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ADDENDUM NO. 2
TO THE
PRELIMINARY DESIGN REPORT
FOR THE
GROUNDWATER REMEDIAL ACTION
REVISION 0
ISSUED MAY 8, 2001

CRAB ORCHARD NATIONAL WILDLIFE REFUGE
PCB OPERABLE UNIT - SITES 32/33
MARION, ILLINOIS

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Section 1
Background

The Preliminary Design Report for the Groundwater Remedial Action – Revision 0 for Sites 32/33 at the PCB Operable Unit (the PD Report) was issued on 8 May 2001. Preliminary review comments on the PD Report were provided by the U.S. Fish and Wildlife Service (F&WS) on 23 May 2001. A conference call was held on 24 May 2001 to discuss the preliminary review comments from the F&WS. As agreed during the conference call, Addendum No. 1 to the PD Report was prepared and issued on 26 June 2001. Addendum No. 1 included estimates of the total volatile organic compound (VOC) mass present in each of the primary VOC source areas, and the VOC mass removal that is estimated to be achievable at each VOC source area using the multi-phase extraction (MPE) and soil vapor extraction (SVE) systems as configured in the PD Report.

Addendum No. 1 was discussed during Technical Working Group (TWG) meeting #6 held at the Refuge headquarters on 11/12 July 2001. At the meeting, modifications of the source area treatment systems were proposed by RMT and Schlumberger. The purpose of the modifications is to address the expected difficulties in recovering significant quantities of VOCs from the clay soil in the source areas, due to the relatively low permeability and high moisture retention capacity of the clay. During the TWG meeting, it was agreed that updated estimates of the effect over time of the proposed treatment system modifications on the VOC plumes downgradient of the source areas following implementation of the proposed modifications would be prepared, using the groundwater contaminant transport model developed for the Focused Feasibility Study (FS) Report. These updated estimates were requested to assist in evaluating the overall effectiveness of the proposed modifications in mitigating groundwater contamination associated with Sites 32/33 by removal of VOCs from the source areas, as defined in the Explanation of Significant Differences (ESD) issued by the United States Environmental Protection Agency (USEPA) in June 2000.

This Addendum No. 2 to the PD Report provides the updated estimates of the effectiveness of the proposed and alternative remedial action approaches, as discussed during the TWG meeting.

A summary of the groundwater quality simulations run using the contaminant transport model that are presented in this addendum is included in Table 1.

Section 2
Buildings I-1-2/I-1-3 Area

2.1 Remedial Action Description

The remedial action for the VOC source areas at Buildings I-1-2 and I-1-3, as proposed during TWG meeting #6, includes MPE wells with pneumatic fracturing of the clay soil. Information describing pneumatic fracturing technology was distributed at TWG meeting #6. The purpose of pneumatic fracturing is to significantly increase the permeability of the Upper Clay and Lower Clay soil. This would greatly improve the ability to dewater the clay, which would expose a substantial volume of voids within the clay for air-phase transport and removal of VOCs via the MPE wells, assisted by passive air vent wells open to the atmosphere. The absence of a continuous Upper Sand layer at these source areas and fewer buried utilities than at the I-1-23 source area makes use of pneumatic fracturing particularly applicable at this location.

The estimated extent of the zone of influence or Treatment Zone of the MPE systems after pneumatic fracturing is shown on figures in Attachment 1. The radius of influence of the MPE wells has been conservatively estimated to be 20 feet. A well spacing of 34 feet would be used, to provide an overlap of approximately 6 feet for the vacuum influence of individual MPE wells.

The term "Treatment Zone" used in this Addendum refers to the estimated 3-dimensional zone of influence of the remediation system within the overall volume of soil comprising the source area.

2.2 Estimated Remedial Action Results

2.2.1 Groundwater Quality

Unlike the Building I-1-23 source area, where the geologic conditions were found to be very similar to the assumed conditions at the time of the Focused FS, the geology and the contaminant distribution within the I-1-2/I-1-3 source areas were found to be significantly different than in the conceptual model used in the Focused FS. The Upper Sand unit is not present as a continuous layer in the area immediately east of Buildings I-1-2 and I-1-3.

To address this new information, the groundwater flow model that was presented in the Groundwater Investigation Report (Revision 1, January 2000) was modified by assigning a lower hydraulic conductivity (K) value to model Layer 2, which corresponded with the Upper Sand unit in other areas of the site. A "K" value that was lower, by an order of magnitude (but higher than that of the Upper Clay), was assigned to Layer 2 in this area. Constant-concentration nodes were also modified from the original model to reflect the refined understanding of the distribution of VOCs in the soil and groundwater within the primary source areas. To represent the two separate source areas at Buildings I-1-2 and I-1-3, two zones of constant-concentration nodes were assigned that corresponded to the zones where the highest VOC concentrations were observed in soil and groundwater. Constant-concentration nodes were also specified for model Layers 1 through 3 in the I-1-2/I-1-3 area (Layer 3 is the Lower Clay unit), whereas only Layer 1 had constant-concentration nodes in the original model. Additional model revisions included the following:

- A tighter model grid in the vicinity of Buildings I-1-2/I-1-3 in model runs where a permeable reactive barrier (PRB) was simulated (discussed further below), so that the width of the PRB could be simulated.
- "Drain" nodes rather than "river" nodes were specified in MODFLOW for a wider area near I-1-2 and I-1-3, near the "intermittent stream" shown on the site plan figures, and at a somewhat lower elevation than in the original model. This change had the effect of lowering the hydraulic head in this area to better match observed heads, and serves as a hydraulic sink for groundwater.

The model was recalibrated after making the set-up adjustments to replicate the existing TCE plume as closely as possible. The adjusted model provides useful projections of the comparative level of improvement in groundwater quality that is likely to be seen over the evaluation time periods of 5 years, 10 years, and 20 years after the start of remediation, resulting from the simulated remediation systems. The estimated plumes representing current conditions are shown on figures in Attachment 1, and closely resemble the simulated plumes previously presented in the model results section of the Groundwater Investigation Report (Revision 1, January 2000).

Similar to the approach used for the I-1-23 area (Section 3), the key estimated input parameter for the model runs is the average TCE concentration that will be present in groundwater within the defined source area boundaries following treatment. This estimated concentration was used in the model as a representative source area groundwater concentration of TCE that was held constant throughout the model run time periods, conservatively simulating the continuing generation of dissolved-phase TCE that will occur due to VOC residuals that will not be removed by the source area treatment.

Using data produced with the EVS Pro software (refer to Addendum No. 1 for description) and additional manual calculations using the VOC concentration contour figures in the PD Report, the VOC mass present in the Treatment Zones is estimated to range from 31 percent of the total VOC mass in the I-1-2 source area, to 71 percent in the I-1-3 source area (refer to Table 2). The estimates of percent achievable VOC removal and VOC mass in the Treatment Zones as a percent of the mass in the overall source areas were then used together to calculate an average estimated achievable VOC removal of 17 percent of the total mass currently present in the overall source area at I-1-2 to 39 percent at I-1-3. This range was estimated based on published performance data from similar sites, and on information from the remediation contractor who is the licensee for application of the patented pneumatic fracturing technology in the United States (ARS Technologies, Inc.). It was then assumed that the average TCE concentration in groundwater within the overall source areas following treatment will be reduced in the same proportion as the estimated range of overall VOC mass removal.

The model is capable of simulating the subsurface behavior and fate of specific organic compounds, rather than an entire class of substances such as total VOCs. For all of the model simulations presented in this addendum (and in the previous Focused FS Report), TCE was selected as the compound for use in the model. TCE is the primary contaminant in soil and groundwater at the site, and is generally representative of the range of VOCs present. Although the discussions and estimates of remediation effectiveness for the VOC source areas are based on the total VOCs present, the groundwater modeling simulations are based on TCE as the most representative single VOC.

The model runs simulate the effects on the TCE plume over time due to dispersion, dilution, advection, sorption, volatilization, and natural degradation through biotic and abiotic means, with the estimated constant average TCE concentration in groundwater within the source area. Although these degradation processes are also expected to reduce the TCE concentrations in groundwater within the primary source area over time to some degree, the more conservative approach of using constant groundwater concentrations within the source area was applied.

The average source area TCE concentration currently present in groundwater, as obtained from groundwater model calibration and confirmed with actual sampling data, was reduced by the average estimated achievable VOC removal. The resulting calculated TCE concentrations were used as constant-source input values for the model runs to simulate the future TCE plumes. The estimated values used with the adjusted groundwater model to prepare the simulated TCE plumes shown on figures in

Attachment 1 are summarized in Table 2. The projections of future groundwater quality using the groundwater model are best evaluated in a relative or comparative sense, rather than taken as absolute numerical estimates of high accuracy.

Figures showing the model simulations for use of MPE wells with pneumatic fracturing are included in Attachment 1 (I-1-2/I-1-3 area, Case 1).

2.2.2 VOC Mass Removal

The estimated VOC mass present in the overall source area at Buildings I-1-2 and I-1-3 is summarized in Table 1 of Addendum No. 1 to the PD Report. These estimates have been revised slightly using the EVS software applied to the overall source areas without distinguishing between soil units. This approach yielded somewhat higher VOC mass estimates than presented in Addendum No. 1. The estimated total VOC mass in the source areas and estimated VOC removal that is achievable using the remediation approach described above are summarized in Table 2 of this addendum. For comparison, the VOC mass removal that is estimated to be achievable using MPE wells without pneumatic fracturing enhancement is summarized in Table 3.

2.3 Alternative Technologies

2.3.1 Background

The F&WS requested that certain technologies be considered for possible application at the Buildings I-1-2/I-1-3 area, as alternatives to the use of MPE wells with pneumatic fracturing. For source area treatment, the general technologies suggested by the F&WS included *in situ* chemical oxidation, and enhancement of *in situ* biodegradation of the VOCs. Specific technology vendors mentioned by the F&WS include In-situ Oxidative Technologies, Inc. (the ISOTEC℠ process), and Regenesis (Hydrogen Release Compound – HRC®). Both of these *in situ* technologies function by destroying VOCs within the soil, without requiring aboveground treatment.

At TWG meeting #6, the approach of abandoning the current remedial action objective of VOC source removal to mitigate future groundwater impacts, and using *in situ* "passive" methods to treat or "cut off" the VOC plume downgradient to the west of the I-1-2/I-1-3 source areas, was also suggested by the F&WS. The technologies provided by *In Situ* Oxidative Technologies (ISOTEC) and Regenesis (HRC) were again mentioned for this approach, as well as the use of *in situ* permeable reactive barriers (PRBs) using zero-valent iron for chemical reduction of dissolved VOCs in the groundwater plume.

In response to these requests and suggestions, RMT contacted several remediation vendors/contractors to obtain their recommendations and proposals for use of their technologies at Sites 32/33. A package of information, including figures, maps, and data tables describing the present site conditions was sent to each company, with follow-up telephone discussions to answer questions and provide further instructions for the proposals. The companies that were contacted are listed in Table 4.

Copies of the proposals received from each company are included in Attachment 4. The proposals received from the companies offering the alternative technologies suggested by the F&WS are included with this addendum to provide general information for the recipients of the PD Report.

2.3.2 VOC Source Areas

In Situ Chemical Treatment

The proposals received for the ISOTEC process and from ARS Technologies (Ferox process) address direct, *in situ* chemical destruction of the VOCs. ISOTEC indicates that their process is not suited for use in the VOC source areas at I-1-2/I-1-3. Their proposal states "The use of chemical oxidation within an aquifer exhibiting such a low (hydraulic) conductivity would provide limited remedial benefits."

Although not requested or suggested by the F&WS, the potential use of pressure-injected zero-valent iron powder for the clay at the I-1-2/I-1-3 source areas was addressed in a proposal from ARS Technologies (the Ferox process). The expected VOC mass destruction efficiency that would result from the proposed single application of Ferox powder into a portion of the source areas was not addressed by ARS.

In Situ Bio-enhancement

A proposal was submitted by Regenesis for application of their HRC treatment at the I-1-2 source area. However, Regenesis did not recommend use of their standard HRC product at the I-1-3 source area, citing possible ineffectiveness due to the "highly contaminated" soil at that location. For the I-1-2 area, Regenesis indicated that up to three separate applications of the HRC chemical into the clay may be necessary. However, the Regenesis proposal did not have any discussion of the expected VOC destruction effectiveness from use of their HRC product.

2.3.3 Cut-off and *In Situ* Treatment of Downgradient Plume

Chemical Treatment

The F&WS requested that consideration be given to an approach of installing a permeable reactive barrier (PRB) in the Upper Sand unit downgradient of the source areas across the width of the VOC plume that extends to the west, to provide passive treatment of dissolved VOCs as the groundwater flows through the PRB.

Proposals were received from two companies to provide a PRB using zero-valent iron (see Attachment 4). Both proposals suggest a similar approach of installing zero-valent iron across the full depth of the Upper Sand unit to the west and downgradient of the source areas. The PRB would be installed along a line approximately 650 to 1,000 feet long across the width of the VOC plume in the Upper Sand, located parallel to, and along the western side of, the main plant access road.

The PRB proposed by ARS Technologies would use their proprietary Ferox iron powder, which would be injected into the sand. The EnviroMetal Technologies, Inc. (EnviroMetal), proposal includes placement of granular iron in a trench excavated to the desired depth (average of 27.5 to 35 feet bgs) using a biopolymer slurry to keep the trench open in the sand while the iron granules are being placed. Although different construction methods are used by these two companies, the treatment effect of the PRB on the VOC plume is expected to be similar. Estimates of the average concentration of TCE in treated groundwater ranged from 5 μg/L (EnviroMetal) to less than 250 μg/L (ARS). A TCE concentration within this range (40 μg/L) was used with the groundwater model to simulate the effect on the TCE plume downgradient of the PRB over time periods of 5 years, 10 years, and 20 years. Figures showing these projections are included in Attachment 1. The treatment effectiveness of the iron PRB may eventually diminish over time, primarily due to the accumulation of mineral precipitate within the PRB zone. However, for the modeling simulations shown in Attachment 1, it was assumed that the estimated TCE concentration in groundwater exiting the PRB would consistently remain 40 μg/L.

To meet the remedial action objective for use of a PRB in lieu of VOC source area treatment, the PRB must function effectively for many decades. If mineral precipitate were allowed to accumulate within the PRB to the point where the

bulk permeability of the PRB is less than the permeability of the natural Upper Sand unit, the contaminated groundwater in the Upper Sand may flow around the PRB. To minimize this possibility, the physical condition and performance of the PRB would need to be monitored and evaluated on a periodic basis, possibly as part of the 5-year reviews of the PCB Operable Unit that will be performed by the USEPA.

The VOC plume that extends eastward from the I-1-2/I-1-3 source areas would not be remediated by use of a PRB for the plume that extends westward from the source areas. However, the modeling results show that the approach of using MPE wells with pneumatic fracturing in the source areas would also not provide a noticeable improvement in groundwater quality to the east of the source areas, compared with reliance on monitored natural attenuation alone, as shown by the model simulation figures in Attachment 1 (I-1-2/I-1-3 area, Cases 2 and 3).

ISOTEC also provided a proposal that includes use of their chemical oxidation method applied in the west VOC plume in the Upper Sand in a configuration similar to the iron PRB. However, unlike the iron PRB, the ISOTEC process would be a one-time treatment event that would provide no long-term treatment or cut-off of the VOC plume. Because the VOCs within the I-1-2/I-1-3 source areas would remain, a VOC plume would continue to be generated at the source areas. The western plume would be re-established or "rebound" following the ISOTEC treatment event, negating the beneficial effect of the treatment. For this reason, use of the ISOTEC process to function as a downgradient PRB in the western plume was not considered to be a viable alternative, and was not simulated using the groundwater model.

Bio-enhancement

The proposal provided by Regenesis includes an approach for the injection of HRC chemical into the Upper Sand unit in the western plume downgradient of the source areas, to function in a manner similar to a PRB. The HRC would provide only a temporary reduction of VOC concentrations in the groundwater as it flows through the HRC zone in the sand, through enhanced biodegradation. Regenesis estimated that the HRC injections would have to be repeated as often as annually, over the full time period that plume cut-off is desired, to maintain treatment effectiveness. However, Regenesis did not provide information on the expected VOC treatment effectiveness of the HRC. The concept of using enhanced biodegradation to provide "cut-off" of the VOC

plume downgradient of the source areas suffers from the same significant limitation as the use of *in situ* chemical oxidation for this purpose. Unless most of the VOCs in the source areas are also removed or destroyed, the western plume with substantial VOC concentrations will continue to be generated for decades. Unless fresh HRC applications in the Upper Sand are repeated, the effectiveness in the HRC treatment zone will be depleted, and the western VOC plume will be re-established relatively quickly. For these reasons, use of HRC to function as a downgradient PRB or treatment zone in the western plume was not considered to be a viable alternative, and was not simulated using the groundwater model.

2.4 Conclusions and Recommendations

The alternative technologies for *in situ* destruction of VOC mass within the primary source areas at I-1-2 and I-1-3 that were suggested in proposals received from remediation contractors (ISOTEC, Ferox, and HRC) are considered to be inappropriate for the site conditions (as stated in the proposals), or to present a high degree of uncertainty regarding the achievable treatment effectiveness. Due to these deficiencies, the remediation approach using MPE wells with pneumatic fracturing enhancement would be expected to be more effective for direct treatment of the source areas than any of the alternative technologies suggested by the remediation contractors.

The use of MPE wells with pneumatic fracturing in the I-1-2 and I-1-3 source areas is expected to remove a significant mass of VOCs from the clay at both areas. However, the modeling simulations show that the VOC mass that would remain after the active treatment period would continue to produce a substantial VOC plume that would show marginal improvement compared with reliance on monitored natural attenuation alone, even after 20 years.

For the alternative remedial action approach involving *in situ* treatment for cut-off of the VOC plume to the west of the main source areas, a PRB using zero-valent iron placed into the Upper Sand unit would provide relatively significant improvement in groundwater quality in the large area between the building complex and Highway 148, as shown by the modeling simulations. A PRB would also offer the benefits of both containment of the higher VOC concentrations in groundwater in the vicinity of the source areas, and continuous *in situ* treatment (destruction) of the VOCs as the contaminated groundwater flows through the PRB in the Upper Sand under natural hydraulic gradients.

The installation of a PRB using zero-valent iron is recommended for implementation to address the Buildings I-1-2/I-1-3 source areas. Monitored natural attenuation would also remain as a component of the remedial action.

Section 3
Building I-1-23 Area

3.1 Remedial Action Description

The remedial action for the Building I-1-23 source area, as proposed during TWG meeting #6, would focus on removal of VOCs from the zones of higher VOC concentrations in the Upper Sand unit, using the treatment approach as described in the PD Report. The treatment system would include the following:

- Horizontal groundwater extraction wells installed along the base of the Upper Sand, above the Lower Clay unit. Per the results of groundwater modeling, three wells may be installed instead of two wells as shown in the PD Report. The objectives of the horizontal wells are to dewater the Upper Sand as much as possible to enhance the effectiveness of vapor-phase VOC removal from the sand, and to recover a significant portion of the VOC plume originating from the I-1-23 source area.
- SVE wells screened in the Upper Sand unit, within the selected Treatment Zones.
- MPE wells installed at locations and with screened intervals selected to recover VOCs from the Treatment Zones that are believed to include the higher VOC concentrations, but located in low spots that may not be effectively dewatered by the horizontal wells alone.

The initial fieldwork task during the construction phase would include drilling at several locations along east-west transects across the source area to obtain information to better define the stratigraphy, particularly the Lower Clay surface contours. The drilling would focus on identifying the location of the depression in the Lower Clay resulting from an apparent buried former stream channel that trends from south to north through the I-1-23 area. Data from the pre-design fieldwork in the fall of 2000 indicated that this depression includes pockets of elevated VOC concentrations that accumulated over time in the sand near the Lower Clay surface. The data produced from this initial drilling effort would be used to locate the three horizontal groundwater extraction wells within the Upper Sand, including one well installed following the buried stream channel depression in the Lower Clay, to the greatest practical extent. Additional MPE wells would also be located along the path of the buried channel within the selected Treatment Zones, screened down to the Lower Clay surface. The objective for installation of the groundwater extraction wells and the deeper MPE wells in the buried channel is to enhance the recovery of VOCs from the deeper portions of the Upper Sand unit.

The estimated extent of the zone of influence or Treatment Zone within the Upper Sand at the I-1-23 area is shown on figures in Attachment 2. As shown on one of these figures, a significant portion of the VOC plume created by the I-1-23 source area is expected to fall within the cone of

depression created by the horizontal extraction wells, which would extend from the source area to a radius of at least 300 feet. During the operating period of the extraction well system, the contaminated groundwater within the I-1-23 source area would be effectively cut off from replenishing the VOC plume in the Upper Sand that discharges into the West Swale and the lake. The removal of one pore volume of groundwater within the capture zone of the horizontal wells is estimated to remove approximately 16 pounds of VOCs from the Upper Sand. Additional VOC mass would be removed with the extracted groundwater as the well system is operated to maintain lowered groundwater heads within the Upper Sand during the operating period of the MPE/SVE well system. The extraction wells would also be available for operation after shutdown of the MPE/SVE system, possibly on an intermittent or reduced flowrate basis, to recover contaminated groundwater that will continue to flow in the Upper Sand downgradient from Building I-1-23 due to VOC residuals that will remain after MPE/SVE treatment. However, continuous long-term pumping from the extraction wells at the full design flowrates appropriate for dewatering of the Upper Sand would have detrimental effects on groundwater quality due to influence on the plumes originating at the Buildings I-1-2/I-1-3 area and at the Repository (discussed further in Subsection 3.2.1).

The MPE wells described in the PD Report for installation within the Upper Clay unit would be omitted, due to the expected limited VOC removal effectiveness resulting from the natural clay properties. Unlike the situation at the Building I-1-2/I-1-3 source areas, the use of pneumatic fracturing to enhance the effectiveness of MPE in the Upper Clay at the I-1-23 area would not be included, for the following reasons:

- Excessive short-circuiting of the created fractures within the clay to the ground surface due to the limited thickness of the Upper Clay in this area, which would limit the radius of influence of each borehole installed for fracturing the clay.
- The presence of buried utilities in the VOC source area (sanitary sewer and manhole; water main; electrical conduits; gas main), which would create multiple pathways for air pressure short-circuiting from the fracturing injection points to the utility lines.

3.2 Estimated Remedial Action Results

3.2.1 Groundwater Quality

The effect of the remedial action described above over time on the VOC plume originating at the I-1-23 source area was estimated using the groundwater flow and contaminant transport model and the same estimating method presented in the Focused FS Report. Minor adjustments were made to the groundwater model to incorporate information developed from the pre-design fieldwork performed in the fall of 2000. Constant-concentration nodes were modified from the original model to reflect the

refined understanding of the distribution of VOCs in the soil and groundwater within the primary source area. Constant-concentration nodes were assigned to areas of high soil/groundwater VOC concentrations within both model Layer 1 (Upper Clay) and Layer 2 (Upper Sand). Previously, only Layer 1 was assigned constant-concentration nodes. Additionally, the thickness of the Upper Sand unit was modified in the vicinity of I-1-23 to reflect the presence of the buried former stream channel that was recently identified. The model was recalibrated after making the set-up adjustments to replicate the existing TCE plume as closely as possible.

Following the method used in the Focused FS, the adjusted model was used to produce simulations of the TCE plume originating at the Building I-1-23 area at times of 5 years, 10 years, and 20 years after startup of the source area treatment system. The simulated TCE plume concentrations are shown on figures in Attachment 2 (I-1-23 area, Case 1). The simulation for the current plume conditions closely resembles the plume concentrations that were simulated using the original model. The model simulations were run using a 2-year operating period for all components of the active remediation system (MPE, SVE, and groundwater extraction), after which the system was shut off.

The key estimated input parameter for the model runs is the average TCE concentration that will be present in groundwater within the defined source area boundaries during and following source area treatment. These estimated concentrations are used in the model as representative source area groundwater concentrations of TCE that are held constant throughout the model run time periods, simulating the continuing generation of dissolved-phase TCE that will occur in the Upper Sand unit due to VOC residuals that will not be removed from the Upper Sand and Upper Clay by the source area treatment.

The model runs simulate the effects on the TCE plume over time due to dispersion, dilution, advection, sorption, volatilization, and natural degradation through biotic and abiotic means, with the estimated constant average TCE concentration in groundwater within the source area. Although these degradation processes are also expected to reduce the TCE concentrations in groundwater within the primary source area over time to some degree, the more conservative approach of using constant groundwater concentrations within the source area was applied.

To estimate the average TCE concentration in groundwater remaining in the source area following treatment, the following estimates and assumptions were made:

- The range of achievable percent removal of total VOC (and TCE) mass present in the Treatment Zone within the Upper Sand unit was estimated.

- The VOC (and TCE) mass present within the Treatment Zone in the Upper Sand unit was estimated, expressed as a percent of the total VOC mass present in the Upper Sand and Upper Clay within the overall source area.
- The conservative assumption was made that the TCE concentration in groundwater in the Upper Clay will not change during or after the active remediation period (i.e., the current average dissolved TCE concentration in the clay will remain constant).
- The assumption was made that the average TCE concentration in groundwater in the overall source area following treatment will be reduced from the current average concentration by the same percentage that the total VOC mass in the overall source area is reduced following treatment.

As presented in Addendum No. 1 to the PD Report, the achievable TCE removal from the Upper Sand using the remediation system described above is estimated to be 45 to 70 percent of the mass present within the Treatment Zone (average of 58 percent). Using data produced with the EVS Pro software (refer to Addendum No. 1 for description) and additional manual calculations using the VOC concentration contour figures in the PD Report, the VOC mass present in the source area was established to be 110 lbs. In Addendum No. 1 of the PD report, the VOC mass in the Upper Clay zone of the source area was estimated to be 48 lbs. VOC mass present in the Treatment Zone and in the capture zone of the horizontal wells within the Upper Sand is estimated to be 42 pounds, which is 68 percent of the VOC mass in the total source area in the Upper Sand [42 lb/(110 lb - 48 lb) = 68%]. Compared to the mass in a broader area that includes lower concentrations surrounding the Treatment Zone, this VOC removal would constitute 39 percent of the total source area mass (68% x 58% = 39%). It was then assumed that the average TCE concentration in groundwater within the Upper Sand following treatment will be reduced in the same proportion as the estimated total VOC mass removal efficiency from the overall source area (39 percent; see Table 2). The conservative assumption was also made that the average dissolved TCE concentration in the Upper Clay following source removal from the Upper Sand would remain the same as the current average concentration.

The resulting calculated TCE concentration for the Upper Sand and the estimated current TCE concentration in the Upper Clay were used as constant-concentration input values for the model runs to simulate the future TCE plumes. The estimated values used with the adjusted groundwater model to prepare the projected TCE plumes shown on the figures in Attachment 2 (I-1-23 area, Case 1) are summarized in Table 2. The projections of future groundwater quality using the groundwater model are best evaluated in a relative or comparative sense, rather than taken as absolute numerical estimates of high accuracy.

3.2.2 VOC Mass Removal

The estimated VOC mass present in the overall source area at Building I-1-23 is summarized in Table 1 of Addendum No. 1 to the PD Report. These estimates have been revised slightly using the EVS software applied to the overall source area without distinguishing between soil units. This approach yielded somewhat higher VOC mass estimates than presented in Addendum No. 1. The estimated VOC removal that is achievable using the remediation approach described above is summarized in Table 2 of this addendum.

Numerous technical references, including USEPA documents, describe the difficulties and inaccuracies inherent in developing estimates of VOC mass present in soil at sites with high concentrations of residual chlorinated VOCs, such as Sites 32/33 of the PCBOU. Several variables that may affect the estimates of VOC mass at this site were discussed in Addendum No. 1 to the PD Report. As discussed in Addendum No. 1 and during TWG meeting #6, the most appropriate approach for assessment of the effectiveness of the proposed remediation systems for the I-1-23 source area, or the effectiveness of any other technology under conditions such as this, is to rely on the best possible estimates of the VOC mass that can be recovered or destroyed as a percent of the total mass present, rather than comparing estimates of absolute values of recoverable (or destructible) and total VOC mass. The percent removal estimates should be based on a variety of sources, such as published results from similar sites, USEPA guidance documents, results of physical and chemical tests of soil samples from the site, pilot test results, information available from reputable remediation contractors, and the experience and professional judgement of the design engineer. Full reliance on absolute estimates of VOC mass present in the soil or recoverable/destructible using a specific technology, developed using software, manual calculations, or other methods is likely to result in inappropriate evaluations and improper decisions regarding selection of the optimum remedial action.

3.3 Additional Model Simulations

The following additional model simulations were run to provide a basis for comparison with the projected results of the remedial action described above on the TCE plume over time.

3.3.1 Long-Term Groundwater Extraction Well Operation with MPE/SVE

Model runs were completed to simulate the effect of continuous long-term operation of the groundwater extraction wells, beyond the assumed 2-year operating period for the other components of the treatment system (MPE and SVE). Figures showing these simulations are included in Attachment 2 (I-1-23 area, Case 2). The results show that

continuous pumping of the wells at the full design flowrate (approximately 100 gpm) used for dewatering the Upper Sand is likely to have a detrimental effect on groundwater quality by influencing and spreading the TCE plumes originating at the Buildings I-1-2/I-1-3 area and at the Repository over significantly wider areas of the site.

3.3.2 Increased VOC Removal Effectiveness

Model runs were completed to simulate the effects on groundwater quality if increased VOC mass removal effectiveness could be achieved from both the Upper Sand and the Upper Clay within the overall source area. Overall VOC mass removal efficiencies of 70 percent and 90 percent were selected for the simulations. Although it is unlikely that these levels of effectiveness could be achieved using MPE/SVE, or any other technology currently available, the simulations were prepared to evaluate whether significant improvement in groundwater quality would result if it were possible. Figures showing the simulations are included in Attachment 2 (I-1-23, Case 3 [70 percent removal] and Case 4 [90 percent removal]). The results show that overall VOC mass removal efficiencies of greater than 70 percent would be required to produce improvements in groundwater quality over time that approach the level of improvement originally projected for the source area remediation, as presented in the Focused FS Report.

3.4 Alternative Technologies

In response to the interest expressed by F&WS in the potential for use of certain alternative technologies, the groundwater model was used to simulate the effect on the TCE plume that would result from the use of two source containment technologies: a PRB, and hydraulic control using groundwater extraction wells. The remedial action objective for use of these alternative approaches would be to contain the higher VOC concentrations in groundwater near the Building I-1-23 source area by cutting-off the migration of dissolved VOCs in groundwater within the Upper Sand unit.

3.4.1 Permeable Reactive Barrier

Site-specific information on the use of a permeable reactive barrier (PRB) in the Upper Sand near Building I-1-23 was not included in the proposals from the remediation contractors included in Attachment 4. However, general information provided in the proposals regarding the Buildings I-1-2/I-1-3 source area that would also be applicable to use of a PRB at the Building I-1-23 area was used to prepare a model simulation of a PRB installed immediately downgradient (north) of Building I-1-23. The PRB using zero-valent iron would be placed through the full depth of the Upper Sand to the Lower Clay surface, and would extend across nearly the full width of the plume. Figures

showing the model simulations for 5, 10, and 20 years after placement of the PRB are included in Attachment 2 (I-1-23 area, Case 5).

3.4.2 Hydraulic Control

Hydraulic control of dissolved VOCs by continuous pumping of a conventional groundwater extraction well in the Upper Sand unit at the main source area at Building I-1-23 was simulated using the groundwater model. The extraction well would be used without the MPE and SVE systems. Several model runs were completed simulating various configurations of extraction wells and pumping rates in the Upper Sand at the source area. These model runs showed that continuous pumping at even relatively low flowrates from the upper portion of the Upper Sand should be capable of establishing a significant zone of influence and effectively capturing dissolved VOCs in the source area. It was determined that a single vertical extraction well screened in the upper portion of the Upper Sand pumping continuously at a rate of approximately 10 to 20 gpm would provide sufficient plume containment. The model runs also showed that continuous pumping at higher flowrates from the lower portion of the Upper Sand would adversely affect groundwater quality over broader areas of the site by spreading-out the plumes originating at the Repository and at the Buildings I-1-2/I-1-3 area (as seen from the figures for the model run for the I-1-23 area, Case 2). This effect is primarily due to the relatively thin and confined nature of the Upper Sand unit over the site.

Figures showing the model simulations for a scenario of one extraction well pumping continuously at 20 gpm for 5, 10, and 20 years are included in Attachment 2 (I-1-23 area, Case 6).

3.5 Conclusions and Recommendations

The modeling results show that use of MPE/SVE and groundwater extraction wells for dewatering the Upper Sand operated for 2 years, with the configuration discussed at TWG meeting #6 and described in Subsection 3.1, would provide relatively limited improvement in groundwater quality over time. During the 2-year active treatment period and for a short time following this period, groundwater quality should show notable improvement particularly in the northern half of the plume. However, after time (10-year and 20-year simulations) the plume would tend to rebound significantly, due to the continued migration of dissolved VOCs in the Upper Sand that originate from the sorbed VOCs remaining in the source area. Additional model simulations showed that removal of greater than 70 percent of the total VOC mass from the I-1-23 source area would be necessary to result in groundwater quality improvement over time that approaches the level of improvement originally projected for the

source area remediation, as presented in the Focused FS Report. The feasibility of achieving this level of effectiveness through design enhancements of an MPE/SVE/extraction wells system at the I-1-23 source area, or through use of any other source treatment technology, is uncertain.

The modeling simulations also showed that use of either a PRB for plume cut-off and *in situ* treatment, or an extraction well for hydraulic control, would provide substantial improvement in groundwater quality over a 20-year period. For the extraction well alternative, it is expected that the pumping rate from a well could be "fine-tuned" to provide effective VOC capture at the I-1-23 source area while preventing undesirable influence on the plumes from the Repository and the Buildings I-1-2/I-1-3 area. The model runs show that hydraulic control using an extraction well would be somewhat more effective in improving groundwater quality over time than using a PRB. However, the groundwater pumping alternative would require long-term operation and maintenance of the well and a groundwater treatment system. A PRB would have no operation requirements and would probably require only infrequent maintenance and/or replacement.

On the basis of the projected substantial groundwater quality improvement that would result from a relatively small-scale groundwater extraction and treatment system, hydraulic control using a vertical groundwater extraction well and a groundwater treatment system is recommended for implementation to address the Building I-1-23 source area. The use of phytoremediation and monitored natural attenuation would also remain as components of the remedial action.

Section 4
Area 9 Repository

4.1 Remedial Action Description

As presented at TWG meeting #6, the remedial action for the VOCs associated with the Area 9 Repository would include phytoremediation to intercept and remove dissolved VOCs in shallow groundwater at locations where groundwater discharges into the Center and East Swales, and monitored natural attenuation for the remainder of the affected groundwater. Active treatment of VOC source areas beneath the Repository would not be included, for the following reasons:

- Significant levels of natural attenuation of the VOCs are occurring in the relatively thin Upper Clay unit beneath the Repository, where the VOC source material is present. Concentrations of total VOCs in groundwater beneath the Repository of > 35,000 μg/L are being reduced to 10 to 30 μg/L within a distance of only approximately 200 feet along the groundwater flow path.
- The groundwater flow velocity in the Upper Clay beneath the Repository is very low (approximately 9 feet/year), thus minimizing the VOC mass flux from the source zones and helping to promote natural attenuation.
- The extent of affected groundwater outside of the Repository footprint is relatively small. All groundwater affected by the VOC sources beneath the Repository discharges into the Center and East Swales within approximately 300 feet of the base of the Repository sideslope. (This is the area where trees will be planted for phytoremediation of the shallow groundwater.)
- The Lower Clay unit, which is present beneath the entire Repository, provides an effective barrier preventing downward migration of VOCs from the Upper Clay.
- The presence of the substantial depth and volume of fill material within the Repository located directly over the VOC source areas in the Upper Clay presents physical difficulties in applying any type of remediation technology for removal or destruction of the VOCs.

4.2 Estimated Remedial Action Results

The calibrated groundwater model was used to provide projections of groundwater quality in the vicinity of the Repository after time periods of 5 years, 10 years, and 20 years, with the remedial action approach of phytoremediation and monitored natural attenuation. Figures showing the simulated plume are included in Attachment 3 (Repository area). The model projections are based on only the natural attenuation component of the action, without accounting for the beneficial effects of phytoremediation on the shallow groundwater at the

drainage swales. Although the groundwater model could be adjusted to simulate the groundwater "pumping" effect of the trees planted for phytoremediation, this "fine-tuning" of the model would require relatively significant effort and time. The concept of the benefits provided by phytoremediation for cut-off and uptake of VOCs from the shallow groundwater is relatively straightforward. Therefore, although model simulations could be developed to demonstrate these benefits over time, it was decided that adjustment of the model to provide these simulations was not warranted or necessary to make informed decisions regarding the appropriate remedial action at the Repository.

4.3 Conclusions and Recommendations

The physical conditions at the Repository currently produce a relatively stable and confined situation with respect to groundwater impacts from VOC sources present beneath the Repository. Substantial levels of natural attenuation are occurring that greatly diminish the VOC concentrations as the groundwater moves slowly toward the nearby drainage swales on the east side of the Repository. Planting of trees to provide phytoremediation of the VOCs remaining in the shallow groundwater near the swales will assist in intercepting and removing the VOCs prior to groundwater discharge into the swales.

The use of monitored natural attenuation with phytoremediation is recommended for implementation to address the VOC sources beneath the Repository.

TABLES

Table 1
Summary of Groundwater Quality Simulations Run Using Groundwater Contaminant Transport Model

VOC SOURCE AREA	DESCRIPTION OF SIMULATIONS	MODEL RUN NO.	CURRENT CONDITIONS	YEARS AFTER START OF REMEDIAL ACTION		
				5	10	20
Buildings I-1-2/I-1-3 Area	Case 1 MPE wells with pneumatic fracturing operated for 2 years then shut-down (no PRB).	520	X	X	X	X
	Case 2 PRB with zero-valent iron in west plume (no source area treatment).	522	X	X	X	X
	Case 3 MNA only (no active source area treatment).	417	X	X	X	X
Building I-1-23 Area	Case 1 MPE wells, SVE wells, & horizontal groundwater extraction wells in Upper Sand operated for 2 years, then all shut-down. 39% VOC removal from overall source area.	520	X	X	X	X
	Case 2 MPE & SVE wells in Upper Sand operated for 2 years, then shut-down. Horizontal groundwater extraction wells at high flowrate operated continuously from initial system startup. 39% VOC removal from overall source area during 2 years active treatment.	519	X	X	X	X
	Case 3 MPE wells, SVE wells, and horizontal groundwater extraction wells in Upper Sand and Upper Clay operated for 2 years, then shut down. 70% VOC removal from overall source area.	521	X	X	X	X
	Case 4 MPE wells, SVE wells, and horizontal groundwater extraction wells in Upper Sand and Upper Clay operated for 2 years, then shut down. 90% VOC removal from overall source area.	526	X	X	X	X

Table 1 (Continued)
Summary of Groundwater Quality Simulations Run Using Groundwater Contaminant Transport Model

VOC SOURCE AREA	DESCRIPTION OF SIMULATIONS	MODEL RUN NO.	CURRENT CONDITIONS	YEARS AFTER START OF REMEDIAL ACTION		
				5	10	20
Building I-1-23 Area (continued)	Case 5 PRB with zero-valent iron. No source area treatment.	522	X	X	X	X
	Case 6 Continuous pumping with one vertical groundwater extraction well at 20 gpm. No MPE/SVE wells.	525	X	X	X	X
	Case 7 MNA only (no active source area treatment).	417	X	X	X	X
Repository Area	MNA only (no active source area treatment). *	417	X	X	X	X

Notes:
MPE = Multi-phase extraction
SVE = Soil vapor extraction
PRB = Permeable reactive barrier
MNA = Monitored natural attenuation
* = Effects of the phytoremediation component of the remedial action were not simulated in the model run.

Table 2
Estimated VOC Mass and Removal Efficiency
(Pneumatic Fracturing Applied at Areas I-1-2 and I-1-3)

AREA	NEAREST SOIL BORING LOCATION	TYPE OF EXTRACTION WELL	NUMBER OF WELLS	RADIUS OF INFLUENCE (ft)	WELL SCREEN INTERVAL (ft bgs)	WELL SCREEN LENGTH (ft)	VOLUME WITHIN TREATMENT ZONE (cf)	AVERAGE VOC CONCENTRATION (ppm)	AVERAGE SOIL DENSITY (lb/cf)	VOC MASS WITHIN TREATMENT ZONE (lb)	VOC MASS WITHIN 1 mg/kg ISOCONTOUR (EVS) (lb)	RANGE OF REMOVAL EFFICIENCY (%)	AVERAGE ESTIMATED ACHIEVABLE VOC REMOVAL FROM SOURCE AREA (%)	PERCENT OF CONCENTRATION/ MASS REMAINING AFTER TREATMENT (%)
I-1-2	SB-102	PF/MPE	3	20	10 - 15	5	17,898	8.3	129	19	--			
	SB-133	PF/MPE	3	20	20 - 30	10	35,796	11.5	129	53	--			
	SB-133	PF/MPE	2	20	13 - 23	10	23,864	5.9	129	18	--	35% to 75%[4]		
									Totals	91	289	(Avg. 55%)	17%	83%
I-1-3	SB-127	PF/MPE	6	20	10 - 20	10	71,592	9.9	129	91	--			
	SB-115	PF/MPE	6	20	18 - 38	20	143,184	13.6	129	251	--			
	SB-126	PF/MPE	2	20	27 - 42	15	35,796	57.7	129	266	--	35% to 75%[4]		
									Totals	609	861	(Avg. 55%)	39%	61%
I-1-23	SB-217	MPE	2	10	40 - 45	5	2,983	4.5	128	2	--			
	SB-202	SVE	5	25	20 - 35	15	139,828	1.3	128	24	--	US only	US only	US only
	--	Horizontal	--	--	--	--	--	--	--	16[5]	--	45% to 70%		
									Totals	42	110	(Avg. 58%)	39%[6]	61%

Notes:

1. Average VOC concentrations are selected from discrete soil samples collected from soil borings located within the treatment zone. See Table 4-2 Preliminary Design Report, May 2001.
2. A 5% reduction in the volume within the treatment zone was made to account for overlapping zones of influence for each well.
3. The mass within the treatment zone for the horizontal wells at I-1-23 is estimated to be the dissolved phase within the capture zone of the horizontal wells.
4. Pneumatic fracturing contractor estimates a recovery rate increase of 5x to 10x; a 5x multiplier was applied to the estimated removal efficiency range previously established for clay.
5. Includes dissolved-phase VOC mass outside of soil treatment zone that is recoverable via pumping with the horizontal wells.
6. Approximately 48 lb. VOCs were estimated in the Upper Clay zone in Addendum No. 1 of the PD Report; so, 58% x 42 lb/(110 lb - 48 lb) = 39% removal from overall source area.

PF/MPE = MPE well where pneumatic fracturing is applied.
US = Upper sand unit.

