Janet Napolitano
Governor

ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

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Stephen A. Owens
Director

CERTIFIED MAIL
Return Receipt Requested

March 12, 2008

Attention: Mike Jaworski, Site Manager
Freeport McMoran Gold & Copper Inc.
Copper Queen Branch
36 W Highway 92
Bisbee, Arizona 85603.

Re: Mitigation Order on Consent, Docket No: P-121-07- Work Plan

Dear Mr. Jaworski:

The Arizona Department of Environmental Quality (ADEQ) has completed its review of the December 17, 2007 Work Plan submitted by Freeport McMoran Gold & Copper Inc., Copper Queen Branch (Freeport), and recommends the comments itemized below be addressed via an Amended Work Plan. As such the Work Plan is not yet approved.

Further, the Community Action Group (CAG) requested an opportunity to comment on the Work Plan prior to ADEQ issuing its review, however, in the interest of expediting the plan's implementation, ADEQ decided to present its comments. Nevertheless, in the interim, ADEQ reserves the right to provide additional comments if the CAG's review proves to be pertinent and/or substantially different to ADEQ's.

Please call me at 602-771-4614 if you have any questions.

Sincerely,

R. Casey

Robert Casey, Manager
Water Quality Enforcement Unit

cc: Stuart M. Brown, President
Bridgewater Group, Inc.
4500 SW Kruse Way Suite 110
Lake Oswego, or 97035

Ray Lazuk, Freeport McMoran Gold & Copper Inc.

Joan Card , Director, WQD, ADEQ
Cindy Campbell, Manager, WQCS, ADEQ
Henry Darwin, Administrative Counsel, ADEQ
David Haag, Senior Hydrologist, Groundwater Section, ADEQ
Michele Robertson, Manager, Groundwater Section, ADEQ

General Comments

The Work Plan summarizes the existing historical operations of the Concentrator Tailings Storage Area (CTSA), geologic setting, groundwater hydrology, water quality, and presents a preliminary conceptual site model (CSM) for the groundwater sulfate plume. The Work Plan also presents Freeport's aquifer characterization plan (ACP), potential interim actions (IAs), Feasibility Study (FS) plan, and a schedule which discusses the time-frame for the work to be conducted and reported. The Quality Assurance Project Plan (QAPP) is included in an appendix.

1. Freeport should add language to the Work Plan stating that upon assessment of gathered data, if it is deemed necessary to perform a task at variance with the Work Plan, Freeport will seek ADEQ's approval in writing prior to performing the task.

2. Freeport should include in the Work Plan a description of how and where monitoring well installation, groundwater sampling, and aquifer testing will be performed.

3. Freeport should submit electronically to ADEQ, all groundwater data collected, for inclusion into the ADEQ Water Quality Database using *Groundwater Data Submittal Guidance Document, version 3.3, dated March 2005*. This document is downloadable from ADEQ's web site using the following links:
   http://www.azdeq.gov/environ/waste/sps/download/version33.pdf; and,
   http://www.azdeq.gov/environ/waste/sps/download/tables33.pdf

4. Freeport should include in the Work Plan a Field Sampling Plan for the work to be conducted.

5. Freeport should discuss the co-mingled total dissolved solids (TDS) plume and how it may relate to the sulfate plume, and the potential of TDS to impact any mitigation action.

6. Freeport should reconstruct the groundwater elevation contour maps. The contour maps provided in the Work Plan were constructed using data from different sampling events which is not acceptable practice. The geologic cross-sections should also be reconstructed using wells that currently exist and sampled, and the sulfate and other contaminant data should be plotted and contoured.

7. During groundwater sampling, for at least the first couple of rounds, groundwater should be sampled for the following parameters: total and dissolved metals, sulfate, TDS, general chemistry, pH, and VOCs.

8. Freeport should revisit and revise the conceptual site model (CSM) for the site. Included in the CSM should be a discussion of potential receptors, a block diagram that shows

source, receptors, geology and hydrogeology, and potential data gaps. Based upon groundwater elevation data, there appears to be a downward vertical gradient, therefore,

the CSM should include a discussion that the sulfate plume may no longer be at the top of the Basin Fill aquifer.

9. Freeport should state in the well inventory discussion that additional methods in addition to using ADWR and ADEQ records will be used to identify wells within a mile of the sulfate plume.

10. Regional groundwater sampling of twice may not provide adequate information for input into a numeric groundwater flow and transport model. Additionally, groundwater elevation data should be collected monthly. Freeport should include language stating that depending on results of monitoring well installation, additional monitoring wells may be installed to meet the objectives of the Mitigation Order, full horizontal and vertical characterization of sulfate plume in the aquifer

11. It is not adequate to conduct only a step-drawdown aquifer test to obtain hydraulic conductivity. Step-drawdown tests are conducted to determine sustainable pumping rates from a well. Once the sustainable pumping rate is determined, a constant-discharge aquifer test to determine aquifer parameters typically follows.

12. For potential interim actions, Freeport should state that samples will be collected from, at a minimum, both the well head and point of entry (POE) into the drinking water system. If a modification to the drinking water system is necessary, it may be necessary to obtain approvals to construct and of construction from ADEQ.

13. Freeport should note that the Bisbee-Naco aquifer is classified as a drinking water aquifer and has been designated a sole-source aquifer by the U.S. EPA.

14 Freeport should modify the Quality Assurance Project Plan (QAPP) to address the following:

- State which laboratory and drilling company will be conducting the work;
- Indicate that all water levels will be collected within 72 hours;
- For the first two rounds, groundwater will be sampled for total and dissolved metals, sulfate, TDS, general chemistry, pH, and VOCs;
- Equipment blanks would be collected for any reusable sampling equipment;
- Discuss how depth specific groundwater samples will be collected;
- Provide the construction details of the proposed groundwater monitoring wells;
- State that step-drawdown testing will be conducted to determine sustainable pumping rates and then constant-discharge aquifer tests conducted to determine aquifer

parameters. It may be necessary to install piezometers to evaluate the aquifer using distance-drawdown equations.

SPECIFIC COMMENTS

1. Section 2.1.1 Description of the CTSA

The last sentence of the second paragraph states "collected stormwater is periodically pumped from the Horseshoe Pond to the South Tailing Impoundment." Freeport should state whether the North and South Tailing Impoundments are capped to prevent infiltration of the CTSA, and whether the impoundments are lined to prevent discharge to the vadose zone and aquifer.

2. Section 2.1.4 Location of the Sulfate Plume

a. This section provides an estimation of the current extent of the sulfate plume based upon limited 2005 groundwater sampling and inferences from the 1996 groundwater sampling. It estimates the sulfate plume as being "approximately 3.5 miles long in a southwesterly direction and 2.5 miles wide, with its northern boundary located at the southern margin of the South Tailing Impoundment and its southern edge south of Naco Water Company (NWC) well 3 (NWC-3) (Figure 4)." Based upon data presented in Figure 4 "Sulfate Plume, 2005 Approximate Boundary of 250 mg/L Sulfate Concentration, Bisbee, Arizona," Attachment #1, ADEQ believes that the sulfate plume is probably slightly longer than depicted. Well NWC-3 had a sulfate concentration of 390 mg/L, while the work plan shows the 250 mg/L contour as being right next to the well. The contour should be at some distance beyond well NWC-3. See Attachment #1 for ADEQ's reconfiguration of the maximum extent of sulfate contamination. This is based upon the limited data collected and reviewing data presented in Figure 14, "Sulfate Concentration Map – July 1989," and Figure 15, "Sulfate Concentration Map – Summer 1996," Attachments #2 and #3, respectively.

b. The third and fourth bullets on Page 11should provide the full explanation of the statute as provided in Arizona Revised Statute (A.R.S.) §49-286.
   a. Economically and technically practicable treatment before ingesting the water.
   b. Such other mutually agreeable mitigation measures as are necessary to achieve the purposes of this section.

c. Freeport should present information on other potential contaminants that may affect the mitigation. For example, in the reference *"Ground-water Resources of the Bisbee-Naco Area, Cochise County, Arizona"* by G.R. Littin, dated June 1987, and Table 4, "Analytical Results for 1996 Groundwater Samples Used for Trilinear Diagrams," indicate that high concentrations of TDS are co-located with the sulfate contamination.

The maximum concentration of TDS in 1996 was 3,800 mg/L. The secondary standard for TDS is 500 mg/L.

3. Section 2.2 Current Sulfate Mitigation Actions

Freeport should state which drinking water well was replaced due to sulfate contamination, and should provide a list of domestic wells that have been impacted by the sulfate contamination.

4. Section 2.3 Geologic Setting

The second to last sentence in this section states "Figures 6 and 7 are geologic cross sections based on borings in the CTSA," however, ADEQ notes that the wells that create the cross-sections, for the most part, have not been sampled. Freeport should construct additional cross-sections that utilize wells containing sulfate data. Also, the lithologic logs for all of the borings and wells completed within, and if available, wells completed outside of the sulfate plume, should be included as an appendix in the work plan.

