532, Section 6; Amended Stats. 1986, ch. 971, Section 3.

WATER CODE

Section
13273.1. Solid waste assessment questionnaires

(a) Except as provided in subdivision (b), an operator of a solid waste disposal site may submit a solid waste assessment questionnaire to the appropriate regional board at least 24 months prior to the site's solid waste water quality assessment test due date as established pursuant to Section 13273. The regional board shall require the operator to submit any additional information, as needed, or require onsite verification of the solid waste assessment questionnaire data in order to render a decision pursuant to subdivision (c).

(b) Any solid waste disposal site which is larger than 50,000 cubic yards or is known or suspected to contain hazardous substances, other than household hazardous wastes, shall be prohibited from submitting a solid waste assessment questionnaire under this section.

(c) The regional board shall complete a thorough analysis of each solid waste assessment questionnaire submitted pursuant to this section by a date 18 months prior to the solid waste assessment test due date. Based upon this analysis, the regional board shall determine whether or not the site has discharged hazardous substances which will impact the beneficial uses of water. If the regional board determines that the site has not so discharged hazardous substances, the regional board shall notify the operator that the operator is not required to prepare a solid waste water quality assessment test pursuant to Section 13273.

(d) If the regional board does not make the determination specified in subdivision (c), the operator shall submit all, or a portion of, a solid waste water quality assessment test. The regional board shall notify the operator of this determination and indicate if all, or what portion of, a solid waste water quality assessment test shall be required. The operator shall submit the solid waste water quality assessment test, or a portion thereof, by the date established pursuant to Section 13273.

(e) The state board shall develop a solid waste assessment questionnaire and guidelines for submittal no later than three months after the effective date of this statute adding this section. The questionnaire shall contain, but not be limited to, a characterization of the wastes, size of the site, age of the site, and other appropriate factors.

(f) Those operators of solid waste disposal sites listed by the state board pursuant to Section 13273 in Rank 3 and seeking an exemption under this section shall submit their solid waste assessment questionnaire no later than July 1, 1988. If the regional board does not make the determination specified in subdivision (c), the regional board shall require the operator to submit all, or a portion of, a solid waste water quality assessment test by July 1, 1990.

HISTORY:

+Added Stats. 1987, ch. 932, Section 2, effective September 22, 1987.

Section
13273.2. **Reevaluation of solid waste disposal site status; requirement to submit or revise solid waste water quality assessment test**

Notwithstanding subdivision (b) of Section 13273.1, a regional board may reevaluate the status of any solid waste disposal site ranked pursuant to Section 13273, including those sites exempted pursuant to Section 13273.1, and may require the operator to submit or revise a solid waste water quality assessment test after July 1, 1989. The regional board shall give written notification to the operator that a solid waste assessment test is required and the due date. This section shall not require submittal of a solid waste water quality assessment test by a date earlier than established in accordance with Section 13273.

HISTORY:

+Added Stats. 1987, ch. 932, Section 3, effective September 22, 1987.

Section
13273.3. Operator defined

As used in Sections 13273, 13273.1, and 13273.2, "operator" means a person who operates or manages, or who has operated or managed, the solid waste disposal site. If the operator of the solid waste disposal site no longer exists, or is unable, as determined by the regional board, to comply with the requirements of Section 13273, 13273.1, or 13273.2, "operator" means any person who owns or who has owned the solid waste disposal site.

HISTORY:

+Added Stats. 1987, ch. 932, Section 4, effective September 22, 1987.

C. HEALTH AND SAFETY CODE

DIVISION 26. Air Resources
PART 4. Nonvehicular Air Pollution Control
CHAPTER 3. Emission Limitations
ARTICLE 2. Nonagricultural Burning

Section
41805.5. Solid waste air quality assessment test report; contents; questionnaires; exemptions

(a) Except as provided in subdivisions (b) and (c), the operator of a solid waste disposal site shall submit to the district on or before July 1, 1987, a solid waste air quality assessment test report that contains all of the following:

(1) Test results to determine if there is any underground landfill gas migration beyond the solid waste disposal site's perimeter.

2) Analyses for specified air contaminants in the ambient air adjacent to the solid waste disposal site to determine the effect of the site on air quality.

(3) Chemical characterization test results to determine the composition of gas streams immediately above the solid waste disposal site, or immediately above the solid waste disposal site and within the solid waste disposal site, as appropriate, as determined by the district.

(4) Any other information which the district board may require, by emergency regulation.

The solid waste air quality assessment test report shall be prepared in accordance with the guidelines developed by the state board pursuant to subdivision (d).

(b) The operator of an inactive solid waste disposal site shall complete and submit the screening questionnaire, developed pursuant to subdivision (e), to the district on or before November 1, 1986, unless the operator is required to submit a report containing the same information specified in subdivision (a) pursuant to a federal, state, or district order, or unless exempted pursuant to subdivision (c). The district shall evaluate the submitted screening questionnaires in accordance with the guidelines developed pursuant to

subdivision (e) and shall determine whether the operator of the site be required to submit all, or a portion of, the information required to be reported in a solid waste air quality assessment test report. The district shall notify the operator in writing on or before January 1, 1987, of the information identified in subdivision (a) to be submitted for the site. After receiving this notification, the operator of the inactive solid waste disposal site shall submit a solid waste air quality assessment test report containing the required information on or before January 1, 1988, to the district.

