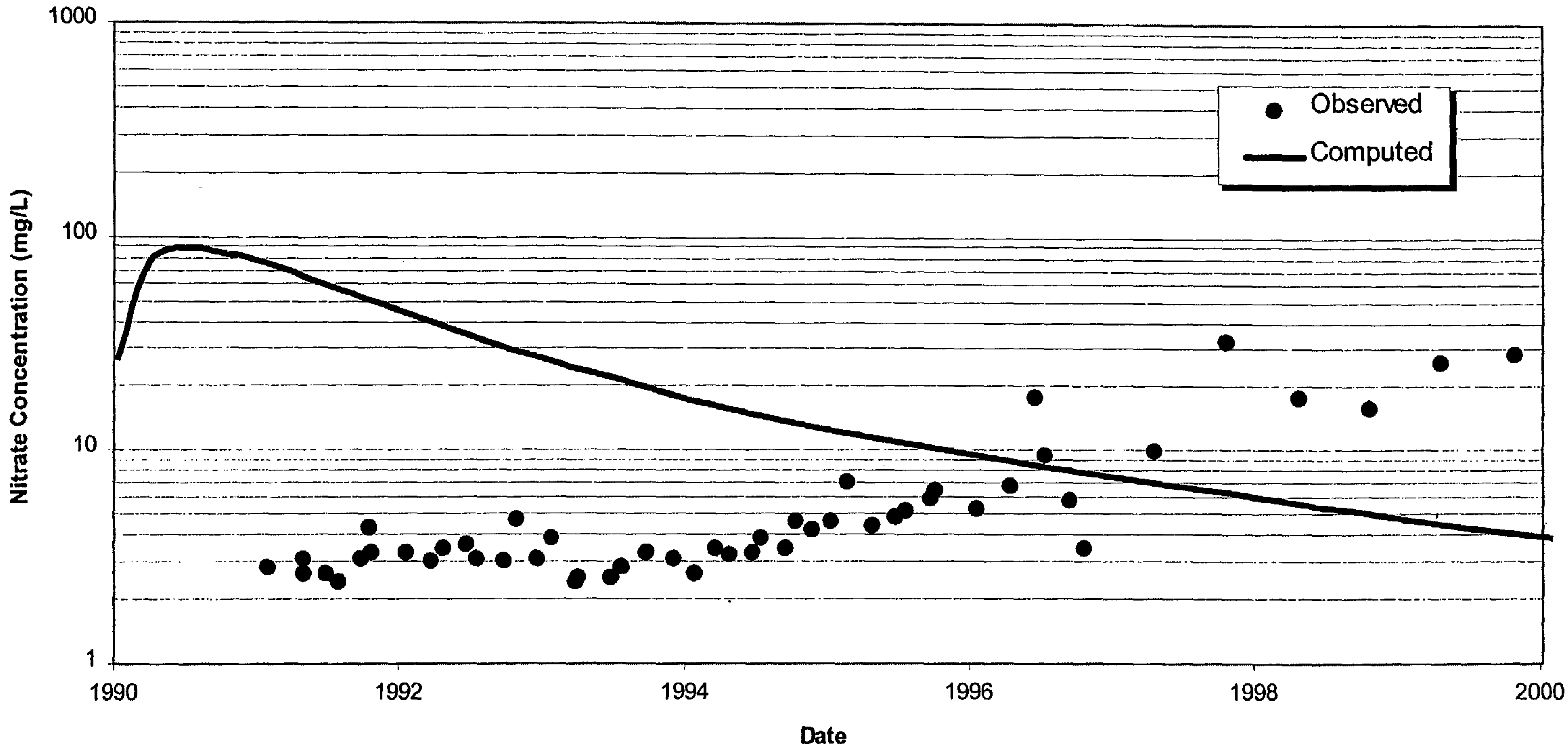


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2301B

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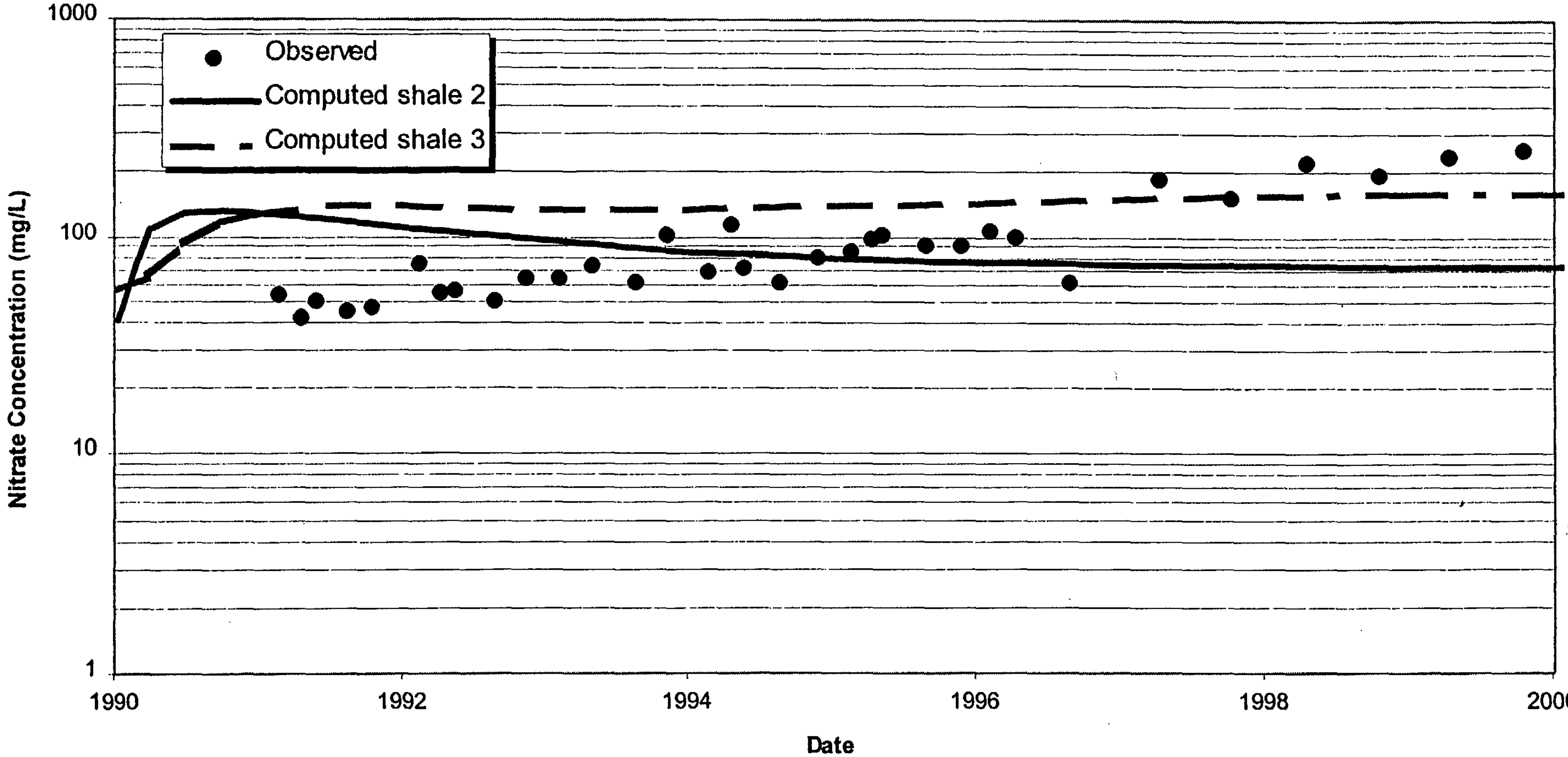


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2303A

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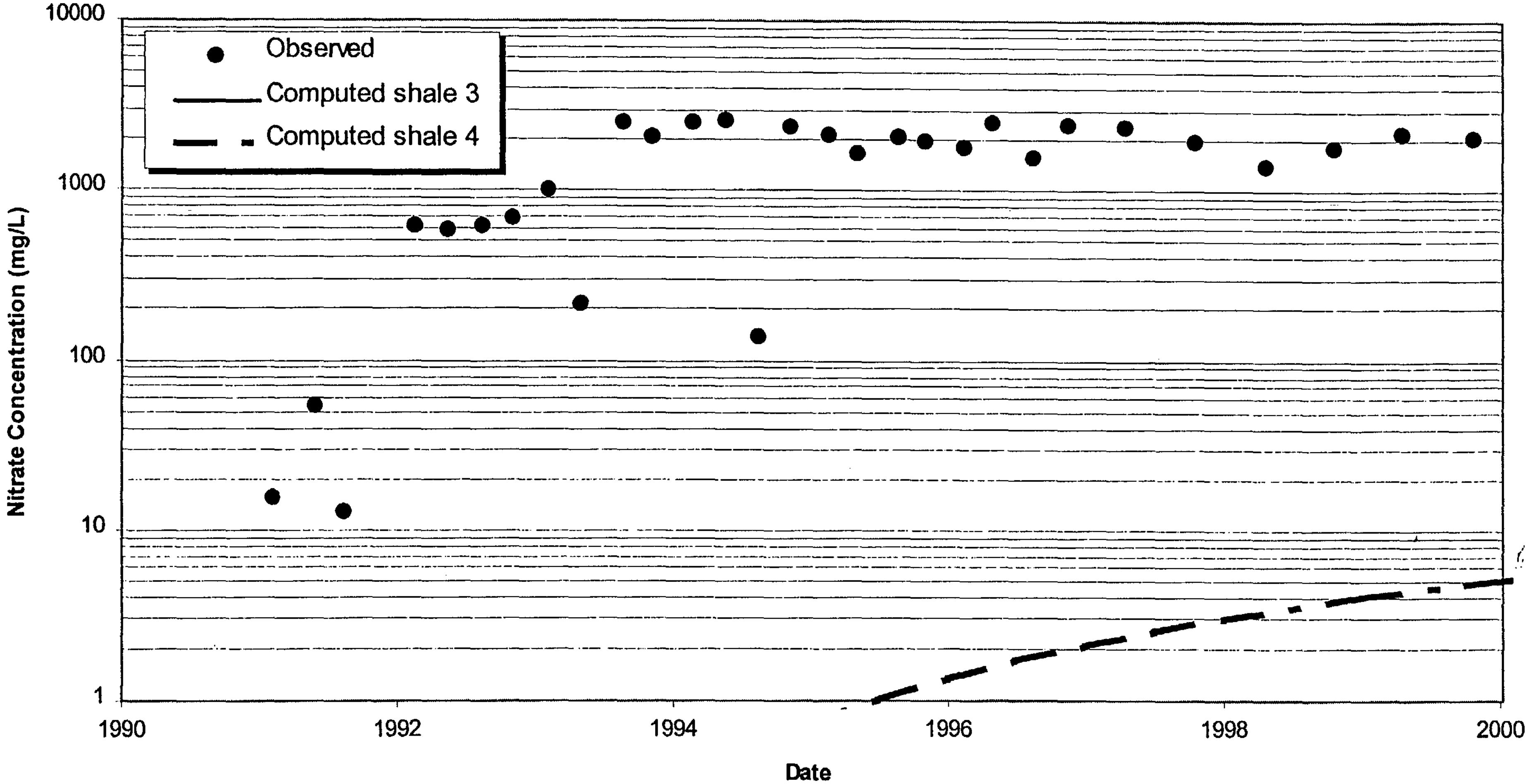


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|---|---|---|
| consulting scientists and engineers | FIGURE<br>NITRATE TRANSPORT CALIBRATION FOR WELL 2322A | Date: AUGUST 2002<br>Project: P:\100734-2\REV CHAR RPT<br>File: NITRATE FIGURES.ppt |