5. Section 2.3.3.1 Cretaceous Sedimentary Rocks

Freeport should describe the depositional environment associated with the Morita Formation, and should also describe the lateral continuity of the fine-grained interbeds.

6. Section 2.4.1.2 Bedrock Complex

The first sentence states "The bedrock complex generally has low permeability unless the permeability is enhanced by faulting and fracturing or dissolution." ADEQ notes that there can be fracturing that is not associated with faulting which can also be dependent on the type of sedimentary rock. ADEQ recommends this sentence be rephrased as follow; "The bedrock complex generally has low *intrinsic* permeability unless *secondary* permeability *has been* enhanced by faulting, fracturing, and/or dissolution *in the case of limestone*."

7. Section 2.4.2 Hydraulic Properties

Freeport should provide a brief discussion on how previous aquifer tests were conducted, and should provide a figure which shows the results of aquifer tests at each well an aquifer test was conducted.

8. Section 2.4.3 Potentiometric Relationships

a. Freeport should provide a discussion as to why water level contours cross the Black Gap Fault south of the tailings impoundments. Does the Black Gap Fault cease acting as a barrier south of the tailings impoundments?

b. Freeport should include groundwater hydrographs from all wells at which groundwater elevations over time have been determined.

c. The fourth paragraph in this section states that to construct the 1989 water level map, 1988 and 1990 data from Naco Water Company (NWC) and American Water Company (AWC) wells were used. Freeport should provide information on whether the domestic well, if water levels were collected, and NWC and AWC wells were pumping prior and/or were pumping during the time water levels were being collected. It is not acceptable practice for the construction of groundwater elevation contour maps to use data collected during other sampling events. That data should be removed from the 1989 water level contour map and the maps re-contoured.

d. Freeport should provide a more detailed discussion on the connectivity between the Glance Conglomerate, Morita Formation and the Basin Fill in the area south of the Abrigo Fault and east of the Black Gap Fault.

9. Section 2.4.4 Groundwater Flow

a. The last sentence of the first paragraph on Page 28 in this section states, "The hydraulic conductivity from the calibrated model of 23 ft/day for silty sand was used to estimate flow velocity because it is the material type used in modeling flow between these wells." Freeport should provide an explanation for this statement. Based upon lithologic description of the Basin Fill provided in Section 2.3.2 Basin Fill Deposits and the estimates of hydraulic conductivity for Basin Fill provided in Section 2.4.2 Hydraulic Properties, the estimate of hydraulic conductivity appears to be low. Freeport should provide an appendix which provides input parameters and equations used to calculate groundwater velocity.

b. The first sentence in the last paragraph of this section states, "In summary, pore velocities based on the ELMA (SRK, 1997) hydraulic conductivity estimates are greater than those based on the SET (1998c) model estimates by a factor of approximately three in the Morita Formation and a factor of two in the basin fill." Freeport should explain this discrepancy, and describe how the company plans to determine groundwater velocity in the area.

10. Section 2.4.5 Recharge Sources

The last sentence in the second paragraph references the wrong figure. The work plan should reference Figure 2 Facilities in the Vicinity of the Concentrator Tailing Storage Area, Bisbee Naco Area, Arizona, 2007.

11. Section 2.5 Water Quality

a. The last paragraph on Page 32 states that five organic compounds have been detected in the past in approximately 1989. Freeport should list the organic compounds that were detected and their concentration; even though the work plan states that the detections were the result of analytical error.

b. Freeport states in the third and fourth sentences in the first full paragraph on Page 34 "However, decreasing concentrations at NWC-4, located approximately 2500 feet south (and down gradient) of TM-16, indicate that the sulfate plume has contracted slightly. NWC-4 was within the plume with a concentration of 255 mg/L in August 1996, and is now outside the plume with October and November 2005 concentrations of 220 mg/L and 200 mg/L, respectively." Freeport should state whether NWC-4 continued serving water during that time period and if so, state whether the pumping rates remain consistent.

12. Section 2.5.1.1 Areal Distribution

The last sentence in this section states, "The post-1989 drop in sulfate concentrations in TM-2 probably reflects a lack of further sulfate source loading when mine water discharge to the evaporation pond stopped in 1987." Freeport should also add that the sulfate concentrations in TM-2 have also probably migrated down-gradient since 1987 since the next closest down-gradient well appears to be approximately 1.5 miles.

13. Section 2.5.1.2 Vertical Distribution

The first three sentences in the second paragraph state, "Sulfate is vertically stratified within the basin fill at the location of GW-47. Depth-specific sampling during drilling indicated that sulfate concentrations in the basin fill decreased from 632 mg/L to 25.8 mg/L between the depths of 280 feet and 345 feet below land surface (Wright, 2001). These data indicate that the sulfate plume is localized in the upper portion of the total 360-foot thickness of the basin fill." In the description of this data, Freeport should provide the depth to water where sampling began, the total depth of the Basin Fill at this location, i.e., feet below land surface (ft bgs), and should provide the results of the depth specific sampling as an appendix.

14. Section 2.5.2 Major Element Chemistry

Freeport should discuss in detail the relationship between sulfate contamination and high TDS concentrations, which is above the secondary standard of 500 mg/L.

15. Section 2.5.3 Metals

The first table on Page 39 indicates that antimony, mercury, and thallium have met or exceeded the aquifer water quality standards (AWQS), based upon highest detected concentrations. The highest antimony concentration was 0.06 mg/L in monitoring well BF-2, located within the sulfate plume. The AWQS for antimony is 0.006 mg/L. The highest mercury concentration was 0.00245 mg/L in monitoring well MW-2, located within the sulfate plume. The AWQS for mercury is 0.002 mg/L. The highest thallium concentration was 0.002 mg/L in monitoring well TM-16, located within the sulfate plume. The AWQS for thallium is 0.002 mg/L. The last two sentences in the last paragraph on Page 39 states "However, at BF-2, antimony was not detected in more than half the samples; at TM-02, mercury was detected only once; and at TM-16, thallium was detected only once. The low detection frequencies of antimony, mercury, and thallium, and lack of consistent detection indicate these constituents are not of concern in the area." Freeport should provide a discussion of the sampling frequency of metals, the detection and reporting limits for metals, and state when was the last time these analytes were detected above the AWQS prior to determining that these constituents are not of concern.

16. Section 2.6 Preliminary Conceptual Model for the Groundwater Sulfate Plume

a. Freeport should use the following guidance in constructing a conceptual site model (CSM):

   a. ASTM E1689-95 *Guide for Developing Conceptual Site Models for Contaminated Sites* (See Attachment #4); and,
   b. Interim Final *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, EPA/540/G-89/004, October 1988.

While this site is not a CERCLA site, these two pieces of guidance provide a good road map on constructing a CSM that can be used to create a successful numeric groundwater flow and fate and transport model and evaluate potential receptors. Additionally, the work plan should provide a relative block diagram that simply portrays the CSM.

b. The CSM should contain a discussion of potential receptors.

c. Freeport should include in the CSM a discussion and table that describes the efforts that have been made to identify all domestic/drinking water wells that are currently within the sulfate plume.

d. Freeport should include in the CSM an evaluation of currently existing monitoring wells and provide a discussion about the potential differences in groundwater flow characteristics between the Basin Fill aquifer, which is a porous media and groundwater flow characteristics in the Morita Formation, which is indurated and may have flow characteristics that are more similar to fracture flow. Based upon this evaluation, Freeport should discuss the usefulness of wells that are screened across formation boundaries and state whether they can still be of use or whether they should be replaced by co-located wells that are screened only in each formation.

e. Included in the CSM should be a discussion of potential data gaps.

f. The last two sentences from the first incomplete paragraph on Page 42 states, "Slightly upward hydraulic gradients over much of the area of the plume were present in the site numerical model prepared by SET, (1998c). However, sustained upward hydraulic gradients have not been detected based on water level measurements in paired monitoring wells (Figure 12)." ADEQ does not agree with these statements. In fact, based upon data presented in Figure 11, "Water Level Map, September 2005," in the following nested wells, TM-2 and TM-2A, screened in the Basin Fill and Glance Conglomerate, respectively; and wells 588577 and GW-47, screened in the Basin Fill and Morita Formation, the vertical gradient is, in 2005, downward. The depth specific sampling conducted during the drilling of GW-47 in 2001, may no longer apply in terms of sulfate being confined to the top of the Basin Fill aquifer and may be present deeper in the Basin Fill aquifer.

17. Section 3.2 <u>Task 1 – Well Inventory of Drinking Water Supply Wells</u>

The first sentence in the second paragraph states, "The well inventory will be based on the ADWR Well Registry Database, which contains records of all registered wells in Arizona." This may not be sufficient. Wells in rural Arizona have not all been registered for a variety of reasons. Freeport should describe additional steps it will take to conduct a comprehensive well survey, including interfacing with the local drillers, county sanitary engineers, and the U.S. Geological Survey (USGS).