(c) A district may exempt from subdivisions (a) and (b) a solid waste disposal site or inactive solid waste disposal site which has accepted or now contains only inert and nondecomposable solids. To receive an exemption, the operator of the site shall submit, on or before November 1, 1986, a copy of all permits, all waste discharge requirements pertinent to the site, and any other data necessary for the district to determine whether an exemption should be granted to the site.

(d) On or before February 1, 1987, the state board, in coordination with the districts, shall develop and publish test guidelines for the solid waste air quality assessment report specifying the air contaminants to be tested for and identifying acceptable testing, analytical, and reporting methods to be employed in completing the report.

(e) On or before October 1, 1986, the state board, in coordination with the districts, shall develop and publish a screening questionnaire for inactive solid waste disposal sites and guidelines for evaluating the questionnaire by the districts pursuant to subdivision (b). The screening questionnaire and guidelines shall require an inactive solid waste disposal site to be evaluated based on the nature and age of materials in the site, the quantity of materials in the site, the size of the site, and other appropriate factors. The guidelines for evaluating the screening questionnaire shall require a district to weigh heavily the proximity of the site to residences, schools, and other sensitive areas, and to pay particular attention to potential adverse impacts on facilities such as hospitals and schools, and on residential areas, within one mile of the site's perimeter.

(f) A district may reevaluate the status of a solid waste disposal site, including sites exempted pursuant to subdivision (c), and require the operator to submit or revise a solid waste air quality assessment test report after January 1, 1987. The district shall give written notification to the operator of the solid waste disposal site that a solid waste air quality assessment test report is to be submitted, or that the existing report is to be revised, and the date by which the report is to be submitted.

(g) A district shall evaluate any solid waste air quality assessment test reports submitted pursuant to subdivisions (a), (b), and (f), and determine if the report's testing, analytical and reporting methods comply with the guidelines developed pursuant to subdivision (d). If the district determines that the solid waste air quality assessment test report complies with the guidelines, it shall evaluate the data. If the district determines, after evaluation of the report and consultation with the state department and the California Waste Management Board, that levels of one or more specified air contaminants pose a health risk to human beings or a threat to the environment, the district shall take appropriate remedial action.

(h) If a district determines that a solid waste air quality assessment test report does not comply with the guidelines developed pursuant to subdivision (d), the district shall provide the operator of the site with a written notice specifying the inadequacies of the report and shall require the operator to correct the deficiencies and resubmit the report by a date determined by the district.

(i) For the purpose of this section, the following definitions apply:

(1) "Inactive solid waste disposal site" means a solid waste disposal site which has not received any solid waste for disposal after January 1, 1984.

(2) "Landfill gas" means any untreated, raw gas derived through a natural process from the decomposition of organic waste deposited in a solid waste disposal site or from the evolution of volatile species in the waste.

(3) "Operator" means the person who operates or manages, or who has operated or managed, the solid waste disposal site. If the operator of the solid waste disposal site no longer exists, or is unable, as determined by the district, to comply with the requirements of this section, "operator" means any person who owns or who has owned the solid waste disposal site.

(4) "Perimeter" means the outer boundary of the entire solid waste disposal site property.

(5) "Solid waste disposal site" means a place, location, tract of land, area, or premises in use, or which has been used, for the landfill disposal of solid waste, as defined in Section 66719 of the Government Code, or hazardous waste, as defined in Section 66714.8 of the Government Code, or both.

(6) "Specified air contaminants" means substances determined to be air contaminants by the state board in coordination with the districts. The state board and the districts shall consider determining the following compounds to be air contaminants for purposes of this paragraph: benzene, chloroethene, 1,2-dibromoethane. 1,2-dichloroethane benzyl chloride, chlorobenzene, dichlorobenzene, 1,1-dichloroethene, dichloromethane, formaldehyde, hydrogen sulfide, tetrachloroethylene, tetrachloromethane, toluene, 1,1,1-trichloroethane, trichloroethylene, trichloromethane, xylene, and any other substance deemed appropriate by the state board or a district.

HISTORY:

+Added Stats. 1984, ch. 1532, Section 4. Added Stats. 1986, ch. 1055, Section 5, effective September 24, 1986; Amended Stats. 1987, ch. 932, Section 1, effective September 22, 1987.

+Former Section: Former Section 41808.5, similar to the present section, was repealed by Stats. 1986, ch. 1055, Section 4, effective September 24, 1986.

APPENDIX 2: SAMPLING AND ANALYSIS PROCEDURES

The operator should specify the indicator parameters and waste constituents to be monitored after considering the following factors:

- The possible types, quantities, and concentrations of constituents in wastes at the waste site.
- The mobility, stability, and persistence of possible waste constituents or their reaction products.

A. FREQUENCY OF SAMPLING

Water quality sampling should consist of measuring indicator parameters (temperature, electrical conductivity, pH) and testing for various waste constituents quarterly for one year. The sampling for an entire year should account for errors in sampling and analyses as well as seasonal fluctuations. The site operator should take a minimum of one sample from each sampling point for each sampling event.

B. SAMPLING PLAN

The site operator should prepare a formal sampling plan addressing all elements contained in this section. Water levels should be noted before each sampling event. The plan should include appropriate quality control/quality assurance practices including standards, laboratory blanks, duplicates, and spiked samples.

C. GROUND WATER SAMPLE COLLECTION

1. WELL PURGING: The chemical properties of water that has been sitting inside the well bore for an expended period of time may differ substantially from that of the formation water. Therefore, it is a common practice to pump from three to five well volumes of water from the well prior to sampling.

   The purging rate should never be fast enough to cause water to vigorously cascade down the sides of the screen.

