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White Paper on Site-Wide Water Balance Model Application - I Rocky Flats Environmental Technology Site

Final
January 30, 2003

Environmental Media Management
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Executive Summary

The Rocky Flats Environmental Technology Site is being closed and converted, from its former use as a nuclear weapons component production facility, into a National Wildlife Refuge. A fully-integrated hydrologic model (the Site-Wide Water Balance [SWWB] model) was developed as a management tool to simulate the hydrologic effects of a range of closure activities (Kaiser-Hill, 2002b). This white paper summarizes the findings of follow-on work for this management tool. Specifically, the following three tasks were performed:

- Assessment of groundwater flow in Volatile Organic Compound (VOC) plume areas;
- Evaluation of remedial designs for groundwater management; and
- Simulation of additional SWWB hypothetical land configuration scenarios.

To accomplish these tasks, observed data were evaluated, previously simulated SWWB modeling results were considered, and additional model simulations were performed (using the SWWB model, with 200-ft.[foot]x 200 ft. grid). The findings are presented below.

Task 1 Findings: Groundwater Flow Assessment in VOC Plume Areas

Based on an initial review of data availability, certain data limitations will present challenges to future VOC modeling. Few historical measurements of groundwater level, water quality, and climate variables exist from 1952 to the late 1980s. This will complicate efforts to simulate of observed plumes from spill date to 2002 (planned approach for model calibration). Further, the historical release information generally lacks details on spill concentrations, volumes, and specific release dates. A thorough evaluation of the data must be completed before additional sampling locations can be identified.

Many factors affect groundwater flow paths. On a regional scale, flow paths are largely controlled by the bedrock surface. Therefore, on a regional scale, groundwater flow paths will not change significantly due to Site closure modifications. However, on a local scale, groundwater flow directions (and hence transport) can also be strongly influenced by other factors. These factors include evapotranspiration (ET), building basements, subsurface utilities, precipitation, saturated zone hydraulic conductivity, storage, Arapahoe Sandstone lenses, unsaturated zone heterogeneity, and historical Site development. These local-scale factors must be taken into consideration for flow and transport modeling.

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Task 2 Findings: Remedial Design Simulations

Slurry walls in the Original Landfill area

Two simulations were conducted to evaluate the effects of a single slurry wall extending through the weathered bedrock at the Original Landfill. Results showed the following:

- The lateral extent of slurry wall effects on groundwater levels was limited to several hundred feet;
- The magnitude of change to upgradient or adjacent groundwater levels was less than about a meter. Groundwater levels increased on the upgradient side of the slurry wall, but decreased within the Original Landfill waste material downgradient of the wall. The increase in water levels caused flow directions to change slightly, upgradient of the wall. This change in flow directions would likely cause the southern extent of the Industrial Area (IA) plumes to be redirected from the current pathway;
- Recharge could not be entirely eliminated with the hypothetical geotechnical cover parameters specified by the Land Configuration Design Basis Project (Kaiser-Hill, 2002a). As a result, the waste material could not be entirely dewatered; and
- Dewatering will take decades to occur within the Original Landfill area, given the relatively low saturated hydraulic conductivities.

Solar Ponds Reactive Barrier System[1]

Based on evaluation of the observed data and SWWB simulation results (note: results resolution limited to grid size of 200- x 200-ft.), the current Solar Ponds reactive barrier appears adequate for capturing the present VOC plumes in this model area. However, it appears inadequate to capture the eastern arm of the present nitrate plume(s).

Hypothetical Interceptor Trenches

Two hypothetical interception trench scenarios were simulated in the IA to evaluate the hydraulic effect of these systems on subsurface flows. Results showed the following:

- The influence of these systems on surrounding subsurface flows was limited due to the shallow aquifer, low aquifer permeabilities, and strong localized influence of recharge and ET; and
- Trenches should be designed to extend across the entire lateral extent of any plume migration pathway to capture VOCs.

[1] The "Solar Ponds Reactive Barrier System" refers to the more recently installed (1999) system in the are of the former Interceptor Trench System (ITS).

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Task 3 Findings: Additional Hypothetical Land Configuration Scenarios

This task involved simulation of four additional hypothetical scenarios using the regional SWWB model. Specifically, the SWWB model was applied to simulate the following:

- Effects of minimal topography change at closure;
- Effects of leaving most drains in place at closure;
- Effects of upgradient gravel mining activities at closure; and
- Hydrologic response to a 100-year precipitation event (currently, and at closure).

Results of these simulations showed the following:

- The current topography did not produce significantly different surface water discharge volumes as compared to the engineered topography. Groundwater levels were higher in some areas and lower in others, relative to simulation of the engineered topography at closure. Though groundwater elevations varied, groundwater depths remained fairly constant in the central IA, regardless of topography;
- Leaving drains in place increased surface water discharge from the IA and lowered IA groundwater levels;
- As simulated, upgradient mining activities had no effect on groundwater levels in the IA at closure (which is consistent with the Site conceptual hydrologic model); and
- The simulated runoff volume and flow rates for the 100-year event decreased at closure, as compared to the current configuration. This decrease, however, was smaller proportionately than the simulated decrease in annual runoff for a typical year at closure.

Next Steps

To continue progress in support of Site Environmental Restoration closure projects and the Comprehensive Risk Assessment (CRA), the follow tasks have been identified as the necessary next steps for modeling:

- Geologic and hydrologic databases developed for the SWWB model will be updated with current information;
- Individual VOC plumes will be defined to the extent possible with available information for the VOCs selected for modeling. Only the IA, Solar Ponds area, and 903 Pad area will be considered. The Present Landfill area will not be evaluated as part of this effort;
- Significant data gaps identified in the delineation of the plumes will noted, including information on sources, water levels, geology, and water quality.
- VOC source and plume information will be incorporated into linked databases, evaluated, and then used to develop conceptual flow and transport models; and
- Local-scale modeling for VOC plume areas will be performed.

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1.0 INTRODUCTION

The Rocky Flats Environmental Technology Site (RFETS or Site) is being closed and converted from its former use as a nuclear weapons component production facility into a National Wildlife Refuge. Closure activities for the Site involve reconfiguring the existing Industrial Area (IA) into a more natural state. These future changes are expected to impact the current Site hydrology, raising concerns about wildlife habitats, wetlands, water quality, and groundwater contaminant transport.

A fully-integrated hydrologic model (SWWB [Site-Wide Water Balance] model) was developed as a management tool to simulate the regional hydrologic effects of a range of closure activities. Development of this model is detailed in The SWWB Model Report (Kaiser-Hill, 2002b). The Site intends to use this tool to assist with closure planning. The Site is also in the process of developing a Comprehensive Risk Assessment (CRA). To support the CRA, a Volatile Organic Contaminant (VOC) transport model is planned based on the regional SWWB hydrologic model.

This white paper presents the results of three tasks related to the SWWB and VOC modeling projects. The first task is a preliminary assessment of groundwater flow in VOC plume areas. The second task is an evaluation of remedial designs, including the trenches and slurry walls. The third task involves simulation of additional SWWB scenarios to better understand the effects of closure decisions on Site-wide hydrology.

1.1 Purpose of this White Paper

This white paper summarizes the findings of three main tasks in support of Site closure activities:

- Assessment of groundwater flow in VOC plume areas;
- Evaluation of remedial designs; and
- Simulation of additional hypothetical land configuration scenarios.

Task 1, assessment of groundwater flow in VOC plume areas, included evaluation of current data and SWWB model results. This task was performed to provide information and guidance for future modeling efforts (groundwater VOC modeling) in support of the CRA. The objectives were as follows:

- Evaluate local groundwater flow in plume areas (including flow direction and seasonal changes in water level);
- Evaluate subsurface structure affecting groundwater flow (including caliche, subsurface utilities, and unsaturated areas in the unconsolidated material);
- Summarize important natural and anthropogenic factors affecting groundwater flow and VOC transport on-Site; and

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Task 2, evaluation of remedial designs, included evaluation of SWWB model results as well as simulation of the effects of slurry walls and trenches. Results from this task should provide general guidance information for remedial actions. Specifically, the following items were evaluated as part of this task:

- Effects of slurry walls in the area of the Original Landfill;
- Groundwater flow dynamics for the Solar Ponds nitrate plume at the Solar Ponds Reactive Barrier System; and
- Groundwater flow response near hypothetical interception trenches in the IA.

Task 3, simulation of additional hypothetical land configuration scenarios, involved performing new simulations with the SWWB model. This task was performed to provide additional insight into the Site hydrology for purposes of Site closure planning. Two hypothetical scenarios were previously simulated as a preliminary application of the SWWB model[2] (presented in Kaiser-Hill, 2002b). Four additional scenarios using the SWWB model were simulated and include:

- Hypothetical Scenario 3[2] – Simulate the effects of minimal topography change at closure;
- Hypothetical Scenario 4 – Simulate the effects of most drains left in place at closure;
- Hypothetical Scenario 5 – Simulate the effects of upgradient gravel mining activities at closure;
- Hypothetical Scenario 6 – Simulate the hydrologic response to a 100-year precipitation event (currently and at closure).

1.2 Organization of Report

This white paper is organized in five sections to present the findings of the three tasks presented above. Section 1 presents a brief introduction to the Site and the three tasks addressed in this paper. Section 2 offers general background information on the Site hydrology and locates the VOC plume areas. Section 3 introduces the approach taken to accomplish the three tasks. Section 4 presents the results of Tasks 1 through 3. Results of Task 1 are presented in Section 4.1; results of Task 2 are detailed in Section 4.2; and results of Task 3 are described in Section 4.3. Section 5 provides the summary and conclusions. The summary is presented by VOC plume area for Task 1, by remediation tool for Task 2, and by Scenario Simulation for Task 3.

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[2] Scenarios 1 and 2 involved discontinuation of imported water and simulation of the Land Configuration Design Basis Closure (Kaiser-Hill, 2002a), respectively. These were performed as part of the original SWWB work, and are detailed in Kaiser-Hill (2002b).

2.0 BACKGROUND

2.1 Site Hydrology

A brief description of the Site hydrology is present in this section. A more detailed description, including the Site conceptual hydrologic model, is presented in the SWWB Modeling Report (Kaiser-Hill, 2002b).

The Site consists of a 385-acre IA surrounded by the 6,200-acre Buffer Zone. The IA includes paved roads, parking lots, building, basements, footing drains, and a variety of subsurface utilities. The Buffer Zone is comprised of grasslands and prairie, mesas, largely ephemeral creeks, and 11 managed ponds. The Site imports water for domestic and industrial use, discharging to the ponds after treatment.

The climate is temperate and semi-arid, with an average annual precipitation of 14.5 inches (368 mm). In general, surface water flows from west to east through the two major drainages within the study area, Walnut Creek and Woman Creek. Groundwater generally follows the topography, flowing toward the creeks. Groundwater in the Buffer Zone is recharged primarily through direct precipitation, and most of the recharge is lost locally through ET before reaching stream channels. Seeps can occur where shallow, less permeable bedrock outcrops.

2.2 VOC Plume Areas

Through Site construction, manufacturing, chemical processing, and laboratory activities, VOCs have been released to the environment since 1951. Three VOC plume areas are considered in this white paper discussion. These areas were defined to be inclusive of the relevant 2001 Annual Report (Kaiser-Hill, 2002d) composite plumes plus the projected, potential migration pathway to surface water. These include the following:

- IA VOC plumes area[3];
- Solar Ponds VOC plumes area[3]; and
- 903 Pad Area VOC plumes area[3].

These three plume areas were chosen based on the designation of the composite plumes in the RFCA annual reports (e.g., Kaiser-Hill, 2002d). It is recognized that these areas do not represent distinct VOC plumes, but instead define multiple, commingled plumes comprised of various VOC contaminants from multiple source areas. Efforts to better

[3] The naming conventions used in this document are based on the naming conventions of the RFCA Annual Groundwater Monitoring Report (Kaiser-Hill, 2002d), which lumped plume designations by general area and composite VOC data sets. Consequently, the plume area names are not necessarily indicative of the contamination sources (e.g. the term Solar Ponds plume area does not identify the Solar Pponds as the VOC source). Further, the term "plume areas" was applied in recognition of the fact that each area contains multiple individual plumes, some of which commingle.

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characterize VOC plume extents and sources are in progress as part of the VOC groundwater modeling project to support the CRA.

Figure 2-1 shows the projected extent of these three VOC plume areas for the purposes of modeling[4].

As shown in Figure 2-1, the Solar Ponds area plumes overlaps with the IA plumes. Although, it is also possible that a portion of the IA plumes could migrate into the 903 Pad area plumes, it is more likely to migrate either north or south, to surface water receptors.

Figure 2-2 (a, b, and c) shows surface water discharge points, or potential receptor areas based on current groundwater flow paths. These are only approximate discharge points based on preliminary identification of seeps, surface channels, or ponds within or adjacent to the extents of the three VOC plume areas shown on Figure 2-1. The final Site configuration will ultimately dictate the location of specific receptor areas (areas where groundwater will discharge to the ground surface).

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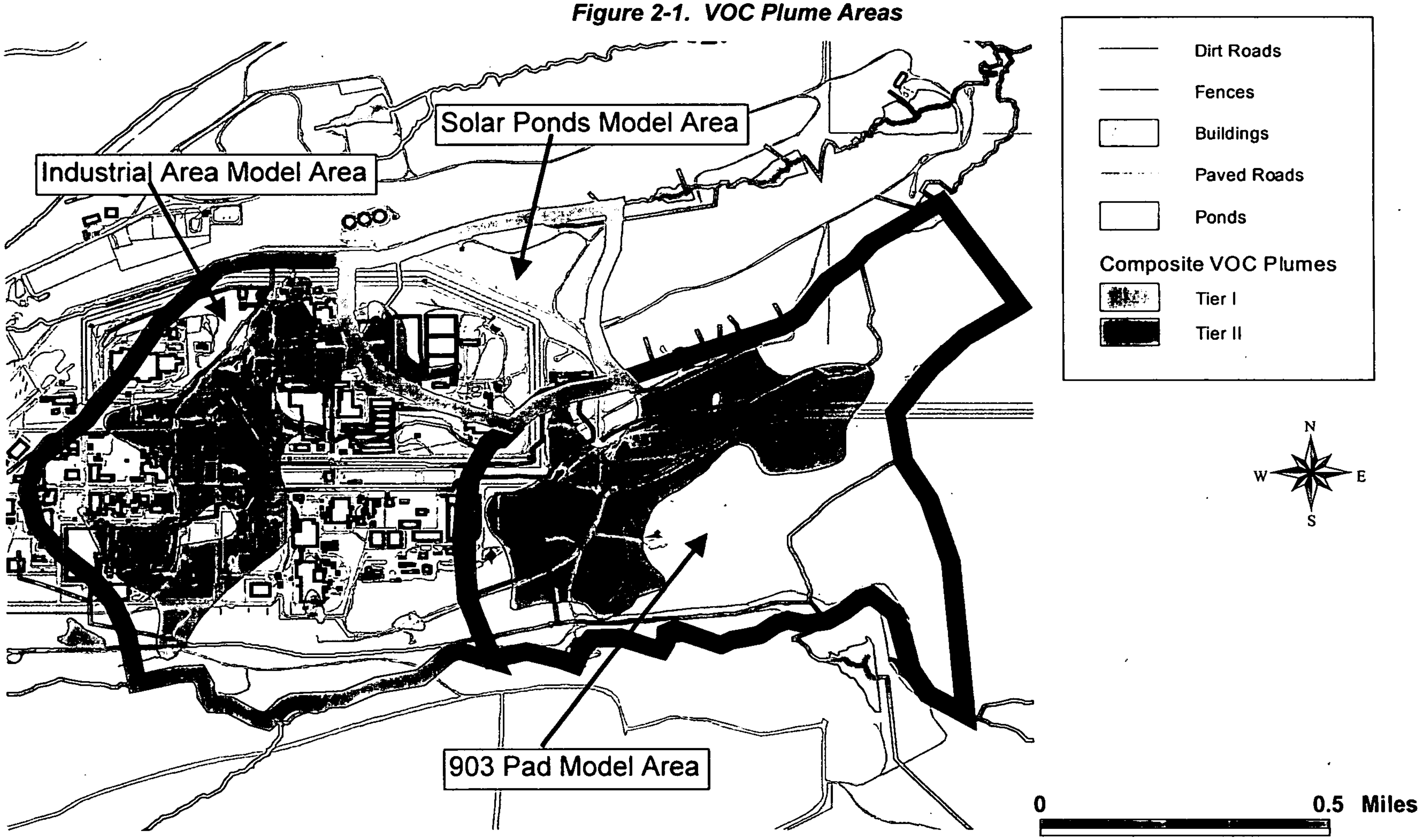
[4] These areas are presented in terms of Tier I and Tier II concentration levels (per Kaiser-Hill, 2002d). Tier I concentrations for the 11 VOCs considered in the composite plume range from 200 to 20,000 μg/L. Tier II levels range from 2 to 200 μg/L.

Figure 2-1. VOC Plume Areas



Note: Extents consider current contamination extents and future extents based on groundwater flow directions.

The Industrial Area Model Area VOC plume(s) may also migrate into parts of the Solar Ponds and 903 Pad Model Areas based on current flow paths. For this reason, a single model area (including all three areas) may be simulated instead of three separate models.

Figure 2-2a. Potential Discharge Points for Groundwater

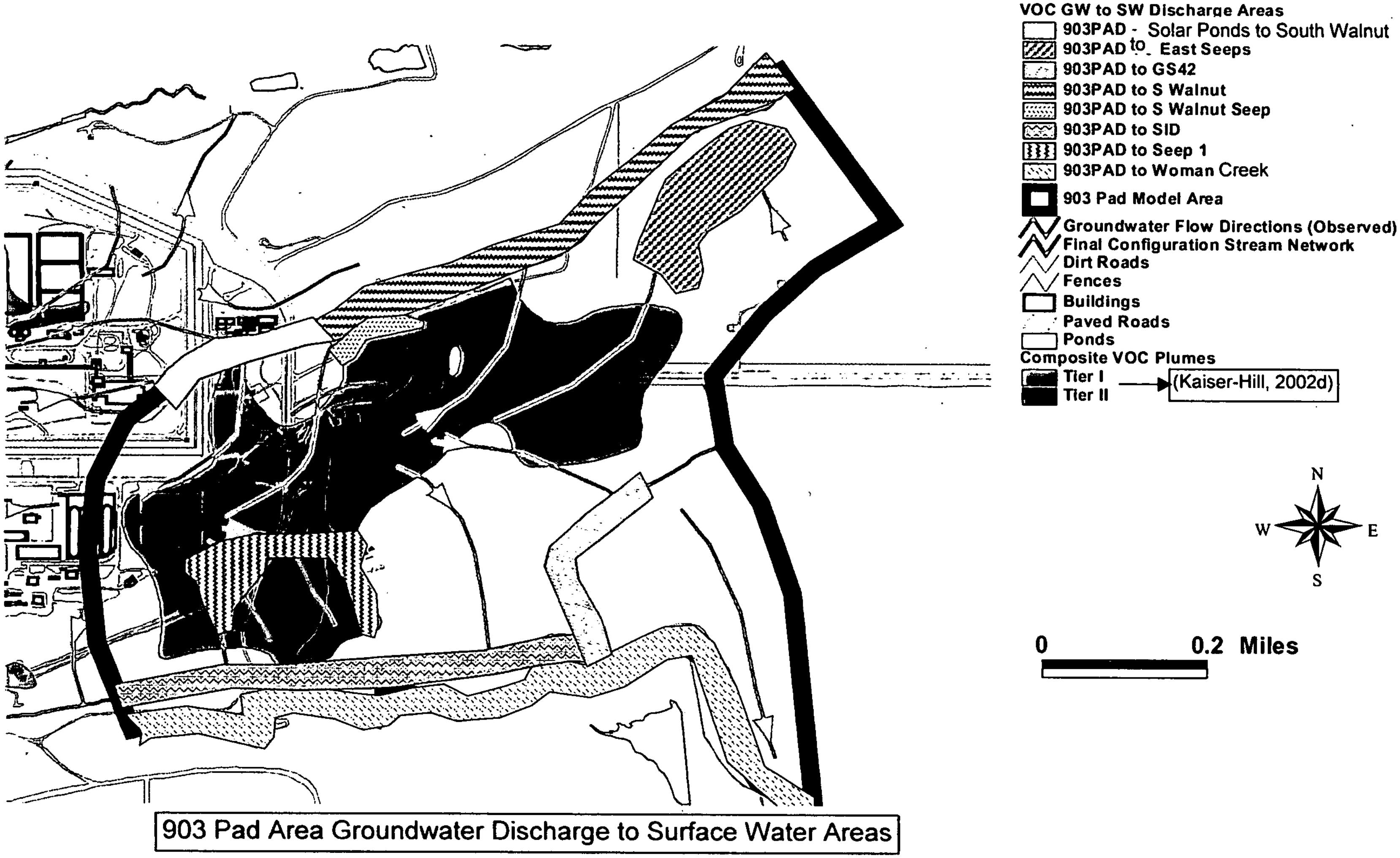


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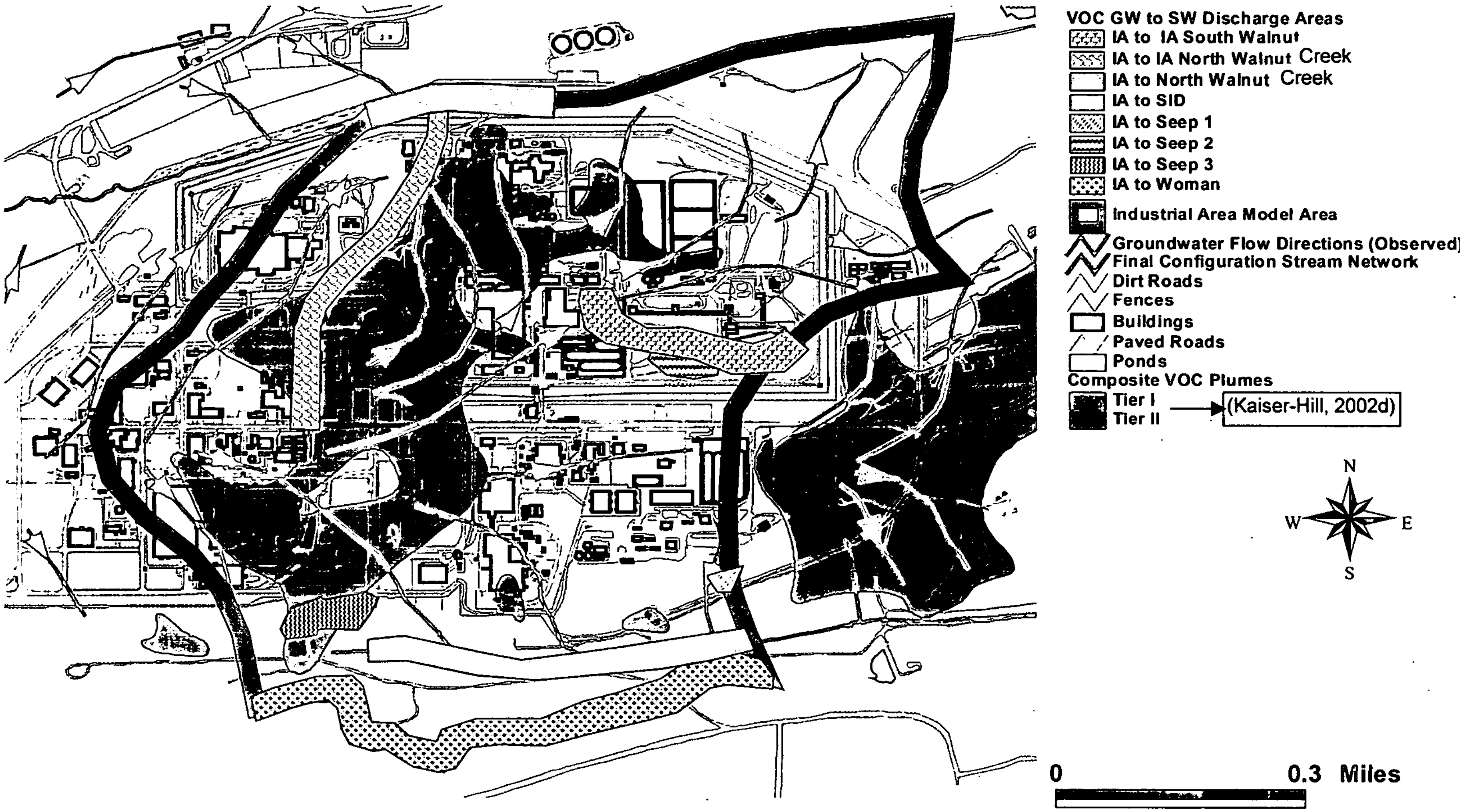
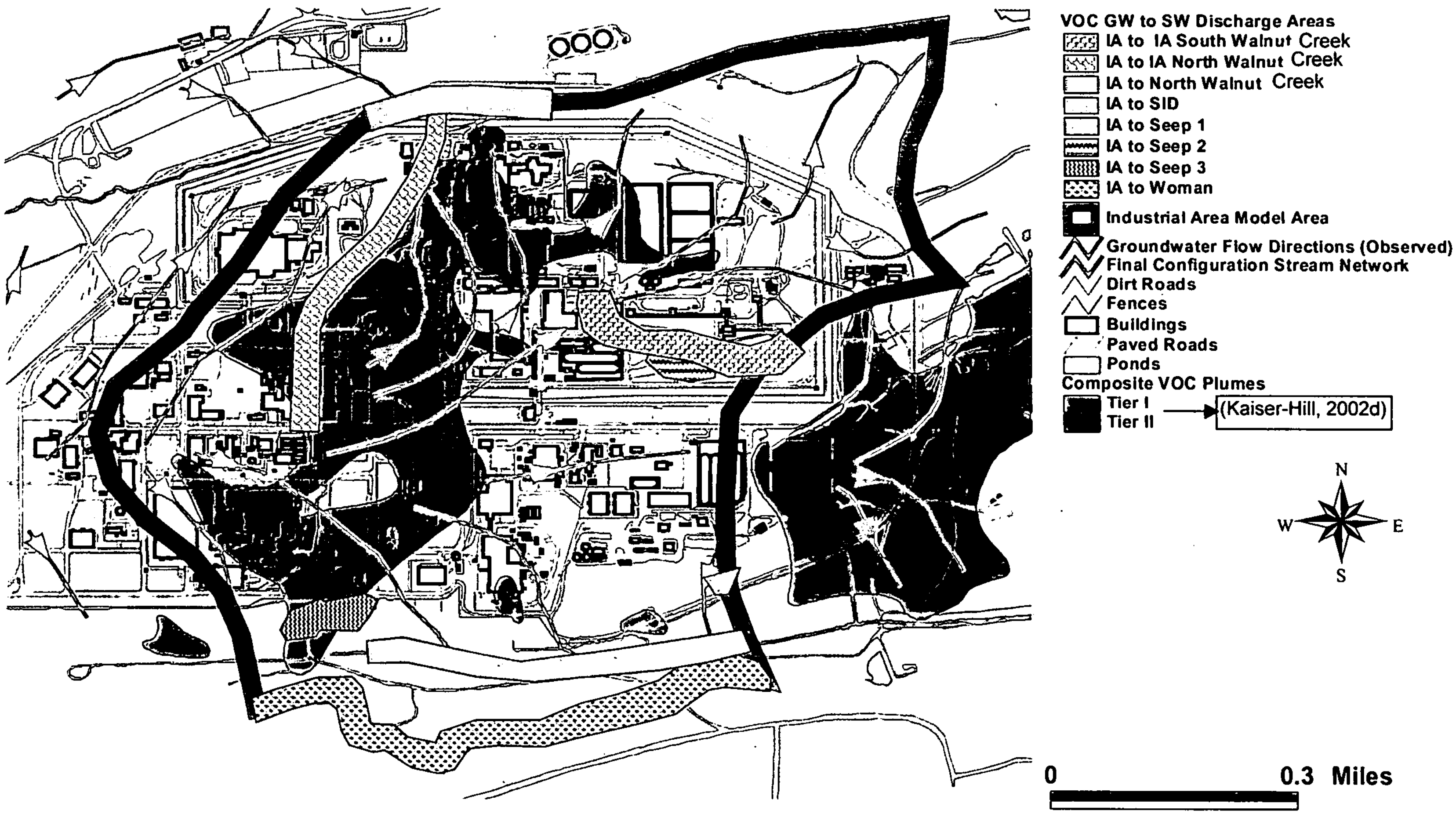
Figure 2-2b. Potential Discharge Points for Groundwater



IA Plume Area Groundwater Discharge to Surface Water Areas

Figure 2-2c. Potential Discharge Points for Groundwater



IA Plume Area Groundwater Discharge to Surface Water Areas

3.0 APPROACH

The approaches applied to complete each of the three tasks described in Section 1.1 are described below in Sections 3.1, 3.2, and 3.3.

