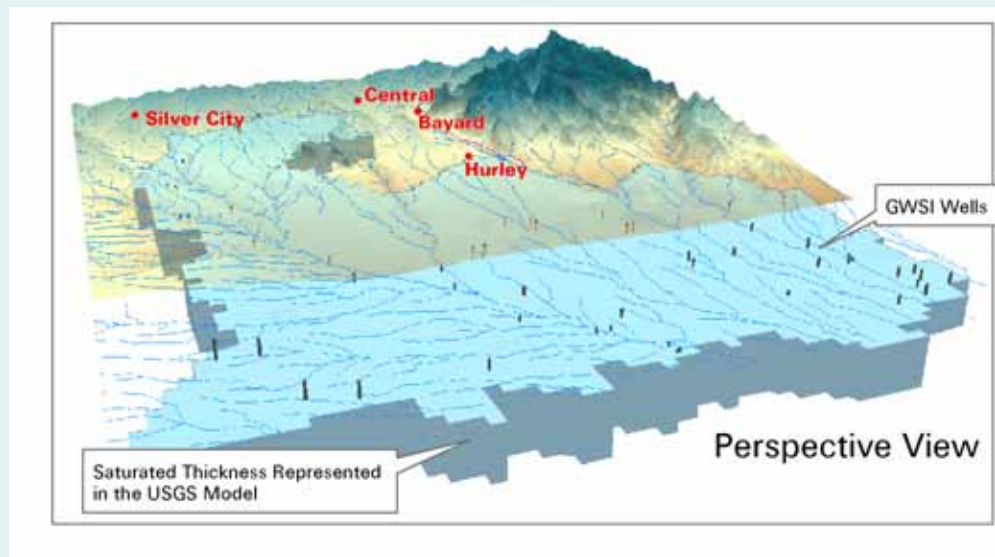
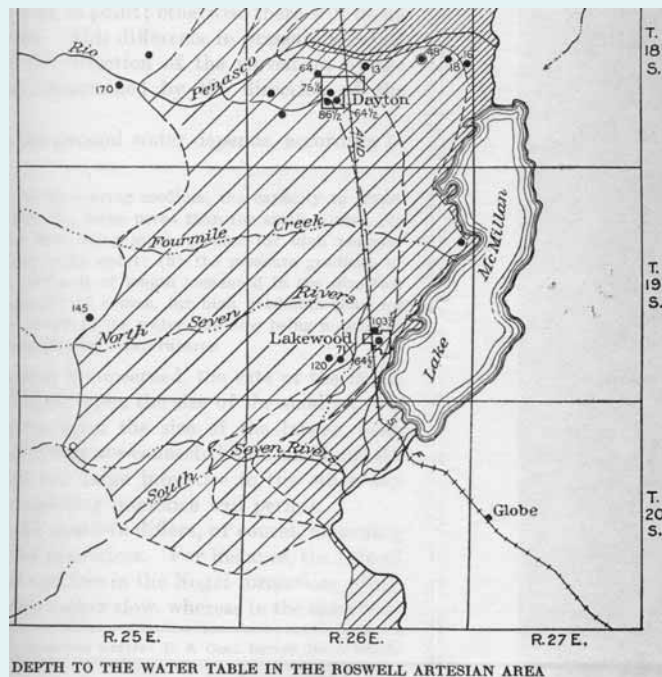


Application of Volumetric GIS Data Objects in Groundwater Resource Investigations

ESRI USER CONFERENCE
JULY 10, 2003

Steven Silver, Balleau Groundwater, Inc.





DEPTH TO WATER MAP

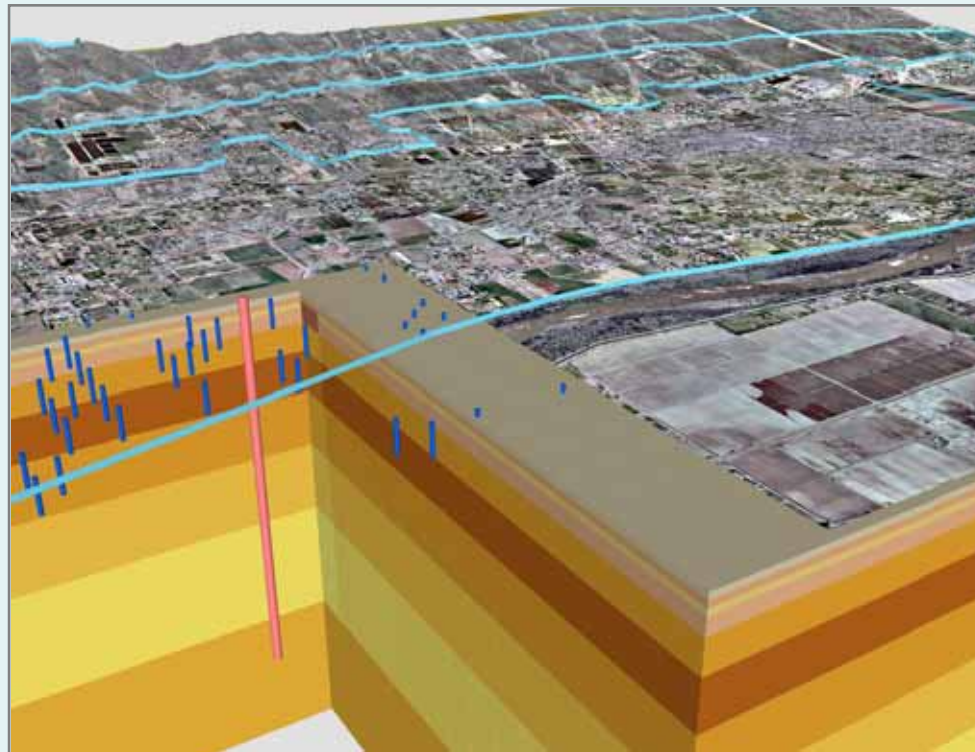
GROUNDWATER MODEL INPUT

LEDGER BASED BLOCK ADMINISTRATION
OF WATER RESOURCES

TABULAR AND MAP DATA

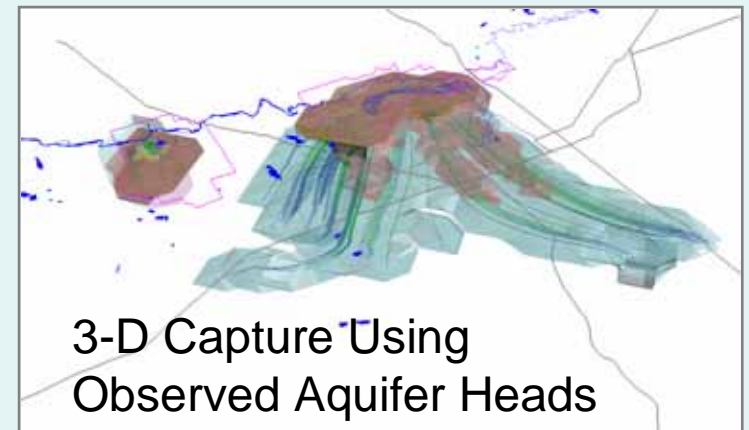
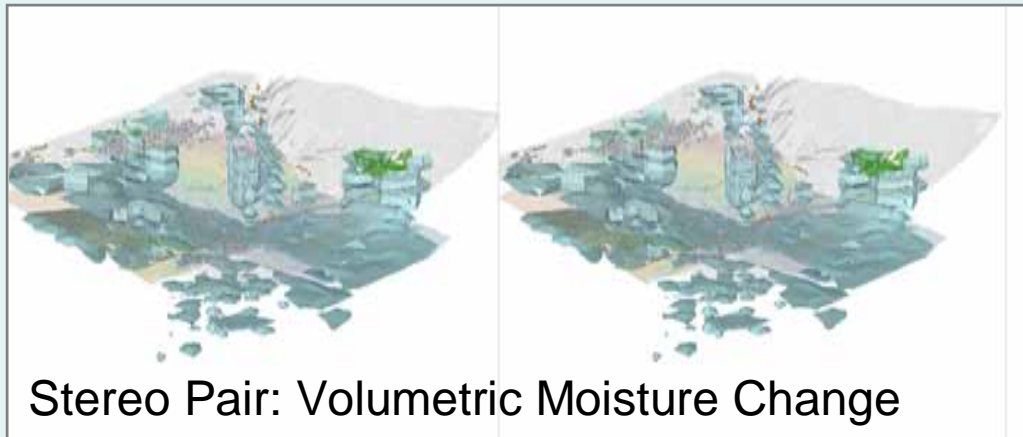
VOLUMETRIC DATA REPRESENTED