Table 3
Estimated VOC Mass and Removal Efficiency
(No Pneumatic Fracturing)

AREA	NEAREST SOIL BORING LOCATION	TYPE OF EXTRACTION WELL	NUMBER OF WELLS	RADIUS OF INFLUENCE (ft)	WELL SCREEN INTERVAL (ft bgs)	WELL SCREEN LENGTH (ft)	VOLUME WITHIN TREATMENT ZONE (cf)	AVERAGE VOC CONCENTRATION (ppm)	AVERAGE SOIL DENSITY (lb/cf)	VOC MASS WITHIN TREATMENT ZONE (lb)	VOC MASS WITHIN 1 mg/kg ISOCONTOUR (EVS) (lb)	RANGE OF REMOVAL EFFICIENCY (%)	AVERAGE ESTIMATED ACHIEVABLE VOC REMOVAL FROM SOURCE AREA (%)	PERCENT OF CONCENTRATION/ MASS REMAINING AFTER TREATMENT (%)
I-1-2	SB-102	MPE	21	5	9 - 14	5	7,830	10.9	129	11	--			
	SB-133	MPE	6	5	20 - 28	8	3,580	11.5	129	5	--	7% to 15%		
									Totals	16	289	(Avg. 11%)	1%	99%
I-1-3	SB-127	MPE	6	5	10 - 25	15	6,712	28.0	129	24	--			
	SB-126	MPE	12	5	2 - 7	5	4,475	87.0	129	50	--			
	SB-126	MPE	6	5	27 - 42	15	6,712	86.0	129	74	--	7% to 15%		
									Totals	149	861	(Avg. 11%)	2%	98%
I-1-23	SB-217	MPE	2	10	40 - 45	5	2,983	4.5	128	2	--			
	SB-202	SVE	5	25	20 - 35	15	139,828	1.3	128	24	--	US only	US only	US only
	--	Horizontal	--	--	--	--	--	--	--	16[5]	--	45% to 70%		
									Totals	42	110	(Avg. 58%)	39%[6]	61%

Notes:

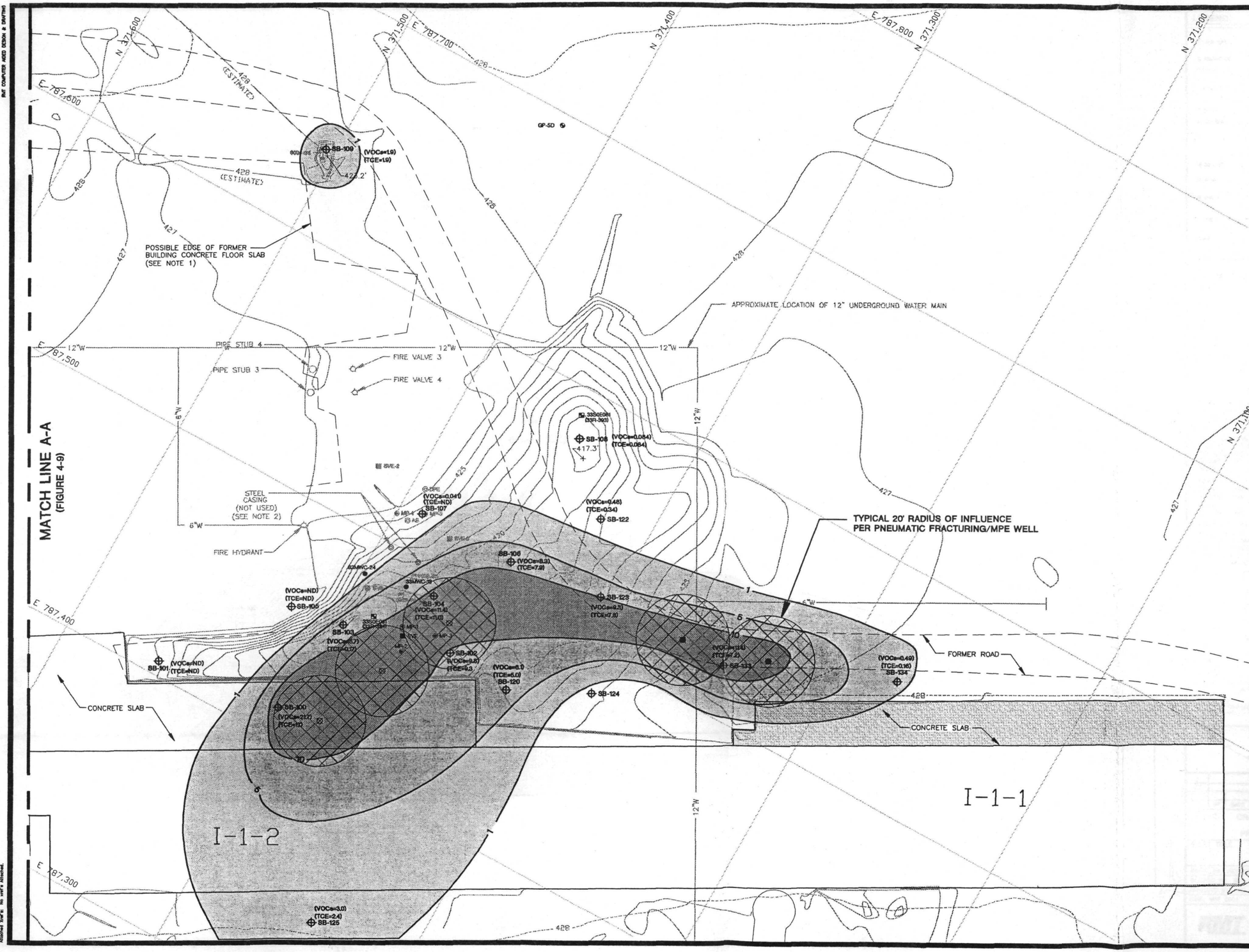
1. Average VOC concentrations are selected from discrete soil samples collected from soil borings located within the treatment zone. See Table 4-2 Preliminary Design Report, May 2001.
2. A 5% reduction in the volume within the treatment zone was made to account for overlapping zones of influence for each well.
3. The mass within the treatment zone for the horizontal wells at I-1-23 is estimated to be the dissolved phase within the zone of influence of the horizontal wells.
5. Includes dissolved-phase VOC mass outside of soil treatment zone that is recoverable via pumping with the horizontal wells.
6. Approximately 48 lb. VOCs were estimated in the Upper Clay zone in Addendum No. 1 of the PD Report; so, 58% x 42 lb/(110 lb - 48 lb) = 39% removal from source area (Upper Sand).

US = Upper sand unit.

Table 4
Vendors/Contractors for Alternative Remediation Technologies

COMPANY	TECHNOLOGY TRADE NAME	TYPE OF PROCESS
In Situ Oxidative Technologies, Inc.	ISOTEC℠	Chemical oxidation using proprietary blends of catalysts, oxidizers, viscosity enhancers, and mobility control agents
EnviroMetal Technologies, Inc	EnviroMetal Process	Metal-enhanced chemical reductive dehalogenation
Regenesis	Hydrogen Release Compound (HRC®)	Enhancement of biodegradation of chlorinated hydrocarbons by anaerobic reductive dechlorination processes
ARS Technologies, Inc.	Ferox™	Chemical reduction of organic compounds using zero-valent iron powder pressure-injected into the soil.

Attachment 1
Figures Associated with Buildings I-1-2/I-1-3 Area



LEGEND

SB-107	GEOPROBE BORING LOCATION (INSTALLED BY RMT IN 2000)
33MWC-24	GROUNDWATER MONITORING WELL (2")
MP-2	MONITORING POINT (2") (INSTALLED BY RMT IN 2000)
SVE	SOIL VAPOR EXTRACTION WELL (2") (INSTALLED BY RMT IN 2000)
GP-11E	GEOPROBE BORING LOCATION (1998)
33R-394	SOIL SAMPLE (IT CORP.)
(10'-15') (13'-23')	MPE WELL WITH PNEUMATIC FRACTURING SCREEN INTERVAL = 10'-15' & 13'-23' 20' RADIUS OF INFLUENCE
92028-B6	SOIL SAMPLE (FDGTI)(1997)
MP-3	MONITORING POINT (2") (INSTALLED BY FDGTI)
SVE-2	SOIL VAPOR EXTRACTION WELL (2") (INSTALLED BY FDGTI)
DPE	DUAL PHASE EXTRACTION WELL (4") (INSTALLED BY FDGTI)
AS	AIR SPARGING WELL (4") (INSTALLED BY FDGTI)
	EXISTING BUILDING
422	PRE-PCB EXCAVATION CONTOURS (IT CORP.) (1994)
422	PCB EXCAVATION CONTOURS (FDGTI) (1997)
W	UNDERGROUND 12" WATER MAIN LOCATION (APPROXIMATE)
(VOCs=8.3)	TOTAL VOCs (mg/kg)
(TCE=7.9)	TRICHLOROETHENE (mg/kg)
1	ISOCONCENTRATION CONTOUR

NOTES

1. CONCRETE SLAB BELIEVED TO HAVE BEEN DEMOLISHED AND REMOVED DURING PCB REMEDIAL ACTION IN 1996. HOWEVER, DOCUMENTATION FOR THIS WORK DOES NOT EXIST.
2. STEEL CASING CUT-OFF APPROXIMATELY 1 FOOT ABOVE GROUND, FILLED WITH GROUT, AND COVER PLATE WELDED TO OPENING. CASINGS WERE INSTALLED DURING THE SUMMER OF 1998 GROUNDWATER INVESTIGATION, BUT WERE NOT COMPLETED AS MONITORING WELLS.
3. CONTOURS OF PRE-PCB EXCAVATION CONDITIONS ARE FROM DRAWINGS PREPARED BY IT CORPORATION CONTAINED IN PRE-FINAL DESIGN DOCUMENTS DATED JULY 27, 1994. ELECTRONIC COPIES OF THESE DRAWINGS WERE PROVIDED TO RMT, INC. BY U.S. FISH & WILDLIFE SERVICE.
4. CONTOURS OF PCB EXCAVATIONS ARE FROM THE DRAWINGS PREPARED BY ROBERT G. SEWELL, PROFESSIONAL LAND SURVEYOR, MARION, ILLINOIS, FOR FLUOR DANIEL, INC. THE DRAWINGS ARE CONTAINED IN A REPORT TITLED FINAL CLOSEOUT REPORT FOR THE PCB OPERABLE UNIT, REV. 0, MARCH 1998, PREPARED BY FLUOR DANIEL GTI.

FIGURE 4-2

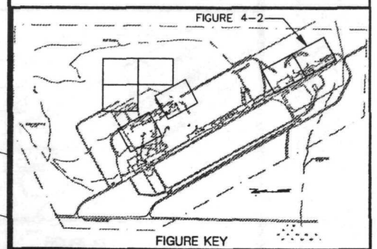


FIGURE KEY

0 20' 40'

NO.	BY	DATE	REVISION	APP'D.
2.				
1.				
0.				

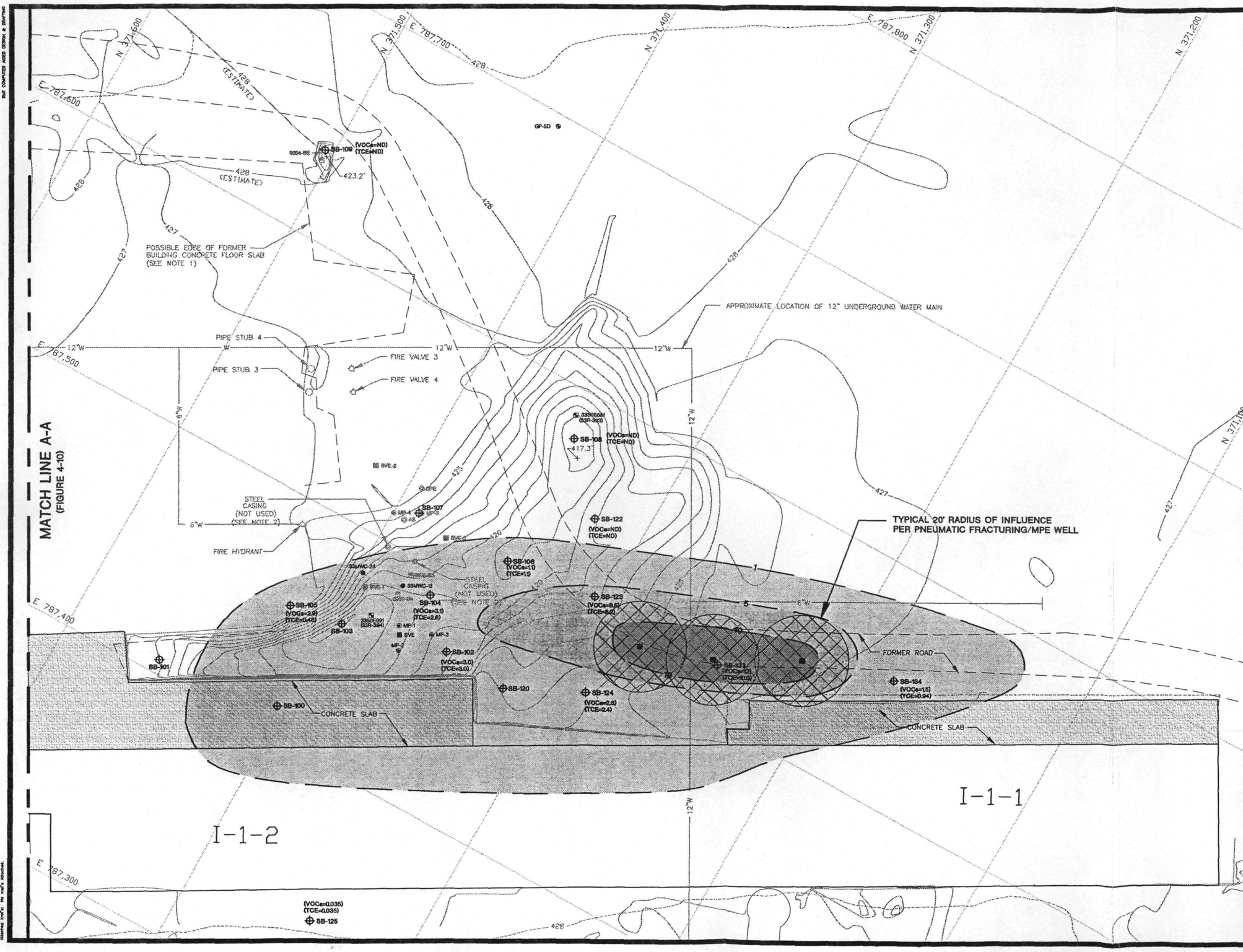
PROJECT: CRAB ORCHARD NWR - PCB O.U.
MARION, ILLINOIS
PRELIMINARY DESIGN REPORT

SHEET TITLE: VOC CONCENTRATIONS IN SOIL
BUILDING I-1-2
12-24 FOOT INTERVAL

DRAWN BY: SIEWERTD	SCALE: 1"=40'	PROJ. NO. 4781.07
CHECKED BY: SLM		FILE NO. 47810714A.DWG
APPROVED BY: TEG	DATE PRINTED:	
DATE: MAY 2001		

RMT
744 Heartland Trail
Madison, WI 53717-1934
P.O. Box 8923
Madison, WI 53708-8923
Phone: 608/831-4444

Revision Level



LEGEND

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SVE	SOIL VAPOR EXTRACTION WELL (2") (INSTALLED BY RMT IN 2000)
GP-1E	GEOPROBE BORING LOCATION (1998)
33R-394	SOIL SAMPLE (IT CORP.)
	MPE WELL WITH PNEUMATIC FRACTURING SCREEN INTERVAL = 20'–30' 20' RADIUS OF INFLUENCE
9004-B5	SOIL SAMPLE (FDGTI)(1997)
MP-3	MONITORING POINT (2") (INSTALLED BY FDGTI)
SVE-2	SOIL VAPOR EXTRACTION WELL (2") (INSTALLED BY FDGTI)
DPE	DUAL PHASE EXTRACTION WELL (4") (INSTALLED BY FDGTI)
AS	AIR SPARGING WELL (4") (INSTALLED BY FDGTI)
	EXISTING BUILDING
422	PRE-PCB EXCAVATION CONTOURS (IT CORP.) (1994)
422	PCB EXCAVATION CONTOURS (FDGTI) (1997)
W	UNDERGROUND 12" WATER MAIN LOCATION (APPROXIMATE)
(VOCs=8.5)	TOTAL VOCs (mg/kg)
(TCE=8.2)	TRICHLOROETHENE (mg/kg)
5	ISOCONCENTRATION CONTOUR (DASHED WHERE INFERRED)

NOTES

1. CONCRETE SLAB BELIEVED TO HAVE BEEN DEMOLISHED AND REMOVED DURING PCB REMEDIAL ACTION IN 1996. HOWEVER, DOCUMENTATION FOR THIS WORK DOES NOT EXIST.
2. STEEL CASING CUT-OFF APPROXIMATELY 1 FOOT ABOVE GROUND, FILLED WITH GROUT, AND COVER PLATE WELDED TO OPENING. CASINGS WERE INSTALLED DURING THE SUMMER OF 1998 GROUNDWATER INVESTIGATION, BUT WERE NOT COMPLETED AS MONITORING WELLS.
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FIGURE 4-3

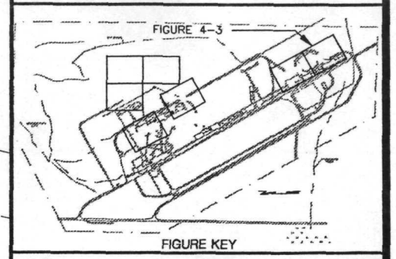

FIGURE KEY

0 20' 40'

NO.	BY	DATE	REVISION	APP'D.
2.				
1.				
0.				

PROJECT: CRAB ORCHARD NWR - PCB O.U.
MARION, ILLINOIS
PRELIMINARY DESIGN REPORT

SHEET TITLE: VOC CONCENTRATIONS IN SOIL
BUILDING I-1-2
24-36 FOOT INTERVAL

DRAWN BY: SIEWERTD	SCALE:	PROJ. NO. 4781.07
CHECKED BY: SLM	1"=40'	FILE NO. 47810734A.DWG
APPROVED BY: TEG	DATE PRINTED:	
DATE: MAY 2001		

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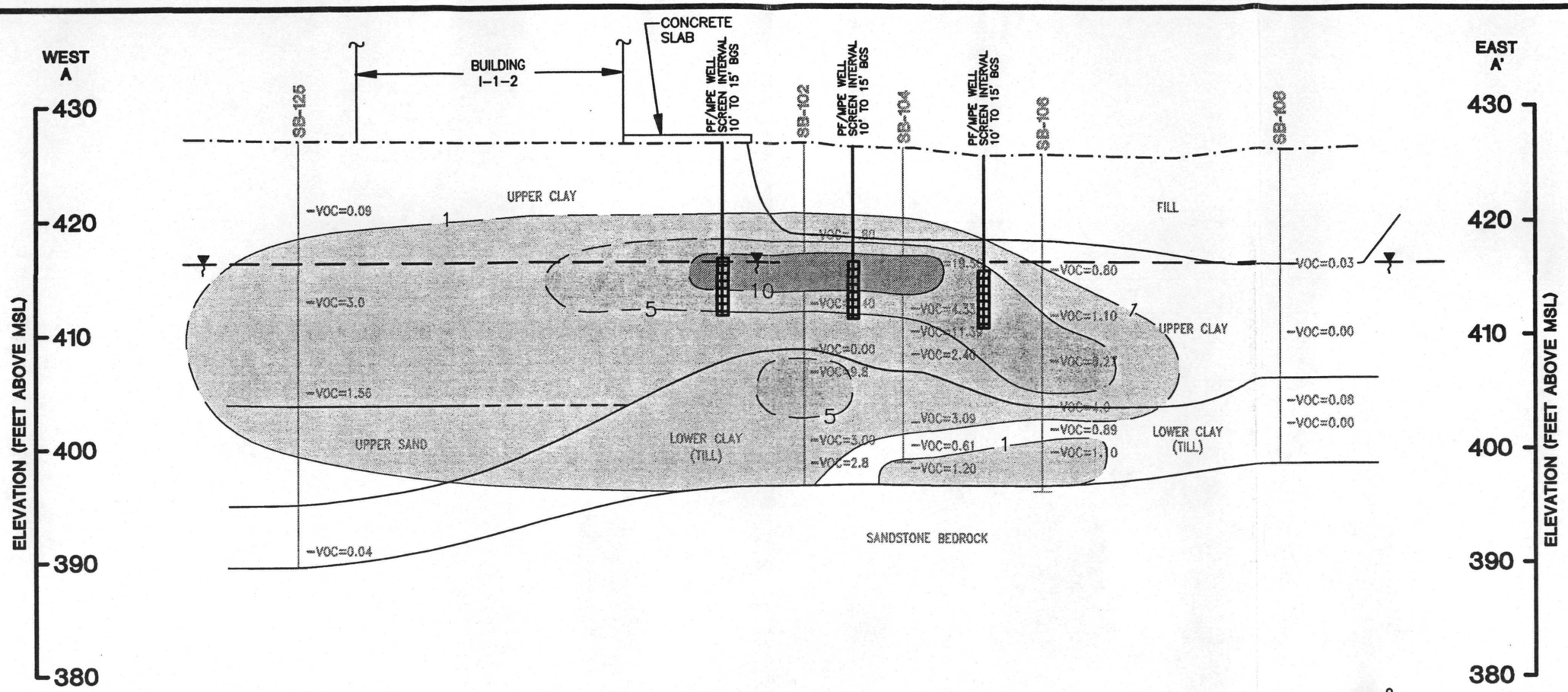
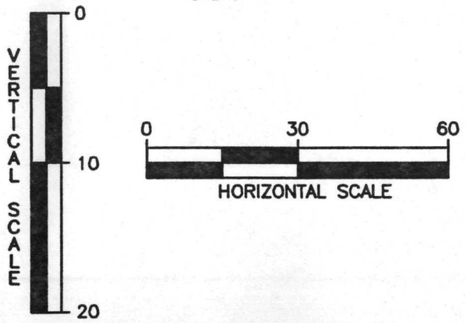
Phone: 608/831-4444

Revision Level

RMT COMPUTER AIDED DESIGN & DRAFTING





NOTES:

1. GROUNDWATER ELEVATION IS INTERPRETED BASED ON THE OCTOBER 2000 WATER TABLE MAP FIGURE 3-27.
2. (VOC=0.03) REPRESENTS TOTAL VOC CONCENTRATION IN SOIL, mg/kg
3. WELL LOCATIONS ARE PROJECTED AND DO NOT NECESSARILY FALL ONTO CROSS SECTIONS.

LEGEND

- EXISTING GROUND SURFACE
- STRATIGRAPHIC BOUNDARY, DASHED WHERE INFERRED
- WATER TABLE SURFACE
- (813.05) GROUNDWATER HEAD ELEVATION (FEET, MSL)

WELL CONSTRUCTION

- WELL SEAL
- WELL CASING
- WELL SCREEN

- 1 — TOTAL VOC CONCENTRATIONS (mg/kg)
- VOC=0.08 — TOTAL VOC CONCENTRATIONS (mg/kg)

- PNEUMATIC FRACTURING/ MULTI-PHASE EXTRACTION SCREEN INTERVAL

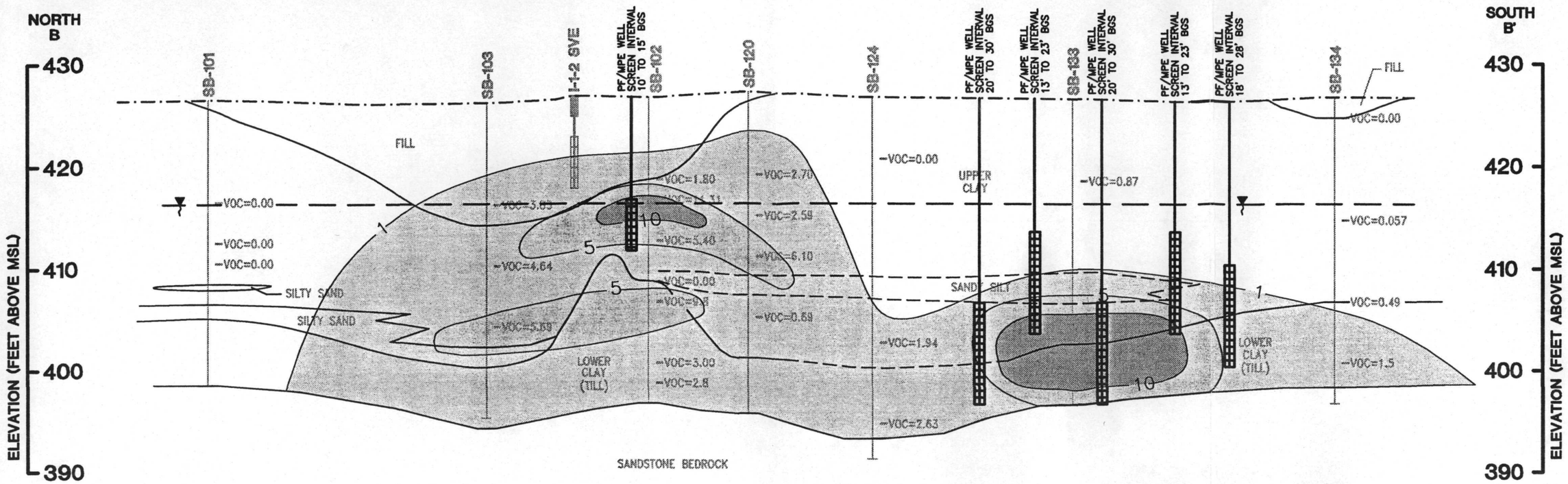
VOC CONCENTRATION CROSS SECTION A-A'
CRAB ORCHARD NWR PCB O.U.
MARION, ILLINOIS
PRELIMINARY DESIGN REPORT

RMT

DWN. BY:	SIEWERTD
APPROVED BY:	TEG
DATE:	MAY 2001
PROJ. #	04781.07
FILE #	47810771A.DWG

FIGURE

Drawing Name: J:\04781\07\47810771A.dwg
Operator Name: SIEWERTD
Scale: 1"=30'
Dwg Size: 12/245 Bytes
Plot Date: Wednesday, August 8, 2001
Plot Time: 11:14:53 AM
Attached Xref's: No xref's attached.



NOTES:

1. GROUNDWATER ELEVATION IS INTERPRETED BASED ON THE OCTOBER 2000 WATER TABLE MAP FIGURE 3-27.
2. (VOC=0.03) REPRESENTS TOTAL VOC CONCENTRATION IN SOIL, mg/kg
3. WELL LOCATIONS ARE PROJECTED AND DO NOT NECESSARILY FALL ONTO CROSS SECTIONS.

LEGEND

- EXISTING GROUND SURFACE
- STRATIGRAPHIC BOUNDARY, DASHED WHERE INFERRED
- WATER TABLE SURFACE
- (813.05) GROUNDWATER HEAD ELEVATION (FEET, MSL)

WELL CONSTRUCTION

- WELL SEAL
- WELL CASING
- WELL SCREEN
- 1 — TOTAL VOC CONCENTRATIONS (mg/kg)
- VOC=0.08 — TOTAL VOC CONCENTRATIONS (mg/kg)
- PNEUMATIC FRACTURING/ MULTI-PHASE EXTRACTION SCREEN INTERVAL

VERTICAL SCALE: 0, 10, 20

HORIZONTAL SCALE: 0, 30, 60

VERTICAL SCALE EXAGGERATED 3X

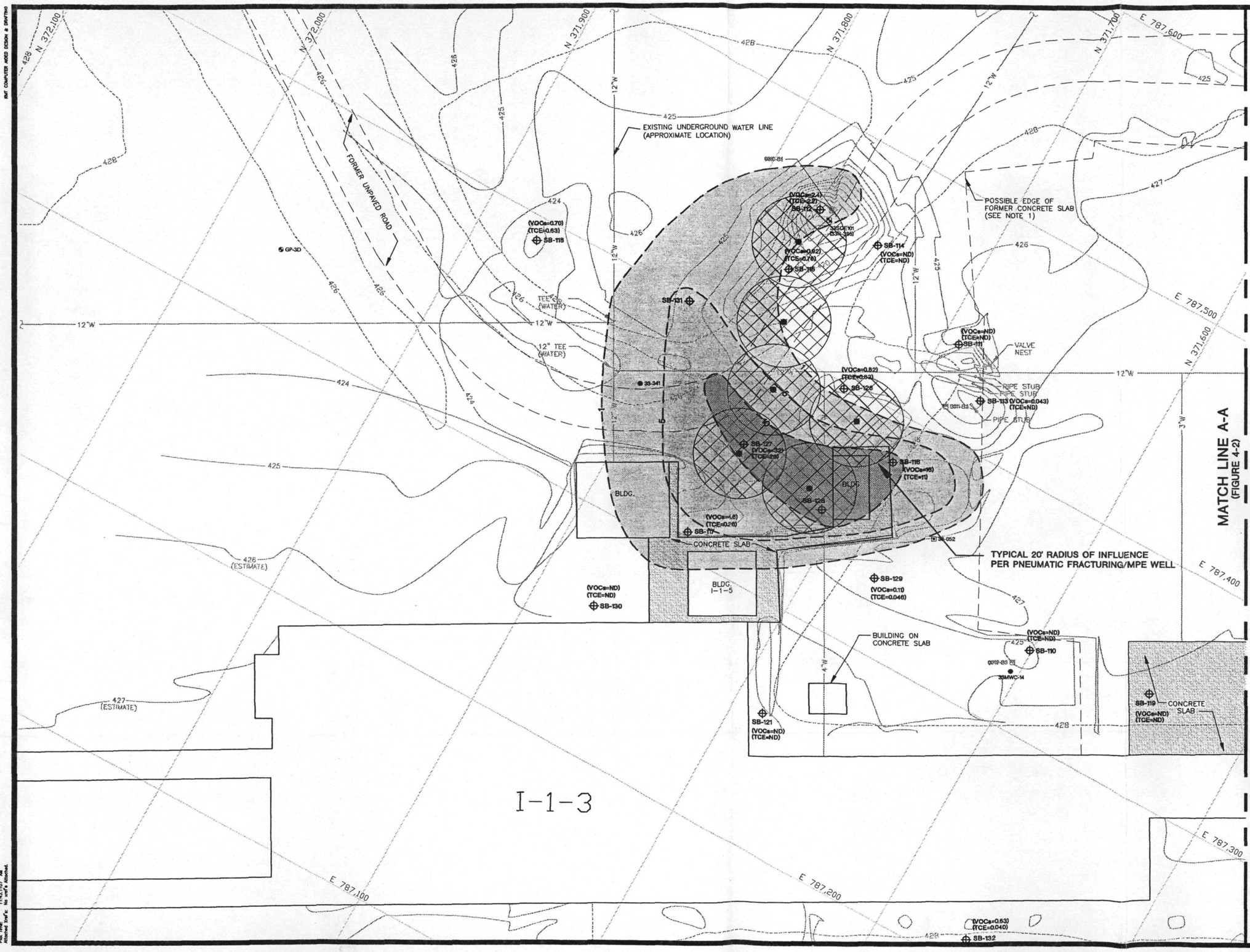
VOC CONCENTRATION CROSS SECTION B-B'
CRAB ORCHARD NWR PCB O.U.
MARION, ILLINOIS
PRELIMINARY DESIGN REPORT

RMT

DWN. BY:	SIEWERTD
APPROVED BY:	TEG
DATE:	MAY 2001
PROJ. #	04781.07
FILE #	47810772A.DWG

FIGURE

Drawing Name: J:\04781\07\47810772A.dwg
Operator Name: SIEWERTD
Scale: 1"=30'
Dwg Size: 100491 bytes
Plot Date: Wednesday, August 8, 2001
Plot Time: 1:34.07 PM
Attached Xref's: No xref's attached.



LEGEND

SB-114	PROPOSED GEOPROBE BORING LOCATION
33MWC-14	GROUNDWATER MONITORING WELL (2")
GP-11E	GEOPROBE BORING LOCATION (1998)
33SOE101	SOIL SAMPLE (IT CORP.)
PF-1	MPE WELL WITH PNEUMATIC FRACTURING SCREEN INTERVAL = 10'–20' 20' RADIUS OF INFLUENCE
0912-83	SOIL SAMPLE (FDGTI)(1997)
	EXISTING BUILDING
422	PRE-PCB EXCAVATION CONTOURS (IT CORP.) (1994)
422	PCB EXCAVATION CONTOURS (FDGTI) (1997)
W	EXISTING UNDERGROUND WATER LINE (APPROXIMATE LOCATION)
(VOCs=0.55)	TOTAL VOCs (mg/kg)
(TCE=0.14)	TRICHLOROETHENE (mg/kg)
1	ISOCONCENTRATION CONTOUR (DASHED WHERE INFERRED)

NOTES

1. CONCRETE SLAB BELIEVED TO HAVE BEEN DEMOLISHED AND REMOVED DURING PCB REMEDIAL ACTION IN 1996. HOWEVER, DOCUMENTATION FOR THIS WORK DOES NOT EXIST.
2. CONTOURS OF PRE-PCB EXCAVATION CONDITIONS ARE FROM DRAWINGS PREPARED BY IT CORPORATION CONTAINED IN PRE-FINAL DESIGN DOCUMENTS DATED JULY 27, 1994. ELECTRONIC COPIES OF THESE DRAWINGS WERE PROVIDED TO RMT, INC. BY U.S. FISH & WILDLIFE SERVICE.
3. CONTOURS OF PCB EXCAVATIONS ARE FROM THE DRAWINGS PREPARED BY ROBERT G. SEWELL, PROFESSIONAL LAND SURVEYOR, MARION, ILLINOIS, FOR FLUOR DANIEL, INC. THE DRAWINGS ARE CONTAINED IN A REPORT TITLED FINAL CLOSEOUT REPORT FOR THE PCB OPERABLE UNIT, REV. 0, MARCH 1998, PREPARED BY FLUOR DANIEL GTI.

FIGURE 4-9

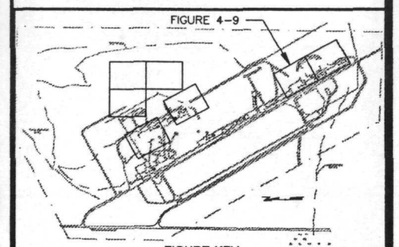


FIGURE KEY

0 20' 40'

NO.	BY	DATE	REVISION	APP'D.
2.				
1.				
0.				

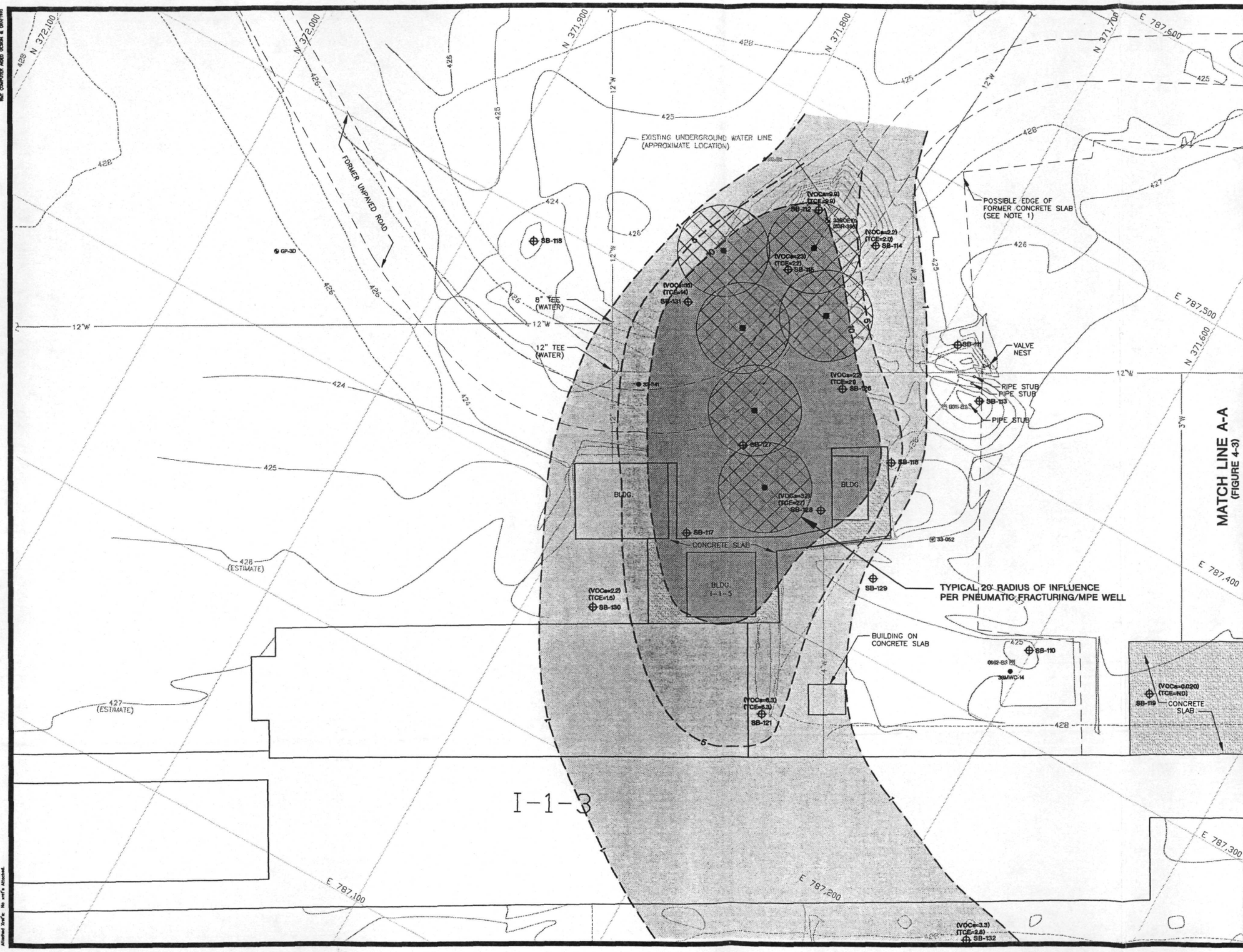
PROJECT: CRAB ORCHARD NWR - PCB O.U.
MARION, ILLINOIS
PRELIMINARY DESIGN REPORT

SHEET TITLE: VOC CONCENTRATIONS IN SOIL
BUILDING I-1-3
12-24 FOOT INTERVAL

DRAWN BY: SIEWERTD	SCALE:	PROJ. NO. 4781.07
CHECKED BY: SLM	1"=40'	FILE NO. 47810738A.DWG
APPROVED BY: TEG	DATE PRINTED:	
DATE: MAY 2001		

RMT
744 Heartland Trail
Madison, WI 53717-1934
P.O. Box 8923
Madison, WI 53708-8923
Phone: 608/831-4444

Revision Level



LEGEND

SB-113	PROPOSED GEOPROBE BORING LOCATION
33MWC-14	GROUNDWATER MONITORING WELL (2")
GP-11E	GEOPROBE BORING LOCATION (1998)
33SOE101	SOIL SAMPLE (IT CORP.)
	MPE WELL WITH PNEUMATIC FRACTURING SCREEN INTERVAL = 18'–38' 20' RADIUS OF INFLUENCE
0932-B3	SOIL SAMPLE (FDGTI)(1997)
	EXISTING BUILDING
422	PRE–PCB EXCAVATION CONTOURS (IT CORP.) (1994)
422	PCB EXCAVATION CONTOURS (FDGTI) (1997)
W	EXISTING UNDERGROUND WATER LINE (APPROXIMATE LOCATION)
(VOCs=0.41)	TOTAL VOCs (mg/kg)
(TCE=0.41)	TRICHLOROETHENE (mg/kg)
1	ISOCONCENTRATION CONTOUR (DASHED WHERE INFERRED)

NOTES

1. CONCRETE SLAB BELIEVED TO HAVE BEEN DEMOLISHED AND REMOVED DURING PCB REMEDIAL ACTION IN 1996. HOWEVER, DOCUMENTATION FOR THIS WORK DOES NOT EXIST.
2. CONTOURS OF PRE–PCB EXCAVATION CONDITIONS ARE FROM DRAWINGS PREPARED BY IT CORPORATION CONTAINED IN PRE–FINAL DESIGN DOCUMENTS DATED JULY 27, 1994. ELECTRONIC COPIES OF THESE DRAWINGS WERE PROVIDED TO RMT, INC. BY U.S. FISH & WILDLIFE SERVICE.
3. CONTOURS OF PCB EXCAVATIONS ARE FROM THE DRAWINGS PREPARED BY ROBERT G. SEWELL, PROFESSIONAL LAND SURVEYOR, MARION, ILLINOIS, FOR FLUOR DANIEL, INC. THE DRAWINGS ARE CONTAINED IN A REPORT TITLED FINAL CLOSEOUT REPORT FOR THE PCB OPERABLE UNIT, REV. 0, MARCH 1998, PREPARED BY FLUOR DANIEL GTI.

FIGURE 4–10

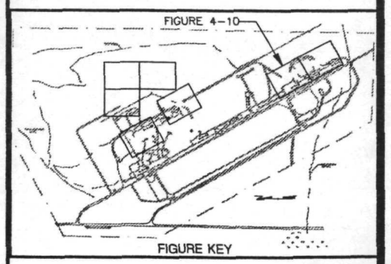


FIGURE KEY

0 20' 40'

NO.	BY	DATE	REVISION	APP'D.
2.				
1.				
0.				

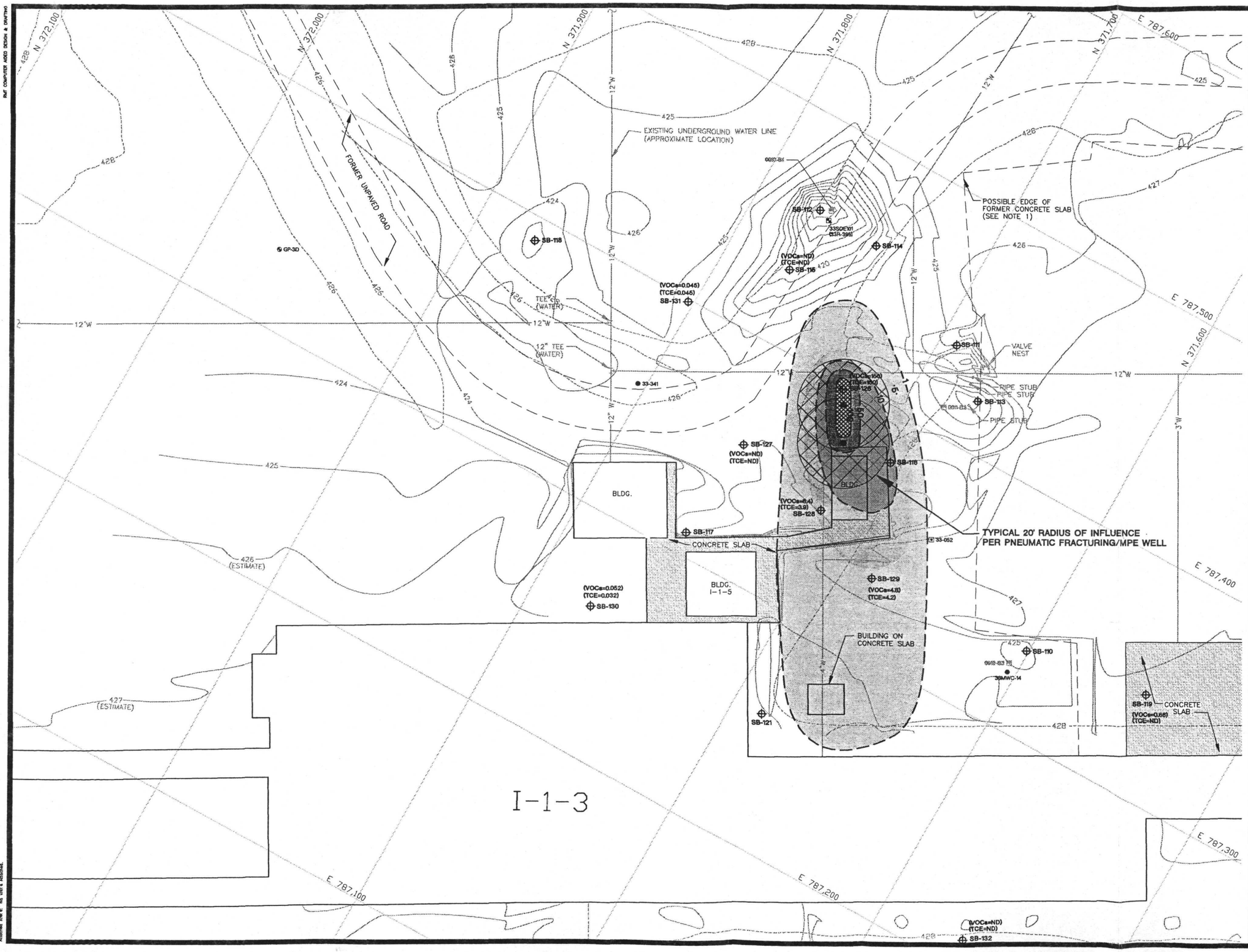
PROJECT: CRAB ORCHARD NWR - PCB O.U.
MARION, ILLINOIS
PRELIMINARY DESIGN REPORT

SHEET TITLE: VOC CONCENTRATIONS IN SOIL
BUILDING I-1-3
24 TO 36 FOOT INTERVAL

DRAWN BY: SIEWERTD	SCALE: 1"=40'	PROJ. NO. 4781.07
CHECKED BY: SLM		FILE NO. 47810748A.DWG
APPROVED BY: TEG	DATE PRINTED:	
DATE: MAY 2001		

RMT
744 Heartland Trail
Madison, WI 53717–1934
P.O. Box 8923
Madison, WI 53708–8923
Phone: 608/831–4444

Revision Level



LEGEND

SB-114	PROPOSED GEOPROBE BORING LOCATION
33MWC-14	GROUNDWATER MONITORING WELL (2")
GP-11E	GEOPROBE BORING LOCATION (1998)
33SOE101	SOIL SAMPLE (IT CORP.)
	MPE WELL WITH PNEUMATIC FRACTURING SCREEN INTERVAL = 27'-42' 20' RADIUS OF INFLUENCE
0022-23	SOIL SAMPLE (FDGTI)(1997)
	EXISTING BUILDING
422	PRE-PCB EXCAVATION CONTOURS (IT CORP.) (1994)
422	PCB EXCAVATION CONTOURS (FDGTI) (1997)
W	EXISTING UNDERGROUND WATER LINE (APPROXIMATE LOCATION)
(VOCs=0.85)	TOTAL VOCs (mg/kg)
(TCE=0.14)	TRICHLOROETHENE (mg/kg)
1	ISOCONCENTRATION CONTOUR

NOTES

1. CONCRETE SLAB BELIEVED TO HAVE BEEN DEMOLISHED AND REMOVED DURING PCB REMEDIAL ACTION IN 1996. HOWEVER, DOCUMENTATION FOR THIS WORK DOES NOT EXIST.
2. CONTOURS OF PRE-PCB EXCAVATION CONDITIONS ARE FROM DRAWINGS PREPARED BY IT CORPORATION CONTAINED IN PRE-FINAL DESIGN DOCUMENTS DATED JULY 27, 1994. ELECTRONIC COPIES OF THESE DRAWINGS WERE PROVIDED TO RMT, INC. BY U.S. FISH & WILDLIFE SERVICE.
3. CONTOURS OF PCB EXCAVATIONS ARE FROM THE DRAWINGS PREPARED BY ROBERT G. SEWELL, PROFESSIONAL LAND SURVEYOR, MARION, ILLINOIS, FOR FLUOR DANIEL, INC. THE DRAWINGS ARE CONTAINED IN A REPORT TITLED FINAL CLOSEOUT REPORT FOR THE PCB OPERABLE UNIT, REV. 0, MARCH 1998, PREPARED BY FLUOR DANIEL GTI.