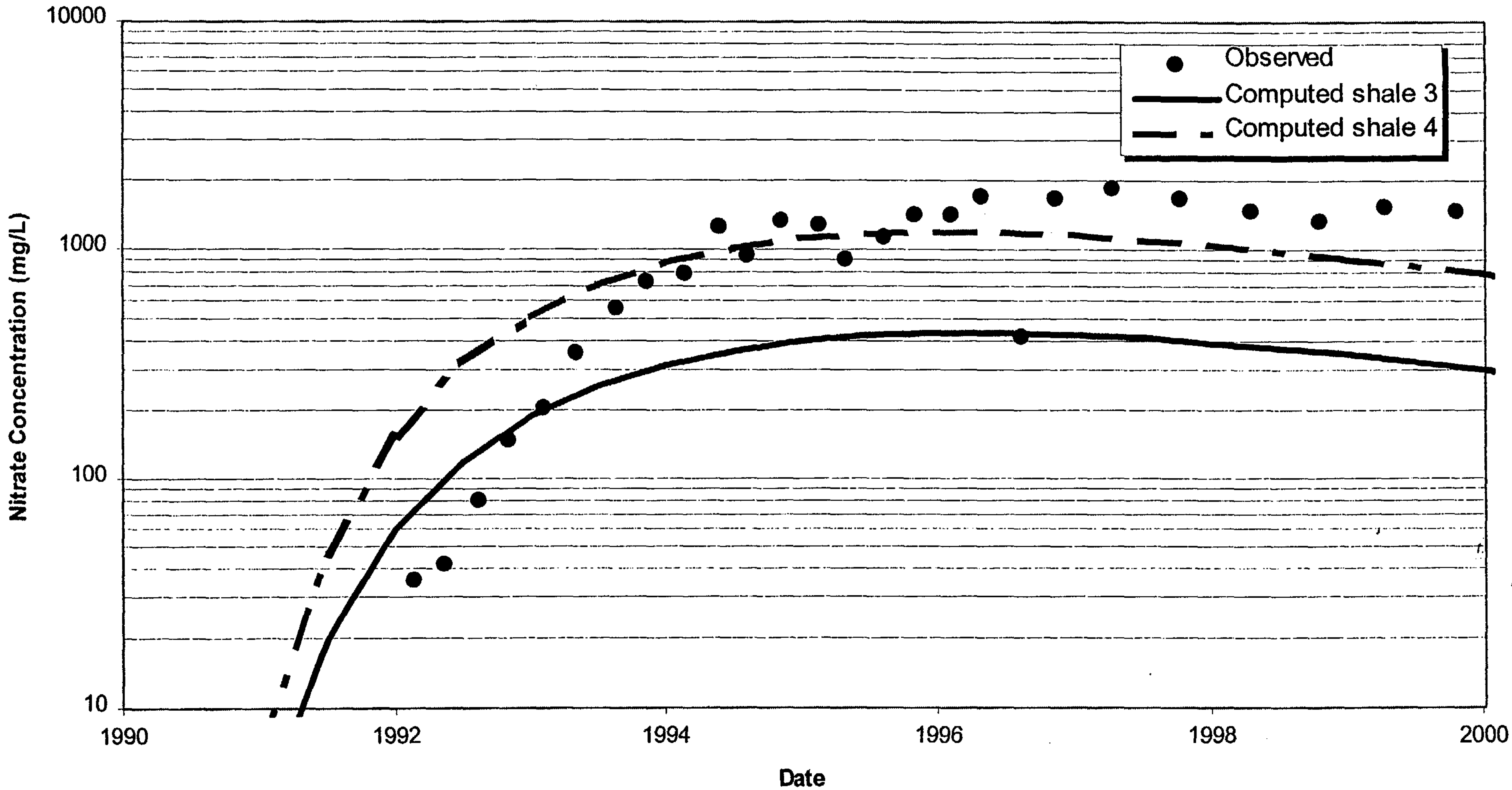


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2341

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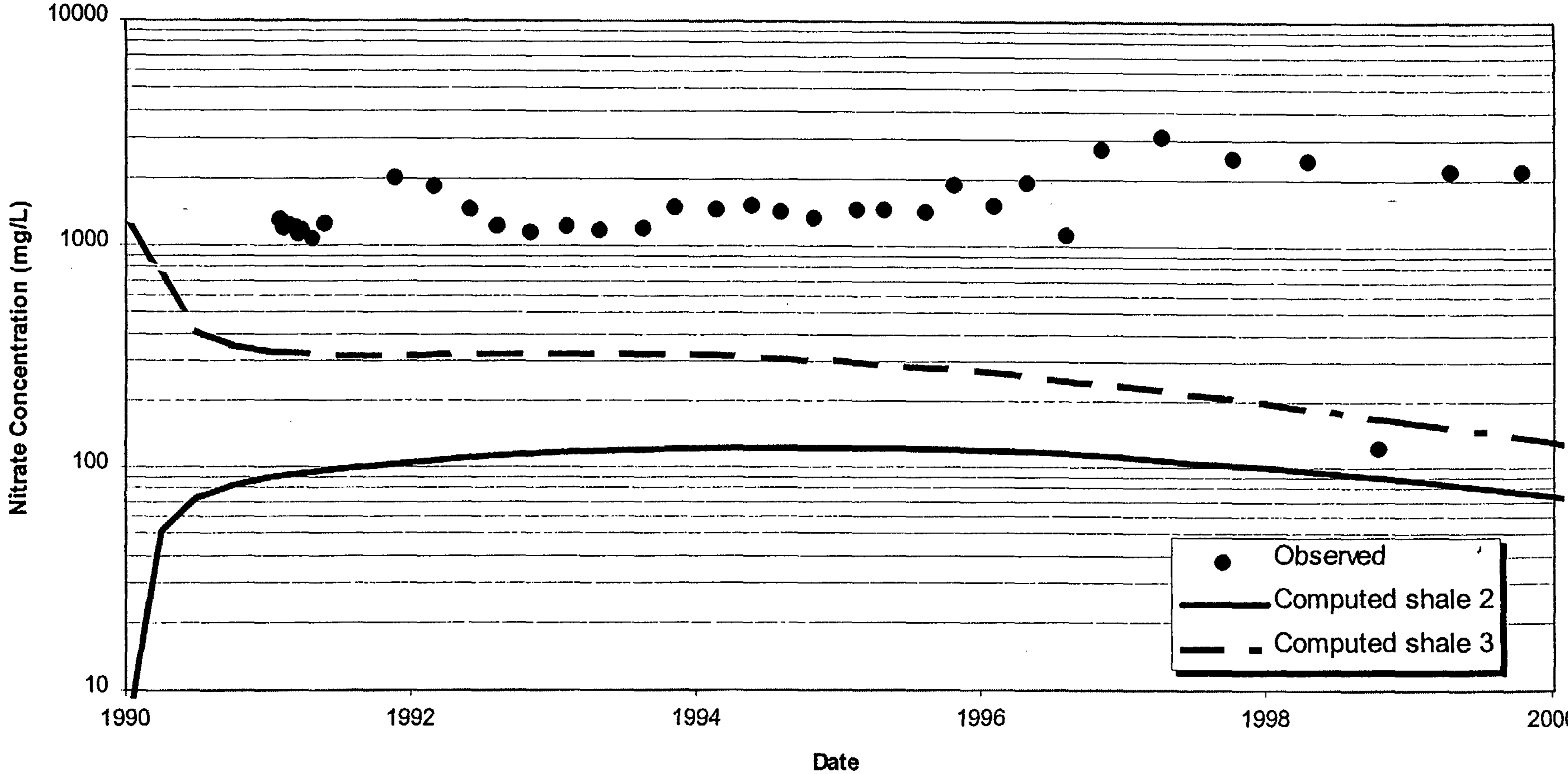


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2343

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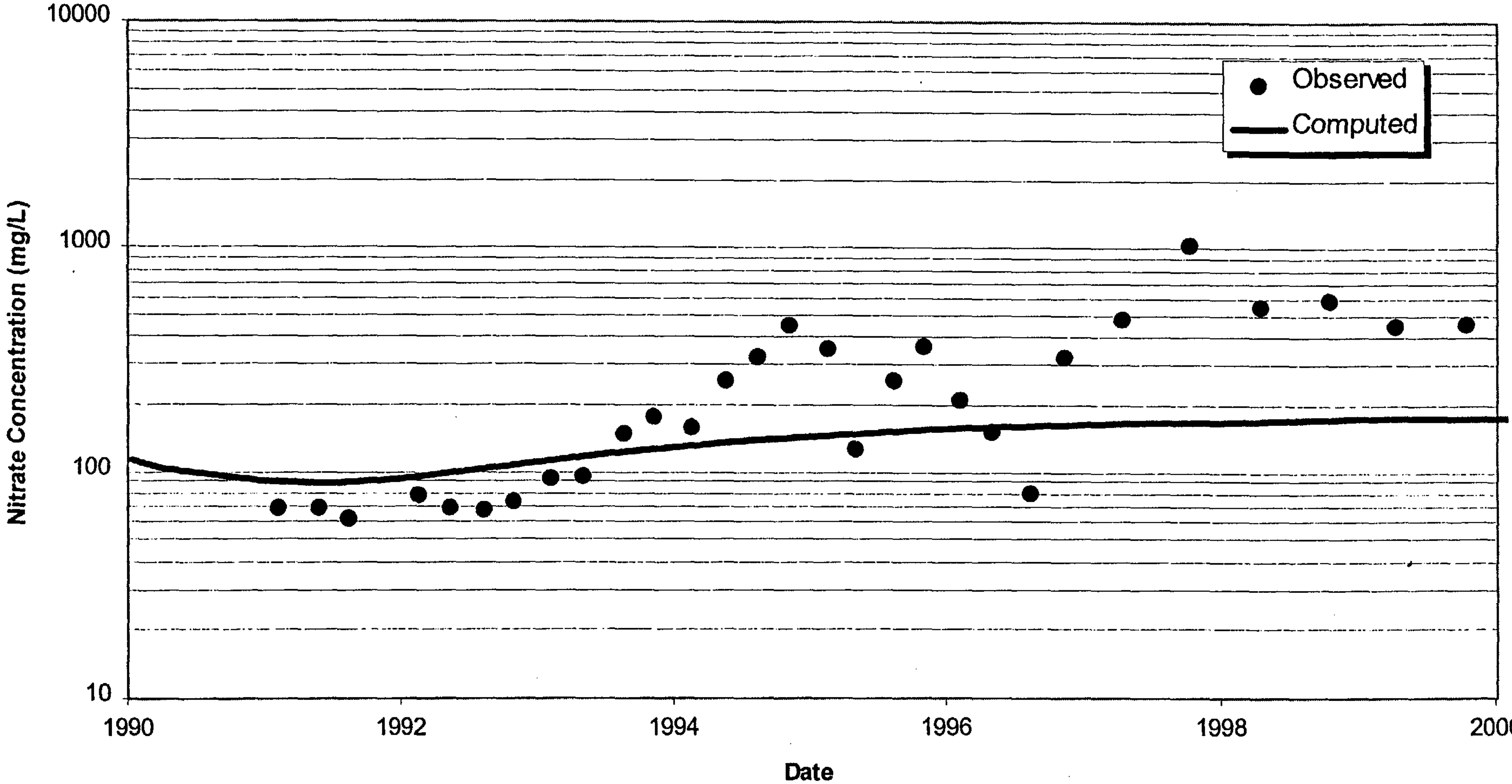


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2346

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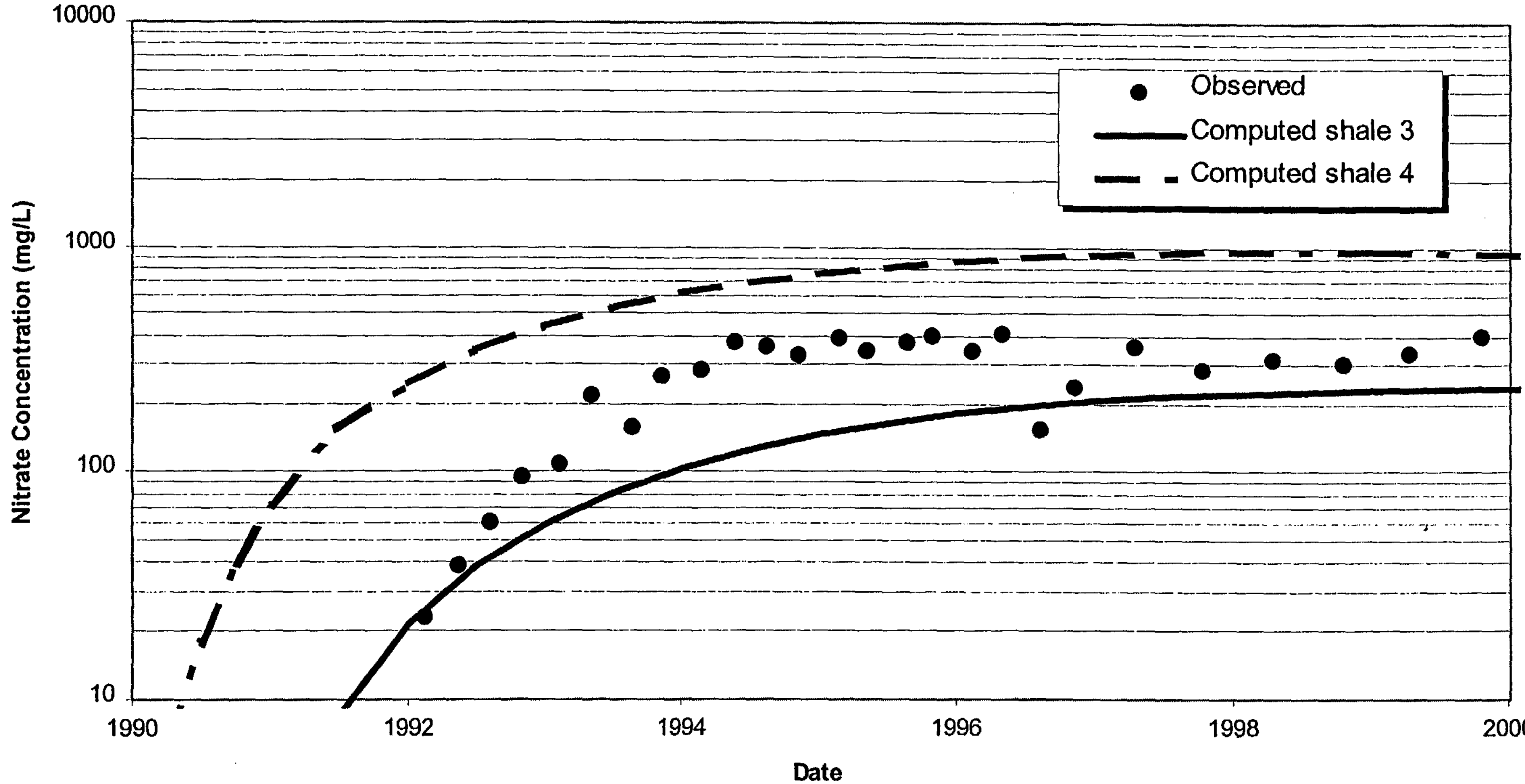


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2349

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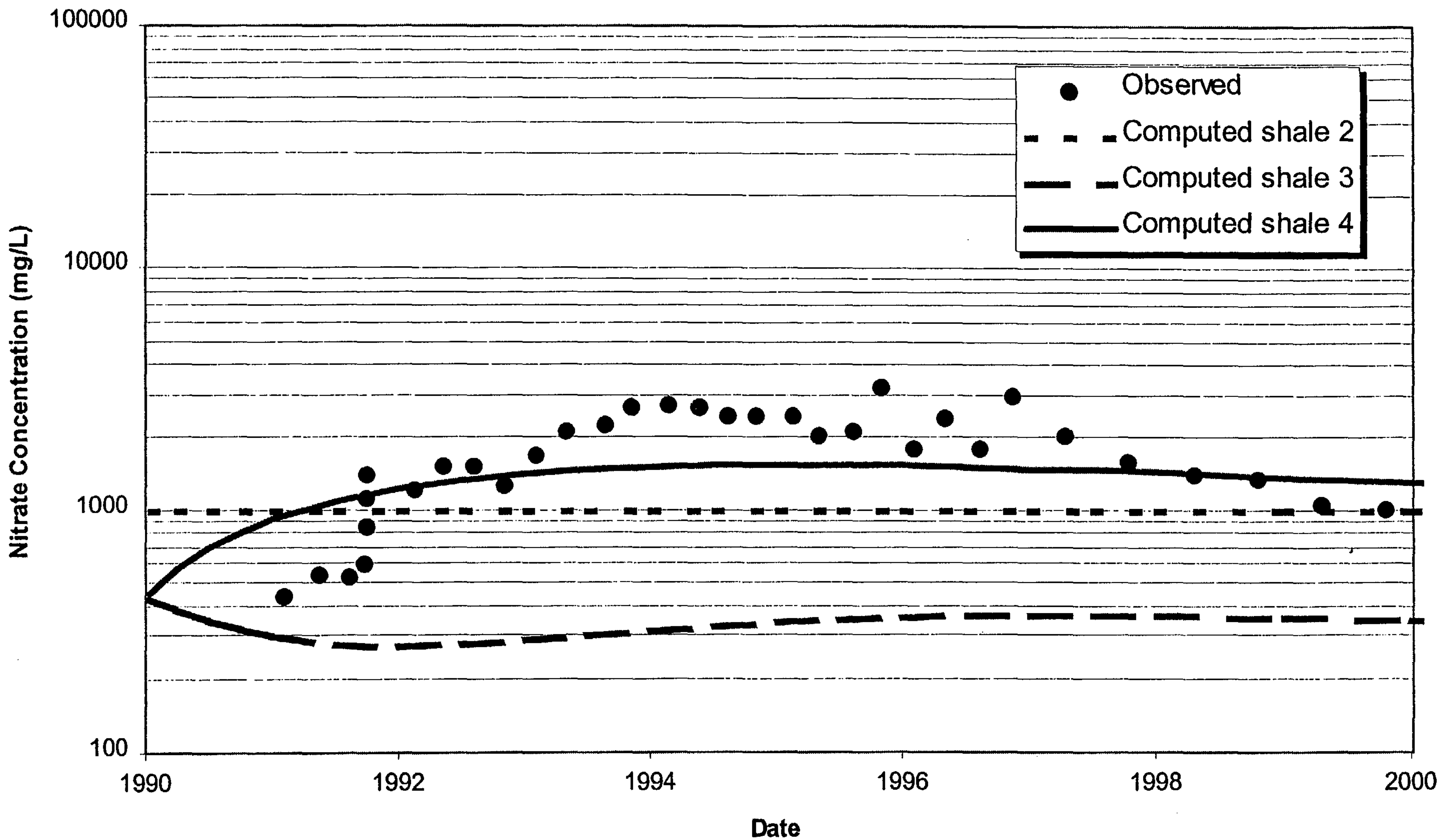


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2352

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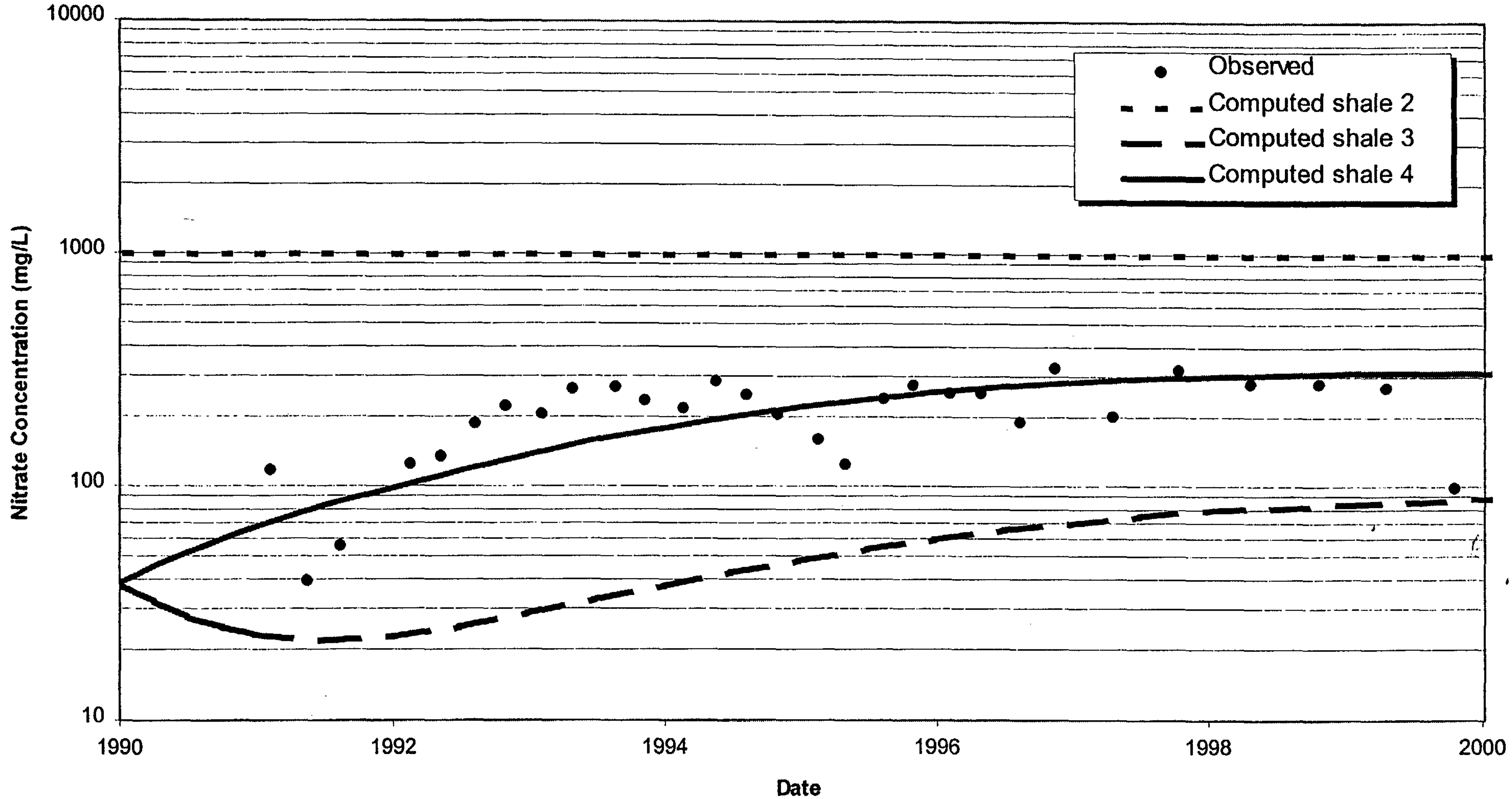


