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DEPARTMENT OF ECOLOGY

November 21, 2000

TO: Don Abbott, Section Manager, TCP-CRO

FROM: Charles F. Pitz, EAP-HQ

SUBJECT: **Alexander Farms Site Groundwater Modeling – Impact of Canal Lining and Surface Tarping on Site Groundwater Conditions**

Introduction

This memo summarizes the results of groundwater modeling I conducted in response to an October 17, 2000 technical assistance request regarding the Alexander Farms Site (Figure 1). Your office requested that a groundwater model, originally constructed in support of site investigation activities, be re-run to assist in predicting the potential aquifer response to proposed changes in local hydraulic conditions. Two changes are currently being evaluated: 1) a proposal to line a portion of the Sunnyside Irrigation District (SVID) canal adjacent to the site to eliminate leakage, and 2) a proposal to reduce recharge through site soils by covering a large area of the site with a low permeability tarp (Figure 2).

Dr. Jay Eliason developed the original three-dimensional, transient-condition groundwater model, using the U.S. Geological Survey MODFLOW code (White Shield Environmental, 1999). Dr. Eliason's model suggests that the high leakage rate from the existing irrigation canal significantly influences site groundwater conditions and contaminant transport on a seasonal basis. As simulated in his original model, recharge of the aquifer system by seasonal leakage from the canal causes a cyclical mounding of the water table beneath the canal, substantially increasing the local water table elevation and hydraulic gradient during the irrigation season. Dr. Eliason also used the particle tracking code MODPATH to demonstrate that this mound temporarily reverses the groundwater flow direction beneath the site. The proposal to line a portion of the canal in the site vicinity to eliminate this leakage (Figure 2) has prompted interest in predicting the changes that could occur to the local groundwater flow field.

In addition, there is a proposal to cover approximately 60,000 square feet of the site surface with a low permeability tarp. The tarp would cover a large portion of the southern half of the site, including the area of a remedial excavation located northeast of the SVID canal (Figure 2). Presumably, the purpose of the tarp is to eliminate recharge to the aquifer through the site vadose zone, in order to minimize subsurface migration of contaminants remaining at the site.

In response to this request, I re-ran the original model with conditions modified to reflect the proposed changes. I modeled the changes in two separate models ("CANAL" and "TARP") to allow an evaluation of each of the proposals independently. In re-running the model, I did not modify any of the input parameters used by Dr. Eliason other than the canal leakage, or site recharge rate. I did not make any attempt to recalibrate or verify the model; *I assumed that the model already acceptably represents site groundwater conditions for your purposes*.

Objectives

The objective of this effort was to evaluate the model-predicted aquifer response to proposed changes in local hydraulic conditions. Model-simulated equipotential contour maps, well hydrographs, and particle tracks were produced to help this evaluation.

Procedures

- CANAL

A variety of canals and waterways are found in the study area, and were included throughout the model domain in the original site model. These waterways are represented in the original model by a series of MODFLOW "river" cells, referred to here as "canal" cells. The main SVID canal runs northwest/southeast, adjacent to the southwestern site boundary (Figure 2). The section of the canal that is proposed for lining is approximately ½ mile long.

Figure 3 shows the canal cells modeled in the near vicinity of the site in the original model. Downward leakage from each of the canal cells is a head-dependent flux. Assuming that the local water table does not rise above the elevation of the canal bottom, leakage is calculated by the model for each cell as a function of an area-adjusted conductance term (i.e. the permeability of the canal bed) and the elevation difference between the canal stage and the canal bottom.

No leakage occurs from a river cell to the water table if the canal stage is set equal to the canal bottom, simulating a dry canal. The original model assigned an appropriate canal stage for each on and off period of canal operation ("stress period") over the length of the model run (White Shield Environmental, 1999). Four stress periods per year were simulated: December 31 to March 20 (canal off), March 20 to July 15 (canal on), July 15 to October 31 (canal on), and October 31 to December 31 (canal off). In the original model, canal leakage during the "canal-on" periods was established to equal a rate ranging between 0.7 and 0.5 cfs/mile.

For the purposes of this study, it was assumed that the lining of a section of the canal would completely isolate the water in that section from the aquifer. Therefore, in the CANAL model, the canal cells were deleted along the length of the canal proposed for lining (model rows 62 through 124, Figure 4). No changes were made to any of the other canal cells within the model domain.

The CANAL model was run under transient conditions for the same 5-year period as the original model. Simulated equipotential contour maps and well hydrographs were used to identify impacts of the canal liner on the site aquifer system.

- TARP

A steady-state annual recharge rate of 3 inches per year (in/yr) was applied to the entire active model domain in the original model. To reflect the impact of a low-permeability tarp being placed over a portion of the site surface, the recharge rate was set to 0 in/yr in the cells that approximate the area proposed to be covered (Figure 5). The TARP model was then run under transient conditions for the same 5-year period as the original model.

Simulated equipotential contour maps and well hydrographs were used to identify impacts of the tarp on the site aquifer system. In addition, particle tracking using the MODPATH code was used to determine if local groundwater flow velocities and pathlines are likely to be affected by the installation of a low-permeability cover. To accomplish this, 10 particles were released in the Touchet aquifer (model layer 1) in the area proposed for tarping. These particles were tracked for a period of 250 days, starting 1196 days into the model run (21 days after the start of a “canal on” period).

Discussion

- CANAL

Two key time steps in the modeled 5-year period are helpful in evaluating the range of aquifer response to the simulated conditions. Stress period 18, time step 4 occurs several years into the model run, and represents the end of a 140-day period of the canal being dry. Figure 6 shows an equipotential contour map for Layer 2 of the CANAL model for this time step (green symbols represent site observation wells, red symbols represent deactivated pumping wells; all equipotential contours are shown in feet of elevation). A comparison of the areal equipotential contours in Figure 6 to the contours for the same time step from the original model (Figure 7) shows a similar configuration for both models. Although the absolute elevations are slightly lower in the CANAL model, neither model shows a localized mounding influence from canal leakage at this time period.

Figures 8 and 9 show the equipotential contours predicted by the CANAL model for stress period 20, time step 4, in areal and profile view (the Figure 9 profile runs south to north through the Tobin well). This time step represents a period of maximum canal impact on the aquifer system; model cells representing the canal have had a “canal on” condition for a prior 225-day period. The predicted head configuration in the CANAL model for this time period (Figures 8 and 9) is distinctly different than that predicted for the same time period in the original model (Figures 10 and 11). *At the time period of maximum canal influence on the aquifer system, the CANAL model shows no evidence of a mounding effect in the area where the river cells were deleted.*

Figures 12 and 13 show predicted (and for reference, field-measured) hydrographs for selected wells within the model domain from the CANAL model. Figures 14 and 15 show hydrographs for the same wells from the original model. The CANAL model hydrographs predict that a seasonal rise and fall of the potentiometric head would continue to occur due to the on and off leakage cycles of the canal cells remaining active in the model. However, the magnitude of head change between seasons is significantly smaller in the CANAL model in comparison to the original model (CANAL model: ~2 feet; original model: ~5 feet), reflecting the absence of the effects of mounding beneath the canal in the site area.

The maximum equilibrium water-table elevation predicted by the CANAL model beneath the site center (YCR-1 area) is approximately 821.5 feet. This value is compared to a maximum predicted water-table elevation in the vicinity of YCR-1 in the original model of approximately 826.7 feet, suggesting an overall decline in the maximum water table elevation beneath the site center of approximately 5 feet.

It should be noted that the Figure 12 and 13 hydrographs suggest that the CANAL model does not quite reach a dynamic steady-state condition within the 5-year time frame using the revised leakage characteristics. This is not considered to change the basic conclusions regarding the predicted impact of canal lining.

- TARP

Figure 16 shows equipotential contours predicted by the TARP model for stress period 18, time step 4, the period of minimal canal impact. Figure 17 shows equipotential contours from the TARP model for stress period 20, time step 4, the period of maximum canal impact. Figure 18 shows predicted and measured hydrographs for selected onsite wells that are located near or within the proposed covered area. Comparison of these figures to the corresponding figures for the original model (Figures 7, 10, and 14 respectively) show essentially no measurable change in aquifer conditions resulting from the reduction of on-site surface recharge.

Figures 19 and 20 show the TARP model particle pathlines for the particles released in the area to be covered, in areal and profile view (the Figure 20 profile runs west to east through the Tobin well). The pathline lengths and paths shown on this figure are essentially the same as those that are predicted by the original model (Figures 21 and 22). The particles show that there is an initial, local reversal of the groundwater flow direction in response to the canal mounding, then the particles turn and move downgradient. The similarity of the TARP model pathlines to those simulated by the original model is evidence that the groundwater flow field will not be substantially affected by a local reduction in recharge while the canal is unlined. It should be noted that the MODFLOW model does not simulate changes that may occur in travel time or pathway of particles moving through the vadose zone.

Summary

Proposed changes to hydraulic conditions on or adjacent to the Alexander Farms Site prompted the need to evaluate potential impacts on the local aquifer system. The first proposed change includes the lining of the SVID irrigation canal in the area adjacent to the site to eliminate canal leakage. The second change is the proposed placement of a low permeability cover over a large portion of the site surface to reduce recharge.

To evaluate the impact of these changes, an existing MODFLOW model was modified to represent the new conditions. Two separate models were used to independently evaluate the proposed changes. The CANAL model was modified by deleting a section of the modeled canal in the vicinity of the site. The TARP model was modified by eliminating surface recharge over an area approximating the footprint of the proposed cover. No other input parameters were modified from the original model, and *it was assumed that the original model is already calibrated and verified within a range of acceptable error for decision making*.

The CANAL model predicts that the mounding effect that was seen below the canal in the original model will be eliminated in the site area if canal leakage is eliminated. As constructed, the CANAL model predicts a cyclical fluctuation of the potentiometric head of the aquifer in response to leakage from canals and watercourses modeled away from the site. The head fluctuation within or immediately adjacent to the site predicted by the CANAL model is, however, significantly reduced in comparison to the original model. The model predicts a reduction of as much as 5 feet in the equilibrated maximum water-table elevation in the YCR-1 area resulting from the elimination of canal leakage.

The TARP model results suggest that little or no effect on the subsurface hydraulic conditions will be caused by the placement of a low permeability cover on the site, as long as canal leakage continues. Canal leakage is the dominant source of recharge to the aquifer system in the model; as a result a local reduction in the areal recharge rate is not predicted to cause a significant change in groundwater flowpaths or travel times. The model does not address changes that may occur to travel times or pathlines within the vadose zone.

Don't forget that the model predictions are only as accurate and representative as the model itself. The error between the field measured heads and the predicted heads in the original model routinely ranged between 1.5 – 2.5 feet, a substantial portion of the predicted drop in maximum water-table elevation. Be cautious of using these predictions if your cost/benefit decisions require greater accuracy. If these engineering changes are implemented in the field, I strongly encourage that you consider collecting data to verify that the aquifer responds in a manner similar to that predicted. This sort of information could also assist in refining the model.