- HYDROGEOLOGIC UNITS
- BOUNDARY CONDITIONS
- GW FLOW FIELD COMPONENTS
- GW QUALITY DISTRIBUTION



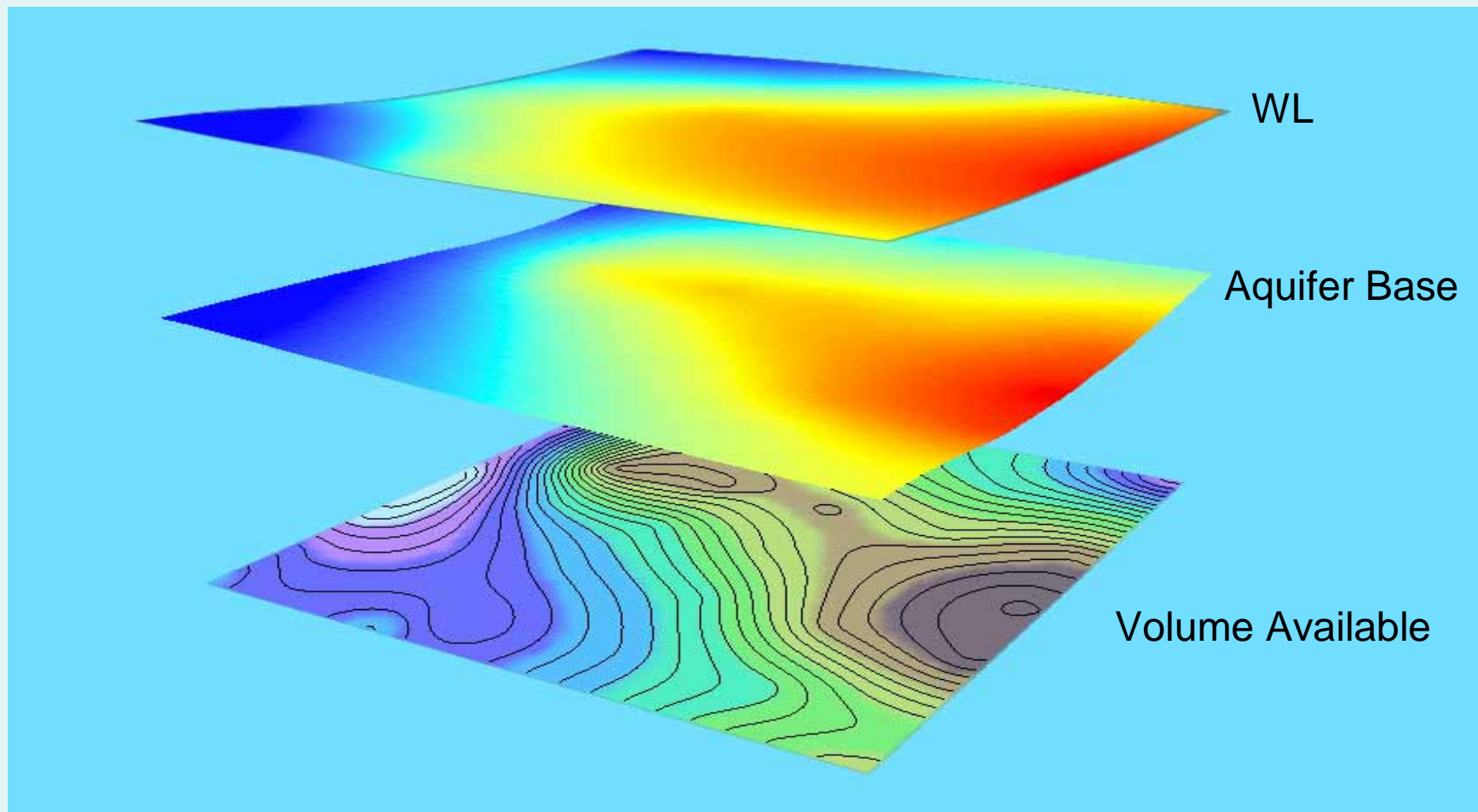
APPLICATIONS

- PROJECT DATABASE FRAMEWORK
- MODELING
- VISUALIZATION
- RESOURCE QUANTIFICATION
- SPATIAL ANALYSIS
- ANALYSIS USING OBSERVED DATA



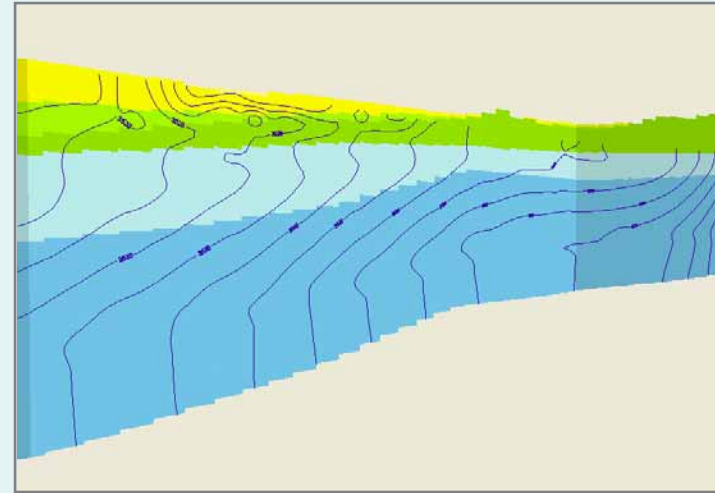
DATA OBJECT REQUIREMENTS

- GEOMETRY (2-D, 2.5-D, 3-D)
- DISCRETIZATION / ANISOTROPY
- SCALAR DATA / TIME SERIES
- TOPOLOGY (GRID AND MESH STRUCTURE)
- MODEL INPUT COMPATIBILITY
- SHAPE FILE, GEODATABASE OR CUSTOM OBJECT



- $\text{Resource} = ([\text{Water Level}] - [\text{Aquifer Base}]) * \text{Cell Area} * \text{Effective Porosity}$
- Zonal Statistics for Spatial Distribution

RASTER



Attributes of Grid

	Shape	ID	RC	Area	LANDS	IBND	STA	MODEL	B	SATTHK	DTW	MEDRIVEL	NDVIAREA	PM	UND	PZM1TOP	PZM1TH
	Polygon	241	26/66	10000	6097	1	6049	4722	1327.4902	47.509766			0.121573	1		6097	1375
	Polygon	241	26/67	10000	6103	1	6059	4728	1331.5297	43.470215			0.068199	1		6103	1375
	Polygon	241	26/68	10000	6049	1	6068	4674	1394.6699	-19.669922	6040.0000000		0.137387	1		5999	1325
	Polygon	241	26/69	10000	6051	1	6067	4676	1391.8901	-16.890137	6047.0000000		0.002965	1		6001	1325
	Polygon	242	26/70	10000	6065	1	6068	4690	1378.8198	-3.819824			0.103782	1		6015	1325
	Polygon	242	26/71	10000	6091	1	6068	4716	1352.3100	22.689941			0.017791	1		6041	1325
	Polygon	242	26/72	10000	6147	1	6066	4772	1294.4599	80.540039			0	1		6097	1325
	Polygon	242	26/73	10000	6171	1	6066	4796	1270.1298	104.870117			0	1		6171	1375
	Polygon	242	26/74	10000	6159	1	6064	4784	1280.6601	94.339844			0.000988	1		6159	1375
	Polygon	242	26/75	10000	6188	1	6056	4813	1243.0600	131.939941			0.005930	1		6188	1375

