GROUNDWATER FLOW MODEL
WAUSAU WATER SUPPLY NPL SITE

Wausau, Wisconsin

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Wausau, Wisconsin

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CONESTOGA-ROVERS & ASSOCIATES

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1.0 INTRODUCTION

The City of Wausau is located in central Wisconsin along the Wisconsin River in Marathon County. Since 1985, numerous studies have been performed characterizing subsurface soils and groundwater conditions within the east and west (in relation to the Wisconsin River) public water supply well fields. Analyses of samples from the public water supply wells had shown contamination by volatile organic compounds (VOCs) and the Wausau Water Supply Site (site) was listed on the National Priorities List (NPL) in December 1985.

Groundwater contamination, consisting primarily of VOCs, was identified in both the east and west water supply well fields . Two locations were identified as the primary sources of the VOC contamination impacting the east side wells and two locations were similarly identified as the primary sources of the VOC contamination impacting the west side wells.

Following issuance of the Record of Decision (ROD) by the United States Environmental Protection Agency (EPA) in September of 1990, Wausau Chemical Corporation, Marathon Electric Manufacturing Company and the City of Wausau (the PRP Group) negotiated a Consent Decree and accompanying scope of work with EPA and the Wisconsin Department of Natural Resources (WDNR), for the PRP Group to design and implement the final remedy.

As specified in Paragraph 12.A.3.c. of the Consent Decree, a groundwater flow model for the Wausau Water Supply NPL Site has been developed. The Consent Decree states that the purpose of the model is "to provide U.S. EPA with information by which to assess the impact of any proposed changes to the municipal groundwater extraction Performance Standards listed in 3.a. and 3.b. [of the Consent Decree]." A copy of the applicable sections of the Consent Decree is provided as Appendix A.

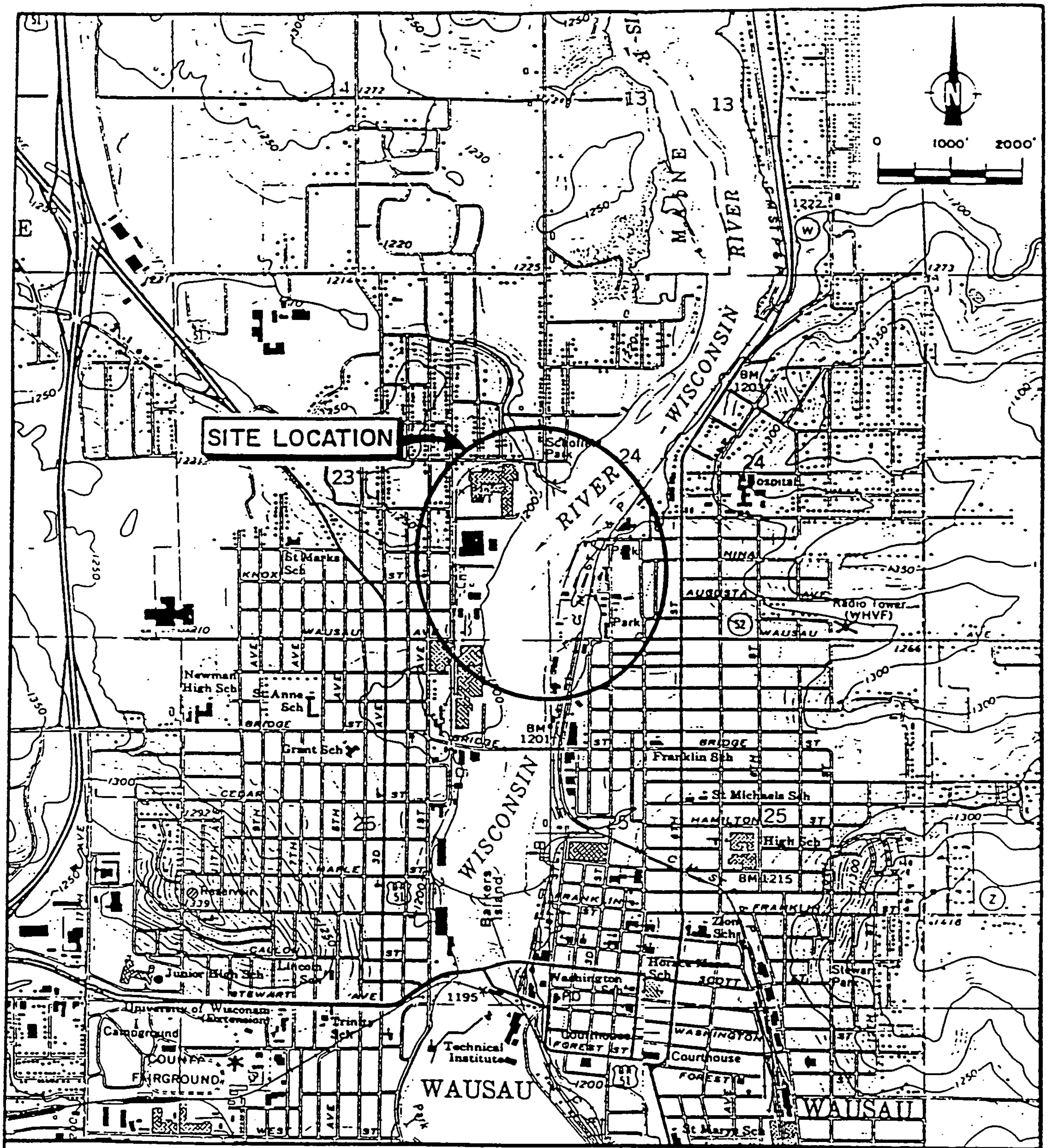
1.1 SITE DESCRIPTION

The Wausau Superfund Site (site) is located within the City of Wausau which is located in north-central Wisconsin along the Wisconsin River, Marathon County, Wisconsin. Figure 1.1 shows the location of the Site and Figure 1.2 presents a Site plan. The Site consists of two areas separated by the Wisconsin River. The property comprising the former City of Wausau landfill is presently owned by Marathon Electric and is located on the west side of the Wisconsin River. The east side location is owned by Wausau Chemical. These two locations are considered source areas for contaminants in the aquifer which is the source of drinking water for the City of Wausau.

The City presently operates seven production wells, six of which are located on the north side of the City. The seventh well, CW-8, is located adjacent to the Wausau Municipal Airport on the south side of the City. Figure 1.2 shows the location of the City water supply wells within the Site. Production wells CW-6, CW-7, CW-9 and CW-10 are located west of the Wisconsin River and are collectively referred to as the west well field. Production wells CW-3 and CW-4 are located on the east side of the Wisconsin River and are referred to as the east well field. Presently, the water from CW-8 has a high concentration of iron and is used only during peak demand periods. The water from CW-4 is also used only during peak demand periods.

The west well field is located in a predominantly residential area. Wausau Chemical is located between production wells CW-3 and CW-4. The east well field is located in a predominantly industrial section of the City. The former City of Wausau landfill is located on the south side of the Marathon Electric property, south of the City of Wausau's west well field. The approximate limits of the former landfill, as determined from a 1942 aerial photograph, are also shown on Figure 1.2.

A groundwater extraction well (EW1) was installed in November 1990 on the Marathon Electric property north of the former City landfill. The approximate location of EW1 is shown on Figure 1.2. EW1



SOURCE : U.S.G.S. WAUSAU WEST QUADRANGLE MAP.

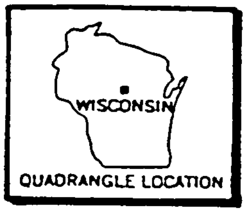


figure 1.1
SITE LOCATION
Wausau Superfund Site

CRA

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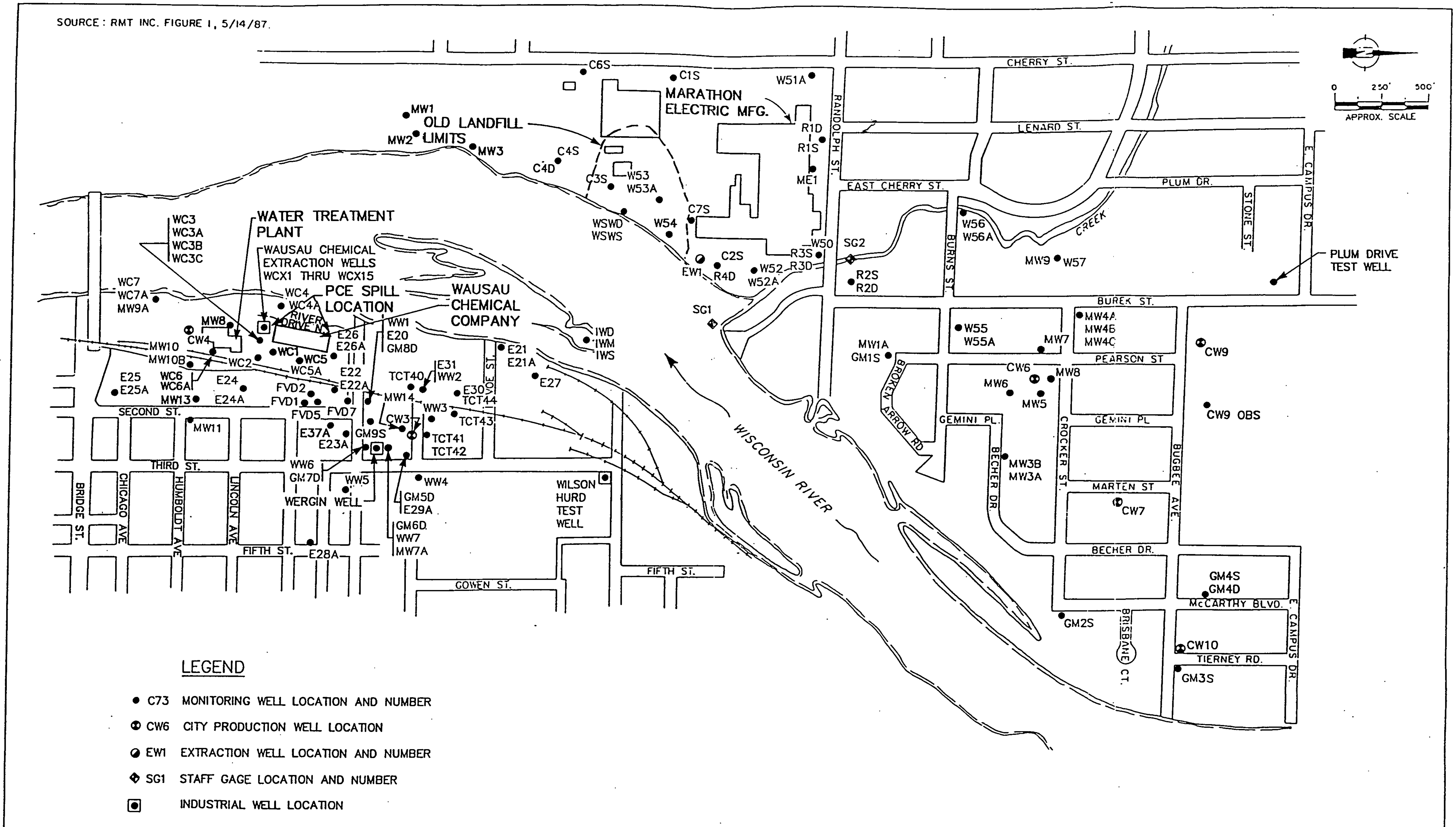


figure 1.2

SITE PLAN

Wausau Superfund Site

CRA

3978-22/05/91-2-0

initially extracted groundwater at an approximate flow rate of 1,600 gallons per minute (gpm). In January 1991, CRA submitted a report entitled "Evaluation of Pumping Rate in Extraction Well No. 1, Marathon Electric Manufacturing Company, Wausau, Wisconsin". The report recommended that the pumping rate for the extraction well be reduced to approximately 800 gpm. The EPA provided written approval of the reduction in the pumping rate and on January 31, 1991, the pumping rate for the extraction well was reduced. The extraction well is currently operating at approximately 850 gpm.

1.2 HYDROGEOLOGIC SETTING

Marathon County is situated near the margin of the exposed Precambrian Shield. The bedrock in the Wausau area is predominantly Precambrian igneous and metamorphic rocks of the Lower and Middle Proterozoic age.

Glacial deposits underlying the Site consist of glacial outwash and alluvial sediments which have filled in the preglacial stream valley in which the Wisconsin River now follows. The surface topography of the project area is controlled by the underlying Precambrian bedrock topography, glacial deposition and post-glacial erosion.

The seven production wells for the City of Wausau provide drinking water for approximately 33,000 people. These wells are screened in the glacial outwash and alluvial sand and gravel deposits which underlie and are adjacent to the Wisconsin River. This alluvial aquifer ranges from 0 to 160 feet thick and has an irregular base and lateral boundaries. The boundaries of the aquifer are defined by the relatively impermeable bedrock which underlie it and form its lateral boundaries within a preglacial valley.

Groundwater flow within the unconfined glacial aquifer has been drastically changed by the installation and operation of EW1 and the City production wells. Under natural conditions, groundwater would flow toward and discharge to the Wisconsin River and its tributary, Bos Creek.

Under existing conditions, however, groundwater flows toward the extraction well and production wells during pumping. Prior to operation of EW1, the natural groundwater flow directions were frequently reversed due to the City well pumping. The pumping of the east well field has appeared to have affected groundwater flow west of the Wisconsin River. Monitoring well nests located at the Marathon Electric property indicated a very slight downward gradient adjacent to the Wisconsin River. Pumpage of the east well field induced recharge of surface water into the aquifer and induced groundwater below the river and on the west side of the river to flow toward CW3. Based on water level data collected since commencing operation of the extraction well, the extraction well has created a cone of influence which extends below the river. The extraction well effectively contains and collects groundwater contamination on the west side of the river south of CW6.

For a more detailed site description and site history, see the RD/RA Work Plan.

2.0 FLOW MODEL DESCRIPTION

Modeling has been used to estimate the optimum pumping rates and minimize well interference associated with excessively large cones of influence for municipal wells CW3 and CW6 and extraction well EW1.

The computer modeling was performed using Flowpath (Version 3) developed by Waterloo Hydrogeologic Software of Waterloo, Ontario, Canada. Flowpath is a numerical, two dimensional horizontal aquifer simulation model. A finite difference method is employed to solve the governing equation for steady-state horizontal flow in heterogeneous, anisotropic, saturated, porous media. Flowpath was selected for the modeling task in the approved RD/RA work plan.

A detailed description of Flowpath is provided in Appendix D of the RD/RA Work Plan.

3.0 FLOW MODEL PARAMETERS

The initial flow model input parameters such as hydraulic conductivity, porosity and aquifer thickness were based on available geologic and hydrogeologic data contained in previous Site reports.

The boundary conditions chosen for the model (constant head, no flow and specified flux) were also based on data available in previous reports and from the Wausau East and Wausau West USGS 7.5 minute quadrangles.

The infiltration values chosen for the model are based on the average precipitation of the area which is 32 inches/year and on the assumption that about two-thirds of the precipitation is lost through evapotranspiration (Kendy and Bradbury, 1988). The river node leakage factors were estimated from typical hydraulic conductivities for sand and gravel sediments and also from leakance values reported by Warzyn for the MODFLOW model which they developed for the Site (Warzyn, July 1989).

4.0 MODEL SETUP AND CALIBRATION

The Flowpath groundwater flow model produces a solution for horizontal flow and the calculated heads are representative of the average head for the entire thickness of the aquifer at a given point. Where vertical gradients become significant, such as near extraction wells, the head solution may not compare well to measured groundwater elevations.

The simulated heads generated for each calibration run were compared to groundwater elevation field data collected on May 20, 1992. Selected monitoring wells were matched to the nearest model node and the simulated and field measured heads were compared. A "sum of differences squared" value was calculated for each calibration run. The values for the model parameters -- hydraulic conductivity, infiltration and river leakage, were systematically raised or lowered to fine tune the head distribution of the model and, thus, minimize the "sum of differences squared" for the calibration well network. Typically, hydraulic conductivity was adjusted along with infiltration or river leakance. In general, if the adjustment was intended to affect the head distribution near the river, then the river leakance and K were adjusted. If the adjustment was intended to affect the head distribution near the east or west model boundaries, then infiltration and K were adjusted.

The early calibration adjustments were generally uniform across the entire model where infiltration and K were both increased by approximately 25 percent. Later adjustments were more selective in nature as the process became more of a "fine tuning" of the head distribution.

The model setup for the final calibration run is presented on Table 4.1. These setup parameters can be compared to the precalibration setup presented on Table 4.2. A 4510 node grid was constructed for a 10,000 foot by 15,000 foot area around the Site. A plot of the grid is shown on Figure 4.1. The grid consists of 54 columns and 81 rows. The grid spacing is smallest in the Site area to increase the accuracy of the simulated heads near the pumping wells.