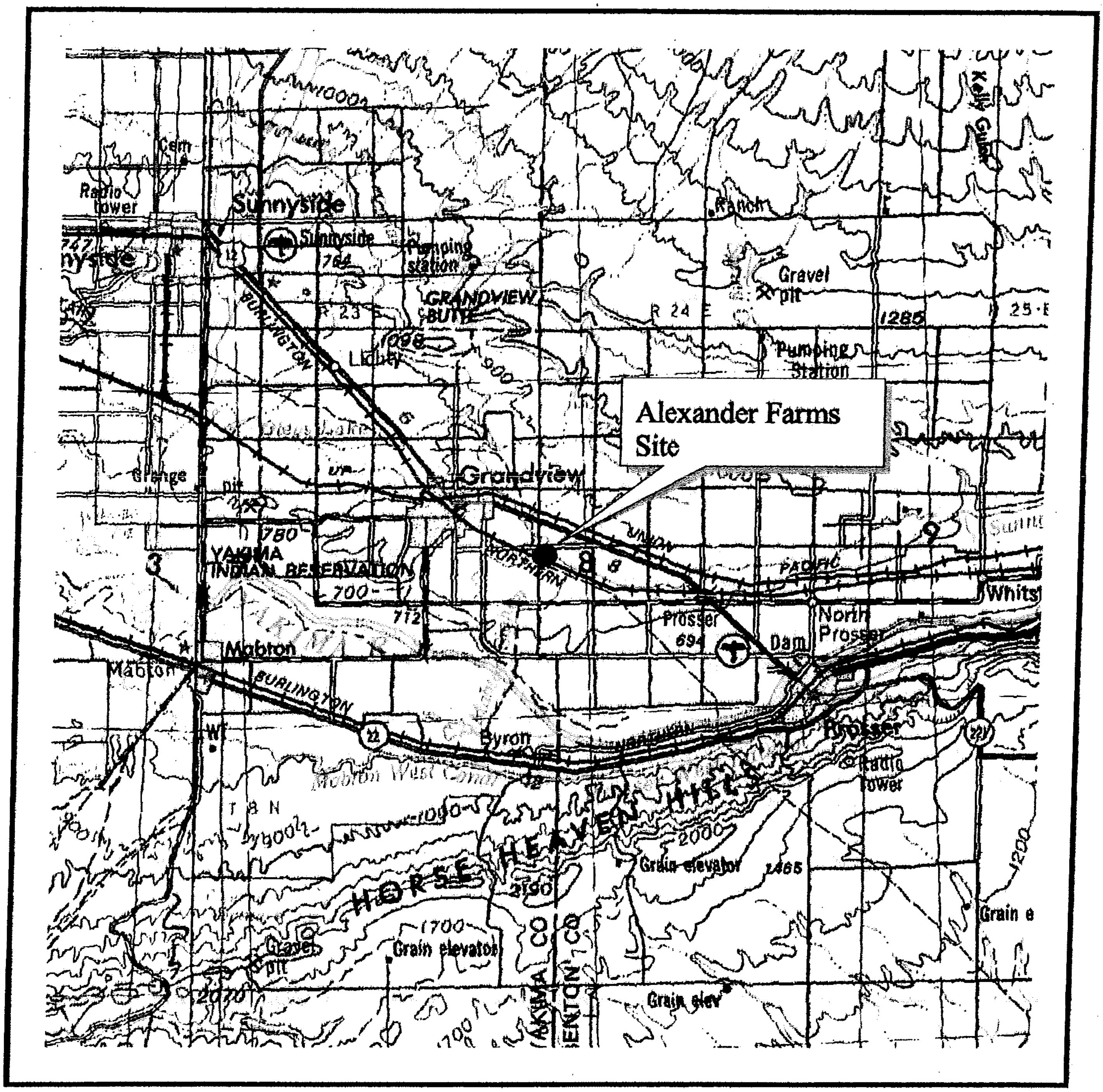
Please let me know if you have any questions about this analysis. I can be reached at (360) 407-6775. Thanks for the opportunity to work on this project.

References

White Shield Environmental, 1999, Groundwater Sampling and Characterization Report, Alexander Farm Site.

CP:jl

cc: Will Kendra, EAP-WES
Dale Norton, EAP-WES
Tom Mackie, TCP-CRO
EAP Publications Library



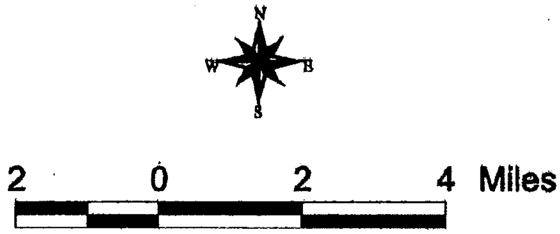


Figure 1
Location Map
Alexander Farms Site

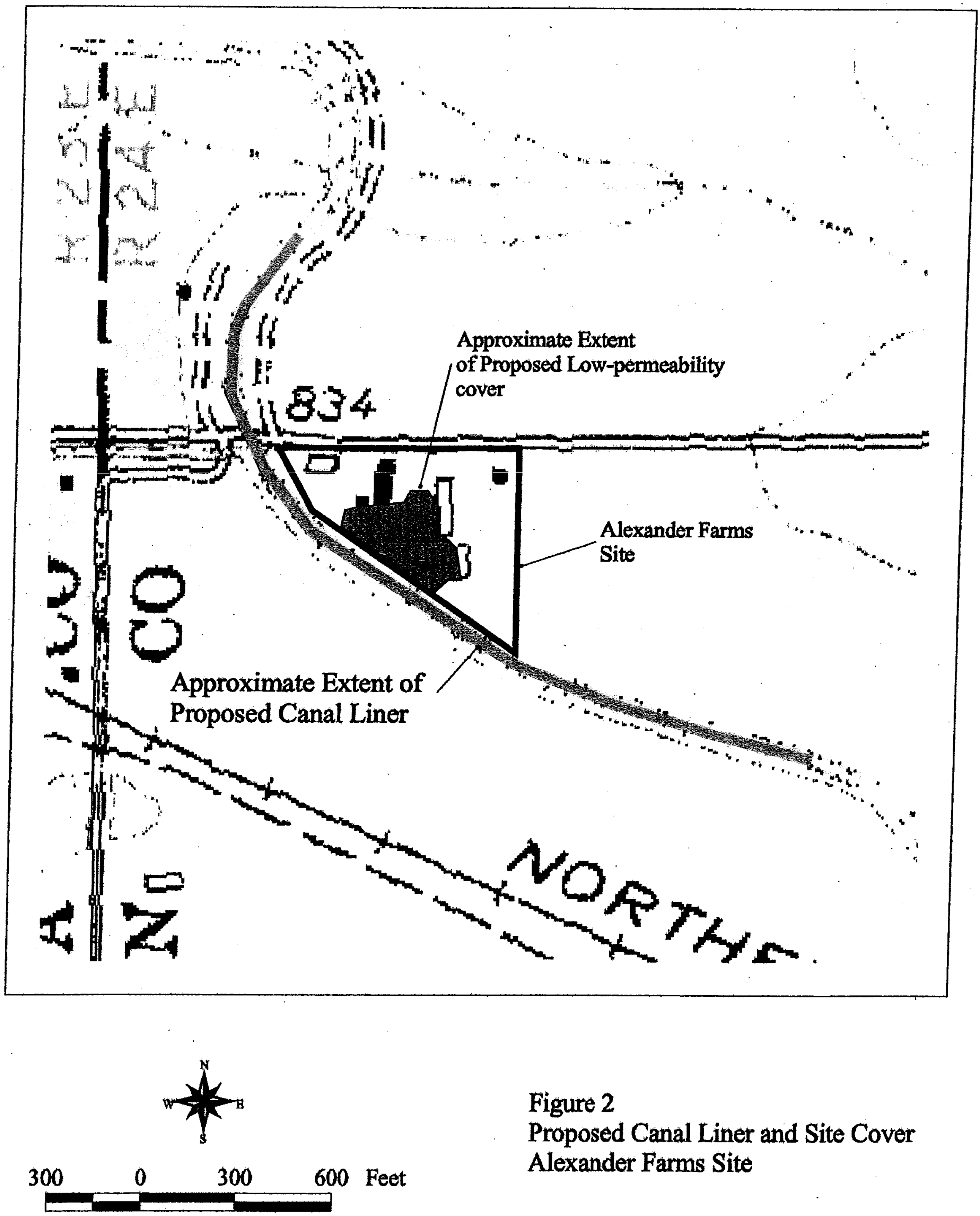
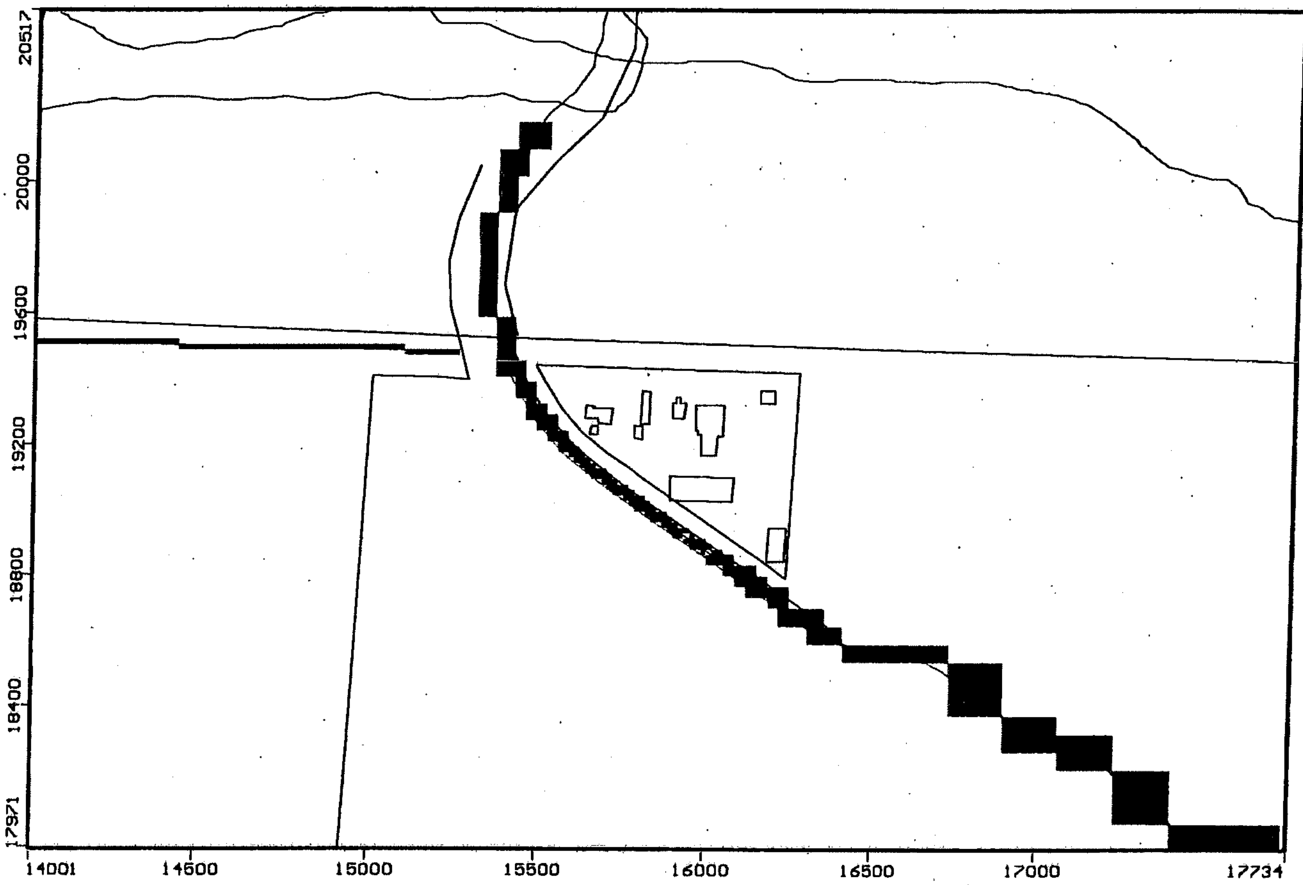