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2353

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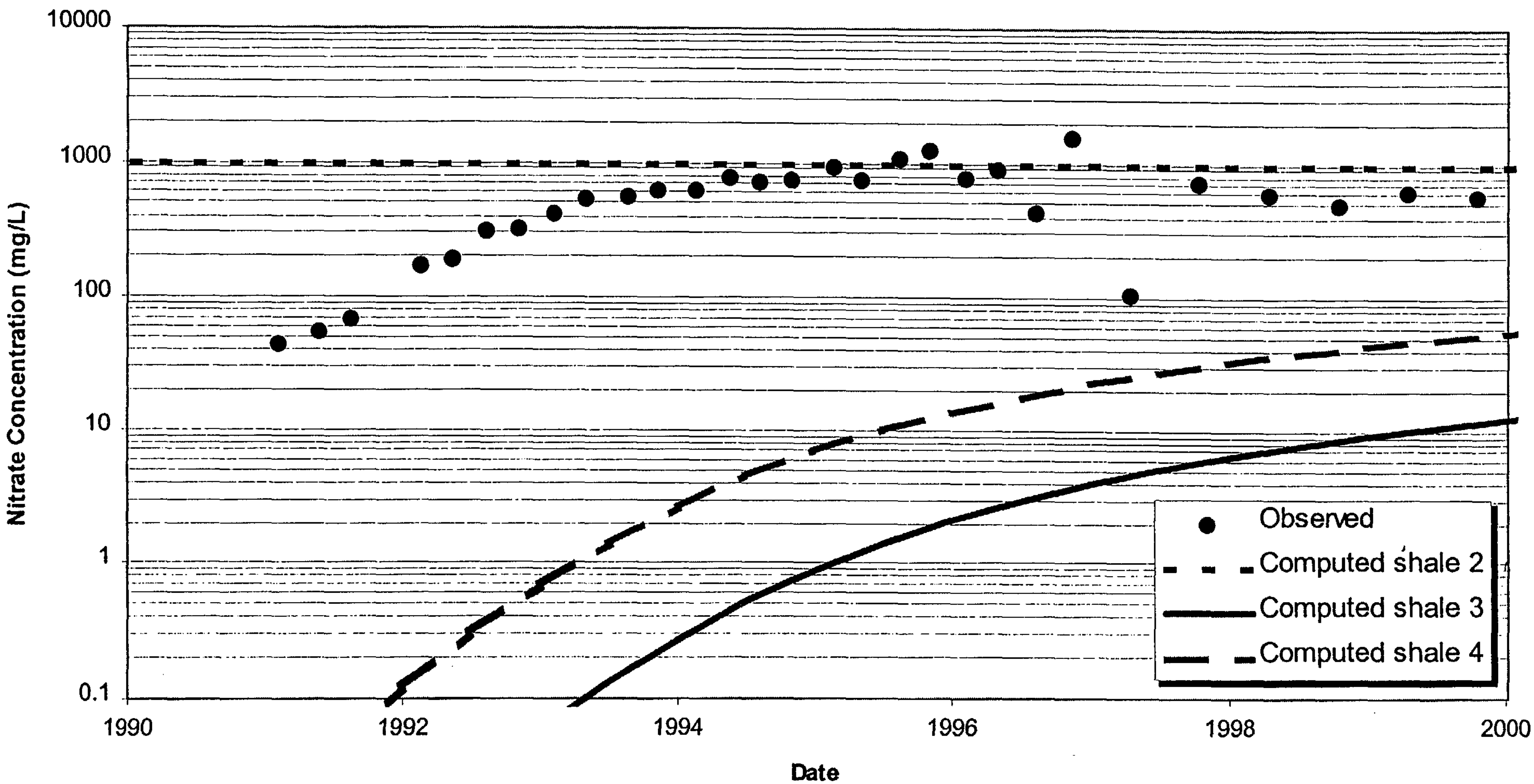


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2354

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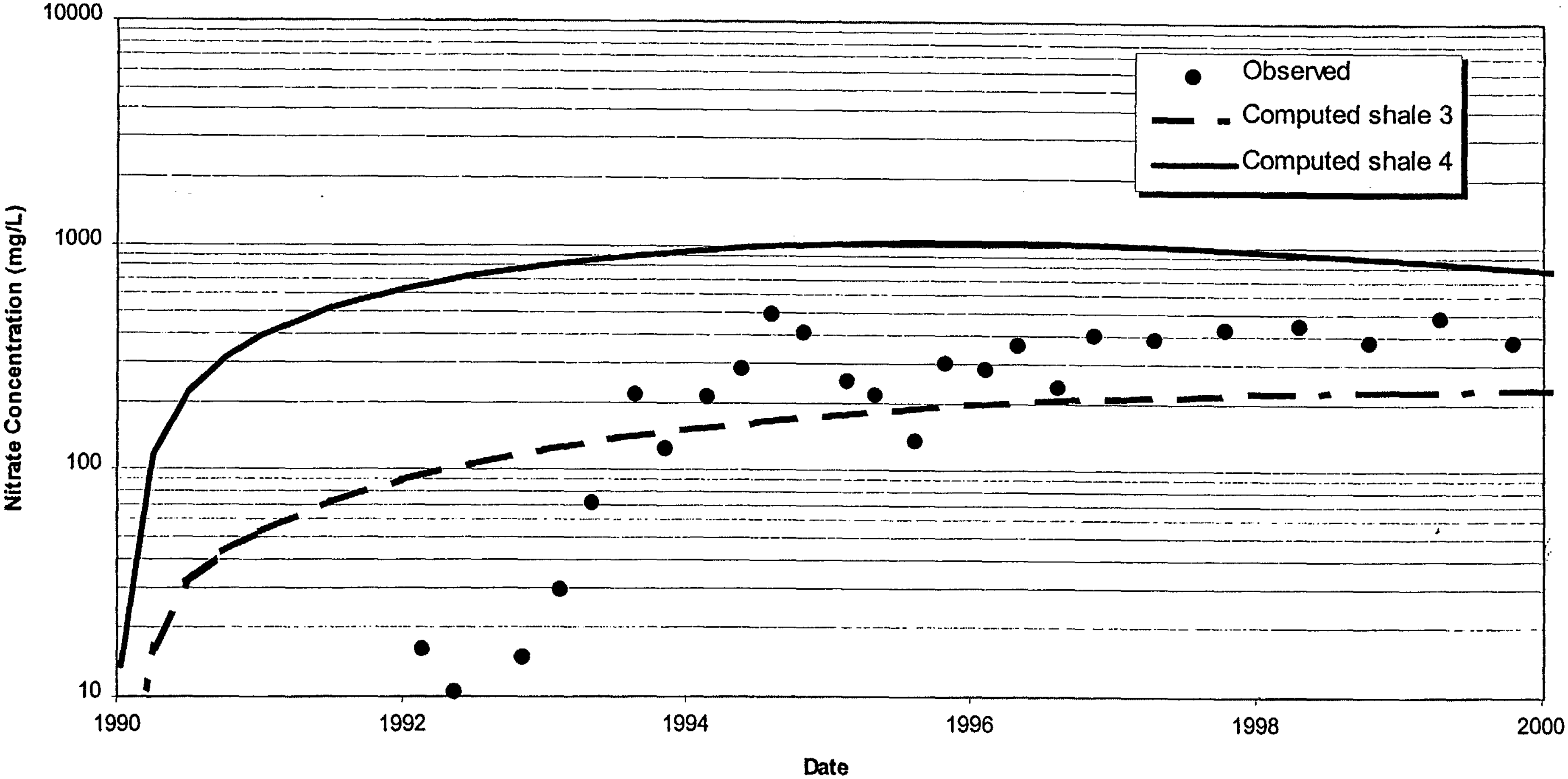


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2355

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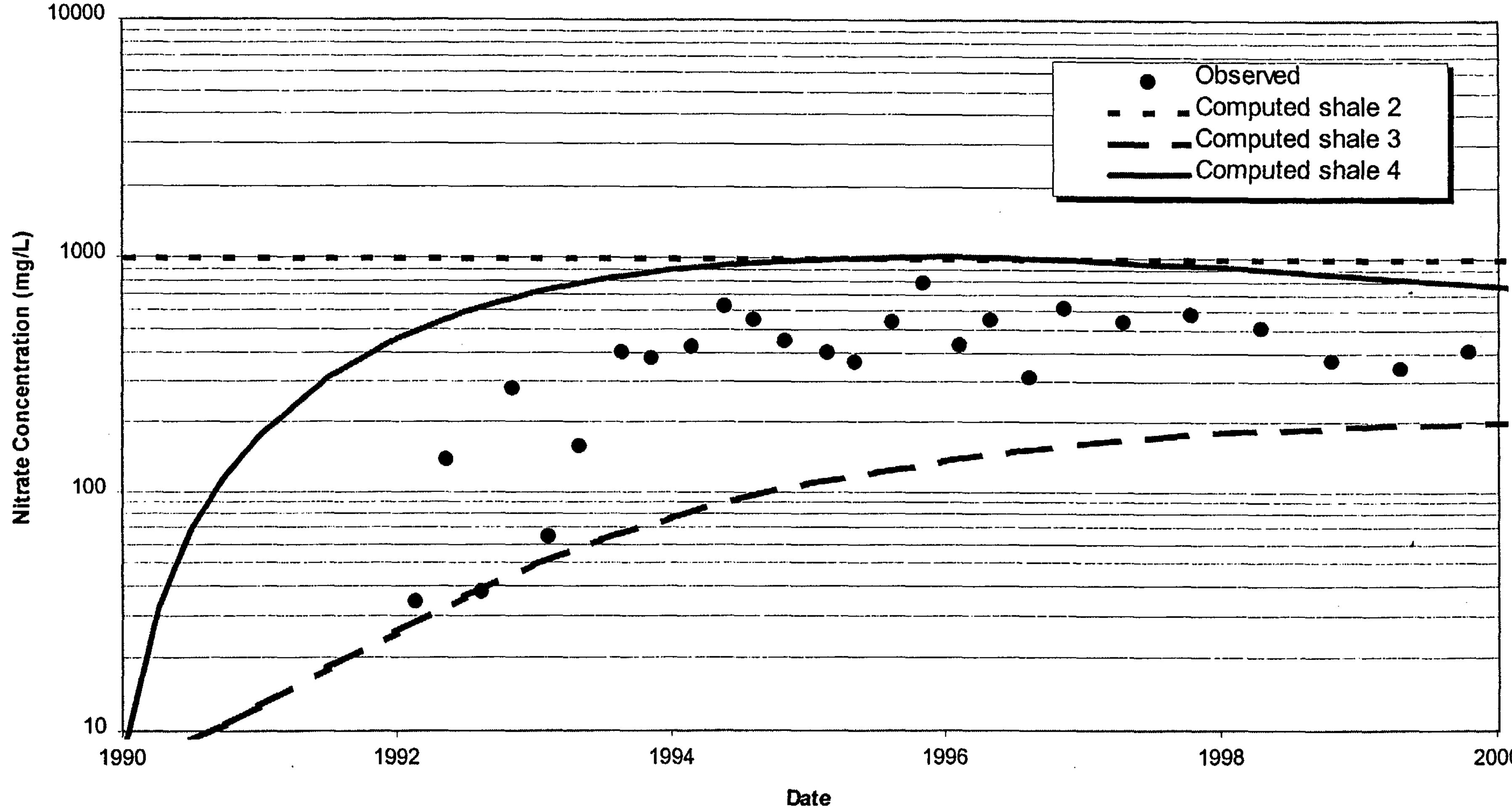


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2356

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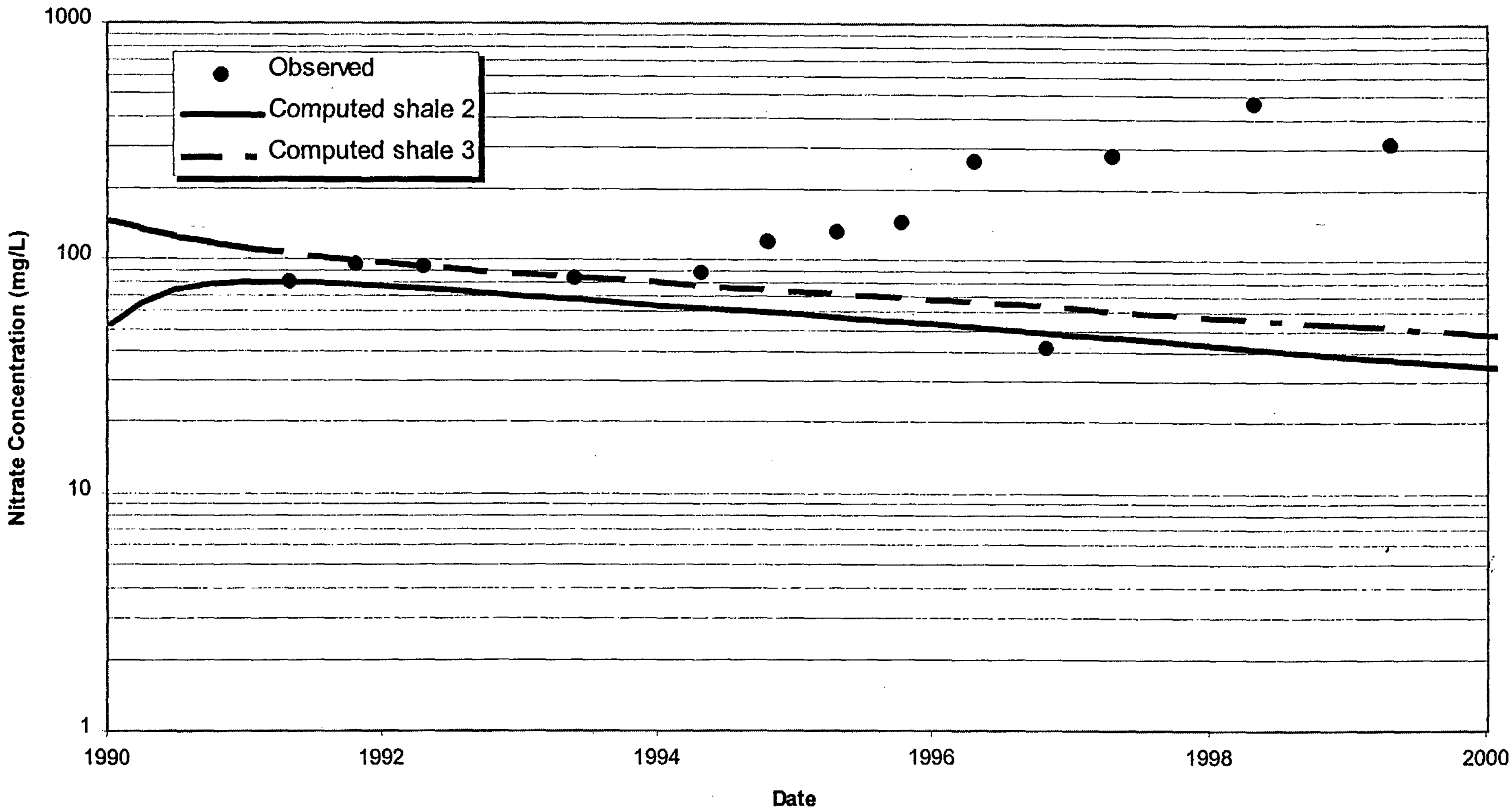