Low yield aquifers may require substantial time to obtain several well volumes. This could lead to degassing of the formation water. These aquifers may need to be sampled with varying purged volumes over time to determine adequate purging values. A low yield aquifer which has only one casing volume of fluid removed, should have the sample tested for pH, temperature, and specific conductance. After recovery, the well should be retested for these parameters. If full recovery of the well exceeds two hours, the sample for retesting should be collected as soon as a sufficient sample is available, but within two hours of the original sampling.

2. SAMPLING DEVICES: The sole task of a sampling device is to obtain a thoroughly representative, reliable sample of the formation water. It is recommended that an individual sampling device be dedicated to each well to save the time, cost, and difficulty of decontaminating the equipment between well sampling. It is critical that there be no significant gain or loss of chemical constituents. It is especially critical to prevent the loss (degassing) of volatile organic constituents such as vinyl chloride and other related chemicals. Extreme care should be taken when transferring the sample from the sampling device to the sample container. Loss of volatiles can be minimized by using a "bottom-emptying device", which eliminates the need to turn the sampling device upside down.

   Acceptable sampling devices for these parameters include fluorocarbon resin or stainless steel bailers, syringe bailers, or bladder pumps.

   a. BAILERS: A bailer consists of a tube with a check ball valve at the bottom or bottom and top. The single check ball valve model is not capable of sampling discrete intervals. It is difficult to transfer the sample from the bailer to the sample container without contaminating the sample, especially in tubes that are not designed for using a bottom-emptying device.

   b. SYRINGE BAILERS: A syringe bailer pulls the sample into the bailer tube either by direct movement of a plunger in the tube or a pump on the

surface moving the plunger. This delivers a highly representative sample.

c. BLADDER PUMPS: Bladder pumps have a flexible bladder inside a rigid body. Rhythmical inflation and deflation of the bladder causes the fluid to rise to the surface. A sampling tube attached to the intake of the pump retains the sample, which may then be withdrawn from the well and transferred to an appropriate sample vial.

D. SURFACE WATER SAMPLE COLLECTION

Surface water sampling methods also vary according to the circumstances. Deeper water bodies are normally sampled with a bailer or "thief" type sampler. Shallow water bodies or seeps must be sampled by construction of a small "pond". After it has filled, the sample bottle can be immersed in the water and filled.

All surface waters and springs within a mile both upgradient and dow gradient from the disposal site should be sampled. Perennial streams should be sampled quarterly. Intermittent streams should also be sampled when water is present, but not during storm events or other periods of high flow. A map showing all sampling points must be included in the report.

Under circumstances where the water body originates on the site, consider your upgradient sample as the springs or seeps (rising water) at the headwaters of the stream. If there is no evidence of rising water, presume that the upgradient water quality is that of the precipitation in the area.

E. SAMPLE STORAGE

Different methods of sample storage are used depending on whether the sample is being tested for metals or organic chemicals.

1. METAL ANALYSES: For metal analyses, the containers should be washed in non-phosphate detergent and tap water, and rinsed with a 1:1 mixture of nitric acid and tap water, a 1:1 mixture of hydrochloric acid and tap water, and Type II reagent water. Only fluoro-

carbon resin or polyethylene containers with polypropylene caps should be used.

Metal analysis samples should be split into two portions. The first portion should be filtered through a 0.45 micron membrane filter, then transferred to a container, and preserved with nitric acid with pH less than 2. The remaining sample should be treated the same way; however, without filtration. (Cr(VI) should not be acidified.)

2. ORGANIC CHEMICALS: For organic chemicals, glass bottles with fluorocarbon resin-lined caps should be used. The containers should be washed first with a non-phosphate detergent in hot water, then rinsed with tap water, distilled water, acetone, and pesticide-quality hexane.

3. OTHERS: Storage of other constituents such as pesticides, extractable organic chemicals, etc., require specific methods of treatment beyond the scope of this document.

In some cases heating and/or treatment of storage containers with chromic acid may have occurred and the presence of chromic acid may result in a sampling error. Residue analysis from clean containers should be available before sampling, if necessary, to document the presence of chromic acid.

F. SAMPLE PRESERVATION

- After transferring the sample from the sampling device to a container, it should not be re-transferred from one container to another as loss of organic material and aeration may occur.
- No headspace should exist in samples for total organic halogens, total organic carbon, and volatile organic chemicals.
- Organic samples should not be filtered.
- An estimate of the turbidity (NTU's) should be made for turbid samples.

G. METHODS OF ANALYSES

The testing program should include a pollutant scan including U.S. Environmental Protection Agency (EPA) methods 601/602. Laboratory orders should request that all peaks be reported. The Regional Board has the option of requiring EPA methods 624/625 (instead of 601/602) or to identify peaks found in initial testing. The Regional Board may also wish to require additional analyses when circumstances indicate that constituents not detected by these tests may be present (see 40 CFR, Part 136 for information on the various analysis methods).

An Inductively Coupled Plasma-Emission Spectroscopy (ICP) scan (EPA Method 6010) or Atomic Absorption Spectroscopy (AA), covered under EPA's 7000 series, should be run for metals and salts. As a minimum, the following substances should be reported from ICP metals procedure: Ag, As, Ba, Be, Ca, Cd, Cr, Cr(VI), Co, Cu, Fe, Hg, K, Mn, Mo, Na, Ni, Pb, Se, Sb, Tl, V, and Zn. Due to the limited detection limits of the ICP metals method for As, Cr(VI), Hg, Mg, and Se, the AA method may be used to analyze for these five elements, if conditions warrant.