<

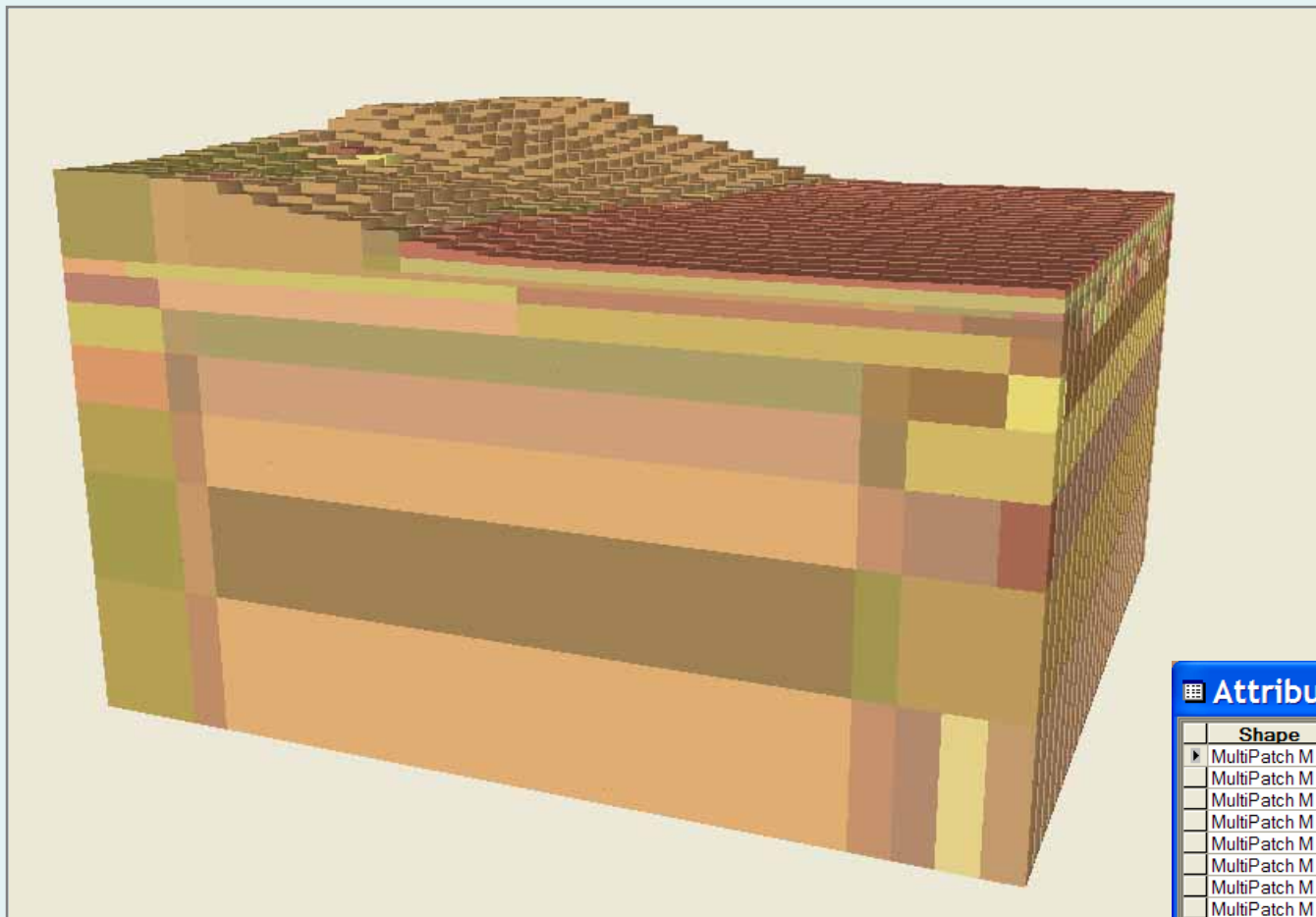
11

>

Record: 2423 Show: All Selected Records (0 out of 8084 Selected.) Options

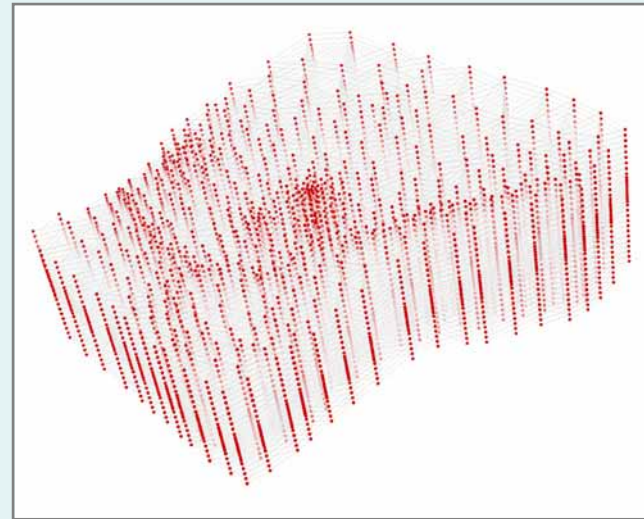
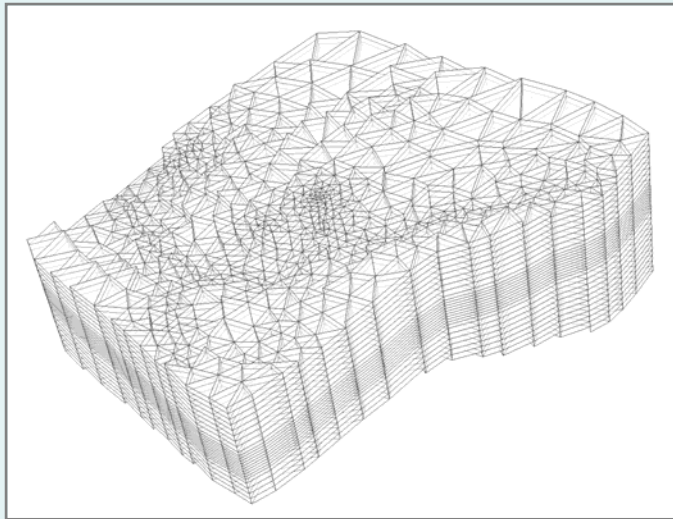
- ANALYSIS PERFORMED USING MAP CALCULATOR OR SPREADSHEET
- GRID EXTRUDED FOR 3-D VISUALIZATION
- PARAMETERS GENERATED BY ZONAL STATISTICS OR INTERSECTION

POLYGON GRID



Attributes of 3D_USGSV2sub				
Shape	LRC	VID	k	XSEC
MultiPatch M	1 134 - 67	1	1	
MultiPatch M	2 134 - 67	2	40	
MultiPatch M	3 134 - 67	3	40	
MultiPatch M	4 134 - 67	4	9.99	
MultiPatch M	5 134 - 67	5	96.26	
MultiPatch M	6 134 - 67	6	48.63	
MultiPatch M	7 134 - 67	7	6.66	
MultiPatch M	8 134 - 67	8	7.5	
MultiPatch M	9 134 - 67	9	7.99	
MultiPatch M	10 134 - 67	10	6.25	
MultiPatch M	11 134 - 67	11	5.28	
MultiPatch M	1 134 - 68	12	1	
MultiPatch M	2 134 - 68	13	40	
MultiPatch M	3 134 - 68	14	40	
MultiPatch M	4 134 - 68	15	10	
MultiPatch M	5 134 - 68	16	96.26	

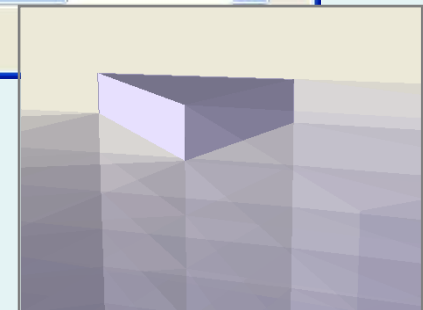
3-D GRID



Attributes of arro

FID	Shape	EL	NODE1	NODE2	NODE3	NODE4	NODE5	NODE6	MAT	X	Y	Z	LAY	TOP	MAT D	RECHARGE
137	MultiPatch M	137	907	1129	1133	713	902	906	8	1560	1471	5331.	9		Coarse	
137	MultiPatch M	137	907	1133	1135	713	906	908	8	1559	1471	5331.	9		Coarse	
137	MultiPatch M	137	921	907	1135	722	713	908	8	1559	1471	5319	9		Coarse	
137	MultiPatch M	137	908	1136	1137	714	909	910	7	1558	1472	5362.	7		Coarse	
137	MultiPatch M	137	1136	908	1131	909	714	903	7	1559	1472	5367.	7		Coarse	
137	MultiPatch M	138	908	1137	915	714	910	717	7	1558	1471	5354.	7		Coarse	
138	MultiPatch M	138	1138	909	1139	911	715	912	6	1558	1472	5399.	6 top		Coarse	arroyo
138	MultiPatch M	138	909	1138	910	715	911	716	6	1558	1472	5394.	6 top		Coarse	arroyo

