Evaluation of the Effectiveness of the M-Area Extraction System

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**EVALUATION OF THE EFFECTIVENESS
OF THE M-AREA EXTRACTION SYSTEM**

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S. S. PAPADOPULOS & ASSOCIATES, INC.
CONSULTING GROUND-WATER HYDROLOGISTS

**EVALUATION OF THE EFFECTIVENESS
OF THE M-AREA EXTRACTION SYSTEM**

PREPARED FOR
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EVALUATION OF THE
EFFECTIVENESS OF THE M-AREA EXTRACTION SYSTEM

INTRODUCTION

The effect of the M-Area extraction system on ground-water flow patterns in the vicinity of the M-Area was investigated using the ground-water flow model of the A- and M-Areas developed by S. S. Papadopoulos & Associates, Inc. The purpose of this investigation was to:

- 1) evaluate the performance of the extraction system, in terms of its capability to prevent migration of volatile organic chemicals from the M-Area, and
- 2) evaluate the length of time required to remove ground water from the capture zones of the extraction wells.

The effectiveness of the ground-water extraction system was evaluated by calculating where the ground water that is pumped from the extraction system enters the ground-water table as recharge, and by calculating the flow paths and travel times for this ground water from the recharge area to the extraction wells. If the ground-water flow paths to the extraction wells encompass the zones containing the chemicals of concern, the extraction system, if operated long enough, will prevent migration of the chemicals from the M-Area. The time required to reduce the concentrations of the chemicals in the ground water is a function of the pattern of ground-water velocity created by the extraction system, the properties of the chemicals of concern, the nature of the source of the chemicals, and the interaction of the chemicals with the ground-water environment. This investigation was focused

on the patterns of ground-water velocity created by the extraction system, the zones of capture for the extraction wells, and the rate of ground-water evacuation from the capture zones.

A diagram of the general ground-water flow pattern toward a typical extraction well in the M-Area is shown on Figure 1. This diagram illustrates concepts that are important to understanding and evaluating the effectiveness of the extraction system. Figure 1 shows the ground-water flow paths toward the extraction well in both plan view and cross-section. The region that encompasses all of the flow paths that end at the well is referred to as the zone of the capture. All ground water within the zone of capture will ultimately discharge at the well (assuming that the well is operated continuously) and all recharge to the ground-water environment within the zone of capture will discharge at the well.

It is important to note the three-dimensional aspects of the zone of capture within the complex aquifer system in the M-Area. The recharge that occurs to the area defined by the intersection of the zone of capture with the water table ^{is assumed to} ~~will~~ equal the pumping rate of the extraction well. The pathways and the time of travel from the water table within this controlled area to the extraction wells will be influenced by the hydraulic properties of the ground-water environment as well as the rate of recharge.

~~Not a transient~~
water removed from volume outside zone of capture.

The evaluation of effectiveness of the M-Area extraction system consisted of three main work items:

- 1) calculation of the zones of capture for the extraction wells;
- 2) calculation of travel times within the zones of capture; and

- 3) estimation of the extent of ground water within the M-Area that contains volatile organic chemicals.

METHODS

The zone of capture for each of the extraction wells and ground-water travel times were calculated by 1) using a ground-water flow model to determine the velocity pattern within the ground-water environment, and 2) using a particle tracking scheme to determine the flow paths and travel times from the water table to each of the extraction wells.

The ground-water flow model of the A- and M-Area will be described in a separate report, and will not be discussed in detail. The A- and M-Areas were simulated by dividing the ground-water environment into five layers as shown schematically on Figure 2. Layers 1, 2, and 3 correspond to the intervals 220-240 feet, 172-220 feet, and 135-172 feet above mean sea level, respectively. The hydraulic properties assigned to each of the layers in the ground-water flow model are listed in Table 1. The values for effective vertical hydraulic conductivity shown in Table 1 were derived from the leakage coefficients used in the ground-water flow model. In simulating the M-Area extraction system, the pumping rates listed in Table 2 were assigned to each of the extraction wells. These rates correspond to the average rate of pumping from the extraction system during November of 1985.

The particle tracking scheme used in the study is a three-dimensional analysis of ground-water flow characteristics developed by S. S. Papadopoulos & Associates, Inc. The scheme tracks particles backward from the extraction

wells to the water table given the three-dimensional velocity distribution calculated with the ground-water flow model.

The extent of ground water containing volatile organic chemicals in the vicinity of the M-Area was calculated by adding the average concentrations of tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene measured in the monitoring and extraction wells in 1985. These data were analyzed graphically to estimate the extent of ground water containing more than 100 ppb of volatile organic chemicals within the depth intervals corresponding to layers 1, 2, and 3 in the ground-water flow model.