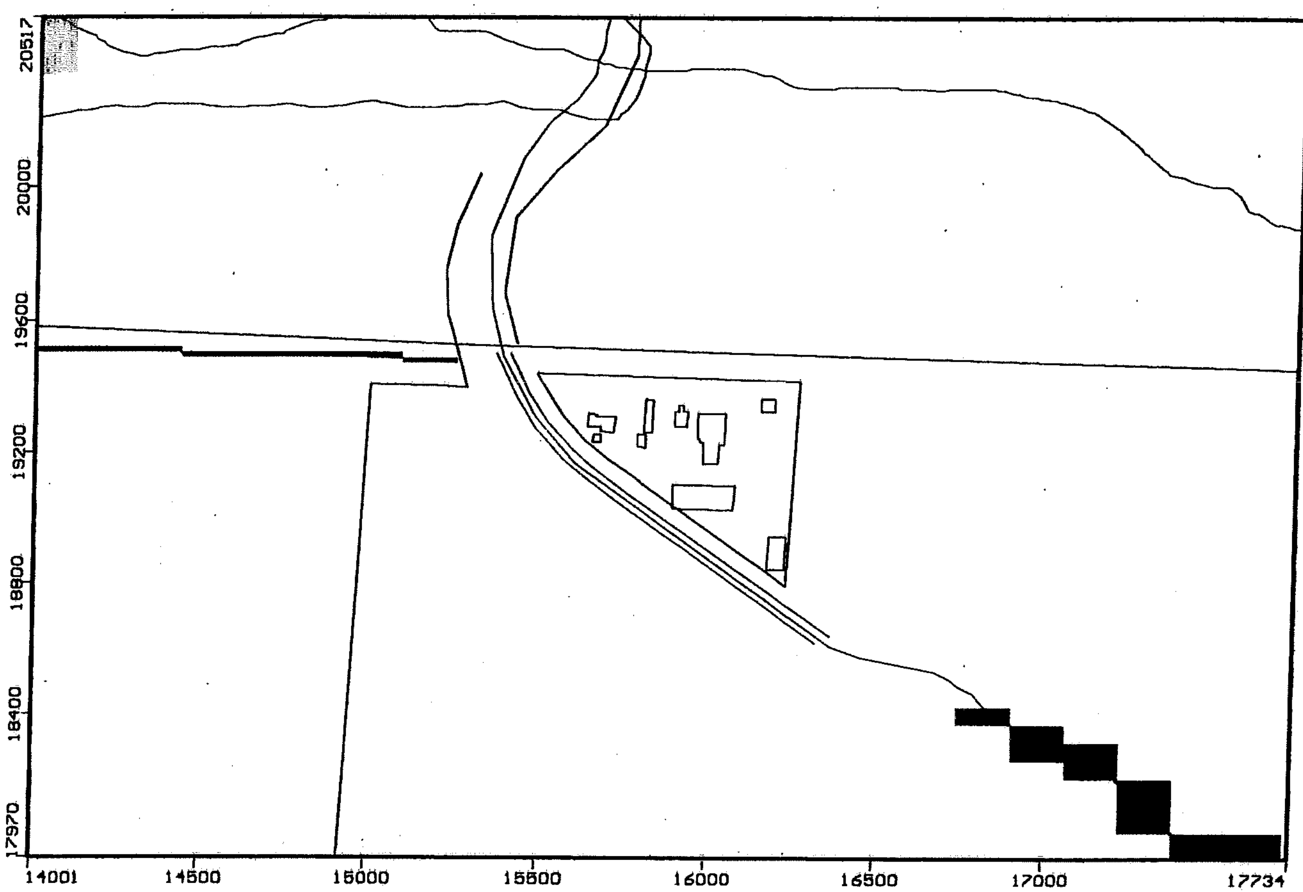
Figure 2
Proposed Canal Liner and Site Cover
Alexander Farms Site



Washington Dept. of Ecology
Project: Alexander Farms
Description: Model 1
Modeller: J. Eliason
24 Oct 00

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 181 NR: 240 NL: 6
Current Layer: 2

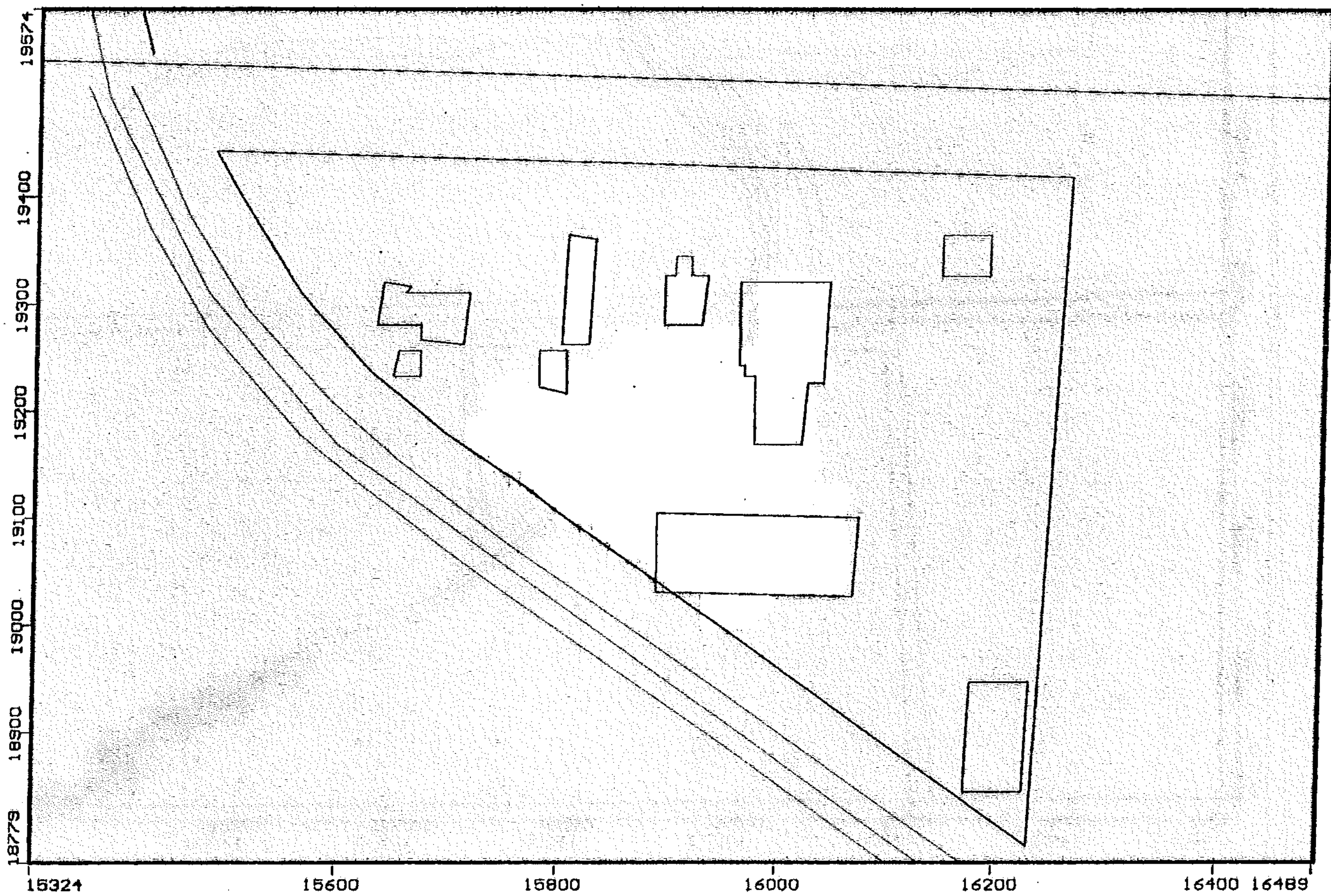
Figure 3
Modeled Canal Cells – Original Model
(Axis scales in feet UTM N and E)



Washington Dept. of Ecology
Project: Alexander Farms
Description: Model 1
Modeller: J. Eliason (modified CFP)
24 Oct 00

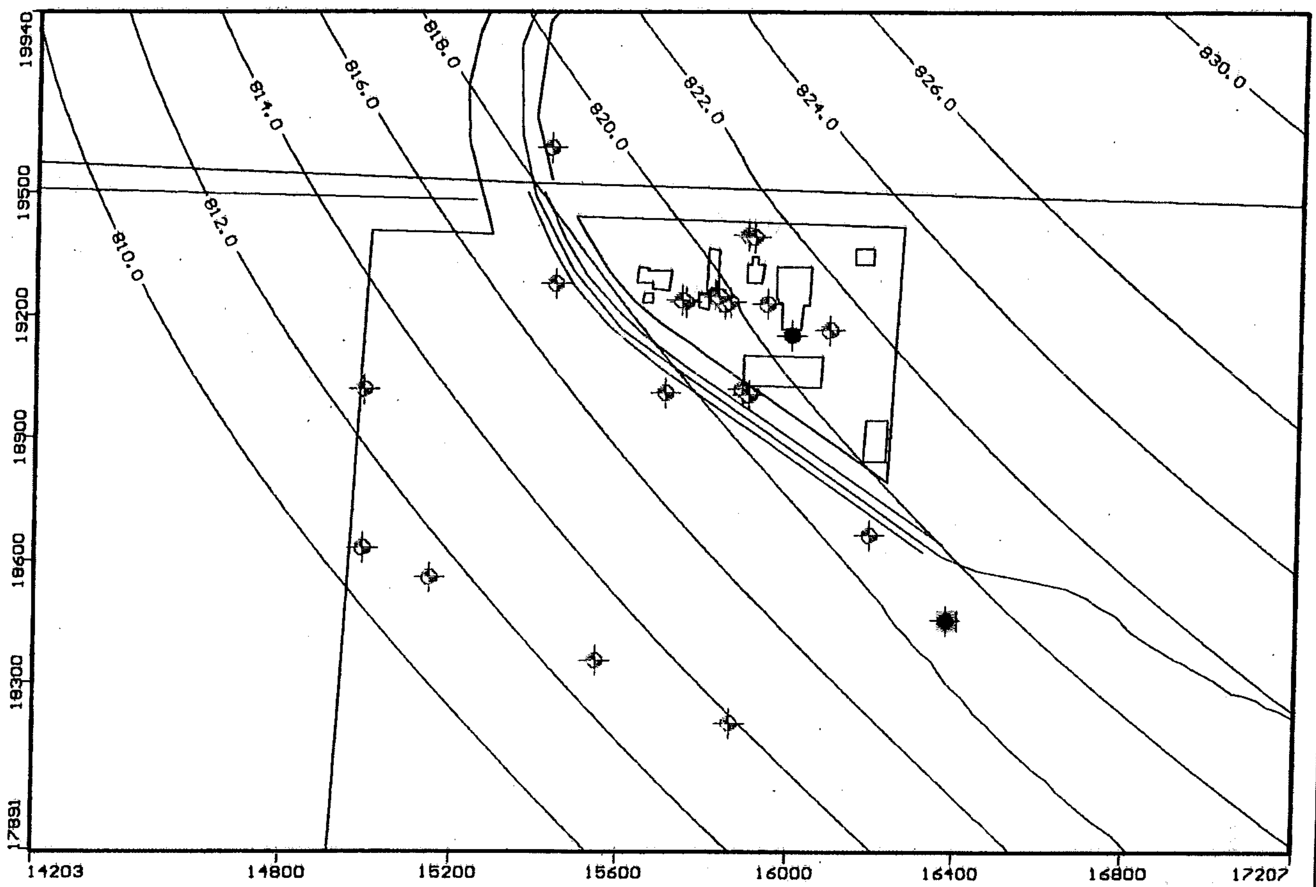
Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 181 NR: 240 NL: 6
Current Layer: 2

Figure 4
Modeled Canal Cells – CANAL Model
(Axis scales in feet UTM N and E)



Washington Dept. of Ecology Project: Alexander Farms Description: Model 1 Modeller: J. Eliason (modified CFP) 25 Oct 00	Visual MODFLOW v.2.7.2, (C) 1995–1997 Waterloo Hydrogeologic, Inc. NC: 181 NR: 240 NL: 6 Current Layer: 1

Figure 5
Area of Zero Recharge – TARP Model
(Axis scales in feet UTM N and E)



Washington Dept. of Ecology
Project: Alexander Farms
Description: Model 1
Modeller: J. Eliason (modified CFP)
24 Oct 00

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 181 NR: 240 NL: 6
Current Layer: 2

Figure 6
Areal Equipotential Contours – CANAL Model
Stress Period 18, Time Step 4, Canal Off
(Axis scales in feet UTM N and E)