FLOW PATH model

TABLE 4.1

GROUNDWATER FLOW MODEL SET UP

Grid Area	-	10,000 ft E/W x 15,000 ft. N/S
Nodal Density	-	55 columns x 82 rows
Hydraulic Conductivity	-	50 ft/day - 300 ft/day
Aquifer Thickness	-	90 feet to 140 feet
Northwest Boundary	-	Specified Flux
Southwest Boundary	-	No Flow
South Central Boundary	-	Constant Head, 1,189 to 1,192 ft.
East Boundary	-	No Flow
Northwest Boundary	-	Constant Head, 1,192 ft.
Hydraulic Gradient	-	0.008
River Surface Elevation	-	1,187 to 1,188 ft.
River Bottom Elevation	-	1,160 to 1,180 ft.
River Leakage Factor	-	0.05 to 0.11 ft/day/ft
Precipitation Infiltration	-	0.002 to 0.02 ft/day (9" to 88"/yr)

Calibration Pumping Rates

CW3	-	1,040,000 gal/day (722 gpm average)
CW4	-	0 gal/day (0 gpm)
CW6	-	1,294,000 gal/day (900 gpm average)
CW7	-	765,000 gal/day (530 gpm average)
CW9	-	270,000 gal/day (188 gpm average)
CW10	-	2,117,000 gal/day (1,470 gpm average)
EW1	-	1,228,000 gal/day (850 gpm average)
Wergin	-	210,000 gal/day (145 gpm average)

TABLE 4.2

PRECALIBRATION MODEL SET UP

Grid Area	-	10,000 ft E/W x 15,000 ft. N/S
Nodal Density	-	38 columns x 61 rows
Hydraulic Conductivity	-	River Area: 90 ft/day East of River: 75 ft/day West of River: 75 to 50 ft/day
Aquifer Thickness	-	90 feet to 140 feet
Northwest Boundary	-	Specified flux, 4.0 to 4.5 gpd/ft^2
Southwest Boundary	-	No flow
South Central Boundary	-	Constant head, 1,189 to 1,192 ft.
East Boundary	-	No flow
Northwest Boundary	-	Constant head, 1,192 ft.
Hydraulic Gradient	-	0.01
River Surface Elevation	-	1,187 to 1,188 ft.
River Bottom Elevation	-	1,160 to 1,175 ft.
River Leakance Factor	-	0.05 to 0.09 ft/day/ft
Precipitation Infiltration	-	0.0 to 0.01 ft/day

FLOW MODEL GRID

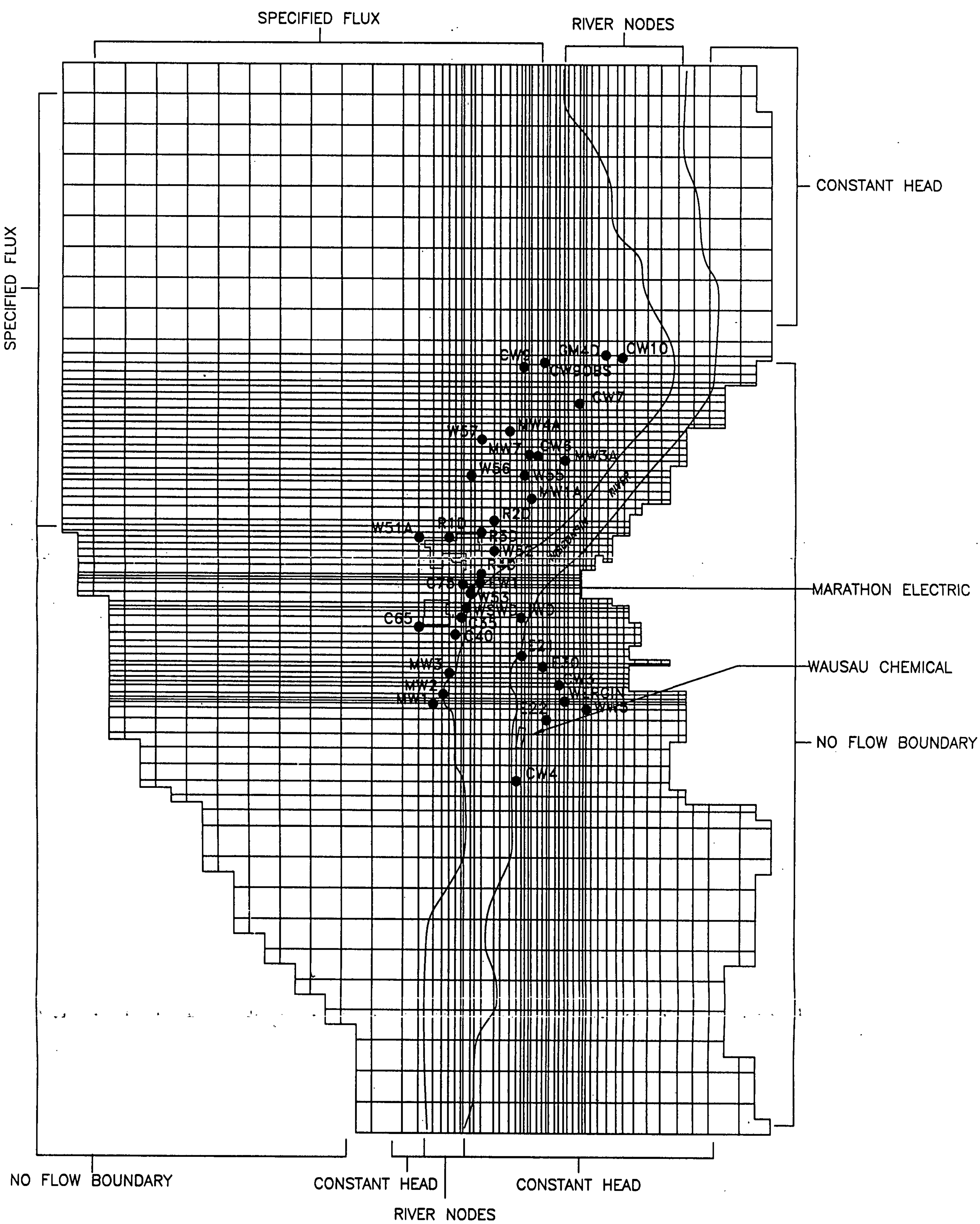


figure 4.1

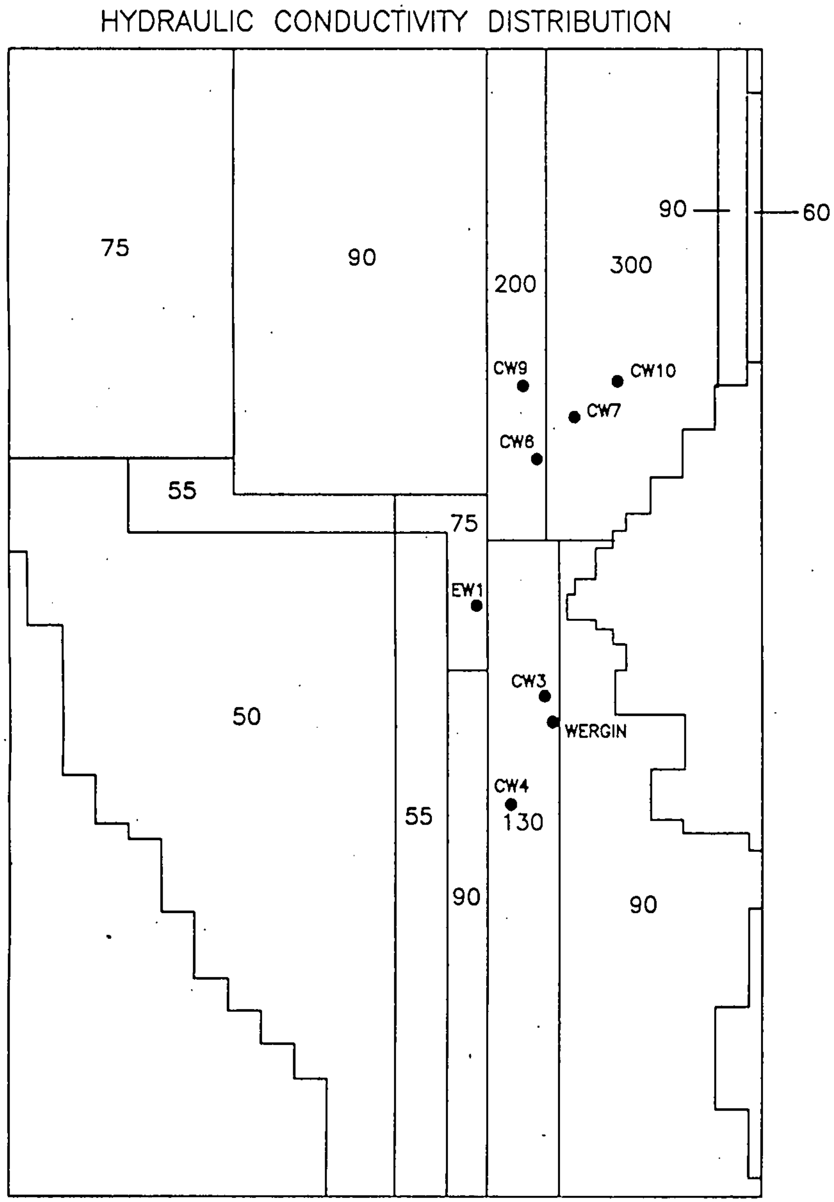
Boundary conditions, aquifer properties and recharge are defined and can be varied for each block on the grid.

No-flow boundaries were set on the southwest and east sides of the model where the crystalline bedrock is near the ground surface. No-flow boundaries were not set on the northwest side of the model to allow for the groundwater flux through the Bos Creek drainage.

Specified flux boundaries were set along the northwest corner of the model. The flux values were chosen to create a horizontal hydraulic gradient of approximately 0.008, which approximates the west-northwest to east-southeast gradient shown on the water level contour figures provided in Warzyn's RI. Specified flux boundaries were used instead of constant head boundaries to alleviate equipotential contour distortion which, potentially, can be caused by boundary interference. The specified flux was increased approximately 20 percent during the calibration process.

Constant head boundaries were set near the river on the north and south ends of the model. The heads were chosen to create a horizontal hydraulic gradient of approximately 0.005 with the flow direction going toward the river. The gradient of 0.005 was chosen based on the assumption that the gradient would flatten near the river where the hydraulic conductivities are higher in the central part of the river valley.

The initial hydraulic conductivities were estimated based on pumping tests performed on EW1 and CW6 and from slug tests performed on several monitoring wells on both sides of the river. During the many calibration runs, hydraulic conductivity input values were continually adjusted to attain a better match at specific wells and portions of the Site. This calibration process serves to refine the results from field testing to attain a more representative regional understanding of the hydraulic conductivity distribution. This is a reasonable procedure since slug tests and pumping tests measure small portions of the aquifer compared to the regional domain under investigation. The resulting distribution of hydraulic conductivities (K) chosen for the model are shown on Figure 4.2. The K values range from 50 feet/day to 300 feet/day. The higher values are centered on the river



50 ft/day
55 ft/day
60 ft/day
75 ft/day
90 ft/day
130 ft/day
200 ft/day
300 ft/day

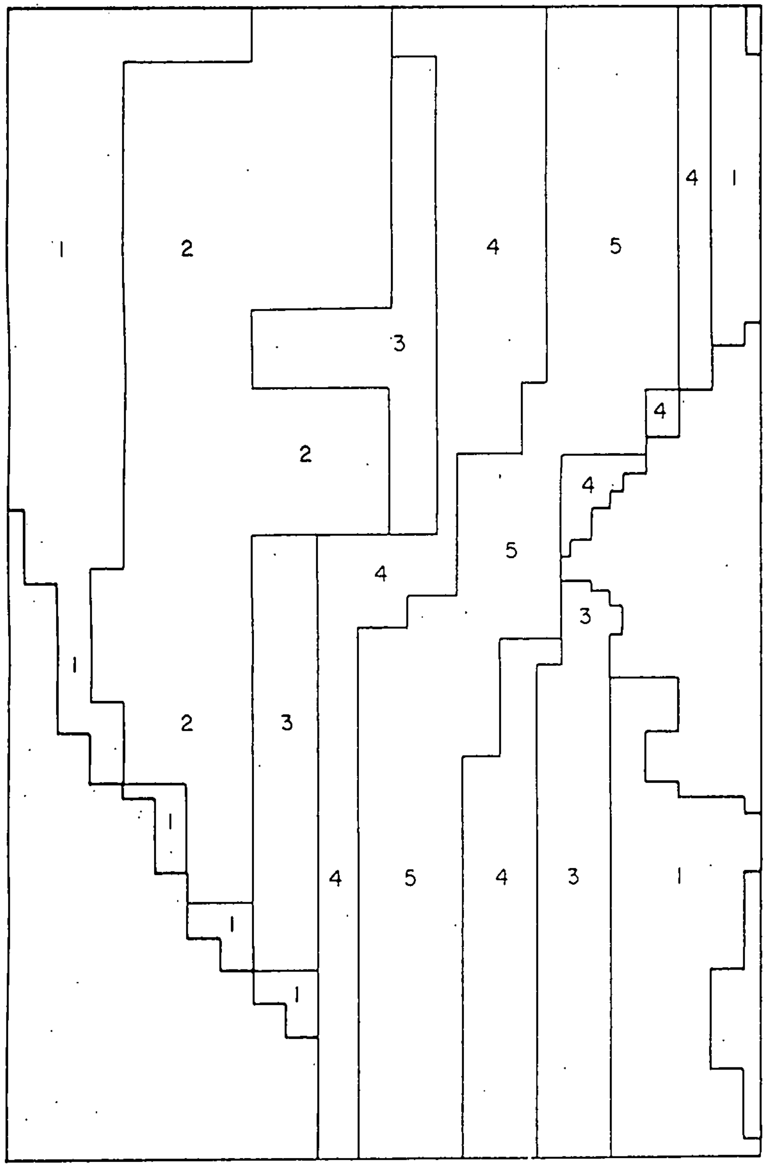
figure 4.2

channel and gradually decrease toward the sides of the model. This is reasonable considering the more permeable sediments were likely deposited in the central portion of the river valley. Also, the northern half of the model has higher K values than the southern half. The hydraulic conductivities chosen for the model approximate values reported by previous investigations. For example, Warzyn reported Ks from 21 single well response tests ranging from 0.5 to 230 feet/day with an average of 67 feet/day and calculated a K of 420 feet/day at CW6. CRA calculated a K of 310 feet/day at EW1 and Kendy and Bradbury (1988) report a hydraulic conductivity of 173 feet/day for Wausau well number 9. The effective porosity (the amount of interconnected pore space through which fluids can pass) of the entire aquifer model is set at 25 percent, which is typical for alluvial sand (Fetter, 1988). The effective porosity has not been varied for the different K values.

The distributions of aquifer base elevations and precipitation infiltration throughout the solution domain are shown on Figures 4.3 and 4.4. The aquifer base elevations are based on borehole data, cross-sections and bedrock contour maps contained in the Warzyn RI. Along the edges of the model the aquifer thicknesses were set greater than those measured in the field. This was done to help prevent computation problems during the iteration process for unconfined aquifers. In early model runs the calculated heads fell below the base of the aquifer, necessitating an increase in thickness near the edge of the model. This is well outside the area of interest and had little impact on the flow patterns in the central portion of the modeled area.

The calibrated precipitation infiltration rates range from 0.002 to 0.02 feet/day. The higher rates are distributed along the model boundaries to help prevent the iteration problems described above. Also, runoff from the bedrock highs would result in increased infiltration where the bedrock is intersected by the valley alluvium. During the calibration process, the increased infiltration along the southwest boundary was removed as a method for reducing the groundwater flux in the southern part of the model.

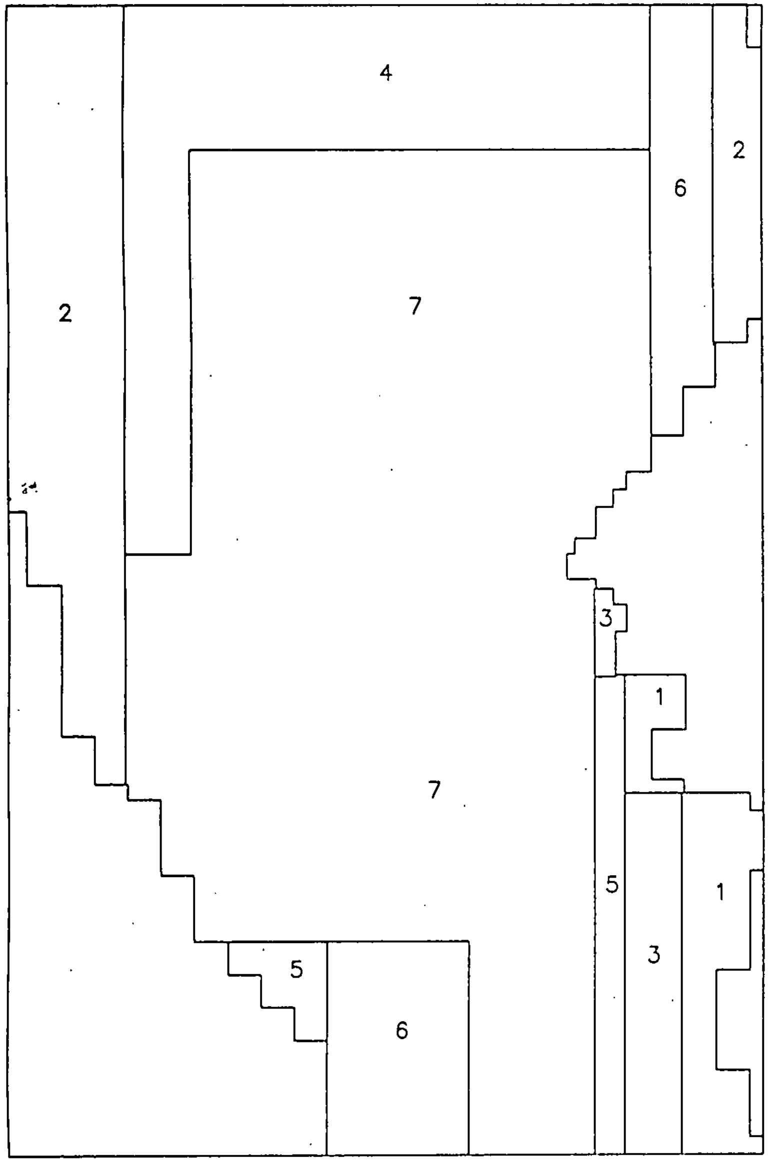
BOTTOM OF AQUIFER ELEVATIONS



1	=	1100 ft. AMSL
2	=	1095 ft. AMSL
3	=	1090 ft. AMSL
4	=	1070 ft. AMSL
5	=	1050 ft. AMSL

figure 4.3

INFILTRATION RATE DISTRIBUTION



1 0.02 ft/day
2 0.01 ft/day
3 0.008 ft/day
4 0.004 ft/day
5 0.003 ft/day
6 0.002 ft/day
7 0.0025 ft/day

figure 4.4

The river node leakage factors were adjusted during the preliminary runs to achieve the best fit across the Site. The leakage factors are based on the thickness and hydraulic conductivity of the river bed: $L = \frac{K}{d}$

where: L = leakage factor

K = hydraulic conductivity

d = thickness of the river bed

The values for the K and d parameters are assumptions. The K of the river bed is assumed to be less than that of the aquifer due to the accumulation of more fine grained sediment since the dam was constructed. The river bed thickness is assumed to be in the range of five to ten feet.

