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Impact of F- and H-Area Pump-Treat-Reinject Remediation Systems on the Old Radioactive Waste Burial Ground (U)

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Large-scale Pump-Treat-Reinject (PTR) remediation systems at the F- and H-area seepage basins are scheduled to begin normal operation in early CY98. In addition, the 76 acre Old Radioactive Waste Burial Ground (ORWBG) was capped in CY97. These remedial actions are expected to have a significant impact on General Separations Area (GSA) groundwater flow. Impacts on groundwater flow and tritium migration at the ORWBG are investigated in this modeling study. The following conclusions are drawn from this investigation:

- ORWBG capping and F- and H-area PTR operation will ultimately affect hydraulic head in the Upper Three Runs aquifer over most of F-area, and parts of E-area and the H-area tank farm (Figures 11 and 17)

- Although most changes will occur over the first weeks and months, the final effects won't be realized for years.
- Capping will depress water levels in the center of the ORWBG by over 2 ft (Figure 23).
- H-area PTR operation will elevate water levels at the southeast corner of the ORWBG by 2 ft (Figure 23).
- Groundwater flowing from the ORWBG to Fourmile Branch will be squeezed into a more narrow corridor along the old F-area effluent ditch (Figures 30 and 31).
- Tritium reinjected above the H-area seepage basins is not expected to migrate beneath the ORWBG (Figure 32).
- The Fourmile Branch seepline immediately south and southeast of the H-area seepage basins may recede 100-200 ft as a result of groundwater extraction (Figure 36).
- ORWBG capping and F- and H-area PTR operation will affect the geometry of the southwest tritium plume and surface discharge locations (Figures 30-31), but have a small effect on total tritium discharge to Fourmile Branch from ORWBG sources (Figure 50).

Background

Large-scale Pump-Treat-Reinject (PTR) remediation systems at the F- and H-area seepage basins are scheduled to begin normal operation in early CY98 (Figure 1). The design recirculation flow rates for the F- and H-area systems are 200 and 150 gpm, respectively. At these pumping rates, the PTR systems are expected to impact water levels and groundwater flow patterns over significant portions of the General Separations Area. In addition, the 76 acre Old Radioactive Waste Burial Ground has recently been capped and is also expected to impact water levels and groundwater flow patterns. This study emphasizes impacts to groundwater flow and tritium migration at the ORWBG, although other effects are also considered. Figure 1 shows the locations of extraction and injection wells within the context of the GSA. Groundwater is extracted from wells south of the basins (down-gradient), while reinjection occurs at wells north of the basins (up-gradient). These remediation well networks provide hydraulic control of contaminant plumes lying between the basins and Fourmile Branch. Figures 2a and 2b identify specific wells, and Tables 1 and 2 list the design and proposed (as of 12/97) flow rates for each well (Day, 1997).

Analysis strategy

Both large- and small-scale phenomena must be simulated in order to address the following issues:

- transient impact on hydraulic head distributions over the entire GSA
- long-term impact on groundwater flow patterns near the ORWBG
- transient impact on future tritium migration from the ORWBG
- long-term impact to wetlands below the H-area seepage basins
- capture zone and bypass flow of the H-area PTR system after long-term operation.

Specifically, the F- and H-area PTR systems are expected to influence hydraulic heads over large regions of the GSA, and require a large model domain. On the other hand, capture zone analyses require fine mesh resolution near each remediation well to simulate detailed groundwater flow patterns. Transport simulations also require mesh refinement compared to a GSA scale flow model.

The initial analysis strategy involved creating various derivative, "zoom-in" models from a GSA wide flow model (Flach and others, 1997) with boundaries extending far enough from the facilities and remediation activities of interest so that constant heads could be prescribed along boundaries. When fine mesh resolution was also required, the result was computational grids with between 200,000 and 400,000 nodes. Grids of this size proved too large for practical computations on an SGI UNIX workstation. Run-times and hard disk storage requirements were marginally acceptable for steady-state flow calculations, but clearly impractical for combined transient flow and transport simulations.

To remedy this situation, an alternative strategy was adopted. For simulations requiring fine scale local mesh resolution, smaller scope models were developed. Transient effects beyond the model domain were handled by first performing the equivalent simulation with a GSA model (Flach and others, 1997) and using the results to derive transient boundary conditions for the smaller scope model. Following this strategy, two models were developed in addition to the GSA flow model, as shown in Figure 1. The "ORWBG/H-Area Seepage Basin" model was used to investigate ORWBG impacts. The "H-Area Seepage Basin" model was used to investigate H-area PTR capture zones and wetland impacts. Figures 3, 4 and 5 illustrate the computational meshes of the three models in plan view. The GSA model has a nominal mesh resolution of 200 ft in the horizontal plane. The mesh

resolution of the OBG/H-Area Seepage Basin is 100 ft. The smallest H-Area Seepage Basin model elements are 25 ft square.

In order to assess both historical and future tritium migration from the ORWBG, 1 steady-state and 3 transient phases of operation were modeled as summarized in Table 3. Steady-state simulation for 1954 (Phase 0) provided initial conditions for transient simulation between 1955 and 1988 (Phase I) when the seepage basins were in operation. Operating data were taken from GeoTrans (1993, Tables 3.5 and 3.6). The basins were assumed to have been capped in 1988, along with the Mixed Waste Management Facility (MWMF). Phase II spans the time interval between 1988 and 1998. ORWBG capping and normal F- and H-area PTR operation are assumed to occur in 1998. Phase III transient simulations were carried out to approximately the year 2035, assuming no additional future large-scale operations affecting groundwater flow.

Changes to GSA model

Initial simulations indicated that changes to the GSA flow model were needed to improve results in two areas. First the GSA rev. 0 model was underpredicting heads between the basins and Fourmile Branch. During PTR operations an extraction well or two would pump dry because the simulated hydraulic head started out too low. To remedy this situation, the horizontal conductivity (K_h) was limited to be a maximum of 10 ft/d south of the H-area seepage basin, except near well HSB000PD. A multiple well pumping test at HSB000PD indicates the conductivity to be 35 ft/d, and this value is locally preserved in the model K_h field. Horizontal conductivity was reduced southwest of the F-area seepage basins by reducing the calibration K_h multiplier from 0.9 to 0.8.

Secondly, initial tritium transport simulations produced excessive downward migration beneath the ORWBG. Evidently leakage through the Gordon confining unit ("green clay") is too large in the GSA rev. 0 model, even though the model K_v value for this unit is already low compared to field data. Field data suggests a value around 4×10^{-4} ft/d, whereas 10^{-4} ft/d was assumed in GSA rev. 0 (Flach and others, 1997). This assessment is consistent with the recent modeling efforts of GeoTrans (1993, Table 4.1, 1.25×10^{-5} ft/d), Sadler (1995, Table 4.1, 10^{-6} ft/d), Flach (1996, Table 6, 10^{-5} ft/d), and Boltz (1997, Table 4.1, 10^{-6} ft/d). These models all used a "green clay" K_v that is 1 or 2 orders of magnitude smaller than the GSA rev. 0 model in order to better simulate tritium migration from the F-area seepage basins, ORWBG, and H-area seepage basins. The vertical conductivity of the Gordon confining unit was changed from 10^{-4} ft/d to 10^{-5} ft/d.

The resulting GSA model is termed "GSA rev. 2" herein, because earlier modifications to GSA rev. 0 for the F-area Burning/Rubble Pit RFI/RI plan involving updated local topography produced GSA rev. 1 (WSRC, 1997). Table 4 summarizes average hydraulic parameters for GSA rev. 0 and GSA rev. 2. Model calibration parameters are compared in Table 5.

Impacts of F- and H-area PTR system operation

Water levels: The overall impacts of F- and H-area PTR system operation on the GSA were investigated using the revised Flach and others (1997) GSA groundwater flow model (GSA rev. 2). The vertically-averaged change in hydraulic head for the "upper" and "lower" UTR aquifer zones is shown in Figures 6-17 for elapsed times following PTR start-up of 2.5 days, 3 weeks, 3 months, 6 months, 1 year and 30 years (steady-state). The analogous results from the smaller scale, higher resolution OBG/H Seepage Basin model are shown in Figures 18-29. These results show that ORWBG capping and F- and H-area PTR operation will ultimately affect water levels over most of F-area, and parts of E-area and the H-area tank farm (Figures 11 and 17). Although most changes will occur over the first weeks and months, the final effects won't be realized for years. Interestingly, the ORWBG cap will mitigate the effects of groundwater reinjection by suppressing the water table near it (Figures 11 and 23). Otherwise, mounding would occur over all of E-area, according to preliminary calculations. The ORWBG cap will depress "upper" UTR head within the burial ground by more than 2 ft, while H-area PTR operation will elevate head by 2 ft at the southeast corner (Figure 23). F-area PTR operation will elevate head by 0.5 to 1 ft along the west side of the old F-area effluent ditch.

Groundwater flow: Figure 30 illustrates simulated groundwater flow paths starting within the ORWBG vadose zone and ending at the point of surface discharge prior to the ORWBG cap and PTR operation at F- and H-area. Figure 31 shows predicted groundwater flow patterns after capping and long-term PTR operation. Flow directions are significantly affected in the east end of the ORWBG because the head gradients are small. The combined effect of all three remedial actions is to concentrate groundwater flow from the ORWBG to a significantly more narrow corridor.

Figures 32 through 35 show groundwater flow patterns associated with the H-area PTR system. These capture zone and bypass flow results show that reinjected tritium contamination is not expected to migrate beneath the ORWBG, at least once steady-state conditions are achieved (Figure 32 and 34). As an aside, the capture zone results also indicate the proposed pumping rates as of 12/97 have compromised the PTR design somewhat. Table 6 compares extraction and reinjection rates for a "west" and "east" grouping of the "upper" UTR wells, for the

design and 12/97 proposed flow rates. Flows are somewhat unbalanced for the 12/97 proposal. As a result, significant bypass flow occurs for groundwater reinjected in the most eastern wells (Figure 32), and excessive capture of clean groundwater occurs at the western most extraction wells (Figure 33).

Wetland impacts: Figure 36 shows projected changes to the Fourmile Branch seepline using the OBG/H Seepage Basin model. The red line denotes the simulated seepline prior to capping and PTR operation. There is some discrepancy between these model results and the surveyed seepline shown in green. More accurate topographic data would be needed to achieve better agreement. The blue color fill denotes the simulated seepline after capping and long-term PTR operation. The gap between the red line and blue color fill is predicted wetland recession. Changes are limited to the region immediately south and southeast of the H-area seepage basins. The model results suggest that the seepline may recede 100-200 ft as a result of nearby groundwater extraction. The finer resolution H Seepage Basin model yields similar results for wetland recession, as shown in Figure 37.

Tritium discharge to Fourmile Branch: In light of the significant changes in ORWBG groundwater flow patterns resulting from capping and PTR operation (Figures 30 and 31), transport simulations were performed to estimate the impact on tritium migration from the ORWBG to Fourmile Branch. The source term model was taken directly from Flach and others (1996), and redistributed to the appropriate nodes in the ORWBG/H Seepage Basin model. The same transport parameters were used as well. Figures 38 through 49 show selected snapshots of vertically-averaged tritium concentration within the "upper" and "lower" UTR aquifer zones from 1965 to 2013. Future tritium discharge to Fourmile Branch was predicted with and without PTR operation. The ORWBG was assumed to be capped in both cases. The results are shown in Figure 50. PTR operation is seem to have a negligible impact on the "bottom-line". The southwest ORWBG plume is practically the sole contributor to Fourmile Branch discharges from the ORWBG. As seen from Figure 23, the area occupied by the plume along the old F-area effluent ditch is relatively unaffected by remedial actions. Therefore, little impact on Fourmile Branch discharge is observed in Figure 50.

The present ORWBG/H Seepage Basin tritium transport model is adequate for the purpose of exploring the relative difference in Fourmile Branch tritium discharge with and without PTR operation. However, the model uses parameters directly from Flach and others (1996) without further calibration, and therefore does not match the historical monitoring data as well as it might. Recalibration to the historical data shown in Figure 50 should be considered if the model is used for other purposes.

Conclusions

The following conclusions are drawn from this investigation:

- ORWBG capping and F- and H-area PTR operation will ultimately affect hydraulic head in the Upper Three Runs aquifer over most of F-area, and parts of E-area and the H-area tank farm (Figures 11 and 17)
- Although most changes will occur over the first weeks and months, the final effects won't be realized for years.
- Capping will depress water levels in the center of the ORWBG by over 2 ft (Figure 23).
- H-area PTR operation will elevate water levels at the southeast corner of the ORWBG by 2 ft (Figure 23).
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- Tritium reinjected above the H-area seepage basins is not expected to migrate beneath the ORWBG (Figure 32).
- The Fourmile Branch seepline immediately south and southeast of the H-area seepage basins may recede 100-200 ft as a result of groundwater extraction (Figure 36).
- ORWBG capping and F- and H-area PTR operation will affect the geometry of the southwest tritium plume and surface discharge locations (Figures 30-31), but have a small effect on total tritium discharge to Fourmile Branch from ORWBG sources (Figure 50).

References

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Day, G. A., 1997, personal communication.

Flach, G. P., L. L. Hamm, M. K. Harris, P. A. Thayer, J. S. Haselow and A. D. Smits, 1996, Groundwater flow and tritium migration from the SRS Old Burial Ground to Fourmile Branch (U), WSRC-TR-96-0037.

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Sadler, W. R., 1995, Groundwater model recalibration and remediation well network design at the F-area Seepage Basins (U), WSRC-RP-95-237.

WSRC, 1997, Phase II, RCRA Facility Investigation/Remedial Investigation Plan for the F-Area Burning/Rubble Pits (231-F and 231-1F) and Rubble Pit (231-2F) (U), WSRC-RP-90-486 Rev. 2.2, September.

Table 1 Design, proposed as of 12/97 (Day, 1997), and simulated operation flow rates for F-Area PTR system.

Well ID	*UTR aquifer zone*	*Design flowrate (gpm)*	*Proposed flowrate (gpm)*	*Simulated flowrate (gpm)*
FEX-1	"upper"	15	15	15
FEX-2	"upper"	12	15	15
FEX-3	"upper"	22	25	25
FEX-4	"upper"	22	25	25
FEX-5	"upper"	15	5	5
FEX-6	"upper"	12	20	20
FEX-7	"upper"	15	15	0 upper screen/ 15 lower screen
FEX-8	"upper"	13	8	3.5 upper screen/ 4.5 lower screen
FEX-9	"upper"	13	12	12
FEX-10	"upper"	30	30	30
FEX-11	"upper"	30	30	30
Total extraction		**199**	**200**	**200**
FIN-1	"upper"	22	25	25
FIN-2	"upper"	22	25	25
FIN-3	"upper"	22	15	15
FIN-4	"upper"	22	25	25
FIN-5	"upper"	22	25	25
FIN-6	"lower"	22	25	25
FIN-7	"lower"	22	15	15
FIN-8	"upper"	13	10	10
FIN-9	"upper"	13	10	10
FIN-10	"upper"	22	25	25
Total injection		**202**	**200**	**200**

Table 2 Design, proposed as of 12/97 (Day, 1997), and simulated operation flow rates for H-area PTR system.

Well ID	*UTR aquifer zone*	*Design flowrate (gpm)*	*Proposed flowrate (gpm)*	*Simulated flowrate (gpm)*
HEX-1	"upper"	15	20	20
HEX-2	"upper"	-	-	-
HEX-3	"upper"	13	15	15
HEX-4	"upper"	22	20	20
HEX-5	"upper"	-	-	-
HEX-6	"upper"	-	-	-
HEX-7	"upper"	-	-	-
HEX-8	"upper"	-	-	-
HEX-9	"upper"	25	10	10
HEX-10	"upper"	-	-	-
HEX-11	"upper"	-	-	-
HEX-12	"lower"	5	5	0.5 upper screen/ 4.5 lower screen
HEX-13	"lower"	-	-	-
HEX-14	"lower"	-	-	-
HEX-15	"lower"	-	-	-
HEX-16	"upper"	10	20	20
HEX-17R	"upper"	18	25	25
HEX-18	"upper"	20	30	30
HEX-19R	"upper"	22	5	5
Total extraction		**150**	**150**	**150**
HIN-1R	"upper"	25	5	5
HIN-2	"upper"	17	25	25
HIN-3	"upper"	18	15	15
HIN-4	"upper"	15	35	35
HIN-5	"upper"	10	20	8 upper screen/ 12 lower screen
HIN-6	"lower"	5	10	0.8 upper screen/ 9.2 lower screen
HIN-7	"lower"	0	10	0.9 upper screen/ 9.1 lower screen
HIN-8	"upper"	20	15	15
HIN-9	"upper"	20	5	5
HIN-10	"upper"	20	10	10
Total injection		**150**	**150**	**150**

Table 3 Simulation phases.

Feature	*Phase 0 <1955*	*Phase I 1955-1988*	*Phase II 1988-1998*	*Phase III 1998-2035+*
F- and H-area PTR operation				×
F- and H-area seepage basins operation		×		
F- and H-area seepage basins cap			×	×
MWMF cap			×	×
ORWBG cap				×

Table 4 Comparison of hydraulic properties between Rev. 0 and Rev. 2 GSA models.

Hydraulic Property	*Averaged over entire GSA region*	
	Rev. 0 GSA model	*Rev. 2 GSA model*
Gordon a.u. K_h	38 ft/d	38 ft/d
Gordon c.u. K_v	10^{-4} ft/d	10^{-5} ft/d
"lower" UTR a.z. K_h	7.1 ft/d	9.3 ft/d
"tan clay" UTR c.z. K_v	6.1×10^{-3} ft/d	6.3×10^{-3} ft/d
"upper" UTR a.z. K_h up to water table	7.5 ft/d	9.6 ft/d
"upper" UTR a.z. K_h up to ground surface	5.7 ft/d	7.7 ft/d
Natural recharge	14.8 in/yr	14.5 in/yr
Artificial recharge from H-area	95 gpm	94 gpm

Table 5 Comparison of Rev. 0 and Rev. 2 GSA models to hydraulic head and stream baseflow calibration targets.

Calibration Target	*Field data estimate*	*Rev. 0 GSA model*	*Rev. 2 GSA model*
Overall r.m.s. head residual	-	3.2 ft	3.3 ft
Gordon UTR a.u. r.m.s. head residual	-	2.0 ft	2.5 ft
"lower" UTR a.z. r.m.s. head residual	-	4.4 ft	4.8 ft
"upper" UTR a.z. r.m.s. head residual	-	2.8 ft	2.6 ft
Baseflow to UTR and tributaries excl. McQueen Branch	18.2 ft^3/s	13.6 ft^3/s*	14.5 ft^3/s
Baseflow to Fourmile Branch and tributaries	2.6 ft^3/s	2.9 ft^3/s	3.6 ft^3/s
Baseflow to McQueen Branch	1.5 ft^3/s	3.5 ft^3/s	4.7 ft^3/s
Baseflow to Crouch Branch	1.8 ft^3/s	1.3 ft^3/s	1.6 ft^3/s
Combined baseflow estimates	24.1 ft^3/s	21.3 ft^3/s	24.4 ft^3/s

* incorrectly listed in Table 8 of WSRC-TR-96-0399 as 10.1 ft^3/s.

Table 6 Comparison of extraction and injection flowrates between western and eastern H-area wells located in the "upper" UTR aquifer zone.

Well group	*Description*	*Design flowrate (gpm)*	*Proposed flowrate (gpm)*	*Change*
HEX-1, 16, 17	Western "upper" UTR extraction wells	43	65	+22 gpm / +51%
HEX-3, 4, 9, 18, 19	Eastern "upper" UTR extraction wells	102	80	-22 gpm / -22%
Total extraction		145	145	-
HIN-1, 8, 9	Western "upper" UTR extraction wells	65	25	-40 gpm / -62%
HIN-2, 3, 4, 5, 10	Eastern "upper" UTR extraction wells	80	105	+25 gpm / +31%
Total injection		145	130	-15 gpm

List of Figures

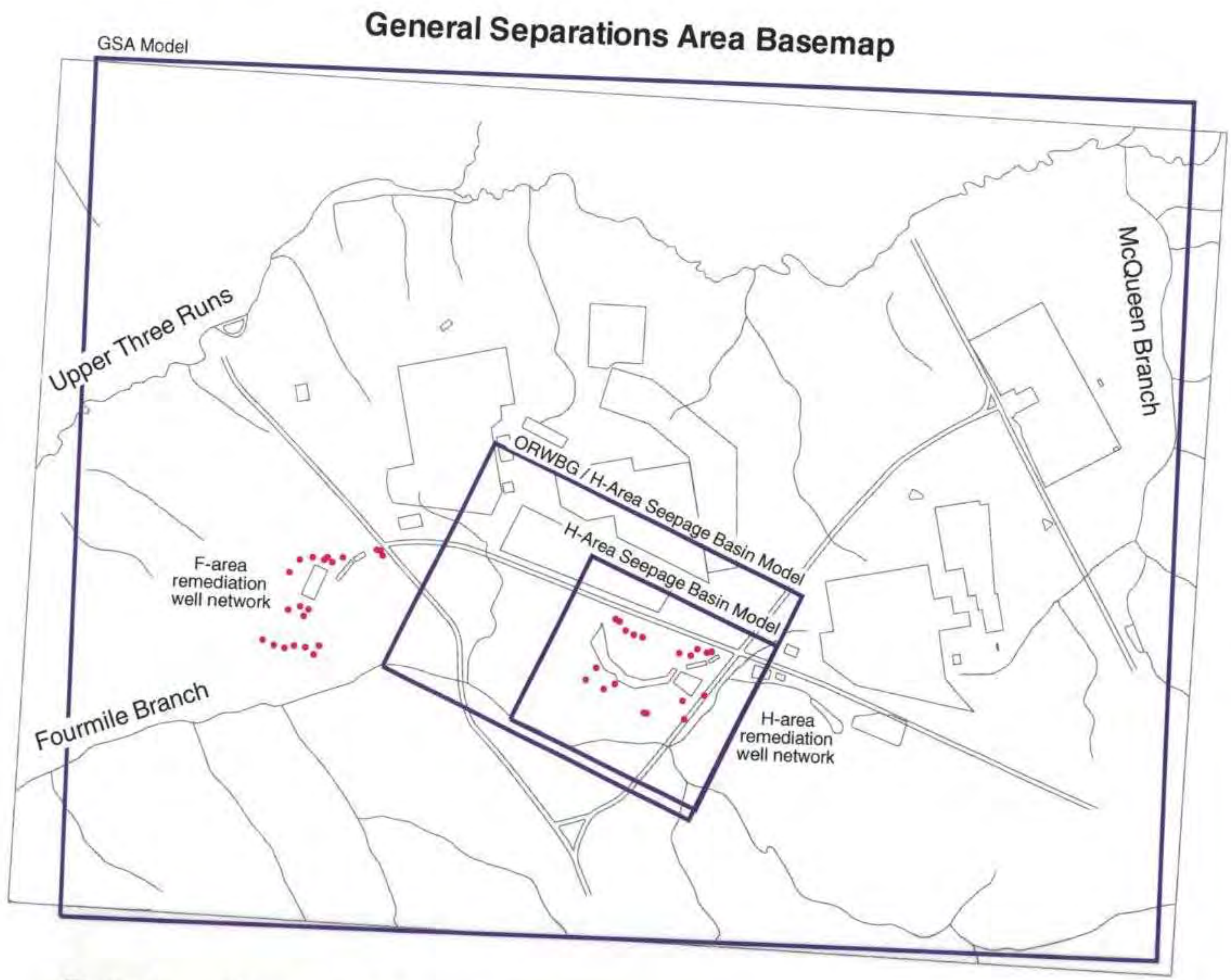

Figure 1 Basemap of General Separations Area (GSA) showing F- and H-area PTR remediation wells and model domains.

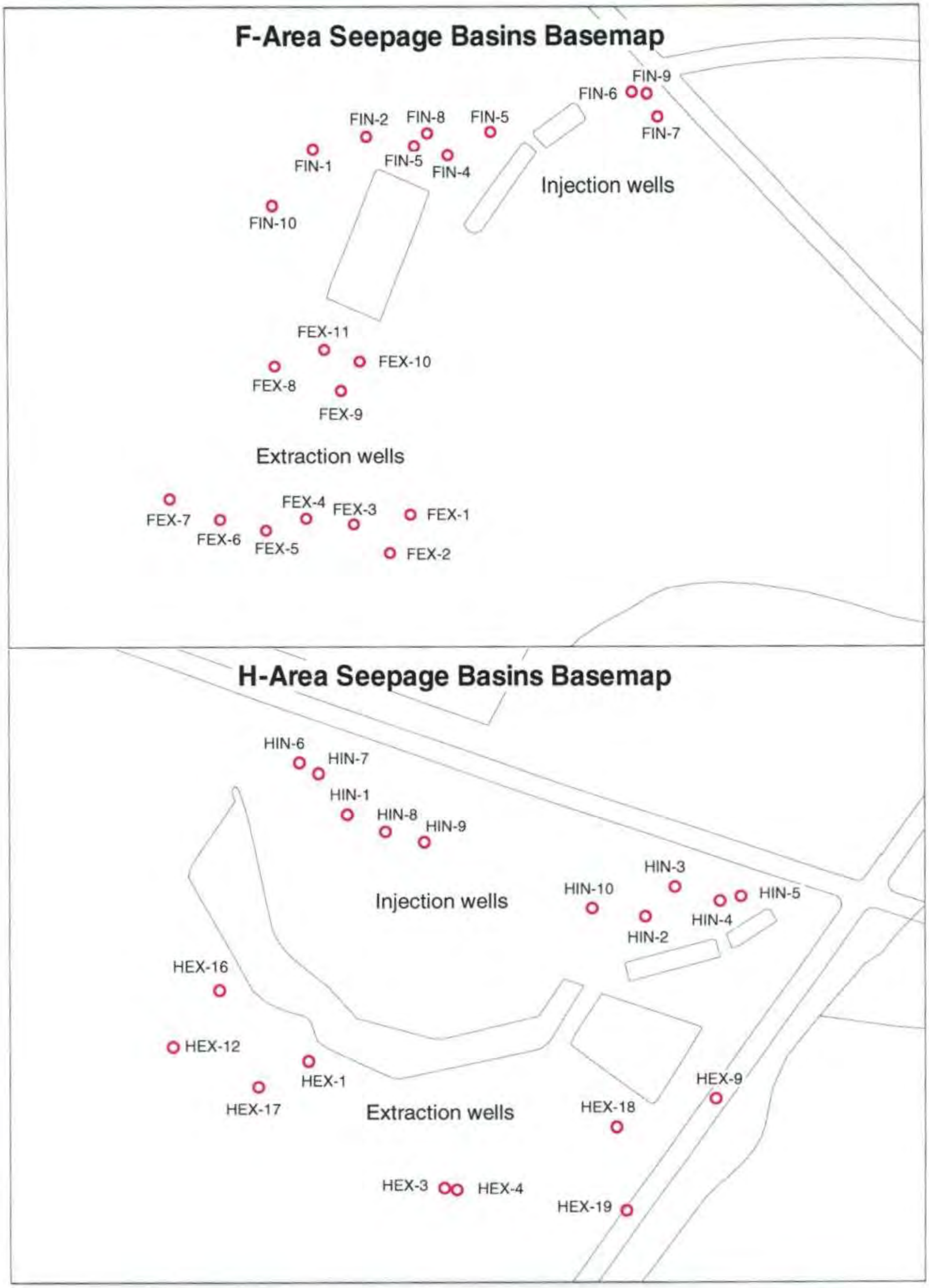

Figure 2 F- and H-area PTR remediation wells.