For initial screening, performing an electrolyte scan or testing conductivity upgradient and downgradient could indicate whether leaching has occurred.

The analytical laboratory performing the chemical analysis must be a hazardous waste testing laboratory certified by the Hazardous Materials Laboratory of DHS.

H. QUALITY ASSURANCE/QUALITY CONTROL

The following QA/QC procedures are excerpted in part from "Department of Health Services Procedures for Conducting a Comprehensive Ground Water Monitoring Evaluation of Hazardous Waste Disposal Facilities" (July, 1986) and EPA's RCRA publication, "Ground-Water Monitoring Technical Enforcement Guidance Document" (September, 1986).

1. Field QA/QC Program

Various types of field blanks should be used to verify that the sample collection and handling process has not affected the quality of the samples. The operator's sampling plan should provide for the routine collection and analysis of two types of Quality Control blanks: trip blanks and equipment blanks. These should be:

Trip Blank: Each time a group of bottles is prepared for use in the field, one bottle of each type (e.g., glass, fluorocarbon resin, polyethylene) should be selected from the batch and filled with deionized water. The bottles filled with the blank should be transported to the sampling location and returned to the laboratory in a manner identical to the handling procedure used for the samples. One trip blank per sampling event is recommended.

Any contaminants found in the trip blanks could be attributed to (1) interaction between the sample and the container, (2) contaminated rinse water, or (3) a handling procedure that alters the sample analysis results.

Equipment Blank: To ensure that the nondedicated sampling device has been effectively cleaned (in the laboratory or field), the device should be filled with deionized water (or pump deionized water through the device). The water should then be transferred to the sample bottle(s), and returned to the laboratory for analysis. Handling procedures should be identical to those used for ground water samples. A minimum of one equipment blank for each day that ground water monitoring wells are sampled is recommended.

The results of the analyses of the blanks should not be used to correct the ground water data. If contaminants are found in the blanks, the concentration levels of any contaminant should be noted and the source of the contamination should be identified. Corrective action, including resampling, should be initiated.

All field equipment that will be used should be calibrated prior to field use and recalibrated in the field before measuring each sample. The SWAT proposal should describe a

program for ensuring proper calibration of field equipment. Other QA/QC practices such as sampling equipment decontamination procedures and chain-of-custody procedures should also be described in the proposal.

2. Laboratory QA/QC Program

Any sample analyses performed for the SWAT should be done only at a certified laboratory. When a commercial laboratory is used to conduct analyses of ground water samples, the operator must ensure that the laboratory of choice is exercising a proper QA/QC program. The QA/QC program used by the laboratory analyzing samples must conform to that described in the SWAT proposal.

The sampling and analysis plan should provide for the use of standards, laboratory blanks, duplicates, and spiked samples for calibration and identification of potential matrix interferences. The quality control program for the laboratory must ensure that the following actions are completed:

Calibration of laboratory instruments to within acceptable limits according to EPA or manufacturer's specifications before, after, and during use. Reference standards must be used when necessary.

Periodic inspection, maintenance, and servicing (as necessary) of all laboratory instruments and equipment.

The use of reference standards and quality control samples (e.g., checks, spikes, laboratory blanks, duplicates, splits), as necessary, to determine the accuracy and precision of procedures, instruments, and operators.

The use of adequate statistical procedures (e.g., quality control charts) to monitor precision and accuracy of the data and to establish acceptable limits.

A continuous review of results to identify and correct problems within the measurement system (e.g., instrumentation problems, inadequate

operator training, inaccurate measurement methodologies).

Documentation of the performance of systems and operations.

Regular participation in external laboratory evaluations to determine the accuracy and overall performance of the laboratory. This should include performance evaluation and interlaboratory comparison studies and formal field unit/laboratory evaluations and inspections.

3. Chain-of-Custody

An owner must include plans for "chain-of-custody" in the sampling and analysis plan to assure the integrity of the sample from the time of collection until it has been analyzed. Adequate chain-of-custody can be described as the ability to trace the possession and handling of samples from the time of collection through analysis and final disposition.

A chain-of-custody program must include:

Sample labels which prevent misidentification of samples;

Sample seals to preserve the integrity of the sample from the time it is collected until it is opened in the laboratory;

Field log book to record information about each sample collected during the ground water monitoring program;

Chain-of-custody-record to establish the documentation necessary to trace sample possession from the time of collection to ultimate disposition;

Sample analysis request sheets which serve as official communication to the laboratory of the particular analysis(es) required for each sample and provide further evidence that the chain-of-custody is complete; and

Laboratory log book which is maintained at the laboratory and records all pertinent information about the sample.

APPENDIX 3: GEOLOGIC WELL LOG DESCRIPTION[4]

The geologic well log gives meaning to analytical results and is the cornerstone of site characterization. A geologic well log should be a complete description of the materials penetrated and a history of activities associated with the drilling. The geologic log should be constructed as drilling advances.

If the observations or data recorded on the geologic log need to be changed or modified, the changes should be made by drawing a single line through the words or phrase which is to be changed and the new notation made. Erasures should not be made on a geological well log. Erasing notations can result in the loss of valuable information and the change may prove to be less accurate than the initial observation. A geologic log of a boring should, at a minimum, contain the following elements:

1) Key Names:

   Name of drilling contractor.

   Name of driller.

   Name and employer of person logging the boring, and

   Name of service companies called onto site, (e.g., electric logging, cementing, etc.).

2) Make and model of drilling equipment.

3) Drilling method.

4) Method of sample collection and preparation.

5) Sampling interval(s).