The calibrated river node leakage factors range from 0.05 to 0.11 feet/day/foot. The resultant factors increase gradually from south to north. The leakage factors for the south part of the river were not changed from the factors used for the original model setup. The factors for the northern portion of the river were increased slightly to increase the contribution of the river to the groundwater system. The river bottom elevations were based on geologic cross-sections contained in the Warzyn RI and range from 1160 to 1182 feet above sea level (ASL). The river surface elevation was set at 1188 feet ASL on the north end to 1187 feet ASL on the south end.

The model setup is calibrated to a May 20, 1992, groundwater elevation monitoring round conducted by CRA. Therefore, the city well and extraction well (EW1) discharge rates were set at the average rates for May, 1992. Average pumping rates over longer periods of time are more accurate measures of resultant stress on the aquifer than the specific pumping rates on the day the wells were monitored because the distribution of head within the aquifer is a product of the accumulated stress that pumping has caused over a period of time. Flowpath assumes that the extraction wells are fully penetrating. This assumption is valid for pumping wells CW3, CW6, CW7, CW9 and CW10 because, when they are pumping, the unconfined aquifer draws down to or very near their respective screened intervals and Flowpath is able to solve this non-linear relationship. EW1 is a partially penetrating well which is screened in the lower half of the aquifer. This partial penetration affects the observed water levels for observation wells which are screened in the upper portion of the aquifer and are less than approximately 600 feet from EW1. The water levels in such wells would be less than would be expected if the pumping well and observation wells were fully penetrating. This is why, where possible, deeper aquifer wells were used for the calibration well network.

The pumping rates used for the model setup are as follows:

CW3	-	1,040,000 gallons/day (722 gpm average)
CW4	-	0 gallons/day
CW6	-	1,294,000 gallons/day (900 gpm average)
CW7	-	765,000 gallons/day (530 gpm average)
CW9	-	270,000 gallons/day (188 gpm average)
CW10	-	2,117,000 gallons/day (1,470 gpm average)
EW1	-	1,228,000 gallons/day (850 gpm average)
Wergin	-	210,000 gallons/day (145 gpm average)(1)

The pumping rates for the city wells were provided by the Wausau Water and Sewer Utilities.

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(1) It has since been learned that the Wergin well was not pumping in May 1992. The model was calibrated assuming, incorrectly, that the Wergin well was pumping. The affect this has on the model setup is that the calculated head distribution in the area of CW6 is slightly lower than it would be if the Wergin well was not pumping. The Wergin well pumping rate was set at 210,000 gallons per day (gal./day), which is about 16 percent of the rate at CW6 (1,294,000 gal./day), which is the only other city well pumping on the east side of the river. For the full scale of the model, 210,000 gal./day represents only about 3 percent of the discharge from the city wells and EW1. This minor error and the slight difference it may have created in the model setup has a negligible affect on the regional head distribution for which the model is intended. The model setup may be slightly less accurate for predicting heads in the area of CW6, but is valid and useful for predicting drawdown, flow directions and capture areas for the regional flow system of the well field areas.

The Wergin well pumping rate was estimated from a rate reported in Appendix C of the Warzyn Feasibility Study (Warzyn, August 1989).

The pumping rate for extraction well EW1 is based on the current constant pumping rate of 850 gpm.

Equipotential contours predicted by the flow model for the final calibration run are shown on Figure 4.5.

Table 4.3 presents the "sum of differences squared" calculation for the final calibration run. Twenty nine monitoring wells were used to compare the simulated head distribution created by the model.

The calibration well network was chosen to cover the area of the east and west city well fields and the area surrounding EW1. Where possible, wells were chosen that are screened in the lower part of the aquifer to lessen errors due to partial penetration effects. The list of potential wells which could be used for calibration was also diminished slightly by the fact that water levels were not always measured on all monitoring wells for a given water level round.

The heads predicted by the model are within 1 foot of the measured groundwater elevations at 16 of the 29 wells. The average difference between the predicted and measured elevations is 1.1 feet. There are, approximately, an even number of simulated heads that are higher and lower than the field measured heads. Most of the larger differences occur at monitoring wells that are either on the far west side of the Site or at the monitoring wells nearest to the pumping wells.

The model calibration was verified further by setting the pumping configuration for a water level monitoring round that was conducted on January 8, 1988. The pumping rates for this calibration run are as follows:

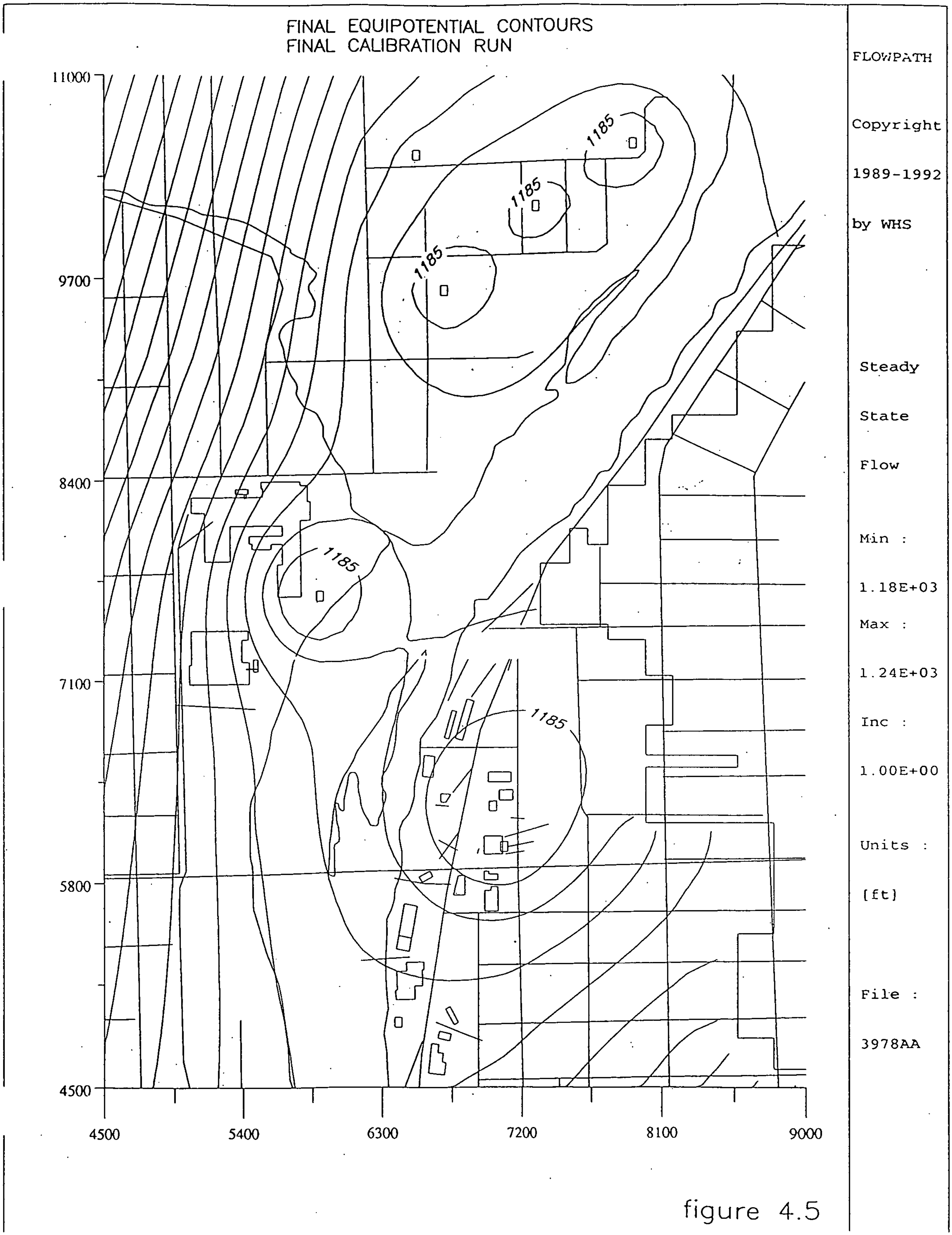

FINAL EQUIPOTENTIAL CONTOURS
FINAL CALIBRATION RUN
11000
9700
8400
7100
5800
4500
4500
5400
6300
7200
8100
9000
1185
1185
1185
1185
1185
FLOWPATH
Copyright
1989-1992
by WHS
Steady
State
Flow
Min :
1.18E+03
Max :
1.24E+03
Inc :
1.00E+00
Units :
[ft]
File :
3978AA

figure 4.5

TABLE 4.3

GROUNDWATER FLOW MODEL
FINAL CALIBRATION RUN

Well No.	Model Coordinates East	Model Coordinates North	05/19/92 Groundwater Elevation (Ft. AMSL)	Model Predicted Elevation (Ft. AMSL)	Difference (Ft.)	Difference Squared
E22	6771	5776	1186.9	1185.9	1.0	1.0
WW5	7355	5926	1186.6	1185.7	0.9	0.8
MW1	5220	6070	1187.8	1188.6	-0.8	0.6
MW2	5344	6135	1187.9	1188.2	-0.3	0.1
MW3	5443	6425	1187.7	1187.8	-0.1	0.0
E30	6773	6514	1187.1	1184.7	2.4	5.8
E21	6577	6669	1187.2	1185.6	1.6	2.6
C4D	5538	6970	1187.3	1187.1	0.2	0.0
C6S	5012	7069	1187.4	1189.0	-1.6	2.4
C3S	5538	7201	1186.5	1186.6	-0.1	0.0
IWD	6520	7201	1187.3	1186.0	1.3	1.6
WSWD	5754	7337	1185.8	1185.3	0.5	0.3
W53	5650	7532	1185.7	1184.6	1.1	1.1
C7S	5620	7650	1185.3	1184.6	0.7	0.5
R4D	5903	7748	1180.5	1181.4	-0.9	0.9
W52	5905	8140	1185.6	1185.5	0.1	0.0
W51A	5010	8330	1186.5	1189.7	-3.2	10.0
R1D	5340	8330	1186.3	1188.0	-1.8	3.1
R3D	5903	8410	1186.0	1186.2	-0.2	0.0
R2D	6086	8570	1186.3	1186.1	0.2	0.0
MW1A	6615	8880	1186.4	1185.7	0.6	0.4
W56	5754	9204	1186.1	1187.5	-1.5	2.1
W55	6470	9204	1186.1	1185.3	0.8	0.7
MW3A	6958	9433	1186.0	1184.7	1.3	1.6
MW7	6580	9624	1182.4	1183.6	-1.2	1.5
W57	5904	9856	1184.9	1187.1	-2.2	4.8
MW4A	6306	9856	1184.0	1185.4	-1.5	2.1
CW9 OBS	6870	10565	1185.0	1185.5	-0.5	0.3
GM4D	7698	10565	1187.0	1184.4	2.6	6.9
				Sum of Differences Squared		51.2

CW3	-	2,000,000 gal/day (1,390 gpm average)
CW4	-	430,000 gal/day (300 gpm average)
CW6	-	1,250,000 gal/day (870 gpm average)
CW7	-	1,800,000 gal/day (1,250 gpm average)
CW9	-	800,000 gal/day (555 gpm average)

The pumping rates for January 7 and 8, 1988 were reported in Warzyn's RI report.

Table 4.4 presents the results of this second calibration. The average difference between the simulated and measured elevations for the second calibration configuration is 2.1 feet. The most significant difference occurs on the south end of the model on the west side of the river at MW1, MW2 and MW3. This may indicate that the model is not good for predicting hydraulic heads for that isolated area south of EW1, however, the model is valid for simulation on the large, regional scale.

4.1 WATER BALANCE

Each time, after running the model, the global water balance was calculated to check the convergence. The Flowpath water balance feature computes all fluxes into and out of the model domain due to pumping or injection, precipitation infiltration, surface water leakage and boundary conditions. To maintain continuity under steady-state conditions, the sum of all fluxes should equal zero. Because Flowpath is a numerical model, there is always some deviation from a perfect water balance. The better the model run has converged, the smaller the global water balance error will be (Flowpath User's Manual, Version 4, Franz and Guiguer, 1991). The maximum tolerance for the water balance error was set at 3 percent based on the recommendation contained in the Flowpath software documentation manual. For non-linear model situations, such as a water table aquifer, the convergence is slow and it is often difficult to reduce the water balance error even for large numbers of iterations (Franz and Guiguer, 1991).

TABLE 4.4

VERIFICATION CALIBRATION

Well No.	Model Coordinates East	Model Coordinates North	01/08/88 Groundwater Elevation (Ft. AMSL)	Model Predicted Elevation (Ft. AMSL)	Difference (Ft.)
E22	6771	5776	1183.8	1183.5	0.3
WW5	7355	5926	1183.5	1182.7	0.8
MW1	5220	6070	1183.7	1188.8	-5.1
MW2	5344	6135	1184.0	1188.3	-4.3
MW3	5443	6425	1183.8	1188.1	-4.3
E30	6773	6514	1184.3	1182.4	1.9
E21	6577	6669	1185.1	1184.9	0.2
C4D	5538	6970	1186.3	1188.3	-2.0
C6S	5012	7069	1186.6	1190.3	-3.7
C3S	5538	7201	1186.4	1188.6	-2.2
IWD	6520	7201	---	---	—
WSWD	5754	7337	---	---	—
W53	5650	7532	---	---	—
C7S	5620	7650	1186.6	1188.8	-2.2
R4D	5903	7748	1186.5	1188.2	-1.7
W52	5905	8140	1186.4	1188.3	-1.9
W51A	5010	8330	1187.3	1191.6	-4.3
R1D	5340	8330	1187.0	1190.2	-3.2
R3D	5903	8410	1186.4	1188.3	-1.9
R2D	6086	8570	1186.2	1187.6	-1.4
MW1A	6615	8880	1185.8	1186.5	-0.7
W56	5754	9204	1186.0	1188.6	-2.6
W55	6470	9204	1185.5	1186.3	-0.8
MW3A	6958	9433	1184.9	1185.5	-0.6
MW7	6580	9624	---	---	—
W57	5904	9856	1184.4	1187.7	-3.3
MW4A	6306	9856	1183.8	1185.9	-2.1
CW9 OBS	6870	10565	1184.1	1185.7	-1.6
GM4D	7698	10565	1186.1	1186.4	-0.3

5.0 SENSITIVITY ANALYSIS

An assessment was performed to determine the sensitivity of the model to incremental changes in the infiltration, river leakage and hydraulic conductivity parameters. Each parameter was individually increased or decreased by 20 percent while keeping all other parameters at their final calibration values. The model sensitivity runs were performed twice for each parameter, once for a 20 percent increase of the final calibration parameter values and once for a 20 percent decrease of the final calibration values.

The "sum of differences squared" calculation was performed after each of the six sensitivity runs. These sums were compared to the final calibration sum to evaluate the model's sensitivity to changes in the various parameters.

The "differences squared" calculations are presented on Tables 5.1, 5.2, 5.3, 5.4, 5.5 and 5.6. The "sum of differences squared" (SDS) value for the final calibration is 51.2. The sensitivity runs show that the model is equally sensitive to changes in infiltration and river leakage. The increases and decreases of both parameters created significant differences to the final calibration run. The SDS values range from 89.6 to 130.8 for the four sensitivity runs performed for these two model parameters.

The model appears to be less sensitive to changes in hydraulic conductivity. A 20 percent increase of K produced a nearly identical SDS value to the SDS of the final calibration run. However, a 20 percent decrease of K introduced a significant amount of error into the model. It is possible that acceptable Ks for the model could fall within the range of those used for the final calibration and those used for the 20 percent increase sensitivity run.