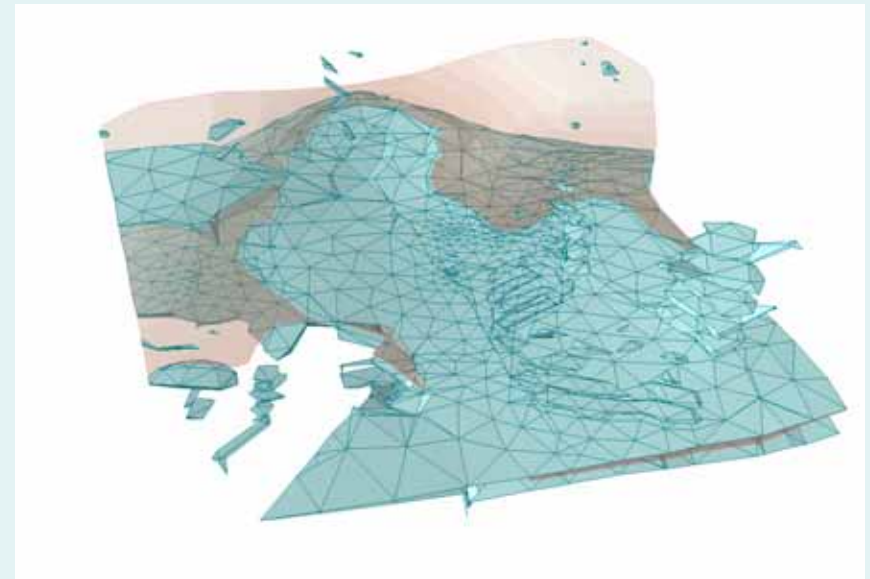
Record: 11 Show: All Selected Records (0 out of 23746 Selected.) Options



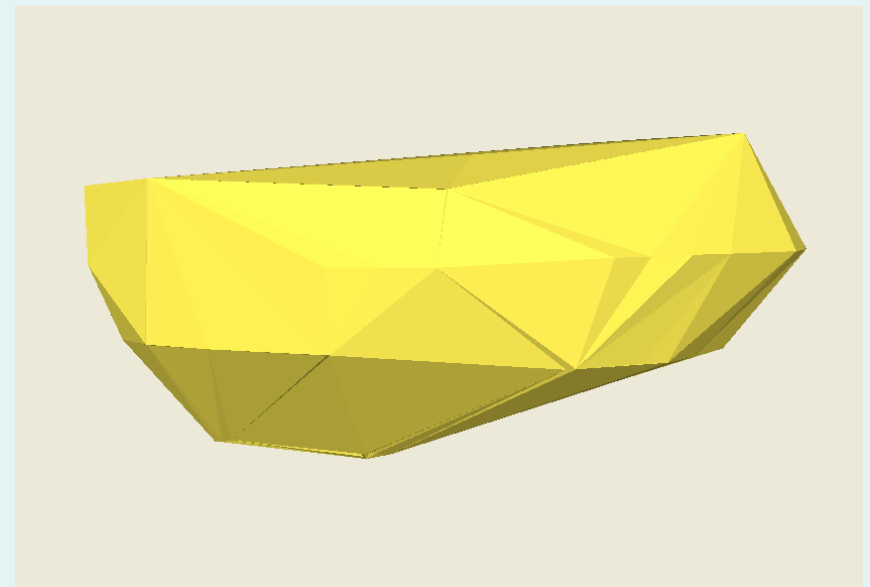
MESH

Attributes of isoeo2001									
FID	Shape*	Material	MAT DES	ELEME	Layer	Value	elev	VOLUME	
0	MultiPatch M	4	Coarse	1	0	-1.1916	5400.94	27.407611	
1	MultiPatch M	4	Coarse	1	0	-1.1916	5400.94	27.407611	
2	MultiPatch M	4	Coarse	1	0	-1.1916	0	27.407611	
3	MultiPatch M	4	Coarse	2	0	-15.915	5370.20	366.049860	
4	MultiPatch M	4	Coarse	2	0	-15.915	5370.36	366.049860	
5	MultiPatch M	4	Coarse	2	0	-15.915	5370.20	366.049860	
6	MultiPatch M	4	Coarse	4	0	-25.606	5370.20	588.954252	
7	MultiPatch M	4	Coarse	4	0	-25.606	5370.19	588.954252	
8	MultiPatch M	4	Coarse	4	0	-25.606	5370.19	588.954252	
9	MultiPatch M	4	Coarse	5	0	-24.291	0	558.693478	
10	MultiPatch M	4	Coarse	5	0	-24.291	0	558.693478	
11	MultiPatch M	4	Coarse	5	0	-24.291	5370.20	558.693478	

Record: 7 Show: All Selected Records (0 out of 30019 Selected)



- VOLUME WITHIN ISOSURFACE IMPLEMENTED USING TETRAHEDRON SAMPLING (VB AND ARCOBJECTS).
- CAPTURE VOLUME PRODUCED FROM SURFACE TRIANGULATION OF REVERSE PARTICLE TRACK (Barber, C.B., Dobkin, D.P., and Huhdanpaa, H.T., "The Quickhull Algorithm for Convex Hulls," ACM Trans. on Mathematical Software, Dec 1996) .

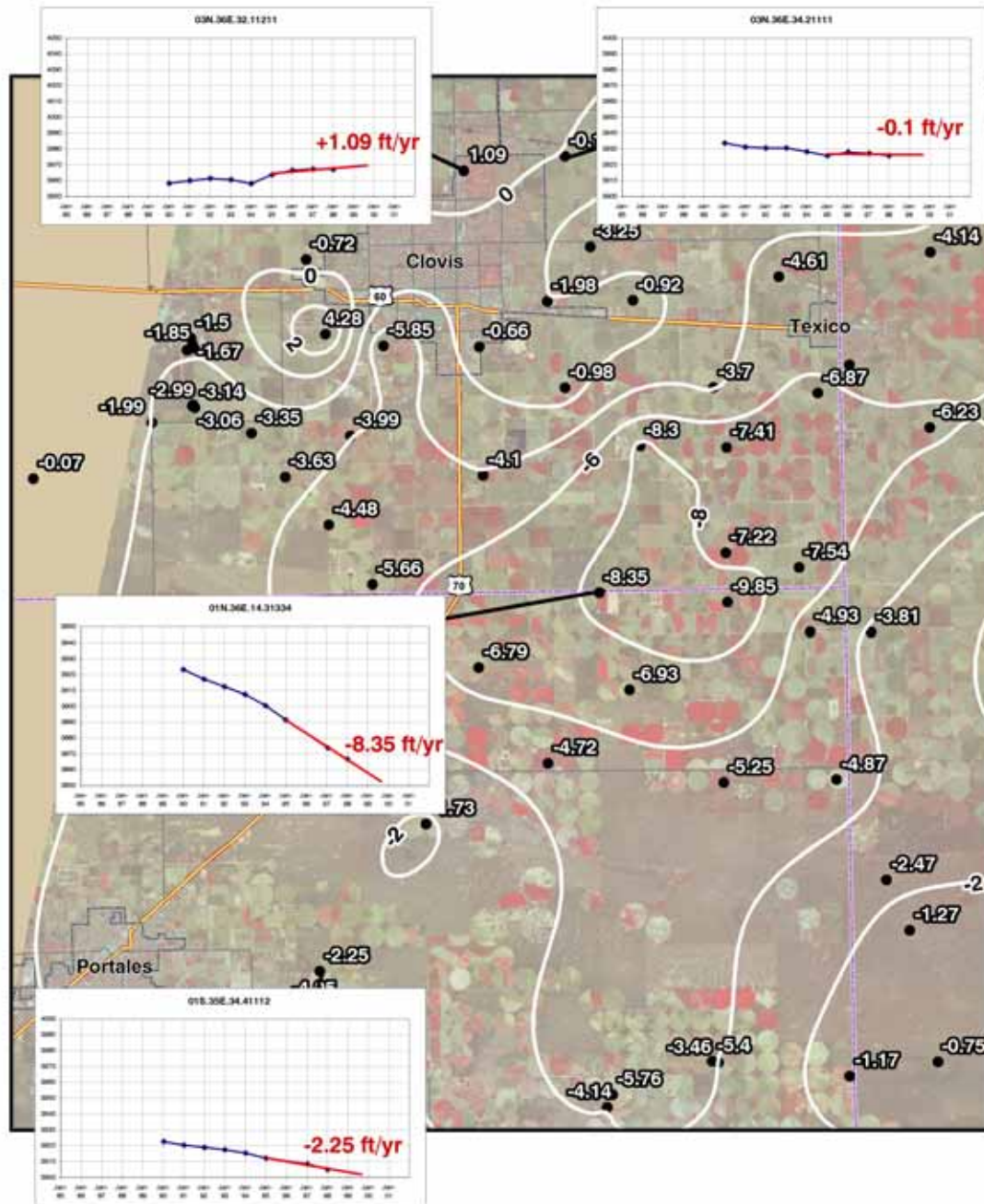


ISOSURFACE AND CAPTURE VOLUME

EXAMPLE APPLICATIONS

- RESOURCE AVAILABILITY ANALYSIS USING RASTER ANALYSIS.
- DATA ORGANIZATION AND MODEL INPUT GENERATION FOR A MODFLOW MODEL.
- DATA ORGANIZATION AND PRESENTATION OF RESULTS FOR A VARIABLY SATURATED 3-D FLOW MODEL.