FIGURE 4-11

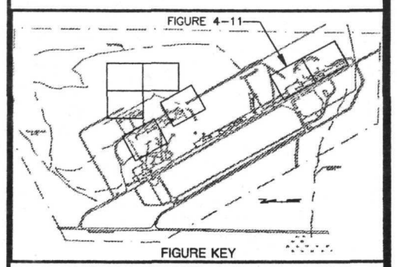


FIGURE KEY

0 20' 40'

NO.	BY	DATE	REVISION	APP'D.
2.				
1.				
0.				

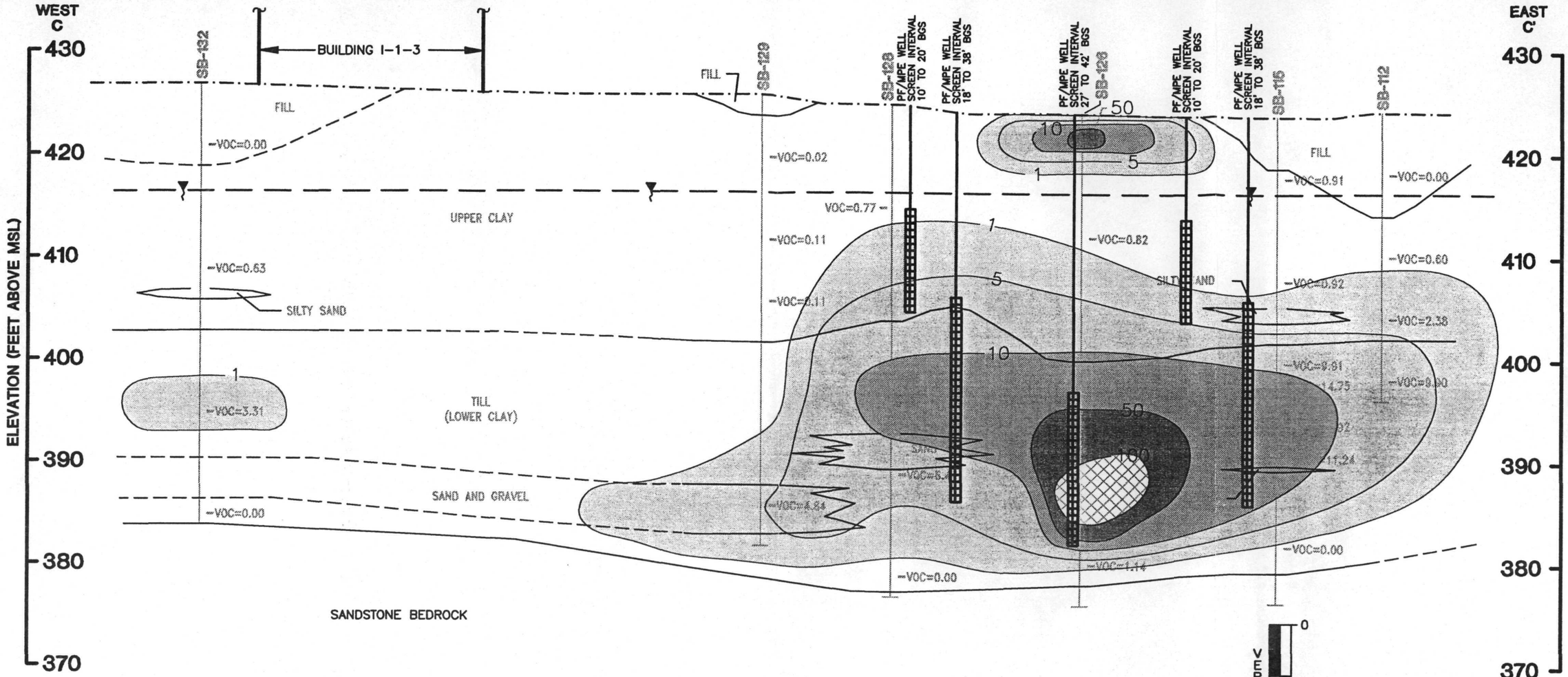
PROJECT: CRAB ORCHARD NWR - PCB O.U.
MARION, ILLINOIS
PRELIMINARY DESIGN REPORT

SHEET TITLE: VOC CONCENTRATIONS IN SOIL
BUILDING I-1-3
36 TO 48 FOOT INTERVAL

DRAWN BY: SIEWERTD	SCALE:	PROJ. NO. 4781.07
CHECKED BY: SLM	1"=40'	FILE NO. 47810739A.DWG
APPROVED BY: TEG	DATE PRINTED:	
DATE: MAY 2001		

RMT.
744 Heartland Trail
Madison, WI 53717-1934
P.O. Box 8923
Madison, WI 53708-8923
Phone: 608/831-4444

Revision Level



NOTES:

1. GROUNDWATER ELEVATION IS INTERPRETED BASED ON THE OCTOBER 2000 WATER TABLE MAP FIGURE 3-27.
2. (VOC=0.03) REPRESENTS TOTAL VOC CONCENTRATION IN SOIL, mg/kg
3. WELL LOCATIONS ARE PROJECTED AND DO NOT NECESSARILY FALL ONTO CROSS SECTIONS.

LEGEND

- EXISTING GROUND SURFACE
- STRATIGRAPHIC BOUNDARY, DASHED WHERE INFERRED
- WATER TABLE SURFACE
- (813.05) GROUNDWATER HEAD ELEVATION (FEET, MSL)

WELL CONSTRUCTION

- WELL SEAL
- WELL CASING
- WELL SCREEN

- —1— TOTAL VOC CONCENTRATIONS (mg/kg)
- VOC=0.08 TOTAL VOC CONCENTRATIONS (mg/kg)

- PNEUMATIC FRACTURING/ MULTI-PHASE EXTRACTION SCREEN INTERVAL

VERTICAL SCALE: 0, 10, 20

HORIZONTAL SCALE: 0, 30, 60

VERTICAL SCALE EXAGGERATED 3X

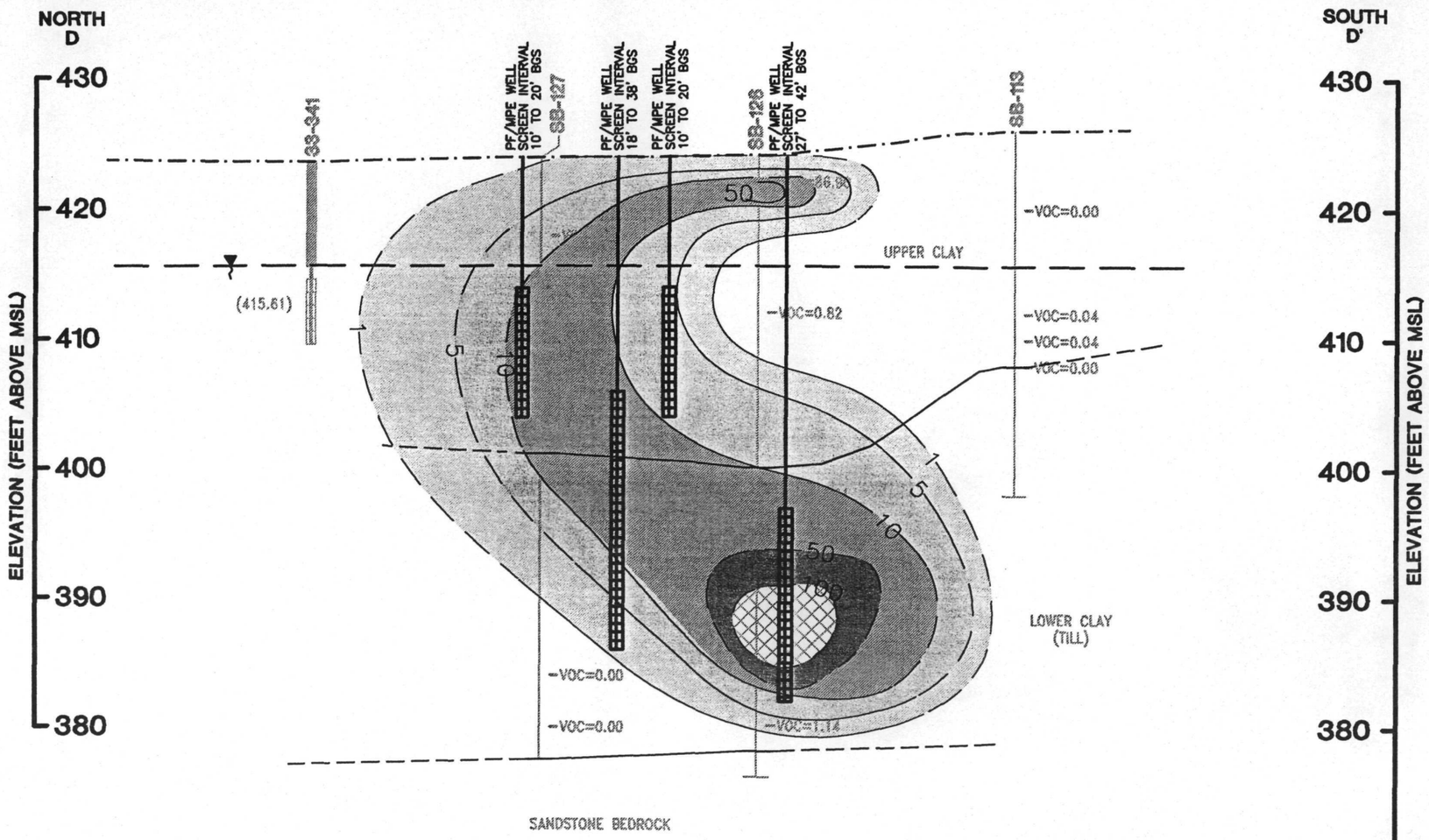
VOC CONCENTRATION CROSS SECTION C-C'
CRAB ORCHARD NWR PCB O.U.
MARION, ILLINOIS
PRELIMINARY DESIGN REPORT

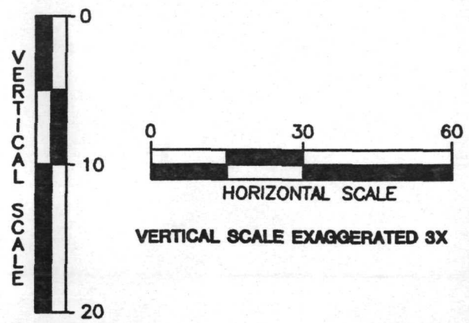
RMT

DWN. BY:	SIEWERTD
APPROVED BY:	TEG
DATE:	MAY 2001
PROJ. #	04781.07
FILE #	47810773A.DWG

FIGURE

Drawing Name: J:\04781\07\47810773A.dwg
Operator Name: SIEWERTD
Scale: 1"=30'
Dwg Size: 235473 bytes
Plot Date: Wednesday, August 8, 2001
Plot Time: 10:23:44 AM
Attached Xref's: No xref's attached.





NOTES:

1. GROUNDWATER ELEVATION IS INTERPRETED BASED ON THE OCTOBER 2000 WATER TABLE MAP FIGURE 3-27.
2. (VOC=0.03) REPRESENTS TOTAL VOC CONCENTRATION IN SOIL, mg/kg
3. WELL LOCATIONS ARE PROJECTED AND DO NOT NECESSARILY FALL ONTO CROSS SECTIONS.

LEGEND

- EXISTING GROUND SURFACE
- STRATIGRAPHIC BOUNDARY, DASHED WHERE INFERRED
- WATER TABLE SURFACE
- (415.61) GROUNDWATER HEAD ELEVATION (FEET, MSL)

WELL CONSTRUCTION

- WELL SEAL
- WELL CASING
- WELL SCREEN

- 1 — TOTAL VOC CONCENTRATIONS (mg/kg)
- VOC=0.08 — TOTAL VOC CONCENTRATIONS (mg/kg)

- PNEUMATIC FRACTURING/ MULTI-PHASE EXTRACTION SCREEN INTERVAL

VOC CONCENTRATION CROSS SECTION D-D'
CRAB ORCHARD NWR PCB O.U.
MARION, ILLINOIS
PRELIMINARY DESIGN REPORT

RMT

DWN. BY:	SIEWERTD
APPROVED BY:	TEG
DATE:	MAY 2001
PROJ. #	04781.07
FILE #	47810774A.DWG

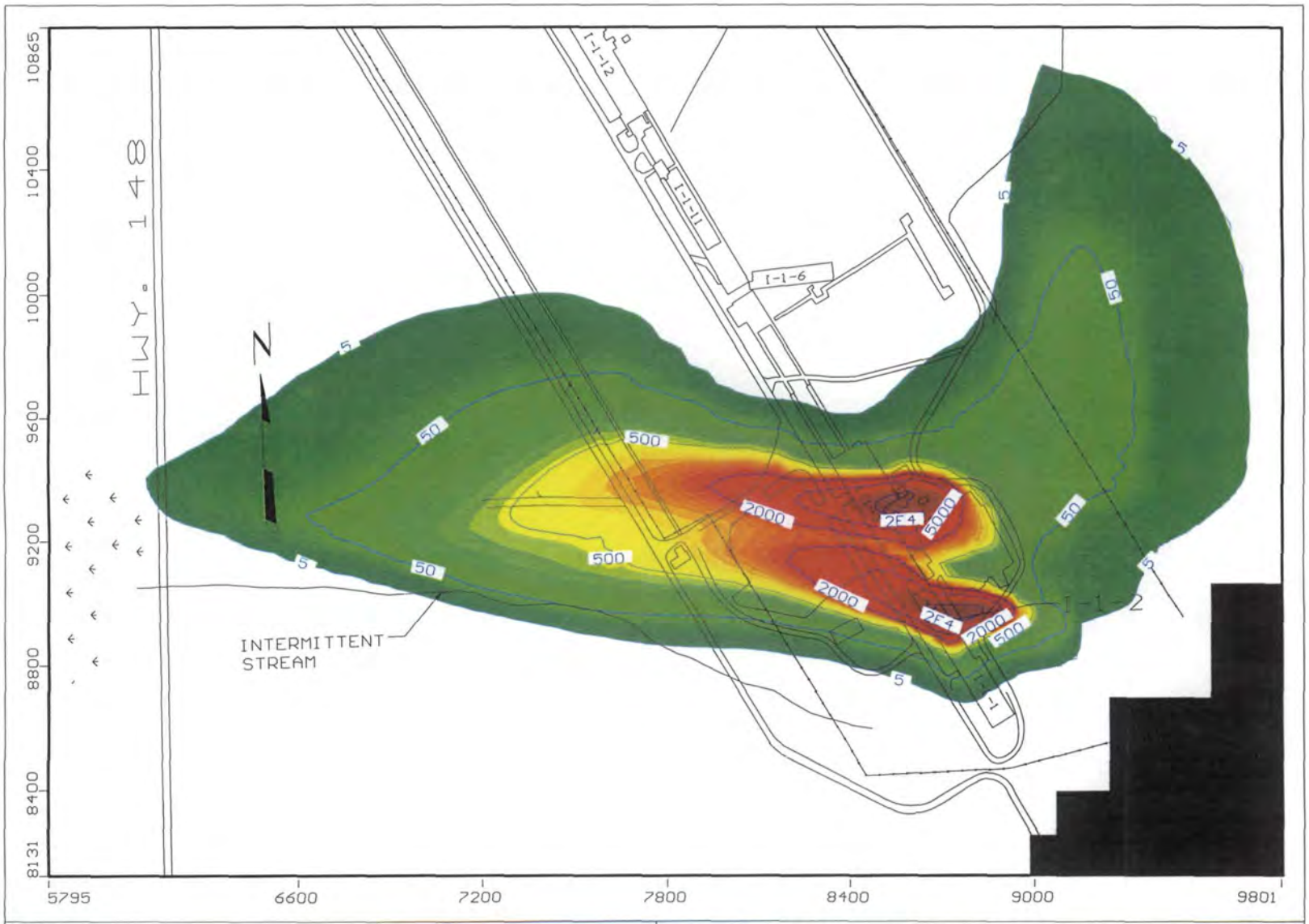
FIGURE

Drawing Name: J:\04781\07\47810774A.dwg
Operator Name: SIEWERTD
Scale: 1"=30'
Dwg Date: Wednesday, August 8, 2001
Plot Date: 10:46.01 AM
Plot Time:
Attached Xref's: No xref's attached.

Buildings I-1-2/I-1-3 Area
Case 1

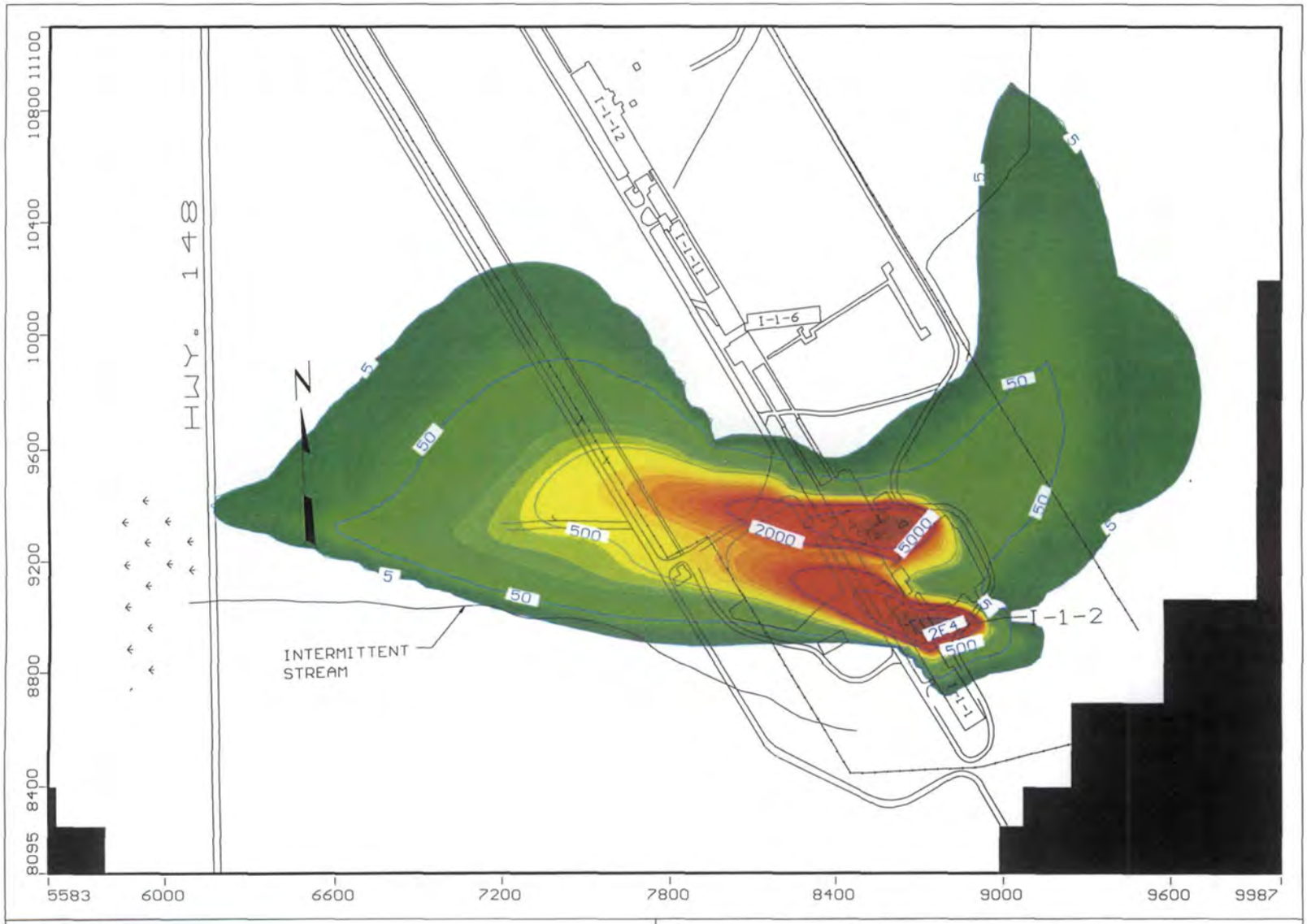
MPE wells with pneumatic fracturing operated for 2 years then shut-down (no PRB).

Model Run No. 520



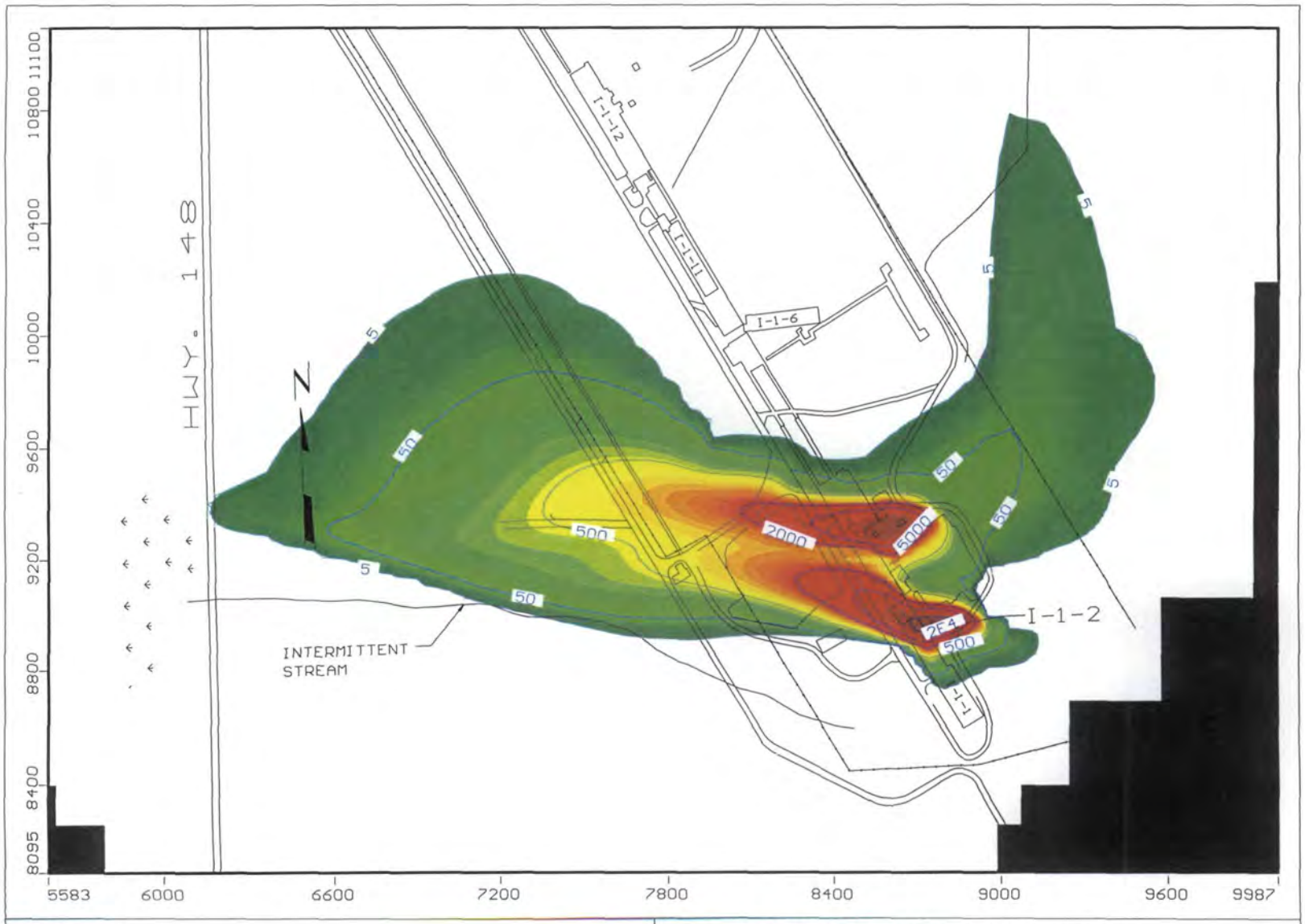
RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: Current Conditions Simul.
Modeller: TCE,ppb t=0 yr
27 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



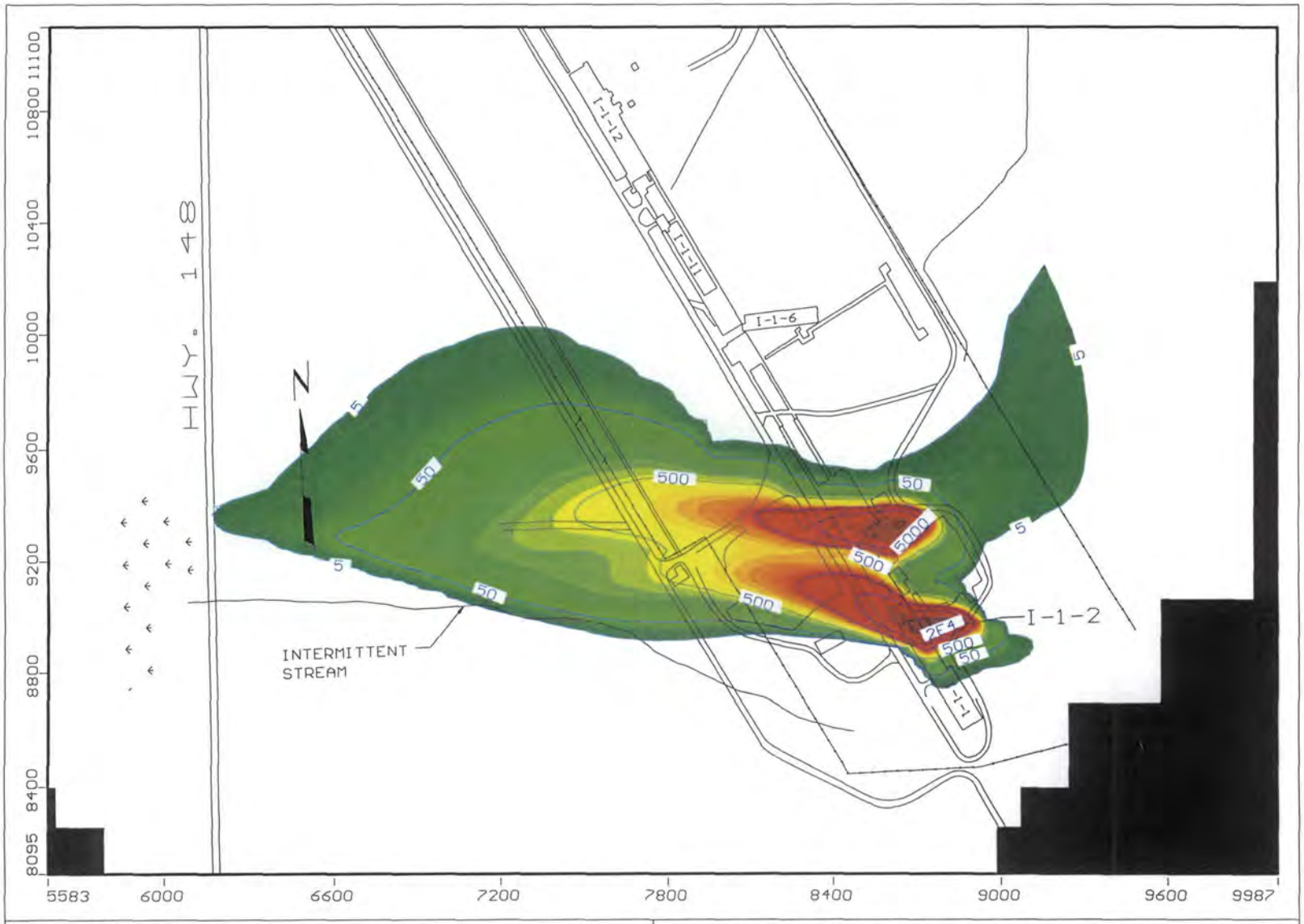
RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: MPE w/Pneu. Fracture
Modeller: TCE,ppb t=5 yr
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: MPE w/Pneu. Fracture
Modeller: TCE,ppb t=10 yr
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



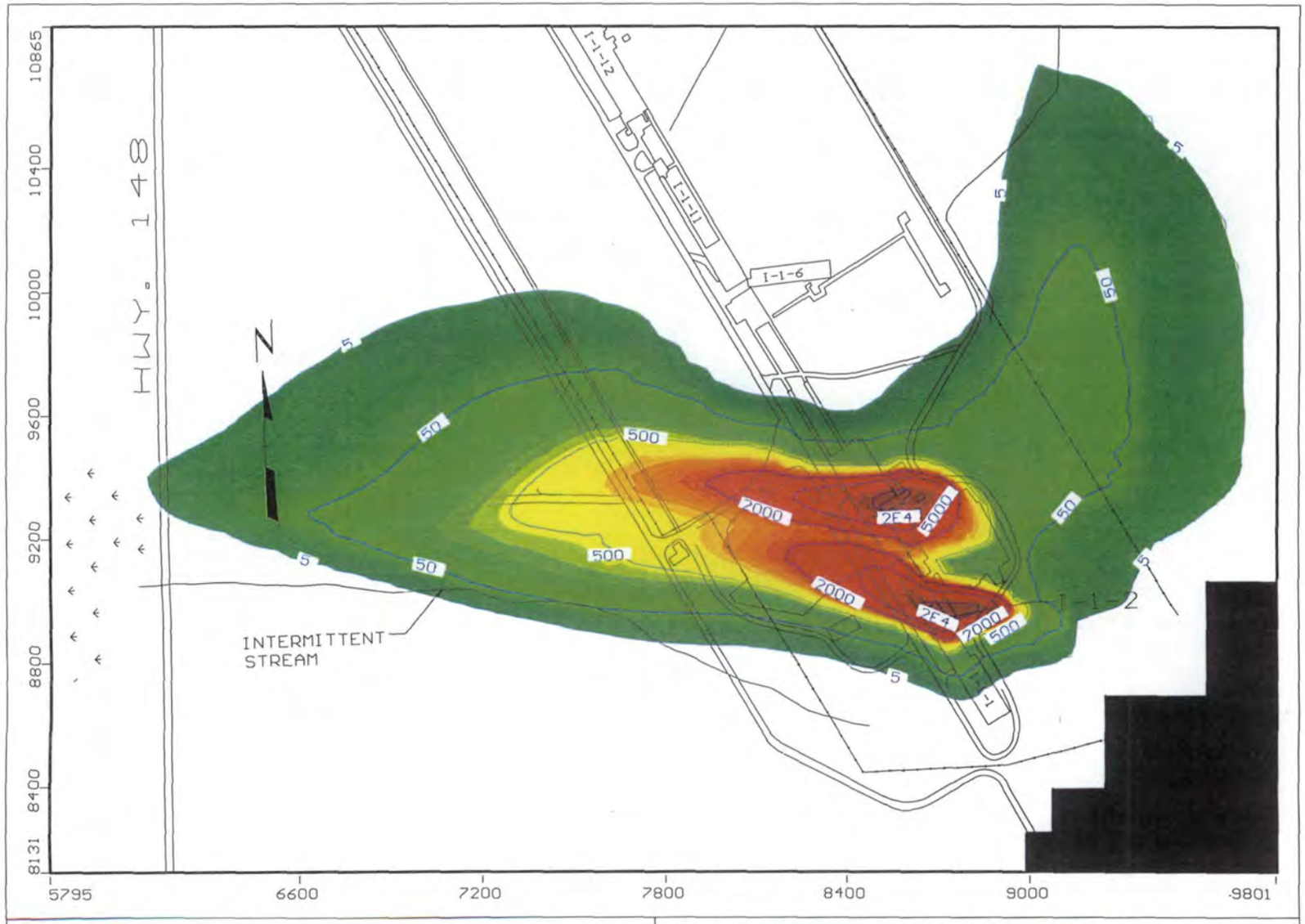
RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: MPE w/Pneu. Fracture
Modeller: TCE,ppb t=20 yr
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

Buildings I-1-2/I-1-3 Area
Case 2

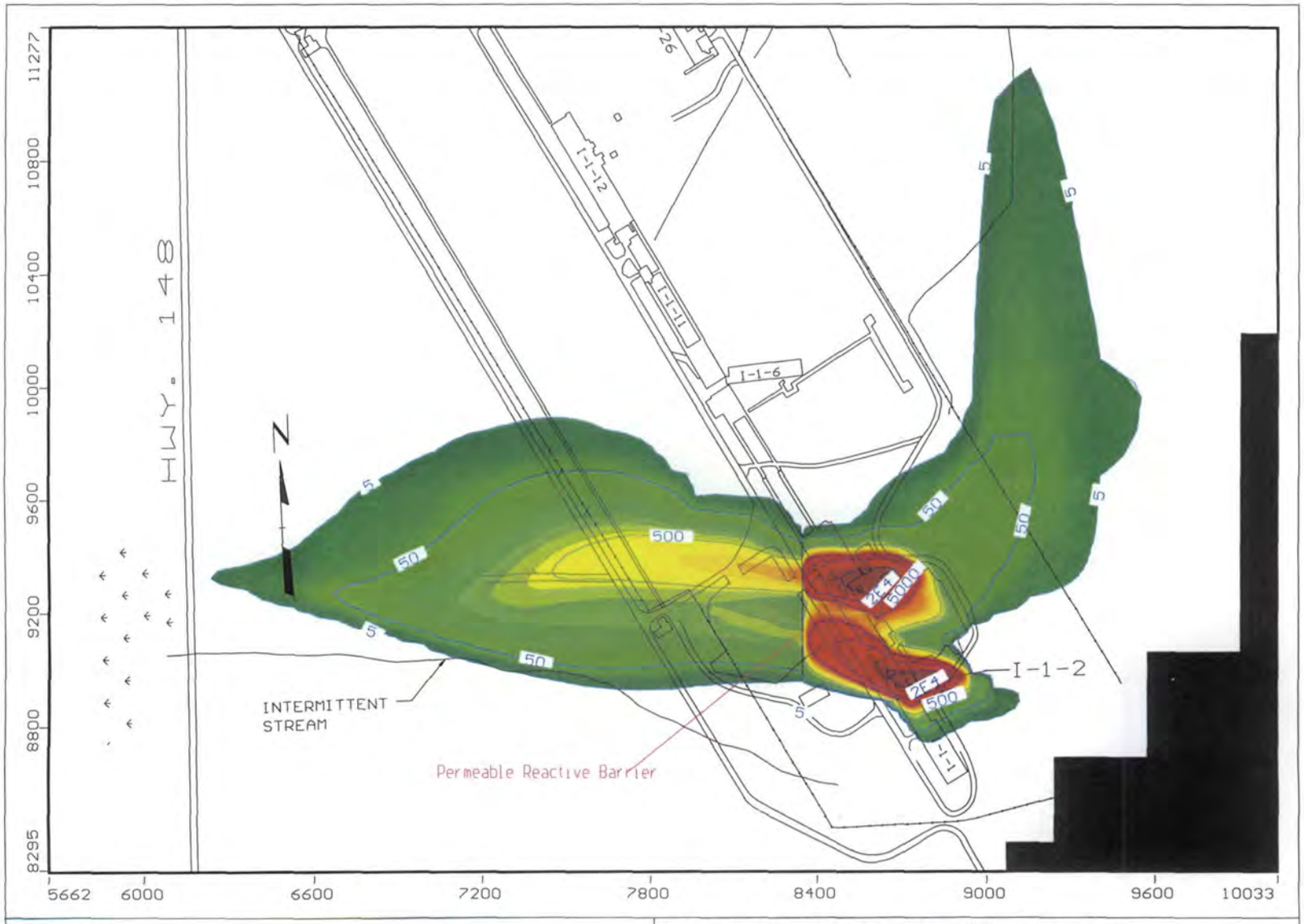
PRB with zero-valent iron in west plume
(no source area treatment).