TABLE 5.1

MODEL SENSITIVITY ANALYSIS
20% DECREASE INFILTRATION

Well No.	Model Coordinates East	North	05/19/92 Groundwater Elevation (Ft. AMSL)	Model Predicted Elevation (Ft. AMSL)	Difference (Ft.)	Difference Squared
E22	6771	5776	1186.9	1185.3	1.6	2.6
WW5	7355	5926	1186.6	1184.7	1.9	3.6
MW1	5220	6070	1187.8	1188.8	-1.0	1.0
MW2	5344	6135	1187.9	1188.3	-0.4	0.2
MW3	5443	6425	1187.7	1187.9	-0.2	0.0
E30	6773	6514	1187.1	1184.2	2.9	8.4
E21	6577	6669	1187.2	1185.3	1.9	3.6
C4D	5538	6970	1187.3	1187.3	0.0	0.0
C6S	5012	7069	1187.4	1189.5	-2.1	4.2
C3S	5538	7201	1186.5	1187.8	-1.3	1.6
IWD	6520	7201	1187.3	1185.9	1.3	1.8
WSWD	5754	7337	1185.8	1185.6	0.2	0.1
W53	5650	7532	1185.7	1185.0	0.7	0.4
C7S	5620	7650	1185.3	1185.0	0.3	0.1
R4D	5903	7748	1180.5	1181.8	-1.3	1.8
W52	5905	8140	1185.6	1185.9	-0.3	0.1
W51A	5010	8330	1186.5	1190.9	-4.4	19.0
R1D	5340	8330	1186.3	1188.9	-2.7	7.0
R3D	5903	8410	1186.0	1186.8	-0.8	0.6
R2D	6086	8570	1186.3	1186.6	-0.3	0.1
MW1A	6615	8880	1186.4	1186.1	0.3	0.1
W56	5754	9204	1186.1	1188.5	-2.5	6.0
W55	6470	9204	1186.1	1185.9	0.2	0.0
MW3A	6958	9433	1186.0	1185.2	0.8	0.6
MW7	6580	9624	1182.4	1184.3	-1.9	3.8
W57	5904	9856	1184.9	1188.3	-3.4	11.6
MW4A	6306	9856	1184.0	1186.2	-2.3	5.1
CW9 OBS	6870	10565	1185.0	1186.1	-1.1	1.3
GM4D	7698	10565	1187.0	1184.8	2.2	4.9
				Sum of Differences Squared		89.6

TABLE 5.2

20% INCREASE INFILTRATION

Well No.	Model Coordinates East	North	05/19/92 Groundwater Elevation (Ft. AMSL)	Model Predicted Elevation (Ft. AMSL)	Difference (Ft.)	Difference Squared
E22	6771	5776	1186.9	1186.2	0.7	0.5
WW5	7355	5926	1186.6	1185.1	1.5	2.3
MW1	5220	6070	1187.8	1189.4	-1.6	2.5
MW2	5344	6135	1187.9	1188.9	-1.0	1.0
MW3	5443	6425	1187.7	1188.4	-0.7	0.5
E30	6773	6514	1187.1	1184.5	2.6	6.8
E21	6577	6669	1187.2	1185.5	1.7	2.9
C4D	5538	6970	1187.3	1187.8	-0.5	0.3
C6S	5012	7069	1187.4	1190.5	-3.1	9.4
C3S	5538	7201	1186.5	1187.4	-0.9	0.8
IWD	6520	7201	1187.3	1186.1	1.2	1.3
WSWD	5754	7337	1185.8	1186.0	-0.2	0.0
W53	5650	7532	1185.7	1185.5	0.2	0.0
C7S	5620	7650	1185.3	1185.6	-0.3	0.1
R4D	5903	7748	1180.5	1182.2	-1.7	3.0
W52	5905	8140	1185.6	1186.5	-0.9	0.8
W51A	5010	8330	1186.5	1192.3	-5.8	33.2
R1D	5340	8330	1186.3	1189.9	-3.7	13.3
R3D	5903	8410	1186.0	1187.4	-1.4	1.9
R2D	6086	8570	1186.3	1187.1	-0.8	0.7
MW1A	6615	8880	1186.4	1186.5	-0.2	0.0
W56	5754	9204	1186.1	1189.4	-3.4	11.2
W55	6470	9204	1186.1	1186.4	-0.3	0.1
MW3A	6958	9433	1186.0	1185.6	0.4	0.1
MW7	6580	9624	1182.4	1184.8	-2.4	6.0
W57	5904	9856	1184.9	1189.1	-4.2	17.6
MW4A	6306	9856	1184.0	1186.8	-2.8	8.1
CW9 OBS	6870	10565	1185.0	1186.7	-1.8	3.1
GM4D	7698	10565	1187.0	1185.2	1.8	3.3
				Sum of Differences Squared		130.8

TABLE 5.3

20% DECREASE RIVER LEAKAGE

Well No.	Model Coordinates East	North	05/19/92 Groundwater Elevation (Ft. AMSL)	Model Predicted Elevation (Ft. AMSL)	Difference (Ft.)	Difference Squared
E22	6771	5776	1186.9	1185.4	1.5	2.3
WW5	7355	5926	1186.6	1185.0	1.6	2.6
MW1	5220	6070	1187.8	1189.1	-1.3	1.6
MW2	5344	6135	1187.9	1188.6	-0.7	0.5
MW3	5443	6425	1187.7	1188.1	-0.4	0.2
E30	6773	6514	1187.1	1184.3	2.8	7.8
E21	6577	6669	1187.2	1185.3	1.9	3.6
C4D	5538	6970	1187.3	1187.4	-0.1	0.0
C6S	5012	7069	1187.4	1189.9	-2.5	6.1
C3S	5538	7201	1186.5	1187.0	-0.5	0.2
IWD	6520	7201	1187.3	1185.8	1.5	2.1
WSWD	5754	7337	1185.8	1185.6	0.2	0.1
W53	5650	7532	1185.7	1185.0	0.7	0.4
C7S	5620	7650	1185.3	1185.1	0.2	0.0
R4D	5903	7748	1180.5	1181.7	-1.2	1.5
W52	5905	8140	1185.6	1186.0	-0.4	0.2
W51A	5010	8330	1186.5	1191.4	-4.9	23.6
R1D	5340	8330	1186.3	1189.2	-3.0	8.7
R3D	5903	8410	1186.0	1186.8	-0.8	0.6
R2D	6086	8570	1186.3	1186.6	-0.3	0.1
MW1A	6615	8880	1186.4	1186.1	0.3	0.1
W56	5754	9204	1186.1	1188.7	-2.7	7.0
W55	6470	9204	1186.1	1185.9	0.2	0.0
MW3A	6958	9433	1186.0	1185.2	0.8	0.6
MW7	6580	9624	1182.4	1184.3	-1.9	3.8
W57	5904	9856	1184.9	1188.5	-3.6	13.0
MW4A	6306	9856	1184.0	1186.3	-2.3	5.5
CW9 OBS	6870	10565	1185.0	1186.2	-1.3	1.6
GM4D	7698	10565	1187.0	1184.8	2.2	4.9
				Sum of Differences Squared		98.7

TABLE 5.4

20% INCREASE RIVER LEAKAGE

Well No.	Model Coordinates East	Model Coordinates North	05/19/92 Groundwater Elevation (Ft. AMSL)	Model Predicted Elevation (Ft. AMSL)	Difference (Ft.)	Difference Squared
E22	6771	5776	1186.9	1185.6	1.3	1.7
WW5	7355	5926	1186.6	1185.2	1.4	2.0
MW1	5220	6070	1187.8	1189.1	-1.3	1.6
MW2	5344	6135	1187.9	1188.6	-0.7	0.5
MW3	5443	6425	1187.7	1188.2	-0.5	0.3
E30	6773	6514	1187.1	1184.6	2.5	6.3
E21	6577	6669	1187.2	1185.7	1.5	2.3
C4D	5538	6970	1187.3	1187.6	-0.3	0.1
C6S	5012	7069	1187.4	1190.0	-2.6	6.6
C3S	5538	7201	1186.5	1187.2	-0.7	0.5
IWD	6520	7201	1187.3	1186.3	1.0	0.9
WSWD	5754	7337	1185.8	1185.9	-0.1	0.0
W53	5650	7532	1185.7	1185.4	0.3	0.1
C7S	5620	7650	1185.3	1185.5	-0.2	0.0
R4D	5903	7748	1180.5	1182.2	-1.7	3.0
W52	5905	8140	1185.6	1186.3	-0.7	0.5
W51A	5010	8330	1186.5	1191.6	-5.1	25.6
R1D	5340	8330	1186.3	1189.5	-3.3	10.6
R3D	5903	8410	1186.0	1187.2	-1.2	1.4
R2D	6086	8570	1186.3	1187.0	-0.7	0.5
MW1A	6615	8880	1186.4	1186.4	-0.1	0.0
W56	5754	9204	1186.1	1189.0	-3.0	8.7
W55	6470	9204	1186.1	1186.2	-0.1	0.0
MW3A	6958	9433	1186.0	1185.5	0.5	0.2
MW7	6580	9624	1182.4	1184.5	-2.1	4.6
W57	5904	9856	1184.9	1188.7	-3.8	14.4
MW4A	6306	9856	1184.0	1186.5	-2.5	6.5
CW9 OBS	6870	10565	1185.0	1186.4	-1.5	2.1
GM4D	7698	10565	1187.0	1185.0	2.0	4.1
				Sum of Differences Squared		105.0

TABLE 5.5

20% DECREASE K

Well No.	Model Coordinates East	Model Coordinates North	05/19/92 Groundwater Elevation (Ft. AMSL)	Model Predicted Elevation (Ft. AMSL)	Difference (Ft.)	Difference Squared
E22	6771	5776	1186.9	1185.0	1.9	3.6
WW5	7355	5926	1186.6	1184.4	2.2	4.8
MW1	5220	6070	1187.8	1189.1	-1.3	1.6
MW2	5344	6135	1187.9	1188.6	-0.7	0.5
MW3	5443	6425	1187.7	1188.1	-0.4	0.2
E30	6773	6514	1187.1	1183.7	3.4	11.6
E21	6577	6669	1187.2	1185.1	2.1	4.4
C4D	5538	6970	1187.3	1187.3	0.0	0.0
C6S	5012	7069	1187.4	1189.8	-2.4	5.6
C3S	5538	7201	1186.5	1186.7	-0.2	0.0
IWD	6520	7201	1187.3	1185.8	1.5	2.1
WSWD	5754	7337	1185.8	1185.2	0.6	0.4
W53	5650	7532	1185.7	1184.4	1.3	1.6
C7S	5620	7650	1185.3	1184.4	0.9	0.8
R4D	5903	7748	1180.5	1180.4	0.1	0.0
W52	5905	8140	1185.6	1185.5	0.1	0.0
W51A	5010	8330	1186.5	1191.1	-4.6	20.8
R1D	5340	8330	1186.3	1188.8	-2.5	6.5
R3D	5903	8410	1186.0	1186.4	-0.4	0.2
R2D	6086	8570	1186.3	1186.2	0.1	0.0
MW1A	6615	8880	1186.4	1185.7	0.6	0.4
W56	5754	9204	1186.1	1188.2	-2.2	4.6
W55	6470	9204	1186.1	1185.3	0.8	0.7
MW3A	6958	9433	1186.0	1184.5	1.5	2.2
MW7	6580	9624	1182.4	1183.2	-0.8	0.7
W57	5904	9856	1184.9	1187.7	-2.8	7.8
MW4A	6306	9856	1184.0	1185.4	-1.5	2.1
CW9 OBS	6870	10565	1185.0	1185.4	-0.5	0.2
GM4D	7698	10565	1187.0	1183.9	3.1	9.7
				Sum of Differences Squared		93.2

TABLE 5.6

20% INCREASE K

Well No.	Model Coordinates East	North	05/19/92 Groundwater Elevation (Ft. AMSL)	Model Predicted Elevation (Ft. AMSL)	Difference (Ft.)	Difference Squared
E22	6771	5776	1186.9	1185.7	1.2	1.4
WW5	7355	5926	1186.6	1185.3	1.3	1.7
MW1	5220	6070	1187.8	1188.3	-0.5	0.2
MW2	5344	6135	1187.9	1188.0	-0.1	0.0
MW3	5443	6425	1187.7	1187.6	0.1	0.0
E30	6773	6514	1187.1	1184.6	2.5	6.3
E21	6577	6669	1187.2	1185.5	1.7	2.9
C4D	5538	6970	1187.3	1187.0	0.3	0.1
C6S	5012	7069	1187.4	1188.7	-1.3	1.6
C3S	5538	7201	1186.5	1186.6	-0.1	0.0
IWD	6520	7201	1187.3	1186.0	1.3	1.6
WSWD	5754	7337	1185.8	1185.5	0.3	0.1
W53	5650	7532	1185.7	1185.0	0.7	0.4
C7S	5620	7650	1185.3	1185.0	0.3	0.1
R4D	5903	7748	1180.5	1182.3	-1.8	3.3
W52	5905	8140	1185.6	1185.7	-0.1	0.0
W51A	5010	8330	1186.5	1189.4	-2.9	8.2
R1D	5340	8330	1186.3	1187.9	-1.7	2.7
R3D	5903	8410	1186.0	1186.4	-0.4	0.2
R2D	6086	8570	1186.3	1186.3	0.0	0.0
MW1A	6615	8880	1186.4	1186.0	0.3	0.1
W56	5754	9204	1186.1	1187.5	-1.5	2.1
W55	6470	9204	1186.1	1185.7	0.4	0.2
MW3A	6958	9433	1186.0	1185.2	0.8	0.6
MW7	6580	9624	1182.4	1184.3	-1.9	3.8
W57	5904	9856	1184.9	1187.3	-2.4	5.8
MW4A	6306	9856	1184.0	1185.8	-1.8	3.4
CW9 OBS	6870	10565	1185.0	1185.9	-1.0	0.9
GM4D	7698	10565	1187.0	1185.0	2.0	4.1
				Sum of Differences Squared		51.7

6.0 OPTIMIZATION OF PUMPING RATES

The goal of optimizing pumping rates is to contain and remove contaminants in the groundwater without extending the cones of influence too far and pumping an undue amount of clean water.

The Consent Decree specified that CW3 should be pumped at a minimum rate of 1,100 gpm for at least 100 hours per week and that CW6 should be pumped at a minimum rate of 1500 gpm for at least 100 hours per week. These rates are equivalent to average weekly pumping rates of 655 gpm and 893 gpm respectively. The Consent Decree also assumes an average monthly pumping rate of 1,257 gpm for CW10 and an average monthly rate of 314 gpm each for CW7 and CW9. One goal of the modeling was to assess these pumping rates over the long term and refine the estimates if possible.

The pumping configuration specified by the Consent Decree is essentially the pumping format that the city is presently using. The differences between the two pumping configurations are so minor that they can be considered to be equal. The Consent Decree rates can be compared to the model calibration rates listed on Table 4.1.

For each pumping configuration used in the pumping rate optimization analysis, the calculated head distributions represent steady-state conditions. The average weekly pumping rates were used to simulate long term average pumping stress on the aquifer. The daily (transient) changes in the pumping schedule do not significantly change the head distribution within the aquifer over the long term or at large distances from the pumping.