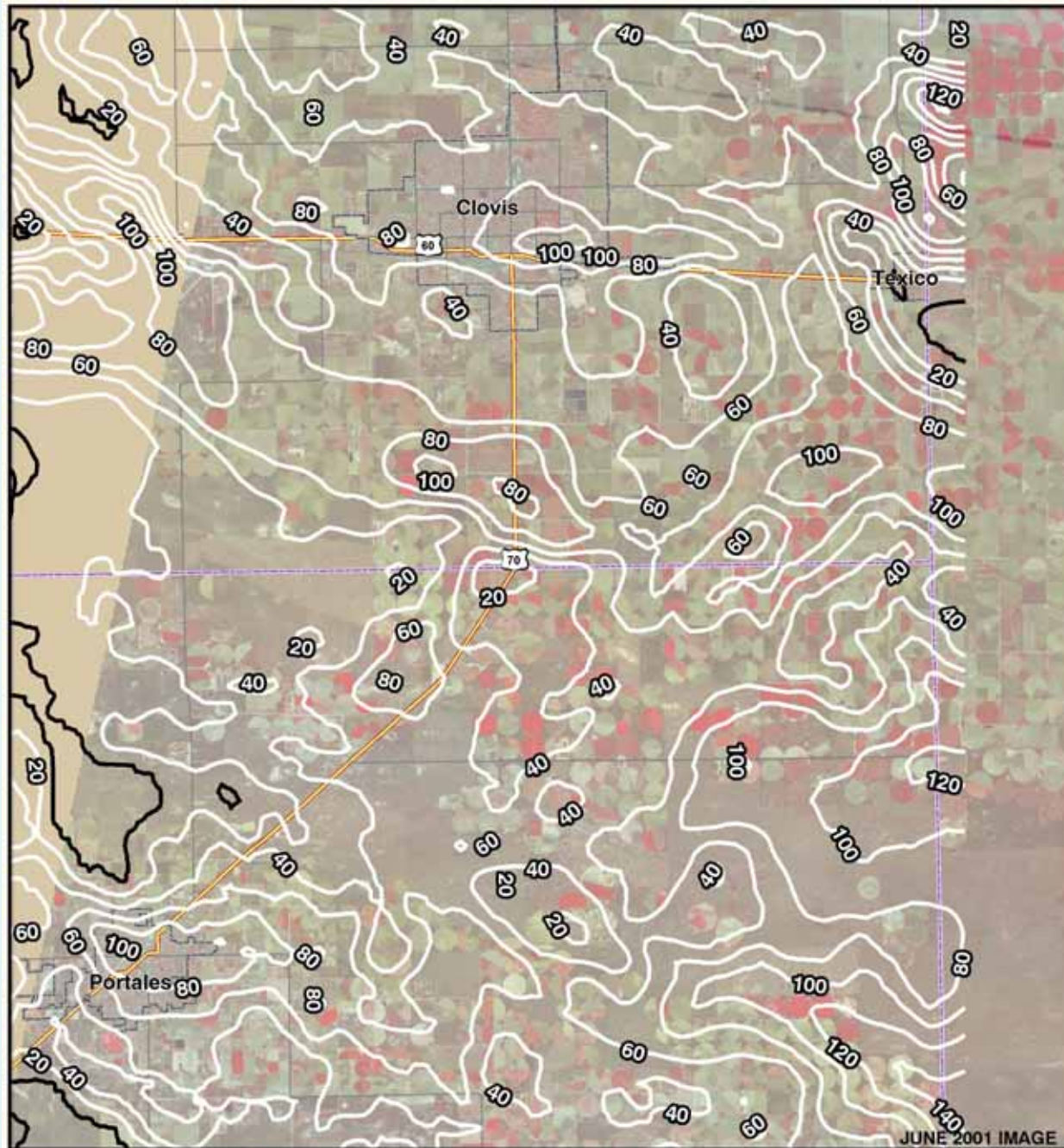
SELECTED WELL HYDROGRAPHS



EXPLANATION

- CONTOURS OF OBSERVED 1994-2000 DECLINE RATES (ft/yr) -- Based on November 1994 - 2001 trendline. (Contour interval = 2 ft/yr)
- Observed 1994-2000 decline rates (ft/yr). Red = trendline.

YEAR 2001 SATURATED THICKNESS



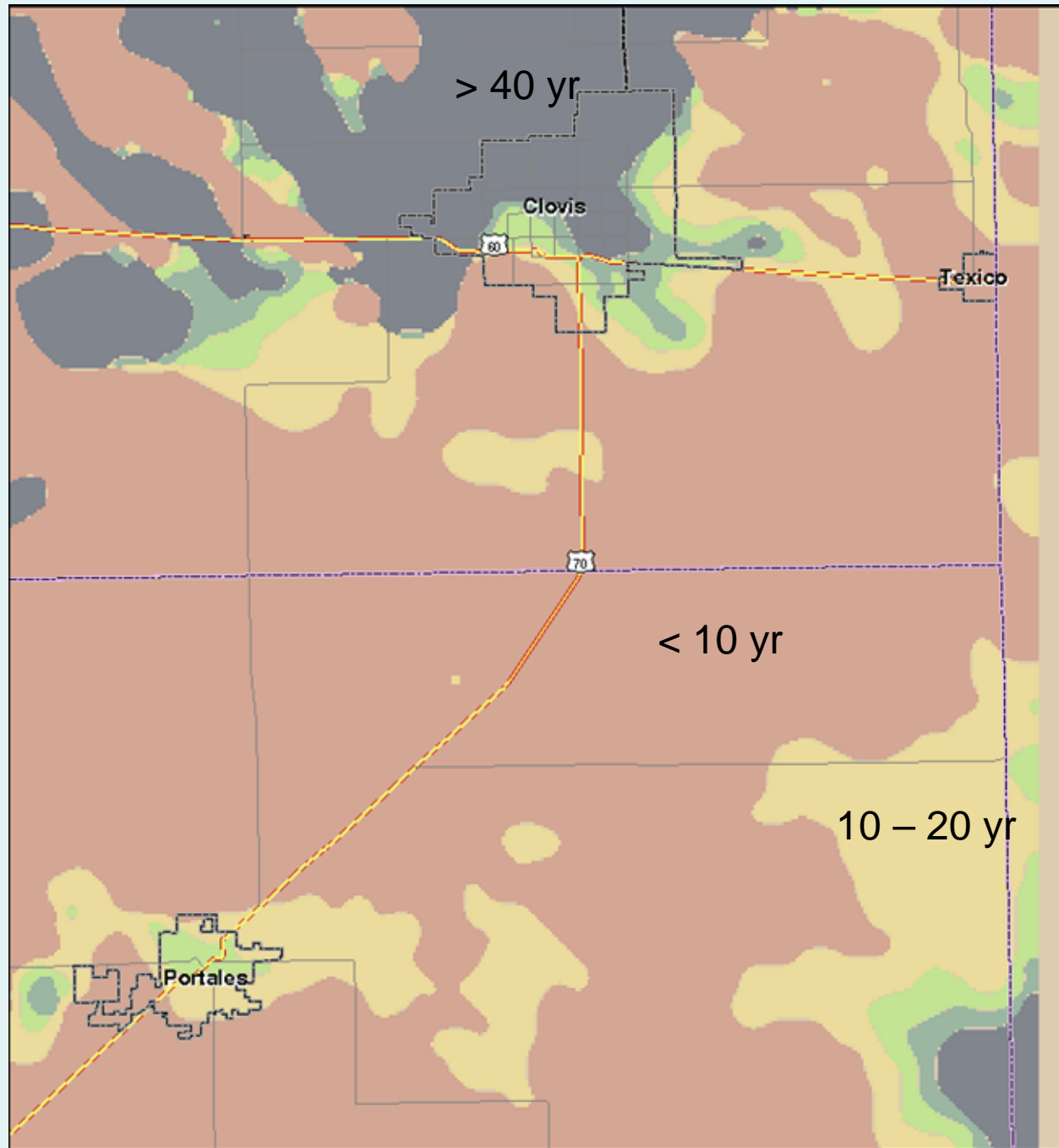
EXPLANATION

PROJECTED WINTER 2001 SATURATED THICKNESS ABOVE 35-FOOT PRACTICAL PUMPING LIMIT -- Based on Winter 1997 water level data and observed 1994-2000 decline rates and Red Bed elevations adapted from NMOSE contours. (Contour interval = 20 feet, NGVD29)