3.1 Assessment of Subsurface Flow in VOC Plume Areas

As described in Section 1.1, Task 1 involved evaluation of SWWB model results and Site data to assess subsurface flow in the VOC plume areas. For the purposes of this task, a single Arcview project was developed in which a substantial amount of geologic, hydrologic, Site, and contaminant information were compiled. This Geographical Information System (GIS) database provided a useful way to organize, interpret, and plot available data to assess the hydrogeologic and contaminant information. Output from SWWB model simulations was also imported into this GIS database for interpretation. Specifically, applying this information, the following activities were completed:

- Evaluation of subsurface flow information regarding
    - Groundwater flow directions (including comparison with simulated flow),
    - Maximum annual level fluctuations,
    - Caliche,
    - Subsurface utilities, and
    - Unsaturated areas within the unconsolidated material; and
- Identification of primary hydrologic factors that affect groundwater flow within the VOC plume areas.

3.2 Evaluation of Remediation Designs

As described in Section 1.1, Task 2 involved evaluation of SWWB model results and simulations to assess the hydraulic effects of hypothetical slurry walls and trenches. To accomplish this, a sub-catchment scale IA model[5] was developed from the SWWB

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[5] The current site-wide model simulates system flow for the entire site. This is computationally inefficient and unnecessary for simulating local IA flow conditions (i.e., 14 hours to simulate a year). A local-scale model was developed, using appropriate boundary conditions to simulate flow conditions within the IA more efficiently. The IA model is based on the same hypothetical land configuration scenario input as specified in the SWWB model report. The model simulates flow conditions within the current VOC plume areas (not future extents) to evaluate the effects of installing slurry walls and interception trenches. This model simulates integrated hydrologic conditions within the IA much more efficiently than the site-wide model (i.e., one hour to simulate a year).

The IA sub-catchment model has 679 active cells (compared to 4,302 for the SWWB model). Appropriate boundary conditions were imposed on the boundary of this model area. For example, because the IA occurs mostly in a mesa and hillslope area, constant-head downgradient boundary conditions are used at stream locations and do not affect flows in the upgradient IA. Flow in all IA streamflow channels included in this model originate within the IA as a result of either surface runoff or baseflow. The WY2000 climate data is used as input to drive the system response.

model. Briefly, the IA sub-catchment model simulates a smaller area than the SWWB model, and as a result runs roughly 14 times faster.

The following three hypothetical simulations were conducted using the IA sub-catchment model:

- Slurry Wall in the Original Landfill Area;
- Three Interception Trenches within the VOC plume areas; and
- Two Interception Trenches within the VOC plume areas.

The primary purpose of the analyses in the Original Landfill Area was to determine the effectiveness of a hypothetical slurry wall combined with a hypothetical geotechnical ET cover to dewater the area containing waste material. The simulated impacts to flows and heads upgradient of the slurry wall were also evaluated to assess possible implications to the IA VOC plumes. The purpose of the second and third simulations was to evaluate the effects of two different interception trench systems on subsurface flow. Specifically, the magnitude and extent of hydraulic impacts of each trench were evaluated. The difference in water levels and groundwater flow arrows from a case without the trenches was used to assess the effects.

3.3 Additional Hypothetical Land Configuration Scenarios

To accomplish this task, the SWWB model was modified to simulate the four hypothetical scenarios listed in Section 1.1. The WY2000 climate was applied to all scenarios, with the exception of the 100-year event simulations. For the 100-year event, the precipitation input was developed from the Drainage and Flood Control Master Plan (EG&G, 1992). Details of assumptions made for each scenario are presented with the results in Section 4.3.

After setup and simulation of the scenarios, the modeling results were evaluated for the following:

- Changes in surface water discharge (quantity, sources, and flow rates);
- Changes in groundwater depth and groundwater level;
- Changes in Site-wide and local area water balances; and
- Changes to flow at *in situ* groundwater treatment/collection systems.

The 100-year event results were also evaluated for simulated flow rates at man-made routing structures such as dams and diversion.

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4.0 RESULTS

4.1 Assessment of Subsurface Flow in VOC Plume Areas

The results for Task 1 are presented in the following sections, subdivided into general subsurface flow results and factors to consider for VOC modeling. Data availability is discussed in the factors to consider section (Section 4.1.2)

4.1.1 General Subsurface Flow Findings

4.1.1.1 GW Flow Directions

Figure 4-1 through Figure 4-3 show a comparison of simulated and interpolated groundwater flow directions for the IA, 903 Pad Area, and Solar Ponds Area plumes, respectively. The simulated flow directions are from the SWWB model. The interpolated groundwater flow directions are based on an interpolated groundwater potentiometric surface from October 1999 data (observed data)[6]. Simulated flow arrows for the hypothetical land configuration scenario simulated in the SWWB modeling report are also included for comparison.

Results show little change between the calibrated year and the hypothetical land configuration scenario, except near areas strongly controlled by footing drains (i.e., building basements) and stream areas that were changed to accommodate the regraded surface topography. Hypothetical scenario flow arrows smoothly flow toward the stream locations within the IA, while the calibrated model flow arrows are directed locally toward footing drains as well as stream areas.

The flow magnitude also changes little as shown in the magnitude-sized flow arrows on Figure 4-1 through Figure 4-3. All hypothetical land configuration changes that lead to changes in groundwater flow should be evaluated in groundwater transport modeling to assess the effect on concentration time-series at surface water discharge areas.

Simulated flow directions for the calibrated model (WY2000 Site configuration conditions) should be similar to the observed data. This is expected because both are influenced by drains, topography, and other features that currently exist in the IA. However, as stated above, the observed flow directions are only approximate based on an interpolated potentiometric surface (of available groundwater level data).

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[6] Groundwater flow directions mostly reflect conditions within the unconsolidated material, but in some areas of the site, where groundwater levels fall into the weathered bedrock, flow directions represent weathered bedrock conditions. Seasonal changes in groundwater levels do not significantly change the flow directions based on review of quarterly water level data from July, 1999 through October, 2000. Therefore, the October, 1999 water level data are adequate for comparing against the simulated flow directions which are extracted from the model for late September.

Figure 4-1. Simulated and Interpolated Groundwater Flow Directions for the Industrial Area VOC Plume(s)

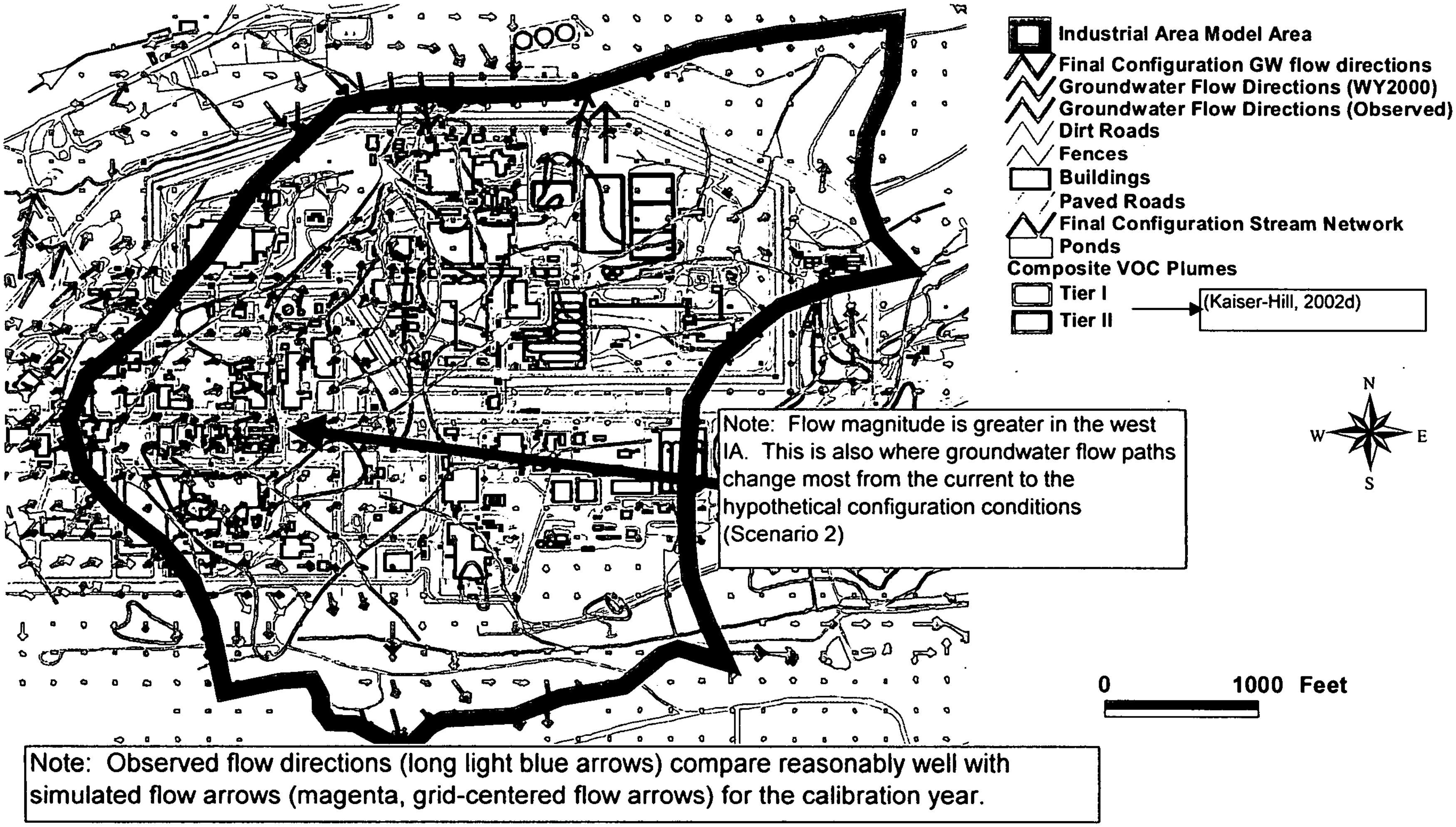
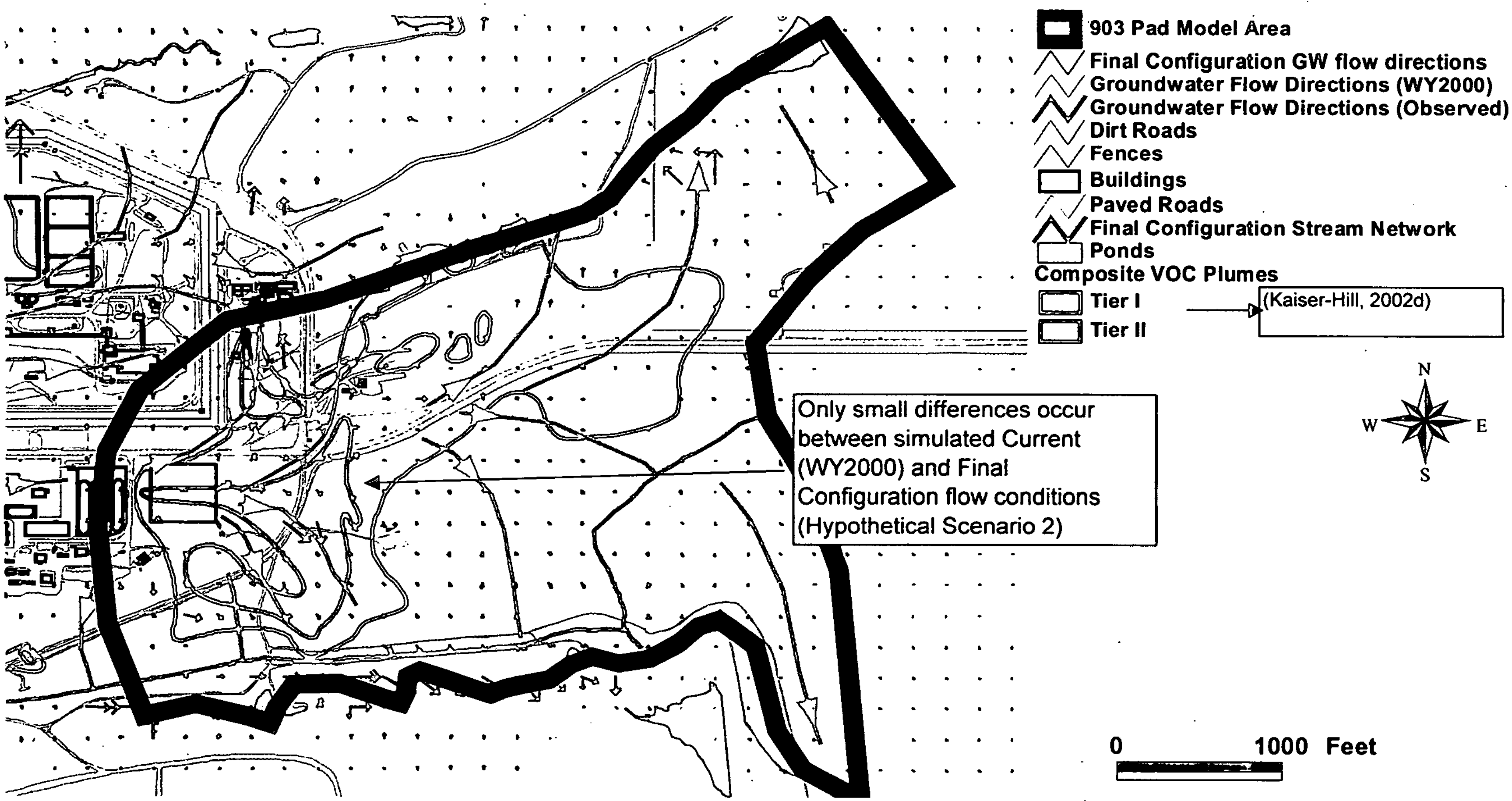


Figure 4-2. Simulated and Interpolated Groundwater Flow Directions for the 903 Pad Area VOC Plume(s)



Note: Observed flow directions (long blue arrows) compare reasonably well with simulated flow arrows (dark blue, grid-centered flow arrows) for the calibration year.

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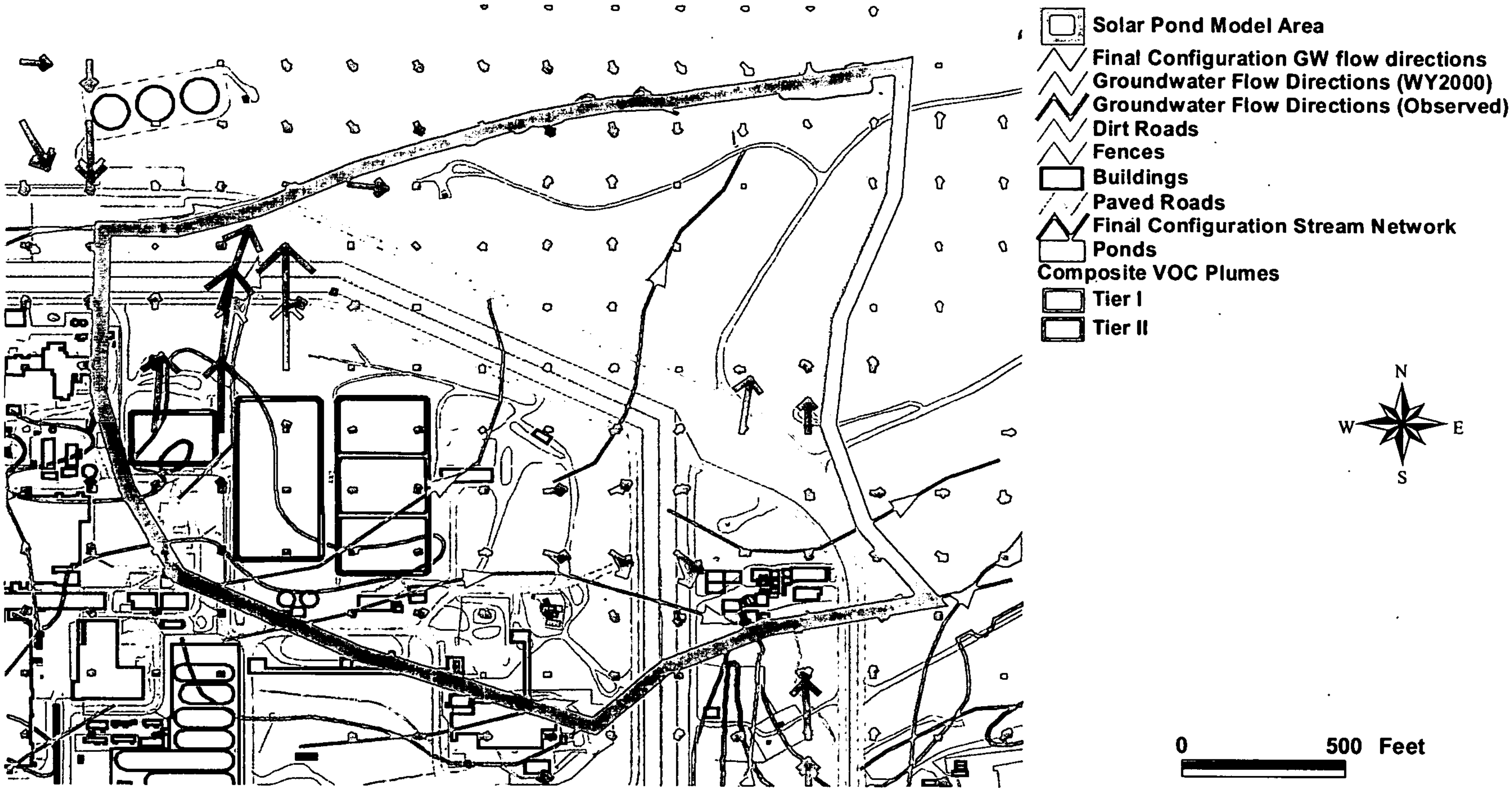
Figure 4-3. Simulated and Interpolated Groundwater Flow Directions for the Solar Ponds Area VOC Plume(s)



Note: Observed flow directions (long blue arrows) compare reasonably well with simulated flow arrows (dark blue, grid-centered flow arrows) for the calibration year.

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These flow directions and the potentiometric surface do not account for local groundwater level controls like the footing drains. As a result, the observed flow directions can only be compared to the general flow paths simulated by the model, which is limited in resolution to the grid scale (200- x 200-ft. [foot]).

In general, the simulated flow directions within each of the VOC plume areas compare well with observed flow directions (compare light blue observed to dark blue simulated flow directions for Figure 4-1 through Figure 4-3). However, when considering VOC transport, it is difficult to interpret plume migration directions from possible source areas using the composite VOC plume information[7] (Tier I and II iso-concentration lines). Individual VOC source areas and their plume extents should be determined using observed water level data. Still, it is recognized that the observed groundwater flow directions are less certain in areas with few wells and in areas with a high density of subsurface utilities.

Composite VOC plume extents (i.e., Tier II) generally appear to follow observed groundwater flow directions. Tier I contours, however, do not reflect the movement of higher concentrations from possible source areas. This is where the use of composite VOC plumes is misleading. When Tier I composite VOC contours are placed over the simulated calibration year groundwater flow directions, there appear to be inconsistencies in each VOC area. This further supports the need to clearly identify individual source areas and downgradient wells.

4.1.1.2 Maximum Annual Water Level Fluctuation

Another important factor to consider in simulating flow and transport of VOCs is the effect of seasonality on groundwater levels and velocities. Figure 4-4 illustrates areas within the VOC plumes which exhibit the highest seasonal variation in levels, as determined through simulations. Dark colors represent areas where the seasonal variation is highest (i.e., greater than 5 feet). It should be noted that the maximum change indicated may be greater than actually occurs because the change in levels was calculated using interpolated surfaces.

Hillslope areas experience the greatest fluctuations in groundwater levels because they are, in addition to recharge effects, subject to greater lateral drainage than the flatter mesa areas. Many of these mesas correspond to areas where water levels fall below the top of the weathered bedrock (i.e., unsaturated unconsolidated areas discussed in detail in Section 4.1.1.6). Within these areas, groundwater flow directions are subject to greater change because they also depend on weathered bedrock characteristics when water levels fall below the top of this bedrock surface (i.e., paleochannels, lower hydraulic conductivities etc.). This dynamic becomes important when simulating transport because the transport direction and velocity can, during certain seasons, be dominated by characteristics of the unconsolidated material, while in other periods, it is dominated by the weathered bedrock characteristics.

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[7] From 2001 RFCA Annual Groundwater Monitoring Report, Plate 13 (Kaiser-Hill, 2002d).

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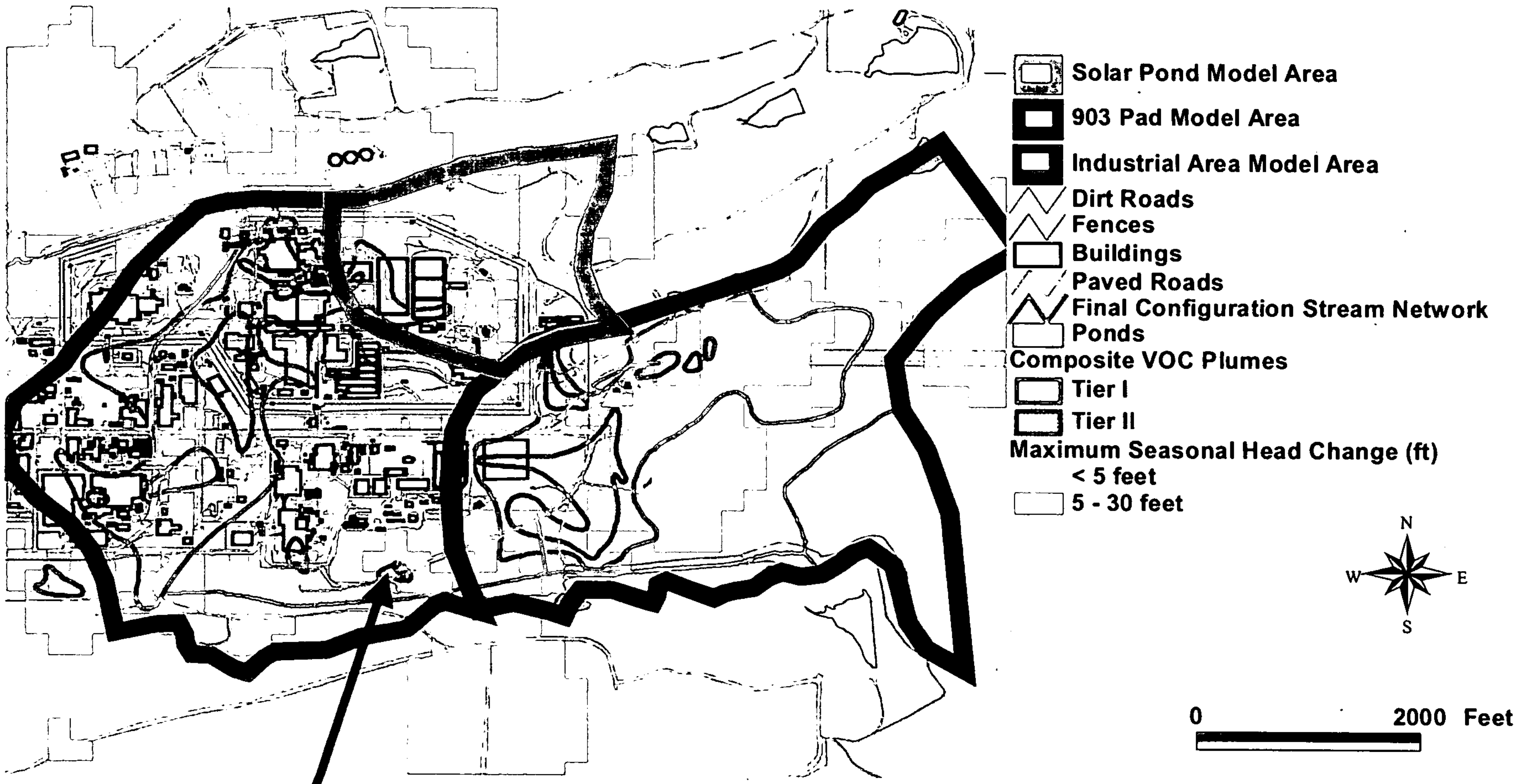
Figure 4-4. Maximum Annual Groundwater Level Change in VOC Plume Areas



Note: Areas of maximum head change throughout the year occur in hillslope areas. These areas are subject to higher lateral drainage (due to higher hydraulic gradients).

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Groundwater flows in southern-facing slopes are subject to higher actual ET rates due to higher incident solar radiation throughout the year (compared to horizontal or north facing slopes). Effects of slope and aspect were not accounted for in the SWWB modeling because of the scale of the model, though, equations are available to consider this effect. These may become more important for transport modeling in the southern and northern facing slopes within each of the primary VOC plume areas. The effect of high hillslope velocities is countered somewhat by the effect of lower saturated hydraulic conductivity values of the colluvium that typically blankets lower portion of the hillslopes.

4.1.1.3 Caliche

Another factor that may affect subsurface flow (unsaturated and saturated zones) is the presence of caliche. Caliche is a hard soil layer, cemented by calcium carbonate and found in deserts and other arid or semi-arid regions. A working map, produced in 1993 by EG&G, was obtained from Rob Smith (former Site geologist). Mr. Smith did not know the source of the map, but indicated that the map was the extent of any information on the presence of caliche at the Site. Figure 4-5 summarizes the distribution of the caliche throughout the Site based on available data at the time the map was prepared.