6) Complete and detailed lithologic description of materials penetrated.

7) Depth interval and estimated rate of discharge for all encountered ground water.

---

[4]Modified from The California Site Mitigation Decision Tree Manual, DHS, May, 1986, pages 3-23 and 3-24.

8) Transient data such as penetration rate (ASTM D1586), bit pressure, drilling fluid weight and viscosity, drill chatter, adjustments made to the drilling machine or drilling procedure, problems or successes and other incidental information that may provide an indication of subsurface conditions.

9) Dates of starting and completion for all phases of the well drilling and construction (e.g., sampling, cementing, etc.).

10) As-built drawings of wells, piezometer, or other devices constructed or installed in the borehole.

APPENDIX 4: PHYSICAL ANALYSIS OF SOIL SAMPLES

Several tests should be performed to determine possible transport pathways and relative rates of leakage. This information, along with the other requested data, should help to determine where leak migration is most likely to occur. Thus, the correct monitoring layout and design can be achieved for both vadose and ground water monitoring.

The first analyses should be for grain size distribution (sieve analysis: ASTM D 422-630). The report should contain the following information:

1) Maximum size of particles.

2) Percentage retained on each sieve.

3) Description of sand and gravel particles (shape and hardness).

4) Specific gravity (ASTM D 854-83).

The pH (ASTM G51-77) of the discrete soil intervals should be submitted. This should be performed by a pH meter.

Soil moisture content (ASTM D 2216-80) should be submitted for discrete soil intervals.

Cation exchange capacity (EPA Method 9080) should be determined to aid in design of vadose zone monitoring. This test consists of replacing the original adsorbed nutrients by barium, potassium, or ammonium ions and determination of the amount of ions adsorbed.

Permeability of on-site soils should be determined by testing nearby soils that have characteristics similar to soils underlying the disposal area. Permeability should be determined by laboratory and field methods.

The laboratory permeability test method (ASTM D 2434) is designed for granular soils and is not as reliable for fine-grained soils. Granular soils should also have their permeability determined by field methods.

An infiltrometer is recommended for permeability determination of fine-grained soils. A double-ring infiltrometer (ASTM D 3385-75) is the preferred method. The report should contain a description of the soils underlying the infiltration test site down to the water table, temperature and pH of fluid used, and difference in rates of flow for inner ring and annular space between rings. Although this test is usually used only on man-made clay liners, it may have some applicability for fine grained solid waste disposal site soils.

APPENDIX 5: PIEZOMETER DESIGN AND PLACEMENT

The purpose of piezometers is to measure ground water gradients (pressure). They may also be used as sampling wells (monitoring wells) in some cases. If so, this should be stated as such in the SWAT proposal. However, this section will focus solely on ground water gradient measurement.

Piezometers should be capable of determining horizontal and vertical components of flow for the uppermost saturated zone. Seasonal and temporal variations should be accounted for. The well screen should be not more than ten feet in length and often may be as short as one foot. Piezometers screened through the water table may have a screen length of up to 20 feet; however, it should be documented by water level data that a significant variation in water table elevations over time necessitates this modification. The filter pack should not extend more than two feet above the screen.

The location and elevation of the top of the well casing should be surveyed to an accuracy of 0.01 feet and permanently marked. The water level measurements should have the same accuracy. The survey mark should be placed on the casing and may need to be resurveyed periodically.

Piezometer water level measurements of all points in the piezometer network should be taken as close together timewise as possible, preferably within a few hours,[5] and definitely within a 24 hour time span. This is necessary to minimize temporal variations in the water level.

The inside diameter of the piezometer casing may be as small as one inch. However, if this well also serves as a monitoring well, a larger size casing is necessary (see Appendix 7: Monitoring Well Design And Placement). Also, most pressure transducers require a one and one-quarter inch or larger inside diameter casing.

A minimum of three piezometers screened at the same depth is needed to determine horizontal gradients. Clustered single completion piezometers are recommended for determination of

---

[5]Where piezometers are located near surface waters having significant water level changes (such as tides or flood flows), tide tables or stream gage data should be provided over the sampling period.

vertical gradients. Each cluster should be installed at one location according to the following guidelines:

- aquifers 50 feet or less in thickness: two depth-staggered piezometers.
- aquifers 50 to 100 feet in thickness: three depth-staggered piezometers.

Piezometer construction should follow the same guidelines as monitoring well construction except for screen length. These guidelines are outlined in Appendix 7: Monitoring Well Design And Placement.

A map showing all piezometer locations and ground water flow directions and equipotential lines (flow net) should be included in the SWAT report along with a full description of piezometer placement and design.

APPENDIX 6: VADOSE ZONE MONITORING

A. INTRODUCTION

Water Code Subsection 13273(b),(2) requires a chemical characterization of the soil-pore liquid in those areas which are likely to be affected if the solid waste disposal site is leaking, as compared to geologically similar areas near the solid waste disposal site which have not been affected by leakage or waste discharge.

Vadose zone (unsaturated zone) monitoring is especially useful where thick unsaturated zones underlie disposal facilities. The contaminant plume may be identified and leakage stopped long before a ground water monitoring well would show any evidence of a problem.

B. PRESSURE/VACUUM LYSIMETERS

1. DESCRIPTION:

The best device for obtaining water samples from the vadose zone is the pressure/vacuum lysimeter. This device consists of a closed cylindrical chamber made of inert material. The soil water intake portion (cup) is made of a porous material of low permeability. Soil moisture is drawn by vacuum into the chamber and collected by access tubes.

