CADIZ GROUNDWATER STORAGE
AND
DRY-YEAR SUPPLY PROGRAM

Final Environmental Impact Report
Final Environmental Impact Statement
Groundwater Monitoring and Management Plan
Volume IV
SCH. No. 99021039

MWD
METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

REPORT NO. 1174

U.S. Department of the Interior
Bureau of Land Management

COVER SHEET

FINAL ENVIRONMENTAL IMPACT REPORT
FINAL ENVIRONMENTAL IMPACT STATEMENT
CADIZ GROUNDWATER STORAGE AND DRY-YEAR SUPPLY PROGRAM
SAN BERNARDINO COUNTY, CALIFORNIA

LEAD AGENCIES:

The Metropolitan Water District
of Southern California
Los Angeles, California

U.S. Department of the Interior
Bureau of Land Management
Riverside, California

COOPERATING AGENCIES:

U.S. Department of the Interior
National Park Service

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

PROPOSED ACTION:

Construction and operation of the Cadiz Groundwater Storage and Dry-Year Supply Program (Cadiz Project) including a groundwater monitoring and management program, amendment of the California Desert Conservation Area (CDCA) Plan for an exception to the utility corridor requirement, and issuance of associated right-of-way grants and permits.

For further information, contact Metropolitan or BLM at:

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Bureau of Land Management
California Desert District
6221 Box Springs Boulevard
Riverside, California 92507-0714
Attention: Mr. James Williams (909) 697-5390

DESIGNATION:

Final EIR/EIS

ABSTRACT:

In February 1999, Metropolitan issued a Notice of Preparation of an EIR for the Cadiz Project which would be constructed and operated by Metropolitan in the Cadiz and Fenner Valleys of the eastern Mojave Desert, San Bernardino County, California. The BLM determined that an EIS would be required as the proposed action includes an amendment of the CDCA Plan for an exception to the utility corridor requirements and grant(s) of right-of-way across federal lands. The BLM issued a Notice of Intent to Prepare an EIS for the proposed action in March 1999. In May 1999, the BLM issued a Notice of Public Meeting and extension of the scoping comment period. The Draft EIR/EIS was published in November 1999 with a 104-day public review period that ended in March 2000.

Because numerous comments raised questions regarding groundwater management issues, a Supplement to the Draft EIR/EIS was prepared to provide additional information and to present the Groundwater Monitoring and Management Plan (Management Plan) that has been incorporated into the proposed project. The Management Plan will govern the water storage and extraction operations in the affected groundwater basins to ensure that project operations will not result in any unacceptable adverse impacts to groundwater resources or air quality. The Supplement to the Draft EIR/EIS was circulated for an 80-day public review period that ended in January 2001.

The Cadiz Project is proposed by Metropolitan who is acting in partnership with the private company Cadiz Inc. The project will involve construction and operation of a 35-mile pipeline for conveying water between the Iron Mountain Pumping Plant on the Colorado River Aqueduct and the Cadiz/Fenner area, a Cadiz Pumping Plant at Metropolitan's existing Iron Mountain Pumping Plant facility, 390 acres of spreading basins for percolation of Colorado River water into the groundwater basin in the Cadiz/Fenner area, a wellfield for extracting stored Colorado River water and indigenous groundwater, and associated power poles and line along the conveyance pipeline and in the wellfield.

This Final EIR/EIS contains comments received on the Draft EIR/EIS and the Supplement to the Draft EIR/EIS, detailed responses to those comments, and integrates the information contained in the Draft EIR/EIS and Supplement to the Draft EIR/EIS with revisions as appropriate in response to comments. The Final EIR/EIS is also available for review on request at the Metropolitan and BLM offices and at the following public libraries:

- Metropolitan Water District
  700 North Alameda Street
  Los Angeles, California 90012

- Bureau of Land Management
  6221 Box Springs Boulevard
  Riverside, California 92507

- Bureau of Land Management
  101 West Spikes Road
  Needles, California 92363

- Norman Feldheym
  Central Library
  555 West 6th Street
  San Bernardino, California 92410

- Needles Branch Library
  1111 Bailey Avenue
  Needles, California 92363

- Twentynine Palms Branch Library
  6078 Adobe Road
  Twentynine Palms, California 92277

- Barstow Branch Library
  304 East Buena Vista Street
  Barstow, California 92311

This Final EIR/EIS has been approved for public distribution.

SEP 13 2001

Tim Salt
District Manager
California Desert District
U.S. Bureau of Land Management

Date

SEP 14 2001

Stephen N. Arakawa
Manager, Water Resources Management Group
Metropolitan Water District of Southern California

Date

The following technical reports and documents for the Cadiz Project are available:

- Final Environmental Impact Report/Environmental Impact Statement (September 2001)
- Public Participation and Response to Comments on the Draft EIR/EIS (September 2001)
- Public Participation and Response to Comments on the Supplement to the Draft EIR/EIS (September 2001)
- Groundwater Monitoring and Management Plan (September 2001)
- Draft EIR/EIS Public Participation (November 1999)
- Environmental Planning Technical Reports:

    - Project Feasibility and Facilities (November 1999)
    - Groundwater Resources (November 1999)
    - Biological Resources (November 1999)
    - Cultural Resources (November 1999)

The Final EIR/EIS shall govern over the Environmental Planning Technical Reports in the event of any discrepancies between the documents.

The Final EIR/EIS and technical reports are available for review at the Metropolitan Water District office located at 700 North Alameda Street, Los Angeles, California and at the BLM offices in Needles (101 West Spike's Road, Needles, California) and Riverside (6221 Box Springs Boulevard, Riverside, California).

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SECTION 1

GROUNDWATER MONITORING AND MANAGEMENT PLAN

SECTION 1
INTRODUCTION

This Groundwater Monitoring and Management Plan (Management Plan) is an integral part of the Cadiz Groundwater Storage and Dry-Year Supply Program (Cadiz Project). The Management Plan governs water use, storage and extraction for the Cadiz Projectand ensures that project operations and future irrigation under the Cadiz Valley agricultural development will be conducted without adverse impacts to critical resources. Agricultural irrigation will also remain subject to the Cadiz Valley Agricultural Development Ground Water Monitoring Plan required by the County of San Bernardino. The Management Plan is designed to ensure there would be no adverse impacts by providing "early warning" of potential adverse impacts to critical resources. With such early warning, adverse impacts would be prevented by implementation of corrective actions. Critical resources identified in the Management Plan are as follows:

- Springs Within Affected Watersheds Including Springs of the Mojave National Preserve and BLM-Managed Lands.
- Aquifer System.
- Brine Resources of Bristol and Cadiz Dry Lakes.
- Air Quality in the Mojave Desert Region.

The Management Plan establishes a comprehensive network of monitoring and data collection facilities combined with procedures for comprehensive scientific review of all actions and decisions. The Management Plan mandates specific action criteria (trigger levels) and specified responses if an action criterion is reached. It establishes a defined process for scientific review of groundwater management, weather and air quality information, a decision-making process to protect critical resources and allows for refinements to the Management Plan. Management Plan reports will be of public record.

The Management Plan has been prepared by the Bureau of Land Management (BLM), National Park Service (NPS), United States Geological Survey (USGS), the Metropolitan Water District of Southern California (Metropolitan), the County of San Bernardino, and Cadiz Inc. Metropolitan will operate the Cadiz Project in compliance with the provisions of the Management Plan. The BLM Authorized Officer will enforce compliance with the Management Plan as terms and conditions of any right-of-way grant(s) issued for the Cadiz Project facilities. The BLM will invite the participation of technical specialists from other public agencies as appropriate in a Technical Review Panel (TRP). The TRP will be established to review data, technical analyses, and Metropolitan's assessment, proposed refinements to the Management Plan, and corrective measures presented to the BLM Authorized Officer and provide technical guidance to the BLM Authorized Officer regarding compliance with the provisions of the Management Plan. The TRP will be comprised of representatives from government agencies such as the NPS, the County of San Bernardino, the USGS, BLM and others as appropriate.

The BLM Authorized Officer will consider the recommendations of the TRP. In the event that there was not a consensus recommendation by members of the TRP, the recommendations of all TRP members will be presented to the BLM Authorized Officer. The BLM Authorized Officer will make a decision in accordance with the terms and conditions set forth in the right-of-way grant(s) issued for the Cadiz Project facilities, and inform Metropolitan of its decision. Metropolitan, in consultation with the BLM Authorized Officer and the TRP, will implement the Management Plan with an initial set of monitoring features and parameters developed from existing data as described in Section 5. The composition, duties and responsibilities of the TRP and the BLM Authorized Officer, and the decision-making process are described in Sections 7, 9 and 10.

The term "feature" refers to any fixed object, either natural or man-made, from which data will be collected. Man-made features include wells from which water level measurements and water quality samples could be retrieved, weather stations, staff gages, etc. A detailed list of monitoring features is shown in Table 1. As new data become available during project operations, these features and parameters will be refined to protect critical resources in and adjacent to the project area. Refinements to monitoring features will be made in accordance with the decision-making process described in Sections 7, 9 and 10.

The project will be comprised of three phases: a pre-operational phase, an operational phase of 50 years, and a post-operational monitoring phase of 10 years or as required by the BLM Authorized Officer. The pre-operational phase will commence upon final BLM approval of the Record of Decision for the Cadiz Project and Metropolitan's receipt of necessary grant(s) of right-of-way required to construct the project facilities. The pre-operational phase will last a minimum of 15 months and maximum of 24 months. The NPS and BLM will complete and deliver all needed permits for monitoring facilities in accordance with the schedule contained in the Record of Decision, as soon as practicable within the pre-operational phase. The project will construct all facilities that are agreed to in the Management Plan and for which permits have been received. Construction of these facilities will be completed within one year of receipt of permits.

1.1 LOCATION OF PROJECT AREA

The Cadiz Project is located in eastern San Bernardino County as shown in Figure 1. The project spreading basins and wellfield will be located on Cadiz Inc. land, centered in the vicinity of Fenner Gap, located between the Marble and Ship mountains as shown in Figure 2.

1.2 PROJECT OBJECTIVES AND DESCRIPTION

The Cadiz Project has two objectives:

- Provide conjunctive-use storage of up to 150,000 acre-feet of imported Colorado River water per year, and total storage at any given time of up to 1 million acre-feet without adversely impacting critical resources. Water to be stored will be conveyed from Metropolitan's Colorado River Aqueduct (CRA) to spreading basins in the project area during periods of surplus supply. This stored water will subsequently be extracted by the project wellfield and conveyed back to the CRA as needed.
- Transfer (provide for the extraction and delivery) of indigenous groundwater to the CRA in compliance with the provisions of this Management Plan, including the avoidance of adverse impacts to critical resources.

The Cadiz Project involves construction and operation of the facilities shown on Figures 2 and 3 and as described below:

- Spreading basins and appurtenant facilities to be constructed on approximately 390 acres.
- A wellfield of approximately 30 extraction wells and appurtenant facilities.
- An approximately 35-mile-long conveyance pipeline and appurtenant facilities from the CRA to the project spreading basins and wellfield.
- A pumping plant on the conveyance pipeline, to be located in proximity to the Iron Mountain Pumping Plant.

Critical Resource Area	Feature No.	Monitoring Features [1]		N	ge Water Quality	Other Monitoring	Post-Operational Monitoring Frequency: Water Level	Water Quality	Other Monitoring
Springs in the Mojave National Preserve and BLM Managed Lands	1	S-Series Observation Wells [3] (2 to 3 per Cluster x 4 total Clusters)	New	4 clu 8-12	Annually		Continuous	Annually	
	2	Springs, Initial Character-ization[4] (28+ total)	Existing	2	-	-	-	-	-
	3	Springs, Monitoring (Approxi-mately 8)[5]	Existing		-	Semi-Annually in Approximately 6 Springs	Continuous at 2 Springs	-	Semi-Annually in 6 Springs
Aquifer System	4	Observation Wells (15 total)	Existing	1	Annually	-	Annually	Triannually	-
			Existing		Annually	-	Annually	Triannually	-
			New		Annually	-	Annually	Triannually	-
	5	Project Area Well Clusters[7,8] - Unsaturated Zone Only (1 per Cluster x 3 total Clusters)	New	3	Semi-Annually	-	-	-	-
	6	Project Area Well Clusters - Saturated Zone Only[8] (2 per Cluster x 3 total Clusters)	New	6	Semi-Annually	-	Continuous (Until No Longer Deemed Necessary)	Annually	-

TABLE 1
PROPOSED MONITORING FEATURES AND FREQUENCIES

Critical Resource Area	Feature No.	Monitoring Features[1]		No.	Pre-Operational Monitoring Frequency			Operational Monitoring Frequency[2]									Post-Operational Monitoring Frequency		
								Recharge			Extraction			Storage					
					Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring
Springs in the Mojave National Preserve and BLM Managed Lands	1	S-Series Observation Wells[3] (2 to 3 per Cluster x 4 total Clusters)	New	4 clusters 8-12 wells	Continuous	Quarterly		Continuous	Annually	-	Continuous	Annually	-	Continuous	Annually		Continuous	Annually	
	2	Springs, Initial Characterization[4] (28+ total)	Existing	28+	-	-	One Time	-	-	-	-	-	-	-	-	-	-	-	-
	3	Springs, Monitoring (Approximately 8)[5]	Existing	8	Continuous at 2 Springs[6]	Semi-Annually	Semi-Annually in Approximately 6 Springs	Continuous at 2 Springs	-	Semi-Annually in Approximately 6 Springs	Continuous at 2 Springs	-	Semi-Annually in Approximately 6 Springs	Continuous at 2 Springs	-	Semi-Annually in Approximately 6 Springs	Continuous at 2 Springs	-	Semi-Annually in 6 Springs
Aquifer System	4	Observation Wells (15 total)	Existing	12	Monthly	4 Quarterly, 8 Annually	-	Monthly for First 3 Months of Cycle; Annually Thereafter	Annually	-	Monthly for First 3 Months of Cycle	Annually	-	Monthly for First 3 Months of Cycle	Annually	-	Annually	Triannually	-
			Existing	2	Continuous	Annually	-	Continuous	Annually	-	Continuous	Annually	-	Continuous	Annually	-	Annually	Triannually	-
			New	1	Monthly	Quarterly	-	Monthly for First 3 Months of Cycle; Annually Thereafter	Annually	-	Monthly for First 3 Months of Cycle	Annually	-	Monthly for First 3 Months of Cycle	Annually	-	Annually	Triannually	-
	5	Project Area Well Clusters[7,8] - Unsaturated Zone Only (1 per Cluster x 3 total Clusters)	New	3 wells	-	-	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	-	-	-
	6	Project Area Well Clusters - Saturated Zone Only[8] (2 per Cluster x 3 total Clusters)	New	6 wells	Continuous	Quarterly	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous (Until No Longer Deemed Necessary)	Annually	-

Critical Resource Area	Feature No.	Monitoring Features [1]		N	ge		Post-Operational Monitoring Frequency		
					Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring
	7	Production Wells (30 total)	Existing		-	Summarize Data Monthly	-	-	-
			New	2	-	Summarize Data Monthly	-	-	-
	8	Recharge Water Quality[8]	Existing		Weekly	-	-	-	-
Aquifer System	9	Spreading Basins	New		-	Summarize Data Monthly	-	-	-
	10	Land Surface Elevation Surveys (22 total)	New Benchmark		-	Annually	-	-	-
			InSAR (if warranted)	2 War	-	Annually	-	-	-
	11	Extensometer (if warranted) (1 total)	New		-	Records Daily	-	-	-
	12	Microgravity Stations (if warranted) (10 total)	New		-	Annually (if warranted)	-	-	Annually (until no longer deemed necessary)
	13	Flowmeter Surveys (5 total)	New		-	-	-	-	-
Bristol and Cadiz Dry Lakes	14	Bristol Dry Lake Well Clusters[10] (3 per Cluster x 3 total Clusters)	New	3 c 9	Semi-Annually	-	Continuous (until no longer deemed necessary)	Annually as necessary	-
	15	Cadiz Dry Lake Well Clusters[11] (3 per Cluster x 3 total Clusters)	New	3 c 9	Semi-Annually	-	Continuous (until no longer deemed necessary)	Annually as necessary	-

TABLE 1
PROPOSED MONITORING FEATURES AND FREQUENCIES (CONTINUED)

Critical Resource Area	Feature No.	Monitoring Features [1]		No.	Pre-Operational Monitoring Frequency			Operational Monitoring Frequency[2]									Post-Operational Monitoring Frequency		
								Recharge			Extraction			Storage					
					Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring
	7	Production Wells (30 total)	Existing	4	-	-	-	-	-	Summarize Data Monthly	-	-	Summarize Data Monthly	-	-	Summarize Data Monthly	-	-	-
			New	26	-	-	-	-	-	Summarize Data Monthly	-	-	Summarize Data Monthly	-	-	Summarize Data Monthly	-	-	-
	8	Recharge Water Quality[8]	Existing	1	-	-	-	-	Weekly (Annually Title 22)	-	-	Weekly	-	-	Weekly	-	-	-	-
Aquifer System	9	Spreading Basins	New	1	-	-	-	-	-	Regular Basis	-	-	Summarize Data Monthly	-	-	Summarize Data Monthly	-	-	-
	10	Land Surface Elevation Surveys (22 total)	New Benchmark	20	-	-	Annually	-	-	Annually	-	-	Annually	-	-	Annually	-	-	-
			InSAR (if warranted)	2/yr (If Warranted)	-	-	Semi-Annually	-	-	Annually	-	-	Semi-Annually	-	-	Annually	-	-	-
	11	Extensometer (if warranted) (1 total)	New	1	-	-	-	-	-	Records Daily	-	-	Records Daily	-	-	Records Daily	-	-	-
	12	Microgravity Stations (if warranted) (10 total)	New	10	-	-	One Time	-	-	Annually (if warranted)	-	-	Annually (if warranted)	-	-	Annually (if warranted)	-	-	Annually (until no longer deemed necessary)
	13	Flowmeter Surveys (5 total)	New	5	-	One Time	One Time	-	-	-	-	-	-	-	-	-	-	-	-
Bristol and Cadiz Dry Lakes	14	Bristol Dry Lake Well Clusters[10] (3 per Cluster x 3 total Clusters)	New	3 clusters 9 wells	Continuous	Quarterly	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous (until no longer deemed necessary)	Annually as necessary	-
	15	Cadiz Dry Lake Well Clusters[11] (3 per Cluster x 3 total Clusters)	New	3 clusters 9 wells	Continuous	Quarterly	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous (until no longer deemed necessary)	Annually as necessary	-

Critical Resource Area	Feature No.	Monitoring Features [1]		N	...ge Water Quality	...ge Other Monitoring	Post-Operational Monitoring Frequency Water Level	Post-Operational Monitoring Frequency Water Quality	Post-Operational Monitoring Frequency Other Monitoring
	16	ET Stations (Eddy Correlation-Type) (2 total)	New	2	-	Continuous	-	-	-
	17	Surface Water Gages[12] (2 total)	New	2	-	-	-	-	-
Bristol and Cadiz Dry Lakes (cont.)	18	Nephelometer Open-Air[13] With Digital Camera (4 total)	New	4	-	Hourly	-	-	-
	19	Resistivity Survey (1 total)	New (if warranted)		-	-	-	-	-
	20	Gamma / EM Logs (up to 6 total)	New		-	-	-	-	-
Other (Regional)	21	Weather Stations (4 total)	Existing		-	Records Daily	-	-	-
			New		-	Records Hourly	-	-	-
	22	Stream Gages (3 total)	Existing		-	Records Daily	-	-	-
			New (if warranted)		-	Records Daily (if warranted)	-	-	-
	23	Soil Moisture Sensors (2 total)	New (if warranted)		-	Records Daily (if warranted)	-	-	-
	24	Meteorological Towers (3 total)	New		-	Records Hourly	-	-	-

TABLE 1
PROPOSED MONITORING FEATURES AND FREQUENCIES (CONTINUED)

Critical Resource Area	Feature No.	Monitoring Features [1]		No.	Pre-Operational Monitoring Frequency			Operational Monitoring Frequency[2]									Post-Operational Monitoring Frequency		
								Recharge			Extraction			Storage					
					Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring
	16	ET Stations (Eddy Correlation-Type) (2 total)	New	2	-	-	Continuous	-	-	Continuous	-	-	Continuous	-	-	Continuous	-	-	-
	17	Surface Water Gages[12] (2 total)	New	2	Continuous	-	-	Continuous	-	-	Continuous	-	-	Continuous	-	-	-	-	-
Bristol and Cadiz Dry Lakes (cont.)	18	Nephelometer Open-Air[13] With Digital Camera (4 total)	New	4	-	-	Hourly	-	-	Hourly	-	-	Hourly	-	-	Hourly	-	-	-
	19	Resistivity Survey (1 total)	New (if warranted)	1	-	-	One Time	-	-	-	-	-	-	-	-	-	-	-	-
	20	Gamma / EM Logs (up to 6 total)	New	6	-	-	One Time	-	-	-	-	-	-	-	-	-	-	-	-
Other (Regional)	21	Weather Stations (4 total)	Existing	3	-	-	Records Daily	-	-	Records Daily	-	-	Records Daily	-	-	Records Daily	-	-	-
			New	1	-	-	Records Hourly	-	-	Records Hourly	-	-	Records Hourly	-	-	Records Hourly	-	-	-
	22	Stream Gages (3 total)	Existing	1	-	-	Records Daily	-	-	Records Daily	-	-	Records Daily	-	-	Records Daily	-	-	-
			New (if warranted)	2	-	-	Records Daily (if warranted)	-	-	Records Daily (if warranted)	-	-	Records Daily (if warranted)	-	-	Records Daily (if warranted)	-	-	-
	23	Soil Moisture Sensors (2 total)	New (if warranted)	2	-	-	Records Daily (if warranted)	-	-	Records Daily (if warranted)	-	-	Records Daily (if warranted)	-	-	Records Daily (if warranted)	-	-	-
	24	Meteorological Towers (3 total)	New	3	-	-	Records Hourly	-	-	Records Hourly	-	-	Records Hourly	-	-	Records Hourly	-	-	-

Notes:

1 See Table 2 for details of monitoring features.
2 Monitoring frequencies pertain to the initial monitorin
3 Four well clusters: (1) in Orange Blossom Wash; (2) ir
4 Identified springs will be field-investigated to determin
5 To be determined.
6 To be monitored using a piezometer equipped with a p well and 2 saturated zone monitoring wells).
7 Well clusters will consist of 2 to 3 wells at the same lo
8 Features 5 and 6 together comprise 3 total clusters. Th
9 Water quality samples of input to artificial recharge fa vater levels and quality).
10 Two well clusters to be installed along the eastern mar
11 Two well clusters to be installed along the northern m
12 Surface water gages will measure depth of ponded sto
13 Open air nephelometers measure light scattered by par

TABLE 1
PROPOSED MONITORING FEATURES AND FREQUENCIES (CONTINUED)

Notes:
1 See Table 2 for details of monitoring features.
2 Monitoring frequencies pertain to the initial monitoring period of operational phase. Monitoring frequencies may be increased or decreased based on the initial monitoring results.
3 Four well clusters: (1) in Orange Blossom Wash; (2) in Clipper Wash; (3) directly south of theClipper Mountains; and (4) in Schulyler Wash (see Figure 4).
4 Identified springs will be field-investigated to determine site specific characterization which includes geology, hydrology, and vegetation characteristics.
5 To be determined.
6 To be monitored using a piezometer equipped with a pressure transducer in the immediate vicinity of the springs.
7 Well clusters will consist of 2 to 3 wells at the same location, screened (i.e. completed) at different intervals. (Note: Well Clusters in the recharge and extraction area will consist of 1 unsaturated zone monitoring well and 2 saturated zone monitoring wells).
8 Features 5 and 6 together comprise 3 total clusters. They have been separated on this table to more completely define the unsaturated and saturated zone monitoring.
9 Water quality samples of input to artificial recharge facilities (i.e. Colorado River Aqueduct water) will be taken from weekly measurements at Lake Havasu.
10 Two well clusters to be installed along the eastern margin of Bristol Dry Lake and one to be installed on Bristol Dry Lake. (Note: All 3 of the wells in these clusters will measure groundwater characteristics, i.e. water levels and quality).
11 Two well clusters to be installed along the northern margin of Cadiz Dry Lake and one to be installed on Cadiz Dry Lake. (See Note: under 9 above)
12 Surface water gages will measure depth of ponded storm water runoff at the ET stations on Bristol and Cadiz Dry Lakes.
13 Open air nephelometers measure light scattered by particles in the atmosphere at Bristol and Cadiz Dry Lakes.

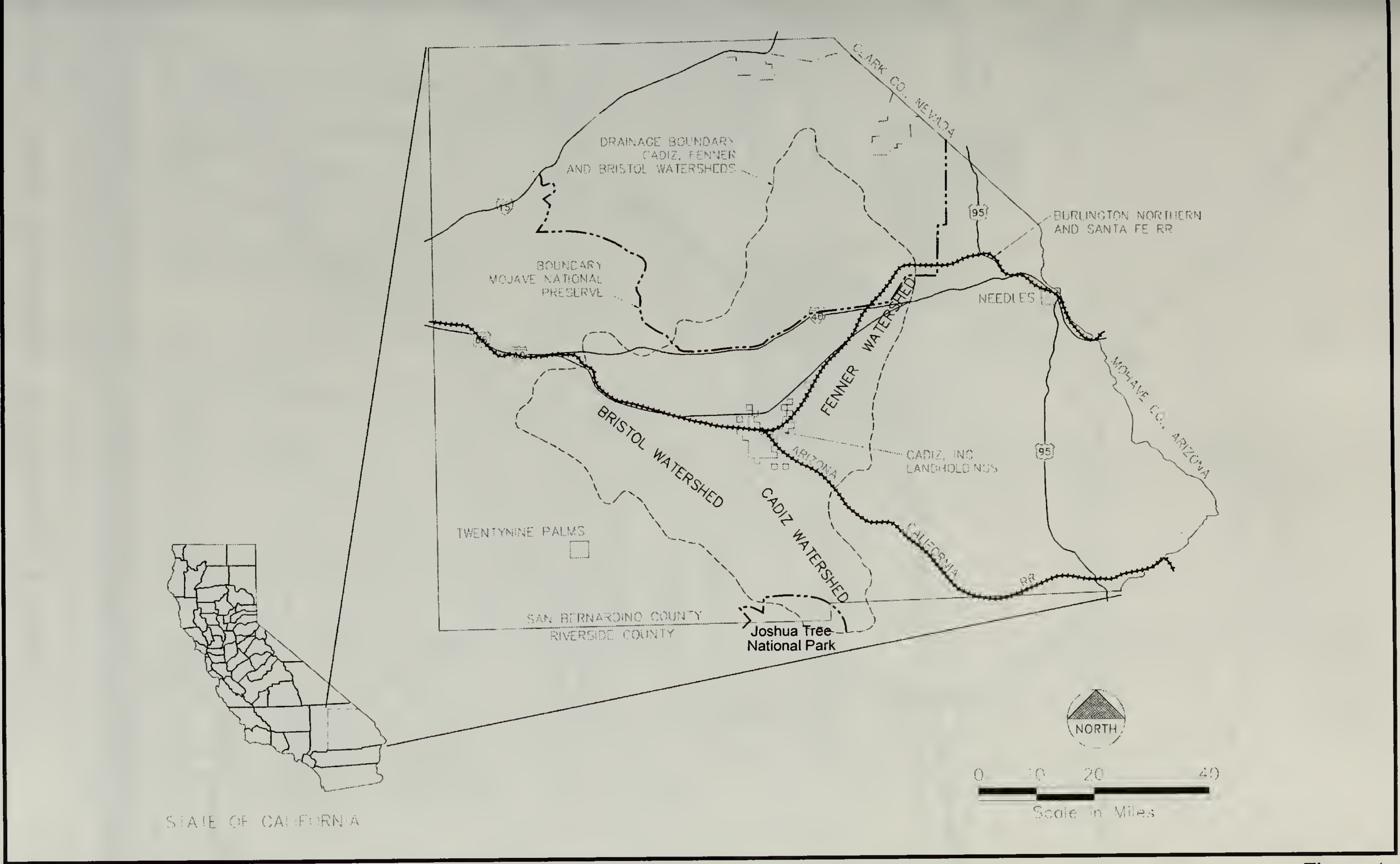
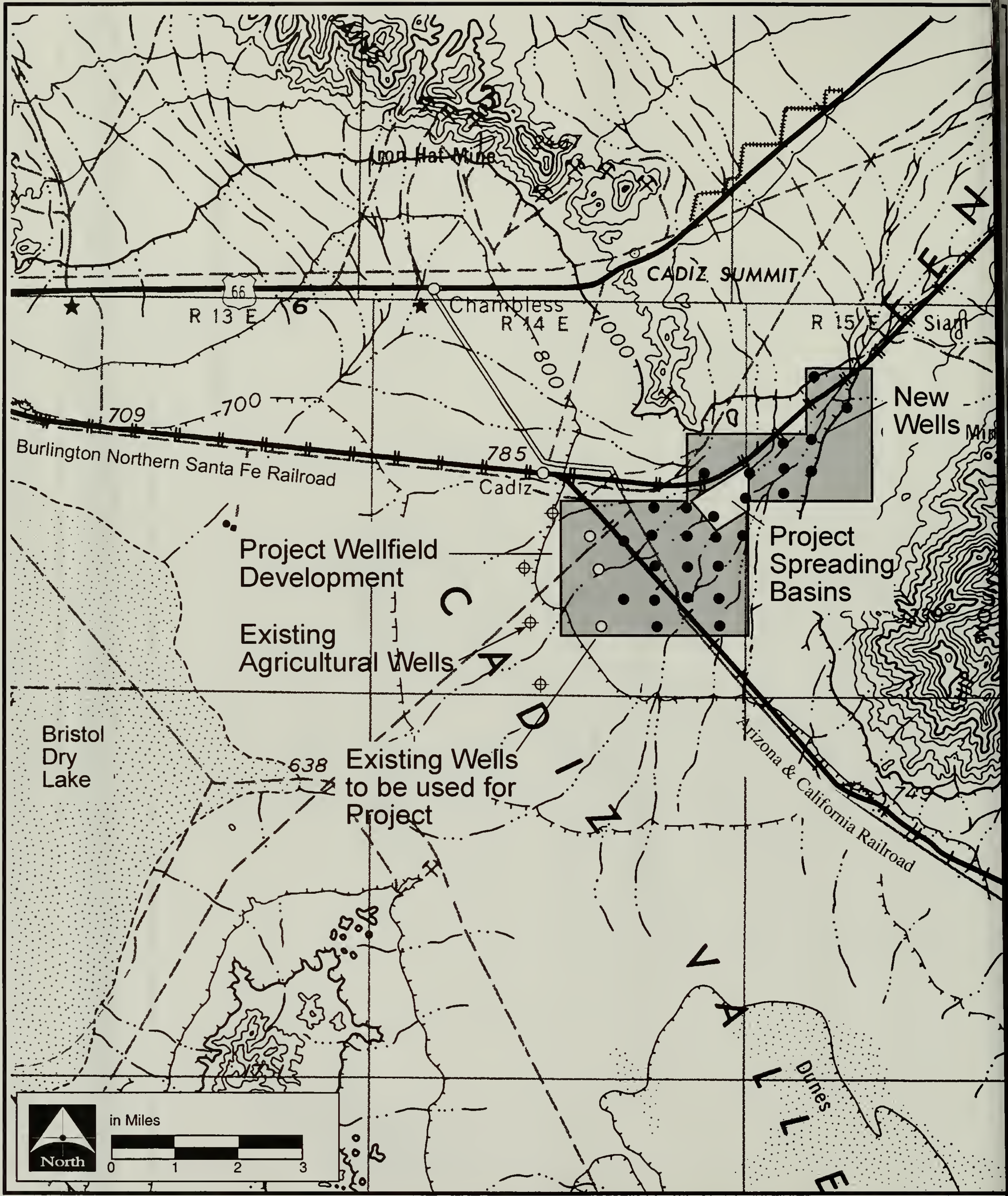


Figure 1

Cadiz Groundwater Storage & Dry-Year Supply Program

Groundwater Monitoring and Management Plan

Location of the Bristol, Cadiz, Fenner and Orange Blossom Wash Watersheds



Source: Metropolitan Water District (1999b).

Figure 2

Cadiz Groundwater Storage & Dry-Year Supply Program

Groundwater Monitoring and Management Plan

Project Wellfield and Spreading Basin Site Plan

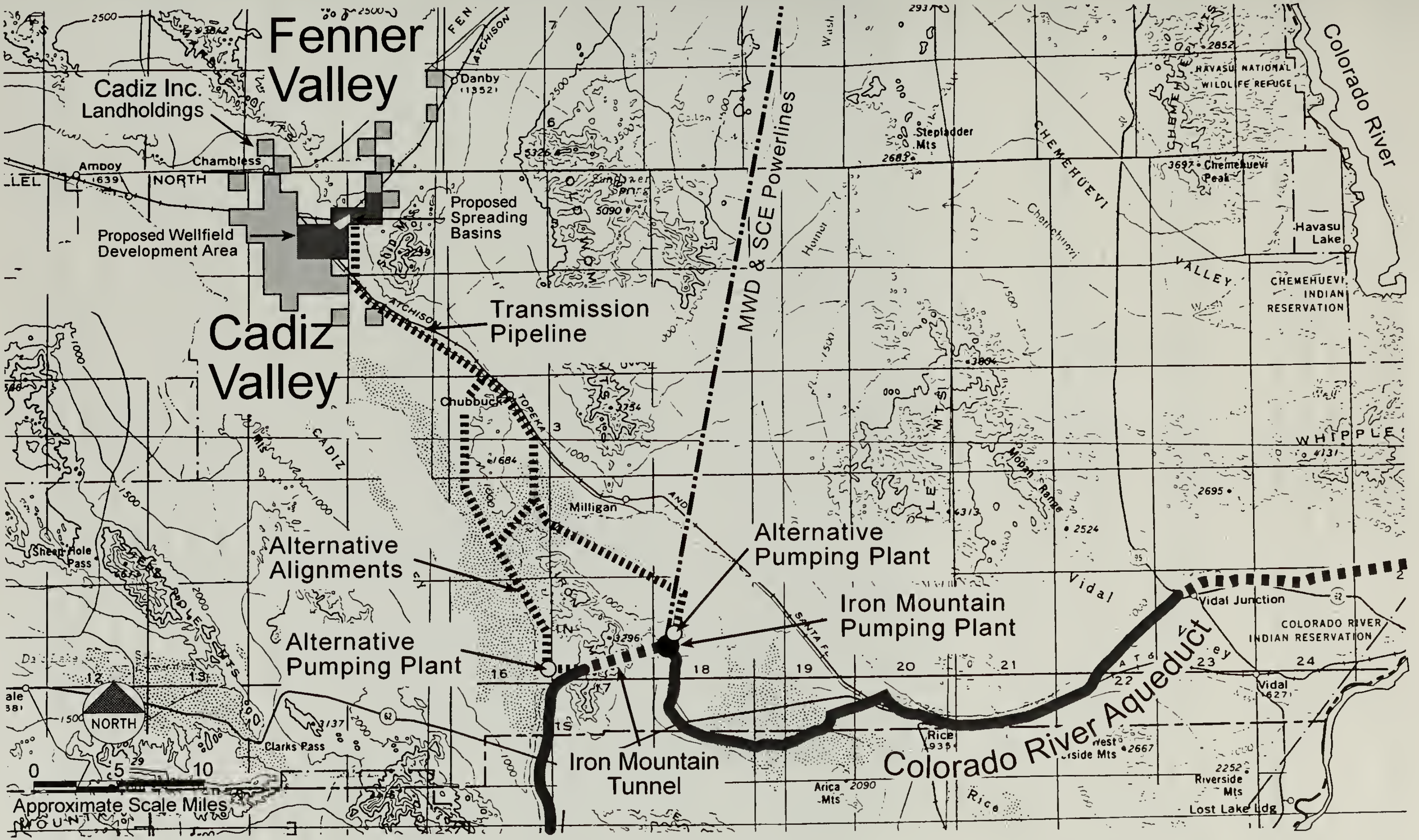


Figure 3

Cadiz Groundwater Storage & Dry-Year Supply Program

Groundwater Monitoring and Management Plan

Proposed Project Facilities

- A power distribution system to be constructed generally parallel to the alignment of the conveyance pipeline.
- Instrumentation and control systems to monitor all project storage and extraction operations.
- Observation wells, cluster wells, land survey benchmarks, evapotranspiration stations, meteorological towers, nephelometers, digital cameras, a weather station and other appurtenant facilities necessary for the Management Plan.

With the exception of most of the conveyance and power distribution facilities, certain observation wells, survey benchmarks, and other monitoring features, all project facilities will be located on land owned by Metropolitan or Cadiz Inc.

1.3 EXISTING GROUNDWATER BASIN MANAGEMENT

Cadiz Inc. owns more than 27,000 acres in the Cadiz and Fenner Valleys of eastern San Bernardino County as shown in Figure 1. Approximately 1,600 acres of this land have been developed for citrus and stone fruit orchards, vineyards, and specialty row crops.

In 1993, San Bernardino County certified a Final Environmental Impact Report (FEIR) and granted various land use approvals for expansion of agricultural operations on this property up to 9,600 acres. As a component of this approval, the County identified specific groundwater monitoring activities to be undertaken by Cadiz. To comply with these monitoring requirements, the Cadiz Valley Agricultural Development Ground Water Monitoring Plan (GWMP) was developed in cooperation with San Bernardino County to monitor all potential environmental impacts that could result from the agricultural irrigation. This Management Plan governs water use, storage and extraction for the Cadiz Project, and ensures that project operations and future irrigation under the Cadiz Valley agricultural development will be conducted without adverse impacts to critical resources. Agricultural irrigation will also remain subject to the Cadiz Valley Agricultural Development Ground Water Monitoring Plan required by the County of San Bernardino.

1.4 PURPOSE AND SCOPE

The purpose of this Management Plan is to ensure protection of the critical resources in or near the Fenner, Bristol and Cadiz Valleys. For purposes of this Management Plan, project operations would be evaluated to include the agricultural operations as outlined in the GWMP.

This Management Plan includes the following:

1) Description of the Cadiz Project location and objectives;
2) Identification of the critical resources and potential adverse impacts in and surrounding the project area due to project groundwater storage and extraction operations;
3) Description of the modeling tools that will be used to refine the monitoring network, and will be used, in the future, to refine action criteria;
4) Description of the monitoring network and identification of the conceptual locations of the features of the monitoring network;
5) Description of the monitoring, testing, and reporting procedures that will be used to collect and analyze data;
6) Description of the potential adverse impacts that may occur to the critical resources;
7) Description of the action criteria established to avoid potential adverse impacts;
8) Description of the decision-making process to be used once the action criteria are met or when BLM considers refinements to the Management Plan;
9) Description of corrective measures that may be implemented to prevent adverse impacts;
10) Description of objectives and requirements for a Closure Plan; and
11) Description of the Technical Review Panel (TRP), and its responsibilities and procedures.

SECTION 2

SECTION 2
CRITICAL RESOURCES AND POTENTIAL ADVERSE IMPACTS IN OR ADJACENT TO THE PROJECT AREA

This Management Plan addresses the following critical resources:

- Springs Within the Affected Watersheds, Including Springs of the Mojave National Preserve and BLM-Managed Lands
- Aquifer System
- Brine Resources of Bristol and Cadiz Dry Lakes
- Air Quality in the Mojave Desert Region

Potential adverse impacts to these critical resources as a result of project operations are discussed below.

2.1 POTENTIAL IMPACTS TO SPRINGS WITHIN THE AFFECTED WATERSHEDS INCLUDING SPRINGS WITHIN THE MOJAVE NATIONAL PRESERVE AND BLM-MANAGED LANDS

- Potential for impact to spring flow within the Mojave National Preserve due to change of groundwater elevations as a result of project operations.
- Potential for impact to spring flow within designated BLM wilderness areas due to change of groundwater elevations as a result of project operations.
- Potential for impact to Bonanza Spring and all other springs located on BLM-managed lands within the affected watersheds of Bristol, Cadiz, Fenner and Orange Blossom Wash due to change in groundwater elevations as a result of project operations.

2.2 POTENTIAL IMPACTS OF THE PROJECT TO THE AQUIFER SYSTEM

For purposes of this Management Plan, the aquifer system includes aquifers of the Fenner, Bristol, and Cadiz basins. However, emphasis is placed on the aquifer system in the vicinity of the project area. The "project area" refers to the area encompassing the proposed artificial recharge facilities and extraction wellfield and is in and around the Fenner Gap area and existing Cadiz agricultural wellfield.

- Potential for impact to indigenous groundwater quality due to storage and extraction related to project operations.
- Potential for impacts to wells owned by neighboring landowners due to project operations.
- Potential for land subsidence and loss of groundwater storage capacity due to groundwater withdrawal.
- Potential for increased risk of liquefaction related to project spreading operations.
- Potential for hydrocompaction related to project spreading operations.
- Potential for induced flow of lower quality water from Bristol and Cadiz dry lakes.
- Potential for long-term drawdown of groundwater.

2.3 POTENTIAL IMPACTS TO BRINE RESOURCES ON BRISTOL AND CADIZ DRY LAKES

- Potential for impacts to brine resources on Bristol and Cadiz dry lakes include:

  - Potential change in groundwater elevations impacting evaporation and brine concentrations.
  - Potential dilution of brine concentration from migration of relatively low total dissolved solids (TDS) concentration of stored water.
  - Potential introduction of non-native chemical constituents into brine water from migration of stored water.

2.4 POTENTIAL IMPACTS TO AIR QUALITY

The Cadiz Project is in the Mojave Desert Air Basin (MDAB). The MDAB is an assemblage of mountain ranges interspersed with long broad valleys that often contain dry lakes. Many of the lower mountains which dot the vast terrain rise from 1,000 to 4,000 feet above the valley floor. Prevailing winds in the MDAB are out of the west and southwest. These prevailing winds are due to the proximity of the MDAB to coastal and central regions and the blocking nature of the Sierra Nevada Mountains to the north; air masses pushed onshore in Southern California by differential heating are channeled through the MDAB. The MDAB is separated from the Southern California coastal and central California Valley regions by mountains where highest elevation reaches approximately 10,000 feet and whose passes form the main channels for these air masses.

The Mojave Desert is bordered on the southwest by the San Bernardino Mountains, which are separated from the San Gabriel Mountains by the Cajon Pass (4,200 feet). A lesser channel, the Morongo Valley, lies between the San Bernardino Mountains and the Little San Bernardino Mountains.

- Potential impacts to air quality in the Mojave Desert region due to mobilization of dust from changes in groundwater levels underlying Bristol and Cadiz dry lakes as a result of project operations.

SECTION 3

SECTION 3
WATER RESOURCES MODELS

A series of water resources models will be developed and calibrated using available data during the pre-operational phase of the Cadiz Project. The models will be refined and recalibrated as additional data are collected during the operational phase of the project. Water resources models, including a rainfall-runoff model, unsaturated and saturated zone flow models, solute-transport models, and a density dependent groundwater flow and solute-transport model will be considered in consultation with the BLM Authorized Officer and the TRP. Metropolitan will prepare and refine the selected models during the pre-operational and operational phases. The BLM Authorized Officer will provide input and guidance throughout the development and refinement of the selected models. The BLM Authorized Officer will receive comments and recommendations from the TRP regarding the development and refinement of the selected models. The BLM Authorized Officer will approve the initial water resources models in accordance with Section 10. Refinements to models will be made in accordance with the decision-making process described in Sections 7, 9 and 10.

Models are only approximations and simplifications of real systems. However, they can be useful management tools, when used in conjunction with measured data, for testing alternative monitoring designs and management options. Accordingly, these models will be used to help guide decisions on further evaluating and refining the monitoring network, and evaluating and refining action criteria.
The models discussed below are examples of models that may be implemented to assist Metropolitan with its periodic review and analyses of project operations. Although there are a number of models discussed below, Metropolitan will utilize those necessary and appropriate for the Management Plan. Ongoing data collected during the term of the project, combined with the modeling tools, will assist Metropolitan in its compliance with the Management Plan.

As the responsible party, Metropolitan will prepare the water resources models.

3.1 DESCRIPTION OF WATER RESOURCES MODELS

3.1.1 RAINFALL-RUNOFF MODEL

Rainfall-runoff models simulate the surface water balance and include parameters specific to the watershed, mean areal rainfall, interception, depression storage, infiltration, soil moisture storage, evapotranspiration, surface runoff, snowmelt runoff, interflow, groundwater baseflow, and channel routing. The rainfall-runoff models would be integrated with other models (e.g. groundwater flow and solute transport models).

Data input would include precipitation and evaporation data distributed as interception loss, rainfall on impervious areas (which contributes directly to runoff), and infiltration. Infiltration is either interflow, which moves through the upper soil zone to channel flow, or deep percolation, which is flow into the lower soil zone, which contributes to active or inactive groundwater storage. The rainfall-runoff model would be initially calibrated using the streamflow data collected during the pre-operational phase of the project.

3.1.2 UNSATURATED ZONE FLOW AND TRANSPORT MODEL

An unsaturated zone flow and transport model would be employed to simulate the movement of infiltrated water under the ephemeral stream channels as well as the project spreading basins. For the purposes of simulation, infiltration under an ephemeral stream would be treated as a line source and would initially be simulated as a two-dimensional process coincident with the stream. Lateral redistribution away from the stream would be simulated as a two-dimensional process perpendicular to the stream. This model (along with other models) would be utilized in analysis and refinement of both the monitoring network and action criteria.

The model input requires volumetric moisture content, moisture potential, porosity, unsaturated and saturated hydraulic conductivity data, and subsurface layering. These data would be estimated from soil cores collected during the pre-operational phase of the project. Unsaturated zone instrumentation would be installed, if necessary, to measure soil suction, pressure head, and water chemistry as the water percolates downward through the unsaturated zone to the water table. Neutron and electromagnetic logs may be used to collect data at selected well sites to monitor the movement of the recharge "wetting" front if warranted following further evaluation. Data collected from the instrumentation would be used to help recalibrate the model when Colorado River water is delivered into the project spreading basins.

3.1.3 SATURATED ZONE FLOW AND TRANSPORT MODEL

A numerical groundwater flow and solute transport model would be developed and calibrated to better understand the dynamics of groundwater flow and solute transport in the project area. The domain of the groundwater flow and transport model would include the Bristol, Cadiz, Fenner and Orange Blossom Wash watersheds. This model along with other models would be utilized in analysis and refinement of both the monitoring network and action criteria.

A conceptual model would first be developed incorporating the area of interest, aquifer systems to be modeled and boundary conditions. It is understood that the conceptual model would be predicated upon a thorough analysis of the available geohydrologic data for the area. Only after a conceptual model is developed can the numerical models be developed. Development of the numerical models requires information on: (1) the aquifer geometry; (2) rate and quality of groundwater inflow and outflow; and (3) aquifer characteristics (hydraulic conductivity, saturated thickness, effective porosity, specific storativity, dispersivity, retardation and leakance). The groundwater flow model would integrate quantities and distribution of recharge estimated from the rainfall-runoff and unsaturated zone models.

3.1.4 DENSITY DEPENDENT GROUNDWATER FLOW AND TRANSPORT MODEL

Density dependent flow and transport models would be developed near both Cadiz and Bristol dry lakes. The models would simulate the transport of solute mass through numerical solution of a mass balance equation involving fluid density. The single solute species could be transported conservatively, or it could undergo sorption. Sources and boundary conditions of fluid and solute would be specified at the upgradient boundary of the model.