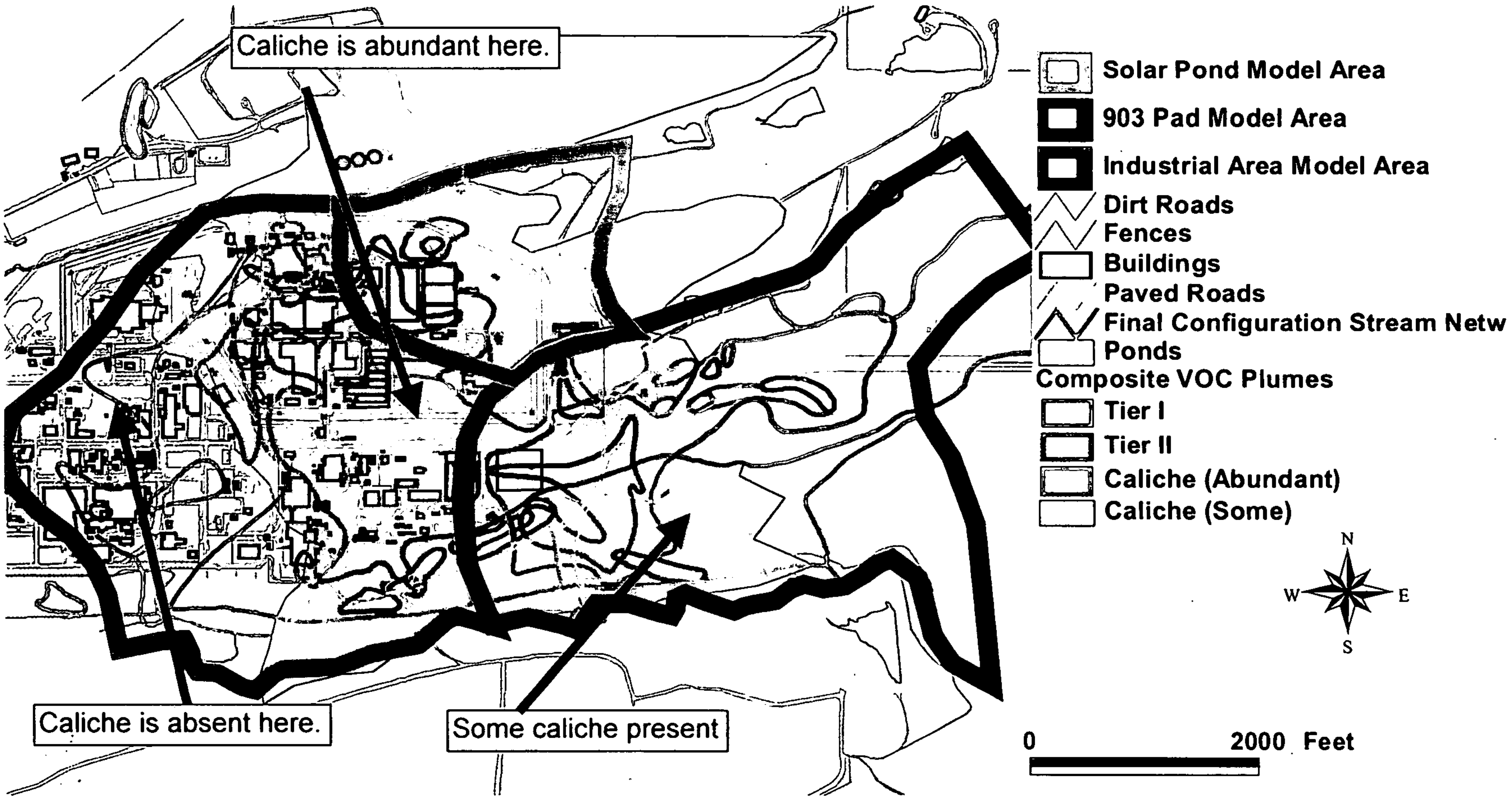
From Figure 4-5, it is clear that abundant caliche occurs within each of the VOC plume areas. The caliche layer may impact recharge rates and dynamics to the saturated zone. On a local-scale, caliche may even affect flow and transport modeling. Continuous groundwater level measurements will be reviewed in greater detail during local-scale flow and transport modeling to assess its importance.

If caliche is found to be an important parameter affecting local scale flow and transport, the model will account for this effect.

4.1.1.4 Subsurface Utilities

Figure 4-6 illustrates the spatial density of subsurface utilities throughout the plume areas. On a local scale, subsurface utilities may influence flow directions for future Site conditions as well as current conditions. Although it is assumed that the more significant piping utilities (i.e., storm and sanitary) will be foamed in contaminated areas, thus preventing groundwater from being exchanged with pipeflow, the utilities may not be fully excavated. Therefore, the more permeable backfill material of the utilities (compared to surrounding natural material) can still affect local flow paths if groundwater levels rise into the depth of the utilities. It should be noted that the highest density of utilities occurs within the central IA plume area. It is likely, however, that the decreasing depth of bedrock to the east is a more dominant factor controlling groundwater flow directions. It should also be noted that historical development (installation) of utilities affected groundwater flow paths and contaminant transport. This will be considered in development and calibration of the groundwater flow and transport model.

Figure 4-5. Distribution of Caliche (Based on Limited Available Information)



4.1.1.5 Subsurface Utilities

Figure 4-6 illustrates the spatial density of subsurface utilities throughout the plume areas. On a local scale, subsurface utilities may influence flow directions for future Site conditions as well as current conditions. Although it is assumed that the more significant piping utilities (i.e., storm and sanitary) will be foamed in contaminated areas, thus preventing groundwater from being exchanged with pipeflow, the utilities may not be fully excavated. Therefore, the more permeable backfill material of the utilities (compared to surrounding natural material) can still affect local flow paths if groundwater levels rise into the depth of the utilities. It should be noted that the highest density of utilities occurs within the central IA plume area. It is likely, however, that the decreasing depth of bedrock to the east is a more dominant factor controlling groundwater flow directions. It should also be noted that historical development (installation) of utilities affected groundwater flow paths and contaminant transport. This will be considered in development and calibration of the groundwater flow and transport model.

4.1.1.6 Unsaturated Areas within the Unconsolidated Material

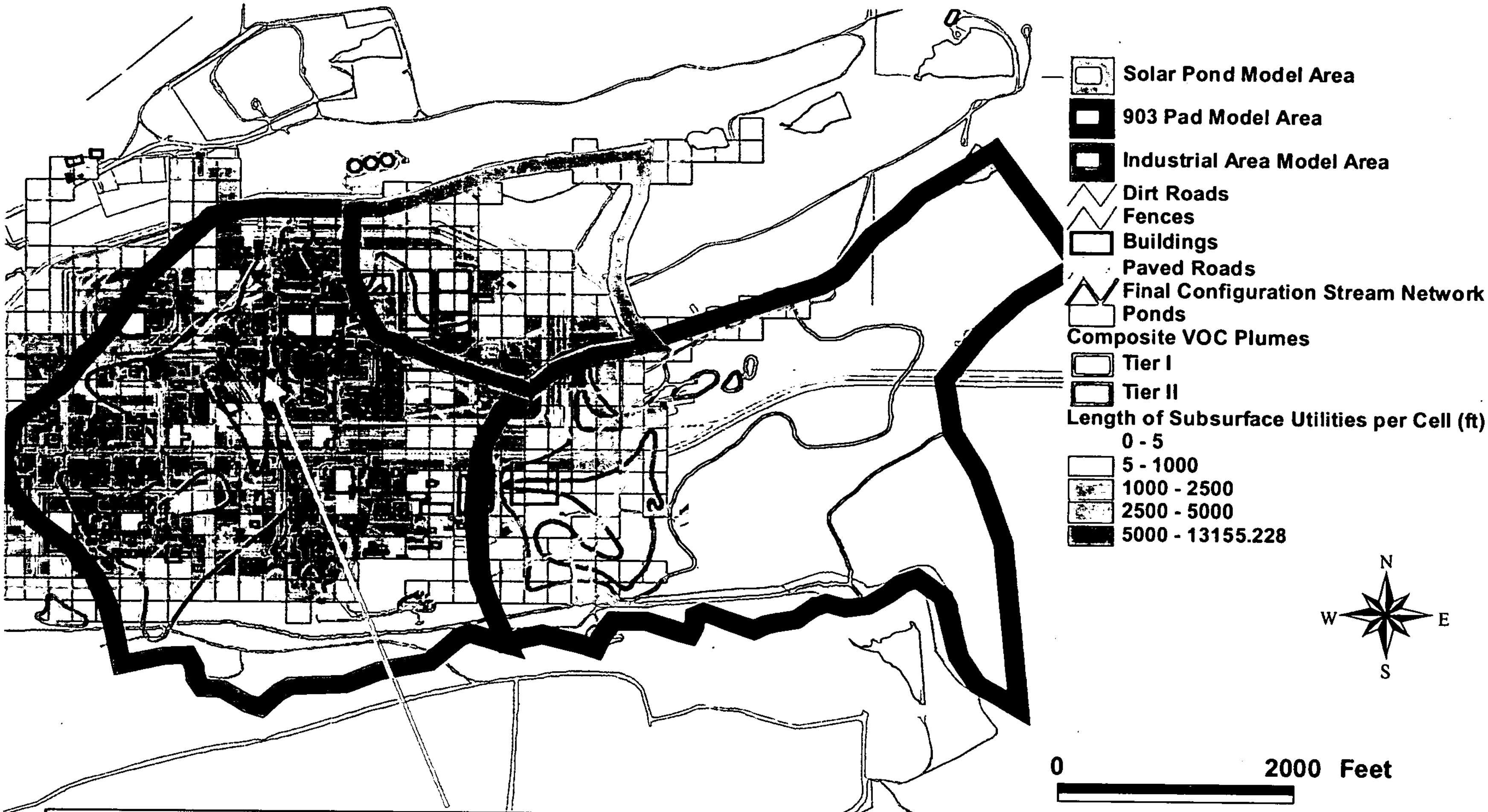
When considering the factors that affect development of the VOC plumes from their sources, it is informative to show areas where unsaturated conditions occur. Unsaturated areas of the unconsolidated materials within the VOC plume areas (based on available observed data for April, 2000) are shown on Figure 4-7. These areas change throughout the year, increasing in extent during non-recharge periods (i.e., summer) when water levels decline. Unsaturated areas do not tend to occur within the IA VOC plumes, but are prevalent within the Solar Ponds area and 903 Pad area plumes because of the higher percentage of hillslope areas and occurrence of Arapahoe Sandstone lenses.

Unsaturated unconsolidated material areas are significant, recognizing the lower permeability of weathered bedrock as compared to the unconsolidated material (where Arapahoe Sandstone Lenses are not present). When flows fall below the bottom of the unconsolidated material, groundwater velocities decrease rapidly, whereas when the levels are within the unconsolidated material, flow rates are higher. Where Arapahoe Sandstone Lenses are present and continuous as in the 903 Pad area plumes, flows are dominated by the shape and outcrop location of the sandstone bodies. As such, it will be important to simulate the occurrence of such unsaturated areas for each of the VOC plume areas. The dispersion of VOC contaminants may also be affected by the seasonal changes in unsaturated zone conditions and will be considered in the modeling.

4.1.2 Factors to Consider for VOC Transport Modeling

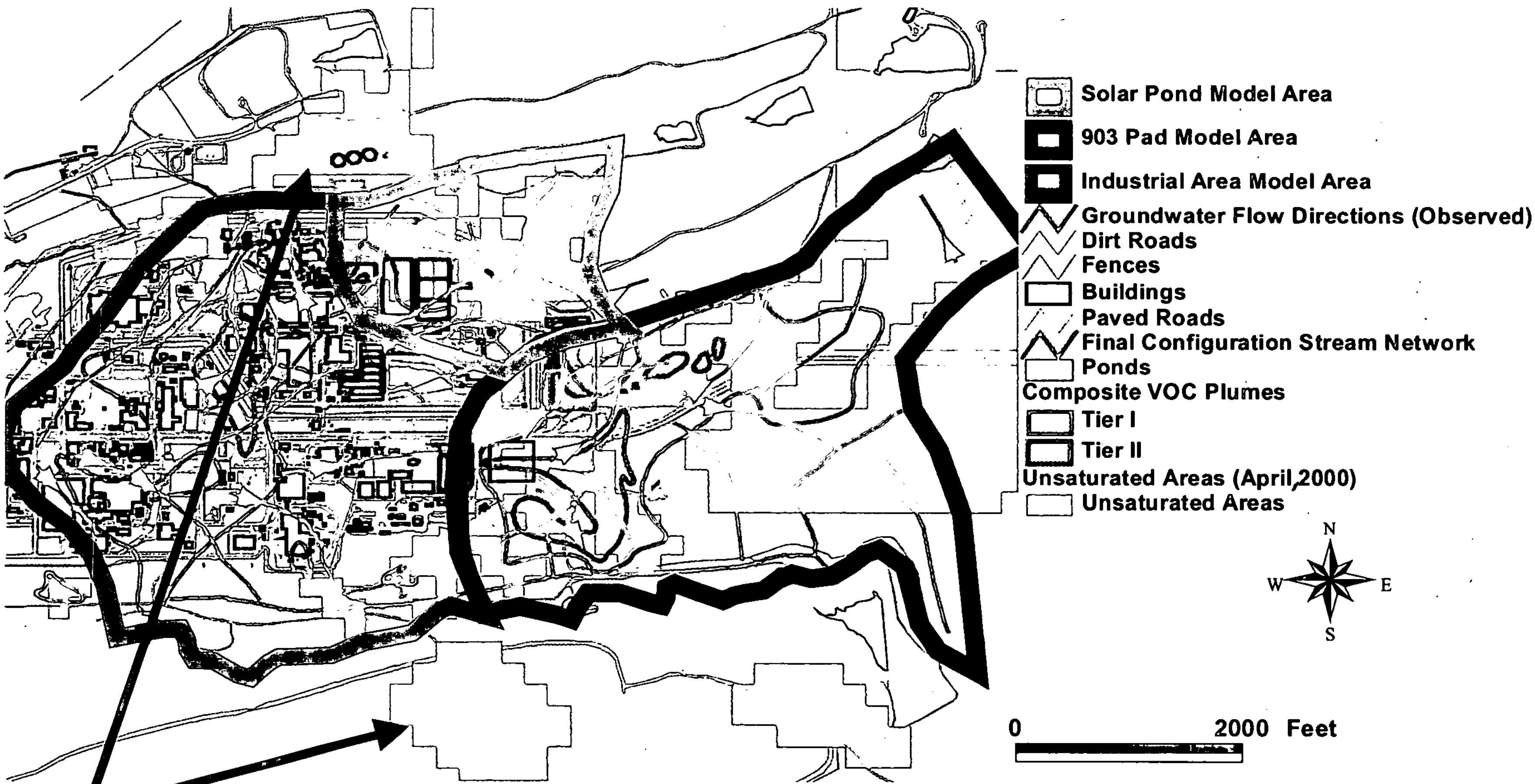
The SWWB model, developed as an integrated hydrologic model, will be used as the starting framework for the VOC modeling. To achieve this, significant modifications to the SWWB model will be made, including grid resolution and boundary changes.

Figure 4-6. Spatial Density of Subsurface Utilities in VOC Plume Areas



Utility density is highest in the IA plume area. Only the very western portion of the 903 Pad plumes area has utilities, while only the mesa area within the Solar Pond plume area has utilities.

Figure 4-7. Unsaturated Areas of the Unconsolidated Material in the VOC Plume Areas



Note: Gray areas indicate unsaturated unconsolidated material (i.e., water table is within the bedrock material).

The following list presents items to be considered carefully for VOC modeling at the Site, based on the Site hydrology and the SWWB model settings. Each item is discussed in terms of influence on groundwater flow and transport. In particular, items are discussed as they relate to the complexity of simulating VOC transport on a local scale.

Data availability and needs are described in general terms. Identification of specific data needs for VOC transport modeling cannot be completed until a more thorough evaluation of the available data is performed.

4.1.2.1 Groundwater Levels

Accurate simulation of groundwater levels is essential for contaminant transport modeling. Figure 4-8 (a, b, and c) summarizes the available well data for the April, 2000 quarter, which represents the most comprehensive set of groundwater level data collected. Data shown include both quarterly monitoring data as well as continuously-monitored well data (nearly 40 locations).

The quantity in each of the VOC plume areas appears adequate for modeling. However, it should be recognized that effects of localized controls (i.e., footing drains etc.) on groundwater levels in the shallow and thin unconsolidated aquifer flow system make it difficult to accurately define groundwater levels near these controls with the available dataset. Near-stream areas are probably most important for calibrating seasonal groundwater discharge response within each VOC plume area. More data could be collected to assess seasonal dynamics in these areas.

It should also be noted that the lack of groundwater level data for early Site operations through the 1980s will confound efforts to simulate plume development (i.e., calibration of the model).

4.1.2.2 Bedrock Surface

Correctly specifying the bedrock surface is critical to simulating accurate groundwater flow directions. This surface is, at a regional scale, strongly correlated to ground surface topography and to the unweathered/weathered bedrock surface. The reason for the strong influence of the unconsolidated material/weathered bedrock surface on the groundwater flow directions is the contrast between hydraulic conductivities of the two materials. The majority of flow occurs within the unconsolidated material with its much higher hydraulic conductivity.

Locations of geologic data (as of January, 2001) are presented in Figure 4-9 (a, b, and c). The IA and Solar Ponds area plumes contain many geologic data points as shown on Figure 4-9 (a, b, and c). However, the 903 Pad area suffers somewhat from a lack of data in the east and southeast areas. As a result, the interpolated bedrock surfaces in these areas are more uncertain than other plume areas with more surface control points.

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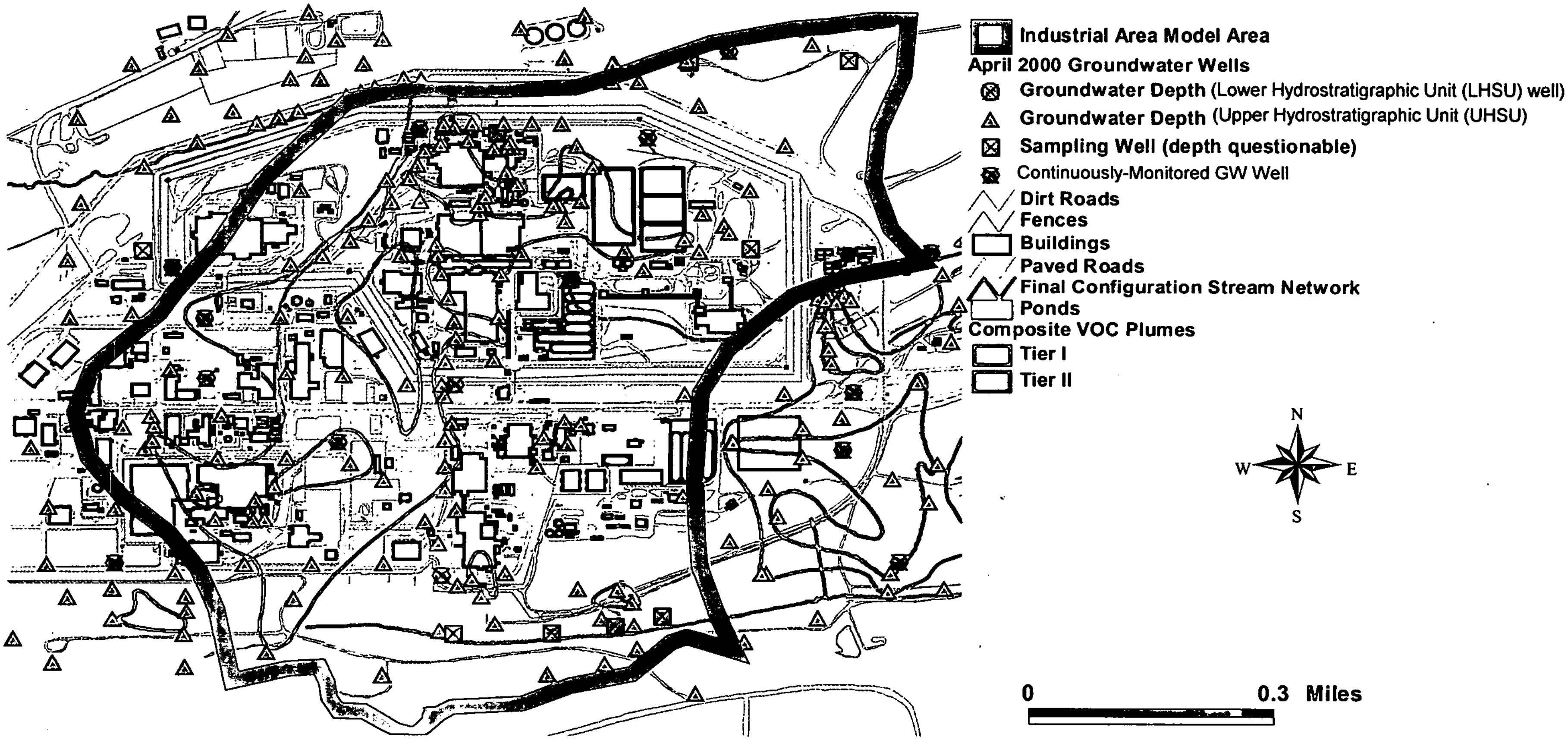
Figure 4-8a. Locations of Groundwater Level Data for April 2000



IA Plume Area - Groundwater Water Level Data Locations

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Figure 4-8b. Locations of Groundwater Level Data for April 2000

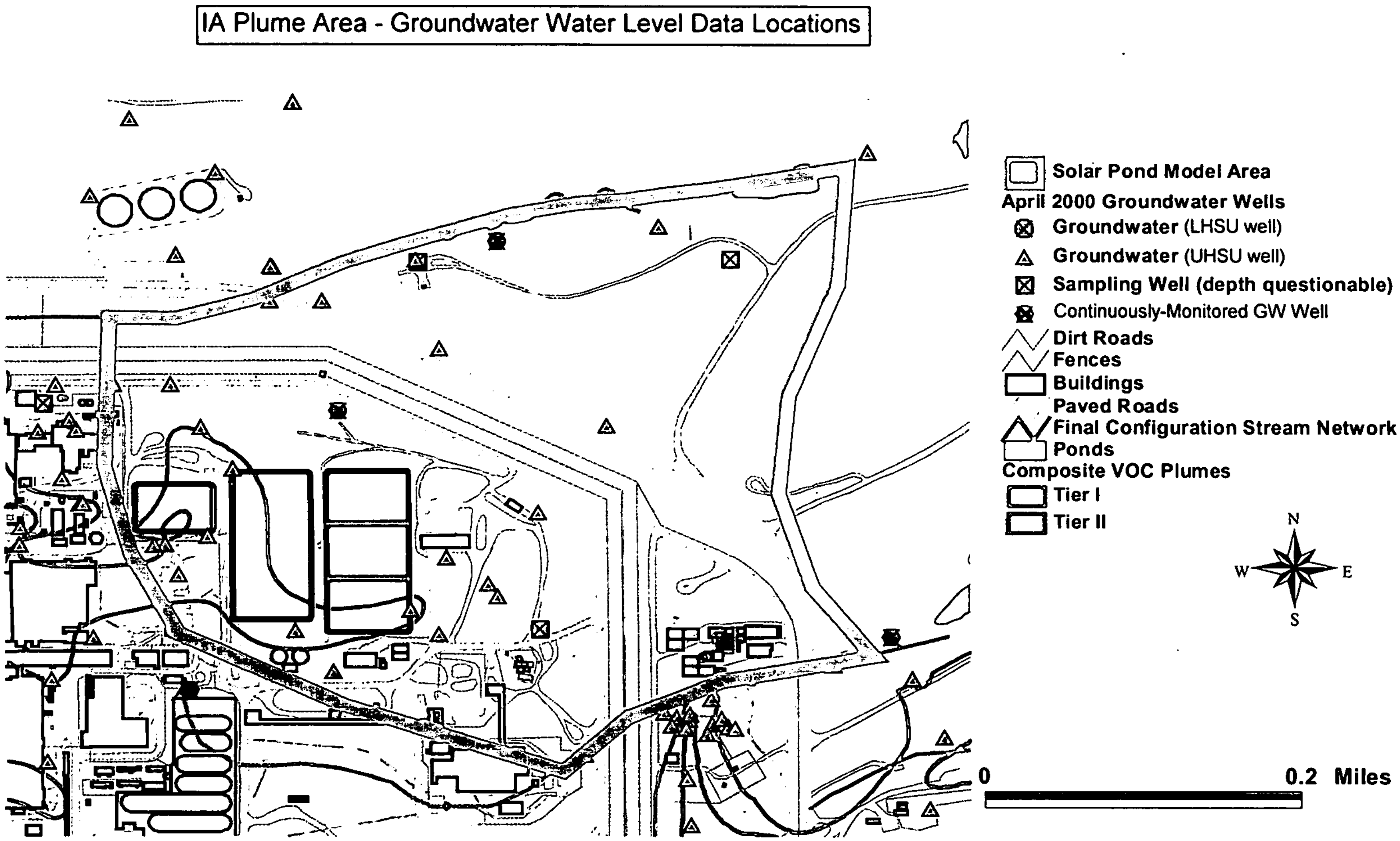
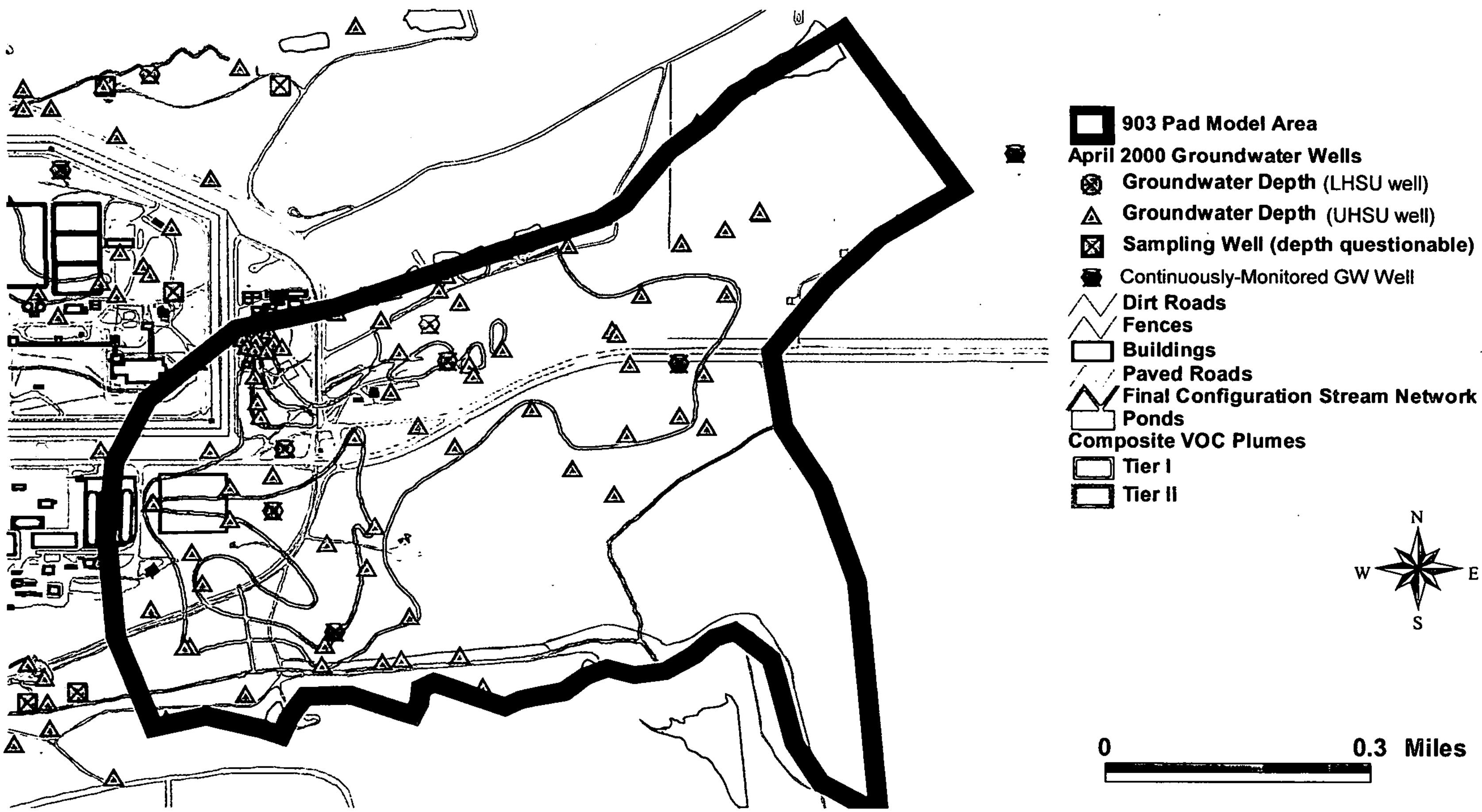
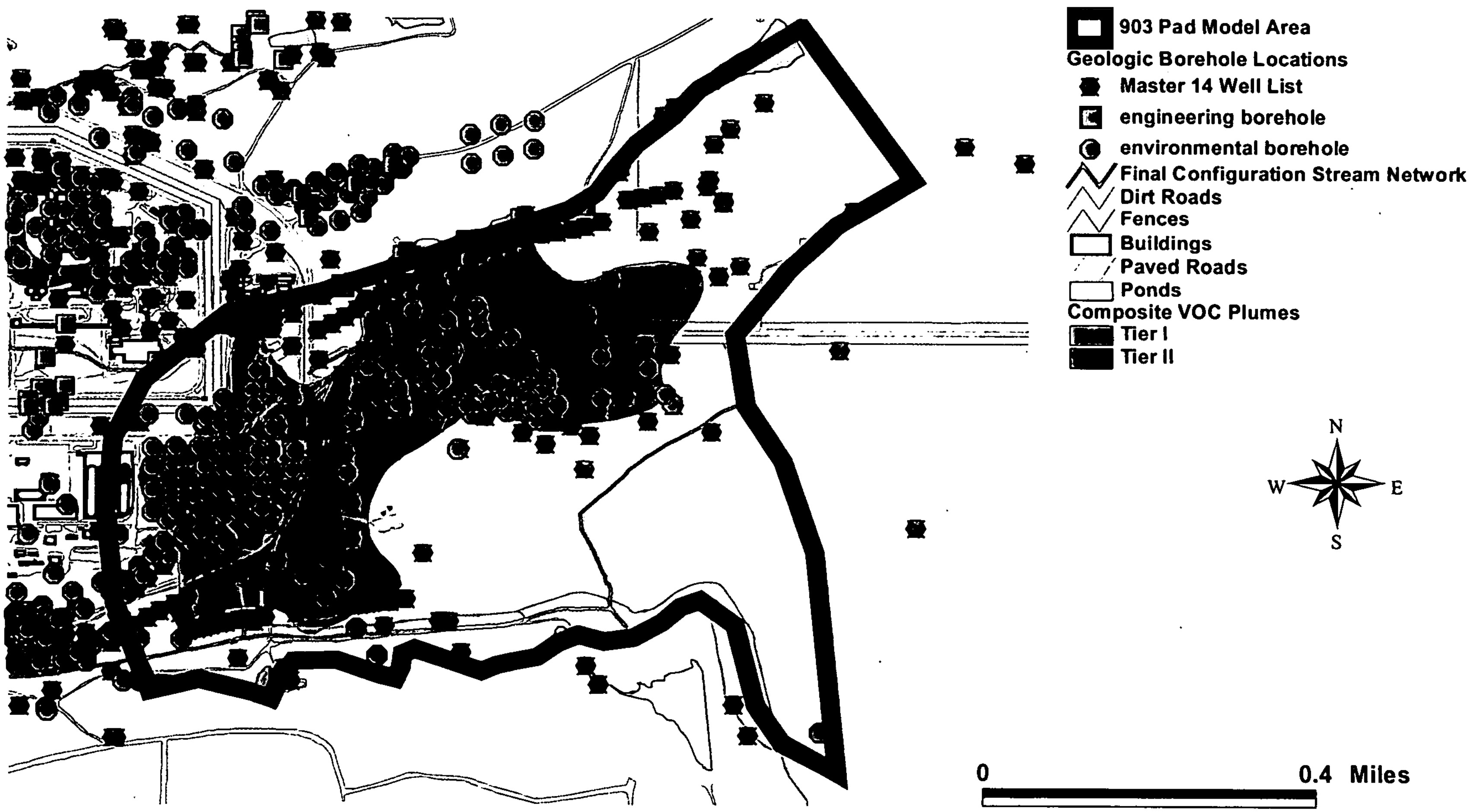