Lysimeters may be placed in either shallow trenches or in borings (either vertical or drilled at an angle below the landfill). The lysimeters should be put in place with a silica flour filter pack to provide continuity with the surrounding formation.

The placement of lysimeters is critical. These devices should be installed at locations which will optimize their efficiency in relation to fluid movement in the vadose zone. The lysimeter should be placed in fine-grained soils (silt or clay) as these materials tend to absorb fluid. Moisture in the vadose zone tends to move rapidly through porous soils thus requiring an excessive vacuum to obtain useful quantities of soil-pore fluid.

Although fluid transport tends to be vertical in the vadose zone, migration will also occur laterally along geologic contacts. Fluid movement also often occurs along small cracks and irregularities.

2. PRELIMINARY WORK:

Continuous soil coring should be performed prior to designing a vadose zone monitoring system. Soils data must be obtained to identify the best depths for placement of the lysimeter. The structure, lithology and soil characteristics of the vadose zone must be determined for correct lysimeter placement. This information can be derived from continuous soil cores. A complete lithologic and soil analysis of the cores should be performed (see Appendix 4: Physical Analysis Of Soil Samples, and ASTM D 422-63 and D 854-83).

3. QUALITY CONTROL PROCEDURES:

Lysimeters have earned an unwarranted reputation among many as being undependable. Much of the problem can be laid to an absence of good quality control work. There is a need for the lysimeter and all tubing to be pressure tested prior to placement in the ground. Further, the whole installation must be field tested after it has been placed at the target location. The system should be placed under vacuum to determine whether there are any significant leaks in the system. Next, the continuity of the lysimeter and its silica flour jacket with the formation should be tested. Distilled water is poured down the tubing and allowed to stand for several days. The lysimeter is then placed under vacuum. If the device fails to produce a relatively steady flow of water, the installation is faulty and should be replaced.

C. ALTERNATIVE DEVICES

Some field conditions create difficulties in using pressure/vacuum lysimeters. These include fractured rock areas or dry gravels. Many have proposed to conduct chemical analyses of soils obtained from drilling. This method fails to obtain representative soil pore fluid samples in that the volatile organic chemicals will be mostly lost.

The following alternative devices do not provide the information required in Subsection 13273(b)(1) (i.e., chemical characterization) but only provide an indication of moisture content. Consultation with the Regional Board is recommended prior to installing an alternative device.

In very dry soils or in granular soils, vacuum/pressure lysimeters may not be able to overcome the soil tension. In this case, tensiometers may be required. A tensiometer consists of an inert cup attached to the bottom of a rigid tube. A smaller tube leads below the sealed top to a recording device. The tensiometer is filled with de-aired water, a solution of ethylene or polyethylene glycol, or a solution of methanol. These devices measure the vacuum that is caused by the fluid leaving the vessel and going into the soil.

Any change in pressure indicates fluid movement through the vadose zone, assuming all components are operating correctly. The same considerations for placement of lysimeters apply to tensiometers.

Soil moisture blocks may be used under some circumstances. These consist of two electrodes embedded in a porous material that is in equilibrium with the soil in the vadose zone. Gypsum, ceramic, capstone, fiberglass, and nylon can be used as the porous material. These devices measure only the presence of moisture and do not yield qualitative results. Calibration curves should be run for each block used. The blocks are tested by being placed in distilled water and the resistance is measured. If it varies more than 50 ohms, the block is defective. The results should be submitted to the Regional Board.

A combination of soil moisture blocks and vacuum/pressure lysimeters may be used. First, soil moisture blocks are installed in a borehole to determine the location of fluid if present. Then a vacuum/pressure lysimeter may be installed in this location to sample the fluid.

Electrical resistivity net methods are not recommended. The results are not reliable except in ideal situations where leachate and soil conductivity are vastly different.

Borehole neutron logs may be used to estimate moisture content. They are the same devices used in downhole geophysical measurements. The device senses the presence

of hydrogen atoms surrounding the cased hole. A hole can be slant drilled under the landfill, cased, and covered. At various testing intervals, this device can be lowered down the hole, the presence of water response noted, and determination of fluid migration (and possible leak) made.

D. REFERENCES

For additional information on vadose zone monitoring techniques, the following publications are recommended:

- Morrison, Robert D., Ground Water Monitoring Technology, published by Timco Manufacturing, Inc., Wisconsin, 1983.

- Everett, L.G., L. G. Wilson, and E. W. Hoylman, Vadose Zone Monitoring For Hazardous Waste Sites, published by Kaman Tempo, Santa Barbara, California, 1983.

There are numerous other articles on the various techniques for vadose zone monitoring. As the field of vadose zone sampling is rapidly changing, it is important to review the latest literature.

APPENDIX 7: MONITORING WELL DESIGN AND PLACEMENT

A. INTRODUCTION

The primary purpose of a monitoring well is to obtain representative water quality samples. In most cases, it is also critical that good soil and ground water samples can be obtained during the drilling of the well. In this way, the hydrogeologic database for the site can be augmented.

In some cases, these wells may be utilized for piezometric measurements as well as for aquifer testing.

For most solid waste disposal sites, a minimum of four monitoring wells should be required including at least one upgradient and three downgradient wells. The monitoring wells shall be in full compliance with Section 2555(c), (d).

B. DRILLING METHODS

1. HOLLOW STEM AUGER:

A hollow stem auger is the method of choice whenever conditions permit (unconsolidated material and shallow depth). The auger leaves the borehole relatively undisturbed. There is no mud cake formed, therefore, no adverse change in the permeability and chemical characteristics of the formations immediately surrounding the borehole. In addition, continuous coring is more easily accomplished with this method.