The model domain would extend outward from the project spreading basins to Bristol and Cadiz dry lakes. The area of interest for the model grid would be determined by further evaluation but would probably extend several miles. The height, and horizontal and vertical grid spacing would be selected based on available data and the intended use of the models. These models include hydraulic conductivity, specific storativity, effective porosity, and dispersion coefficients for each model element. Specified flux and chloride mass fraction would be provided by the regional groundwater flow and solute transport model described previously.

3.2 EVALUATION OF POTENTIAL ADVERSE IMPACTS USING NUMERICAL MODELS

The water resources models developed during the pre-operational phase of the project will be used to simulate the impacts of planned project operations. Water resources models, including a rainfall-runoff model, unsaturated zone flow and transport model, saturated zone flow and transport model and density dependent groundwater flow and transport model will be considered in consultation with the BLM Authorized Officer and the TRP. Metropolitan will select the models that are necessary and appropriate to be used in evaluating the potential impacts. The BLM Authorized Officer will provide input and guidance regarding the selection and development of the models. The BLM Authorized Officer will receive comments and recommendations from the TRP regarding the selection and development of the models. The BLM Authorized Officer will approve the initial water resources models in accordance with Section 10. The results of the simulations will be used to evaluate and refine action criteria and the locations of certain monitoring features. Models will also be used to simulate potential impacts for feasible project operations (including Cadiz agricultural operations) within the estimated ranges of natural recharge (low and high estimates). Evaluation of the model results could result in refinements to action criteria as well as identifying areas where collection of additional data may be needed to improve the monitoring network.

3.2.1 EVALUATION OF VARIABLE RECHARGE ESTIMATES AND LONG-TERM IMPACTS

Models, in conjunction with measured data, will be used to refine the estimates of natural recharge as well as groundwater travel times from areas of recharge to areas of discharge. The models will be run for various operational scenarios using a range of natural recharge estimates. The put (artificial recharge) and take (extraction) cycles will be tested for the range of natural recharge estimates to evaluate the sensitivity of the aquifer system, the action criteria, and the monitoring network to low and high estimates of natural recharge. Impacts from the project could have delayed effects which could persist after the termination of the project. Therefore, the project operation (put and take cycles) will be simulated with different natural recharge characteristics into the future until simulated water-level and water-quality changes approach a steady state condition. These models will enable evaluation of the potential for adverse impacts during the operational and post-operational phases and well into the future.

3.2.2 MODEL REFINEMENT AND MULTI-YEAR PREDICTIONS

During the term of the project, new data and analysis as well as any new project operational considerations will be used to refine the calibration of the various water resources models. This model refinement will take place approximately every two years, or as otherwise determined to be necessary. The refined models will be used to provide five-year predictions based on the current stage of the project. For example, a five-year prediction should be simulated before the first “put” cycle. Two years into the “put” cycle the model should be refined based on the new data and analysis to produce another five-year prediction.

The models will be a necessary part of the Management Plan and provide input to the decision-making process. These model results will assist Metropolitan with its periodic analyses of monitoring data and action criteria, and for example, show how the system might respond under the varying natural recharge conditions. Ongoing data collected during the operational phase combined with the predictive modeling tools will help to resolve project-related issues. If, for example, the “take” cycle caused a one-foot decline in an S-Series well (an observation-well cluster located upgradient of the project wellfield), and the decision was made to modify project operations, this management decision could then be simulated with the model to predict how long it may take for the system to recover assuming different natural recharge rates. Modifications of project operations could include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

SECTION 4

SECTION 4
AIR QUALITY ANALYSES RELATED TO MOBILIZATION OF LAKEBED DUST

4.1 AIR QUALITY MONITORING AT BRISTOL AND CADIZ DRY LAKES

The water resources models discussed in Section 3 will be integrated to interpret groundwater level data at locations between the project area and dry lakes, dry lake margins and beneath the dry lakebeds gathered by the monitoring wells. This modeling allows evaluations to be made so that, if necessary, appropriate modifications can be made to the Cadiz Project operations so that the project does not cause groundwater level declines beneath the surface of the dry lakes which could contribute to or cause an increase in the mobilization of dust from the surface of the dry lakebeds.

Well clusters on the dry lakes will be aligned with well clusters at the dry lake margins and monitoring wells closer to the immediate project area. This configuration of observation wells will provide a series of early warning monitoring locations. This information, together with the monitoring and analysis of other groundwater and meteorological information will be used to manage project operations to ensure that any water level changes beneath the surface of the dry lakes attributable to project operations will not cause an increase in the mobilization of dust from the surface of the dry lakes. Groundwater flow models, including density dependent models at the dry lakes, will also be used to predict potential impacts to groundwater levels and potential for dust mobilization due to project operations.

Additionally, lakebed surface soil moisture and evapotranspiration will be monitored. Air quality instrumentation (open-air nephelometers) and weather stations will be installed on each dry lakebed to obtain continuous data on dust mobilization and wind speed and direction. Analysis of mobilization and wind data will indicate whether there is any changing relationship between these two factors (reduced wind speed required for dust mobilization). This dust/wind speed relationship will also be compared with any changes in surface soil moisture of the dry lakebeds and groundwater levels beneath the dry lakebeds.

Monitoring features 4, 6, and 13 through 17 discussed in Section 5 will be used in the groundwater models to provide predictive analysis and avoidance of potential increased dust mobilization from Bristol and Cadiz dry lakes as a result of the Cadiz Project.

Meteorological data (Final EIR/EIS main volume Section 5.5.1 and Figure 5.5-8) indicates that the highest wind speeds are associated with winds from the west-northwest, west and southeast. Therefore, open-air nephelometers will be located at the western and eastern edges of Bristol Dry Lake, and are expected to be at upwind and downwind locations of the lakebed during high-wind periods. The downwind open-air nephelometer would detect high concentrations of wind-mobilized particulate matter from the lakebed, while the upwind open-air nephelometer would identify region-wide dust storms. Solar-powered open-air nephelometers will be used. The open-air nephelometers will measure large increases in light scattering associated with dust storms. Additionally, an automated digital camera will be located to provide periodic photographs of the lakebed as further documentation of the occurrence of dust mobilization from the lake.

Meteorological data in the vicinity of Cadiz Dry Lake are not available. However, it is believed likely that the mountains that lie to the east and the west of the dry lake channel wind flow, leading to predominantly northwesterly and southeasterly winds. Therefore, open-air nephelometers will be located at the northwestern end of the lakebed, in the vicinity of the new cluster wells to be installed there, and at the southeastern end of the lake. An automated digital camera will also be located to provide periodic photographs of the lakebed as further documentation of the occurrence of high concentrations of wind-mobilized particulate matter from the lake. Data from the open-air nephelometers will be analyzed in tandem with wind velocity and direction information obtained from the weather stations on Bristol and Cadiz dry lakes included as part of Feature 16.

Placement of the open-air nephelometers at Bristol and Cadiz dry lakes will be reviewed, and adjustments made should the meteorological data indicate that they are not located at appropriate upwind or downwind locations.

4.2 REGIONAL METEOROLOGICAL MONITORING

Beginning in the pre-operational phase of the project and extending into the initial years of the project operational phase, three meteorological towers will be installed in the region for a period of five years to establish patterns of regional wind speed and direction (see Section 6.4). Data collection from any or all of the meteorological towers may be extended if determined by Metropolitan to be necessary or required by the BLM Authorized Officer in accordance with the decision-making process described in Section 10.

This baseline information will be used in conjunction with lakebed data for groundwater levels and soil moisture to determine whether (a) the project could contribute to lakebed dust mobilization and (b) if any project-mobilized lakebed dust could be transported throughout the Mojave Desert region. This review will consider whether existing dust storms on the dry lakebeds occur simultaneously with regional winds that are capable of transporting lakebed dust beyond the localized lakebed areas.

SECTION 5

SECTION 5
MONITORING NETWORK

The development of the monitoring network will involve a "phased approach." Integral with the phased approach will be the development and refinement of a number of water resources models as described in Section 3. The Management Plan will be implemented with an initial set of monitoring features and parameters developed by Metropolitan from the existing data. The BLM Authorized Officer will provide input and guidance throughout the development and refinement of the initial implementation. The BLM Authorized Officer will receive comments and recommendations from the TRP regarding the development and refinement of the initial implementation. The BLM Authorized Officer will approve the initial monitoring network in accordance with Section 10. As new data become available, the monitoring features defined below will be refined as necessary to protect critical resources in and adjacent to the project area. If Metropolitan proposes a refinement to monitoring features, it will submit a written proposal describing the refinement along with supporting data and materials to the BLM Authorized Officer. The BLM Authorized Officer will make a decision on Metropolitan's proposal through the decision-making process described in Section 10.

A total of 24 different monitoring features have been identified for assessing potential impacts to the four critical resources during the term of the Cadiz Project. As described in Section 2, these critical resources include springs located within the Mojave National Preserve and BLM-managed lands, the aquifer system, and Bristol and Cadiz dry lakes as relates to brine resources and dust mobilization from Bristol and Cadiz dry lakes. A summary of the types of monitoring features, as well as monitoring frequencies, is provided in Table 1. A detailed list of each monitoring feature is provided in Table 2. Generalized locations are shown in Figures 4 and 5.

Installation of certain monitoring features will be subject to site-specific approval and permitting by applicable regulatory agencies. The NPS and BLM will complete and deliver all needed permits for monitoring facilities in accordance with the schedule contained in the Record of Decision as soon as practicable within the pre-operational phase. The project will construct all facilities that are agreed to in the Management Plan and for which permits have been received. Construction of these facilities will be completed within one year of receipt of permits. If the implementation of monitoring features currently contained in the Management Plan is not approved, Metropolitan will evaluate and implement alternate monitoring sites subject to approval by the applicable regulatory agencies.

The following text describes in detail the various proposed monitoring features.

5.1 PROPOSED "S-SERIES" OBSERVATION WELLS (FEATURE 1)

A series of "early-warning" observation wells known as the "S-Series" wells will be established to monitor groundwater-level fluctuations in the project aquifer system, in order to detect any impacts to the aquifer system due to project operations before such impacts reach the boundary of the Mojave National Preserve. Water-level fluctuations in these observation wells will act as an "early warning" measure of potential adverse impacts that might extend to springs in the Mojave National Preserve or BLM-managed lands in the affected watersheds.

Four S-Series observation-well clusters will be established upgradient of the project wellfield and spreading basins, which are approximately equidistant between (1) the project wellfield and spreading basins and (2) the boundary of the Mojave National Preserve. One S-Series observation-well cluster will be established in each of the following four general locations, as shown on Figure 4: (1) in Orange

TABLE 2
SUMMARY OF MONITORING FEATURES AND PROTOCOLS

Critical Resource Area	Feature No.	Feature Type	When Monitored	Name	State Well Number	Location Coordinates[a]	Monitoring Protocol		
							Water Level	Water Quality	Other Monitoring
Springs in the Mojave National Preserve and BLM Managed Lands	1	S-Series Well Clusters[b] (2 to 3 per Cluster x 4 total Clusters)	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Section 6.1	See Appendices C & D	-
			Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Section 6.1	See Appendices C & D	-
			Pre-Operational Operational Post-Operational	TBD	TBD[c]	TBD	Transducer, See Section 6.1	See Appendices C & D	-
			Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Section 6.1	See Appendices C & D	-
	2	Initial Spring Survey (28+ total)	Pre-Operational	TBD	NA[d]	TBD	-	See Section 6.1 and Appendix D	See Section 6.1
	3	Springs, Monitoring (8 total)	Pre-Operational Operational Post-Operational	TBD	NA	TBD	Transducer, See Section 6.1	-	See Section 6.1
Aquifer System	4	Observation Well	Pre-Operational Operational	New Well	5N/14E-31L2	TBD	Transducer, See Sections 5 and 6.2	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	Dormitory	5N/14E-5F1	34° 32' 38" N 115° 31' 57" W	Transducer, See Sections 5 and 6.2	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	6/15-29	6N/15E-29Q1	34° 34' 20" N 115° 26' 04" W	Transducer, See Sections 5 and 6.2	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	SCE-11	5N/14E-13R1	34° 25' 52 N 115° 27' 25" W	Transducer, See Sections 5 and.6.2	See Appendices C & D	-

TABLE 2
SUMMARY OF MONITORING FEATURES AND PROTOCOLS (Continued)

Critical Resource Area	Feature No.	Feature Type	When Monitored	Name	State Well Number	Location Coordinates[a]	Monitoring Protocol		
							Water Level	Water Quality	Other Monitoring
Aquifer System	4	Observation Well	Pre-Operational Operational	CI-3	5N/14E-24D2	34° 30' 40" N 115° 28' 01" W	Transducer, See Sections 5 and 6.2	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	Archer Siding #1	4N/15E-24E1	34° 25' 11" N 115° 21' 57" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	Essex	8N/17E-31	34° 43' 49" N 115° 14' 53" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	Fenner	8N/17E-2	34° 48' 59" N 115° 10' 40" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	Goffs	10N/18E-26	34° 54' 57" N 115° 03' 44" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	Labor Camp	5N14E-16H1	34° 31' 22" N 115° 30' 46" W	Transducer, See Sections 5and 6.2	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	SCE-5	5N/14E-31L1	34° 28' 38" N 115° 33' 09" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	SCE-9	5N/13E-14B1	34° 31' 36" N 115° 35' 18" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	SCE-10	5N/14E-34Q1	34° 28' 11" N 115° 30' 03" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	SCE-17	5N/15E-29B1	34° 29' 45" N 115° 31' 57" W	Manual, See Appendix B	See Appendices C & D	-

TABLE 2
SUMMARY OF MONITORING FEATURES AND PROTOCOLS (Continued)

Critical Resource Area	Feature No.	Feature Type	When Monitored	Name	State Well Number	Location Coordinates[a]	Monitoring Protocol		
							Water Level	Water Quality	Other Monitoring
Aquifer System	4	Observation Well	Pre-Operational Operational	SCE-18	5N/13E-11R1	34° 26' 34" N 115° 34' 52" W	Manual, See Appendix B	See Appendices C & D	-
	5	Project Area Well Clusters[e]- Vadose Only (1 per Cluster x 3 total Clusters)	Operational	TBD	TBD	TBD	Manual, See Appendix B	See Appendices C & D	-
	6	Project Area Well Clusters[e]- Groundwater (2 per Cluster x 3 total Clusters)	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 5 and 6.2	See Appendices C & D	-
	7	Existing Production Wells (4 total)	Operational	PW-1	5N/14E-24D1	34° 30' 41" N 115° 27' 53" W	-	-	See Sections 5 and 6.2
			Operational	22	5N/14E-22K1	34° 30' 21" N 115° 29' 01" W	-	-	See Sections 5 and 6.2
			Operational	27N	5N/14E-27B1	34° 29' 54" N 115° 29' 59" W	-	-	See Sections 5 and 6.2
			Operational	27S	5N/14E-27Q1	34° 28' 14" N 115° 29' 59" W	-	-	See Sections 5 and 6.2
	7	New Production Wells (26 total)	Operational	TBD	TBD	TBD	-	-	See Sections 5 and 6.2
	8	Recharge Water Quality	Operational	Lake Havasu	NA	TBD	-	See Sections 5 and 6.2	-

TABLE 2
SUMMARY OF MONITORING FEATURES AND PROTOCOLS (Continued)

Critical Resource Area	Feature No.	Feature Type	When Monitored	Name	State Well Number	Location Coordinates[a]	Monitoring Protocol		
							Water Level	Water Quality	Other Monitoring
Aquifer System	9	Spreading Basins	Operational	Fenner Gap	NA	TBD	See Sections 5 and 6.2	-	-
	10	Benchmark Stations (20 total)	Pre-Operational Operational	TBD	NA	TBD	-	-	See Sections 5 and 6.2
		InSAR (2 per year, if warranted)	Pre-Operational Operational	NA	NA	NA	-	-	See Sections 5 and 6.2
	11	Extensometer (if warranted) (1 total)	Operational	TBD	NA	TBD	-	-	See Sections 5 and 6.2
	12	Microgravity Stations, if warranted (10 total)	Pre-Operational Operational Post-Operational	TBD	NA	TBD	See Sections 5 and 6.2	-	-
	13	Flowmeter Surveys (5 total)	Pre-Operational	TBD	TBD	TBD	-	-	See Sections 5 and 6.2
Bristol and Cadiz Dry Lakes	14	Bristol Dry Lake Well Cluster[f]	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 5 and 6.3	See Appendices C & D	-
		Bristol Dry Lake Well Cluster[f]	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 5 and 6.3	See Appendices C & D	-
		Bristol Dry Lake Well Cluster[g]	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 5 and 6.3	See Appendices C & D	-
	15	Cadiz Dry Lake Well Cluster[h]	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 5 and 6.3	See Appendices C & D	-
		Cadiz Dry Lake Well Cluster[h]	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 5 and 6.3	See Appendices C & D	-

TABLE 2
SUMMARY OF MONITORING FEATURES AND PROTOCOLS (Continued)

Critical Resource Area	Feature No.	Feature Type	When Monitored	Name	State Well Number	Location Coordinates[a]	Monitoring Protocol		
							Water Level	Water Quality	Other Monitoring
Bristol and Cadiz Dry Lakes	14	Cadiz Dry Lake Well Cluster[i]	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 5 and 6.3	See Appendices C & D	-
	16	ET Station (Bristol Dry Lake)	Pre-Operational Operational Post-Operational	TBD	NA	TBD	-	-	See Sections 5 and 6.3
		ET Station (Cadiz Dry Lake)	Pre-Operational Operational Post-Operational	TBD	NA	TBD	-	-	See Sections 5 and 6.3
	17	Staff Gage (Bristol)	Pre-Operational Operational	TBD	NA	TBD	See Sections 5 and 6.3	-	-
		Staff Gage (Cadiz)	Pre-Operational Operational	TBD	NA	TBD	See Sections 5 and 6.3	-	-
	18	Nephelometers (4 total) with Digital Cameras(2 total)	Pre-Operational Operational Post-Operational	TBD	NA	TBD	-	-	See Sections 5 and 6.3
	19	Resistively Survey (1 total)	Pre-Operational	NA	NA	TBD	-	-	See Sections 5 and 6.3
	20	Gamma/EM Logs (up to 6 total)	Pre-Operational	TBD	TBD	TBD	-	-	See Sections 5 and 6.3
Other (Basin-wide)	21	Weather Station	Pre-Operational Operational	Amboy	NA	34° 31' 52" N 115° 41' 42" W	-	-	See Sections 5 and 6.4
		Weather Station	Pre-Operational Operational	Mitchell Caverns	NA	34° 56' 06" N 115° 30' 58" W	-	-	See Sections 5 and 6.4
		Weather Station	Pre-Operational Operational	Fenner Gap	NA	TBD	-	-	See Sections 5 and 6.4

TABLE 2
SUMMARY OF MONITORING FEATURES AND PROTOCOLS (Continued)

Critical Resource Area	Feature No.	Feature Type	When Monitored	Name	State Well Number	Location Coordinates[a]	Monitoring Protocol		
							Water Level	Water Quality	Other Monitoring
		Weather Station	Pre-Operational Operational	TBD	NA	TBD	-	-	See Sections 5 and 6.4
Other (Basin-wide)	22	Stream Gage	Pre-Operational Operational	Caruthers Canyon	NA	35° 14' 42" N 115° 17' 53" W	-	-	See Sections 5 and 6.4
		New Stream Gages (2 total)	Pre-Operational Operational	TBD	NA	TBD	-	-	See Sections 5 and 6.4
	23	Soil Moisture Sensors (2 total)	Operational	TBD	NA	TBD	-	-	See Sections 5 and 6.4
	24	Meteorological Towers (3 total)	Pre-Operational Operational	Orange Blossom Wash, Valley between Clipper and Marble Mtns & Unnamed Valley	NA	TBD	-	-	See Sections 5 and 6.4

NOTES:

a – Location coordinates to be verified in the field during initial Pre-Operational activity.

b – Four S-Series well clusters: (1) in Orange Blossom Wash; (2) in Clipper Wash (between the Marble Mountains and the Clipper Mountains); (3) directly south of the Clipper Mountains (generally south of Bonanza Spring); and (4) in Schulyler Wash.

c - To Be Determined.

d – Not Applicable.

e – Three new well clusters to be installed within project area.

Each cluster will consist of 2 groundwater monitoring wells and 1 unsaturated zone monitoring well.

f – Two new well clusters to be installed at eastern margin of Bristol Dry Lake.

g – One new well cluster to be installed on Bristol Dry Lake.

h – Two new well clusters to be installed north of Cadiz Dry Lake.

i – One new well cluster to be installed on Cadiz Dry Lake.

Blossom Wash; (2) in Clipper Wash (between the Marble Mountains and the Clipper Mountains); (3) directly south of the Clipper Mountains (generally south of Bonanza Spring); and (4) in Schulyler Wash. Each S-Series observation-well cluster will consist of two or three separate well casings installed within their own individual boreholes, and completed and screened at different depths including wells screened in the production aquifer(s) and one screened across the water table. These well clusters will be used to provide information regarding potentiometric head and water quality with depth.

A typical observation well cluster completion is illustrated on Figure 6. Screened intervals for each of the wells within each cluster will be determined from logging of cuttings and geophysical logging of the deep borehole which will be drilled first. Each deep well will be completed with PVC or other suitable well casing and screen to allow for dual induction geophysical logging. Shallow and intermediate wells will be completed with PVC or other suitable well casing and screen.

All new observation well drilling and well installation will be conducted in accordance with the protocols specified in ASTM D5092-90 (see Appendix A). During drilling, selected core intervals will be collected and classified from the borehole for each of the deepest cluster wells. All soil samples will be classified in the field according to the Unified Soil Classification System (USCS). Selected cores will be submitted to a State certified laboratory for analysis of vertical permeability by ASTM D5084.

5.2 SPRINGS (FEATURES 2 AND 3)

An inventory of 28 known springs within the Fenner and Orange Blossom Wash watersheds will be prepared in cooperation with the agencies within the Department of the Interior, as described in Section 5. During the term of the Cadiz Project, approximately eight springs will be selected as long-term monitoring sites, as described in Section 5. Likely long-term monitoring sites include: (1) one spring site on the south side of the Granite Mountains (e.g. Budweiser Spring, Willow Spring Basin, or Cove Spring); (2) one spring in the Van Winkle Mountains (Van Winkle spring); (3) one spring on the east side of the Providence Mountains (e.g. Quail spring or Foshay spring); (4) one spring on the south side of Wild Horse Mesa (most likely Whiskey spring); (5) one spring on the east side of the Fenner Valley within the Mojave National Preserve (probably Vontrigger spring); (6) Bonanza spring on the south side of the Clipper Mountains; (7) one spring in the Clipper Mountains Wilderness Area (e.g. Hummingbird spring), and (8) one spring in the Old Woman Wilderness Area (e.g. Barrel spring).

5.3 OBSERVATION WELLS (FEATURES 4 THROUGH 6)

A total of 14 existing observation wells will be used to monitor groundwater levels during the project (see Tables 1 and 2). Locations of these wells are shown on Figures 4 and 5. Six of these wells were installed in the 1960's by Southern California Edison as part of a regional investigation (wells whose designation begins with “SCE”). Three of the observation wells (Labor Camp, Dormitory, and 6/15-29) are owned and monitored by Cadiz as part of their agricultural operation. Well CI-3 was installed in Fenner Gap during the pilot spreading basin test for the project. Wells at Essex, Fenner, Goffs, and Archer Siding #1 are related to railroad operations or municipal supply. Wells will be utilized provided that appropriate permission and approval is obtained.

The project will incorporate 14 existing observation wells and 1 new (to be installed) observation[1] well for the purposes of monitoring groundwater levels and collecting water quality samples in the vicinity of the project. Two different types of observation wells will be monitored: existing single completion observation wells and proposed multiple completion cluster wells. A total of 14 existing observation wells (each consisting of a single cased well with one screened interval) will be used as monitoring wells

[1] Installation of any new monitoring facilities will be subject to approval by the applicable regulatory agencies.

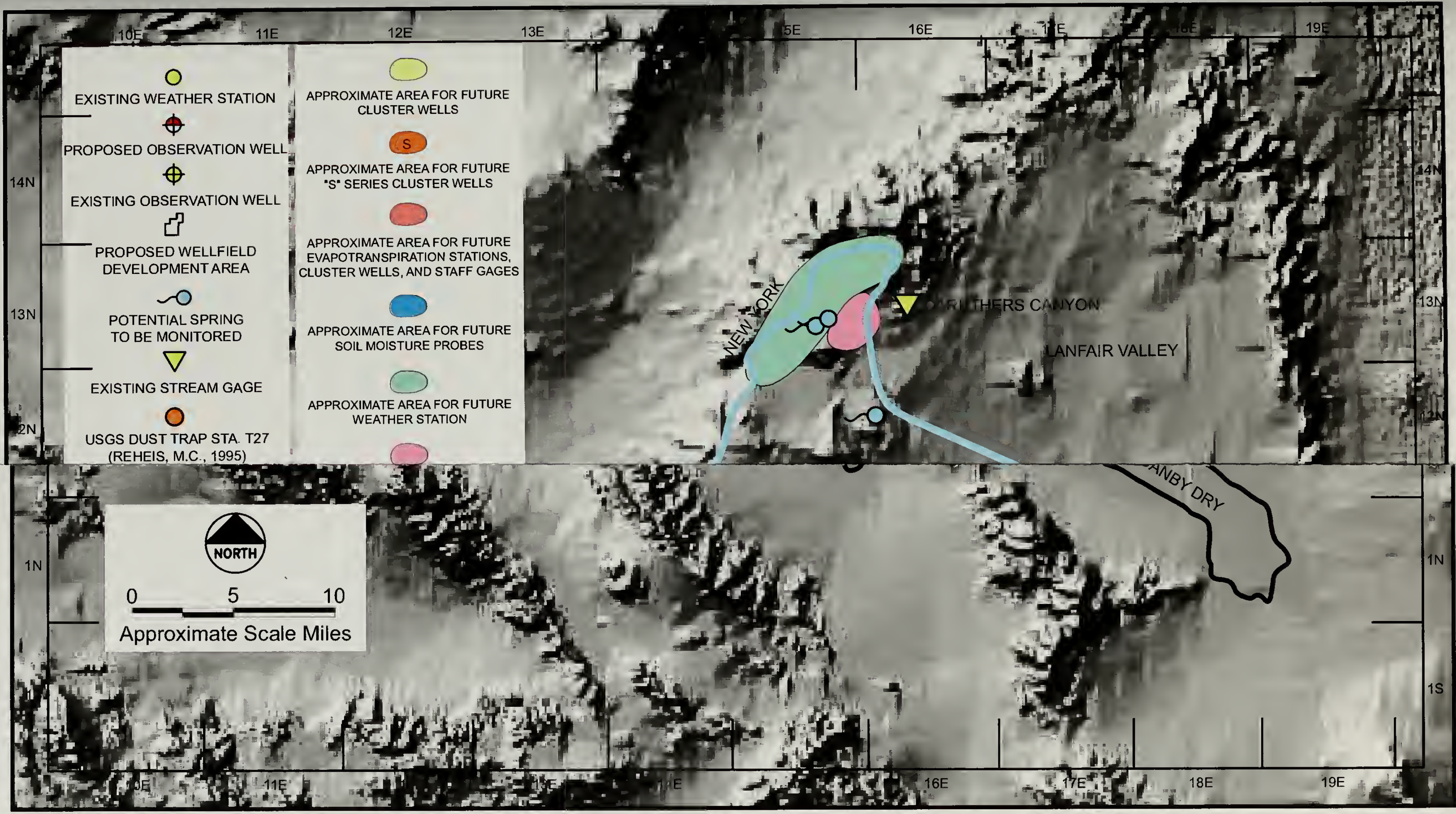


Figure 4

Cadiz Groundwater Storage & Dry-Year Supply Program

Groundwater Monitoring and Management Plan

Monitoring Features (Regional)

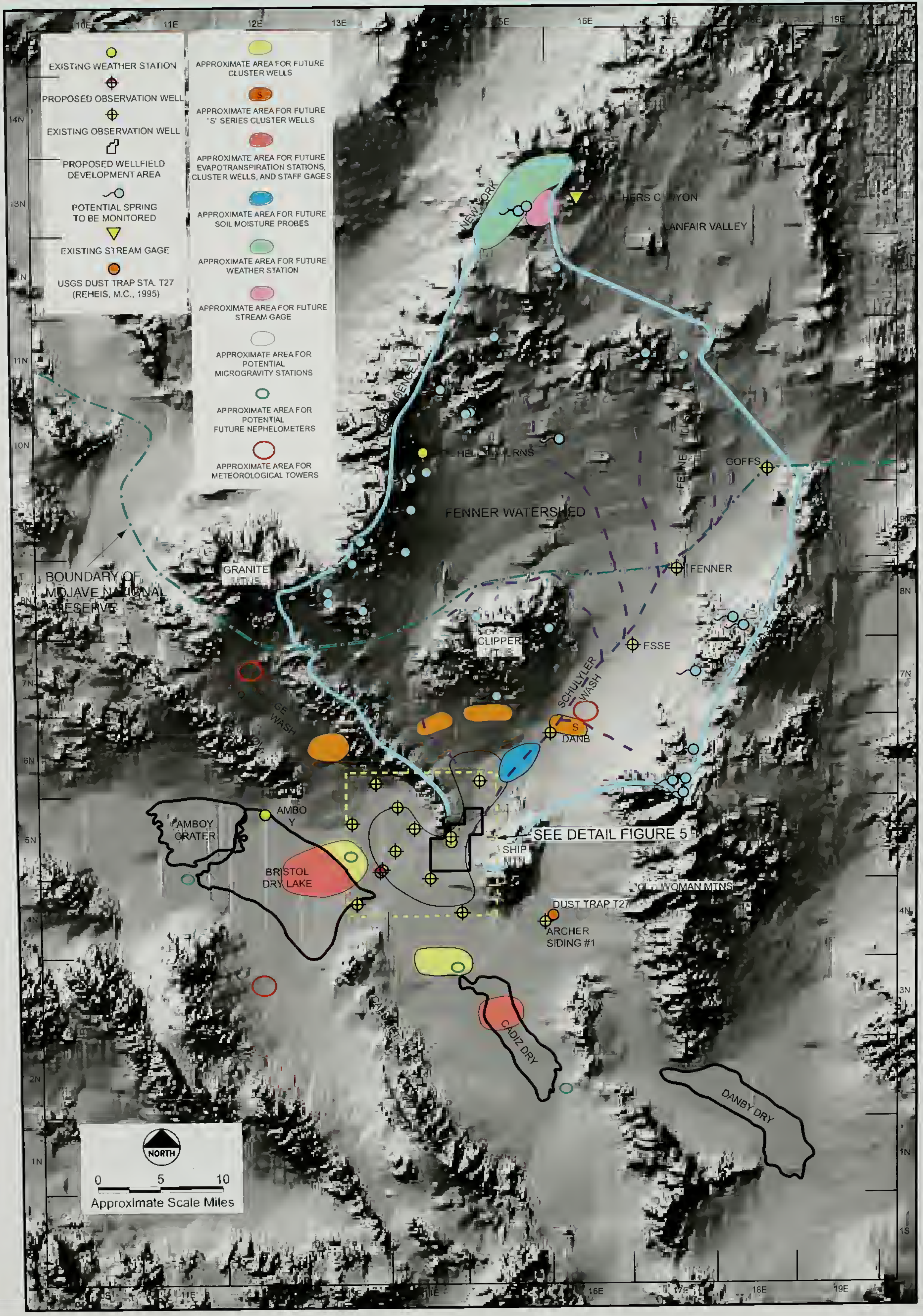


Figure 4

Cadiz Groundwater Storage & Dry-Year Supply Program
Groundwater Monitoring and Management Plan

Monitoring Features (Regional)

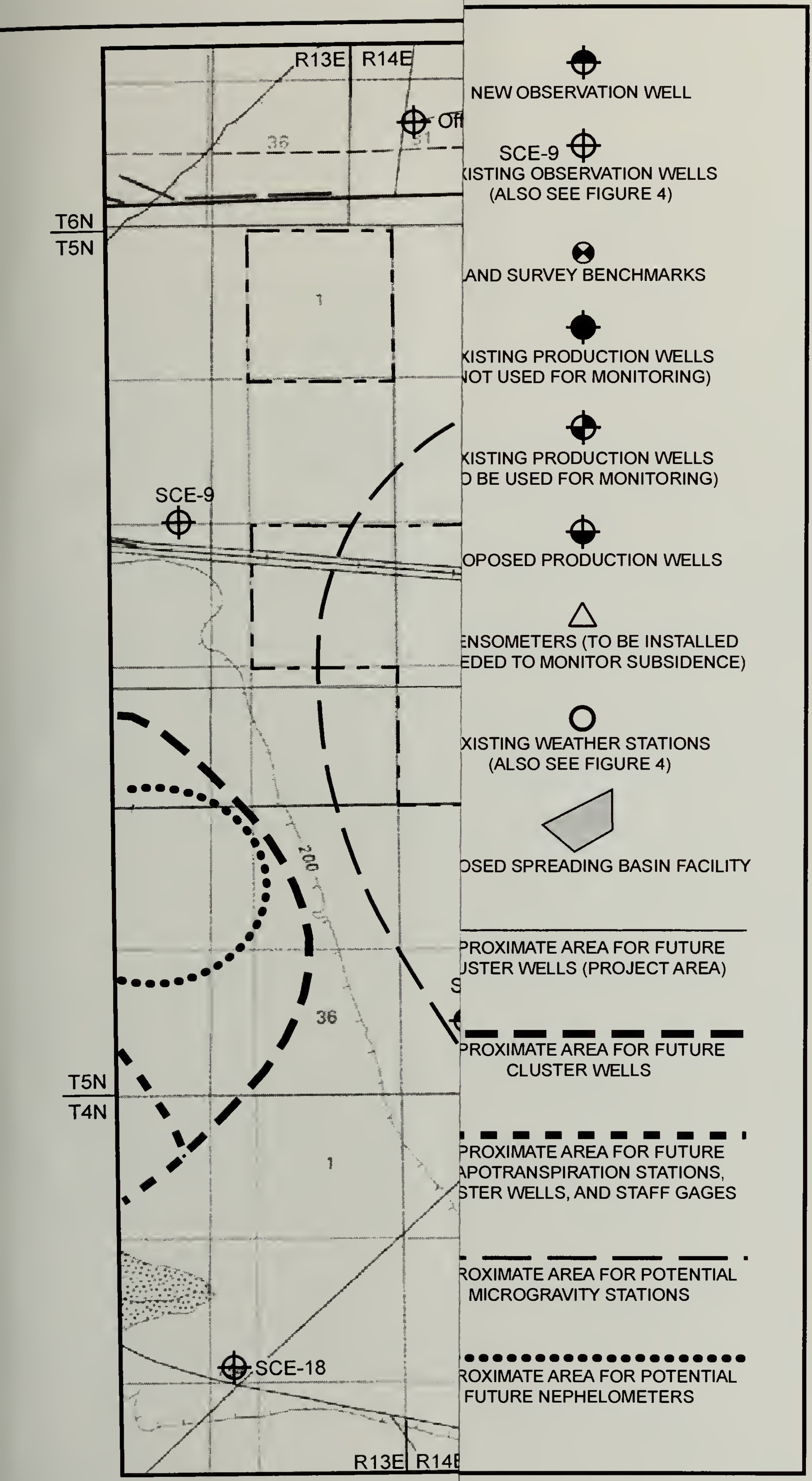


Figure 5

Cadiz Groundwater Storage & Dry-Year Supply Program

Groundwater Monitoring and Management Plan

Monitoring Features (Detail of Project Area)

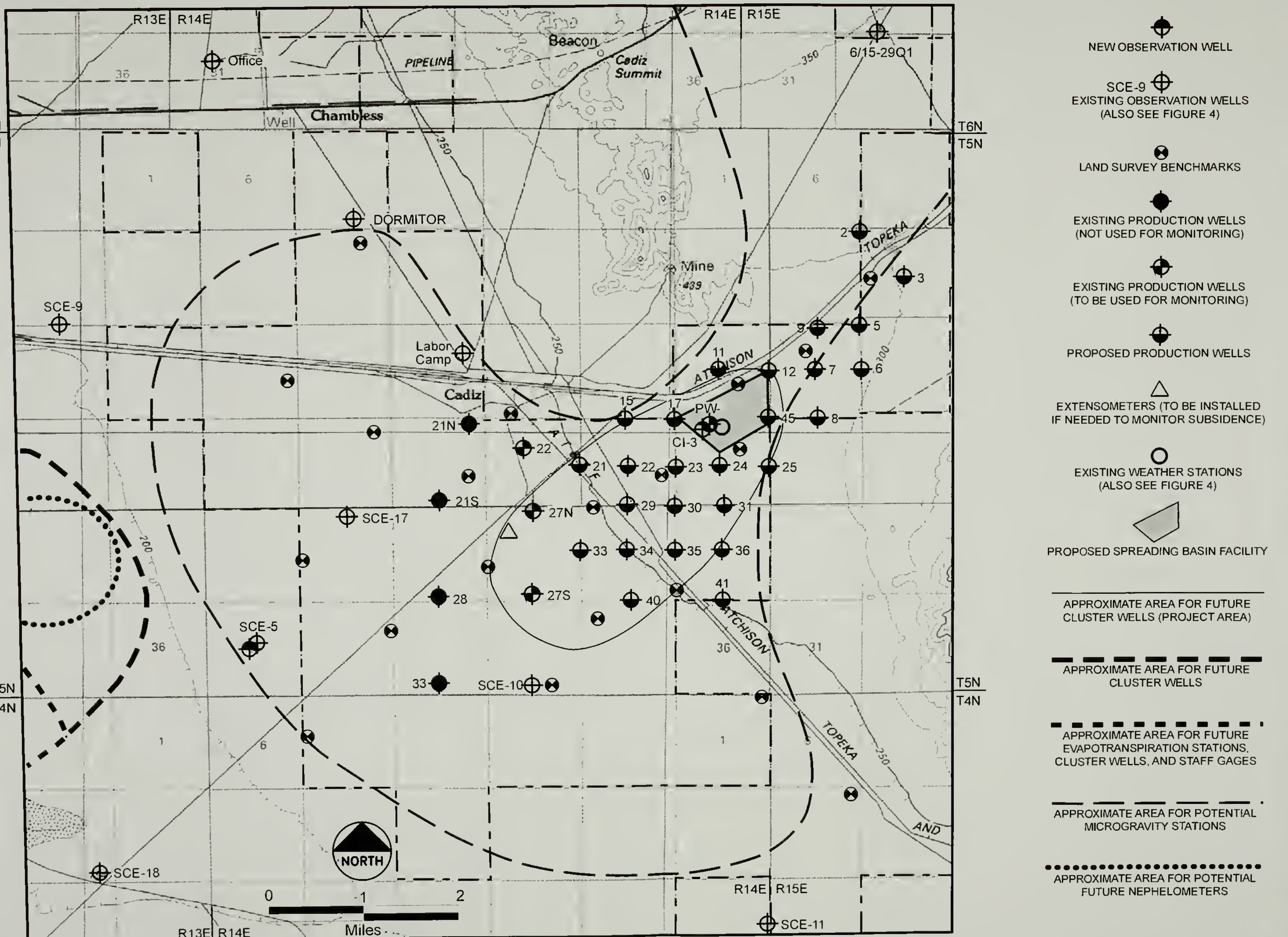


Figure 5

Cadiz Groundwater Storage & Dry-Year Supply Program

Groundwater Monitoring and Management Plan

Monitoring Features (Detail of Project Area)

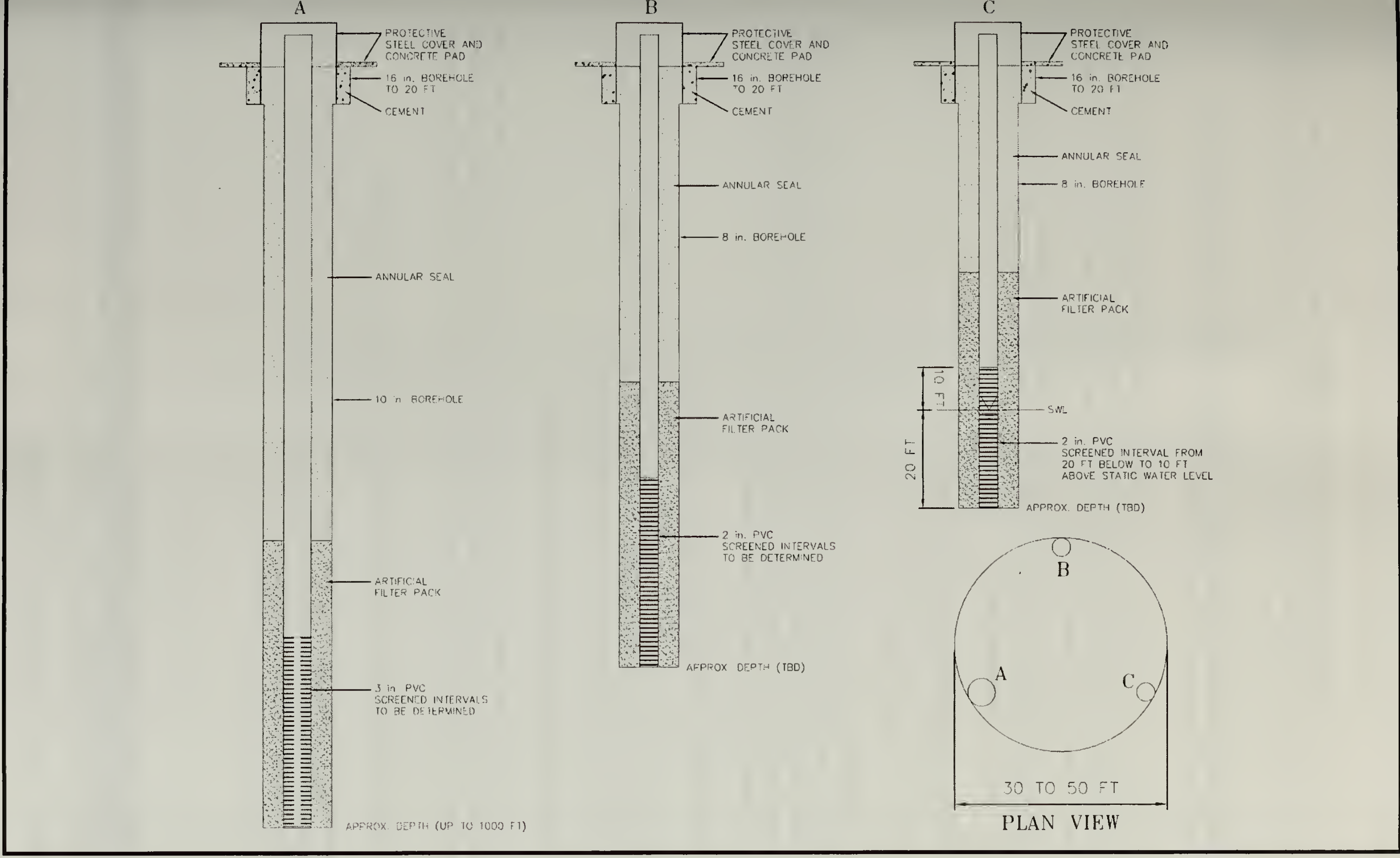


Figure 6

Cadiz Groundwater Storage & Dry-Year Supply Program

Groundwater Monitoring and Management Plan

Typical Observation Well Cluster Cross Section

during the project. One new deep observation well will be installed adjacent to existing observation well SCE-5. A total of three new observation well clusters will be installed in the immediate project vicinity and monitored during the project[2].

5.4 PROPOSED OBSERVATION WELL CLUSTERS WITHIN THE IMMEDIATE PROJECT AREA (FEATURES 5 AND 6)

Three well clusters will be established in the immediate vicinity of the project spreading basins and wellfield (see Figure 5). The uppermost screened interval of each cluster location will be above the pre-operational static water table (in the saturated zone of the future storage mound) to enable monitoring of elevated total dissolved solids water that would result from the leaching of salts out of the unsaturated zone during the initial infiltration of Colorado River water. The middle and lower screened intervals will be in the upper and lower aquifers, respectively. One well cluster will be developed around existing well CI-3, which is screened in the upper aquifer.

5.5 PROJECT PRODUCTION WELLS (FEATURE 7)

5.5.1 EXISTING CADIZ AGRICULTURAL WELLS

The Cadiz agricultural operation owns and operates seven agricultural wells used for irrigation, which are located west and southwest of the project spreading basins (see Figure 2). Three of the seven Cadiz irrigation wells could be incorporated into the project wellfield (Wells 22, 27N, and 27S). In addition, one production well (PW-1) has already been constructed as part of the pilot spreading basin test and is located in the vicinity of the proposed project spreading basins.

5.5.2 NEW PRODUCTION WELLS

The project wellfield would consist of approximately 26 additional production wells to be located as shown on Figure 2. Each new well would be completed to a depth of about 1,000 feet (see Figure 7). The total capacity of the wellfield would range from 200 to 250 cfs.

5.6 RECHARGE WATER QUALITY (FEATURE 8)

Delivery of Colorado River water to the project spreading basin facilities would be recorded from totalizer readings of flow at the Iron Mountain Pumping Plant. During operation of the project spreading basins, analyses of Colorado River water quality would be conducted on a weekly basis from samples collected at Lake Havasu.

5.7 SPREADING BASINS - WATER LEVEL STAFF GAGES (FEATURE 9)

Calibrated water level staff gages would be placed in each subbasin of the project spreading basin. Each staff gage would be located on the floor of the basin but close enough to the berm slope so as to be readable from the top of the berm.

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[2] Tables 1 and 2 separate features 5 and 6 to indicate that monitoring will occur in both the unsaturated and saturated zones. However, features 5 and 6 together total 3 clusters (not 3 clusters for each feature).