Model Run No. 522



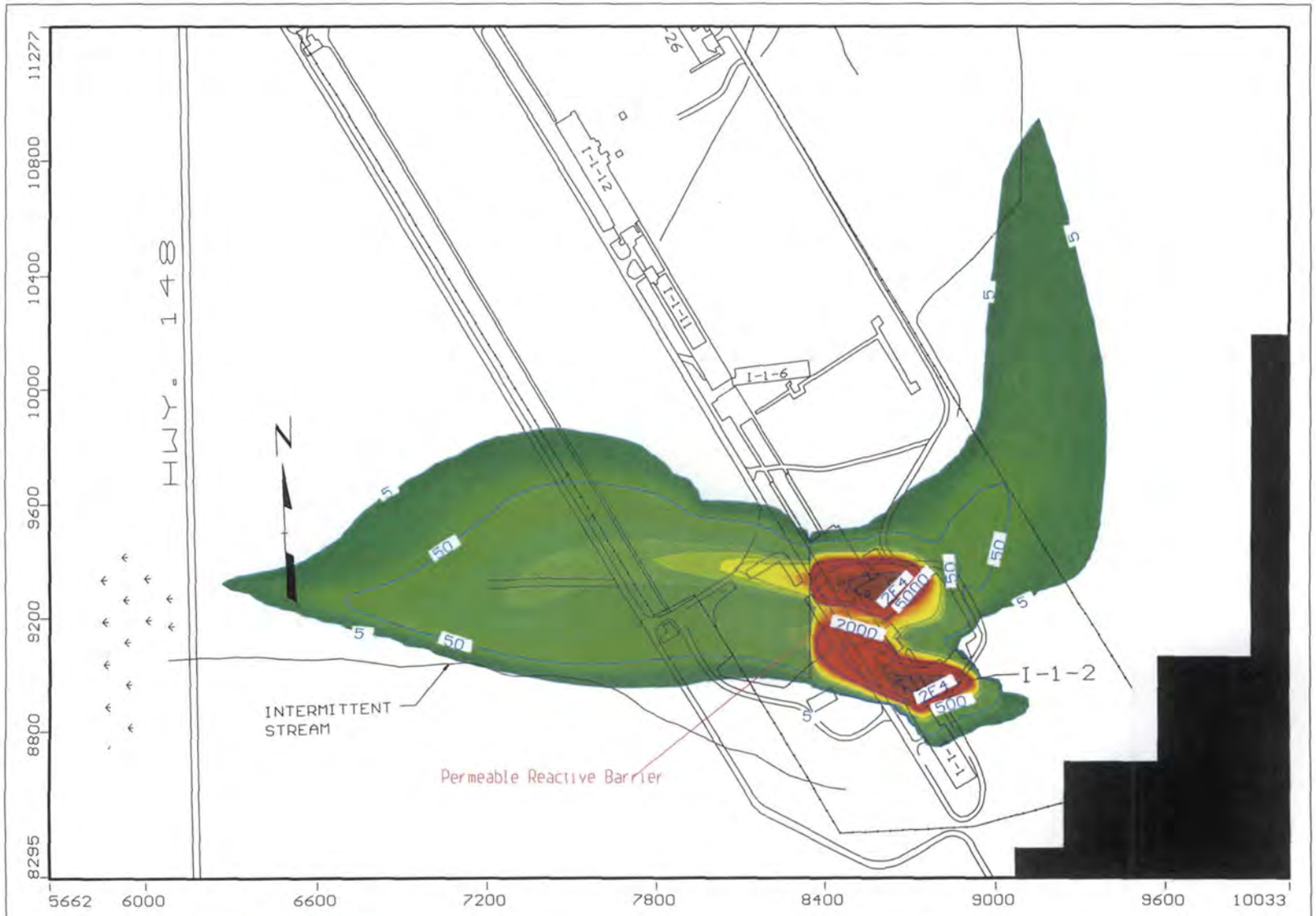
RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: Current Conditions Simul.
Modeller: TCE,ppb t=0 yr
27 Aug 01

Visual MODFLOW v.2.8.2. (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



RMT, Inc.
Project: CRAB ORCHARD Crab522
Description: Perm. Reactive Barrier
Modeller: TCE,ppb t=5 years
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 119 NR: 135 NL: 5
Current Layer: 2



RMT, Inc.
Project: CRAB ORCHARD Crab522
Description: Perm. Reaction Barrier
Modeller: TCE,ppb t=10 years
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 119 NR: 135 NL: 5
Current Layer: 2

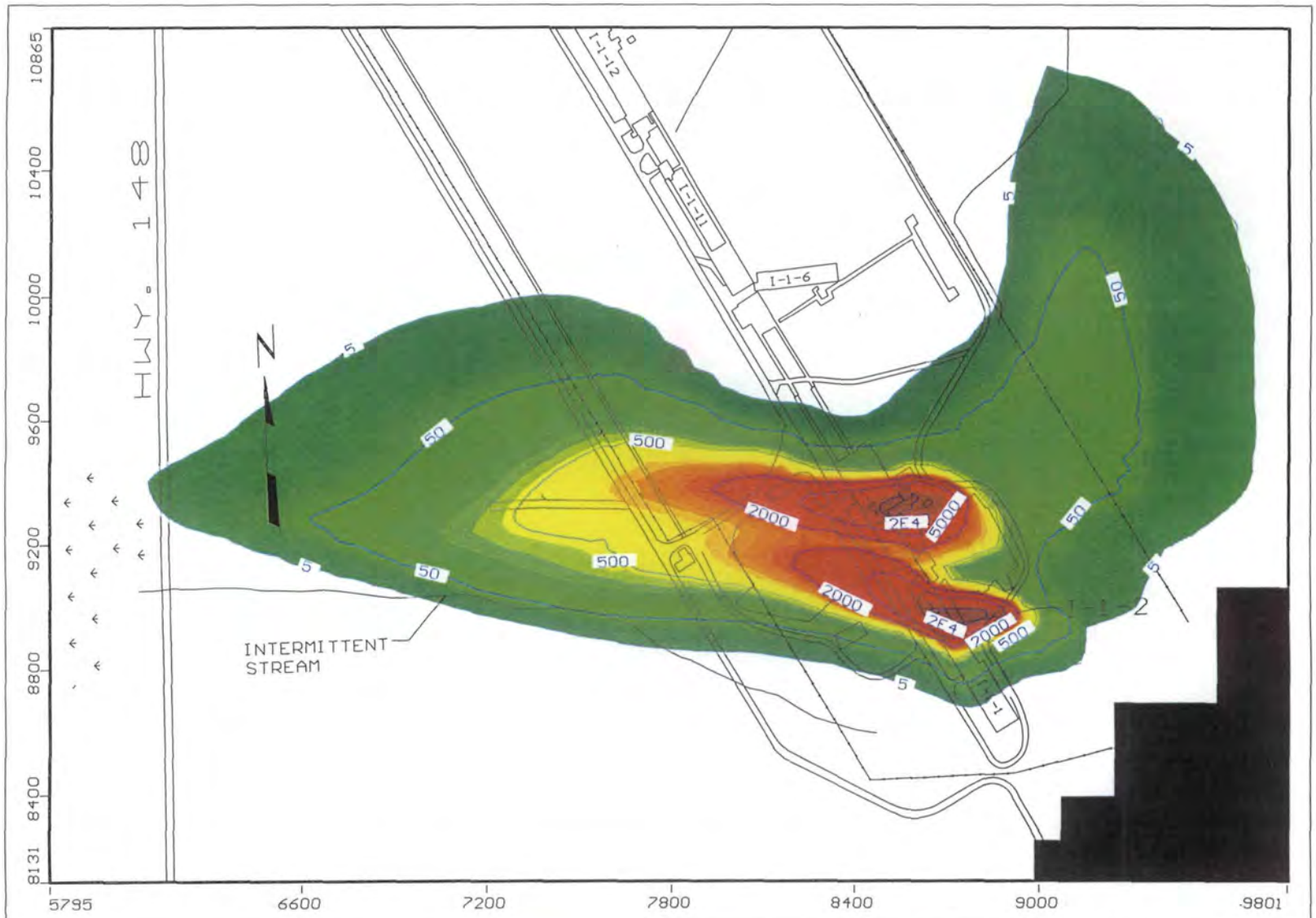
RMT, Inc.
Project: CRAB ORCHARD Crab522
Description: Perm. Reactive Barrier
Modeller: TCE,ppb t=20 years
27 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 119 NR: 135 NL: 5
Current Layer: 2

Buildings I-1-2/I-1-3 Area
Case 3

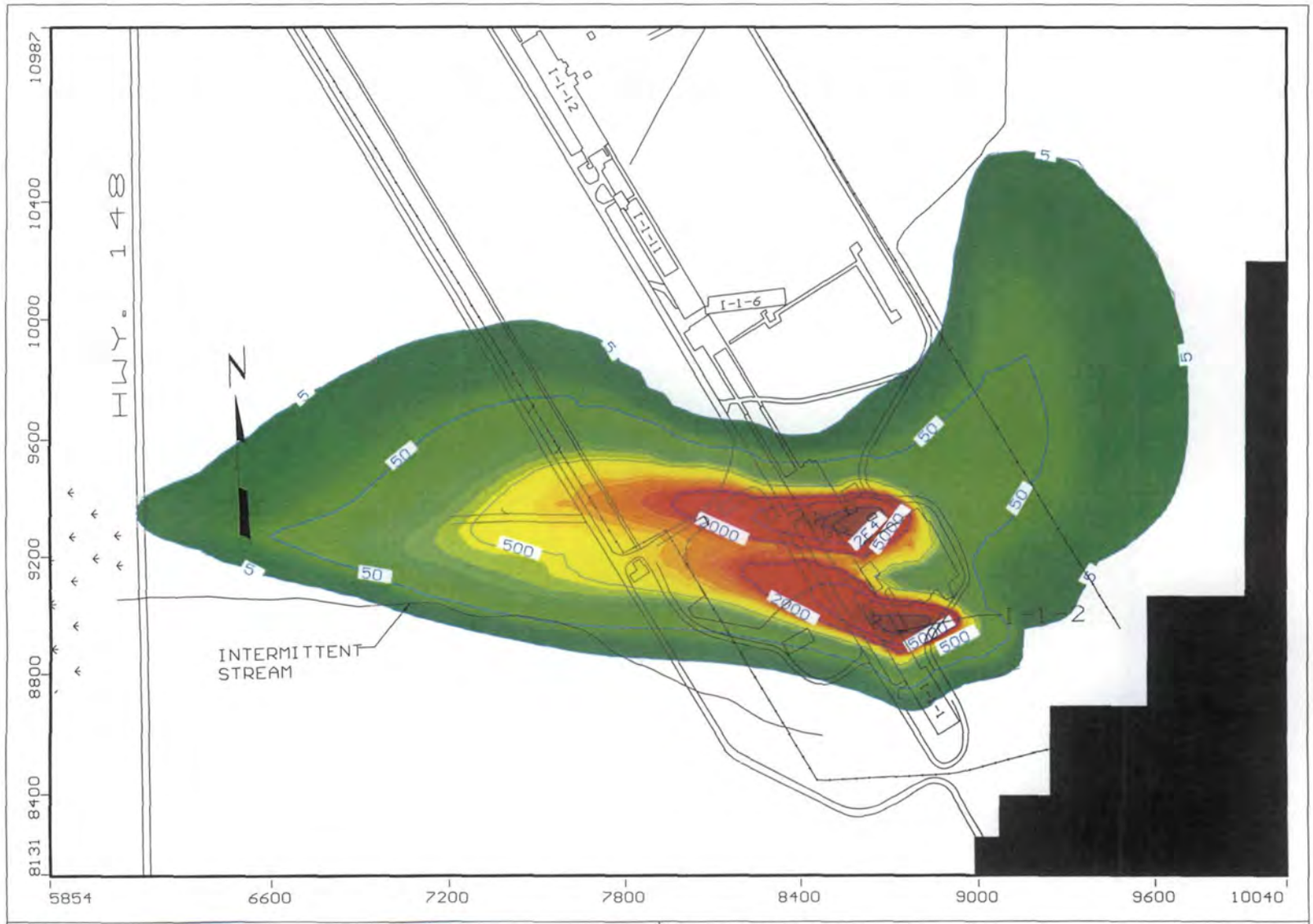
MNA only (no active source area treatment).

Model Run No. 417



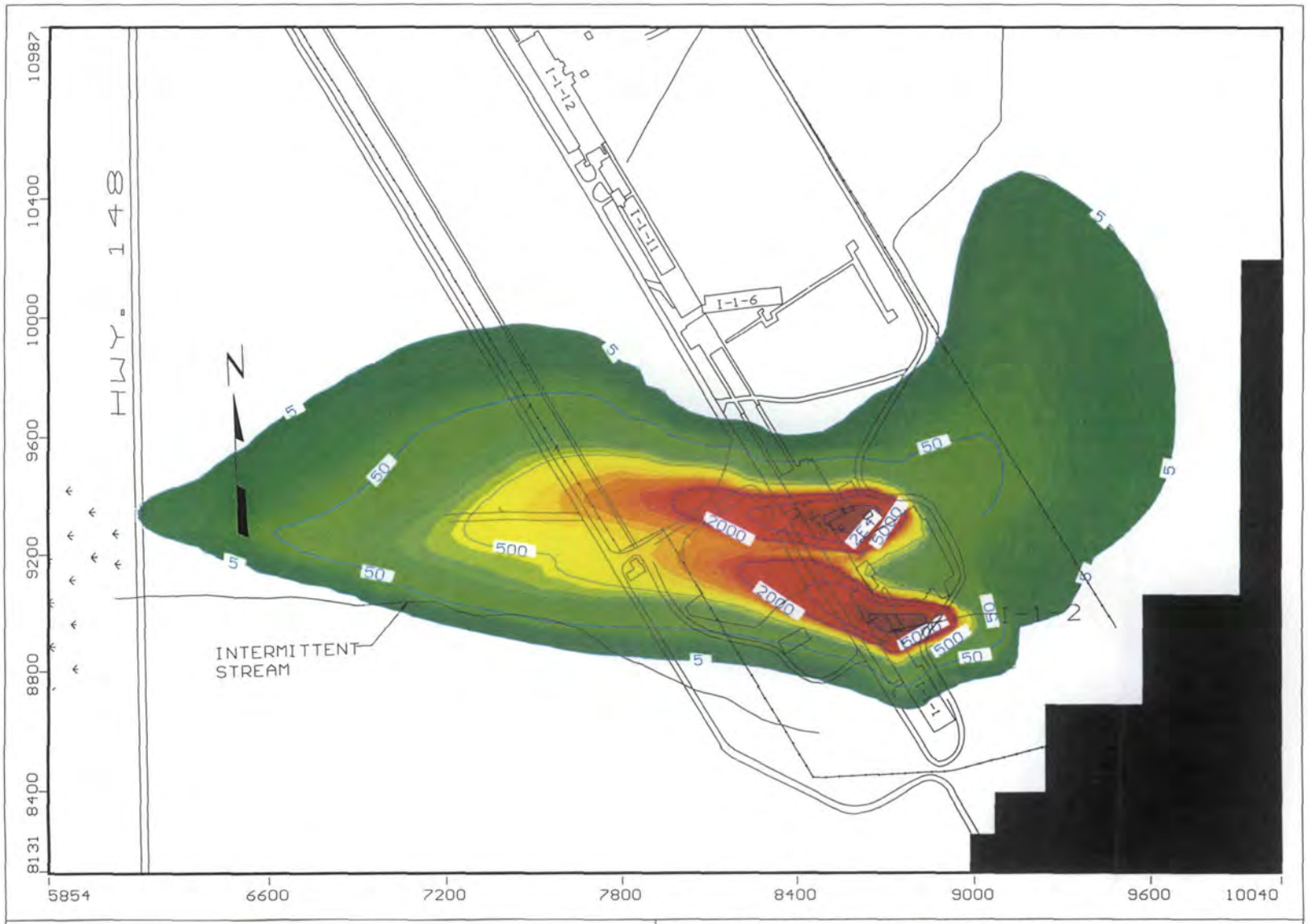
RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: Current Conditions Simul.
Modeller: TCE,ppb t=0 yr
27 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



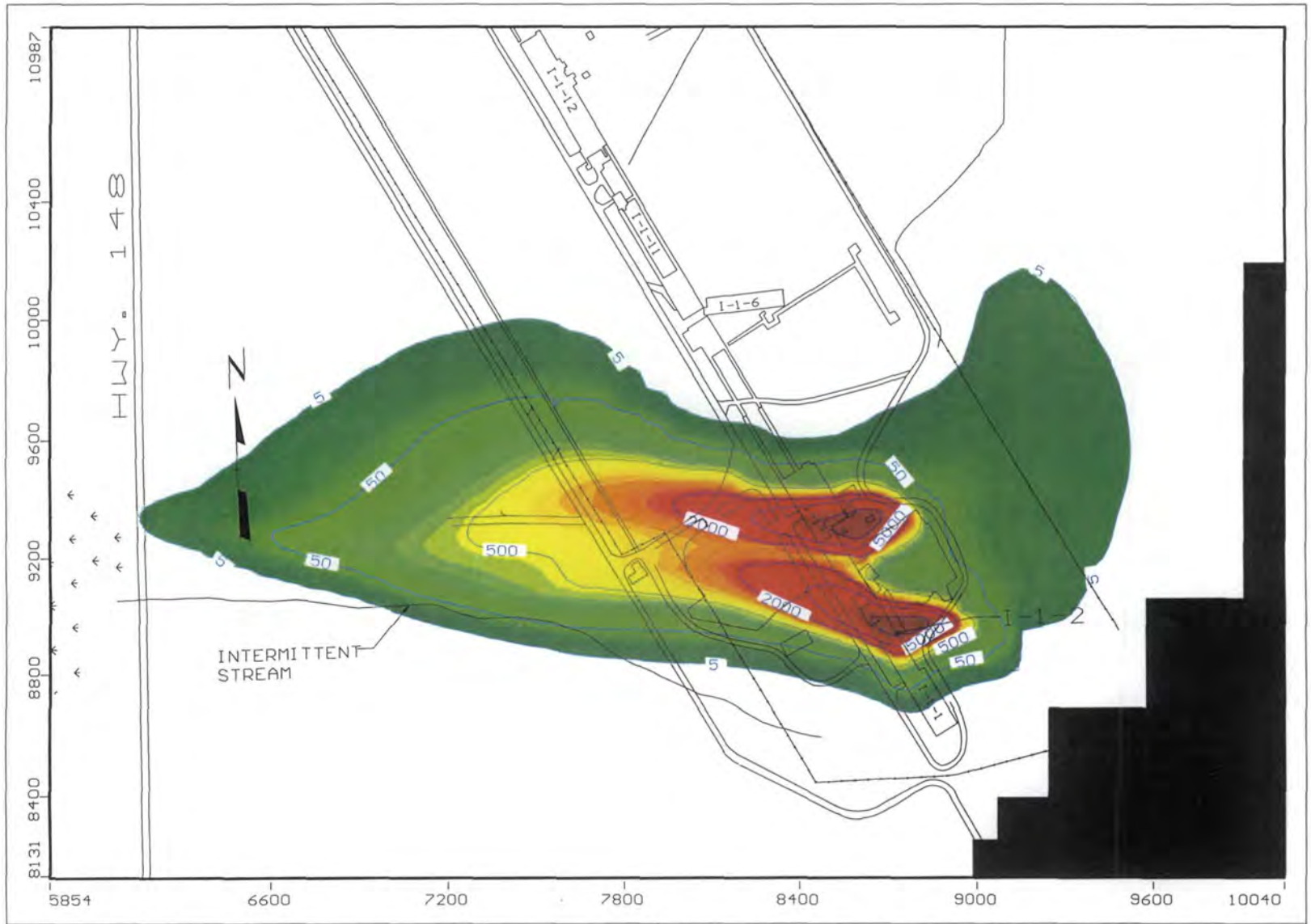
RMT, Inc.
Project: CRAB ORCHARD Crab417
Description: Monit. Nat. Atten. Only
Modeller: TCE,ppb t=5yr
20 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



RMT, Inc.
Project: CRAB ORCHARD Crab417
Description: Monit. Nat. Atten. Only
Modeller: TCE,ppb t=10yr
20 Aug 01

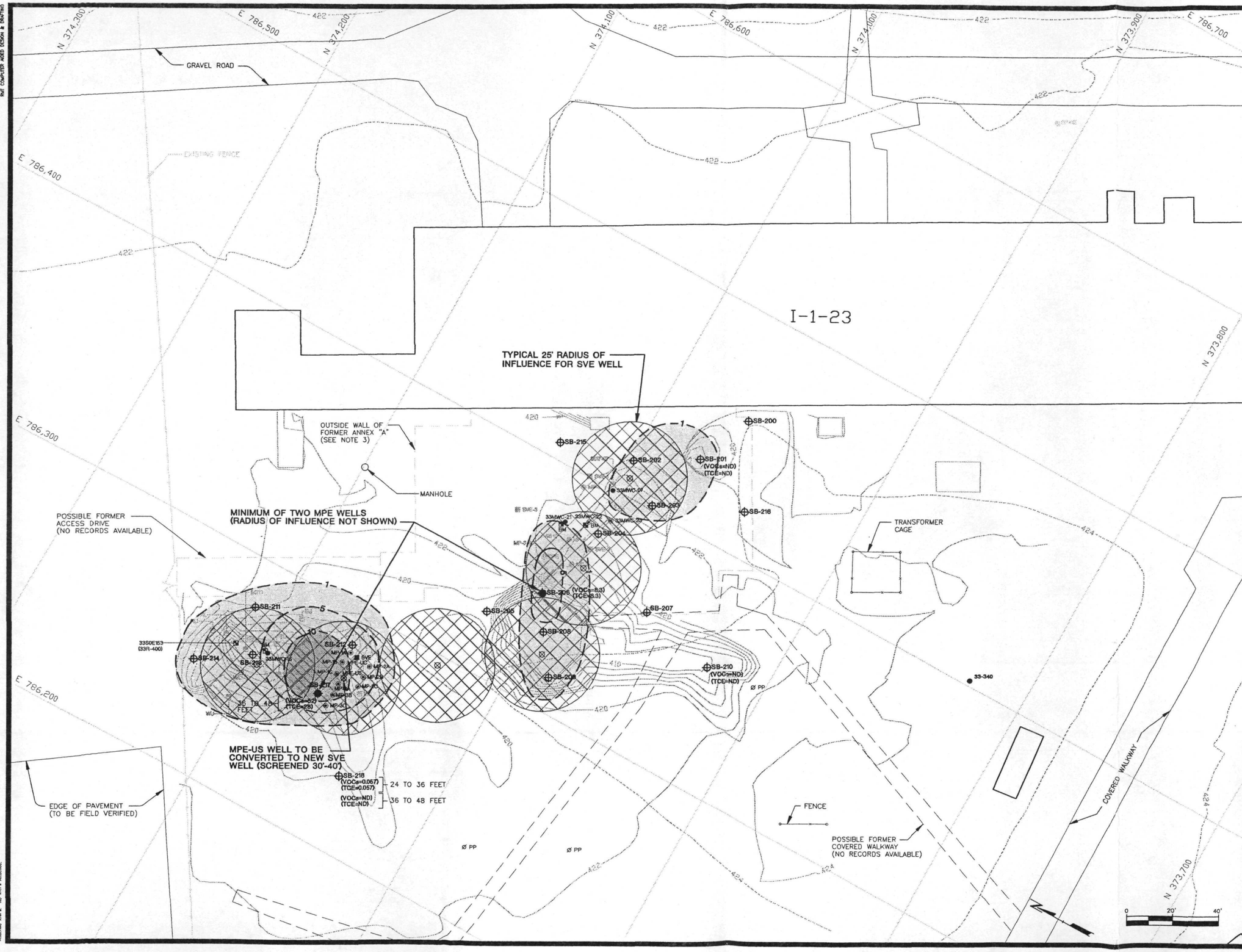
Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



RMT, Inc.
Project: CRAB ORCHARD Crab417
Description: Monit. Nat. Atten. Only
Modeller: TCE,ppb t=20yr
20 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

Attachment 2
Figures Associated with Building I-1-23 Area



LEGEND

SB-200	GEOPROBE BORING LOCATION (INSTALLED BY RMT IN 2000)
33MWC-23	GROUNDWATER MONITORING WELL (2")
MP-3	MONITORING POINT (2") (INSTALLED BY RMT IN 2000)
SVE	SOIL VAPOR EXTRACTION WELL (2") (INSTALLED BY RMT IN 2000)
DPE-UC	MULTI PHASE EXTRACTION WELL (4") (UPPER CLAY) (INSTALLED BY RMT IN 2000)
MPE-US	MULTI PHASE EXTRACTION WELL (4") (UPPER SAND) (INSTALLED BY RMT IN 2000)
	GEOPROBE BORING LOCATION (1998)
33R-393	SOIL SAMPLE (IT CORP.)
	SVE WELL SCREEN INTERVAL = 20'-35' 25' RADIUS OF INFLUENCE
	MPE WELL SCREEN INTERVAL = 40'-45'
	SOIL SAMPLE (FDGTI)(1997)
	MONITORING POINT (2") (INSTALLED BY FDGTI)
	SOIL VAPOR EXTRACTION WELL (2") (INSTALLED BY FDGTI)
	DUAL PHASE EXTRACTION WELL (4") (INSTALLED BY FDGTI)
	AIR SPARGING WELL (4") (INSTALLED BY FDGTI)
BM	BENCH MARK
PP	POWER POLE
	EXISTING FENCE
	EXISTING BUILDING
422	PRE-PCB EXCAVATION CONTOURS (IT CORP.) (1994)
422	PCB EXCAVATION CONTOURS (FDGTI) (1997)
1	ISOCONCENTRATION CONTOUR (DASHED WHERE INFERRED)
(VOCs=0.41)	TOTAL VOCs (mg/kg)
(TCE=0.41)	TRICHLOROETHENE (mg/kg)

NOTES

1. CONTOURS OF PRE-PCB EXCAVATION CONDITIONS ARE FROM DRAWINGS PREPARED BY IT CORPORATION CONTAINED IN PRE-FINAL DESIGN DOCUMENTS DATED JULY 27, 1994. ELECTRONIC COPIES OF THESE DRAWINGS WERE PROVIDED TO RMT, INC. BY U.S. FISH & WILDLIFE SERVICE.
2. CONTOURS OF PCB EXCAVATIONS ARE FROM THE DRAWINGS PREPARED BY ROBERT G. SEWELL, PROFESSIONAL LAND SURVEYOR, MARION, ILLINOIS, FOR FLUOR DANIEL, INC. THE DRAWINGS ARE CONTAINED IN A REPORT TITLED FINAL CLOSEOUT REPORT FOR THE PCB OPERABLE UNIT, REV. 0, MARCH 1998, PREPARED BY FLUOR DANIEL GTI.
3. ANNEX "A" WAS DECONTAMINATED AND DEMOLISHED DURING THE PCB REMEDIAL ACTION IN 1997.

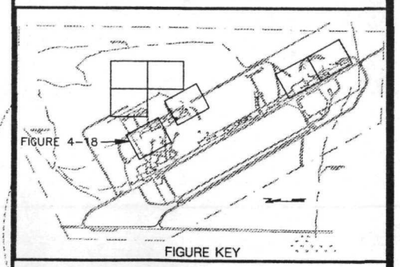


FIGURE KEY

NO.	BY	DATE	REVISION	APP'D.
2.				
1.				
0.				

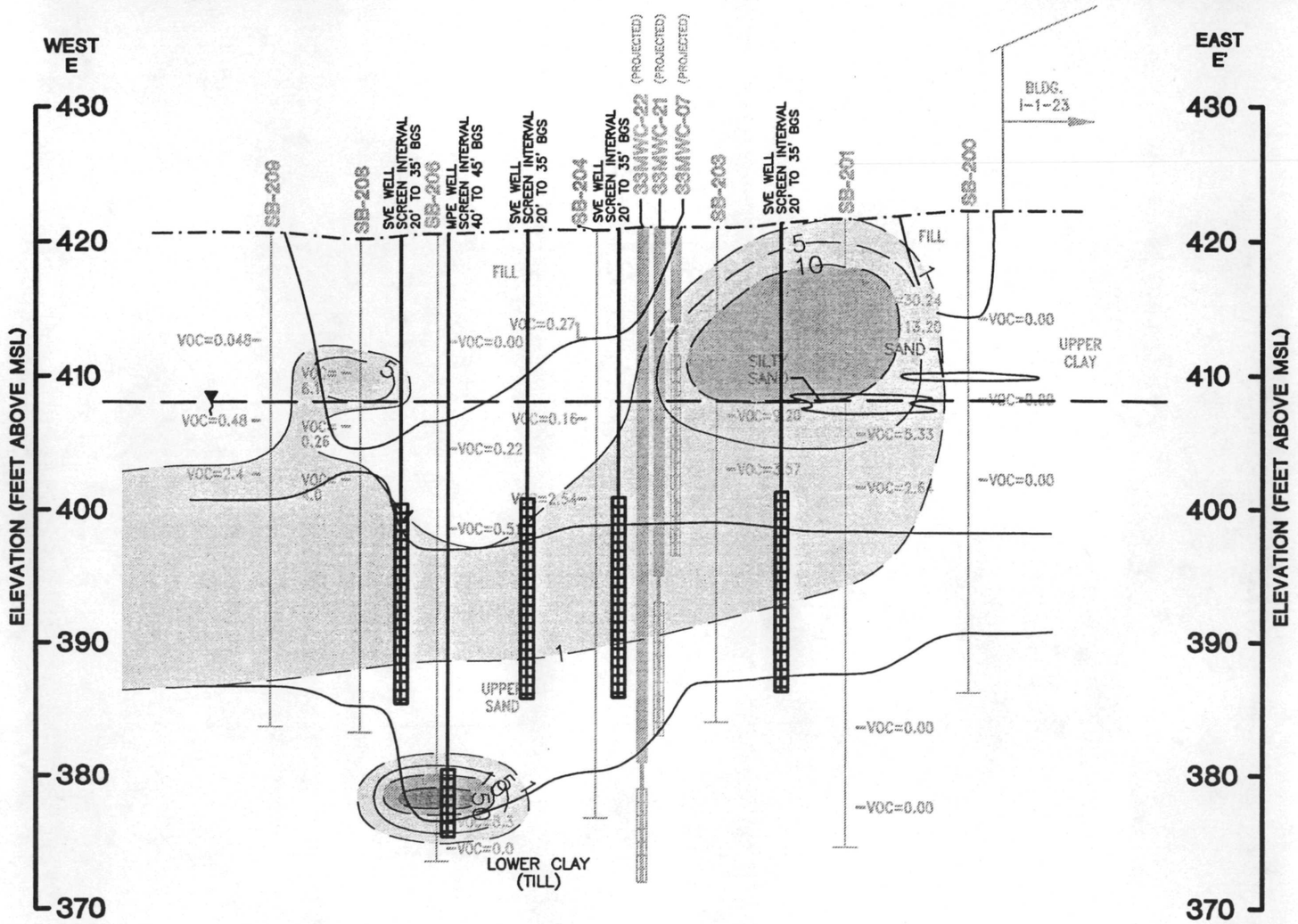
PROJECT: CRAB ORCHARD NWR - PCB O.U.
MARION, ILLINOIS
PRELIMINARY DESIGN REPORT

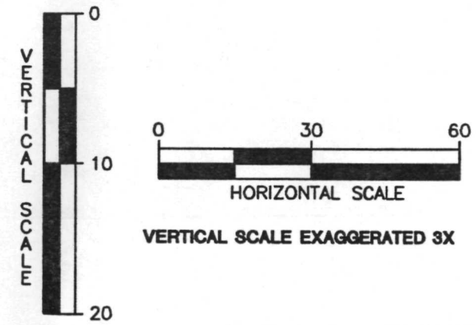
SHEET TITLE: VOC CONCENTRATIONS IN SOIL
BUILDING I-1-23
DEEPER THAN 24 FOOT INTERVAL

DRAWN BY: SIEWERTD	SCALE: 1"=40'	PROJ. NO. 4781.07
CHECKED BY: SLM		FILE NO. 47810744A.DWG
APPROVED BY: TEG	DATE PRINTED:	
DATE: MAY 2001		

RMT
744 Heartland Trail
Madison, WI 53717-1934
P.O. Box 8923
Madison, WI 53708-8923
Phone: 608/831-4444

Revision Level





VERTICAL SCALE EXAGGERATED 3X

NOTES:

1. GROUNDWATER ELEVATION IS INTERPRETED BASED ON THE OCTOBER 2000 WATER TABLE MAP FIGURE 3-27.
2. (VOC=0.03) REPRESENTS TOTAL VOC CONCENTRATION IN SOIL, mg/kg
3. WELL LOCATIONS ARE PROJECTED AND DO NOT NECESSARILY FALL ONTO CROSS SECTIONS.

LEGEND

- EXISTING GROUND SURFACE
- STRATIGRAPHIC BOUNDARY, DASHED WHERE INFERRED
- WATER TABLE SURFACE
- (813.05) GROUNDWATER HEAD ELEVATION (FEET, MSL)

WELL CONSTRUCTION

- WELL SEAL
- WELL CASING
- WELL SCREEN

- 1 — TOTAL VOC CONCENTRATIONS (mg/kg)
- VOC=0.08 — TOTAL VOC CONCENTRATIONS (mg/kg)

- MULTI-PHASE/SOIL VAPOR EXTRACTION SCREEN INTERVAL

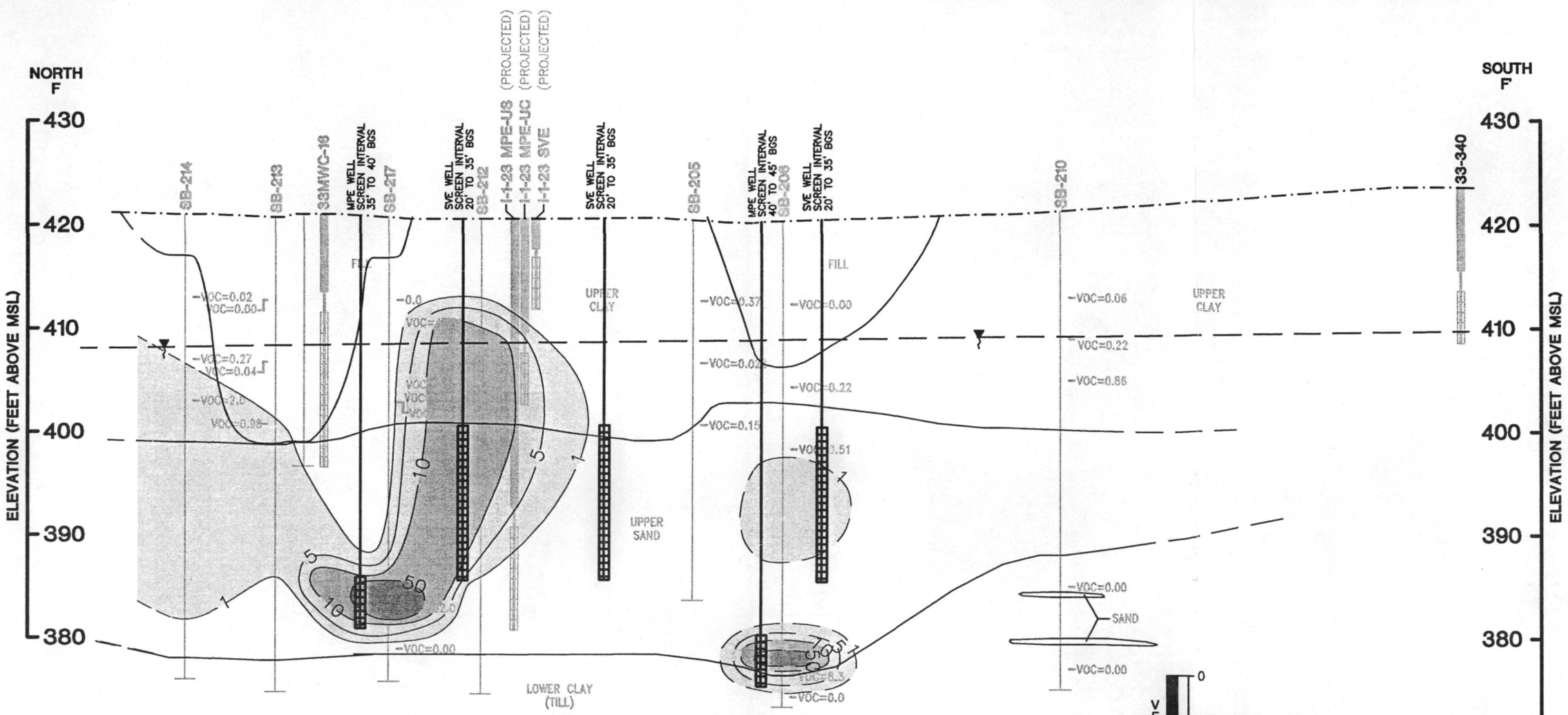
VOC CONCENTRATION CROSS SECTION E-E'
CRAB ORCHARD NWR PCB O.U.
MARION, ILLINOIS
PRELIMINARY DESIGN REPORT

RMT

DWN. BY:	SIEWERTD
APPROVED BY:	TEG
DATE:	MAY 2001
PROJ. #	04781.07
FILE #	47810775A.DWG

FIGURE

Drawing Name: J:\04781\07\47810775A.dwg
Operator Name: SIEWERTD
Scale: 1"=30'
Dwg Size: 40x265 bytes
Plot Date: Wednesday, August 8, 2001
Plot Time: 12:17:09 PM
Attached Xref's: No xref's attached.



NOTES:

1. GROUNDWATER ELEVATION IS INTERPRETED BASED ON THE OCTOBER 2000 WATER TABLE MAP FIGURE 3-27.
2. (VOC=0.03) REPRESENTS TOTAL VOC CONCENTRATION IN SOIL, mg/kg
3. WELL LOCATIONS ARE PROJECTED AND DO NOT NECESSARILY FALL ONTO CROSS SECTIONS.

LEGEND

- EXISTING GROUND SURFACE
- STRATIGRAPHIC BOUNDARY, DASHED WHERE INFERRED
- WATER TABLE SURFACE
- (813.05) GROUNDWATER HEAD ELEVATION (FEET, MSL)

WELL CONSTRUCTION

- WELL SEAL
- WELL CASING
- WELL SCREEN

- 1 TOTAL VOC CONCENTRATIONS (mg/kg)
- VOC=0.08 TOTAL VOC CONCENTRATIONS (mg/kg)

- MULTI-PHASE/SOIL VAPOR EXTRACTION SCREEN INTERVAL

VOC CONCENTRATION CROSS SECTION F-F'
CRAB ORCHARD NWR PCB O.U.
MARION, ILLINOIS
PRELIMINARY DESIGN REPORT

RMT

DWN. BY:	SIEWERTD
APPROVED BY:	TEG
DATE:	MAY 2001
PROJ. #	04781.07
FILE #	47810776B.DWG

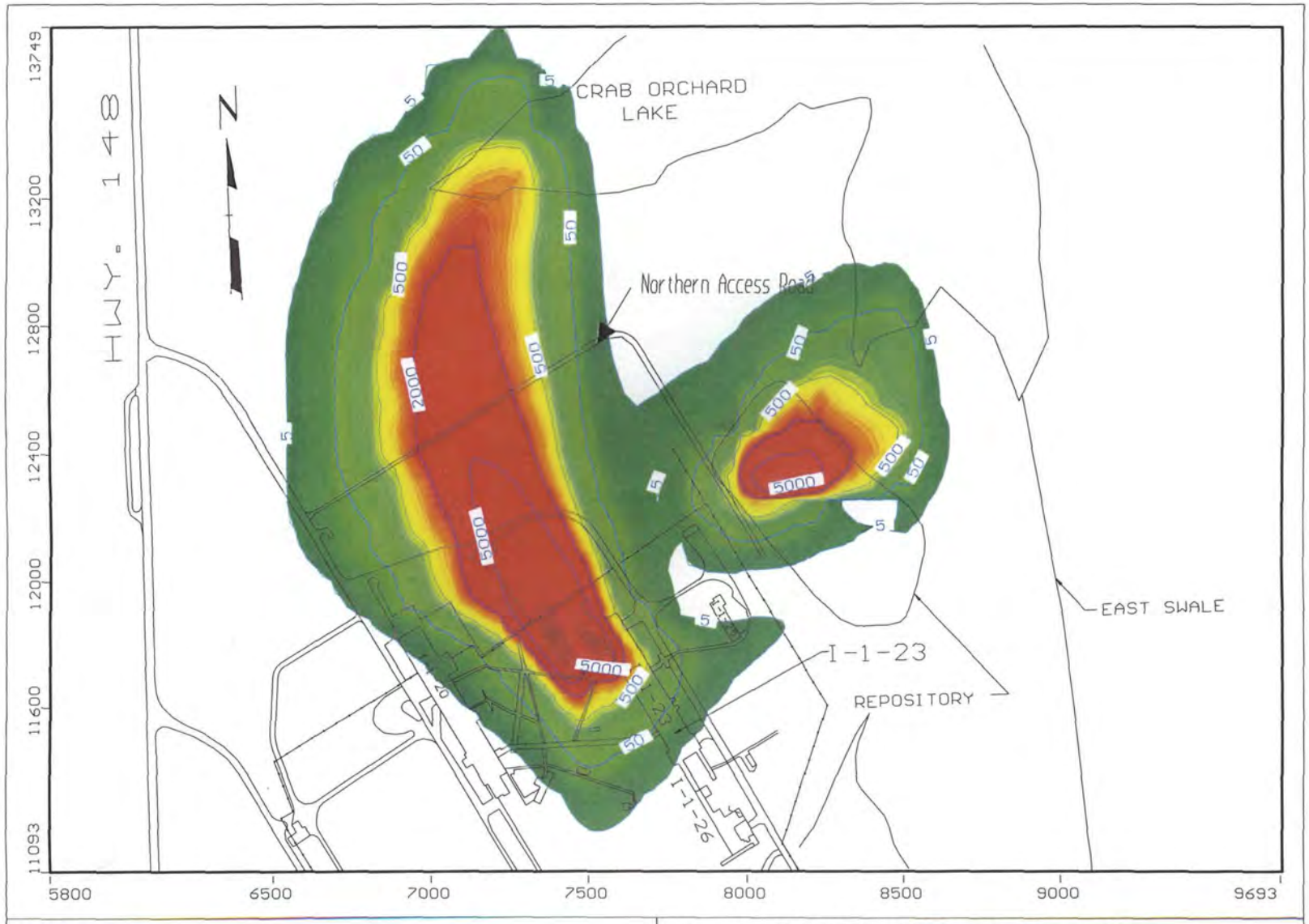
FIGURE

Drawing Name: J:\04781\07\47810776B.dwg
Operator Name: SIEWERTD
Scale: 1"=20'
Dwg Size: 770611 Bytes
Plot Date: Wednesday, August 8, 2001
Plot Time: 12:51:33 PM
Attached Xref's: No xref's attached.

Building I-1-23 Area
Case 1

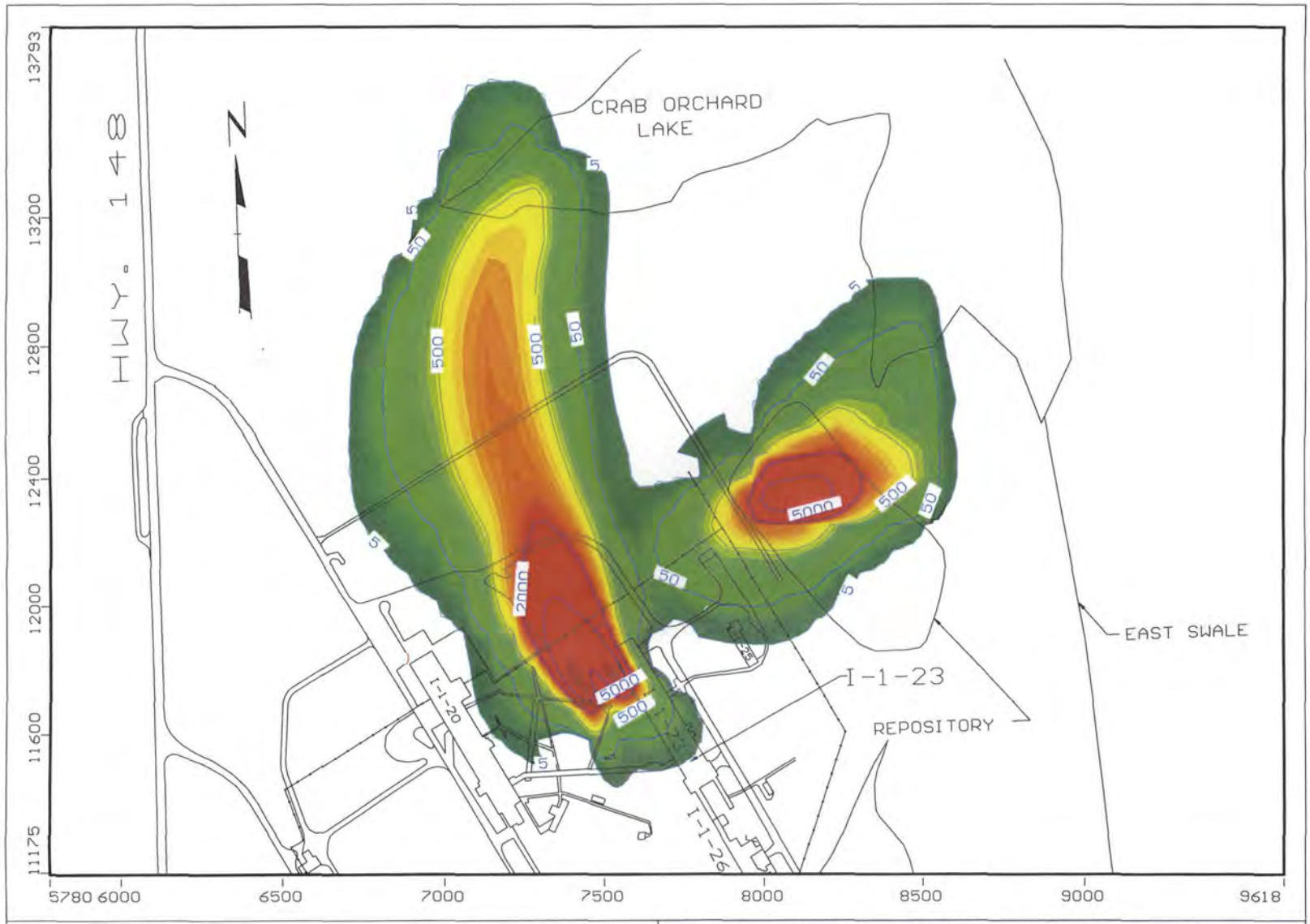
MPE wells, SVE wells, & horizontal groundwater extraction wells in Upper Sand operated for 2 years, then all shut-down; 39% VOC removal from overall source area.