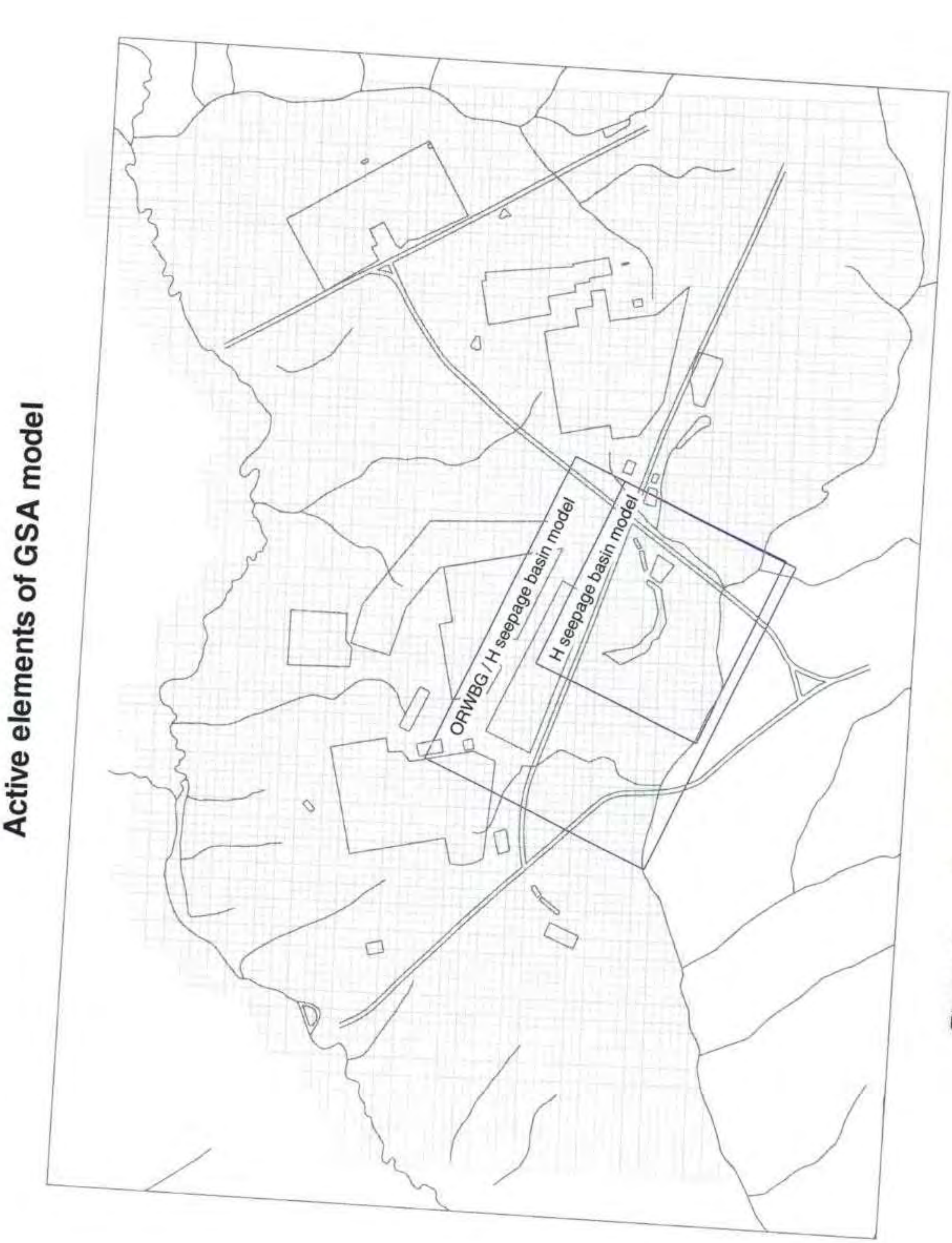

Figure 3 Plan view of GSA flow model mesh.

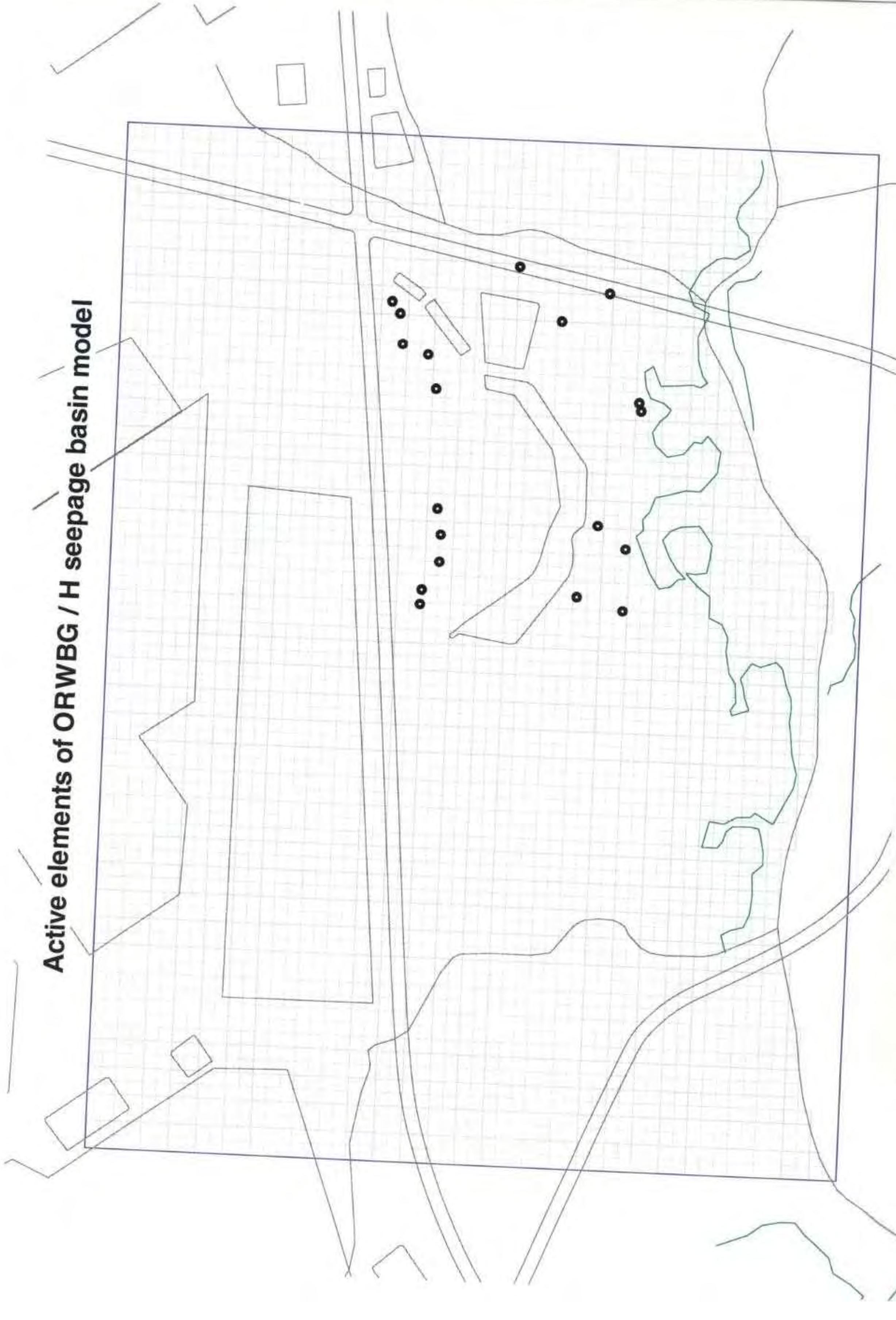

Figure 4 Plan view of ORWBG/H-Area Seepage Basin model mesh.

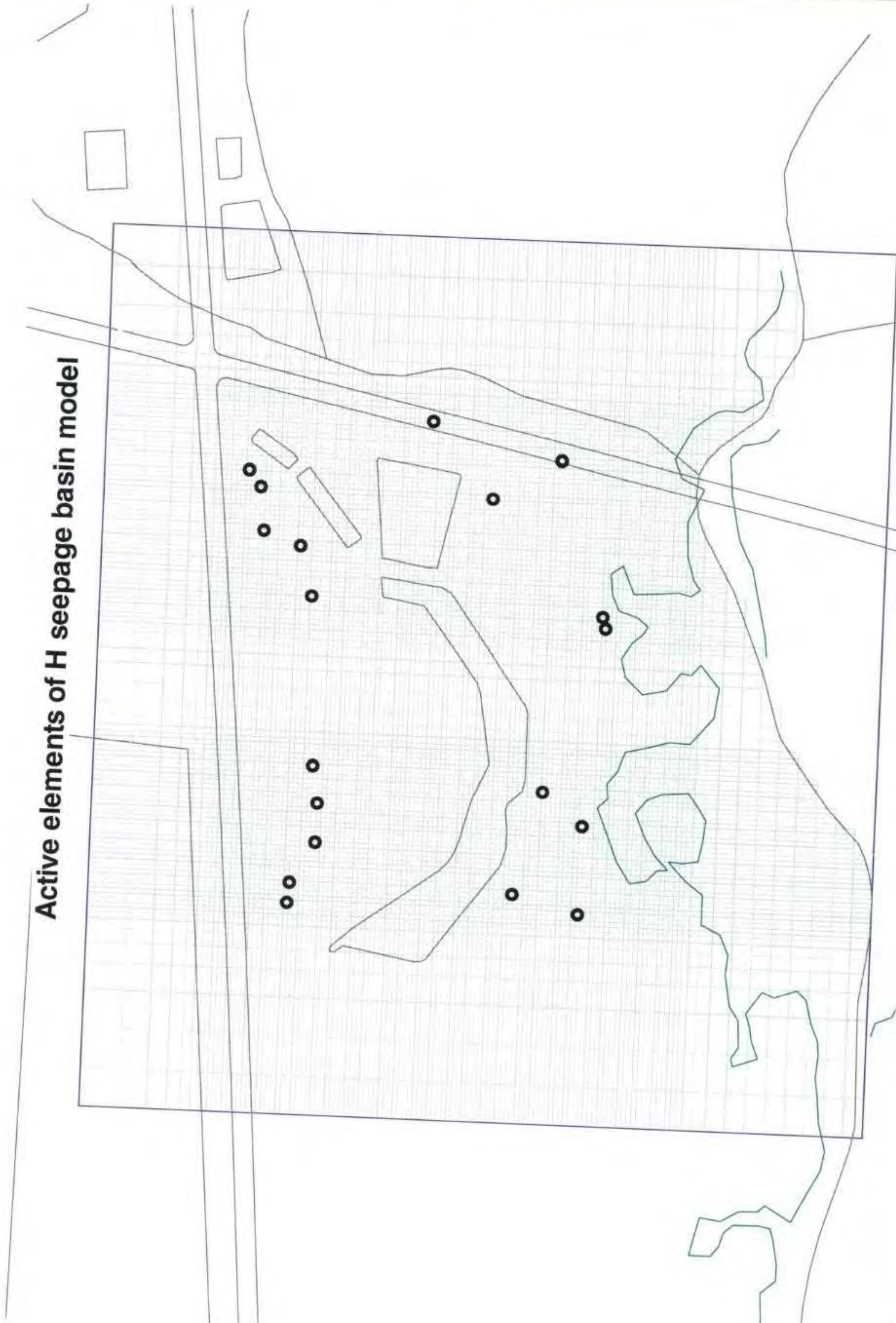

Figure 5 Plan view of H-Area Seepage Basin model mesh.

Vertically-averaged head difference due to F and H remediation and ORWBG cap UTR "upper" aquifer zone; 2.5 day elapsed time

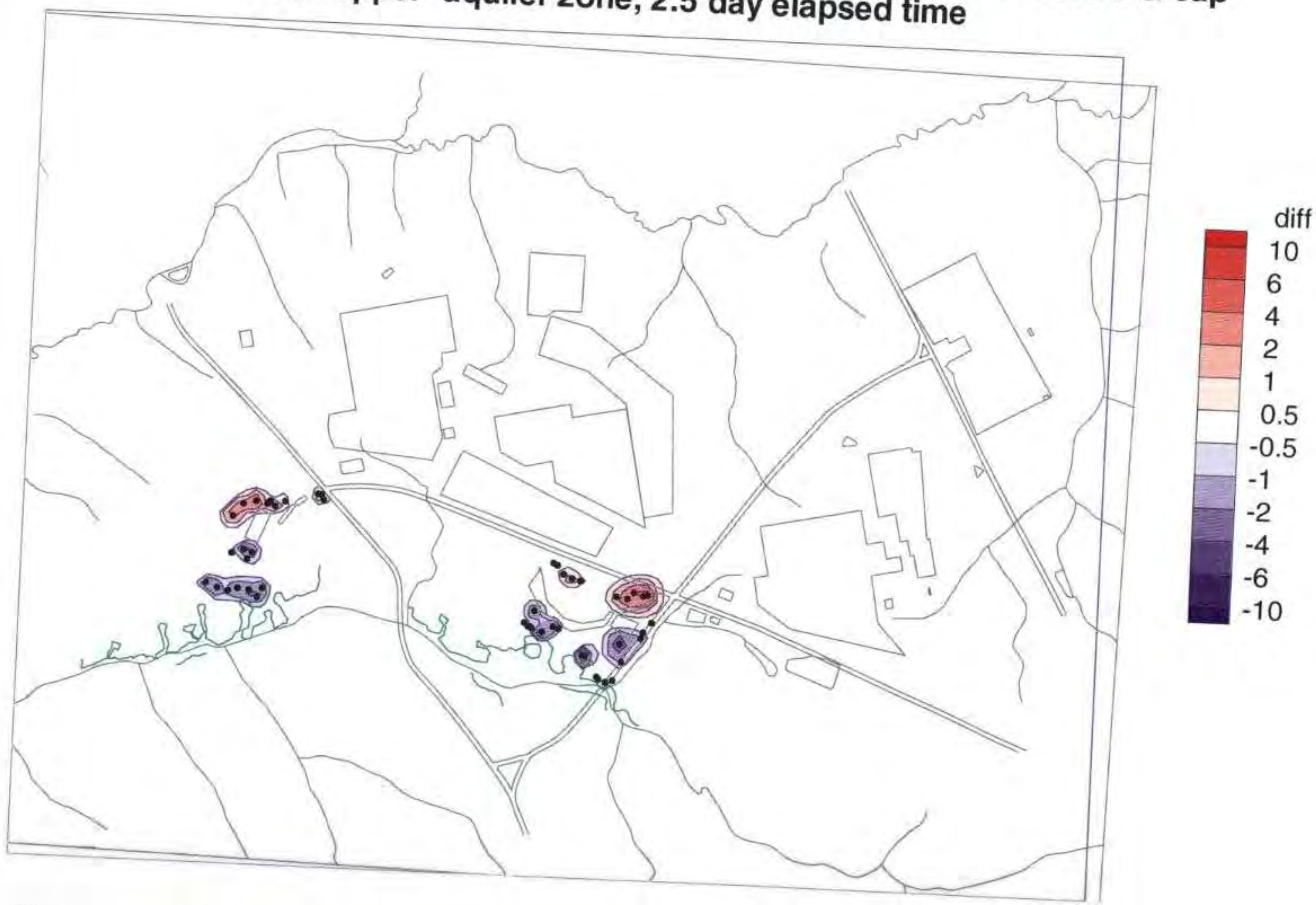

Figure 6 Vertically averaged change in head within the "upper" UTR aquifer zone; entire GSA; 2.5 days following system start-up.

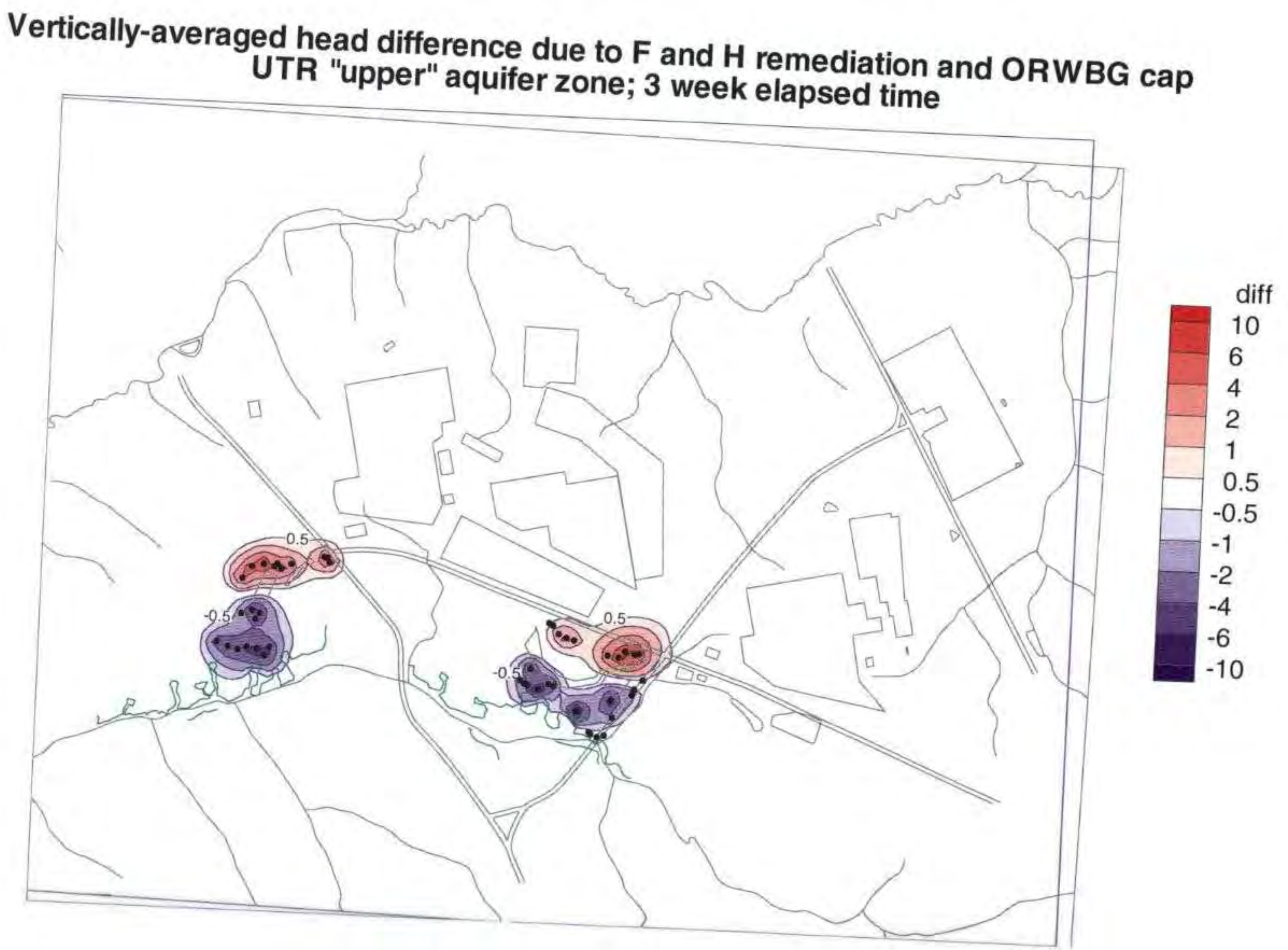

Figure 7 Vertically averaged change in head within the "upper" UTR aquifer zone; entire GSA; 3 weeks following system start-up.

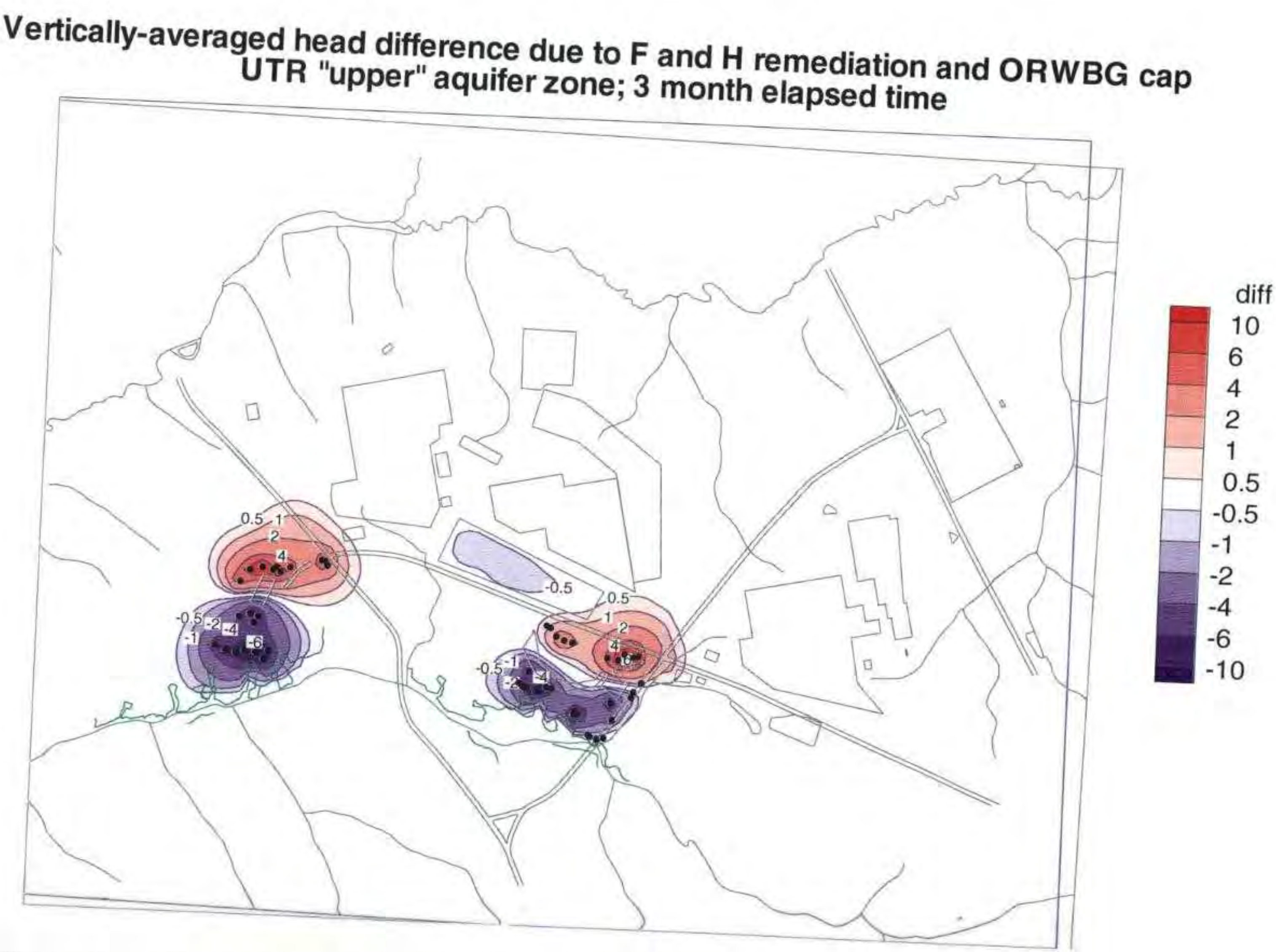

Figure 8 Vertically averaged change in head within the "upper" UTR aquifer zone; entire GSA; 3 months following system start-up.

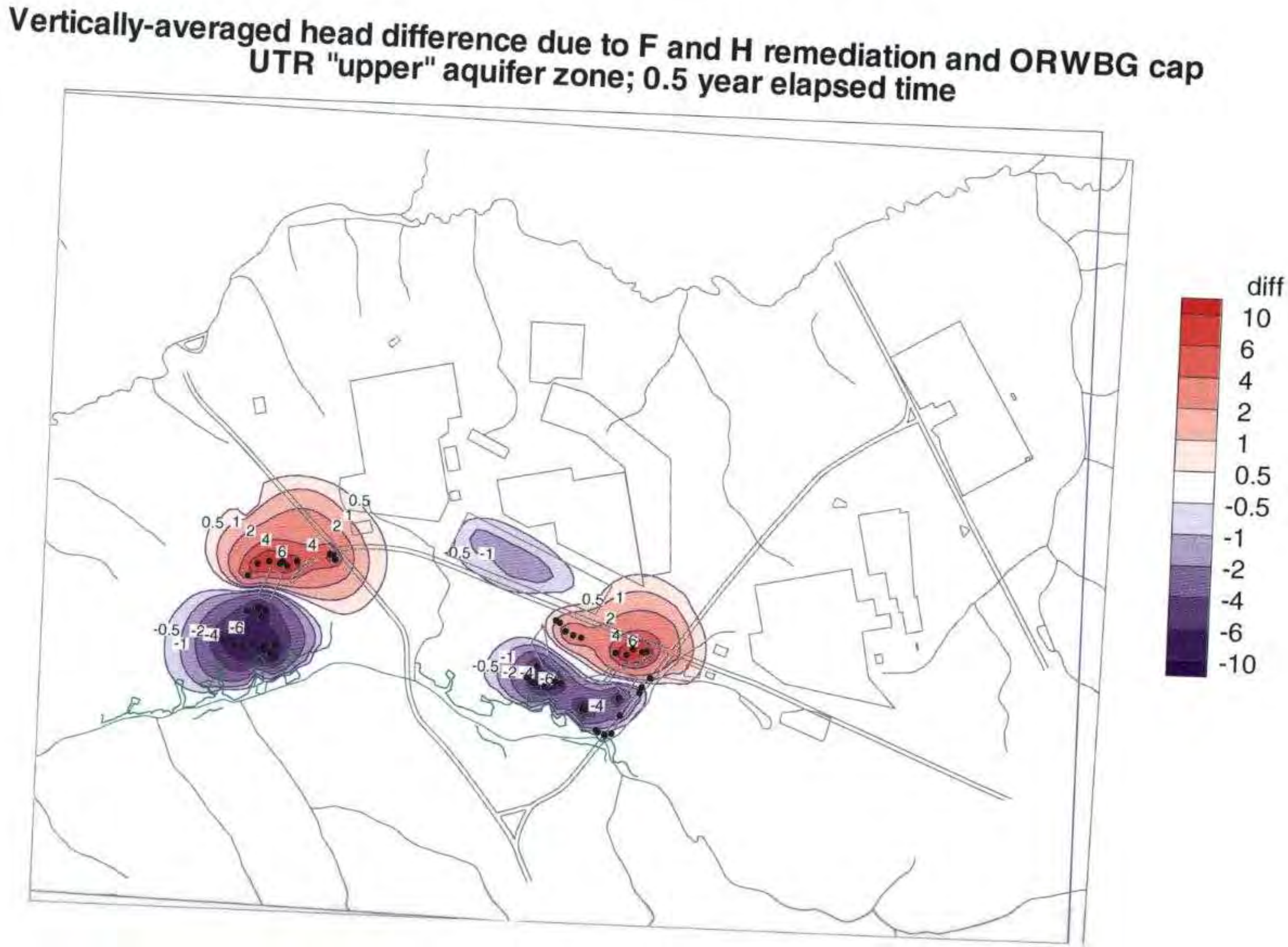

Figure 9 Vertically averaged change in head within the "upper" UTR aquifer zone; entire GSA; 6 months following system start-up.