Figure 4-8c. Locations of Groundwater Level Data for April 2000



903 Pad Plume Area - Groundwater Water Level Data Locations

Figure 4-9a. Locations of Geologic Data



903 Pad Plume Area - Geologic Borehole Information

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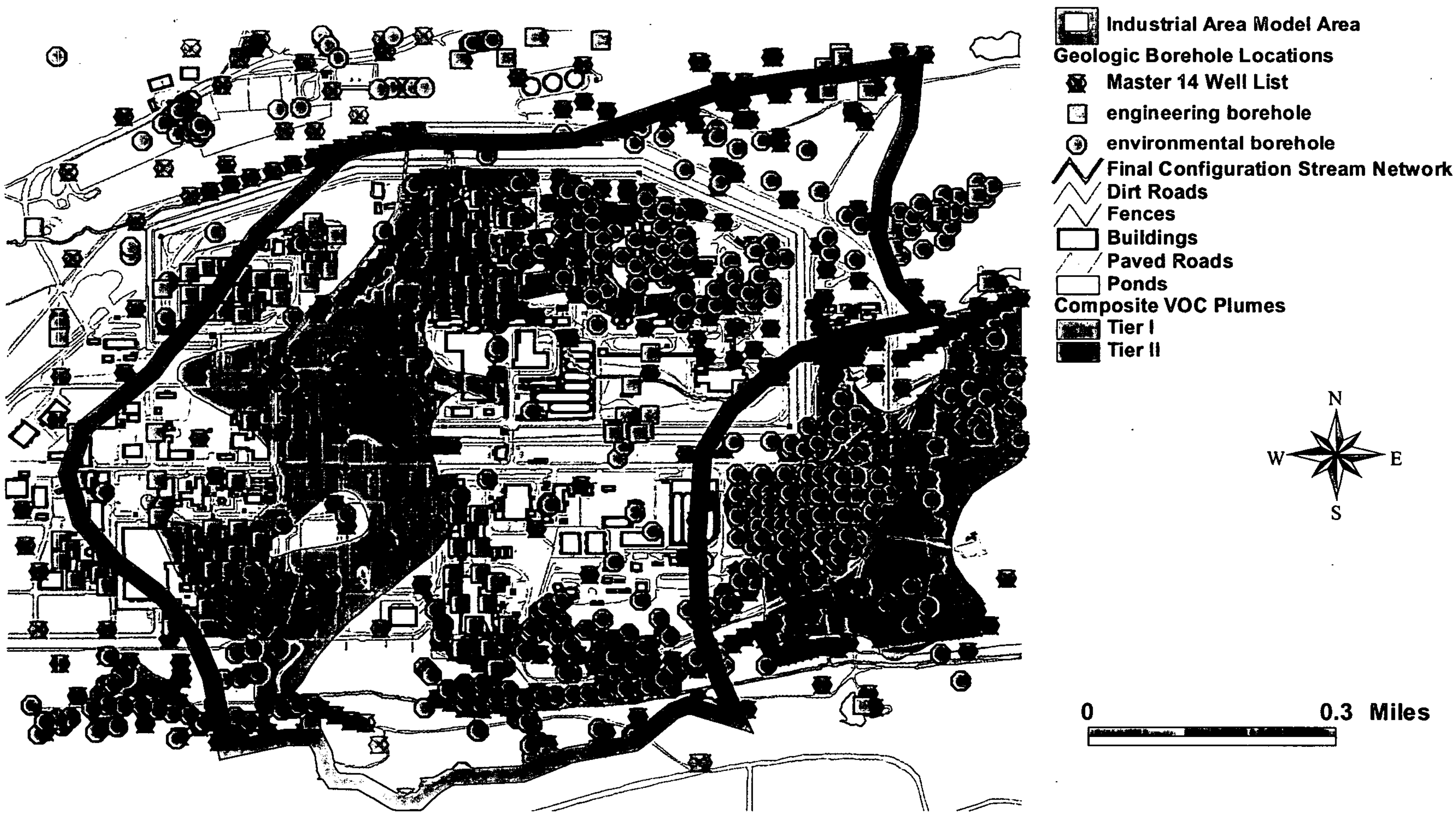
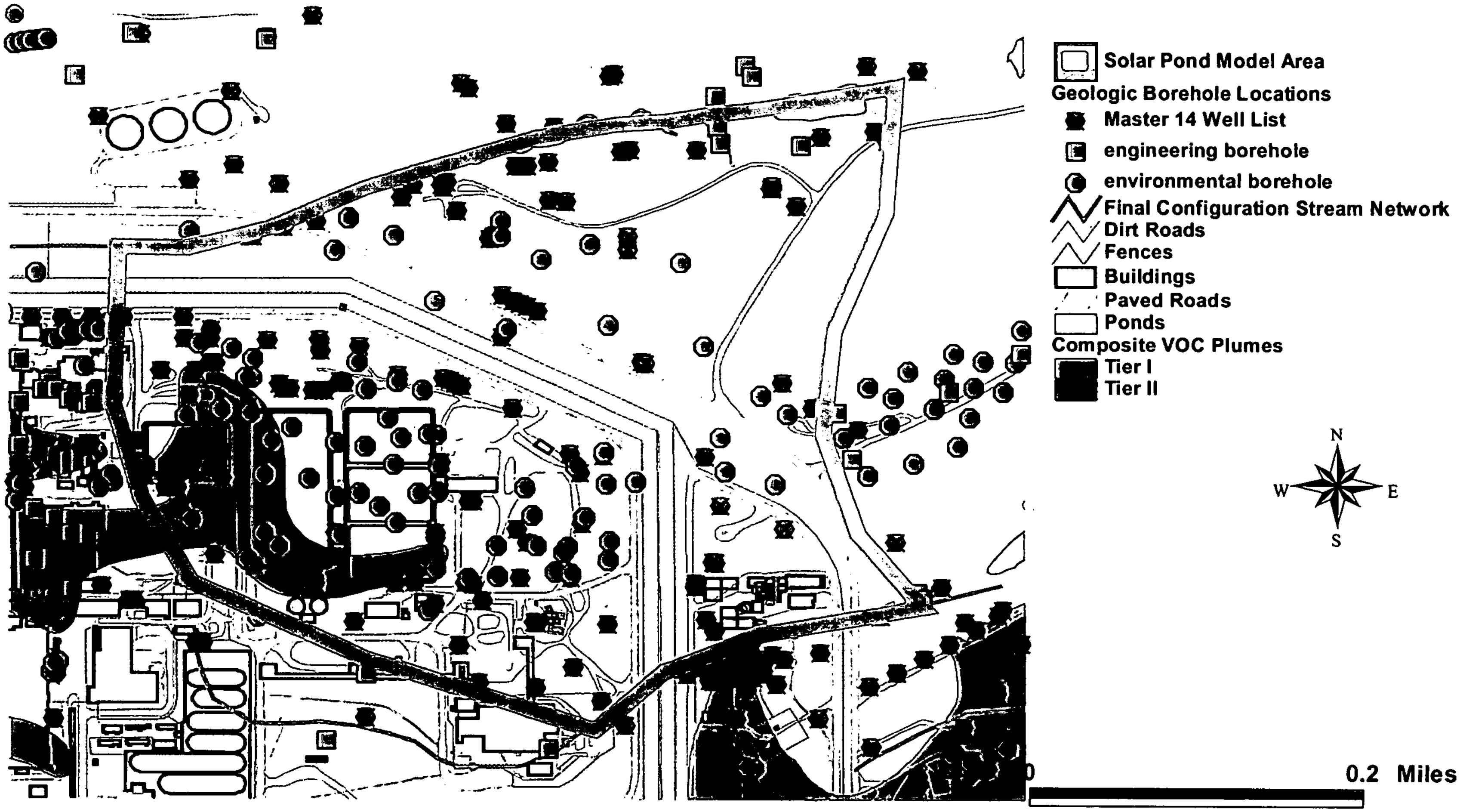
Figure 4-9b. Locations of Geologic Data



IA Plume Area - Geologic Borehole Information

Figure 4-9c. Locations of Geologic Data



Solar Ponds Plume Area - Geologic Borehole Information

The interpolated weathered bedrock surface, prepared for the SWWB model, is presented in Figure 4-10. The bedrock surface is particularly important in the 903 Pad area plumes because flow from the 903 Pad location is largely divergent. The 903 Pad area divergence is consistent with the bedrock surface, and is also influenced by the unsaturated zone.

The weathered bedrock surface is also important in locations like the IA plumes where it becomes shallow (i.e., less than 5 feet from the ground surface). In these areas, groundwater levels often occur within the weathered bedrock, causing unsaturated conditions to occur. This is important in contaminant transport; where the groundwater flowing in the higher permeability unconsolidated materials encounters unsaturated conditions, its lateral flow rates are rapidly reduced. This occurs, for example, in the east-central part of the IA plumes, where the higher Tier I level concentrations appear to head either north or south. This divergence of flow is likely caused by the shallow bedrock to the east of this area rather than by the high density of utility trenches.

Though the bedrock surface plays an important role in VOC transport on a regional scale, the factors discussed below become more important at a local scale.

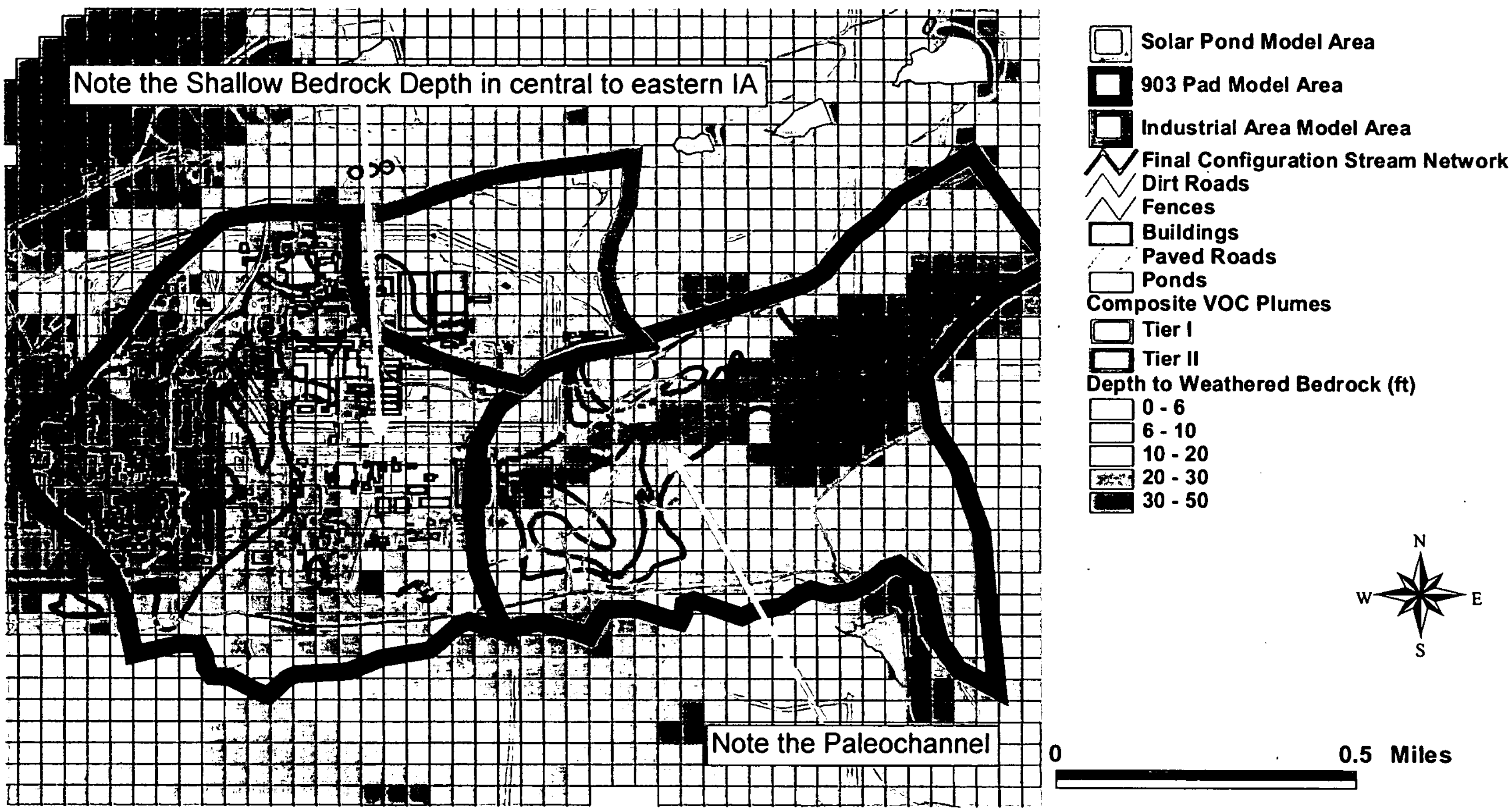
4.1.2.3 ET

The input Potential Evapotranspiration (PET) values can be bracketed fairly well. Vegetation-specific parameters are more difficult to bracket. These parameters are used in the model to control the time-variation in plant water uptake characteristics. These parameters (e.g., Leak Area Index, Root Depth Function, Interception, etc.) can strongly affect the unsaturated zone water balance. Simulations of the IA show that groundwater is strongly influenced by these factors. Vegetation characteristics will lay a more important role in ground water levels in areas of shallow groundwater. Therefore, these vegetation parameters must be calibrated well.

4.1.2.4 Basements

In the SWWB model for the current Site configuration, basements affect flows only by their footing drains. For hypothetical future scenario conditions, the model simulates basements as flow barriers to lateral groundwater flow. At a local scale, vertical walls left in place will impede lateral movement of groundwater and will likely cause groundwater levels to increase slightly in these areas. Of the VOC plume areas evaluated here, basements should only affect flows in the IA plumes. Horizontal slabs left in place will reduce vertical flows between fill material placed within former building basements and material outside of the basement walls. The net effect will be to cause local groundwater to flow beneath the basement slabs. The degree to which water levels will rise within basements will depend on the leakage coefficients and ET parameters specified in the model for these areas. Historical construction of buildings and basements will also need to be considered in development and calibration of the model.

Figure 4-10. Depth to Weathered Bedrock Surface



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4.1.2.5 Utilities

Although the SWWB model simulates effects of subsurface utilities on flows, at a local scale the coarse resolution of the model is of limited accuracy. As a result many of the local scale flow effects due to utilities are not accounted for in the SWWB model. Finer resolution flow models should more accurately account for such features and their effects on groundwater flow and transport. Historical installation and removal of utilities will also need to be considered in development and calibration of the model.

4.1.2.6 Streams

Streams should only affect groundwater flow and VOC transport within the IA VOC plumes. The upper reach of North Walnut Creek extends into the center of this plume area, but other plumes areas do not include major surface channels. This is a significant feature that must be accounted for in any model developed for this area. Historical modification of stream channels will also need to be considered in development and calibration of the model.

4.1.2.7 Precipitation

Adequate simulation of historical precipitation will be important for correct simulation of recharge and subsequent effects on plume migration. In other words, significant differences in annual recharge across the Site could affect groundwater flow directions and possibly transport. This is a key factor in determining the overall timestep for the transport simulations over a long time-period (i.e., 40 years).

It should also be noted that limited climate data for early Site operations through the 1980s will confound efforts to simulate plume development (i.e., calibration of the model). Daily precipitation records have been compiled from Site data sets; however, in general, the most of the climate data lacks the spatial and temporal resolution applied to develop the SWWB model.

4.1.2.8 Saturated Zone Hydraulic Conductivity

This parameter is significant as demonstrated in the sensitivity analyses summarized in the SWWB Modeling Report (Kaiser-Hill, 2002b). Increasing the range of conductivities by a factor of 10 in the unconsolidated material resulted in notable changes in groundwater flow directions and magnitudes. Higher conductivity values would likely make the bedrock surface a more dominant factor controlling flow directions. Current plume extents from source areas suggest that the conductivity values, despite being lower than available mean lab/field values, are probably reasonable. In other words, the velocities calculated based on source dates, gradients and model conductivity values are similar to model-derived velocities in source areas.

4.1.2.9 Storage

Groundwater storage could be more variable than assumed in the SWWB model (i.e., constant specific yield of 0.1 for unconsolidated material). Storage coefficients affect the rate at which groundwater levels change. As a result, they are used to calibrate the seasonal groundwater level response, but are constrained by their effect on the total amount of water stored in the saturated zone.

4.1.2.10 Arapahoe Sandstone

Figure 4-11 (a and b) shows the occurrence, thickness, and subcropping areas of the Arapahoe Sandstone, based on information from January, 2001. Although the Arapahoe Sandstone apparently occurs within each of the primary VOC plume areas, it only subcrops within the 903 Pad and Solar Ponds area plumes. As a result, these two areas will likely be more influenced by the existence of these subcropping sandstones than within the IA plumes (i.e., embedded sandstone has less effect than subcropping sandstone). This may be important to consider, as contaminants will flow more rapidly through these units of higher hydraulic conductivity, if saturated. The increased thickness, extension of the sandstone and groundwater level fluctuations and directions within the 903 Pad area plumes suggest that the Arapahoe Sandstone Formation is probably a dominant factor controlling the hydrology in this area compared to the other plume areas.

4.1.2.11 Faults

On-Site, fault locations have only been inferred, and not specifically studied or mapped. With little information, it is not yet clear whether faults influence VOC transport at the Site.

Any significant effects of faults on transport should be apparent with the detailed analysis of VOC data at the Site. For example, the spatial distribution of observed contamination should reflect the presence of any inferred fault with a significant effect on transport. Any such observations will be documented and considered in the modeling process. Recommendations for additional data collection may also be proposed.

The hydraulic effect of the inferred faults would be difficult to simulate numerically for the transport model because faults are thin compared to model cells; a specialized code would be required.

4.1.2.12 Unsaturated Zone Heterogeneity

Vertical heterogeneity within the unsaturated zone column may impact the vertical unsaturated/ET dynamics and resulting recharge to the saturated zone. The unsaturated zone was simulated in the SWWB model as a uniform medium. However, there are indications that vertical heterogeneity occurs (i.e., caliche – see Section 4.1.1.3).

Figure 4-11a. Occurrence, Thickness, and Outcropping of Arapahoe Sandstones

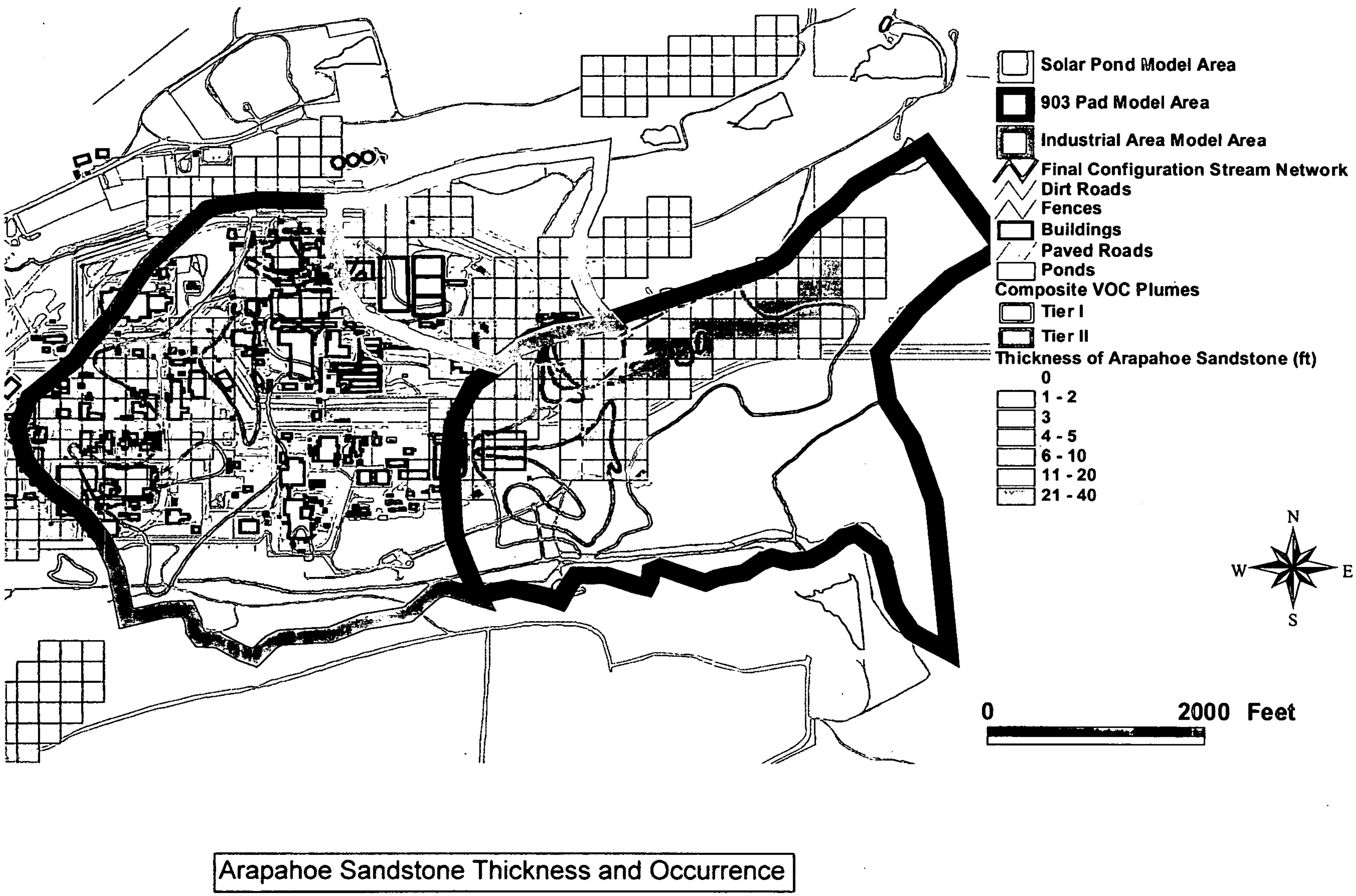
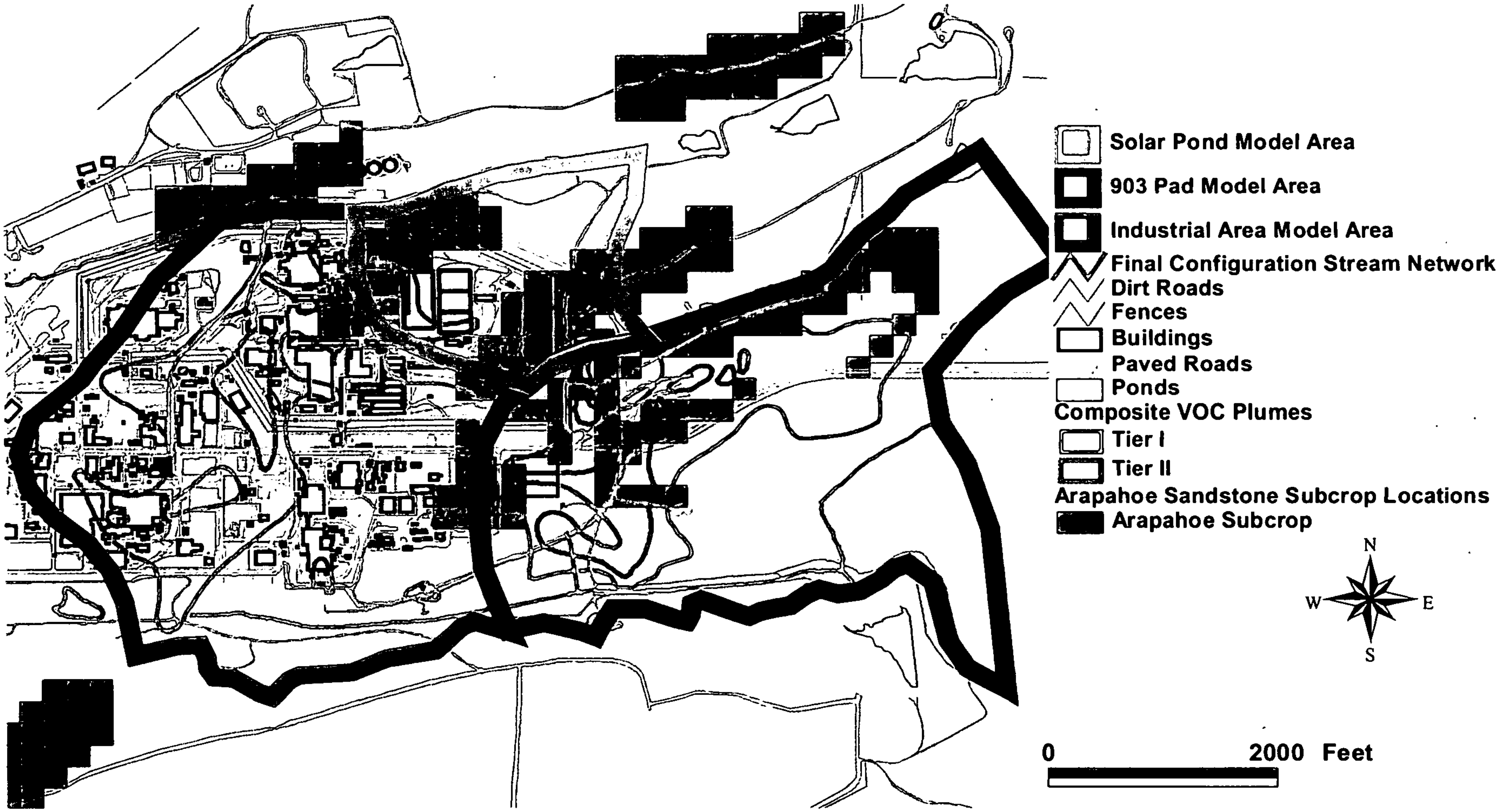


Figure 4-11b. Occurrence, Thickness, and Outcropping of Arapahoe Sandstones



Arapahoe Sandstone Subcrop Locations

4.1.2.13 Historical Site Development

From the time of a contaminant release into the system (particularly for early releases), significant historical Site development may have occurred. This development could influence recharge and drainage for groundwater. Therefore, this factor must be considered as contaminant transport is simulated from release time to present distribution.