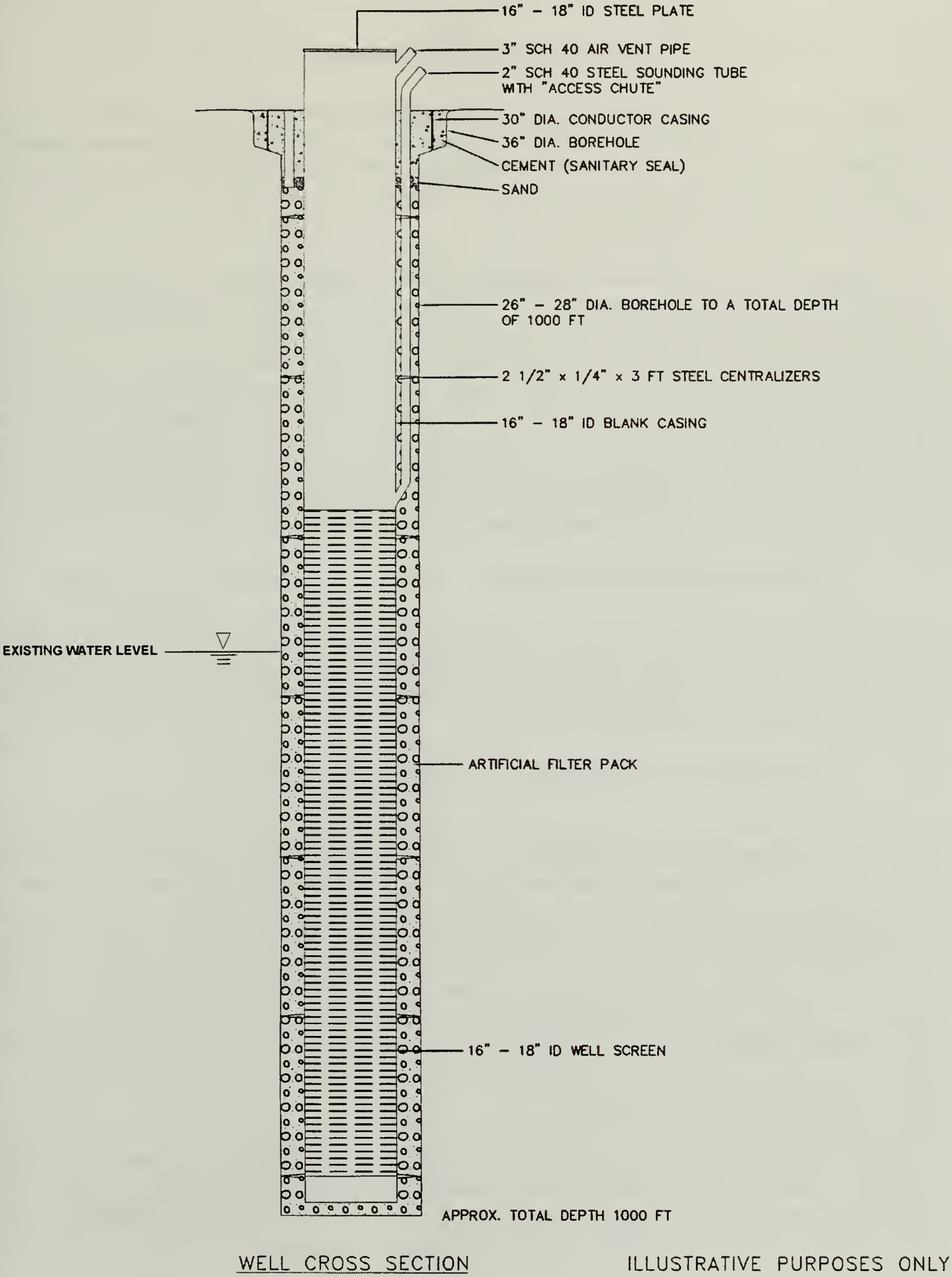

Figure 7

Cadiz Groundwater Storage & Dry-Year Supply Program

Groundwater Monitoring and Management Plan

Typical Production Well Cross Section

5.8 LAND SURFACE MONITORING (FEATURE 10)

A network of approximately 20 survey benchmarks will be installed at the approximate locations shown on Figure 5 to monitor changes in land surface elevation should they occur. Each benchmark will be established and surveyed by a California licensed land surveyor. All locations will be dependent upon permitting from the appropriate agencies. Benchmark surveys will be conducted on an annual basis during the term of the Cadiz Project (see Table 1).

Pre-operational baseline Interferometric Synthetic Aperture Radar ("InSAR")[3] data may be necessary to evaluate potential impacts. If determined by Metropolitan to be necessary, or required by the BLM Authorized Officer in accordance with the decision-making process described in Section 10, Metropolitan will obtain surveyed baseline land surface elevations which then will be compared to each other along with any InSAR data collected during the course of the project. The InSAR data would be used to monitor relative changes of land surface elevation, which could be related to aquifer system deformation in the project area. This pre-operational InSAR data (collected at two separate times during the year prior to the operational phase of the project) would complement the land survey data to establish changes in land surface elevations. The InSAR images would be obtained and evaluated semi-annually during the project, as necessary to evaluate potential impacts.

5.9 EXTENSOMETERS (FEATURE 11)

If necessary to evaluate potential impacts, as determined by the annual benchmark surveys, Metropolitan would construct one extensometer well in the area of the highest probability of subsidence (see Figure 5). The extensometer would be constructed to measure non-recoverable compaction of fine-grained materials interbedded within the alluvial aquifer systems.

5.10 MICROGRAVITY REFERENCE STATIONS (FEATURE 12)

If determined by Metropolitan to be necessary, or required by the BLM Authorized Officer in accordance with the decision-making process described in Section 10, Metropolitan will install up to 10 surveyed reference points for use in conjunction with gravity surveys within the project area (see Figure 5). The gravity method (or gravimetry) is a potential field method based on the principle that density differences in subsurface materials (e.g. between unsaturated sediment and saturated sediment) would cause minute, but measurable, changes in the gravity field. Microgravity surveys would be evaluated for estimating changes in the depth to groundwater in areas where wells have not been installed. If utilized, the microgravity surveys will be calibrated against groundwater levels measured in observation wells. The surveyed reference points will allow comparison of gravity data at the same location during subsequent surveys. Other surveyed features (i.e. wells, land surface elevation benchmarks, etc.) will also be used as reference points for the gravity surveys.

Microgravity surveys, if utilized to evaluate potential impacts, will be conducted annually throughout the term of the Cadiz Project to help assess changes in groundwater levels in areas where no data are available or where access is limited for the installation of observation wells. Reference point locations will be determined from groundwater modeling results during the pre-operational phase of the project.

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[3] InSAR measures changes in the distance between the radar antenna and the land surface with an accuracy of +/- 2 to 4 mm (0.08 to 0.16 inches) (Amelung, et al., 1999).

5.11 FLOWMETER SURVEYS (FEATURE 13)

Downhole flowmeter surveys will be generated in five selected extraction wells. The flowmeter surveys will provide data regarding vertical variation in groundwater flow to the well screens. Depth-specific water quality samples will also be collected to assess vertical variation of groundwater quality in the project wellfield area. Data will be used to help refine geohydrologic parameters regarding layer boundaries used in the groundwater models.

5.12 PROPOSED OBSERVATION WELL CLUSTERS AT BRISTOL DRY LAKE (FEATURE 14)

A total of three new observation well clusters will be installed and monitored in the vicinity of Bristol Dry Lake during the initial phases of the Cadiz Project (see Table 1 and Figure 4). Two well clusters will be located along the eastern margin of Bristol Dry Lake to monitor the effects of project operations on the movement of the fresh water/saline water interface (see Figure 4). One additional well cluster will be installed on the Bristol Dry Lake playa to monitor brine levels and chemistry at different depths beneath the dry lake surface. This well cluster will be positioned in relation to the well clusters at the margin of the dry lake so as to provide optimum data for the density dependent transport model.

5.13 PROPOSED OBSERVATION WELL CLUSTERS AT CADIZ DRY LAKE (FEATURE 15)

Two well clusters will be located along the northern margin of Cadiz Dry Lake to monitor the effects of project operations on the movement of the fresh water/saline water interface in this area (see Figure 4). One additional well cluster will be installed on the Cadiz Dry Lake playa to monitor brine levels and chemistry at different depths beneath the dry lake surface.

5.14 EVAPOTRANSPIRATION STATIONS (FEATURE 16)

Two evapotranspiration (ET) monitoring stations will be established, one each on Bristol and Cadiz dry lakes (see Figure 4). Each station will be instrumented to enable the calculation of evapotranspiration using a turbulent flux (eddy correlation) method. Each station will be capable of measuring ambient air temperature, vertical and horizontal wind speed and direction, humidity, water vapor density, solar radiation, net radiation, soil temperature, soil heat flux, precipitation, and soil water content or soil suction. Each ET station will be equipped with a data logger for data collection and data storage.

5.15 SURFACE WATER MONITORING STATIONS ON THE DRY LAKES (FEATURE 17)

A staff gage will be established at the locations of the ET stations on each of the dry lakes. These staff gages will be established to measure surface water accumulation on the dry lakes from storm runoff. A staff gage will consist of a calibrated measuring rod vertically mounted into the lakebed surface. During periods of storm water runoff and surface water accumulation, continuous monitoring of surface water depth will be obtained on each dry lake.

5.16 AIR QUALITY MONITORING (FEATURE 18)

5.16.1 MONITORING AT BRISTOL AND CADIZ DRY LAKES

This air quality monitoring feature will evaluate wind-mobilized particulate matter from the dry lakebeds. The objective of monitoring is to detect any increases in the frequency of occurrence and magnitude of wind-mobilized particulate matter from the dry lakebeds caused by the project. Because these mobilization events are intermittent, continuous monitoring will be employed in order to most accurately integrate dust mobilization and wind data. A pair of open-air nephelometers (instruments that measure the light scattered by particles in the atmosphere), a digital camera, and an ET station (Feature 16) will be used on each dry lake.

5.16.2 REGIONAL METEOROLOGICAL MONITORING

Beginning in the pre-operational phase of the project and extending into the initial years of the project operational phase, three meteorological towers will be installed in the region for five years to establish patterns of regional wind speed and direction (see Feature 24).

This baseline wind data will be used in conjunction with lakebed data for wind speed and direction and groundwater levels and soil moisture to determine whether (a) the project could contribute to lakebed dust mobilization and (b) if any project-mobilized lakebed dust could be transported throughout the region. This review will consider whether existing dust storms on the dry lakebeds occur simultaneously with regional winds that are capable of transporting lakebed dust beyond the localized lakebed areas. Data collection from any or all of the meteorological towers may be extended if warranted.

5.17 RESISTIVITY SURVEY (FEATURE 19)

If necessary to evaluate potential impacts, resistivity profiles would be conducted at the margins of Bristol and Cadiz dry lakes, to assess the lateral distribution of brine concentrations in the groundwater in this area. Resistivity is a measure of the specific resistance of a material to the flow of electric current (opposite of electrical conductivity). Groundwater resistivity is based on the ion concentration of the water such that the higher the concentration of ions (salts), the lower the resistivity. This principle may be used to map variation in brine concentrations and lithology at selected locations of the margins of Bristol and Cadiz dry lakes using resistivity profiles.

Results from the resistivity profiles could aid in the location of observation well clusters at the margins of Bristol and Cadiz dry lakes and, if deemed necessary, would be conducted during the pre-operational phase of the Cadiz Project.

5.18 GAMMA-RAY/DUAL INDUCTION DOWNHOLE GEOPHYSICAL LOGS (FEATURE 20)

Gamma-ray and dual induction electric logs will be run for the deepest observation wells of each well cluster to be installed at the dry lakes (six total). These downhole geophysical techniques allow for the measurement of groundwater electrical conductivity with depth and could be conducted in observation wells constructed of PVC casing and screen.

Gamma-ray/dual induction geophysical logs will be run as a one-time measurement to be conducted during observation well cluster installation during the pre-operational phase of the Cadiz Project.

5.19 WEATHER STATIONS (FEATURE 21)

Data from three existing weather stations will be collected over the course of the project (see Figures 4 and 5). Existing weather stations include the Mitchell Caverns weather station (located in the Providence Mountains), the project weather station (located in Fenner Gap adjacent to the spreading basins), and the Amboy weather station (located near Bristol Dry Lake in the town of Amboy).

One additional weather station will be established in the higher elevations of the Fenner Watershed (e.g. the Providence or New York Mountains) based on a statistical analysis of regional precipitation patterns from the precipitation stations summarized on Figure 8. The statistical analysis will provide a basis for placement of the new weather station in an area that will provide the most meaningful data for further evaluation of available precipitation. Because potential sites for the new weather station are in the Mojave National Preserve, final site selection and installation would be dependent upon approval from the appropriate agency.

The Mitchell Caverns weather station and new weather stations would provide precipitation, temperature, and other climatic data for the mountain regions of the Fenner watershed, with the new station providing additional control for the highest elevations of the watershed. The Fenner Gap weather station would provide climatic data in the immediate vicinity of the project area. The Amboy weather station would provide climatic data representative of the lowest area of the regional watershed.

5.20 STREAM GAGE (FEATURE 22)

Stream flow in the mountainous areas of the Fenner watershed will initially be monitored using an existing stream gage located in Caruthers Canyon in the New York Mountains near the northerly extent of the watershed (see Figure 4). As more data are collected and the surface water and groundwater flow models are expanded and refined, up to two additional gages may be established in areas identified as critical data gaps (see Figure 4).

5.21 SOIL MOISTURE SENSORS (FEATURE 23)

If necessary to evaluate potential impacts, soil moisture sensors would be installed to monitor infiltration from natural surface water runoff (as during storm events). If utilized, soil moisture sensors would be installed within boreholes drilled at strategic locations near the project area (e.g. Schulyler Wash near Danby). Final location of the infiltration sites, if deemed necessary, would be based on evaluation of aerial photographs, analysis of available storm runoff records in the upper Fenner watershed, preliminary analysis of storm runoff routing from the revised rainfall runoff model, field reconnaissance, and permission for physical access to the monitoring sites.

If utilized, soil moisture sensors would be installed in the unsaturated zone to measure surface water infiltration below the root zone of plants. Soil cores would be collected at selected intervals during drilling and logged according to the USCS standards. Selected soil samples would be analyzed for physical parameters of relative permeability, water characteristic curves, porosity, and bulk density. Other samples would be analyzed for moisture content, water potential, chloride, and tritium.

5.22 METEOROLOGICAL TOWERS (FEATURE 24)

In addition to the four weather stations (Feature 21), three 10-meter-tall meteorological towers with wind instrumentation will be installed in the region to establish patterns of regional wind direction and speed. Instruments on each tower will include an anemometer, wind vane, and data acquisition system. The meteorological towers will be located throughout the region to determine where dust emissions from Bristol and Cadiz dry lakebeds could be transported. Conceptual locations for the towers are (1) in the vicinity of Orange Blossom Wash, (2) in the vicinity of the S-series observation well at Danby, and (3) in the unnamed valley between the Sheephole and Calumet Mountains and between Bristol Dry Lake and the northern boundary of Joshua Tree National Park (see Figure 3). These locations will be refined or revised, as appropriate. The meteorological towers will be installed in the pre-operational phase of the Cadiz Project and will operate for a period of five years. Data collection for any or all of the

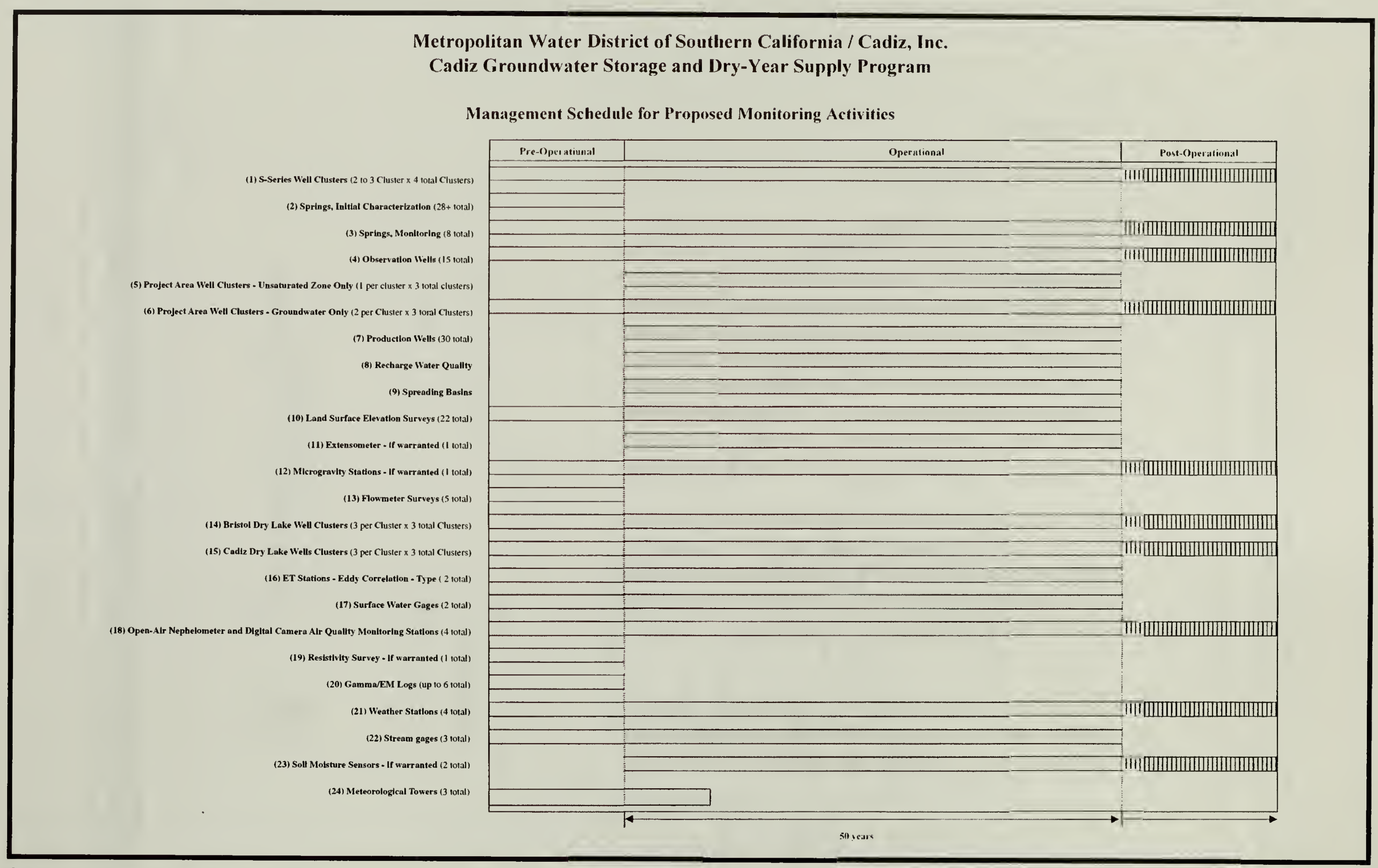
Figure 8

Cadiz Groundwater Storage & Dry-Year Supply Program

Groundwater Monitoring and Management Plan

Location of Precipitation Stations in the Desert Southwest Region meteorological towers may be extended if determined by Metropolitan to be necessary or required by the BLM Authorized Officer in accordance with the decision-making process described in Section 10.

For an implementation schedule of these 24 monitoring features, see Figure 9.



Source: P&D Consultants, Inc. (1999).

Figure 9

Cadiz Groundwater Storage & Dry-Year Supply Program

Groundwater Monitoring and Management Plan

Management Schedule for Proposed Monitoring Activities

SECTION 6

SECTION 6
MONITORING, TESTING AND REPORTING PROCEDURES

General and specific monitoring features, which are described in the context of critical resources in Tables 1 and 2, will be monitored at varying frequencies during three project phases: pre-operational, operational, and post-operational. It is the intent of Metropolitan that facilities for monitoring will be installed during the pre-operational phase, concurrent with construction of facilities for project operations. The pre-operational phase will commence upon final BLM approval of the Record of Decision for the Cadiz Project and Metropolitan's receipt of necessary grant(s) of right-of-way required to construct the project facilities. The pre-operational phase will last a minimum of 15 months and maximum of 24 months. Monitoring of existing wells identified in Section 5.3 will be commenced as soon as practicable prior to the operational phase to collect important baseline data regarding groundwater levels. Refinements to the monitoring network will be evaluated in accordance with the decision-making process for proposed changes to the Management Plan described in Section 10.

6.1 MONITORING OF SPRINGS ON MOJAVE NATIONAL PRESERVE AND BLM-MANAGED LANDS IN THE AFFECTED WATERSHEDS

6.1.1 PRE-OPERATIONAL MONITORING OF SPRINGS

During the pre-operational phase of the monitoring period, 28 springs will be characterized and approximately eight springs will be selected for ongoing monitoring during the term of the Cadiz Project. In addition, the S-Series wells will be installed and monitored.

Groundwater Levels in the S-Series Wells (Feature 1)

During the pre-operational phase, groundwater levels will be monitored in the S-Series observation wells on a continuous basis using downhole electronic pressure transducers, compensated for atmospheric pressure. Pressure transducers will be installed below the water table within the wells and record relative differences in head pressure above the transducer setting on a regular basis. Head pressures will be converted to water level data and stored in data loggers at each well site.

Springs (Features 2 and 3)

During the pre-operational phase, field reconnaissance will be conducted of 28 known springs in the Fenner and Orange Blossom Wash watersheds. Each of these springs will be classified based on discharge rate in accordance with the following criteria as specified by Meinzer (1942), as shown in Table 3.

TABLE 3
SPRING CLASSIFICATION CRITERIA

Magnitude	Discharge
First	100 cubic feet per second (cfs) or more
Second	10 to 100 cfs
Third	1 to 10 cfs
Fourth	100 gallons per minute (gpm) to 1 cfs
Fifth	10 to 100 gpm
Sixth	1 to 10 gpm
Seventh	1 pint per minute to 1 gpm
Eighth	Less than 1 pint per minute

Data to be collected and recorded at each spring will include:

- GPS coordinates
- Spring Type
- Geology of Immediate Surroundings
- Vegetation Type and Cover
- Flow Rate and/or Water Level in Associated Shallow Piezometer
- Temperature, Electrical Conductivity, and pH

All data will be recorded on standardized field data collection forms. Photographs of each spring will be taken to document pre-operational physical conditions.

- Based on the initial field reconnaissance, approximately eight springs will be identified for monitoring.
- Two springs will be monitored continuously during the pre-operational and operational phases of the Cadiz Project using small diameter (3/4- to 1-inch diameter) PVC piezometers installed in the immediate vicinity of the selected springs. The piezometers will be hand-driven to a point of refusal or a depth of 10 feet below the water table. Each piezometer casing will be screened from the total depth to the ground surface. The piezometers will be equipped with downhole pressure transducers for measuring relative changes in hydraulic head near the spring.
- The remaining springs will be monitored semi-annually during the rest of the pre-operational phase, and throughout the term of the project. The adequacy of the monitoring frequency will be reevaluated as needed.
- During the pre-operational monitoring, water quality samples from the approximately eight selected springs on a semi-annual basis will be collected and analyzed for general mineral and physical parameters, tritium/He^3, chlorofluorocarbons, and stable isotopes of hydrogen and oxygen to help determine the age and source of water from the springs (see Table D-2 in Appendix D for specific constituents). All samples will be collected in laboratory prepared containers and submitted to a State-certified analytical laboratory or other qualified laboratory for analysis according to the protocols described in Appendices C and D.

6.1.2 OPERATIONAL MONITORING OF SPRINGS

During the operational phase, groundwater levels will be monitored in the S-Series observation wells on a continuous basis using downhole electronic pressure transducers, compensated for atmospheric pressure.

Spring flow and spring water parameters (temperature, electrical conductivity, and pH) in six of the approximately eight springs selected will be monitored in the field on a semi-annual basis throughout the term of the Cadiz Project. Water levels measured in piezometers in the immediate vicinity of two of the approximately eight springs will be monitored continuously using downhole pressure transducers. Metropolitan will reevaluate spring monitoring frequency as needed.

6.1.3 POST-OPERATIONAL MONITORING OF SPRINGS

During the post-operational phase, groundwater levels will be monitored in the S-Series observation wells on a continuous basis using downhole electronic pressure transducers, compensated for atmospheric pressure.

Spring flow and spring water parameters (temperature, electrical conductivity, and pH) will be monitored in the field in six of the approximately eight springs selected on a semi-annual basis during the post-operational monitoring period until it is no longer warranted. Water levels measured in piezometers in the immediate vicinity of two of the approximately eight springs will be monitored continuously using downhole pressure transducers during the post-operational period until it is no longer warranted. Metropolitan will reevaluate spring monitoring frequency as needed.

6.2 AQUIFER SYSTEM

6.2.1 PRE-OPERATIONAL MONITORING AQUIFER SYSTEM

Groundwater Levels

During the pre-operational monitoring period, static groundwater levels will be monitored on a monthly basis in each of the observation wells identified as Feature 4 in Tables 1 and 2. Monthly groundwater level monitoring will begin upon project approval by Metropolitan and the BLM. Groundwater levels will be measured in accordance with the monitoring procedure presented in Appendix B.

Groundwater levels in the cluster wells that were screened below the static water table will be monitored continuously during the pre-operational phase of the Cadiz Project using downhole pressure transducers. Monitoring will begin immediately upon completion of installation and development of the cluster wells.

The initial project monitoring well network will be supplemented, if necessary to evaluate potential impacts, with a network of microgravity stations located in the immediate project vicinity (Feature 12). The microgravity stations are intended to measure changes in the depth to groundwater by identifying subsurface density differences. Such microgravity data will be used in conjunction with water levels measured in observation wells.

Groundwater Quality

Groundwater samples will be collected on a quarterly basis from five of the 15 wells specified as Feature 4 in Tables 1 and 2 during the pre-operational phase of the Cadiz Project. Groundwater samples will be collected on a quarterly basis from wells within each project area well cluster that are screened below the static groundwater level (Feature 6). It is important that samples collected to test for groundwater quality are representative of the aquifer groundwater. This implies that the wells are properly developed in order that the sampling obtains representative samples of aquifer ground-water quality. If this cannot be achieved, then alternative sampling will be conducted and may include production wells already equipped with deep well pumps.

Groundwater samples will be collected from the remaining 10 observation wells on an annual basis. All samples would be collected according to the protocol described in Appendix C. Field parameters such as groundwater temperature, pH, electrical conductivity, and total dissolved solids (TDS) will be collected at each well during well purging and prior to sampling. Samples from each well will be analyzed for the general mineral and physical parameters specified in Appendix D. In addition, all samples collected during the pre-operational phase will also be analyzed for bromide, boron, iodide barium, arsenic, nitrate, and perchlorate. The sample analytical protocol is presented in Appendix D.

Subsidence

All benchmarks will be established and surveyed on an annual basis by a California licensed land surveyor. Horizontal and vertical accuracy will be established in accordance with a second order Class I survey standard (1:50,000). If determined by Metropolitan to be necessary, or required by the BLM Authorized Officer in accordance with the decision-making process described in Section 10, InSAR satellite data will be obtained during two different seasons during the pre-operational monitoring period and evaluated for use to supplement the land survey data.

Downhole Flowmeter (Spinner), Water Quality and Temperature Surveys

Downhole flowmeter surveys will be conducted in five selected extraction wells. Depth-specific water quality samples will also be collected at the time of the flowmeter surveys. Samples collected for water quality will be analyzed for general mineral and physical parameters: chloride, bromide, boron, iodide, barium, stable isotopes of oxygen and deuterium, tritium and isotopes of carbon. Vertical temperature surveys will be conducted on two of the existing extraction wells, at each cluster well location along the margins of the dry lakes,[1] and one upgradient observation well. The temperature surveys, in conjunction with field-measured temperature readings on observation wells, will be used to generate a depth-specific isotherm map of the project area.

6.2.2 OPERATIONAL MONITORING OF AQUIFER SYSTEM

Groundwater Level Monitoring Procedures

Groundwater levels will be monitored on an annual basis and on a monthly basis for the first three months after start-up and shut-down of each recharge and extraction cycle in each of the observation wells identified as Feature 4 in Tables 1 and 2. In addition, continuous monitoring will be implemented on Well T6N/R15E-29Q1, shown on Figure 5, and another well to be selected. Groundwater levels will be measured in accordance with the monitoring procedure presented in Appendix B.

Microgravity surveys may be conducted on an annual basis during the operational phase to compare groundwater levels with previous surveys.

Groundwater Quality Monitoring Procedures

During the operational phase, groundwater samples will be collected on an annual basis from the observation wells specified in Table 2. All samples will be collected according to the groundwater sampling and analytical protocols specified for the operational phase of the Cadiz Project in Appendices C and D. Results of water quality analyses will be summarized in tables in the annual report. Measurement of vertical temperature profiles may also be performed on a periodic basis in selected wells.

Groundwater Production Monitoring

Data from the wellfield (project wells and Cadiz agricultural wells) will be collected to provide information on the groundwater levels and discharge rates. Production data from the project wells will be verified using totaled readings of flow at the Iron Mountain Pumping Plant.

Recharge Water Quality (Inflow to Spreading Basins)

During storage operations, deliveries of Colorado River water to the project spreading basins will be sampled at Lake Havasu. Water quality samples will be collected and analyzed on a weekly basis by Metropolitan. Annually collected samples of Colorado River water will be analyzed for a full suite of Title 22 analyses (see Appendix D).

Spreading Basins

All spreading activities will be monitored with periodic site visits for inspection and maintenance. Notes regarding spreading basin berm conditions, berm leakage, siltation, algal growth, and other observations

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1 At each cluster well location the deepest well will be surveyed.

will be recorded. Spreading basins will be inspected monthly during storage cycles of the Cadiz Project. During recharge operations the depth of surface water in the spreading basins will be measured on a regular basis using graduated staff gages located within each respective subbasin.

Subsidence Monitoring

A State of California licensed land surveyor would annually survey the benchmark network. Results will be included, along with any available InSAR satellite results and comparisons, in the annual report.

6.2.3 POST-OPERATIONAL MONITORING OF AQUIFER SYSTEM

During the post-operational phase of the Cadiz Project, groundwater levels will be monitored on a continuous basis in the project well clusters screened beneath the static groundwater level (Feature 6) until no longer necessary to evaluate potential impacts, and annually in the 15 observation wells (Feature 4) located in the project area. Metropolitan will reevaluate groundwater level monitoring frequency. Microgravity surveys would also be conducted as necessary to evaluate potential impacts, during the post-operational monitoring period to supplement the observation well data. Water quality samples will be collected on an annual basis during the post-operational phase.

6.3 BRISTOL AND CADIZ DRY LAKES

6.3.1 PRE-OPERATIONAL MONITORING OF BRISTOL AND CADIZ DRY LAKES

Groundwater Levels

During the pre-operational phase, static groundwater levels will be monitored on a continuous basis from each well cluster (Features 14 and 15) using downhole pressure transducers. Monitoring will begin immediately following well installation and development.

Data will be obtained documenting the initial depth to groundwater and soil moisture within this continuous soil column between the groundwater level and the lakebed surfaces during installation of well clusters at Bristol and Cadiz dry lake margins and on the dry lakes (Features 14 and 15).

Groundwater Quality

Groundwater samples will be collected on a quarterly basis from the dry lake well clusters (Features 14 and 15) after well installation but prior to startup of the Cadiz Project. All samples will be collected according to the protocol described in Appendix C. Field parameters such as groundwater temperature, pH, electrical conductivity, and total dissolved solids will be collected at each well during well purging and prior to sampling. Samples from each well will be analyzed for the general mineral and physical parameters specified in Appendix D. Samples from selected wells will also be analyzed for bromide, arsenic, nitrate, and perchlorate. The sample analytical protocol is presented in Appendix D.

Geophysical Surveys

A resistivity survey will be conducted along the margins of Bristol and Cadiz dry lakes to aid in the location of well clusters in this area.

Gamma ray and dual induction electric logs will be run for the deepest observation wells of each well cluster to be installed at the dry lakes (up to six total). Downhole geophysical logging will be conducted after the deep wells are installed.

6.3.2 OPERATIONAL MONITORING OF BRISTOL AND CADIZ DRY LAKES

Groundwater Levels

During the operational phase, static groundwater levels will be monitored on a continuous basis from each well cluster (Features 14 and 15) using downhole pressure transducers.

Groundwater Quality

Groundwater samples will be collected on a semi-annual basis from the dry lake well clusters (Features 14 and 15) over the term of the Cadiz Project. All samples will be collected according to the protocol described in Appendix C. Field parameters such as groundwater temperature, pH, electrical conductivity, and total dissolved solids will be collected at each well during well purging and prior to sampling. Samples from each well will be analyzed for the general mineral and physical parameters specified in Appendix D. The sample analytical protocol is presented in Appendix D.

Evapotranspiration

Evapotranspiration monitoring stations, located on Bristol and Cadiz dry lakes, will record ambient air temperature, vertical and horizontal wind speed and direction, humidity, water vapor density, solar radiation, net radiation, soil temperature, soil heat flux and soil water content or soil suction on an hourly basis.

Surface Water

During periods of flooding, measurements of surface water depth data will be obtained from automated instrumentation backed up by manual readings of the staff gages on each dry lake, as needed.

Geophysical Surveys

If determined by Metropolitan to be necessary, or required by the BLM Authorized Officer in accordance with the decision-making process described in Section 10, Metropolitan will run gamma ray and dual induction electric logs on an annual basis for the deepest observation wells of each well cluster to be installed at the dry lakes (up to six total). Downhole geophysical logging will be conducted after the deep wells are installed.

6.3.3 POST-OPERATIONAL MONITORING OF BRISTOL AND CADIZ DRY LAKES

Groundwater Levels

During the post-operational phase, static groundwater levels will continue to be monitored on a continuous basis from each well cluster (Features 14 and 15) using downhole pressure transducers. The necessity of continuing the groundwater level monitoring will be reevaluated by Metropolitan on an ongoing basis.

Groundwater Quality

Groundwater samples will be collected on an annual basis from the dry lake well clusters (Features 14 and 15) during the post-operational phase of the Cadiz Project. All samples will be collected according to the protocol described in Appendix C. The necessity of continuing groundwater quality monitoring will be reevaluated by Metropolitan on an ongoing basis.

6.4 AIR QUALITY

6.4.1 PRE-OPERATIONAL AIR QUALITY AND RELATED MONITORING

During the pre-operational phase, air quality monitoring will consist of gathering baseline data with respect to (1) groundwater between the project area and the dry lakebeds, at the lakebed margins and on the dry lakebeds, (2) surface soil moisture at the dry lakebeds, and (3) ET, air temperature and wind velocity and direction on the dry lakebeds. Open-air nephelometers and automated digital cameras will be installed at the dry lakebeds to collect data on ambient dust mobilization from the dry lakebeds. Additionally, data will be collected with the installation of the well clusters on the lakebed margins and within the dry lakebeds establishing initial depth to groundwater and a soil moisture profile between the groundwater and surface of the dry lakebeds. In the case that the baseline data (monitoring, modeling, and/or statistical analyses) alters the understanding of the relationship between groundwater levels and dust mobilization from the dry lakebeds, the groundwater level action criteria for air quality may be modified.

Additionally, three 10-meter-tall meteorological towers with wind instrumentation will be installed in the region to establish patterns of regional wind speed and direction. Instruments on each tower will include an anemometer, wind vane, and data acquisition system. Conceptual locations for the towers are (1) in the vicinity of Orange Blossom Wash north of Bristol Dry Lake, (2) in the vicinity of the S-series observation well at Danby, and (3) in the unnamed valley between the Sheephole and Calumet Mountains and between Bristol Dry Lake and the northern boundary of Joshua Tree National Park (see Figure 3). These locations will be refined or revised, as appropriate, and will operate for a period of five years. Data collection for any or all of the meteorological towers may be extended if determined by Metropolitan to be necessary, or required by the BLM Authorized Officer in accordance with the decision-making process described in Section 10.

The purpose of the air quality monitoring is to anticipate, avoid, and confirm avoidance of the potential effects, if any, of project operations on air quality due to the mobilization of wind-blown dust on Bristol or Cadiz dry lakes. Information will be collected from a broad spectrum of monitoring features as described here.

Well Clusters

Well clusters will provide information regarding the natural moisture content of the soil above the groundwater surface as well as groundwater level information for different depth-specific zones beneath the dry lakes. Groundwater levels in the wells will be monitored as described in Section 6.3.

Evapotranspiration Stations

Evapotranspiration monitoring stations, located on Bristol and Cadiz dry lakes, will record ambient air temperature, vertical and horizontal wind speed and direction, humidity, water vapor density, solar radiation, net radiation, soil temperature, soil heat flux, precipitation and soil water content or soil suction on an hourly basis.

Evapotranspiration stations will be installed in the immediate vicinity of the well clusters on the dry lakes (see Section 5.3.3). The evapotranspiration stations will be equipped with instrumentation to monitor soil water content and soil suction on an hourly basis throughout the term of the project. Soil moisture data collected from the evapotranspiration stations during the pre-operational phase of the project, in conjunction with soil moisture analyses from continuous core samples collected during drilling, will provide a baseline soil moisture condition with which to compare data collected during the operational phase of the project. Soil moisture data will be evaluated in the context of measured groundwater levels to establish a relationship between changes in groundwater levels, soil moisture content, and potential for dust mobilization.

Surface Water Staff Gages

During periods of flooding, continuous monitoring of surface water depth will be obtained on each dry lake. Staff gages will be established at each evapotranspiration station to measure surface water accumulation on the dry lakes as a result of storm runoff (see Feature 17). Surface water effects on soil moisture and shallow groundwater levels will be evaluated to distinguish natural conditions from those attributable to project operations.

Open-Air Nephelometers and Digital Cameras

This air quality monitoring feature will detect wind-mobilized particulate matter from the dry lakebeds with the objective of detecting any increases in this wind-mobilized particulate matter due to project operations. Because this particulate matter is mobilized by wind storms and is intermittent, continuous monitoring will be employed using open-air nephelometers, which measure the light scattered by particles in the atmosphere. An automated digital camera will be installed in conjunction with each pair of nephelometers to further document dust mobilization events. This monitoring will allow comparison of wind velocity data to short-term increases in dust mobilization.

Weather Stations and Analysis of Air Quality and Related Data

Meteorological and other data collected as part of the groundwater monitoring program will be evaluated to identify the wind speeds and directions that lead to high emissions of wind-mobilized particulate matter. Both theory and measurements indicate that wind-mobilized particulate matter does not occur until the wind speed exceeds a threshold velocity and depend on characteristics of the surface, such as moisture content, surface particle size, presence of crusts, vegetative cover, etc. (Fugitive Dust Expert Panel Workshop Final Report, Western Regional Air Partnership, April 2001) Therefore, a decrease in the threshold wind speed associated with wind-mobilized particulate matter would be expected to occur if project operations cause changes in the lakebed surface characteristics that lead to an increase in wind-mobilized particulate matter. A variety of statistical analyses will be used to establish the threshold wind speeds associated with wind-mobilized particulate matter. The analyses will also include factors that could affect surface characteristics, such as precipitation, storm flow run-on and surface moisture. These analyses will be performed separately for data collected during pre-operational and operational monitoring to attempt to detect any statistically significant reductions in threshold wind speed. If statistically significant differences are identified, additional data, such as groundwater levels at the edges of the lakes, will be evaluated to help determine if the differences could have been caused by the project's operations.

The analyses used to establish these relationships will be based on data collected to develop an understanding of the behavior of wind-mobilized particulate matter from Bristol and Cadiz dry lakes. The following approaches are anticipated to be used for data collected during the pre-operational monitoring:

1. Examination of joint frequency distributions of wind speed and direction to determine if elevated wind speeds are associated with specific wind directions. These analyses would utilize short-term (e.g. five minute) average values, because wind gusts are more likely than longer-term average wind speeds to lead to particulate matter.
2. Examination of joint frequency distributions of wind speed and the standard deviation of wind direction to determine the variability of wind direction during higher wind speed periods. This information will be used to refine the siting of the upwind and downwind nephelometers.
3. Examination of histograms of the difference between the downwind and upwind nephelometer readings to determine the frequency of occurrence of wind-mobilized particulate matter.
4. Examination of the scatter plots of the difference between the downwind and upwind nephelometer readings to evaluate the relationships between wind speed and the onset of wind-mobilized particulate matter. Because the threshold wind speed is affected by surface characteristics, the data will be stratified by various other data, including soil moisture and the time since the last occurrence of precipitation. The objective of these analyses will be to establish the threshold wind speeds.

These analyses will be performed separately by season of the year to reduce the variability caused by seasonal differences in wind speeds and directions and in precipitation. At least one year of data is anticipated to be needed to establish the baseline threshold wind speeds associated with wind-mobilized particulate matter. Because of natural year-to-year variability, additional data will be used to further refine the analysis. In particular, additional data beyond the first year is expected to improve the estimates of threshold wind speeds.

Metropolitan will gather data and perform a quarterly analysis of air quality data during the first year of the pre-operational phase. Gathered data will be made available on a quarterly basis. The results of the analyses will be included in the annual report prepared for the Management Plan.

Spreading Basins

Metropolitan will install and operate digital cameras at the spreading basins during the pre-operational phase of the project in order to monitor the surface conditions of the spreading basins. This monitoring will continue throughout the operational and post-operational phases of the project. A monitoring and mitigation plan for the spreading basins, including a reporting mechanism, must be submitted and approved by the BLM Authorized Officer prior to installing and operating monitors at the spreading basins. The BLM Authorized Officer will consult with the TRP upon receipt of the spreading basin monitoring and mitigation plan to determine the adequacy of the plan with repect to protection of critical resources. If warranted, based on physical inspection of the spreading basins or digital images, appropriate mitigation measures will be implemented, including but not necessarily limited to application of a soil binder.

6.4.2 OPERATIONAL AIR QUALITY MONITORING

All air quality monitoring activities would continue on an ongoing basis, unless otherwise determined.

The analyses of the pre-operational monitoring data described above will be refined using the data from the operational monitoring. Threshold wind speeds for dust-mobilized particulate matter derived from data gathered during the operational monitoring will be compared with threshold wind speeds derived from data gathered during pre-operational monitoring to determine if statistically significant decreases occur.

Modifications of the air quality action criteria may be implemented should monitoring, modeling, and/or statistical analyses indicate it is appropriate to do so (see Section 9.2).

6.4.3 POST-OPERATIONAL AIR QUALITY MONITORING STATIONS

During the post-operational phase of the project, the nephelometers and digital cameras will continue to monitor airborne particulate matter on Bristol and Cadiz dry lakes. This information will be correlated with groundwater levels, wind velocities, and lakebed soil moisture. This air quality monitoring will be conducted for the same duration as groundwater level monitoring at the margins of Bristol and Cadiz dry lakes.

Weather Stations

During the post-operational phase of the project, wind direction and velocity and ET will continue to be monitored on Bristol and Cadiz dry lakes. This information will be correlated with nephelometer readings, groundwater levels, and lakebed soil moisture. This weather station monitoring will be conducted for the same duration as groundwater level monitoring at the margins of Bristol and Cadiz dry lakes.

Soil Moisture Sensors

During the post-operational phase of the project, soil moisture will continue to be monitored on Bristol and Cadiz dry lakes. This information will be correlated with nephelometer readings, groundwater levels, and wind velocities. This soil moisture monitoring will be conducted for the same duration as groundwater level monitoring at the margins of Bristol and Cadiz dry lakes.

Spreading Basins

During the post-operational phase of the project, the digital cameras will continue to monitor the surface conditions of the spreading basins.

6.5 OTHER MONITORING (REGIONAL)

6.5.1 PRE-OPERATIONAL REGIONAL MONITORING

Climatological Monitoring

Climatological monitoring will be undertaken during the pre-operational phase of the project utilizing the four weather stations. Data to be collected at the Mitchell Caverns and Amboy stations will include ambient air temperature, evaporation, and precipitation (including snow accumulation). Data to be collected at the Fenner Gap and a new weather station will include ambient air temperature, evaporation, precipitation, wind speed and direction, barometric pressure, relative humidity, and soil temperature. In addition, each weather station will be equipped with precipitation collectors to be used for chemical analyses. Data from the Mitchell Caverns and Amboy stations will be obtained in electronic form on a yearly basis from the San Bernardino County Flood Control District. Data from the Fenner Gap and new weather stations will be continuously recorded.

The project weather station will include a fresh water evaporation pan that is set up in accordance with National Weather Bureau standards. Water levels within this pan will be generally maintained between four and eight inches. Pan water levels will be measured using three internal gages located 120 degrees from each other. The pan water level will be measured on a monthly basis as the average of the three gages.

Surface Water Flow

An existing stream gage located in Caruthers Canyon in the New York Mountains will be utilized to monitor stream flow in the higher elevations of the watershed. The gage site will be inspected in the field to assess:

- Hydraulic Control (in an area where the stage discharge relationship is constant and measurable);
- Channel Geometry (well established single flowing channel that is relatively straight and doesn't meander); and
- Local Tributary Inflow.

If warranted, two additional stream gage locations would be identified as a result of additional rainfall/runoff modeling. Each new gage would be constructed and monitored in accordance with Rantz et al., 1982 (Appendix B) and the United States Geological Survey's *Surface Water Quality Assurance Plan for the California District of the United States Geological Survey* (Meyer, 1996).

Infiltration Monitoring

If necessary, subsurface soil moisture sensors installed in boreholes strategically located in major washes and nearby terraces would record soil moisture on a daily basis unless otherwise determined. If feasible, the soil moisture sensor boreholes would be positioned to correspond to stream gage locations so surface water runoff/infiltration relationships in the sandy-bottomed washes can be quantified.

6.5.2 OPERATIONAL REGIONAL MONITORING

Climatological Monitoring

Climatological data will be collected throughout the term of the Cadiz Project using the weather stations and procedures described in Section 6.4. Meteorological towers to collect wind data will continue to operate in the early years of the operational phase, and will conclude after five years of data collection. Data collection from any or all of the meteorological towers may be extended if determined by Metropolitan to be necessary, or required by the BLM Authorized Officer in accordance with the decision-making process described in Section 10.

Stream Gage Monitoring

Surface water flow at the Caruthers Canyon stream gage will be downloaded periodically from the United States Geological Survey website. Surface water flow at this gage is recorded on a continuous basis. Surface water data will be tabulated and summarized in the annual reports. Stream flow data from any newly installed gages will also be recorded on a daily basis.

Infiltration Monitoring

If soil moisture sensors are utilized, subsurface soil moisture beneath the washes selected during the pre-operational phase would be monitored as described in Section 6.5.1.

6.6 QUALITY ASSURANCE/QUALITY CONTROL

For this project, quality assurance (QA) is defined as the integrated approach designed to assure reliability of monitoring and measurement data. Quality control (QC) is defined as the routine application of specified procedures to obtain prescribed standards of performance in the monitoring and measurement process (ASTM D-18). Metropolitan will be responsible for assuring that the precision, accuracy, and completeness of data collected during the project are known and documented.

All groundwater samples collected during the pre-operational and operational phases will be placed in laboratory-prepared sample containers and properly labeled, packaged and preserved, prior to submittal to the laboratory. All groundwater samples will be submitted to the laboratory under chain-of-custody protocol within 24 hours of collection.

All analytical work will be conducted by a State of California certified analytical laboratory. Laboratory calibration procedures will be conducted in accordance with approved Environmental Protection Agency (EPA) guidelines and the recommendations promulgated in Title 21 of the Code of Federal Regulations Part 58 "Good Laboratory Practices" (see Appendix D). All groundwater samples will be analyzed in accordance with standard EPA or ASTM methods.

QA/QC reports from the laboratory will be provided with the analytical reports and included with the annual reports. All data will be validated with respect to accuracy, precision, and completeness to ensure that they are representative of actual field conditions.

Use of the nephelometers will follow protocols to be developed that will include procedures for routine operational checks, calibrations and data validation. The instrumentation on the meteorological towers will be calibrated using guidelines set forth in the EPA *Quality Assurance Handbook for Air Pollution Measurement Systems, Vol. IV: Meteorological Measurements*, March 1995.

6.7 DATA MANAGEMENT

During the course of the Cadiz Project, a large amount of data will be collected, stored, processed, analyzed, tabulated, and presented in annual reports. Detailed procedures for the management of the project database are presented in Appendix E.

6.8 REPORTING PROCEDURES

Annual reports summarizing all monitoring data will be prepared as described below. The annual report will include a refinement of the basin parameters, monitoring data, and input and output from refined groundwater models. The BLM Authorized Officer may require preparation of other reports as necessary, such as a baseline conditions report or a pre-operational report.

6.8.1 ANNUAL REPORTS

Baseline groundwater level and groundwater quality conditions will be established for comparison with the data compiled for each annual report. Historical records, pre-dating Cadiz Project operations, will be used to establish baseline conditions whenever feasible. The results of the first land survey and any initial InSAR data obtained will serve as the baseline condition for annual comparison.

The pre-operational phase and initial years of the operational phase will be used to collect baseline air quality dust mobilization data on Bristol and Cadiz dry lakes, and to establish patterns of regional wind speed and direction. The dust emissions data from the dry lakebeds will be used to establish a baseline for future evaluations of project effects, as described in Section 6.4.1. The regional wind data will be used to determine if any project mobilized dust could be transported throughout the Mojave Desert region.