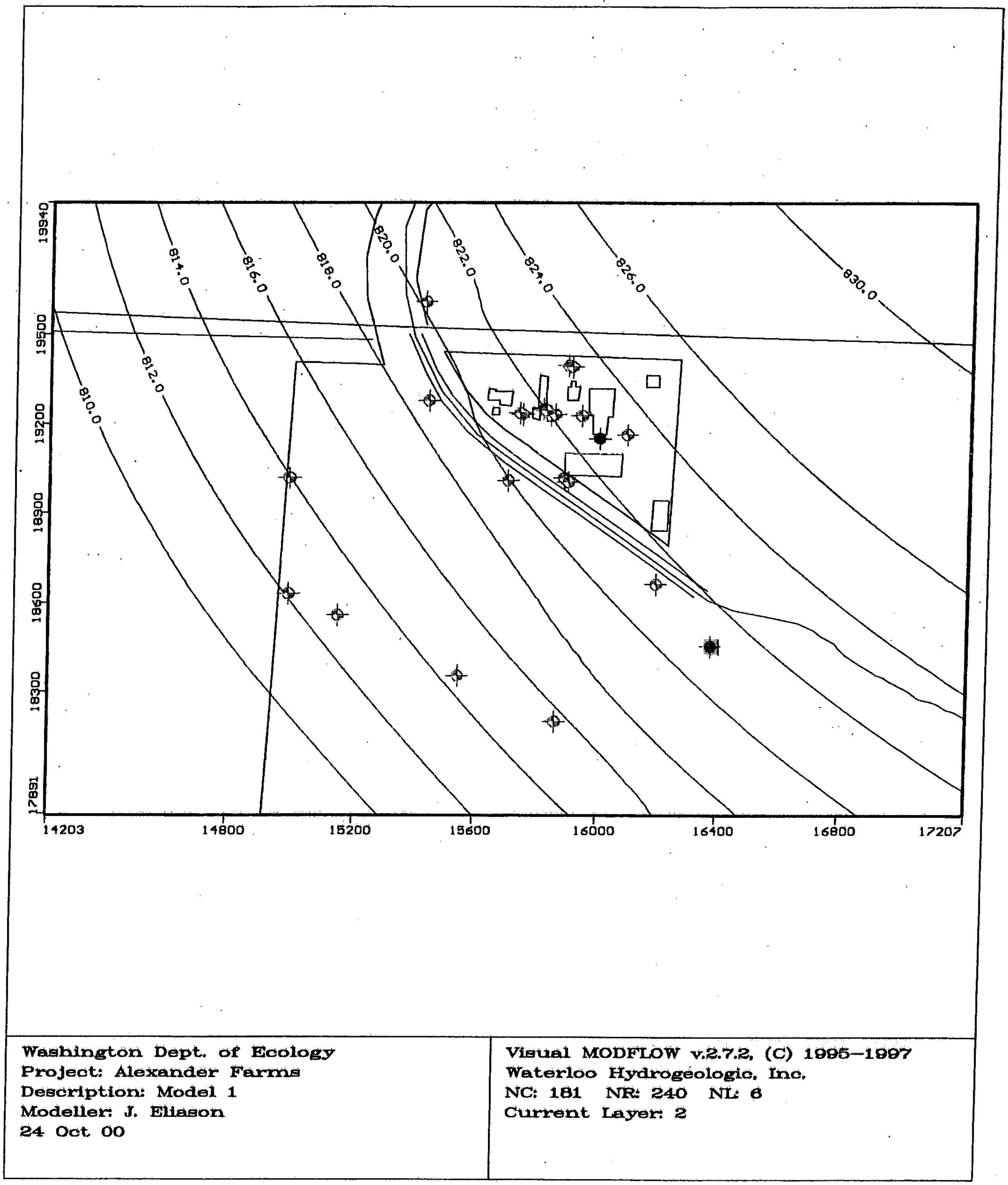
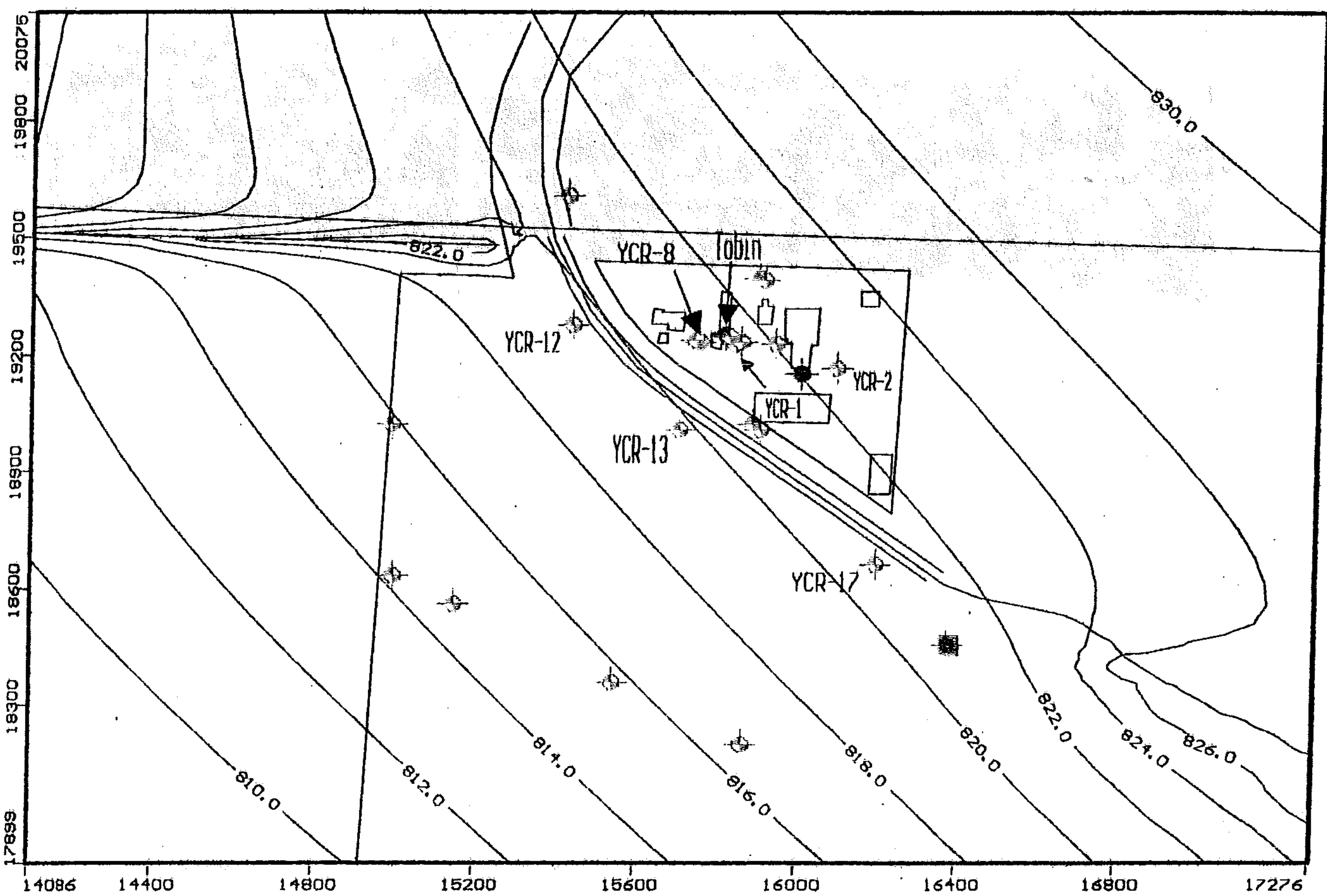


Figure 7
Areal Equipotential Contours – Original Model
Stress Period 18, Time Step 4, Canal Off
(Axis scales in feet UTM N and E)



Washington Dept. of Ecology Project: Alexander Farms Description: Model 1 Modeller: J. Eliason (modified CFP) 2 Nov 00	Visual MODFLOW v.2.7.2, (C) 1995–1997 Waterloo Hydrogeologic, Inc. NC: 181 NR: 240 NL: 6 Current Layer: 2

Figure 8
Areal Equipotential Contours – CANAL Model
Stress Period 20, Time Step 4, Canal On
(Axis scales in feet UTM N and E)