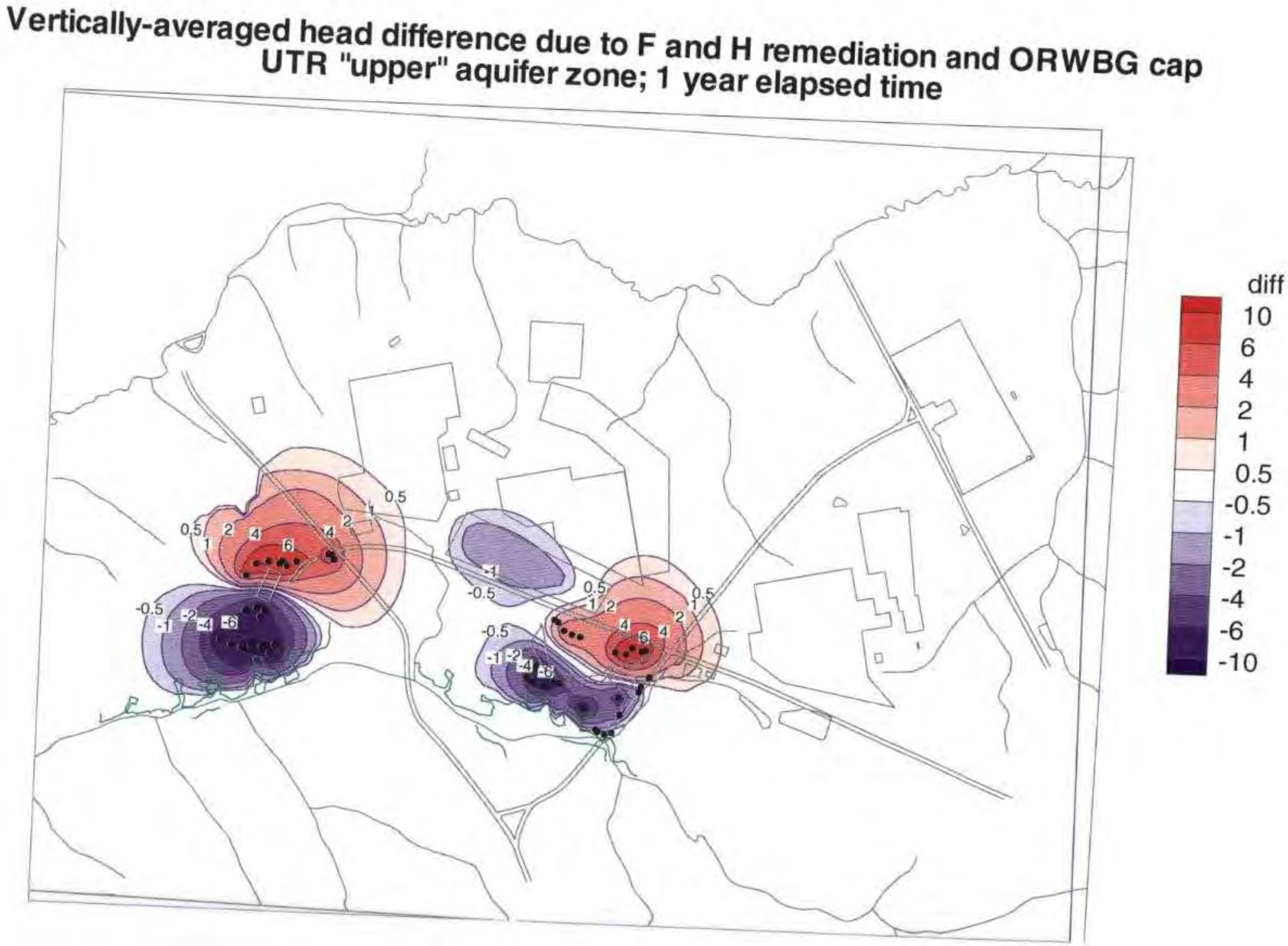

Figure 10 Vertically averaged change in head within the "upper" UTR aquifer zone; entire GSA; 1 year following system start-up.

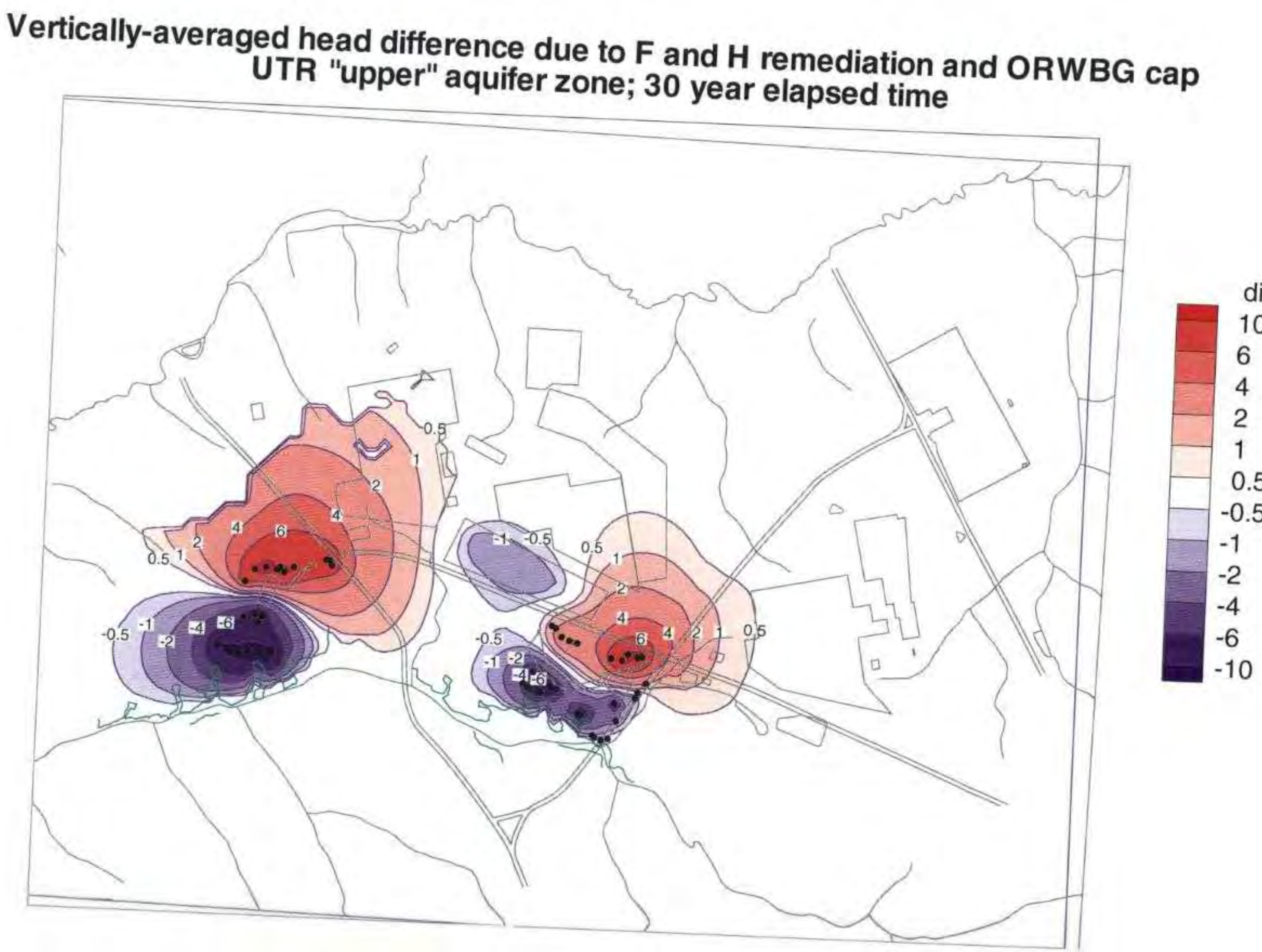

Figure 11 Vertically averaged change in head within the "upper" UTR aquifer zone; entire GSA; 30 years following system start-up (steady-state).

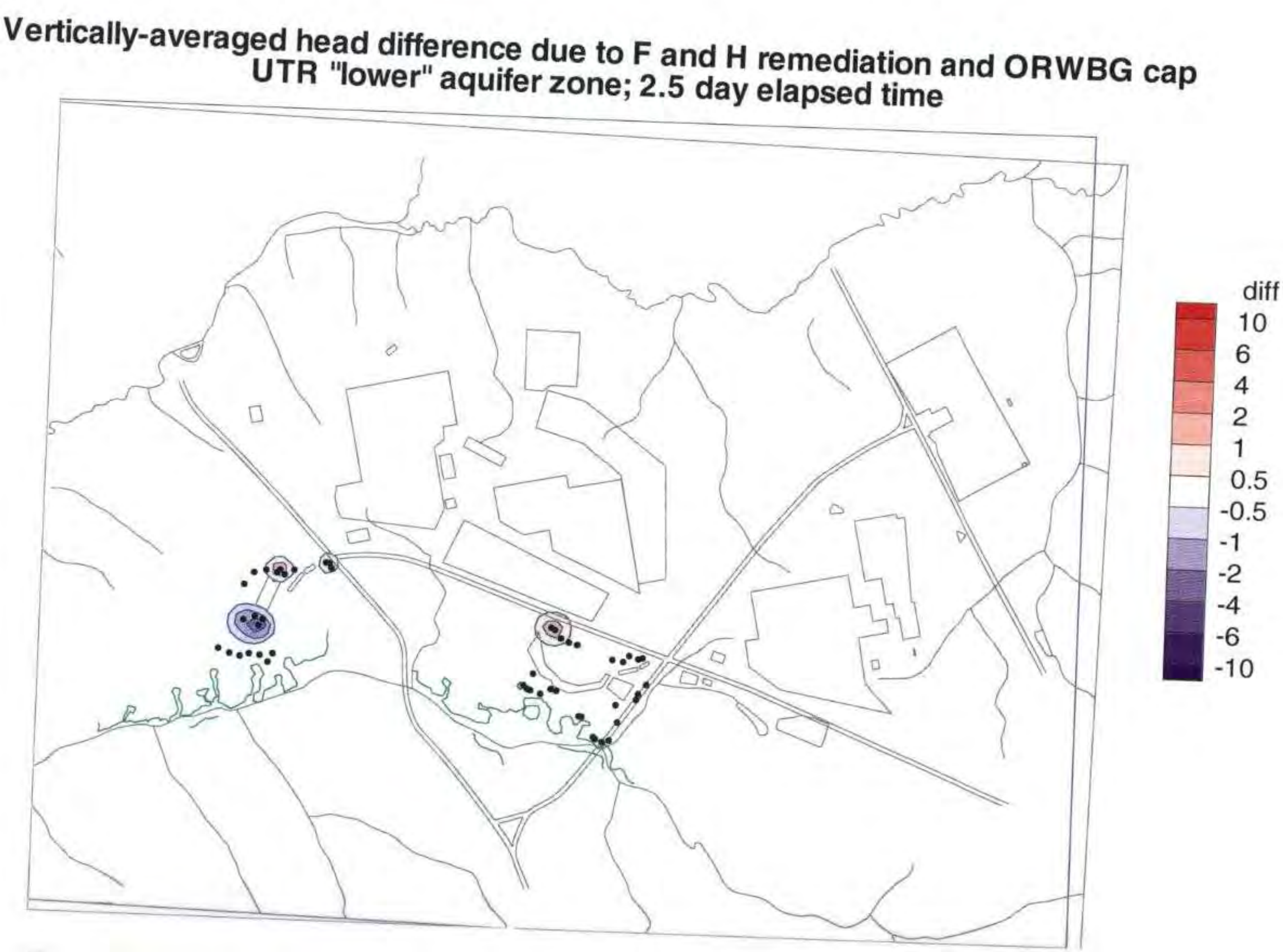

Figure 12 Vertically averaged change in head within the "lower" UTR aquifer zone; entire GSA; 2.5 days following system start-up.

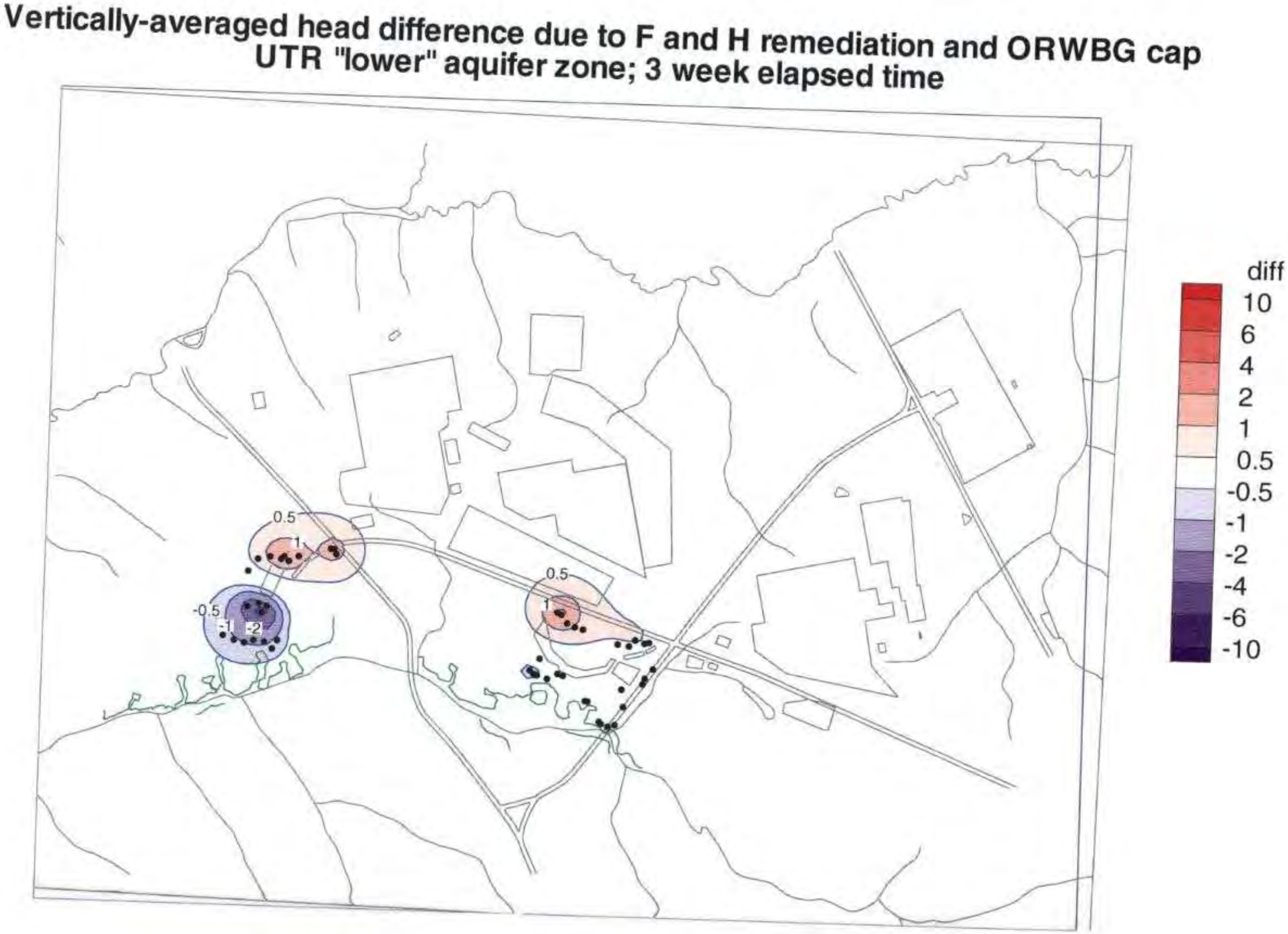

Figure 13 Vertically averaged change in head within the "lower" UTR aquifer zone; entire GSA; 3 weeks following system start-up.

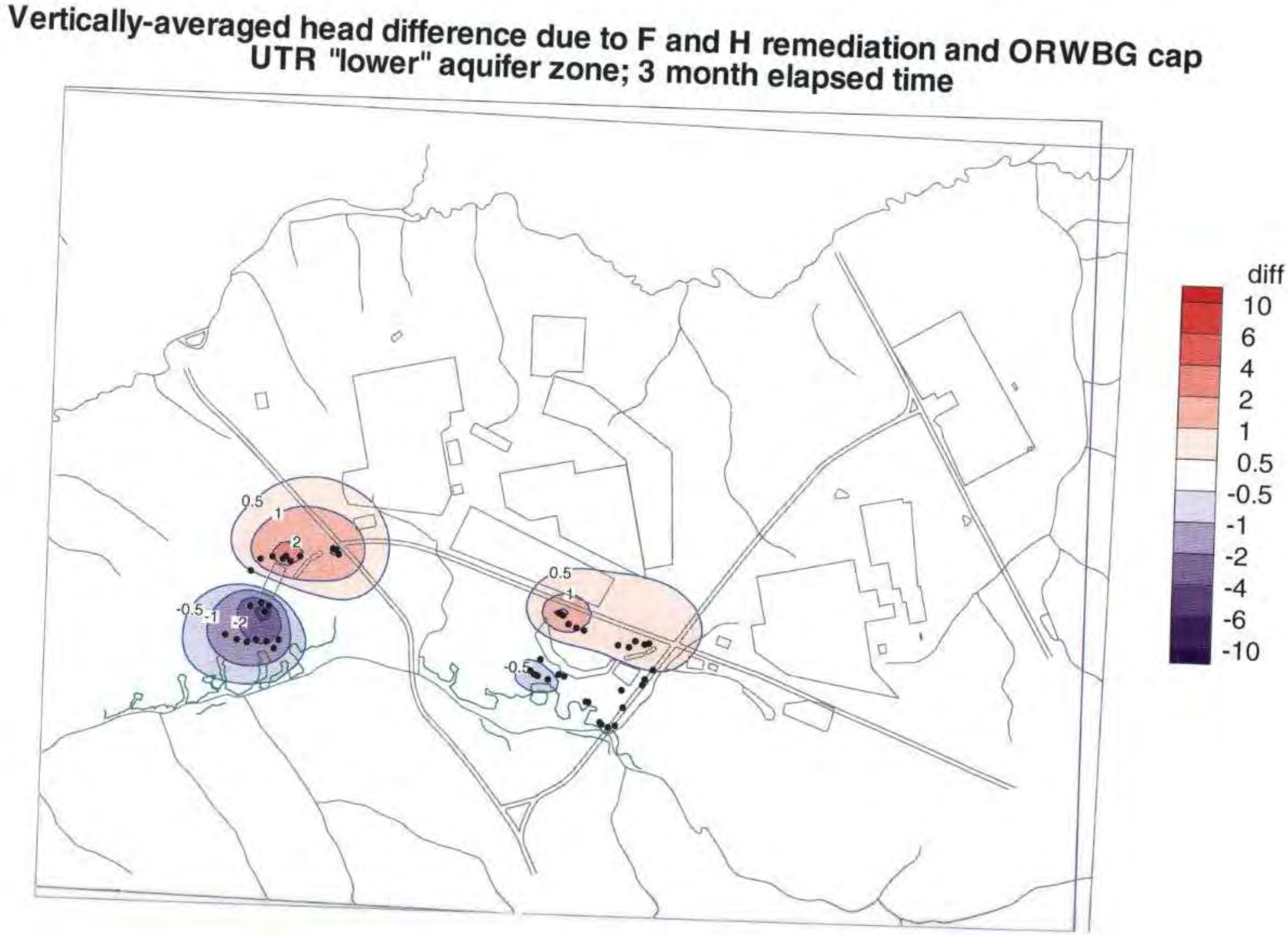

Figure 14 Vertically averaged change in head within the "lower" UTR aquifer zone; entire GSA; 3 months following system start-up.

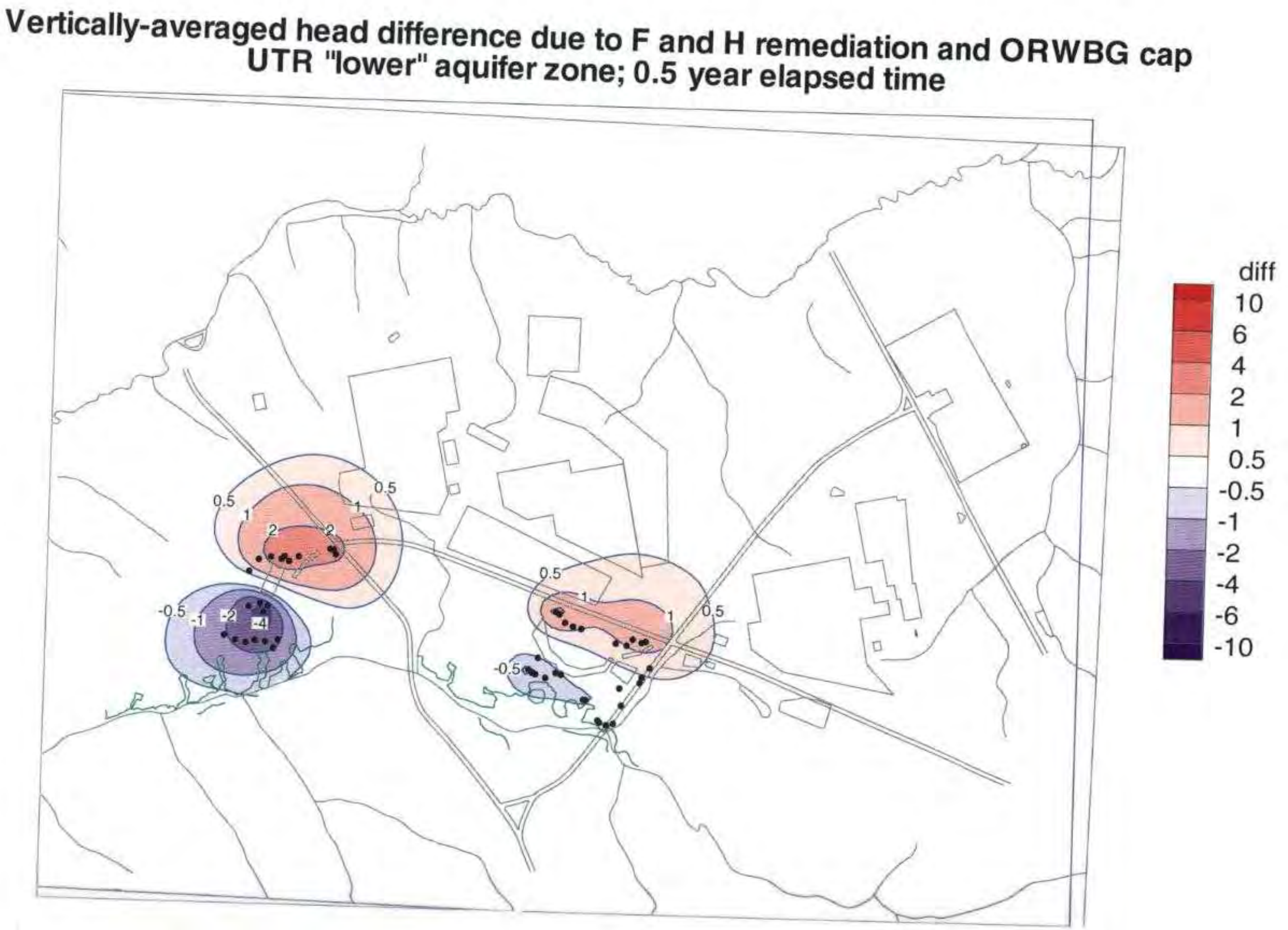

Figure 15 Vertically averaged change in head within the "lower" UTR aquifer zone; entire GSA; 6 months following system start-up.

Vertically-averaged head difference due to F and H remediation and ORWBG cap UTR "lower" aquifer zone; 1 year elapsed time

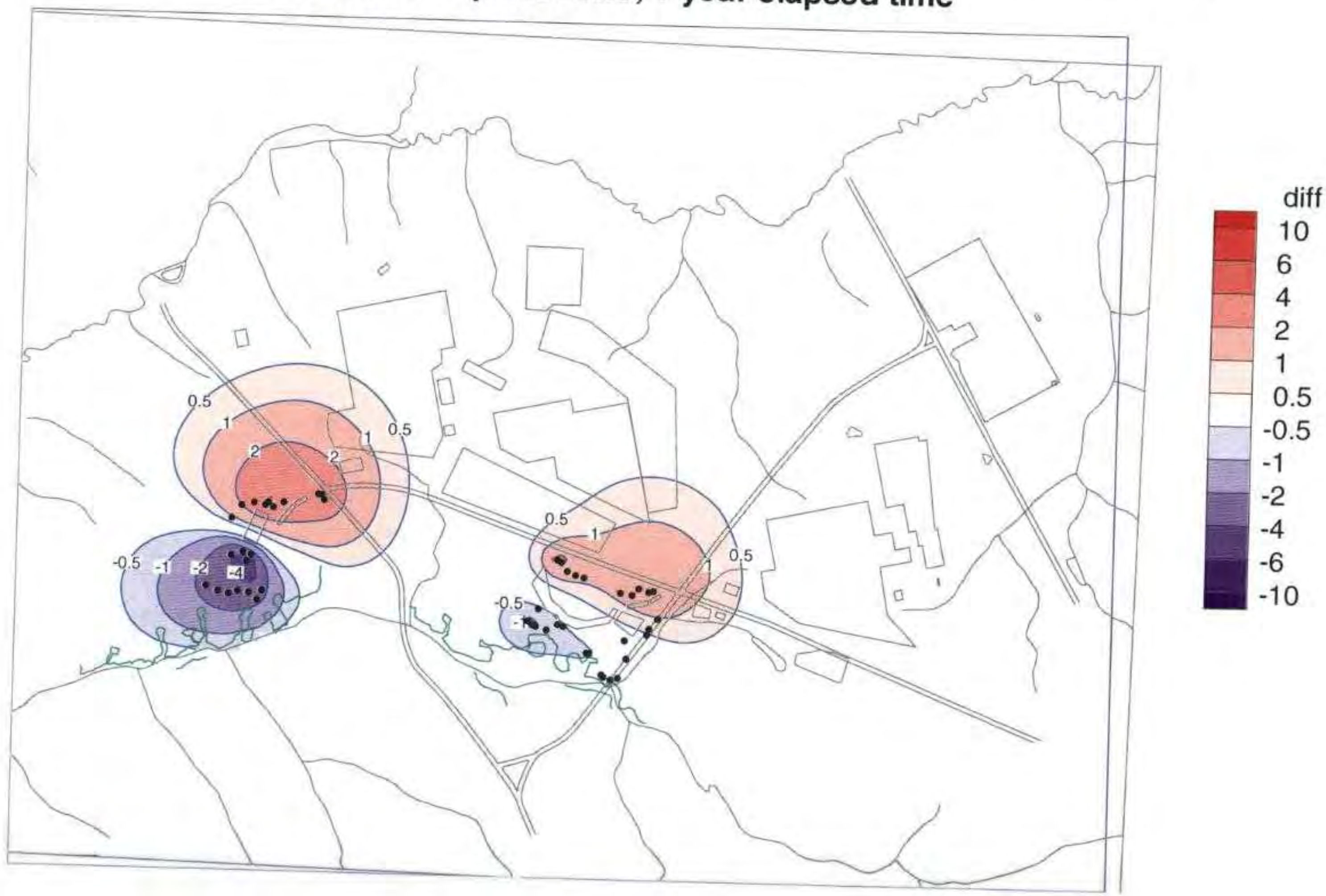

Figure 16 Vertically averaged change in head within the "lower" UTR aquifer zone; entire GSA; 1 year following system start-up.