2. CABLE TOOL:

This drilling technique has been used by well drillers for many decades. It is particularly effective for penetrating cobbles. Its main drawback, however, is the inability to obtain good soil samples.

3. ROTARY DRILL:

This drilling technique is widely used in both drilling of oil wells, water wells, and foundation borings. Drilling fluids or compressed air are required to bring the cuttings up to the top of the hole.

This method is particularly useful where resistant geologic formations are present and greater completion depths are required.

Most commonly, drilling mud is circulated as the drilling fluid, forming a mudcake which supports the borehole and reduces caving. Because the mud (or other drilling fluid) may affect formation permeability as well as the chemical characteristics of the aquifer, considerable effort must be employed to clean mud from the borehole and the formation. In many cases, the mud or other fluid cannot be entirely removed; thus, the chemistry of any drilling fluids used should be analyzed in order to determine their effects on ground water samples. Further, it is almost impossible to identify small inflows of ground water.

Less commonly, compressed air is used. The disadvantages of this method are lack of support for the borehole during drilling and substantial air pressure needed to remove the cuttings from the hole. The high-velocity air flow may dry out a seep to the point where it is not recognized.

4. CASING HAMMER:

This tool is operated by driving the casing into the ground at or a short distance behind the drill bit. In this way, caving of the hole is prevented without any degradation of the formation with drilling mud. It is particularly useful for drilling in unconsolidated materials such as gravels and cobbles. Depth limitations are inherent with driving casing due to the friction between the casing and the surrounding formation.

C. WELL DESIGN

Drawings and data should show construction details of monitoring facilities. These data should include:

- map of well locations
- borehole depth
- casing diameter and length
- casing materials (PVC, stainless steel, etc.)

- type, size and position of perforations (provide justification)
- method of joining sections of casing
- description of filter material (provide justification)
- depth and composition of seals
- method of cementing
- method and length of time of development (provide justification)

D. MATERIAL SELECTION

Casing and screen material selection is important for representative sampling results. The material should be chemically inert and should have high tensile and compressive strength. The selection of materials should be based on downhole conditions.

1. POLYVINYL CHLORIDE (PVC):

Drinking water quality PVC casing and screen are often used in shallow, corrosive environments. However, ketones, esters, and aromatic hydrocarbons tend to adsorb and desorb from this material. Thus, determination of absolute concentration is not possible and very low concentrations may not be detected. The relatively weak tensile strength of PVC will usually not allow placement much past 300 feet. The annular space should be larger than the three inches needed to accommodate centralizers (see section on Well Integrity) without placing undue stress on the PVC. No glued joints should be used in the casings; only threaded joints should go into the hole.

2. FLUOROCARBON RESINS (FR):

The FR have the same structural limitations as PVC. However, it is a more inert material and is more resistant to corrosives. Some adsorption and desorption occur here, also, although at a far lesser degree than PVC. Scratching of the FR will cause accelerated adsorption and desorption.

3. STAINLESS STEEL (SS):

Use of SS 316 is often a good choice. It is more chemically resistant overall then PVC and has a high

tensile strength. However, it may corrode and leach some trace metals over time. Stainless steel may act as a catalyst in some organic reactions. It may also act as a bacterial substrate and is susceptible to corrosion from chloride. SS 304 is not as resistant to corrosion as SS 316.

The above materials can be combined to create hybrid wells. These consist of more than one material being used in the casing and screen. However, two different metals cannot be installed next to each other due to cathodic corrosion.

The cost of installation is usually given too much priority. Considering the costs for chemical analyses on a 20-year well, the initial construction costs are less than one percent of the total cost.

E. WELL FILTER PACK DESIGN

Proper filter pack[6] design ensures correct screen entrance velocity so volatile organic chemicals will not be stripped out of the water sample. The filter pack also prevents clogging of the perforations. The filter pack design is governed by the aquifer material. A sieve analysis (described in Appendix 4: Physical Analyses of Soil Samples) should be performed on the portion of the aquifer open to the filter pack. If this is not possible, representative samples (at least three) should be taken at similar portions of the aquifer.

The sieve data is plotted on semi-log paper and a curve constructed. The uniformity coefficient (UC) is then calculated.[7] The D70 size is then multiplied by a number between 4 and 9, depending on the UC:

---

[6]See The California Site Mitigation Decision Tree Manual, DHS, May, 1986, pages 3-64 through 3-68.

[7]This coefficient is determined by dividing the dimension of the mesh opening of the sieve which retains 40 percent of the sample (D40) by mesh opening which retains 90 percent, (D90).

- If the UC is less than or equal to 2.5, use a multiple of 4 or 5. If 10 percent or more of the formation passes through the 200 sieve, use 4 as the multiplier; otherwise, use 5.

- If the UC is between 2.5 and 5, use a number between 5 and 7. If 10 percent or more of the formation passes through, use 6; otherwise, use 7.

This value is plotted on the graph and a curve parallel to the original curve is constructed.

If the UC is greater than or equal to 5.0, a different method is used. The D70 is multiplied by 6 and 9, and the result plotted. Parallel lines with a UC of less than or equal to 2.5 are constructed. These are the boundaries of the filter pack. If 10 percent or more of the formation passes through the 200 sieve, the filter pack curve is to be near the lower boundary line. If less than 10 percent passes through, the filter pack curve is near the upper boundary line.

The filter pack should be no less than three inches wide and no larger than five inches.