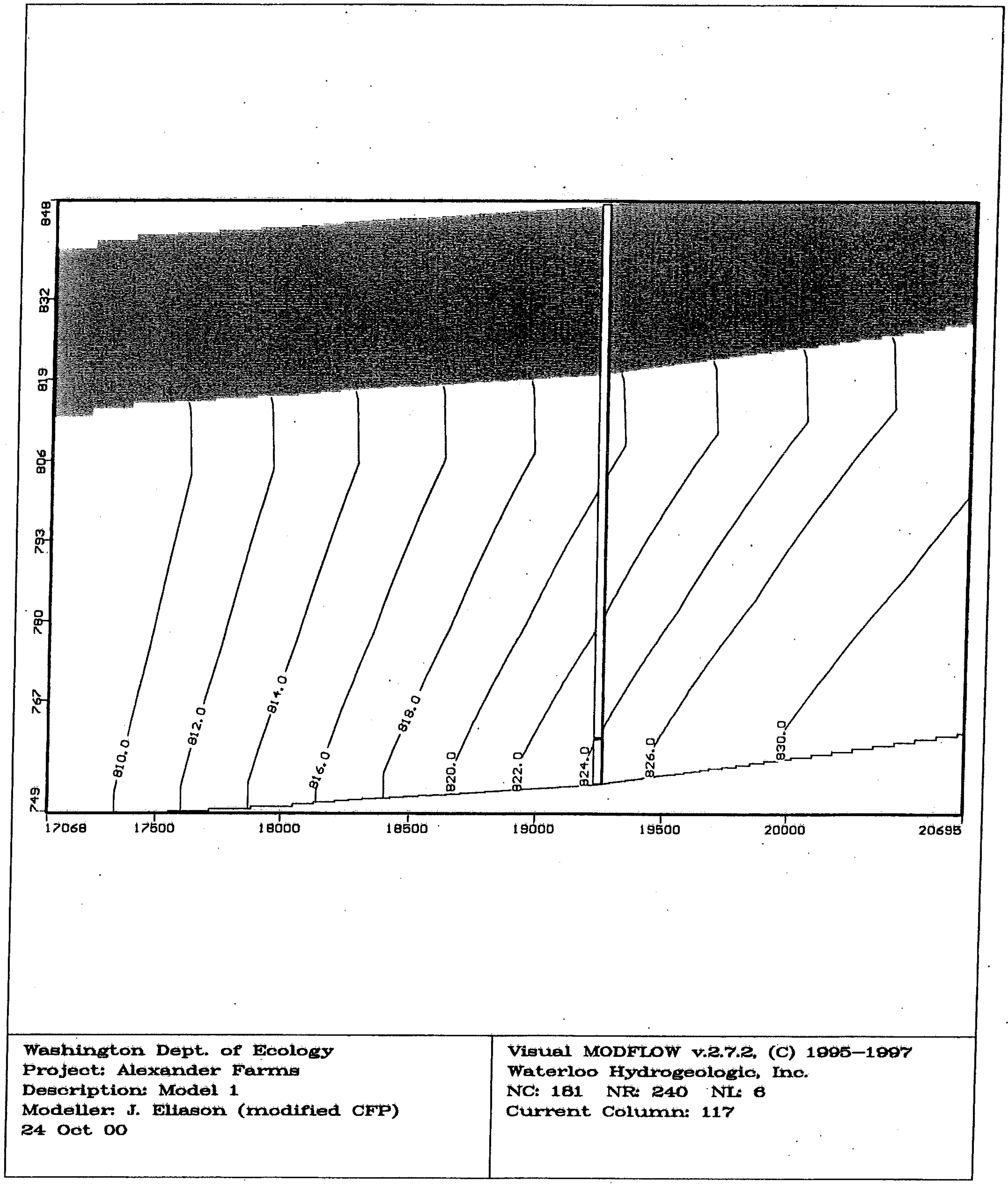
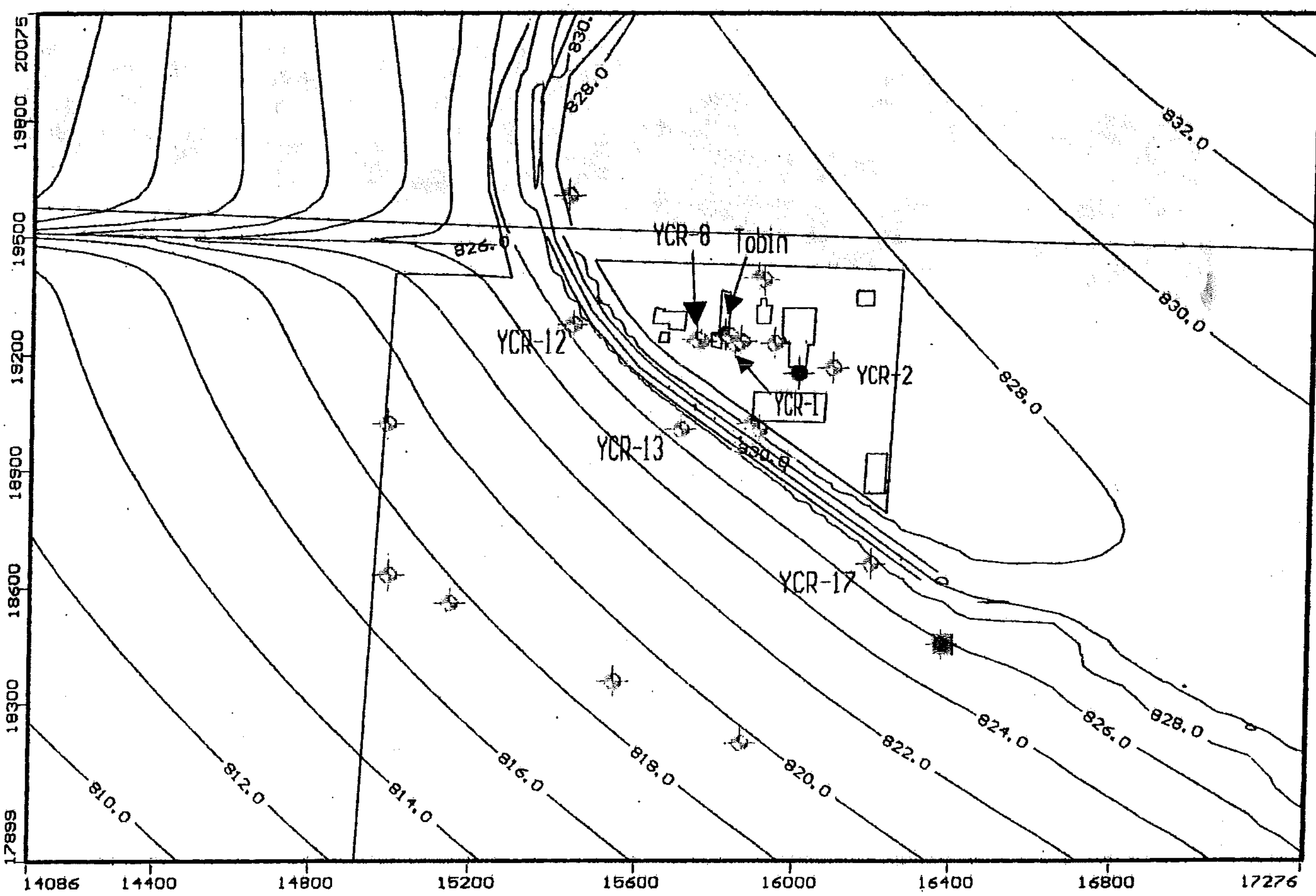
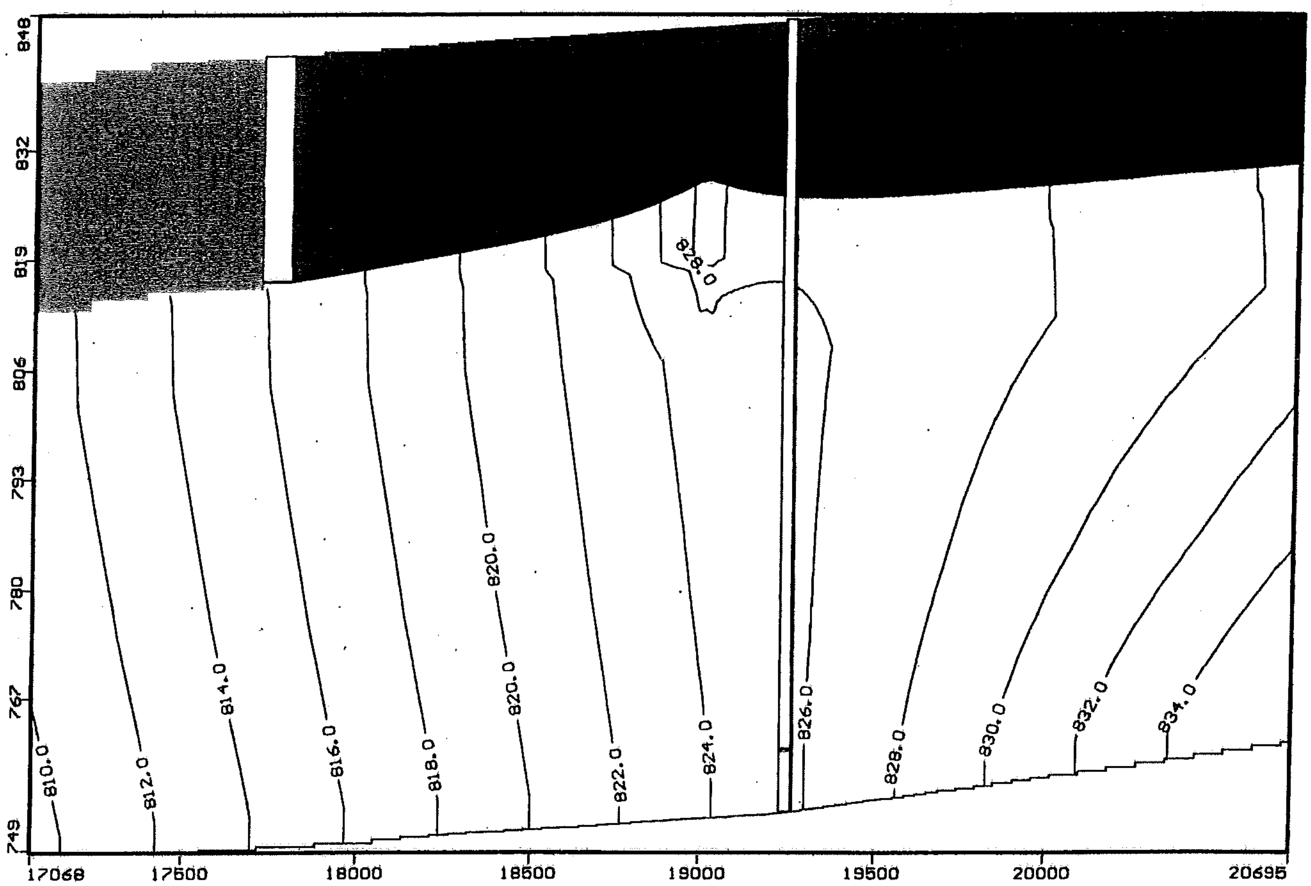


Figure 9
Profile Equipotential Contours – CANAL Model
Stress Period 20, Time Step 4, Canal On
(Vertical scale in feet elevation, horizontal scale in feet UTM S to N)



Washington Dept. of Ecology Project: Alexander Farms Description: Model 1 Modeller: J. Eliason 2 Nov 00	Visual MODFLOW v.2.7.2, (C) 1995–1997 Waterloo Hydrogeologic, Inc. NC: 161 NR: 240 NL: 6 Current Layer: 2

Figure 10
Areal Equipotential Contours – Original Model
Stress Period 20, Time Step 4, Canal On
(Axis scales in feet UTM N and E)



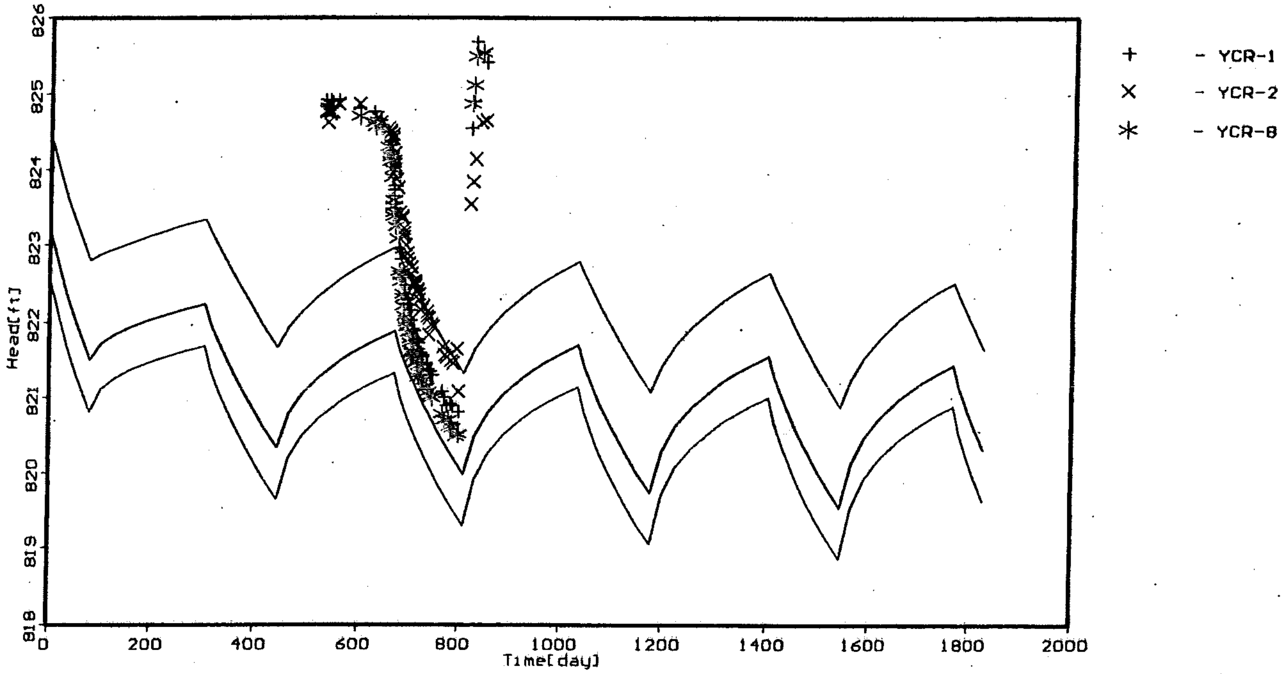
Washington Dept. of Ecology Project: Alexander Farms Description: Model 1 Modeller: J. Eliason 24 Oct 00	Visual MODFLOW v.2.7.2, (C) 1995–1997 Waterloo Hydrogeologic, Inc. NC: 181 NR: 240 NL: 6 Current Column: 117