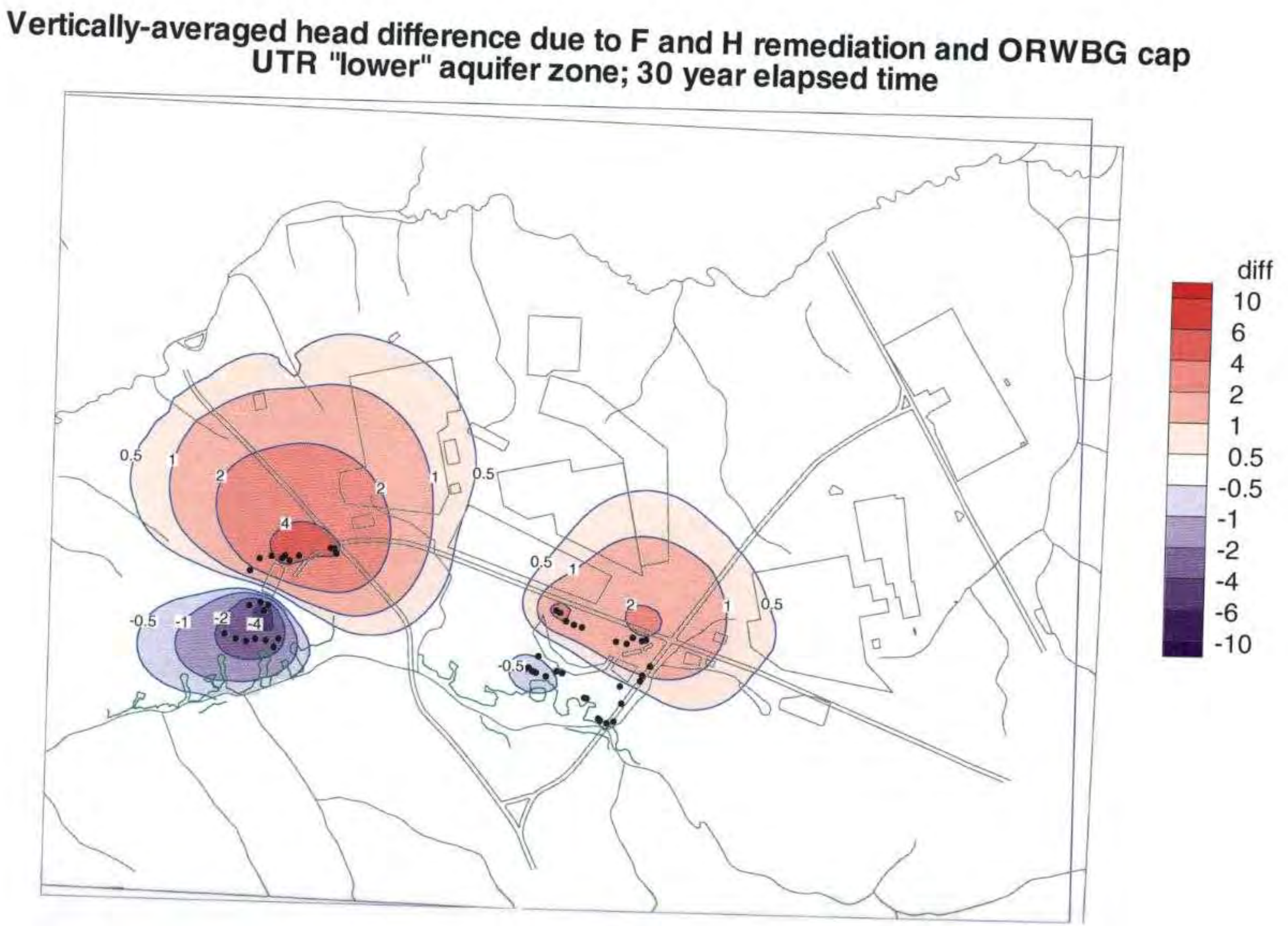

Figure 17 Vertically averaged change in head within the "lower" UTR aquifer zone; entire GSA; 30 years following system start-up (steady-state).

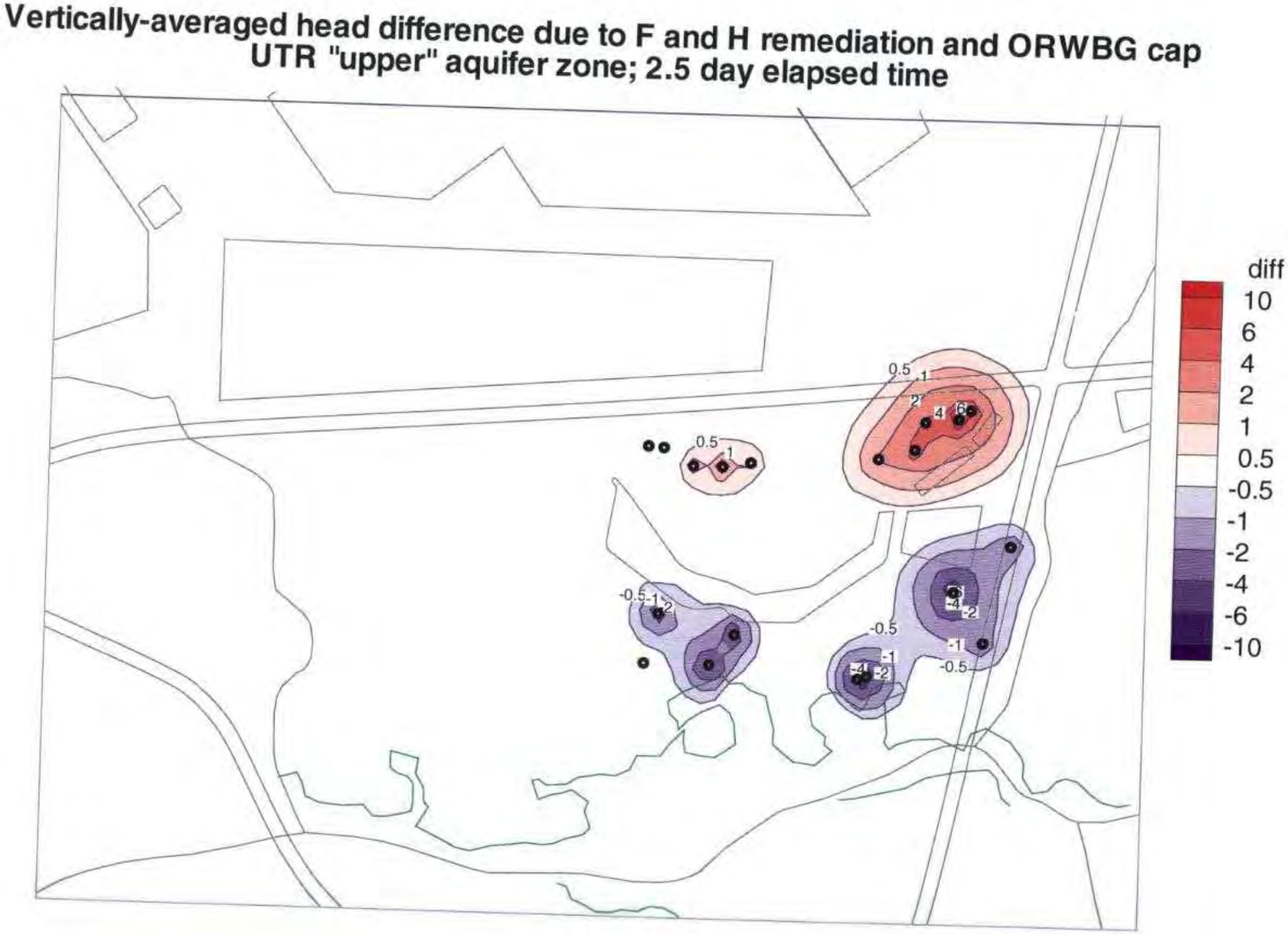

Figure 18 Vertically averaged change in head within the "upper" UTR aquifer zone; ORWBG and H seepage basin area; 2.5 days following system start-up.

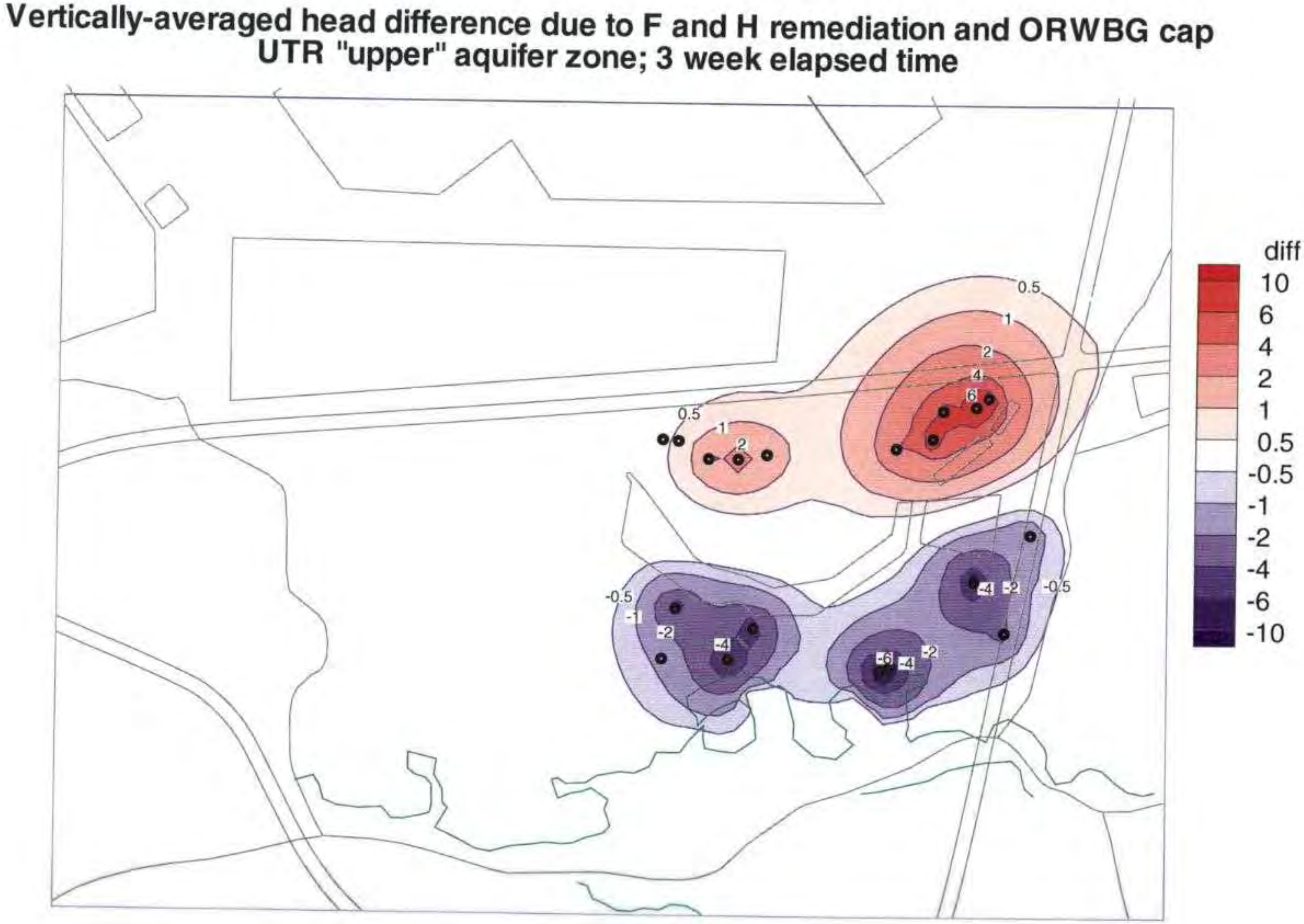

Figure 19 Vertically averaged change in head within the "upper" UTR aquifer zone; ORWBG and H seepage basin area; 3 weeks following system start-up.

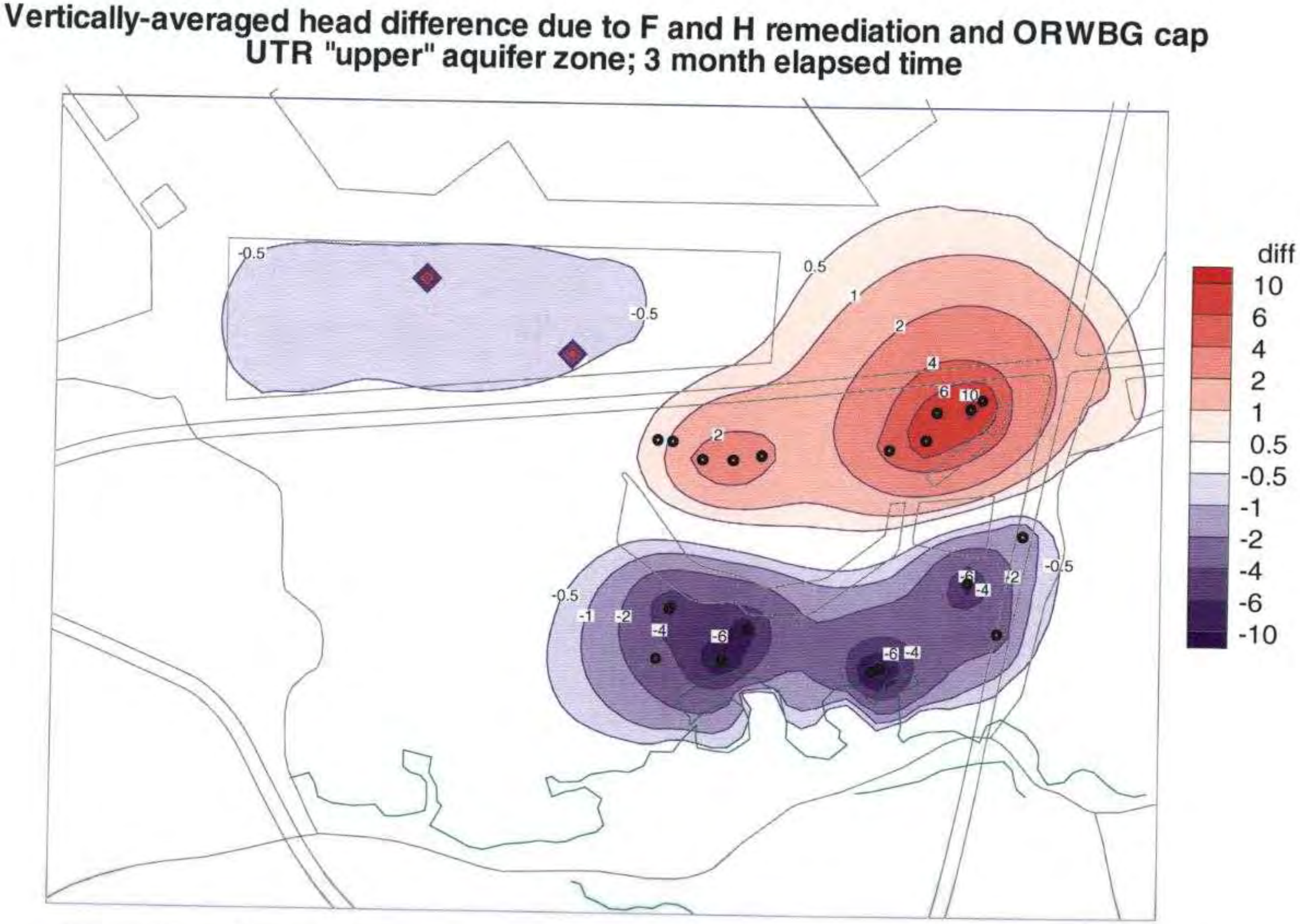

Figure 20 Vertically averaged change in head within the "upper" UTR aquifer zone; ORWBG and H seepage basin area; 3 months following system start-up.

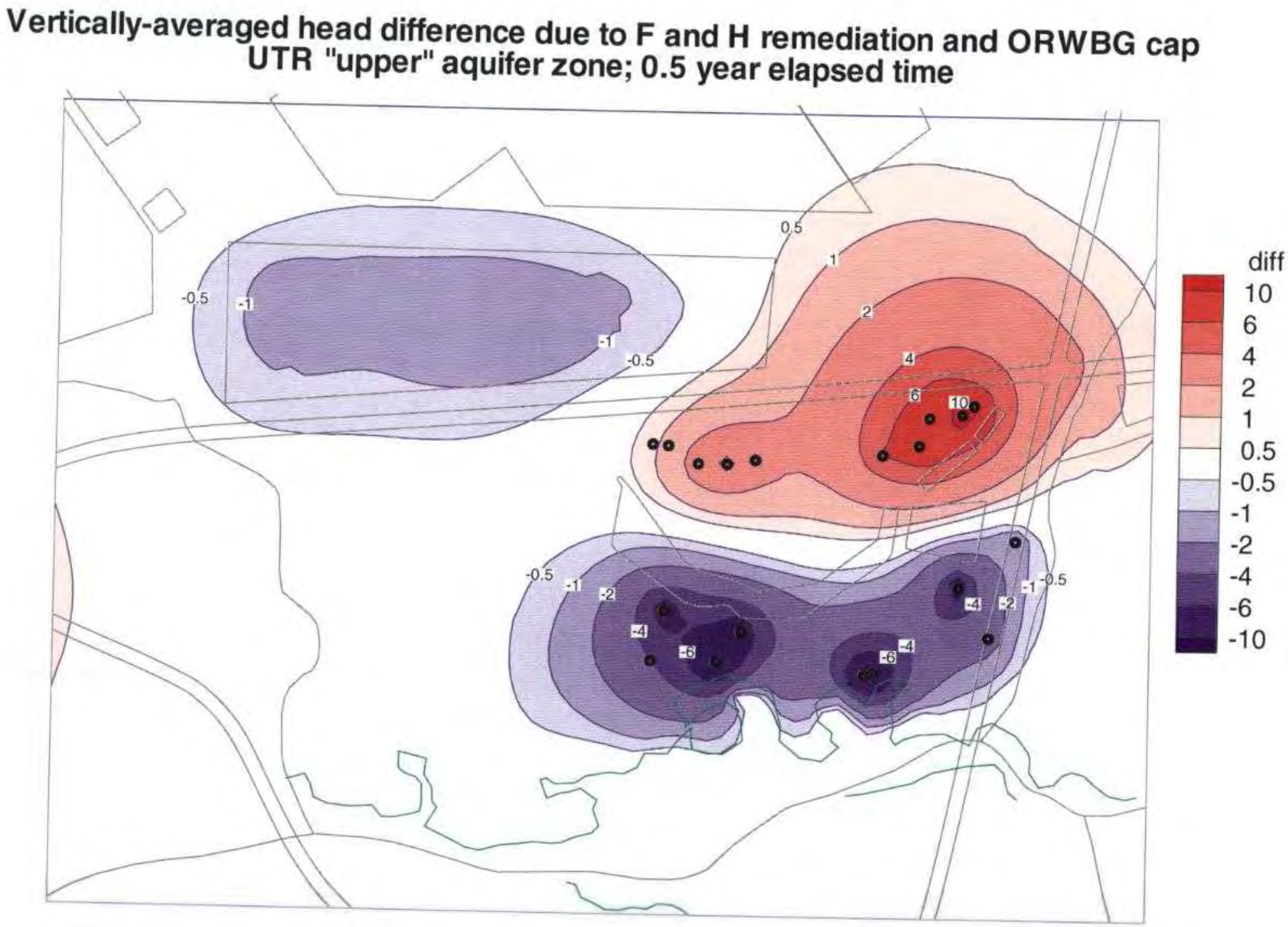

Figure 21 Vertically averaged change in head within the "upper" UTR aquifer zone; ORWBG and H seepage basin area; 6 months following system start-up.

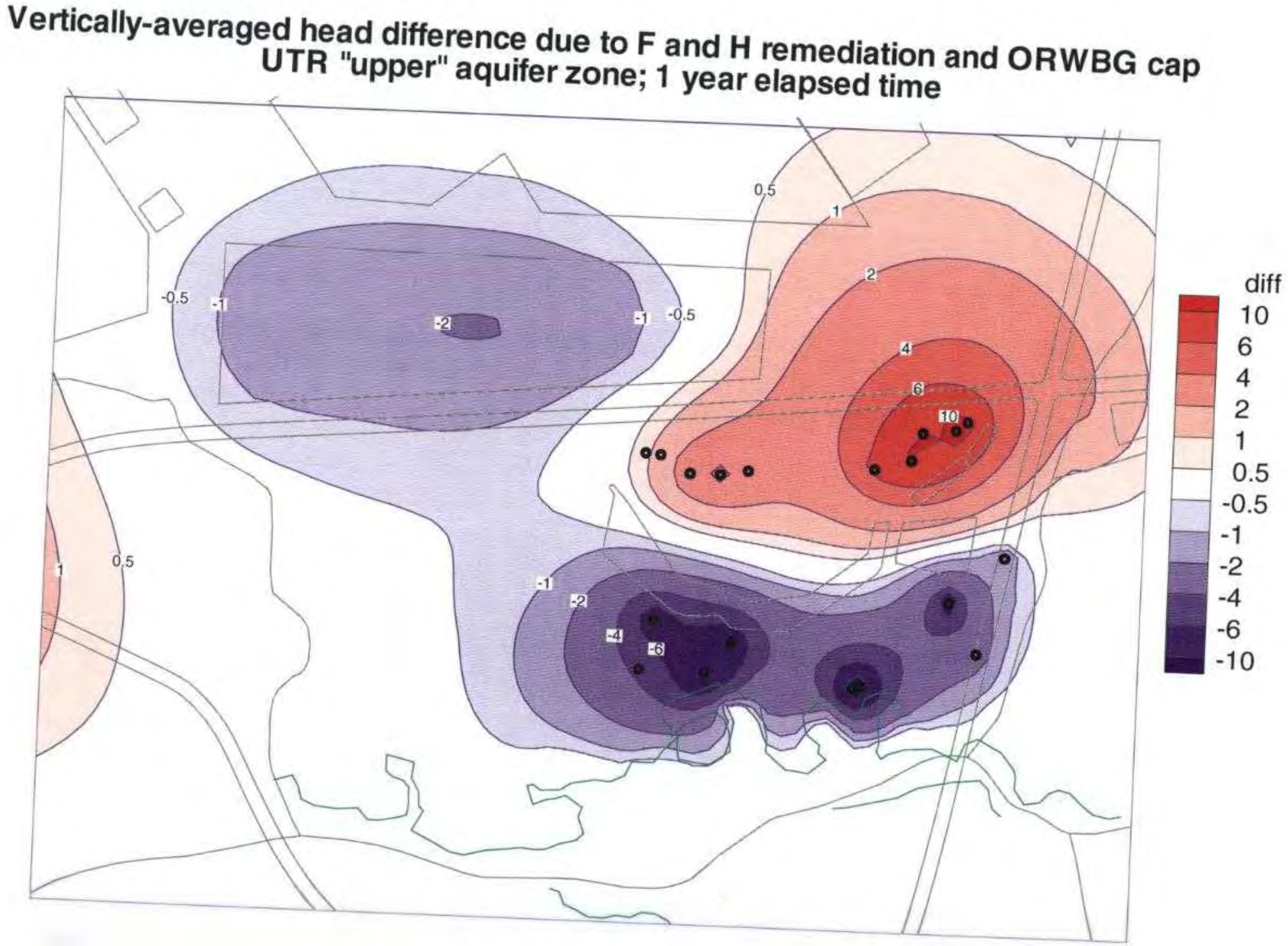

Figure 22 Vertically averaged change in head within the "upper" UTR aquifer zone; ORWBG and H seepage basin area; 1 year following system start-up.