F. SCREEN DESIGN

The screen is designed after the filter pack design is determined. For a filter pack having a UC less than or equal to 2.5, a slot size small enough to keep out 90 percent of the filter pack should be used. If the UC is larger than 2.5, use a slot size small enough to keep out 80 percent of the filter pack.

The entrance velocity through the well screen is a function of the open area of the screen and the pumping rate.[8] The optimal water entrance velocity is 0.1 feet per second or less. If it is any faster, volatile organic chemicals may be stripped away.

---

[8]The pumping rate is determined by the transmitting capacity of the screen. Multiply the number of square inches of open area per foot of casing by the conversion factor of .31. This is the capacity of that screen in gallons per minute per foot. Multiply this by the total feet of screen to determine the pumping rate.

G. WELL DEVELOPMENT

For optimum well performance, all fine-grained soil that may have been introduced into the formation during the drilling process should be removed. (Turbid samples indicate that the well was not correctly designed or developed.) The recommended method for well development is the use of vented surge blocks.

H. WELL INTEGRITY

Centralizers are commonly used for centering the well screen and blank casing in the borehole. Without the centralizers in place, it is likely that the casing will be lying against the borehole at many points. These areas thus would not receive a cement grout mixture in sufficient quantity to assure a seal on the well. A poor seal can occur anywhere along the casing and cause surface infiltration and cross-contamination.

The annular space of the well should be at least three inches wide. This allows centralizer placement (as well as filter pack placement). A smaller annular space will put too much stress on the casing and not allow adequate development. In the case of PVC casing, an even larger annular space is required due to PVC's relatively slight tensile strengths. Hollow stem augers do not require the use of centralizers.

Centralizers in all types of wells should be placed every 20 feet on well screens longer than 20 feet in length. The beginning one is set at the bottom. If the screen is less than 20 feet in length, a centralizer should be set at the bottom and the top. The blank casing should have centralizers placed every 40 feet. The centralizers should be lined up to avoid interference with the tremie pipe during cementing. They should be set equidistant around the casing (120°).

I. CEMENTING

A seal should be placed above the filter pack to seal it from the grout[9]. The seal should consist of three to five feet of sodium bentonite placed directly on the filter pack. The bentonite is usually emplaced by a conductor (tremie) pipe or, if only a few feet below the ground surface, poured into the annulus. The bentonite mixture must be allowed sufficient time to hydrate before emplacement of the grout.

Two types of cement are acceptable for grouting of the wells. One is a cement-sand grout, and the other (for situations requiring lower density materials) is a cement-bentonite grout. The cement mixture should be jet mixed, and injected through a tremie pipe into the annular space. All ingredients should be dry, uniform, uncontaminated, and lump free.

The cement-sand grout formulation should consist of API Class A Portland cement, 20-40 grade sand, and potable water. The proportions should be 5.2 gallons of water per 85 pounds of cement (added last) to yield 1.70 cubic feet of grout.

The cement bentonite grout mix may be prepared by either prehydrating the bentonite or dry batching the cement and bentonite.

- The prehydration formulation consists of a 94 pound sack of API Class A Portland cement being added to a smooth jet mixed mixture of API cement-grade bentonite and water (proportions of 10 gallons water/2.0 pounds of bentonite). This yields 1.85 cubic feet of grout.

- Dry batching consists of mixing the cement and bentonite as dry ingredients in a special portable mixing plant. The formulation is 9.1 gallons of water (added at job site), 5.6 pounds of bentonite, and a 94 pound sack of cement, yielding 1.73 cubic feet of grout. If bentonite that is not API cement-

---

[9] If grout has been placed below the filter pack, a bentonite seal should likewise be placed on top of the grout below the filter pack.

grade is used, the mixture may be unpumpable. If the driller has had experience with proprietary grouts (i.e., Volclay), use of these grouts may be considered.

The end of the tremie pipe should be submerged in the grout at all times during cementing. The pipe should be maintained full.

Many "E-Loggers" are prepared to conduct a cement bond log to determine the quality of the cementing job. This valuable tool works well with steel casing; however, it gives highly suspect data in PVC-cased wells.

J. WELL CONSTRUCTION

Multiple-screened wells are not recommended for the reasons outlined in Appendix 5: Piezometer Design and Placement.

The diameter of the wells should be related to the drilling conditions, transmissivity of the aquifer and size of the equipment to be lowered down the well. Larger diameter wells generally allow faster purging and have a larger area of influence. Small diameter wells, on the other hand, require far smaller purging quantities.

K. WELL PLACEMENT

At a minimum, four monitoring wells are usually required, one upgradient, and three downgradient from the solid waste disposal site.

The number, location, and depths of background (upgradient) monitoring wells must be capable of yielding ground water samples that are representative of background ground water quality in the uppermost aquifer beneath the landfill. The wells must be in the area of the aquifer not affected by the facility. Depending on the hydrogeologic characteristics of the site, more than one background well may be needed. In instances where it is impractical to get an upgradient well to serve as a background well (such as in steeply dipping aquifers), it may be possible to monitor a downgradient well. However, it must not be in a portion of the aquifer affected by the facility.

Downgradient wells should be located so as to detect any waste constituents migrating from the landfill as well as seasonal or temporal and naturally or artificially induced variations in ground water flow. The wells should be installed as close as physically possible to the edge of the landfill, ideally at the point where a plume will first enter the ground water. In most cases, this will be the uppermost aquifer; however, conduits (solution channels, open fractures, etc.) may actually provide a faster migration path to a deeper aquifer. These deeper aquifers may require monitoring also.