18. Section 3.3 <u>Task 2 – Plume Characterization</u>

At the top of Page 49, there are 5 bullets that describe the data quality objectives (DQOs) from the QAPP. The second bullet states, "Characterize the materials, structure, and permeability of water-bearing units in the CTSA through geologic analysis of cuttings from drill holes and aquifer testing to support groundwater modeling of plume migration." The determination of the location and extent of faulting may not be possible with drilling. Due to the importance of faulting on the groundwater system, ADEQ suggests that the use of surface geophysics may provide additional information for use in the CSM and numeric groundwater flow model.

19. Section 3.3.2 Task 2.2 – Groundwater Monitoring

a. This section states that water levels and groundwater sampling will take place from private and public supply wells. As part of the information collected in Task 2.1, Freeport should obtain the following well information: well construction details, pumping details, and whether Freeport would be willing to install a sounding tube to monitor depth to water in domestic wells.

b. The last full paragraph on page 51states, "Regional monitoring will be conducted twice, once in winter and once in summer, to characterize any seasonality in water elevations." This may not be sufficient if the information is to be used to input into a numeric groundwater flow model. ADEQ suggests that Freeport collect water levels data from these regional wells monthly.

c. The third sentence in the only full paragraph on Page 52 states that groundwater will only be analyzed for sulfate. ADEQ recommends that for at least the first two sampling rounds, groundwater from near and in the plume should be analyzed for total and dissolved metals, sulfate, TDS, general chemistry parameters and pH. In addition, since VOCs have been detected from groundwater samples in the past, VOC groundwater samples should also be collected.

20. Section 3.3.3 Task 2.3 – New Monitoring Well Installation and Testing

a. This section includes language stating that some of the proposed twelve monitor well locations may not be installed if other "suitable" wells are found near the proposed locations. Freeport should also state that additional monitoring wells may be installed in addition to the proposed wells if information is obtained that indicates that additional wells are needed, and include a discussion on the maximum depth of the proposed monitoring wells and construction details.

b. This section on Page 56 states that after well development, a short-duration (10-24 hour), "step rate pumping test" would be conducted in all newly installed monitoring wells. Freeport should describe in detail how the step-test would be conducted. Typically, a step-test is useful in determining sustainable pumping rates within a well. The tests can be up to 8-hours in length. However, to obtain defendable and more scientific data, a constant-discharge and recovery test should be conducted. The constant-discharge aquifer test is designed to stress the aquifer and therefore, obtain realistic hydraulic values. Without additional information, ADEQ is not convinced that the information obtained from the proposed procedure would provide useful data.

21. Section 3.3.4 Task 2.4 Additional Hydraulic Testing

Freeport should describe in detail how aquifer testing would be conducted on existing monitoring, domestic, and public supply wells.

22. Section 3.4 Task 3 – Sulfate Fate and Transport Evaluation

Freeport should provide information regarding which parts of the previous specific groundwater numeric and fate and transport model(s) it plans to use to conduct the proposed modeling effort, and provide a discussion on whether the use of previous modeling is appropriate. Freeport should describe the modeling grid size, the number of layers that may be used, the type of boundary conditions, etc., model calibration and the sensitivity analysis.

23. Section 4 Potential Interim Actions

The second sentence states, "The sulfate concentrations will be determined based on discrete samples collected at the point of use or the point of entry (POE) to the supply system unless there is downstream blending." Freeport should state that if there is downstream blending, samples for sulfate determination will be collected at a location up gradient of the blending location or at the well head of the specific well in question. ADEQ recommends that samples should be collected at the well head to characterize the aquifer at that location, and at the (POE). It should be noted on Page 64 that changes to a water system infrastructure may require Freeport obtaining approvals to and of construction from ADEQ.

24. Section 5.1 Identification and Screening of Mitigation Actions and Technologies

Freeport states on Page 69 "Additional mitigation actions to be considered include monitoring of groundwater and drinking water, institutional controls, such as restrictions on well drilling, natural attenuation, and if needed, alternatives that could reduce sulfate loading to groundwater from the CTSA." Since the Bisbee-Naco aquifer has been classified as a sole-source aquifer by the EPA and is classified by the State of Arizona as a drinking water aquifer, any attempt to restrict well drilling may be resisted.

25. Figure 21 Proposed Well Locations for Groundwater Monitoring (Task 2.2)

Freeport should either include the proposed monitoring wells that are to be installed, or the title should change to state that this figure shows the proposed groundwater monitoring for currently installed wells. An additional figure should then be added that shows all wells, new and old, that are to be sampled during this effort.

Appendix F – Quality Assurance Project Plan Comments

1. Section 2.8 Laboratory QA Manager

   Freeport should provide in Appendix F the name of the laboratory that will be used for the project.

2. Section 2.9 Drilling Subcontractors

   Freeport should provide the name of the drilling subcontractor(s) that will be used for the project.

3. Section 3.1 Data Quality Objectives

   The first bullet should be modified based upon comments provided above to the work plan.

4. Section 4.2 Groundwater Sampling Activities

   Freeport should add a sub-section that discusses decontamination procedures for the portable submersible pump and other re-useable equipment.

5. Section 4.2.1.1 Depth to Water Measurements

   Freeport should state that all water levels that will be used to construct groundwater elevation contour maps will be collected within 72 hours from the first well to the last well measured.

6. Section 4.2.1.3 Groundwater Sample Collection

a. Freeport should include a discussion and appropriate changes to other portions of the QAPP when discussing the sampling of total and dissolved metals, sulfate, TDS, general chemistry parameters, pH, and VOCs for the first couple of rounds as described in Comment No. 19 c above.

b. Page F-22 of the QAPP states that all groundwater samples will be filtered using a 0.45 micron filter. While determination of dissolved constituents is important to contaminant transport, it is equally import to sample for total constituents unless the water suppliers filter the water prior to delivering it for human consumption. This information may be necessary for the Feasibility Study to evaluate treatment technologies. Therefore, the QAPP should be modified to include collecting samples for total constituents.

7. Section 4.2.1.5 Field Quality Control Samples

Freeport should state that equipment blanks will be collected, at least once per day, in addition to the field duplicate and field blank samples. Additionally, Freeport should state that field duplicate and field blank samples will be collected once every 20 samples or once a day, whichever is more.

8. Section 4.2.1.6 Equipment Decontamination

Freeport should describe in detail how the equipment will be decontaminated.

9. Section 4.3.4 Reconnaissance Groundwater Sampling from Boreholes

Freeport should discuss how groundwater grab samples will be collected at 40 foot intervals from when the first water is encountered. Freeport states the samples would be collected from the air rotary return, which is an inappropriate sampling technique as the precise location where the water originated is unknown and cross-contamination may occur. Freeport should state that for the QAPP and future FSP, grab samples will be collected by appropriate methods, i.e., HydroPunch® or other sampling technology.

10. Section 4.3.5 Well Construction

Freeport states that the well materials will be decided during drilling, but should have an idea regarding the screen size and gravel pack since the company already has monitoring wells in the area. Freeport should provide a description of the most likely well construction information, and state that all sand, bentonite seal, and cement grout seal be placed in the well with the use of a tremie pipe.

11. Section 4.3.6 Well Completion

Freeport should state that the well registry number and other pertinent information will be placed per ADWR rules and guidance, rather than using a permanent black maker on the concrete.