Model Run No. 520



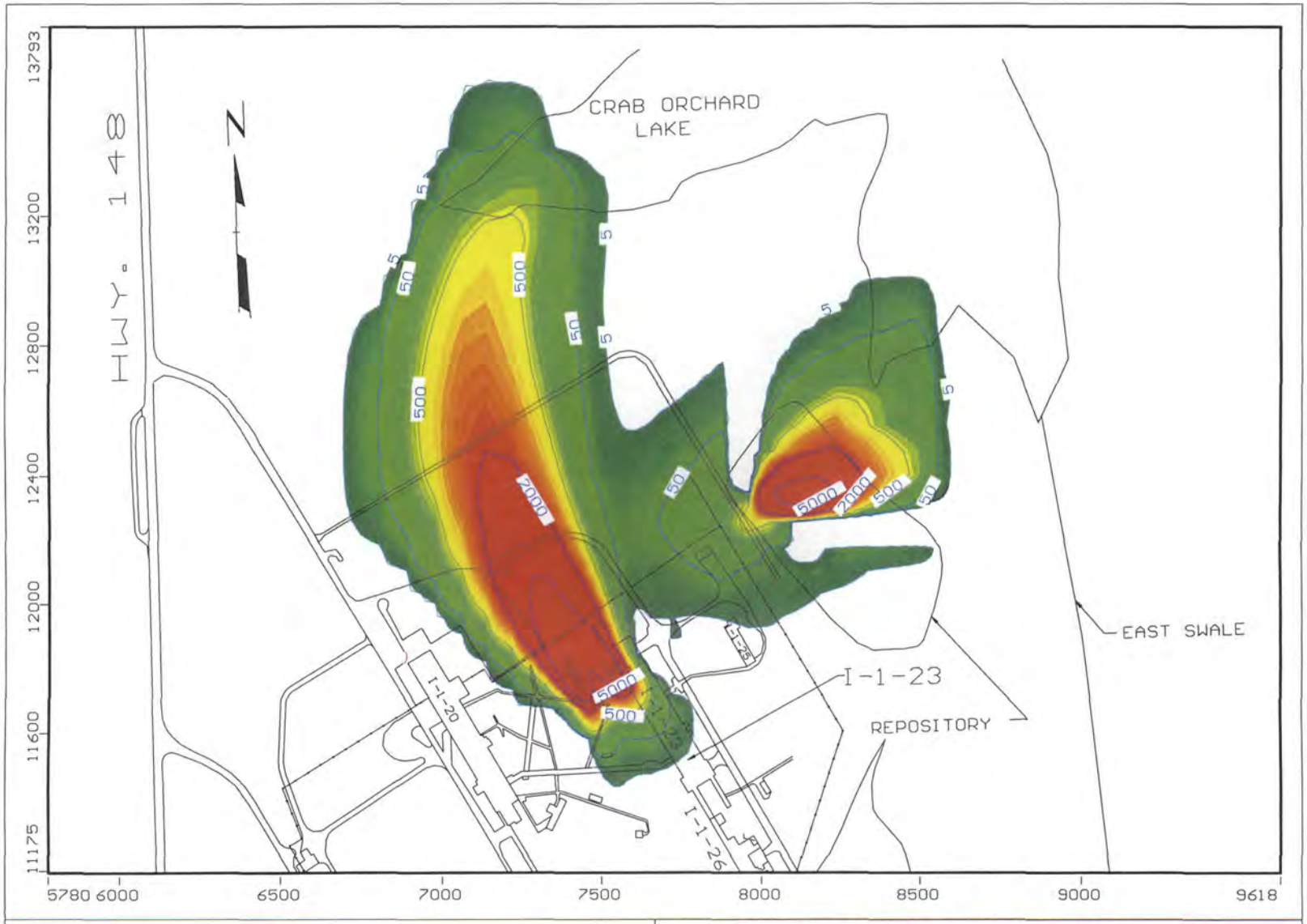
RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: Current Conditions Simul.
Modeller: TCE,ppb t=0 yr
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



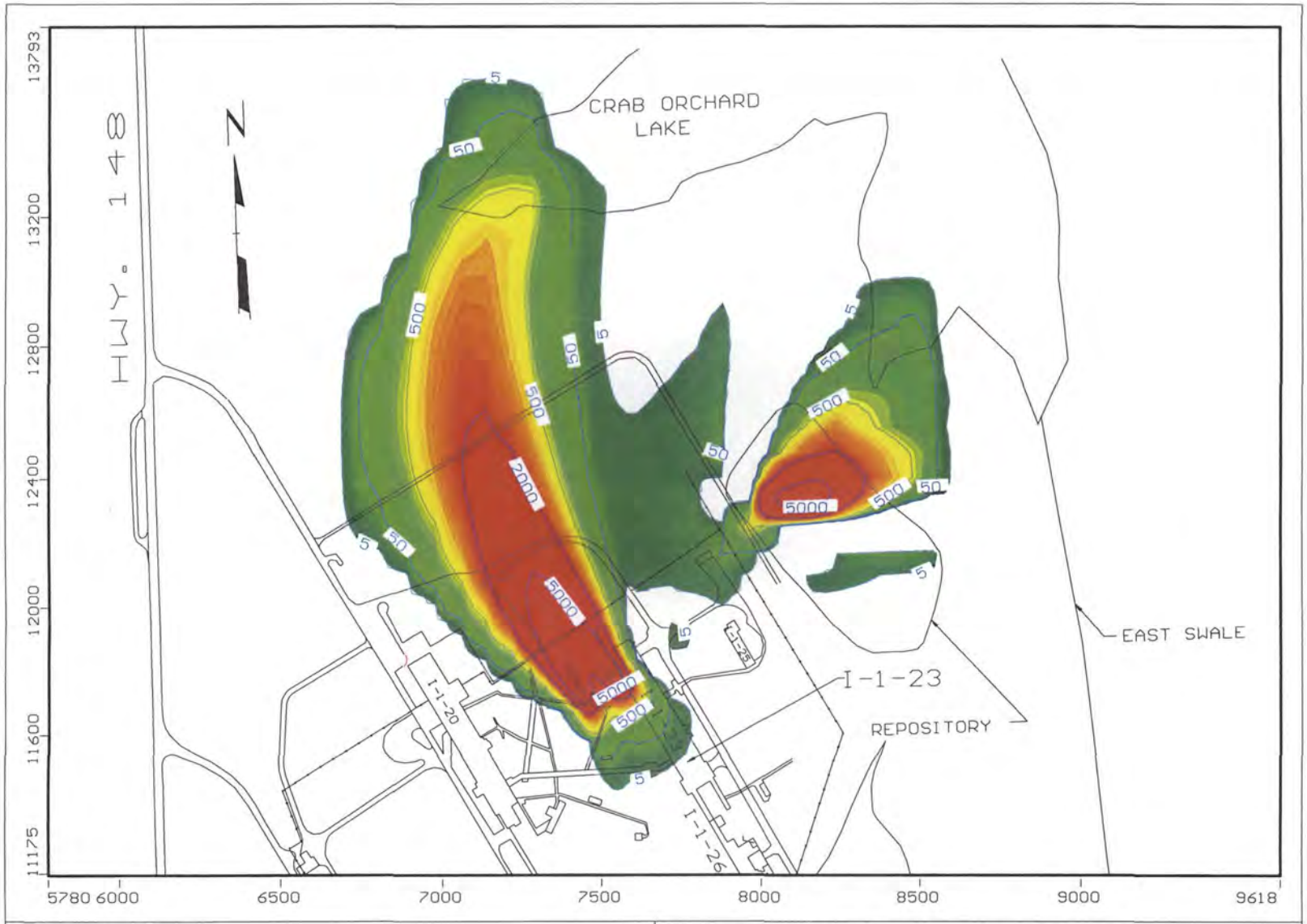
RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: MPE/SVE/Pump for 2 yr.
Modeller: TCE,ppb t=5 yr
21 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: MPE/SVE/Pump for 2 yr.
Modeller: TCE,ppb t=10 yr
21 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



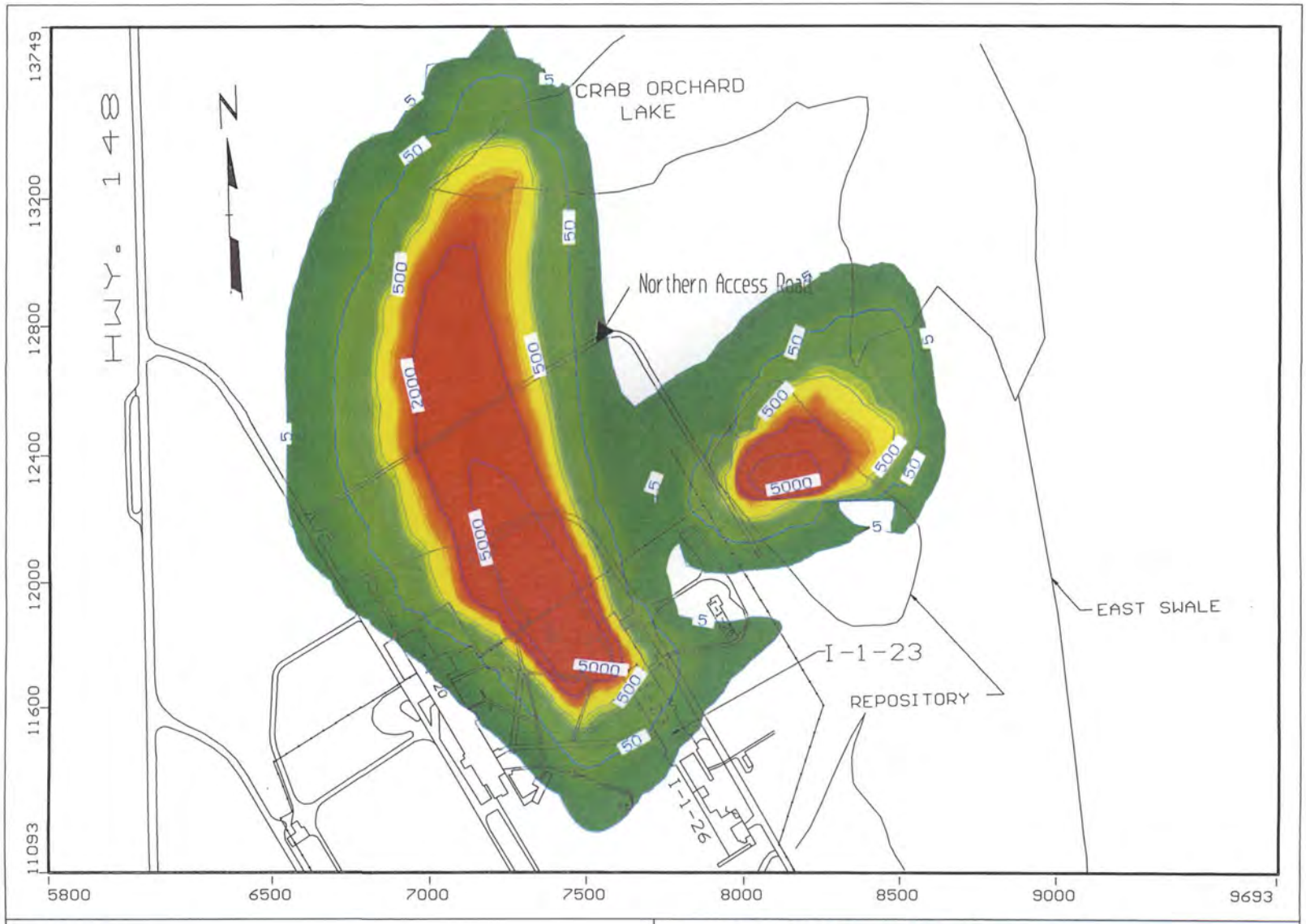
RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: MPE/SVE/Pump for 2 yr.
Modeller: TCE,ppb t=20 yr
21 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

Building I-1-23 Area
Case 2

MPE & SVE wells in Upper Sand operated for 2 years, then shut-down. Horizontal groundwater extraction wells at high flowrate operated continuously from initial system startup. 39% VOC removal from overall source area during 2 years active treatment.

Model Run No. 519



RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: Current Conditions Simul.
Modeller: TCE,ppb t=0 yr
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

RMT, Inc.
Project: CRAB ORCHARD Crab519
Description: MPE/SVE– 2yr; Cont. Pump
Modeller: TCE,ppb t=5 yr
27 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

RMT, Inc.
Project: CRAB ORCHARD Crab519
Description: MPE/SVE- 2yr; Cont. Pump
Modeller: TCE,ppb t=10 yr
27 Aug 01

Visual MODFLOW v.2.8.2. (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

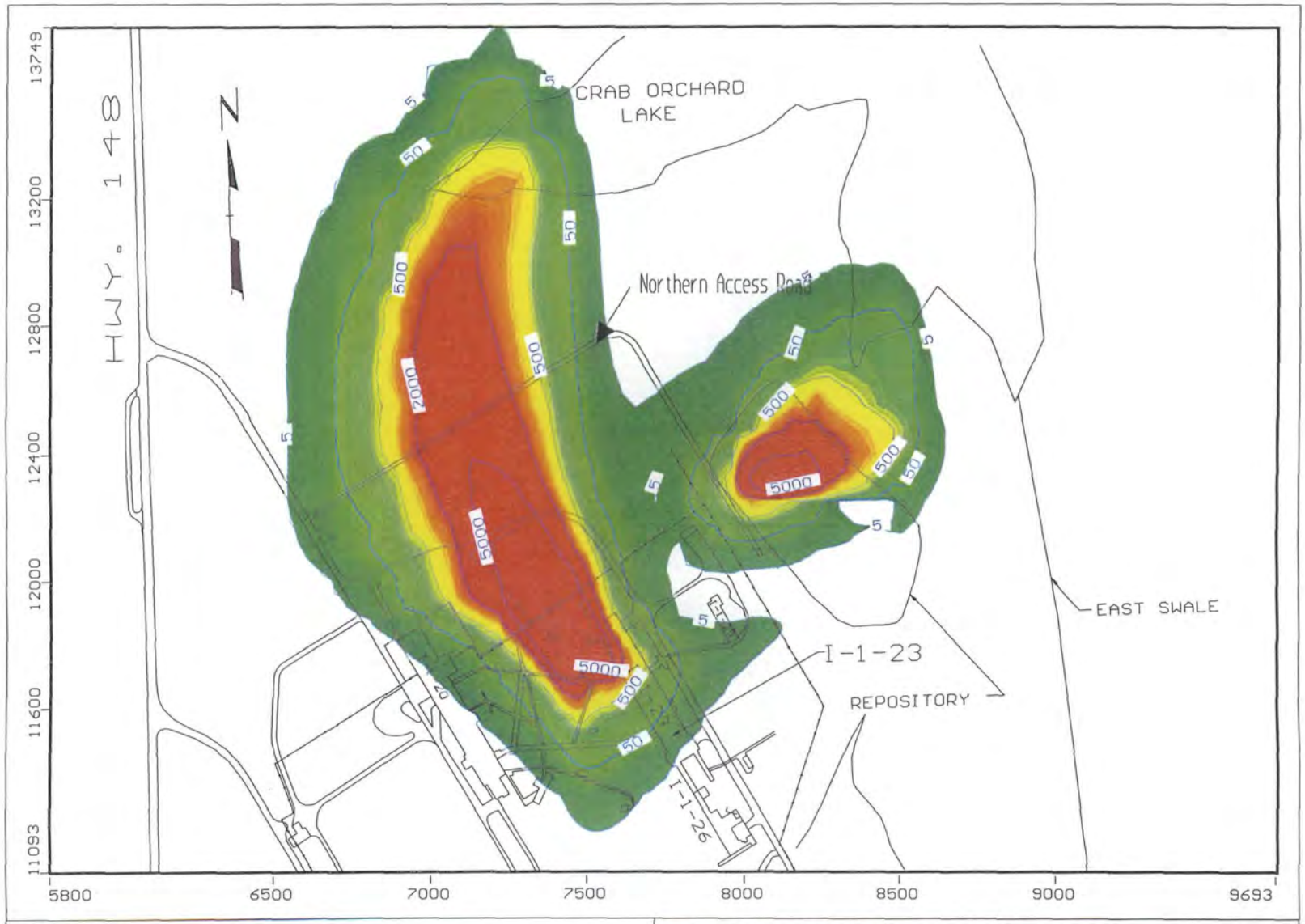
RMT, Inc.
Project: CRAB ORCHARD Crab519
Description: MPE/SVE– 2yr; Cont. Pump
Modeller: TCE,ppb t=20 yr
27 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

Building I-1-23 Area
Case 3

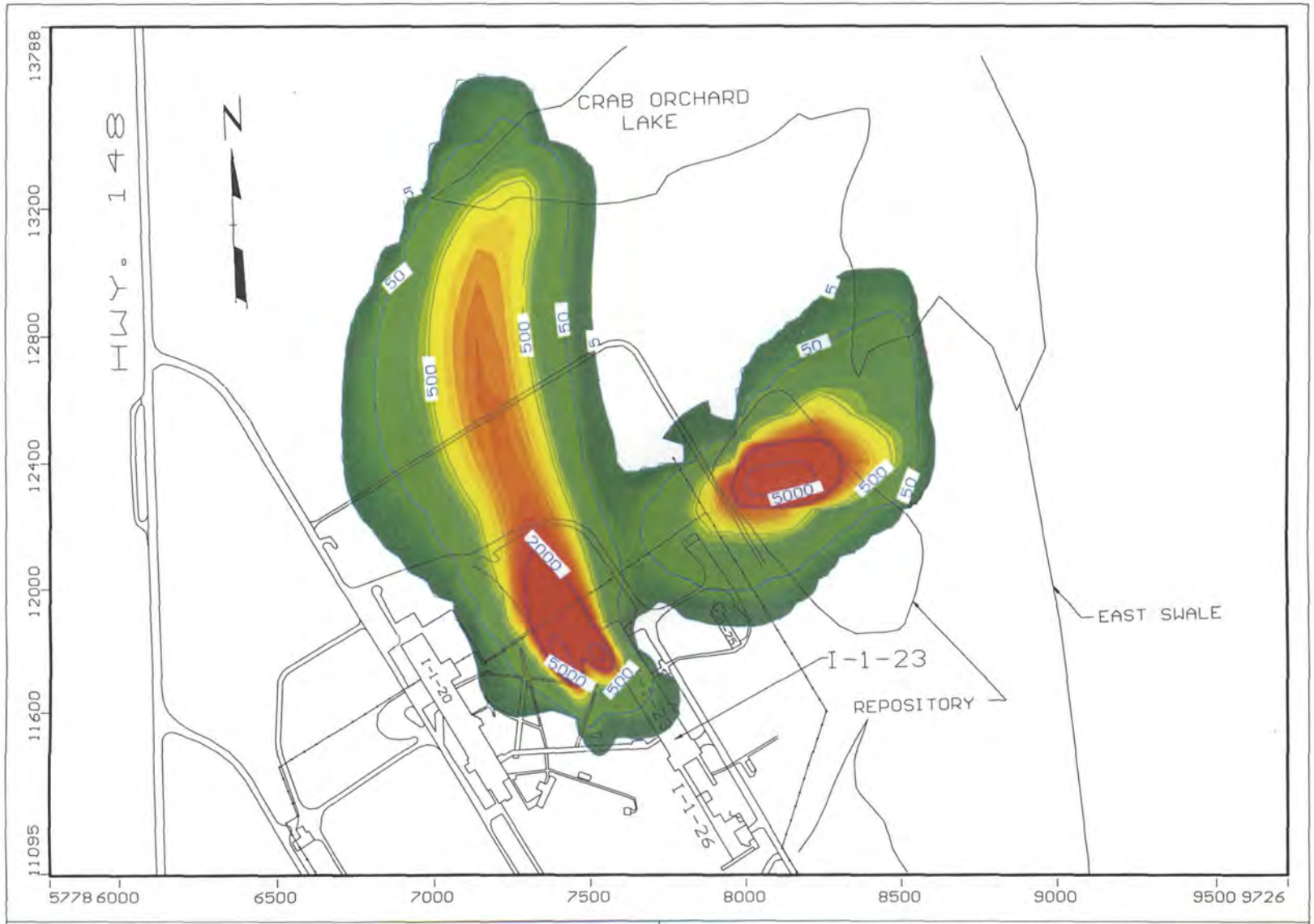
MPE wells, SVE wells, and horizontal groundwater extraction wells in Upper Sand and Upper Clay operated for 2 years, then shut down. 70% VOC removal from overall source area.

Model Run No. 521



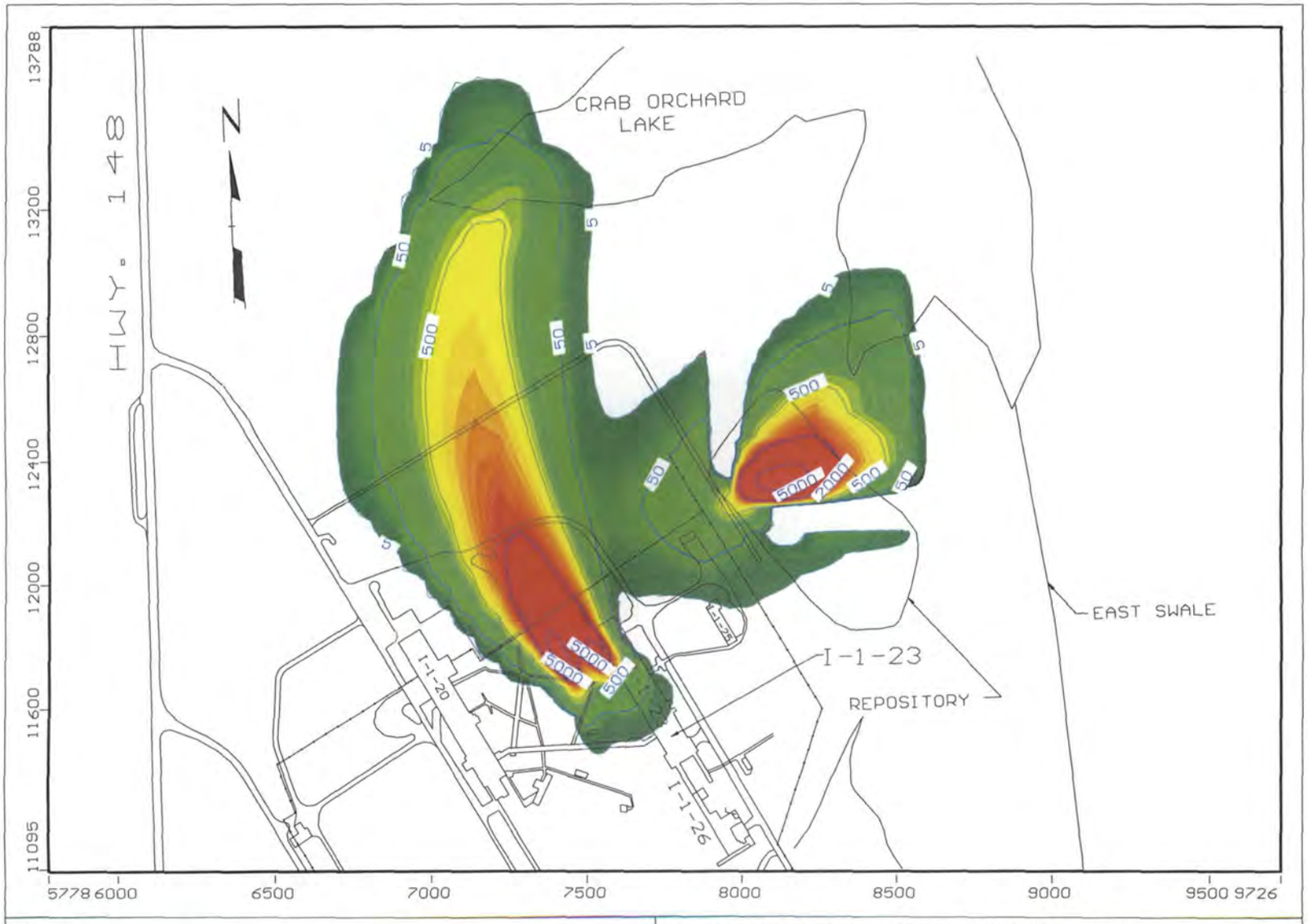
RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: Current Conditions Simul.
Modeller: TCE,ppb t=0 yr
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



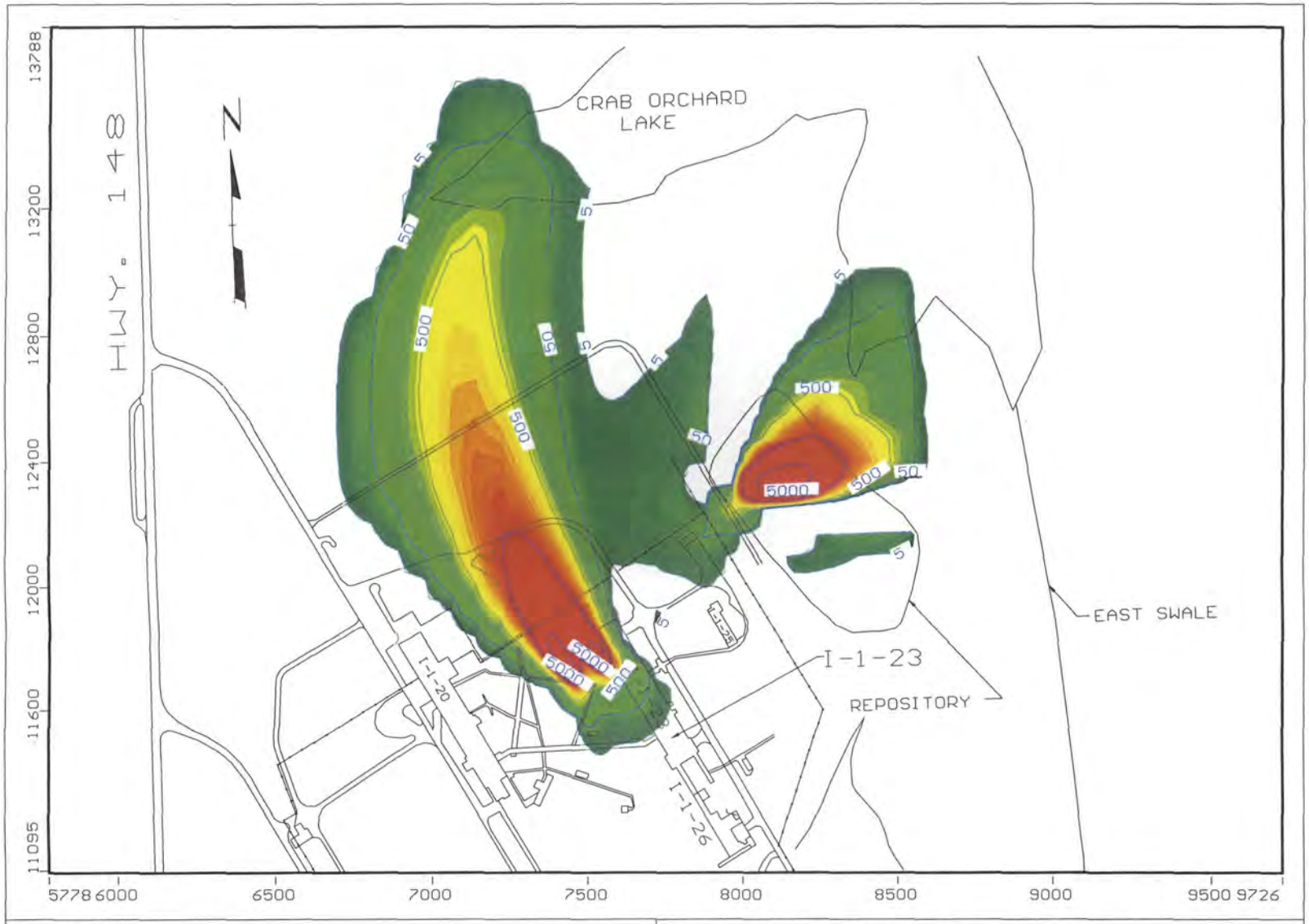
RMT, Inc.
Project: CRAB ORCHARD Crab521
Description: MPE/SVE/Pump for 2 yr.
Modeller: TCE,ppb 70% remov t=5 yr
27 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



RMT, Inc.
Project: CRAB ORCHARD Crab521
Description: MPE/SVE/Pump for 2 yr.
Modeller: TCE,ppb 70% remov t=10 yr
27 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



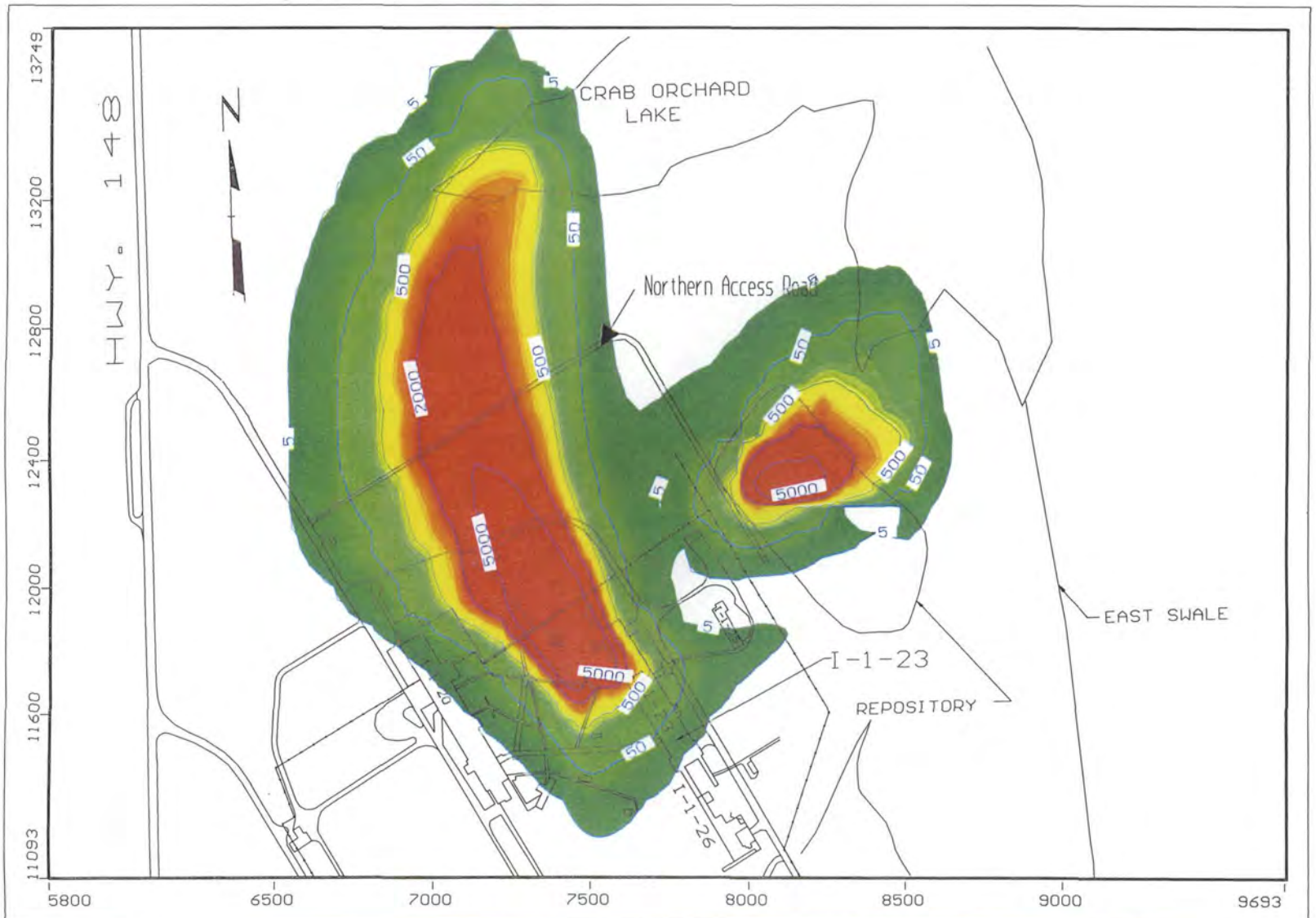
RMT, Inc.
Project: CRAB ORCHARD Crab521
Description: MPE/SVE/Pump for 2 yr.
Modeller: TCE,ppb 70% remov t=20 yr
27 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

Building I-1-23 Area
Case 4

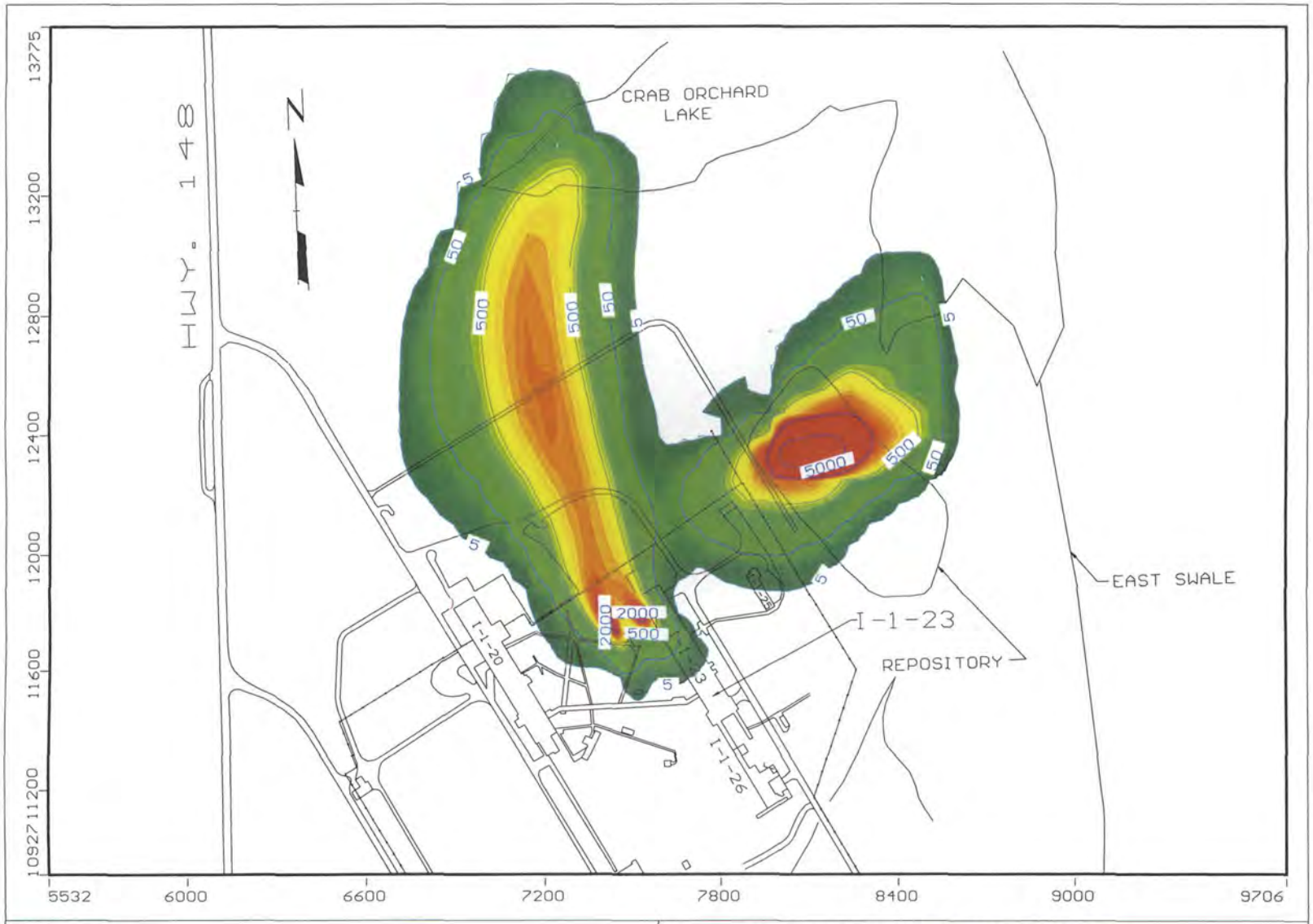
MPE wells, SVE wells, and horizontal groundwater extraction wells in Upper Sand and Upper Clay operated for 2 years, then shut down. 90% VOC removal from overall source area.

Model Run No. 526



RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: Current Conditions Simul.
Modeller: TCE,ppb t=0 yr
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

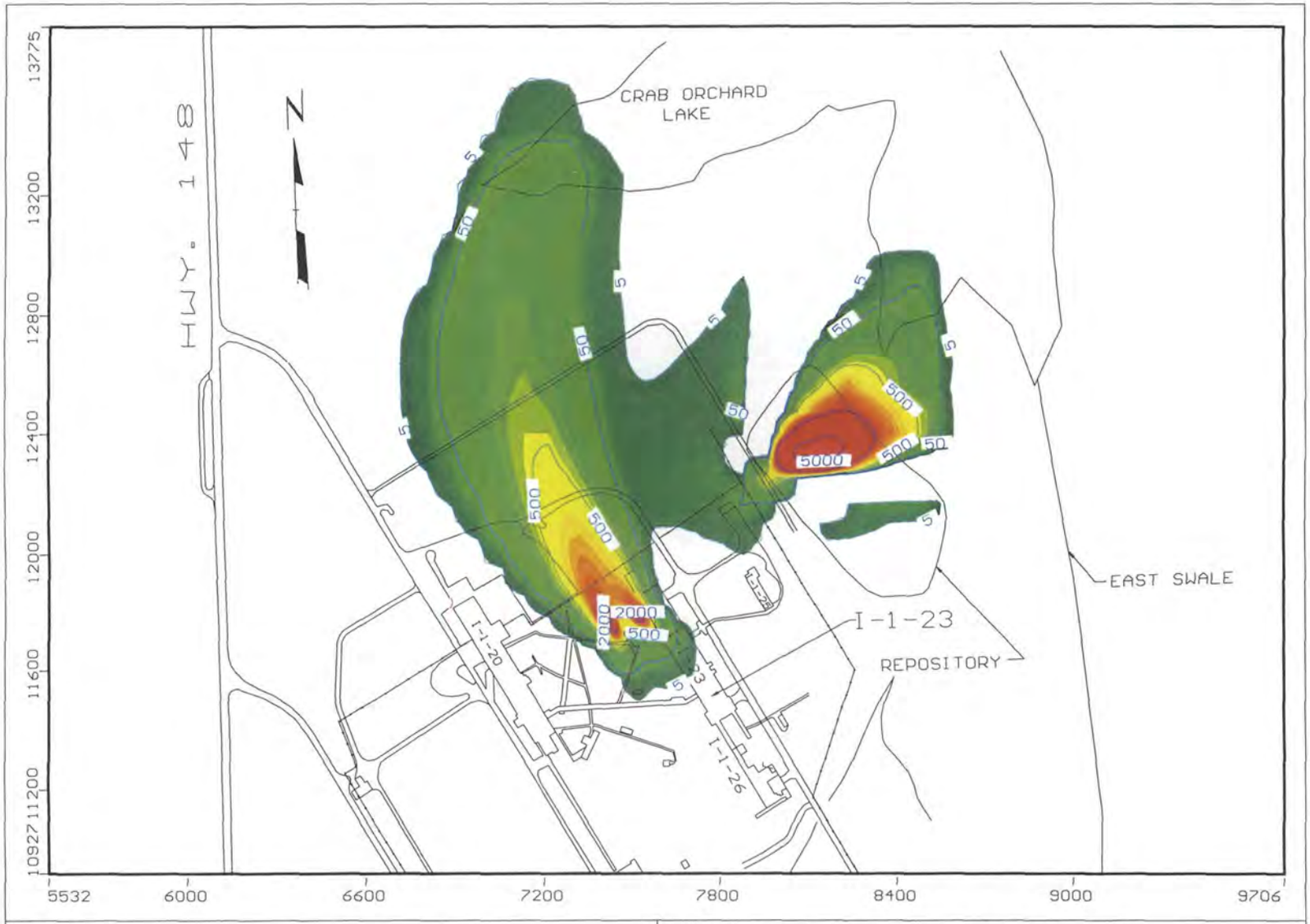


RMT, Inc.
Project: CRAB ORCHARD Crab526
Description: MPE/SVE/Pump for 2yr
Modeller: TCE,ppb 90% remov t=5 yr
27 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

RMT, Inc.
Project: CRAB ORCHARD Crab526
Description: MPE/SVE/Pump for 2yr
Modeller: TCE,ppb 90% remov t=10 yr
27 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



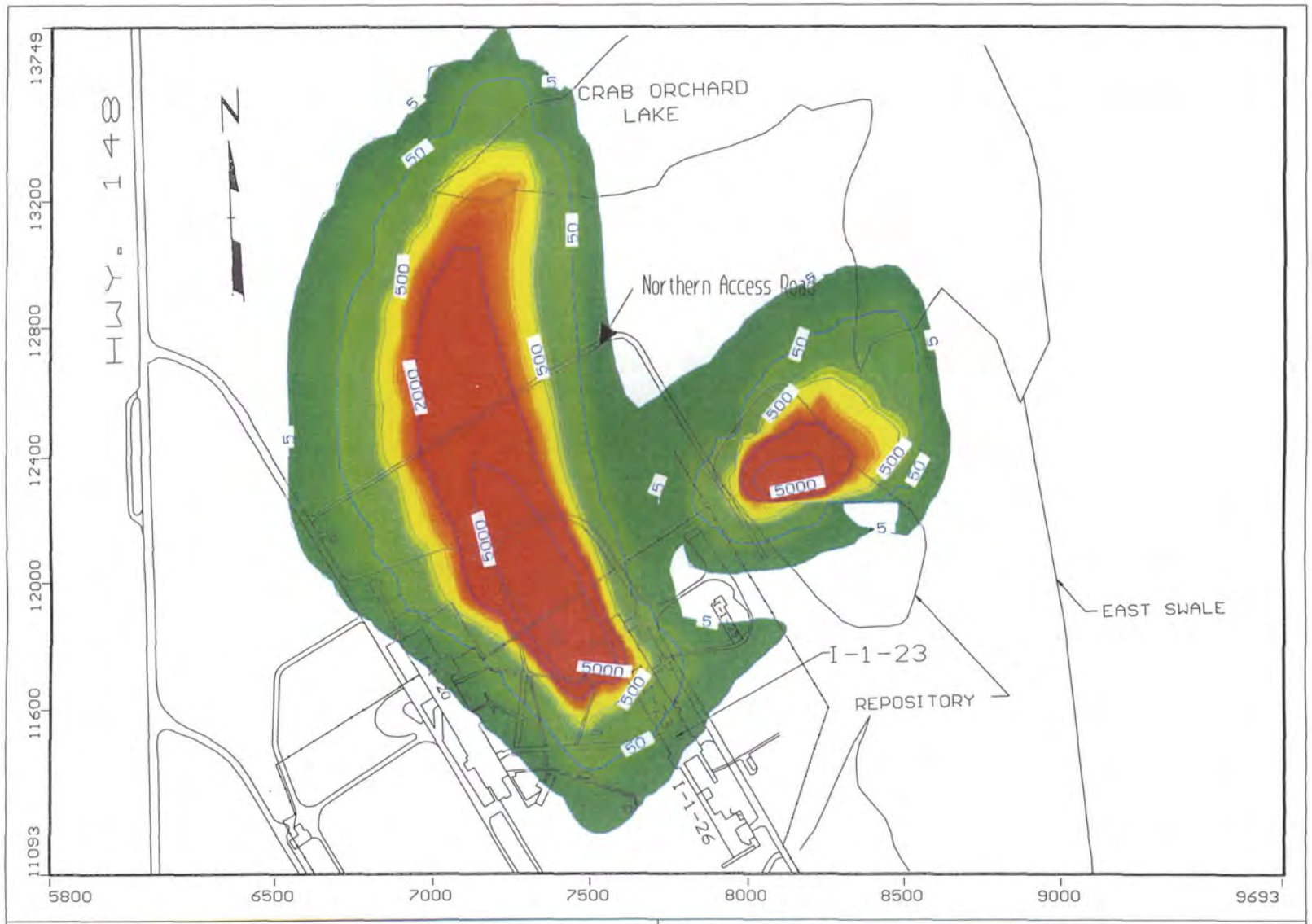
RMT, Inc.
Project: CRAB ORCHARD Crab526
Description: MPE/SVE/Pump for 2yr
Modeller: TCE,ppb 90% remov t=20 yr
27 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

Building I-1-23 Area
Case 5

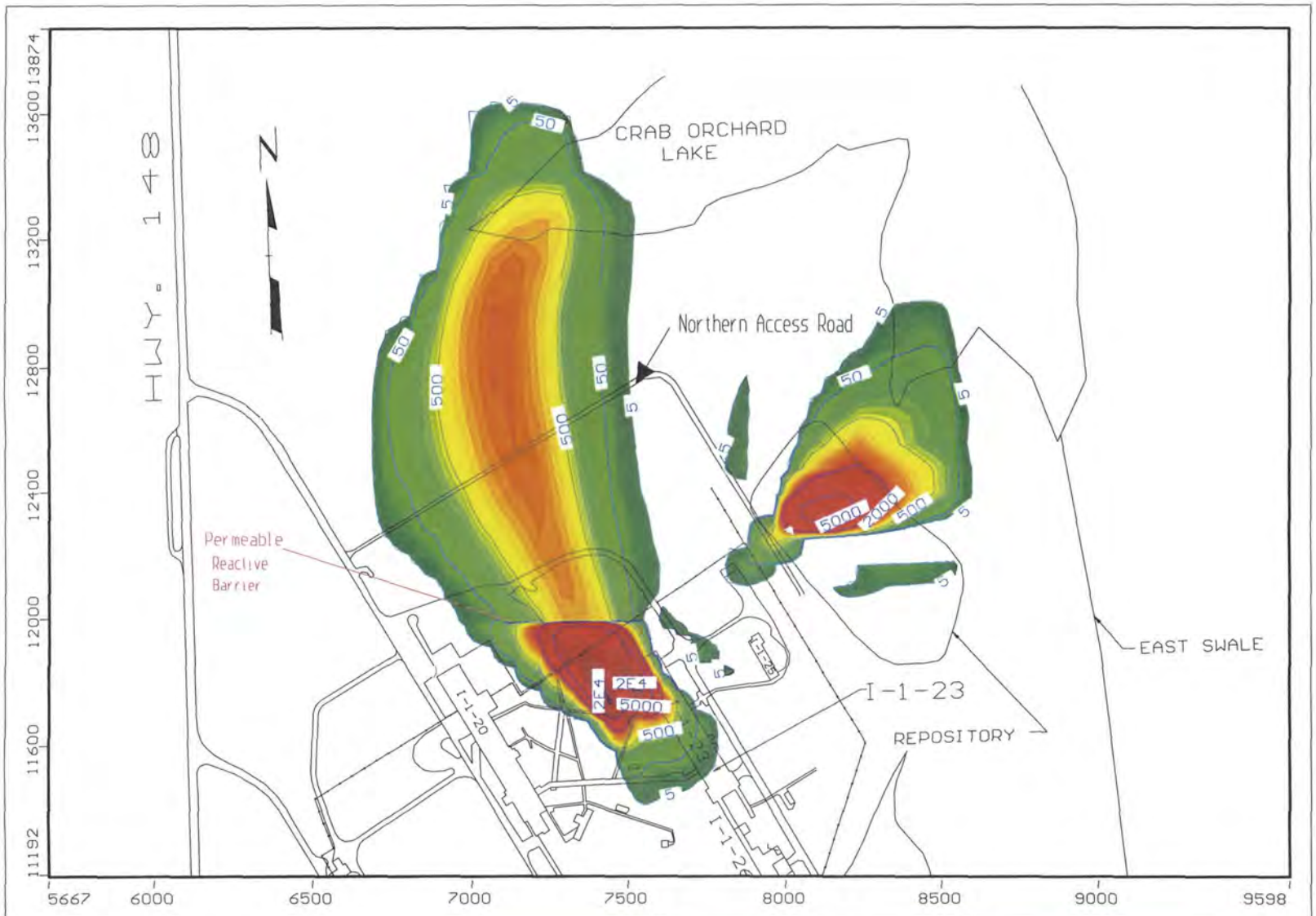
PRB with zero-valent iron. No source area treatment.