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW012A

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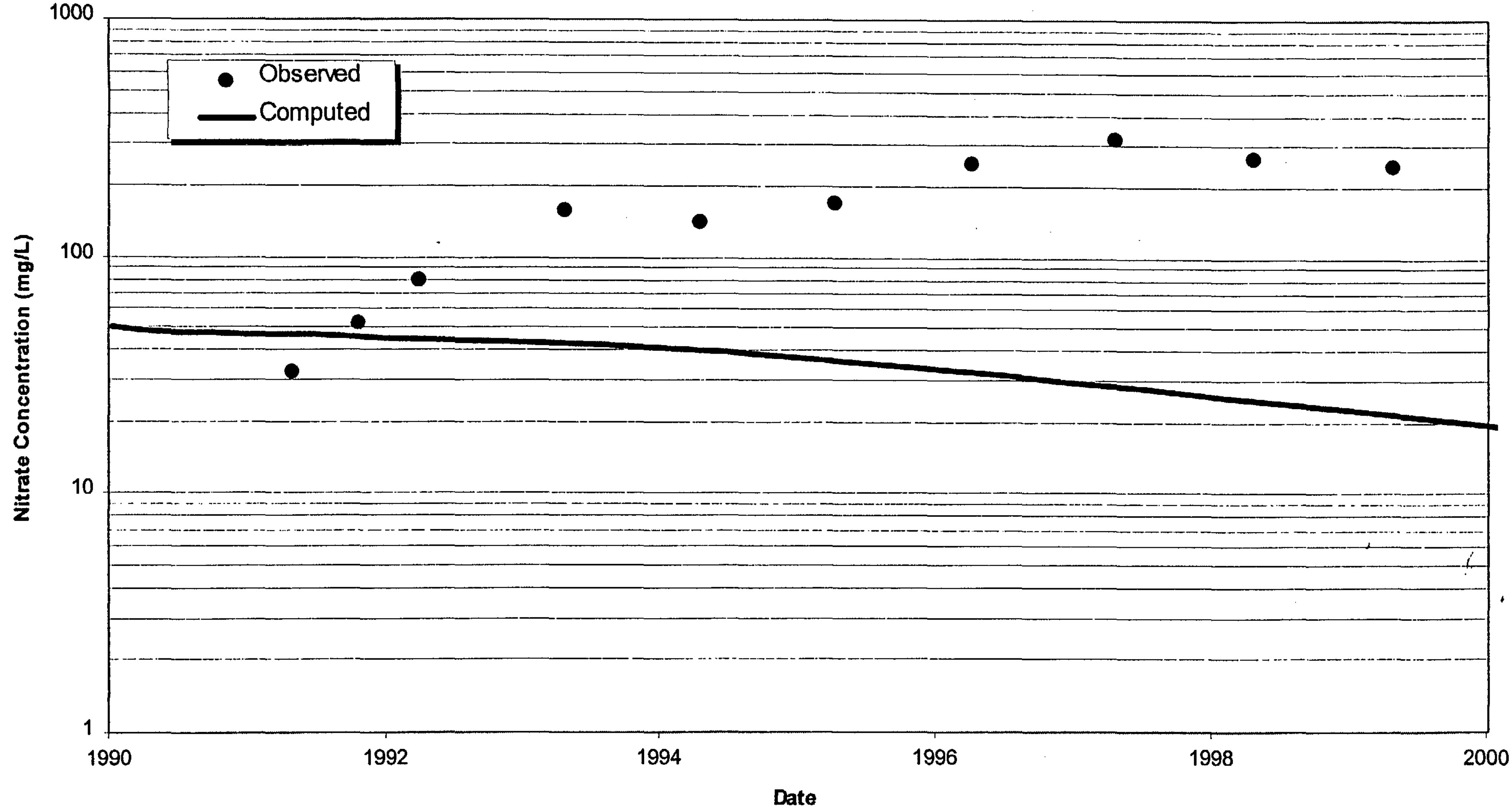


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW012

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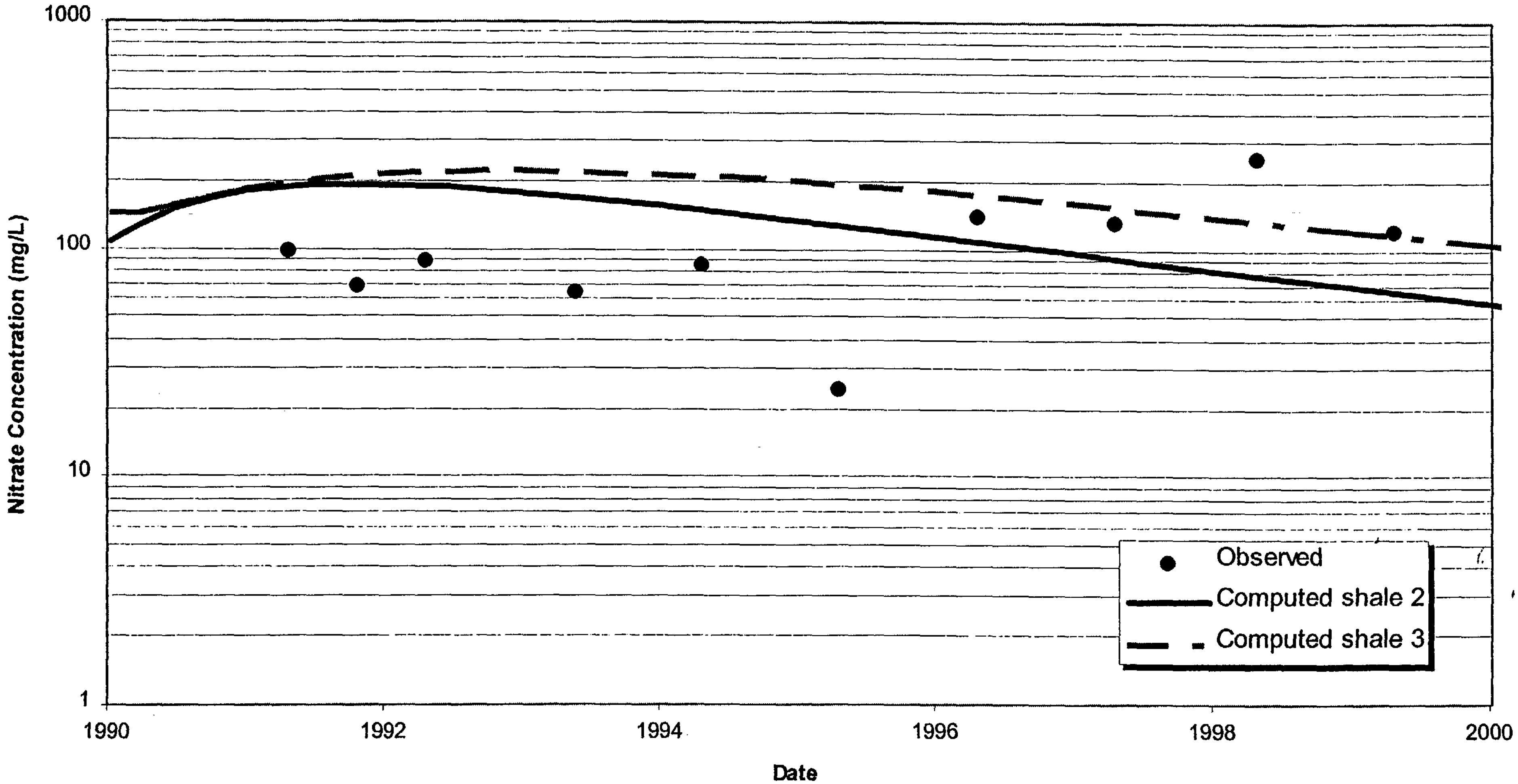


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW014A

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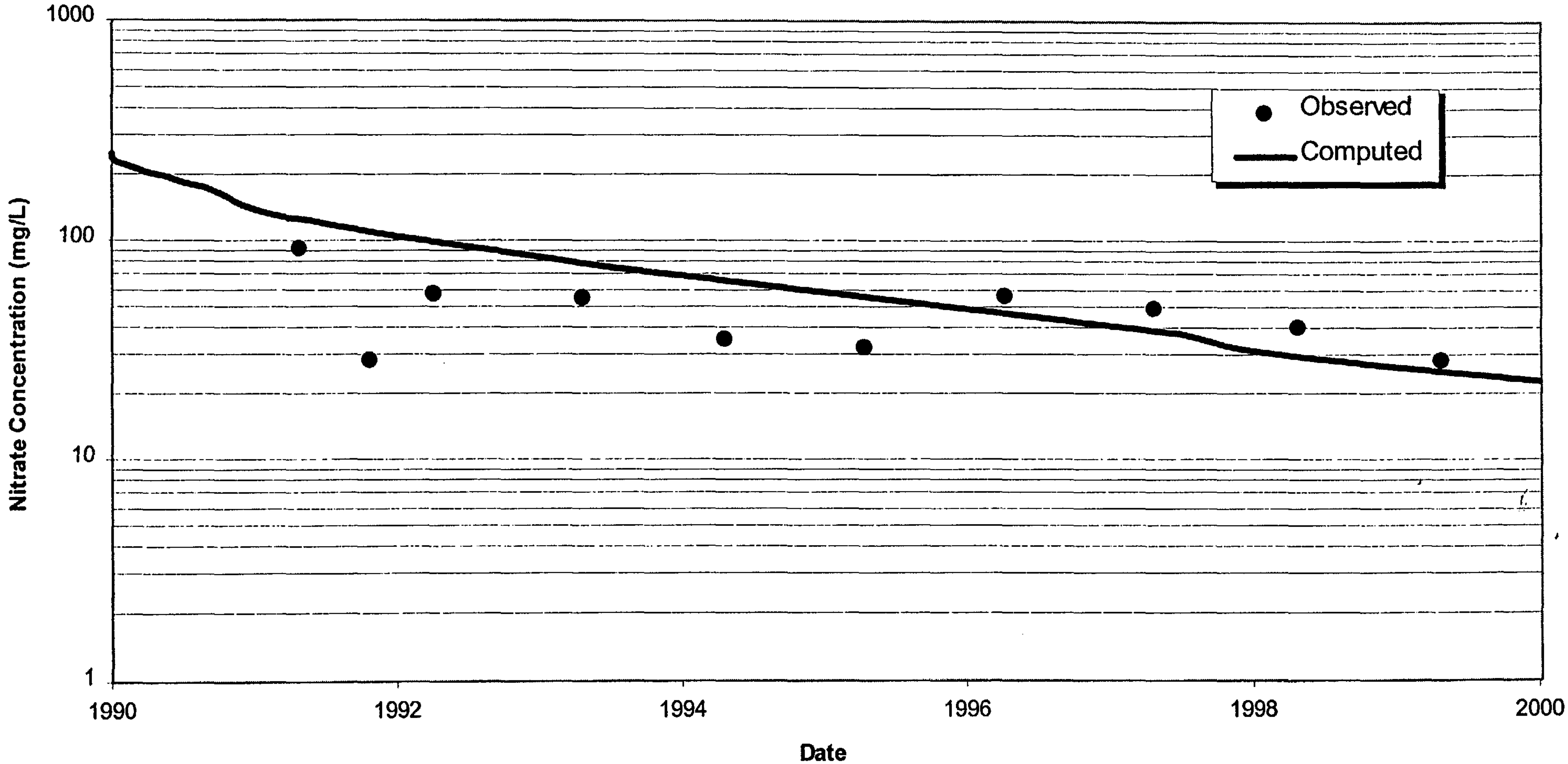


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FIGURE
NITRATE TRANPORT CALIBRATION FOR WELL MW014

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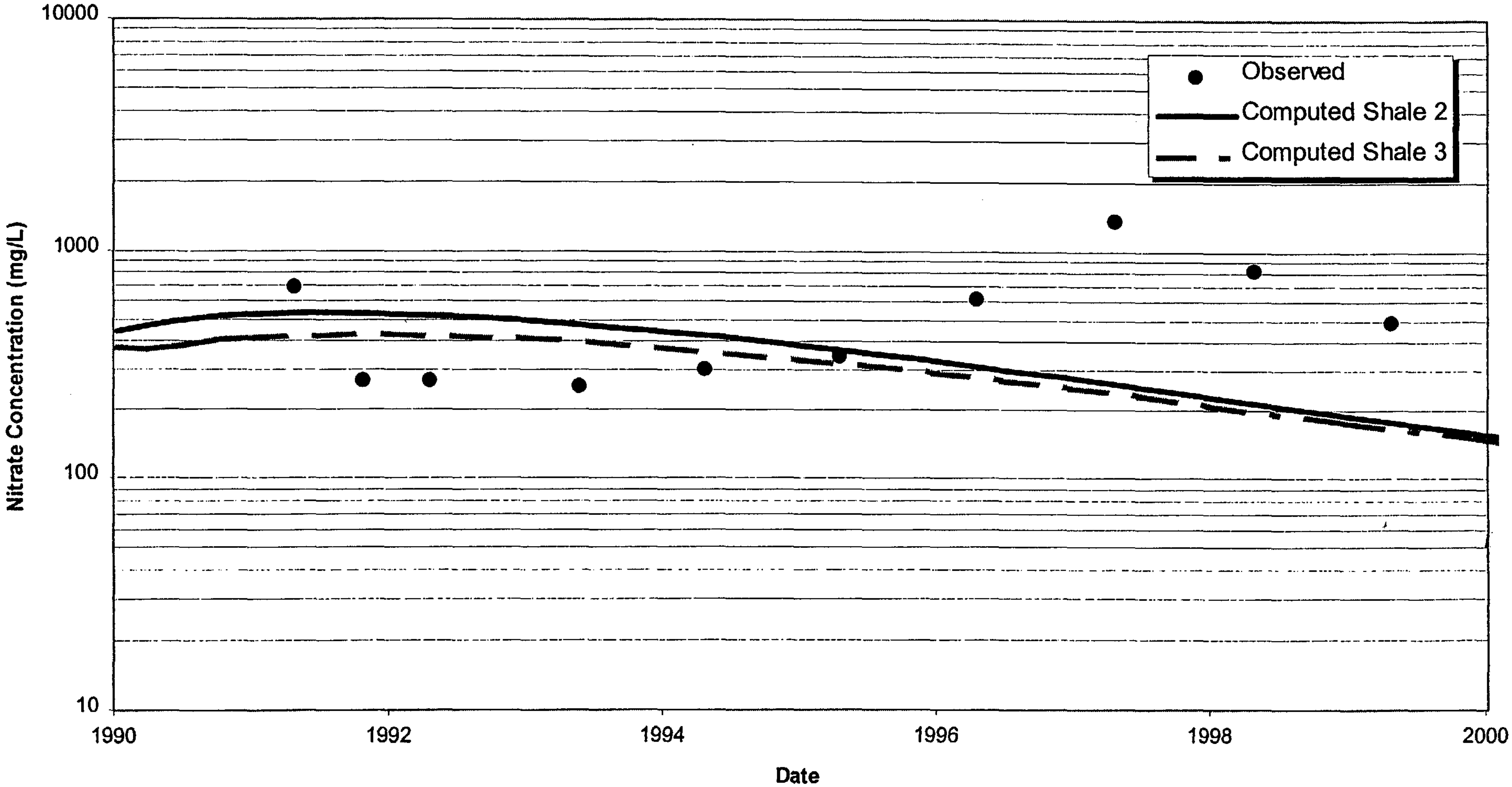


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW024A

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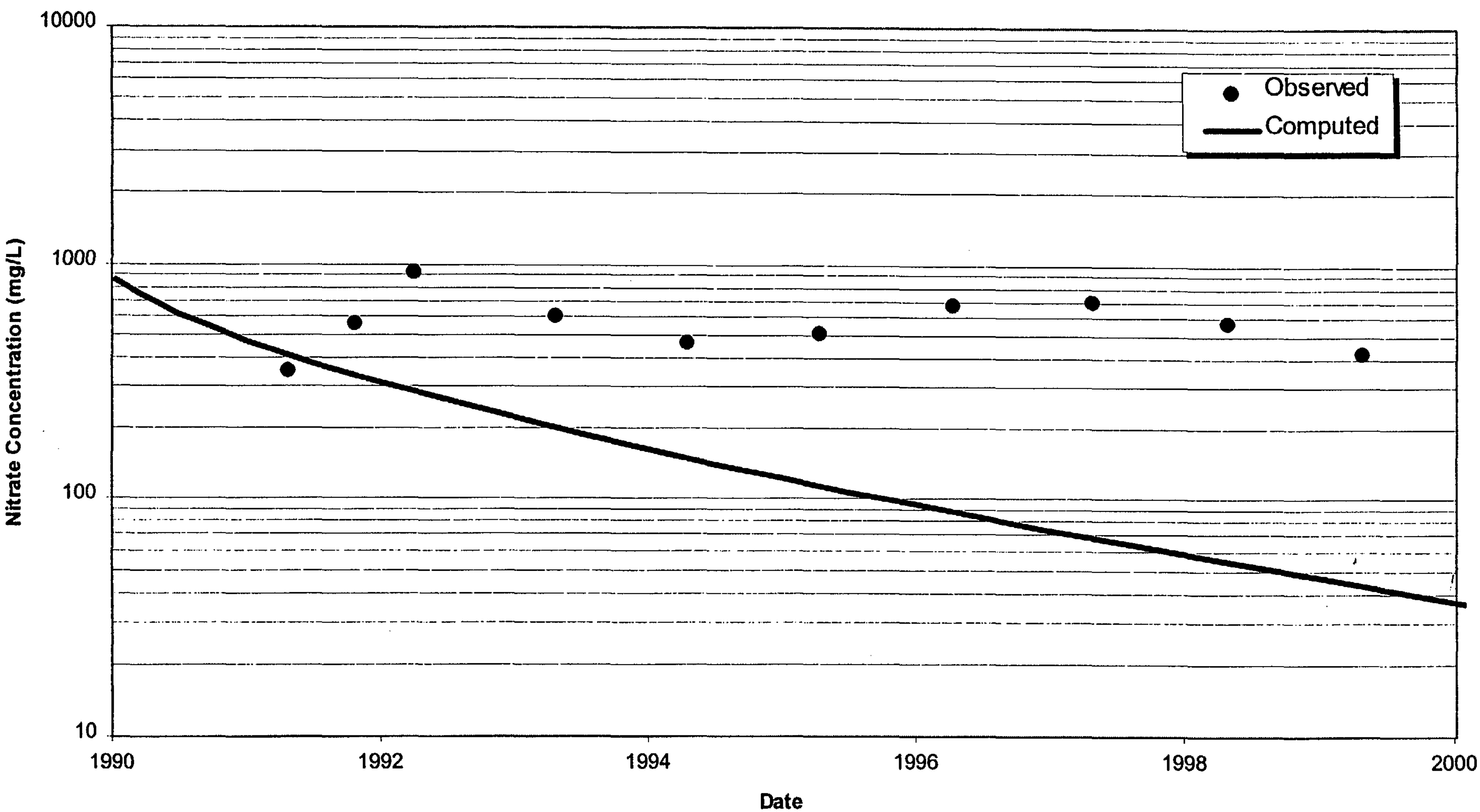