12. Section 4.3.7 Well Development

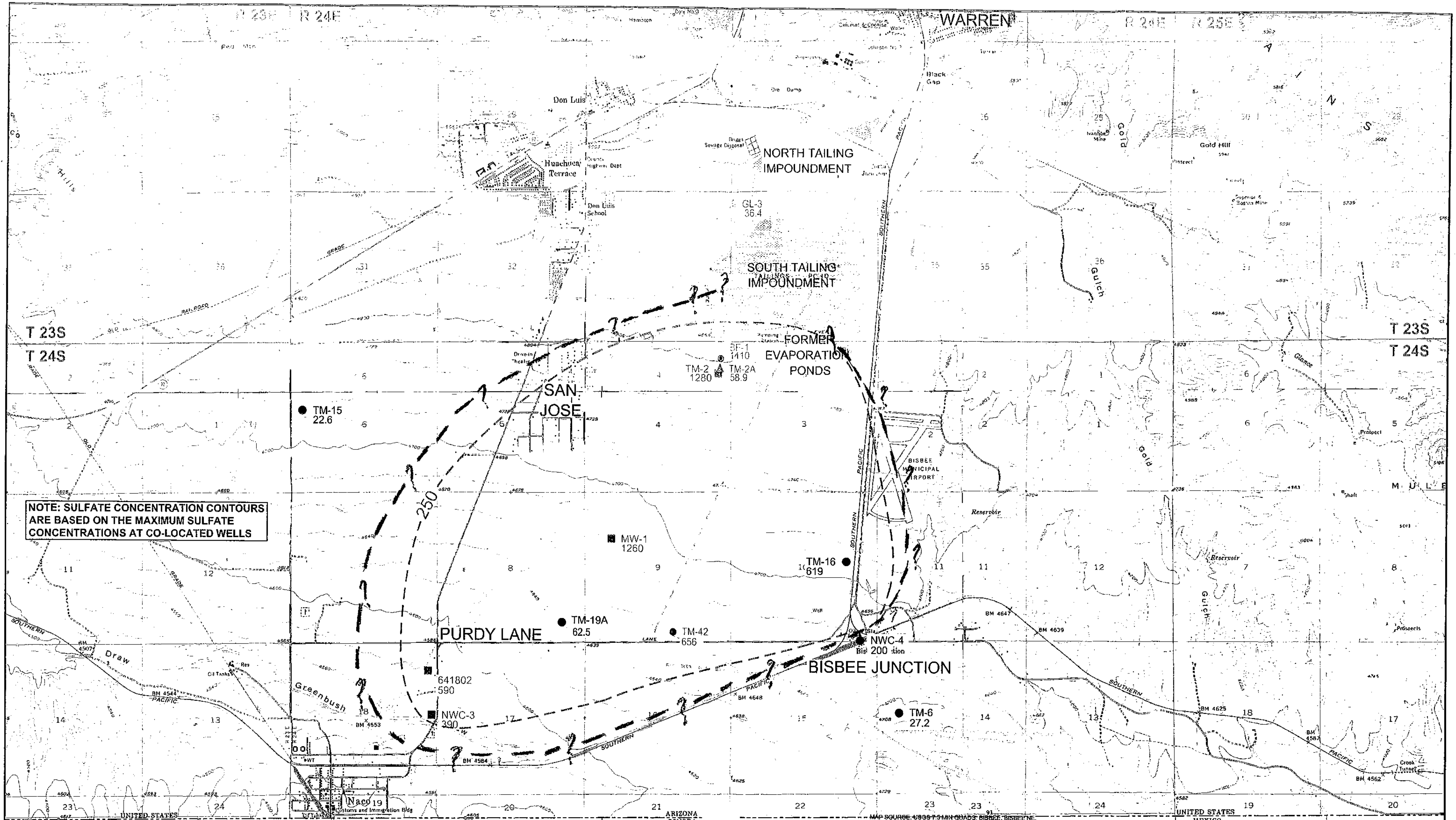
Freeport should state how long after well installation, the well would be developed. It is typical to wait at least 72 hours.

13. Section 4.3.8 Hydraulic Testing and Well Sampling

Freeport should state when a step-test and when a constant-discharge aquifer test would be conducted on the newly installed groundwater monitoring wells. ADEQ recommends that both tests be conducted on all of the newly installed wells. The step-test determines the proper pumping rate for each well and the constant-discharge test provides appropriate information about aquifer characteristics. Freeport should also describe the type of transducer to be used, vented or unvented. If unvented transducers are used, Freeport should record barometric pressure readings so the transducer values can be calibrated. Freeport should state the frequency of collecting manual water levels during the aquifer test, and indicate if additional wells will be monitored during each test. If so, the QAPP and FSP should identify which wells will be monitored. If additional wells are going to be monitored, Freeport should place a transducer into a background well to determine background conditions for the water table or potentiometric surface.

14 Section 5 Analytical Laboratory Procedures

Freeport discusses the analytical laboratory requirements in generalities. The QAPP is intended to provide specifics. Freeport should provide the name of the analytical laboratory and provide specifics for the work to be conducted. Additionally, Freeport should include the chosen laboratory's Quality Assurance Manual as an Attachment to the QAPP.



EXPLANATION

- BASIN FILL
- MORITA FORMATION
- GLANCE CONGLOMERATE
- PALEOZOIC SEDIMENTS
- MIXED, BASIN FILL AND MORITA FORMATION
- MURAL LIMESTONE
- UNKNOWN
- FAULT (DASHED WHERE INFERRED) FROM SET 1998c
- SULFATE, DASHED WHERE UNCERTAIN
- MW-1 1260 WELL ID, SULFATE CONCENTRATION

0 1/2 1 MILE
0 2000 4000 6000 FEET
0 .5 1 2 KILOMETER

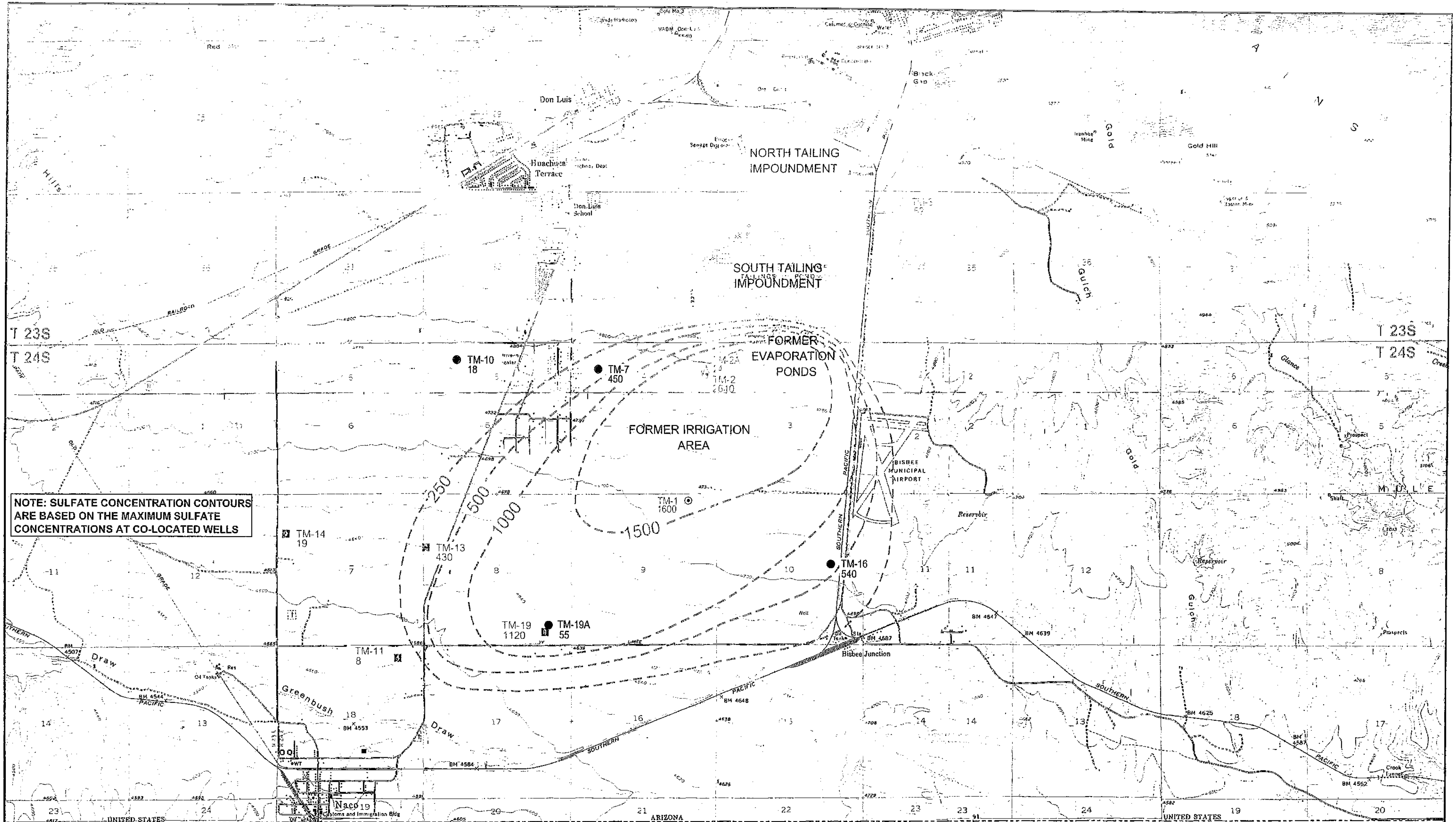
N

Attachment #1

HYDRO GEO CHEM, INC.