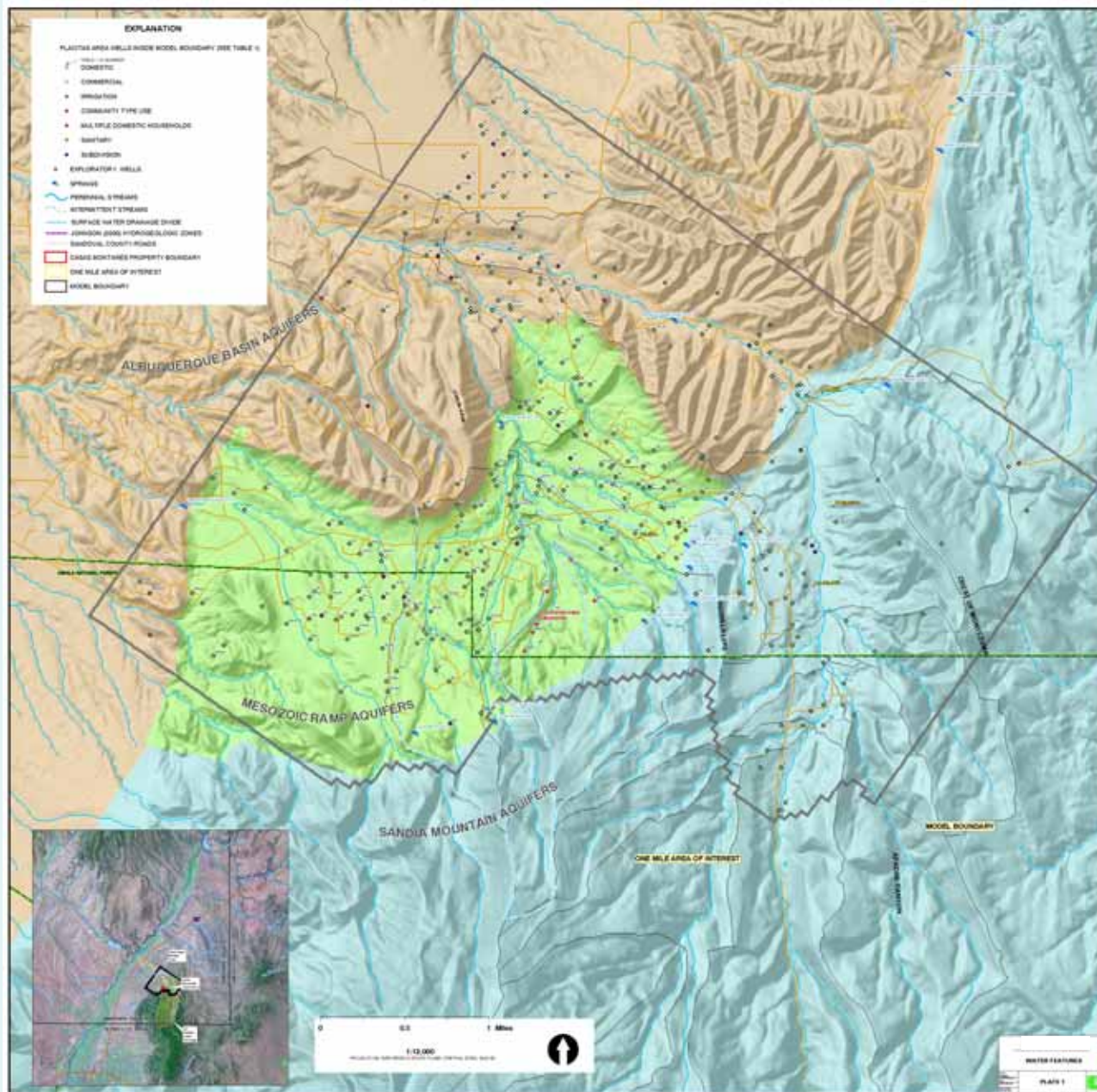
PROJECTED WINTER 2001 LINE OF ZERO SATURATED THICKNESS

REMAINING AQUIFER LIFE

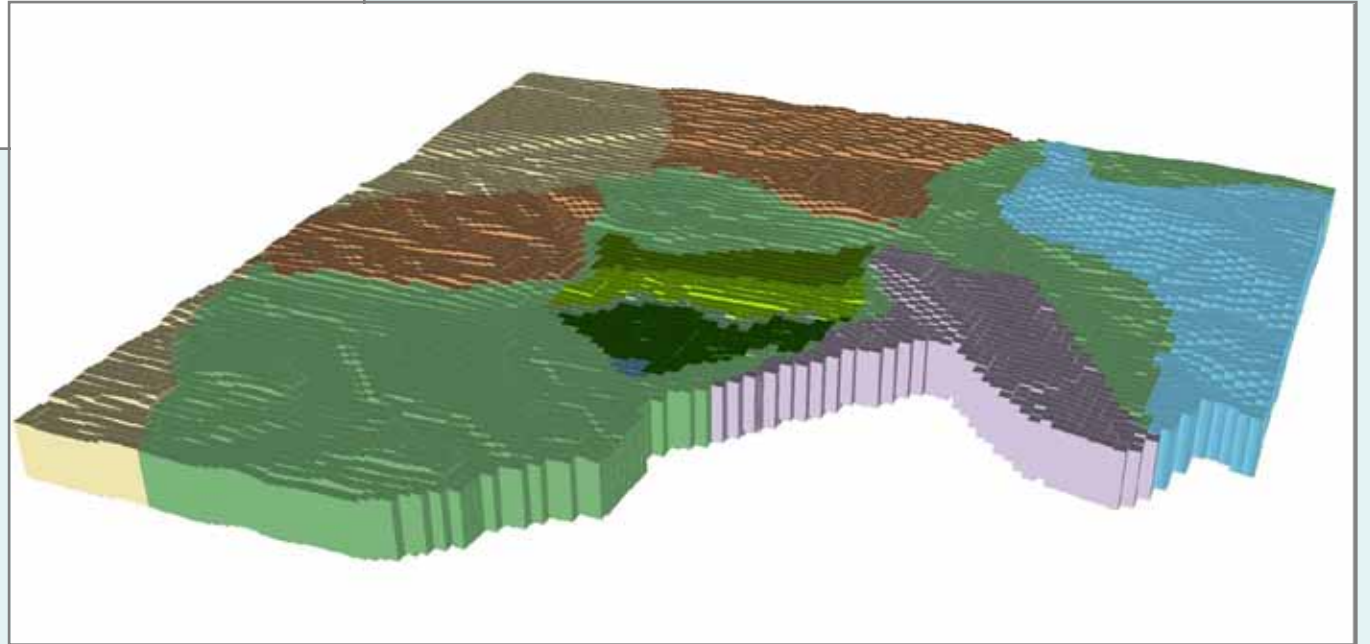
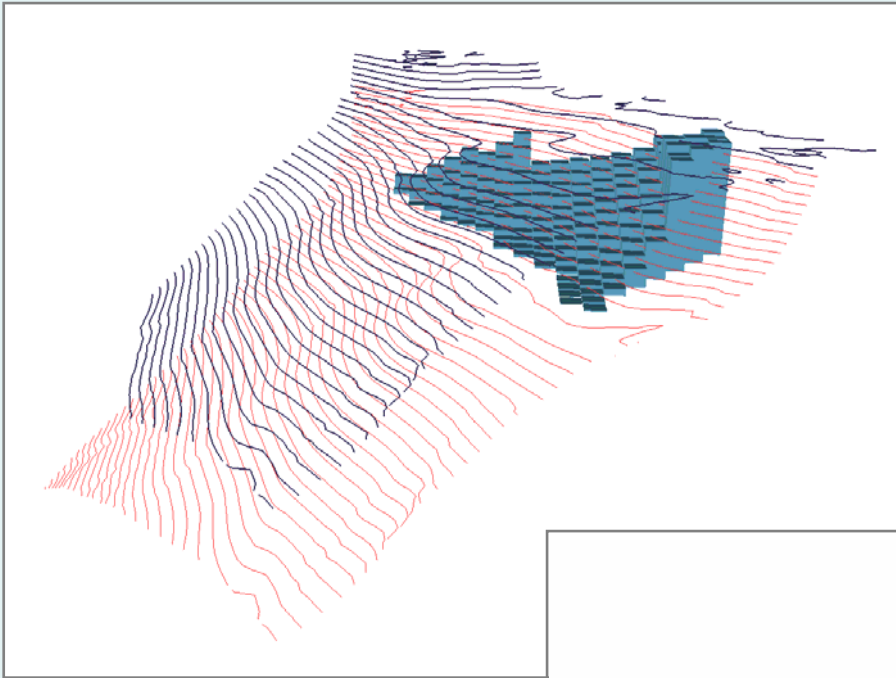