RESULTS

The areal extent of the zones of capture of the extraction wells at the water table (layer 1 in the model) is shown on Figure 3. Some of the calculated flow paths are also shown (in plan view), with tick marks delineating five-year travel-time intervals. Approximately 30 years is required for ground water to travel from the water table at the edges of the zone of capture to the extraction wells. The plan view of the zones of capture of the extraction wells within the depth interval corresponding to model layer 3 is shown as the shaded area on Figure 3. The plan view of the capture zones within layer 3 is about 40 percent smaller than the areal extent of the capture zones at the water table. The plan view of the capture zone in layer 2 is only slightly smaller than the extent of the capture zone at the water table because ground-water movement within model layer 1 is predominantly vertical.

A cross section through the capture zone of extraction well RWM-8 is

shown on Figure 4. The flow paths and travel times to the extraction well are also shown on this figure.

The estimated extent of ground water within the depth interval corresponding to model layer 3 that contained more than 100 ppb of volatile organic chemicals in 1985 is shown superimposed with the calculated capture zone on Figure 5. Note that ground water containing more than 100 ppb of volatile organics extended downgradient of the calculated zone of capture of the extraction system. Upgradient of the extraction wells, much of the region containing ground water with more than 100 ppb of volatile organics is within the calculated zone of capture.

The calculated capture zone in layer 2 and the extent of ground water within the corresponding depth interval containing volatile organic chemicals in excess of 100 ppb is shown on Figure 6. A similar diagram depicting conditions in model layer 1 is shown on Figure 7. In both layers 1 and 2, the calculated capture zones encompass a large portion, but not all, of the region containing ground water with total volatile organic concentrations in excess of 100 ppb.

CONCLUSIONS

1. The ground-water extraction system in the M-Area is capturing a large part, but not all, of the ground water containing concentrations of volatile organic chemicals that exceed 100 ppb.
2. The zones of capture for the extraction wells do not extend any appreciable distance below the depth of the wells and do not extend

more than about 300 feet downgradient from the southernmost wells in the system.

3. The travel time from the peripheral parts of the capture zones at the water table to the extraction wells is estimated to be about 30 years.

a) Plan view of flow to extraction well

b) Cross-sectional view of flow to extraction well

EXPLANATION

- Zone of capture
- Projection of typical ground-water flow path with flow direction
- Direction of regional ground-water flow

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GENERAL PATTERN OF GROUND-
WATER FLOW TO AN EXTRACTION
WELL IN THE M-AREA

FIGURE
1

¹ Elevation of formation contacts vary throughout modeled region.

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DEFINITION OF HYDROGEOLOGIC UNITS
IN GROUND-WATER FLOW MODEL

FIGURE
2

EXPLANATION

- Extent of calculated zones of capture at the water-table
- Calculated zone of capture in layer 3
- Areal projection of typical ground-water flow path.
Travel time between tick marks is five years
- Extraction wells
- Location of cross section shown in figure 4

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ZONES OF CAPTURE OF
M-AREA EXTRACTION SYSTEM

FIGURE
3

EXPLANATION

- Calculated zone of capture.
- Approximate ground-water flow path with flow direction.
Travel time between tick marks is one year.
- Approximate contour of equal travel times, in years.

EXPLANATION

Calculated Extent of Zone of Capture

- △ < 10
- ▲ 10-100
- 100-1,000
- > 1,000

Average Total Volatile Organic
Concentration in 1985, in ppb

— 100 — Estimated extent of ground water containing
total volatile organics greater than 100 ppb

EXPLANATION

Calculated Extent of Zone of Capture

- △ < 10
- ▲ 10-100
- 100-1,000
- > 1,000

Average Total Volatile Organic
Concentration in 1985, in ppb

--- 100 --- Estimated extent of ground water containing
total volatile organics greater than 100 ppb

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AVERAGE TOTAL VOLATILE ORGANIC CONCENTRATIONS IN 1985 AND
CALCULATED AREAL EXTENT OF ZONE OF CAPTURE IN LAYER 2

FIGURE
6

EXPLANATION

Calculated Extent of Zone of Capture

< 10

10-100

100-1,000

> 1,000

Average Total Volatile Organic
Concentration in 1985, in ppb

— 100 —

Estimated extent of ground water containing
total volatile organics greater than 100 ppb

$\Sigma^2\text{P}$

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AVERAGE TOTAL VOLATILE ORGANIC CONCENTRATIONS IN 1985 AND
CALCULATED AREAL EXTENT OF ZONE OF CAPTURE IN LAYER 1

FIGURE
7

TABLE 1
HYDROGEOLOGIC PROPERTIES USED IN GROUND-WATER FLOW MODEL

Layer	Transmissivity (ft ² /day)	Effective Vertical Hydraulic Conductivity (ft/day)
1	175	.0061
2	2,210	.020
3	1,290	.015
4	1,580	.011
5	12,440	.0065

TABLE 2
PUMPING RATES OF M-AREA EXTRACTION WELLS

Well Number	Pumping Rate* (gpm)
RWM1	25.3
RWM2	2.2
RWM3	45.7
RWM4	34.0
RWM5	50.6
RWM6	21.8
RWM7	26.6
RWM8	27.8
RWM9	42.1
RWM10	31.2
RWM11	41.6
Total	348.9

* Pumping was distributed equally between layers 2 and 3. Rates are for November 1985.

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