Metropolitan will be responsible for preparation of the annual reports beginning one year after commencement of project construction, which will contain the following components:

- Baseline water level and water quality conditions (to be defined in the first annual report). Presentation of baseline conditions will include water level elevation contours, water quality contours, and a figure showing the results of the initial land survey;
- Tables summarizing groundwater production for each project extraction well;
- Tables summarizing depth to static water level and groundwater elevation measurements for all observation wells;
- Inventory of springs;
- Hydrographs for all observation wells;
- Groundwater elevation contours;
- Tables summarizing water quality analyses for the observation wells;
- Results of land subsidence monitoring surveys and any changes relative to baseline;
- Summary tables of any data collected from wells owned by neighboring landowners in proximity to the project area (provided that permission was granted for such data collection);
- Summary of project developments, such as changes in storage or extraction operations or construction of new production wells;
- Discussion of project storage and extraction operations, and trends in groundwater levels and groundwater quality as compared to the baseline conditions;
- Updated groundwater flow and quality model results;
- Tables summarizing changes in frequency and severity of dust mobilization recorded on Bristol and Cadiz dry lakes and analysis correlating dust emissions with wind speed and direction, groundwater levels underlying the dry lakebeds, and soil moisture on the lakebed surfaces;
- Tables and figures (wind roses) summarizing wind data from regional meteorological towers addressing wind speed and direction, and stability frequency distributions. This data would be collected for five years. Data collection for any or all of the meteorological towers may be extended if required by the BLM Authorized Officer.
- Summary of Metropolitan's assessments, proposed refinements to the Management Plan, and corrective measures.

All annual reports will include electronic data files and model input and output files. The annual reports will be available to agencies, organizations, interest groups and the general public upon request from Metropolitan. The annual reports will be distributed to the lead and cooperating federal agencies, San Bernardino County, and made available to the public electronically.

6.8.2 FIVE-YEAR REPORT

Metropolitan will prepare a five-year report five years from commencement of construction, which will contain the following components in addition to the components of previous annual reports:

- Summary of total project storage and extraction operations;
- Documentation of any trends in groundwater levels evident from the monitoring data;
- Documentation of any trends in water quality measurements evident from the monitoring data;

- Contours of the most recent static groundwater level elevations and groundwater level elevation changes over the previous five years;
- Documentation of any impacts to wells owned by neighboring landowners (provided that permission was granted to monitor such wells);
- Tables summarizing changes in frequency and magnitude (to the extent that can be determined from the data) of dust mobilization recorded on Bristol and Cadiz dry lakes and analysis correlating wind-mobilized particulate matter with wind speed and direction, groundwater levels underlying the dry lakebeds, and soil moisture on the lakebed surfaces; and
- Summary of regional wind data (in the first five-year report, and subsequent reports as applicable) with conclusions for potential for project-mobilized lakebed dust to be transported throughout the Mojave Desert region.

As part of the evaluation of the hydrogeology of the project area, the five-year report will also include:

- Hydrogeologic analysis and interpretation of all project storage and extraction operations during the five-year period;
- Hydrogeologic analysis and interpretation of all water level elevation, water quality, and land survey data collected during the five-year period;
- Results of refined model output from the rainfall-runoff model, unsaturated and saturated groundwater flow and solute transport models, the density dependent groundwater flow model and the solute transport model;
- Detailed evaluation of impacts (if any) of project operations on surface or groundwater resources;
- Proposed refinements to the Management Plan to address any identified inadequacies; and
- Summary of project operations designed to prevent declines in static groundwater levels in excess of 100 feet from pre-operational levels at the end of project operations or lead to projections of adverse impacts to critical resources during or after the post-operational phase.

All five-year reports will include electronic data files and model input and output files. The annual reports will be available to agencies, organizations, interest groups and the general public upon request from Metropolitan. The five-year report will be distributed to the lead and cooperating federal agencies, San Bernardino County, and made available to the public electronically.

SECTION 7

SECTION 7
ACTION CRITERIA, DECISION-MAKING PROCESS AND CORRECTIVE MEASURES

This Management Plan identifies specific quantitative criteria (action criteria) that will "trigger" review to determine whether the measured change is attributable to the project operations[5], and if so, which specific corrective measures would be implemented to avoid adverse impacts to critical resources. It is the intent of this Management Plan to identify deviations from natural conditions at monitoring features as early as possible in order to identify and prevent the occurrence of adverse impacts to critical resources as a result of project operations. A decision-making process has been developed, which outlines the process to be followed in the event that an action criterion is exceeded or when BLM considers refinements to the Management Plan. Finally, potential corrective measures to be implemented, if appropriate, are identified. Critical resources, action criteria, the decision-making process, and potential corrective measures are discussed below and summarized in Table 4.

The initial action criteria and corrective measures presented in this Management Plan are considered conservative and may be refined throughout the term of the Cadiz Project. Metropolitan would have the discretion to propose refinements to the action criteria and monitoring network. However, any such refinement would occur in accordance with the terms of this Management Plan. If Metropolitan proposes a refinement to action criteria or monitoring features, it will submit a written proposal describing the refinement along with supporting data and materials to the BLM Authorized Officer. The BLM Authorized Officer will make a decision regarding the proposed refinement in accordance with the decision-making process described in Section 10. Action criteria are intended to be used as predictors of potential impacts to critical resources, and exceedance of these criteria does not necessarily constitute an impact to critical resources. The water resources models and air quality analysis methodologies developed during the pre-operational and operational phases of the project will be used, in conjunction with measured data, to evaluate and refine action criteria and the monitoring network.

The decision-making process followed in this Management Plan, if an action criterion is exceeded or when BLM considers refinements to the Management Plan, is illustrated in Figure 10 and described in detail as follows. If an action criterion (defined in Sections 7.1 through 7.4) were exceeded, the decision-making process would be initiated. Metropolitan will promptly inform the BLM Authorized Officer that an action criterion has been exceeded. The BLM Authorized Officer will then inform the TRP that an action criterion has been exceeded.

Metropolitan will make an assessment to determine whether the measured change is attributable to project operations. If Metropolitan determines that the change is not attributable to project operations, it would make no change to project operations and submit the results of its assessment to the BLM Authorized Officer. If Metropolitan determines that the change is attributable to project operations, it will assess whether the measured change is a precursor or predictor of a potential adverse impact. If Metropolitan determines that the measured change is not a precursor or predictor of a potential adverse impact, it would make no change to project operations and may implement verification monitoring and/or propose refinements to the Management Plan. Such refinements may include modifications of the monitoring network (e.g. location, frequency, etc.) and the action criteria. Metropolitan will submit the results of its assessment to the BLM Authorized Officer. If Metropolitan proposes a refinement to action criteria or monitoring features, it will submit a written proposal describing the refinement along with supporting data and materials to the BLM Authorized Officer. The BLM Authorized Officer will make a decision

[5] 'Attributable to project operations' as used in this document includes both the water use by the Cadiz Project and Cadiz Valley agricultural development.

TABLE 4
SUMMARY OF ACTION CRITERIA, IMPACTS AND CORRECTIVE MEASURES

Potential Impact	Method of Measurement	Triggers (Action Criteria)	Corrective Measures
Adverse Impacts to Springs	Groundwater Observation Wells (S-Series Wells)	Measured Water Level Change in Excess of 1 ft in Any S-Series Observation Wells	Modification of Project Extraction Operations to Prevent Adverse Impacts.
Adverse Impacts to Indigenous Groundwater Quality from Spreading Colorado River Water	CRW Sample Collection/Analysis at Lake Havasu	Exceedance of 1,000 mg/L TDS Level of Colorado River Water During Periods When Water is Being Delivered to the Spreading Basins.	Compliance with California RWQCB, Colorado River Basin Region Basin Plan, Curtail Putting CRW into Storage, or Provide Treatment Before Recharging.
Adverse Impacts to Wells Owned by Neighboring Land Owners	Groundwater Observation Wells	Written Complaint Stating Adverse Impacts to Yields and/or Increased Pumping Costs and/or Degraded Water Quality in Wells Owned by Neighboring Land Owners	Deepen Well / Improve Well Efficiency. Blend Impacted Well Water with Another Local Source Modify Project Storage and Withdrawal Operations. Construct Replacement Wells.
Land Subsidence	Benchmark Stations; InSAR (if warranted); Extensometers (if warranted)	Elevation Changes of Greater than 0.5 ft within the Project Area	Repair Damaged Structures. Modification of Program Wellfield Operations to Halt Aquifer Compaction.
Liquefaction	Groundwater Observation Wells	Static Groundwater Levels Measure Less than 50 ft Below Ground Surface Outside a Radius of 500 ft from the Boundary of the Project Spreading Basins	Modify Project Operations to Lower Groundwater Levels Such That Minimum Depth to Static Groundwater is Greater Than 50 ft. Outside a Radius of 500 ft from the Boundary of the Project Spreading Basins.
Hydrocompaction	Benchmark Stations	Tangible Damage (3 ft Drop in Elevation) in the Immediate Vicinity of the Project Spreading Basins	Repair or Replace Damaged Structures

TABLE 4
SUMMARY OF ACTION CRITERIA, IMPACTS AND CORRECTIVE MEASURES (CONTINUED)

Potential Impact	Method of Measurement	Triggers (Action Criteria)	Corrective Measures
Induced Flow of Lower-Quality Water from Bristol and Cadiz Dry Lakes	Groundwater Observation Wells (Cluster Wells at Dry Lakes)	TDS Concentration Changes in Excess of 25% of Background Concentrations in Cluster Wells at the Margin of the Dry Lakes	Modification of Project Storage and Extraction Operations to Re-establish the Natural Hydraulic Gradient and Background TDS Concentrations at the Margins of the Dry Lakes.
Adverse Impacts to Brine Resources Underlying Bristol and Cadiz Dry Lakes	Groundwater Observation Wells (Cluster Wells at Dry Lakes)	TDS Concentration Changes in Excess of 25% of Background Concentrations in Cluster Wells at the Margins of the Dry Lakes and/or Brine Level Changes of more than 1 ft Above/Below Static Levels in Cluster Wells on the Dry Lakes	Modification of Project Storage and Extraction Operations to Re-establish the Natural Hydraulic Gradient in and at the Margins of the Dry Lakes.
Mobilization of Wind-Blown Dust at Bristol and Cadiz Dry Lakes	Groundwater Observation Wells (Cluster Wells at Dry Lakes), ET Stations (with Soil Moisture Sensors), Open-air, Nephelometers, Digital Cameras, Surface Water Staff Gages	Water Level Changes of more than 0.5 feet Below Static Water Levels in Wells at ET Stations on the Dry Lakes	Modification of Project Storage and Extraction Operations to Re-establish the Natural Hydraulic Gradient in and at the Margins of the Dry Lakes.

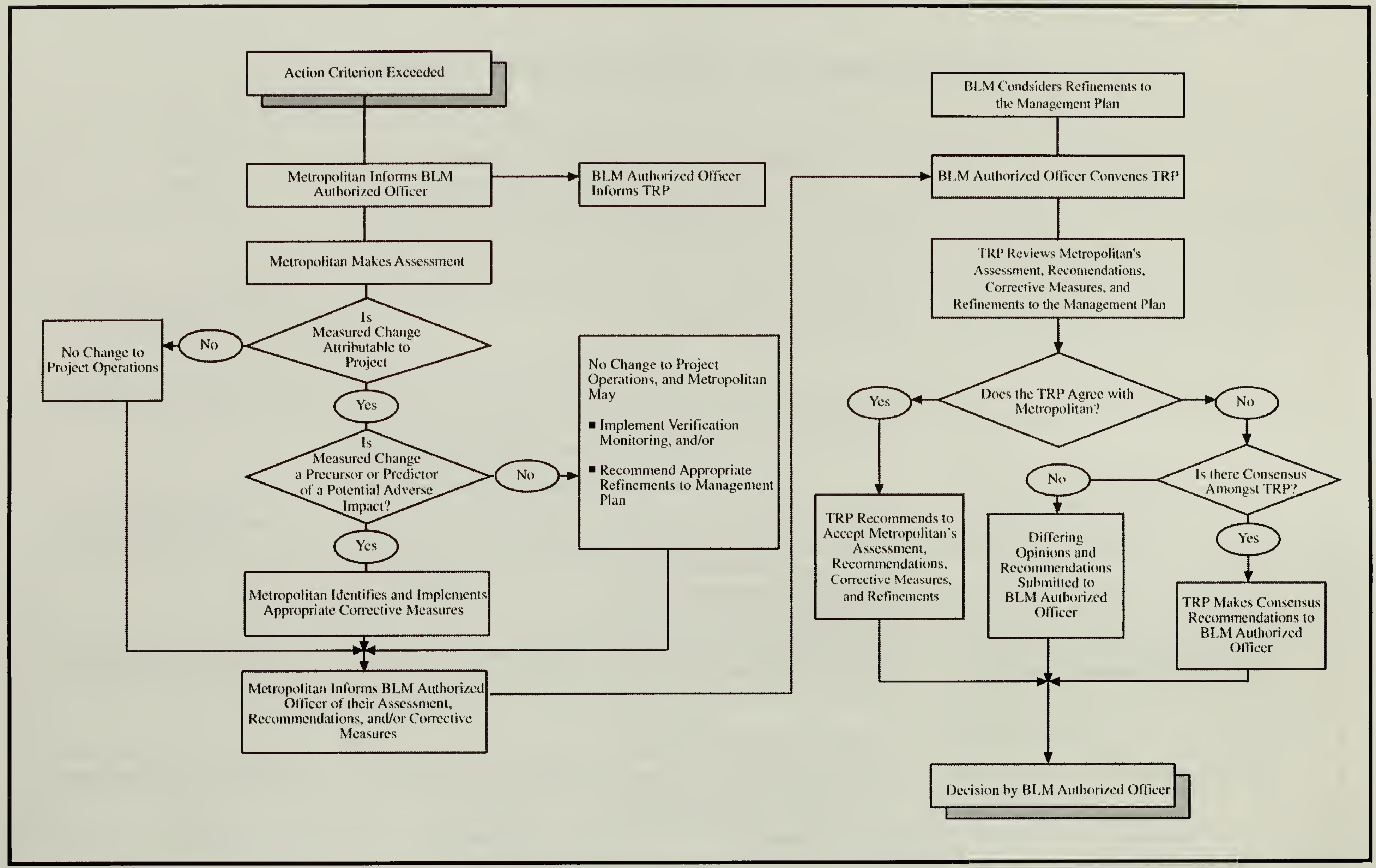

Figure 10

Cadiz Groundwater Storage & Dry-Year Supply Program

Groundwater Monitoring and Management Plan

Decision-Making Process

regarding the proposed refinement in accordance with the decision-making process described in Section 10.

If Metropolitan determines that the measured change is a precursor or predictor of a potential adverse impact, it will identify and implement the appropriate corrective measures. Metropolitan will promptly inform the BLM Authorized Officer of the result of its assessment and the corrective measures that it implemented.

After receiving the results of Metropolitan's assessment if an action criterion is exceeded or when BLM considers refinements to the Management Plan, the BLM Authorized Officer will, if appropriate, promptly notify the TRP by telephone or email, to arrange for the TRP to convene. Convening the TRP may include face-to-face meetings, telephone conferencing, or video conferencing.

The TRP would review Metropolitan's assessment, proposed refinements to the Management Plan, and corrective measures. If the TRP agreed with Metropolitan's assessment, proposed refinements to the Management Plan, and corrective measures, the TRP would recommend to the BLM Authorized Officer to accept them. If the TRP disagreed with Metropolitan's assessment, proposed refinements to the Management Plan, and/or corrective measures, the TRP would recommend to the BLM Authorized Officer that changes be made. Such changes may include: (1) verification monitoring; (2) refinements to the Management Plan; (3) implementation of corrective measures including modification of project operations; and/or (4) modification of the corrective measures that have been implemented by Metropolitan. If consensus within the TRP could not be reached regarding Metropolitan's assessment, proposed refinements to the Management Plan, and corrective measures, all differing opinions and recommendations would be forwarded to the BLM Authorized Officer.

After taking into consideration input from Metropolitan and from the TRP, when requested, the BLM Authorized Officer will determine whether Metropolitan's assessment, proposed refinements to the Management Plan, and/or corrective measures are in accordance with the Management Plan, or determine that other action is required to enforce the terms and conditions of any right-of-way grant(s) issued for the Cadiz Project facilities. The BLM Authorized Officer will make any decision regarding proposed refinements in accordance with the decision-making process described in Section 10. In accordance with legal requirements and BLM policies, the BLM Authorized Officer may provide public notice prior to making any final decisions. Decisions of the BLM Authorized Officer are subject to appeal to the Interior Board of Land Appeals (IBLA) in accordance with the regulations governing such appeals under Title 43 Code of Federal Regulations Part 4.

7.1 SPRINGS

7.1.1 POTENTIAL FOR IMPACTS TO SPRINGS IN THE MOJAVE NATIONAL PRESERVE AND BLM MANAGED LANDS IN THE AFFECTED WATERSHEDS

To avoid adverse impacts to springs within the Fenner Valley and Orange Blossom Wash watersheds or groundwater levels beneath the Mojave National Preserve as a result of project operations, and to understand the connection between springflow and groundwater; monitoring of springs and groundwater levels will be conducted as follows: Approximately eight springs (the number of springs may be evaluated to increase or decrease the recommended number) will be selected for long-term monitoring (based on pre-operational field reconnaissance). In addition, the S-Series observation wells will be monitored continuously throughout the term of the Cadiz Project to ensure protection of the springs by measuring groundwater level impacts from project operations and to demonstrate that no groundwater level declines reach the Mojave National Preserve and no impact to springs occurs on BLM managed lands.

Action Criteria:

The decision-making process will be initiated if the action criteria are exceeded. The action criteria are a measured groundwater level change in excess of 1 foot in any of the S-Series observation wells. If such a groundwater level change occurs, the decision-making process will be initiated (Figure 10).

Decision-Making Process (See Figure 10):

If the action criteria are exceeded, the decision-making process will continue as follows:

- Metropolitan will inform the BLM Authorized Officer, and determine if measured changes in groundwater levels are attributable to project operations.
- If groundwater level changes exceed the action criteria in any of the S-Series observation wells and are not attributable to project operations (as indicated by groundwater level distributions throughout the entire monitoring network and other factors), then no change to project operations would be required, and Metropolitan may propose that the action criteria or monitoring network be modified.

  a) If groundwater level changes exceed the action criteria in any of the S-Series observation wells and are attributable to project operations, an assessment would be made to determine whether this change will result in an adverse impact based on the Management Plan groundwater models and other data collected and measured in accordance with the Management Plan.

If no adverse impact were identified, potential actions would include:

a) No action, or
b) Refinement of the location and/or magnitude of the action criteria, or
c) Verification monitoring, or
d) Revision of the monitoring frequency or location at long-term monitoring springs.

- If groundwater level changes exceeded the action criteria in any of the S-Series observation wells and were determined to be attributable to project operations, and the groundwater level change would result in an adverse impact, then corrective measures would be implemented. An adverse impact includes: (1) the determination that this groundwater level change will cause a reduction in the flow of any spring based on the Management Plan groundwater models and other data collected and measured in accordance with the Management Plan; or (2) the determination that this groundwater level change will cause groundwater level declines at the boundary of the Mojave National Preserve based on the Management Plan groundwater models and other data collected and measured in accordance with the Management Plan.
- Metropolitan will inform the BLM Authorized Officer of its assessment and the corrective measures that were implemented, if any (see Figure 10). BLM will seek appropriate technical assistance from the TRP as necessary to complete BLM's evaluation of Metropolitan's compliance with the provisions of the Management Plan. The TRP would provide recommendations to the BLM Authorized Officer as described in Section 9. The BLM Authorized Officer would enforce the terms and conditions of the right-of-way grant(s) in accordance with the process described in Section 10.

Corrective Measures:

Corrective measures that would be implemented include:

Modification of project operations to prevent adverse impacts. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

Responsible Party:

Metropolitan Water District of Southern California

7.2 AQUIFER SYSTEM

7.2.1 POTENTIAL IMPACTS TO INDIGENOUS GROUNDWATER QUALITY DUE TO PROJECT OPERATIONS

Pursuant to California law, the California Regional Water Quality Control Board, Colorado River Basin Region adopted a Water Quality Control Plan in 1994 (Basin Plan) which identifies surface waters and groundwater within its geographical jurisdiction, existing and potential future beneficial uses of those waters, and water quality objectives to protect the beneficial uses of the waters. The Basin Plan identifies that the Bristol groundwater hydrologic unit has municipal, industrial and agricultural beneficial uses and that the Cadiz groundwater hydrologic unit has municipal and industrial beneficial uses.

The Basin Plan also indicates that Colorado Regional Board's goal is to maintain the existing water quality of all nondegraded groundwater basins. Additionally, State Board policy states that when existing water quality is better than the quality established in policies, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with the maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water, and will not result in water quality less that described in the policies (Resolution No. 68-16, Statement of Policy with Respect to Maintaining High Quality of Waters in California). The State of California Department of Health Services (DHS) has identified a secondary water quality standard of 1,000 mg/L for TDS in drinking water.

Action Criteria:

The decision-making process will be initiated if the action criteria are exceeded. The action criteria is the exceedance of the DHS secondary drinking water quality standard of 1,000 mg/L TDS level during periods when water is being delivered to the spreading basins. During storage operations, the quality of Colorado River water in the CRA would be tested and analyzed weekly by Metropolitan at Lake Havasu. The analysis will be performed to ensure that storage of Colorado River water in the aquifer will not impair the water quality of the indigenous groundwater for beneficial use. The Regional Water Quality Control Board has identified municipal, industrial and agricultural uses as beneficial uses of the basin.

Future updates of the applicable Basin Plan may alter the requirements that Cadiz Project operations must meet. Should this occur, the decision-making process would be initiated to ensure compliance with the revised requirements.

Decision-Making Process:

If the water quality tests of Colorado River water indicate that it exceeds the DHS secondary drinking water quality standard of 1,000 mg/L TDS, the decision-making process will be implemented as follows:

- Metropolitan will make an assessment to determine whether the quality of the Colorado River water will constitute an adverse impact to the aquifer if delivered for storage. Adverse impact includes the impairment of the water quality of the indigenous groundwater for the beneficial use for municipal, industrial and agricultural purposes, as determined by the California Regional Water Quality Control Board, Colorado River Basin Region.
- Metropolitan will inform the BLM Authorized Officer of its assessment, and the corrective measures that were implemented, if any, to comply with the Regional Water Quality Control Board's Basin Plan.

Corrective Measures:

Corrective measures that would be implemented include:

1. Curtail delivery of Colorado River water to the spreading basins, or
2. Treat Colorado River water prior to putting it into storage, or
3. Implement other corrective measures as required by the California Regional Water Quality Control Board, Colorado River Basin Region.

Responsible Party:

Metropolitan Water District of Southern California

7.2.2 POTENTIAL IMPACTS TO WELLS OWNED BY NEIGHBORING LANDOWNERS DUE TO PROJECT OPERATIONS

It is the intent of the project to operate without impacts to wells owned by neighboring landowners in the vicinity of the project area. To avoid such potential impacts, the groundwater monitoring network will include wells located near such landholdings. Groundwater levels will be monitored on a monthly basis. Water quality will be monitored on a quarterly basis during the pre-operational phase and annually thereafter during the term of the Cadiz Project.

Action Criteria:

The decision-making process will be initiated if the action criteria are exceeded. The action criteria are written complaints regarding decreased groundwater production yield, degraded water quality, or increased pumping costs submitted by neighboring landowners.

Decision-Making Process:

If a written complaint is received, the decision-making process will be implemented as follows:

- Metropolitan will arrange for an interim supply of water to the impacted party and inform the BLM Authorized Officer of the receipt of a written complaint.
- Metropolitan will determine if water level changes, decreased yields, increased pumping costs, and/or degraded water quality in neighboring landowner wells are attributable to project operations.

- If water level changes, decreased yields, increased pumping costs and/or degraded water quality in neighboring landowner wells are not attributable to project operations, then no action would be taken and Metropolitan would discontinue its arrangement to provide water.
- If water level changes, decreased yields, increased pumping costs and/or degraded water quality in neighboring landowner wells are attributable to project operations, then further corrective measures would be implemented.
- Metropolitan will inform the BLM Authorized Officer of its assessments and the corrective measures that were implemented, if any (see Figure 10). BLM will seek appropriate technical assistance from the TRP as necessary to complete BLM's evaluation of Metropolitan's compliance with the provisions of the Management Plan. The TRP would provide recommendations to the BLM Authorized Officer as described in Section 9. The BLM Authorized Officer would enforce the terms and conditions of the right-of-way grant(s) in accordance with the process described in Section 10.

Corrective Measures:

Upon receipt of the written complaint, and during the decision-making process, Metropolitan will arrange for an interim supply of water to the impacted party as necessary. Additional corrective measures that would be implemented include one or more of the following:

1. Deepen or otherwise improve the efficiency of the impacted well(s); or
2. Blend impacted well water with another local source; or
3. Construct replacement wells; or
4. Modify project operations until adverse impacts are no longer present at the impacted well(s). Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

Responsible Party:

Metropolitan Water District of Southern California

7.2.3 POTENTIAL FOR LAND SUBSIDENCE

Twenty benchmarks will be established and surveyed on an annual basis to identify and quantify potential subsidence within the project area (see Figure 3-5). As a result of the land surface subsidence monitoring surveys, an extensometer well may be constructed in areas of known or anticipated subsidence. The extensometer well, if constructed, would verify if the land surface changes (identified from land surveys supplemented, if necessary, with semi-annual InSAR satellite data) were due to (1) subsidence due to groundwater withdrawal or (2) other mechanisms (e.g. regional tectonic movement). Use of predictive modeling of subsidence due to groundwater withdrawal would aid in this analysis.

Action Criteria:

The decision-making process will be initiated if the action criteria are exceeded. The action criteria is a change in the ground surface elevation of more than 0.5 ft within the project area.

Decision-Making Process:

If the action criteria are exceeded, the decision-making process will be implemented as follows:

- Metropolitan will inform the BLM Authorized Officer and determine if the subsidence is attributable to project operations. Metropolitan may construct an extensometer well near the center of the subsidence area, or utilize InSAR surveys as needed to determine if the subsidence is non-recoverable compaction.
- If land surface elevation changes equal to or in excess of the action criteria are not attributable to project operations, then no action would be required, and Metropolitan may propose refinement of the action criteria or monitoring network.
- If land surface elevation changes equal to or in excess of the action criteria are attributable to project operations, then an assessment will be made to determine whether the subsidence constituted a potential adverse impact to the aquifer. Adverse impact includes the determination that there will be damage to structures as a result of differential settlement or fissuring, or general subsidence sufficient to alter natural drainage patterns or cause damage to structures, or a non-recoverable loss of aquifer storage capacity that affects the beneficial uses of the basin. If no such impacts were identified, potential actions may include:

  a) No action, or
  b) Refinement of the action criteria, or
  c) Verification monitoring, or
  d) Revision of the benchmark survey monitoring frequency

- If land surface elevation changes equal to or in excess of the action criteria were determined to be attributable to project operations and the changes constituted a potential adverse impact in the project area, then corrective measures would be implemented.
- Metropolitan will inform the BLM Authorized Officer of its assessments and the corrective measures that were implemented, if any (see Figure 10). BLM will seek appropriate technical assistance from the TRP as necessary to complete BLM's evaluation of Metropolitan's compliance with the provisions of the Management Plan. The TRP would provide recommendations to the BLM Authorized Officer as described in Section 9. The BLM Authorized Officer would enforce the terms and conditions of the right-of-way grant(s) in accordance with the process described in Section 10.

Corrective Measures:

Corrective measures that would be implemented include:

1. Modification of wellfield operations to halt aquifer compaction. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, or (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact.
2. Repair any structures damaged as a result of subsidence attributable to project operations.

Responsible Party:

Metropolitan Water District of Southern California

7.2.4 POTENTIAL FOR INCREASED RISK OF LIQUEFACTION RELATED TO PROJECT SPREADING OPERATIONS

Groundwater levels will be monitored continuously in project area well clusters (Features 5 and 6) in the vicinity of the project spreading basins.

Action Criteria:

The decision-making process will be initiated if the action criteria are exceeded. The action criteria is a rise in groundwater levels, to within 50 feet of the ground surface outside a radius of 500 ft from the boundary of the project spreading basins. If such a change in groundwater levels occurs, the decision-making process will be initiated. (Figure 10)

Decision-Making Process:

If the action criteria were exceeded, the decision-making process will be implemented as follows:

- Metropolitan will inform BLM Authorized Officer, and determine if changes in groundwater levels are attributable to project operations.
- If a water level rise equals or exceeds the action criteria in the project area observation well clusters but is not attributable to project operations, then no change to project operations would be required and Metropolitan may propose refinement of the action criteria or monitoring network.
- If water level rise equals or exceeds the action criteria in the project area observation well clusters and is attributable to project operations an assessment would be made to determine whether the water level rise constituted an increased risk of liquefaction. If no such adverse impact was identified, potential actions would include:

  a) No action, or
  b) Refinement of the action criteria, or
  c) Verification monitoring, or
  d) Revision of the monitoring frequency or location of monitoring wells.

- If water level rise in the project area observation well clusters is determined to be attributable to project operations, and the levels constitute an increased risk of liquefaction, then corrective measures will be implemented.
- Metropolitan will inform the BLM Authorized Officer of its assessments and the corrective measures that were implemented, if any (see Figure 10). BLM will seek appropriate technical assistance from the TRP as necessary to complete BLM's evaluation of Metropolitan's compliance with the provisions of the Management Plan. The TRP would provide recommendations to the BLM Authorized Officer as described in Section 9. The BLM Authorized Officer would enforce the terms and conditions of the right-of-way grant(s) in accordance with the process described in Section 10.

Corrective Measures:

Corrective measures that would be implemented include:

Modification of project operations to lower groundwater levels beneath the spreading basins such that the minimum depth to static groundwater was equal to or below 50 feet outside a radius of 500 feet from the boundary of the project spreading basins.

Responsible Party:

Metropolitan Water District of Southern California

7.2.5 POTENTIAL FOR HYDROCOMPACTION RELATED TO PROJECT SPREADING OPERATIONS

Benchmarks will be established and surveyed on an annual basis to identify and quantify potential hydrocompaction in the immediate vicinity of the project spreading basins.

Action Criteria:

The decision-making process will be initiated if the action criteria are exceeded. The action criteria is a 3 foot drop in land surface elevation in the immediate vicinity of the project spreading basins. If such changes in land surface elevation changes are measured, the decision-making process will be initiated (see Figure 10).

Decision-Making Process:

If the action criteria are exceeded, the decision-making process will be implemented as follows:

- Metropolitan will inform BLM Authorized Officer, and determine if the land surface elevation changes are attributable to project operations.
- If land surface elevation changes equal to or in excess of the action criteria are not attributable to project operations, then no change in project operations would be required, and Metropolitan may propose refinement of the action criteria or monitoring network.
- If land surface elevation changes equal to or in excess of the action criteria are attributable to project operations, an assessment would be made to determine whether the subsidence constituted a potential adverse impact to manmade structures in the project area. If no such impacts were identified, potential actions may include:

  a) No action, or
  b) Refinement of the action criteria, or
  c) Verification monitoring, or
  d) Revision of the benchmark survey monitoring frequency.

- If land surface elevation changes equaling or exceeding the action criteria are determined to be attributable to project operations and to constitute a potential adverse impact to manmade structures in the immediate vicinity of the project spreading basins, then corrective measures will be implemented.
- Metropolitan will inform the BLM Authorized Officer of its assessment and corrective measures that were implemented, if any (see Figure 10). BLM will seek appropriate technical assistance from the TRP as necessary to complete BLM's evaluation of Metropolitan's compliance with the provisions of the Management Plan. The TRP would provide recommendations to the BLM Authorized Officer as described in Section 9. The BLM Authorized Officer would enforce the terms and conditions of the right-of-way grant(s) Metropolitan in accordance with the process described in Section 10.

Corrective Measures:

Corrective measures that would be implemented include:

1. Repair damage to project spreading basins and related appurtenances due to hydrocompaction.
2. Repair or replace any other facilities in the immediate vicinity of the project spreading basins damaged by hydrocompaction, attributable to project operations.

Responsible Party:

Metropolitan Water District of Southern California

7.2.6 POTENTIAL FOR INDUCED FLOW OF LOWER-QUALITY WATER FROM BRISTOL AND CADIZ DRY LAKES

A network of "cluster type" observation wells will be established between the project wellfield and the margins of Bristol and Cadiz dry lakes (see Figures 4 and 5). Groundwater TDS concentrations in the well clusters will be monitored on a quarterly basis during the pre-operational phase of the Cadiz Project, semi-annually throughout the operational phase and annually during the post-operational phase of the project.

Action Criteria:

The decision-making process will be initiated if the action criteria are exceeded. The action criteria is a change in TDS concentration in excess of 25% of background concentrations in the cluster wells at the margin of the dry lakes. If such a TDS change is measured, the decision-making process will be initiated.

Decision-Making Process:

If the action criteria are exceeded, the decision-making process will be implemented as follows:

- Metropolitan will inform the BLM Authorized Officer and determine if the changes are attributable to project operations.
- If groundwater TDS concentration changes equal to or in excess of the action criteria in the observation well clusters at the margins of the dry lakes are not attributable to project operations, then no change in project operations would be required and Metropolitan may propose refinement of the action criteria.
- If groundwater TDS concentration changes equal to or in excess of the action criteria in the observation well clusters at the margins of the dry lakes are attributable to project operations, then an assessment will be made whether the TDS concentration changes constituted a potential adverse impact to (1) the aquifer system, (2) mining operations, or (3) project area production wells. Adverse impact includes the determination that beneficial use of the groundwater basin will be impaired as determined under the policies of the Regional Water Quality Control Board, Colorado River Basin Region in effect during the Cadiz Project. If no such impacts were identified, potential actions may include:

    a) No action, or
    b) Refinement of the action criteria, or
    c) Verification monitoring, or
    d) Revision of the monitoring frequency of the observation well clusters at the margins of the dry lakes.

- If groundwater TDS changes equal to or in excess of the action criteria in observation well clusters at the margins of the dry lakes are determined to be attributable to the project and that the changes constituted a potential adverse impact to (1) the aquifer system, (2) mining operations, or (3) project area production wells, then corrective measures will be implemented.
- Metropolitan will inform the BLM Authorized Officer of its assessment and corrective measures that were implemented, if any (see Figure 10). BLM will seek appropriate technical assistance from the TRP as necessary to complete BLM's evaluation of Metropolitan's compliance with the provisions of the Management Plan. The TRP would provide recommendations to the BLM Authorized Officer as described in Section 9. The BLM Authorized Officer would enforce the terms and conditions of the right-of-way grant(s) in accordance with the process described in Section 10.

Corrective Measures:

Corrective measures that would be implemented include:

Modification of project storage and extraction operations to reestablish the natural hydraulic gradient and background TDS concentrations at the margins of Bristol and Cadiz dry lakes. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

Responsible Party:

Metropolitan Water District of Southern California

7.3 BRISTOL AND CADIZ DRY LAKES

7.3.1 POTENTIAL FOR IMPACTS TO THE BRINE RESOURCES UNDERLYING BRISTOL AND CADIZ DRY LAKES

A network of "cluster type" observation wells will be established between the project wellfield and the margins of Bristol and Cadiz dry lakes (see Figures 4 and 5). Groundwater TDS concentrations in the well clusters will be monitored on a quarterly basis during the pre-operational phase of the project, semi-annually throughout the operational phase, and annually throughout the post-operational phase of the Cadiz Project. Groundwater levels will be monitored on a continuous basis throughout the term of the project.

Action Criteria:

The decision-making process will be initiated if action criteria are exceeded. The action criteria is a change in TDS concentration in excess of 25% of background concentrations, or a change in water or brine levels of 1 ft from pre-operational static levels in the cluster wells at the margins of the dry lakes. If such a TDS or water/brine level change is measured, the decision-making process will be initiated.

Decision-Making Process:

If the action criteria are exceeded, the decision-making process will be implemented as follows:

- Metropolitan will inform the BLM Authorized Officer, and determine whether the change in TDS concentrations or water/brine level change is attributable to project operations.

- If groundwater TDS concentration or water/brine level changes equal to or in excess of the action criteria in the observation well clusters at the margins of the dry lakes are not attributable to project operations, then no change to project operations would be required, and Metropolitan may propose refinement of the action criteria.
- If groundwater TDS concentration or water/brine level changes equal to or in excess of the action criteria in the observation well clusters at the margins of the dry lakes are attributable to project operations, then an assessment will be made to determine whether the TDS concentration and/or water/brine level changes constituted a potential adverse impact to brine operations on the dry lakes. Adverse impact includes changes in brine chemistry or yields from existing brine production wells or trenches attributable to project operations. If no such impacts were identified, potential actions may include:

  a) No action, or
  b) Refinement of the action criteria, or
  c) Verification monitoring, or
  d) Revision of the monitoring frequency at the observation well clusters at the margins of the dry lakes,

- If groundwater TDS concentration or water/brine level changes equal to or in excess of the action criteria in observation well clusters at the margins of the dry lakes are determined to be attributable to project operations and the changes constituted a potential adverse impact to brine operations on the dry lakes, then corrective measures will be implemented.
- Metropolitan will inform the BLM Authorized Officer of its assessment and corrective measures that were implemented, if any (see Figure 10). BLM will seek appropriate technical assistance from the TRP as necessary to complete BLM's evaluation of Metropolitan's compliance with the provisions of the Management Plan. The TRP would provide recommendations to the BLM Authorized Officer as described in Section 9. The BLM Authorized Officer would enforce the terms and conditions of the right-of-way grant(s) in accordance with the process described in Section 10.

Corrective Measures:

Corrective measures that would be implemented include:

Modification of Cadiz Project storage and extraction operations to re-establish the natural hydraulic gradient in and at the margins of the dry lakes. Modifications to project operations would include one or more of the following: (a) a reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

Responsible Party:

Metropolitan Water District of Southern California

7.4 AIR QUALITY

7.4.1 POTENTIAL IMPACTS TO AIR QUALITY DUE TO DUST MOBILIZATION FROM WATER-LEVEL DECLINES BENEATH BRISTOL AND CADIZ DRY LAKES

A network of "cluster type" observation wells will be established between the project wellfield and Bristol and Cadiz dry lakes (see Figures 4 and 5). Groundwater levels will be monitored on a continuous basis throughout the term of the project.

A pair of nephelometers, a digital camera, and a weather station will also be installed at each dry lake to collect data on ambient dust mobilization and wind speed and direction on the dry lakebeds.

Action Criteria:

The decision-making process will be initiated if the action criteria is exceeded. The action criteria is a change in groundwater levels of 6 inches from pre-operational static levels in the cluster wells on the dry lakebeds. If such a groundwater level change is measured, the decision-making process will be initiated.

Decision-Making Process:

If the action criteria are exceeded, the decision-making process will be implemented as follows:

- Metropolitan will inform the BLM Authorized Officer, and determine whether the change in groundwater levels is attributable to project operations.
- If groundwater level changes, equal to or in excess of the action criteria in the observation well clusters on the dry lakebeds are not attributable to Cadiz Project operations, then no change to project operation would be required, and Metropolitan may propose refinement the action criteria.

If groundwater level changes equal to or in excess of the action criteria in the observation well clusters on the dry lakebeds are attributable to project operations, then an assessment will be made to determine whether the groundwater level changes are accompanied by a decrease in soil moisture, and an adverse change in air quality at a dry lakebed attributable to project operations. This determination will be accomplished by comparing the groundwater level data with data for soil moisture at the lakebed surface, wind velocity data obtained from weather stations on the dry lakebeds, and with dust mobilization data obtained from the instrumentation installed upwind and downwind of Bristol and Cadiz dry lakebeds. Statistical analyses would be performed as described in Sections 6.4.1 and 6.4.2 to identify an adverse change in air quality. The changes in light extinction (a quantitative measurement of the light scattering component of visibility impairment) that can be detected by the instrumentation depend on the level of airborne particulate matter. In very clean air, changes of about 20% to 30% can be detected reliably. Changes in light extinction as small as 10% can be detected in air with higher particle concentrations. The differences between the downwind and upwind readings from the open-air nephelometers that can be reliably attributed to wind-mobilized particulate matter from the dry lakebed surfaces will be established during analyses of the baseline monitoring. An adverse change in air quality is defined as a measurable increase in seasonal dust mobilization, attributable to project operations, based on the analyses of baseline monitoring. If no such impacts are identified, potential actions may include:

a) No action, or
b) Refinement of the action criteria, or
c) Verification monitoring, or
d) Revision of the monitoring frequency at the observation well clusters on the dry lakebeds.

- If groundwater level changes equal to or in excess of the action criteria in observation well clusters on the dry lakebeds were determined to be attributable to project operations and the changes constituted a potential adverse impact to air quality at a dry lakebed, then corrective measures would be implemented.
- Metropolitan will inform the BLM Authorized Officer of its assessment and corrective measures that were implemented, if any (see Figure 10). BLM will seek appropriate technical assistance from the TRP as necessary to complete BLM's evaluation of Metropolitan's compliance with the provisions of the Management Plan. The TRP would provide recommendations to the BLM Authorized Officer as described in Section 9. The BLM Authorized Officer would enforce the terms and conditions of the right-of-way grant(s) in accordance with the process described in Section 10.

Corrective Measures:

Corrective measures that would be implemented include:

Modification of project storage and extraction operations to re-establish the natural hydraulic gradient in and at the margins of the dry lakes. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

Responsible Party:

Metropolitan Water District of Southern California

SECTION 8

SECTION 8
CLOSURE PLAN AND POST-OPERATIONAL REPORTING

8.1 CLOSURE PLAN

A Closure Plan will be developed as part of the Management Plan to ensure that no residual effects of project operations will result in adverse impacts to critical resources (as defined in Section 7) in or adjacent to the project area during or after the post-operational phase.

A Closure Plan would be prepared when static groundwater levels have declined by 10 feet from pre-operational levels. A Closure Plan will be prepared by Metropolitan no later than at year 25 of project operations. Metropolitan will work closely with the BLM Authorized Officer, who will provide input and guidance throughout the development and refinement of the Closure Plan. The BLM Authorized Officer will, as determined appropriate, receive comments and recommendations from the TRP regarding the development and refinement of the Closure Plan. The Closure Plan will monitor groundwater levels and groundwater quality for a minimum period of 10 years to protect critical resources and groundwater quality for beneficial uses as required by federal and State law, including the requirements of the California Water Quality Control Board, Colorado River Basin Region. The provisions and mitigation obligations under this Management Plan will be in effect and run concurrently with the term of the Closure Plan. Once prepared, the Closure Plan will be reevaluated every five years in consultation with the TRP. Such reevaluation may include refinements to the Closure Plan.

Under this Management Plan, Metropolitan will review and analyze groundwater levels, water quality information, and all other monitoring data; as well as prepare the annual and five-year reports. One purpose of the five-year reports is to identify any actions that would be taken with the objective to ensure that any decline in pre-operational static groundwater levels would not exceed 100[6] feet at the end of project operations (Closure Groundwater Levels) or lead to projections of adverse impacts to critical resources during or after the post-operational phase.

As noted in Section 1.1 of the Final EIR/EIS main volume, all pumping of groundwater in the project area by the Cadiz Agricultural Development will be subject to the provisions of this Management Plan. With the combination of the Cadiz Agricultural Development and the project, there may be declines in static groundwater levels at the termination of project operations. Implementation of the Closure Plan is intended to ensure that the Closure Groundwater Levels are not exceeded and that the groundwater quality will be protected for beneficial uses as described in the policies of the Regional Water Quality Control Board, Colorado River Basin Region, including any applicable new or revised standards that may be adopted by the Regional Water Quality Control Board[7].

8.2 POST-OPERATIONAL REPORTING

During the post-operational phase, Metropolitan would collect, analyze and summarize water level and quality data in a report to confirm compliance with the Closure Plan. These post-operational reports will be distributed to the Regional Water Quality Control Board and the BLM Authorized Officer, and will be available to interested parties upon request.

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[6] Closure Plan groundwater levels and static groundwater levels for the five-year reports will be calculated by averaging static groundwater levels in all project area production wells.

[7] Closure Plan water quality for the five-year reports will be calculated by averaging water quality data in all project area production wells.

SECTION 9

SECTION 9
TECHNICAL REVIEW PANEL

An integral part of the Management Plan involves regular and ongoing review of data collected during the term of the Cadiz Project. The understanding and analysis of the data will require technical expertise that may not be readily available within BLM. For that reason, the BLM Authorized Officer will consult with technical specialists from other public agencies in a Technical Review Panel (TRP) annually and as necessary. The TRP would review data and technical analyses presented to the BLM Authorized Officer by Metropolitan and provide technical comments and recommendations to the BLM Authorized Officer regarding the implementation of the Management Plan and the operation of the Cadiz Project.

9.1 REPRESENTATION

The TRP shall consist of experts in various fields from the National Park Service, the U.S. Geological Survey, the County of San Bernardino and BLM. Additionally, the BLM Authorized Officer may consult with any other federal agency deemed to have relevant expertise (e.g., Environmental Protection Agency for air quality issues), the California State Department of Water Resources and/or the Regional Water Quality Control Board, as necessary.

The BLM Authorized Officer may invite Metropolitan and Cadiz Inc. to participate in meetings of the TRP to present, explain or clarify the data and analyses collected in accordance with the Management Plan.

9.2 RESPONSIBILITIES

The BLM Authorized Officer will convene a meeting(s) of the TRP during the pre-operational phase to review the detailed plan to be submitted by Metropolitan for installing the initial set of monitoring features and developing and calibrating an initial series of water resource models. Such detailed plan shall specify the locations for construction and/or installation of the monitoring wells and other monitoring equipment, and include the details of the water resources models to be utilized to evaluate the data collected. Metropolitan may also consult directly with the TRP to obtain review of any plans or water resources models prior to submitting them to the BLM Authorized Officer. During the operational phase, the TRP will meet annually and at the request of the BLM Authorized Officer when necessary to:

- Review and analyze data collected;
- Review models updated with data collected during project operations (to be provided in electronic form with the annual reports);
- Review the annual and five-year monitoring reports and provide recommendations to the BLM Authorized Officer;
- Review any assessments, proposed refinements to the Management Plan, and corrective measures submitted by Metropolitan and make recommendations to the BLM Authorized Officer regarding the assessments, proposed refinements to the Management Plan, and corrective measures;
- Review data and assessments of air quality analyses and provide recommendations regarding the analyses to the BLM Authorized Officer;
- Assess potential adverse impacts to critical resources and provide recommendations to the BLM Authorized Officer; and
- Review the Closure Plan and provide recommendations to the BLM Authorized Officer.

9.3 ANNUAL AND FIVE-YEAR MONITORING REPORTS

As the annual and five-year monitoring reports will include electronic copies of all monitoring data, model runs and model input and output data, the TRP will have the opportunity to review these models and data in performing their review of project operations. Data will be made available to the TRP through an electronic network (e.g. web page within 90 days of its collection) or other appropriate means to enable regular updates on Cadiz Project operation and management activities.

9.4 RECOMMENDATIONS TO THE BLM AUTHORIZED OFFICER

TRP members will interpret the project information and provide comments and recommendations to the BLM Authorized Officer. Recommended actions may include:

- changes to the number or location of monitoring features,
- changes in monitoring frequency,
- changes in monitoring technology,
- refinements of action criteria for critical resources,
- refinements of models,
- modification of the Management Plan,
- revisions to the Closure Plan, and/or
- changes in operations of the Cadiz Project if any action criteria (as defined in Sections 7.1 to 7.4) were exceeded due to project operations and would cause an adverse impact to critical resource(s).