PROJECTED AQUIFER LIFE (ABOVE 35 FOOT PPL)

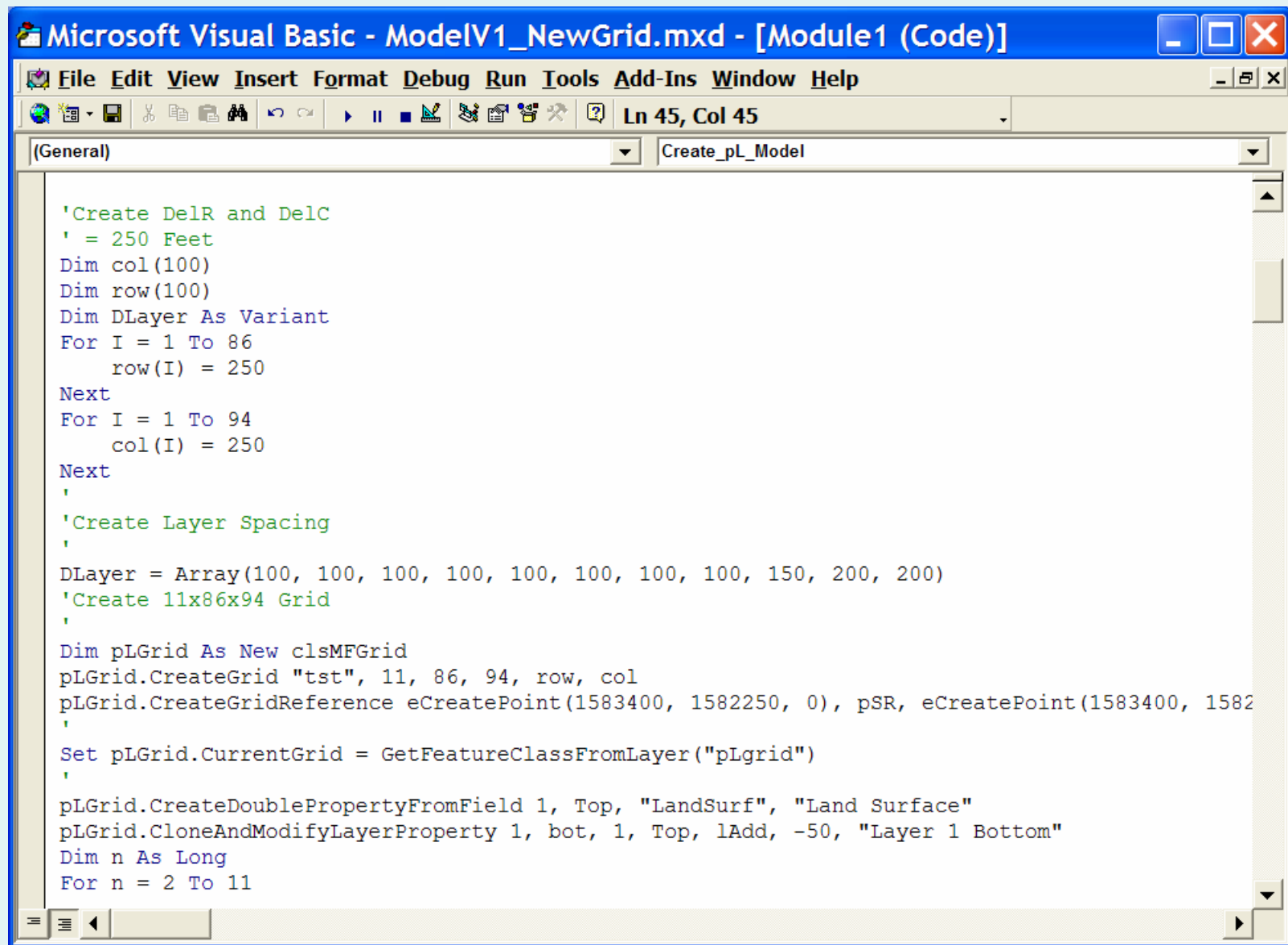
- LESS THAN 10 YEARS
- 10 TO 20 YEARS
- 20 TO 30 YEARS
- 30 TO 40 YEARS
- >40 YEARS AND AREAS OF RISING WATER LEVELS



REGIONAL DATA



HYDROGEOLOGIC SOLIDS MODEL

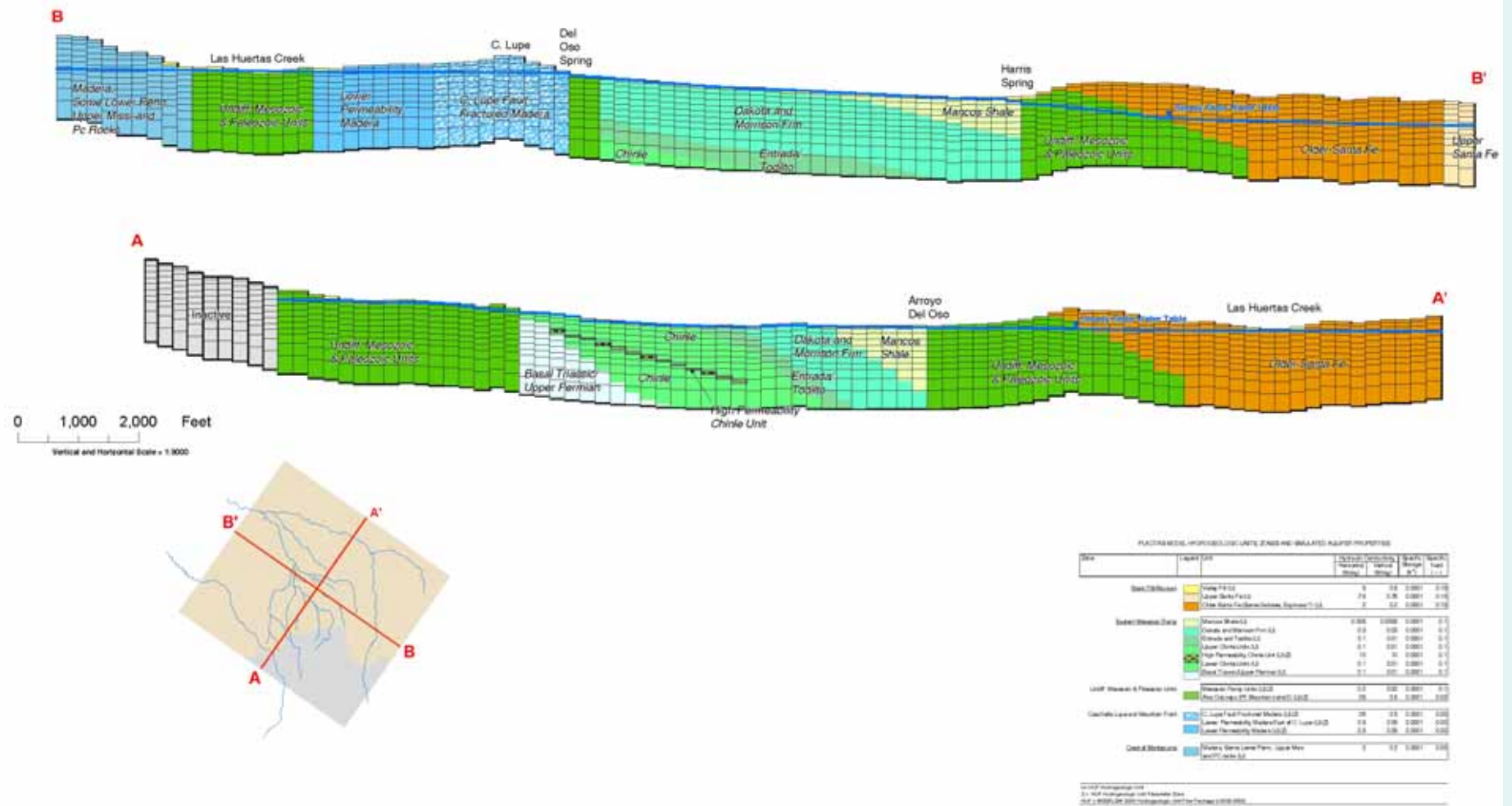


The image shows a screenshot of the Microsoft Visual Basic code editor window. The title bar reads "Microsoft Visual Basic - ModelV1_NewGrid.mxd - [Module1 (Code)]". The menu bar includes File, Edit, View, Insert, Format, Debug, Run, Tools, Add-Ins, Window, and Help. The toolbar contains various icons for file operations and development. The status bar at the bottom indicates "Ln 45, Col 45". The code editor displays the following VBA code:

```
(General) Create_pL_Model

'Create DelR and DelC
' = 250 Feet
Dim col(100)
Dim row(100)
Dim DLayer As Variant
For I = 1 To 86
    row(I) = 250
Next
For I = 1 To 94
    col(I) = 250
Next
'
'Create Layer Spacing
'
DLayer = Array(100, 100, 100, 100, 100, 100, 100, 100, 150, 200, 200)
'Create 11x86x94 Grid
'
Dim pLGrid As New clsMFGrid
pLGrid.CreateGrid "tst", 11, 86, 94, row, col
pLGrid.CreateGridReference eCreatePoint(1583400, 1582250, 0), pSR, eCreatePoint(1583400, 1582
'
Set pLGrid.CurrentGrid = GetFeatureClassFromLayer("pLgrid")
'
pLGrid.CreateDoublePropertyFromField 1, Top, "LandSurf", "Land Surface"
pLGrid.CloneAndModifyLayerProperty 1, bot, 1, Top, lAdd, -50, "Layer 1 Bottom"
Dim n As Long
For n = 2 To 11
```