The Consent Decree pumping rates were substituted into the flow model which was then used to calculate aquifer head distribution and capture zones for the city wells and EW1. The EW1 pumping rate of 850 gpm was not changed. The capture zones estimated for CW3, CW6 and EW1 are shown on Figure 6.1. These capture zones represent the four year capture areas that the wells would create at steady-state conditions. As the figure

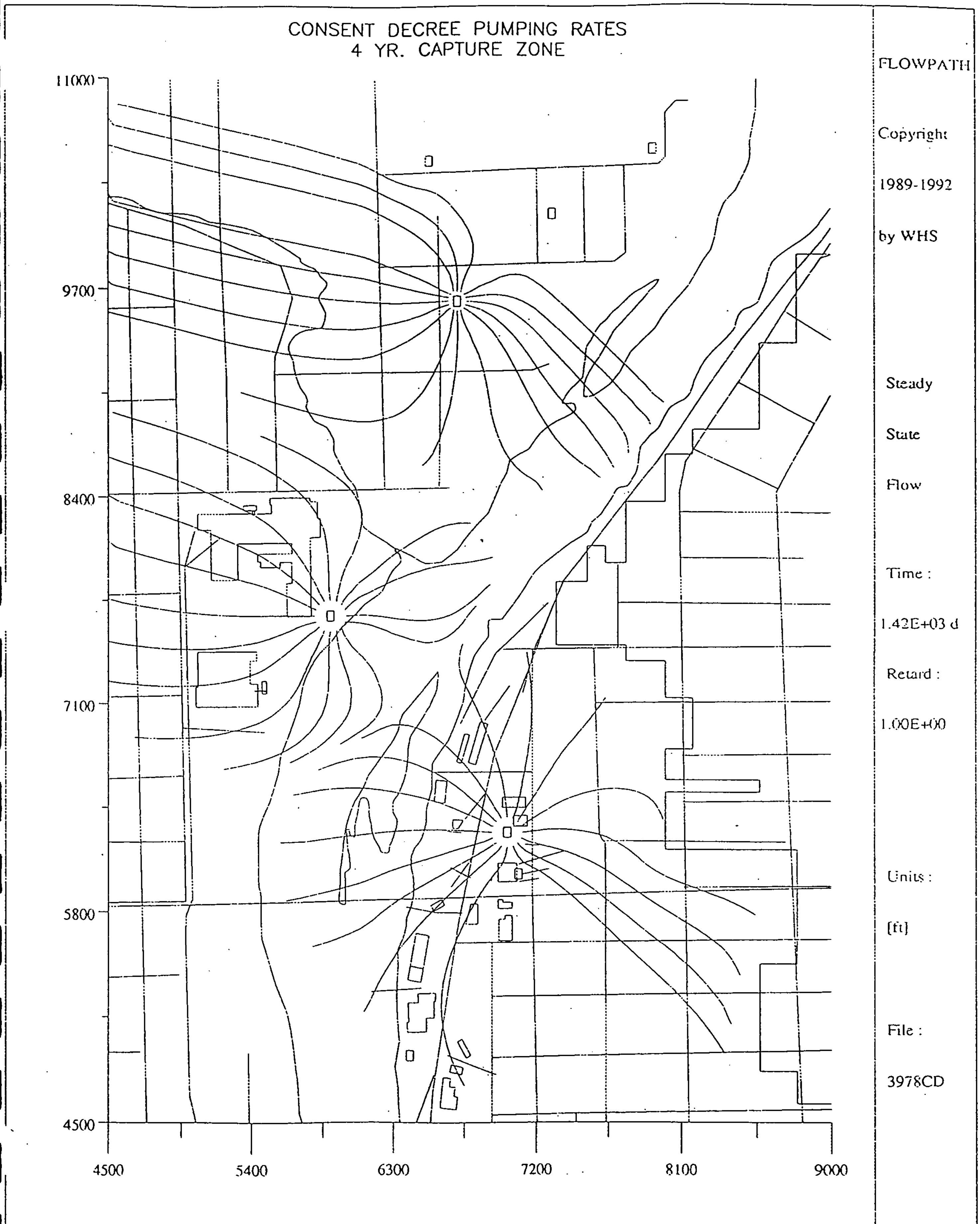

CONSENT DECREE PUMPING RATES
4 YR. CAPTURE ZONE
11000
9700
8400
7100
5800
4500
4500
5400
6300
7200
8100
9000
FLOWPATH
Copyright
1989-1992
by WHS
Steady
State
Flow
Time :
1.42E+03 d
Retard :
1.00E+00
Units :
[ft]
File :
3978CD

figure 6.1

illustrates, the capture zones extend beyond all areas of the contaminated portion of the aquifer. Figure 6.2 shows the one year capture area for the same configuration. This figure shows that CW3 and EW1 are close enough to the source areas to effectively remove contaminated groundwater from beneath the source areas.

Optimizing the pumping configuration for CW3, CW6 and EW1 is intended to achieve two objectives:

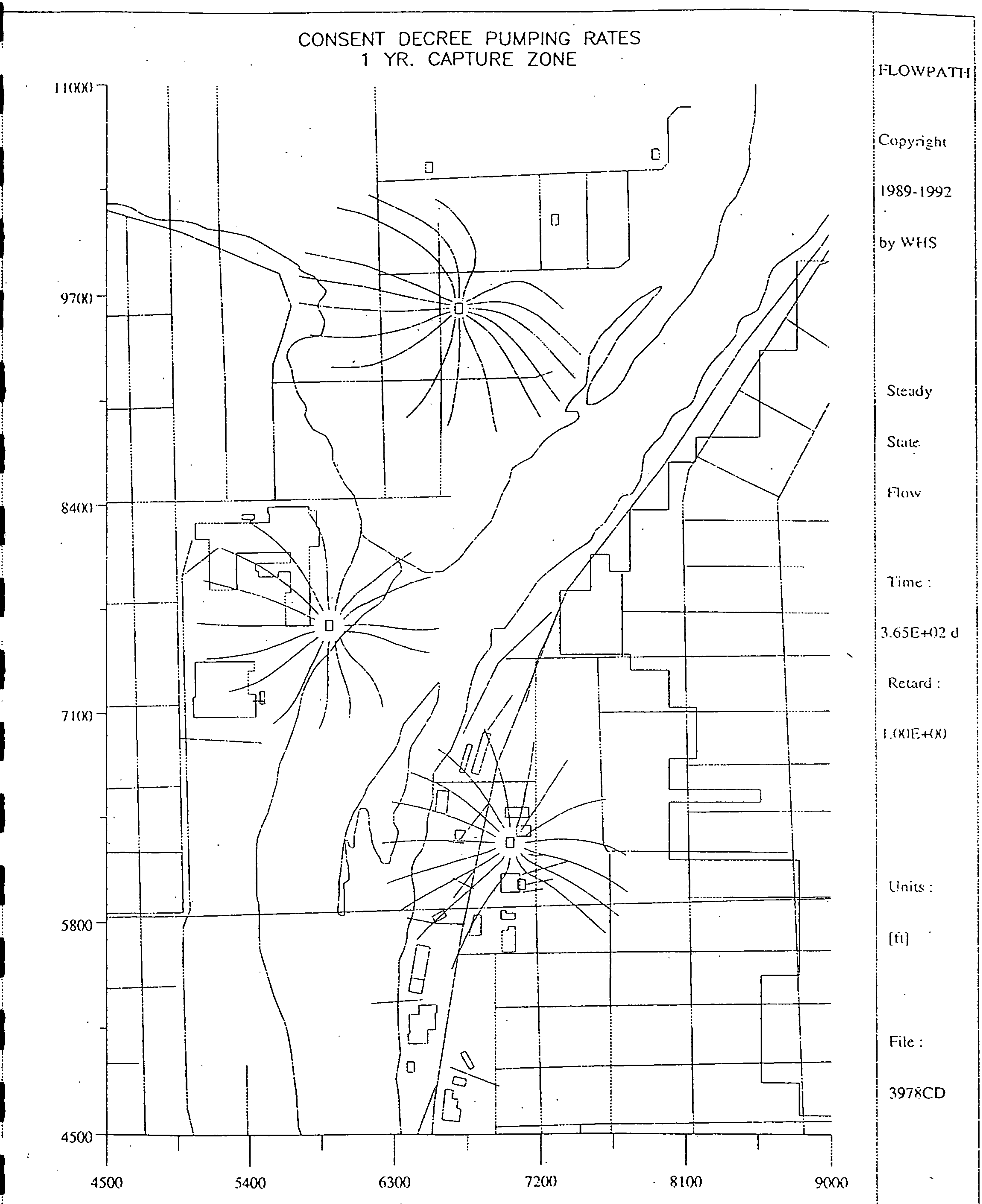
- the complete capture of the contaminant plume, and
- efficiency of aquifer cleanup.

An important consideration is having a pumping schedule that could potentially accommodate the city water supply requirements and provide some flexibility for routine operation and maintenance without diminishing the removal of the contaminant plume.

The Flowpath model does not simulate contaminant transport and therefore cannot predict aquifer cleanup times, however it is assumed that higher groundwater pumping rates would accelerate the removal of contaminants from the aquifer based on mass removal rates.

The flow model was run repeatedly while the pumping rates for CW3, CW6 and EW1 were varied over a wide range of pumping combinations. These runs were initially used to set lower limits for pumping rates at the three wells. These lower limits represent the approximate pumping rate for an individual well at which point the contaminant plume was no longer contained. Based on the flow model estimates, the minimum pumping rate for each well is approximated as follows:

CW3	-	2,300,000 gal/week (230 gpm, weekly average)
CW6	-	4,200,000 gal/week (420 gpm, weekly average)
EW1	-	2,400,000 gal/week (240 gpm)



CONSENT DECREE PUMPING RATES
1 YR. CAPTURE ZONE
11000
9700
8400
7100
5800
4500
4500
5400
6300
7200
8100
9000
FLOWPATH
Copyright
1989-1992
by WHS
Steady
State
Flow
Time :
3.65E+02 d
Retard :
1.00E+00
Units :
[ft]
File :
3978CD

figure 6.2

These minimum pumping rate estimates assume that the other two of the three wells would be pumping at approximately their current rates.

These relatively low volumes show that containment and capture of the contaminant plume can be easily achieved at current, or lower, combined pumping rates.

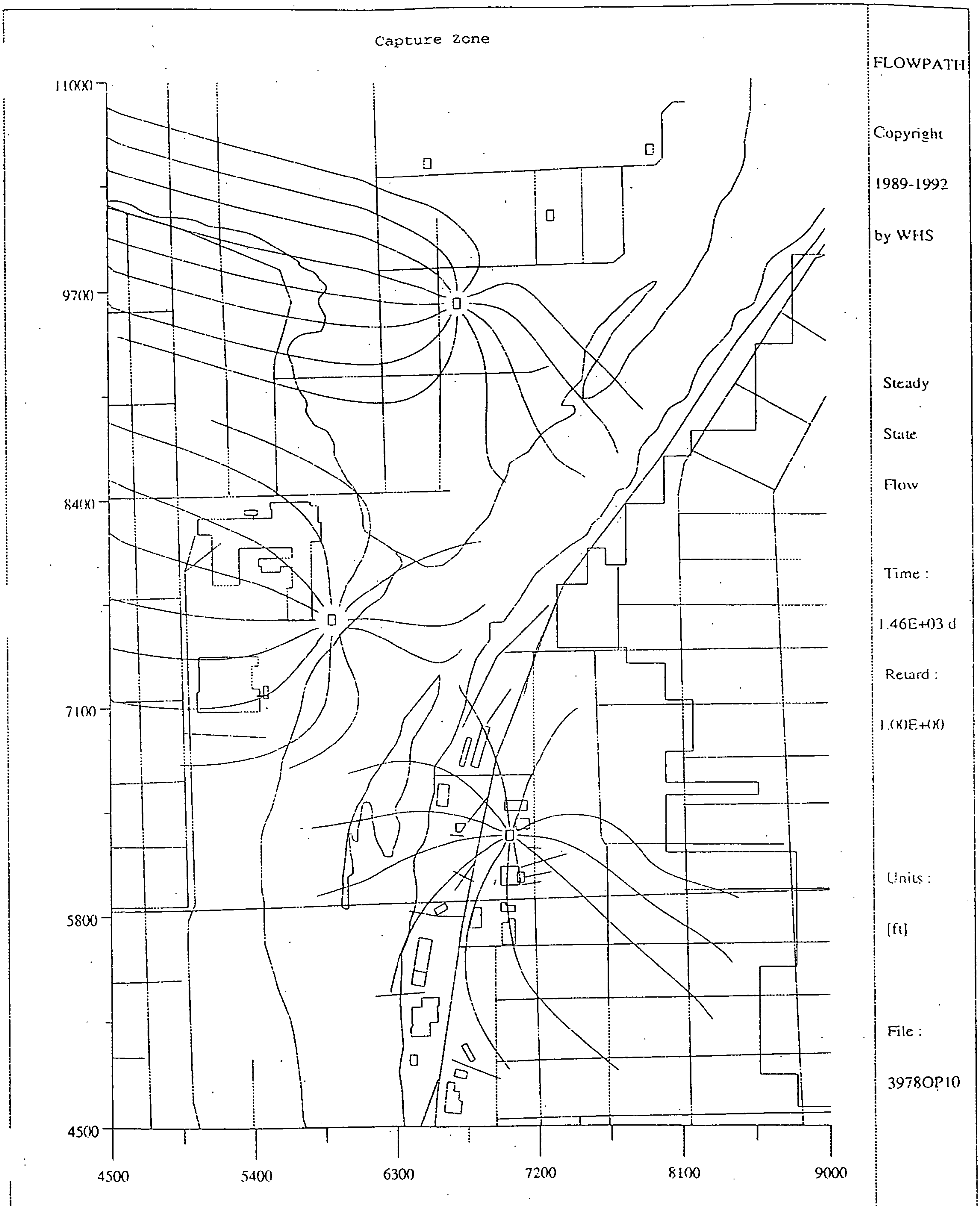
The Wausau Water and Sewerage Utilities has informed CRA that CW3 and CW6 could be operated more efficiently by slightly decreasing their current pumping rate. Also, they would gain some needed flexibility in their pumping schedule if their required pumping terms for CW3 and CW6 could be decreased from a combined 200 hours per week to a combined time of 150 hours per week. These changes would also alleviate the problem of disposal of treated water that is in excess of the city's water supply needs.

The effect of these proposed changes was tested using the particle tracking feature of the Flowpath flow model. The pumping rates used for the wells are as follows:

EW1	-	8,568,000 gal/week (850 gpm)
CW6	-	6,720,000 gal/week (1400 gpm for 80 hr/wk)
CW3	-	5,040,000 gal/week (1200 gpm for 70 hr/wk)

The Wergin well pumping rate was set to zero for this model run and for the remaining runs that are discussed in this section. According to the City of Wausau, to the best of their knowledge, the Wergin well is not currently in use and has not been used in the recent past. In order to optimize the pumping rate for CW3, the worst case scenario is when the Wergin well is not pumping. When the Wergin well is pumping, the cone of influence created by CW3 is greater than when the Wergin well is not pumping.

The resulting capture zones are illustrated on Figure 6.3. These capture zones represent the area of capture for a four year period at



CW3=70 hr/wk
CW6=80 hr/wk

figure 6.3

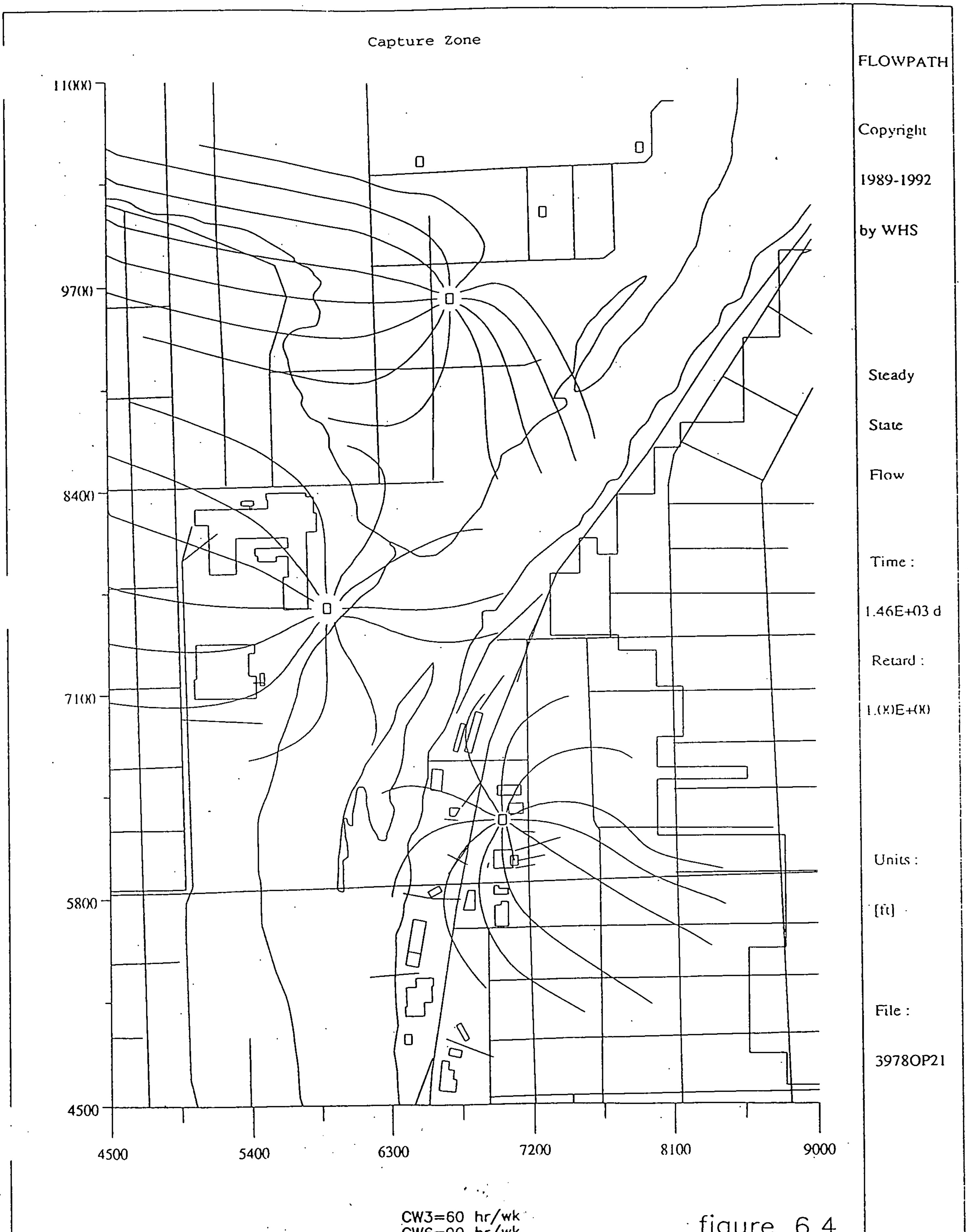
steady-state conditions. These capture zones compare favorably with the capture zones shown on Figure 6.1 which were estimated based on the pumping rates required by the Consent Decree. The capture zones represented on the two figures (Figures 6.1 and 6.3) are very nearly the same size and the same shape. The difference in the particle tracking patterns is primarily related to the pumping time. This is as expected since higher pumping rates will draw water from a larger area in a given time increment.