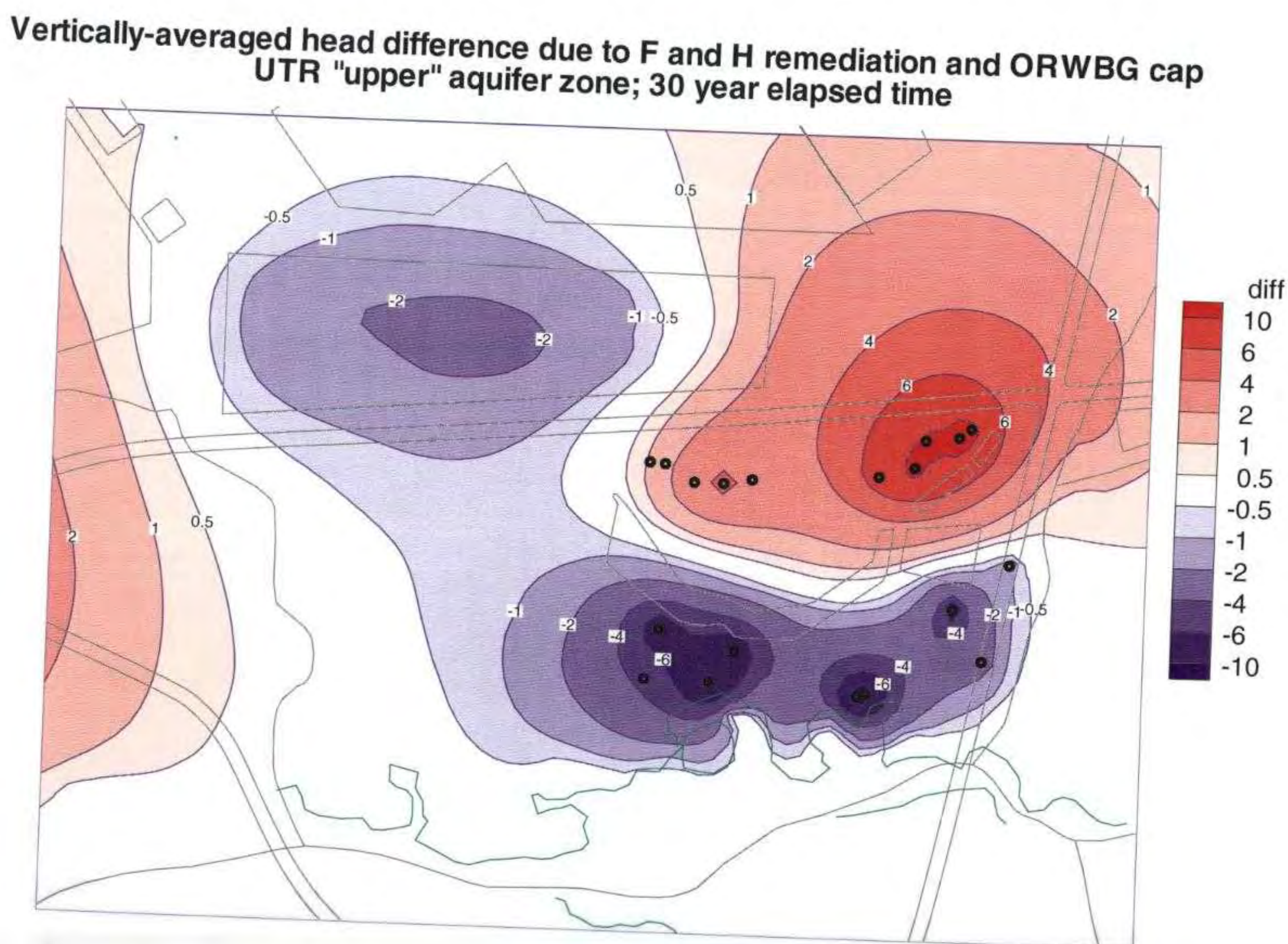

Figure 23 Vertically averaged change in head within the "upper" UTR aquifer zone; ORWBG and H seepage basin area; 30 years following system start-up (steady-state).

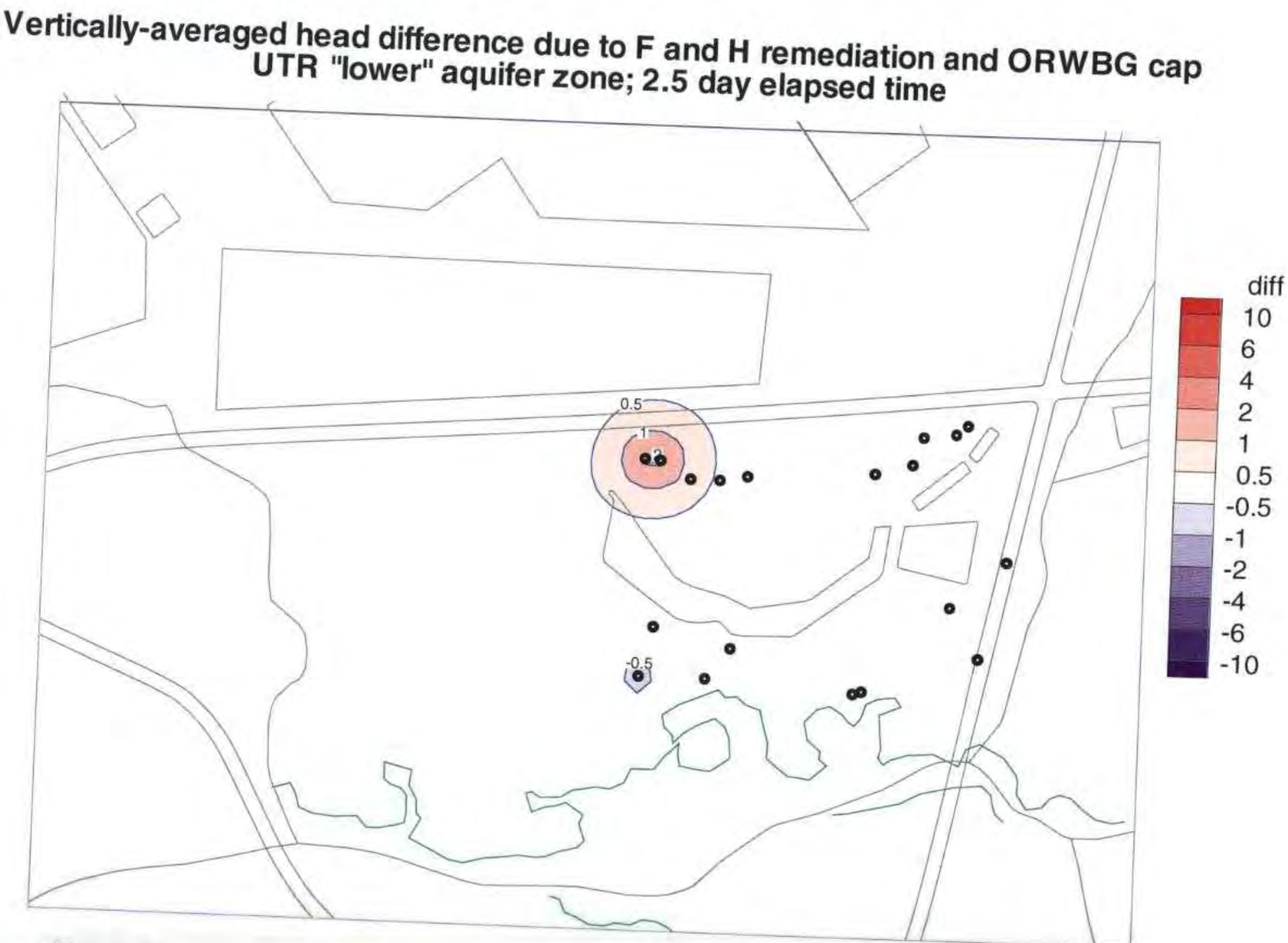

Figure 24 Vertically averaged change in head within the "lower" UTR aquifer zone; ORWBG and H seepage basin area; 2.5 days following system start-up.

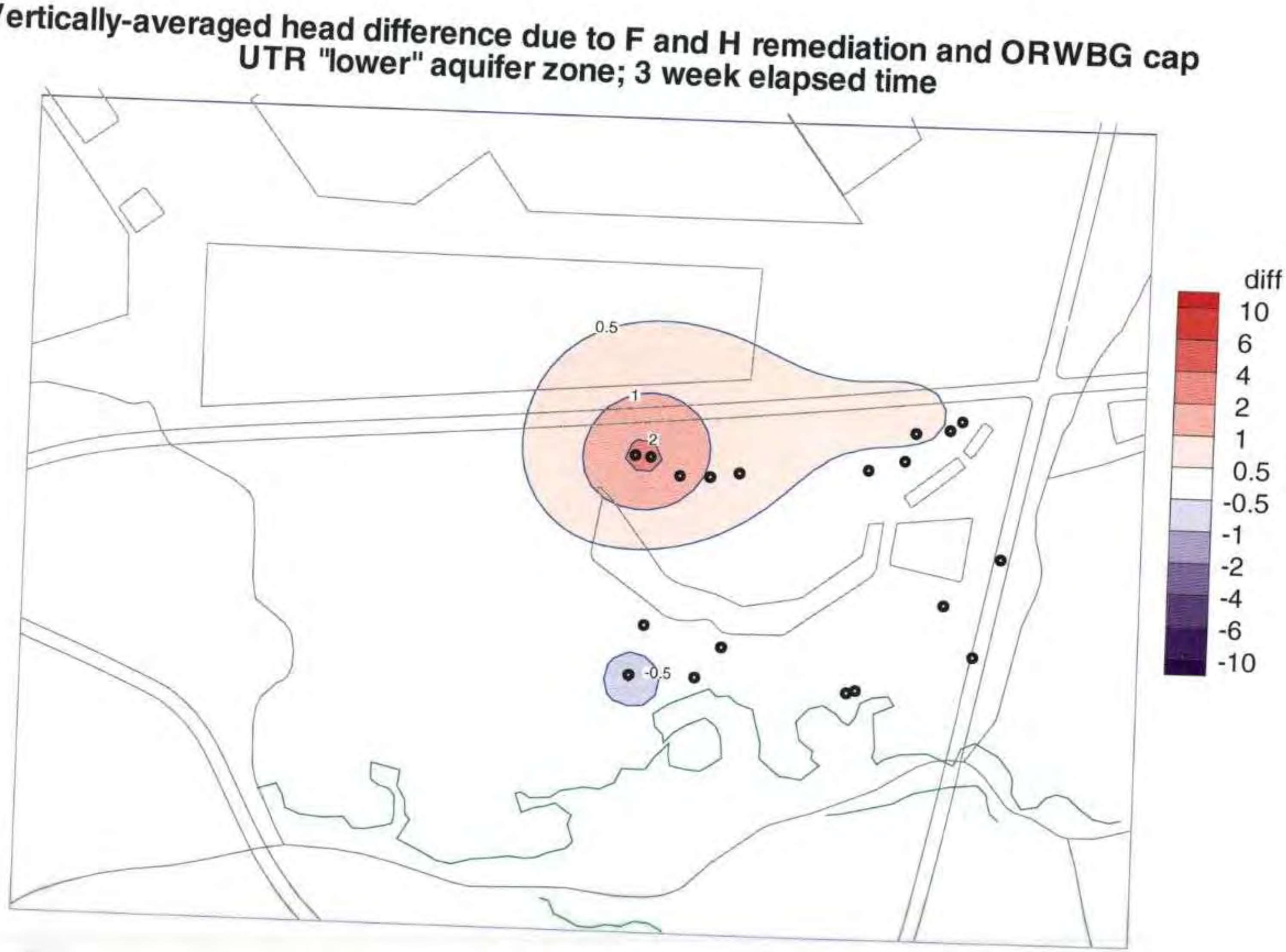

Figure 25 Vertically averaged change in head within the "lower" UTR aquifer zone; ORWBG and H seepage basin area; 3 weeks following system start-up.

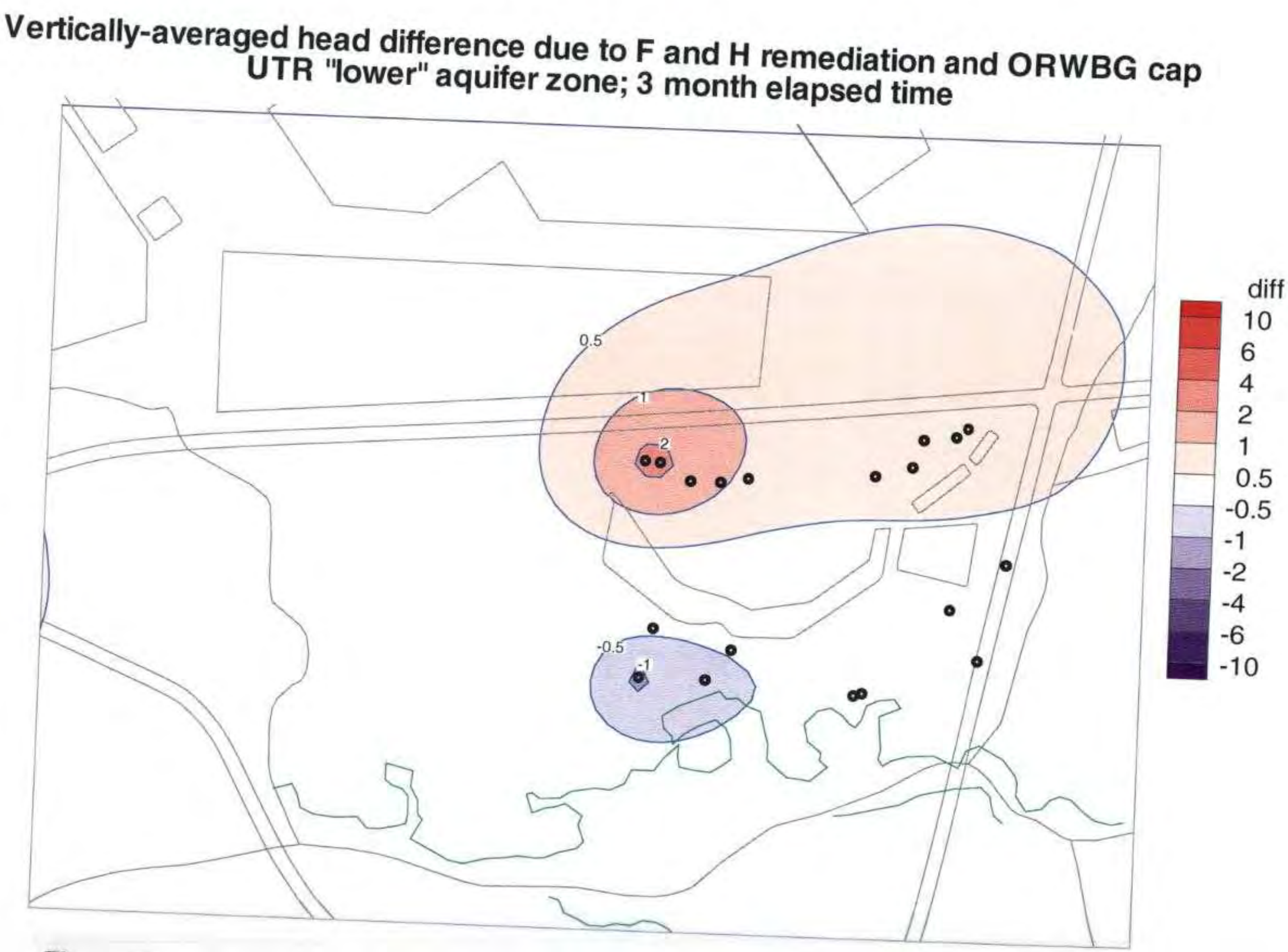

Figure 26 Vertically averaged change in head within the "lower" UTR aquifer zone; ORWBG and H seepage basin area; 3 months following system start-up.

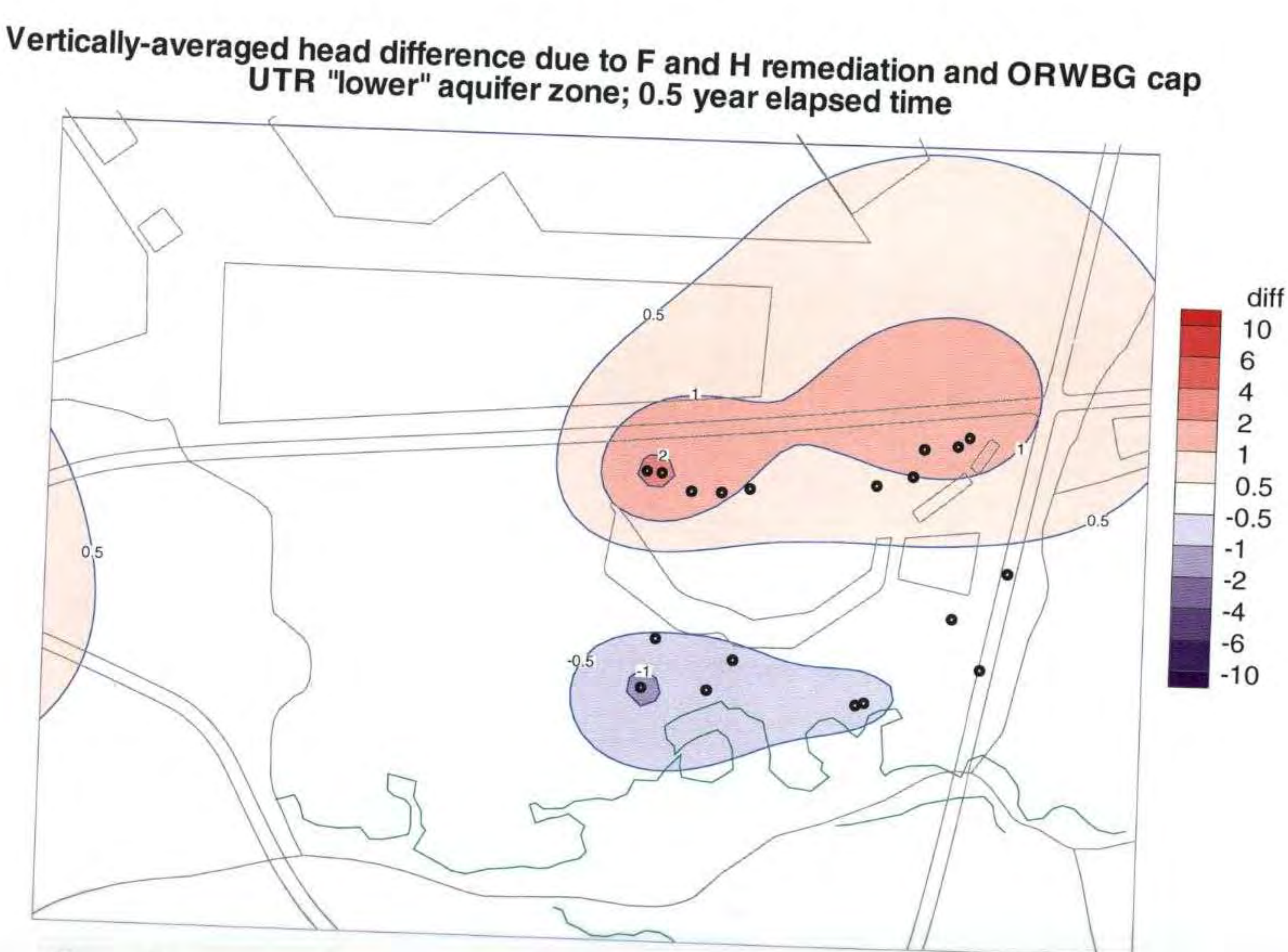

Figure 27 Vertically averaged change in head within the "lower" UTR aquifer zone; ORWBG and H seepage basin area; 6 months following system start-up.

Vertically-averaged head difference due to F and H remediation and ORWBG cap UTR "lower" aquifer zone; 1 year elapsed time

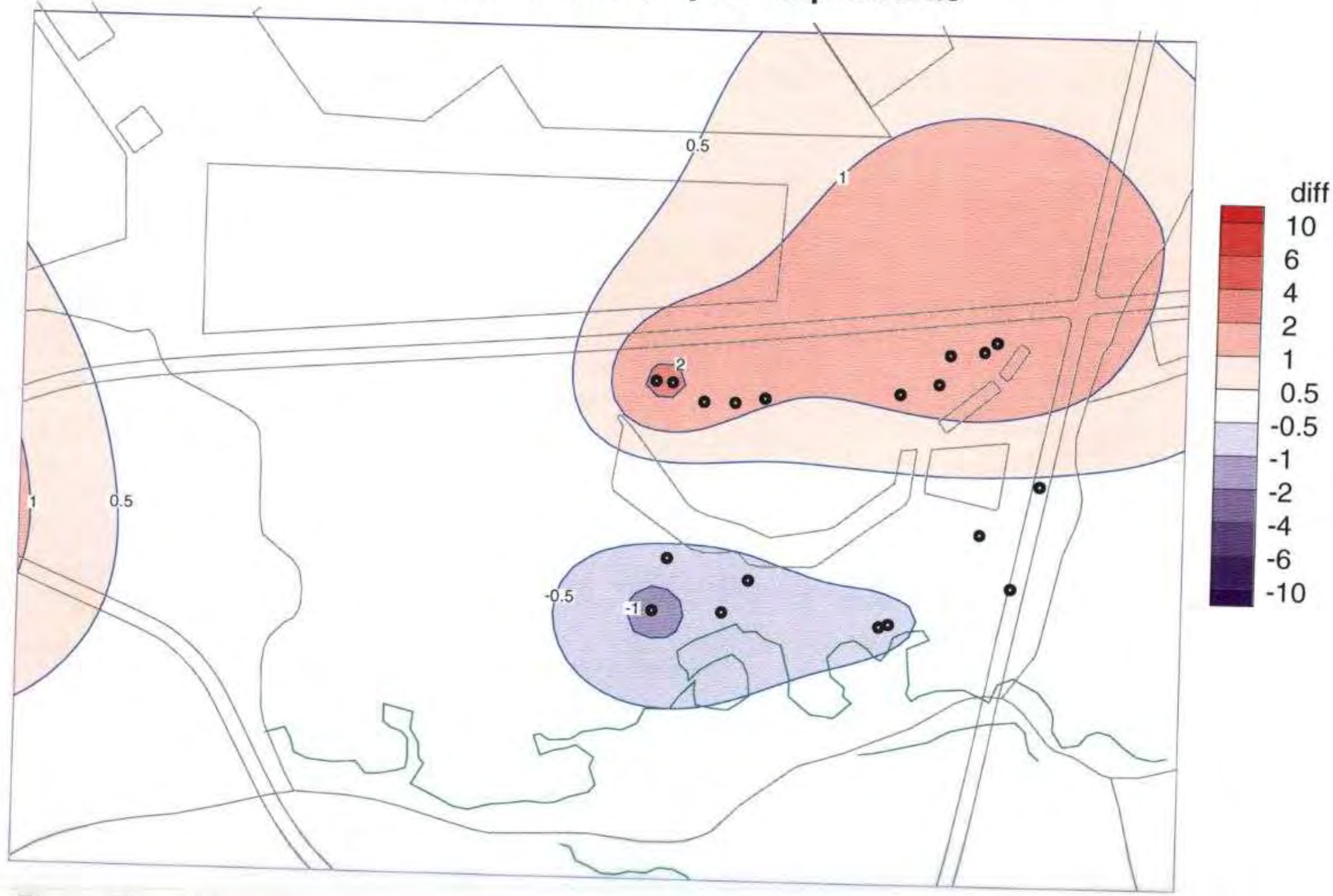

Figure 28 Vertically averaged change in head within the "lower" UTR aquifer zone; ORWBG and H seepage basin area; 1 year following system start-up.

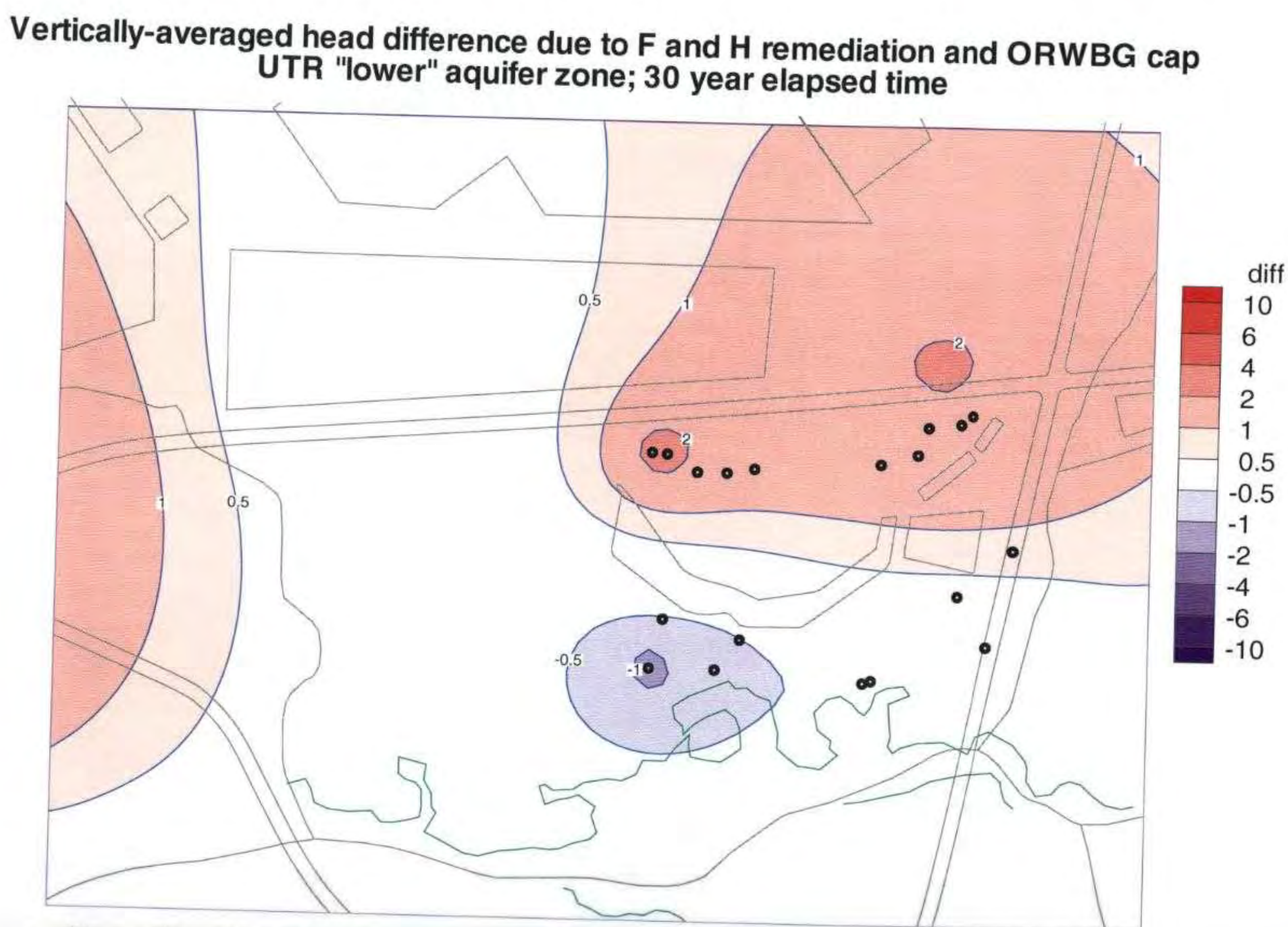

Figure 29 Vertically averaged change in head within the "lower" UTR aquifer zone; ORWBG and H seepage basin area; 30 years following system start-up (steady-state).