SECTION 10

SECTION 10
BLM AUTHORIZED OFFICER

A BLM Authorized Officer will be designated to enforce the terms and conditions of any right-of-way grant(s) the BLM issues for the Cadiz Project facilities in accordance with the statutory and regulatory provisions governing the right-of-way grant.

10.1 RESPONSIBILITIES

The BLM Authorized Officer shall be responsible to exercise BLM's enforcement authority to require compliance with the terms and conditions of the right-of-way grant(s) issued for the project facilities. The BLM Authorized Officer will:

- Work closely with Metropolitan to review and provide input and guidance on the detailed plan submitted by Metropolitan for installing the initial set of monitoring features and developing and calibrating an initial series of water resources models;
- Review and determine whether to approve or modify the initial set of monitoring features and water resources models during the pre-operational phase of the project;
- Review the data, analyses, proposed refinements to the Management Plan and corrective measures submitted by Metropolitan, and require modifications if necessary, and approve or reject proposed refinements. The BLM Authorized Officer will provide a written response to Metropolitan within sixty (60) days regarding when a decision on proposed refinements will be made, provided that such decisions will be made within 180 days and will include a statement of the scientific basis and data used in making the decision;
- Review and consider comments and recommendations made by the TRP for the refinement of action criteria, refinement of water resources models and air quality analysis methodologies in conjunction with measured data, the refinement of the Management Plan, and the modification of project operations;
- Enforce the terms and conditions of the right-of-way grant by requiring changes in project operations, where applicable, to protect critical resources;
- Work closely with Metropolitan to review and provide input and guidance regarding the Closure Plan for the Cadiz Project;
- Review and determine whether to approve or modify the Closure Plan on the basis of input from Metropolitan and the TRP;
- Call for meetings of the TRP and consider requests for such meetings by the TRP members for the purposes of considering the matters set forth above;
- Provide for public participation at BLM discretion;
- This Management Plan will be a condition of the Right-of-Way Grant and may not be revised without the written approval of the BLM Authorized Officer.

10.2 DECISION-MAKING PROCESS

The decision-making process will be initiated if (a) an action criterion is exceeded, or (b) if Metropolitan requests any proposed refinements to the Management Plan, or (c) if BLM otherwise determines a need to propose refinements to the Management Plan. The BLM Authorized Officer shall consider the data, analysis, assessments, and proposed refinements of the Management Plan received from Metropolitan, together with any comments and recommendations submitted by members of the TRP and the public. The BLM Authorized Officer will provide a written response to Metropolitan within sixty (60) days regarding when a decision on proposed refinements will be made, provided that such decisions will be made in accordance with Title 43 Code of Federal Regulations Part 2800, and will be issued within 180 days and include a statement of the scientific basis and data used in making the decision.

In accordance with the terms and conditions set forth in the right-of-way grant issued for the project to ensure compliance with the Management Plan (i.e. project operations and corrective measures will not adversely impact critical resources identified in the Management Plan), the BLM Authorized Officer shall have the enforcement authority to require a change in the Management Plan, project operations and/or implemented corrective measures, in accordance with Title 43 Code of Federal Regulations Part 2800. The BLM Authorized Officer will provide Metropolitan with written notice and opportunity to respond to any such changes proposed by the BLM Authorized Officer, provided that such notice shall include a statement of the scientific basis and data considered in proposing the change.

The decisions of the BLM Authorized Officer shall be subject to appeal to the Interior Board of Land Appeals (IBLA) in accordance with the regulations governing such appeals under Title 43 Code of Federal Regulations Part 4.

APPENDIX A

ASTM STANDARDS ON GROUND WATER AND VADOSE ZONE INVESTIGATIONS

Sponsored by ASTM Committee D-18
on Soil and Rock

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Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers[1]

This standard is issued under the fixed designation D 5092; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This practice for the design and installation of ground water monitoring wells in aquifers will promote (*1*) durable and reliable construction, (*2*) extraction of representative ground water quality samples, and (*3*) efficient and site hydrogeological characterizations. The guidelines established herein are affected by governmental regulations and by site specific geological, hydrogeological, climatological, topographical, and subsurface chemistry conditions. To meet these geoenvironmental challenges, this guidance promotes the development of a conceptual hydrogeologic model prior to monitoring well design and installation.

1. Scope

1.1 This practice considers the selection and characterization (that is, defining soil, rock types, and hydraulic gradients) of the target monitoring zone as an integral component of monitoring well design and installation. Hence, the development of a conceptual hydrogeologic model for the intended monitoring zone(s) is recommended prior to the design and installation of a monitoring well.

1.2 These guidelines are based on recognized methods by which monitoring wells may be designed and installed for the purpose of detecting the presence or absence of a contaminant, and collecting representative ground water quality data. The design standards and installation procedures herein are applicable to both detection and assessment monitoring programs for facilities.

1.3 The recommended monitoring well design, as presented in this practice, is based on the assumption that the objective of the program is to obtain representative ground water information and water quality samples from aquifers. Monitoring wells constructed following this practice should produce relatively turbidity-free samples for granular aquifer materials ranging from gravels to silty sand and sufficiently permeable consolidated and fractured strata. Strata having grain sizes smaller than the recommended design for the smallest diameter filter pack materials should be monitored by alternative monitoring well designs which are not addressed in this practice.

1.4 The values stated in inch-pound units are to be regarded as standard. The values in parentheses are for information only.

1.5 *This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of r[...] limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 150 Specification for Portland Cement[2]
C 294 Descriptive Nomenclature of Constituents [...]ural Mineral Aggregates[3]
D 653 Terminology Relating to Soil, Rock, and C[...] Fluids[4]
D 1452 Practice for Soil Investigation and Sam[...] Auger Borings[4]
D 1586 Method for Penetration Test and Spl[...] Sampling of Soils[4]
D 1587 Practice for Thin-Walled Tube Sampling [...]
D 2113 Practice for Diamond Core Drilling [...] Investigation[4]
D 2487 Test Method for Classification of Soils f[...]neering Purposes[4]
D 2488 Practice for Description and Identification [...] (Visual-Manual Procedure)[4]
D 3282 Practice for Classification of Soils and Soil[...]gate Mixtures for Highway Construction Purpos[...]
D 3550 Practice for Ring Lined Barrel Sampling o[...]
D 4220 Practice for Preserving and Transporti[...] Samples[4]

3. Significance and Use

3.1 An adequately designed and installed groun[...] monitoring well system for aqueousphase liquids [...] essential information for decisions pertaining to one [...] of the following subjects:

3.1.1 Aquifer and aquitard properties, both geolo[...] hydraulic;

[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21.05 on Design and Installation of Ground-Water Monitoring Wells.

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[2] *Annual Book of ASTM Standards*, Vol 04.01.
[3] *Annual Book of ASTM Standards*, Vol 04.02.
[4] *Annual Book of ASTM Standards*, Vol 04.08.

3.1.2 Potentiometric surface of a particular hydrologic unit(s);

3.1.3 Water quality with respect to various indicator parameters;

3.1.4 Migration characteristics of a contaminant release;

3.1.5 Additional installations or decommissioning of installations, or both, no longer needed.

4. Terminology

4.1 *Definitions:*

4.1.1 *annular space; annulus*—the space between two concentric tubes or casings, or between the casing and the borehole wall. This would include the space(s) between multiple strings of tubing/casings in a borehole installed either concentrically or multi-cased adjacent to each other.

4.1.2 *assessment monitoring*—an investigative monitoring program that is initiated after the presence of a contaminant in ground water has been detected. The objective of this program is to determine the concentration of constituents that have contaminated the ground water and to quantify the rate and extent of migration of these constituents.

4.1.3 *ASTM cement types*—Portland cements meeting the requirements of Specifications C 150. Cement types have slightly different formulations that result in various characteristics which address different construction conditions and different physical and chemical environments. They are as follows:

4.1.3.1 *Type I (Portland)*—a general-purpose construction cement with no special properties.

4.1.3.2 *Type II (Portland)*—a construction cement that is moderately resistant to sulfates and generates a lower head of hydration at a slower rate than Type I.

4.1.3.3 *Type III (Portland; high early strength)*—a construction cement that produces a high early strength. This cement reduces the curing time required when used in cold environments, and produces a higher heat of hydration than Type I.

4.1.3.4 *Type IV (Portland)*—a construction cement that produces a low head of hydration (lower than Types I and II) and develops strength at a slower rate.

4.1.3.5 *Type V (Portland)*—a construction cement that is a high sulfate resistant formulation. Used when there is severe sulfate action from soils and ground water.

4.1.4 *bailer*—a hollow tubular receptacle used to facilitate withdrawal of fluid from a well or borehole.

4.1.5 *ballast*—materials used to provide stability to a buoyant object (such as casing within a borehole filled with water).

4.1.6 *blow-in*—the inflow of ground water and unconsolidated material into a borehole or casing caused by differential hydraulic heads; that is, caused by the presence of a greater hydraulic head outside of a borehole/casing than inside.

4.1.7 *borehole* a circular open or uncased subsurface hole created by drilling.

4.1.8 *borehole log*—the record of geologic units penetrated, drilling progress, depth, water level, sample recovery, volumes, and types of materials used, and other significant facts regarding the drilling of an exploratory borehole or well.

DISCUSSION—The definition of aquifer as currently included in Terminology D 653 varies from the definition as prescribed by US federal regulations. Since this federal definition is associated with the installation of many monitoring wells it is provided herein as a technical note:

aquifer—a geologic formation, group of formation, or part of a formation that is saturated, and is capable of providing a significant quantity of water.

4.1.9 *bridge*—an obstruction within the annulus which may prevent circulation or proper emplacement of annular materials.

4.1.10 *casing*—pipe, finished in sections with either threaded connections or bevelled edges to be field welded, which is installed temporarily or permanently to counteract caving, to advance the borehole, or to isolate the zone being monitored, or combination thereof.

4.1.11 *casing, protective*—a section of larger diameter pipe that is emplaced over the upper end of a smaller diameter monitoring well riser or casing to provide structural protection to the well and restrict unauthorized access into the well.

4.1.12 *casing, surface*—pipe used to stabilize a borehole near the surface during the drilling of a borehole that may be left in place or removed once drilling is completed.

4.1.13 *caving; sloughing*—the inflow of unconsolidated material into a borehole which occurs when the borehole walls lose their cohesive strength.

4.1.14 *cement; Portland cement*—commonly known as Portland cement. A mixture that consists of a calcareous, argillaceous, or other silica-, alumina-, and iron-oxide-bearing materials that is manufactured and formulated to produce various types which are defined in Specification C 150. Portland cement is also considered a hydraulic cement because it must be mixed with water to form a cement-water paste that has the ability to harden and develop strength even if cured under water (see *ASTM cement types*).

4.1.15 *centralizer*—a device that assists in the centering of a casing or riser within a borehole or another casing.

4.1.16 *circulation*—applies to the fluid rotary drilling method; drilling fluid movement from the mud pit, through the pump, hose and swivel, drill pipe, annular space in the hole and returning to the mud pit.

4.1.17 *conductance (specific)*—a measure of the ability of the water to conduct an electric current at 77°F (25°C). It is related to the total concentration of ionizable solids in the water. It is inversely proportional to electrical resistance.

4.1.18 *confining unit*—a term that is synonymous with "aquiclude," "aquitard," and "aquifuge;" defined as a body of relatively low permeable material stratigraphically adjacent to one or more aquifers.

4.1.19 *contaminant*—an undesirable substance not normally present in water or soil.

4.1.20 *detection monitoring*—a program of monitoring for the express purpose of determining whether or not there has been a contaminant release to ground water.

4.1.21 *drill cuttings*—fragments or particles of soil or rock, with or without free water, created by the drilling process.

4.1.22 *drilling fluid*—a fluid (liquid or gas) that may be used in drilling operations to remove cuttings from the borehole, to clean and cool the drill bit, and to maintain the integrity of the borehole during drilling.

4.1.23 *d-10*—the diameter of a soil particle (preferably in millimetres) at which 10 % by weight (dry) of the particles of a particular sample are finer. Synonymous with the effective size or effective grain size.

4.1.24 *d-60*—the diameter of a soil particle (preferably in millimetres) at which 60 % by weight (dry) of the particles of a particular sample are finer.

4.1.25 *flow path*—represents the area between two flow lines along which ground water can flow.

4.1.26 *flush joint or flush coupled*—casing or riser with ends threaded such that a consistent inside and outside diameter is maintained across the threaded joints or couplings.

4.1.27 *gravel pack*—common nomenclature for the terminology, primary filter of a well (see *primary filter pack*).

4.1.28 *grout (monitoring wells)*—a low permeability material placed in the annulus between the well casing or riser pipe and the borehole wall (that is, in a single-cased monitoring well), or between the riser and casing (that is, in a multi-cased monitoring well), to maintain the alignment of the casing and riser and to prevent movement of ground water or surface water within the annular space.

4.1.29 *grout shoe*—a *plug* fabricated of relatively inert materials that is positioned within the lowermost section of a permanent casing and fitted with a passageway, often with a flow check device, through which grout is injected under pressure to fill the annular space. After the grout has set, the grout shoe is usually drilled out.

4.1.30 *head (static)*—the height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point. The static head is the sum of the elevation head and the pressure head.

4.1.31 *head (total)*—the sum of three components at a point: (*1*) elevation head, h_e, which is equal to the elevation of the point above a datum; (*2*) pressure head, hp, which is the height of a column of static water than can be supported by the static pressure at the point; and (*3*) velocity head, hv, which is the height the kinetic energy of the liquid is capable of lifting the liquid.

4.1.32 *hydrologic unit*—geologic strata that can be distinguished on the basis of capacity to yield and transmit fluids. Aquifers and confining units are types of hydrologic units. Boundaries of a hydrologic unit may not necessarily correspond either laterally or vertically to lithostratigraphic formations.

4.1.33 *jetting*—when applied as a drilling method, water is forced down through the drill rods or casings and out through the end aperture. The jetting water then transports the generated cuttings to the ground surface in the annulus of the drill rods or casing and the borehole. The term jetting may also refer to a development technique (see well screen jetting).

4.1.34 *loss of circulation*—the loss of drilling fluid into strata to the extent that circulation does not return to the surface.

4.1.35 *mud pit*—usually a shallow, rectangular, open, portable container with baffles into which drilling fluid and cuttings are discharged from a borehole and that serves as a reservoir and settling tank during recirculation of the drilling fluids. Under some circumstances, an excavated pit wit lining material may be used.

4.1.36 *multi-cased well*—a well constructed by using cessively smaller diameter casings with depth.

4.1.37 *neat cement*—a mixture of Portland cement (S ification 150) and water.

4.1.38 *observation well*—typically, a small diameter used to measure changes in hydraulic heads, usually response to a nearby pumping well.

4.1.39 *oil air filter*—a filter or series of filters placed in air flow line from an air compressor to reduce the oil cont of the air.

4.1.40 *oil trap*—a device used to remove oil from compressed air discharged from an air compressor.

4.1.41 *packer (monitoring wells)*—a transient or dedica device placed in a well that isolates or seals a portion of well, well annulus, or borehole at a specific level.

4.1.42 *potentiometric surface*—an imaginary surface r resenting the static head of ground water. The water table particular potentiometric surface.

DISCUSSION—Where the head varies with depth in the aquife potentiometric surface is meaningful only if it describes the st head along a particular specified surface or stratum in that aqui More than one potentiometric surface is required to describe distribution of head in this case.

4.1.43 *primary filter pack*—a clean silica sand or sand a gravel mixture of selected grain size and gradation that installed in the annular space between the borehole wall a the well screen, extending an appropriate distance above screen, for the purpose of retaining and stabilizing particles from the adjacent strata. The term is used in pla of *gravel pack*.

4.1.44 *PTFE tape*—joint sealing tape composed of po tetrafluoroethylene.

4.1.45 *riser*—the pipe extending from the well screen or above the ground surface.

4.1.46 *secondary filter pack*—a clean, uniformly grad sand that is placed in the annulus between the primary filt pack and the over-lying seal, or between the seal a overlying grout backfill, or both, to prevent movement seal or grout, or both, into the primary filter pack.

4.1.47 *sediment sump*—a blank extension beneath t well screen used to collect fine-grained material from t filter pack and adjacent strata. The term is synonymous wi rat trap or tail pipe.

4.1.48 *shear strength (monitoring wells)*—a measure the shear or gel properties of a drilling fluid or grout.

4.1.49 *single-cased well*—a monitoring well construct with a riser but without an exterior casing.

4.1.50 *static water level*—the elevation of the top of column of water in a monitoring well or piezometer that not influenced by pumping or conditions related to w installation, hydrologic testing, or nearby pumpage.

4.1.51 *tamper*—a heavy cylindrical metal section tubing that is operated on a wire rope or cable. It slips ov the riser and fits inside the casing or borehole annulus. It generally used to tamp annular sealants or filter pa materials into place and prevent bridging.

4.1.52 *target monitoring zone*—the ground water flo path from a particular area or facility in which monitori wells will be screened. The target monitoring zone should stratum (strata) in which there is a reasonable expectation that a vertically placed well will intercept migrating contaminants.

4.1.53 *test pit*—a shallow excavation made to characterize the subsurface.

4.1.54 *transmissivity*—the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

DISCUSSION—It is equal to an integration of the hydraulic conductivities across the saturated part of the aquifer perpendicular to the flow paths.

4.1.55 *tremie pipe*—a pipe or tube that is used to transport filter pack materials and annular sealant materials from the ground surface into the borehole annulus or between casings and casings or riser pipe of a monitoring well.

4.1.56 *uniformly graded*—a quantitative definition of the particle size distribution of a soil which consists of a majority of particles being of the same approximate diameter. A granular material is considered uniformly graded when the uniformity coefficient is less than about five (Test Method D 2487). Comparable to the geologic term *well sorted*.

4.1.57 *vented cap*—a cap with a small hole that is installed on top of the riser.

4.1.58 *washout nozzle*—a tubular extension with a check valve utilized at the end of a string of casing through which water can be injected to displace drilling fluids and cuttings from the annular space of a borehole.

4.1.59 *weep hole*—a small diameter hole (usually ¼ in.) drilled into the protective casing above the ground surface that serves as a drain hole for water that may enter the protective casing annulus.

4.1.60 *well completion diagram*—a record that illustrates the details of a well installation.

4.1.61 *well screen*—a filtering device used to retain the primary or natural filter pack; usually a cylindrical pipe with openings of a uniform width, orientation, and spacing.

4.1.62 *well screen jetting (hydraulic jetting)*—when jetting is used for development, a jetting tool with nozzles and a high-pressure pump is used to force water outwardly through the screen, the filter pack, and sometimes into the adjacent geologic unit.

4.1.63 *zone of saturation*—a hydrologic zone in which all the interstices between particles of geologic material or all of the joints, fractures, or solution channels in a consolidated rock unit are filled with water under pressure greater than that of the atmosphere.

5. Site Characterization

5.1 *General*—Soil mechanics, geomorphological concepts, geologic structure, stratigraphy, and sedimentary concepts, as well as the nature and behavior of the solutes of interest, must be combined with a knowledge of ground water movement to make a complete application of the results of the monitoring well design and installation guidance. Therefore, development of a conceptual hydrogeologic model that identifies potential flow paths and the target monitoring zone(s) is recommended prior to monitoring well design and installation. Development of the conceptual model is accomplished in two phases—an initial reconnaissance and a field investigation. When the hydrogeology of a project area is relatively uncomplicated and well documented in the literature, the initial reconnaissance may provide sufficient information to identify flow paths and the target monitoring zone(s). However, where little background data is available or the geology is complicated, a field investigation will generally be necessary to completely develop a conceptual hydrogeologic model.

5.2 *Initial Reconnaissance of Project Area*—The goal of the initial reconnaissance of the project area is to identify and locate those zones with the greatest potential to transmit a fluid from the project area. Identifying these flow paths is the first step in selecting the target ground water monitoring zone(s).

5.2.1 *Literature Search*—Every effort should be made to collect and review all applicable field and laboratory data from previous investigations of the project area. Data such as, but not limited to, topographic maps, aerial imagery, site ownership and utilization records, geologic and hydrogeologic maps and reports, mineral resource surveys, water well logs, personal information from local well drillers, agricultural soil reports, geotechnical engineering reports, and other engineering maps and report related to the project area should be reviewed.

5.2.2 *Field Reconnaissance*—Early in the investigation, the soil and rocks in open cut areas in the vicinity of the project should be studied, and various soil and rock profiles noted. Special consideration should be given to soil color and textural changes, landslides, seeps, and springs within or near the project area.

5.2.3 *Preliminary Conceptual Model*—The distribution of the predominant soil and rock units likely to be found during subsurface exploration may be hypothesized at this time in a preliminary hydrogeologic conceptual model using data obtained in the literature search and field reconnaissance. In areas where the geology is relatively uniform, well documented in the literature, and substantiated by the field reconnaissance, further refinement of the conceptual model may not be necessary unless anomalies are discovered in the well drilling stage.

5.3 *Field Investigation*—The goal of the field investigation is to refine the preliminary conceptual hydrogeologic model so that the target monitoring zone(s) is selected prior to monitoring well installation.

5.3.1 *Exploratory Borings and Test Pits*—Characterization of the flow paths conceptualized in the initial reconnaissance involves defining the porosity, hydraulic conductivity, gradation, stratigraphy, lithology, and structure of each hydrologic unit. The characteristics are defined by conducting an exploratory boring program which may include test pits. Exploratory borings and test pits should be deep enough to develop the required engineering and hydrogeologic data for determining the flow path(s), target monitoring zone, or both.

5.3.1.1 *Sampling*—Soil and rock properties should not be predicted wholly on field identification or classification, but should be checked by laboratory and field tests made on samples. Representative soil or rock samples, or both, of each material that is significant to the analysis and design of the monitoring system should be obtained and evaluated by a geologist, hydrogeologist, or engineer trained and experienced in soil and rock analysis. Soil sample extraction should be conducted according to Practice D 1452, Method D 1586, Practice D 3550, or Practice D 1587, whichever is appropriate given the anticipated characteristics of the soil samples. Rock samples should be extracted according to Practice D 2113. Soil samples obtained for evaluation of hydraulic properties should be containerized and identified for shipment to a laboratory. Special measures to preserve either the continuity of the sample or the natural moisture are not usually required. However, soil and rock samples obtained for evaluation of chemical properties often require special field preparation and preservation to prevent significant alteration of the chemical constituents during transportation to a laboratory (see Practice D 4220). Rock samples for evaluation of hydraulic properties are usually obtained using a split-inner-tube core barrel. Evaluation and logging of the core samples is usually made in the field before the core is removed from half of the split inner tube core barrel.

5.3.1.2 *Boring Logs*—Care should be taken to prepare and retain a complete boring log and sampling record for each exploratory borehole and test pit.

NOTE 1—Site investigations for the installation of ground-water monitoring wells can vary greatly due to the availability of reliable site data or the lack thereof. The general procedure would however be as follows: (*1*) gather factual data regarding the surficial and subsurface conditions, (*2*) analyze the data, (*3*) develop a conceptual model of the site conditions, (*4*) locate the monitoring wells based on the first three steps. Monitoring wells should only be installed with sufficient understanding of the geologic and hydrogeologic conditions present on site. Monitoring wells often serve as part of an overall site investigation for a specific purpose, such as determining the extent of contamination present, or for prediction of the effectiveness of aquifer remediations. In these cases extensive additional geotechnical and hydrogeologic information may be required that would go beyond the Section 5 Site Characterization description.

Boring logs should include the location, geotechnical (that is, penetration rates or blow counts), and sampling information for each material identified in the borehole either by symbol or word description, or both. Identification of all soils should be in accordance with Practice D 2488 or Practice D 3282. Identification of rock material should be based on Nomenclature C 294 or by an appropriate geologic classification system. Observations of seepage, free water, and water levels should also be noted. The boring logs should be accompanied by a report that includes a description of the area investigated; a map illustrating the vertical and horizontal location (with reference to nearest National Geodetic Vertical Datum [NGVD] and to a standardized survey grid, respectively) of each exploratory borehole or test pit, or both; and color photographs of rock cores, soil samples, and exposed strata labeled with a date and identification.

5.3.2 *Geophysical Exploration*—Geophysical surveys may be used to supplement borehole and outcrop data and to aid in interpretation between boreholes. Surface geophysical methods such as seismic surveys, and electrical-resistivity and electromagnetic conductance surveys can be particularly valuable when distinct differences in the properties of contiguous subsurface materials are indicated. Borehole methods such as resistivity, gamma, gamma-gamma, neutron, and caliper logs can be useful to confirm specific subsurface geologic conditions. Gamma logs are particularly useful in existing cased wells.

5.3.3 *Ground Water Flow Direction*—Ground water flow direction is generally determined by measuring the vertical and horizontal hydraulic gradient within each conce ized flow path. However, because water will flow alo path of least resistance, flow direction may be oblique hydraulic gradient (buried stream channels or glacial v for example). Flow direction is determined by first ins piezometers in the exploratory boreholes. The dept location of the piezometers will depend upon antic hydraulic connections between conceptualized flow and their respective lateral direction of flow. Foll careful evaluation, it may be possible to utilize e private or public wells to obtain water level data construction integrity of such wells should be verifi ensure that the water levels obtained from the wel representative only of the zones of interest. Following level data acquisition, a potentiometric surface map s be prepared. Flow paths are ordinarily determined to right angles, or nearly so, to the equipotential lines.

5.4 *Completing the Conceptual Model*—A seri hydrogeologic cross sections should be developed to the conceptual model. This is accomplished by first pl logs of soil and rock observed in the exploratory bori test pits, and interpreting between these logs usin geologic and engineering interrelationships between soil and rock data observed in the initial reconnaissan with geophysical techniques. Extrapolation of data adjacent areas should be done only where geolog uniform subsurface conditions are known to exist. The step is to integrate the profile data with the piezomete for both vertical and horizontal hydraulic gradients. view and cross-sectional flow nets may need to be structed. Following the analysis of these data, conclu can be made as to which flow path(s) is the appropriate monitoring zone(s).

NOTE 2—Ground water monitoring is difficult and may no reliable technology in fine-grain, low hydraulic conductivity, p porosity strata because of (*1*) the disproportionate influence microstratigraphy has on ground water flow in fine-grain strata; (2 lines proportionally higher for the vertical flow component i hydraulic conductivity strata; and (*3*) the presence of indig metallic and inorganic constituents that make water quality evaluation difficult.

6. Monitoring Well Construction Materials

6.1 *General*—The materials that are used in the cons tion of a monitoring well and that come in contact wit water sample should not measurably alter the che quality of the sample for the constituents being exam using the appropriate sampling protocols. Furthermore riser, well screen, and annular sealant injection equip should be steam cleaned or high-pressure water clean appropriate for the selected riser material) immediately to well installation or certified clean from the manufac and delivered to site in a protective wrapping. Samples cleaning water, filter pack, annular seal, and mixed should be retained to serve as quality control unti completion of at least one round of ground water q sampling and analysis.

6.2 *Water*—Water used in the drilling process, to pr grout mixtures and to decontaminate the well screen, and annular sealant injection equipment, should be obt from a source of known chemistry that does not co nstituents that could compromise the integrity of the well stallation.

6.3 *Primary Filter Pack:*

6.3.1 *Materials*—The primary filter pack (gravel pack) nsists of a granular material of known chemistry and lected grain size and gradation that is installed in the nulus between the screen and the borehole wall. The filter ck is usually selected to have a 30 % finer (d-30) grain size at is about 4 to 10 times greater than the 30 % finer (d-30) ain size of the hydrologic unit being filtered (see Fig. 1). sually, the filter is selected to have a low (that is, less than 5) uniformity coefficient. The grain size and gradation of e filter are selected to stabilize the hydrologic unit adjacent the screen and permit only the finest soil grains to enter e screen during development. Thus, after development, a rrectly filtered monitoring well is relatively turbid-free.

NOTE 3—When installing a monitoring well in Karst or highly actured bedrock, the borehole configuration of void spaces within the rmation surrounding the borehole is often unknown. Therefore, the stallation of a filter pack becomes difficult and may not be possible.

6.3.2 *Gradation*—The filter pack should be uniformly aded and comprised of hard durable siliceous particles ashed and screened with a particle size distribution derived y multiplying the d-30 size of the finest-grained screened ratum by a factor between 4 and 10. Use a number between ur and six as the multiplier if the stratum is fine and iform; use a factor between six and ten where the material as highly nonuniform gradation and includes silt-sized rticles. The grain-size distribution of the filter pack is then otted using the d-30 size as the control point on the graph. he selected filter pack should have a uniformity coefficient approximately 2.5 or less.

NOTE 4—This practice presents a design for monitoring wells that ll be effective in the majority of aquifers. Applicable state guidance ay differ from the designs contained in this practice.

NOTE 5—Because the well screen slots have uniform openings, the ter pack should be composed of particles that are as uniform in size as practical. Ideally, the uniformity coefficient (the quotient of the 60 % ssing, D-60 size divided by the 10 % passing D-10 size [effective size]) the filter pack should be 1.0 (that is, the D-60 % and the D-10 % sizes ould be identical). However, a more practical and consistently hievable uniformity coefficient for all ranges of filter pack sizes is 2.5. is value of 2.5 should represent a maximum value, not an ideal.

NOTE 6—Although not recommended as standard practice, often a oject requires drilling and installing the well in one phase of work. Therefore, the filter pack materials must be ordered and delivered to the drill site before soil samples can be collected. In these cases, the suggested well screen slot size and filter pack materials are presented in Table 1.

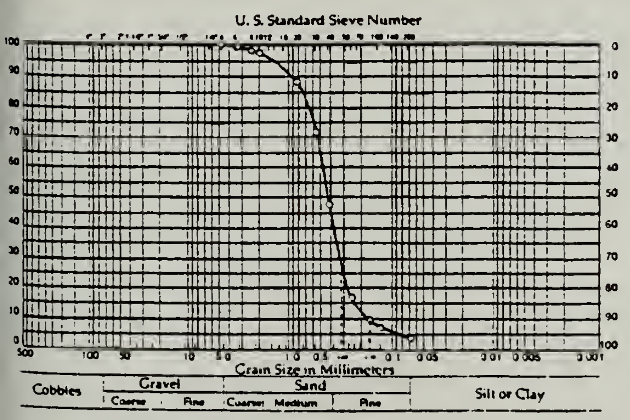

FIG. 1 **Example Grading Curve for Design of Monitoring Well Screens**

6.4 *Well Screen:*

6.4.1 *Materials*—The well screen should be new, machine-slotted or continuous wrapped wire-wound and composed of materials most suited for the monitoring environment and site characterization findings. The screen should be plugged at the bottom. The plug should be of the same material as the well screen. This assembly must have the capability to withstand installation and development stresses without becoming dislodged or damaged. The length of the slotted area should reflect the interval to be monitored. Immediately prior to installation, the well screen should be steam cleaned or high-pressure water cleaned (if appropriate for the selected well screen materials) with water from a source of known chemistry if not certified by the manufacturer, delivered, and maintained clean at the site.

NOTE 7—Well screens are most commonly composed of PVC, stainless steel, fiberglass, or fluoropolymer materials.

6.4.2 *Diameter*—The minimum nominal internal diameter of the well screen should be chosen based on the particular application. However, in most instances, a minimum of 2 in. (50 mm) is needed to allow for the introduction and withdrawal of sampling devices.

6.4.3 *Slot Size*—The slot size of the well screen should be determined relative to the grain size analysis of the stratum interval to be monitored and the gradation of the filter pack material. In granular non-cohesive strata that will fall in easily around the screen, filter packs are not necessary. In these cases of natural development, the slot size of the well screen is to be determined using the grain size of the materials in the surrounding strata. The slot size and arrangement should retain at least 90 % and preferably 99 % of the filter pack. The method for determining the correct gradation of filter pack material is described in 6.3.2.

6.5 *Riser:*

6.5.1 *Materials*—The riser should be new and composed of materials that will not alter the quality of water samples for the constituents of concern and that are appropriate for the monitoring environment. The riser should have adequate wall thickness and coupling strength to withstand installation and development stresses. Each section of riser should be steam cleaned or high-pressure water cleaned (if appropriate for the selected material) using water from a source of known chemistry immediately prior to installation.

NOTE 8—Risers are generally constructed of PVC, stainless steel, fiberglass, or fluoropolymer materials.

6.5.2 *Diameter*—The minimum nominal internal diameter of the riser should be chosen based on the particular application. However, in most instances, a minimum of 2 in. (50 mm) is needed to accommodate sampling devices.

6.5.3 *Joints (Couplings)*—Threaded joints are recommended. Glued or solvent welded joints of any type are *not* recommended since glues and solvents may alter the chemistry of the water samples. In most cases, square profile flush joint threads do not require PTFE taping, however, tapered thread joints should be PTFE taped to prevent leakage of water into the riser. Alternatively, O-rings composed of

TABLE 1 Recommended (Achievable) Filter Pack Characteristics for Common Screen Slot Sizes

Size of Screen Opening, mm (in.)	Slot No.	Sand Pack Mesh Size Name(s)	1 % Passing Size (D-1), mm	Effective Size, (D-10), mm	30 % Passing Size (D-30), mm	Range of Uniformity Coefficient	Roundness (Po Scale)
0.125 (0.005)	5[A]	100	0.09 to 0.12	0.14 to 0.17	0.17 to 0.21	1.3 to 2.0	2 to 5
0.25 (0.010)	10	20 to 40	0.25 to 0.35	0.4 to 0.5	0.5 to 0.6	1.1 to 1.6	3 to 5
0.50 (0.020)	20	10 to 20	0.7 to 0.9	1.0 to 1.2	1.2 to 1.5	1.1 to 1.6	3 to 6
0.75 (0.030)	30	10 to 20	0.7 to 0.9	1.0 to 1.2	1.2 to 1.5	1.1 to 1.6	3 to 6
1.0 (0.040)	40	8 to 12	1.2 to 1.4	1.6 to 1.8	1.7 to 2.0	1.1 to 1.6	4 to 6
1.5 (0.060)	60	6 to 9	1.5 to 1.8	2.3 to 2.8	2.5 to 3.0	1.1 to 1.7	4 to 6
2.0 (0.080)	80	4 to 8	2.0 to 2.4	2.4 to 3.0	2.6 to 3.1	1.1 to 1.7	4 to 6

[A] A 5-slot (0.152-mm) opening is not currently available in slotted PVC but is available in Vee wire PVC and Stainless; 6-slot opening may be substituted in these c

materials that would not impact the water sample for the constituents of concern may be selected for use on flush joint threads.

6.6 *Casing*—Where conditions warrant, the use of permanent casing installed to prevent communication between water-bearing zones is encouraged. The following subsections address both temporary and permanent casings.

6.6.1 *Materials*—The material type and minimum wall thickness of the casing should be adequate to withstand the forces of installation. All casing that is to remain as a permanent part of the installation (that is, multi-cased wells) should be new and cleaned to be free of interior and exterior protective coatings.

NOTE 9—The exterior casing (temporary or permanent multi-cased) is generally composed of steel, although other appropriate materials may be used.

6.6.2 *Diameter*—Several different casing sizes may be required depending on the subsurface geologic conditions penetrated. The diameter of the casing for filter packed wells should be selected so that a minimum annular space of 2 in. (50 mm) is maintained between the inside diameter of the casing and outside diameter of the riser. In addition, the diameter of the casings in multi-cased wells should be selected so that a minimum annular space of 2 in. is maintained between the casing and the borehole (that is, a 2-in. diameter screen will require first setting a 6-in. (152-mm) diameter casing in a 10-in. (254-mm) diameter boring).

NOTE 10—Under difficult drilling conditions (collapsing soils, rock, or cobbles), it may be necessary to advance temporary casing, under these conditions a smaller annular space may be maintained.

6.6.3 *Joints (Couplings)*—The ends of each casing section should be either flush-threaded or bevelled for welding.

6.7 *Protective Casing:*

6.7.1 *Materials*—Protective casings may be made of aluminum, steel, stainless steel, cast iron, or a structural plastic. The protective casing should have a lid capable of being locked shut by a locking device.

6.7.2 *Diameter*—The inside dimensions of the protective casing should be a minimum of 2 in. (50 mm) and preferably 4 in. (101 mm) larger than the nominal diameter of the riser to facilitate the installation and operation of sampling equipment.

6.8 *Annular Sealants*—The materials used to seal the annulus may be prepared as a slurry or used un-mixed in a dry pellet, granular, or chip form. Sealants should be selected to be compatible with ambient geologic, hydrogeologic, and climatic conditions and any man-induced conditions anticipated to occur during the life of the well.

6.8.1 *Bentonite*—Bentonite should be powdered, granular, pelletized, or chipped sodium montmorillonite nished in sacks or buckets from a commercial source free of impurities which adversely impact the water qu in the well. Pellets consist of roughly spherical or disk sha units of compressed bentonite powder. Chips are la irregularly shaped, and coarse granular units of bento free of additives. The diameter of pellets or chips selectec monitoring well construction should be less than one the width of the annular space into which they are place reduce the potential for bridging. Granules consist of co particles of unaltered bentonite, typically smaller than 0. (50 mm).

6.8.2 *Cement*—Each type of cement has slightly diffe characteristics that may be appropriate under various p ical and chemical conditions. Cement should be one of five Portland cement types that are specified in Specifica C 150. The use of quick-setting cements containing addit is not recommended for use in monitoring well installat Additives may leach from the cement and influence chemistry of the water samples.

6.8.3 *Grout*—The grout backfill that is placed above bentonite annular seal and secondary filters (see Fig. ordinarily a liquid slurry consisting of either a bento (powder or granules, or both) base and water, or a Portl cement base and water. Often, bentonite-based grouts used when it is desired that the grout remain flexible (tha to accommodate freeze-thaw) during the life of the inst tion. Cement or bentonite-based grouts are often used w the filling in of cracks in the surrounding geologic mate adherence to rock units, or a rigid setting is desired.

6.8.3.1 *Mixing*—The mixing (and placing) of a g backfill should be performed with precisely recorded wei and volumes of materials, and according to proced stipulated by the manufacturer that often include the o of component mixing. The grout should be thorou mixed with a paddle type mechanical mixer or recirculating the mix through a pump until all lumps disintegrated. Lumpy grout should not be used in construction of a monitoring well to prevent bridging wi the tremie.

NOTE 11—Lumps do not include lost circulation materials that be added to the grout if excessive grout losses occur.

6.8.3.2 *Typical Bentonite Base Grout*—When a bento base grout is used, bentonite, usually unaltered, *must* be first additive placed in the water through a venturi devic typical unbeneficiated bentonite base grout consists of ab 1 to 1.25 lb (0.57 kg) of unaltered bentonite to each 1 gal L) of water. After the bentonite is mixed and allowe "yield or hydrate," up to 2 lb (0.9 kg) of Type I Portl cement (per gallon of water) is often added to stiffen the

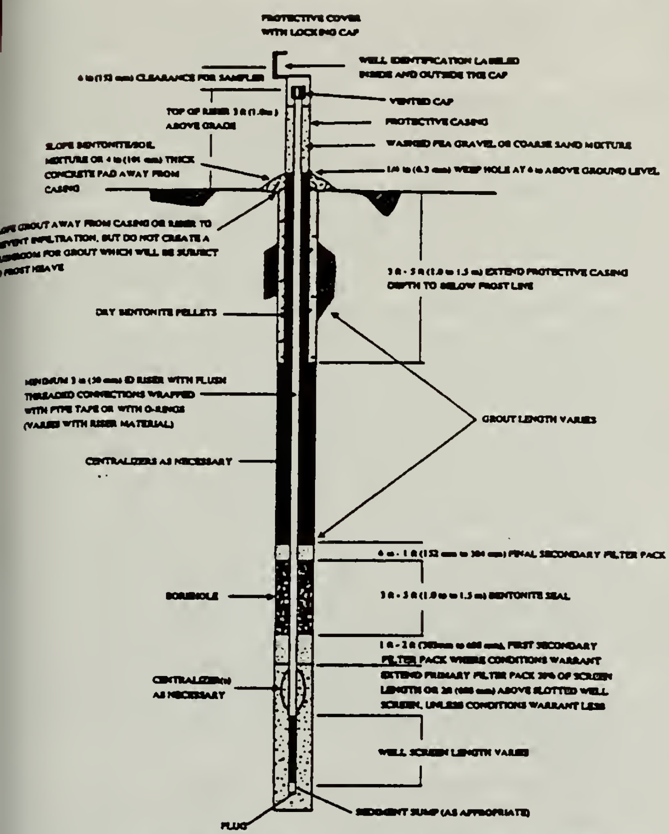

FIG. 2 Monitoring Well Design—Single-Cased Well

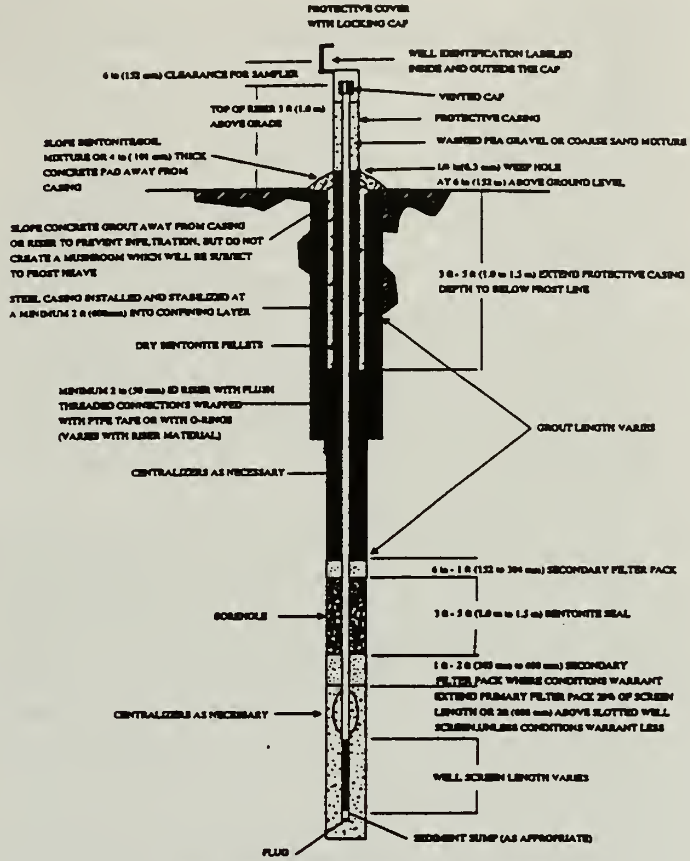

FIG. 3 Monitoring Well Design—Multi-Cased Well

)0 % Bentonite grouts should not be used solely for onitoring well annular sealants in the vadose zone of arid gions because of their propensity to desiccate. This could sult in non-representative waters affecting the target mon- oring zone.

Note 12—High solids bentonite grouts (minimum 20 % by weight th water) and other bentonite-based grouts may contain granular ntonite to increase the solids content and other components added der manufacturer's directions to either stiffen or retard stiffening of e mix.

All additives to grouts should be evaluated for their effects on bsequent water samples.

6.8.3.3 *Typical Cement Base Grout*—When a cement- ısed grout is used, cement is usually the first additive placed the water. A typical cement-based grout consists of about to 7 gal (23 to 26 L) of water per 94-lb (43-kg) bag of Type Portland cement. From 0 to 10 % (by dry weight of ment) of unaltered bentonite powder is often added after e initial mixing of cement and water to retard shrinkage ıd provide plasticity. The bentonite is added *dry* to the ment-water slurry without first mixing it with water.

6.9 *Secondary Filter Packs:*

6.9.1 *Materials*—A secondary filter pack is a layer of aterial placed in the annulus between the primary filter ıck and the bentonite seal, and between the bentonite seal ıd the grout backfill (see Figs. 2 and 3).

6.9.2 *Gradation*—The secondary filter pack should be ıiformly graded fine sand with a 100 % by weight passing e No. 30 U.S. Standard sieve, and less than 2 % by weight ıssing the 200 U.S. Standard sieve.

6.10 *Annular Seal Equipment*—The equipment used to inject the annular seals and filter pack should be steam cleaned or high-pressure water cleaned (if appropriate for the selected material) using water from a source or known quality prior to use. This procedure is performed to prevent the introduction of materials that may ultimately alter the water sample quality.

7. Drilling Methods

7.1 The type of equipment required to create a stable, open, vertical borehole for installation of a monitoring well depends upon the site geology, hydrology, and the intended use of the data. Engineering and geological judgment is required for the selection of the drilling methods utilized for drilling the exploratory boreholes and monitoring wells. Whenever feasible, drilling procedures should be utilized that do not require the introduction of water or liquid fluids into the borehole, and that optimize cuttings control at ground surface. Where the use of drilling fluid is unavoidable, the selected fluid should have as little impact as possible on the water samples for the constituents of interest. In addition, care should be taken to remove as much drilling fluid as possible from the well and the aquifer during the well development process. It is recommended that if an air compressor is used, it is equipped with an oil air filter or oil trap.

8. Monitoring Well Installation

8.1 *Stable Borehole*—A stable borehole must be constructed prior to attempting to install the monitoring well screen and riser. Steps must be taken to stabilize the borehole before attempting installation if the borehole tends to cave or blow-in, or both. Boreholes that are not straight or are partially obstructed should be corrected prior to attempting the installations described herein.

8.2 *Assembly of Well Screen and Riser:*

8.2.1 *Handling*—The well screen, bottom plug, riser, should be either certified clean from the manufacturer or steam cleaned or high-pressure water cleaned (if appropriate for the selected material) using water from a source of known chemistry immediately prior to assembly. Personnel should take precautions to assure that grease, oil, or other contaminants that may ultimately alter the water sample do not contact any portion of the well screen and riser assembly. As one precaution, for example, personnel should wear a clean pair of cotton or surgical (or equivalent) gloves while handling the assembly.

8.2.2 *Riser Joints (Couplings)*—Flush joint risers with square profile threads normally do not require additional PTFE taping to obtain a water tight seal. In addition, O-rings of known chemistry, selected on the basis of prevailing environmental or physical conditions, may be used to assure a tight seal of flush-joint couplings. Couplings are often tightened by hand; however, if necessary, steam cleaned or high-pressure water cleaned wrenches may be utilized. Precautions should be taken to prevent damage to the threaded joints during installation.

8.3 *Setting the Well Screen and Riser Assembly*—When the well screen and riser assembly is lowered to the predetermined level and held into position, the assembly may require ballast to counteract the tendency to float in the borehole. Ballasting may be accomplished by continuously filling the riser with water from a source of known chemistry or, preferably, water which was previously removed from the borehole. Alternatively, the riser may be slowly pushed into the fluid in the borehole with the aid of hydraulic rams on the drill rig and held in place as additional sections of riser are added to the column. Care must be taken to secure the riser assembly so that personnel safety is assured during the installation. The assembly must be installed straight with the appropriate centralizers to allow for the introduction and withdrawal of sampling devices. Difficulty in maintaining a straight installation may be encountered where the weight of the well screen and riser assembly is significantly less than the buoyant force of the fluid in the borehole. The riser should extend above grade and be capped temporarily to deter entrance of foreign materials during completion operations.

8.4 *Installation of the Primary Filter Pack:*

8.4.1 *Volume of Filter Pack*—The volume of filter pack required to fill the annular space between the well screen and borehole should be computed, measured, and recorded on the well completion diagram during installation. To be effective, the filter pack should extend above the screen for a distance of about 20 % of the length of the well screen but not less than 2 ft (600 mm) (see Figs. 2 and 3). Where there is hydraulic connection between the zone to be monitored and the overlying strata, this upward extension should be gauged to prevent seepage from overlying hydrologic units into the filter pack. Seepage from other units may al[...]
water sample.