Maximum SULFATE PLUME, ~~2005~~ Based on 2005 and older data
APPROXIMATE BOUNDARY OF
250 mg/L SULFATE CONCENTRATION
BISBEE, ARIZONA

Approved	Date	Revised By	Date	File Name	Figure
JRN	04/04/07	KSW	07/18/07	8720015A	4



R 23E | R 24E

R 24E | R 25E

MAP SOURCE: USGS 7.5 MIN QUADS: BISBEE, BISBEE NE, BISBEE SE, AND NACO, ARIZONA
NAD 27 ZONE 12 CENTRAL, METERS

Attachment # 2

EXPLANATION

- BASIN FILL
- MORITA FORMATION
- GLANCE CONGLOMERATE
- MIXED, BASIN FILL AND MORITA FORMATION
- FAULT (DASHED WHERE INFERRED) FROM SET 1998c
- SULFATE CONCENTRATION ISOLINE
- TM-19 / 1120.0 — WELL ID, SULFATE CONCENTRATION

OPEN SYMBOL DENOTES ABANDONED WELL AS OF 2007

0 — 1/2 — 1 MILE

0 — 2000 — 4000 — 6000 FEET

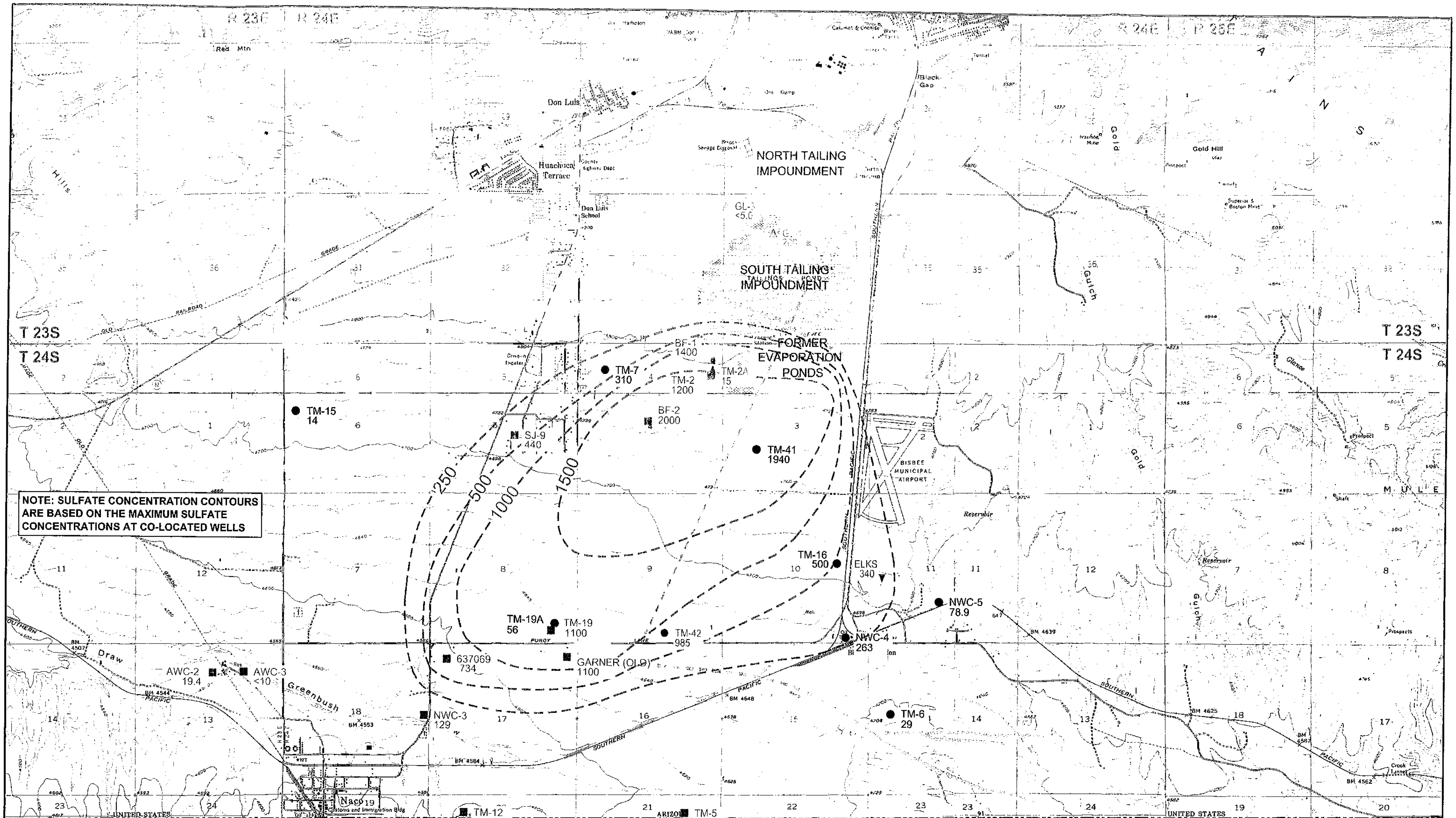
0 — .5 — 1 — 2 KILOMETER

N

HYDRO GEO CHEM, INC.

SULFATE CONCENTRATION MAP - JULY 1989
CONCENTRATOR TAILING STORAGE AREA AND VICINITY
BISBEE, ARIZONA

Approved	Date	Revised By	Date	File Name	Figure
JRN	4/4/07	KSW	07/17/07	8720003A	14



EXPLANATION

- BASIN FILL
- MORITA FORMATION
- GLANCE CONGLOMERATE
- MIXED, BASIN FILL AND MORITA FORMATION
- UNKNOWN
- TM-12 7.0 — WELL ID, SULFATE CONCENTRATION
- FAULT (DASHED WHERE INFERRED) FROM SET 1998c
- SULFATE CONCENTRATION ISOLINE

[1] DATA FOR JULY, 1997

MAP SOURCE: USGS 7.5 MIN QUADS: BISBEE, BISBEE NE, BISBEE SE, AND NACO, ARIZONA
NAD 27 ZONE 12 CENTRAL, METERS

0 1/2 1 MILE
0 2000 4000 6000 FEET
0 .5 1 2 KILOMETER

N

Attachment #3

HYDRO GEO CHEM, INC.

SULFATE CONCENTRATION MAP - SUMMER 1996
CONCENTRATOR TAILING STORAGE AREA AND VICINITY
BISBEE, ARIZONA

Approved	Date	Revised By	Date	File Name	Figure
JRN	04/04/07	KSW	04/04/07	8720004A	15

Attachment #4

Attachment 4

Standard Guide for Developing Conceptual Site Models for Contaminated Sites[1]

This standard is issued under the fixed designation E 1689; 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 is intended to assist in the development of conceptual site models to be used for the following: (*1*) integration of technical information from various sources, (*2*) support the selection of sample locations for establishing background concentrations of substances, (*3*) identify data needs and guide data collection activities, and (*4*) evaluate the risk to human health and the environment posed by a contaminated site. This guide generally describes the major components of conceptual site models, provides an outline for developing models, and presents an example of the parts of a model. This guide does not provide a detailed description of a site-specific conceptual site model because conditions at contaminated sites can vary greatly from one site to another.

1.2 The values stated in either inch-pound or SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 This guide is intended to apply to any contaminated site.

1.4 *This standard does not purport to address all of the safety concerns, 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. Referenced Documents

2.1 *ASTM Standard:*

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[2]

2.2 *EPA Documents:*[3]

Guidance for Data Useability in Risk Assessment (Part A) Final, Publication 9285.7-09A, PB 92-963356, April 1992

Guidance for Data Useability in Risk Assessment (Part B), OSWER Directive 9285.7-09B, May 1992

Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, OSWER Directive 9355.3-01, October 1988

3. Terminology

3.1 *Definitions:*

3.1.1 *background concentration, n*—the concentration of a substance in ground water, surface water, air, sediment, or soil at a source(s) or nearby reference location, and not attributable to the source(s) under consideration. Background samples may be contaminated, either by naturally occurring or manmade sources, but not by the source(s) in question.

3.1.2 *conceptual site model, n*—for the purpose of this guide, a written or pictorial representation of an environmental system and the biological, physical, and chemical processes that determine the transport of contaminants from sources through environmental media to environmental receptors within the system.

3.1.3 *contaminant, n*—any substance, including any radiological material, that is potentially hazardous to human health or the environment and is present in the environment at concentrations above its background concentration.

3.1.4 *contaminant release, n*—movement of a substance from a source into an environmental medium, for example, a leak, spill, volatilization, runoff, fugitive dust emission, or leaching.

3.1.5 *environmental receptor, n*—humans and other living organisms potentially exposed to and adversely affected by contaminants because they are present at the source(s) or along contaminant migration pathways.

3.1.6 *environmental transport, n*—movement of a chemical or physical agent in the environment after it has been released from a source to an environmental medium, for example, movement through the air, surface water, ground water, soil, sediment, or food chain.

3.1.7 *exposure route, n*—the process by which a contaminant or physical agent in the environment comes into direct contact with the body, tissues, or exchange boundaries of an environmental receptor organism, for example, ingestion, inhalation, dermal absorption, root uptake, and gill uptake.

3.1.8 *migration pathway, n*—the course through which contaminants in the environment may move away from the source(s) to potential environmental receptors.

3.1.9 *source, n*—the location from which a contaminant(s) has entered or may enter a physical system. A primary source, such as a location at which drums have leaked onto surface soils, may produce a secondary source, such as contaminated soils; sources may hence be primary or secondary.

4. Summary of Guide

4.1 The six basic activities associated with developing a conceptual site model (not necessarily listed in the order in which they should be addressed) are as follows: (*1*) identification of potential contaminants; (*2*) identification and characterization of the source(s) of contaminants; (*3*) delin-

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[1] This guide is under the jurisdiction of ASTM Committee E-47 on Biological Effects and Environmental Fate and is the direct responsibility of Subcommittee E47.13 on Assessment of Risk to Human Health and the Environment from Hazardous Waste Sites.