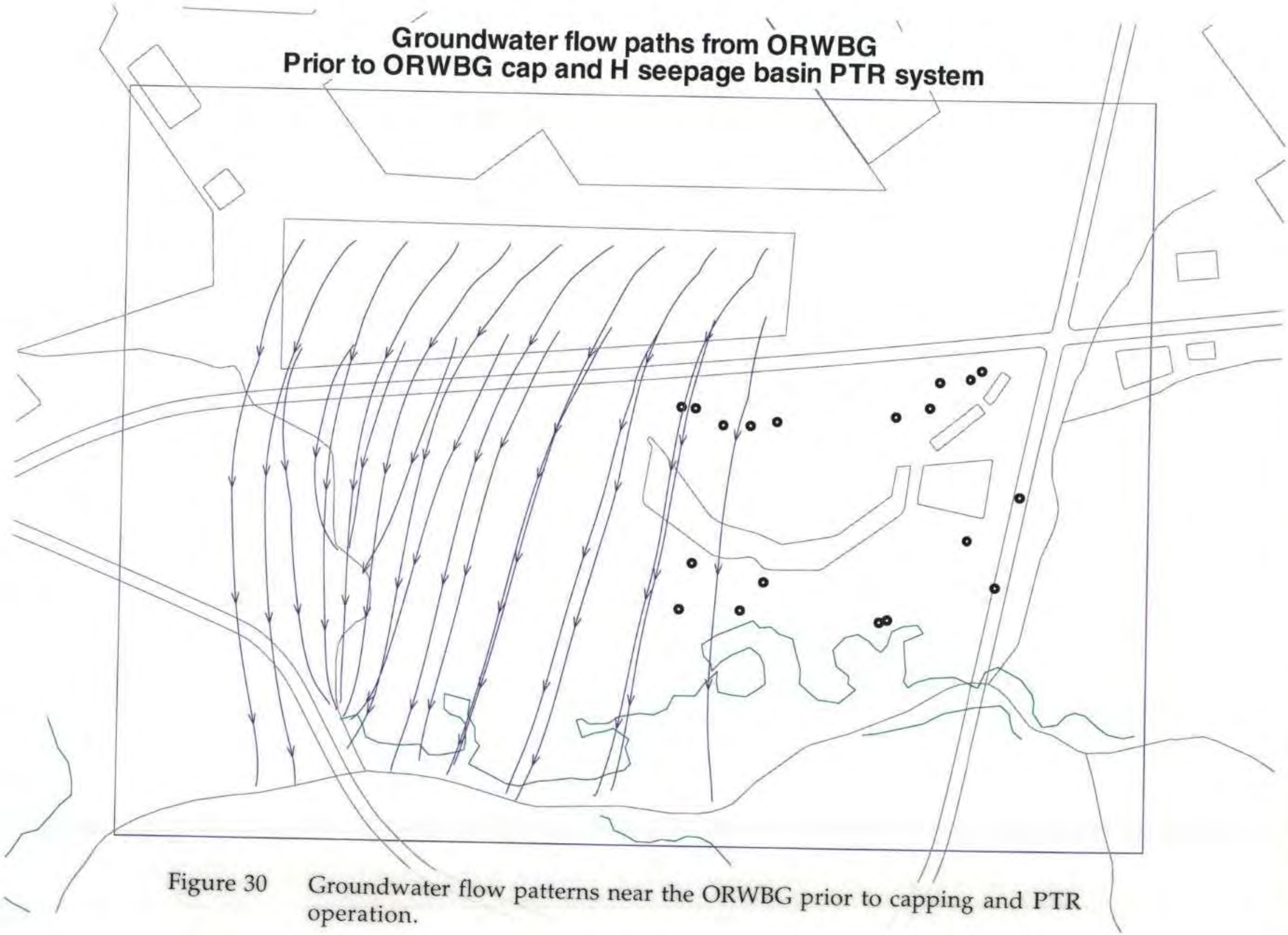

Figure 30 Groundwater flow patterns near the ORWBG prior to capping and PTR operation.

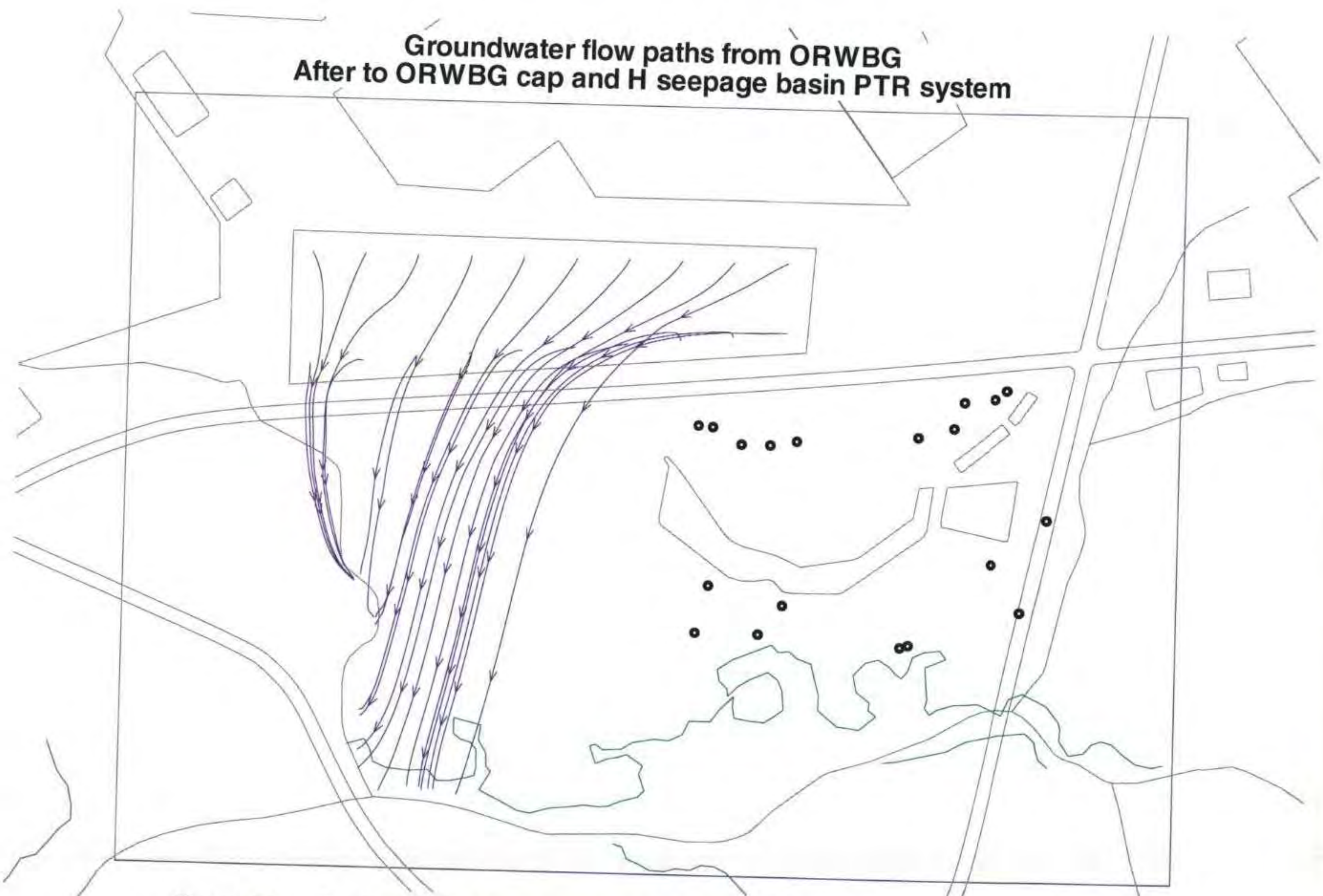

Figure 31 Groundwater flow patterns near the ORWBG after capping and long-term PTR operation.

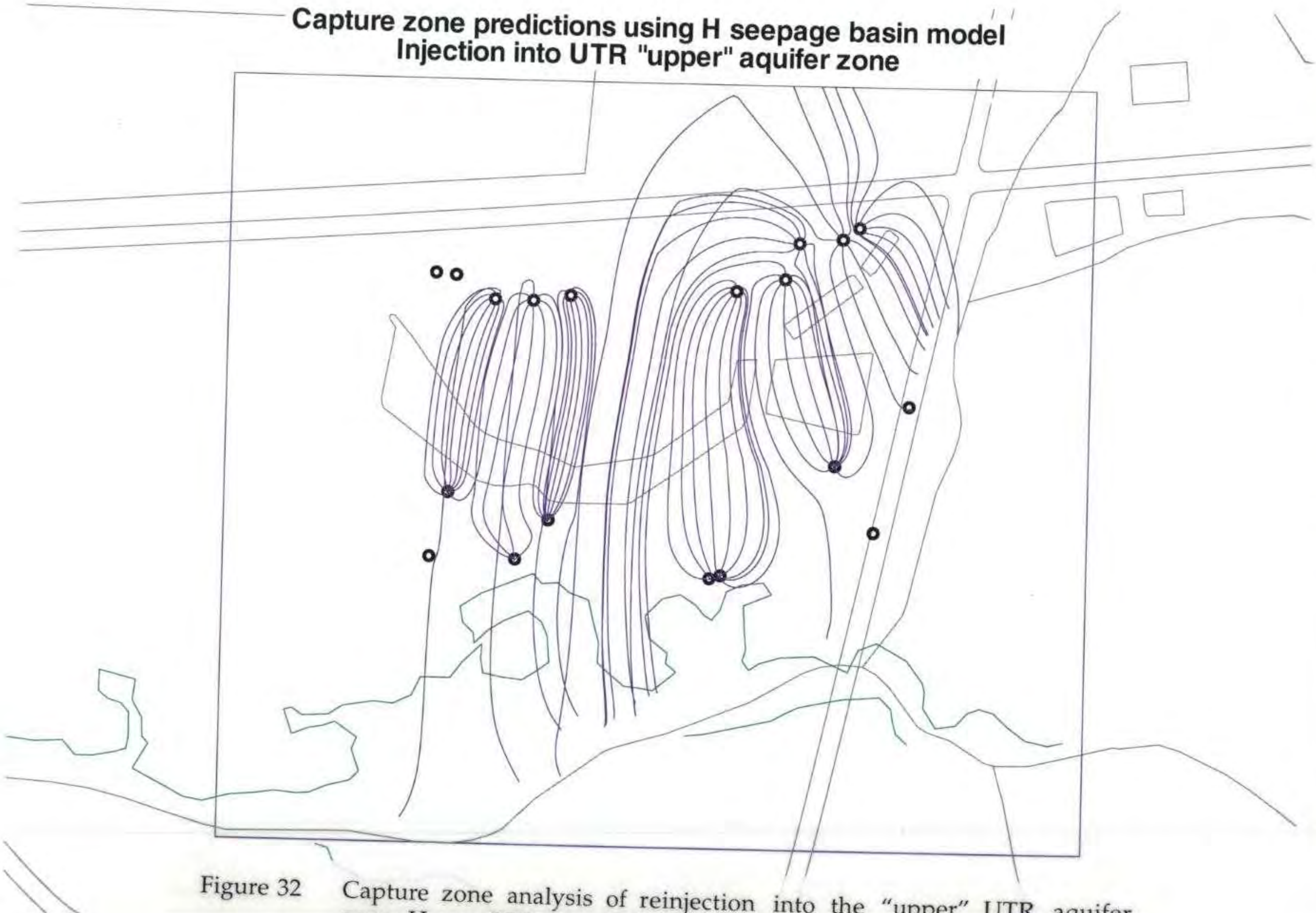

Figure 32 Capture zone analysis of reinjection into the "upper" UTR aquifer zone; H-area PTR remediation system.

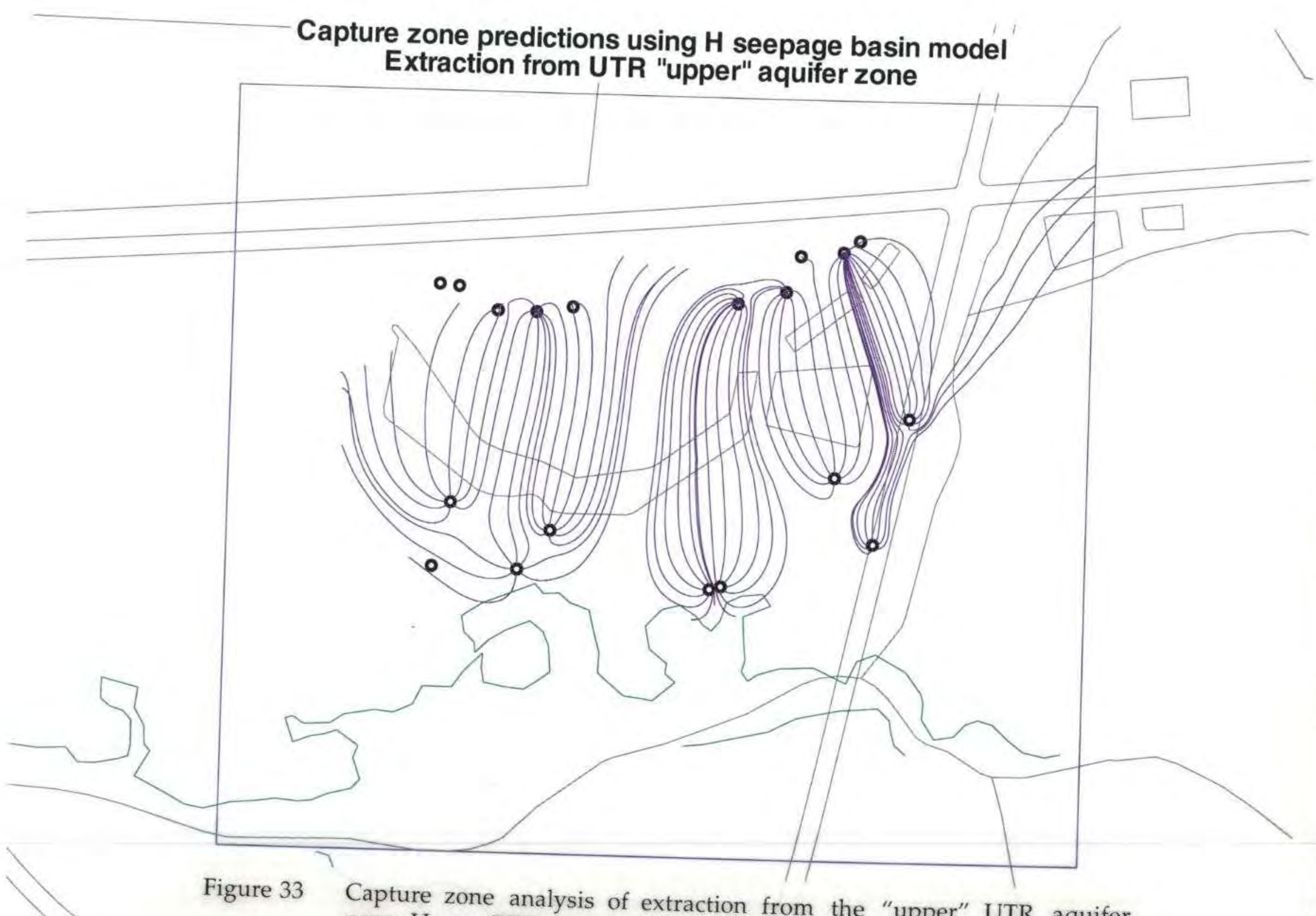

Figure 33 Capture zone analysis of extraction from the "upper" UTR aquifer zone; H-area PTR remediation system.

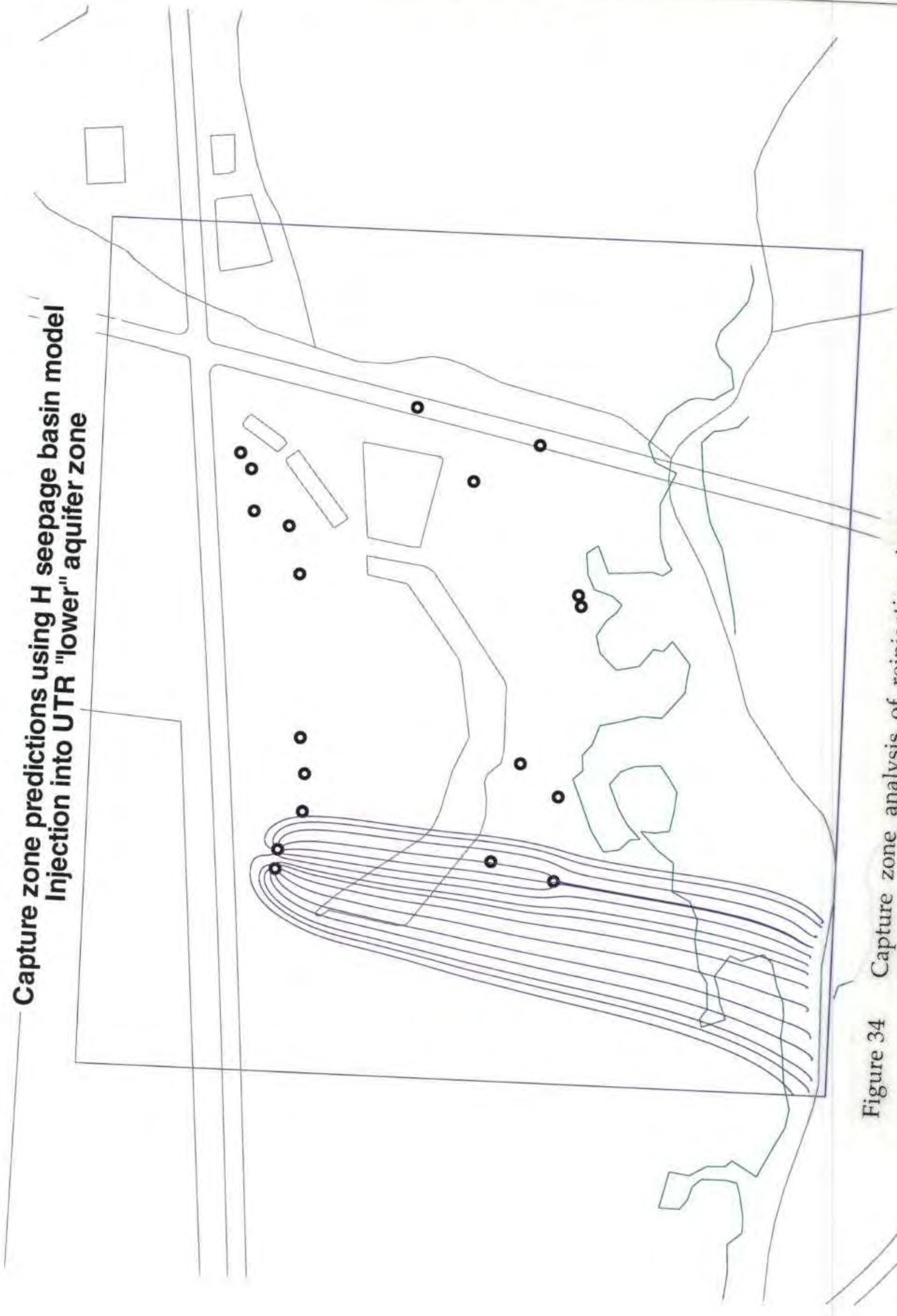

Figure 34 Capture zone analysis of reinjection into the "lower" UTR aquifer zone; H-area PTR remediation system.

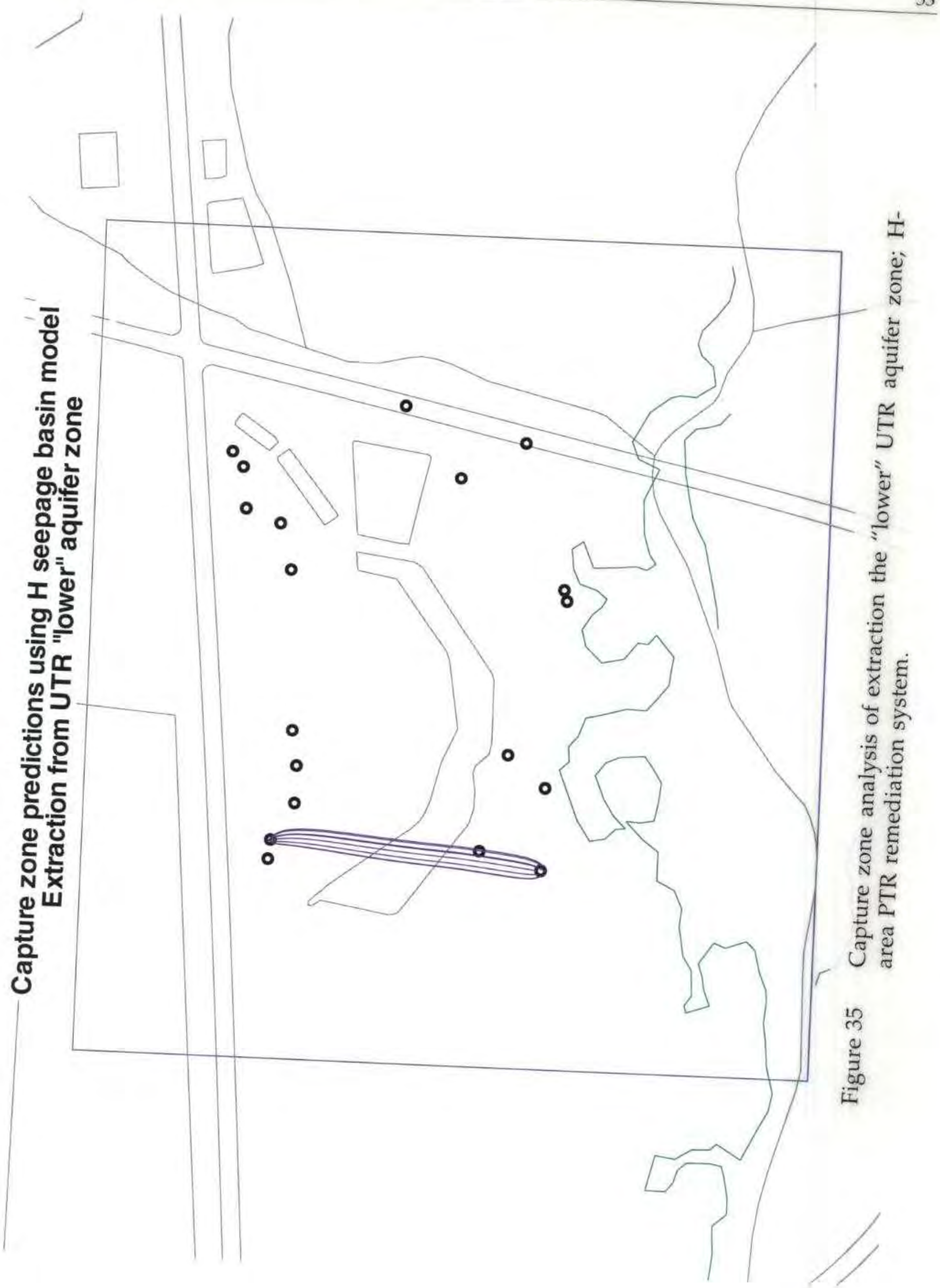

Figure 35 Capture zone analysis of extraction the "lower" UTR aquifer zone; H-area PTR remediation system.

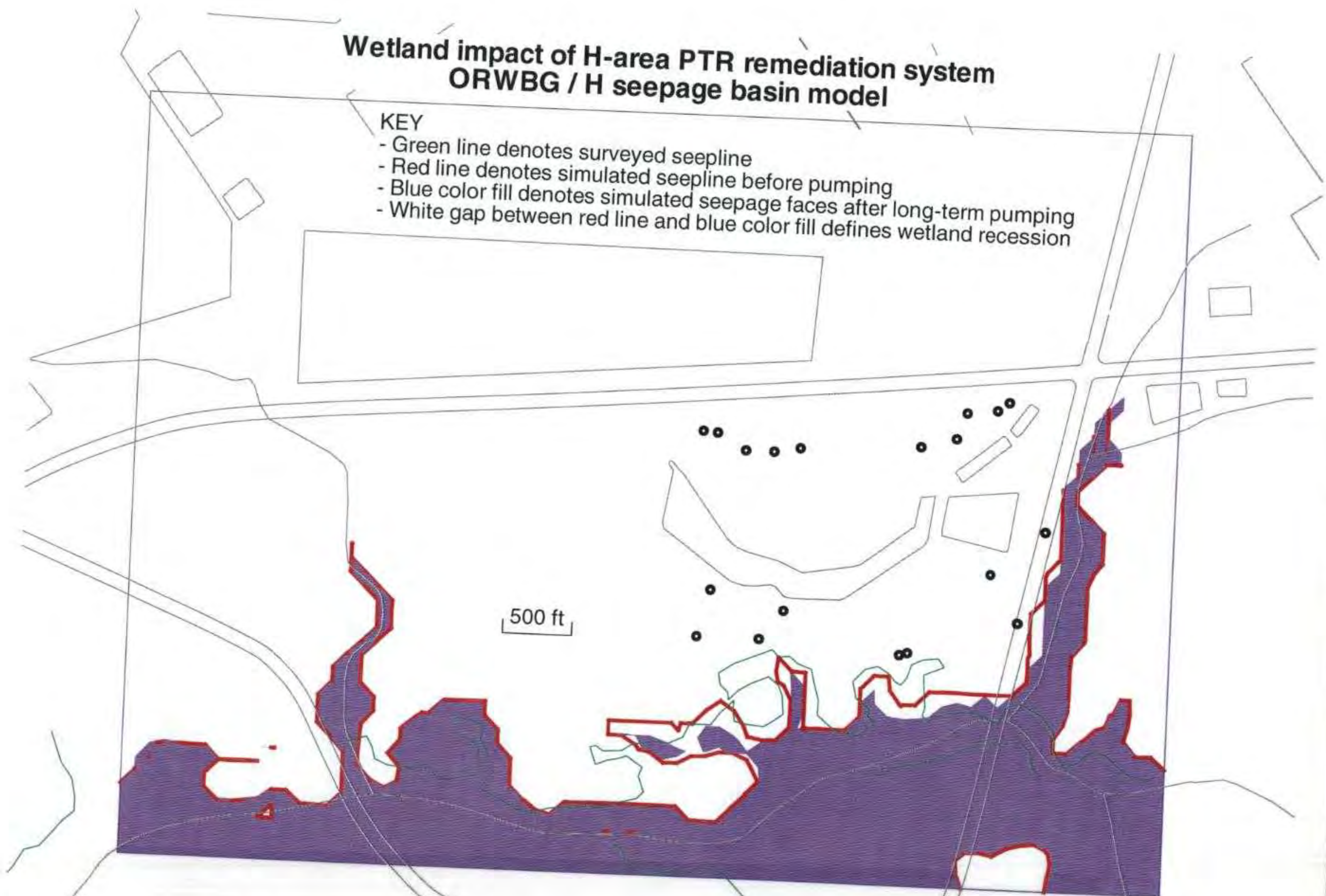

Figure 36 Wetland impacts due to H-area PTR operation; ORWBG/H Seepage Basin model predictions.