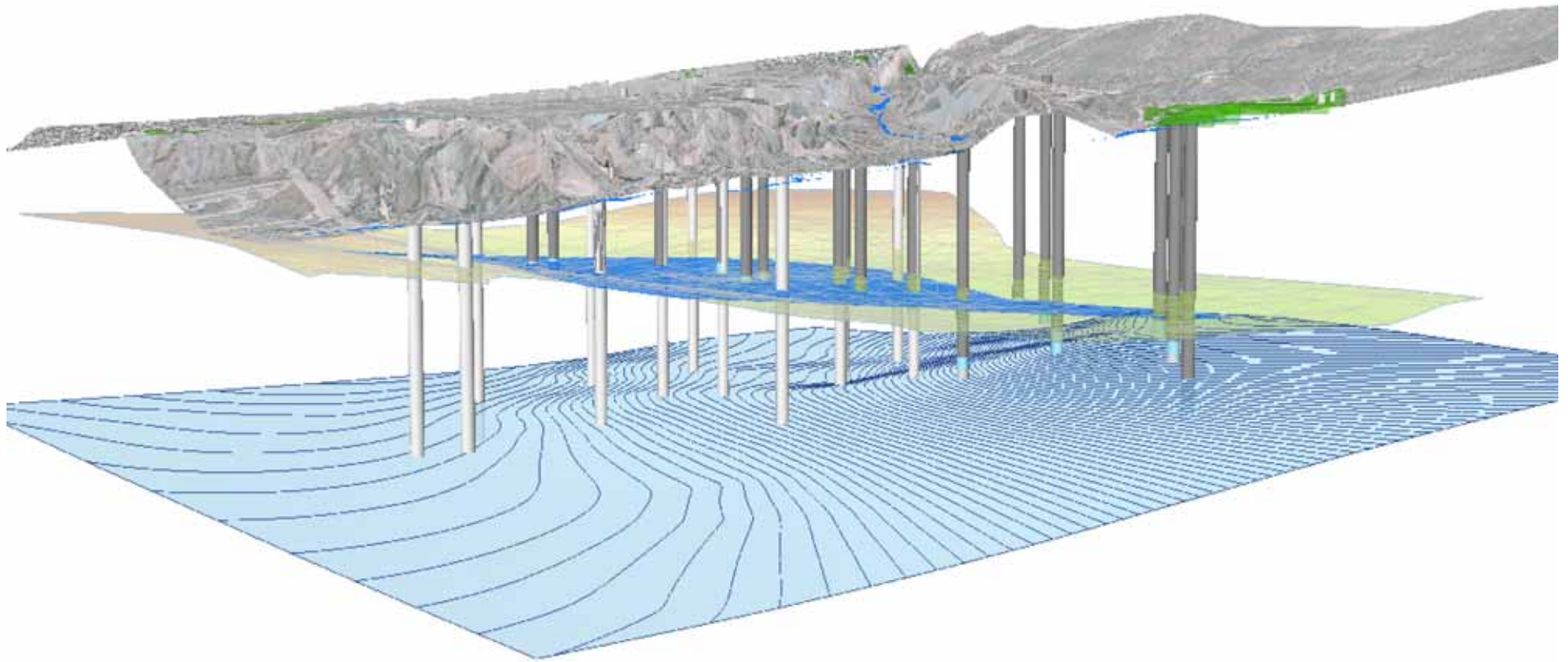
MODFLOW INPUT GENERATION



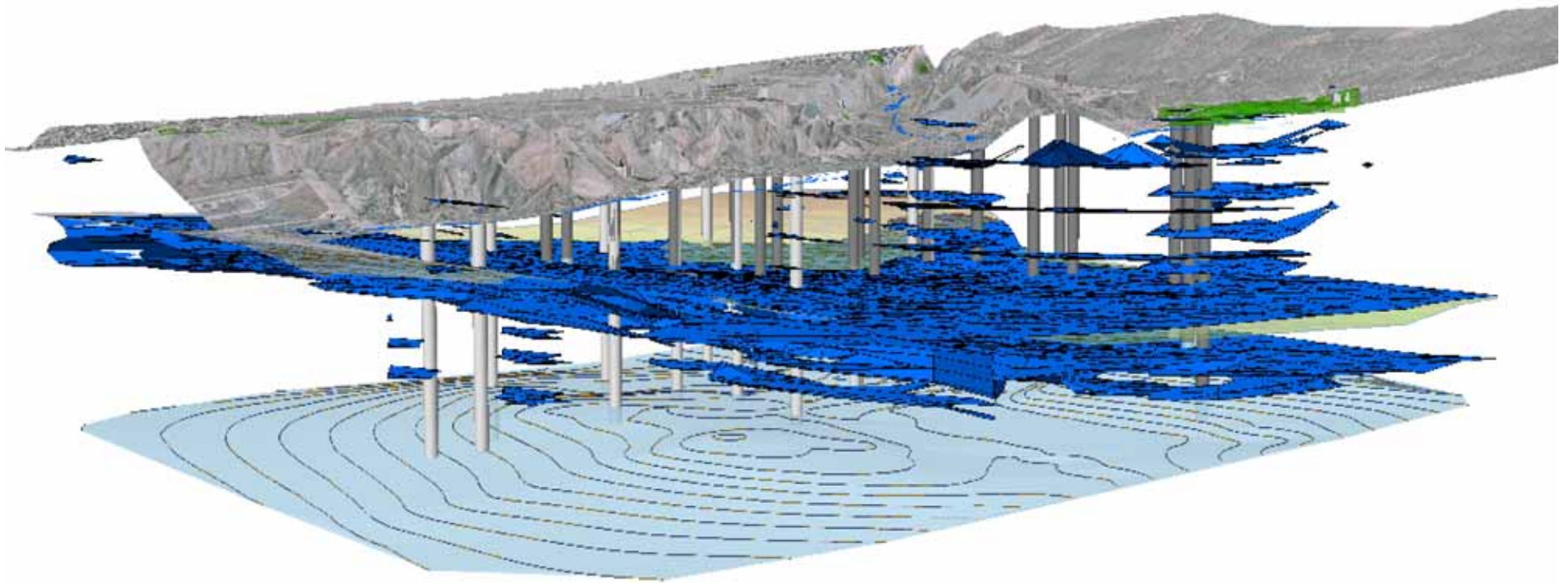
CROSS SECTIONS



STEADY STATE RESULTS



FIELD



MODEL

CONCLUSIONS AND RECOMMENDATIONS

- **VOLUMETRIC DATA SPATIAL DATA OBJECTS APPLIED TO WATER RESOURCE INVESTIGATIONS ALLOW NOVEL APPLICATIONS AND FLEXIBILITY IN VISUALIZATION, MAPPING AND ANALYSIS.**

CONCLUSIONS AND RECOMMENDATIONS (CONT.)

- **IN MANY CASES CUSTOM OBJECTS AND DATA MODEL ARE AN IMPROVEMENT OVER AD-HOC OBJECTS. THEY PROVIDE AN ANALYSIS STRUCTURE WHILE MAINTAINING THE FLEXIBILITY OF THE GIS SYSTEM.**

CONCLUSIONS AND RECOMMENDATIONS (CONT.)

- ARCOBJECT SUPPORT FOR INTERSECTION, UNION, DISSOLVE, BUFFER AND QUERY OPERATIONS ON MULTIPATCH, SURFACE PATCH 3-D VECTOR AND RAY DATA TYPES.