Model Run No. 522



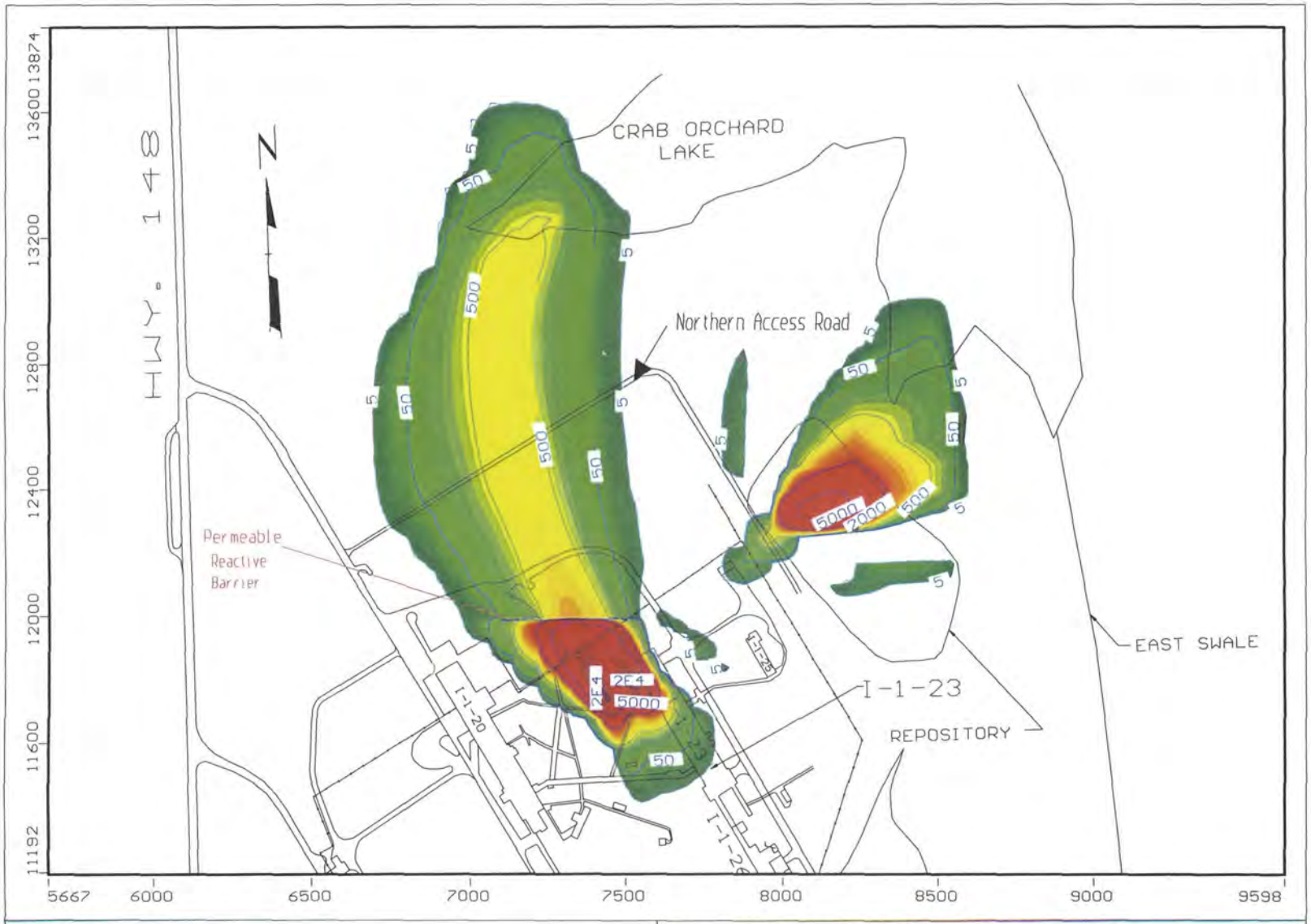
RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: Current Conditions Simul.
Modeller: TCE,ppb t=0 yr
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



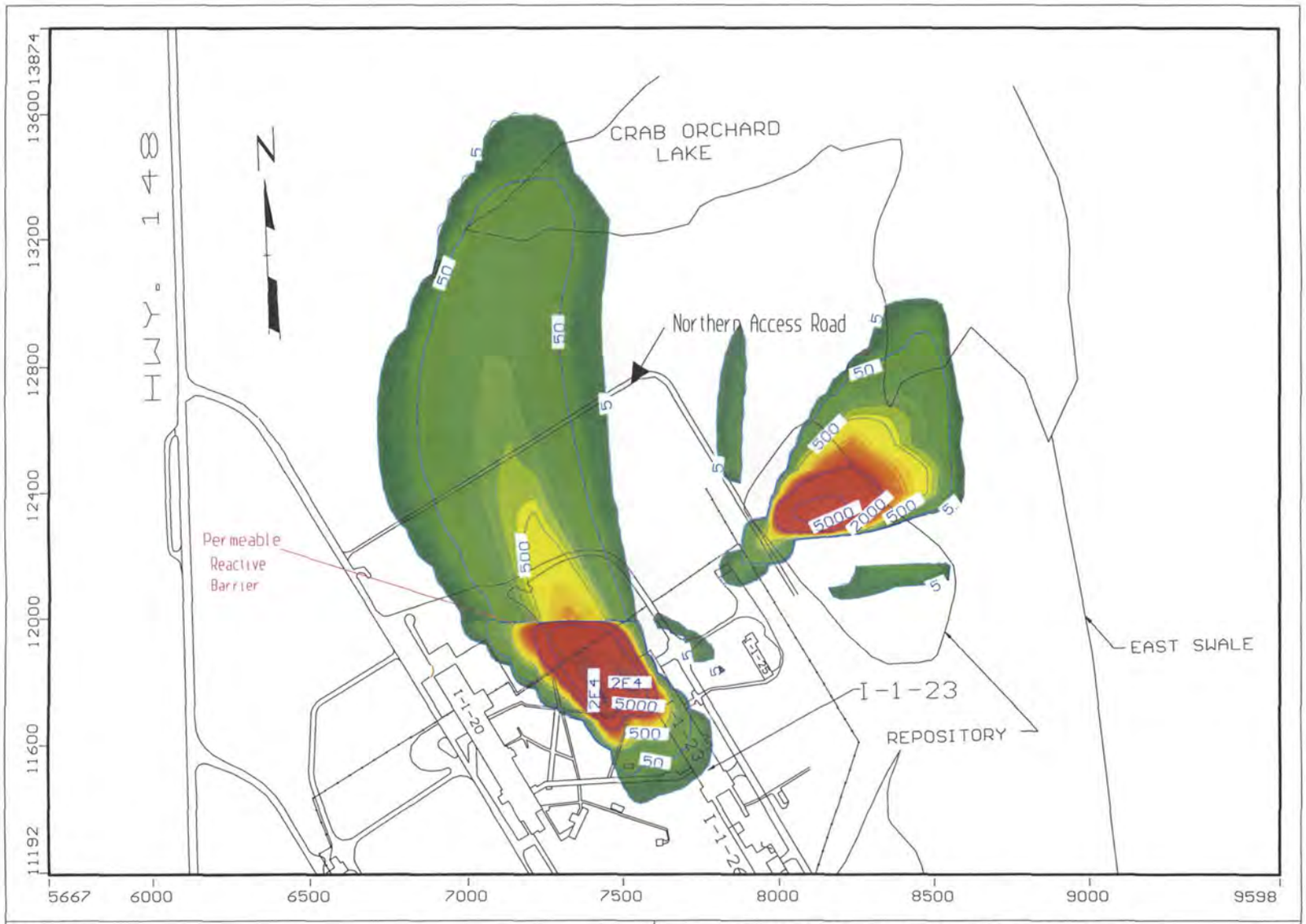
RMT, Inc.
Project: CRAB ORCHARD Crab522
Description: Perm. Reactive Barrier
Modeller: TCE,ppb t=5 years
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 119 NR: 135 NL: 5
Current Layer: 2



RMT, Inc.
Project: CRAB ORCHARD Crab522
Description: Perm. Reactive Barrier
Modeller: TCE,ppb t=10 years
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 119 NR: 135 NL: 5
Current Layer: 2



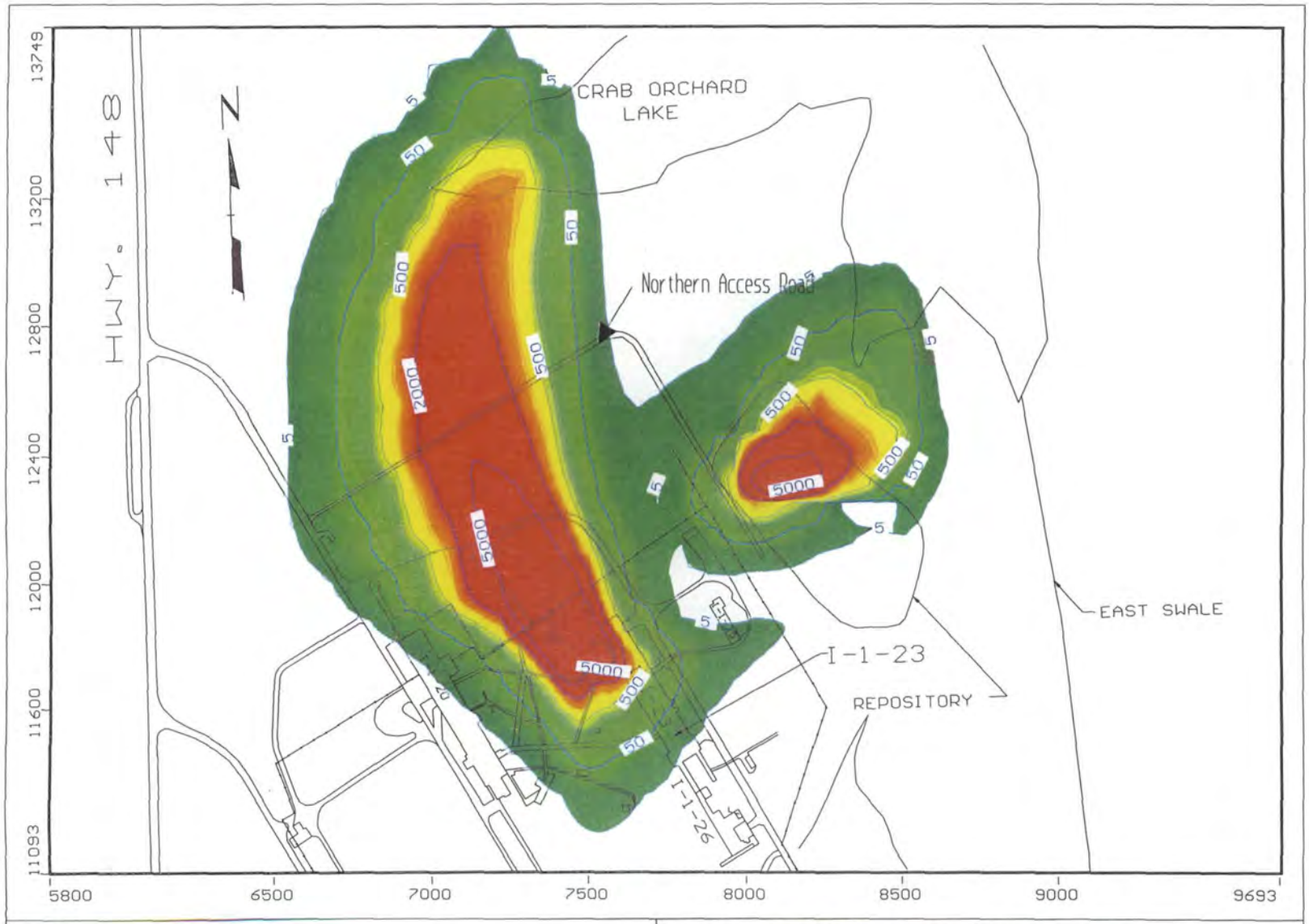
RMT, Inc.
Project: CRAB ORCHARD Crab522
Description: Perm. Reactive Barrier
Modeller: TCE,ppb t=20 years
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 119 NR: 135 NL: 5
Current Layer: 2

Building I-1-23 Area
Case 6

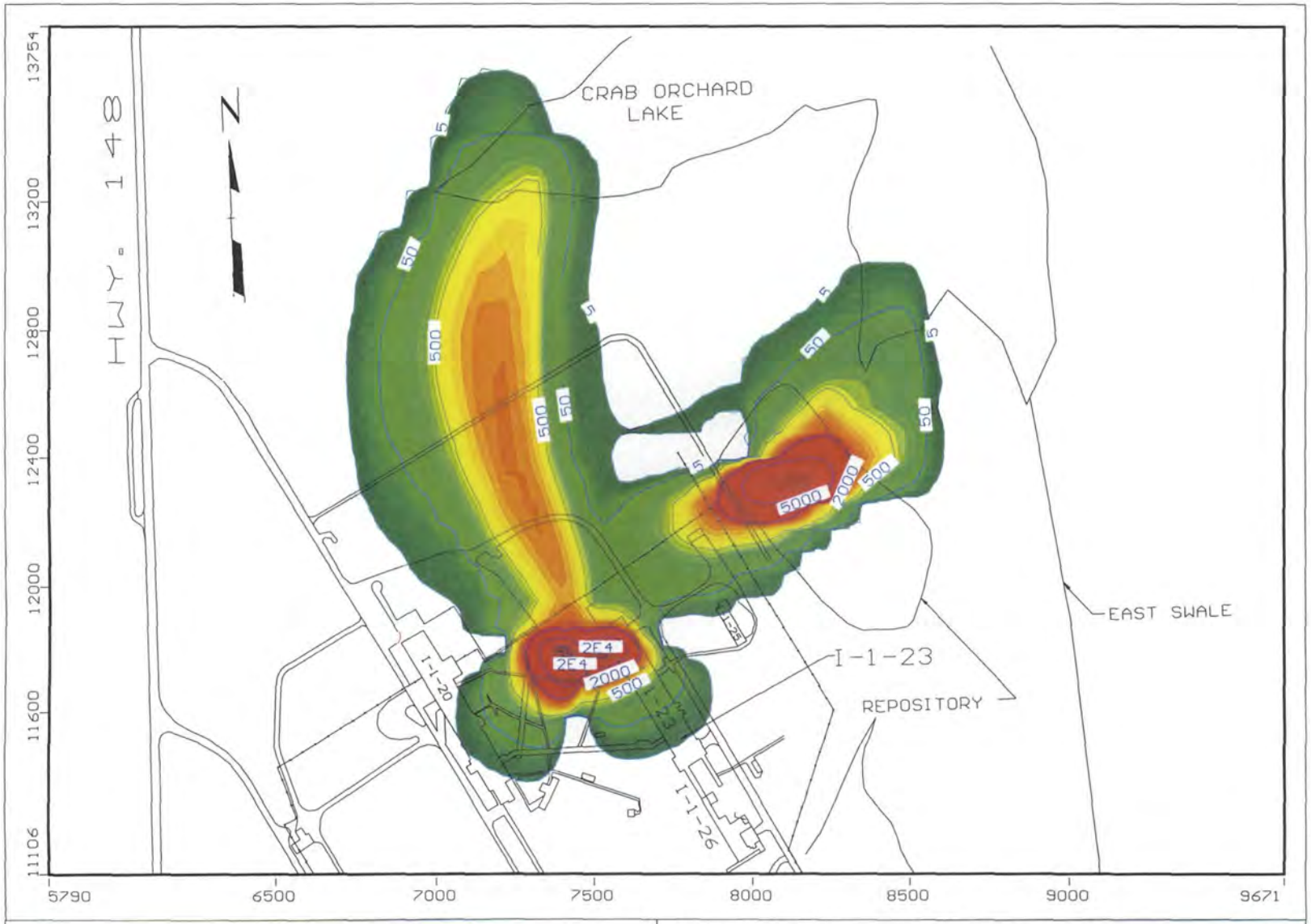
Continuous pumping with one vertical groundwater extraction well at 20 gpm. No MPE/SVE wells.

Model Run No. 525



RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: Current Conditions Simul.
Modeller: TCE,ppb t=0 yr
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



RMT, Inc.
Project: CRAB ORCHARD Crab525
Description: Contin. Pump, lower rate
Modeller: 1well, 20gpm 5 yr
23 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

RMT, Inc.
Project: CRAB ORCHARD Crab525
Description: Contin. Pump, lower rate
Modeller: 1well, 20gpm 10 yr
23 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

RMT, Inc.
Project: CRAB ORCHARD Crab525
Description: Contin. Pump, lower rate
Modeller: 1well, 20gpm 20 yr
23 Aug 01

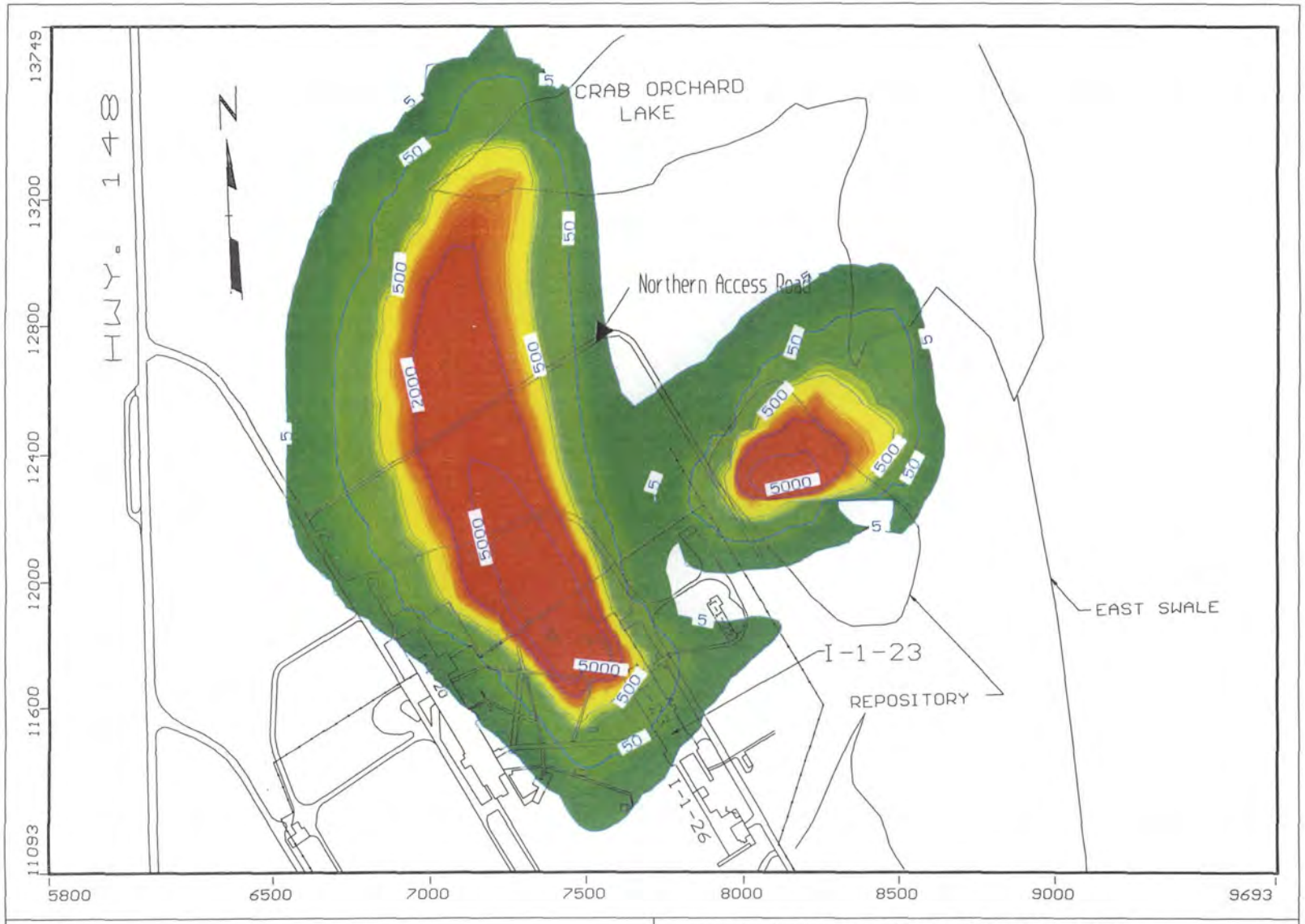
Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

Building I-1-23 Area
Case 7

MNA only (no active source area treatment).

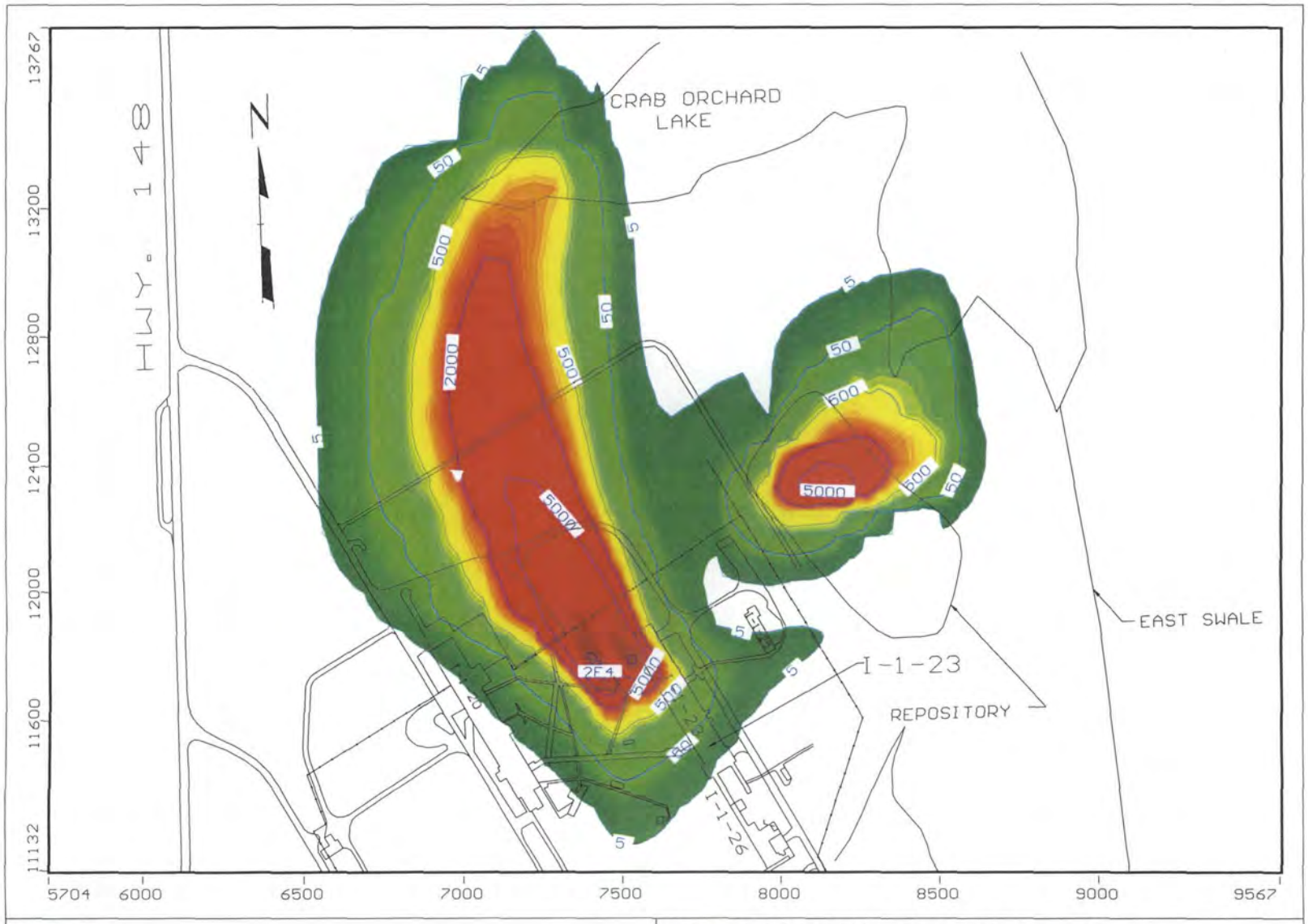
Model Run No. 417

Attachment 3
Figures Associated with Area 9 Repository



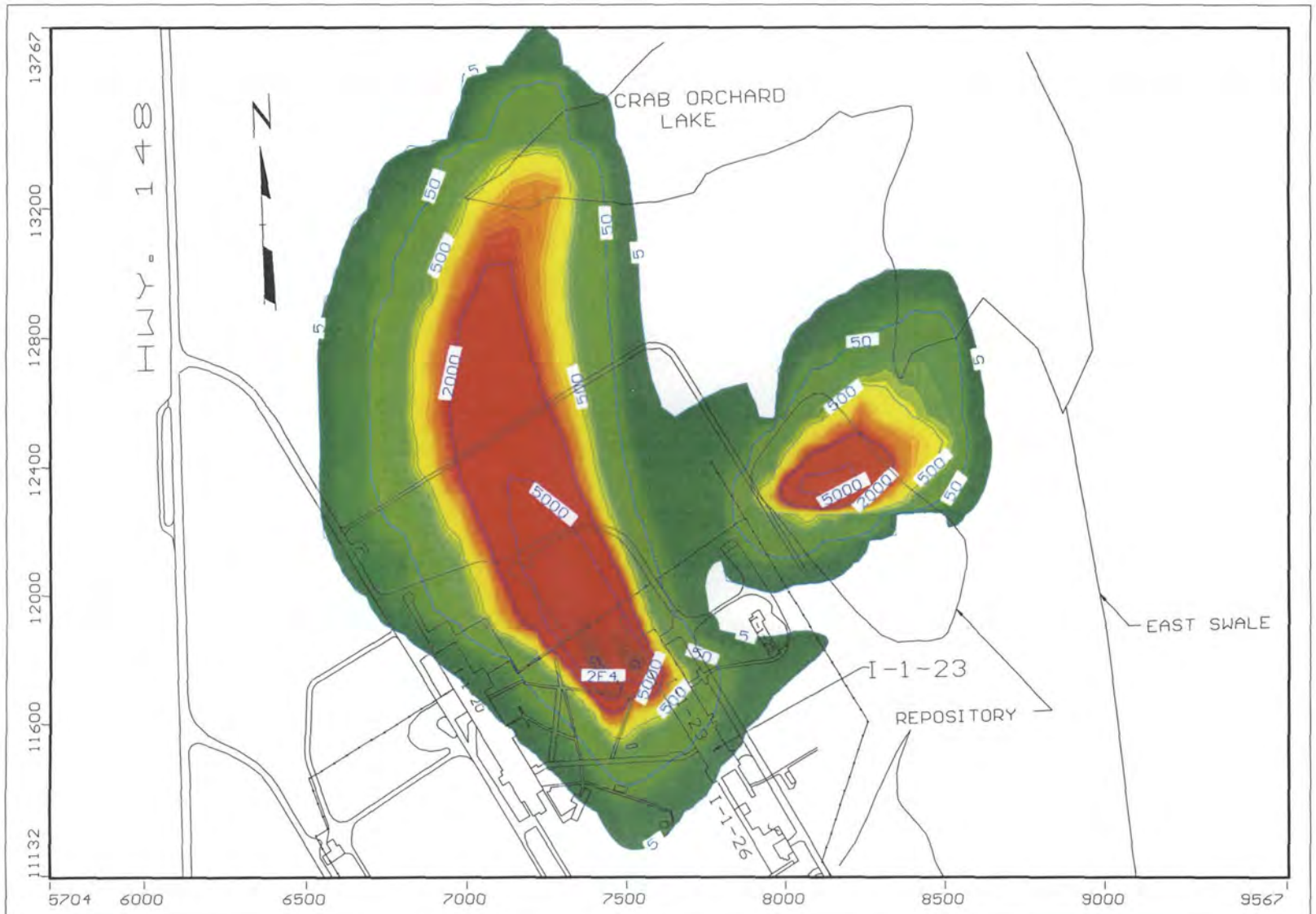
RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: Current Conditions Simul.
Modeller: TCE,ppb t=0 yr
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



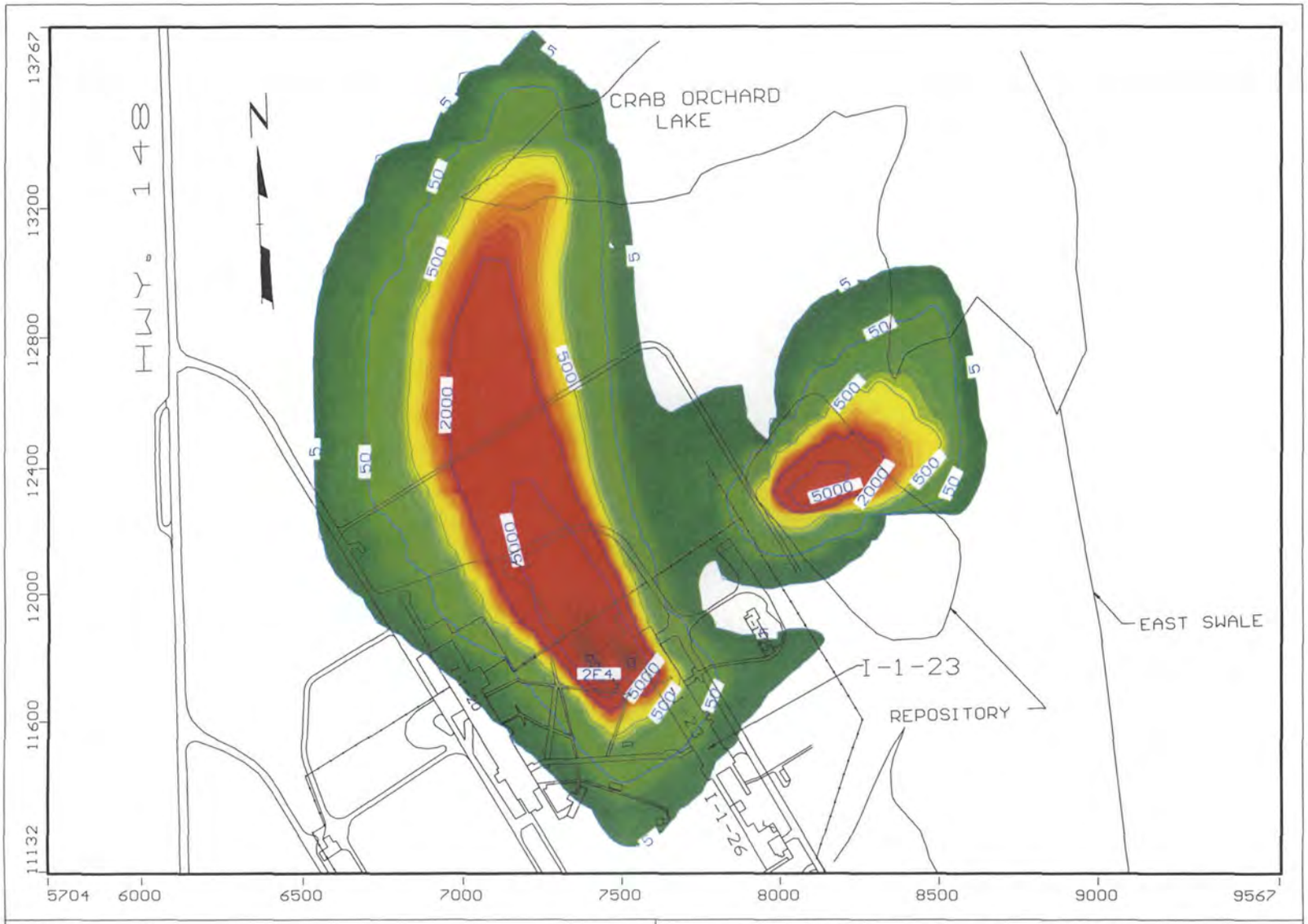
RMT, Inc.
Project: CRAB ORCHARD Crab417
Description: Monit. Nat. Atten. Only
Modeller: TCE,ppb t=5yr
20 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995-1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



RMT, Inc.
Project: CRAB ORCHARD Crab417
Description: Monit. Nat. Atten. Only
Modeller: TCE,ppb t=10yr
20 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



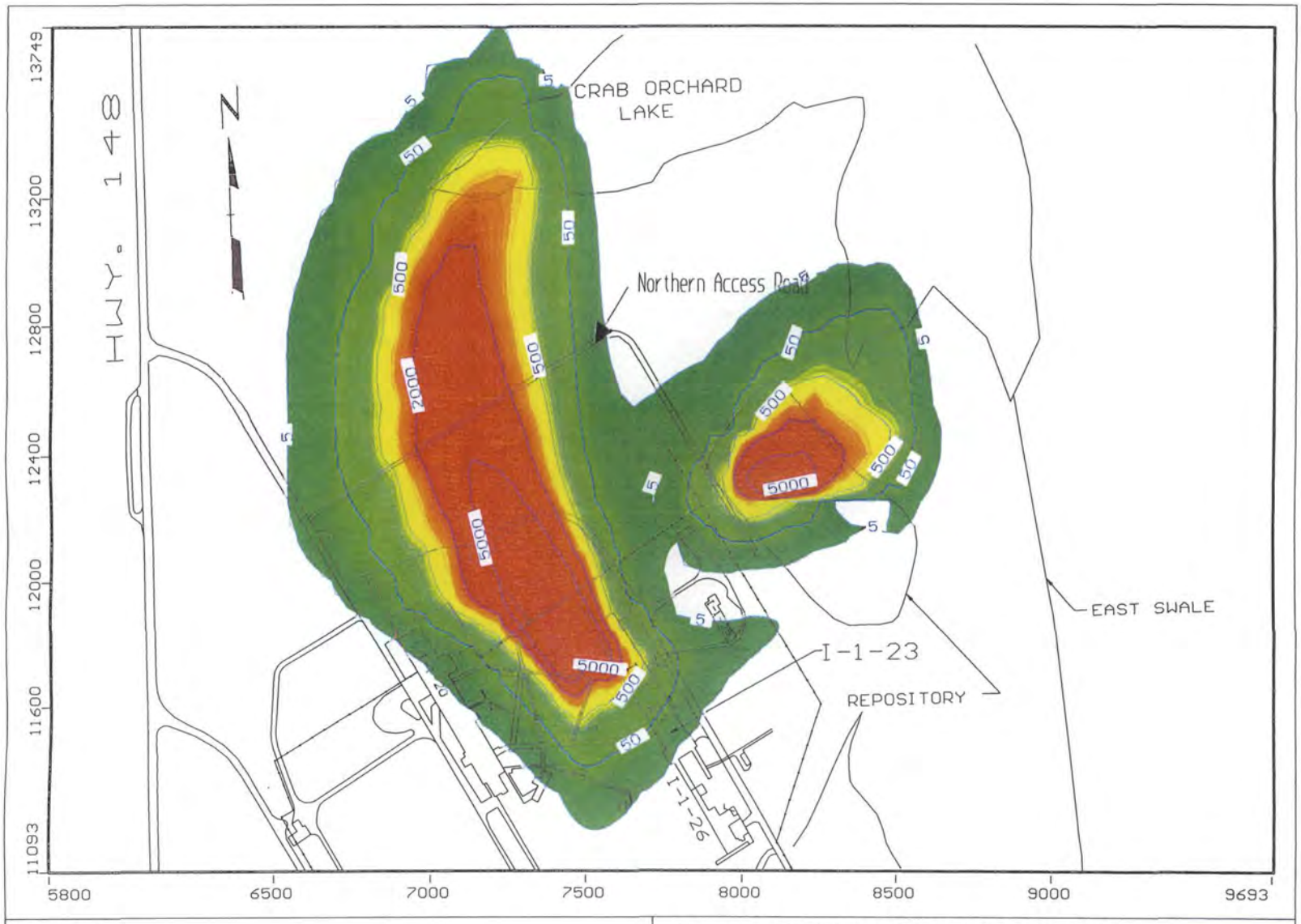
RMT, Inc.
Project: CRAB ORCHARD Crab417
Description: Monit. Nat. Atten. Only
Modeller: TCE,ppb t=20yr
20 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

Repository Area

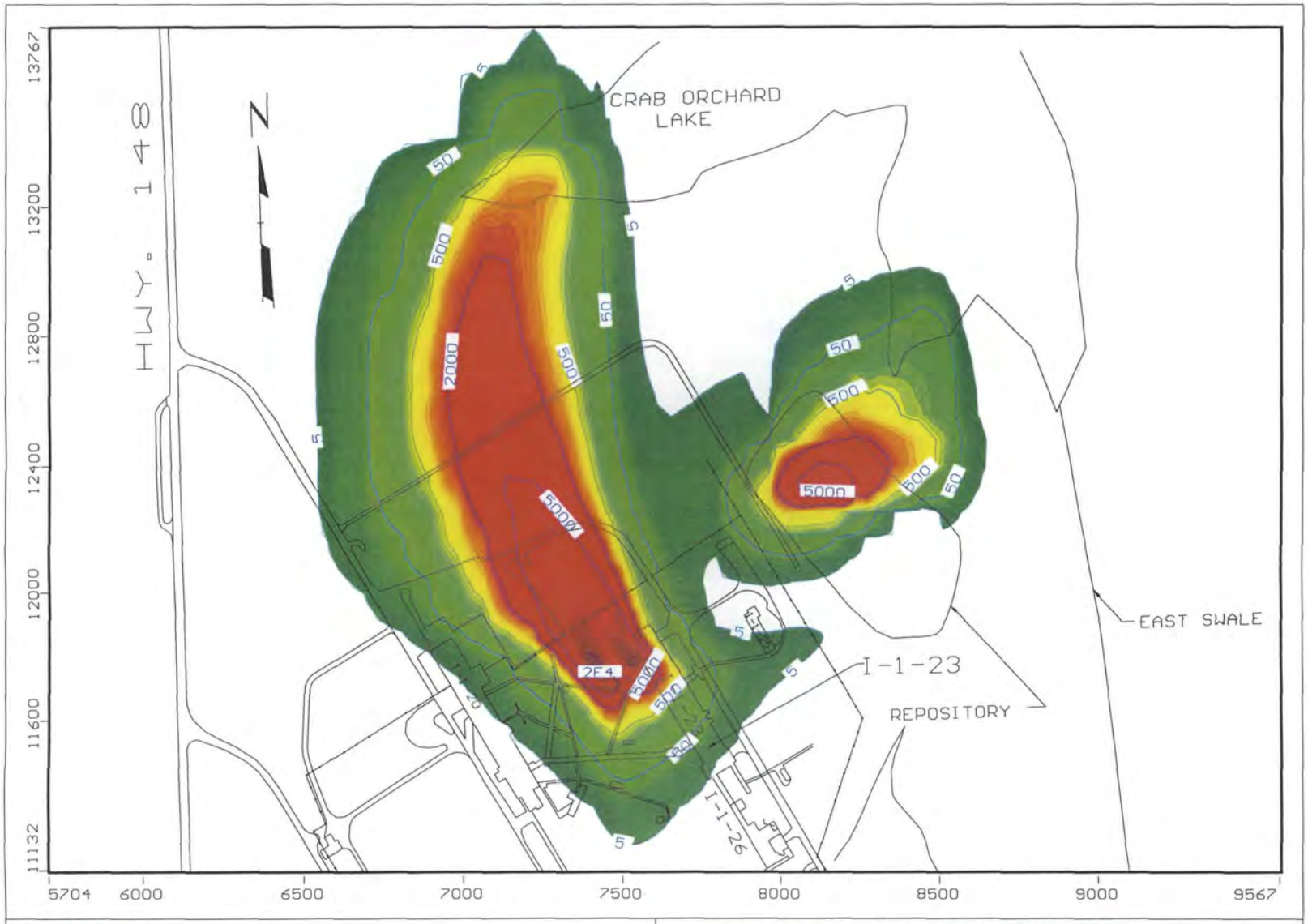
MNA only (no active source area treatment).