Additional model runs were performed using the same pumping rates with alternative pumping term combinations for CW6 and CW3. Figure 6.4 shows the estimated capture zone for CW6 pumping 90 hours per week and CW3 pumping 60 hours per week. Figure 6.5 shows the estimated capture zone for CW6 pumping 85 hours per week and CW3 pumping 65 hours per week. The capture zones shown on these figures do not differ much from those shown on Figures 6.1 and 6.3.

Model runs were also performed to assess even shorter pumping intervals for CW3 and CW6. Figure 6.6 shows the estimated capture zone for CW6 pumping 70 hours per week at 1,400 gpm and CW3 pumping 60 hours per week at 1,200 gpm. Figure 6.7 shows the estimated capture zones for the same pumping configuration except that the CW3 pumping interval is 50 hours per week.

Each of these pumping configurations, represented by Figures 6.3 through 6.7, are acceptable for capture and removal of the contaminant plume. However, the lower pumping periods of 50 and 60 hours per week for CW3 would slightly decrease the rate of contaminant removal.

The extraction well on Marathon Electric property (EW1) is currently pumping continuously at 850 gpm. The pump in the well was sized to pump 1,600 gpm. The original performance criteria for EW1 specified that the well should pump sufficient groundwater to create groundwater flow divides beneath the river to the east and beneath Bos Creek to the north.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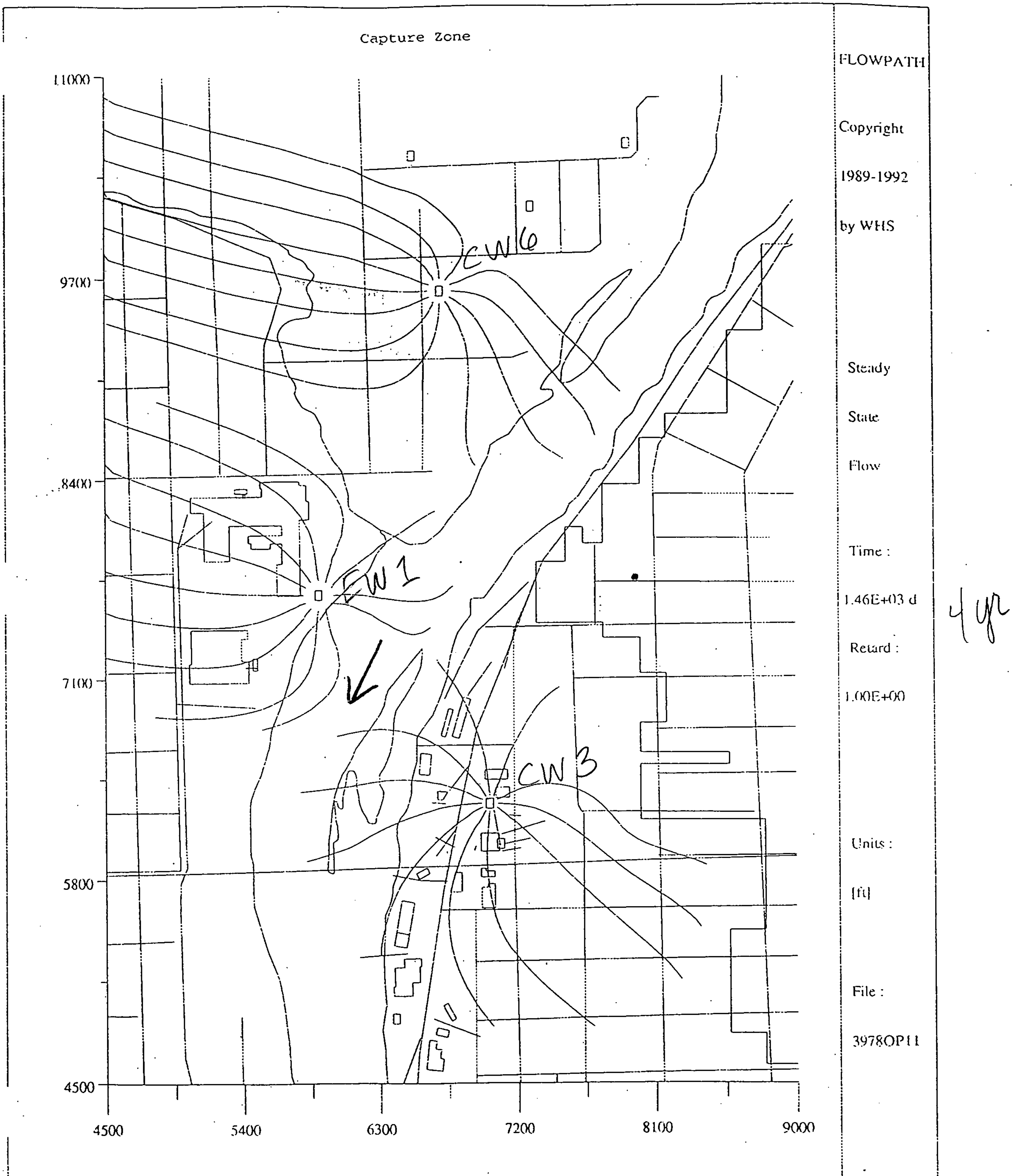
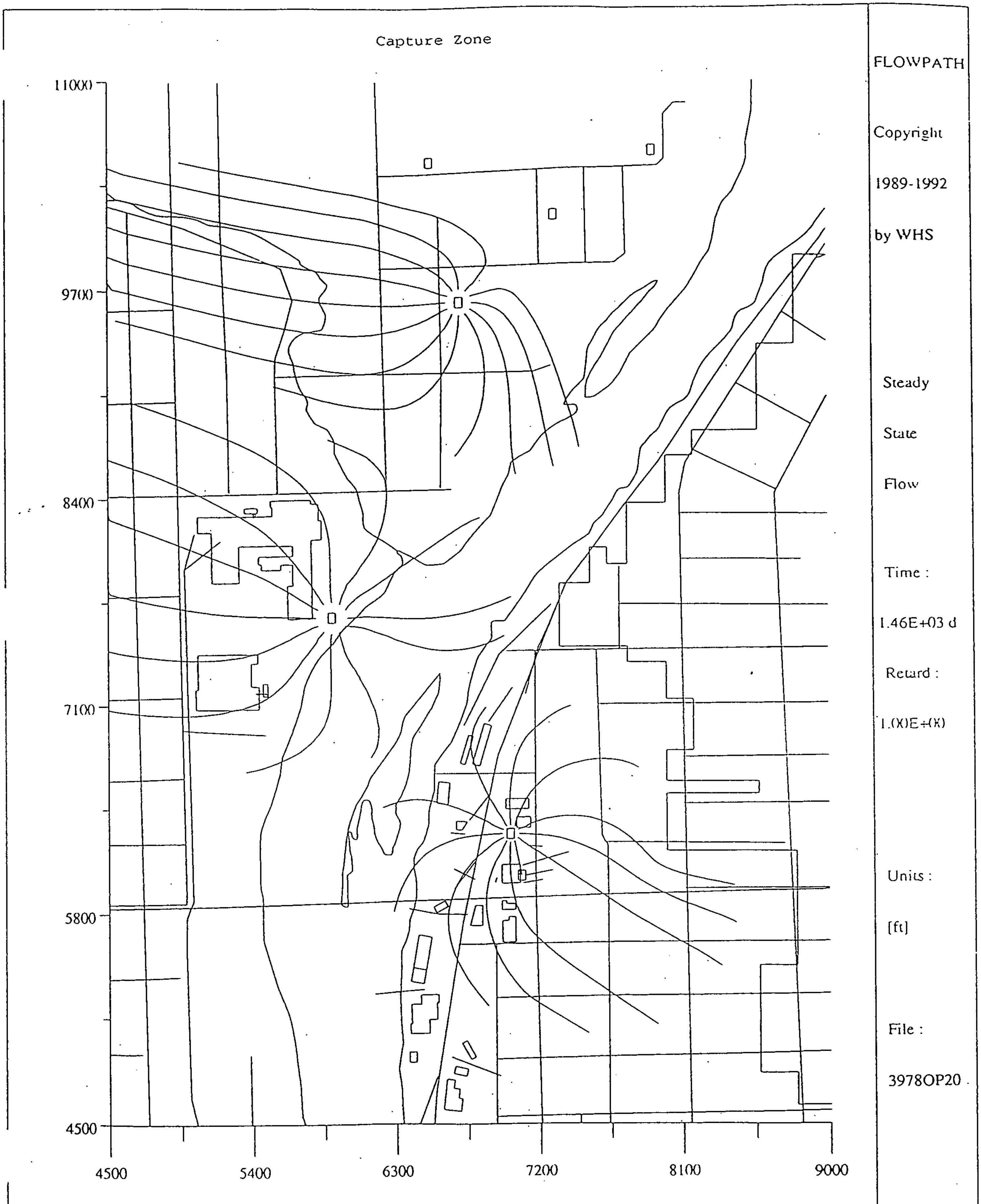
9700
8400
7100
5800
4500
4500
5400
6300
7200
8100
9000
FLOWPATH
Copyright
1989-1992
by WHS
Steady
State
Flow
Time :
1.46E+03 d
Retard :
1.00E+00
Units :
[ft]
File :
3978OP21
CW3=60 hr/wk
CW6=90 hr/wk

figure 6.4



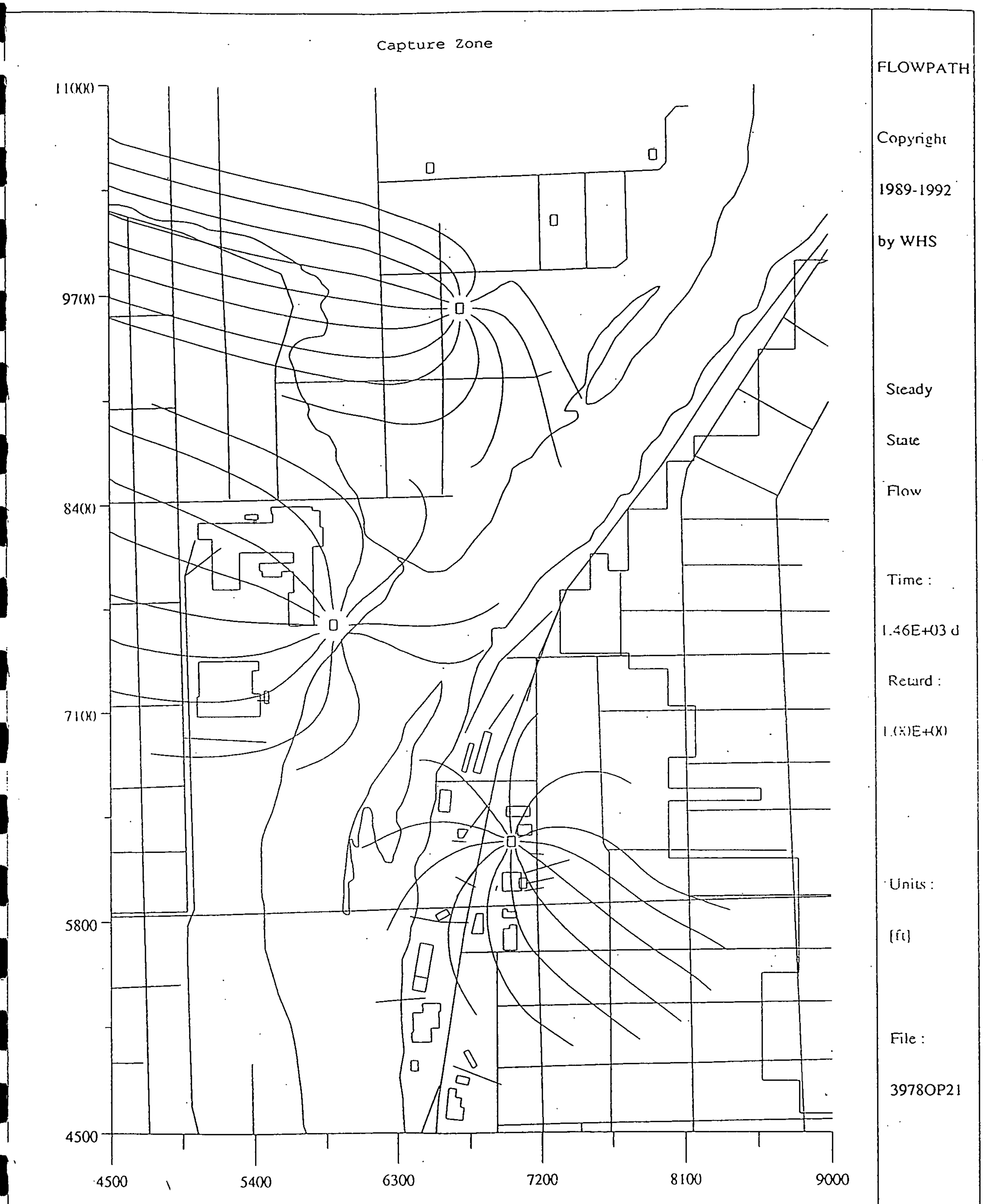
CW3=65 hr/wk
CW6=85 hr/wk

figure 6.5



CW3= 60 hrs.
CW6= 70 hrs.

figure 6.6

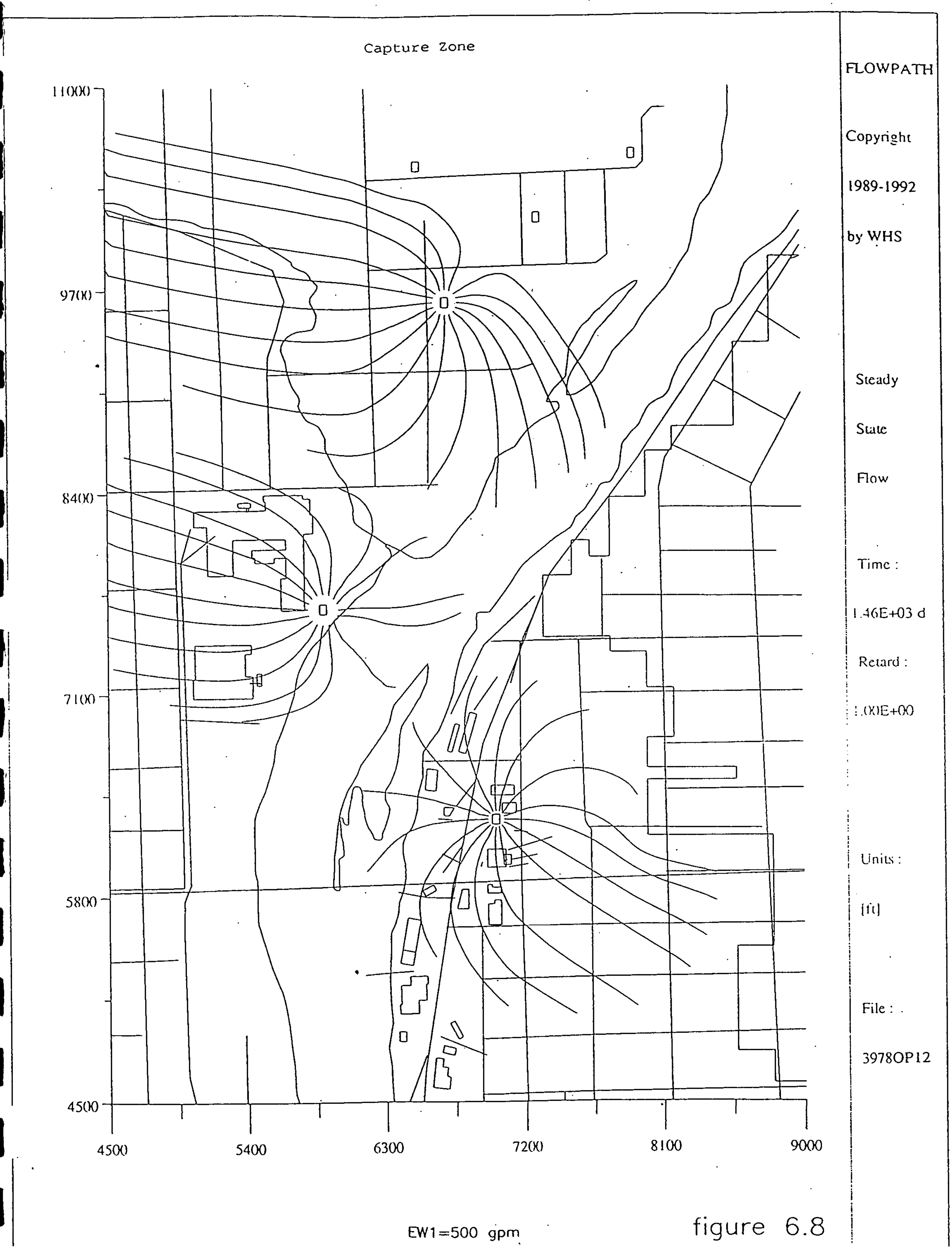


CW3= 50 hrs.
CW6= 70 hrs.