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW024

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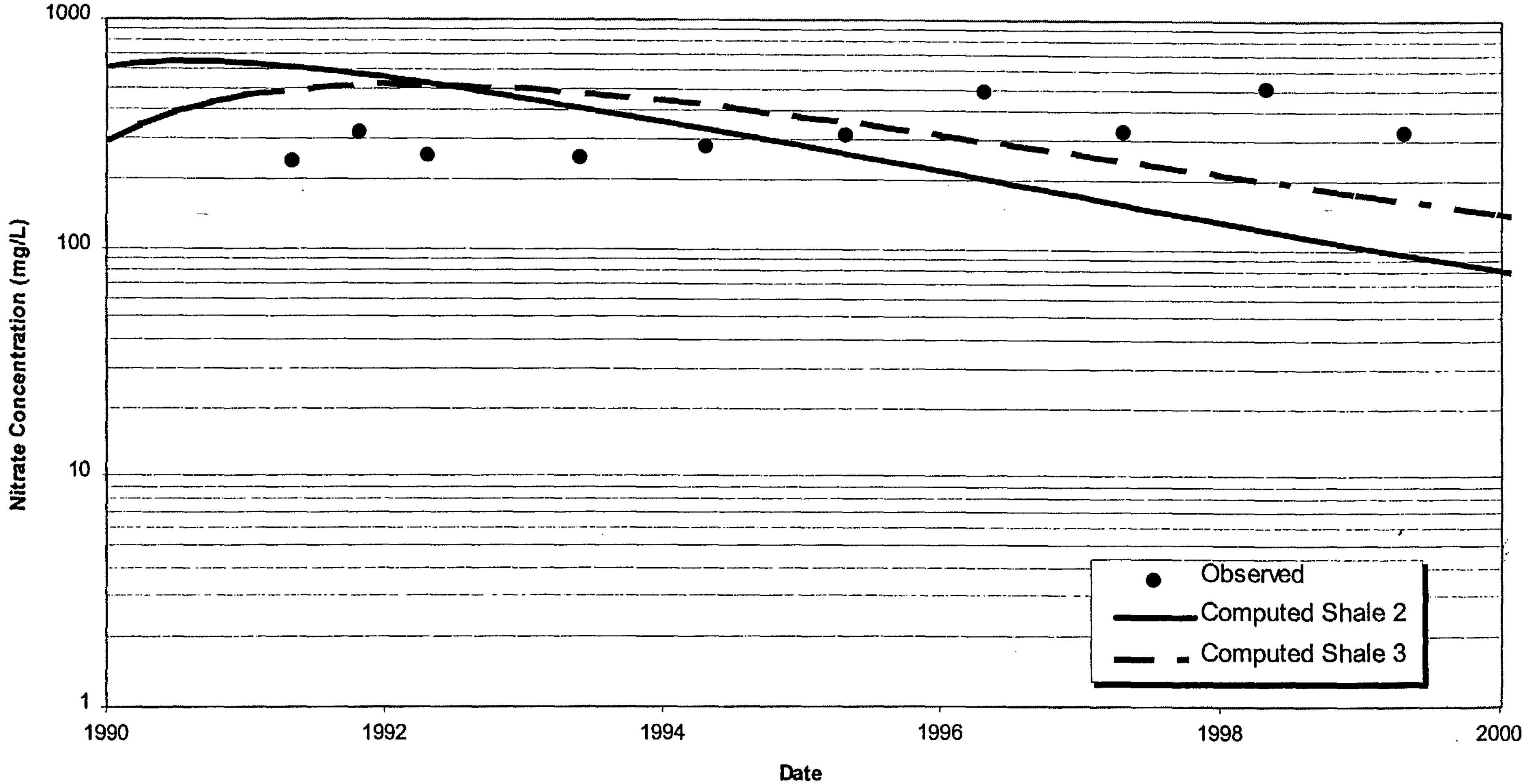


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW025A

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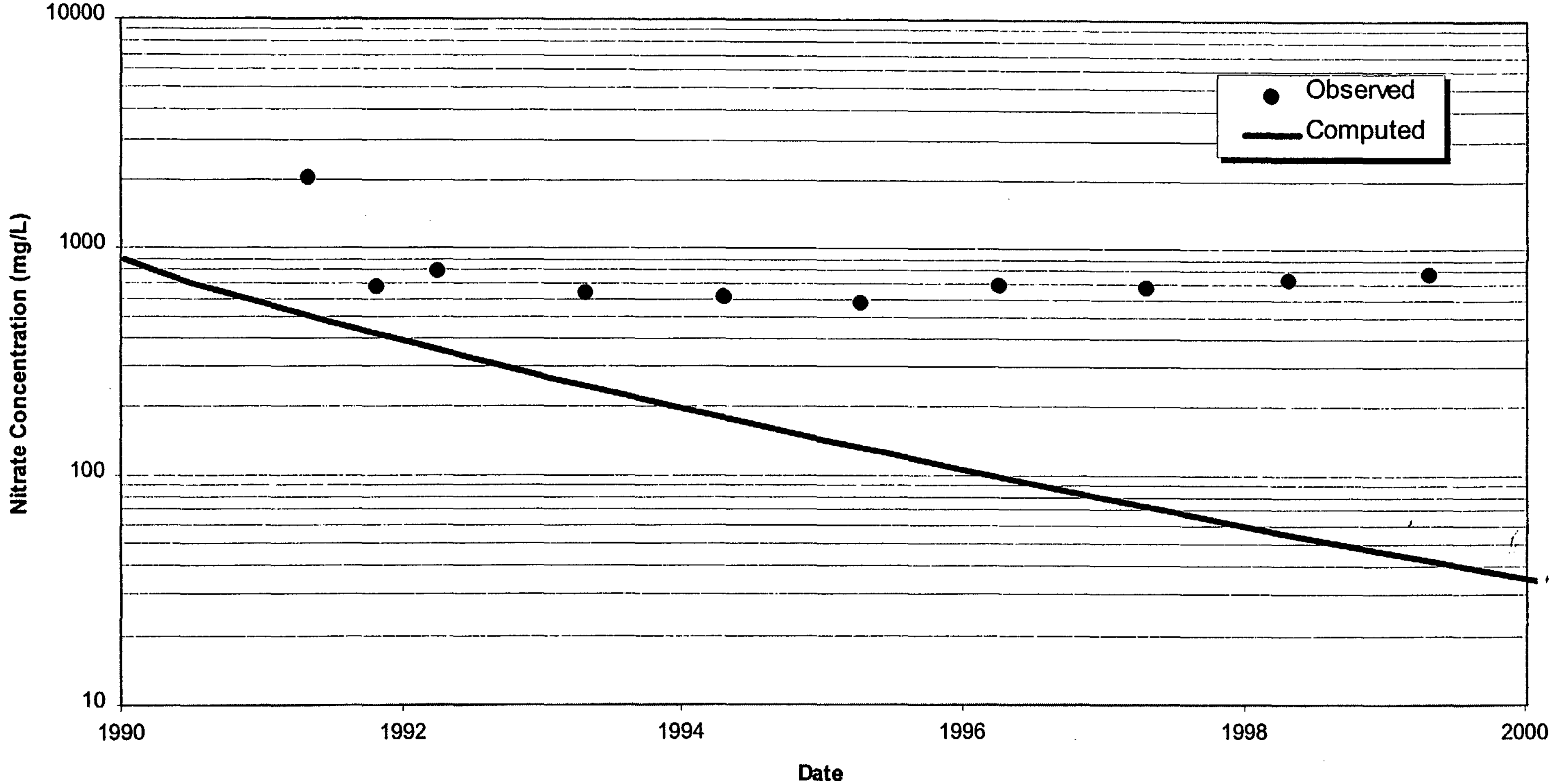


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW025

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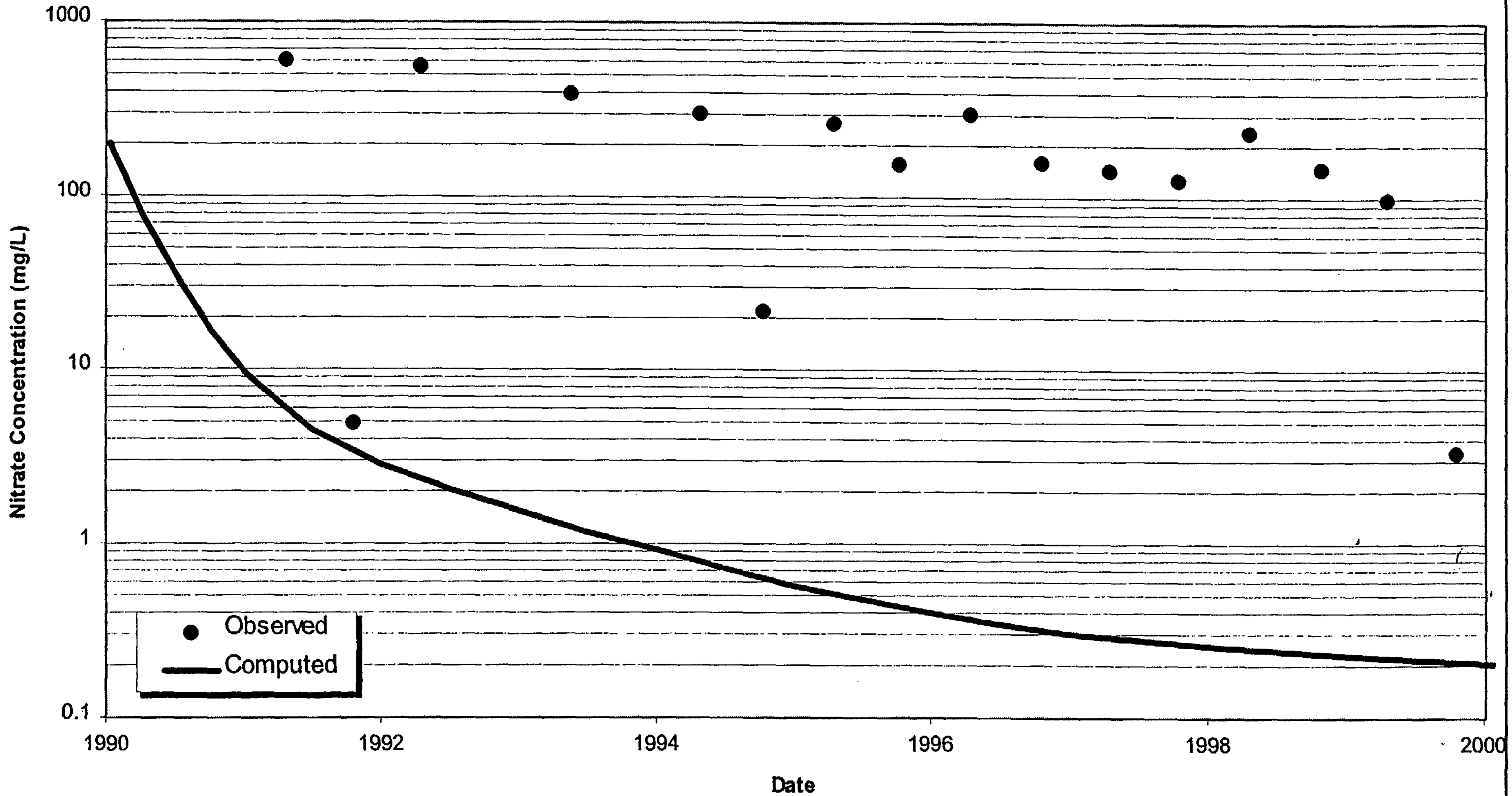


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW035A

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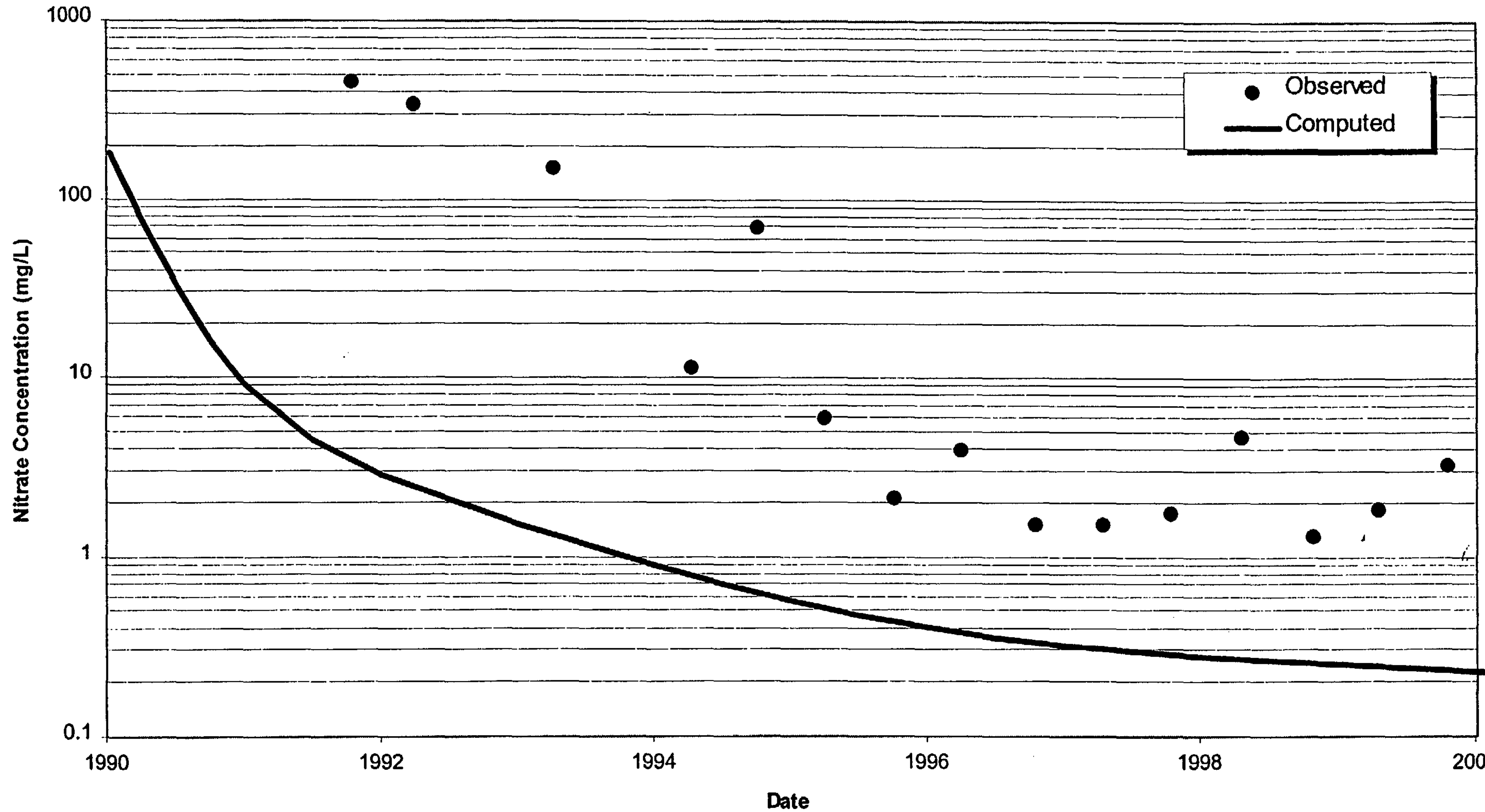