Figure 11

Profile Equipotential Contours – Original Model

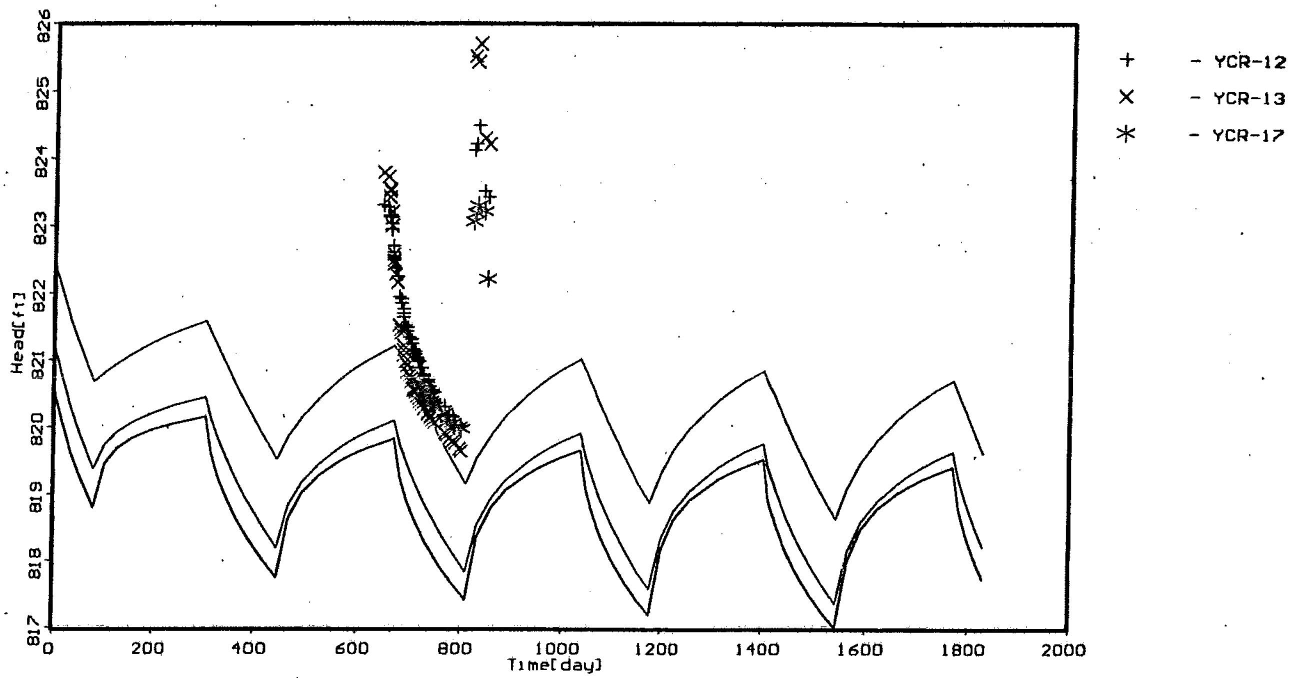
Stress Period 20, Time Step 4, Canal On

(Vertical scale in feet elevation, horizontal scale in feet UTM S to N)



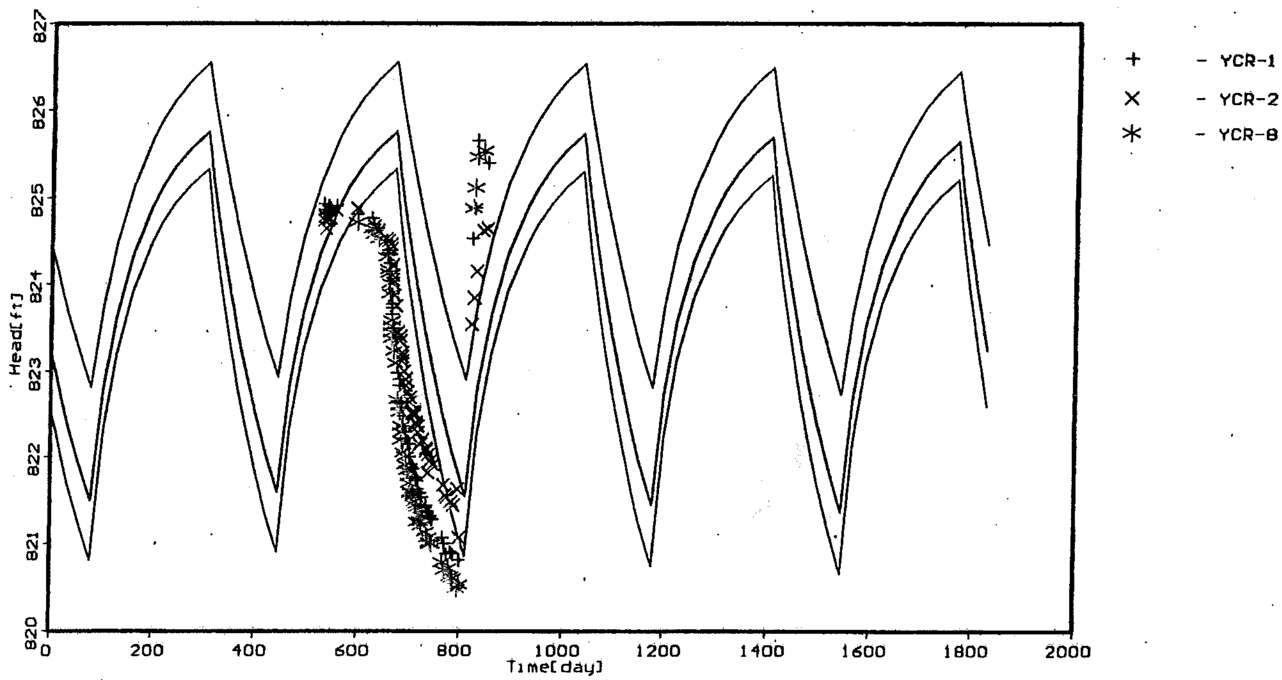
Washington Dept. of Ecology Project: Alexander Farms Description: Model 1 Modeller: J. Eliason (modified CFP) 24 Oct 00	Visual MODFLOW v.2.7.2, (C) 1995–1997 Waterloo Hydrogeologic, Inc. NC: 181 NR: 240 NL: 6 Current Layer: 2

Figure 12
Well Hydrographs – YCR - 1, 2, 8 – CANAL Model



Washington Dept. of Ecology	Visual MODFLOW v.2.7.2, (C) 1995—1997
Project: Alexander Farms	Waterloo Hydrogeologic, Inc.
Description: Model 1	NC: 181 NR: 240 NL: 6
Modeller: J. Eliason (modified CFP)	Current Layer: 2
24 Oct 00	

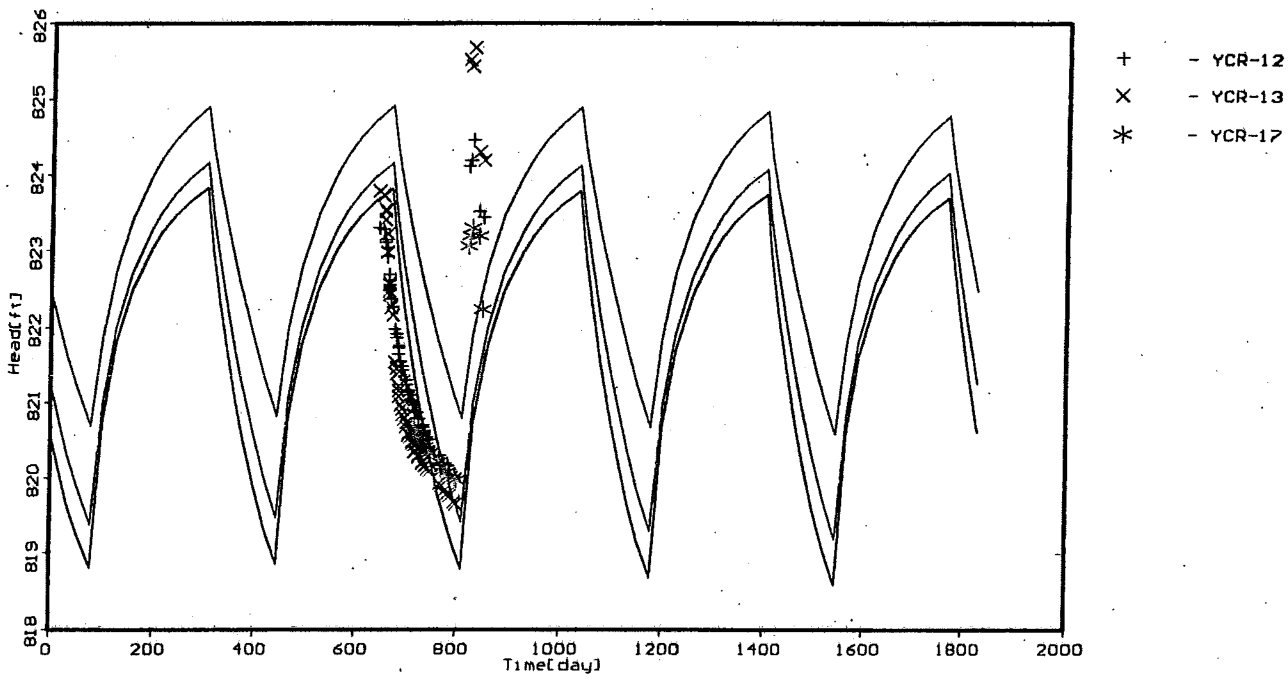
Figure 13
Well Hydrographs – YCR - 12, 13, 17 – CANAL Model



Washington Dept. of Ecology
Project: Alexander Farms
Description: Model 1
Modeller: Jay Eliason
19 Oct 00

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 181 NR: 240 NL: 6
Current Layer: 4

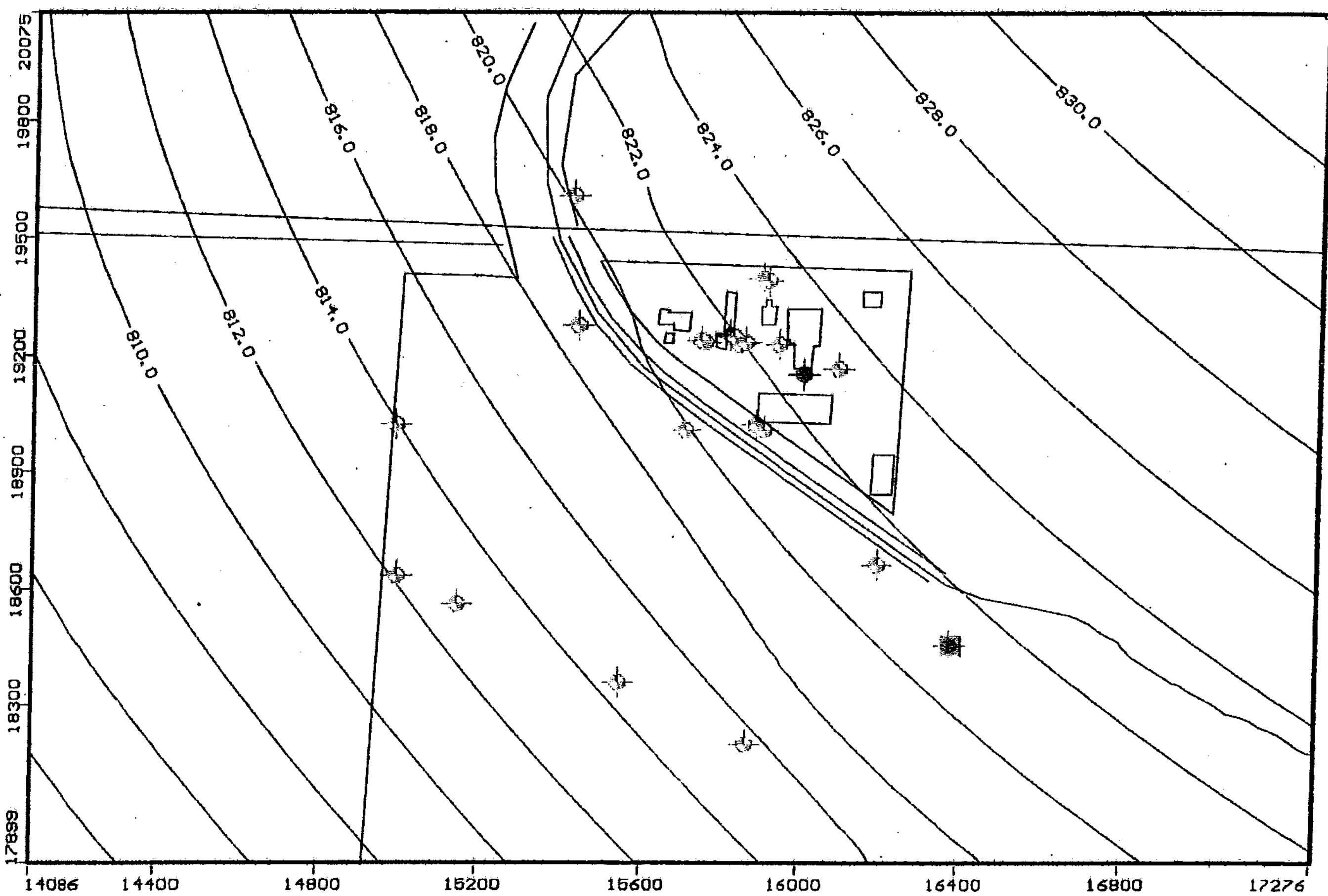
Figure 14
Well Hydrographs – YCR - 1, 2, 8 – Original Model