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[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] Available from Standardization Documents Order Desk, Bldg 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

eation of potential migration pathways through environmental media, such as ground water, surface water, soils, sediment, biota, and air; (*4*) establishment of background areas of contaminants for each contaminated medium; (*5*) identification and characterization of potential environmental receptors (human and ecological); and (*6*) determination of the limits of the study area or system boundaries.

4.2 The complexity of a conceptual site model should be consistent with the complexity of the site and available data. The development of a conceptual site model will usually be iterative. Model development should start as early in the site investigation process as possible. The model should be refined and revised throughout the site investigation process to incorporate additional site data. The final model should contain sufficient information to support the development of current and future exposure scenarios.

4.3 The concerns of ecological risk assessment are different from those of human-health risk assessment, for example, important migration pathways, exposure routes, and environmental receptors. These differences are usually sufficient to warrant separate descriptions and representations of the conceptual site model in the human health and ecological risk assessment reports. There will be elements of the conceptual site model that are common to both representations, however, and the risk assessors should develop these together to ensure consistency.

5. Significance and Use

5.1 The information gained through the site investigation is used to characterize the physical, biological, and chemical systems existing at a site. The processes that determine contaminant releases, contaminant migration, and environmental receptor exposure to contaminants are described and integrated in a conceptual site model.

5.2 Development of this model is critical for determining potential exposure routes (for example, ingestion and inhalation) and for suggesting possible effects of the contaminants on human health and the environment. Uncertainties associated with the conceptual site model need to be identified clearly so that efforts can be taken to reduce these uncertainties to acceptable levels. Early versions of the model, which are usually based on limited or incomplete information, will identify and emphasize the uncertainties that should be addressed.

5.3 The conceptual site model is used to integrate all site information and to determine whether information including data are missing (data gaps) and whether additional information needs to be collected at the site. The model is used furthermore to facilitate the selection of remedial alternatives and to evaluate the effectiveness of remedial actions in reducing the exposure of environmental receptors to contaminants.

5.4 This guide is not meant to replace regulatory requirements for conducting environmental site characterizations at contaminated (including radiologically contaminated) sites. It should supplement existing guidance and promote a uniform approach to developing conceptual site models.

5.5 This guide is meant to be used by all those involved in developing conceptual site models. This should ideally include representatives from all phases of the investigative and remedial process, for example, preliminary assessment, remedial investigation, baseline human health and ecological risk assessments, and feasibility study. The conceptual site model should be used to enable experts from all disciplines to communicate effectively with one another, resolve issues concerning the site, and facilitate the decision-making process.

5.6 The steps in the procedure for developing conceptual site models include elements sometimes referred to collectively as site characterization. Although not within the scope of this guide, the conceptual site model can be used during site remediation.

6. Procedure

6.1 *Assembling Information*—Assemble historical and current site-related information from maps, aerial images, cross sections, environmental data, records, reports, studies, and other information sources. A visit(s) to the site by those preparing the conceptual site model is recommended highly. The quality of the information being assembled should be evaluated, preferably including quantitative methods, and the decision to use the information should be based on the data's meeting objective qualitative and quantitative criteria. For more information on assessing the quality and accuracy of data, see *Guidance for Data Useability in Risk Assessment (Part A)* and *Guidance for Data Useability in Risk Assessment (Part B)*. Methods used for obtaining analytical data should be described, and sources of information should be referenced. A conceptual site model should be developed for every site unless there are multiple sites in proximity to one another such that it is not possible to determine the individual source or sources of contamination. Sites may be aggregated in that case. A conceptual model should then be developed for the aggregate.

6.2 *Identifying Contaminants*—Identify contaminants in the ground water, surface water, soils, sediments, biota, and air. If no contaminants are found, the conceptual site model should be used to help document this finding.

6.3 *Establishing Background Concentrations of Contaminants*—Background samples serve three major functions: (*1*) to establish the range of concentrations of an analyte attributable to natural occurrence at the site; (*2*) to establish the range of concentrations of an analyte attributable to source(s) other than the source(s) under consideration; and (*3*) to help establish the extent to which contamination exceeds background levels.

6.3.1 The conceptual site model should include the naturally occurring concentrations of all contaminants found at the site. The number and location of samples needed to establish background concentrations in each medium will vary with specific site conditions and requirements. The model should include sufficient background samples to distinguish contamination attributable to the source(s) under consideration from naturally occurring or nearby anthropogenic contamination. The procedures mentioned in 6.2 and 6.3 are sometimes grouped under the general heading of contaminant assessment and may be performed as a separate activity prior to the development of a conceptual site model.

6.4 *Characterizing Sources*—At a minimum, the following source characteristics should be measured or estimated for a site:

6.4.1 Source location(s), boundaries, and volume(s).

Sources should be located accurately on site maps. Maps should include a scale and direction indicator (for example, north arrow). They should furthermore show where the source(s) is located in relationship to the property boundaries.

6.4.2 The potentially hazardous constituents and their concentrations in media at the source.

6.4.3 The time of initiation, duration, and rate of contaminant release from the source.

6.5 *Identifying Migration Pathways*—Potential migration pathways through ground water, surface water, air, soils, sediments, and biota should be identified for each source. Complete exposure pathways should be identified and distinguished from incomplete pathways. An exposure pathway is incomplete if any of the following elements are missing: (*1*) a mechanism of contaminant release from primary or secondary sources, (*2*) a transport medium if potential environmental receptors are not located at the source, and (*3*) a point of potential contact of environmental receptors with the contaminated medium. The potential for both current and future releases and migration of the contaminants along the complete pathways to the environmental receptors should be determined. A diagram (similar to that in Fig. X1.4) of exposure pathways for all source types at a site should be constructed. This information should be consistent with the narrative portion and tables in the exposure assessment section of an exposure or risk assessment. Tracking contaminant migration from sources to environmental receptors is one of the most important uses of the conceptual site model.

6.5.1 *Ground Water Pathway*—This pathway should be considered when hazardous solids or liquids have or may have come into contact with the surface or subsurface soil or rock. The following should be considered further in that case: vertical distance to the saturated zone; subsurface flow rates; presence and proximity of downgradient seeps, springs, or caves; fractures or other preferred flow paths; artesian conditions; presence of wells, especially those for irrigation or drinking water; and, in general, the underlying geology and hydrology of the site. Other fate and transport phenomena that should be considered include hydrodynamic dispersion, interphase transfers of contaminants, and retardation. Movement through the vadose zone should be considered.

6.5.2 *Surface Water and Sediment Pathway*—This pathway should always be investigated in the following situations: (*1*) a perennial body of water (river, lake, continuous stream, drainage ditch, etc.) is in direct contact with, or is potentially contaminated by a source or contaminated area, (*2*) an uninterrupted pathway exists from a source or contaminated area to the surface water, (*3*) sampling and analysis of the surface water body or sediments indicate contaminant concentrations substantially above background, (*4*) contaminated ground water or surface water runoff is known or suspected to discharge to a surface water body, and (*5*) under arid conditions in which ephemeral drainage may convey contaminants to downstream points of exposure.

6.5.3 *Air Pathway*—Contaminant transport through the air pathway should be evaluated for contaminants in the surface soil, subsurface soil, surface water, or other media capable of releasing gasses or particulate matter to the air. The migration of contaminants from air to other environmental compartments should be considered, for example, deposition of particulates resulting from incineration onto surface waters and soil.

6.5.4 *Soil Contact Pathway*—Contaminated soils that may come into direct contact with human or ecological receptors should be investigated. This includes direct contact with chemicals through dermal absorption and direct exposure to gamma radiation from radioactively contaminated soil. There is a potential for human and ecological receptors to be exposed to contaminants at different soil depths (for example, humans may be exposed to only surface and subsurface soils, whereas plants and animals may encounter contaminants that are buried more deeply). This should be considered when contaminated soils are being evaluated.

6.5.5 *Biotic Pathway*—Bioconcentration and bioaccumulation in organisms and the resulting potential for transfer and biomagnification along food chains and environmental transport by animal movements should be considered. For example, many organic, lipophilic contaminants found in soils or sediments can bioaccumulate and bioconcentrate in organisms such as plankton, worms, or herbivores and biomagnify in organisms such as carnivorous fish and mammals or birds. The movement of contaminated biota can transport contaminants.

6.6 *Identifying Environmental Receptors*—Identify environmental receptors currently or potentially exposed to site contaminants. This includes humans and other organisms that are in direct contact with the source of contamination, potentially present along the migration pathways, or located in the vicinity of the site. It is advisable to compile a list of taxa representative of the major groups of species present at the site. It will rarely be possible or desirable to identify all species present at a site. It is recommended that the conceptual site model include species or guilds representative of major trophic levels. The complexity and iterative nature of the conceptual site model has already been mentioned in 4.2.