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW035

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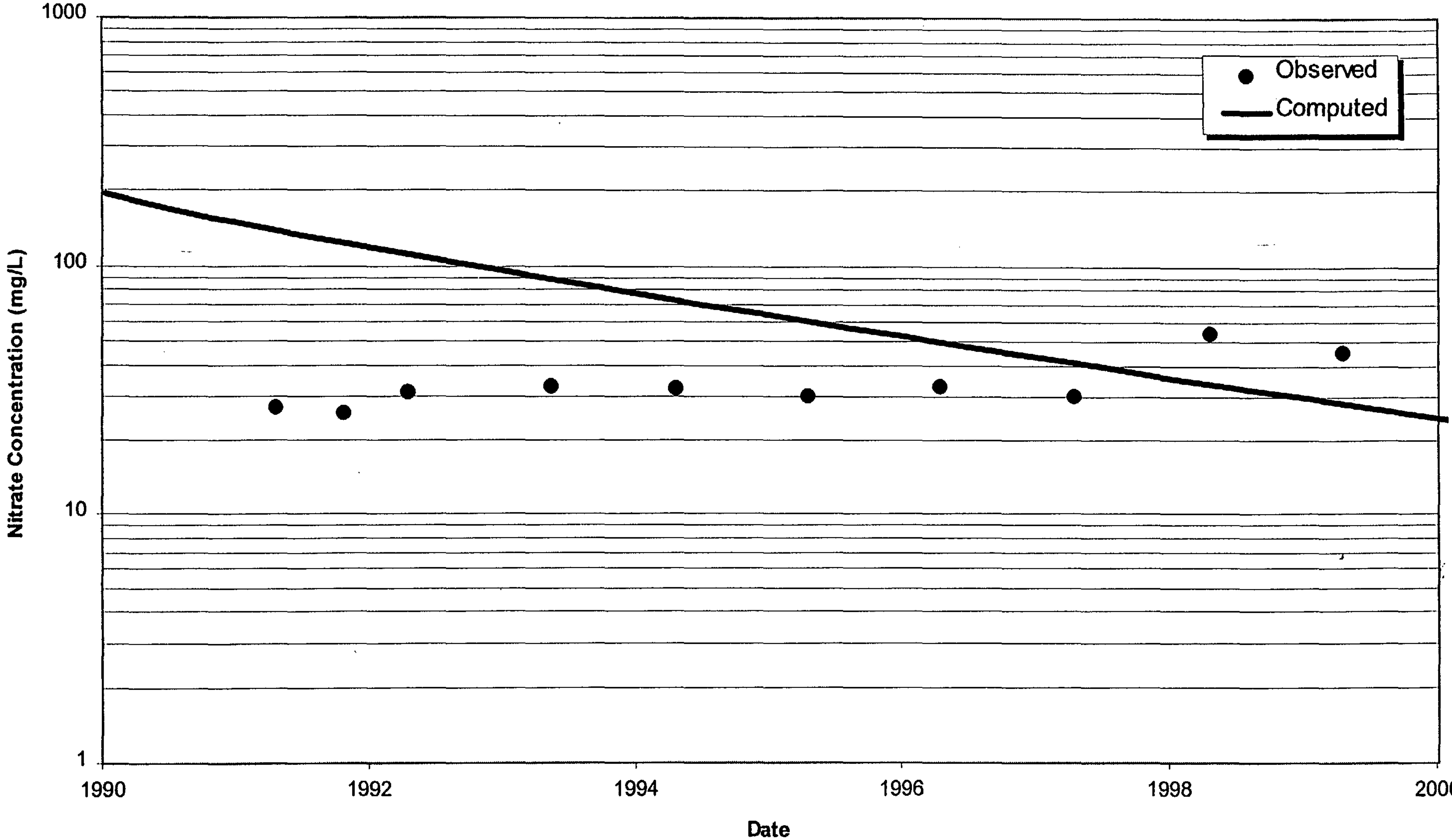


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|---|---|
| consulting scientists and engineers | FIGURE<br>NITRATE TRANSPORT CALIBRATION FOR WELL MW036A |

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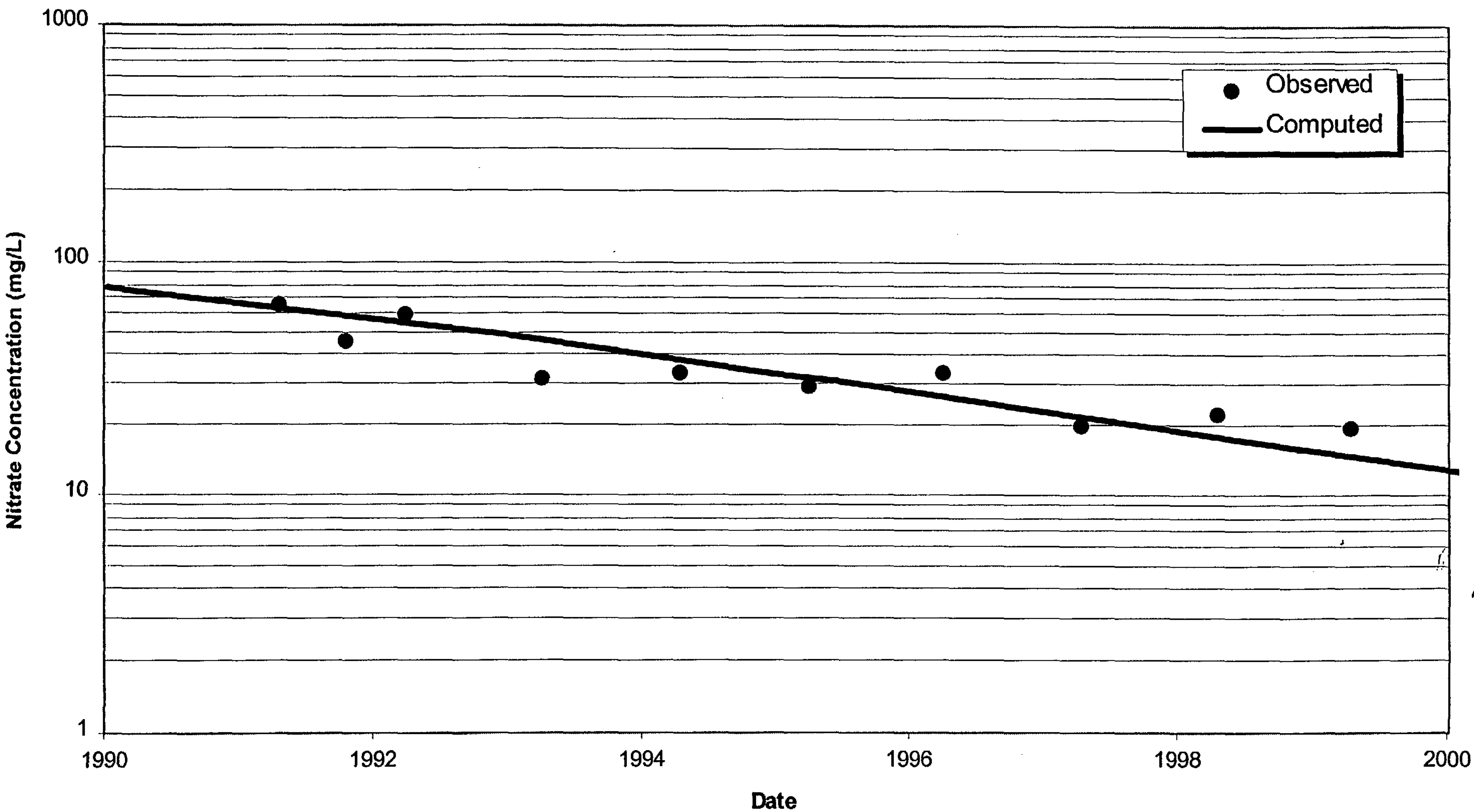


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW036

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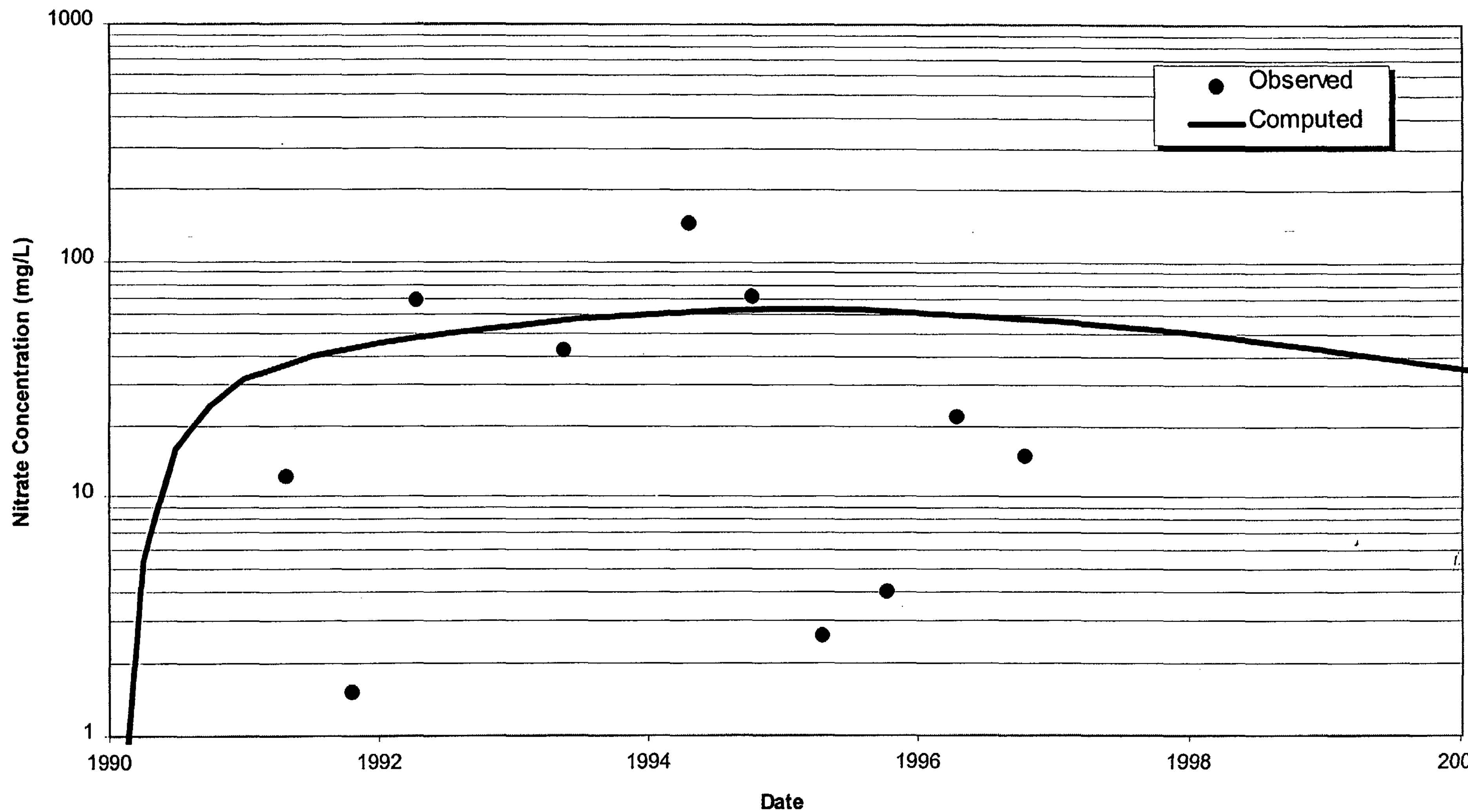


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW038A

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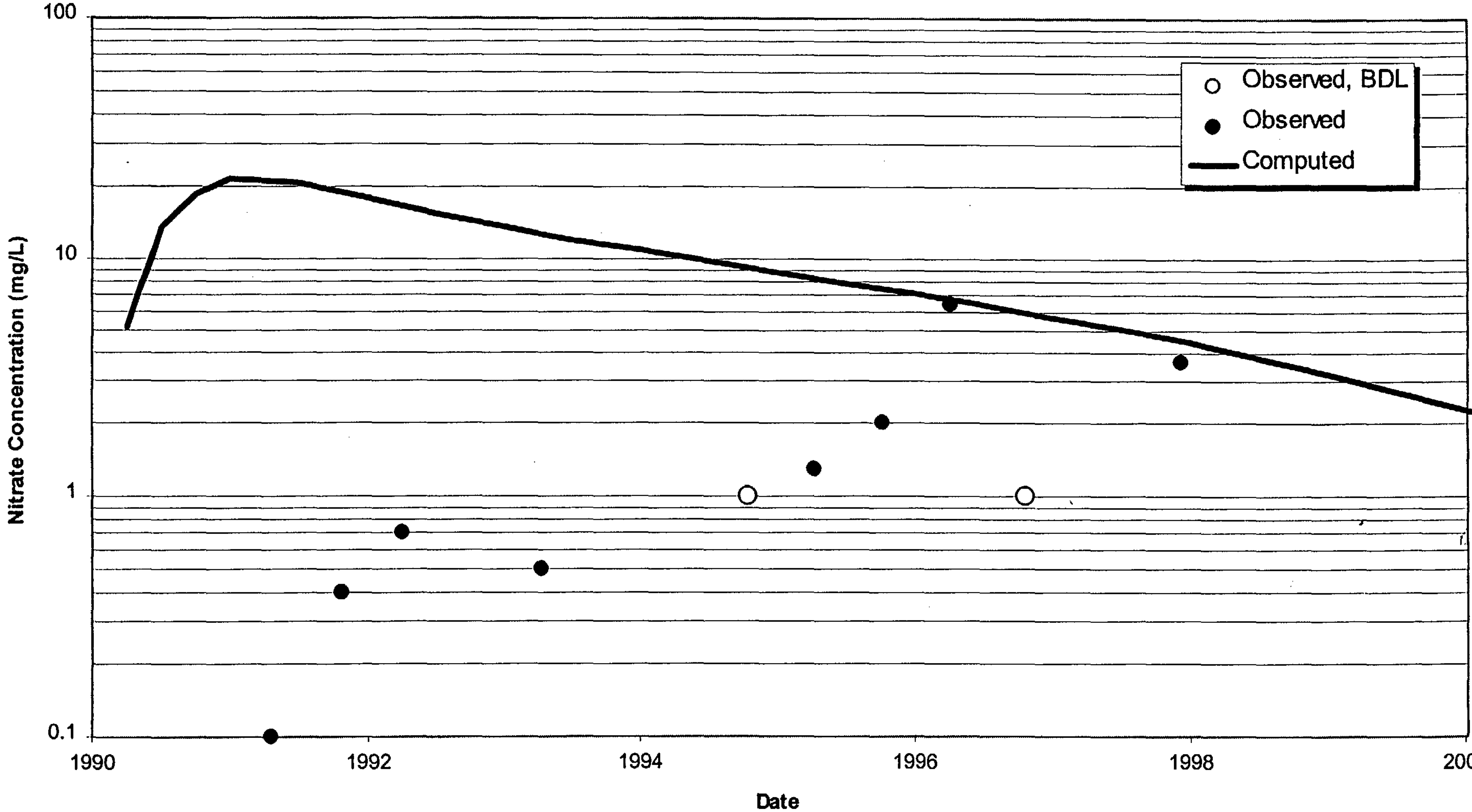