Washington Dept. of Ecology
Project: Alexander Farms
Description: Model 1
Modeller: Jay Eliason
19 Oct 00

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 181 NR: 240 NL: 6
Current Layer: 4

Figure 15
Well Hydrographs – YCR - 12, 13, 17 – Original Model



Washington Dept. of Ecology
Project: Alexander Farms
Description: Model 1
Modeller: J. Eliason (modified CFP)
25 Oct 00

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 181 NR: 240 NL: 6
Current Layer: 2

Figure 16
Areal Equipotential Contours – TARP Model
Stress Period 18, Time Step 4, Canal Off
(Axis scales in feet UTM N and E)

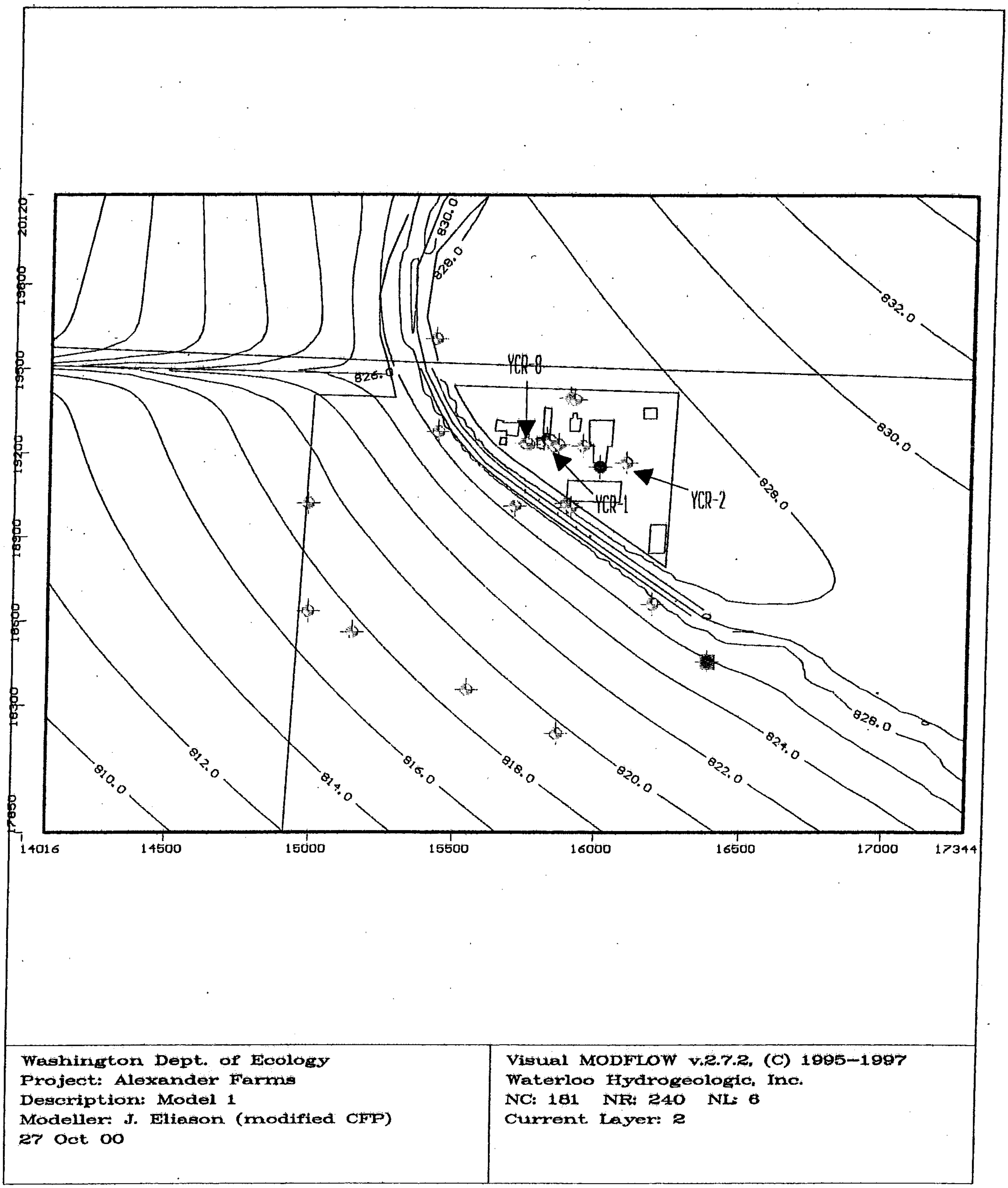
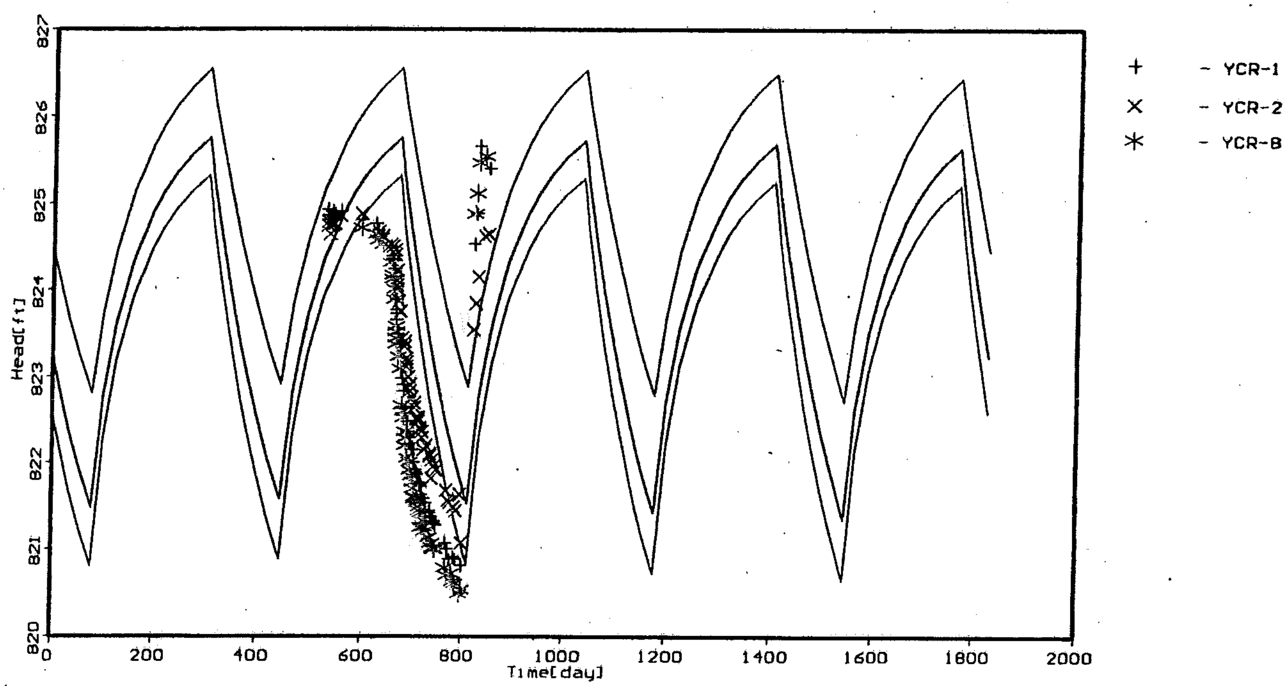


Figure 17

Areal Equipotential Contours – TARP Model

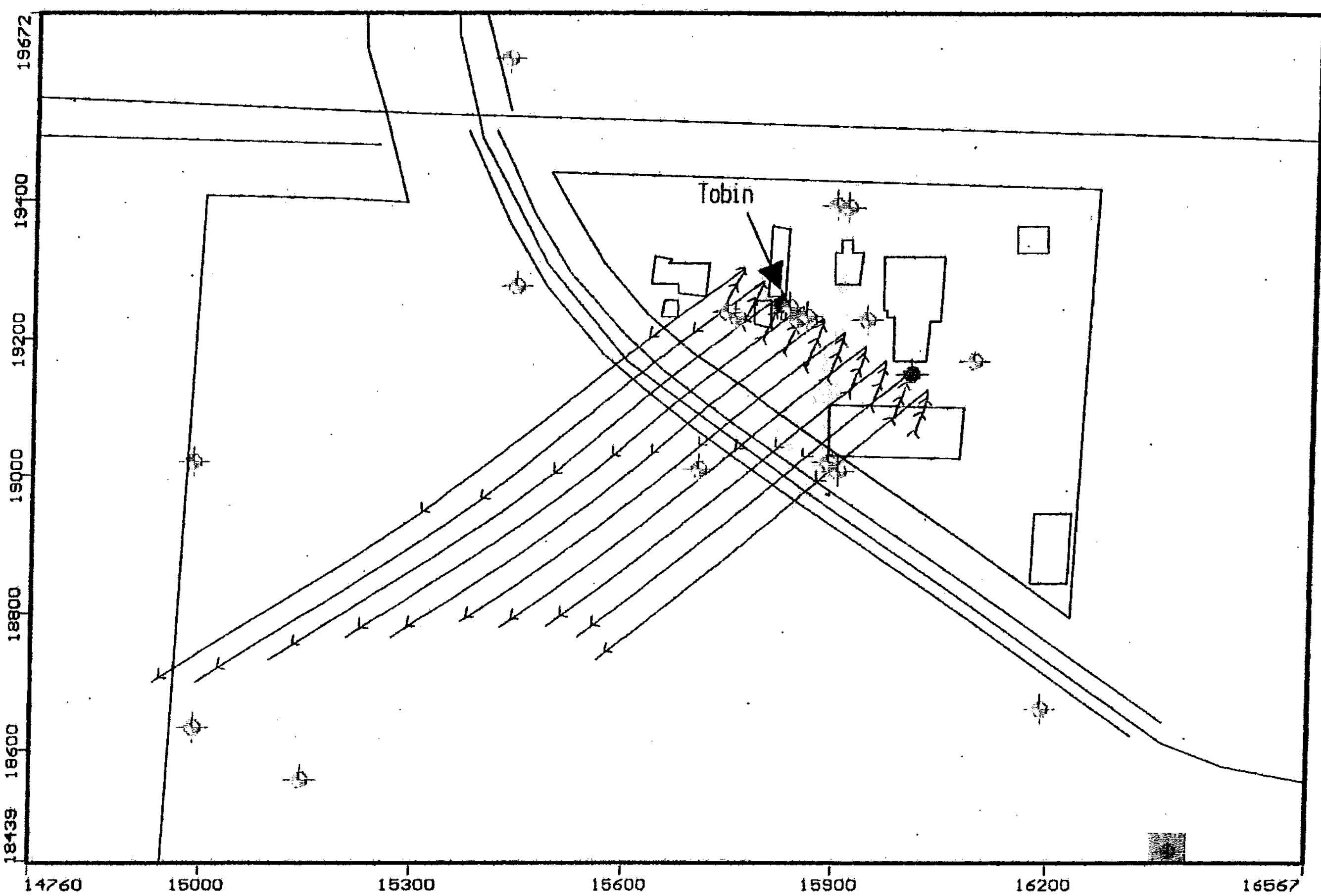
Stress Period 20, Time Step 4, Canal On

(Axis scales in feet UTM N and E)



Washington Dept. of Ecology Project: Alexander Farms Description: Model 1 Modeller: J. Eliason (modified CFP) 25 Oct 00	Visual MODFLOW v.2.7.2, (C) 1995–1997 Waterloo Hydrogeologic, Inc. NC: 181 NR: 240 NL: 6 Current Layer: 2

Figure 18
Well Hydrographs – YCR - 1, 2, 8 – TARP Model



Washington Dept. of Ecology Project: Alexander Farms Description: Model 1 Modeller: J. Eliason (modified CFP) 2 Nov 00	Visual MODFLOW v.2.7.2, (C) 1995-1997 Waterloo Hydrogeologic, Inc. NC: 181 NR: 240 NL: 6 Current Layer: 2

Figure 19
250-Day Particle Pathlines – TARP Model
(Axis scales in feet UTM N and E; pathline arrows represent 50-day time steps)