figure 6.7

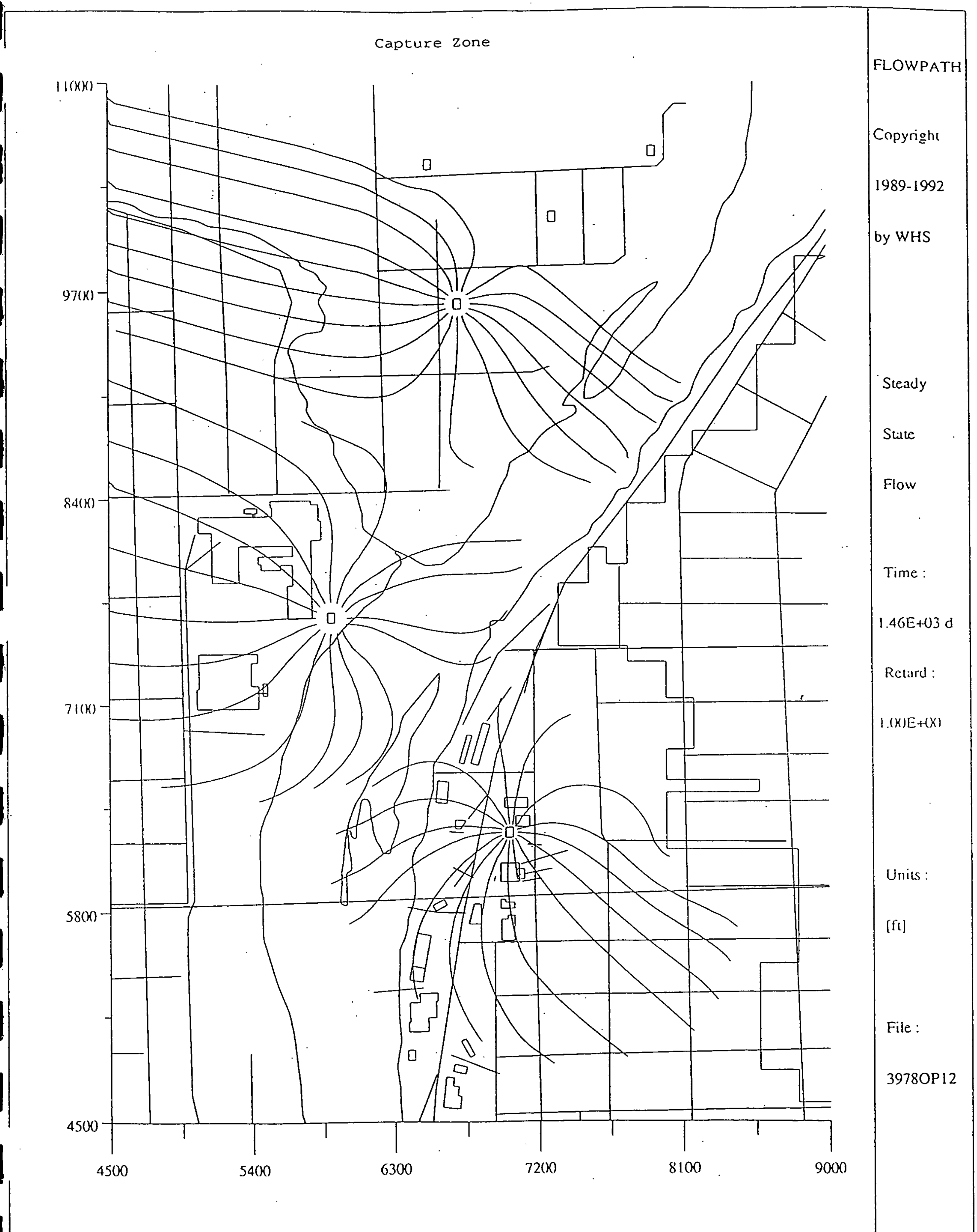
Several model runs were performed to assess the hydraulic performance of EW1. The pumping rates for EW1 were varied from 300 gpm to 1600 gpm and the resulting capture zones estimates for EW1 were compared.

The capture zone comparison showed that pumping rates below 500 gpm did not meet the capture criteria and pumping rates above 1,200 gpm created a capture zone that reached beyond Bos Creek to the north and across to the east bank of the Wisconsin River. Figure 6.8 and 6.9 show the predicted four year capture zones for EW1 pumping at 500 gpm and 1,200 gpm respectively. The capture zone simulated by the flow model and, more importantly, the drawdown measured in the field show that the capture zone created by the well pumping at 850 gpm is appropriate for meeting the original performance criteria.



Capture Zone
11000
9700
8400
7100
5800
4500
4500
5400
6300
7200
8100
9000
FLOWPATH
Copyright
1989-1992
by WHS
Steady
State
Flow
Time :
1.46E+03 d
Retard :
1.00E+00
Units :
[ft]
File :
3978OP12
EW1=500 gpm

figure 6.8



EW1=1200 gpm

figure 6.9

7.0 MODEL LIMITATIONS AND UNCERTAINTY OF RESULTS

Flowpath is a numerical, two-dimensional, aquifer simulation model for steady-state horizontal flow. Each model solution is unique for each of the different pumping configurations tested. The resulting head distribution calculated for each model run represents the potentiometric surface of the unconfined aquifer which has been developed as a result of the average pumping rates of the city wells and EW1 over the long term. This is valid and the model is useful for predicting capture zones because groundwater flow rates are small compared to the area of capture created by the wells and, therefore, the hydraulic response of the aquifer results more from the average stress over time than from short term (daily) fluctuations in pumping.

Groundwater flow models simplify and generalize the complexities of the aquifer and flow system which is being simulated. Small scale aquifer heterogeneities, local recharge areas, river bed heterogeneities and other small scale features of the flow system cannot be simulated in a large scale model. As a result, the calibrated model is best suited for predicting groundwater head distributions over the scale of the model and is less reliable for predictions within discreet areas of the model.

The reliability of the flow model output is dependent on the accuracy of the various input parameters used for the simulation. Input variables such as hydraulic conductivity, river bed leakance, infiltration, bedrock elevation and pumping rates are based on available field data, however, the data is not complete for the entire area of the model and assumptions have been made for areas where there is no field data available. The reliability of the flow model predictions is limited by the accuracy of these assumptions.

The monitoring well network used for the calibration of the model are screened at different depths within the aquifer and, generally, the pumping wells are screened through the bottom half of the aquifer. The hydraulic head distribution predicted by Flowpath represents the average head for the full thickness of the aquifer at each model node. Also, Flowpath assumes that the pumping wells are fully penetrating. These differences between the actual field conditions and the theoretical basis of the model output introduce an inherent difference between the field measured head in the calibration well network and the model-predicted head at those well locations. This difference should be more pronounced in the upper aquifer near the pumping wells where the vertical hydraulic gradient is significant. For this reason, the deeper well at a given well nest location was chosen for the calibration well network.

Based on the evaluation of the model calibration runs and sensitivity analyses, the model has achieved the objectives set forth in the Consent Decree.

8.0 CONCLUSIONS

The following conclusions are made regarding the groundwater flow model and the model prediction discussed in the report:

1. The model calibration and verification demonstrate that the model setup is appropriate for simulating groundwater flow beneath the Site.

2. The current pumping rate of 850 gpm at EW1 is appropriate for contaminant removal and containment in the former landfill area beneath Marathon Electric property. EW1 pumping rates between 500 gpm and 1,200 gpm would achieve the capture zone criteria originally set for EW1.

3. The pumping rates specified in the Consent Decree for CW3 and CW6 exceed what is necessary for containing and removing the contaminated groundwater. These wells could be pumped less and still maintain complete capture of the contaminant plume.

4. The optimum pumping configuration determined with the model for CW3 and CW6 comprises a range of pumping times that will achieve the capture criteria stated in the Consent Decree.

   CW3: 65 hours per week at 1,200 gpm to 100 hours per week at 1,100 gpm.
   CW6: 85 hours to 100 hours per week at 1,400 gpm.
   EW1: 800 to 900 gpm continuously.

5. Shorter pumping times for CW3 and CW6 from the current 200 hours per week, combined, to 150 hours per week combined (e.g. 85 hours for CW6 at 1,400 gpm and 65 hours for CW3 at 1,200 gpm) would not diminish the plume capture provided by the current pumping configuration. This would decrease the amount of pumping of clean water from areas beyond the plume and would add flexibility to the pumping schedule as well as some efficiency to the maintenance and operation of the pumping system. These shorter pumping times assume that EW1 continues pumping at 850 gpm.

All of Which is Respectfully Submitted,

CONESTOGA-ROVERS & ASSOCIATES

Brian C. Boevers

Charles E. Ahrens

Daniel V. Sola

REFERENCES

CRA, Evaluation of Pumping Rate in Extraction Well No. 1, Marathon Electric Manufacturing Company, Wausau, Wisconsin, January 1991.

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Fetter, C.W., Applied Hydrogeology, Second Edition, Merrill Publishing Company 1988.

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Kendy, Eloise and Bradbury, K.R., Hydrogeology of the Wisconsin River Valley in Marathon County, Wisconsin, Wisconsin Geological and Natural History Survey, Information Circular 64, 1988.

Warzyn Engineering Inc., Feasibility Study, Wausau Water Supply NPL Site, Wausau, Wisconsin, August 1989.

Warzyn Engineering Inc., Remedial Investigation, Wausau Water Supply NPL Site, Wausau, Wisconsin, July 1989.

APPENDIX A

CONSENT DECREE
PARAGRAPHS 12.A.2. AND 12.A.3.

2. Operable Unit Groundwater Extraction System Performance Standards

Settling Defendants shall operate the operable unit groundwater extraction system to meet the Performance Standards set forth below, at all times, unless otherwise approved by U.S. EPA in consultation with the State.

a. The operable unit extraction well shall be pumped at a minimum of 1600 gallons per minute (gpm) for at least 125 hours per week, until the Cleanup Standards set forth in paragraph 12.B., and any other Cleanup Standards set by U.S. EPA pursuant to paragraph 12.B., are achieved, as determined by U.S. EPA, in consultation with the State.

b. Settling Defendants shall treat extracted groundwater utilizing the treatment system specified in the approved final RD/RA Work Plan. At a minimum, any discharges shall meet all requirements of the CWA, including application of CWA Section 301 BAT, and all requirements of Wisconsin Water Quality Standards (promulgated pursuant to Wis. Stat. Chaps. 144 and 147), prior to discharge.

c. Settling Defendants shall implement an U.S. EPA approved monitoring program to provide U.S. EPA with data demonstrating that the operable unit extraction system is meeting Performance Standards.

d. Settling Defendants shall implement and operate the second extraction well as delineated in the Interim ROD, if determined necessary and as approved by U.S. EPA in consultation with the State.

3. Municipal Groundwater Extraction Well System Performance Standards.

Settling Defendants shall operate the Municipal Groundwater Extraction Well System (City Wells CW3 and CW6) to meet the Performance Standards set forth below, at all times, unless otherwise directed by EPA, in consultation with the State. It is understood that the Wausau Water Utility operates the water supply system for the City of Wausau, including CW3 and CW6 and that the Utility is controlled by the City of Wausau. Failure of the Utility to meet the applicable terms of this Consent Decree shall constitute failure of Settling Defendants to meet the terms of the Consent Decree.

The pumping rates set forth below for CW3 and CW6 are based on modelling which assumes an average monthly pumping rate of 1257 gpm for CW10, and 314 gpm for each CW7 and CW9. To the extent possible, the Settling Defendants agree to operate the municipal water supply system so as to approximate the average monthly pumping rates for CW7, CW9 and CW10, in order to achieve timely completion of the final remedy.

a. CW3 shall be pumped at a minimum rate of 1100 gpm for at least 100 hours per week.

b. CW6 shall be pumped at a minimum rate of 1500 gpm for at least 100 hours per week.

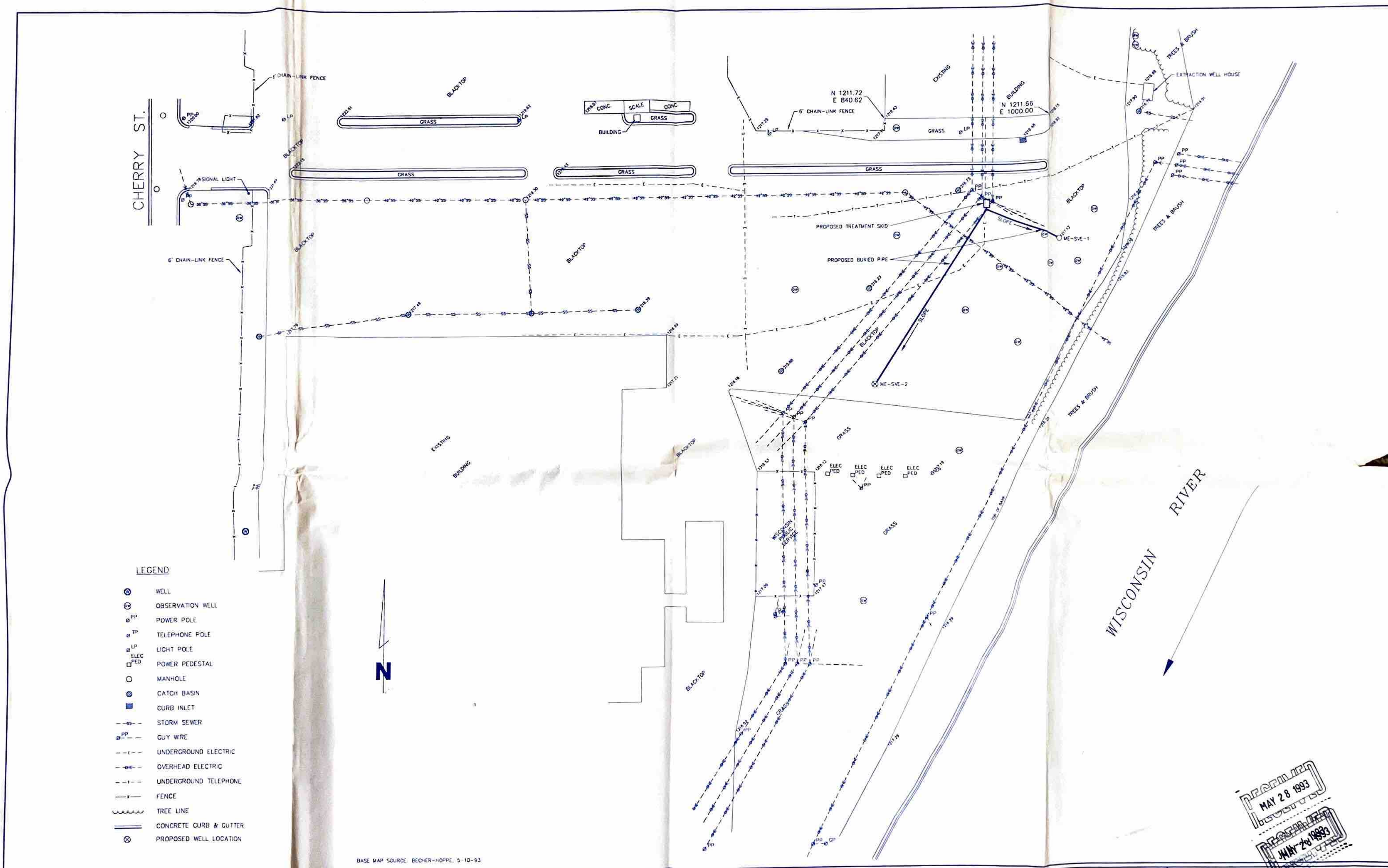
c. Settling Defendants shall perform groundwater modelling, utilizing a MODFLOW/RANDOM WALK model or its equivalent, as approved by U.S. EPA in consultation with the State, to provide U.S. EPA with information by which to assess the impact of any proposed changes to the municipal groundwater extraction Performance Standards listed in 3.a. and 3.b. above. Alternatively, U.S. EPA may perform the necessary modelling, and Settling Defendants shall pay for the U.S. EPA modelling as part of Oversight costs.

d. Treatment of extracted groundwater from CW3 and CW6 shall be performed utilizing the existing air strippers. The air strippers shall be maintained and operated such that 99% VOC removal efficiency is maintained at all times.

e. Settling Defendants shall notify U.S. EPA at least twenty-four (24) hours in advance of any shutdowns of CW3 and CW6. In cases of emergency shutdowns, Settling Defendants shall notify U.S. EPA within twenty-four (24) hours of such shutdown, and shall provide an explanation for the shutdown.

f. Settling Defendants shall include in the Draft RD/RA Work Plan a detailed description and explanation of the operation of the Wausau Water Utility's municipal water supply system. The description shall explain how the operation of the municipal well system will be adjusted to accommodate the required operation of CW3 and CW6 and the goal of approximating the average monthly pumping rates set forth above for CW7, CW9 and CW10. The description shall include the rationale and strategy for operation of the system, and shall describe provisions for meeting changing conditions and contingencies (e.g. changing demand, seasonal variations, precipitation events, breakdowns, maintenance, etc.).

g. Settling Defendants shall include in the monthly progress reports the pumping and maintenance schedule realized for the previous month for the water supply system. This subparagraph shall be effective beginning with the month following the month in which Settling Defendants receive U.S. EPA approval for operation of the municipal well groundwater extraction component of the final remedy.