Model Run No. 417



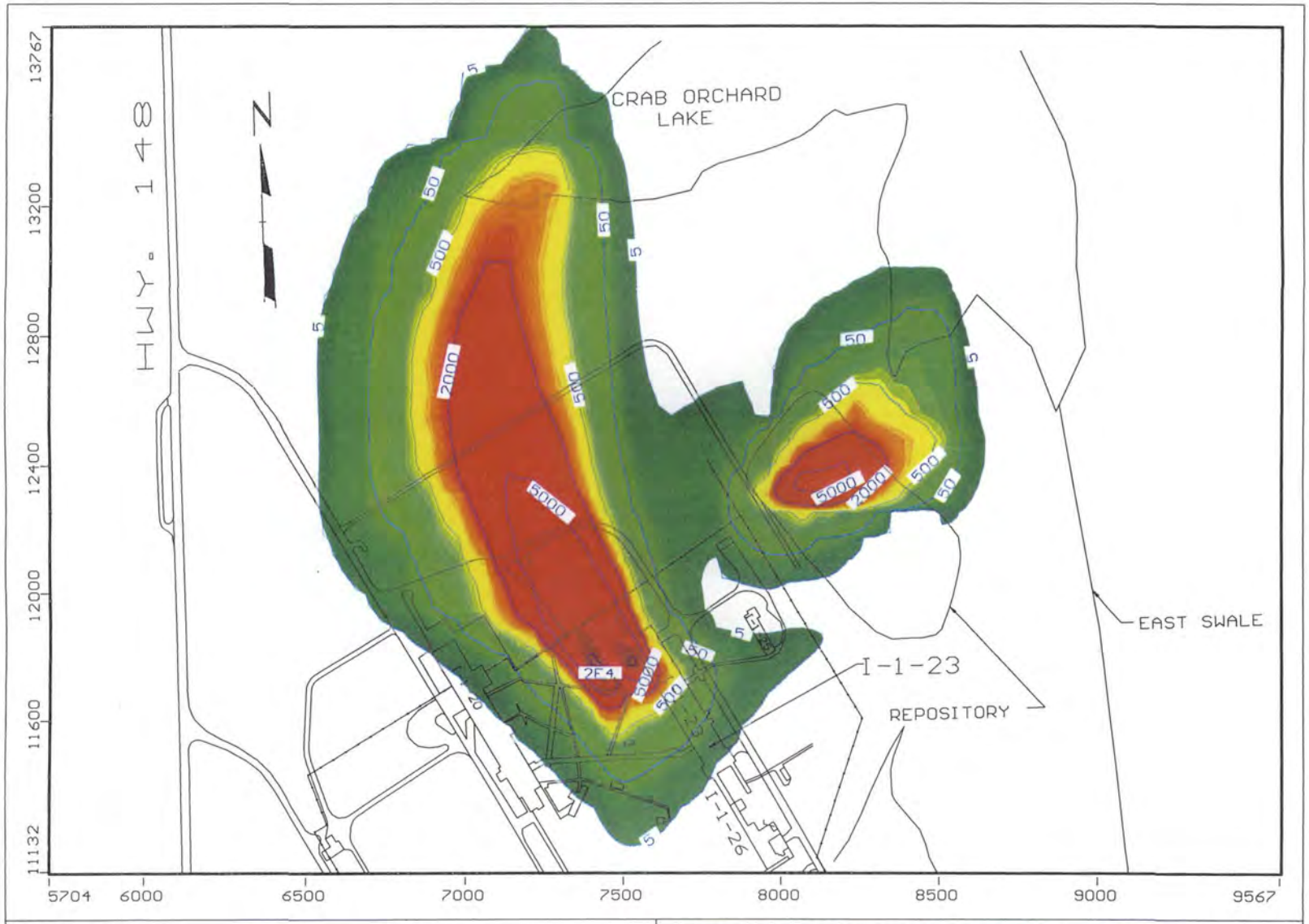
RMT, Inc.
Project: CRAB ORCHARD Crab520
Description: Current Conditions Simul.
Modeller: TCE,ppb t=0 yr
22 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



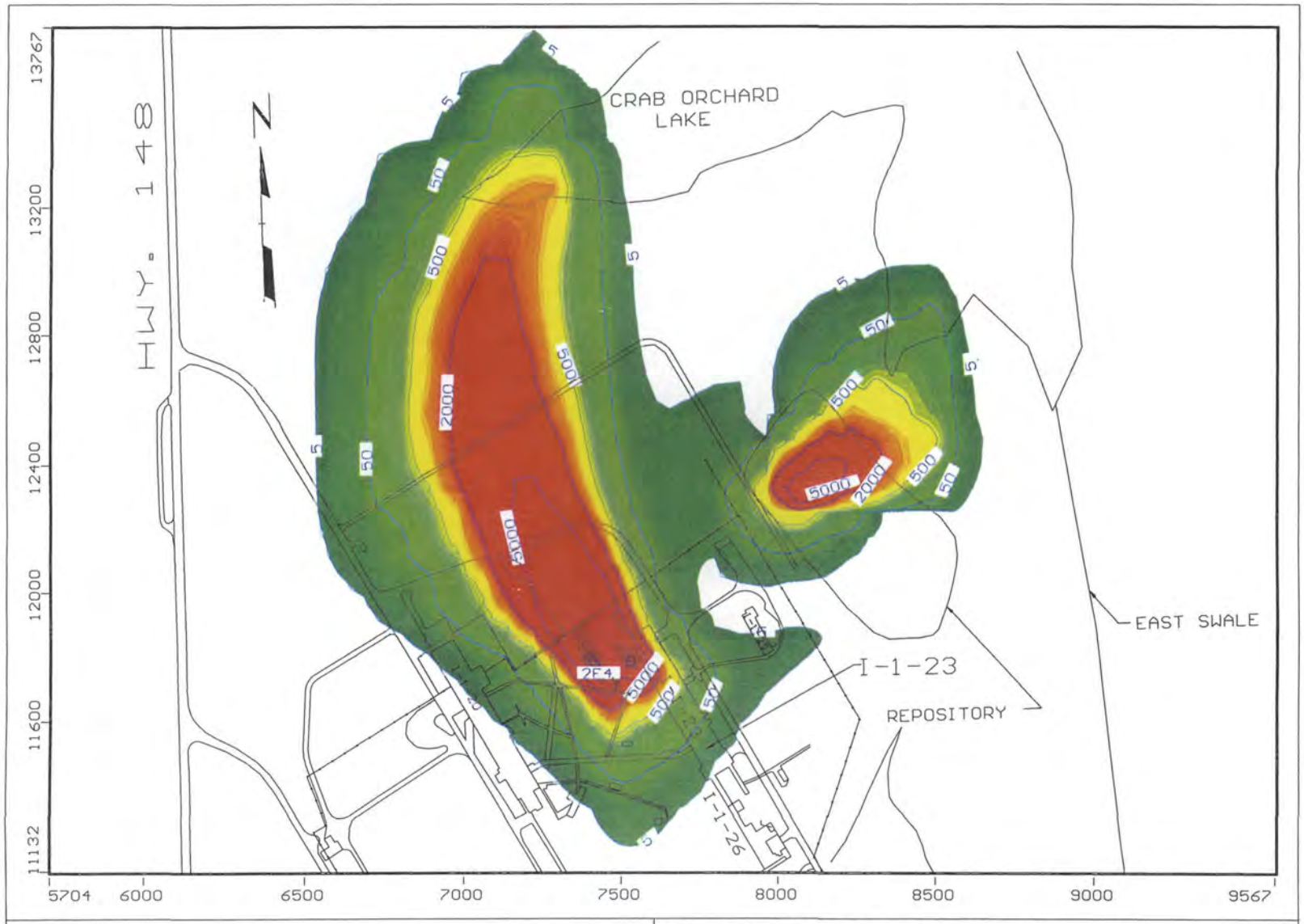
RMT, Inc.
Project: CRAB ORCHARD Crab417
Description: Monit. Nat. Atten. Only
Modeller: TCE,ppb t=5yr
20 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



RMT, Inc.
Project: CRAB ORCHARD Crab417
Description: Monit. Nat. Atten. Only
Modeller: TCE,ppb t=10yr
20 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2



RMT, Inc.
Project: CRAB ORCHARD Crab417
Description: Monit. Nat. Atten. Only
Modeller: TCE,ppb t=20yr
20 Aug 01

Visual MODFLOW v.2.8.2, (C) 1995–1999
Waterloo Hydrogeologic, Inc.
NC: 113 NR: 127 NL: 5
Current Layer: 2

Attachment 4
Proposals from Regenesis; EnviroMetal Technologies, Inc.; In-Situ Oxidative Technologies, Inc.; and ARS Technologies, Inc.

REGENESIS

July 31, 2001

Proposal No. H678

Jack Anderson
RMT, Inc.
744 Heartland Trail
Madison, WI 53717-1934
Fax: 608-831-3334, Phone: 608-831-4444

Subject: Proposal for Acceleration of Natural Attenuation at the Crab Orchard Site, Marion IL

Dear Mr. Anderson:

We have reviewed the information that you provided for the above-referenced site. In the following sections, we provide design and cost information for a potential site remediation approach. This information should be considered preliminary since a number of assumptions have been made concerning site conditions and the extent of the contaminant plume requiring remediation. We look forward to working with you to develop a specific strategy that meets your objectives.

Use of HRC to Accelerate Bioremediation

Hydrogen Release Compound (HRC®) is used to enhance in situ biodegradation rates for chlorinated hydrocarbons (CHs) by supporting anaerobic reductive dechlorination processes. Reductive dechlorination is now recognized as one of the primary attenuation mechanisms by which chlorinated solvent groundwater plumes can be contained and/or remediated.

HRC is a proprietary polylactate ester that, upon being deposited into the subsurface, slowly releases lactate. Lactate is metabolized by naturally occurring microorganisms, resulting in the creation of anaerobic aquifer conditions and the production of hydrogen. Naturally occurring microorganisms capable of reductive dechlorination then use the hydrogen to progressively remove chlorine atoms from chlorinated hydrocarbon contaminants (i.e. convert tetrachloroethene [PCE] to trichloroethene [TCE] to dichloroethene [DCE] to vinyl chloride [VC] to ethene).

HRC is manufactured as a viscous gel that can be injected into the saturated zone in a grid or barrier configurations for either localized area or cutoff-based treatment approaches. The use of HRC for groundwater remediation offers a comparatively simple and cost effective remediation alternative for sites that would otherwise require unacceptably long periods of time for natural attenuation or the high levels of capital investment and operating expense associated with active remediation technologies.

Preliminary Design and Cost Information for Full Scale Remediation

It is assumed that the full-scale remediation approach for the site would consist of a combination of grid-based application to reduce contaminant levels in one of the contaminant source areas and a barrier-based application to reduce risk associated with downgradient contaminant migration. The proposed source zone treatment will be in an area approximately 100 by 100 feet centered around Well 33MWC-13. Concentrations in this area are considered indicative of the presence of residual DNAPL; however, we have evidence that HRC can be effective at these concentrations. In the vicinity of Boring SB128 (the other, more highly contaminated source area), we are not proposing HRC treatment at this time; however; Regenesis has applied an extended release HRC formulation at a site with similar levels of contamination resulting in successful contaminant mass reduction. Please call us to discuss this potential remedial option for the vicinity of Boring SB128. The proposed barrier-based application will be approximately 700 feet long. It will be located downgradient of the source area(s) extending across the 100 ug/L concentration contour. The approximate locations of the proposed grid- and barrier-based applications are shown on an attached figure. Typical grid and barrier layouts are also shown on attached figures.

Design/Proposal Assumptions

Using the information you provided, we have made the following assumptions to estimate system design variables and dose amounts.

- Plume area requiring treatment:

  100 feet x 100 feet source area treatment

  700-foot long downgradient barrier

- Representative contaminant concentrations:

  Source Area – 29 mg/L TCE, and 1.9 mg/L cis-1, 2-DCE

  Downgradient Barrier – 8 mg/L TCE, and 2 mg/L cis-1,2-DCE

- Contaminated saturated zone thickness requiring treatment:

  Source Area – 25 feet (8 to 33 feet bgs)

  Downgradient Barrier – 15 feet (20 to 35 feet bgs)

- Estimated groundwater velocity: up to 6.5 feet/year. Note that groundwater velocity controls the extent to which new contaminant is brought into the treatment zone. This contaminant loading must be considered when specifying HRC dosing requirements.

- Current groundwater geochemistry and competing electron acceptor demand for HRC-supplied electron donor (assumed):

  Source Area – Assumed to be generally anaerobic with oxygen <1 mg/L and nitrate <1 mg/L, potential manganese reduction demand <5 mg/L, potential ferric iron reduction demand <25 mg/L, and potential sulfate reduction demand <150 mg/L. Higher competing electron acceptor-based demand may require increased amounts of HRC to achieve remedial goals.

  Downgradient Barrier – Assumed to be generally aerobic with oxygen <5 mg/L and nitrate <5 mg/L, potential manganese reduction demand <5 mg/L, potential ferric iron reduction demand <25 mg/L, and potential sulfate reduction demand <200 mg/L. Higher competing electron acceptor-based demand may require increased amounts of HRC to achieve remedial goals.

The design specifications and costs provided below represent a preliminary design for an accelerated bioremediation project. This design may need to be adjusted as detailed design and regulatory oversight issues are finalized. For instance, the following design variables may need to be adjusted prior to the implementation:

- Treatment areas may need to be increased or decreased depending on the overall site remediation strategy.
- Exact delivery locations should be selected in the final design process. Delivery locations may need to be adjusted to take into account site features such as underground utilities and other site structures.

Regenesis' applications engineering staff is available to assist in the selection of an appropriate final design.

HRC Source Area Grid Treatment	
Design Feature	**Specification**
Saturated thickness requiring treatment	25 feet (approx. 8 to 33 feet bgs)
Treatment Area	100 feet x 100 feet
Delivery Pt. Spacing and Configuration	10 ft-on-center bet. rows, 10 ft-on-center within rows 10 rows of 10 points; 100 total points
HRC dose rate in lbs/vertical foot of injection	12.5 lbs/foot, (312.5 lbs/point)
Material requirement	100 pts. x 25 feet x 12.5 lbs/ft = 31,250 lbs Round up to 31,260 lbs. (HRC is shipped in 30 lb buckets)
*Material cost at $5.25/lb	*$164,115 plus shipping and applicable sales tax

HRC Downgradient Barrier Treatment	
Design Feature	**Specification**
Saturated thickness requiring treatment	15 feet (approx. 20 to 35 feet bgs)
Treatment Area	700 foot long barrier
Delivery Pt. Spacing and Configuration	10 ft-on-center within rows 2 rows of 70 points; 140 total points
HRC dose rate in lbs/vertical foot of injection	3 lbs/foot, (45 lbs/point)
Material requirement	140 pts. x 15 feet x 3 lbs/ft = 6,300 lbs
*Material cost at $5.75/lb	*$36,225 plus shipping and applicable sales tax

*Based on the above-proposed HRC applications, the total amount of HRC proposed for this initial "full-scale" injection for both the grid-based and barrier-based applications at the site is 37,560 pounds. At a per pound cost of $5.25/pound, the total cost of 37,560 pounds of HRC is $197,190, plus applicable sales tax and shipping. If less or more HRC is purchased than the total amount proposed, the cost per pound may be greater or less than the $5.25 cost per pound proposed above. Please see the attached price sheet for HRC volume pricing structure. Please be aware that the next volume purchase price break is at 40,000 pounds ($5.00/pound). Thus, for an additional $2,810.00 an additional 2,440 pounds of HRC could be purchased at a unit cost of $1.15/pound.

Total Project Cost

The total cost of an accelerated bioremediation project can be estimated as the sum of the following items:

- HRC material and shipping costs.
- HRC application fieldwork costs. Customers are responsible for selecting a local injection/application subcontractor.
- Groundwater monitoring well construction (if necessary to monitor project performance).
- Periodic groundwater sampling and analysis.
- Consultant oversight and reporting. Regenesis data evaluation and technical support are provided free of charge.

The costs provided in this letter apply to HRC material costs for *one application*. The need for re-applications will depend on your plume management strategy, site specific biodegradation performance, remedial goals for the site, and other technical or regulatory considerations. For plume area treatments, one to two re-applications could be necessary over the course of the project, although each re-application would most likely be done over a reduced area and dose amount

compared to the initial application. For barrier-based designs, re-applications will be necessary every one to two years as long as there is a need to prevent contaminant migration.

HRC Delivery to Contaminated Zone

Typically, HRC is applied using direct push hydraulic equipment. Drive rods are pushed to the bottom of the contaminated saturated zone and then HRC is injected as the rods are withdrawn. The minimum recommended rod size is a 0.625-inch inner diameter.

For sites where direct push is not feasible, auger-based equipment can be used to deliver HRC. Also, the use of permanent, small diameter re-injection wells may be a more cost-effective approach for sites requiring repeated applications of HRC. Technical support personnel at Regenesis are available to discuss the suitability of alternate HRC delivery methods.

Costs for HRC injection should be obtained from local subcontractors. If necessary, Regenesis can assist in locating qualified HRC injection subcontractors. Budgetary cost estimates for direct push-based injection range from $1,000 to $2,000 per day. Typically, one to two HRC injection points can be completed per hour and up to 20 points can be completed per day, depending on soil type, depths of injection, and subcontractor experience.

HRC should be injected using an appropriate pump capable of processing a material with a viscosity of 20,000 centipoise at flow rates of 3 to 10 gallons per minute at pressures ranging from 200 psig to 1,500 psig. Failure to use appropriate equipment could increase field time and result in improper application of the HRC. Regenesis has evaluated a number of pumps and has found that the RE Rupe and the Geoprobe GS-2000 pumps provide suitable volume and pressure. The RE Rupe as well as the GS-2000 pumps can be purchased directly from the manufacturers. RE Rupe Co. can be contacted at (515) 682-7029, while Geoprobe Systems can be reached at (800) 436-7762. The Geoprobe GS-2000 is available for rent through Probe-Lease. Probe-Lease can be reached at (800) 645-2009.

Recommended Groundwater Monitoring Program for Pilot/Full Scale Treatment

Monitoring of selected wells should be conducted to validate the HRC-based enhancement of reductive dechlorination processes. The monitoring well network would ideally include wells from the following locations:

Inside treatment area (optional for barrier applications)	Provides information on geochemical conditions and contaminant trends induced by HRC
Downgradient of treatment area	Provides information about residence time effects. Since the contaminant has to be in contact with the electron donor for a given length of time, the actual performance may be evident at downgradient locations for sites with moderate to high groundwater velocities.
Upgradient of treatment area	Provides a measure of contaminant mass and competing electron acceptor load entering treatment area

Background	Allows comparison of geochemical changes induced by addition of HRC.

An initial or "baseline" round of sampling should be performed to identify pre-HRC installation groundwater conditions. After application of the HRC, samples can be collected every other month for a six to eight month period. After the initial biodegradation and geochemical trends have been identified, the monitoring frequency can be decreased to a quarterly, semiannual, or annual program.

The monitoring protocol should call for standard low flow groundwater sampling techniques and include the measurement of the following field/chemical parameters:

- all relevant contaminants
- field parameters: dissolved oxygen, ORP, pH, temperature, and ferrous iron (optional field measurement)
- natural attenuation/inorganic parameters: dissolved iron and manganese, nitrate, sulfate, sulfide, chloride, and alkalinity
- HRC-based electron donor: total organic carbon and metabolic acids (lactic, pyruvic, acetic, propionic, and butyric)
- End-product dissolved gases: carbon dioxide, methane, ethane and ethene

A specially qualified laboratory should do the analytical testing for the metabolic acids, otherwise most laboratories can provide testing for the remaining parameters. A typical cost for the above testing program is approximately $300 per sample.

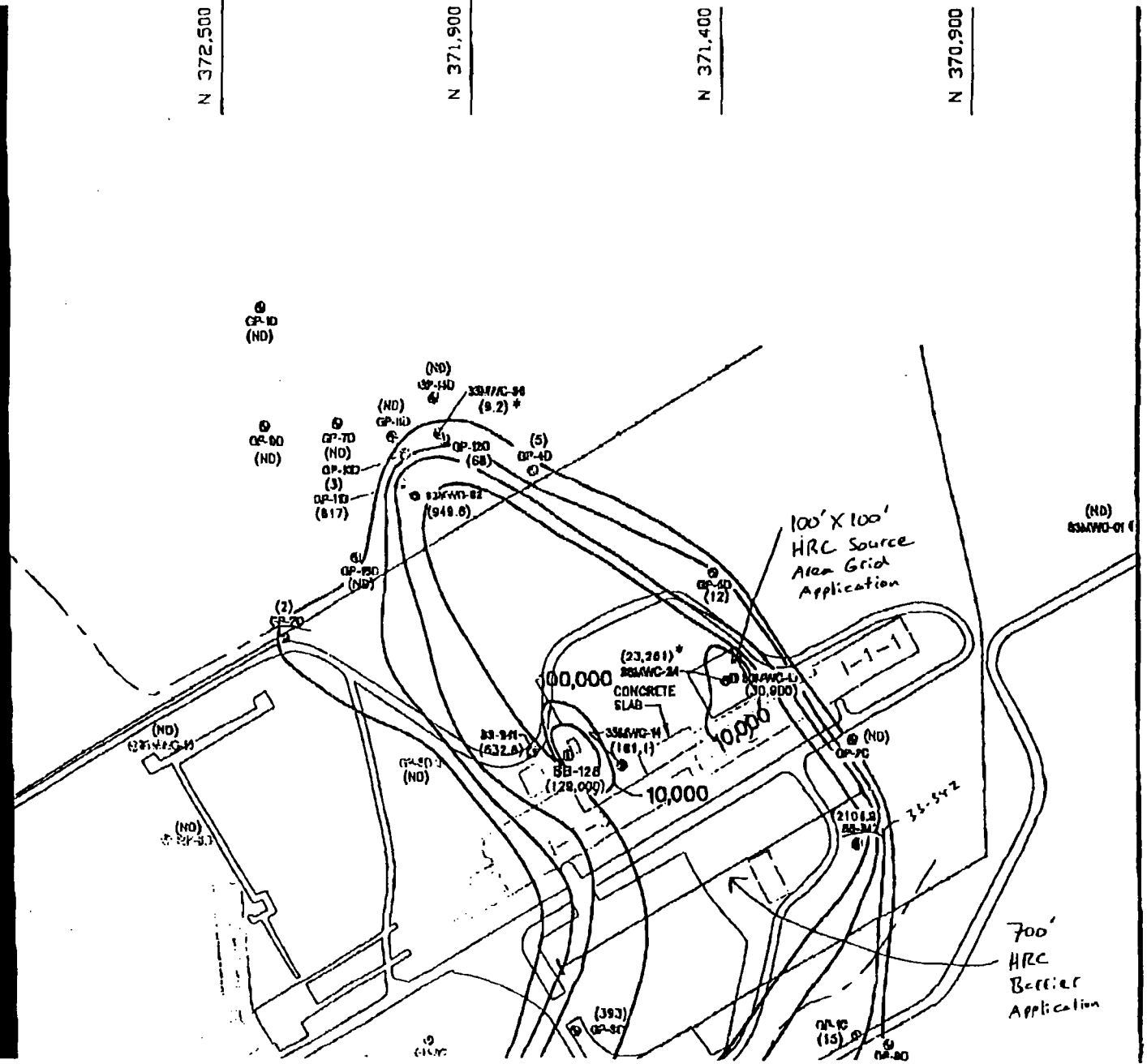
Regenesis appreciates the opportunity to provide this information for your project. Please feel free to contact me at 949-366-8000 (e-mail at dreilly@regenesis.com), or your local technical representative, Scott Mullin, at 630-753-0836 (e-mail at scott@regenesis.com), with any questions or comments.

Sincerely,

David C. Reilly
Applications Engineer

Attachments

E:\HRC\Proposals\RMT, Inc\CrabOrchard\Crabpro1.doc



LEGEND

80-5	LOCATION OF SURFACE WATER STAFF GAUGE – INSTALLED FALL 2000
33MWC-42	SHALLOW MONITORING WELL (UPPER CLAY) – INSTALLED FALL 2000
33MWC-43	SHALLOW MONITORING WELL (UPPER SAND) – INSTALLED FALL 2000
33MWC-80	SHALLOW MONITORING WELL
33MWC-22	PIEZOMETER
SG-4	EXISTING STAFF GAUGE REPLACED DURING PRE-DESIGN INVESTIGATION
325-242	SURFACE WATER SAMPLING LOCATION
GP-1A	GEOPROBE SAMPLE LOCATION
32-061	MONITORING WELL, ABANDONED (APPROXIMATE LOCATION)
	APPROXIMATE CENTERLINE OF SURFACE DRAINAGE CHANNEL/SWALE
	FENCE
	APPROXIMATE LIMITS OF SOIL EXCAVATION
	APPROXIMATE FOOTPRINT OF AREA 9 REPOSITORY
10	TOTAL CVOC ISOCONCENTRATION CONTOUR, LOGARITHMIC CONTOUR INTERVAL (ug/L) (DASHED WHERE INFERRED)
(393)	TOTAL CONCENTRATION OF CHLORINATED VOLATILE ORGANIC COMPOUNDS (CVOCs) DETECTED IN GROUNDWATER (ug/L).
ND	NOT DETECTED
	WOODED AREA
SB-128	GEOPROBE BORING LOCATION (INSTALLED BY RMT IN 2000)

NOTES

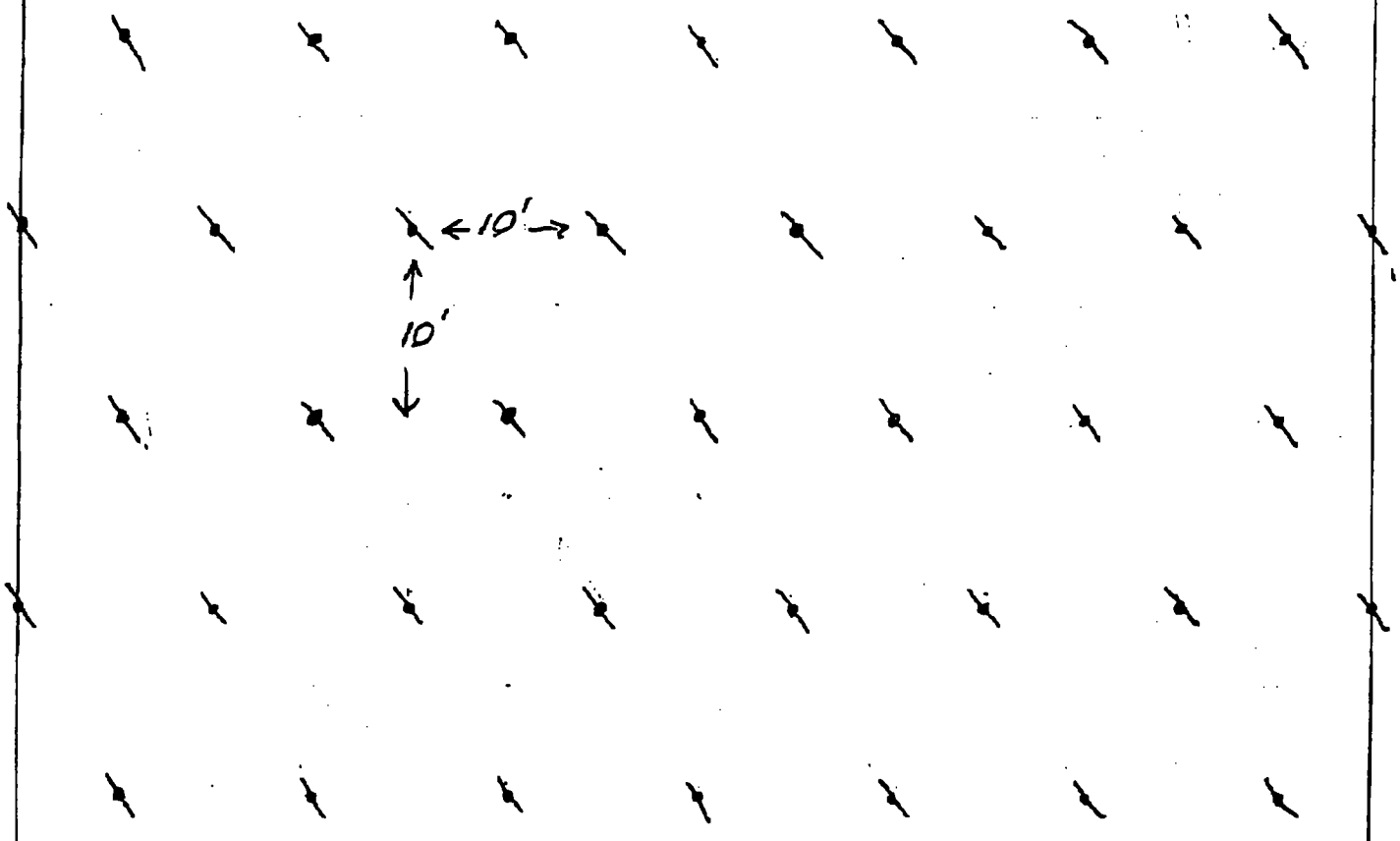
1. SOURCE: BASE MAP FROM "1998 TCE INVESTIGATION, WO AND PILOT STUDY FOR THE PCB OPERABLE UNIT AT THE ORCHARD NATIONAL WILDLIFE REFUGE SUPERFUND SITE, ILLINOIS" REV. 1, MAY 1998, PREPARED BY FLUOR DANIE

2. * INDICATES WELL IS SCREENED ACROSS THE UPPER BA UNIT. OTHER BORINGS AND MONITORING WELLS ARE COMPLETED IN THE UPPER CLAY AND/OR THE UPPERMOST PORTION OF THE UPPER SAND UNIT.

3. CVOC DATA FOR MONITORING WELLS 33MWC-07, 33MWC-08, 33MWC-13, 33MWC-21, 33MWC-24, 33MWC 33MWC-30, AND 33MWC-42 THROUGH 33MWC-48, AND ALL "SB-" DESIGNATED BORINGS ARE FROM THE FALL 2 INVESTIGATION. CVOC DATA FOR THE REMAINING WELLS A THE DECEMBER 1998 SAMPLING EVENT. CVOC DATA FRO

SAEDTLER® ... 83, ... E
Engineer's Computation Pad

Typical HRC Grid-Based Application Injection Point Layout



* Carry out above injection pattern throughout entire grid.

0 10'
Scale

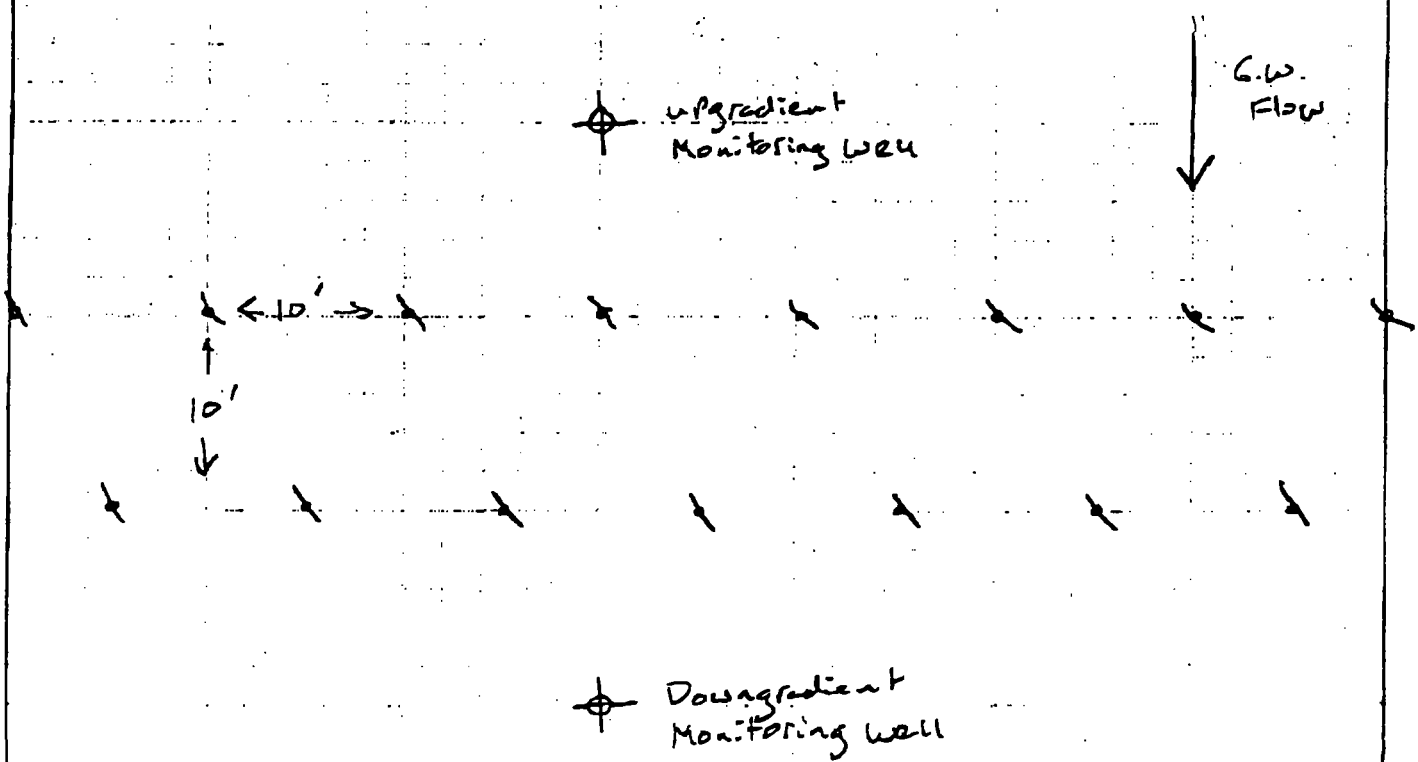
Legend

HRC Injection Point

* Note - Place injection points no closer than 5 feet to Monitoring well.

STAEDTLER® NO. 937 811E Engineer's Computation Pad

HRC Barrier Layout



* Note - carry out above injection Point Layout throughout barrier

Legend

HRC Injection Point

0 10'
Scale

REGENESIS

Hydrogen Release Compound, HRC®

Price Sheet: Effective September 1, 2000

Cost Effective Treatment of Chlorinated Solvents

Hydrogen Release Compound (HRC) offers a passive, low-cost approach to rapid remediation of chlorinate solvent impacted sites. HRC is a proprietary, environmentally safe polylactate ester specially formulated for slo release of lactic acid upon hydration. When placed within a contaminated aquifer, HRC stimulates a multi-ste process resulting in the degradation of chlorinated solvent compounds such as PCE, TCE and their derivatives a well as other groundwater contaminants. ***The use of HRC results in the cost-effective and rapid restoration o property values.***

HRC* Pricing

Regenesis offers a volume discount structure for the purchase of HRC as follows:

Quantity (lbs.)	HRC Price/lb. (US $)	Quantity (lbs.)	HRC Price/lb. (US $)
150	$8.00	6,000	$5.75
500	$7.50	10,000	$5.50
1,500	$7.00	20,000	$5.25
3,000	$6.00	40,000	$5.00

* HRC is shipped in four-and-a-quarter gallon containers weighing approximately 30 pounds. Material Safety Data Sheet is included with each shipment.

Freight – All freight is FOB San Clemente, CA unless otherwise specified when order is placed.

Minimum Order – 150 lbs. ($1,200.00)

Bench-Scale Laboratory Testing

Laboratory testing of soil and groundwater is available to confirm the ability of HRC to stimulate dechlorination. However, such testing is generally not required. Testing cost is $2,500 per groundwater/soil slurry sample.

Payment Terms – Net 30 days. Accounts outstanding after 30 days will be assessed 1.5% interest per month. Accounts outstanding over 90 days will be re-invoiced at the undiscounted price of $8.00 per pound.

Return Policy – A 15% restocking fee will be charged for all returned product. Return freight must be prepaid. All requests to return product must be pre-approved by Regenesis. Returned product must be in original condition and no product will be accepted for return after a period of 90 days from time of delivery.

Terms & Conditions – Other terms and conditions are on reverse side.

Order From – **REGENESIS**---- 1011 Calle Sombra• San Clemente, CA 92673-6244
Tel: 949.366.8000 • Fax: 949.366.8090 • www.regenesis.com • orc@regenesis.com

Remittance Address: Department 8873
Los Angeles, CA 90084-8873

® Registered Trademark of REGENESIS Bioremediation Products

REGENESIS

Hydrogen Release Compound, HRC®

TERMS AND CONDITIONS

1. CASUALTY AND AVAILABILITY OF RAW MATERIALS. REGENESIS Bioremediation Products ("Seller") shall not b liable for delays in delivery or failure to manufacture or deliver due to causes beyond its reasonable control, including but not limited to ac of God, acts of buyer, acts of military or civil authorities, fires, strikes, flood, epidemic, war, riot, delays in transportation or car shortages, c inability to obtain necessary labor, materials, components or services through seller's usual and regular sources at usual and regular prices. I any such event seller may, without notice to buyer, at any time and from time to time, postpone the delivery dates under this contract or mak partial delivery or cancel all or any portion of this and any other contract with buyer without further liability to buyer. Cancellation of ar part of this order shall not affect seller's right to payment for any product delivered hereunder.

2. LIMITED WARRANTY. Seller warrants that the product sold hereunder is made with HRC as specified on face of invoice. Sell makes no other warranty of any kind respecting the product, and expressly DISCLAIMS ALL OTHER WARRANTIES OF WHATEVE KIND RESPECTING THE PRODUCT, INCLUDING ALL WARRANTIES OF MERCHANTABILITY AND FITNESS FO PARTICULAR PURPOSE. BUYER'S SOLE REMEDY FOR BREACH OF THIS LIMITED WARRANTY SHALL BE REFUND OF TH PURCHASE PRICE, PROVIDED THAT ANY UNUSED PORTION OF THE PRODUCT IS PROMPTLY RETURNED TO SELLEI UNDER NO CIRCUMSTANCES WILL SELLER BE LIABLE FOR ANY CONSEQUENTIAL OR OTHER DAMAGES.

3. DISCLAIMER. Seller disclaims to the full extent permitted by law all warranties, expressed or implied, including any implie warranty of merchantability, fitness for any particular purpose or against infringement, to any person other than buyer. Where warranties to person other than buyer may not be disclaimed under law, seller extends to such a person the same warranty seller makes to buyer or less as set forth herein, subject to all disclaimers, exclusions and limitations of warranties, all limitations of liability and all other provisions s forth in the Terms and Conditions herein. Buyer agrees to transmit a copy of the Terms and Conditions set forth herein to any and a persons to whom buyer sells, or otherwise furnishes the products and/or services provided buyer by seller and buyer agrees to indemni seller for any liability, loss, costs and attorneys' fees which seller may incur by reason, in whole or in part, of failure by buyer to transmit tl Terms and Conditions as provided herein.

4. LIMITATION OF SELLER'S LIABILITY AND LIMITATION OF BUYER'S REMEDY. Seller's liability on any clai of any kind, including negligence, for any loss or damage arising out of, connected with, or resulting from the manufacture, sale, deliver resale, repair or use of any goods or services covered by or furnished hereunder, shall in no case exceed the lesser of the cost of repairing c replacing goods failing to conform to the forgoing warranty or the price of the goods or services or part thereof which gives rise to the clair IN NO EVENT SHALL SELLER BE LIABLE FOR SPECIAL INCIDENTAL OR CONSEQUENTIAL DAMAGES, OR FOR DAMAGE IN THE NATURE OF PENALTIES.

5. INDEMNIFICATION. Buyer agrees to defend and indemnify seller of and from any and all claims or liabilities asserted against sell in connection with the manufacture, sale, delivery, resale or repair or use of any goods covered by or furnished hereunder arising in whole in part out of or by reason of the failure of buyer, its agents, servants, employees or customers to follow instructions, warnings recommendations furnished by seller in connection with such goods, by reason of the failure of buyer, its agents, servants, employees customers to comply with all federal, state and local laws applicable to such goods, or the use thereof, including the Occupational Safety a Health Act of 1970, or by reason of the negligence of buyer, its agents, servants, employees or customers.

6. EXPENSES OF ENFORCEMENT. In the event Seller undertakes any action to collect amounts due from Buyer, or otherwi enforce its rights hereunder, Buyer agrees to pay and reimburse Seller for all such expenses, including, without limitation, all attorneys a collection fees.

7. TAXES. Liability for all taxes and import or export duties, imposed by any city, state, federal or other governmental authority, shall assumed and paid by buyer. Buyer further agrees to defend and indemnify seller against any and all liabilities for such taxes or duties a legal fees or costs incurred by seller in connection therewith.

8. ASSISTANCE AND ADVICE. Upon request, seller in its discretion will furnish as an accommodation to buyer such techni advice or assistance as is available in reference to the goods. Seller assumes no obligation or liability for the advice or assistance given esults obtained, all such advice or assistance being given and accepted at buyer's risk.

9. ENTIRE AGREEMENT. This agreement constitutes the entire contract between buyer and seller relating to the goods or servi identified herein. No modifications hereof shall be binding upon the seller unless in writing and signed by seller's duly authori epresentative, and no modification shall be effected by seller's acknowledgment or acceptance of buyer's purchase order forms containi lifferent provisions. Trade usage shall neither be applicable nor relevant to this agreement, nor be used in any manner whatsoever to expla qualify or supplement any of the provisions hereof. No waiver by either party of default shall be deemed a waiver of any subsequent defaul

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envirometal
technologies
inc.

2 August 2001

Jack Anderson
RMT, Inc.
744 Heartland Trail
Madison, WI 53717-1934

Reference: ***In-Situ* Application of the EnviroMetal Process at the I-1-2/I-1-3 Site, Crab Orchard NWR, Marion, IL – 31617B.88**

Dear Jack:

Thank you for your interest in using the EnviroMetal Process for remediation of contaminated groundwater at the I-1-2/I-1-3 Site, Crab Orchard NWR, Marion, IL. We believe the iron technology has the potential to provide a cost-effective remedy for treatment of the chlorinated VOCs identified in groundwater at the site. Attached are our initial recommendations regarding technology application. We would be happy to visit your company or the client and provide you with an update of our technology, as well as discuss the site in more detail.

Sincerely,

EnviroMetal Technologies Inc.

Robert Focht, M.Sc., P.Eng.
Remediation Engineer

Stephanie O'Hannesin, M.Sc.
Senior Project Director

Encl.

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technologies
inc.

IN-SITU APPLICATION OF THE ENVIROMETAL PROCESS AT THE I-1-2/I-1-3 SITE, CRAB ORCHARD NWR, MARION, IL

Prepared For:

RMT, Inc.
744 Heartland Trail
Madison, WI
USA 53717-1934

Prepared By:

EnviroMetal Technologies Inc.
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Canada N2V 2G6

ETI Reference: 31617B.88

2 August 2001

1.0 INTRODUCTION

EnviroMetal Technologies Inc. (ETI) is pleased to provide the following preliminary conceptual design and revised cost estimate for the installation of an *in-situ* permeable reactive barrier (PRB) at the I-1-2/I-1-3 Site, Crab Orchard NWR, Marion, IL. ETI received preliminary water quality data and hydrogeologic information for the site from RMT on 23 July 2001. From our initial review of the data, we are confident that the EnviroMetal Process (metal enhanced reductive dehalogenation) will degrade the chlorinated ethenes and ethanes present in the site groundwater.

Since 1994, 61 PRBs containing granular iron have been installed to remediate VOCs. There are currently 40 full-scale *in-situ* systems removing VOCs from groundwater, in addition to 21 pilot-scale systems that have been installed to provide "proof of concept" data and more recently to demonstrate innovative construction methods.

ETI is typically retained by site owners, environmental consultants, or government agencies to assist in the design and implementation of PRBs for treatment of VOCs. ETI currently has a staff of five professionals who assist in all phases of design, installation and evaluation of PRBs. Senior staff at ETI have been involved with the technology from the initial development and are amongst the most experienced professionals in the application of PRBs.

2.0 RECOMMENDED APPROACH

ETI's involvement in a project can typically be divided into four phases:

Phase I:	Data Review
Phase II:	Bench-Scale Testing (If Required)
Phase III:	Assistance with Field Design and Implementation
Phase IV:	Performance Monitoring

2.1 Phase I: Data Review

The purpose of this phase is to review available site hydrogeologic, geochemical and geotechnical data as related to the application of the EnviroMetal Process. The concentration and distribution of organic compounds, inorganic groundwater chemistry and the

hydrogeology of the site are examined to determine the feasibility and possible PRB configurations. When considering *in-situ* treatment, particular attention must be given to:

- depth and fluctuations of the water table
- depth to the top and bottom of the contaminated zone
- spatial variation in VOC and inorganic concentrations
- lateral boundaries of the contaminated zone
- flow direction
- groundwater velocity
- hydraulic conductivity
- geotechnical data as they pertain to "constructability" issues

Based on a review of the available data for the site, ETI can work with the project team to identify any data gaps and if necessary assist in the development of a plan for additional data collection. ETI has been involved in the design of numerous PRBs and can provide insight from our experience on these designs.

We encourage that the data review be accompanied by a site visit and meeting in order to obtain additional information regarding site characteristics, possible construction constraints and regulatory requirements. We could also discuss the use of groundwater modeling to facilitate design of the field-scale PRB. A presentation regarding the technology could also be made at this time to the involved parties. We have found that a site visit greatly facilitates project communication and co-ordination. A cost estimate for Phase I is given in Table 1.

2.2 Phase II: Bench-Scale Testing (If Required)

Phase II involves bench-scale testing of the EnviroMetal Process using groundwater from the site and commercially available granular iron material. The bench-scale test typically involves a laboratory column test to establish site-specific VOC degradation rates under flowing conditions. This test enables us to predict system performance and provide data for field design.

The degradation rates determined from the column tests are used to determine the required residence time in the granular iron. Using the residence time and the expected groundwater flow rate, the flow-through thickness of the PRB is determined. The laboratory column test also includes inorganic sampling of column influent and effluent. This provides information

concerning potential mineral precipitation in the reactive material caused by changing redox potential (Eh) and pH conditions. The potential for mineral precipitation must be considered in the field design.

The standard laboratory protocols and measurement methods are designed to provide high quality data at minimal cost. The column is made of Plexiglas™ with an inner diameter of 1.5 inches and a length of either 1.6 ft or 3.2 ft. Groundwater from the site is supplied to the influent end of the column at a constant flow velocity using a laboratory pump. The flow velocity is selected to approximate the groundwater velocity expected in a field-scale PRB. This flow velocity is determined through consultation with the client. VOC concentrations are measured along the column until a steady-state profile is achieved. Eh and pH profiles are measured periodically during the test. Inorganic parameters (major cations, anions, and alkalinity) are monitored to help predict possible mineral precipitation. If necessary, other chemical parameters relevant to a particular site and/or proposed construction method can also be measured.

The water shipped from the site should have characteristics (VOC concentrations and inorganic chemistry) similar to the groundwater expected to enter a field-scale PRB. Shipping instructions are provided by ETI once the project proceeds.