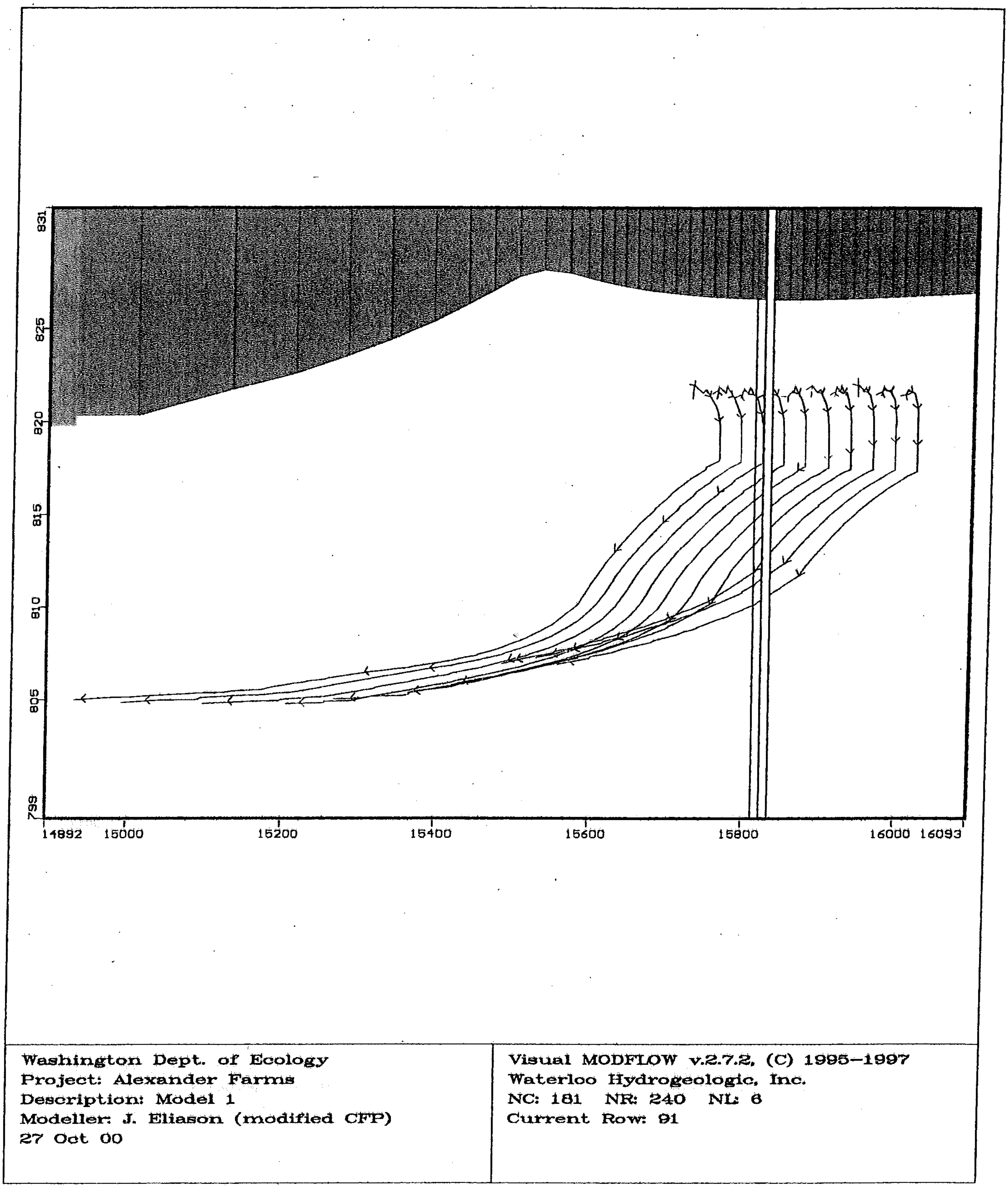


Figure 20

250-Day Particle Pathlines – East-West Profile – TARP Model

(Vertical scale in feet elevation, horizontal scale in feet UTM W to E; pathline arrows represent 50-day time steps)

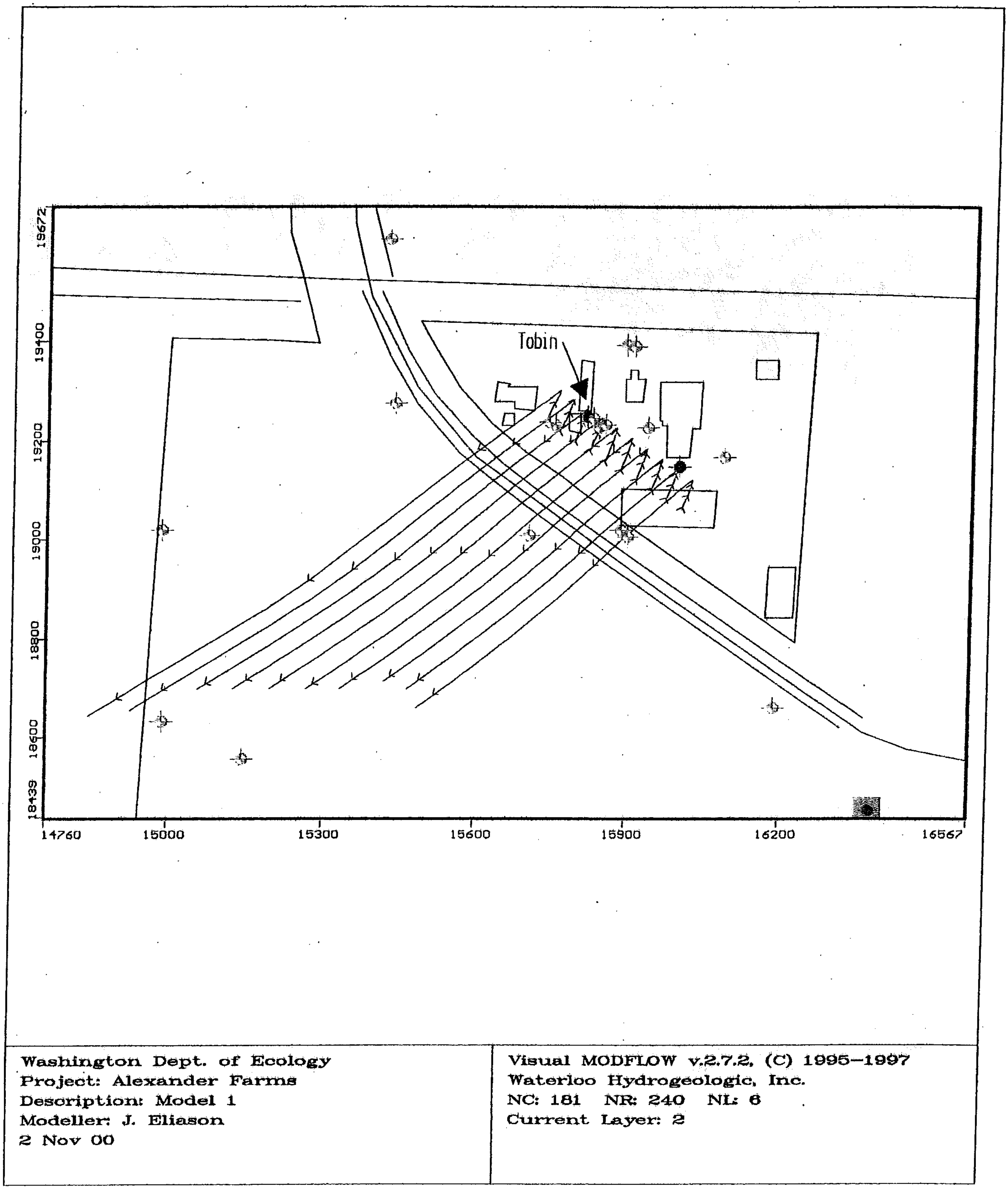
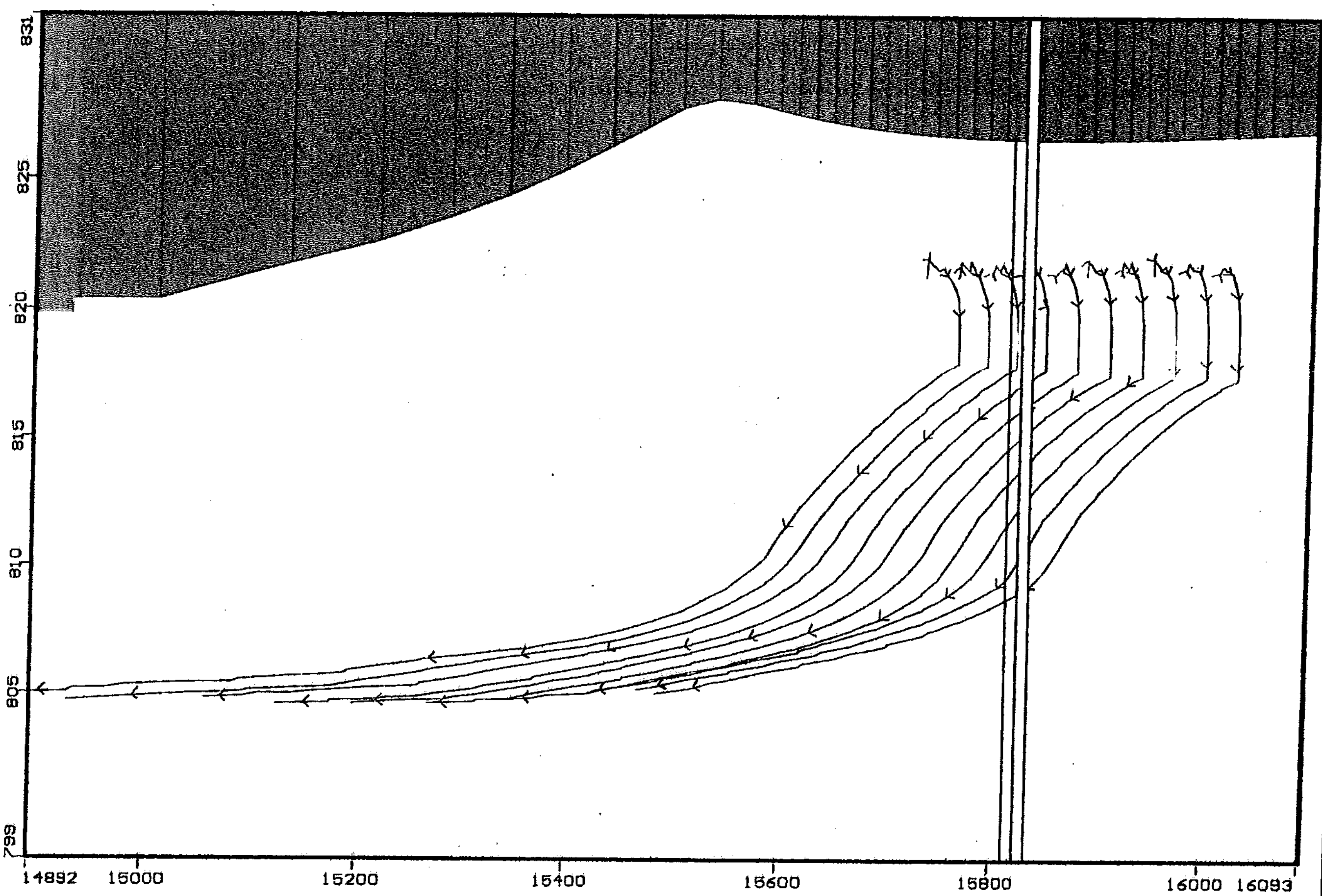


Figure 21
250-Day Particle Pathlines – Original Model
(Axis scales in feet UTM N and E; pathline arrows represent 50-day time steps)



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Project: Alexander Farms
Description: Model 1
Modeller: J. Eliason
27 Oct 00

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 181 NR: 240 NL: 6
Current Row: 91

Figure 22
250-Day Particle Pathlines – East-West Profile – Original Model
(Vertical scale in feet elevation, horizontal scale in feet UTM W to E; pathline arrows represent 50-day time steps)