8.4.2 *Placement of Primary Filter Pack*—Placem[...] the well screen is preceded by placing no less than 2 [...] no more than 10 % of the primary filter pack in [...] bottom of the borehole using a decontaminated, [...] threaded, 1-in. (25-mm) minimum internal diameter [...] pipe. Alternatively, the filter pack may be added d[...] between the riser pipe and the auger or borehole or [...] and the top of the filter pack located using a tampe[...] weighted line. The well screen and riser assembly i[...] centered in the borehole using one or more centralize[...] alternative centering device located not more than 1[...] m) above the bottom of the well screen (see Figs. 2 a[...] The centralizer should not be located in the bentonit[...] The remaining primary filter pack is then placed in [...] ments as the tremie is gradually raised. As primary filte[...] material is poured into the tremie pipe, water from a [...] of known chemistry may be added to help move th[...] pack. The tremie pipe or a weighed line inserted throu[...] tremie pipe can be used to measure the top of the p[...] filter pack as work progresses. If bridging of the primar[...] pack occurs, the bridged material should be broken m[...] ically prior to proceeding with the addition of mor[...] pack material. The elevation, volume, and gradati[...] primary filter pack is recorded on the well comp[...] diagram.

8.4.3 *Withdrawal of the Temporary Casing/Aug[...]* used, the temporary casing or hollow stem auger is [...] drawn, usually in stipulated increments. Care shou[...] taken to minimize lifting the riser with the withdrawal [...] temporary casing/augers. To limit borehole collaps[...] temporary casing or hollow stem auger is usually with[...] until the lower most point on the temporary casing or [...] stem auger is at least 2 ft (608 mm), but no more tha[...] (1.5 m), above the filter pack for unconsolidated ma[...] or at least 5 ft, but no more than 10 ft (3.0 m[...] consolidated materials. In highly unstable formations [...] drawal intervals may be much less. After each increm[...] should be ascertained that the primary filter pack h[...] been displaced during the withdrawal operation (tha[...] weighed measuring device).

8.5 *Placement of First Secondary Filter*—A sec[...] filter pack may be installed above the primary filter p[...] prevent the intrusion of the bentonite grout seal in[...] primary filter pack (see Figs. 2 and 3). To be eff[...] measured and recorded volume of secondary filter m[...] should be added to extend 1 to 2 ft (304 to 608 mm) [...] the primary filter pack. As with the primary fi[...] secondary filter must not extend into an overlying hyd[...] unit (see 8.4.1). The well designer should evaluate th[...] for this filter pack by considering the gradation [...] primary filter pack, the hydraulic heads between ac[...] units, and the potential for grout intrusion into the p[...] filter pack. The secondary filter material is poured in[...] annular space through a decontaminated, flush thr[...] 1-in. (25-mm) minimum internal diameter tremie [...] lowered to within 3 ft (1.0 m) of the placement in[...] Water from a source of known chemistry may be ad[...] help move the filter pack into its proper location. The [...] pipe or weighed line inserted through the tremie pipe ed to measure the top of the secondary filter pack as work ogresses. The elevation, volume, and gradation of the condary filter pack is recorded on the well completion agram.

8.6 *Installation of the Bentonite Seal*—A bentonite pellet a slurry seal is placed in the annulus between the borehole d the riser pipe on top of the secondary or primary filter ck (see Figs. 2 and 3). This seal retards the movement of nent-based grout backfill into the primary or secondary er packs. To be effective, the bentonite seal should extend ove the filter packs approximately 3 to 5 ft (1.0 to 1.5 —depending on local conditions. The bentonite seal ould be installed using a tremie pipe lowered to the top of filter packs and slowly raised as the bentonite pellets or slurry fill the annular space. Bentonite pellets may bridge d block the tremie pipe in deep wells. In these cases, pellets y be allowed to free-fall into the borehole. As a bentonite let seal is poured into the tremie pipe or allowed to e-fall into the borehole, a tamper or weighed line may be essary to tamp pellets into place. If the seal is installed ove the water level, water from a source of known emistry would be added to allow proper hydration of the nular seal. The tremie pipe or a weighed line inserted ough the tremie pipe can be used to measure the top of bentonite seal as the work progresses. If a bentonite pellet l is being constructed above the water level, approxi- tely 5 gal (20 L) of water from a source of known mistry can be poured into the annulus to ensure that the lets hydrate. Sufficient time should be allowed for the tonite pellet seal to hydrate or the slurry annular seal to and prior to grouting the remaining annulus. The volume l elevation of the bentonite seal material should be asured and recorded on the well completion diagram.

.7 *Final Secondary Filter Pack*—A 6-in. to 1-ft (152 to -mm) secondary filter may be placed above the bentonite in the same manner described in 8.5 (see Figs. 2 and 3). s secondary filter pack will provide a confining layer over bentonite seal to limit the downward movement of nent-based grout backfill into the bentonite seal. The ume, elevation, and gradation of this final secondary filter k should be documented on the well completion diagram.

.8 *Grouting the Annular Space:*

.8.1 *General*—Grouting procedures vary with the type of l design. The following procedures will apply to both le- and multi-cased monitoring wells. Paragraphs 8.8.2 8.8.3 detail those procedures unique to single- and ti-cased installations, respectively.

.8.1.1 *Volume of Grout*—The volume and location of ut used to backfill the remaining annular space is rded on the well completion diagram. An ample volume grout should be premixed on site to compensate for xpected losses. The use of alternate grout materials, uding grouts containing gravel, may be necessary to trol zones of high grout loss.

8.1.2 *Injection Procedures*—The grout backfill should njected under pressure to reduce the chance of leaving ls in the grout, and to displace any liquids and drill ings that may remain in the annulus. Depending upon well design, grouting may be accomplished using a sure grouting technique or by gravity feed through a nie pipe. With either method, grout is introduced in one continuous operation until full strength grout flows out at the ground surface without evidence of drill cuttings or fluid. The grout should slope away from the riser or casing at the surface, but care should be taken not to create a grout mushroom that would be subjected to frost heave.

8.8.1.3 *Grout Setting and Curing*—The riser or casing or both should not be disturbed until the grout sets and cures for the amount of time necessary to prevent a break in the seal between the grout and riser or grout and casing or both. The amount of time required will vary with grout content and climatic conditions and should be documented on the well completion diagram.

8.8.2 *Specific Procedures for Single-Cased Wells*—Grouting should begin at a level directly above the final secondary filter pack (see Fig. 2). Grout should be injected using a tremie pipe equipped with a side discharge; this dissipates the fluid-pumping energy against the borehole wall and riser, reducing the potential for infiltration of grout into the primary filter pack. The tremie pipe should be kept full of grout from start to finish with the discharge end of the pipe completely submerged as it is slowly and continuously lifted. Approximately 5 to 10 ft (1.5 to 3.0 m) of tremie pipe should remained submerged until grouting is complete. For deep installations or where the joints or couplings of the selected riser cannot withstand the shear or collapse stress exerted by a full column of grout as it sets, a staged grouting procedure may be considered. If used, the temporary casing or hollow stem auger should be removed in increments immediately following each increment of grout installation and in advance of the time when the grout begins to set. If casing removal does not commence until grout injection is completed, then, after the casing is removed, additional grout may be periodically injected into the annular space to maintain a continuous column of grout up to the ground surface.

8.8.3 *Specific Procedures for Multi-Cased Wells*—If the outer casing of a multi-cased well cannot be driven to form a tight seal between the surrounding stratum (strata) and the casing, it should be installed in a predrilled borehole. After the borehole has penetrated not less than 2 ft (608 mm) of the first targeted confining stratum, the outer casing is lowered to the bottom of the boring and the annular space is filled with grout. Grouting may be accomplished using a pressure grouting method or gravity feed through a tremie pipe. Pressure grouting will require the use of a grout shoe or packer installed at the end of the outer casing to prevent grout from moving up into the casing. If a tremie pipe is used to inject grout into the annular space, it should be equipped with a side discharge. With each alternative, the grout must be allowed to cure and form a seal between the casing and the grout prior to advancing the hole to the next hydrologic unit. This procedure is repeated as necessary to advance the borehole to the desired depth. Upon reaching the final target depth, the riser and screen is set through the inner casing. Subsequent to the placement of the filter packs and bentonite seal, the remaining annular space is grouted as described in 8.8.2 (see Fig. 3).

NOTE 13—When using a packer, pressure may build up during grout injection and force grout up the sides of the packer and into the casing.

8.9 *Well Protection*—Well protection refers specifically to installations made at the ground surface to deter unauthorized entry to the monitoring well and to prevent surface water from entering the annulus.

8.9.1 *Protective Casing*—The protective casing should extend from below the frost line (3 to 5 ft [1.0 to 1.5 m]) below the grade depending on local conditions to slightly above the well casing tip. The protective casing should be initially placed before final set of the grout backfill. The protective casing should be sealed and immobilized in concrete placed around the outside of the protective casing above the set grout backfill. The casing should be positioned and stabilized in a position concentric with the riser (see Figs. 1 and 2). Sufficient clearance, usually 6 in. (152 mm) should be maintained between the lid of the protective casing and the top of the riser to accommodate sampling equipment. A ¼-in. (6.3-mm) diameter weep hole should be drilled in the casing 6 in. above the ground surface to permit water to drain out of the annular space. In cold climates, this hole will also prevent water freezing between the well protector and the well casing. Dry bentonite pellets, granules, or chips should then be placed in the annular space below ground level within the protective casing. Coarse sand or pea gravel or both is placed in the annular space above the dry bentonite pellets and above the weep hole to prevent entry of insects. All materials chosen should be documented on the well completion diagram. The monitoring well identification number should be clearly visible on the inside and outside of the lid of the protective casing.

8.9.2 *Completion of Surface Installation*—The well protection installation may be completed in one of three ways:

8.9.2.1 In areas subject to frost heave, place a soil or bentonite/sand layer adjacent to the protective casing sloped to direct water drainage away from the well.

8.9.2.2 In regions *not* subject to frost heave, a 4-in. (101-mm) thick concrete pad sloped to provide water drainage away from the well may be placed around the installation. Care must be taken not to lock the concrete pad onto the protective casing if subsidence of the surface may occur in the future.

8.9.2.3 Where monitoring well protection must be flushed with the ground, an internal cap should be fitted on top of the riser within the manhole or vault. This cap should be leak-proof so that if the vault or manhole should fill with water, the water will not enter the well casing. Ideally, the manhole cover cap should also be leak-proof.

8.9.3 *Additional Protection*—In areas where there is a high probability of damaging the well (high traffic, heavy equipment, poor visibility), it may be necessary to enhance the normal protection of the monitoring well through the use of posts, markers, signs, etc. The level of protection should meet the damage threat posed by the location of the well.

9. Well Development

9.1 *General*—The development serves to remove the finer grained material from the well screen and filter pack that may otherwise interfere with water quality analyses, restore the ground-water properties disturbed during the drilling process and to improve the hydraulic characteristics of the filter pack and hydraulic communication between the well and the hydrologic unit adjacent to the well screen. Methods of well development vary with the physical characteristics of hydrologic units in which the monitoring well is screened and with the drilling method used.

9.2 *Development Methods*—Methods of develop most often used include mechanical surging and baili pumping, over-pumping, air-lift pumping, and jetting important factor in any method is that the develop work be stated slowly and gently and be increased in vig the well is developed. Most methods of well develop require the application of sufficient energy to disturb filter pack, thereby freeing the fines and allowing them drawn into the well. The coarser fractions then settle ar and stabilize the screen. The well development me chosen should be documented on the well comple diagram.

NOTE 14—Any time an air compressor is used, it should be equi with an oil air filter or oil trap to minimize the introduction of oi the screen area. The presence of oil would impact the organic co uent concentrations of the water samples.

NOTE 15—Development procedures for wells completed in fine and silt strata should involve methods that are relatively gentle so the strain material will not be incorporated into the filter pack. Vigo surging for development can produce mixing of the fine strata and pack and produce turbid samples from the installation. Also, dev ment methods should be carefully selected based upon the pote contaminant(s) present, quality of waste water generated, and req ments for containerization or treatment of waste water.

9.2.1 *Mechanical Surging*—In this method, water forced to flow into and out of the well screen by operatin plunger (or surge block) or bailer up and down in the rise pump or bailer should then be used to remove the dislod sediments following surging.

9.2.2 *Over Pumping*—With this method, the monitor well is pumped at a rate considerably higher than it would during normal operation. The fine-grain materials would dislodged from the filter pack and surrounding strata in enced by the higher pumping rate. This method is usu conducted in conjunction with mechanical surging.

9.2.3 *Air Lift Pumping*—In this method, an air lift pu is operated by cycling the air pressure on and off for sl periods of time. This operation will provide a surging ac that will dislodge fine-grained particles. Applying a stea low pressure will remove the fines that have been drawn i the well by the surging action. Efforts should be made (is, through the use of a foot valve) to avoid pumping air i the filter pack and adjacent hydrologic unit because the may lodge there and inhibit future sampling efforts and r alter ambient water chemistry. Furthermore, applicatior high air pressures should be avoided to prevent damage small diameter PVC risers, screens, and filter packs.

9.2.4 *Well Jetting*—Another method of development volves jetting the well screen area with water while simu neously air-lift pumping the well. However, the water ad during this development procedure will alter the natu ambient water quality and may be difficult to remo Therefore, the water added should be obtained from a sou of known chemistry. Water from the monitoring well be developed may also be used if the suspended sediments first removed.

9.3 *Duration of Well Development*—Well developm should begin after the monitoring well is completely insta and prior to water sampling. Development should be c tinued until representative water, free of the drilling flu cuttings, or other materials introduced during well constu is obtained. Representative water is assumed to have [b]n obtained when pH, temperature, and specific conduc[tivit]y readings stabilize and the water is visually clear of [susp]ended solids. The minimum duration of well develop[men]t should vary in accordance with the method used to [dev]elop the well. For example, surging and pumping the well [may] provide a stable, sediment-free sample in a matter of [min]utes; whereas, bailing the well may require several hours [of c]ontinuous effort to obtain a clear sample. The duration [of w]ell development and the pH, temperature, and specific [con]ductivity readings should be recorded on the well com[plet]ion diagram.

[9].4 *Well Recovery Test*—A well recovery test should be [per]formed immediately after and in conjunction with well [dev]elopment. The well recovery test not only provides an [ind]ication of well performance but also provides data for [det]ermining the transmissivity of the screened hydrologic [uni]t. Estimates of the hydraulic conductivity of the unit can [als]o be determined. Readings should be taken at intervals [sug]gested in the table below until the well has recovered to [90]% of its static water level.

[N]OTE 16—If a monitoring well does not recover sufficiently for [sam]pling within a 24-h period and the well has been properly developed, [the i]nstallation should not generally be used as a monitoring well for [dete]cting or assessing low level organic constituents. The installation [may], however, be used for long-term water level monitoring if measure[men]ts of shorter frequency water level changes are not required.

[10.] Installation Survey

[10].1 *General*—The vertical and horizontal position of [eac]h monitoring well in the monitoring system should be [surv]eyed and subsequently mapped by a licensed surveyor. [The] well location map should include the location of all [mon]itoring wells in the system and their respective identifi[cati]on numbers, elevations of the top of riser position to be used as the reference point for water level measurements, and the elevations of the ground surface protective installations. The locations and elevations of all permanent benchmark(s) and pertinent boundary marker(s) located on-site or used in the survey should also be noted on the map.

10.2 *Water Level Measurement Reference*—The water level measurement reference point should be permanently marked, for instance, by cutting a V-notch into the top edge of the riser pipe. This reference point should be surveyed in reference to the nearest NGVD reference point.

10.3 *Location Coordinates*—The horizontal location of all monitoring wells (active or decommissioned) should be surveyed by reference to a standardized survey grid or by metes and bounds.

[TAB]LE 2 **Suggested Recording Intervals for Well Recovery Tests**

Time Since Starting Test	Time Interval
0 to 15 min	1 min
15 to 50 min	5 min
50 to 100 min	10 min
100 to 300 min (5 h)	30 min
300 to 1440 min (24 h)	60 min

11. Monitoring Well Network Report

11.1 To demonstrate that the goals as set forth in Section 1, the Scope, have been met, a monitoring well network report should be prepared. This report should:

11.1.1 Locate the area investigated in terms pertinent to the project. This should include sketch maps or aerial photos on which the exploratory borings, piezometers, sample areas, and monitoring wells are located, as well as topographic items relevant to the determination of the various soil and rock types, such as contours, streambeds, etc. Where feasible, include a geologic map and geologic cross sections of the area being investigated.

11.1.2 Include copies of all well boring test pits and exploratory borehole logs, initial and post-completion water levels, all laboratory test results, and all well completion diagrams.

11.1.3 Include the well installation survey.

11.1.4 Describe and relate the findings obtained in the initial reconnaissance and field investigation (Section 5) to the design and installation procedures selected (Sections 7 to 9) and the surveyed locations (Section 10).

11.1.5 This report should include a recommended decommission procedure that is consistent with the well construction and local regulatory requirements.

12. Keywords

12.1 aquifer; borehole drilling; geophysical exploration; ground water; monitoring well; site investigation

APPENDIX B

APPENDIX B
Groundwater Water Level Monitoring Protocol

All groundwater level measurements will be made using an electric water level sounder calibrated to the nearest 0.01 foot. The sounder will be cleaned before monitoring and between use in each well using a Liqui-Nox soap (or equivalent) solution wash and potable and distilled water rinses. Measurements will be made to the nearest 0.01 foot relative to an established reference mark at the top of each well casing. Water level depths will be compared, in the field, to previous results and re-measured if significantly different. Water level measurements will be recorded using a permanent ink pen on established forms and subsequently entered into an electronic database. Depth to groundwater measurements will be converted to groundwater elevations (above mean sea level) by subtracting the depth to water from the reference point elevation.

APPENDIX C

APPENDIX C
GROUNDWATER SAMPLING PROTOCOL

Prior to collecting groundwater samples from monitoring wells, approximately three to four well casing volumes of groundwater will be removed from each well using a positive displacment piston pump set at least 10 feet above the bottom of the well.

During pumping, temperature, pH, electrical conductivity and total dissolved solids will be measured periodically using field calibrated instrumentation. Groundwater samples will be collected when parameters have stabilized in three consecutive readings. If the field parameters do not stabilize before three casing volumes have been removed, additional groundwater will be bailed until the parameters stabilize. Total water volume removed will be approximated using a 5-gallon bucket or inline flowmeter. In the event the well goes dry before three casing volumes have been removed or before parameters have stabilized, the well will be allowed to recover to at least 80 percent of the static water level before the sample is collected.

Field parameter data will be collected using instruments calibrated to standard solutions at the beginning of each sampling day. Calibration results will be recorded in the field daily report. Deviations in calibration will be noted. Field parameter data will be checked and validated by a Certified Hydrogeologist.

Groundwater samples will be collected following pumping using a Teflon or stainless steel bailer that has been cleaned using a Liqui-Nox soap (or equivalent) solution wash and potable and distilled water rinses. Samples will be decanted from the bailer into properly labeled, laboratory-prepared sample containers. Each sample label will include the well number, project number, date and time sampled, analytical test, preservative (if any) and sampler's initials. Samples will be sealed in sealable plastic bags and placed in a field cooler with ice immediately after collection.

For QA/QC purposes, duplicate samples will be collected in the field from two wells during each sampling event. These samples will be submitted to the laboratory "blind" with a fictitious well designation so the repeatability of the analytical results can be objectively evaluated. Duplicate samples will be collected from the same bailer whenever possible to maximize the representativeness of the analytical results. The label given the duplicate sample will be noted on standard sampling forms and/or in the field daily notes to enable later identification and comparison.

If sampling bailers are used in multiple wells, one equipment blank per day of sampling will be collected to ensure the effectiveness of bailer cleaning between wells. The blank sample will consist of distilled water decanted from a cleaned bailer into a laboratory prepared sample container. The blank sample will be collected between sampling of wells.

All groundwater samples will be submitted to a California Department of Health Services certified laboratory under chain-of-custody protocol within 24 hours of collection.

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Standard Guide for Sampling Groundwater Monitoring Wells[1]

This standard is issued under the fixed designation D 4448; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers procedures for obtaining valid, representative samples from groundwater monitoring wells. The scope is limited to sampling and "in the field" preservation and does not include well location, depth, well development, design and construction, screening, or analytical procedures.

1.2 This guide is only intended to provide a review of many of the most commonly used methods for sampling groundwater quality monitoring wells and is not intended to serve as a groundwater monitoring plan for any specific application. Because of the large and ever increasing number of options available, no single guide can be viewed as comprehensive. The practitioner must make every effort to ensure that the methods used, whether or not they are addressed in this guide, are adequate to satisfy the monitoring objectives at each site.

1.3 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Summary of Guide

2.1 The equipment and procedures used for sampling a monitoring well depend on many factors. These include, but are not limited to, the design and construction of the well, rate of groundwater flow, and the chemical species of interest. Sampling procedures will be different if analyzing for trace organics, volatiles, oxidizable species, or trace metals is needed. This guide considers all of these factors by discussing equipment and procedure options at each stage of the sampling sequence. For ease of organization, the sampling process can be divided into three steps: well flushing, sample withdrawal, and field preparation of samples.

2.2 Monitoring wells must be flushed prior to sampling so that the groundwater is sampled, not the stagnant water in the well casing. If the well casing can be emptied, this may be done although it may be necessary to avoid oxygen contact with the groundwater. If the well cannot be emptied, procedures must be established to demonstrate that the sample represents groundwater. Monitoring an indicative parameter such as pH during flushing is desirable if such a parameter can be identified.

2.3 The types of species that are to be monitored as w[...] the concentration levels are prime factors for sele[...] sampling devices (1, 2).[2] The sampling device and materials and devices the water contacts must be constru[...] of materials that will not introduce contaminants or alte[...] analyte chemically in any way.

2.4 The method of sample withdrawal can vary with parameters of interest. The ideal sampling scheme w[...] employ a completely inert material, would not subject sample to negative pressure and only moderate posi[...] pressure, would not expose the sample to the atmosphere preferably, any other gaseous atmosphere before conveyi[...] to the sample container or flow cell for on-site analysis.

2.5 The degree and type of effort and care that goes in[...] sampling program is always dependent on the chem[...] species of interest and the concentration levels of interest[...] the concentration level of the chemical species of analyt[...] interest decreases, the work and precautions necessary sampling are increased. Therefore, the sampling objec[...] must clearly be defined ahead of time. For example, prepare equipment for sampling for mg/L (ppm) levels Total Organic Carbon (TOC) in water is about an order magnitude easier than preparing to sample for µg/L (p[...] levels of a trace organic like benzene. The specific prec[...] tions to be taken in preparing to sample for trace organics different from those to be taken in sampling for trace met[...] No final Environmental Protection Agency (EPA) protoco[...] available for sampling of trace organics. A short guida[...] manual, (3) and an EPA document (4) concerning mo[...] toring well sampling, including considerations for tra[...] organics are available.

2.6 Care must be taken not to cross contaminate samp[...] or monitoring wells with sampling or pumping devices materials. All samples, sampling devices, and contain[...] must be protected from the environment when not in u[...] Water level measurements should be made before the well flushed. Oxidation-reduction potential, pH, dissolved o[...] ygen, and temperature measurements and filtration shou[...] all be performed on the sample in the field, if possible. A[...] but temperature measurement must be done prior to a[...] significant atmospheric exposure, if possible.

2.7 The sampling procedures must be well planned and [...] sample containers must be prepared and labeled prior [...] going to the field.

3. Significance and Use

3.1 The quality of groundwater has become an issue [...] national concern. Groundwater monitoring wells are one [...]

[1] This guide is under the jurisdiction of ASTM Committee D-34 on Waste Management and is the direct responsibility of Subcommittee D34.01 on Sampling and Monitoring.

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[2] The boldface numbers in parentheses refer to a list of references at the end [...] this guide.

TABLE 1 Typical Container and Preservation Requirements for a Ground-Water Monitoring Program

Sample and Measurement	Volume Required (mL)	Container P—Polyethylene G—Glass	Preservative	Maximum Holding Time
Metals As/Ba/Cd/Cr/Fe Pb/Se/Ag/Mn/Na	1000–2000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Mercury	200–300	P/G (special acid cleaning)	high purity nitric acid to pH <2 +0.05 % $K_2Cr_2O_7$	28 days
Radioactivity alpha/beta/radium	4000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Phenolics	500–1000	G	cool, 4°C H_2SO_4 to pH <2	28 days
Miscellaneous	1000–2000	P	cool, 4°C	28 days
Fluoride	300–500	P		28 days
Chloride	50–200	P/G		28 days
Sulfate	100–500	P/G		48 hours
Nitrate	100–250	P/G		6 h
Coliform	100	P/G		on site/24 h
Conductivity	100	P/G		on site/6 h
pH	100	P/G		48 h
Turbidity	100	P/G		
Total organic carbon (TOC)	25–100	P/G	cool, 4°C or cool, 4°C HCl or H_2SO_4 to pH <2	24 h 28 days
Pesticides, herbicides and total organic halogen (TOX)	1000–4000	G/TFE-fluorocarbon lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Extractable organics	1000–2000	G/TFE-fluorocarbon-lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Organic purgeables acrolein/acrylonitrile	25–120	G/vial TFE-fluorocarbon-lined septum	cool, 4°C	14 days 3 days

the more important tools for evaluating the quality of groundwater, delineating contamination plumes, and establishing the integrity of hazardous material management facilities.

3.2 The goal in sampling groundwater monitoring wells is to obtain samples that are truly representative of the aquifer or groundwater in question. This guide discusses the advantages and disadvantages of various well flushing, sample withdrawal, and sample preservation techniques. It reviews the parameters that need to be considered in developing a valid sampling plan.

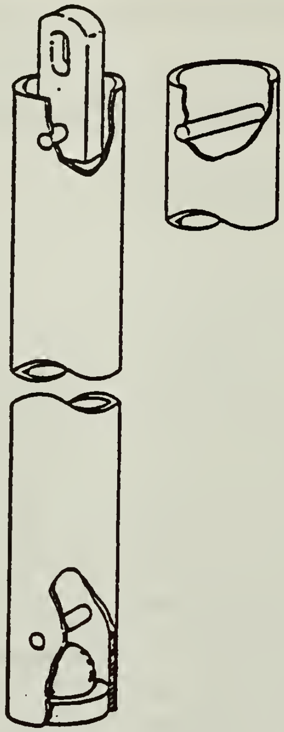
4. Well Flushing (Purging)

4.1 Water that stands within a monitoring well for a long period of time may become unrepresentative of formation water because chemical or biochemical change may cause water quality alterations and even if it is unchanged from the time it entered the well, the stored water may not be representative of formation water at the time of sampling, or both. Because the representativeness of stored water is questionable, it should be excluded from samples collected from a monitoring well.

4.2 The surest way of accomplishing this objective is to remove all stored water from the casing prior to sampling. Research with a tracer in a full scale model 2 in. PVC well (5) indicates that pumping 5 to 10 times the volume of the well via an inlet near the free water surface is sufficient to remove all the stored water in the casing. The volume of the well may be calculated to include the well screen and any gravel pack if natural flow through these is deemed insufficient to keep them flushed out.

4.3 In deep or large diameter wells having a volume of water so large as to make removal of all the water impractical, it may be feasible to lower a pump or pump inlet to some point well below the water surface, purge only the volume below that point then withdraw the sample from a deeper level. Research indicates this approach should avoid most contamination associated with stored water (5, 6, 7). Sealing the casing above the purge point with a packer may make this approach more dependable by preventing migration of stored water from above. But the packer must be above the top of the screened zone, or stagnant water from above the packer will flow into the purged zone through the well's gravel/sand pack.

4.4 In low yielding wells, the only practical way to remove all standing water may be to empty the casing. Since it is not always possible to remove all water, it may be advisable to let the well recover (refill) and empty it again at least once. If introduction of oxygen into the aquifer may be of concern, it would be best not to uncover the screen when performing the above procedures. The main disadvantage of methods designed to remove all the stored water is that large volumes may need to be pumped in certain instances. The main advantage is that the potential for contamination of samples with stored water is minimized.



NOTE—Taken from Ref (15).

FIG. 1 Single Check Valve Bailer

4.5 Another approach to well flushing is to monitor one or more indicator parameters such as pH, temperature, or conductivity and consider the well to be flushed when the indicator(s) no longer change. The advantage of this method is that pumping can be done from any location within the casing and the volume of stored water present has no direct bearing on the volume of water that must be pumped. Obviously, in a low yielding well, the well may be emptied before the parameters stabilize. A disadvantage of this approach is that there is no assurance in all situations that the stabilized parameters represent formation water. If significant drawdown has occurred, water from some distance away may be pulled into the screen causing a steady parameter reading but not a representative reading. Also, a suitable indicator parameter and means of continuously measuring it in the field must be available.

4.6 Gibb (4, 8) has described a time-drawdown approach using a knowledge of the well hydraulics to predict the percentage of stored water entering a pump inlet near the top of the screen at any time after flushing begins. Samples are taken when the percentage is acceptably low. As before, the advantage is that well volume has no direct effect in the duration of pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stored water due to effects other than drawdown (for example density differences) is not accounted for in this approach.

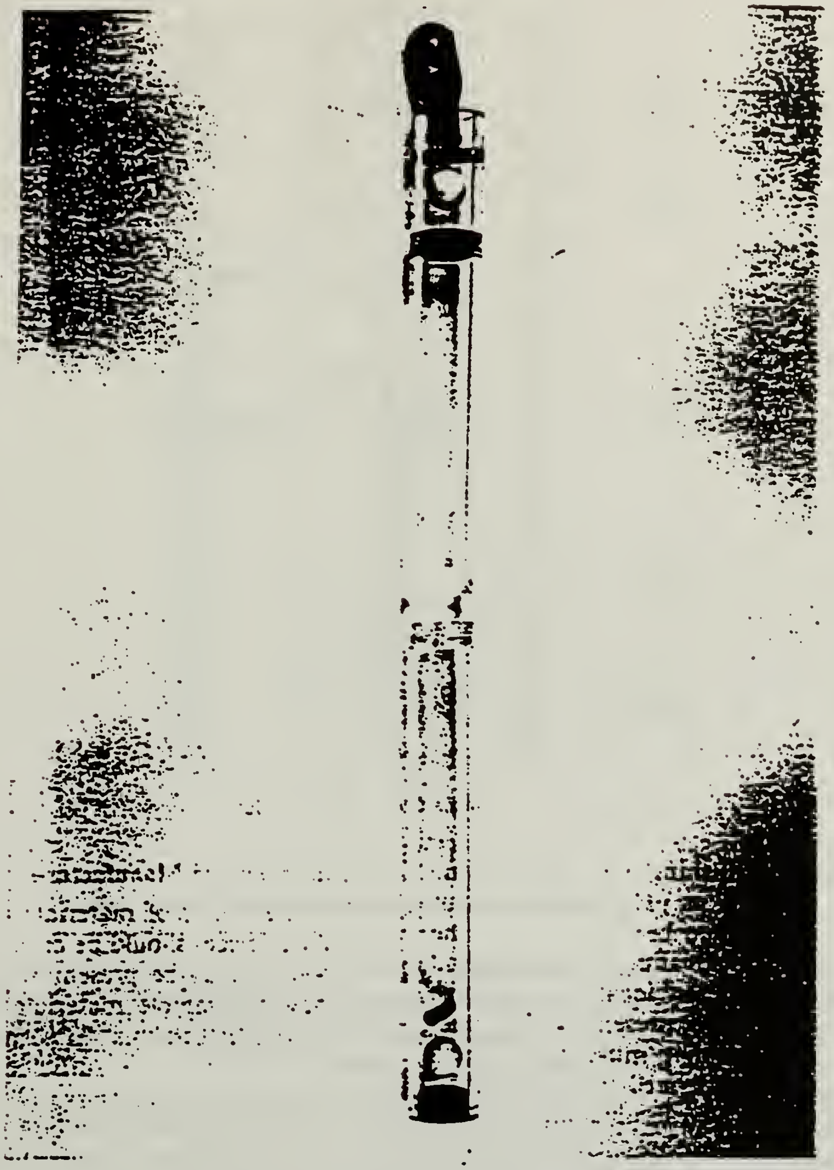
4.7 In any flushing approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns around a well and can cause contaminants that were not present originally to be drawn into the well.

5. Materials and Manufacture

5.1 The choice of materials used in the constructio sampling devices should be based upon a knowledge of compounds may be present in the sampling environ and how the sample materials may interact via leach adsorption, or catalysis. In some situations, PVC or other plastic may be sufficient. In others, an all apparatus may be necessary.

5.2 Most analytical protocols suggest that the devices in sampling and storing samples for trace organics ana (μg/L levels) must be constructed of glass TFE-fluorocarbon resin, or both. One suggestion advan by the EPA is that the monitoring well be constructed so only TFE-fluorocarbon tubing be used in that portion of sampling well that extends from a few feet above the w table to the bottom of the borehole. (3, 5) Although this of well casing is now commercially available, PVC casings are currently the most popular. If adhesives avoided, PVC well casings are acceptable in many although their use may still lead to some problems if organics are of concern. At present, the type of backgrou presented by PVC and interactions occurring between P and groundwater are not well understood. Tin, in the form an organotin stabilizer added to PVC, may enter samp taken from PVC casing. (9)

5.3 Since the most significant problem encountered trace organics sampling, results from the use of P adhesives in monitoring well construction, threaded joi might avoid the problem (3, 5). Milligram per litre (parts million) levels of compounds such as tetrahydrofur methyl-ethyl-ketone, and toluene are found to leach i



NOTE—Taken from Ref (17).

FIG. 2 Acrylic Point Source Bailer

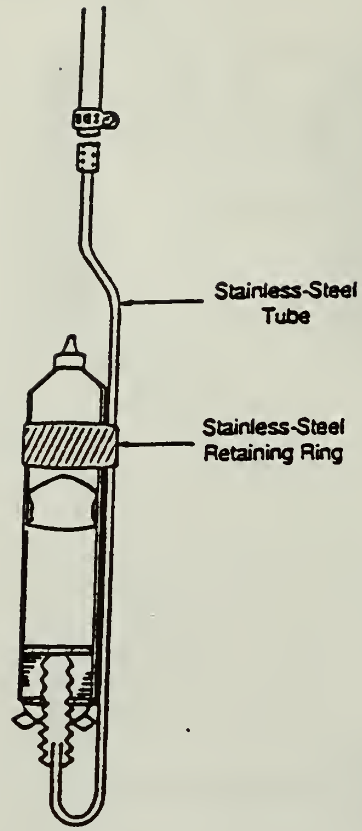
groundwater samples from monitoring well casings sealed with PVC solvent cement. Pollutant phthalate esters (8, 10) are often found in water samples at ppb levels: the EPA has found them on occasion at ppm levels in their samples. The ubiquitous presence of these phthalate esters is unexplained, except to say that they may be leached from plastic pipes, sampling devices, and containers.

5.4 TFE-fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication of sampling devices and well casings. Molded parts are exposed to high temperature during fabrication which destroys any organic contaminants. The evolution of fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin is heated to its melting point.

5.5 Extruded tubing of TFE-fluorocarbon for sampling may contain surface traces of an organic solvent extrusion aid. This can be removed easily by the fabricator and, once removed by flushing, should not affect the sample. TFE-fluorocarbon FEP and TFE-fluorocarbon PFA resins do not require this extrusion aid and may be suitable for sample tubing as well. Unsintered thread-sealant tape of TFE-fluorocarbon is available in an "oxygen service" grade and contains no extrusion aid and lubricant.

5.6 Louneman, et al. (11) alludes to problems caused by a lubricating oil used during TFE-fluorocarbon tubing extrusion. This reference also presents evidence that a fluorinated ethylene-propylene copolymer adsorbed acetone to a degree that later caused contamination of a gas sample.

5.7 Glass and stainless steel are two other materials generally considered inert in aqueous environments. Glass is probably among the best choices though it is not inconceivable it could adsorb some constituents as well as release other contaminants (for example, Na, silicate, and Fe). Of course, glass sampling equipment must be handled carefully in the field. Stainless steel is strongly and easily machined to



NOTE—Taken from Ref (21).

FIG. 3 Schematic of the Inverted Syringe Sampler

fabricate equipment. Unfortunately, it is not totally immune to corrosion that could release metallic contaminants. Stainless steel contains various alloying metals, some of these (for example Ni) are commonly used as catalysts for various reactions. The alloyed constituents of some stainless steels can be solubilized by the pitting action of nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over a range of pH conditions. Aluminum, titanium, polyethylene, and other corrosion resistant materials have been proposed by some as acceptable materials, depending on groundwater quality and the constituents of interest.

5.8 Where temporarily installed sampling equipment is used, the sampling device that is chosen should be non-plastic (unless TFE-fluorocarbon), cleanable of trace organics, and must be cleaned between each monitoring well use in order to avoid cross-contamination of wells and samples. The only way to ensure that the device is indeed "clean" and acceptable is to analyze laboratory water blanks and field water blanks that have been soaked in and passed through the sampling device to check for the background levels that may result from the sampling materials or from field conditions. Thus, all samplings for trace materials should be accompanied by samples which represent the field background (if possible), the sampling equipment background, and the laboratory background.

5.9 Additional samples are often taken in the field and spiked (spiked-field samples) in order to verify that the sample handling procedures are valid. The American Chemical Society's committee on environmental improvement h[...] published guidelines for data acquisition and data evaluatio[...] which should be useful in such environmental evaluatio[...] (**10, 12**).

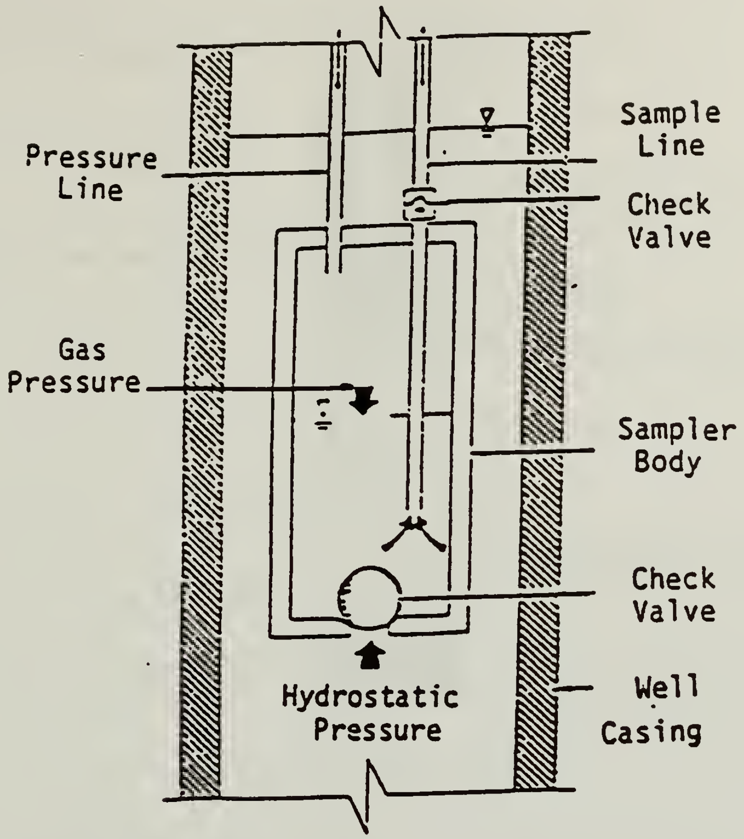
6. Sampling Equipment

6.1 There is a fairly large choice of equipment present[...] available for groundwater sampling from single screene[...] wells and well clusters. The sampling devices can be categ[...]rized into the following eight basic types.

6.1.1 *Down-Hole Collection Devices:*

6.1.1.1 Bailers, messenger bailers, or thief samplers (1[...] 14) are examples of down-hole devices that probably provi[...] valid samples once the well has been flushed. They are n[...] practical for removal of large volumes of water. The[...] devices can be constructed in various shapes and sizes from[...] variety of materials. They do not subject the sample [...] pressure extremes.

6.1.1.2 Bailers do expose part of the sample to t[...] atmosphere during withdrawal. Bailers used for sampling [...] volatile organic compounds should have a sample cock [...] draft valve in or near the bottom of the sampler allowi[...] withdrawal of a sample from the well below the expos[...] surface of the water or the first few inches of the samp[...] should be discarded. Suspension lines for bailers and oth[...] samplers should be kept off the ground and free of oth[...] contaminating materials that could be carried into the we[...] Down-hole devices are not very practical for use in de[...]



NOTE—Taken from Ref (5).

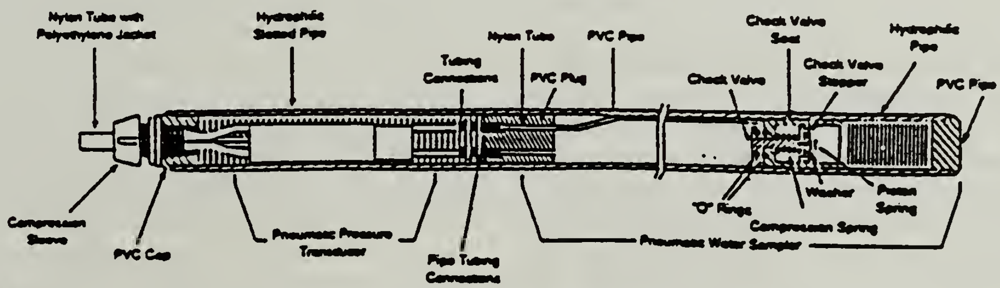
FIG. 4 The Principal of Gas Displacement Pumping

vells. However, potential sample oxidation during transfer of the sample into a collection vessel and time constraints for owering and retrieval for deep sampling are the primary disadvantages.

6.1.1.3 Three down-hole devices are the single and double check valve bailers and thief samplers. A schematic of a single check valve unit is illustrated in Fig. 1. The bailer may be threaded in the middle so that additional lengths of blank casing may be added to increase the sampling volume. TFE-fluorocarbon or PVC are the most common materials used for construction (15).

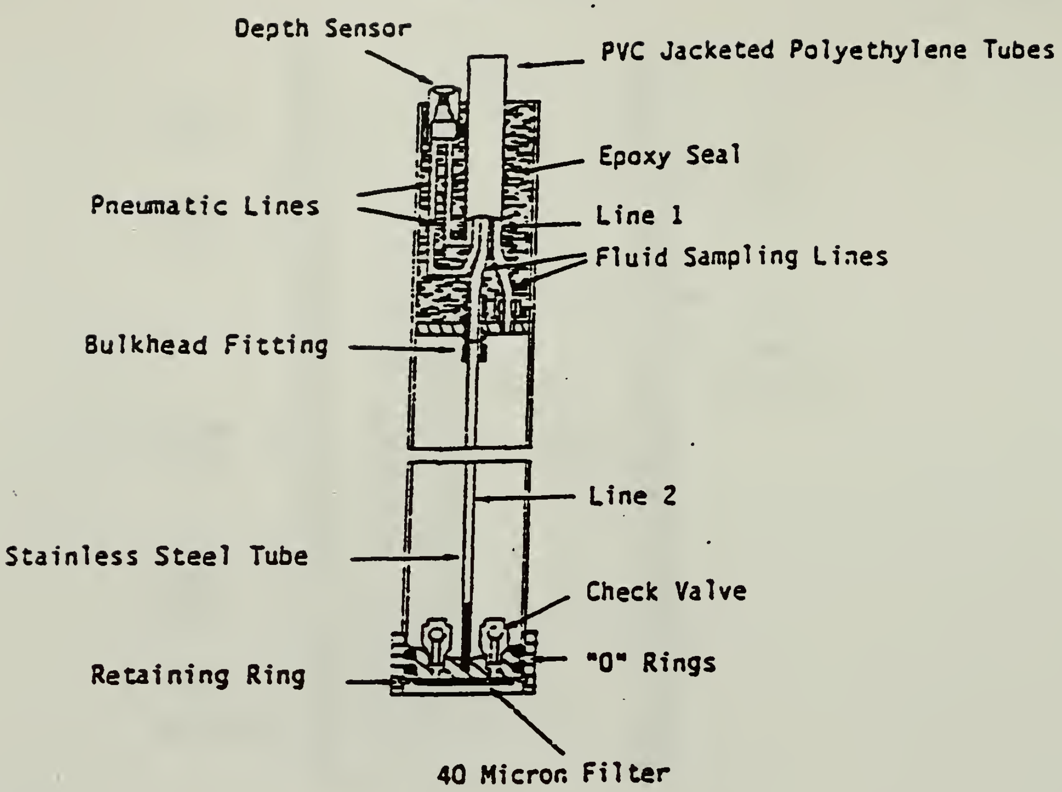
6.1.1.4 In operation, the single check valve bailer is owered into the well, water enters the chamber through the bottom, and the weight of the water column closes the check valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check valve seat during chamber filling. Upon bailer withdrawal, the ball will immediately seat without any samples loss through the check valve. A similar technique involves lowering a sealed sample container within a weighted bottle into the well. The stopper is then pulled from the bottle via a line and the entire assembly is retrieved upon filling of the container (14, 16).

6.1.1.5 A double check valve bailer allows point source sampling at a specific depth (15, 17). An example is shown in Fig. 2. In this double check valve design, water flows through the sample chamber as the unit is lowered. A venturi tapered inlet and outlet ensures that water passes freely through the



NOTE—Taken from Ref (41).

FIG. 5 Pneumatic Water Sampler With Internal Transducer



NOTE—Taken from Ref (42).

FIG. 6 Pneumatic Sampler With Externally Mounted Transducer

unit. When a depth where the sample is to be collected is reached, the unit is retrieved. Because the difference between each ball and check valve seat is maintained by a pin that blocks vertical movement of the check ball, both check valves close simultaneously upon retrieval. A drainage pin is placed into the bottom of the bailer to drain the sample directly into a collection vessel to reduce the possibility of air oxidation. The acrylic model in Fig. 2 is threaded at the midsection allowing the addition of threaded casing to increase the sampling volume.

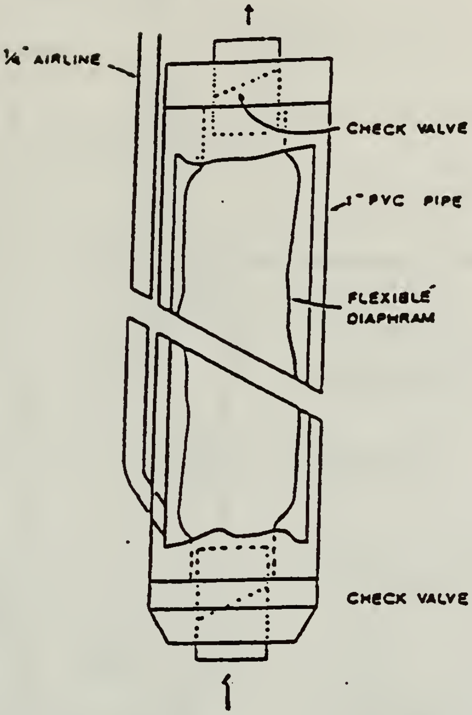
6.1.1.6 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber (18). Foerst, Kemmerer, and Bacon samplers are of this variety (14, 17, 19). A simple and inexpensive pneumatic sampler was recently described by Gillham (20). The device (Fig. 3) consists of a disposable 50 mL plastic syringe modified by sawing off the plunger and the finger grips. The syringe is then attached to a gas-line by means of a rubber stopper assembly. The gas-line extends to the surface, and is used to drive the stem-less plunger, and to raise and lower the syringe into the hole. When the gas-line is pressurized, the rubber plunger is held at the tip of the syringe. The sampler is then lowered into the installation, and when the desired depth is reached, the pressure in the gas-line is reduced to atmospheric (or slightly less) and water enters the syringe. The sampler is then retrieved from the installation and the syringe detached from the gas-line. After the tip is sealed, the syringe is used as a short-term storage container. A number of thief or messenger devices are available in variou materials and shapes.