6.6.1 *Human Receptors*—The conceptual site model should include a map or maps indicating the physical boundaries of areas within which environmental receptors are potentially or currently exposed to the source(s) or migration pathways; separate maps may be prepared to illustrate specific contaminants or groups of contaminants. In addition, the human receptors should be represented in a figure similar to Fig. X1.4, which is based on *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*. Fig. X1.4 shows the potentially exposed populations, sources, and exposure routes. It represents a clear and concise method of displaying exposure information.

6.6.2 *Ecological Receptors*—The conceptual site model should include a map or maps identifying and locating terrestrial and aquatic habitats for plants and animals within and around the study area or associated with the source(s) or migration pathways. Consult local and state officials, U.S. Environmental Protection Agency regional specialists, and Natural Resource Trustees to determine whether any of the areas identified are critical habitats for federal- or state-listed threatened or endangered species or sensitive environments. Identify all dominant, important, declining, threatened, endangered, or rare species that either inhabit (permanently, seasonally, or temporarily) or migrate through the study area.

7. Keywords

7.1 conceptual site model; ecological; hazardous waste site; human health; risk assessment; site characterization

APPENDIX

(Nonmandatory Information)

X1. OUTLINE FOR A CONCEPTUAL SITE MODEL FOR CONTAMINATED SITES

X1.1 The conceptual site model should include a narrative and set of maps, figures, and tables to support the narrative. An outline of the narrative sections, along with an example for each section, is given below. The example is based on an hypothetical landfill site at which only preliminary sampling data are available. *The landfill site example is intentionally simplified and is for illustrative purposes only. Conceptual site models may contain considerably more detail than provided in this example.*

X1.1.1 *Brief Site Summary*—Summarize the information available for the site as this information relates to the site contaminants, source(s) of the contaminants, migration pathways, and potential environmental receptors. A brief description of the current conditions at the site (photographs optional) should be included. The inclusion of a standard 7.5-min United States Geological Survey topographic quadrangle map or geologic quadrangle map, or both, that shows the location of the site is recommended. All maps should contain directional information (for example, north arrow) and a scale.

Example—Geophysical surveys, aerial photographs, and subsurface exploration at Landfill No. 1 (LF-1) reveal the presence of at least one northeast-southwest trending waste trench. The trench is 300-ft (91-m) long and 100-ft (30-m) wide. Maximum depth of the trench indicated by the soil borings is 22 ft (7 m). As determined from the soil boring program, the waste material samples indicated that metal concentrations were at or below background concentrations, with the exception of cadmium and manganese in one sample. However, solvents (methylene chloride and trichloroethene (TCE) and pesticides (DDE, DDT, and DDD) were found at concentrations above background in soil boring samples. Soil samples taken from beneath the fill indicate that downward migration of contaminants has occurred. The surficial aquifer (ABC Formation) contains naturally high dissolved solids (>2000 mg/L) with yields of less than 4 gpm. Ground water flow in the surficial aquifer is toward the southeast at a rate of approximately 15 ft (5 m) per year. The terrain is flat with seeded and natural grasses and small (15-ft (5-m)), widely spaced loblolly pine tress covering the site. The site is fenced and unused currently.

X1.1.2 *Historical Information Concerning the Site:*

X1.1.2.1 *Site Description*—Describe the history of the site, paying particular attention to information affecting the present environmental condition of the site.

Example—LF-1, operated from 1960 to 1968. This trench-type landfill was reportedly used for the disposal of construction rubble and debris, packing material, paper, paints, thinners, unrinsed pesticide containers, oils, solvents, and contaminated fuels. Most of the trenches for waste disposal were reportedly oriented east-west and were 75-ft (23-m) wide, 350-ft (107-m) long, and an estimated 20-ft (6-m) deep. A few empty containers presumably buried in the landfill have worked their way to the surface and are partially exposed at the site. The site was partly covered by an unpaved industrial haulage road. The site was fenced in 1985 and has been unused since.

X1.1.2.2 *Source Characterization*—Present site-specific information to identify and define the location, size, and condition of the source(s) of contamination at the site.

Example—Four soil borings were used to characterize the waste disposal units at LF-1. Fig. X1.1 illustrates the soil boring locations. The depth of the soil borings were SB05 = 28 (9 m), SB06 = 30 ft (9 m), SB07 = 30 ft (9 m) and SB08 = 30 ft (9 m) below ground surface. Two of the borings, SB07 and SB08, encountered refuse/waste material. In SB08, the refuse was encountered from approximately 8 to 22 ft (2 to 7 m) below ground surface. The material was noted to be burnt debris, glass, and organic matter. A much dryer and thinner waste zone was encountered at SB07. The base of the excavation at this location was approximately 10 ft (3 m). Material that appeared to be burnt trash was noted in the backfill. The remaining two borings, SB05 and SB06, did not encounter waste. One sample was collected from each of these borings (SB05 and -06). These samples were used as background samples. Additional samples were collected from SB07 and SB08, within the landfill, to characterize the source. Analytical results are summarized in Table X1.1.

Petroleum hydrocarbons, which were suspected of being contaminants based on the site history, were not detected in any of the samples.

Volatile organic compounds found in the samples included methylene chloride and TCE. Methylene chloride was found in all soil samples in trace amounts (0.005 to 0.008 mg/kg).

The field quality control information suggests that methylene chloride may be a field artifact. The chlorinated solvent, TCE, was found significantly above background only at SB08 at a concentration of 0.05 mg/kg.

Organochlorine pesticides (DDE, DDD, and DDT), which were suspected of being present based on the site history, were not present above the detection limit in any of the samples.

Comparing metal concentrations of soil samples from SB05 and SB06 (background samples) with the remaining soil samples (SB07 and SB08) reveals that SB08 metals data exceeded the background soils data substantially for one analyte. That analyte was manganese (4320 mg/kg).

X1.1.2.3 *Migration Pathway Descriptions*—Describe the route(s) potentially taken by contaminants from the site as they migrate away from the source through the environmental media (ground water, surface water, air, sediment, soils, and food chain).

Example: *Ground Water Migration*—Three monitor wells (MWs) were installed at LF-1. The bedrock formation is typically nonwater-bearing and consists of thick clay and clay-stone (Fig. X1.2). The unconsolidated materials above the bedrock include a layer of fluvial terrace deposits. The sand and gravels that lie above the bedrock contain water with flow velocities of approximately 13 to 18 ft/year (4 to 5 m/year). Flow velocities were estimated from permeability tests conducted at MW06. Recharge at the site is from runoff associated with the nearby area that pools and stagnates at and near the site. Table X1.2 contains the water quality analyses from samples of MW05, MW06 (upgradient), and MW07 (downgradient). The upgradient samples contained no contaminants at concentrations above the detection limits, while the downgradient sample contained organic contaminants (pesticides). A comparison of metals from the downgradient and upgradient

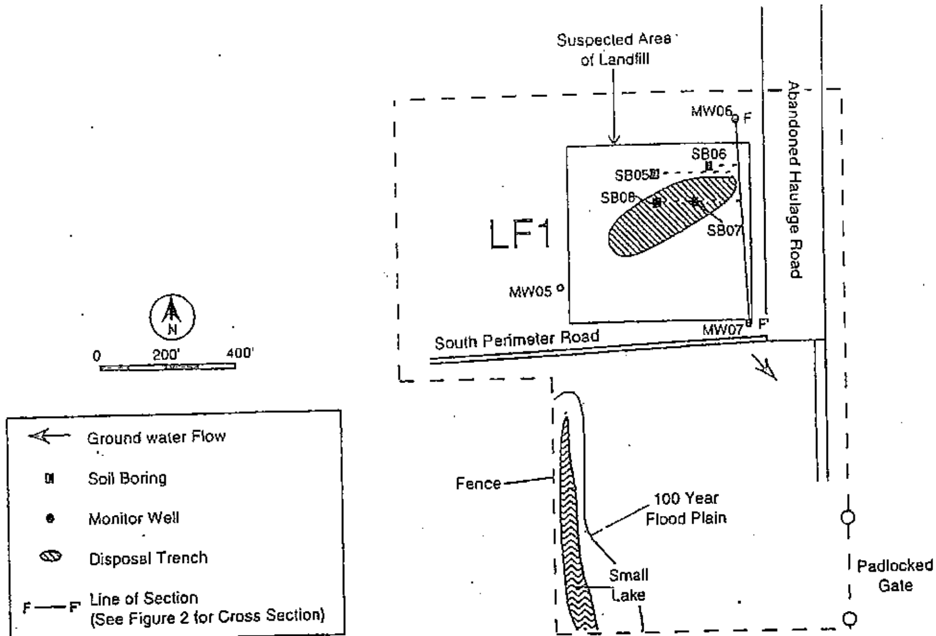

FIG. X1.1 Location Map for Landfill Number 1; Contours Showing the Potentiometric Surface from which Ground Water Flow Direction was Determined Could be Included in a Separate Figure to Avoid Clutter

TABLE X1.1 Summary of Analytical Results at LF-1[A]