Nº	Revision	Date	Initial

Approved

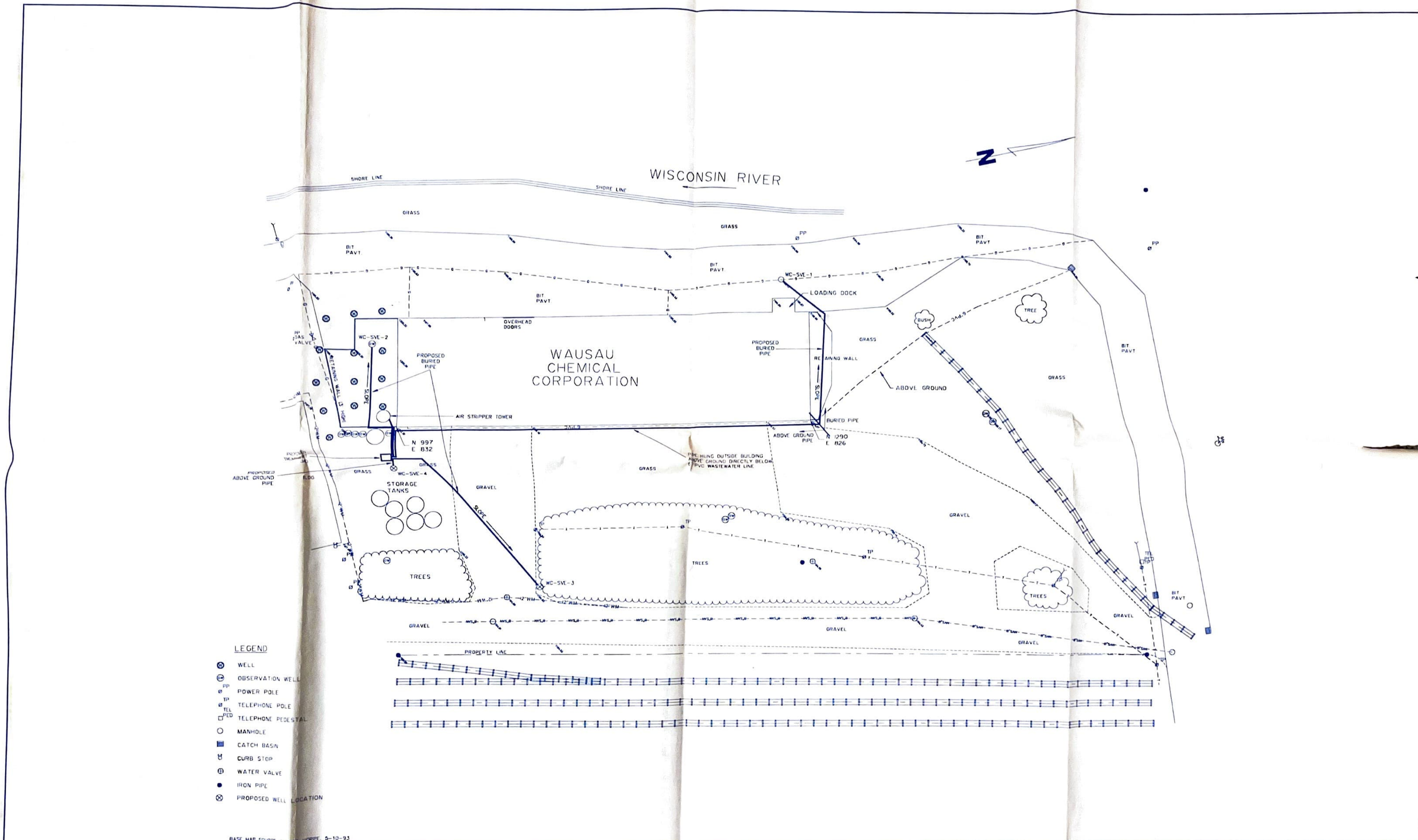
WAUSAU WATER SUPPLY SITE
WAUSAU, WISCONSIN

LOCATION OF FACILITIES
WEST BANK

CRA
CONESTOGA-ROVERS & ASSOCIATES

Drawn by: CAA	Scale: 1"=40'	Date: MAY 17, 1993	File Nº: P-01	Rev.Nº: 0
Designed by: MP	Field book:	Project Nº: 3978	Drawing Nº: PLAN 1	
Checked by: CC				

MAY 14,1993



Nº	Revision	Date	Initial

Approved

WAUSAU WATER SUPPLY SITE
WAUSAU, WISCONSIN

LOCATION OF FACILITIES
EAST BANK

CRA
CONESTOGA-ROVERS & ASSOCIATES

Drawn by: CAA	Scale: 1"=30'	Date: MAY 17, 1993	File Nº P-02	Rev Nº 0
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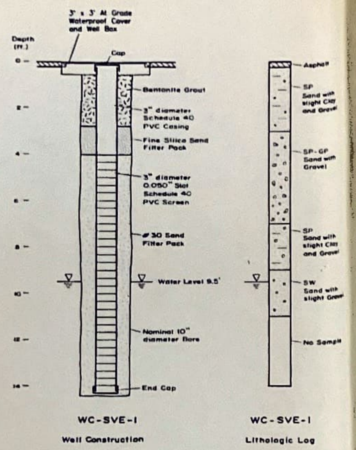
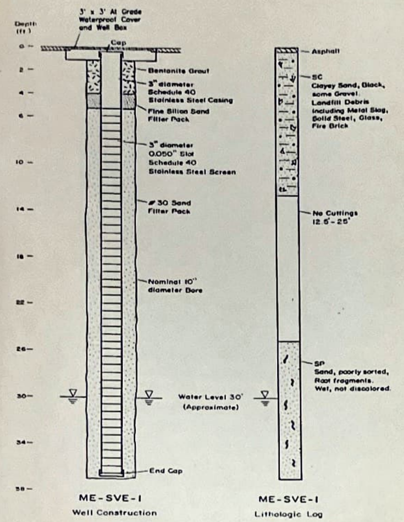
Checked by: CC				

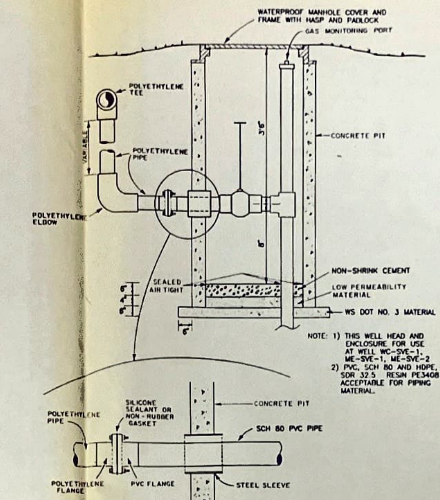
MAY 14, 1993



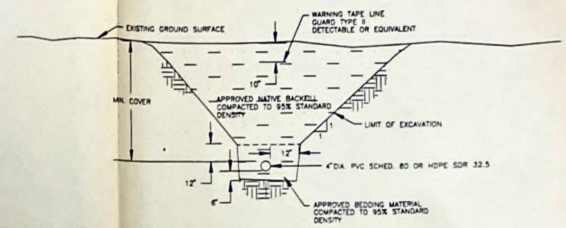
EXISTING VENT WELL WC-SVE-1



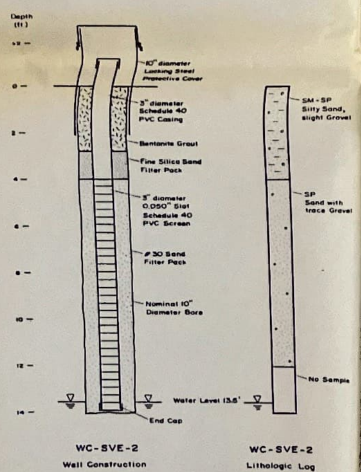
EXISTING VENT WELL ME-SVE-1



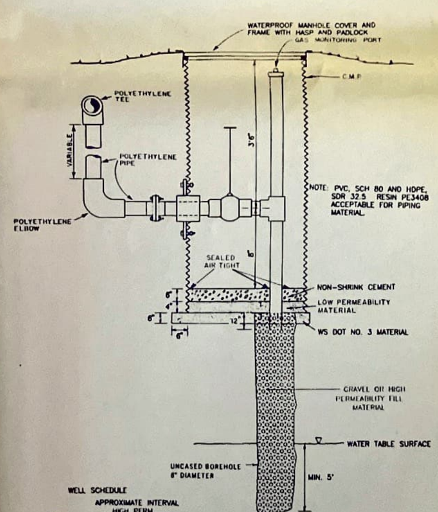
TRAFFIC AREA
TYPICAL LATERAL WELL CONNECTION



TYPICAL TRENCH CROSS SECTION
ONE PIPE BURIED
WAUSAU SOIL TREATMENT



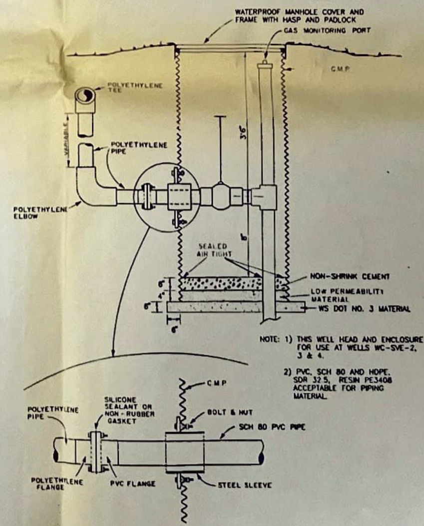
EXISTING VENT WELL WC-SVE-2



WELL SCHEDULE

WELL	TD	APPROXIMATE INTERVAL HIGH PERM MATERIAL
WC-SVE-3	17'	5'-17'
WC-SVE-4	17'	5'-17'
ME-SVE-2	35'	5'-35'

PROPOSED VENT WELL



NON TRAFFIC AREA
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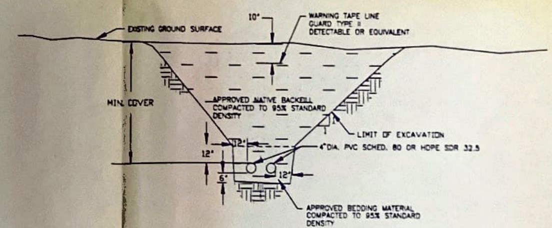


TYPICAL TRENCH CROSS SECTION
TWO PIPES BURIED
WAUSAU SOIL TREATMENT

No	Revision	Date	Initial

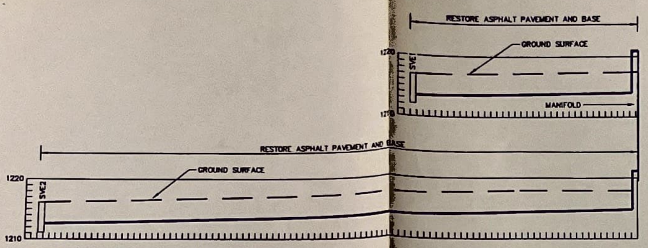
Approved

WAUSAU WATER SUPPLY SITE
WAUSAU, WISCONSIN

CONSTRUCTION DETAILS

CRA
CONESTOGA-ROVERS & ASSOCIATES

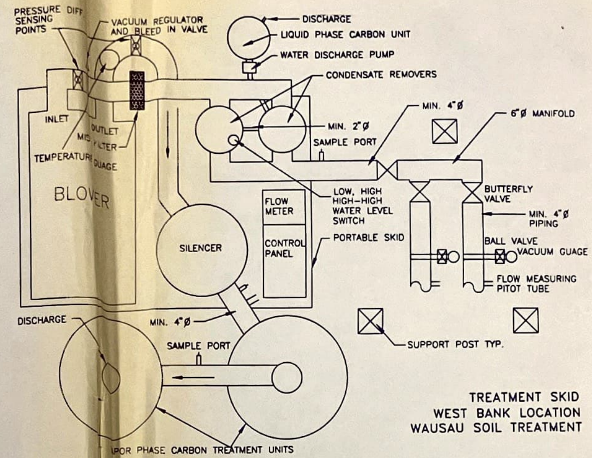
Drawn by: CAA	Scale: NOT TO SCALE	Date: MAY 1993	File No: P-03
Designed by: MP	Field book	Project No: 3978	Drawing No: PLAN 3
Checked by: CC			



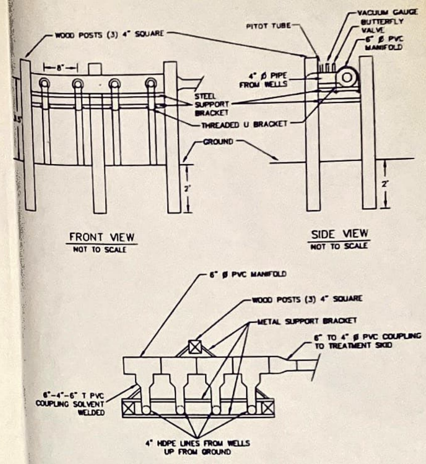
SCALE: 1"=20' HOR., 1"=10' VER.

NOTES: 1) ALL PIPING TO BE SLOPED .5% MIN. DOWN TOWARDS WELLS

VENT PIPING PROFILE
WEST BANK



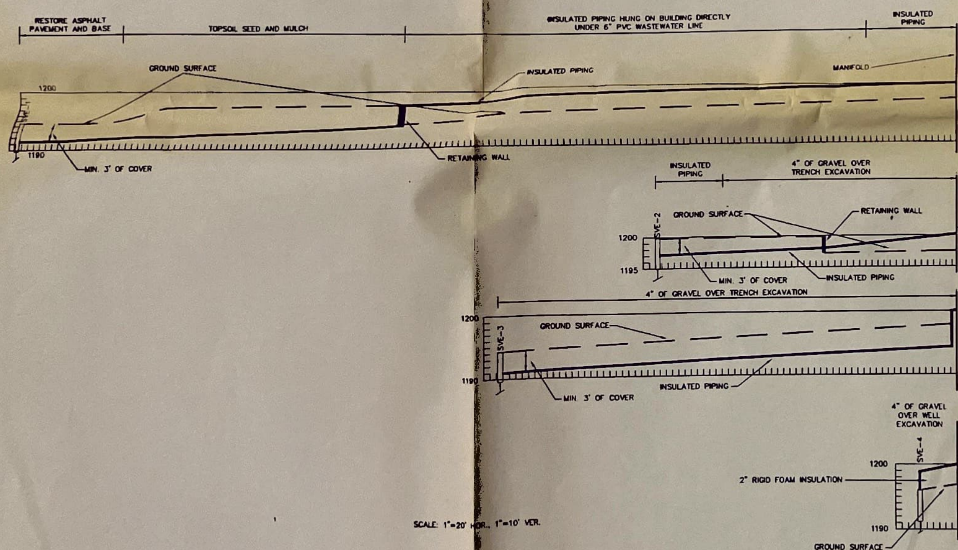
TREATMENT SKID
WEST BANK LOCATION
WAUSAU SOIL TREATMENT



NOTES: 1) WEST BANK LAYOUT IS THE SAME WITH THE EXCEPTION OF HAVING TWO PIPES.

2) ALL PVC IS TO BE SCHEDULE 80

MANIFOLD DETAIL
EAST BANK

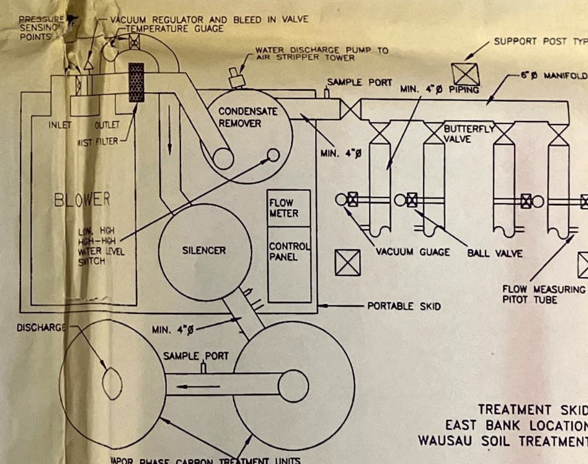


SCALE: 1"=20' HOR., 1"=10' VER.

NOTES: 1) ALL PIPING TO BE SLOPED .5% MIN. DOWN TOWARDS WELLS

2) ALL PIPING ABOVE AND BELOW GROUND TO BE INSULATED
4" RIGID FOAM >3.5' BGS
2" TRYMER WRAPAROUND <3.5' BGS
AND ABOVE GROUND

VENT PIPING PROFILE
EAST BANK



TREATMENT SKID
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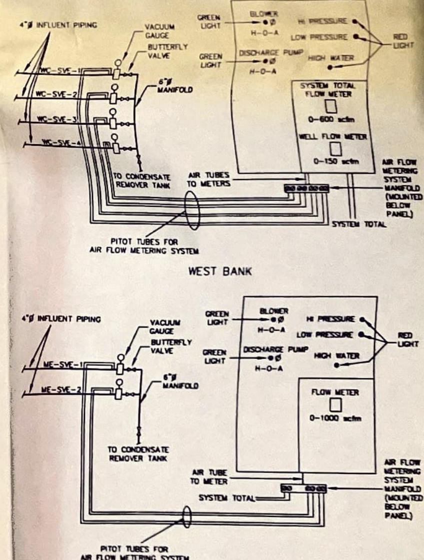
WAUSAU SOIL TREATMENT



CONTROL PANELS

Nº	Revision	Date	Initial

Approved

WAUSAU WATER SUPPLY SITE
WAUSAU, WISCONSIN

CONSTRUCTION DETAILS

CRA
CONESTOGA-ROVERS & ASSOCIATES

Drawn by	CAA	Scale	SHOWN	Date	MAY 1993	File Nº	P-04
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