4.2 Evaluation of Hypothetical Remedial Designs

This section presents the results of the preliminary evaluation of hypothetical remedial designs, including slurry walls and interception trenches. The first section presents the evaluation of a proposed hypothetical slurry wall in the Original Landfill Area. The second section presents the simulated effects of two test cases for hypothetical interceptor trenches in the IA.

4.2.1 Hypothetical Original Landfill Area Slurry Wall

A hypothetical slurry wall in the Original Landfill Area on the south hillside of the IA was simulated to evaluate its effect on the subsurface hydrology of the area. Two hypothetical scenarios were simulated. In the first, a hypothetical slurry wall is simulated in combination with a hypothetical ET geotechnical cover. In the second simulation, only a hypothetical cover is simulated. The difference in simulated response after 10 years was calculated to better evaluate the hydraulic effect of the slurry wall. Only regional effects could be evaluated using the 200- x 200-ft grid.

Results showed that a hypothetical slurry wall combined with a hypothetical geotechnical cover cause water levels to decrease downgradient of the wall and increase upgradient of the wall. The ability of a hypothetical slurry wall to lower water levels downgradient of a wall depends on the leakage coefficient prescribed for a hypothetical slurry wall in the model and on the ability of a hypothetical geotechnical cover to prevent groundwater recharge. In the latter case, although the cover reduces annual recharge, some recharge still takes place. This causes the groundwater levels to decline more slowly. Under this condition (with some recharge), groundwater levels will actually reach some depth that depends on both the recharge rate and the saturated hydraulic conductivity downgradient of the slurry wall. Unless recharge is entirely eliminated, the landfill area may not become completely de-watered.

Groundwater levels on the upgradient side of a hypothetical slurry wall increase slightly (up to 1.3 m after 10 years) to within about 0.5 m of the ground surface where they are limited by ET (influence of root depths). Groundwater flow directions change only slightly in two upgradient areas, the western end of the slurry wall and the eastern end. As a result of the slight buildup of groundwater levels upgradient of the slurry wall, the groundwater system responds by either flowing back north (instead of south) in the western end, or increasing flow along an easterly direction around the end of a hypothetical slurry wall. Effects of the slurry wall do not extend far from the wall (i.e., less than 0.1 m depth change within 200 to 400 feet after 10 years). This is largely due to the relatively thin aquifer thickness combined with the low saturated hydraulic conductivities used in the model. Most of the flow into and out of each model grid cell occurs as recharge and ET, respectively, rather than lateral redistribution of flows.

4.2.2 Hypothetical Interception Trenches

Hypothetical interception trenches that extend down to the unweathered/weathered bedrock contact were simulated to evaluate their effect on flow directions and groundwater levels in their vicinity using the IA sub-catchment model (see Section 3.2). The trenches were located in key VOC plume areas. This information is important in the design of these types of remedial systems intended to capture VOC contaminants. The hypothetical land configuration of the Kaiser-Hill (2002b) report was applied, including surface regrading, elimination of subsurface drains, and re-vegetation.

To simulate the effects of hypothetical interception trenches, constant head boundary conditions were assigned to a series of internal model cells. The groundwater levels were set to the bottom of the weathered bedrock to simulate a highly efficient trench system. For Test 2, trenches were located in three different locations around the IA VOC plume. For Test 3, trenches were located in two different locations. (Note: Test 1 referred to the slurry wall simulation described in Section 4.2.1).

The change in groundwater levels (relative to the case without the trenches) after 7 years is illustrated on Figure 4-12 for Tests 2 and 3. The locations of the trenches are shown on each plot, while the underlying color distribution represents the magnitude and direction of groundwater level change. Negative values indicate water levels have declined (compared to the case without the trenches), while positive values indicate increased levels.

In general, groundwater levels in all cases appear to decline with the exception of near the 903 Pad area plumes where they increased slightly upgradient of a hypothetical trench. The reason for this increase is not entirely clear, but may be an artifact of the numerical solution accuracy (if the solution is forced to oscillate around a model layer it may become unstable) and complexity associated with the occurrence of Arapahoe Sandstone in the area. It is interesting to note that the lateral extent (based on –0.1 to –0.5 m interval) influenced by the trenches are all about the same. In addition, the influence extends further downgradient (between 200 m and 600 m distance from the trench) than upgradient.

Although, levels would continue to drop with a longer simulation period, it is unlikely that the lateral extent would increase significantly. This suggests that interception trenches can be effective (hydraulically) at extracting contaminants, but they must be located across the entire contaminant flow path. In other words, a short interception trench segment will not likely capture a plume that is much wider than the trench length, because it is limited hydraulically by the relatively thin aquifer, low saturated hydraulic conductivity and strong local influence of recharge and ET on groundwater flow conditions.

Figure 4-13 (a, b, and c) shows the impact of a hypothetical trenches in Test 2 on groundwater flow directions and magnitude in each trench area compared to the hypothetical land configuration scenario flow arrows after 7 years. These results show that flow directions are largely unaffected, with only slight changes in most adjacent cells. However, in many cells adjacent to the trenches, the magnitude of flow is reduced notably.

For the hypothetical land configuration scenario, groundwater levels rise to within a meter of ground surface throughout much of the central IA. This increase likely results from the sensitivity of the recharge through the unsaturated zone to ET (vegetation) parameters[8]. As a result, this system response for long simulation periods (i.e., 10 years) may mask some of the water level drawdown response to the interception trenches or slurry wall. Additional long-term simulations were performed that confirm it is likely the ET parameters, rather than saturated or unsaturated zone parameters, that have a notable impact on this groundwater level increase. The flow and transport models developed for the VOC plume areas will address this through flow calibration.

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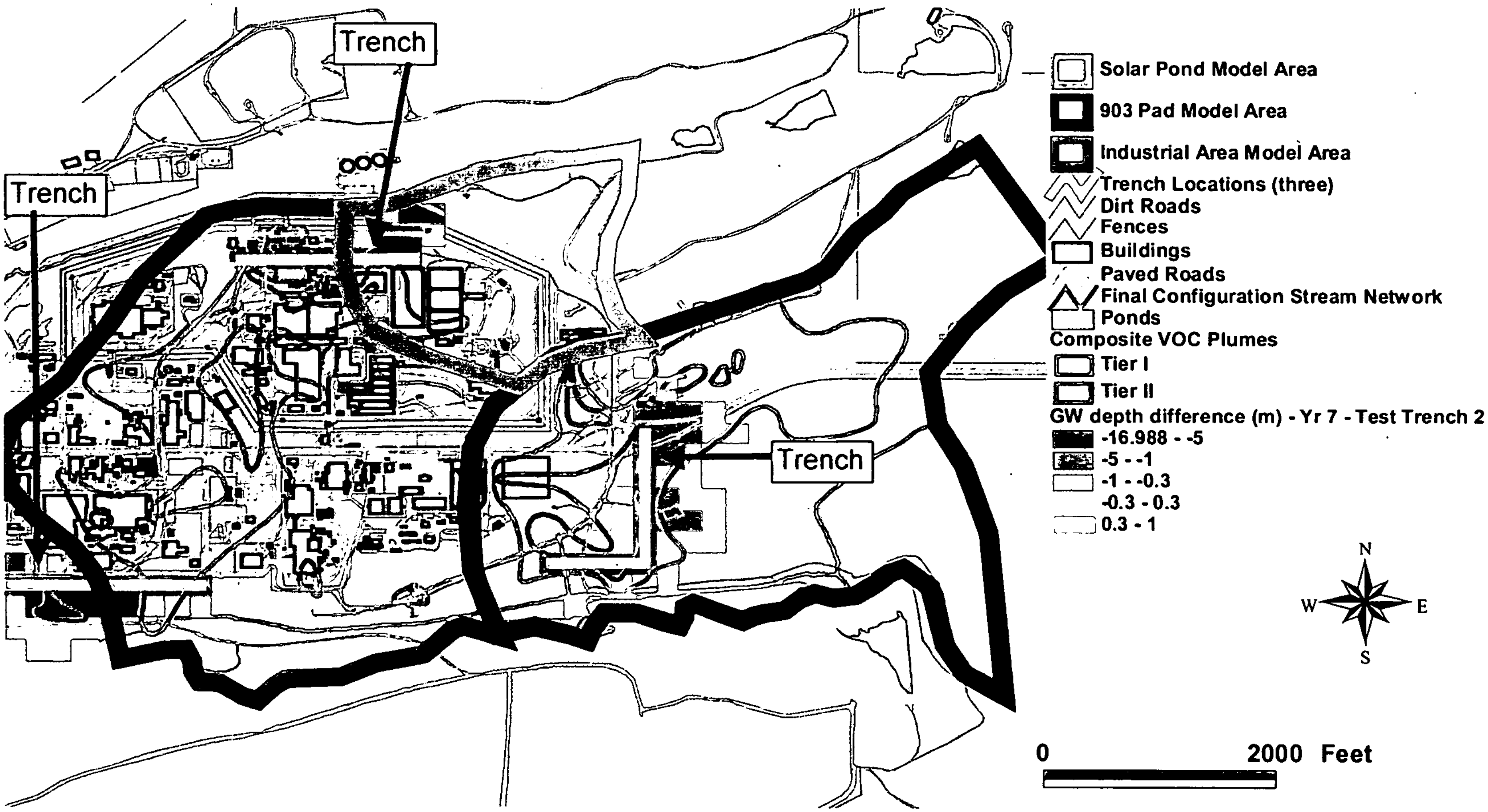
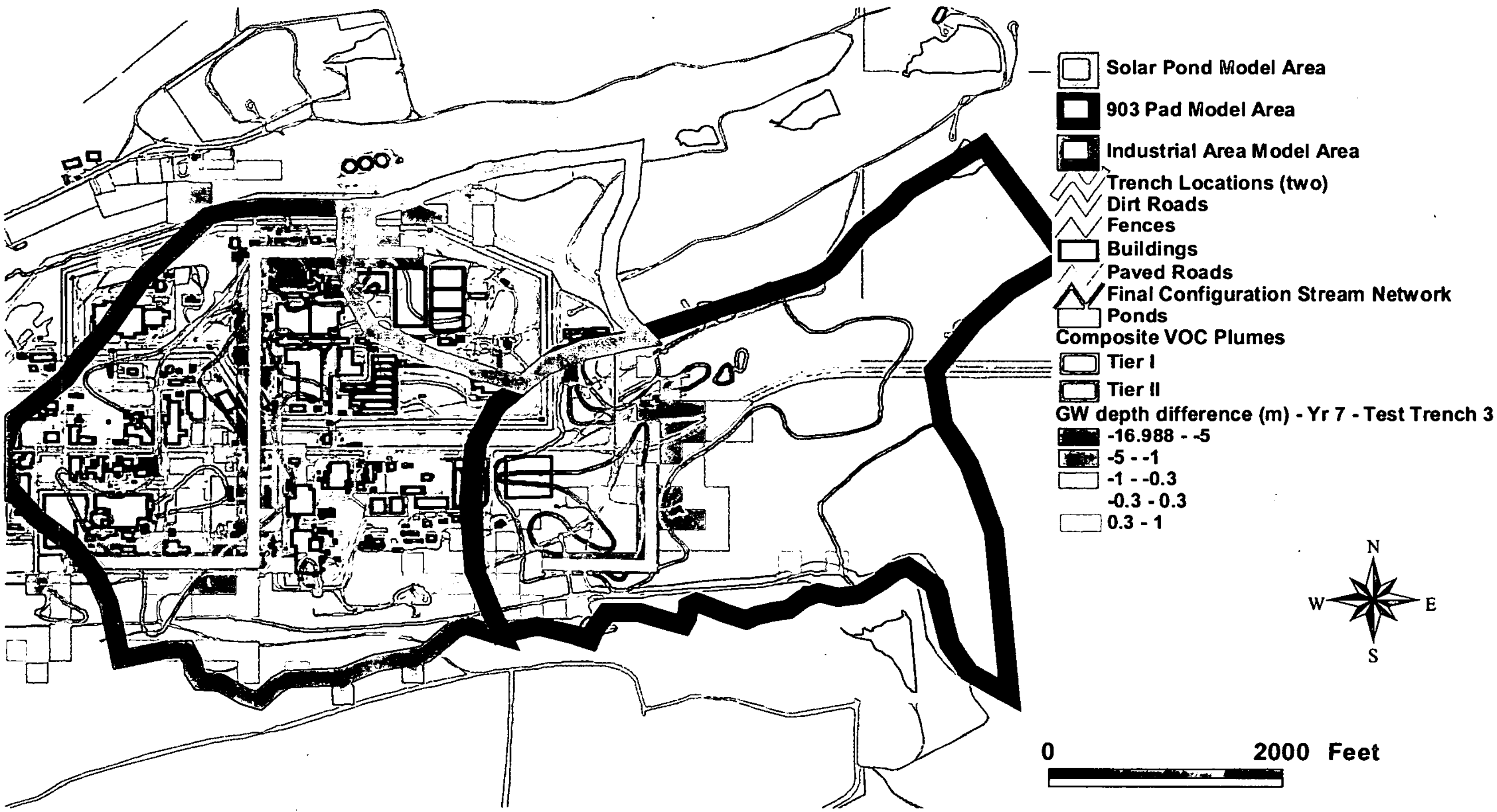
[8] Vegetation parameters for this hypothetical scenario were set based on specification of the Land Configuration Design Basis (Kaiser-Hill, 2002a).

Figure 4-12a. Simulated Change in Groundwater Levels for Hypothetical Trench Configurations



Test 2 - Three interception trenches that extend to the weathered bedrock are shown. Heads decrease more downgradient of each trench. The lateral extent affected after 7 years is limited.

Figure 4-12b. Simulated Change in Groundwater Levels for Hypothetical Trench Configurations



Test 3 - Two interception trenches extend to the weathered bedrock surface are shown. Note that heads decrease more downgradient. The lateral extent affected after 7 years is limited.

Figure 4-13a. Simulated Groundwater Flow Directions and Magnitudes for Hypothetical Trench Configurations

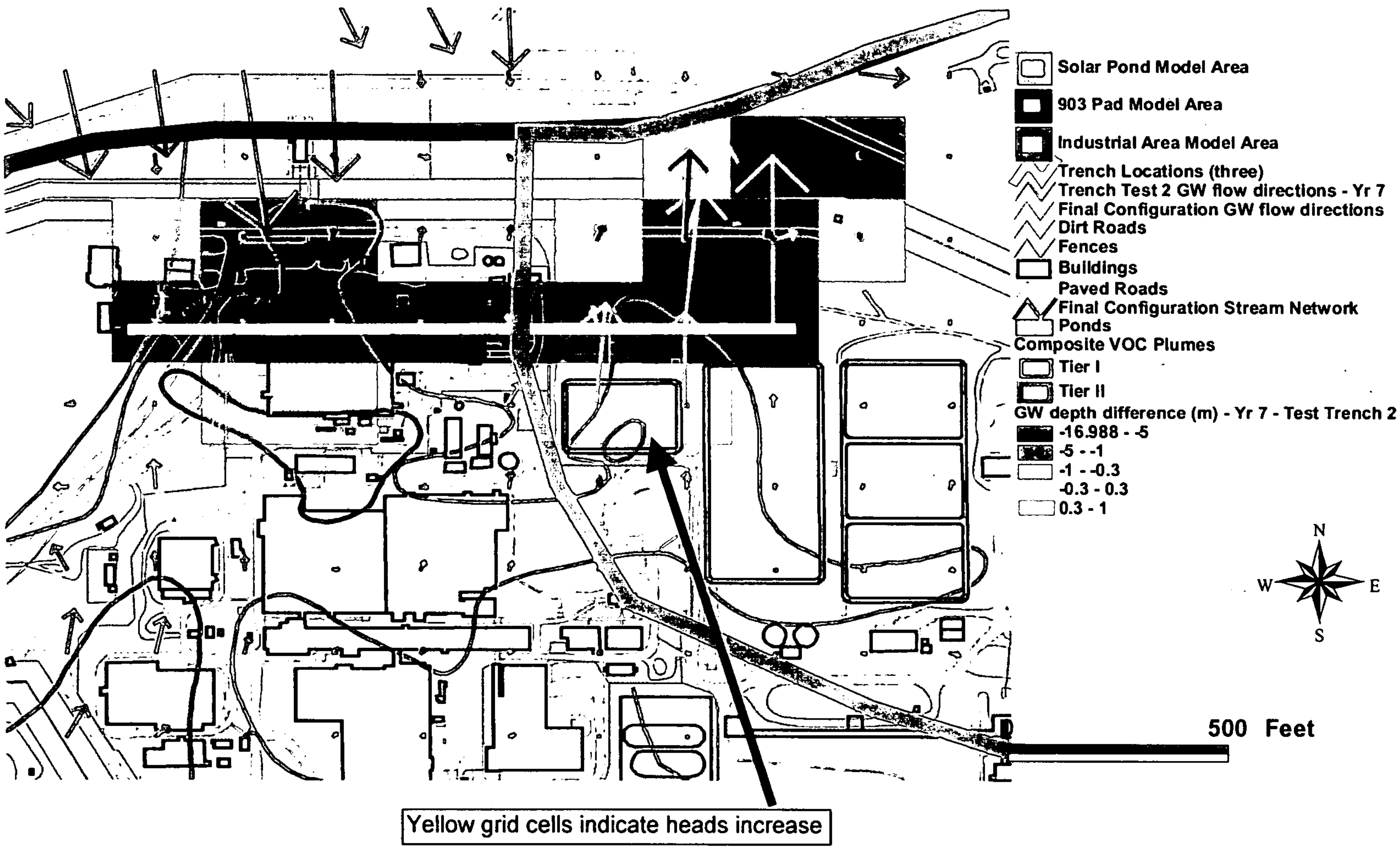


Figure 4-13b. Simulated Groundwater Flow Directions and Magnitudes for Hypothetical Trench Configurations

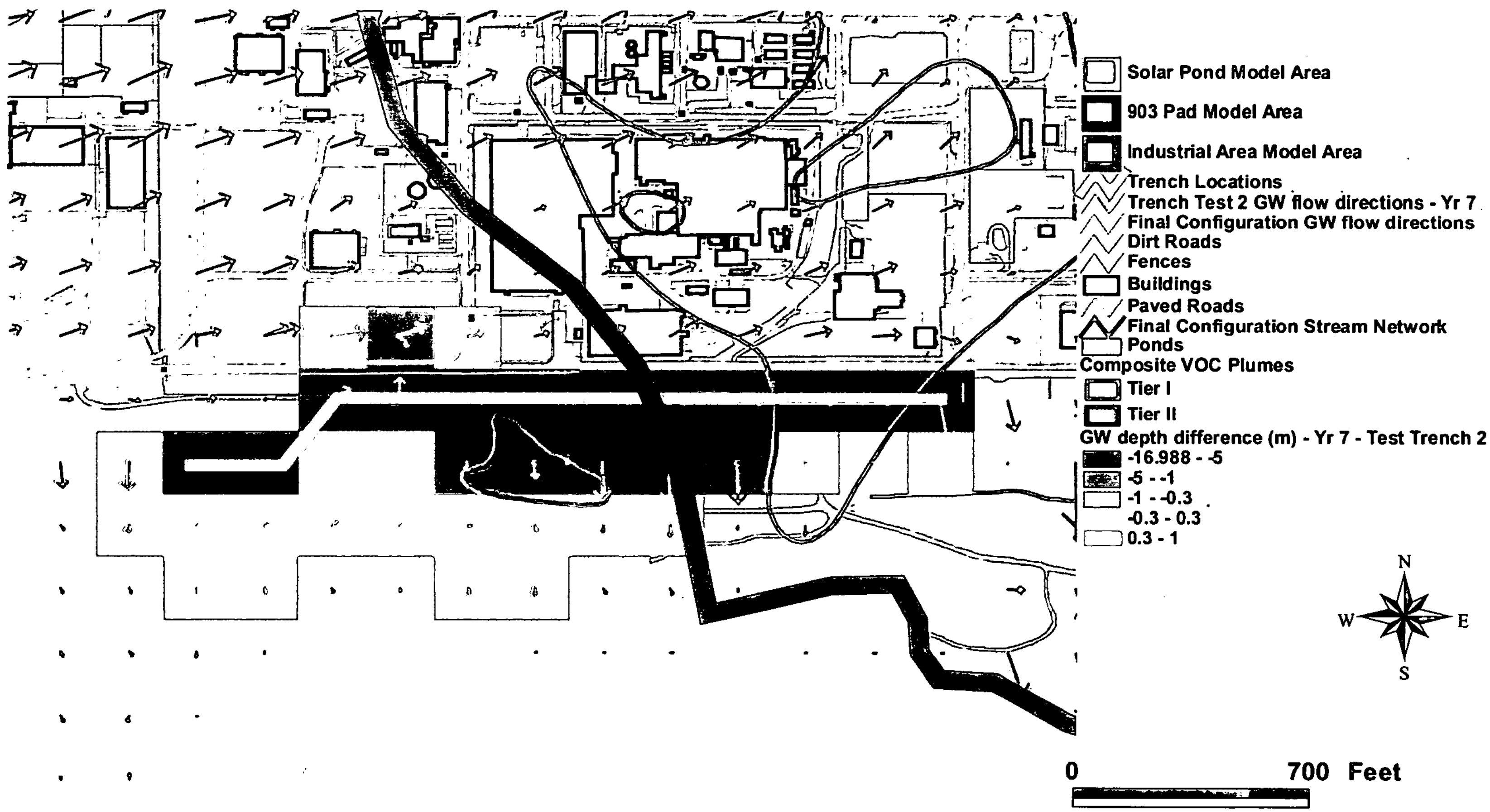
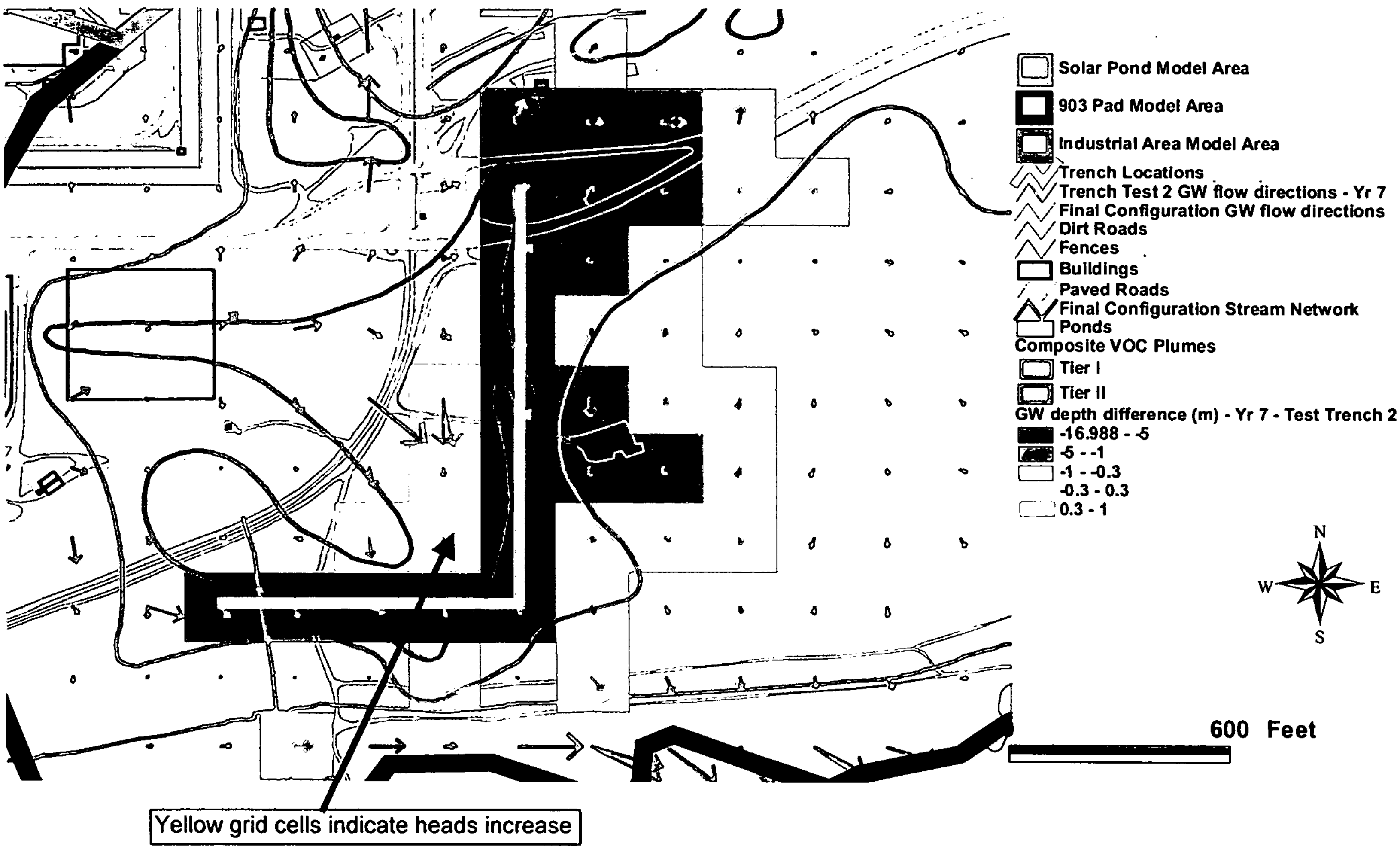


Figure 4-13c. Simulated Groundwater Flow Directions and Magnitudes for Hypothetical Trench Configurations



4.3 Additional Hypothetical Land Configuration Scenarios

4.3.1 Hypothetical Scenario 3 – Current Topography

The purpose of this simulation was to assess the effects of the IA topography on the Site-wide hydrology at closure. Specifically, in hypothetical Scenario 3, conditions of closure (buildings, pavement, and subsurface utilities removed) were simulated with the current (WY2000) topography. This simulation was intended for comparison to hypothetical Scenario 2, where conditions of closure were simulated with the engineered topography and channels of the Land Configuration Design Basis (LCDB) configuration (Kaiser-Hill, 2002a). Scenario 2 was presented in Kaiser-Hill (2002b).