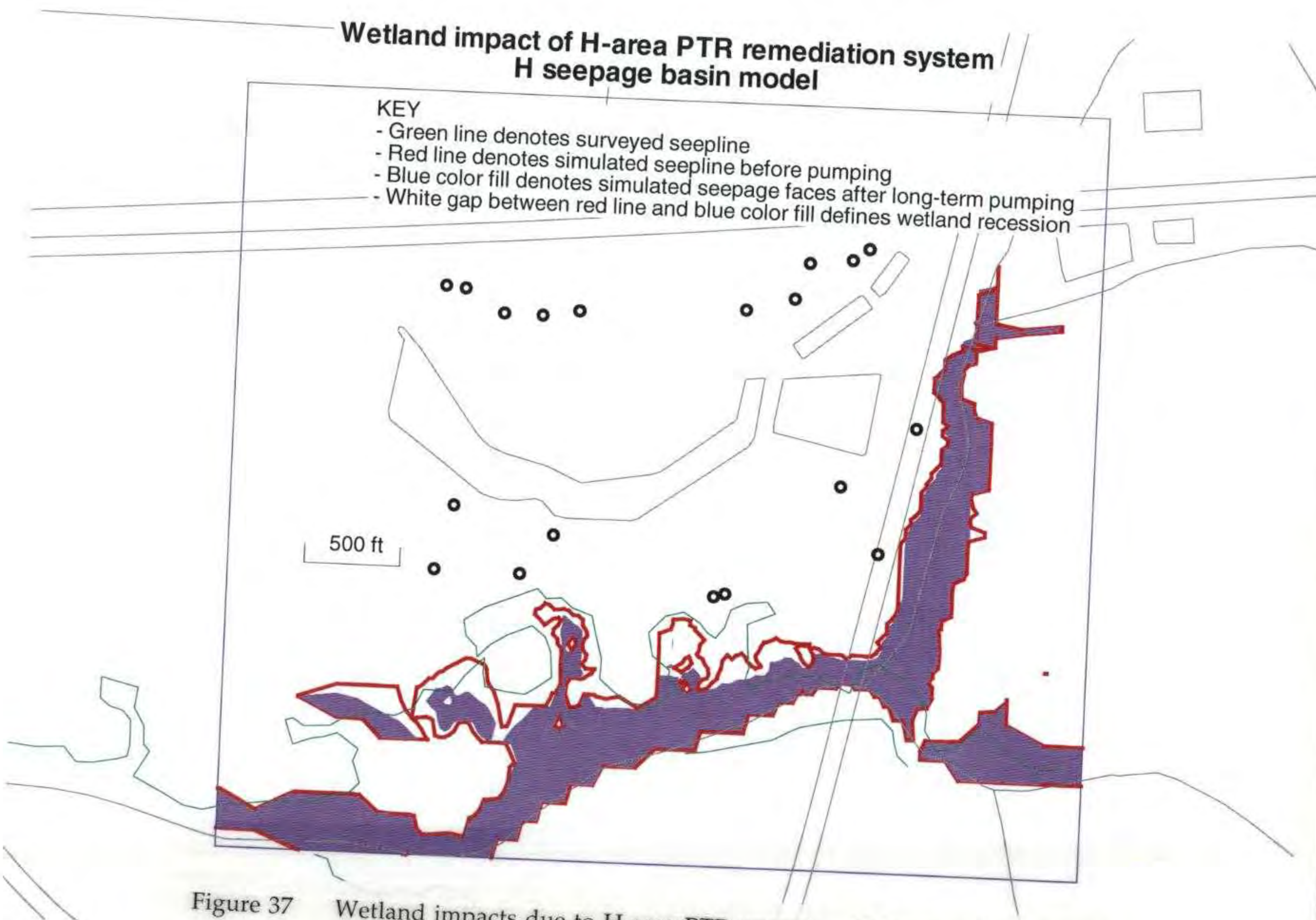

Figure 37 Wetland impacts due to H-area PTR operation; H Seepage Basin model predictions.

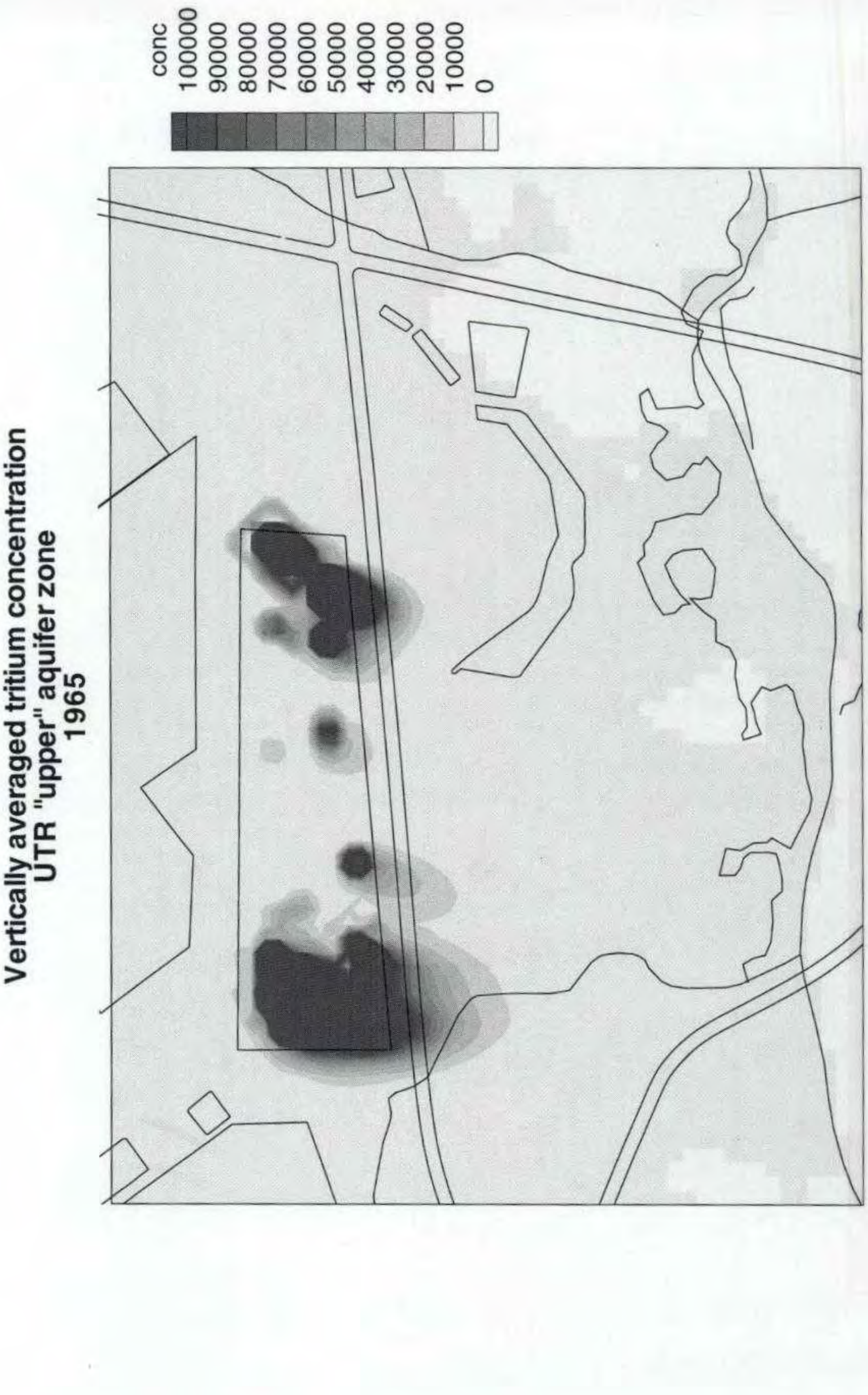

Figure 38 Vertically averaged tritium concentration in the "upper" UTR aquifer zone; 1965.

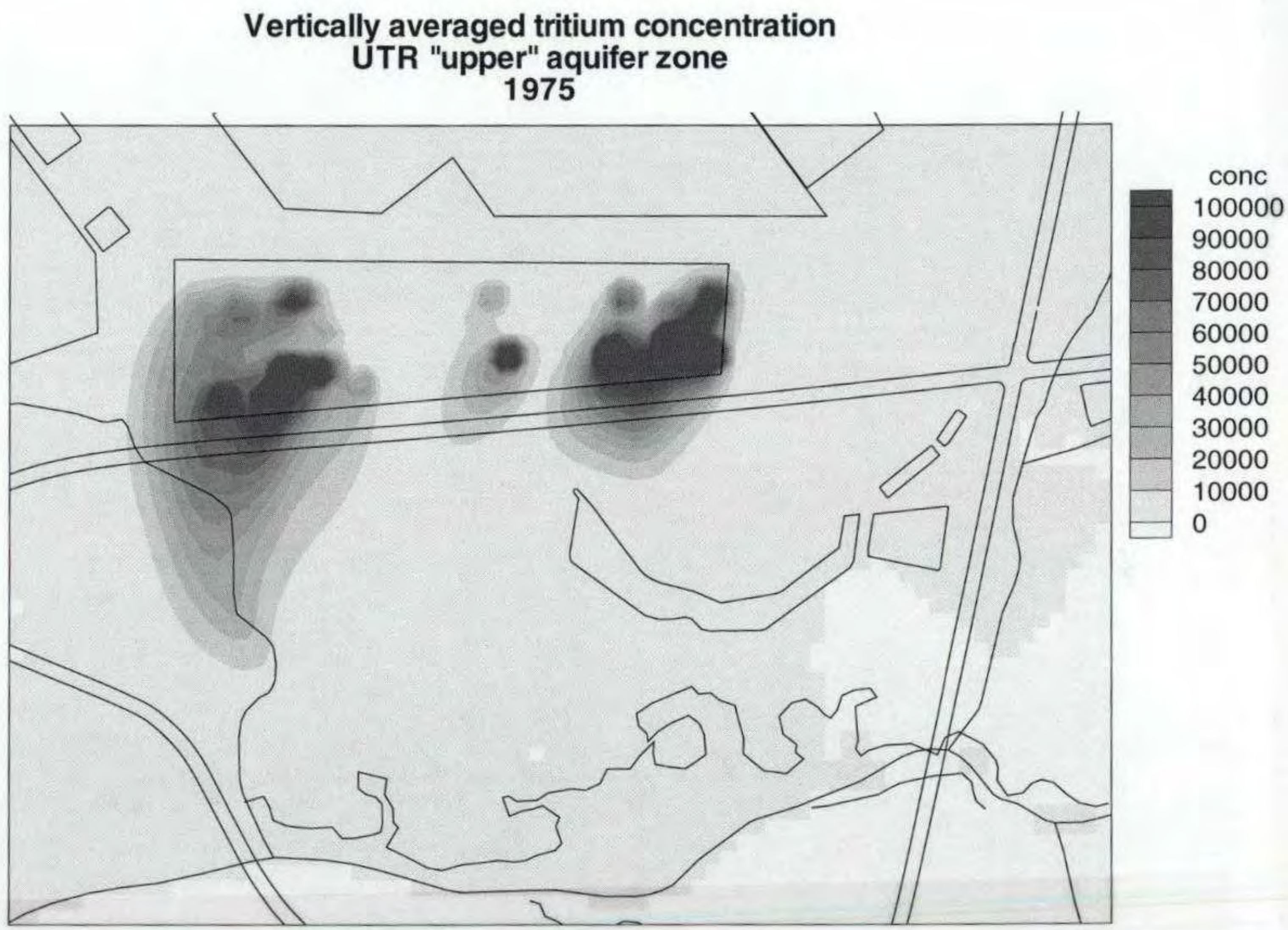

Figure 39 Vertically averaged tritium concentration in the "upper" UTR aquifer zone; 1975.

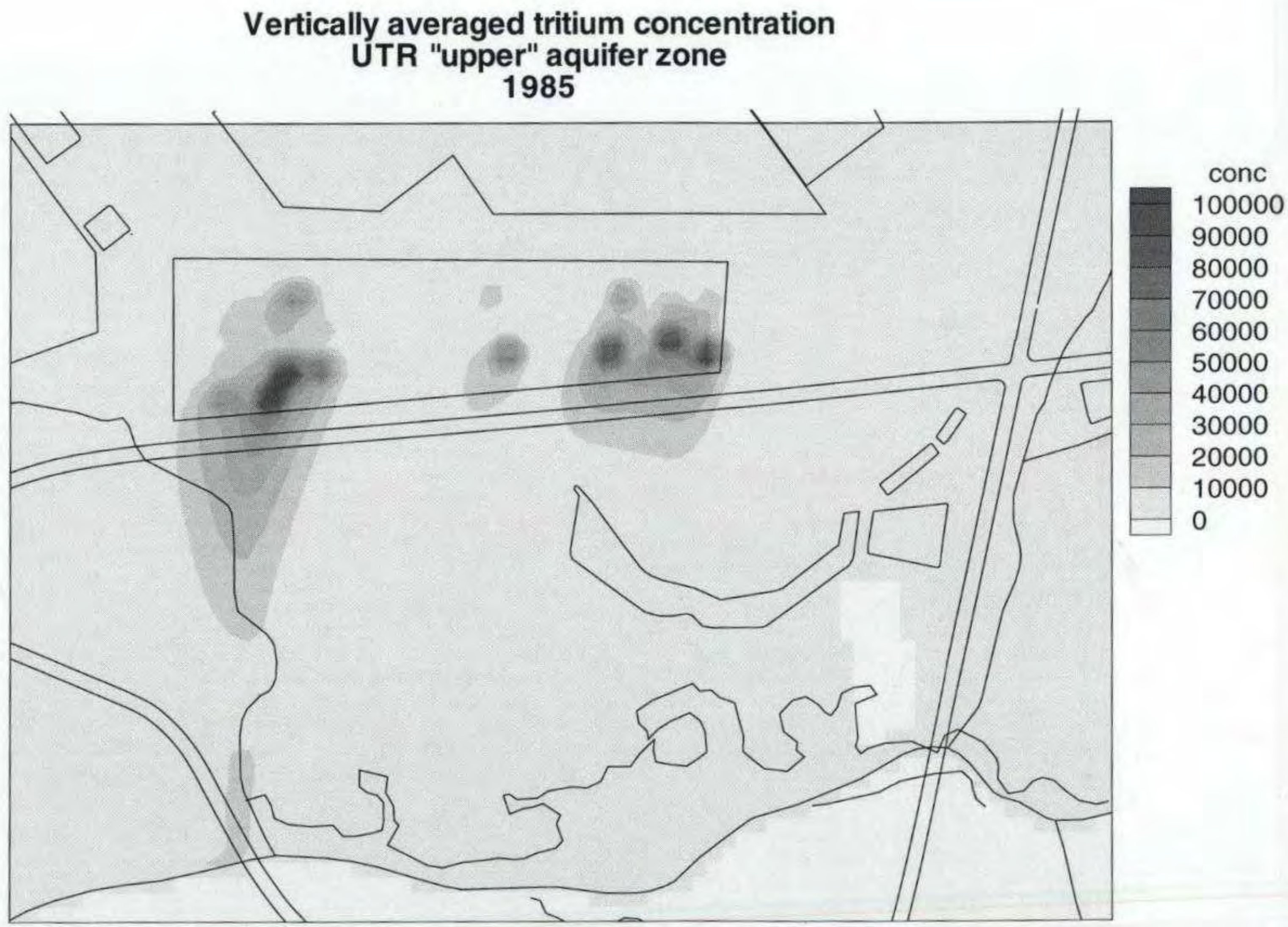

Figure 40 Vertically averaged tritium concentration in the "upper" UTR aquifer zone; 1985.

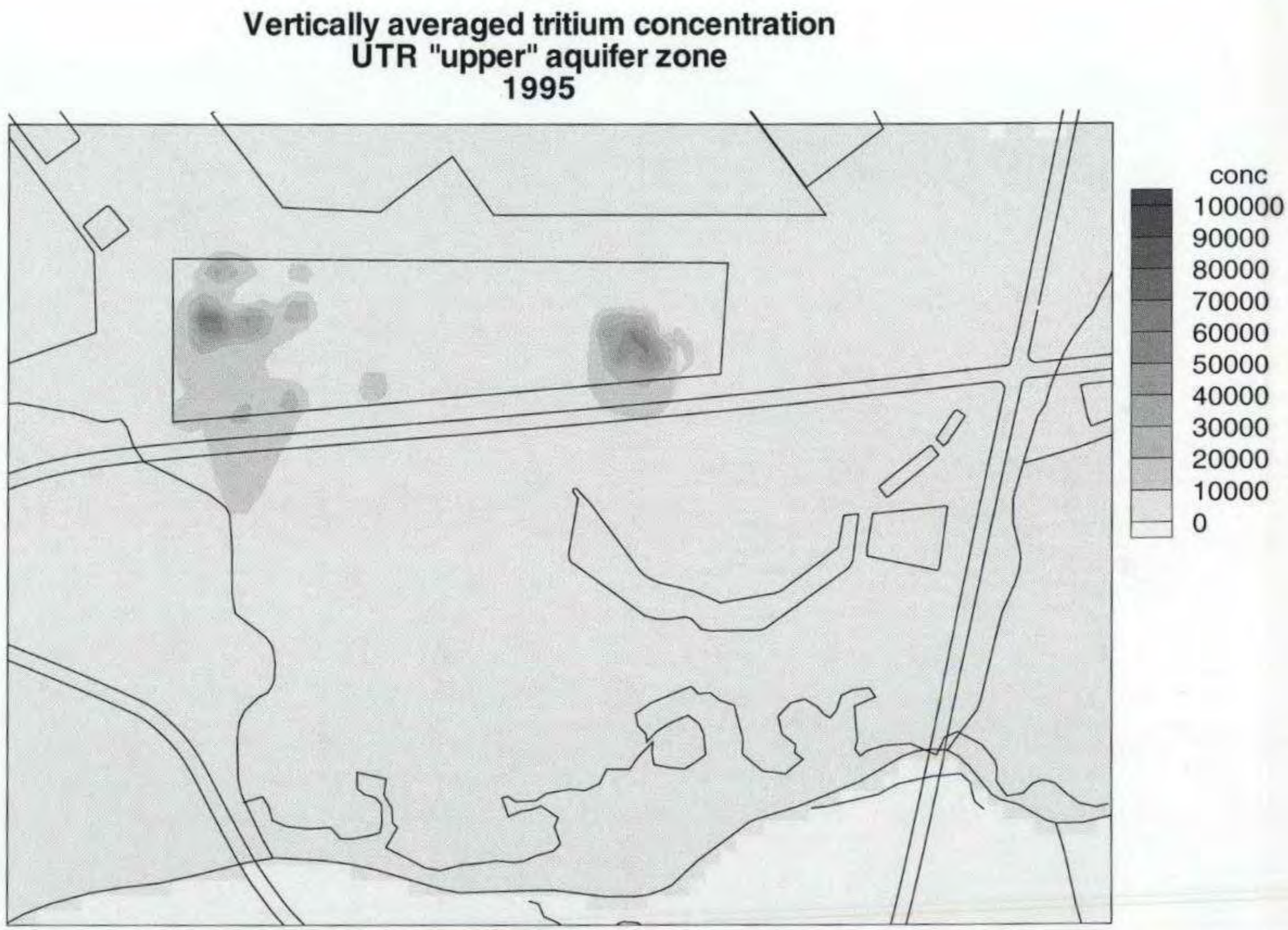

Figure 41 Vertically averaged tritium concentration in the "upper" UTR aquifer zone; 1995.

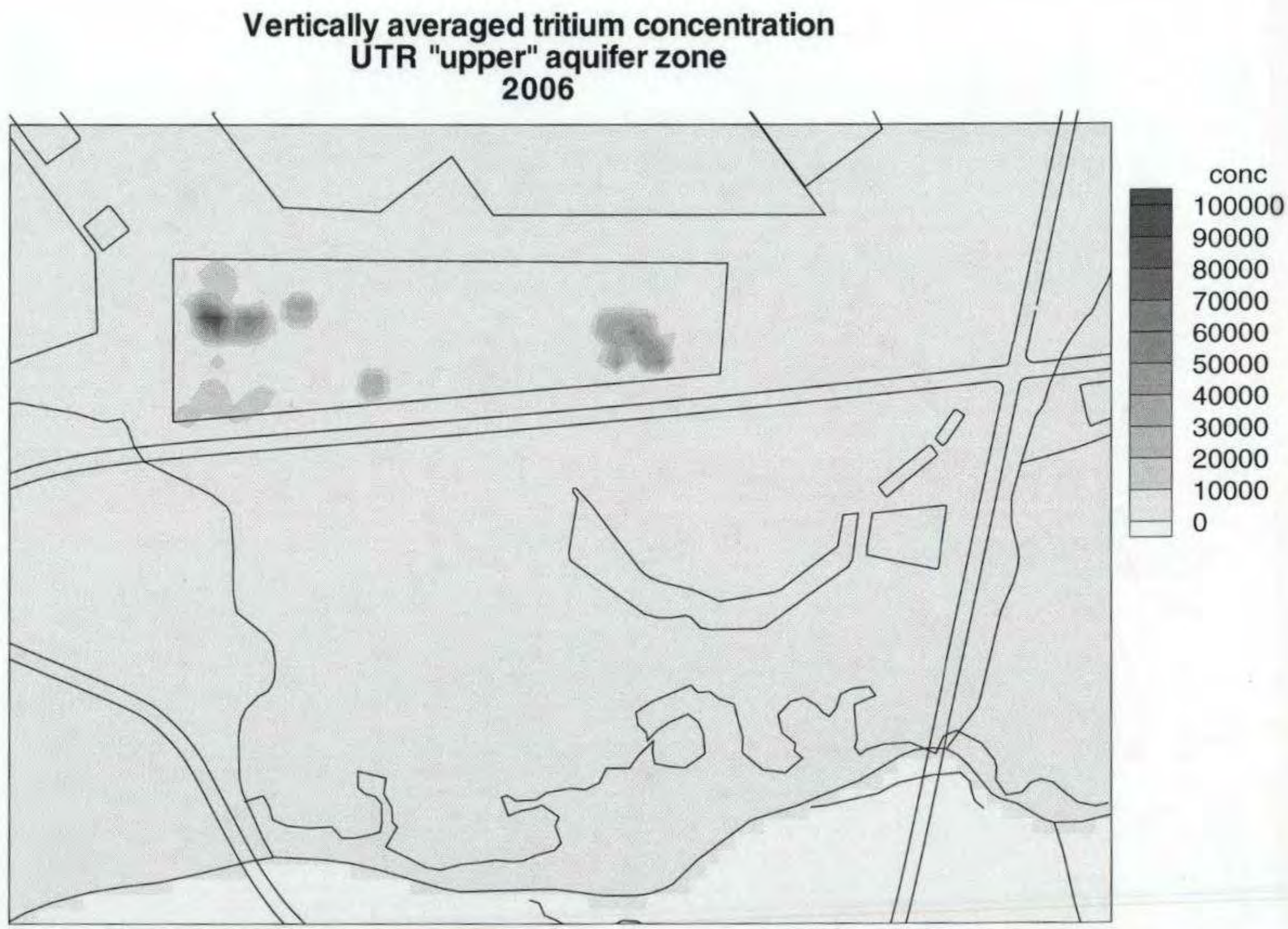

Figure 42 Vertically averaged tritium concentration in the "upper" UTR aquifer zone; 2006.

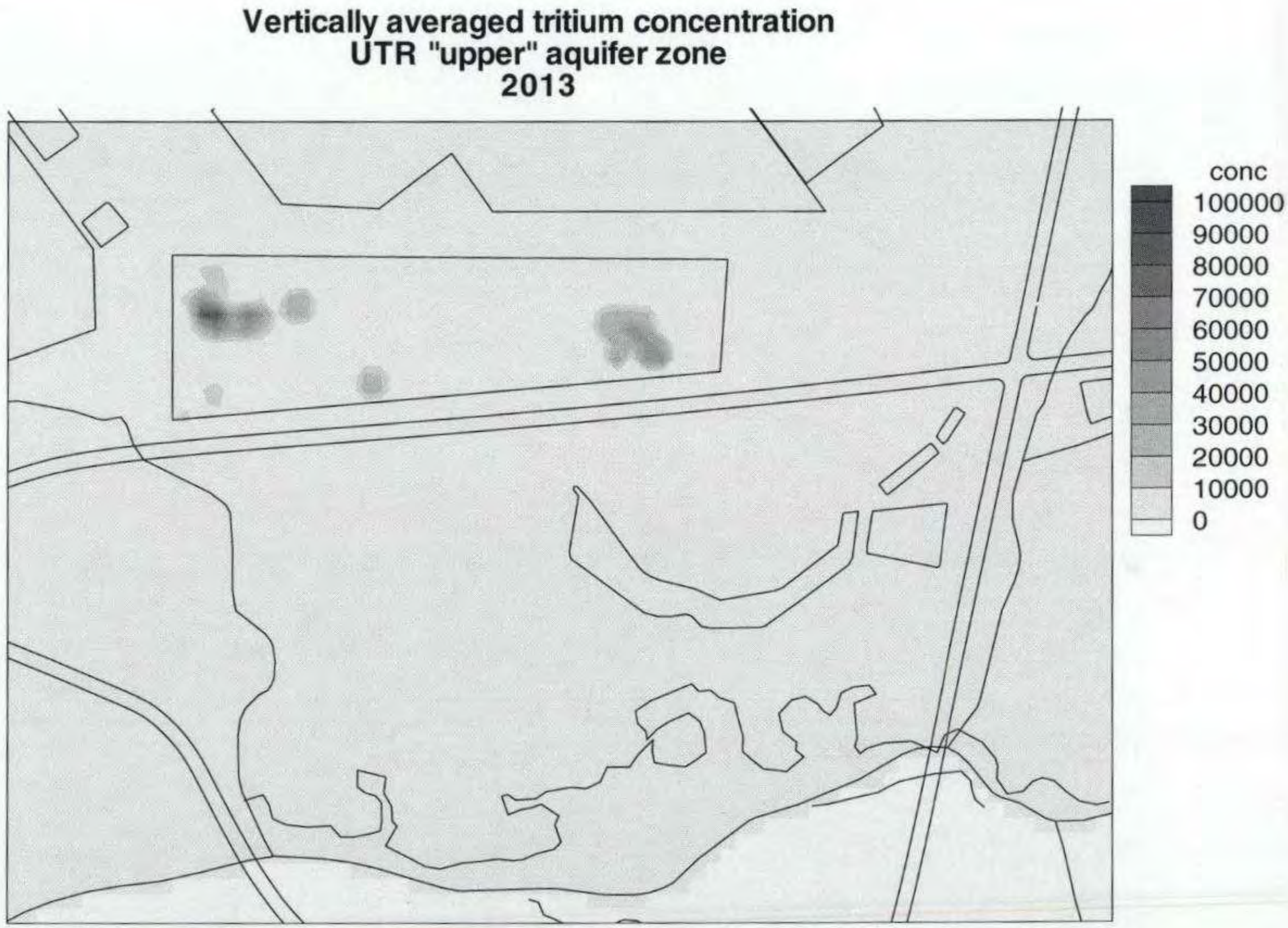

Figure 43 Vertically averaged tritium concentration in the "upper" UTR aquifer zone; 2013.