6.1.2 *Suction Lift Pumps:*

6.1.2.1 Three types of suction lift pumps are the dire line, centrifugal, and peristaltic. A major disadvantage of an suction pump is that it is limited in its ability to raise wate by the head available from atmospheric pressure. Thus, if th surface of the water is more than about 25 ft below th pump, water may not be withdrawn. The theoretical suctio limit is about 34 ft, but most suction pumps are capable o maintaining a water lift of only 25 ft or less.

6.1.2.2 Many suction pumps draw the water throug some sort of volute in which impellers, pistons, or othe devices operate to induce a vacuum. Such pumps ar probably unacceptable for most sampling purposes becaus they are usually constructed of common materials such a brass or mild steel and may expose samples to lubricants They often induce very low pressures around rotating vane or other such parts such that degassing or even cavitatio may occur. They can mix air with the sample via small leak in the casing, and they are difficult to adequately clea between uses. Such pumps are acceptable for purging o wells, but should not generally be used for sampling.

6.1.2.3 One exception to the above statements is a peri- staltic pump. A peristaltic pump is a self-priming, lo volume suction pump which consists of a rotor with bal bearing rollers (21). Flexible tubing is inserted around the pump rotor and squeezed by heads as they revolve in a circular pattern around the rotor. One end of the tubing is placed into the well while the other end can be connected



NOTE—Taken from Ref (4).

FIG. 7 Bladder Pump

directly to a receiving vessel. As the rotor moves, a reduced pressure is created in the well tubing and an increased pressure (<40 psi) on the tube leaving the rotor head. A drive shaft connected to the rotor head can be extended so that multiple rotor heads can be attached to a single drive shaft.

6.1.2.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The sample may still be degassed (cavitation is unlikely) but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pumphead itself. A section of silicone tubing is commonly used within the peristaltic pumphead, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement (22) recommends using medical grade silicone tubing for organic sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Medical grade silicone tube is, however, limited to use over a restricted range of ambient temperatures. Various manufacturers offer tubing lined with TFE-fluorocarbon or Viton[3] for use with their pumps. Gibb (1, 8) found little difference between samples withdrawn by a peristaltic pump and those taken by a bailer.

6.1.2.5 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two way stopper bottle and a hand held or mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism (5, 23, 24).

6.1.2.6 A centrifugal pump can be attached to a length of plastic tubing that is lowered into the well. A foot valve is usually attached to the end of the well tubing to assist in priming the tube. The maximum lift is about 4.6 m (15 ft) for such an arrangement (23, 25, 26).

6.1.2.7 Suction pump approaches offer a simple sample retrieval method for shallow monitoring. The direct line method is extremely portable though considerable oxidation and mixing may occur during collection. A centrifugal pump will agitate the sample to an even greater degree although pumping rates of 19 to 151 Lpm (5 to 40 gpm) can be attained. A peristaltic pump provides a lower sampling rate with less agitation than the other two pumps. The withdrawal rate of peristaltic pumps can be carefully regulated by adjustment of the rotor head revolution.

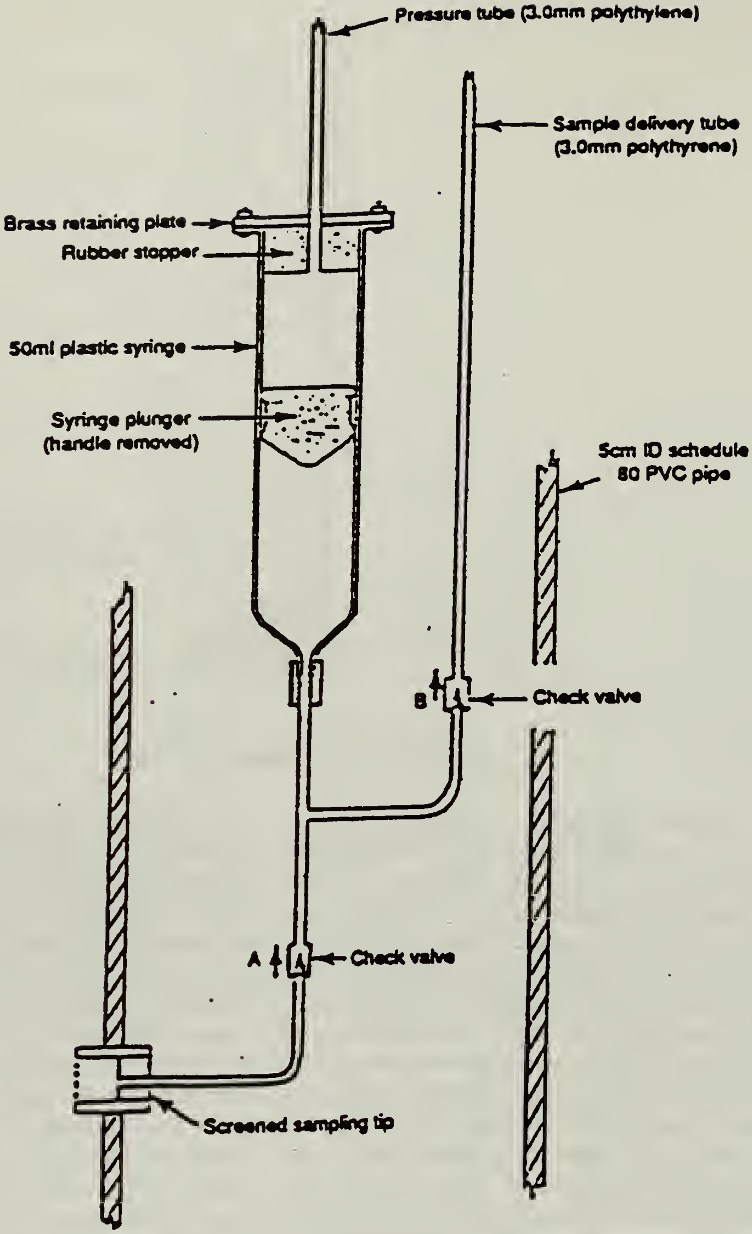
6.1.2.8 All three systems can be specially designed so that the water sample contacts only the TFE flourocarbon or silicone tubing prior to sample bottle entry. Separate tubing is recommended for each well or piezometer sampled.

6.1.3 *Electric Submersible Pumps:*

6.1.3.1 A submersible pump consists of a sealed electric motor that powers a piston or helical single thread worm at a high rpm. Water is brought to the surface through an access tube. Such pumps have been used in the water well industry for years and many designs exist (5, 26).

6.1.3.2 Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction

[3] Viton is a trademark of E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.



NOTE—Taken from Ref (46).

FIG. 8 Positive Displacement Syringe Pump

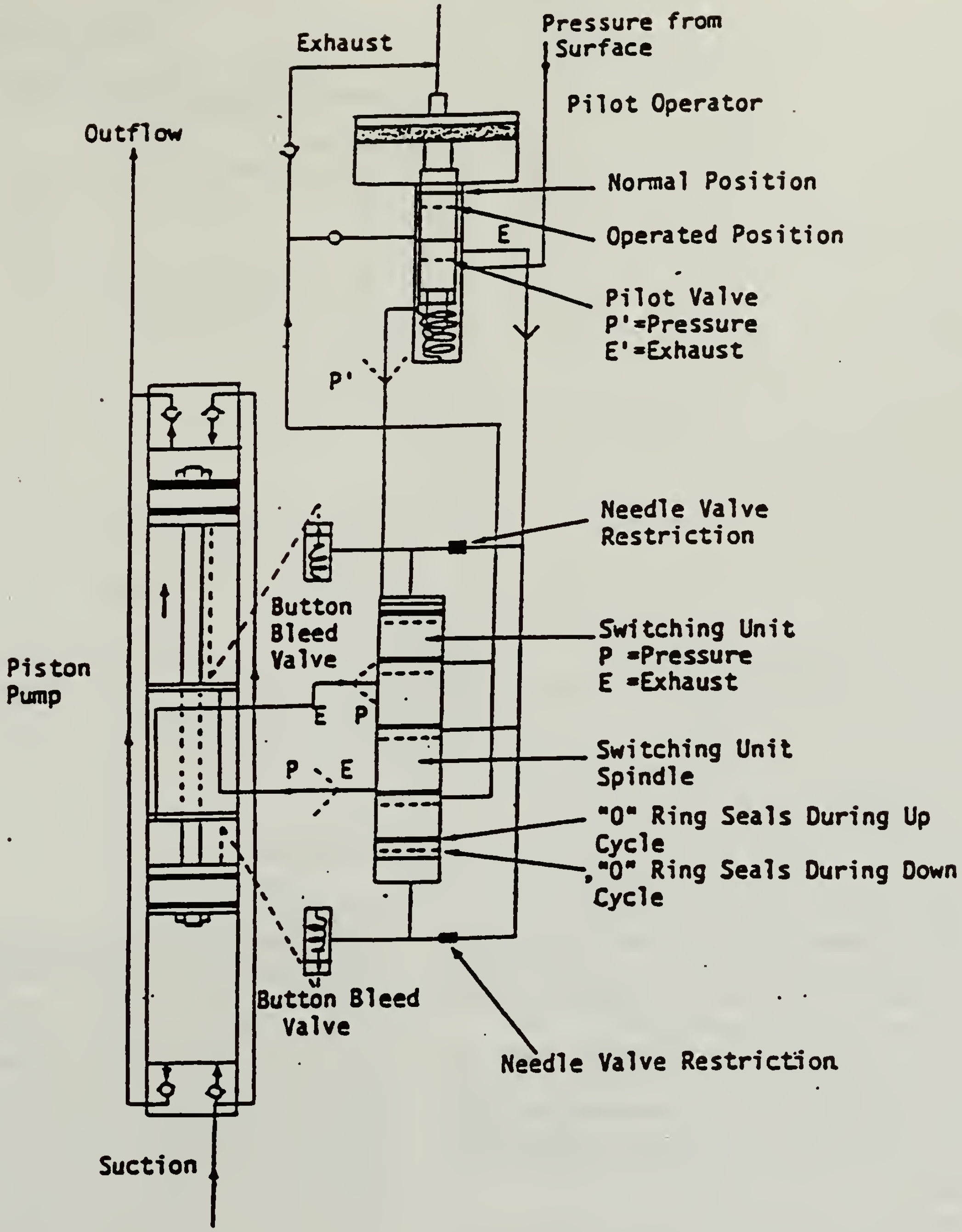
lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 Lpm (1.2 gpm) flow rate at 33.5 m (110 ft) has been developed (27). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 Lpm (14 gpm) depending upon the depth of the pump (28).

6.1.3.3 A submersible pump provides higher extraction rates than many other methods. Considerable sample agitation results, however, in the well and in the collection tube during transport. The possibility of introducing trace metals into the sample from pump materials also exists. Steam cleaning of the unit followed by rinsing with unchlorinated, deionized water is suggested between sampling when analysis for organics in the parts per million (ppm) or parts per billion (ppb) range is required (29).

6.1.4 *Gas-Lift Pumps:*

6.1.4.1 Gas-lift pumps use compressed air to bring a sample to the surface. Water is forced up an eductor that may be the outer casing or a smaller diameter inserted into the well annulus below the water level (30

6.1.4.2 A similar principle is used for a unit that co of a small diameter plastic tube perforated in the lowe This tube is placed within another tube of slightly diameter. Compressed air is injected into the inner tub air bubbles through the perforations, thereby lifting the sample via the annulus between the outer and inner t (32). In practice, the eductor line should be submerge depth equal to 60 % of the total submerged eductor l during pumping (26). A 60 % ratio is considered op although a 30 % submergence ratio is adequate.



NOTE—Taken from Ref (49).

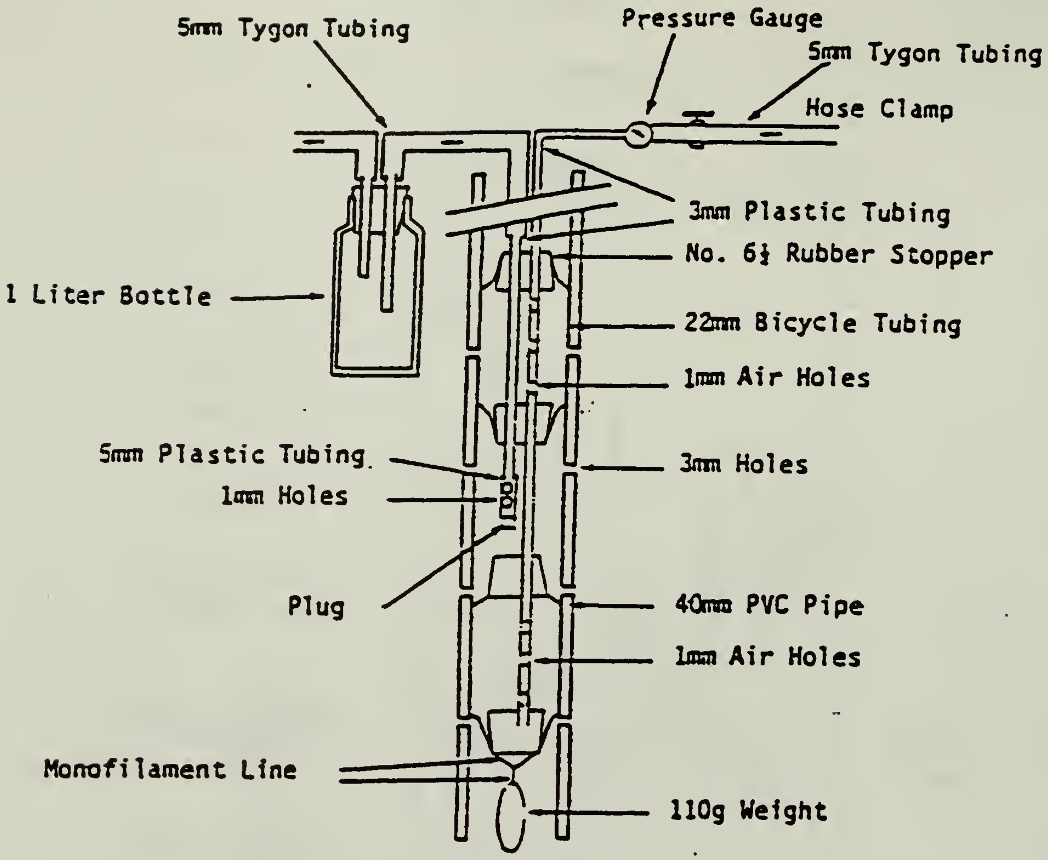
FIG. 9 Gas Driven Piston Pump

6.1.4.3 The source of compressed gas may be a hand ımp for depths generally less than 7.6 m (25 ft). For greater pths, air compressors, pressurized air bottles, and air mpressed from an automobile engine have been used.

6.1.4.4 As already mentioned, gas-lift methods result in nsiderable sample agitation and mixing within the well, d cannot be used for samples which will be tested for latile organics. The eductor pipe or weighted plastic tubing a potential source of sample contamination. In addition, bb (8) uncovered difficulties in sampling for inorganics. ıese difficulties were attributed to changes in redox, pH, and species transformation due to solubility constant changes resulting from stripping, oxidation, and pressure changes.

6.1.5 *Gas Displacement Pumps:*

6.1.5.1 Gas displacement or gas drive pumps are distinguished from gas-lift pumps by the method of sample transport. Gas displacement pumps force a discrete column of water to the surface via mechanical lift without extensive mixing of the pressurized gas and water as occurs with air-lift equipment. The principle is shown schematically in Fig. 4. Water fills the chamber. A positive pressure is applied to the



NOTE—Taken from Ref (53).

FIG. 10 Packer Pump Arrangement

gas line closing the sampler check valve and forcing water up the sample line. By removing the pressure the cycle can be repeated. Vacuum can also be used in conjunction with the gas (30). The device can be permanently installed in the well (33, 34, 35) or lowered into the well (36, 37).

6.1.5.2 A more complicated two stage design constructed of glass with check valves made of TFE-fluorocarbon has been constructed (38, 39). The unit was designed specifically for sample testing for trace level organics. Continuous flow rates up to 2.3 Lpm (0.6 gpm) are possible with a 5.1 cm (2 in.) diameter unit.

6.1.5.3 Gas displacement pumps have also been developed with multiple functions. The water sample in Fig. 5 provides piezometric data measurements with an internally mounted transducer (40). A sample with its transducer exposed externally for piezometric measurements is illustrated in Fig. 6 (41). The sensor can activate the gas source at the surface to cause sample chamber pressurization at the predetermined depth. Another design can be used as a water sampler or as a tool for injecting brine or other tracers into a well (42).

6.1.5.4 Gas displacement pumps offer reasonable potential for preserving sample integrity because little of the driving gas comes in contact with the sample as the sample is conveyed to the surface by a positive pressure. There is, however, a potential loss of dissolved gasses or contamination from the driving gas and the housing materials.

6.1.6 *Bladder Pumps:*

6.1.6.1 Bladder pumps, also referred to as gas-op squeeze pumps, consist of a flexible membrane enclose rigid housing. Water enters the membrane through a valve in the vessel bottom; compressed gas injected in cavity between the housing and bladder forces the s through a check valve at the top of the membrane and discharge line (Fig. 7). Water is prevented from re-en the bladder by the top check valve. The process is repea cycle the water to the surface. Samples taken from dep 30.5 m (100 ft) have been reported.

6.1.6.2 A variety of design modifications and ma are available (43, 44). Bladder materials include neo rubber, ethylene propylene terpolymer (E.P.T.), nitrile the fluorocarbon Viton.[3] A bladder made of TFE-fl carbon is also under development (45). Automated sam systems have been developed to control the time be pressurization cycles (46).

6.1.6.3 Bladder pumps provide an adaptable sam tool due primarily to the number of bladder shapes th feasible. These devices have a distinct advantage ove displacement pumps in that there is no contact wit driving gas. Disadvantages include the large gas vol required, low pumping rates, and potential contamin from many of the bladder materials, the rigid housin both.

6.1.7 *Gas Driven Piston Pumps:*

6.1.7.1 A simple and inexpensive example of a gas driven piston pump is a syringe pump (47). The pump (Fig. 8) is constructed from a 50 mL plastic syringe with plunger stem removed. The device is connected to a gas line to the surface and the sample passes through a check valve arrangement to a sampling container at the surface. By successively applying positive and negative pressure to the gas-line, the plunger is activated driving water to the surface.

6.1.7.2 A double piston pump powered by compressed air is illustrated in Fig. 9. Pressurized gas enters the chamber between the pistons: the alternating chamber pressurization activates the piston which allows water entry during the suction stroke of the piston and forces the sample to the surface during the pressure stroke (48). Pumping rates between 9.5 and 30.3 L/hr (2.5 to 8. gal/hr) have been reported from 30.5 m (100 ft). Depths in excess of 457 m (1500 ft) are possible.

6.1.7.3 The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. Nevertheless, contribution of trace elements from the stainless steel and brass is a potential problem and the quantity of gas used is significant.

6.1.8 *Packer Pump Arrangement:*

6.1.8.1 A packer pump arrangement provides a means by which two expandable "packers" isolate a sampling unit between two packers within a well. Since the hydraulic or pneumatic activated packers are wedged against the casing wall or screen, the sampling unit will obtain water samples only from the isolated well portion. The packers are deflated for vertical movement within the well and inflated when the desired depth is attained. Submersible, gas lift, and suction pumps can be used for sampling. The packers are usually constructed from some type of rubber or rubber compound (48, 49, 50, 51). A packer pump unit consisting of a vacuum sampler positioned between two packers is illustrated in Fig. 10 (52).

6.1.8.2 A packer assembly allows the isolation of discrete sampling points within a well. A number of different samplers can be situated between the packers depending upon the analytical specifications for sample testing. Vertical movement of water outside the well casing during sampling is possible with packer pumps but depends upon the pumping rate and subsequent disturbance. Deterioration of the expandable materials will occur with time with the increased possibility of undesirable organic contaminants contributing to the water sample.

7. Sample Containers and Preservation

7.1 Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Therefore, insuring the timely analysis of a sample should be one of the foremost considerations in the sampling plan schedule. Methods of preservation are somewhat limited and are intended to retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce the volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration and freezing. For water samples, immediate refrigeration just above freezing (4°C in wet ice) is often the best preservation technique available, but it is not the only measure nor is it applicable in all cases. There may be special cases where it might be prudent to include a recording thermometer in the sample shipment to verify the maximum and minimum temperature to which the samples were exposed. Inexpensive devices for this purpose are available.

7.2 All bottles and containers must be specially precleaned, pre-labelled, and organized in ice-chests (isolating samples and sampling equipment from the environment) before one goes into the field. Otherwise, in any comprehensive program utter chaos usually develops in the field or laboratory. The time in the field is very valuable and should be spent on taking field notes, measurements, and in documenting samples, not on labelling and organizing samples. Therefore, the sampling plan should include clear instructions to the sampling personnel concerning the information required in the field data record logbook (notebook), the information needed on container labels for identification, the chain-of-custody protocols, and the methods for preparing field blanks and spiked samples. Example of detailed plans and documentation procedures have been published (14, 53).

7.3 The exact requirements for the volumes of sample needed and the number of containers to use may vary from laboratory to laboratory. This will depend on the specific analyses to be performed, the concentration levels of interest, and the individual laboratory protocols. The manager of the sampling program should make no assumptions about the laboratory analyses. He should discuss the analytical requirements of the sampling program in detail with the laboratory coordinator beforehand. This is especially the case since some analyses and preservation measures must be performed at the laboratory as soon as possible after the samples arrive. Thus, appropriate arrangements must be made.

7.4 There are a number of excellent references available which list the containers and preservation techniques appropriate for water and soils (13, 14, 50, 54, 55, 56). The "Handbook for Sampling and Sample Preservation of Water and Wastewater" is an excellent reference and perhaps the most comprehensive one (14). Some of this information is summarized in Table 1.

7.5 Sample containers for trace organic samples require special cleaning and handling considerations (57). The sample container for purgeable organics consist of a screw-cap vial (25 to 125 mL) fitted with a TFE-flourocarbon faced silicone septum. The vial is sealed in the laboratory immediately after cleaning and is only opened in the field just prior to pouring sample into it. The water sample then must be sealed into the vial headspace free (no air bubbles) and immediately cooled (4°C) for shipment. Multiple samples (usually about four taken from one large sample container) are taken because leakage of containers may cause losses, may allow air to enter the containers, and may cause erroneous analysis of some constituents. Also, some analyses are best conducted on independent protected samples.

7.6 The purgeable samples must be analyzed by the laboratory within 14 days after collection, unless they are to be analyzed for acrolein or acrylonitrile (in which case they are to be analyzed within 3 days). For samples for solvent extractions (extractable organics-base neutrals, acids and pesticides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been precleaned, rinsed with the extracting organic solvent and oven dried at 105°C for at least 1 h. These bottles must be sealed with TFE-fluorocarbon lined caps (Note). Samples for organic extraction must be extracted within 7 days and analyzed within 30 days after extraction. Special pre-cleaned, solvent rinsed and oven-dried stainless steel beakers (one for each monitoring well) may be used for transferring samples from the sampling device to the sample containers.

NOTE—When collecting samples, the bottles should not be overfilled or prerinsed with sample before filling because oil and other materials may remain in the bottle. This can cause erroneously high results.

7.7 For a number of groundwater parameters, the most meaningful measurements are those made in the field at the time of sample collection or at least at an on-site laboratory. These include the water level in the well and parameters that sometimes can change rapidly with storage. A discussion of the various techniques for measuring the water level in the well is contained in a NCASI publication (5) and detailed procedures are outlined in a U.S. Geological Survey publication (58). Although a discussion of these techniques is beyond the scope of this guide, it is important to point out that accurate measurements must be made before a well is flushed or only after it has had sufficient time to recover. Parameters that can change rapidly with storage include specific conductance, pH, turbidity, redox potential, dissolved oxygen, and temperature. For some of the other parameters, the emphasis in groundwater monitori the concentration of each specific dissolved compon the total concentration of each. Samples for these measurements should be filtered through 0.45 μn brane filters ideally in the field or possibly at an laboratory as soon as possible. Analyses often r filtered samples include all metals, radioactivity par total organic carbon, dissolved orthophosphate (if and total dissolved phosphorous (if needed) (13, metals are to be analyzed, filter the sample prior preservation. For TOC organics, the filter material sh tested to assure that it does not contribute to the TC type or size of the filter to be used is not well und However, if results of metal, TOC or other paramet could be effected by solids are to be compared, th filtering procedure must be used in each case. R analytical results should state whether the sampl filtered and how they were filtered.

7.8 Shipment and receipt of samples must be coor with the laboratory to minimize time in transit. All for organic analysis (and many other parameters). arrive at the laboratory within one day after it is ship be maintained at about 4°C with wet ice. The best wa them to the laboratory in good condition is to send sturdy insulated ice chests (coolers) equipped with dividers. 24-h courier service is recommended, if p delivery service is not practical.

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APPENDIX D

APPENDIX D
WATER QUALITY ANALYTICAL PROTOCOL

Prior to the initiation of preproject groundwater sampling, a state of California-certified laboratory will be selected to conduct analytical testing. The laboratory will provide a copy of its QA/QC manual to Metropolitan's technical experts for review. The laboratory will be contracted contingent on acceptance of the QA/QC manual by Metropolitan's technical experts and Metropolitan. If necessary, an audit of the laboratory will be conducted.

In general, the selected laboratory will adhere to those recommendations promulgated in Title 21, Code of Federal Regulations, CFR Part 58 *Good Laboratory Practices*; criteria described in *Methods for Chemical Analysis of Water and Wastes* (EPA 1979; EPA-600/4-79-202); and requirements outlined in *Users Guide to the Contract Laboratory Program* (EPA, 1986). Groundwater samples collected for chemical analysis during this Project will be tested in accordance with the standard analytical procedures established by the EPA. The laboratory will be required to submit analytical results that are supported by sufficient backup data and QA/QC results to enable Metropolitan's technical experts to conclusively determine the validity of the data.

Analytical tests to be conducted during quarterly groundwater sampling events are summarized in Table D-1. The table summarizes each individual analyte to be tested, the appropriate EPA method number, and the proposed detection limit to be achieved.

General mineral constituents and physical parameters to be analyzed during baseline and annual spring water sampling events are summarized in Table D-2. The table summarizes each individual analyte to be tested, the appropriate EPA method number, and the proposed detection limit to be achieved.

Analytical tests to be conducted during annual Title 22 sampling of Colorado River Water are summarized in Table D-3. This table also summarizes each individual analyte to be tested, the appropriate EPA method number, and the proposed detection limit to be achieved.

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Quarterly Analytical Suite

General Classification	Constituent	Method	Detection Limit
Gen. Physical	Color	110.2	1
Gen. Physical	Odor	140.1	1
Gen. Physical	Turbidity	180.1	0.1
Gen. Mineral	pH	9040	0.01
Gen. Mineral	Bicarbonate	SM2320B	2
Gen. Mineral	Carbonate	SM2320B	2
Gen. Mineral	Alkalinity	310.1	2
Gen. Mineral	Hydroxide	SM2320B	2
Gen. Mineral	Hardness	130.2	1
Gen. Mineral	Total Dissolved Solids	160.1	10
Gen. Mineral	Surfactants (MBAS)	425.1	0.05
Gen. Mineral	Electrical Conductivity	425.1	1
Gen. Mineral	Chloride Cl^-	325.3	1
Gen. Mineral	Sulfate SO_4^{--}	375.4	2
Gen. Mineral	Nitrate as N	SM4500NO3D	1
Gen. Mineral	Calcium	6010	0.2
Gen. Mineral	Copper	6010	0.01
Gen. Mineral	Iron	6010	0.05
Gen. Mineral	Magnesium	6010	0.1
Gen. Mineral	Manganese	6010	0.005
Gen. Mineral	Potassium	6010	0.1
Gen. Mineral	Sodium	6010	2
Gen. Mineral	Zinc	6010	0.01
Other Inorganics	Arsenic	200.7	0.005
Other Inorganics	Bromide Br^-	320.1	0.02
Other Inorganics	Perchlorate		0.005

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Annual Spring Water Analytical Suite

General Classification	Constituent	Method	Detection Limit
Gen. Physical	Color	110.2	1
Gen. Physical	Odor	140.1	1
Gen. Physical	Turbidity	180.1	0.1
Gen. Mineral	pH	9040	0.01
Gen. Mineral	Bicarbonate	SM2320B	2
Gen. Mineral	Carbonate	SM2320B	2
Gen. Mineral	Alkalinity	310.1	2
Gen. Mineral	Hydroxide	SM2320B	2
Gen. Mineral	Hardness	130.2	1
Gen. Mineral	Total Dissolved Solids	160.1	10
Gen. Mineral	Surfactants (MBAS)	425.1	0.05
Gen. Mineral	Electrical Conductivity	425.1	1
Gen. Mineral	Chloride Cl^-	325.3	1
Gen. Mineral	Sulfate SO_4^{--}	375.4	2
Gen. Mineral	Nitrate as N	SM4500NO3D	1
Gen. Mineral	Calcium	6010	0.2
Gen. Mineral	Copper	6010	0.01
Gen. Mineral	Iron	6010	0.05
Gen. Mineral	Magnesium	6010	0.1
Gen. Mineral	Manganese	6010	0.005
Gen. Mineral	Potassium	6010	0.4
Gen. Mineral	Sodium	6010	2
Gen. Mineral	Zinc	6010	0.01
Chlorofluorocarbons	-	524.2	0.01
Tritium	-	*	1 pCi/L

Note: All concentrations are in milligrams per liter except where noted
* To be analyzed by LLNL

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Title 22 Analytical Suite

	Classification	Constituent	Units	Detection Limit	Method Number
Inorganics	General Physical Properties	Color	Standard unit	1	110.2
		Odor	Standard unit	1	140.1
		Turbidity	NTU	0.05	180.1
	General Minerals	Bicarbonate	mg/L	1	310.1
		Carbonate	mg/L	1	310.1
		Total Alkalinity	mg/L	1	310.1
		Calcium	mg/L	0.2	6010
		Chloride	mg/L	1	300
		Fluoride	mg/L	0.1	300
		Magnesium	mg/L	0.1	EPA 6010
		Nitrate (as N)	mg/L	0.4	300
		Nitrite (as N)	mg/L	0.4	300
		Total Nitrogen	mg/L	0.4	300
		pH	unit	N/A	150.1
		Potassium	mg/L	0.1	EPA 6010
		Sodium	mg/L	0.1	EPA 6010
		Sulfate	mg/L	0.5	300
		Specific Conductance	umhos/cm	1	120.1
		Total Dissolved Solids	mg/L	1	160.1
		Total Hardness	mg/L	1	130.2
	Other Inorganics	Perchlorate	µg/L	5	
		Cyanide	mg/L	0.05	335.2
		Bromide	mg/L	0.033	320.1
		Foaming Agents (MBAS)	µg/L	0.05	425.1
		Total Organic Carbon	mg/L	1	415.1
		Asbestos[8]	0.2 million fibers/L > 10µm		
		Ultra Violet 254	NS	NS	NS
	Metals	Aluminum	mg/L	0.01	200.8
		Antimony	mg/L	0.006	200.8
		Arsenic	mg/L	0.002	200.8
		Barium	mg/L	0.1	200.8
		Beryllium	mg/L	0.001	200.8
		Cadmium	mg/L	0.001	200.8

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Title 22 Analytical Suite

Classification	Constituent	Units	Detection Limit	Method Number
Metals (cont.)	Chromium	mg/L	0.01	200.8
	Copper	mg/L	0.01	200.8
	Iron	mg/L	0.01	200.8
	Lead	mg/L	0.005	200.8
	Manganese	mg/L	0.005	200.8
	Mercury	mg/L	0.001	200.8
	Nickel	mg/L	0.01	200.8
	Selenium	mg/L	0.005	200.8
	Silver	mg/L	0.01	200.8
	Thallium	mg/L	0.001	200.8
	Zinc	mg/L	0.05	200.8
Radiological	Gross Alpha	pCi/L	1	NS
	Gross Beta	pCi/L	1	NS
	Radium 226	pCi/L	0.5	NS
	Radium 228	pCi/L	0.5	NS
	Radon 222	pCi/L	20	NS
	Strontium 90	pCi/L	1	NS
	Tritium	pCi/L	1	NS
	Uranium	pCi/L	1	NS
Organics Organochlorine Pesticides	Alachlor	mg/L	0.001	507
	Aldrin	mg/L	0.00075	508
	Chlorothalonil	mg/L	0.005	508
	Dieldrin	mg/L	0.00002	508
	Endrin	mg/L	0.0001	508
	Lindane	mg/L	0.0002	508
	Methoxychlor	mg/L	0.01	508
	Toxaphene	mg/L	0.001	508
	Chlordane	mg/L	0.0001	508
	Heptachlor	mg/L	0.00001	508
	Heptachlor epoxide	mg/L	0.00001	508
	Propachlor	mg/L	0.0005	508
	Polychlorinated Biphenyls (PCBs)	mg/L	0.0005	508

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Title 22 Analytical Suite

Classification	Constituent	Units	Detection Limit	Method Number
Organochlorine Herbicides	2,4-D	mg/L	0.01	515.1
	2,4,5-TP Silvex	mg/L	0.001	515.1
	2,4,5-T	mg/L	NS	515.1
	Bentazon	mg/L	0.002	515.1
	Dalapon	mg/L	0.01	515.1
	Dicamba	mg/L	0.000081	515.1
	Dinoseb	mg/L	0.002	515.1
	Picloram	mg/L	0.001	515.1
	Pentachlorophenol	mg/L	0.0002	515.1
N-P Pesticides	Atrazine	mg/L	0.001	507
	Molinate	mg/L	0.002	507
	Simazine	mg/L	0.001	507
	Thiobencarb	mg/L	0.001	507
	Butachlor	mg/L	0.00038	507
	Diazinon	mg/L	0.00002	507
	Dimethoate	mg/L	0.01	507
	Malathion	mg/L	NS	507
	Prometryn	mg/L	0.02	507
	Bromacil	mg/L	0.01	507
	Metolachlor	mg/L	NS	507
	Metribuzin	mg/L	NS	507
Fumigants	Ethylene Dibromide (EDB)	mg/L	0.00002	504
	Dibromochloropropane (DBCP)	mg/L	0.00001	504
Carbamates	Diuron	mg/L	0.01	531
	Aldicarb	mg/L	0.03	531
	Aldicarb sulfone	mg/L	NS	531
	Aldicarb sulfoxide	mg/L	NS	531
	Oxamyl	mg/L	0.02	531
	Carbofuran	mg/L	0.005	531
	Carbaryl	mg/L	0.05	531
	3-Hydroxycarbofuran	mg/L	0.03	531
	Methomyl	mg/L	0.02	531
	Baygon (Propoxur)	mg/L	NS	531

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Proposed Title 22 Analytical Suite

Classification	Constituent	Units	Detection Limit	Method Number
Misc. Pesticides	Glyphosate	mg/L	0.025	547
	Endothail	mg/L	0.045	548
	Diquat & Paraquat	mg/L	0.004	549
	Polynuclear Aromatic Hydrocarbon	mg/L	NS	550
	2,3,7,8-TCDD Dioxin	mg/L	$5x10^{-9}$	
Semi-Volatile Organic Compounds	Benzo(a)pyrene	mg/L	0.0001	525
	Di(2-ethylhexyl)adipate	mg/L	0.005	525
	Di(2-ethylhexyl)phthalate	mg/L	0.003	525
	Hexachlorobenzene	mg/L	0.0005	525
	Hexachlorocyclopentadiene	mg/L	0.001	525
Volatile Organic Compounds	Benzene	mg/L	0.0005	524.2
	Carbon Tetrachloride	mg/L	0.0005	524.2
	1,2-Dichlorobenzene	mg/L	0.0005	524.2
	1,4-Dichlorobenzene	mg/L	0.0005	524.2
	1,1-Dichloroethane	mg/L	0.0005	524.2
	1,2-Dichloroethane	mg/L	0.0005	524.2
	cis-1,2-Dichloroethene	mg/L	0.0005	524.2
	trans-1,2-Dichloroethene	mg/L	0.0005	524.2
	1,1-Dichloroethene	mg/L	0.0005	524.2
	1,2-Dichloropropane	mg/L	0.0005	524.2
	1,3-Dichloropropene	mg/L	0.0005	524.2
	Ethylbenzene	mg/L	0.0005	524.2
	Methylene Chloride	mg/L	0.0005	524.2
	Methyl tert-butyl-ether (MTBE)	mg/L	0.0005	524.2
	Monochlorobenzene	mg/L	0.0005	524.2
	Styrene	mg/L	0.0005	524.2
	1,1,2,2-Tetrachloroethane	mg/L	0.0005	524.2
	Tetrachloroethene	mg/L	0.0005	524.2
	1,2,4-Trichlorobenzene	mg/L	0.0005	524.2
	1,1,1-Trichloroethane	mg/L	0.0005	524.2
	1,1,2-Trichloroethane	mg/L	0.0005	524.2
	Trichloroethene	mg/L	0.0005	524.2
	Trichlorofluoromethane	mg/L	0.005	524.2

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Proposed Title 22 Analytical Suite

Classification	Constituent	Units	Detection Limit	Method Number
Volatile Organic Compounds continued	1,1,2-Trichloro-1,2,2-trifluoroethane	mg/L	0.01	524.2
	Toluene	mg/L	0.0005	524.2
	Vinyl chloride	mg/L	0.0005	524.2
	Xylenes	mg/L	0.0005	524.2
	1,2-Dichlorobenzene	mg/L	0.0005	524.2
	Dibromomethane	mg/L	0.0005	524.2
	1,1-Dichloropropene	mg/L	0.0005	524.2
	1,3-Dichloropropane	mg/L	0.0005	524.2
	Chloromethane	mg/L	0.0005	524.2
	Bromomethane	mg/L	0.0005	524.2
	1,2,3-Trichloropropane	mg/L	NS	524.2
	1,1,1,2-Tetrachloroethane	mg/L	0.0005	524.2
	Chloroethane	mg/L	0.0005	524.2
	2,2-Dichloropropane	mg/L	0.0005	524.2
	o-Chlorotoluene	mg/L	0.0005	524.2
	p-Chlorotoluene	mg/L	0.0005	524.2
	Bromobenzene	mg/L	0.0005	524.2
	Dichlorodifluoromethane	mg/L	0.001	524.2
	1,2,4-Trimethylbenzene	mg/L	0.0005	524.2
	1,2,3-Trichlorobenzene	mg/L	0.0005	524.2
	n-Propylbenzene	mg/L	0.0005	524.2
	n-Butylbenzene	mg/L	0.0005	524.2
	Naphthalene	mg/L	NS	524.2
	Hexachlorobutadiene	mg/L	0.0005	524.2
	1,3,5-Trimethylbenzene	mg/L	0.0005	524.2
	p-Isopropyltoluene	mg/L	0.0005	524.2
	Isopropyltoluene	mg/L	0.0005	524.2
	Tert-butylbenzene	mg/L	0.0005	524.2
	Sec-butylbenzene	mg/L	0.0005	524.2
	Bromochloromethane	mg/L	0.0005	524.2
	Bromodichloromethane	mg/L	0.0005	524.2
	Bromoform	mg/L	0.0005	524.2
	Chlorodibromomethane	mg/L	0.0005	524.2
	Chloroform			

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Title 22 Analytical Suite

Classification	Constituent	Units	Detection Limit	Method Number
Microbiological Compounds	Heterotrophic Plate Count	CFU/ml	NS	SM9215B
	Total Coliforms	MPN/100 ml	NS	SM9221B
	Fecal Coliforms	MPN/100 ml	NS	SM9221C
	Cryptosporidium	NS	NS	EPA 1622
	Giardia	NS	NS	EPA 1623
	Enteric Viruses	NS	NS	EPA 1624

N/A - Not applicable

NS - Not specified in MWD analyte list or GEOSCIENCE laboratory analyte lists

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

DRINKING WATER STANDARDS AND HEALTH ADVISORIES TABLE

DECEMBER 1995

Contact: Bruce Macler, Regional Toxicologist, (415) 744-1884
Drinking Water Branch, Water Management Division

REGION 9 DRINKING WATER STANDARDS AND HEALTH ADVISORIES TABLE

The USEPA Region 9 Drinking Water Standards and Health Advisories Table is a compendium of standards, health advisories and related information for chemicals and other contaminants which may be found in ground and surface waters. It provides a comprehensive listing of all current and proposed National Primary Drinking Water Regulations (NPDWRs), Maximum Contaminant Levels (MCLs) for California, Arizona and Hawaii, and California Drinking Water Action Levels. Where available, it includes USEPA Integrated Risk Information System (IRIS) cancer risk levels and oral reference dose (RfD) values, and USEPA Office of Ground Water and Drinking Water (OGWDW) Health Advisories for drinking water contaminants.

In order to make this table a manageable size, very few explanations or caveats for the values are included in the body of the table. Because of this, and the fact that background documentation and understanding of the derivation of specific values are critical to the proper use of this information, this table should not be used as a sole source of information for decision making. While the Appendix contains brief explanations of the different standards, criteria and advisories, consideration must be given to the context in which these numbers will be used. The appropriate reference materials should be consulted to determine the applicability of the number being considered. Some references are listed in the Appendix.

The values in this table are current to the publication date, but are subject to change. The user is advised to contact Bruce Macler, Regional Toxicologist, USEPA Region 9, at (415) 744-1884, if questions arise regarding current values.

INFORMATION IN THIS TABLE

The information for specific contaminants in this table is arranged by contaminant type. Inorganic chemicals are listed first, followed by radionuclides, organic chemicals, microbial contaminants and water quality factors.

For each contaminant, any applicable or proposed USEPA National Primary Drinking Water Regulation is listed. These include the enforceable **Maximum Contaminant Levels (MCLs)**, the health-based **Maximum Contaminant Level Goals (MCLGs)**, and the aesthetics-based **Secondary MCLs**. A given contaminant may have both a MCL and a Secondary MCL, as well as a MCLG. The regulatory status of these values is indicated. **Proposed MCLs or MCLGs** have been formally proposed by USEPA, but not promulgated. **Final MCLs or MCLGs** have been promulgated, but are not yet effective as of the publication date. The effective date, if available, is indicated. **Current MCLs or MCLGs** are in effect.

In addition to regulatory information, health risk information is provided in the table. Data from IRIS for cancer and non-cancer health effects associated with drinking water contaminants is listed. The **RfD** is the daily oral intake (on a body weight basis) that is below the level USEPA believes to be without adverse, non-cancer health risks (i.e., zero risk). The **IRIS 10^{-6} risk level** is that contaminant concentration (in ug/liter) in drinking water that would yield no greater than an additional risk of one-in-a-million (10^{-6}) after a lifetime of drinking that water. The USEPA OGWDW Health Advisories provide information on acceptably safe levels of exposures to contaminants in drinking water. The **Acute 10-day** values apply specifically to acute toxic effects on children, but should be protective for adults. The **chronic (lifetime)** values for non-cancer health effects should be protective of health even with a lifetime exposure. For non-carcinogenic chemicals, this value is typically the same as the MCLG, if one has been established. The chronic (lifetime) values for cancer are set at a level that should yield no greater than an additional 10^{-6} risk over a lifetime exposure. EPA **cancer weight of evidence** determinations are listed to provide additional information on EPA's judgement of carcinogenicity for each chemical. The weight of evidence classifications are as follows:

A known human carcinogen
B1 probable human carcinogen based on human data
B2 probable human carcinogen based on animal data
C possible human carcinogen based on animal data
D insufficient data to classify chemical
E not a human carcinogen

APPLICABILITY AND USES OF THIS TABLE

The different types of standards and advisories contained in this table are based upon approaches and assumptions that are specific to each and consequently may have varying applications depending on their derivation. Use of specific types of information should be guided by the relevant legal requirements and an understanding of the meaning of the information itself.

MCLs and treatment techniques are the only federally enforceable NPDWRs. They are set to be health protective as well as feasible, and take into account analytical and treatment limitations. More stringent state-specific MCLs are enforceable in the indicated state. MCLGs, based solely on health information, are not enforceable, but provide health-based guidance for decision making. MCLGs for chemicals causing non-carcinogenic health effects are based on the RfD and set at a level believed to be safe. MCLGs for chemicals believed to be carcinogens are set at zero, from the perspective that no level of carcinogen is safe. Feasibility is not considered in setting MCLGs. Secondary MCLs are not enforceable, but provide information on aesthetics and palatability.

Health advisories and criteria are not formally promulgated in regulations and are subject to change as new data and analyses become available. MCLGs, values in IRIS and health advisories are developed by different offices and on different schedules. Therefore, values for similar effects from a given chemical may not be consistent throughout the table. The derivations of MCLGs and chronic (lifetime) health advisories for non-carcinogenic chemicals are based on the same assumptions regarding endpoints of toxicity. Slight differences in the table are due to rounding of numbers by different offices.

When considering a value to use for determining an acceptable level of contaminant in drinking water, the MCL should be selected first. In the absence of existing or proposed MCLs, users may have to decide which criteria are most appropriate. USEPA recommends a priority ranking to first consider any proposed MCLG (if other than zero), followed by the IRIS RfD or cancer risk level, and finally the chronic health advisory values.

Under the **Superfund Program**, remdial actions must comply with the **Applicable or Relevant and Appropriate Requirements (ARARs)**. For actions involving contamination of drinking water supplies, the ARARs under the Safe Drinking Water Act are the MCLs. Where there are no MCLs, or where the MCLs are determined to be insufficiently protective because of multiple contaminants, reference should be made to Superfund guidance documents to determine clean-up policy. For remedial actions impacting aquatic organisms and waters regulated under the Clean Water Act, consult the National Ambient Water Quality Criteria (NAWQC).

FDA STANDARDS FOR BOTTLED WATER

The U.S. Food and Drug Administration is responsible for regulating bottle water quality. It is required to adopt health-protective allowable limits for bottled water based on NPDWRs. FDA has adopted these MCLs:

Barium	Dibromochloropropane	o-Dichlorobenzene
Cadmium	2,4-D	p-Dichlorobenzene
Chromium	Ethylene dibromide	cis 1,2-Dichloroethylene
Mercury	Heptachlor	trans1,2-Dichloroethylene
Nitrate	Heptachlor epoxide	1,2-Dichloropropane
Nitrite	Lindane	Ethylbenzene
Selenium	Methoxychlor	Monochlorobenzene
Alachlor	Pentachlorophenol	Styrene
Atrazine	PCBs	Tetrachloroethylene
Carbofuran	Toxaphene	Toluene
Chlordane	2,4,5-TP (Silvex)	Xylenes

Allowable limits based on Secondary MCLs apply for aluminum and silver. In addition, bottled water must not exceed 5 ug/L lead and 1 mg/L copper.