4.3.1.1 Assumptions

The hypothetical Scenario 3 simulation was prepared from a hypothetical Scenario 2 setup (LCDB Closure Configuration), including removal of drains, buildings, and pavement, with the following modifications:

- The current configuration topography (based on data from 2000) was applied across the Site. (In areas of the Present and Original Landfill, however, LCDB covers were applied as in Scenario 2.) As a result, the Scenario 3 and Scenario 2 topographies are identical throughout the Buffer Zone and in the areas of the landfill covers, but differ across the IA. The difference in ground surface elevation between the two scenarios varies across the IA, ranging from +4.3 m (increase in elevation) to – 4.0 m (decrease in elevation). The difference is shown spatially in Figure 4-14; and
- The surface water channel network in the IA is consistent with the WY2000 channel network, instead of the LCDB configuration engineered IA channels of Scenario 2. LCDB engineered channels could not be applied because channel slopes and elevations would not match the simulated topography. The differences in the surface water channel networks of Scenarios 2 and 3 are presented in Figure 4-15.

4.3.1.2 Simulation Time-Frame

Scenario 3 was simulated for five years, applying the WY2000 climate to each year. The five-year simulation was performed to allow groundwater levels to stabilize to initial conditions. Results from all scenarios presented below are from the fifth year of simulation.

Figure 4-14. Difference in Ground Surface Elevation Between Scenarios 2 and 3 (Positive value indicates higher ground surface in Scenario 3 vs Scenario 2)

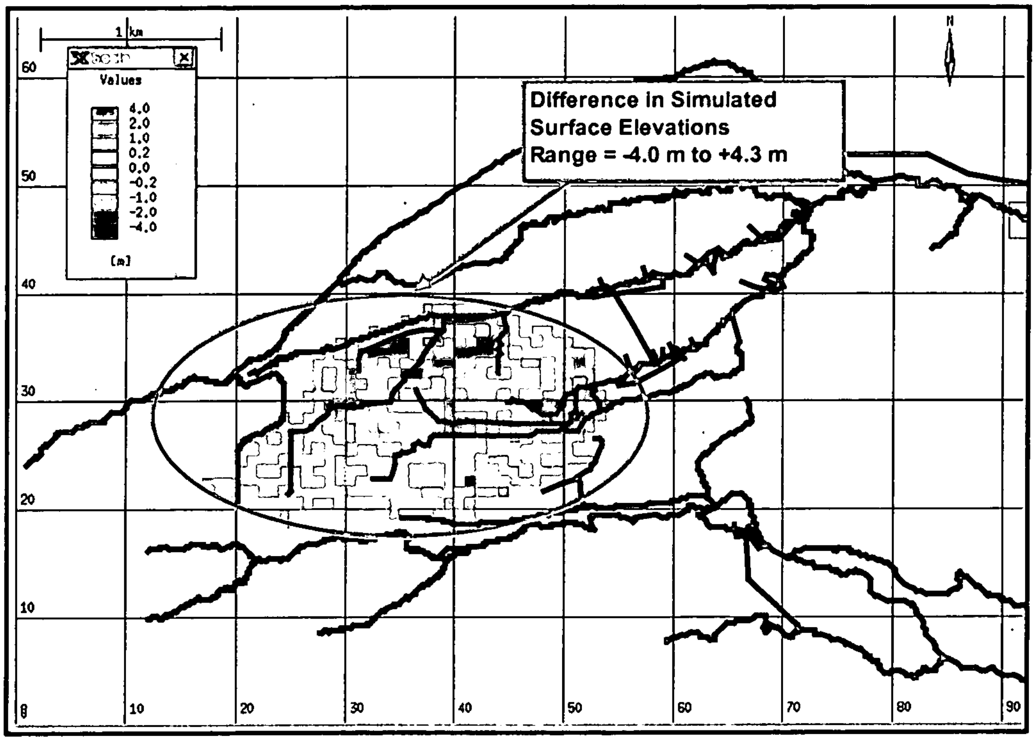
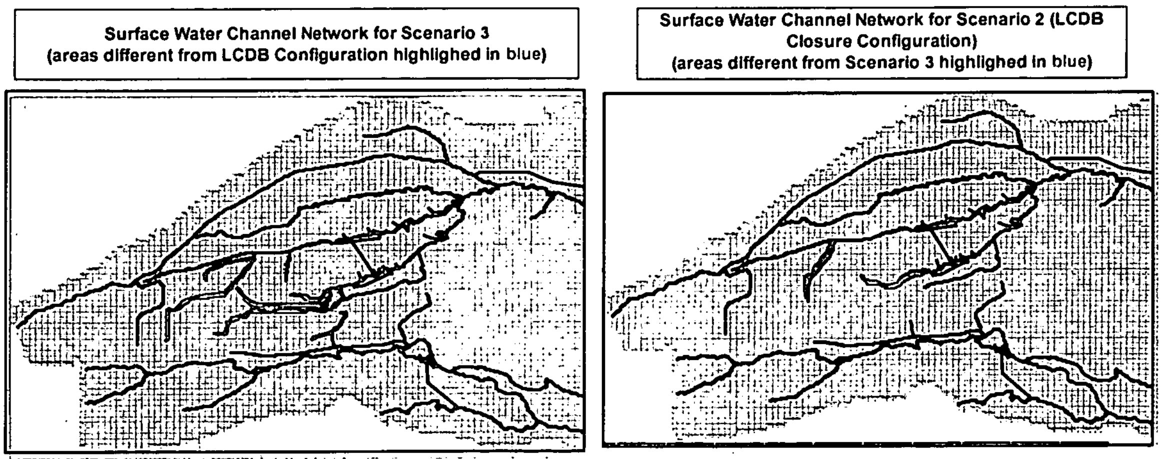


Figure 4-15. Difference in Surface Water Channel Network Between Scenarios 2 and 3



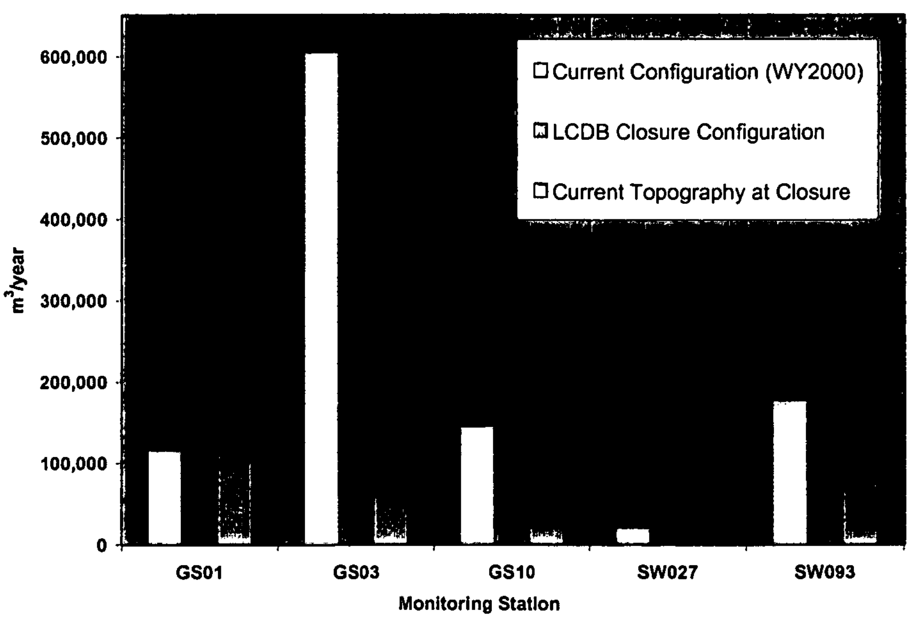
4.3.1.3 Results

To assess the relative effect on Site-wide hydrology of the IA topography at closure, simulation results for Scenario 3 (Current Topography at Closure) were summarized and compared to results from Scenario 2 (LCDB Configuration at Closure). In general, the topography at closure was found to have a little effect on surface water flow, but a notable effect on groundwater levels. Annual surface flow volumes, baseflow, groundwater levels, groundwater treatment/ collection systems, and water balances were compared for Scenario 2 and 3 and are discussed below.

4.3.1.3.1 Annual Surface Water Discharge

Simulated annual discharge volumes for Scenarios 2 and 3 are compared in Figure 4-16 for the major Site gaging locations. Simulated discharge volumes for the current Site configuration (WY2000) are also shown in Figure 4-16 for comparison. As shown, slight increases in annual discharge volume were simulated for Scenario 3 at all major gages except GS01. Specifically, the annual discharge from the IA gages, GS10, SW027, and SW093, increased 12% for Scenario 3 relative to Scenario 2. The lack of effect at GS01 was anticipated based on the effective isolation of this drainage from the IA by Pond C-2. Despite this difference, both Scenarios 2 and 3 compare similarly to the current configuration, predicting decreases in discharge of 71% and 74%, respectively, for an average year.

Figure 4-16. Annual Surface Water Discharge Volumes - Scenarios 2 and 3



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4.3.1.3.2 Groundwater Levels

Scenario 3 results showed a small average increase in groundwater levels in the IA of less than 0.05 m (as compared to Scenario 2). The change in individual cells ranged from -3.2 m to +4.3 m. No significant effects on groundwater levels outside of the IA were noted after the five-year simulation. These results are presented in Figure 4-17.

To better understand the results as a function of the change in topography, a comparison of groundwater depths is presented in Figure 4-18. The results show that the groundwater depths remain relatively constant in the central portion of the IA between the two simulations, though the simulated elevations differ. This effect may reflect the strong influence of vegetation on groundwater levels on this mesa, where groundwater is relatively shallow (<1 m). This effect was not as apparent on the hillslopes of the IA.

Figure 4-17. Simulated Difference in Groundwater Levels for Scenario 3 verses Scenario 2 (Positive change indicates higher groundwater elevation for Scenario 3)

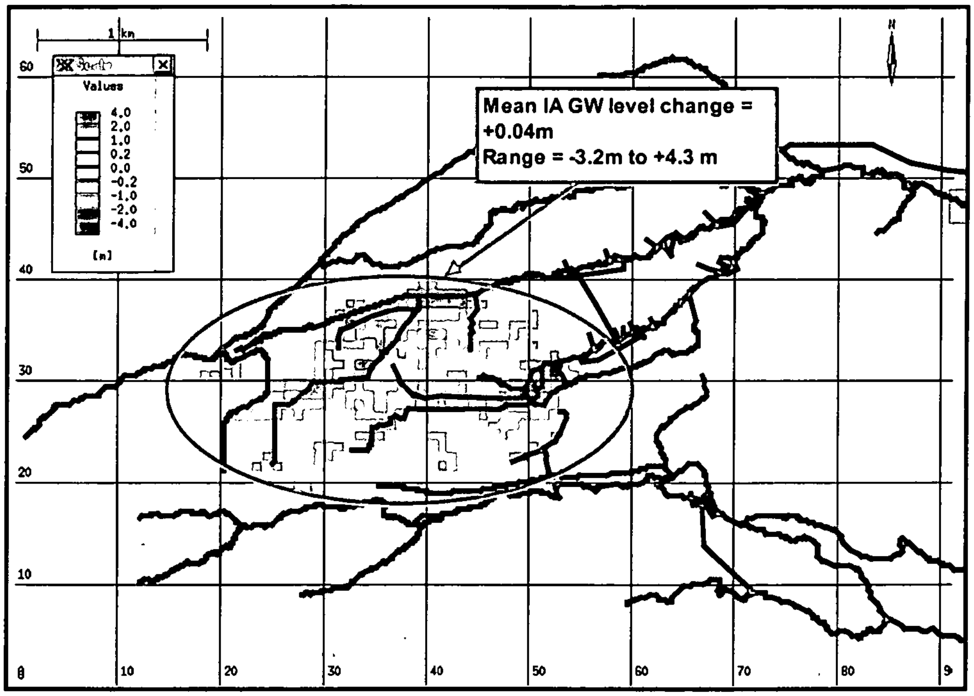

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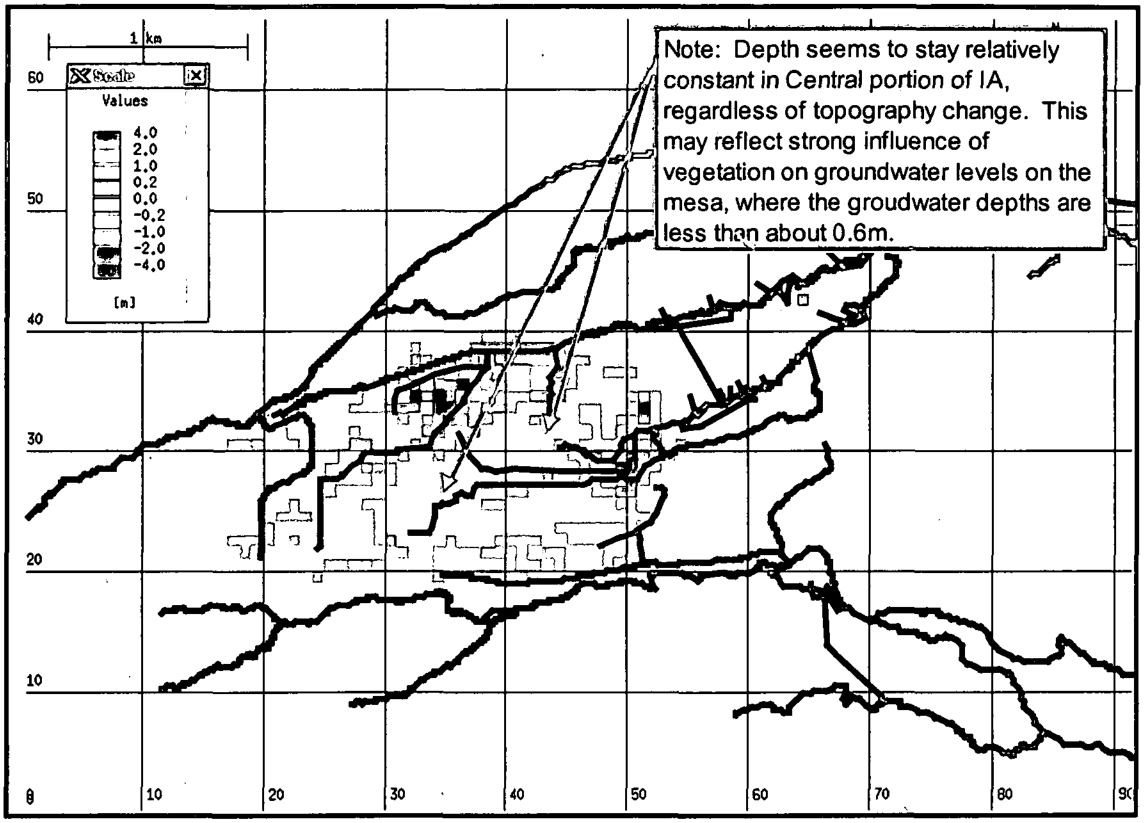
Figure 4-18. Simulated Difference in Groundwater Depth for Scenario 3 verses Scenario 2 (Positive value indicates more shallow groundwater for Scenario 3)



4.3.1.3.3 Groundwater Treatment/ Collection Systems

No significant effects on groundwater treatment/ collection systems were simulated in Scenario 3 relative to Scenario 2. These results are presented in Figure 4-19. The slight increases and decreases in annual discharge volumes can be directly attributed to the simulated increases and decreases in groundwater levels in the collection areas.

4.3.1.3.4 Water Balance Results

The small increase in surface water discharge can be better understood by evaluating the IA water balance results. Annual IA water balance totals are presented in Figure 4-20 for precipitation, ET, overland runoff, drain discharge, surface water discharge, and baseflow. Results are presented for Scenarios 2 and 3, as well as for the current configuration simulation (WY2000) for comparison. Most water balance components, including ET and drain flow, show minimal response to the change in topography. Small effects on baseflow and overland runoff are discussed below.

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Figure 4-19. Groundwater Treatment/ Collection Systems - Simulated Annual Volumes for Scenario 3, Scenario 2, and Current Configuration (WY2000)

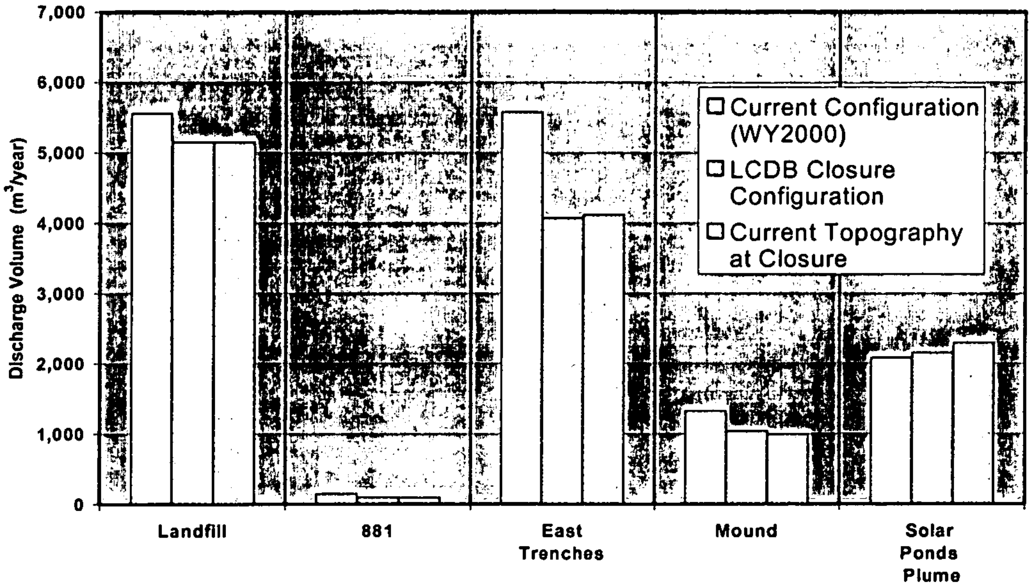
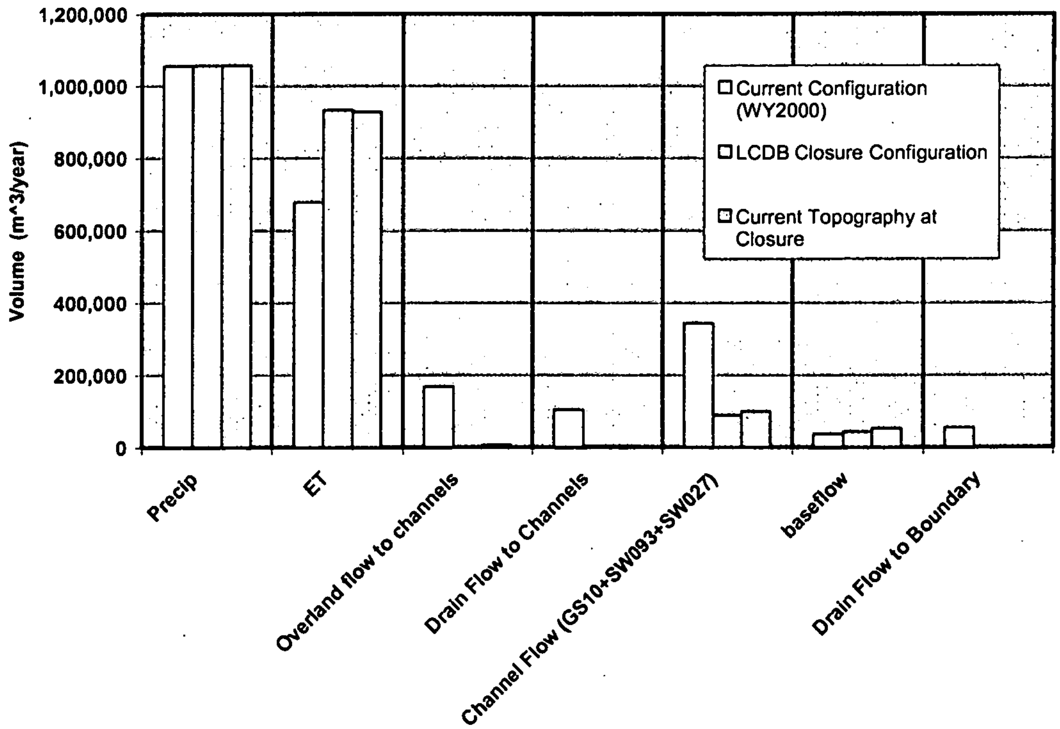


Figure 4-20. Annual Industrial Area Water Balance Totals for Current Configuration (WY2000), Scenario 2, and Scenario 3



To begin, the model indicates that baseflow in the IA is 20% higher in Scenario 3 (Current Topography at Closure) as compared to Scenario 2 (LCDB Configuration at Closure). As discussed, average groundwater levels across the IA do not show a significant increase (Figure 4-17); therefore, the small increase in baseflow is likely due to localized increases in groundwater levels and the different channel network of Scenario 3. The Scenario 3 channel network is more extensive and deeper (more incised) in some areas, providing more opportunity for groundwater and surface water to interact.

Another water balance component to consider here is overland runoff. Though overland runoff is small in both Scenarios, it is higher in Scenario 3 (relative to Scenario 2) by 15 times in the IA, though this amounts to only a 15% increase in overland runoff Site-wide. This increased runoff may be attributed to the steeper surfaces of the Scenario 3 topography as compared to the engineered topography of Scenario 2. Also, the more incised channels of Scenario 3 may lead to more runoff due to saturation excess near the channels. It should be noted again that overland runoff is a small component of the water balance. Further, this difference in overland runoff between Scenario 2 and 3 is negligible when both results are compared to the current configuration simulation (WY2000). (i.e., Scenario 2 predicts a 99% decrease in IA overland runoff, while Scenario 3 predicts a 96% decrease.)

4.3.2 Hypothetical Scenario 4 - Subsurface Utilities in Place at Closure

The purpose of this simulation was to assess the general hydrologic effects of leaving subsurface utilities and trenches in place at closure. In addition to leaving subsurface utilities and trenches in place, hypothetical Scenario 4 applied the current topography and IA channel network, as for hypothetical Scenario 3 (Current Topography at Closure). Therefore, the results of this simulation (hypothetical Scenario 4) are intended for comparison to hypothetical Scenario 3. The current (WY2000) topography and channel network are applied to maintain current routing of drain flow to surface channels. This approach should provide a conservatively high bound on groundwater routing to channels, given the scenario assumptions. In other words, of the range of likely closure configurations, this simulation maximizes drain flow to channels.

4.3.2.1 Assumptions

To prepare this simulation, all aspects of Scenario 3 (Current Topography at Closure) were applied, with the following exceptions:

- All subsurface trench material was left in place, as simulated by effective hydraulic conductivity values in the first layer of the model; and
- All subsurface utilities were left in place, except
    - Footing drains were removed from all buildings except Buildings 371, 881, 771, and 991. This was based on the assumption that, when encountered during demolition, footing drains would be removed as obvious conduits for potential contaminant migration. Buildings 371, 771,

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881, and 991 represent deep systems, which may not be fully excavated leaving footing drains routing water to the surface; and

- Sanitary lines were removed to simulate the lines being grouted shut. The backfill material around the sanitary lines, however, was left in place in the simulation.

4.3.2.2 Simulation Time-Frame

Scenario 4 was simulated for five years, applying the WY2000 climate to each year. The five-year simulation was performed to allow groundwater levels to stabilize to initial conditions. Results from all scenarios presented below are from the fifth year of simulation.

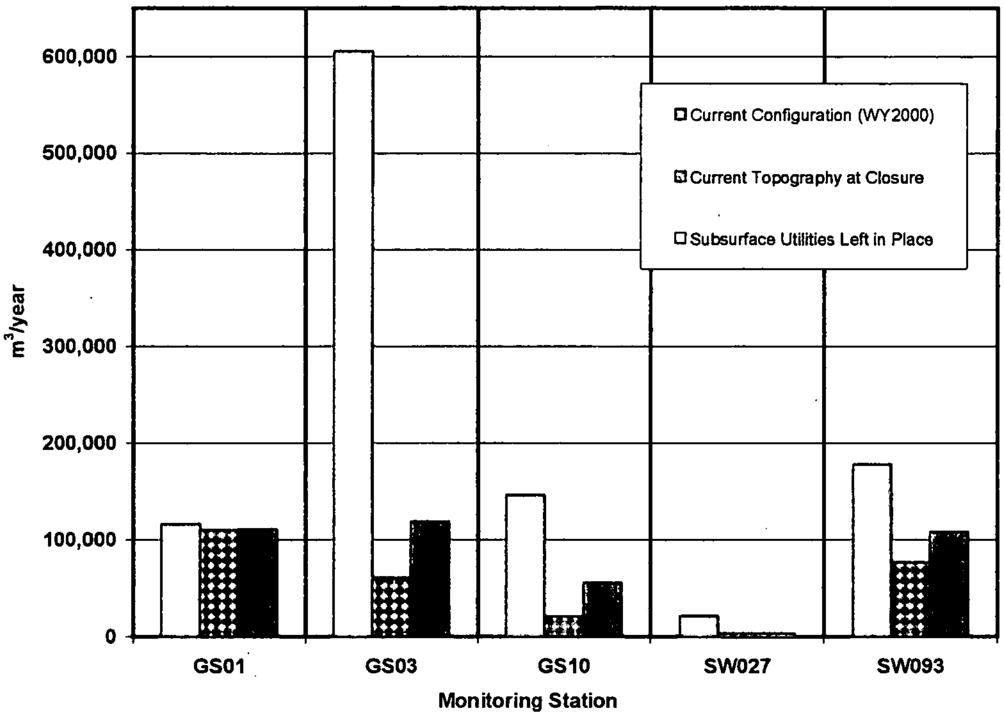
4.3.2.3 Results

Simulation results for hypothetical Scenario 4 were summarized and compared to results from Scenario 3, to assess the relative effect on Site-wide hydrology of leaving subsurface utilities and trenches in place at closure. In general, leaving drains and backfill trenches in place increases surface water baseflow rates in the IA and decreases groundwater levels in the IA. Annual surface flow volumes, baseflow, groundwater levels, groundwater treatment/collection systems, and water balances were compared and are discussed below.