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW038

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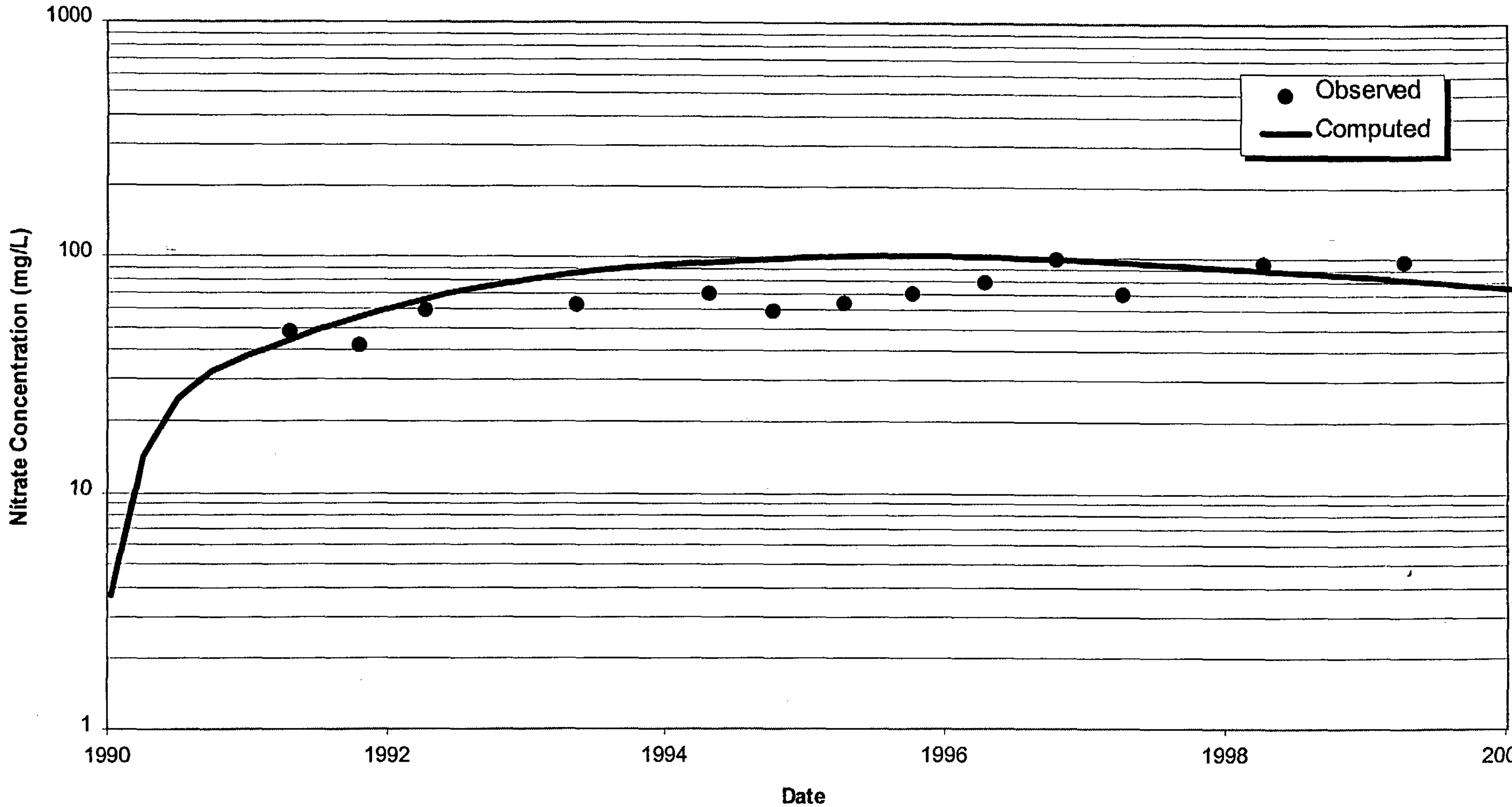


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW039A

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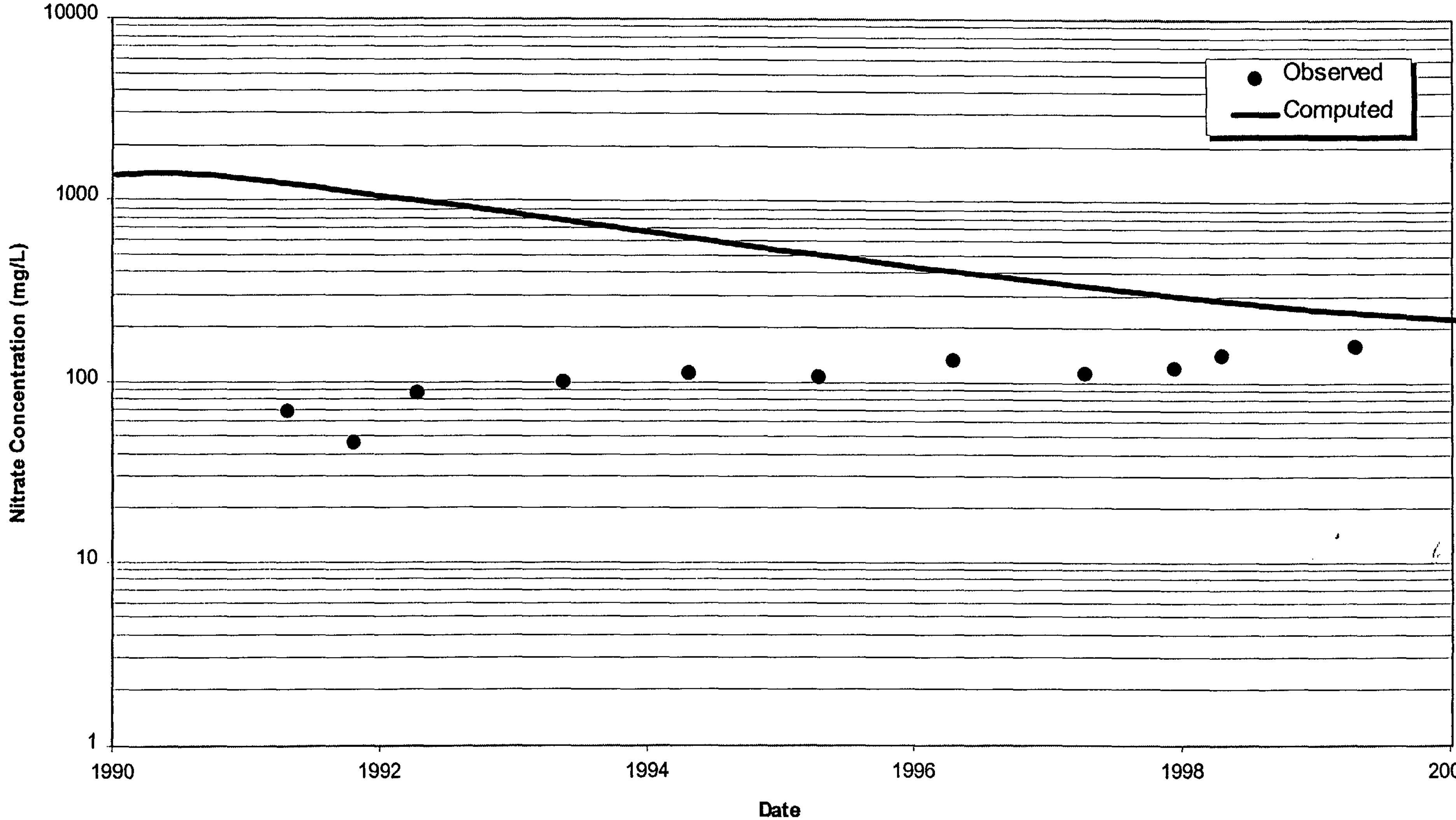


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW040A

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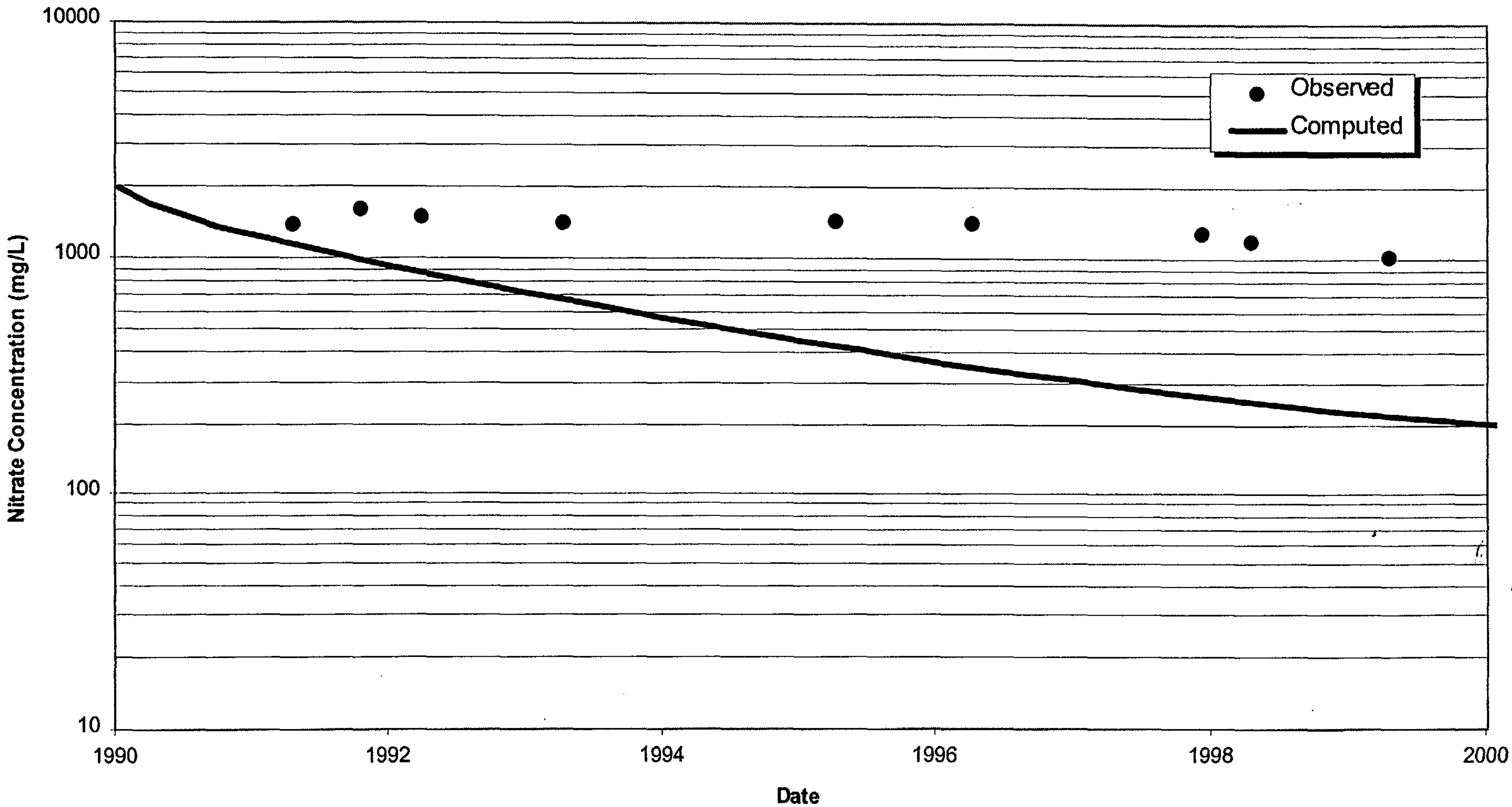


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW040

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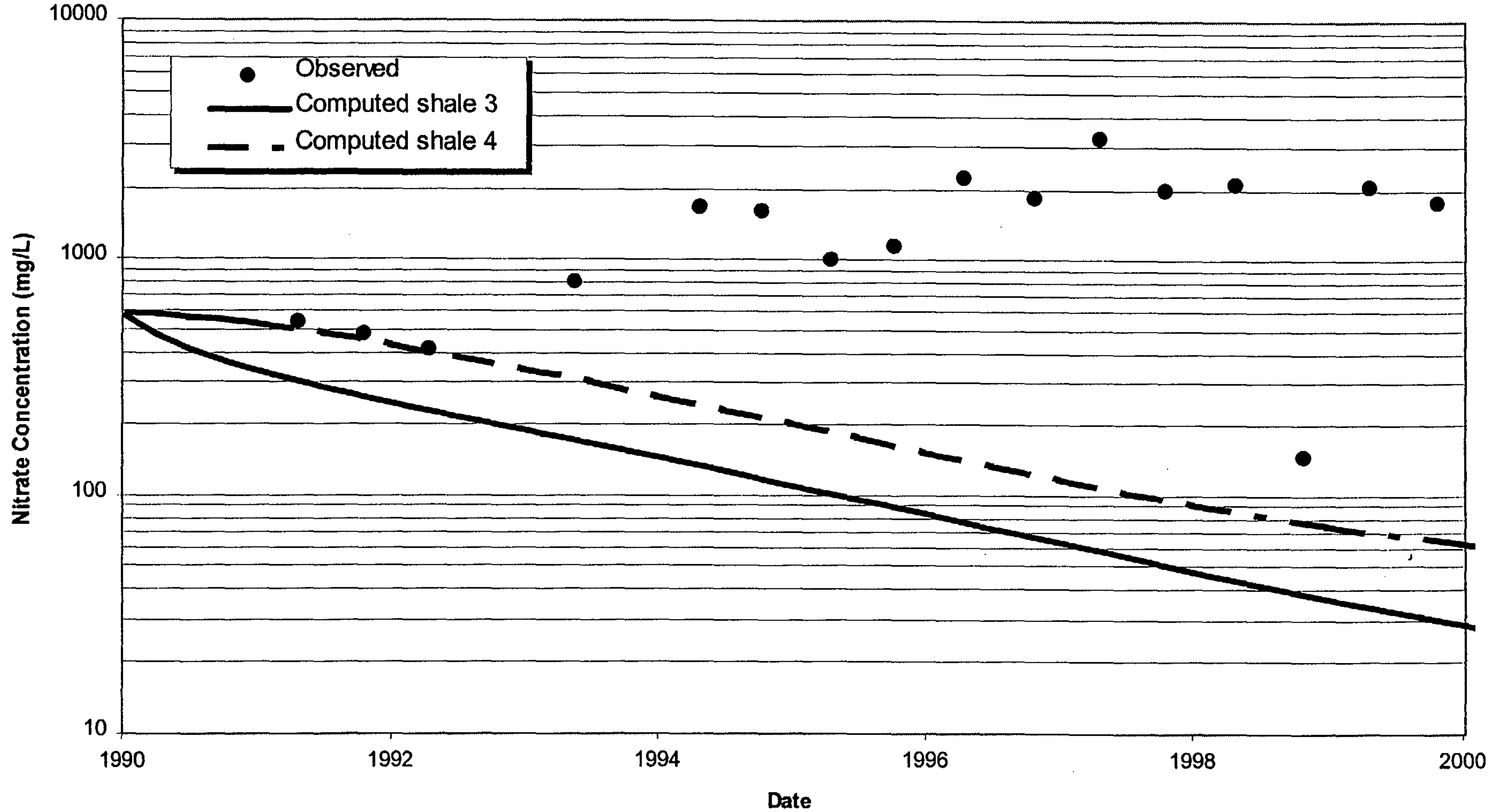


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW046A

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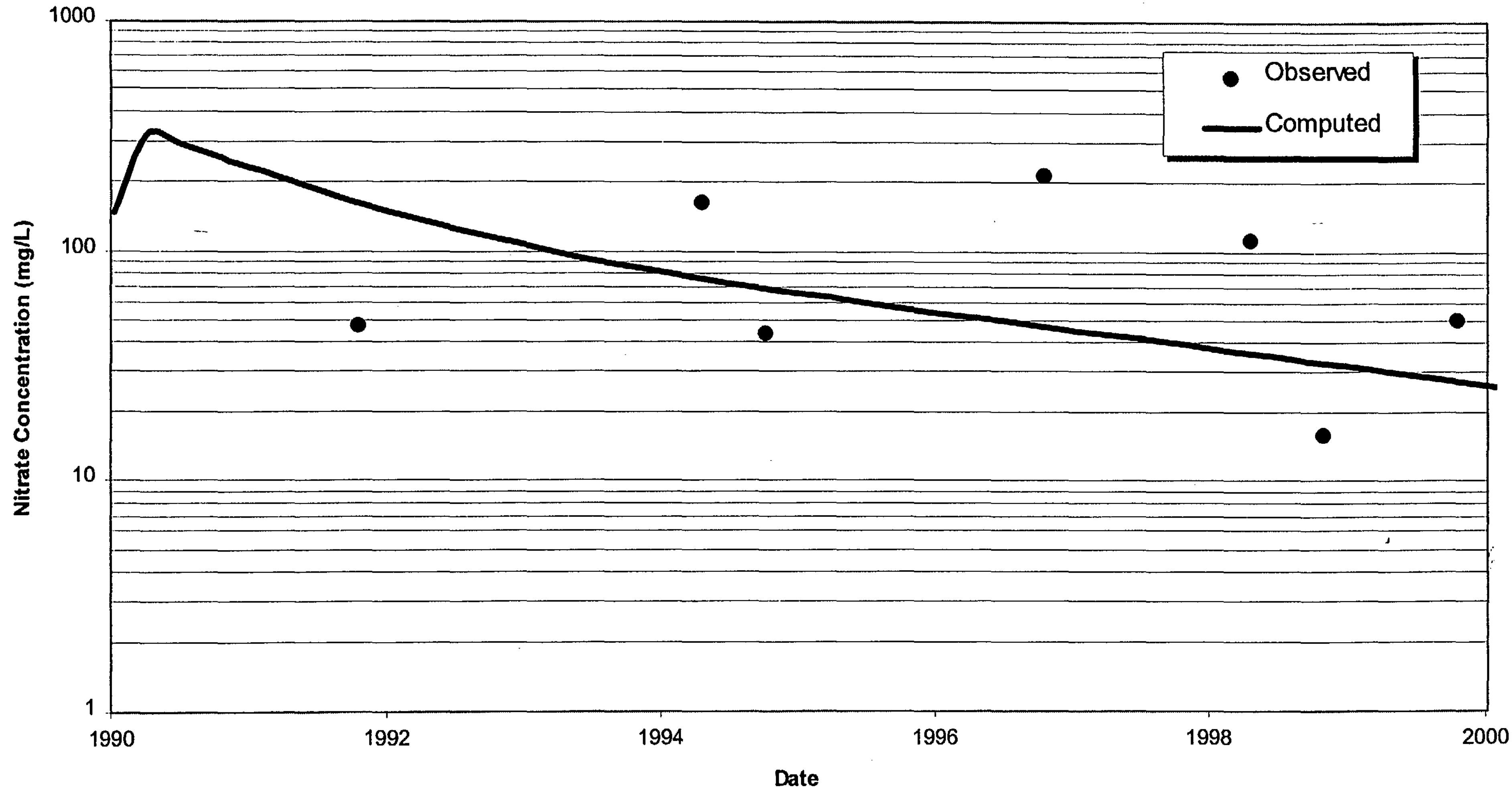