SYMBOLS USED IN THE TABLE

mg/l = milligrams per liter, equivalent to parts per million (ppm)
ug/l = micrograms per liter, equivalent to parts per billion (ppb)

Note: values in table are in ug/l unless otherwise stated

IRIS = USEPA Integrated Risk Information System
RfD = Reference dose for daily oral ingestion in micrograms per kilogram body weight per day (ug/kg-d)
10^{-6} = one in a million excess lifetime cancer risk
TT = treatment technique, set in lieu of numeric MCL
+ = value from USEPA Final Draft Health Advisory
td = temperature dependent value
LOQ = Limit of quantification
T&O = taste and odor refers to a value based upon organoleptic data for controlling undersirable taste and odor qualities

INORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Aluminum	Secondry	50-200								1000 200 Scd		
Ammonia							30,000		D			
Antimony	Current	6	6	0.4		15	3		D	6		
Arsenic	Current	50		0.3	0.02			0.02	A	50		50
Asbestos	Current	7E+6 10um fibers	7E+6 10um fibers						A	7E+6 fibers		
Barium	Current	2,000	2,000	70			2,000+		D	1,000		1000
Beryllium	Current	4	4	5	.008	30,000		0.008	B2	4		
Boron				90		900	600		D		1000	
Bromate	Proposed	10	0		0.05				B2			
Cadmium	Current	5	5	.5		40+	5+		D	5		10
Chloramines	Proposed	MRDL* 4.0mg/L as Cl2	MRDLG* 4 mg/L as Cl2	100		1000	3000-4000		D			
Chlorate									D			
Chloride	Secondry	250mg/L								250-600 Secondr		
Chlorine	Proposed	MRDL* 4.0mg/L as Cl2	MRDLG* 4 mg/L as Cl2	80					D			

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
* - MRDL, MRDLG: Maximum residual disinfectant level and goal. Apply only if this disinfectant is used.

INORGANIC		EPA		IRIS		Health Advisories			Wt.	California		Arizona
Chemicals	Standard	MCL	MCLG	RfD µg/kg-d	10^{-6} Risk	Acute 10 Day	Chronic(Lifetime) Non-Cancer	Cancer	of Evid.	MCL	Action Level	MCL
:hlorine Dioxide	Proposed	MRDL* 0.8mg/L as ClO2	MRDLG* 0.3mg/L as ClO2	10			300		0			
:hlorite	Proposed	1.0mg/L	80	3			80		D			
:hromium(Total)	Current	100	100	5		1,000+	100+		0	50		50
:opper	Current Secondry	TT## 1,000	1,300						0	1000 Secondr		
.,anide	Current	200	200	22		200+	200+		0	200		
:luoride	Current Proposed secondry	4 mg/L 2 mg/L	4 mg/L	120						1400-2400td		
.ron	Secondry	300								300 Secondr		
.ead	Current	TT#	0						B2	50		
:anganese	Secondry	50		140 (food) 5(water)						50 Scd		
ercury inorganic)	Current	2	2	0.3			2+		D	2		
olybdenum				5		40	40		0			
ickel				20		1,000+	100+		D	100		
itrate (as N)	Current	10mg/L	10mg/L	1.6mg/L		10 mg/L***			D	45 mg/L as NO3		10mg/L (as N)
itrite (as N)	Current	1 mg/L	1 mg/L	160		1 mg/L***			D	1 mg/L		

alues are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

ral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
* - Treatment technique in lieu of numeric MCL
# - Treatment technique triggered at Action Level of 1300 ppb
d - td- temperature dependent value
- Treatment technique and public notification triggered at Action Level of 15 ppb
** - 10-day HA for nitrate/nitrite for 4kg child (protective of 10kg child & adults); also used for chronic (lifetime)

INORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Selenium	Current	50	50	5						50		50
Silver	Secondry	100		5		200	100		D	100 Scd		50
Strontium				600		25 mg/L	17 mg/L		D			
Sulfate	Secondry Proposed	250mg/L 400/500 mg/L	 400/500 mg/L							250-600 Secondr		
Thalium	Current	2	0.5	0.07		7	0.4			2		
Vanadium				7					D			
White Phosphorous				.02			0.1		D			
Zinc	Secondry	5 mg/L		300		6 mg/L	2 mg/L		D	5 mg/L Secondr		5 mg/L
RADIONUCLIDES												
Gross Alpha, excl. Uranium & Radon	Current	15pCi/L						.15pCi/L	A	15pCi/L		
Gross Beta	Current	4mrem per yr						0.04mrem per year	A	50pCi/L		
Radium 226	Current Proposed	5 pCi/L (+228) 20pCi/L	 0					.20 pCi/L	A	5 pCi/L (+Ra 22		
Radium 228	Current Proposed	5 pCi/L (+226) 20pCi/L	 0					.20 pCi/L	A	5 pCi/L (+Ra 22		
Radon	Proposed	300 pCi/L	0					1.5pCi/L	A			

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.

RADIONUCLIDES	EPA			IRIS		Health Advisories			Wt. of Evid.	California		Arizona
Chemicals	Standard	MCL	MCLG	RfD µg/kg-d	10^{-6} Risk	Acute 10 Day	Chronic(lifetime) Non-Cancer	Cancer		MCL	Action Level	MCL
Strontium 90									A	8pCi/L		
Tritium									A	20nCi/L		
Uranium	Proposed	20 ppb	0	3				0.7 ppb	A	20pCi/L		35pCi/
ORGANIC												
Acenaphthylene (acenapthene)				60								
Acephata				4					C			
Acetone				100					D			
Acatophenone				100								
Acifluorfen				13	1.0	2,000+		1.0+	B2			
Acrolein									C			320
Acrylamide	Current	TT	0	1.0	.01	200		0.01+	B2			
Acrylonitrile					0.06	20+		0.06+	B1			10
Adipates (di(athylhexyl)-adipate)	Current	400	400	600	30	20,000	400	30	C			
Alachlor	Current	2	0	10	0.4	100+		0.4+	B2	2		0.2

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
TT - Treatment technique in lieu of numeric MCL
a - Effective date postponed

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(Lifetime) Non-Cancer	Health Advisories Chronic(Lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Aldicarb	Final(a)	3	1	1.0			7+		D		10	9
Aldicarb Sulfone	Final(a)	2	1	1.0			7+		D			
Aldicarb Sulfoxide	Final(a)	4	1	1.0			7+		D			
Aldrin				0.03	.002	0.3		0.002	B2		LOQ (0.05)	
Allyl alcohol				5								
Ametryn				9		9,000+	60+		D			
Ammonium Sulfamate				280		20,000+	2,000+		D			
Anthracene (PAH)				300					D			
Atrazine	Current	3	3	35	0.16	100+	3+		C	3		(HI 3)
Baygon (Propoxur)				4		40+	3+		C		90	
Benefin				300								
Bentazon (Basagran)				2.5		300+	20+		D	18		
Benz(a)anthracene (PAH)	Proposed	0.1	0						B2			
Benzene	Current	5	0		1	200+		1.0+	A	1		5

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
a - Effective date postponed
HI - State of Hawaii MCL

ORGANIC Chemicals	EPA Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Benzene hexachloride α, β isomers (BHC)											0.7 α 0.3 β	
Benzo(a)pyrene (PAH)	Current	0.2	0					.002	B2	0.2		
Benzo(b)fluoranthene (PAH)	Proposed	0.2	0						B2			
Bolero (thiobencarb)				20						70 1 Scd		
Bromacil				130		5,000+	90+		C			
Bromochloromethane				13		1,000	90					
Bromodichloromethane (TTHM)	Current Proposed	100 a 80 a	 0	20	0.6	7,000+		0.6	B2			
Bromoform (TTHM)	Current Proposed	100 a 80 a	 0	20	4	2,000		4	B2			
Bromomethane (Methyl Bromide)				1		100+	10+		D			2.5
Butyl benzyl-phthlate (PAE)	Proposed	100	0	200					C			
Butylate				50		2,000+	350+		D			
Captafol				2	4				C			
Captan				130					B2		350	
Carbaryl (Sevin)				100		1,000+	700+		D		60	

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
a - Total Trihalomethanes MCL is sum of bromoform, chloroform, bromodichloromethane, dibromochloromethane.
b - See Trihalomethanes

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(Lifetime) Non-Cancer	Health Advisories Chronic(Lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Carbofuran	Current	40	40	5		50+	40+		E	18		36
Carbon Disulfide				100								830
Carbon Tetrachloride	Current	5	0	0.7	0.3	200+		0.3+	B2	0.5		5
Carboxin				100		1,000+	700+		D			
Chloral Hydrate (Trichloroacet-aldehyde, CH)	Proposed	**	40	1.6	0.4	1,400	60		C			
Chloramben				15		3,000+	100+		D			
Chlordane	Current	2	0	0.06	0.03	60+		0.03+	B2	0.1		
Chlorobenzene (Monochlorobenzene)	Current	100	100	20		2,000+	100+		D	70		
Chlorodibromomethane (Dibromochloro-methane, TTHM)	Current Proposed	100 a 80 a	 60	20		7,000	60		C			
Chloroform (trichloromethane) (TTHM)	Current Proposed	100 a 80 a	 0	10	6	4,000		6.0	B2			
bis-2-Chloroiso-propyl ether				40		4,000+	300+		D			
Chloromethane				4		400	3		C			
2-Chlorophenol				5		50	40		D			
Chloropicrin											50(37 T&O)	

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
** - No chloral hydrate MCL. MCLs for TTHMs and THAAs, precusor removal as control.
a - Total Trihalomethanes MCL is sum of bromoform, chloroform, bromodichloromethane, dibromochloromethane.
a - See Trihalomethanes

ORGANIC Chemicals	EPA Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Ariz MCL
Chlorothalonil				15	1.5	200+		1.5+	B2			
Chlorotoluene(o,p)				20		2,000+	100+		D		45	
Chlorpyrifos				3		30+	20+		D			
CIPC (Chlorpropham) (isopropylN(3chloro-phenyl) carbamate)				200							350	
Cresol(o,m)				500					C			
Cresol(p)				5					C			
Cyanazine				2		100+	1		C			
Dalapon	Current	200	200	26		3,000+	200+		D	200		
DCPA (Dacthal)				500		80,000+	4,000+		D			
DDT				0.5	0.1				B2			
Di(ethylhexyl)-adipate (Adipates)	Current	400	400	600	30	20,000	400+	30	C	400		
Diazinon				0.09		20+	0.6+		E		14	
Dibromoacetonitrile				20		2000	20		C			
Dibromochloromethane (Chlorodibromo-methane, TTHM)	Current Proposed	100 a 80 a	60	20		7,000	60		C			

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
a - Total Trihalomethanes MCL is sum of bromoform, chloroform, bromodichloromethane, dibromochloromethane.
b - See Trihalomethanes
I - State of Hawaii MCL

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
1,2-Dibromo-3-chloro propane (DBCP)	Current	0.2	0		0.03	50+		0.03	B2	0.2		(HI.04)
Dibutyl phthalate (PAE)				100					D			
Dicamba				30		300+	200+		D			
Dichloroacetic Acid (HAA5, THAA)	Proposed	60 @@	0	4		1000			B2			
Dichloroacetonitrile				8		1000+	6+		C			
1,2-Dichlorobenzene (o-Dichlorobenzene)	Current Proposed secondry	600 10	600	90		9,000+	600+		D	600	130 *** (10T&O)	
1,3-Dichlorobenzene (m-Dichlorobenzene)				90		9,000+	600+		D		130 *** (20T&O)	
1,4-Dichlorobenzene (p-Dichlorobenzene)	Current Proposed secondry	75 5	75	100		10,000+	75+		C	5		750
Dichlorodifluoro-methane (Freon 12)				200		40,000+	1,000+		D		1000	1.0
1,1-Dichloroethane										5		
1,2-Dichloroethane	Current	5	0		0.4	700+		0.4	B2	0.5		5.0
1,1-Dichloroethylene	Current	7	7	9		1,000+	7+		C	6		7.0
cis-1,2-Dichloro-ethylene	Current	70	70	10		3,000+	70+		D	6		
trans-1,2-Dichloro-ethylene	Current	100	100	20		2,000+	100+		D	10		

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
@ - See Haloacetic acids
@@ - Haloacetic acids (5) MCL is sum of mono-, di- and trichloroacetic acids and mono- and dibromoacetic acids.
*** - Action Level is for a single isomer or sum isomers

ORGANIC	EPA			IRIS		Health Advisories			Wt.	California		
							Chronic(lifetime)		of		Action	Arizona
Chemicals	Standard	MCL	MCLG	RfD µg/kg-d	10^{-6} Risk	Acute 10 Day	Non-Cancer	Cancer	Evid.	MCL	Level	MCL
Dichloromethane (Methylene chloride)	Current	5	0	60		2,000+		5+	B2	5		
2,4-Dichlorophenol				3		30+	20+		D			
2,4-Dichlorophenoxy -acetic acid (2,4-D)	Current	70	70	10		300+	70+		D	100		100
1,2-Dichloropropane	Current	5	0		0.5	90+		0.6+	B2	5		
1,3-Dichloropropene				0.3	0.2	30+		0.2+	B2	0.5		
Dieldrin				0.05	.002	0.5+		0.002+	B2		.05	
Diethylphthalate (PAE)				800			5000+		D			
Diisopropylmethyl-phosphonate				80		8,000+	600+		D			
Dimethoate				0.2							140	
Dimethrin				300		10,000+	2,000+		D			
Dimethylaniline				20	0.05				C			
Dimethyl methyl-phosphonate				200	7	2000	100	7	C			
2,4-Dimethylphenol				200							400	
1,3 Dinitrobenzene				0.1		40	1		D			

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
tg - technical grade dinitrotoluene only

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
2,4-Dinitrotoluene				2	.05 (tg)	500		.05 (tg)	B2 (TG)			
2,6-Dinitrotoluene				1.0	.05 (tg)	400		.05 (tg)	B2 (TG)			
Dinoseb	Current	7	7	1		300+	7+		D	7		
1,4-Dioxane (p-Dioxane)					7	400+		7+	B2			
Dioxin (2,3,7,8-TCDD)	Current	3E-5	0	1E-6	2E-7	1E-4		2E-7+	B2	3E-5		
Diphenamid(e)				30		300+	200+		D		40	
Diphenylamine				30		1000	200		D			
Di(ethylhexyl)-phthalate (PAE) (Phthalates)	Current	6	0	20	3			3+	B2	4		
Diquat	Current	20	20	2.2			20+		D	20		
Disulfoton				0.04		10+	0.3+		E			
1,4-Dithiane				10		400	80		D			
Diuron				2		1,000+	10+		D			
Endothall	Current	100	100	20		800+	100+		D	100		
Endrin	Current	2	2	0.3		20+	2+		D	2		0.2

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
tg - technical grade dinitrotoluene only
TT - Treatment technique in lieu of numeric MCL

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Chronic(lifetime) Non-Cancer	Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Epichlorohydrin	Current	TT	0	2	4	100+		4	B2			
Ethion				0.5							35	
Ethylbenzene	Current Proposed secondry	700 30	700	100		3,000+	700+		D	700		
Ethylene Dibromide (dibromoethane) (EDB)	Current	0.05	0		4E-4	8		0.0004	B2	0.05		(HI.04
Ethylene Glycol				2,000		6,000+	7,000+		D			
Ethylene Thiourea (ETU)				0.08	0.3	300+		0.3	B2			
Fenamiphos				0.25		9+	2+		D			
Fluometuron				13		2,000+	90+		D			
Fluorotrichloro-methane				300		7,000+	2,000+		D			
olpet				100					B2			
Fonofos				2		20+	10+		D			
Formaldehyde				150		5,000+	1,000+		B1		30	
Glycidaldehyde				4					B2			
Glyphosate	Current	700	700	100		20,000+	700+		D	700		

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
HI - State of Hawaii MCL
a - Haloacetic acids (5) MCL is sum of mono-, di- and trichloroacetic acids and mono- and dibromoacetic acids.

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Haloacetic acids (5) (HAAS, THAAs)	Proposed	60 30										
Heptachlor	Current	0.4	0	0.5	.008	10+		0.008+	B2	0.01		
Heptachlor epoxide	Current	0.2	0	0.013	.004			0.004	B2	0.01		
Hexachlorobenzene (Perchlorobenzene) (HCB)	Current	1	0	0.8	0.02	50+		0.02+	B2	1		
Hexachlorobutadiene				2		300+	1+		C			
Hexachlorocyclo-pentadiene (HEX)	Current Proposed secondary	50 8	50	7					D	50		
n-Hexane						4,000+			D			
Hexazinone				33		3,000+	200+		D			
HMX				50		5,000+	400+		D			
Isophorone				200		15,000+	100+	40	C			
Lindane (gamma-HCCH) (gamma-BHC)	Current	0.2	0.2	0.3		1,000+	0.2+	0.03	C	0.2		
Linuron				2					C			
Malathion				20		200+	200+		D		160	
Maleic Hydrazide				500		10,000+	4,000+		D			

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Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic (lifetime) Non-Cancer	Health Advisories Chronic (lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Ariz MCL
MCPA				1.5		100+	11+		E			
Merphos				0.03								
Methomyl (Lannate)				25		300+	200+		D			
Methoxychlor	Current	40	40	5		50	40		D	40		
Methylene Chloride (Dichloromethane)	Current	5	0	60	5	2,000+		5+	B2		40	
Methyl ethyl ketone (MEK, 2-Butanone)				600					D			
Methyl Parathion				.25		300+	2+		D		30	
Methyl t-butyl ether				30		24,000	200		C		35	
Metolachlor				150		2,000+	100+		C			
Metribuzin				13		5,000	100		D			
Mirex				0.2	.02				B2			
Molinate				2						20		
Napthalene				4		500+	20+		D			
Nitroguanidine				100		10,000+	700+		D			

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Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic (lifetime) Non-Cancer	Health Advisories Chronic (lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Oxamyl (Vydate)	Current	200	200	25		200+	200+		E	200		
Paraquat				4.5		100+	30+		E			
Parathion (Ethyl Parathion)				6					C		30	
Pentachloronitro-benzene (Terrachlor)				3	0.1				C		0.9	
Pentachlorophenol	Current	1	0	30	0.3	300+		0.3	B2	1	30	
Phenol				600		6,000+	4,000+		D		5(T&O) Cl2Syst	
Phthalates (di(ethylhexyl)-phthalate)	Current	6	0	20	3			3+	B2	4		
Picloram	Current	500	500	70		20,000+	500+		D	500		
Polychlorinated Biphenyls (PCBs)	Current	0.5	0		.005			0.005	B2	0.5		
Polynuclear Aromatic Hydrocarbons (PAHs) (benzo(a)pyrene)	Current	0.2	0						B2			
Prometon				15		200+	100+		D			
Pronamide				75		800+	50+		C			
Propachlor				13		500+	90+		D			
Propazine				20		1,000+	10+		C			

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Ari M
Propnam				20		5,000+	100+		D			
RDX				3	0.3	100+	2+	.3	C			
Simazine	Current	4	4	5		70	4+		C	4		
Styrene	Current Proposed secondary	100 10	100	200		2,000+	100+		C	100		
Tebutiuron				70		3,000+	500+		D			
Terbacil				13		300+	90+		E			
Terbufos				.13		5+	0.9+		D			
Terrachlor (pentachloro-nitrobenzene)				3	0.1				C		0.9	
1,1,1,2-Tetrachloro-ethane				30	1	2,000+	70+	1+	C			
1,1,2,2-Tetrachloro-ethane									C	1		
Tetrachloroethylene (Perchloroethylene)	Current	5	0	10	0.7	2,000+		0.7+	B2	5		
2,3,7,8-Tetrachloro-dibenzo-p-dioxin (Dioxin)	Current	3E-5	0	1E-6	2E-7	1E-4+		2E-7+	B2	3E-5		
Thiobencarb (Bolero)				20						70 1 Scd		
Toluene	Current Proposed secondary	1,000 40	1,000	200		2,000+	1,000+		D	150		

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Toxaphene	Current	3	0	100	0.03	40+		0.03+	B2	3		5
Tribromomethane (Bromoform, TTHM)	Current Proposed	100 a 80 a		20	4	2,000+		4	B2			
Trichloroacet-aldehyde (Chloral hydrate)	Proposed	**	40	1.6	0.4				C			
Trichloroacetic acid (HAA5, THAA)	Proposed	60 aa	300	100		4000	300		C			
1,2,4-Trichloro-benzene	Current	70	70	1		100+	70		D	70		
1,3,5-Trichloro-benzene				6		600+	40+		D			
1,1,1-Trichloro-ethane	Current	200	200	35		40,000+	200+		D	200		200
1,1,2-Trichloro-ethane	Current	5	3	4		400+	3+		C	5		
Trichloroethylene	Current	5	0		3			3	B2	5		5
Trichlorofluoro-methane (Freon 11)				700						150	150	
2,4,6-Trichloro-phenol					3			3	B2			
2,4,5,-Trichloro-phenoxyacetic acid (2,4,5-T)				10		800+	70+		D			
2,4,5 Trichlorophen-oxypropionic acid (2,4,5-TP) (Silvex)	Current	50	50	7.5		200+	50+		D	50		10
1,2,3-Trichloro-propane				6	5	600+	40+	5	B2			(HI .8)

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
a - Total Trihalomethanes MCL is sum of bromoform, chloroform, bromodichloromethane, dibromochloromethane.
a - See Trihalomethanes
** - No chloral hydrate MCL. MCLs for TTHMs and THAAs, precusor removal as control.
aa - Haloacetic acids (5) MCL is sum of mono-, di- and trichloroacetic acids and mono- and dibromoacetic acids.
aa - See Haloacetic acids
HI - State of Hawaii MCL

Appendix

ORGANIC Chemicals	EPA Standard	MCL	MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Chronic(Lifetime) Non-Cancer	Chronic(Lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)										1200		
Trifluralin				7.5		80+	5+	5+	C			
Trihalomethanes (TTHM)	Current Proposed	100 a 80 a							B2	100		
Trinitroglycerol						5	5					
Trinitrotoluene				0.5	1	20	2	1	C			
Trithion											7	
Vinyl Chloride	Current	2	0		.015	3,000+		0.015+	A	0.5		
Xylenes- sum of isomers	Current Proposed secondry	10ppm 20	10ppm	2000		40,000+	10,000+		D	1750		
MICROB.-TURBIDITY												
Cryptosporidium	Proposed	TT	0									
Giardia Lamblia	Current	TT	.									
Heterotrophic Plate Count	Current	TT β	NA									
Legionella	Current	TT β	0									
Total Coliforms	Current	P/A aa	0									

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
a - Total Trihalomethanes MCL is sum of bromoform, chloroform, bromodichloromethane, dibromochloromethane.
TT - Treatment technique in lieu of numeric MCL
β - Surface waters and groundwater under the direct influence of surface water only.
aa - P/A - MCL is based on the presence/absence of total coliforms
δ - 0.5 NTU, conv. or direct filtration; 1.0 NTU, DE or slow sand filtration

MICROB.-TURBIDITY Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Turbidity	Current	0.5 or 1.0 NTU a	NA									
Viruses	Current	TT β	0									
WATER QLTY.SECONDARY MAX.CONT.LEV												
Color	Secondry	15color units										
Corrosivity	Secondry	Noncorrosive										
Foaming Agents	Secondry	500										
Odor (Odor threshold)	Secondry	3.0 OT#										
Total Dissolved Solids (TDS)	Secondry	500 ppm										
pH	Secondry	6.5-8.5										

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
TT - Treatment technique in lieu of numeric MCL
β - Surface waters and groundwater under the direct influence of surface water only.
- Odor Threshold Numbers

TABLE 2

PRIORITY LIST OF CONTAMINANTS WHICH MAY REQUIRE REGULATION UNDER THE SDWA (1991 VERSION)

Microorganisms

Cryptosporidium

Inorganics

Aluminum
Boron
Chloramines
Chlorate
Chlorine
Chlorine dioxide
Chlorite
Cyanogen chloride
Hypochlorite ion
Manganese
Molybdenum
Strontium
Vanadium
Zinc

Pesticides

Asulan
Bentazon
Bromacil
Cyanazine
Cyromazine
DCPA (and acid metabolites)
Dicamba
Ethylenethiourea
Fomesafen
Latofen/Acifluorfen
Metalaxyl
Methomyl
Metolachlor
Metribuzin
Parathion degradation product (4-nitrophenol)
Prometon
2,4,5-T
Thiodicarb
Trifluralin

Synthetic Organic Chemicals

Acrylonitrile
Bromobenzene
Bromochloroacetonitrile
Bromodichloromethane
Bromoform
Bromomethane
Chloroethane
Chloroform
Chloromethane
Chloropicrin
o-Chlorotoluene
p-Chlorotoluene
Dibromoacetonitrile
Dibromochloromethane
Dibromomethane
Dichloroacetonitrile
1,3-Dichlorobenzene
Dichlorodifluoromethane
1,1-Dichloroethane
2,2-Dichloropropane
1,3-Dichloropropane
1,1-Dichloropropene
1,3-Dichloropropene
2,4-Dinitrophenol

Synthetic Organic Chemicals (con't)

2,4-Dinitrotoluene
2,6-Dinitrotoluene
1,2-Diphenylhydrazine
Fluorotrichloromethane
Hexachlorobutadiene
Hexachloroethane
Isophorone
Methyl ethyl ketone
Methyl isobutyl ketone
Methyl t-butyl ether
Naphthalene
Nitrobenzene
1,1,1,2-Tetrachloroethane
1,1,2,2-Tetrachloroethane
Tetrahydrofuran
Trichloroacetonitrile
1,2,3-Trichloropropane

Chlorination/ chloramination byproducts (misc.): haloacetic acids, haloketones, chloral hydrate, 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX-2), N-organochloramines

Ozonation byproducts: aldehydes, epoxides, peroxides, nitrosamines, bromate, iodate

APPENDIX

DESCRIPTION OF STANDARDS AND ADVISORIES

Authority

Under the authority of the Safe Drinking Water Act (SDWA, Public Law 93-523), the USEPA is mandated to establish National Primary Drinking Water Regulations for contaminants occurring in drinking water. Primary NPDWRs are established and enforced to protect the public from adverse health effects resulting from a drinking water contaminant. Included in these regulations are the drinking water standards which set either 1) treatment techniques to control a contaminant, or 2) the Maximum Contaminant Level (MCL) allowable for the contaminant in drinking water. An MCL is set when an appropriate method of detection for the contaminant exists. A treatment technique approach is used when it is not possible to quantify the contaminant at the level necessary to protect public health. Secondary standards are established based on non-health related aesthetic qualities of appearance, taste and odor. These secondary standards are not federally enforceable.

States may choose to accept responsibility (Primacy Status) for the oversight and enforcement of US drinking water regulations. States which have primacy status from USEPA must adopt State drinking water standards that are at least as stringent as federal standards. A state may choose to enforce secondary standards as well as primary standards.

USEPA Maximum Contaminant Level Goals (MCLGs)

MCLGs are developed by the Office of Science and Technology in the USEPA Office of Water as a required first step toward promulgation of NPDWRs. MCLGs are non-enforceable health goals which are to be set at levels at which no known or anticipated adverse effects on the health of persons occur, and which allow for an adequate margin of safety. Prior to the SDWA Amendments of 1986, these levels were called Recommended Maximum Contaminant Levels (RMCLs). MCLGs are strictly health-based levels and are derived from relevant toxicological data.

For chemicals that produce adverse health effects and are not believed to be carcinogenic (non-carcinogens), the MCLG is based on the Reference Dose (RfD). A RfD is calculated from toxicological data to represent a contaminant level that should be without risk of adverse health effects even with a lifetime exposure. USEPA assumes that a threshold exists for non-cancer health effects from chemical contaminants, below which the effect will not occur. Thus the MCLG will be a non-zero number. The RfD, which is based on the total daily amount of contaminant taken up by a person on a body weight basis, is converted to a Drinking Water Equivalent Level (DWEL) concentration and adjusted for the percentage contribution of other sources (relative source contribution, RSC) of the contaminant besides drinking water (air, food, etc) to arrive at the MCLG. This calculation assumes a lifetime consumption of 2 liters of drinking water per day by a 70 kg adult. Unless otherwise noted, the RSC from drinking water for organic and inorganic compounds is respectively 20% and 10%.

USEPA assumes that no threshold exists for cancer and thus, there is no absolutely safe level of contamination. For chemicals that are known (Group A) or probable (Group B) human carcinogens, USEPA policy directs that the MCLG be set at zero, in accordance with a recommendation by the US Congress. For contaminants believed to be possible human carcinogens (Group C), the MCLG may be derived based on relevant non-cancer health effects as described above. In this case, the RfD is divided by an additional uncertainty factor of 10. In some cases, Group C chemicals will have MCLGs set based on calculated maximum lifetime cancer risks of between 1/10,000 and 1/million.

Maximum Contaminant Levels (MCLs)

MCLs are federally enforceable limits for contaminants in drinking water established as NPDWRs. The MCL for a given contaminant is set as close to the corresponding MCLG as is feasible. "Feasible" is defined in the 1986 SDWA Amendments as "feasible with the use of the best technology, treatment techniques and other means which the Administrator finds, after examination for efficacy under field conditions and not solely under laboratory conditions, are available (taking cost into consideration)." To promulgate a MCL for a contaminant requires that a method of detection for that contaminant is available suitable for the level desired and a Best Available Technology is identified that can feasibly remove the contaminant to the desired level.

Secondary Maximum Contaminant Levels

Secondary MCLs are established under the SDWA to protect the public welfare. Such regulations apply to contaminants in drinking water that adversely affect its odor, taste or appearance and consequently cause a substantial number of persons to discontinue its use. Secondary MCLs are not based on direct adverse health effects associated with the contaminant, although some contaminants may have both a MCL and a SMCL. SMCLs are considered as desirable goals and are not fereally enforceable. However, states may choose to promulgate and enforce SMCLs at the state level.

Health Advisories

Health Advisories (HAs) for drinking water contaminants are levels considered to be without appreciable health risk for specific durations of exposure. HAs should be considered guidance and are not enforceable drinking water standards. HAs were previously know as Suggested No Adverse Response Levels (SNARLs).

USEPA HAs are develcped and published initially as External Review Drafts, and then as a Final Draft. This designation indicates that the HA will be always subject to change as additional information becomes available. HAs are developed for one-day, 10-day, longer-term (approximately 7 years) and lifetime (70 year) exposures based on data describing non-carcinogenic health effects resulting from the contaminant. One-day and 10-day HAs use parameters which reflect exposures and effects for a 10 kg child consuming 1 liter of water per day. Lifetime HAs consider a 70 kg adult consuming 2 liters of water per day. Longer-term HAs can incorporate either child or adult parameters. A relative source contribution from water is also factored into the lifetime HA calculation to account for exposures from other sources (air, food, soil, etc) of the contaminant.

For known or probably human carcinogens, the lifetime HA level is based on an upper-bound excess lifetime cancer risk of 1/million. This means that **USEPA considers that the risk from a lifetime consumption of water at the given level is unlikely to be greater than 1/million, is most likely substantially less and may be zero.**

Reference Dose (RfD) and Drinking Water Equivalent Level (DWEL)

The RfD is a daily exposure level which is believed to be without appreciable health risk to humans over a lifetime. The RfD is usually derived from an experimental "no observed adverse effect level" (NOAEL), identified as the highest dose in the most relevant study that did not result in a known adverse effect. The NOAEL is divided by various uncertainty factors to derive the RfD. These uncertainty factors account for the variation in human response, extrapolation to human responses if animal experiments were used, data quality and relevance. The RfD takes the form of dose ingested per unit body weight per day (ug/kg-d).

The DWEL is the conversion of the RfD into an equivalen water concentration. It assumes that a 70 kg adult consumes two liters of water per day and that the total dose to a person results solely from drinking water. It is important to remember that actual exposures in the environment may occur through other routes, such as inhalation or dermal contact, or from other sources, such as from food or soil.

California Action Levels

California Department of Health Services Action Levels are health-based criteria derived much in the same way as EPA Health Advisories. Specific approaches to determining cancer risks and exposure assumptions may differ in some ways from those used by USEPA. California Action Levels are not enforceable drinking water standards, but are levels at which CA DOHS strongly urges water purveyors to take corrective action to reduce the level of contamination in the water they supply. Action Levels cease to exist when CA State MCLS are promulgated.

Integrated Risk Information System (IRIS)

IRIS is an EPA catalogue of Agency risk assessment and risk management information for chemical substances. It is available electronically in several formats. The risk assessment information contained in IRIS, unless specifically noted, has been reviewed and agreed upon by intra-agency work groups and represents Agency consensus. Chemical contaminants listed in IRIS may have descriptions of relevant toxicological experiments and risk assessment approaches used in the determination of RfDs, cancer risks and health advisories. Extensive bibliographies are included. Regulations and regulatory status for different media may be presented.

REFERENCES

EPA NPDWRs: Code of Federal Regulations, Title 40, Part 141

NPDWRs; Synthetic Organic Chemicals, Inorganic Chemicals and Microorganisms; Proposed Rule: FR 50, n. 219, November 13, 1985. (Phase I contaminants.)

NPDWRs; Volitile Synthetic Organic Chemicals, Final Rule and Proposed Rule: FR 50, n. 219, November 13, 1985. (Phase I chemicals.)

NPDWRs; Fluoride; Final Rule and Proposed Rule: FR 50, n. 220, November 14, 1985.

NPDWRs; Fluoride; Final Rule: FR 51, n. 63, April 2, 1986.

NPDWRs; Volatile Organic Chemicals; Final Rule: FR 52, n. 130, July 8, 1987. (Phase I chemicals.)

NPDWRs; Filtration and Disinfection; Turbidity, Giardia lamblia, Viruses, Legionella, and Heterotrophic Bacteria; Proposed Rule: FR 52, n. 212, November 3, 1987.

Drinking Water; NPDWRs; Total Coliforms; Proposed Rule: FR 52, n. 212, November 3, 1987.

Drinking Water Regulations; MCLGs and NPDWRs for Lead and Copper; Proposed Rule: FR 53, n. 160, August 18, 1988.

NPDWRs, Proposed Rule: FR 54, n. 97, May 22, 1989. (Phase II inorganics, VOCs, SOCs.)

Drinking Water; NPDWRs; Filtration, Disinfection; Turbidity, Giardia lamblia, Viruses, Legionella, and Heterotrophic Bacteria; Final Rule: FR 54, n. 124, June 29, 1989.

Drinking Water; NPDWRs; Total Coliforms (Including Fecal Coliforms and E. coli); Final Rule: FR 54, n. 124, June 29, 1989.

NPDWRs; Synthetic Organic Chemicals and Inorganic Chemicals; Proposed Rules: FR 55, n. 143, July 25, 1990. (Phase V chemicals.)

Priority List of Substances Which May Require Regulation Under the Safe Drinking Water Act; Notice: FR 56, n. 9, January 14, 1991.

NPDWRs, Final Rule: FR 56, n. 20, January 30, 1991. (Phase II inorganics, VOCs, SOCs.)

NPDWRs, Proposed Rule: FR 56, n. 20, January 30, 1991. (Aldicarb, Aldicarb Sulfoxide, Aldicarb Sulfone, Pentachlorophenol, Barium.)

MCLGs and NPDWRs for Lead and Copper; Final Rule: FR 56, n. 110, June 7, 1991.

NPDWRs; Final Rule: FR 56, n. 126, July 1, 1991. (Aldicarb, Aldicarb Sulfoxide, Aldicarb Sulfone, Pentachlorophenol, Barium.)

NPDWRs; Radionuclides; Proposed Rule: FR 56, n. 138, July 18, 1991.

NPDWRs; Synthetic Organic Chemicals and Inorganic Chemicals; Final Rule: FR 57, n. 138, July 17, 1992. (Phase V chemicals.)

NPDWRs; Disinfectants and Disinfection Byproducts; Proposed Rule: FR 59, n. 145, July 29, 1994.

NPDWRs; Enhanced Surface Water Treatment Requirements; Proposed Rule, FR 59, n. 145, July 29, 1994.

Drinking Water Standards

Primary Maximum Contaminant Levels (MCLs) and Lead and Copper Action Levels

Last Update: February 11, 2000

Primary MCLs
Lead and Copper

Primary maximum contaminant levels (MCLs) are established by the Department of Health Services (DHS) for a number of chemical and radioactive contaminants. Primary MCLs can be found in Title 22 California Code of Regulations (CCR) for

inorganic chemicals
(§64431),
trihalomethanes
(§64439),
radioactivity
(§64441 and §64443) and
organic chemicals
(§64444). (See DHS' compilation of drinking water statutes and regulations)

PRIMARY MAXIMUM CONTAMINANT LEVELS	
All values are in milligrams per liter (mg/L), unless otherwise noted	
Contaminant	**Primary MCL**
22 CCR §64431, Table 64431-A— Inorganic Chemicals	
Aluminum (Aluminum also as a secondary MCL of 0.2 mg/L)	1
Antimony	0.006
Arsenic	0.05
Asbestos (MFL = million fibers per liter, MCL is for fibers exceeding 10 microns in length)	7 MFL
Barium	1
Beryllium	0.004
Cadmium	0.005
Chromium	0.05
Cyanide	0.2
Fluoride	2
Mercury	0.002
Nickel	0.1
Nitrate (as NO_3)	45
Nitrate + Nitrite (sum as nitrogen)	10

PRIMARY MAXIMUM CONTAMINANT LEVELS	
All values are in milligrams per liter (mg/L), unless otherwise noted	
Contaminant	**Primary MCL**
Nitrite (as nitrogen)	1
Selenium	0.05
Thallium	0.002
22 CCR §64433.2, Table 64433.2-A, Optimal Fluoride Levels See also the Fluoride MCL, 22 CCR §64431, Table 64431-A	
Annual average of maximum daily air temperature (degrees Fahrenheit, °F)	**Optimal Level (Range)**
50.0 to 53.7 °F	1.2 (1.1-1.7)
53.8 to 58.3 °F	1.1 (1.0-1.6)
58.4 to 63.8 °F	1.0 (0.9-1.5)
63.9 to 70.6 °F	0.9 (0.8-1.4)
70.7 to 79.2 °F	0.8 (0.7-1.3)
79.3 to 90.5 °F	0.7 (0.6-1.2)
22 CCR §64441 and §64443— Radioactivity	
Gross alpha particle activity (including radium-226 but excluding radon and uranium)	15 picocuries per liter (pCi/L)
Gross beta particle activity	50 pCi/L

PRIMARY MAXIMUM CONTAMINANT LEVELS	
All values are in milligrams per liter (mg/L), unless otherwise noted	
Contaminant	**Primary MCL**
Combined Radium-226 and Radium-228	5 pCi/L
Strontium-90	8 pCi/L
Tritium	20,000 pCi/L
Uranium	20 pCi/L
22 CCR §64439— Total Trihalomethanes	
Sum of bromodichloromethane, dibromochloromethane, bromoform, and chloroform	0.1
22 CCR §64444— Organic Chemicals	
(a) Volatile Organic Chemicals (VOCs)	
Benzene	0.001
Carbon tetrachloride	0.0005
1,2-Dichlorobenzene (o-Dichlorobenzene)	0.6
1,4-Dichlorobenzene (p-DCB)	0.005
1,1-Dichloroethane (1,1-DCA)	0.005
1,2-Dichloroethane (1,2-DCA)	0.0005
1,1-Dichloroethylene (1,1-DCE)	0.006

PRIMARY MAXIMUM CONTAMINANT LEVELS	
All values are in milligrams per liter (mg/L), unless otherwise noted	
Contaminant	**Primary MCL**
cis-1,2-Dichloroethylene	0.006
trans-1,2-Dichloroethylene	0.01
Dichloromethane (Methylene chloride)	0.005
1,2-Dichloropropane (Propylene dichloride)	0.005
1,3-Dichloropropene	0.0005
Ethylbenzene (Phenylethane)	0.7
Monochlorobenzene (Chlorobenzene)	0.07
Methyl tert-Butyl Ether (MTBE) (MTBE also has a secondary MCL of 0.005 mg/L and an action level of 0.013 mg/L)	0.013 (proposed)
Styrene (Vinylbenzene)	0.1
1,1,2,2-Tetrachloroethane	0.001
Tetrachloroethylene (PCE)	0.005
Toluene (Methylbenzene)	0.15
1,2,4-Trichlorobenzene (Unsym-Trichlorobenzene)	0.07
1,1,1-Trichloroethane (1,1,1-TCA)	0.2
1,1,2-Trichloroethane (1,1,2-TCA)	0.005

PRIMARY MAXIMUM CONTAMINANT LEVELS	
All values are in milligrams per liter (mg/L), unless otherwise noted	
Contaminant	**Primary MCL**
Trichloroethylene (TCE)	0.005
Trichlorofluoromethane (Freon 11)	0.15
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	1.2
Vinyl chloride	0.0005
Xylenes (single isomer or sum of isomers)	1.75
(b) Non-Volatile Synthetic Organic Chemicals (SOCs)	
Alachlor (Alanex)	0.002
Atrazine (Aatrex)	0.003
Bentazon (Basagran)	0.018
Benzo(a)pyrene	0.0002
Carbofuran (Furadan)	0.018
Chlordane	0.0001
2,4-D	0.07
Dalapon	0.2
1,2-Dibromo-3-chloropropane (DBCP)	0.0002
Di(2-ethylhexyl)adipate	0.4

PRIMARY MAXIMUM CONTAMINANT LEVELS	
All values are in milligrams per liter (mg/L), unless otherwise noted	
Contaminant	**Primary MCL**
Di(2-ethylhexyl)phthalate (DEHP)	0.004
Dinoseb	0.007
Diquat	0.02
Endrin	0.002
Endothal	0.1
Ethylene dibromide (EDB)	0.00005
Glyphosate	0.7
Heptachlor	0.00001
Heptachlor epoxide	0.00001
Hexachlorobenzene	0.001
Hexachlorocyclopentadiene	0.05
Lindane (gamma-BHC)	0.0002
Methoxychlor	0.04
Molinate (Ordam)	0.02
Oxamyl	0.2

PRIMARY MAXIMUM CONTAMINANT LEVELS	
All values are in milligrams per liter (mg/L), unless otherwise noted	
Contaminant	**Primary MCL**
Pentachlorophenol	0.001
Picloram	0.5
Polychlorinated biphenyls (PCBs)	0.0005
Simazine (Princep)	0.004
2,4,5-TP (Silvex)	0.05
2,3,7,8-TCDD (Dioxin)	0.00000003
Thiobencarb (Bolero) (Thiobencarb also has a secondary MCL of 0.001 mg/L)	0.07
Toxaphene	0.003

Lead and copper
have specific regulations in 22 CCR, Chapter 17.5 §64670, *et seq*. The lead and copper regulations use the term "action level" for each substance, for purposes of regulatory compliance. These action levels should not be confused with DHS'

advisory action levels for unregulated chemical contaminants

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Action levels for copper and lead, which are to be met at customer tap, are used to determine the treatment requirements that a water system is required to complete. The action level for copper is exceeded if the concentration of copper in more than 10 percent of tap water samples collected during any monitoring period conducted in accordance with 22 CCR §64682-§64685 is greater than 1.3 mg/L. Similarly, the action level for lead is exceeded if the concentration of lead in more than 10 percent of tap water samples collected in accordance with 22 CCR §64682-§64685 is greater than 0.015 mg/L. Failure to comply with the applicable requirements for lead and copper (22 CCR Chapter 17.5) is a violation of primary drinking water standards for these substances.

California Department of Health Services

PRIMARY MAXIMUM CONTAMINANT LEVELS	
All values are in milligrams per liter (mg/L), unless otherwise noted	
Contaminant	**Primary MCL**
LEAD AND COPPER ACTION LEVELS (22 CCR §64672.3)	
Chemical	**Action Level (mg/L)**
Copper	1.3
Lead	0.015

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HOME

APPENDIX E

APPENDIX E
DATA MANAGEMENT PLAN

1.0 MANAGEMENT

During the Project, a large amount of data will be generated. The purpose of this data management plan is to establish guidance for data filing, storage, and security during the Project and after Project completion. Data will be filed and stored in both a Project file and in a computer database.

2.0 PROJECT FILES

Project files that store all technical project documents will be established. Technical documents include, but are not limited to, the following:

- All correspondence to/from regulatory agencies,
- Memoranda containing technical information or documentation of technical decisions,
- Reports,
- Field data sheets,
- Field logs/daily reports,
- Laboratory reports,
- Computer files of technical data,

- Minutes of meetings with regulatory agencies,
- Permits,
- Legal documents,
- Press clippings,
- Fact sheets,
- Photographs,
- Calculations,
- Quality assurance/quality control (QA/QC) reports.

Information regarding each document will be entered into a computer database and the document filed in the Technical Project File.

2.1 Storage and Security

Active Project files will be maintained at a place to be designated by Metropolitan while the Project is ongoing. Technical Project records will be stored and secured in locking file cabinets. Prior to storage, records will be assigned a sequential number and entered into the project reference database. The database will include the following items of information for each document to assist in retrieval:

- Document number,
- Date document was generated or received,
- Type of document,
- Author and corporation,
- Addressee,
- Subject (description of document contents),
- Source of document, and
- Project/Task No. (and associated task description).

2.2 File Access

Once placed in the Technical Project File, records will be checked out by placing a checkout card in the file in place of the project record. Access will be limited to Metropolitan's technical experts, Metropolitan personnel and/or their legal representative, Cadiz, Inc. personnel, and agency representatives. Personnel who are not directly involved with the project may obtain access to project files only after receiving approval from the Project Manager or a designated project representative.

2.3 File Closure

At the close of the Project, files will be closed and transferred to Metropolitan.

3.0 PROJECT DATABASE

Data also will be stored, organized, and secured in a computer database created specifically for the project. The database will store data in an efficient and usable manner.

Types of data to be sorted in the computer database may include, but are not limited to, technical information such as results of groundwater analytical records, well construction details, and water levels. Project tracking records, such as schedules and records management data, also will be most effectively organized using a computer database and related programs. Storage and organization of project tracking records will follow guidelines outlined in this section.

Technical and database programs used during the Project will be those designed to run on IBM-compatible computers. If programs designed for other operating systems are used, the data files will be transferable to an IBM-compatible format.

Access, Paradox or other equivalent relational database software will be used for general database applications. Specific technical programs used for data analysis will be selected based on the specific technical question to be answered.

3.1 Database Construction

The database construction process will consist of three phases: design, implementation, and testing. The database will be designed to meet the output requirements of the dataset and will be structured to avoid redundant input of information by separating data into separate files when possible. Data items will be coded when possible and standard naming conventions for similar data items will be used.

Databases will be implemented using software that is best suited for storage and manipulation of the data to meet the output requirements. Once the physical construction of the database has been completed, a sample set of data will be input and thorough testing will be performed to ensure that the required output can be achieved.

3.2 Maintenance

Databases created for a specific task will be maintained by the Database Manager. This individual will be responsible for the creation, implementation, testing, documentation, and security of the database. The Database Manager will ensure that data entered into the database is complete and correct.

The Database Manager also will coordinate the many individual databases created for the investigation so that the database design is appropriate and the data are represented in a consistent manner according to standard formats. The Database Manager will provide a central storage location for data files and documentation.

3.3 Documentation

Documentation will be prepared regarding the database files and file structure, QC of data entry, and analysis and manipulation of the data. The objective of documentation is to provide enough information for individuals unfamiliar with the data to work efficiently within the database. It also will provide a clear work history to simplify data reconstruction, if necessary. Documentation records will be submitted to the Database Manager for permanent storage when the database is complete.

File documentation will include a complete description of database fields and types. Codes will be listed with an explanation of the data they summarize. The relationship between files will also be included. A list of files using the described structures and including the date of creation, number of records, and sources of data will be provided as a part of the file documentation.

Data entered manually (typed in) will be printed out and compared to the source document. The printout will be initialed and dated when the QC review is performed and when corrections are made to the data file. If data are imported from other sources, randomly chosen records will be compared to the source file. If discrepancies occur, the entire importing process will be reviewed, corrected, and re-executed. If no discrepancies occur, a document will be submitted listing the date of the comparison, which file was checked, and the individual who performed the QC review.

3.4 Security

Proper back-up and security measures will be taken to prevent accidental loss of data and tampering with the database. Exact duplicates of working files will be made at least once each work session. The backup files will be stored in a separate physical location from the working files. Both the backup and working files will be kept in a locked storage area.

If the software program used offers data protection through passwords, passwords will be used for working and backup files. The password protection will be removed when files are submitted for permanent storage.