4.3.2.3.1 Annual Surface Water Discharge

Simulated annual discharge volumes for Scenarios 4 and 3 are compared in Figure 4-21 for the major Site gaging locations. Simulated discharge volumes for the current Site configuration (WY2000) are also shown in Figure 4-21 for comparison. As shown, an increase in annual discharge is simulated for Scenario 4 at Walnut Creek gages GS10, SW093, and GS03. Specifically, the annual discharges at gages GS10 and SW093 increase by 140% and 40%, respectively, as compared to Scenario 3 results. The observed 50% increase at GS03 is in direct response to the increased discharge from the IA. No significant changes in predicted discharge volumes are simulated for SW027 and GS01. It should be noted that these relative effects apply only to the simulated climatic conditions of WY2000. Results are expected to vary for simulations with larger precipitation events.

Figure 4-21. Annual Surface Water Discharge Volumes - Scenarios 3 and 4



4.3.2.3.2 Groundwater Levels

Scenario 4 (Subsurface Utilities in Place at Closure) results show a decrease in average IA groundwater levels of 0.3 m, as compared to Scenario 3 (Current Topography at Closure). The observed change in individual cells ranges from –5.6m to +1.0m. These results are presented in Figure 4-22. The fairly uniform decrease in groundwater levels relative to Scenario 3 indicates the effectiveness of the subsurface utilities at controlling the groundwater levels in the IA. No significant effects on groundwater levels outside of the IA are noted after the five-year simulation.

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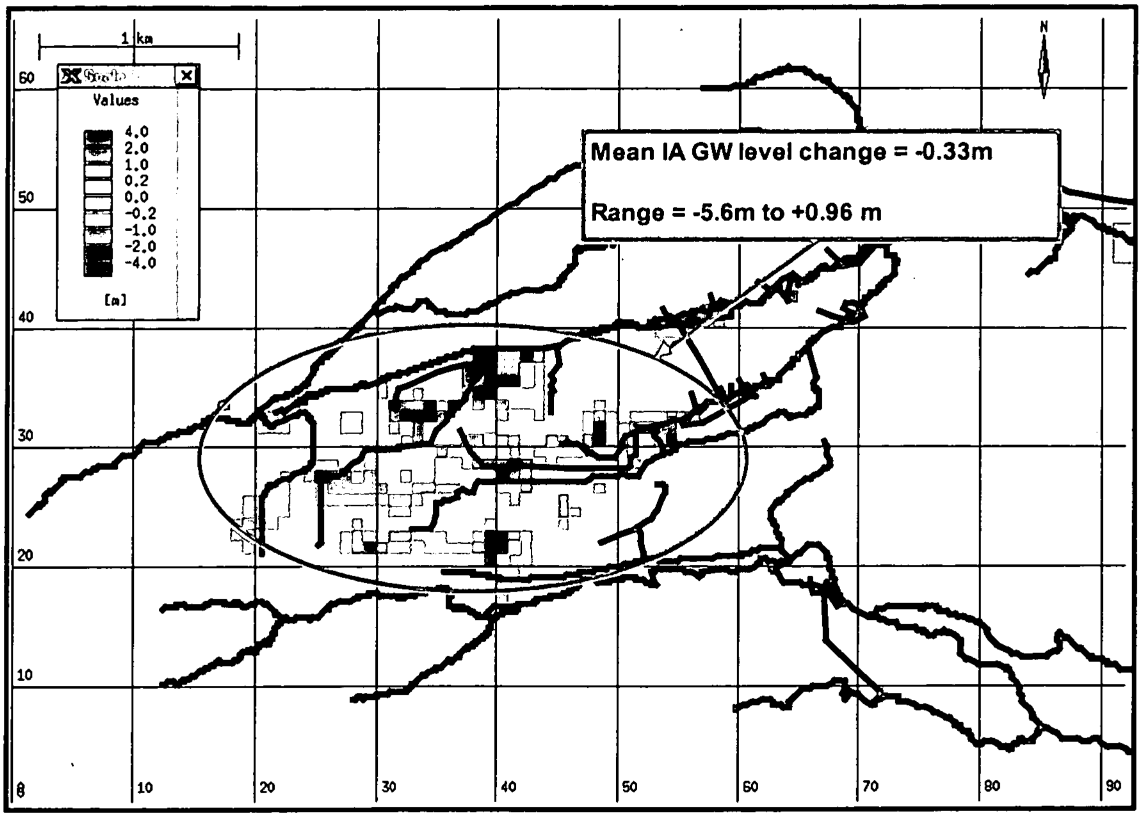
Figure 4-22. Simulated Difference in Groundwater Levels for Scenario 4 verses Scenario 3 (Positive change indicates higher groundwater elevation for Scenario 4)

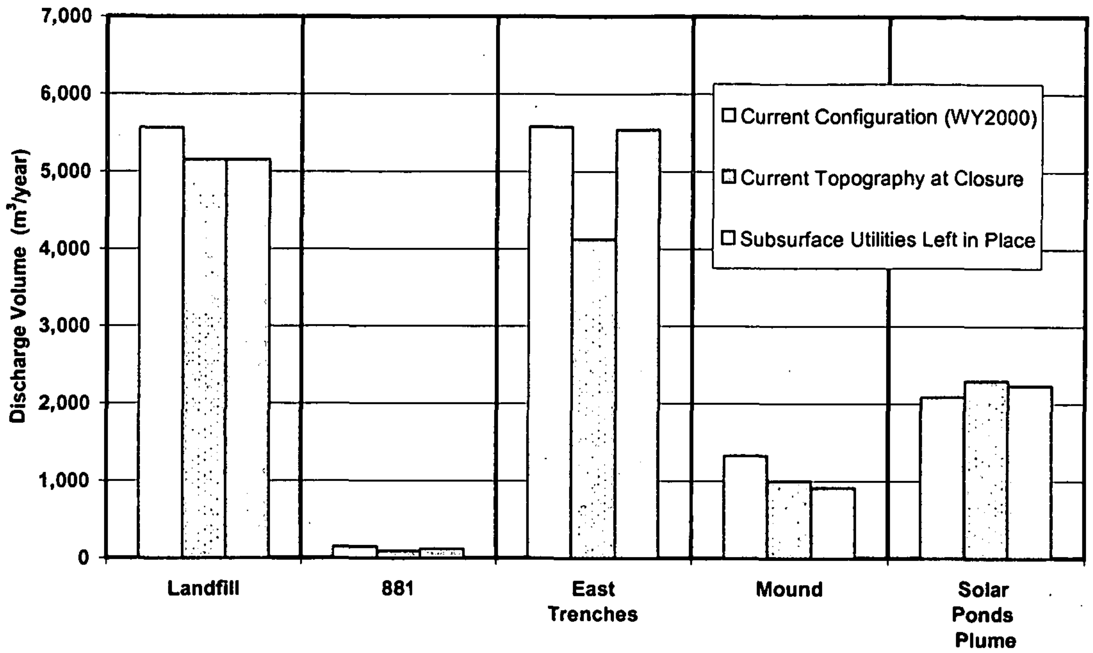


4.3.2.3.3 Groundwater Treatment/Collection Systems

No significant effects on groundwater treatment/collection systems are noted in hypothetical Scenario 4 results relative to Scenario 3, with the exception of a small increase in discharge at the East Trenches System. In Scenario 4, drain cells allow more water to be routed to the East Trenches System. It is important to note that the volume of discharge simulated for these systems is very small (<6,000 m^3/ yr.), and differences in discharge are even less (~1,000 m^3/ yr.). Given the resolution limitations of the applied grid, these simulated differences should not be over-interpreted.

The slight increases and decreases in annual discharge volumes of the other systems can be directly attributed to the simulated changes in groundwater levels in the collection areas (i.e., simulated increases in groundwater levels results in increased simulated discharges at groundwater treatment/collection systems). These results are presented in Figure 4-23. It should be noted that simulated changes in groundwater level in the area of the treatment collection systems are reasonable indicators of system response;

Figure 4-23. Groundwater Treatment/Collection Systems - Simulated Annual Volumes for Scenario 4, Scenario 3, and Current Configuration (WY2000)



however, accurate modeling of the groundwater treatment/collection systems would require refinement of the model grid size.

4.3.2.3.4 Water Balance Results

The simulated hydrologic response to conditions of hypothetical Scenario 4 (Subsurface Utilities in Place at Closure) can be better understood by evaluating the simulated IA water balance component response. Annual IA water balance totals are presented in Figure 4-24 for precipitation, ET, overland runoff, drain discharge, surface water discharge, and baseflow. Results are presented for Scenarios 3 (Current Topography at Closure) and 4, as well as the Current Configuration Simulation (WY2000) for comparison.

The results can be interpreted by considering the effects of the drains on the integrated hydrology. The simulation indicates a 20% decrease in baseflow in the IA, in direct response to the decrease in groundwater levels. This decrease is more than accounted for by the increase in discharge to the channels from the drains. The net result of these two competing effects is apparent in the low flow portion of the annual hydrographs for the IA gages. Figure 4-25 shows the net increase in the constant, low-flow discharge at the major IA surface water gages.

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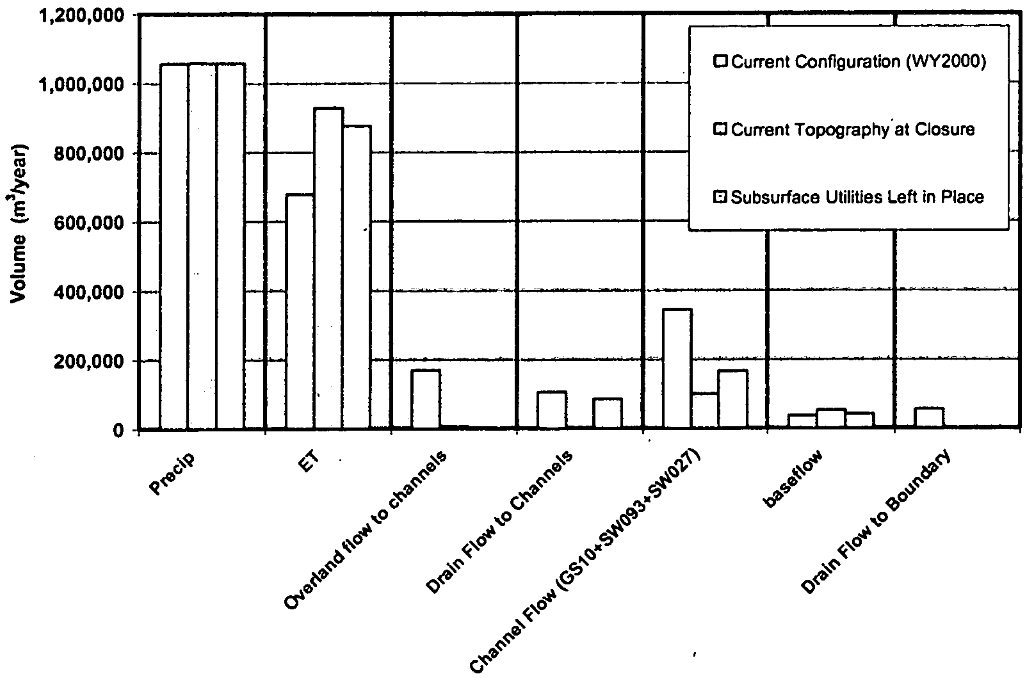
Figure 4-24. Annual Industrial Area Water Balance Totals for Current Configuration (WY2000), Scenario 3, and Scenario 4



The net effects of decreased baseflow and increased drain flow account for the majority of the increase in surface water discharge; however, overland runoff must also be considered. The overland runoff component of the IA water balance decreases in Scenario 4 relative to Scenario 3. This may be attributed to the lower average groundwater levels in the IA, which in turn may reduce the area that could become saturated and runoff during rainfall events.

Finally, the ET component of the IA water balance decreased by 6 % in Scenario 4 relative to Scenario 3. This can also be attributed to the lower groundwater levels. Lower groundwater levels result in decreased influence of vegetation roots, thereby reducing loss to ET. From another perspective, the drains route a portion of the water to the channels before it can be used by vegetation.

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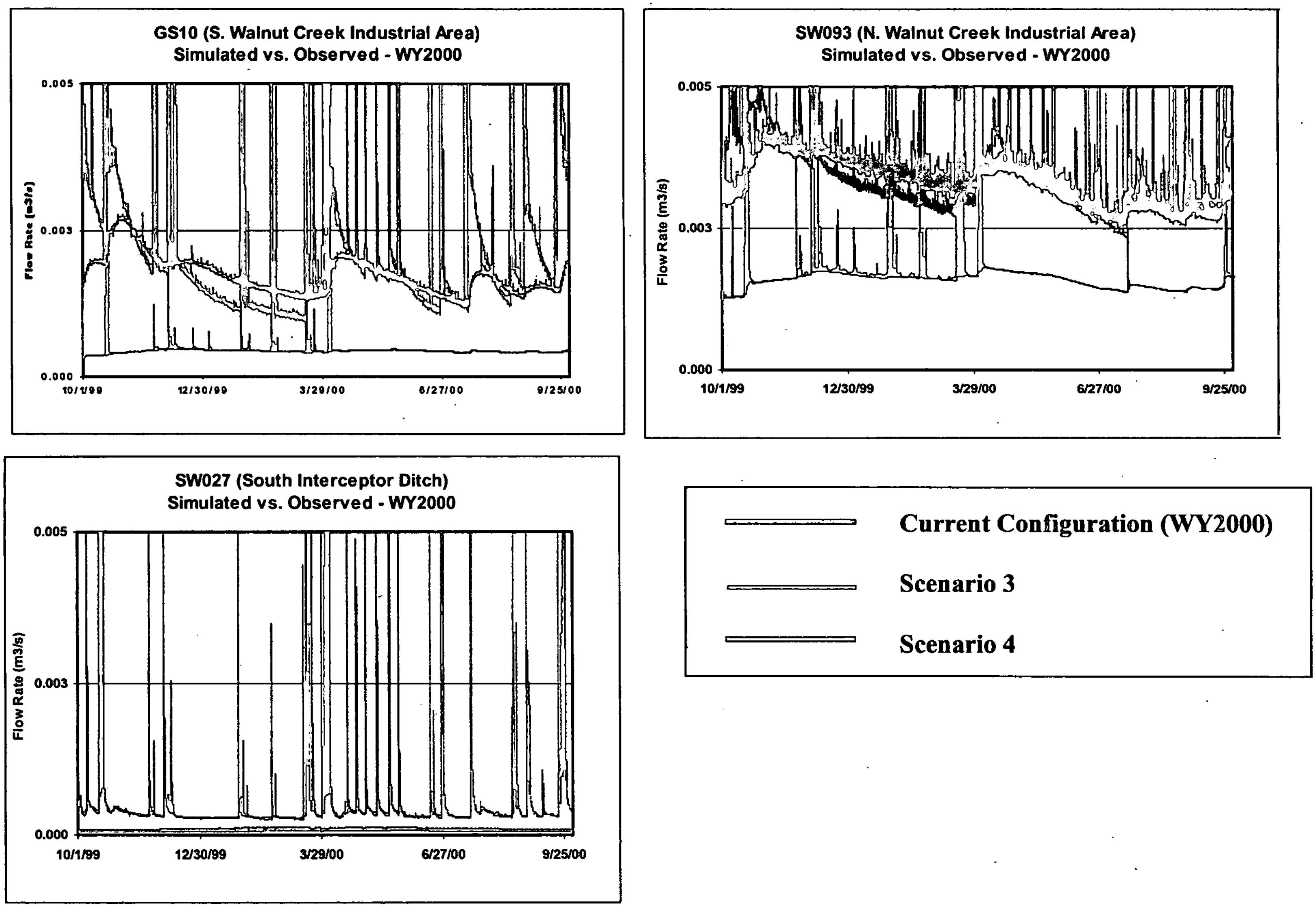
***Figure 4-25. Low Flow Close-up for Annual Industrial Area Hydrographs-
Current Configuration (WY2000), Scenario 3, and Scenario 4***



All axes on common vertical scales.

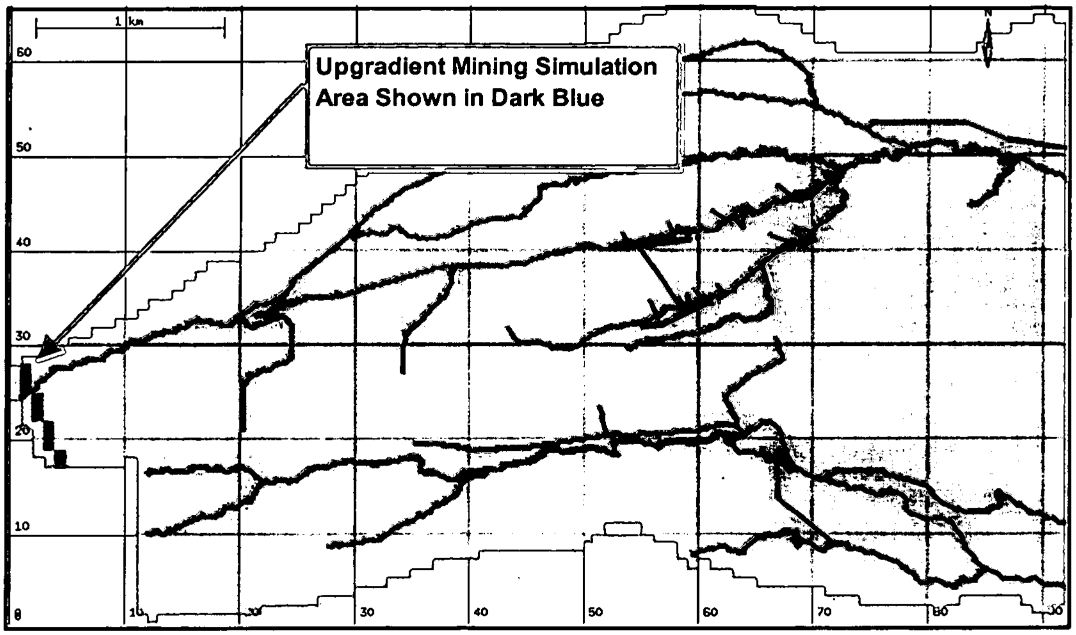
4.3.3 Hypothetical Scenario 5 - Upgradient Hypothetical Mining after Closure

The purpose of this simulation was to assess the effects on the Site-wide hydrology of potential expansion of mining activities west of the Site. The results of this simulation are intended for comparison to hypothetical Scenario 2 (LCDB Closure Configuration).

4.3.3.1 Assumptions

To prepare this simulation, all aspects of hypothetical Scenario 2 (LCDB Closure Configuration) were applied, with one excetption. A deep trench was simulated to the west of the Site in the area of current gravel-mining activities. The hypothetical mining trench extends 18 to 25 m below the ground surface and drains groundwater that seeps into it. In the model, water is extracted from the trench by using drains in MIKE SHE (which require specifying leakage values and invert depths). High leakage values were assigned to simulate relatively constant heads within the trench. The location of the trench is shown below in Figure 4-26.

Figure 4-26. Location of Simulated Hypothetical Mining Activities for Scenario 5



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4.3.3.2 Simulation Time-Frame

Scenario 5 was simulated for five consecutive years, applying the WY2000 climate to each year. The five-year simulation was performed to allow groundwater levels to stabilize to initial conditions. Results from all scenarios presented below are from the fifth year of simulation.

4.3.3.3 Results

Simulation results for Scenario 5 (Upgradient Mining at Closure) were summarized and compared to results from Scenario 2 (LCDB Closure Configuration), to assess the relative effect on Site-wide hydrology of upgradient mining activities at closure. In general, the simulation results indicate that upgradient mining activities have no effects on surface water or groundwater in the IA or downstream. This result supports the conceptual model that the system is largely controlled vertically by recharge and ET. Annual surface flow volumes, baseflow, groundwater levels, groundwater treatment/collection systems, and water balances were compared and are discussed below.

4.3.3.4 Annual Surface Water Discharge

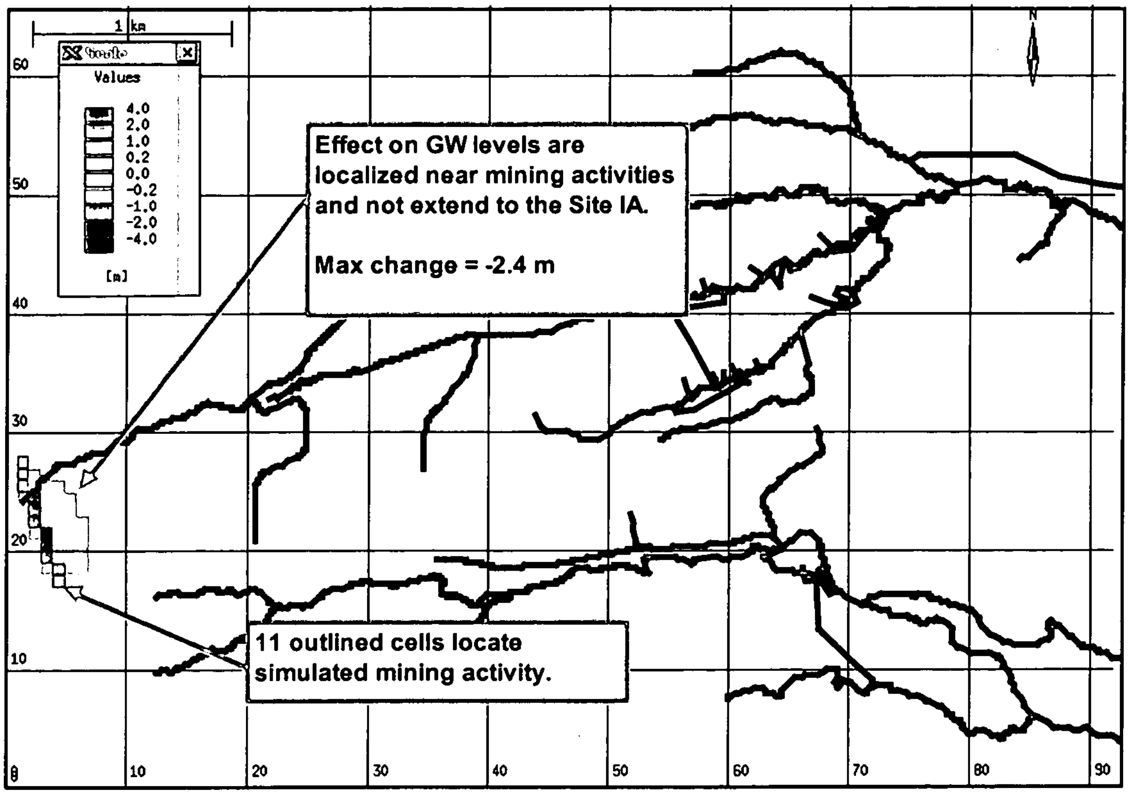
Simulations for groundwater and surface water for Scenario 5 and Scenario 2 were indistinguishable, except in the immediate area of the simulated mining activities. Specifically, surface water discharge, groundwater collection/ treatment systems, and IA water balance components were unaffected by the simulated mining activities.

Figure 4-27 shows the simulated change in groundwater levels for Scenario 5 relative to Scenario 2. As shown, groundwater levels are simulated to decrease in the area of the mining activity, but the effect does not extend downgradient far enough to impact the IA. This is consistent with the Site conceptual model for groundwater, described in detail in Kaiser-Hill (2002).

4.3.4 Hypothetical Scenario 6 - 100-Year Event Simulations

The 100-year return frequency precipitation event was simulated for several reasons. First, the model had not yet been tested under extreme hydrologic conditions, and such events will be important for design considerations. Second, the relative difference in runoff response between current and hypothetical closure configurations, and the effect of topography at closure on runoff response to the 100-year event are of interest.

Figure 4-27. Simulated Difference in Groundwater Levels for Scenario 5 verses Scenario 2 (Positive change indicates higher groundwater elevation for Scenario 5)



4.3.4.1 Assumptions

To prepare simulations of the hypothetical 100-year event, input climate files of precipitation and PET were prepared based on the following assumptions:

- The 100-year event precipitation input was based on the 100-year, 6-hour event described in the Site Master Drainage Plan (EG&G, 1992[9]). The hyetograph for the event is shown in Figure 4-28;
- The event was input at 5-minute time-step intervals and distributed uniformly across the Site;
- The storm was assigned to occur on May 1 in the 2000 climate files (starting at 3 p.m.). As a result, the antecedent soil moisture conditions and pond levels were designated at the simulated values for this climate day for the given configuration;
- Inflow hydrographs for the surface channels crossing the western model boundary were assigned based on predictions in the Master Drainage Plan (EG&G, 1992).

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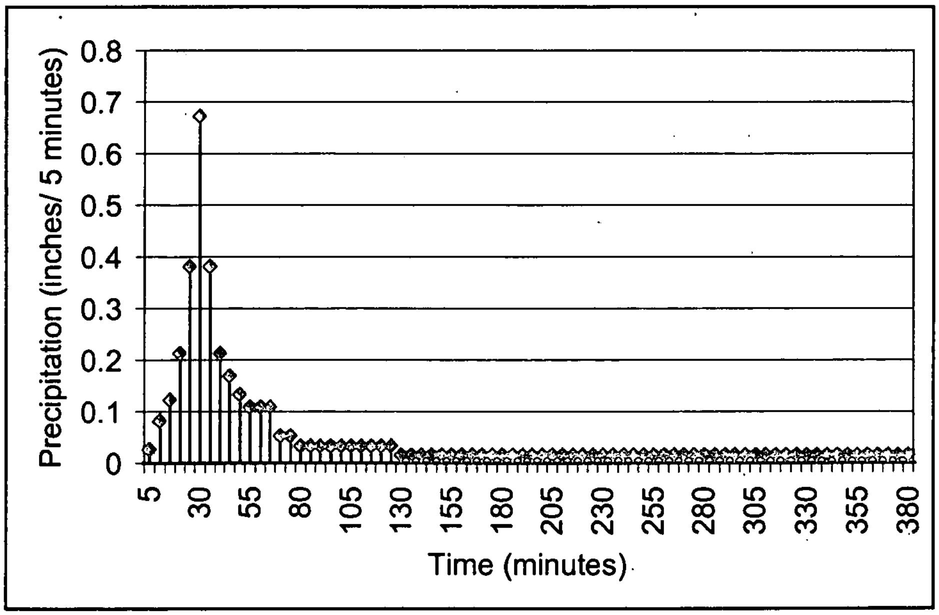
[9] EG&G. 1992. *Rocky Flats Plant Drainage and Flood Control Master Plan.* Rocky Flats Plant, Jefferson CO. April.

These inflow hydrographs are likely overestimates (as they were developed with very conservative assumptions for design purposes). However, because the same hydrographs were applied to all simulations being compared, the effect on system response should be minimal when results are assessed by comparison; and

- The PET record for the day of the event was taken from an event observed on May 8, 2000. This allowed for realistic PET estimates for early May. May 8 , 2000 data was chosen because it was a cloudy and rainy day (clouding from morning through the late evening) very close in time to the May 1, 2000 date when the 100-year event was simulated. Though PET is the second largest component of the annual water balance (largest is precipitation), its influence is not expected to be the controlling factor in runoff response to such a large, short-duration event.