The report issued at the conclusion of the laboratory tests will include:

- results of all chemical analyses
- calculated degradation rates
- summary tables of major results
- graphs showing degradation profiles

Estimated residence time requirements for the field application will also be calculated, based on laboratory results and VOC design influent concentrations and effluent maximum contaminant levels (MCLs).

2.3 Phase III: Assistance with Field Design and Implementation

ETI's typical role in Phase III is to act as a design consultant. That is, the lead consultant would have responsibility for the overall program (completion of design documents, obtaining construction permits, general construction oversight and co-ordination, implementation of

monitoring program, etc.). ETI would assist in these tasks, and bill on a time and materials basis for this work. Particular tasks that involve ETI staff include:

- determination of residence time requirements for VOC treatment
- consultation on system design, in particular, iron PRB dimensions
- consultation on system modeling
- assistance in selecting construction method
- specification/procurement/quality assurance of reactive material
- assistance during field installation
- development of a performance monitoring program

Typically several design scenarios (varying depth, length, treatment levels) are evaluated during the design. ETI has developed a degradation model to simulate the EnviroMetal Process and can utilize this model to predict the PRB performance for various design scenarios.

ETI has several standard specifications for granular iron quality, granular iron handling and construction verification. ETI can either prepare these specification sections or provide the information to the site consultant. ETI can also provide overall assistance with preparing the specification and provide input based on past experience preparing specifications. We have also been involved in construction contractor bid evaluation.

Site construction management is normally handled by engineering or contracting firms (or, your organization if you provide construction services). ETI retains the right to have on-site representation during the installation phase of the project.

Work on subsequent phases of the design and installation will be billed on a time and materials basis. Once the scope of the project is more fully defined, we can provide cost estimates for these activities. On past projects of this size, our costs have been on the order of about $5,000 to $10,000.

ETI has been granted exclusive rights for commercialization of this patented technology by the patent holder, the University of Waterloo. A site license fee of 15 percent of capital construction costs will be charged should full-scale implementation of the technology at the site proceed. The fee is based on the cost of delivered iron to the site and the PRB construction (i.e. cost for the construction of a continuous wall or funnel and gate system installation, including mobilization and demobilization).

2.4 Phase IV: Performance Monitoring

ETI typically assists with the data interpretation and evaluation of system performance over time. This includes preparation and/or review of compliance monitoring documents for submission to the regulatory agencies involved. As ETI has been involved with the performance assessment of most of the installed PRBs, we can provide a detailed evaluation of the system performance incorporating our experience from other sites.

ETI's involvement in performance monitoring will also be billed on a time and materials basis. Because performance monitoring detail and schedules vary from site to site, cost estimates for this phase can be given as the need arises.

3.0 PRELIMINARY CONCEPTUAL DESIGN FOR A FULL-SCALE PRB

The following provides a preliminary conceptual design for a full-scale iron PRB at the I-1-2/I-1-3 Site, Crab Orchard NWR, Marion, IL. The design will focus on the Upper Sand unit at the site. This conceptual design is based on the information received to date. Other design scenarios and configurations can be evaluated in Phase I once more site data is available.

3.1 Location and Configuration

Plume maps and geologic cross sections showing VOC concentrations in the Upper Sand unit were provided by RMT. The proposed PRB location is downgradient (southwest) of buildings I-1-2 and I-1-3. From the plume maps the plume appears to be about 650 ft in width in the Upper Clay and Upper Sand units at this location. The Upper sand unit is below the Upper Clay unit at a depth of about 20 to 35 ft to a total depth of 30 to 40 ft. The Upper Sand unit ranges in thickness from about 5 to 10 ft.

There are two basic designs for a PRB, a continuous PRB or a funnel and gate. In a continuous PRB configuration the granular iron is distributed across the entire path of the contaminated groundwater. In the case of granular iron, the iron has a hydraulic conductivity greater than many aquifers and thus should not significantly alter the natural groundwater

flow path or velocity. The continuous PRB has been the most common configuration used to date.

A funnel and gate configuration uses low permeability materials (funnel) to direct groundwater towards a permeable treatment zone (gate). By directing or funneling the groundwater towards a treatment gate the natural groundwater flow velocity may be increased several times. For a funnel and gate system, groundwater flow modeling is required to estimate the velocity through the gates in order to determine the flow-through thickness required. The mass of iron required is generally the same regardless of the configuration since the same contaminant flux must be treated. Funnel and gate designs need to extend beyond the extent of the plume to ensure that all of the contaminated groundwater is captured and treated. The length of a funnel and gate system may be on the order of 1.2 to 2.5 times the plume width depending on the number of gates and the funnel to gate ratio. To ensure that flow beneath the system does not occur, funnel and gate systems must be keyed into a competent underlying low permeable zone.

ETI has assumed that a continuous PRB would be constructed. The advantages and disadvantages of constructing a continuous permeable wall versus a funnel and gate system or alternate configuration could be discussed further during the data review phase (Phase I).

3.2 Granular Iron Requirements

Based on chlorinated ethene degradation rates from our database of bench-scale tests and field sites, a residence time of about 3.5 days would be required to degrade a maximum of 50 mg/L of trichloroethene (TCE) and associated breakdown products to below US Federal maximum contaminant levels (MCLs). Given the reported groundwater flow velocity of 80 to 150 ft/yr, a 100% granular iron PRB would need to be a maximum of 1.5 ft in thickness to provide sufficient residence time.

If the construction method requires that the treatment zone be larger than 1.5 ft, the iron could be mixed with sand to minimize materials cost. Therefore, for example, a 60% by volume iron and 40% by volume sand mixture in a 2.5 ft wide trench would provide the equivalent 100% iron thickness of 1.5 ft. ETI recommends that the minimum amount of iron in an iron-sand mixture should be 20% by volume.

The total volume of iron required for the 650 ft wide groundwater plume in the Upper Sand unit (average thickness of 7.5 ft) is (650 ft × 7.5 ft × 1.5 ft =) 7,313 ft^3. The *in-situ* bulk density of granular iron is approximately 0.075 tons/ft^3. Therefore, a total of 549 tons of granular iron would be required. If the groundwater flow velocity was around 80 ft/yr in areas along the 650 ft length of the proposed PRB, then the iron costs could be reduced.

3.3 Construction Methods

A 1.5 ft in thickness PRB to a depth of about 40 ft could be constructed using either an injection based method such as jetting or an excavation based method such as biopolymer supported trenching. Using a jetting method the upper 25 to 30 ft of subsurface would not need to be excavated. However, given the relative thickness of the PRB two or more parallel rows of injections would be required to emplace sufficient iron. Thus, an excavation using biopolymer may be more cost effective. Due to the limited site geology/geotechnical data provided, it is difficult to determine which construction methods are best suited for the site. Each of the above methods has been used to construct treatment zones containing iron and each has its advantages and disadvantages. For this preliminary cost estimate we have assumed that the PRB would be constructed using excavation with biopolymer. These construction methods and alternate ones can be discussed and more detailed cost estimates developed in Phase I.

Jetting uses high pressures (about 5,000 to 6,000 psi) to jet fine grained iron into the natural aquifer formation. The jetting tool is advanced into the formation to the desired depth. An iron/biodegradable slurry is then injected from nozzles as the tool is withdrawn. If the tool is rotated a columnar iron zone is created. If the tool is not rotated, and has only one or two opposing nozzles, a thin diaphragm treatment wall can be created. Diaphragm walls may be about 3 inches thick near the point of injection, but may be several inches of an iron-aquifer mixture further away. The diameter of injection will depend on several factors, but distances of 2 to 6 ft are expected for columnar walls and diameters of up to 15 ft have been reached for diaphragm walls. Therefore, large treatment zones require several injections. A successful jetting demonstration to a depth of 65 ft occurred in June 1999 at Travis AFB in California and a full-scale application occurred later the same summer in North Carolina.

Installation of a treatment zone of iron using biopolymer slurry is similar to constructing a conventional impermeable slurry wall. The biopolymer used is typically guar based. As the trench is excavated, biopolymer provides stability to the trench walls. Granular iron can then

be placed into the trench through the biopolymer. After some time, the biopolymer breaksdown (i.e. become less viscous) allowing groundwater to flow through the iron treatment zone.

3.4 Preliminary Cost Estimate

The following cost estimate for technology application at the site is presented to provide a degree of insight with respect to the full-scale implementation costs. We emphasize that the costs presented here are based on costs we obtained for construction at other sites, and would need to be refined based on a more complete review of site conditions and quotations for construction costs from qualified contractors.

The costs for constructing a PRB using the biopolymer excavation method are summarized in Table 3. At a delivered unit cost of about $450/ton, the cost of 549 tons of granular iron would be approximately $247,000. Estimated costs for installation of a 650 ft continuous PRB to an average depth of about 27.5 ft to 35 ft bgs would be approximately $350,000, which includes mobilization/demobilization costs of $50,000.

The total estimated cost, including site license is $687,000. Other costs which may be incurred including site preparation, utility relocation, soil disposal, site restoration, permitting, construction management, and engineering design and oversight should also be estimated and included in the overall cost.

3.5 Operation and Maintenance Cost

The frequency and amount of groundwater monitoring that will be required is dependent on the site and/or regulatory requirements. Guidance for a monitoring schedule can be found in the ITRC document "Regulatory Guidance for Permeable Reactive Barriers Designed to Remediate Chlorinated Solvents 2nd Edition, December 1999" (www.itrcweb.com).

Other than groundwater monitoring, the major factor affecting O&M costs is the possible need for periodic rejuvenation of iron sections affected by mineral precipitates. The iron material itself should last for decades. The precipitates (if significant) will likely form in a zone on the upgradient face of the PRB.

We note that no significant precipitates were observed in cores from a PRB at an Ontario test site four years after it was installed. This PRB performed consistently for over 5 years. There is also no evidence of sliming or plugging in commercial *in-situ* systems operating successfully for over 6 years.

The objective of rejuvenation of the granular iron would be to restore the permeability loss due to precipitates and possibly to remove the precipitate from the iron to restore any lost reactivity. Since it is presumed that the majority of the precipitate formation will occur on the upgradient face of the PRB, rejuvenation methods would likely target the upgradient face. Possible rejuvenation methods include:

- Jetting the PRB with water under high pressure;
- Using ultrasound to break-up the precipitate on the upgradient face; and
- Using a pressure wave hydraulic pulse method to break-up the precipitate.

To date these possible rejuvenation methods have not been needed and only ultrasound has been tested on a limited scale in the field-scale to determine its effectiveness. At this point we can only state that these methods may prove to be successful in rejuvenating a PRB. To be conservative, we recommend that costing models consider implementation of these possible methods on a 10 year interval. Costs for mechanical agitation methods such as jetting or augering are estimated to be in the range of $4 to $6 per square foot.

5.0 SUMMARY

Based on our review of the data you have provided, the *in-situ* iron technology has the potential to provide a technically feasible method for remediation of the VOCs present at the site. The VOCs present at the site have been treated in previous field applications, and the construction depths, etc., are within reasonable limits where the technology can be successfully applied.

Table 1: Preliminary Cost Estimate for ETI's Involvement, I-1-2/I-1-3 Site, Crab Orchard NWR, Marion, IL

Phase		Estimated Cost (US$)
I	Data review	$1,000
	Site Visit and Meeting[a]	$4,000
II	Bench-Scale Testing[b] (if required)	$17,500
III	Assistance with Field Design and Implementation	$5,000 - $10,000
V	Performance Monitoring	Variable

Notes:

[a] Includes travel

[b] Costs of sample collection and shipment are not included.

Table 2: Summary of PRB Design Parameters, I-1-2/I-1-3 Site, Crab Orchard NWR, Marion, IL

Parameter	Conceptual Design Value
Dimensions	***Upper Sand Unit***
Plume Width	650 ft
Total Depth	30 to 40 ft
Saturated Thickness	5 to 10 ft
Hydraulic Parameters	
Maximum Groundwater Velocity	0.41 ft/day
VOC Concentrations	
TCE and Associated Breakdown Products	<50,000 µg/L

Table 3: Summary of PRB Design, I-1-2/I-1-3 Site, Crab Orchard NWR, Marion, IL

PRB Design Parameter	Parameter Value
Length	650 ft
Saturated Thickness	7.5 ft
Estimated Residence Time	3.5 days
Iron Flow-Through Thickness	1.5 ft
Volume of Granular Iron	7,313 ft^3
Mass of Granular Iron (@0.075 ton/ft^3)	549 tons
Cost Estimate[a] ($US)	
Mobilization	$50,000
Excavation using Biopolymer	$300,000
Total Construction	**$350,000**
Iron Supply and Delivery (@ $450/ton)	$247,000
Sub Total	**$597,000**
Site License Fee (15%)	$90,000
TOTAL	**$687,000**

Notes:

[a] Based on cost data from other sites. Would need to be refined based on a more complete review of site data and quotation from local construction contractors. Does not include costs for activities such as site preparation, permitting, soil disposal, site construction management, etc.

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ISOTEC

Sent Via Fax (608) 831-3334 and First Class Mail

July 31, 2001

RMT, Inc
744 Heartland Trail
Madison, WI 53717-1934
Attn: Mr. Jack Anderson

RE: ***Proposal for ISOTEC℠ Laboratory and Pilot Programs***
Crab Orchard NWR
Marion, Illinois
ISOTEC Proposal #800421

Dear Mr. Anderson:

In-Situ Oxidative Technologies, Inc. (ISOTEC℠) has reviewed the submitted information received with respect to the above referenced site for possible use with their remedial treatment process. Based on our review of the information received, plus type and levels of contaminants present, we believe the downgradient portion of the site to be a viable candidate to reduce the organic contaminant loading using the ISOTEC process. The geology of the source area consists of clays exhibiting a hydraulic conductivity in the range of 10^{-6} cm/sec. The use of chemical oxidation within an aquifer exhibiting such a low conductivity would provide limited remedial benefits. Costs associated with the ISOTEC laboratory study and remedial treatment pilot program will be charged on a lump sum basis as indicated. ISOTEC has been asked to provide a pilot program proposal to reduce contaminant levels in ground water of dissolved phase organic compounds (see attached map). The primary contaminant of concern is TCE. Unsaturated soils are not a continuing source of ground water contamination in this area. For this pilot proposal ISOTEC will target ground water contamination (ground water and saturated soils) within the most contaminated portion of the downgradient ground water plume. The targeted portion of the aquifer is found at the 38-44' below grade aquifer interval. Levels of targeted ground water contaminants have recently been found in the 2-3 ppm range within the ground water plume. The mean hydraulic conductivity for the targeted upper sand aquifer unit has been calculated at 3.0×10^{-4} cm/sec. The ISOTEC process is most effective on dissolved phase contamination in areas with no ongoing sources of contamination. *Based upon the proposed treatment location recontamination of this treated zone may occur due to the ongoing upgradient sources of contamination.* **ISOTEC does not utilize any acids or pH modifiers as part of their treatment process. ISOTEC injection activities utilize low peroxide concentrations and a gravity feed or low pressure injection system (15-30 psi).**

The ISOTEC Process

ISOTEC is an in-situ remedial technology that destroys organic contamination through a novel remediation process. ISOTEC's process treats organic contaminants within the subsurface, by utilizing our proprietary blends of catalysts, oxidizers, viscosity enhancers and mobility control agents. ISOTEC compounds are injected through a site specific delivery system providing sufficient distribution to selectively treat the contaminants around an area of concern. A specific stoichiometry is first determined through a lab study, with preliminary treatment quantities calculated. Application is typically tested in the field during a pilot program to determine the efficiency and extent of treatment which varies depending on the site's subsurface characteristics. Based upon a successful lab study and remedial pilot treatment program, design and implementation of full scale remediation is proposed (if required). The ISOTEC approach works via the in-situ destruction of contaminants, while creating minimal disturbance to site operations.

Lab Study

In order to further evaluate the site specific efficiency of ISOTEC, we require both ground water and soil samples, exhibiting detectable levels of dissolved phase contamination, be collected and sent to our research department. The samples will be subjected to a series of studies using the ISOTEC process to first evaluate if the ISOTEC process can successfully treat the contamination and, if the process is successful, to determine the optimum treatment quantities based on the contaminants detected. The initial and treated samples will be further analyzed following each run to determine the effects of the ISOTEC process on the contaminants of concern (chlorinated organics). Results, which will be available within five weeks of sample collection, will be submitted within a letter report.

Should the lab study indicate that the ISOTEC process could not successfully treat the compounds noted, there will be only a charge for the lab study, and no further costs would be incurred by you for the remedial treatment program.

ISOTEC Laboratory Study (Lump Sum) *$6,500.00*

Remedial Pilot Treatment Program

Based on a successful ISOTEC lab study, ISOTEC will perform a remedial pilot treatment program: (1) to gather additional data to evaluate the effectiveness of this remedial alternative; (2) as an initial step toward remediating the plume; and (3) to reduce the organic loading in the treated areas. The pilot program consist of introducing ISOTEC's proprietary blend of catalyst, oxidizer, viscosity enhancers and mobility

control agents into the subsurface over a short time period. The contamination which will be targeted during the pilot program consists of dissolved phase organic compounds consisting primarily of TCE.

During this pilot program ISOTEC is proposing to reduce the organic contaminants within the pilot target area through a series of direct push injection points. The injection pathway system should produce an estimated radial effect of 12-15' around each proposed injection point within the target area. Injections will be conducted over **two separate field events, with each field event lasting 9-10 days**. An estimated 40-50 direct push points will be utilized for the pilot target area (actual number of injection points will be based on field conditions encountered during injection activities, 9-10 days of injection activities per event will be conducted with the most contaminated areas targeted first). The 38-44' bgs aquifer interval will be targeted during the pilot program. ISOTEC believes the proposed injection system would provide sufficient distribution of our proprietary blend of catalysts, oxidizers, viscosity enhancers and mobility control agents into the impacted media at the location. *The pilot test will determine if additional injection points or additional treatment applications will be necessary to adequately treat the area of contamination.* The extent of remediation is preliminary during the initial injection event and may vary plus/minus pending site subsurface characteristics. **Installation of the injection system is the responsibility of RMT**. Since ISOTEC (i.e. chemical oxidation) is a contact treatment, the numerous injection points would help ensure total interaction of reagents within the target area, with the ultimate goal of slightly overlapping treatment areas.

A typical ISOTEC injection team consists of a field supervisor, along with 2-3 field technicians. All members of the injection team have completed health and safety training consistent with the Occupational Safety and Health Act (Title 29 of the Code of Federal Regulations 1910.120). Based on review of the subsurface characteristics, field activities for the pilot program are estimated at 18-20 working days (this would consist of two 9-10 day field events). ISOTEC proposes to complete the initial application over a 90 day period in an effort to: 1) reach cleanup objectives in the areas to be treated and/or 2) substantially reduce the organic loading in the areas treated. ISOTEC can typically begin injections within 45 days of receipt of regulatory approval.

Specific site monitoring should be performed during the treatment program to obtain information related to the treatment process and subsurface characteristics. Sufficient monitoring locations to determine ISOTEC efficiency and regulatory compliance should be sampled and analyzed. ISOTEC suggests utilizing a representative number of monitoring points within the area of treatment for ground water analyses. Ground water samples should be collected and analyzed for targeted organics, total organic carbon (TOC), total dissolved solids (TDS), total iron (Fe), sulfate, pH and any other regulatory parameter required by the State. Field parameters measured by ISOTEC during the treatment program include aqueous qualitative tests for the oxidizer and catalyst. **Post**

treatment samples should be collected three weeks after each 9-10 day round of field injection activities has taken place. It is ISOTEC's understanding RMT will be responsible for all ground water monitoring and any soil sampling which may be conducted. Pre and post soil sampling (targeted organics, TOC, Fe, sulfate and pH) is recommended to verify soil organic loading decreases in the finer grained saturated aquifer soils. ISOTEC may ask for split samples during each sampling event. All split sample costs will be the responsibility of ISOTEC. Results of all ground water and soil samples should be submitted to ISOTEC for inclusion into the final pilot report.

A bound report, will be submitted outlining details of the ISOTEC process, field activities, laboratory analysis, with recommendations and/or a proposal for continued remediation of the entire contaminant plume, as necessary.

Treatment Program & Reporting costs include:

Initial Treatment Application (est. 40-50 direct push injection points) *$130,700.00*

- *includes: estimated 18-20 days of field injection activities, ISOTEC chemicals; all labor, equipment, travel, mobilization and demobilization costs, health and safety plan plus treatment program summary report.*

Notes:

1. *ISOTEC will require standard AC electrical power and a source of water supply to perform pilot program activities. Access and costs associated with this request will be provided/incurred by the Client and/or Property Owner. ISOTEC will supply AC electrical power at a cost of $100/day, if requested.*
2. *Work to be performed in modified Level D personal protective equipment (PPE). Higher level PPE will require a change order for additional costs associated with such.*
3. *Should regulatory and or regulatory/client meetings be necessary to obtain approvals, only direct travel and associated direct expenses will be billed.*
4. *Additional injection activities into the same injection points are typically billed at a rate of 8-10% less than the initial treatment application cost.*
5. *ISOTEC requires adequate and secure staging area for reagent preparation.*
6. *Pilot Program reagent volume costs presented within this proposal are based on a standard single treatment dosage as outlined within the Lab Study (LS) scope. Actual reagent volume to be utilized for field activities will be a standard single treatment dosage based on LS results with optimum reagent dosage determined.*
7. *Costs associated with permits have not been included within this proposal and are not the responsibility of ISOTEC.*
8. *Pilot program scheduling is based on a first come first serve basis, with an authorized proposal (or subcontract) being the primary basis for scheduling, followed by payment history. ISOTEC will not schedule field work without an authorized proposal (or subcontract), or outstanding receivables over 30 days.*

The ISOTEC Oxidative Approach

ISOTEC's treatment approach (2 nine-ten day field events) for the site is based upon the high levels of dissolved phase contaminants in ground water and anticipated levels of sorbed contamination within the finer grained aquifer saturated soils. The ISOTEC process works through contaminant desorption from the soil phase, the conversion of product into an aqueous phase, followed by oxidation in the aqueous phase. Areas where high concentrations of organics exist require a greater amount of reagent to be applied as the high organic concentration causes a more aggressive reaction and the oxidant is rapidly consumed. ISOTEC utilizes a stabilized low concentration hydrogen peroxide as their oxidant, which allows the reaction (i.e. formation of hydroxyl radicals) to continue for up to 21 days. Therefore, detectable levels of dissolved phase contaminants sometime increase in an area during the initial oxidative field events. This is typically caused by the desorption process of organics from the site soils and initial reagent quantities calculated not being sufficient to oxidize all organic contamination which may have been present in the treatment area. This is overcome by additional treatment applications, as proposed by ISOTEC, and an increase in total reagent volume injected.

Agency Approvals and Permits

The ISOTEC process has been accepted by several EPA Region's and numerous state agencies, including California, Florida, Pennsylvania, New York and New Jersey, as a remedial treatment alternative. ISOTEC typically schedules treatment programs within 45 days following issuance of a permit-by-rule authorizing a discharge to a Class V Underground Injection Control (UIC) system under the National Pollutant Discharge Elimination System (NPDES) regulations or similar State guidelines.

Costs associated with regulatory authorization are typically budgeted based upon the status and phase of the project. As this case appears to be under an active program, ISOTEC anticipates minor questions and/or delays in obtaining approvals from the regulatory agency. For this case, ISOTEC would submit a letter report to the regulatory agency requesting a 180 day pilot treatment program (typical regulatory approval time frame). It should be noted that treatment program approval may not be granted until full delineation of the contaminated plume has been completed.

Costs have not been budgeted for the submission of a more comprehensive report, such as a Remedial Action Workplan (RAW), if requested by the regulatory agency. ISOTEC will submit a separate proposal for preparation of a more comprehensive report, if requested.

Summary of Lab Study & Pilot Program Costs

Lab Study (lump sum)	*$6,500.00*
Initial Treatment Application (two field events)	*$130,700.00*
Remedial Treatment Report	*N/C*
TOTAL	***$137,200.00***

Terms and Conditions

This estimate is based upon on numerous assumptions and the information received from Client and that ISOTEC has not inspected the proposed site and test area. If ISOTEC determines upon receipt of additional data and future site visits to the test area conditions varying from that reviewed, treatment costs within this estimate may vary significantly. Free phase product if noted during the remedial pilot treatment program and full scale remediation, and additional and/or different contaminant compounds or concentrations not listed within the data supplied will effect the overall degree of contaminant removal. Should any free phase and/or contaminant compounds not noted within the data presented be encountered, ISOTEC shall be allowed an additional amount to cover the cost involved in performing the ISOTEC process on a full scale remedial treatment.

Prices quoted on materials, equipment, excavation and repair costs are subject to federal, state or municipal taxes which may be imposed prior to the actual shipment of materials and equipment.

All consulting prices quoted are pending Agency approval of remedial plans as submitted. Substantial modifications imposed by the approving Agency may incur additional charges. Any additional charges will be discussed with the client for approval prior to the initiation of additional work.

Client agrees to prevent unauthorized persons from entering the work area. If any unauthorized persons enter the work area, ISOTEC will not be responsible for any injury or damage which may occur to that individual or his property. Client shall provide a complete utility markout and map of all known underground utilities. Injection point locations may be modified pending a review of subsurface utility locations.

The work performed pursuant to this proposal will be undertaken in a professional manner in accordance with best prevailing industry standards. ISOTEC shall not be liable for direct, indirect, incidental, special or consequential damages or liability caused by pollutants remaining on the property or adjacent property due to acts or omissions by ISOTEC or its subcontractors unless such damages or liabilities are caused by ISOTEC's or its subcontractors' failure to act in a professional manner in accord with prevailing industry standards. ISOTEC's liability for such failure to act shall not exceed the value of this contract measured by the fees paid by client or due under this contract and fees previously paid or due for work performed at the property or in connection therewith. No limitation of liability shall apply however for damages, either direct or indirect for bodily injury, property damage, or otherwise due to ISOTEC's or its subcontractors' willful misconduct or gross negligence.

Any payment due which is not received within 30 days will be subject to a service charge of 1.5% monthly. Any payments not received within sixty (60) days will be put out for collection. Payment terms for lump sum and T&M items (invoiced monthly) are net 30 days, and are as follows:

Lab Study	100% at signing of contract
Treatment Program (lump sum)	50% upon written authorization to proceed with each treatment application & prior to field activities 50% upon completion of each application

This Agreement and the rights and duties of the parties, shall be governed by and construed in accordance with the laws of the State of New Jersey. The parties consent to the jurisdiction of the State courts of the State of New Jersey, and agree that venue shall be proper in any such courts to the exclusion of the courts in any other State or Country. The parties further agree that such designated forum is proper and convenient. The parties hereby unconditionally and irrevocably waive any and all rights to a trial by jury in any suit, counterclaim, or cross-claim arising in connection with, out of, or otherwise relating to this Agreement.

ISOTEC shall help obtain required Agency permits/approvals and comply with all applicable laws. Permit fees are not included within the quoted prices and shall be itemized separately to include an additional 15% handling charge, or be paid directly by the Client.

All prices quoted are valid for a period of sixty (60) days from the time this proposal was written. After a period of 60 days, ISOTEC will not be held to the terms and prices quoted herein.

We hope that this proposal will meet your needs and look forward to working with you on this project to a satisfactory completion. We trust that you find this proposal acceptable and indicate so by signing in the space provided below. If you have any questions or need additional information, please contact me at (609) 275-8500 extension 119.

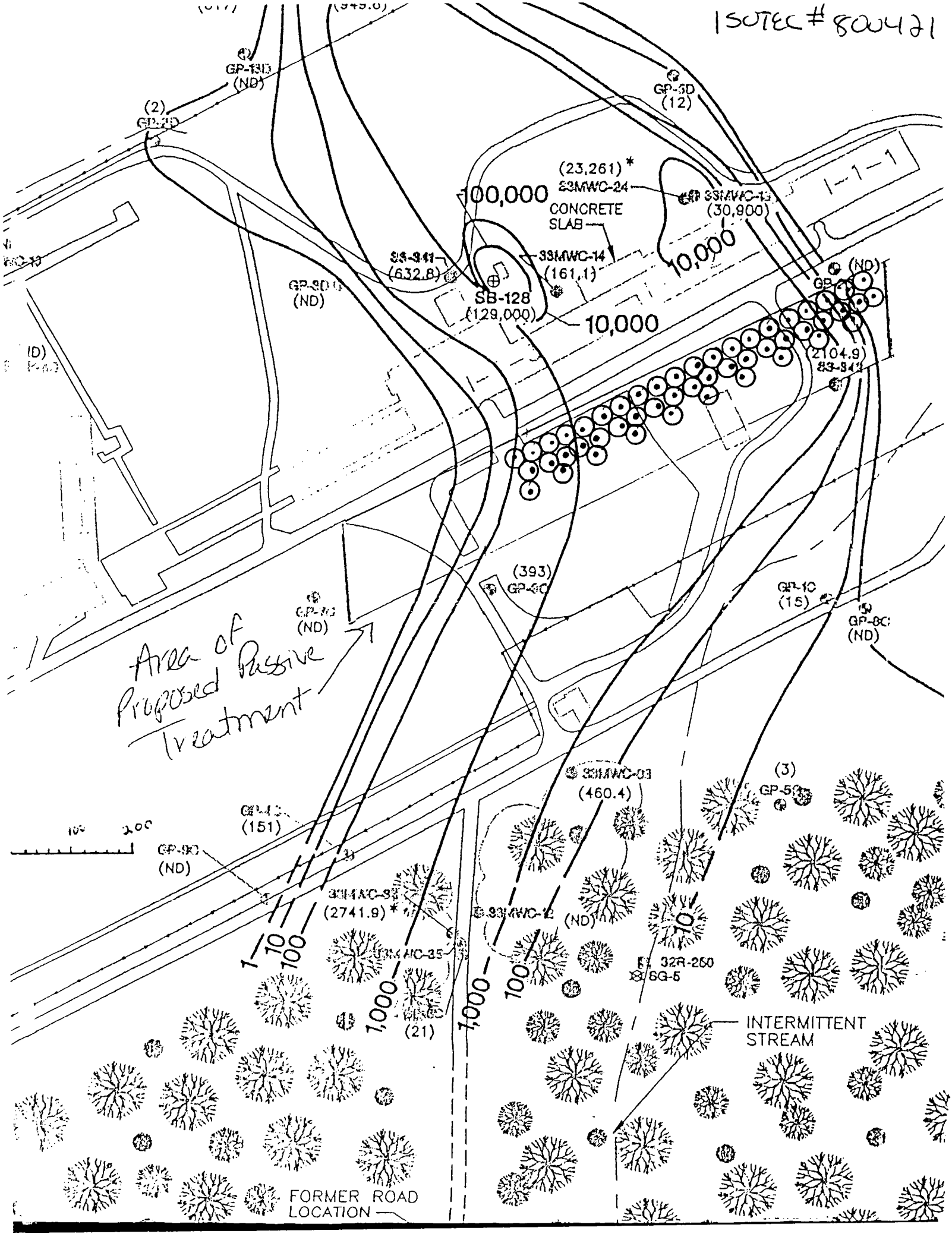
Very truly yours,
In-Situ Oxidative Technologies, Inc.

David S. Zervas, President

ACKNOWLEDGED AND ACCEPTED:

_____ _____
(print name, title) (signature, date)

ISOTEC # 800421



ISOTEC Bench Test Procedures for a Soil-Water Matrix

ISOTEC performs bench scale testing to achieve the following objectives:

- Demonstrate proof that the oxidative process is effective under site-specific conditions.
- Demonstrate proof of the effectiveness of the oxidative process in the presence of aquifer solids (i.e. soil).
- Demonstrate proof that the oxidative process is capable of achieving significant contaminant destruction.
- Determine the optimum mix for subsequent pilot scale testing by performing the bench testing using various catalyst/oxidizer amendments.

Sample Collection

Please refer to attached ISOTEC's "Laboratory Study Sample Collection Protocol" for exact information on sample collection. Site soil for bench testing shall be collected at a location representative of site contamination and characteristics. Soils may be collected from different locations and composited, if necessary, to obtain a representative sample. A minimum of 6000 grams of soil should be collected via decontaminated hand auger or sampling trowel. One- (1) liter amber jars with screw top caps may be used to collect soils if they are contaminated. If the soils collected are not contaminated, Zip Lock bags may be used for sample collection. In addition, one soil sample should be collected in a 4-oz jar and tightly capped for use during bench testing for control purposes.

Site groundwater for bench testing shall be collected from a monitoring well point exhibiting highest contamination after 3 well volumes have been purged. Samples from wells containing free product cannot be used during bench scale testing, and shall be excluded. A minimum of 3 liters of groundwater should be collected and stored in glass containers with zero headspace (no preservative to be used). In addition, two samples should be collected in 40-ml vials preserved in HCl to be used during bench testing for control purposes.

Reaction Vessel Preparation

The laboratory experiments will be performed in 120 ml sealed batch reactors. For each vessel, adequate site soil and groundwater will be introduced to achieve 1:1(w/w) soil-water slurry, leaving enough headspace for pre-determined reagent volumes to be injected. The vessels will be sealed with caps fitted with Teflon lined septa to facilitate subsequent injections of reagent. Samples of the site soil and groundwater will be collected for subsequent analyses to determine the initial concentrations of VOCs in the reaction vessels.

Bench Test Treatments

The bench scale experiments will be performed by injecting a series of catalyst and oxidizer amendments into the reaction vessels. The stoichiometric molar ratio of the reagent combination utilized will be different in each reaction vessel. The merits of stepwise injection will be compared to single aggressive treatment for each reagent combination used. The total volume of external reagent solution utilized in each treatment vessel will be equalized by injecting adequate volume of distilled water as may be necessary. The lab study monitoring will be conducted by setting up parallel monitoring vessels in a similar manner, which will receive same doses as the corresponding main reaction vessels. Samples will be periodically withdrawn from the monitoring vessels for hydrogen peroxide analysis. Additional treatments to designated reaction vessels will be injected based on residual peroxide concentrations remaining. One of the reaction vessels will initially be isolated for control purposes and will receive equivalent volume of distilled water to compensate for reagent volumes injected into treatment vessels.

Following the last treatment, all reaction vessels will remain undisturbed at room temperature for 24 hours or until such time that the oxidizer is completely consumed. Soil and groundwater from each of the reaction vessels will be analyzed for residual VOC concentrations.

Sample Analyses

The results of sample analysis of the 40-ml vials collected in the field will establish groundwater quality in the pilot study area at the Site.

The samples generated from the treatability studies will be submitted to a certified analytical laboratory for VOC analyses by Method 624/ 8260. The samples will include:

- The 40 ml vial "field" collected sample;
- The 4 oz jar "field" collected soil sample;
- The "initial conditions" soil and groundwater samples collected during preparation of the reactor vessels;
- The "control" sample from the reactor vessel to which only distilled water was injected; and
- The treatment samples from the reactor vessels to which varying volumes of catalyst and hydrogen peroxide were injected.

In addition, site soil will be tested for Fe, Mn, and TOC concentrations to evaluate the native conditions. Results of analyses performed on these samples will be evaluated to determine if the objectives of the bench testing stated at the beginning have been achieved.

ISOTEC Laboratory Study Sample Collection

In order to perform an ISOTEC lab study, a representative soil and/ or groundwater sample must be collected from an area of concern at the site exhibiting the highest detected levels of contaminants.

Please purge the well prior to groundwater sampling. Field and trip blanks are not required. For soil samples, please collect a representative soil sample or a composite. A summary of the sample containers required for our volatile organics (VOC) laboratory study is provided below. Higher volumes will be needed for Semivolatile organics (SVOC) laboratory study. Please contact ISOTEC for sample requirements other than VOCs.

*****Please ensure zero head space in 1 liter jars and 40 ml vials*****

For Groundwater Treatability Study Only (VOC-Test Only)

Container Type	Number of Containers	Preservative
1 liter, amber	2	None
40 ml vials	2	HCl
250 ml, amber	1	None

For Both Soil-Slurry Treatability Study and Groundwater Treatability Study (VOC-Test Only)

Container Type	Number of Containers	Sample Type	Preservative
1 liter, amber	5	Groundwater	None
40 ml vials	2	Groundwater	HCl
250 ml, amber	1	Groundwater	None
1 gal-Zip lock bags/ Paint cans/ 1-liter amber jars/ other glass jars	3 (approx. 15-lbs soil)	Soil	None

The samples should be packaged in a cooler (with ice) and shipped overnight (AM) delivery to the following address:

In-Situ Oxidative Technologies, Inc.
51 Everett Drive, Suite #A-10
West Windsor, New Jersey 08550
Attn: Prasad Kakarla

If you should need to be supplied with sample containers and/or a sample shuttle, they are provided by ISOTEC at an additional charge. Please enclose a standard chain-of-custody with the samples. **In addition, please enclose contaminant information by including latest laboratory analytical data on the above samples collected.**

ISOTEC must be notified **at least 48 hours** prior to sample shipment to prepare for lab study.

If you should have any questions concerning the sampling event, please do not hesitate to contact Jim Revak (ext. 109) or Prasad Kakarla at (609) 275-8500 (ext. 111).

August 1, 2001

Jack Anderson, P.E.
RMT
744 Heartland Trail
Madison, WI 53717-1934

RE: Ferox Project at Crab Orchard Site,

Dear Jack:

ARS Technologies Inc. is pleased to present this budgetary level cost estimate for application of our patented chemical reduction technology, Ferox^{sm}, for treatment of TCE impacted groundwater located at the Crab Orchard NWR, located in Marion, Illinois.

In reviewing the data package provided to ARS, ARS believes an integrated approach using our patented zero valent iron (ZVI) powder technology to address both dissolve phase ground water contamination and source zone contamination will provide for effective treatment at the site.

TECHNOLOGY BACKGROUND

ARS' Ferox^{sm} technology is a patented in-situ subsurface remediation process for the treatment of halogenated organic compounds. The Ferox^{sm} technology involves the subsurface injection and dispersion of specific quantities of highly reactive zero-valent iron powder directly into the saturated contaminated zone at the site.

In-situ chemical reduction of organic compounds using ZVI has been extensively studied in the form of permeable reaction barriers or funnel/gate systems. However, the PRB's rely exclusively on the flow of ground water and treat only soluble phase compounds. These systems are not capable of addressing adsorbed contaminants bound to the soil and are cost effectively limited below depths of 20-25 feet bgs. In addition, the conventional excavation method is not applicable when buildings, structures and utilities are present at the site. The Ferox^{sm} technology presents a breakthrough from such limitations.

ARS' expertise in subsurface injections and fracturing provides a unique method of applying the ZVI to overcome the limitations of conventional technologies through direct access and remediation of the both dissolved and adsorbed organic compounds. A significant advantage of the Ferox^{sm} process is that it provides the ability to modify injection parameters and iron dosages to mirror subsurface contaminant heterogeneities present at the site. As a result, in-situ treatment times are dependent upon average contaminant concentrations rather than being limited by the highest levels present.

The ZVI used by ARS in all its Ferox[sm] applications is a 98+% pure reduced powder imported from Japan. The powder's particle size, shape and carbon content result in an extremely reactive material. Numerous laboratory tests have demonstrated the superior reactivity benefits of this powder over cheaper, less pure domestic-grade iron powders.

TECHNICAL APPROACH

In developing a corrective action strategy for the SB-128 plume and source areas, ARS used several assumptions based upon prior technology applications to derive budgetary cost estimates. Specifically, these assumptions included:

Down-gradient Plume Treatment

Length of treatment zone	1000	Ft
Width of treatment zone	70	Ft
Average Thickness of treatment zone	7	Ft
Treatment zone volume	490000	ft3
Soil bulk density	105	lb/cu ft
Mass of soils	51450000	Lb
Est. Mass of iron required based upon 0.5 % iron to soil mass ratio	257250	lb
Volume of Groundwater	147000	Ft
	4163040	L
Concentration of TCE in water	5	mg/L
Mass of dissolved TCE	20.8	Kg
Mass of Iron based upon a 200:1 Iron to TCE Ratio	9159	lb
	4163	Kg
Number of injection points	48	
Mass of iron per hole	1700	Lb
	772.9	Kg
Mass of iron per injection interval	728.8	Lb
	331.3	Kg

In utilizing the more conservative iron dosage criteria of 0.5% of soil mass, the overall Ferox[sm] reaction zone would be comprised of 32 injection points to create a subsurface reaction zone 70 feet wide, 7 feet thick and 1000 feet long. The purpose of this reactive zone will be to treat dissolved phase TCE migrating within the ground-water down-gradient from source area SB-128. In our cost estimate, it was assumed that a TCE

ground water concentration of 5000 ug/l would be treated to below 250 ug/l. Based upon other applications, it can be expected that this iron dosage will have a minimum lifespan of 2+ years.

In addition to the down-gradient plume treatment area, this proposal also suggests the use of the Ferox^{sm} application within the two source areas located up-gradient. Based on site information, the total mass of TCE present in soil within the two source areas located up-gradient of the proposed reactive zone was estimated. The volumes were calculated using the contoured cross sections provided by RMT, assuming a circular area. Mass calculations were made using a soil bulk density of 100 lb/cu ft. Total iron calculations were made using a TCE to iron ration of 200:1. Results are given in the tables below.

Source Area 1

Concentration [100 mg/kg]	Volume of Soil [ft^3]	Mass of Soil [kg]	Mass of TCE [kg]	Total Iron Required @ 200:1 ratio [kg]
100	2,453	111,500	11.15	2,230
50	16,622	755,545	37.8	7,560
10	288,645	131,202	131.2	26,240
5	328,130	14,915,000	74.6	14,920
1	306,150	13,915,909	13.9	2,780
			Total [kg]	**53,730**
			Total [lbs]	**118,206**

Source Area 2

Concentration [100 mg/kg]	Volume of Soil [ft^3]	Mass of Soil [kg]	Mass of TCE [kg]	Total Iron Required @ 200:1 ratio [kg]
10	9,950	452,272	4.5	900
5	91,533	4,160,591	20.8	4,160
1	1,307,550	59,434,091	59.4	11,880
			Total [kg]	**16,940**
			Total [lbs]	**37,268**

Please note: The total iron amount calculated for the two source zones (155,474 lbs), is based on chemical loading estimates. Physical restrictions of the formation may limit the actual injection amounts and cannot be determined until injections are initiated. With ARS' experience, we feel that 100,000 lbs of iron powder is a more realistic amount that could be emplaced within these low permeable zones.

COST BUDGET BREAKDOWN

The overall turn-key cost budget to install the plume treatment system as defined above is **$750,500**. This cost is inclusive of all design, Treatability Testing, drilling, injections and

one round of post injection soil and ground water sampling to confirm the iron powder distribution in the subsurface. This cost is broken down as follows:

Project Management/Site Meetings/Design/Mobilization/Demobilization	$55,000
Ferox^{sm} Material 257,250 lbs	$430,000
Ferox^{sm} Injections (3-4 weeks)	$250,000
Post Injection Sampling/Data Analysis and Reporting	$15,500
	$750,500

The overall turn-key cost budget to install the source zone treatment systems as defined above is **$175,000**. This cost is inclusive of all Design, Treatability Testing, drilling, injections and one round of post injection soil and ground water sampling to confirm the iron powder distribution in the subsurface. This cost assumes the source areas will be completed under the plume treatment system mobilization. The cost is broken down as follows:

Project Management/Site Meetings/Design/Mobilization/Demobilization	$0
Ferox^{sm} Material 1000,000 lbs	$96,000
Ferox^{sm} Injections (1 week)	$175,000
Post Injection Sampling/Data Analysis and Reporting	$5,000
	$276,000

Factors Affecting Cost and Performance of System

The largest variable in the overall treatment approach proposed above is the subsequent mass loading of TCE originating from the SB-128 area into the plume treatment system. Unless the SB-128 source zone is treated, it is difficult to estimate the lifespan of the plume treatment system. In both our cost derivations above, ARS has utilized an excess of iron to serve as an engineering factor of safety to accommodate the changing contaminant transport conditions at the site. Though we have estimated loadings of ZVI into the subsurface, the physical limit that one can emplace within the sand aquifer or the caly layers in the source zones is not known at this time. Only after the field injections are initiated, can the injectable quantity of ZVI be concluded.

Please contact us at 732-296-6620 with any questions related to our cost estimates.

Sincerely,

John J. Liskowitz
President

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