Parameter (Method)			Field Identification Number			
	DL[B]	Units	SB05[C]	SB06	SB07	SB08
Moisture (Test Method D 2216)	N/A[D]	%	20.6	19.1	12.7	21.1
Petroleum hydrocarbons (SW3550/E418.1)	25	mg/kg	ND_{25}[E]	ND_{25}	ND_{25}	ND_{25}
Volatile organics (SW8240)						
Methylene chloride[F]	0.005	mg/kg	0.008	$ND_{0.0050}$	$ND_{0.0050}$	$ND_{0.0050}$
Trichloroethene	0.005	mg/kg	0.006	$ND_{0.0050}$	$ND_{0.0050}$	0.05
Organochlorine pesticides (SW3550/8080)		mg/kg				
4,4-DDE	0.0033	mg/kg	$ND_{0.0033}$	$ND_{0.0033}$	$ND_{0.0033}$	$ND_{0.0033}$
4,4-DDD	0.0033	mg/kg	$ND_{0.0033}$	$ND_{0.0033}$	$ND_{0.0033}$	$ND_{0.0033}$
4,4-DDT	0.0033	mg/kg	$ND_{0.0033}$	$ND_{0.0033}$	$ND_{0.0033}$	$ND_{0.0033}$
Metals (SW3050/6010)						
Cadmium	0.5	$ND_{0.5}$	$ND_{0.5}$	$ND_{0.5}$	$ND_{0.5}$	$ND_{0.5}$
Manganese	2	mg/kg	284	178	228	4320

[A] All results are expressed on a dry weight basis.
[B] DL = detection limit.
[C] SB = soil boring.
[D] N/A = not applicable.
[E] ND_x = not detected at concentration x.
[F] Suspected laboratory contaminant.

samples indicates that the concentration of metals in the downgradient ground water does not exceed background (upgradient) concentrations.

Example: *Surface Water and Sediment Migration*—The site surface water drainage map is shown in Fig. X1.3. Three surface water runoff samples and three sediment samples were collected at locations shown on the map. Samples SW-02 and SD-02 were collected to determine background, while SW-03, SW-04, SD-03, and SD-04 were placed downstream of the site. The analytical results given in Table X1.2 indicate that no contaminants are present above background in any of the samples. There appears to be no contamination entering the surface water pathway from the site.

Example: *Air Migration*—No air samples were taken since there was no indication that vapor or dust can enter the air pathway. The contamination is buried and effectively prevented from reaching the air pathway, and the site is covered by a thick layer of vegetation, which effectively acts as a natural cap and prevents dust from becoming airborne. Qualitative air monitoring showed no evidence of any organic vapors being present at the site during the initial stages of the site investigation.

Example: *Soils*—This pathway is not complete for humans because the site is surrounded by a 6-ft (2-m) fence with a padlocked gate and posted with no trespassing signs. Soil and sediment samples taken for the surface water pathway did not indicate the presence of contamination above background concentrations. Also, there was no loose soil at the site since the site was covered by a thick layer of vegetation. Exposed, empty containers have been tested for the presence of contaminant residues, and none have been found. The site was inspected for evidence of burrowing mammals and other small mammals, reptiles, amphibians, or birds that might not be deterred by the fence. There was no evidence of any threat to ecological receptors from the soils or direct contact.

Example: *Food Chain Transfer*—Samples collected from surface water, sediment, and soils indicate that there are no contaminants present at concentrations above background. There is therefore no concern for food chain transfer (biomagnification) in and around the landfill.

X1.1.2.4 *Environmental Receptor Identification and Discussion*—Current and future human and ecological receptor groups should be identified and located on site maps. The migration pathways and source(s) that place or potentially

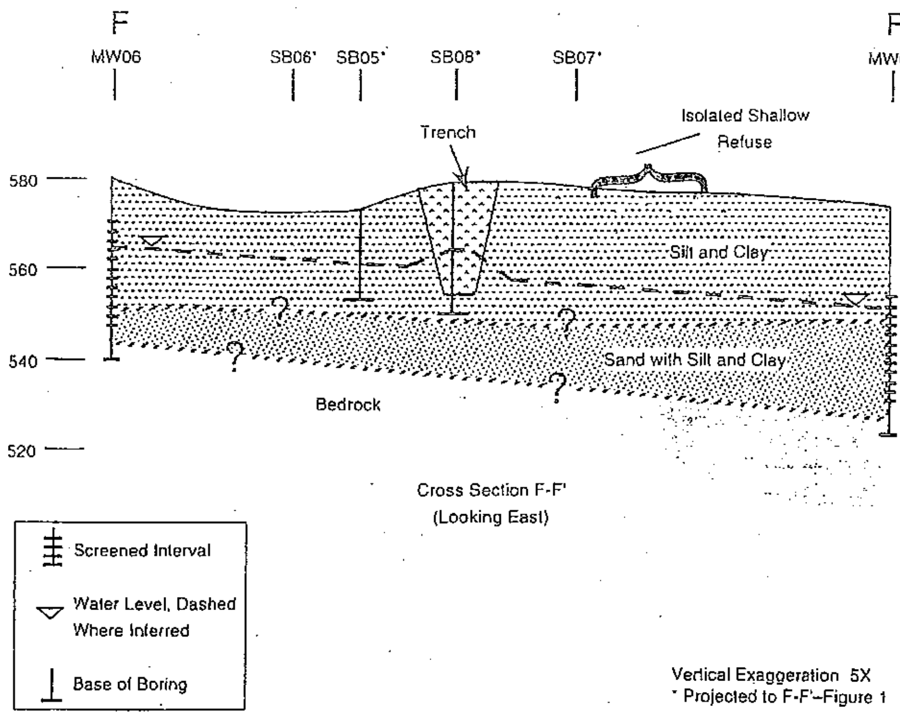

FIG. X1.2 Cross Section of Landfill Number 1

TABLE X1.2 Ground and Surface Water Quality Analysis at LF-1

Parameter	Field Identification Number						
	DL[A]	MW-05 µg/L	MW-06 µg/L	MW-07 µg/L			
Volatile organics							
Trichloroethene	5	ND_5[B]	ND_5	ND_5			
Methylene chloride	5	ND_5	ND_5	ND_5			
Organochlorine pesticides							
4,4-DDE	0.1	$ND_{0.1}$	$ND_{0.1}$	1			
4,4-DDD	0.1	$ND_{0.1}$	$ND_{0.1}$	3			
4,4-DDT	0.1	$ND_{0.1}$	$ND_{0.1}$	4			
Metals							
Cadmium	5	ND_5	ND_5	ND_5			
Manganese	15	ND_{15}	ND_{15}	ND_{15}			
	DL Water	µg/L SW-02	µg/L SW-03	µg/L SW-04	mg/kg SD-02	mg/kg SD-03	mg/kg SD-04
Petroleum hydrocarbons	1000	ND_{1000}	ND_{1000}	ND_{1000}	ND_{1000}	ND_{1000}	ND_{1000}
Volatile organics							
Trichloroethene	1	ND_1	ND_1	ND_1	ND_1	ND_1	ND_1
Methylene chloride	2	ND_2	ND_2	ND_2	ND_2	ND_2	ND_2
Organochlorine pesticides							
4,4-DDE	0.04	$ND_{0.04}$	$ND_{0.04}$	$ND_{0.04}$	$ND_{0.04}$	$ND_{0.04}$	$ND_{0.04}$
4,4-DDD	0.1	$ND_{0.1}$	$ND_{0.1}$	$ND_{0.1}$	$ND_{0.1}$	$ND_{0.1}$	$ND_{0.1}$
4,4-DDT	0.1	$ND_{0.1}$	$ND_{0.1}$	$ND_{0.1}$	$ND_{0.1}$	$ND_{0.1}$	$ND_{0.1}$
Metals							
Cadmium	5	ND_5	ND_5	ND_5	$ND_{0.5}$	$ND_{0.5}$	$ND_{0.5}$
Manganese	20	ND_{20}	ND_{20}	ND_{20}	ND_2	ND_2	ND_2

[A] DL = detection limit.
[B] ND_x = not detected at concentration *x*.

place the environmental receptors at risk should be discussed.

Example: The only residential housing in the vicinity of the site is approximately 2100 ft northwest of the landfill. The surficial aquifer is not used as a source of drinking water by the residents, and the ground water flow is toward the southeast and away from the residential housing. There is an active golf course just to the west of the residential housing. Golf Course Lake is recharged from north of the lake and is not influenced by LF-1. The golf course does not use the surficial aquifer for a drinking water source or for irrigating the golf course. There are no other human receptors in the vicinity of the site. There are no local, state, or federally designated declining, endangered, or rare species that inhabit or migrate through the vicinity of the study area. Other wildlife species that were observed on-site show no evidence of harm from the site. Plants on-site include seeded, cool-season grasses, and volunteer native grasses; herbian vegetation; upland shrubs; and coniferous trees. None of the vegetation shows signs of stress. The most likely potentially threatened aquatic habitats are Small Lake and Big River, south of the landfill. However, environmental sampling of surface water and sediments (Table X1.2) has not shown any evidence of contaminant migration from the landfill to the lake or river. Fig. X1.4 illustrates the