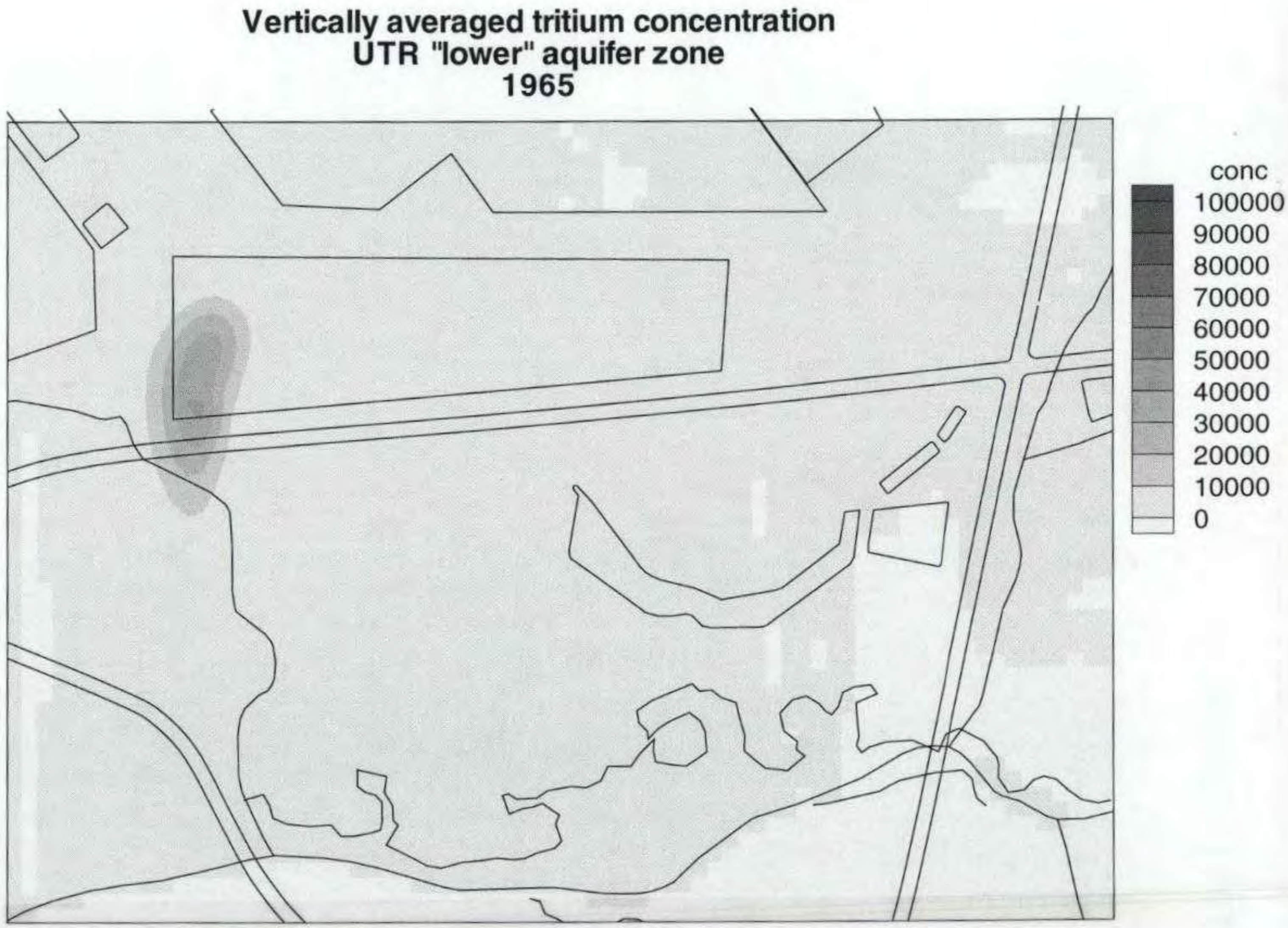

Figure 44 Vertically averaged tritium concentration in the "lower" UTR aquifer zone; 1965.

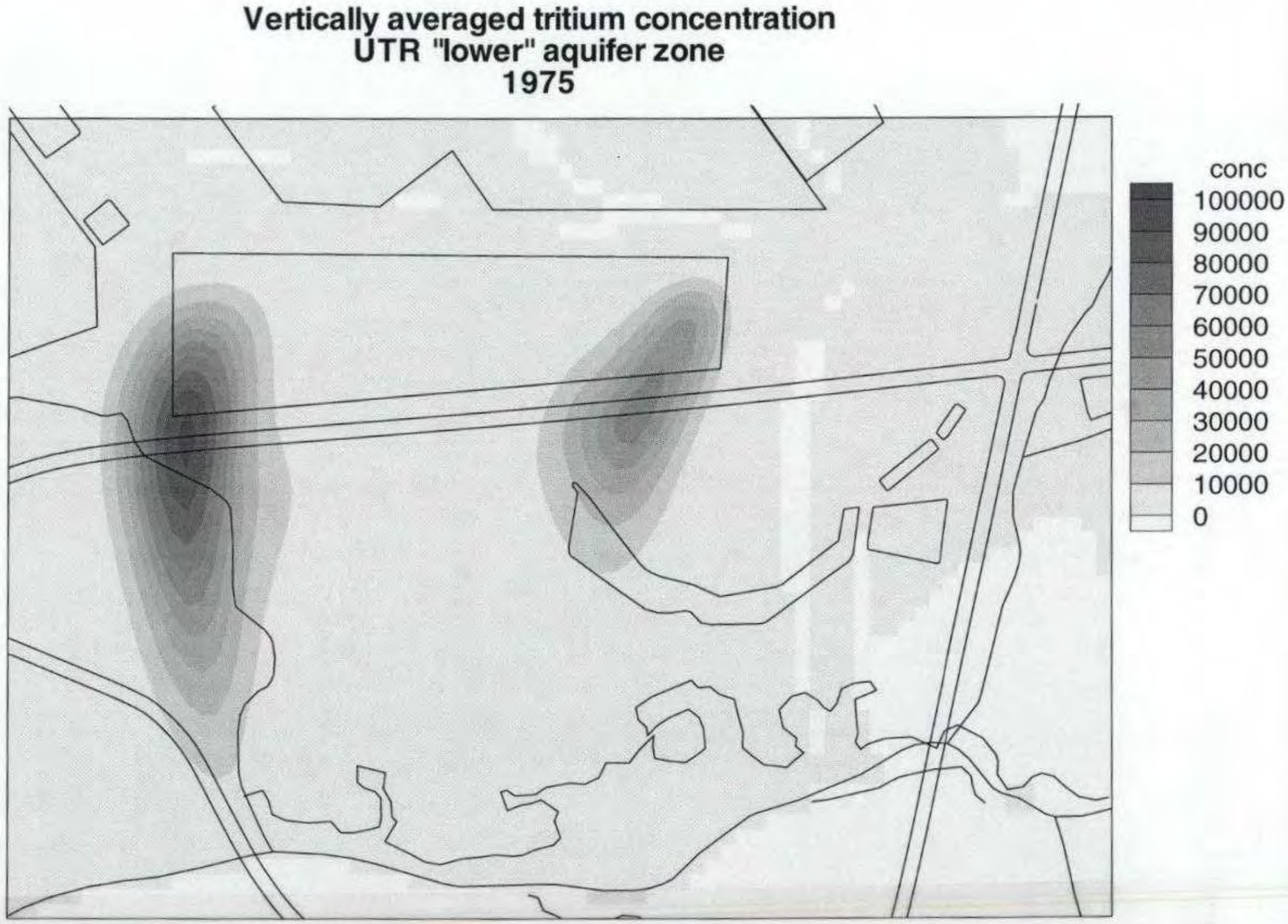

Figure 45 Vertically averaged tritium concentration in the "lower" UTR aquifer zone; 1975.

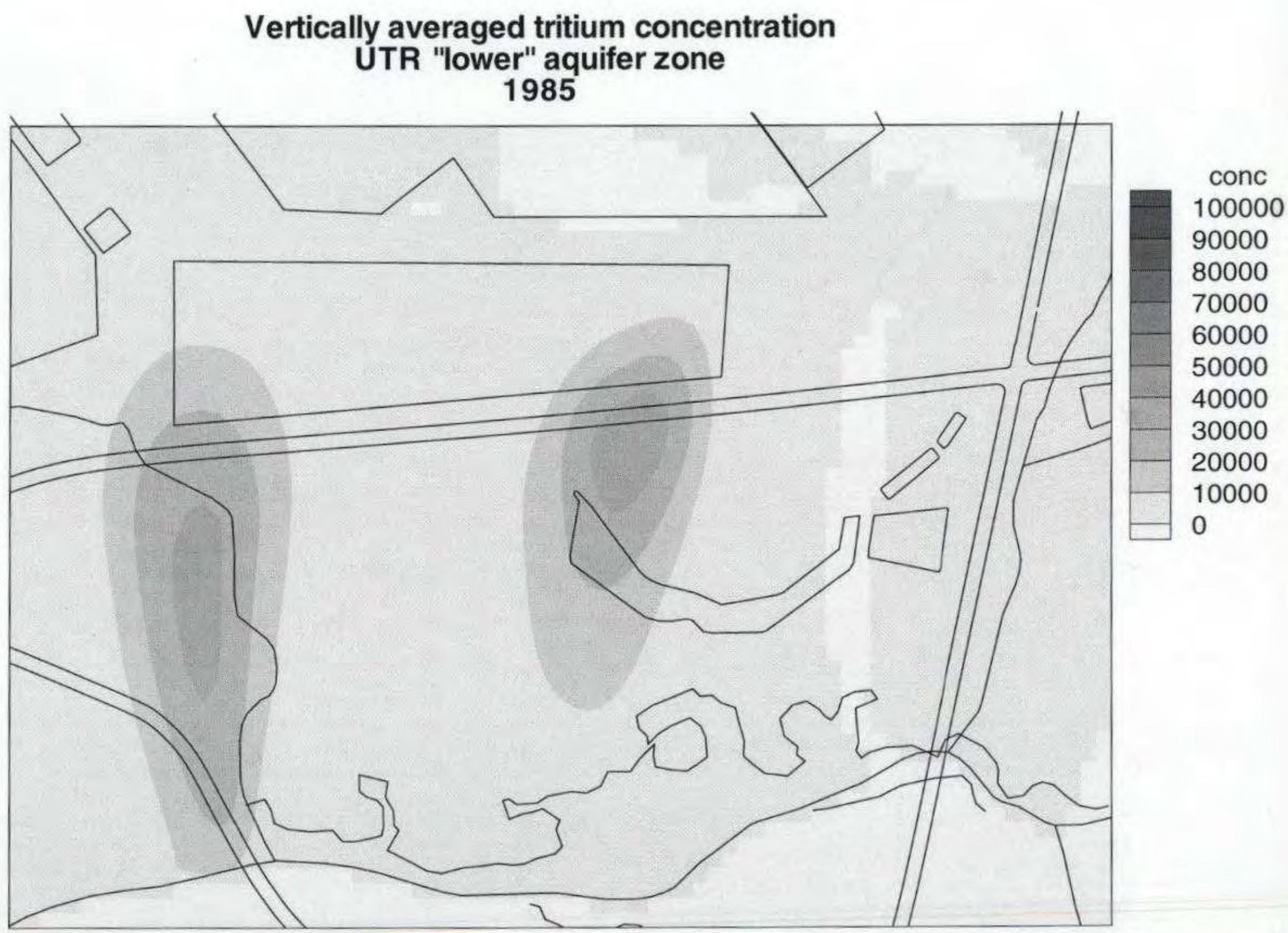

Figure 46 Vertically averaged tritium concentration in the "lower" UTR aquifer zone; 1985.

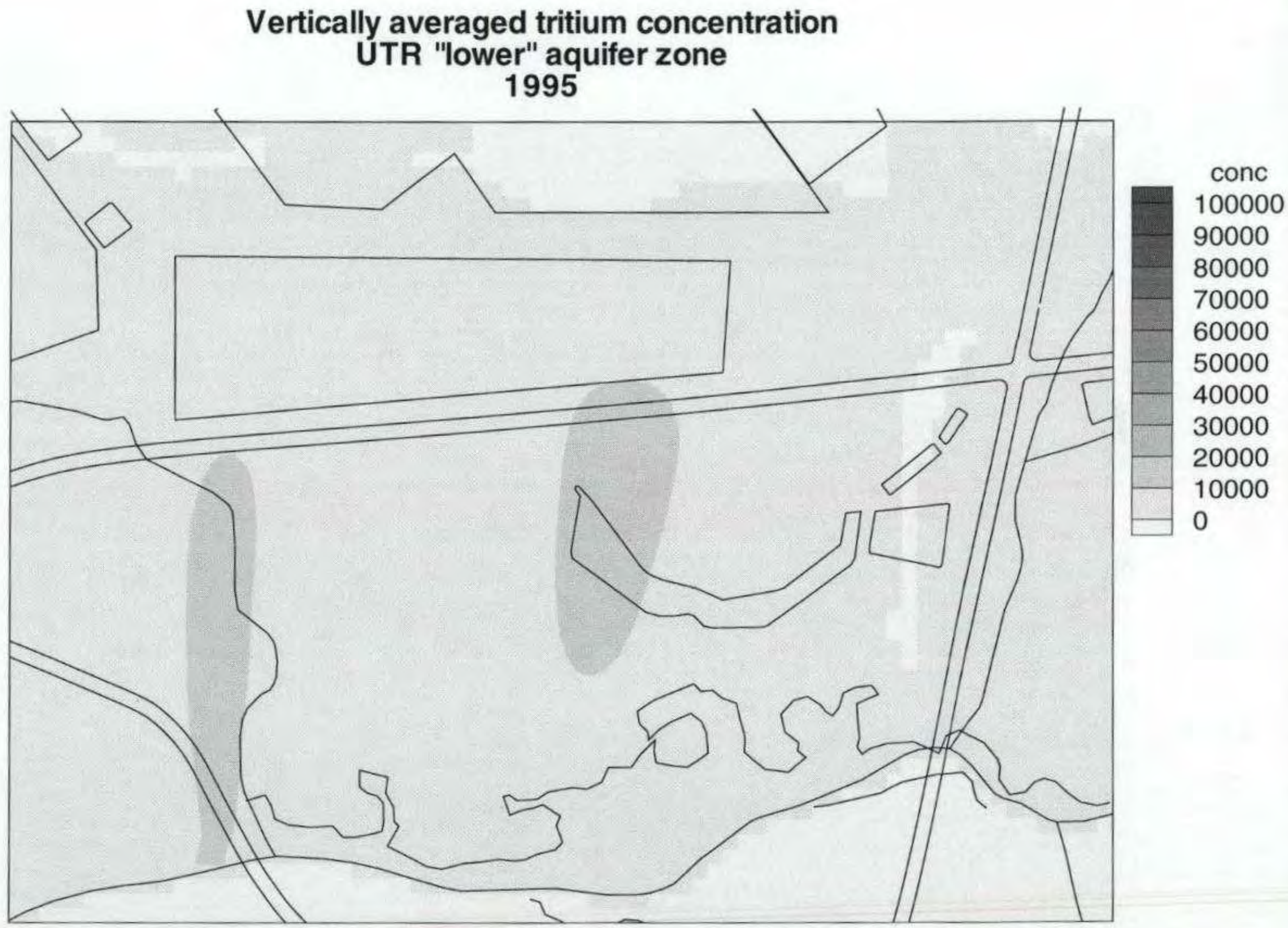

Figure 47 Vertically averaged tritium concentration in the "lower" UTR aquifer zone; 1995.

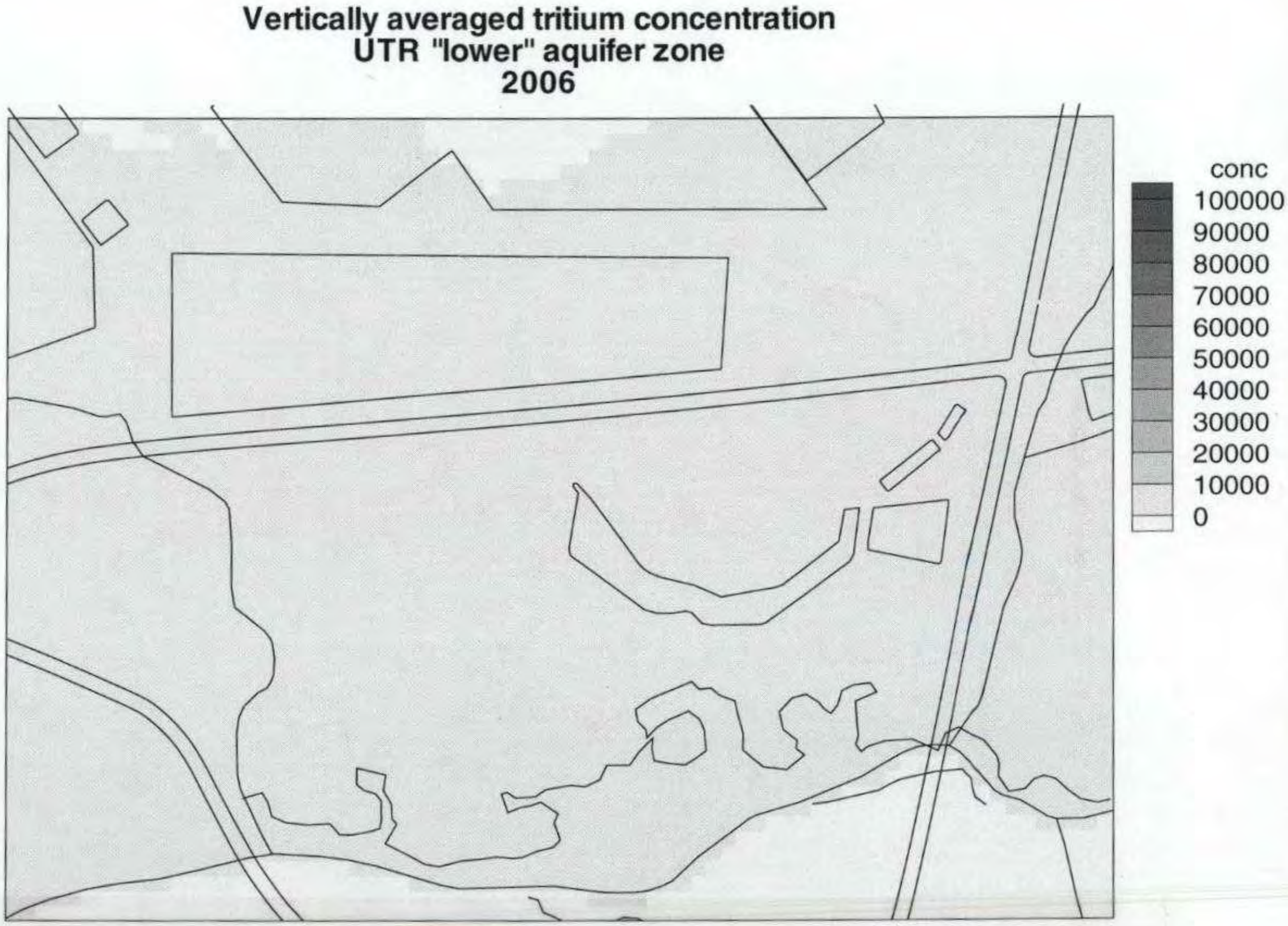

Figure 48 Vertically averaged tritium concentration in the "lower" UTR aquifer zone; 2006.

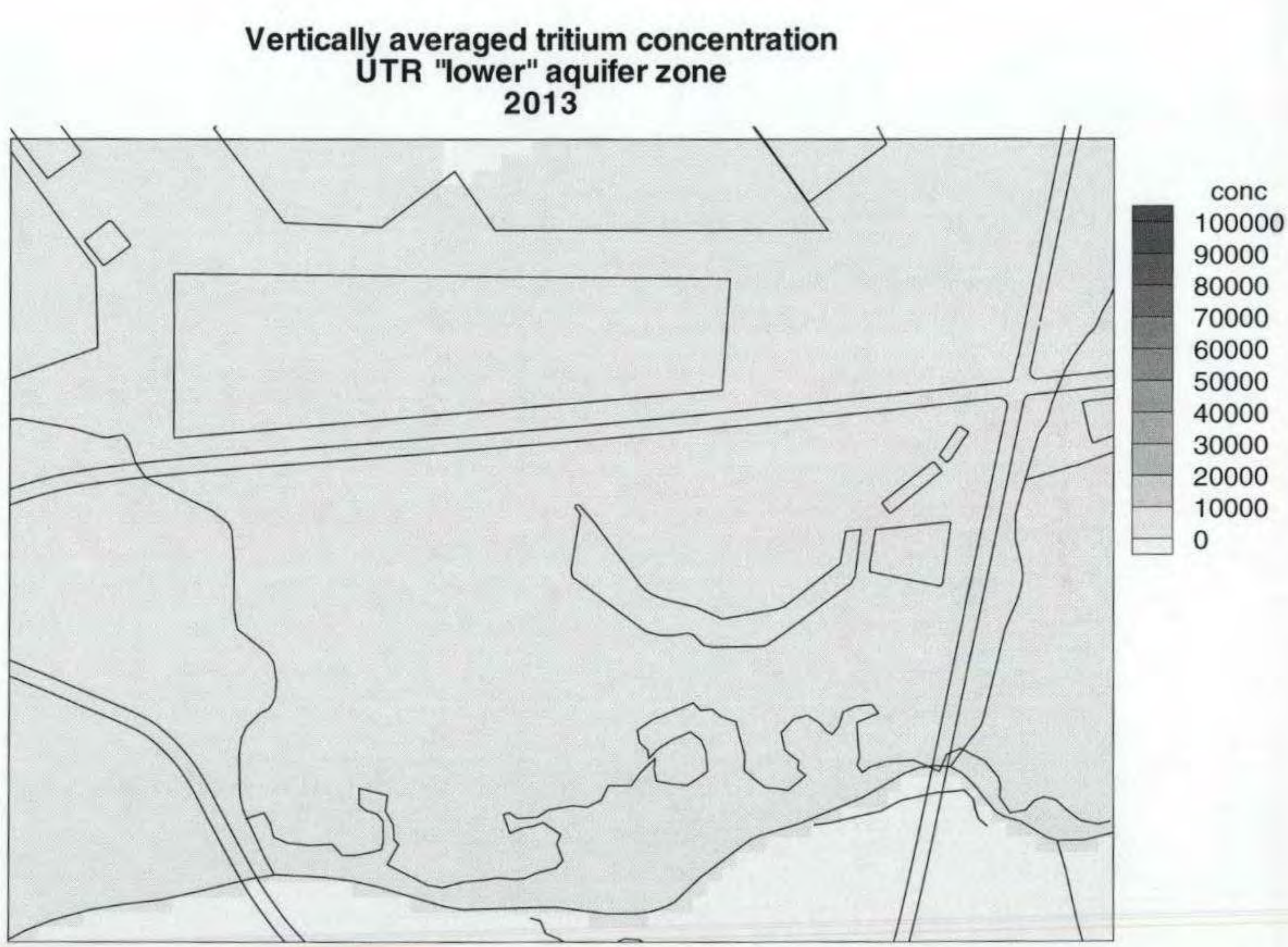

Figure 49 Vertically averaged tritium concentration in the "lower" UTR aquifer zone; 2013.

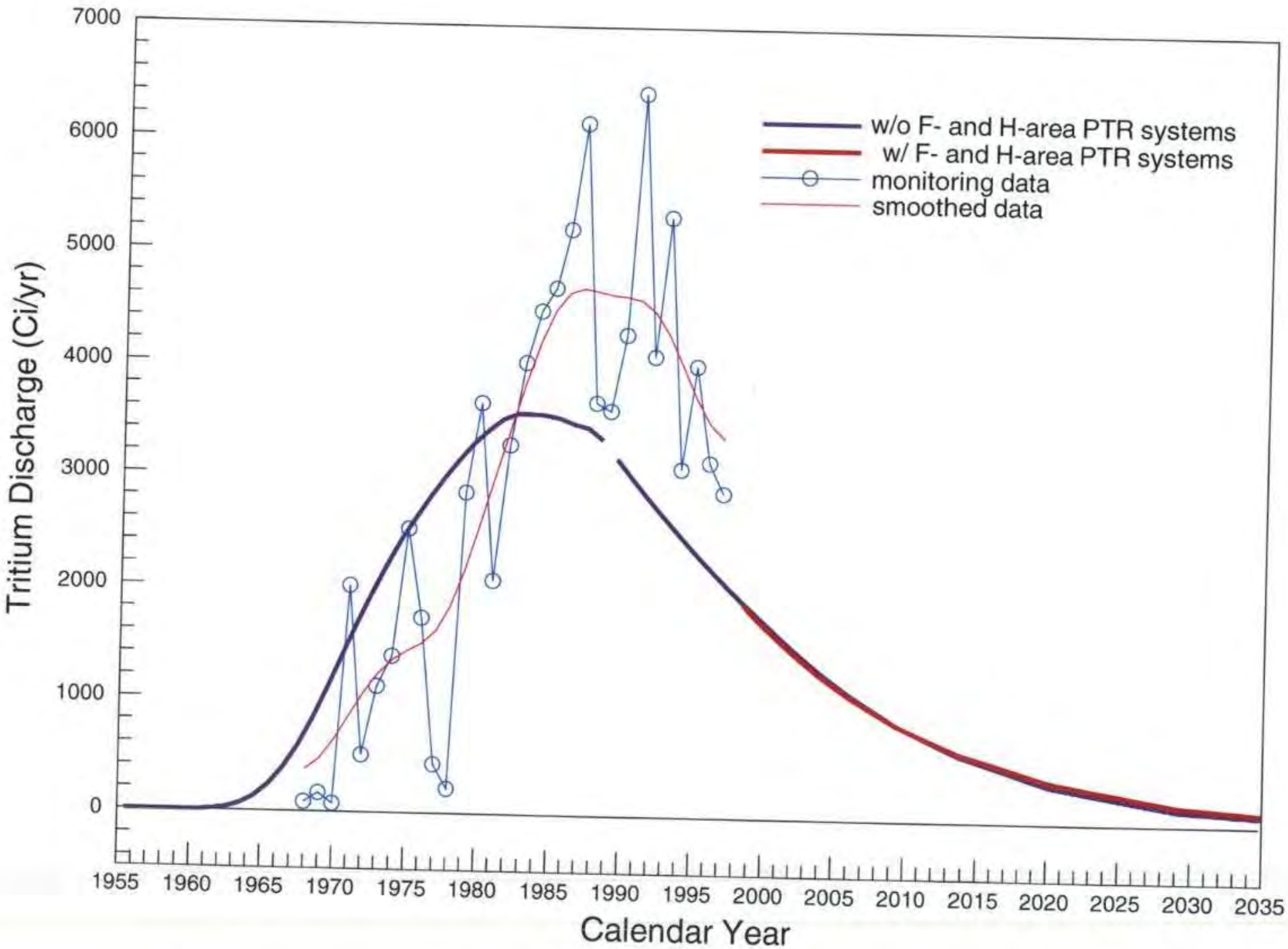

Figure 50 Tritium discharge to Fourmile Branch from ORWBG sources.