Figure 4-28. Precipitation Hyetograph of 100-Year Precipitation Event



4.3.4.2 Simulation Time-Frame

All hypothetical 100-year event simulations were performed by "hotstarting" the model during April of the fifth consecutive year of simulating the WY2000 climate. "Hotstarting" means simulated conditions at the specified point in time from a previous model run were applied as the initial conditions for the given simulation. In short, hotstarting refers to starting a new model run from the conditions of a specified moment of a previous simulation. The 100-year event was simulated to occur on May 1. The simulation was continued through May 10.

The simulation time-step in the surface channel flow component was reduced from 0.5 minutes to 0.1 minutes. This modification was made to allow for stable and accurate simulation of large volumes of surface water.

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The 100-year event was simulated for the following Site configurations[10]:

- Current (WY2000) Configuration;
- Scenario 2 (LCDB Closure Configuration); and
- Scenario 3 (Current Topography at Closure).

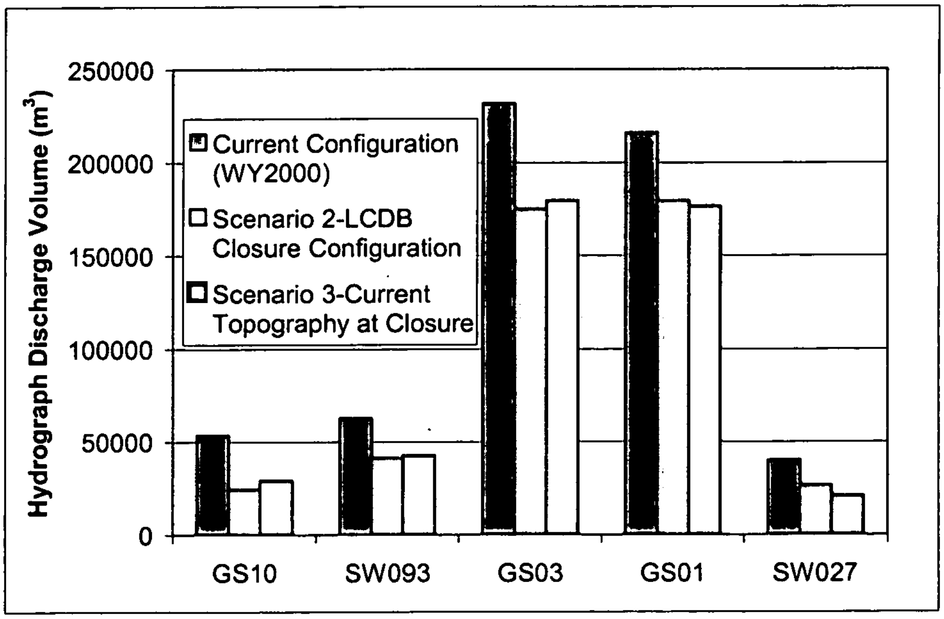
4.3.4.3 Results

Simulation results for the hypothetical 100-year event simulations are presented in the following sections for surface water flow volumes, peak flow rates, and structural capacity issues.

4.3.4.3.1 Flow Volumes

Figure 4-29 shows the simulated surface water volumes for the major Site gages. These volumes represent the simulated discharge volume from May 1 through May 10 to account for the majority of the storm hydrograph response, including pond discharges. Peak discharge rates are discussed in the following section.

Figure 4-29. 100-Year Event Discharge Totals for Current Configuration, Scenario 2, and Scenario 3 (10-day totals)



[10] The SWWB model was calibrated to typical events; however, no large events were available on record for calibration. Therefore, these 100-year event simulations applied a set of infiltration rates from the Report on Soil Erosion and Surface Water Sediment Transport Modeling for the Actinide Migration Evaluation (AME) (Kaiser-Hill, 2001). These soil infiltration rates are lower than those of the calibrated SWWB model. Lower infiltration rates increase the runoff for large events. This set of soil infiltration rates was chosen as a conservative assumption for the 100-year event simulations. The AME soil infiltration rates do not significantly affect simulated flow rates for events observed in WY2000 or WY2001.

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An important point illustrated in Figure 4-29 is the magnitude of the simulated discharge; the simulated response is on the order of tens to hundreds of thousands of cubic meters. As a frame of reference, it is useful to compare the event totals to the annual totals presented in Figure 4-16 and Figure 4-21. For Scenario 2 (LCDB Closure Configuration) and Scenario 3 (Current Topography at Closure), the 100-year event discharge volumes are only slightly less than the annual discharge volumes for the entire year of simulation with the WY2000 climate (one-third to one-half when comparing to annual totals for the Current Configuration with the WY2000 climate).

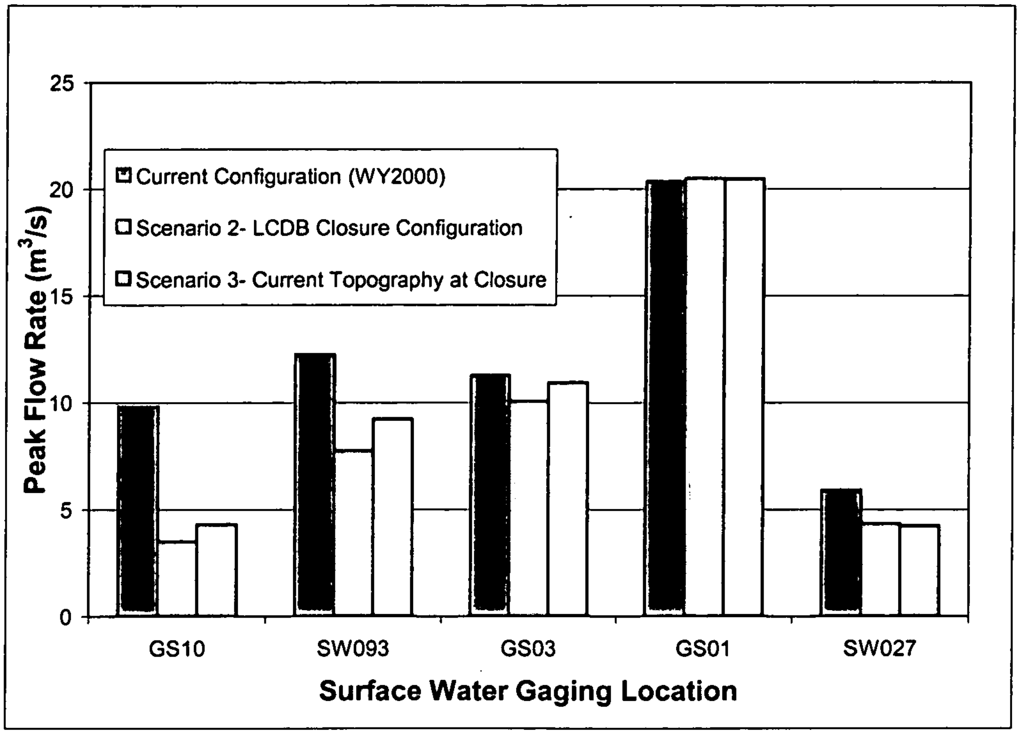
Second, it is noteworthy to compare the 100-year event simulation results for the Current Configuration results with those of Scenario 2 (LCDB Closure Configuration) and Scenario 3 (Current Topography at Closure) to assess the effects of closure on response to a large precipitation event (Figure 4-29). The 100-year event discharge volumes for Scenarios 2 and 3 are 15 to 55% lower than simulated volumes for the current configuration. As expected, the smallest effect (15% decrease) is found for the GS01 drainage which is largely unaffected by simulated closure changes. The biggest effect (55% decrease) is found for the GS10 subdrainage, which is the most highly paved system in the Current Configuration. Though this represents a significant decrease in discharge, it is less than the average 80% decrease simulated for the annual WY2000 totals (see Figure 4-16). This indicates that, though the surface water response to the 100-year event will be reduced at closure, it will not be reduced proportionately with the expected reduction in annual discharge for a typical year.

Third, Figure 4-29 provides information on the relative effect of the topography at closure on the system response to a large event. Comparing the total simulation volumes for Scenario 2 (LCDB Closure Configuration) and Scenario 3 (Current Topography at Closure), it is clear that the topography has little effect on the discharge volume for the 100-year event. Pavement is the primary factor affecting runoff in the IA, and paved surfaces were removed for both Closure Scenarios 2 and 3.

4.3.4.3.2 Peak Flow Rates

Figure 4-30 depicts the simulated peak flow rates for the 100-year event at the major Site gaging stations. As noted for the total hydrograph volumes (Figure 4-29), peak discharge rates decrease for the closure scenarios (2 and 3) as compared to the Current Configuration simulation. Also, peak flow rates are slightly higher for the minimally-changed topography (Scenario 3) as compared to the engineered topography (Scenario 2). As expected, little difference is observed at the GS01 drainage, which derives most of its response from non-IA areas. The minimal effect on peak discharge rates at GS03 can be attributed to pond management, which controls pond discharge rates to Walnut Creek.

Figure 4-30. 100-Year Event Peak Flow Rates for Current Configuration, Scenario 2, and Scenario 3



4.3.4.3.3 Structural Capacity Issues

The simulated flow rates and volumes were considered to assess the response of man-made structures to the 100-year storm event. Structures considered include the A-1 and B-1 bypasses, all pond dams, and the McKay Bypass Canal spillway to Walnut Creek. The assessment was performed for the Current Configuration Scenario, Scenario 2 (LCDB Closure Configuration), and Scenario 3 (Current Topography at Closure). The results are summarized below:

- The capacity of the A-1 bypass is exceeded during the 100-year event simulation for all three scenarios, indicating that water would spill over into Pond A-1;
- The capacity of the B-1 bypass is exceeded only for the Current Configuration Scenario. The closure scenario simulations (Scenarios 2 and 3) produce peak discharge rates below the design maximum for the B-1 bypass. For the Current Configuration Scenario, Ponds A-1, A-3, B-3, and B-5 were simulated to flow the spillways due to inflow rates exceeding structural maximum outlet rates or pumping rates;
- For both Closure Configuration Scenarios (Scenarios 2 and 3), only Pond A-1 flowed the spillway. This difference from the Current Configuration results can be attributed to reduced peak discharge rates and reduced hydrograph volumes; and

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- The McKay Bypass Canal spillway to Walnut Creek flowed for all three scenarios. It should be noted that this may be partially attributed to the simulated inflow hydrographs on the upstream end of the McKay Bypass Canal (from the Master Drainage Plan- EG&G, 1992). It is expected that this hydrograph is an overestimate, as it was developed from conservative assumptions for design purposes.

It should be noted that these simulations do not account for the conditions of debris clogging the bypass, outlet, or spillway structures. Such debris would be expected in a large event. Further, the initial pond levels at the advent of a 100-year storm could be higher than simulated here. Higher initial pond levels could result in more spillways being activated. In general, however, the system at closure, as simulated, should be better able to accommodate a 100-year event.

5.0 SUMMARY OF FINDINGS

Three main tasks were addressed in this study:

- Assessment of groundwater flow in VOC plume areas;
- Evaluation of remedial designs; and
- Simulation of additional SWWB hypothetical land configuration scenarios.

To accomplish these tasks, observed data were evaluated, previously-simulated modeling results were considered, and additional model simulations were performed. The major findings for these three tasks are summarized in the following sections.

5.1 Findings of Subsurface Flow Assessment in VOC Plume Areas

Three VOC plume areas are considered in this white paper discussion. These include the following:

- IA VOC plumes;
- Solar Ponds Area VOC plumes; and
- 903 Pad Area VOC plumes.

These areas were evaluated in terms of data availability, individual plume areas, and factors that affect local-scale groundwater flow. Findings of these evaluations are presented in the following sections.

5.1.1 Data Availability

A thorough evaluation of data needs for VOC modeling cannot be completed until the evaluation of hydrologic, geologic, and water quality data is completed, and the conceptual models are evaluated for consistency. The assessment of water quality data, is currently in progress. An initial sense of data limitations as they may impact local-scale flow and VOC transport models can be made based on initial reviews of data. Initial reviews of both geologic, hydrologic, and water quality data have been completed.

In general, the Site has good spatial distribution of geologic (bedrock surfaces), climatic, and groundwater level data sets. There are some significant limitations, however, that will present challenges in the VOC modeling effort. First, few historical groundwater level measurements exist between 1950 and the early 1990s. Second, historical precipitation records are limited for the same period. These limitations will complicate efforts to accurately simulate both Site-specific contaminant time-series and the existing VOC plume distributions.

Initial reviews of VOC source and plume data availability also indicate some limitations that will affect modeling efforts. Groundwater sampling at the Site has not been focussed

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on identifying sources or linking observed contamination to sources. Consequently, developing the initial conceptual models will be challenging.

Limitations are also present in contaminant source information. The quantity, concentration, composition, and/or release dates are uncertain for most releases. All available information will be used as applicable; however, the conceptual modeling effort will have to test multiple hypotheses and develop assumptions to proceed without this information.

5.1.2 Factors Affecting Local-Scale Groundwater Flow

Many factors affect groundwater flow paths. On a regional scale, flow paths are largely controlled by the bedrock surface, and they will not change significantly at closure. However, on a local scale, groundwater flow directions will be strongly influenced by other factors. This must be taken into consideration for flow and transport modeling. These factors are summarized below in *Table 5-2*.

5.1.3 Findings for Individual VOC Plume Areas

Highlights for each VOC plume area are summarized in the following three sections.

5.1.3.1 Industrial Area VOC Plumes

The IA VOC plumes occur in an area of higher density of subsurface utilities, building basements, and stream channels (North Walnut Creek), as compared to the other VOC plume areas. Consequently, it is anticipated that these local scale features may be important considerations in simulating transport in the IA plumes area. It is likely, however, that the decreasing depth of bedrock to the east remains the dominant factor controlling groundwater flow directions. The apparent divergence in the Tier I level VOC plumes in the IA is likely caused by this shallow bedrock to the east.

5.1.3.2 Solar Ponds Area VOC Plumes

Unsaturated areas within the unconsolidated material are prevalent within the Solar Ponds area plumes because of the higher percentage of hillslope areas and the occurrence of Arapahoe Sandstone Lenses. When water levels fall below the bottom of the unconsolidated material, groundwater velocities decrease rapidly; whereas when the levels are within the unconsolidated material, flow rates will be higher. This will be an important consideration in VOC modeling.

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Table 5-1. Factors Affecting Local-Scale Groundwater Flow

Parameter of Importance	General Description
Bedrock Surface	Though the bedrock surface plays an important role in VOC transport on a regional scale, the factors discussed below become more important at a local scale.
ET	Vegetation-specific parameters used in the model strongly affect the unsaturated zone water balance, thereby affecting recharge, saturated flow, and transport.
Basements	At a local scale, vertical walls left in place will impede lateral movement of groundwater and affect levels and transport.
Subsurface Utilities	Finer resolution flow models should more accurately account for utilities and their effects on groundwater flow and transport.
Streams	Streams could affect groundwater flow and VOC transport within the IA VOC plumes, where North Walnut Creek extends into the plume area.
Precipitation	Adequate simulation of historical precipitation is important for correct simulation of recharge and subsequent effects on plume migration. Effects on simulated flow of climate generation and temporal averaging will have to be assessed.
Saturated Zone Hydraulic Conductivity	Saturated zone hydraulic conductivity significantly affects groundwater levels and flow (see SWWB sensitivity analysis - Kaiser-Hill, 2002b). Determining appropriate local vertical and horizontal distributions within each model area will be key to successfully modeling flow and transport.
Storage	Groundwater storage coefficients affect the rate at which groundwater levels change and the amount of water available in the subsurface. Therefore, variability in storage on a local scale may be important to VOC plume simulations.
Arapahoe Sandstone	The location of Arapahoe Sandstone Lenses is important locally because contaminants will flow more rapidly through these units of higher hydraulic conductivity, if saturated.
Faults	It is not yet clear whether faults exist at the Site, but if they do, they could influence VOC transport. Evidence of faulting will be evaluated in the conceptual development phase.

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Parameter of Importance	General Description
Unsaturated Zone Heterogeneity	Vertical heterogeneity (e.g., caliche) within the unsaturated zone column may impact the vertical unsaturated/ ET dynamics and resulting recharge. Special care will be taken in evaluating historical, current, and future unsaturated zone characteristics, including vegetation dynamics.
Historical Site Development	Historical and future Site development may influence recharge, ET, and drainage, thereby affecting contaminant transport.

5.1.3.3 903 Pad Area VOC Plumes

Unsaturated areas within the unconsolidated material are also prevalent within the 903 Pad area plumes because of the higher percentage of hillslope areas and the occurrence of Arapahoe Sandstone Lenses. As discussed, when water levels fall below the bottom of the unconsolidated material, groundwater velocities decrease rapidly. Further, where Arapahoe Sandstone Lenses are present and continuous as in the 903 Pad area plumes, groundwater flow will be dominated by the shape, extent, and outcropping of the sandstone bodies.

The paleochannel that starts near the 903 Pad and extends to the east and northeast is consistent with the location of the thickest occurrence of Arapahoe Sandstone. The 903 Pad area divergence is consistent with the bedrock surface, and it is also influenced by the unsaturated zone.

The 903 Pad area suffers somewhat from a lack of geologic data in the east and southeast areas. As a result, the interpolated bedrock surfaces in these areas are more uncertain than other plume areas with more surface control points.

5.1.4 Data Needs and Limitations for VOC Modeling

The success of a flow and transport model depends to a large extent on the quality and quantity of available data. Adequate data are critical to the development of physically realistic conceptual models. Poorly defined conceptual models lead to higher uncertainty in simulated output from numerical models. Further, the ability of a model to simulate VOC transport in the subsurface typically depends mostly on advective flow rather than factors like dispersion. As a result, accurate flow models are essential to accurately predicting transport and require adequate supporting data.

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It is generally difficult to assess the implications of data gaps on modeling without actually creating a model and then simulating flow and transport conditions. Only through this process can the sensitivity of assumptions be assessed. Before model development, an initial review of available data can also indicate areas where data are limited. The initial review of data produced the following items of concern:

- **Geologic Data.** More information on the degree of vertical heterogeneity in the unconsolidated material must be gathered. Some of this information may be available in original borehole logs. These will be reviewed and if necessary, synthesized and evaluated to clearly identify subsurface trends that may affect local contaminant transport. Other geologic information like faults can affect local flows and transport but these features have not been clearly identified. Conceptual model development should indicate any significant effects of faulting and respective data needs.
- **Hydrologic Data.** Though there is fairly good groundwater level data across the VOC plume areas, other types of useful hydrologic data are much more limited. For example, surface flow gage data at key groundwater discharge points would be very helpful in defining losing/gaining rates. Seep flow rates under varying climate and subsurface conditions would also be useful.
- **Vegetation Parameters.** Other factors like vegetation will have a substantial impact on future hydrologic conditions and likely transport. Little Site-specific information is available on seasonal effects of vegetation parameters like Leaf Area Index, root depth, density (crop coefficient), or interception.
- **Historical Data.** Significant gaps in historical data have been noted. For example, groundwater level data and climate data are very limited between 1950 and the early 1990's. These data limitations will require assumptions in the modeling work and increased uncertainty.

5.2 Findings of Hypothetical Remedial Design Simulations

5.2.1 Hypothetical Slurry Walls in the Original Landfill Area

Two simulations were conducted to evaluate the effects of a hypothetical single slurry wall extending through the weathered bedrock in the Original Landfill area. Results show the following:

- The lateral extent affected by a hypothetical slurry wall is limited to several hundred feet;
- The magnitude of change to upgradient or adjacent groundwater levels is less than about a meter. Groundwater levels increase on the upgradient side of the slurry wall, but decrease within the Original Landfill waste material downgradient of the wall. The increase in heads will cause flow directions to change slightly upgradient of the wall. This change in flow directions will probably cause the southern extent of the IA plumes to be redirected from the current pathway;
- Recharge could not be entirely eliminated with the designed geotechnical cover as specified; and

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- Dewatering will take decades to occur within the Original Landfill area given the relatively low saturated hydraulic conductivities.
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5.2.2 Hypothetical Interceptor Trenches in the Industrial Area

Two hypothetical interception trench scenarios in the IA were simulated to evaluate the hydraulic effect of these systems on subsurface flows. Results showed that the influence of these systems on surrounding subsurface flows is limited due to the shallow aquifer, low aquifer permeabilities and strong localized influence of recharge and ET. The implication to remedial design is that trenches must be designed to extend across the entire lateral extent of any plume migration pathway to capture VOCs.

5.3 Findings of Additional Hypothetical Land Configuration Scenarios

Task 2 involved simulation of four new hypothetical scenarios, using the SWWB model. The description of each scenario and the major findings are summarized in Table 5-2. Scenarios performed as part of the earlier study (Kaiser-Hill, 2002b), are also presented in the table for reference.

Table 5-2. Summary of Hypothetical Model Scenarios and Major Findings

Hypothetical Simulation	Description	Major Finding
Current Configuration Simulation	Simulation of Site hydrology as configured in 2000.	The calibrated SWWB model simulates current hydrology well. (see Kaiser-Hill, 2002b)
Scenario 2 – LCDB Closure Configuration	Simulation of Site hydrology at closure – closure configuration based on LCDB Report.	Significant decrease (~75%) in surface water discharge will occur at closure in Walnut Creek. (see Kaiser-Hill, 2002b)
Scenario 3 – Current Topography at Closure	Simulation of Site hydrology at closure – identical to Scenario 2, but topography simulated as current topography instead of engineered LCDB topography.	Leaving the current topography in place at closure should not produce significantly different surface water discharge volumes as compared to the engineered topography. Groundwater levels are higher in some areas, and lower in others, relative to Scenario 2. Groundwater depths remain fairly constant in the central IA.
Scenario 4 – Subsurface Utilities in Place at Closure	Simulation of Site hydrology at closure – Identical to Scenario 3, but subsurface utilities left in place.	Leaving drains in place at closure increases surface water discharge from the IA and lowers IA groundwater levels, relative to Scenario 3.
Scenario 5 – Upgradient Mining at Closure	Simulation of Site hydrology at closure – Identical to Scenario 2, but mining activities simulated on west side of Site.	As simulated, upgradient mining activities at closure indicate no effect on groundwater levels in the IA. This is in agreement with the Site conceptual model.
100- Year Events (multiple simulations)	100-Year precipitation event - simulated for the current configuration, Scenario 2, and Scenario 3 (for a range of soil infiltration rates).	First, the SWWB model is capable of simulating large events like the 100-year event. The simulated runoff volume and flow rates for the 100-year event decrease at closure, as compared to the current configuration. This decrease, however, is smaller proportionately than the decrease in annual surface water discharge for a typical year at closure.

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6.0 NEXT STEPS

To continue progress in support of Site Environmental Restoration closure projects and the CRA, the following tasks have been identified as the necessary next steps for modeling:

- **Geologic and hydrologic databases developed for the SWWB model will be updated.**

  Recently collected geologic and hydrologic information will be incorporated into the GIS database originally developed for the SWWB model (2000).

- **VOC source and plume information will be gathered into linked databases and evaluated to develop conceptual models.**

  Current efforts are towards compiling, reviewing, and conceptualizing source information and monitoring data for VOCs in groundwater. Source information is being collected from the Historical Release Reports (EG&G, 1992, 1993a,b,c,d,e; 1994a, b,c,d; 1995a,b,c; RMRS, 1996, 1997, 1998, 1999; Kaiser-Hill, 2000b, 2001b, 2002c) into an electronic database, including spatial information. Simultaneously, VOC data are being collected from the Site Soil Water Database (SWD). These data will be assessed spatially and temporally. The VOC conceptual models will be developed combining source information with monitoring data and the hydrologic conceptualizations. This is important to develop prior to modeling so that clear and concise models can be produced.

- **Focused modeling for VOC Plume Areas will be performed.**

  The existing SWWB model (regional-scale) will be used as the basis of a flow and transport model to simulate migration of VOCs for the CRA. This will revolve refinement of the SWWB hydrologic model and coupling with a compatible transport model. The refinement will allow for simulation of features affecting local-scale flow and transport in key VOC contaminated areas.

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7.0 REFERENCES

EG&G, 1992. Historical Release Report for the Rocky Flats Plant- Final. U.S. Department of Energy. Golden, CO. June, 1992.

EG&G, 1993a. Quarterly Update to the Historical Release Report. U.S. Department of Energy. Golden, CO. September, 1992.

EG&G, 1993b. Quarterly Update to the Historical Release Report. U.S. Department of Energy. Golden, CO. January, 1993.

EG&G, 1993c. Quarterly Update to the Historical Release Report. U.S. Department of Energy. Golden, CO. April, 1993.

EG&G, 1993d. Quarterly Update to the Historical Release Report. U.S. Department of Energy. Golden, CO. July, 1993.

EG&G, 1993e. Quarterly Update to the Historical Release Report. U.S. Department of Energy. Golden, CO. October, 1993.

EG&G, 1994a. Quarterly Update to the Historical Release Report. U.S. Department of Energy. Golden, CO. January, 1994.

EG&G, 1994b. Quarterly Update to the Historical Release Report. U.S. Department of Energy. Golden, CO. April, 1994.

EG&G, 1994c. Quarterly Update to the Historical Release Report. U.S. Department of Energy. Golden, CO. July, 1994.

EG&G, 1994d. Quarterly Update to the Historical Release Report. U.S. Department of Energy. Golden, CO. October, 1994.

EG&G, 1995a. Quarterly Update to the Historical Release Report. U.S. Department of Energy. Golden, CO. January, 1995.

EG&G, 1995b. Quarterly Update to the Historical Release Report. U.S. Department of Energy. Golden, CO. April, 1995.

EG&G, 1995c. Quarterly Update to the Historical Release Report. U.S. Department of Energy. Golden, CO. August, 1995.

Kaiser-Hill, 2000a. 1999 Annual Groundwater Report for Rocky Flats Environmental Technology Site. Golden, CO.

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Kaiser-Hill, 2000b. Annual Update for the Historical Release. Revision 0, September, 2000.

Kaiser-Hill, 2001a. Report on Soil Erosion and Surface Water Sediment Transport Modeling for the Actinide Migration Evaluation. Rocky Flats Environmental Technology Site. August, 2001.

Kaiser-Hill, 2001b. Annual Update for the Historical Release. Revision 0, September, 2001.

Kaiser-Hill, 2002a. Land Configuration Design Basis – Preliminary Report. Prepared for Rocky Flats Environmental Technology Site. March, 2002.

Kaiser-Hill, 2002b. Site-Wide Water Balance Model Report for the Rocky Flats Environmental Technology Site. May, 2002.

Kaiser-Hill, 2002c. Annual Update for the Historical Release. Revision 0, September, 2002.

Kaiser-Hill, 2002d. Final 2001 Rocky Flats RFCA Annual Groundwater Monitoring Report. November, 2002.

RMRS, 1996. Annual Update for the Historical Release. August, 1996. RF/ER-96-0046.

RMRS, 1997. Annual Update for the Historical Release. Revision 0, September, 1997. RF/RMRS-97-073.UN.

RMRS, 1998. Annual Update for the Historical Release. Revision 0, September, 1998. RF/RMRS-98-269.UN.

RMRS, 1999. Annual Update for the Historical Release. Revision 0, September,1999 RF/RMRS-99-428.UN.

Weidemeier, T.H., Rifai, H.W., Newell, C.J., and Wilson, J.T., 1999. Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface. New York: John Wiley & Sons.

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