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW047A

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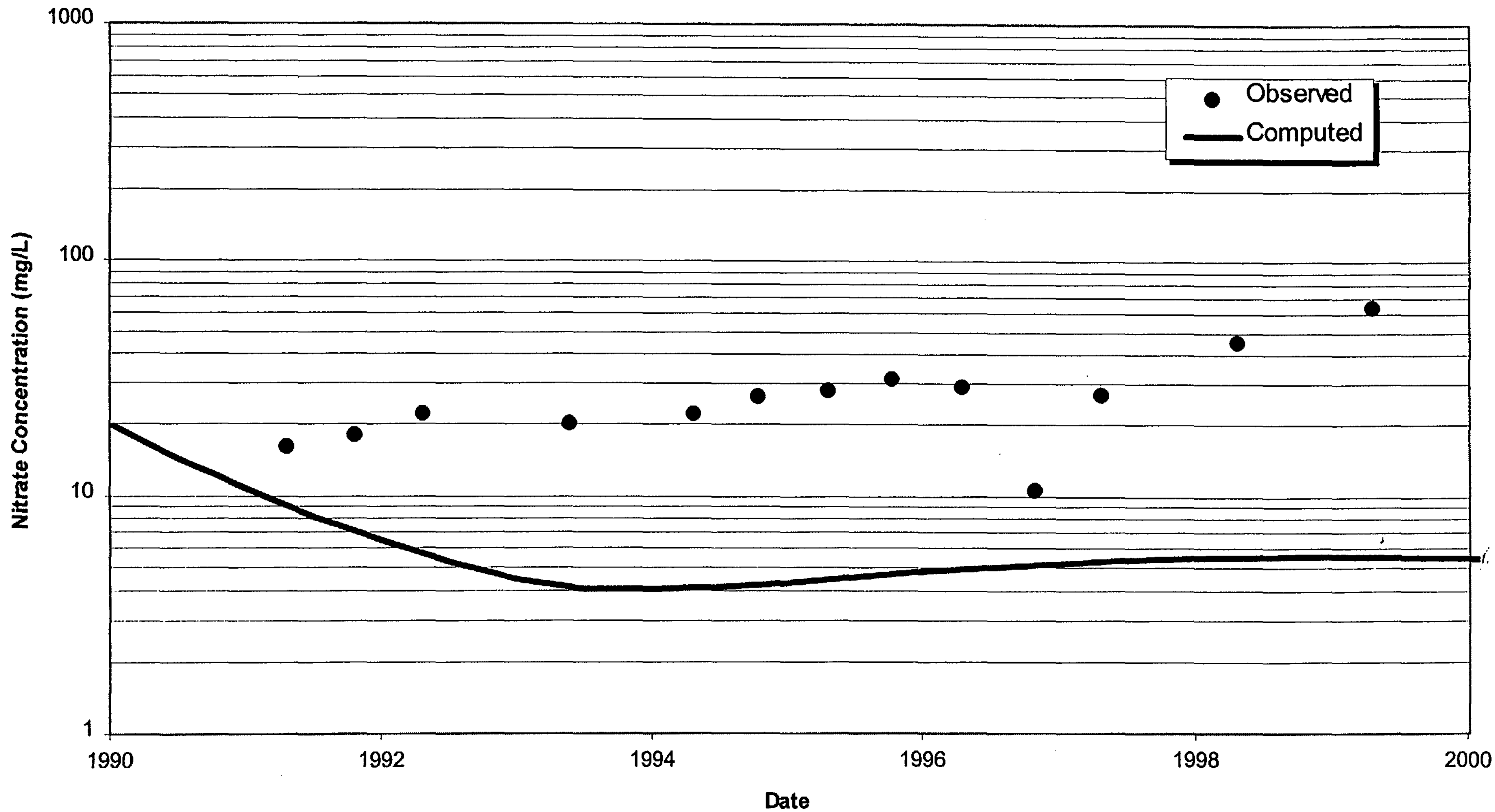


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW049A

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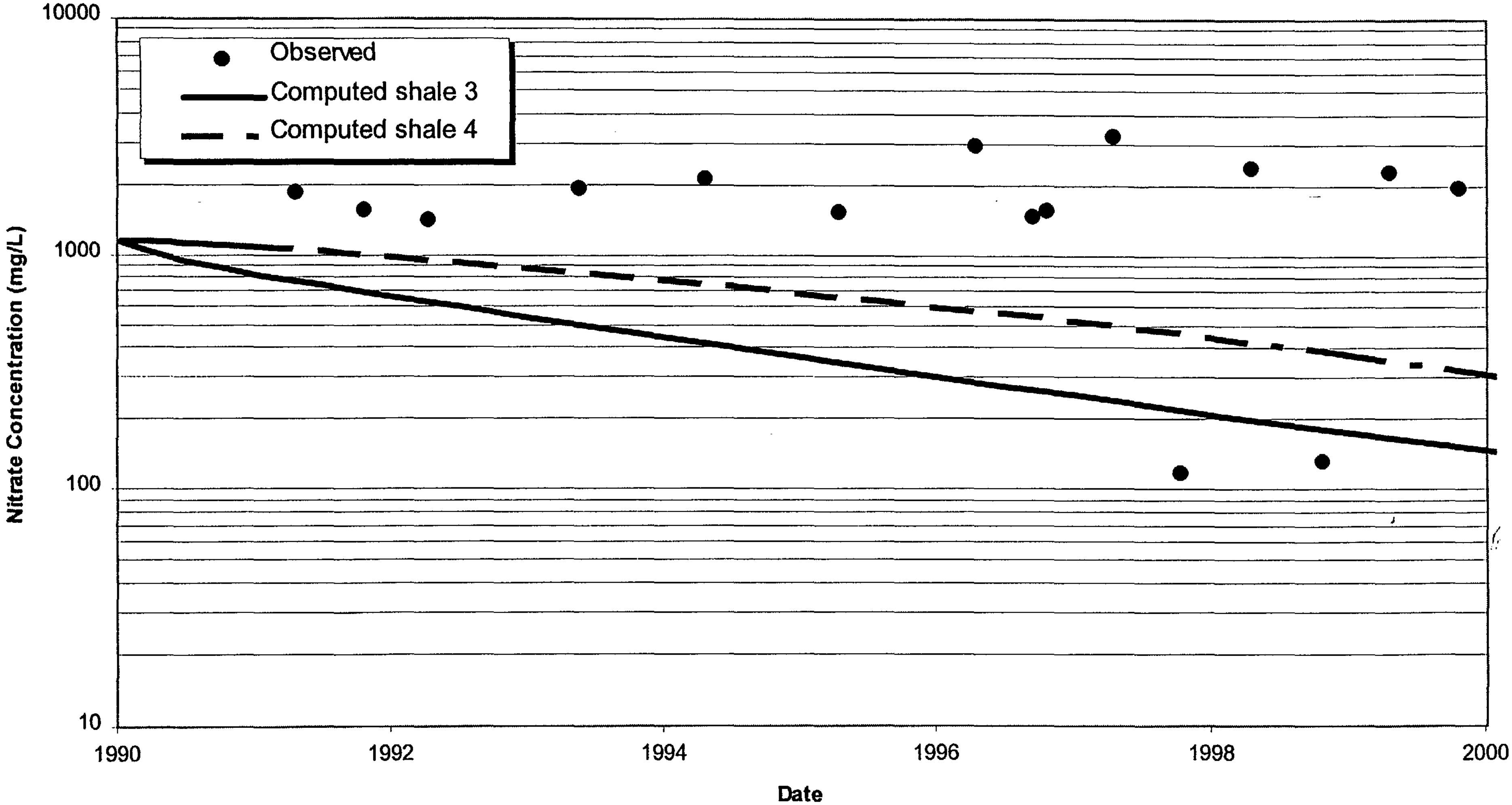


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW051A

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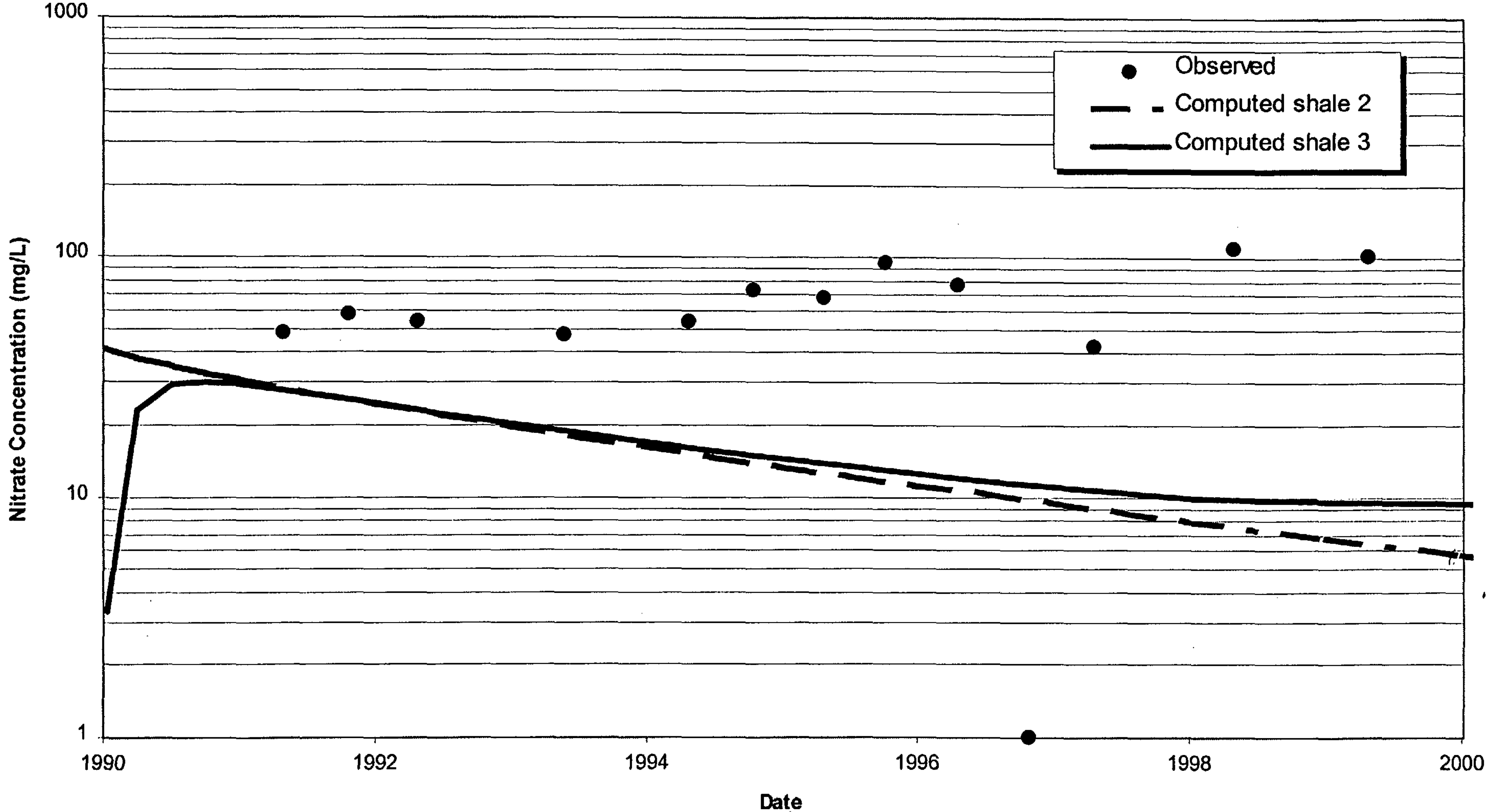


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW053A

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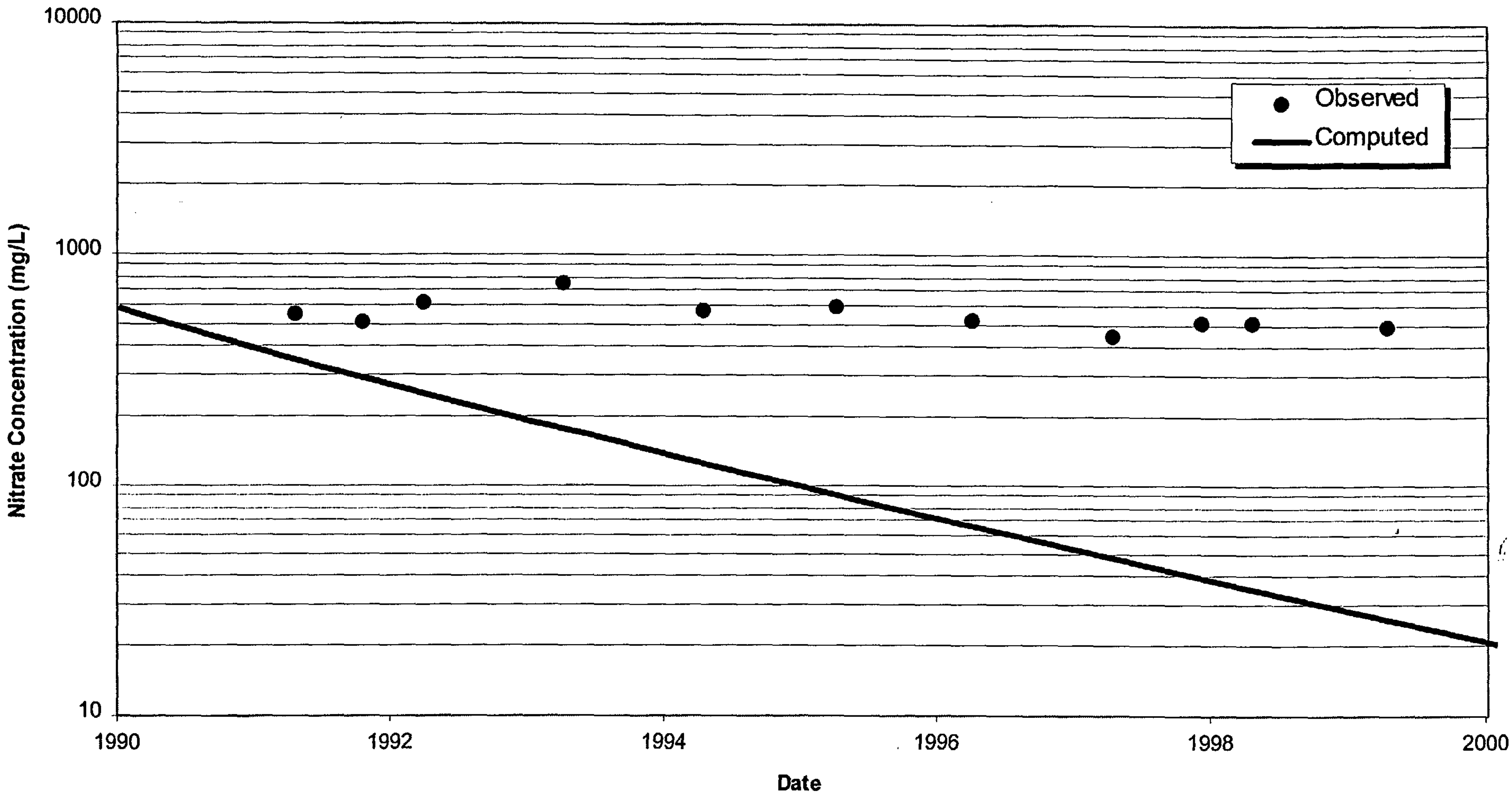


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW054

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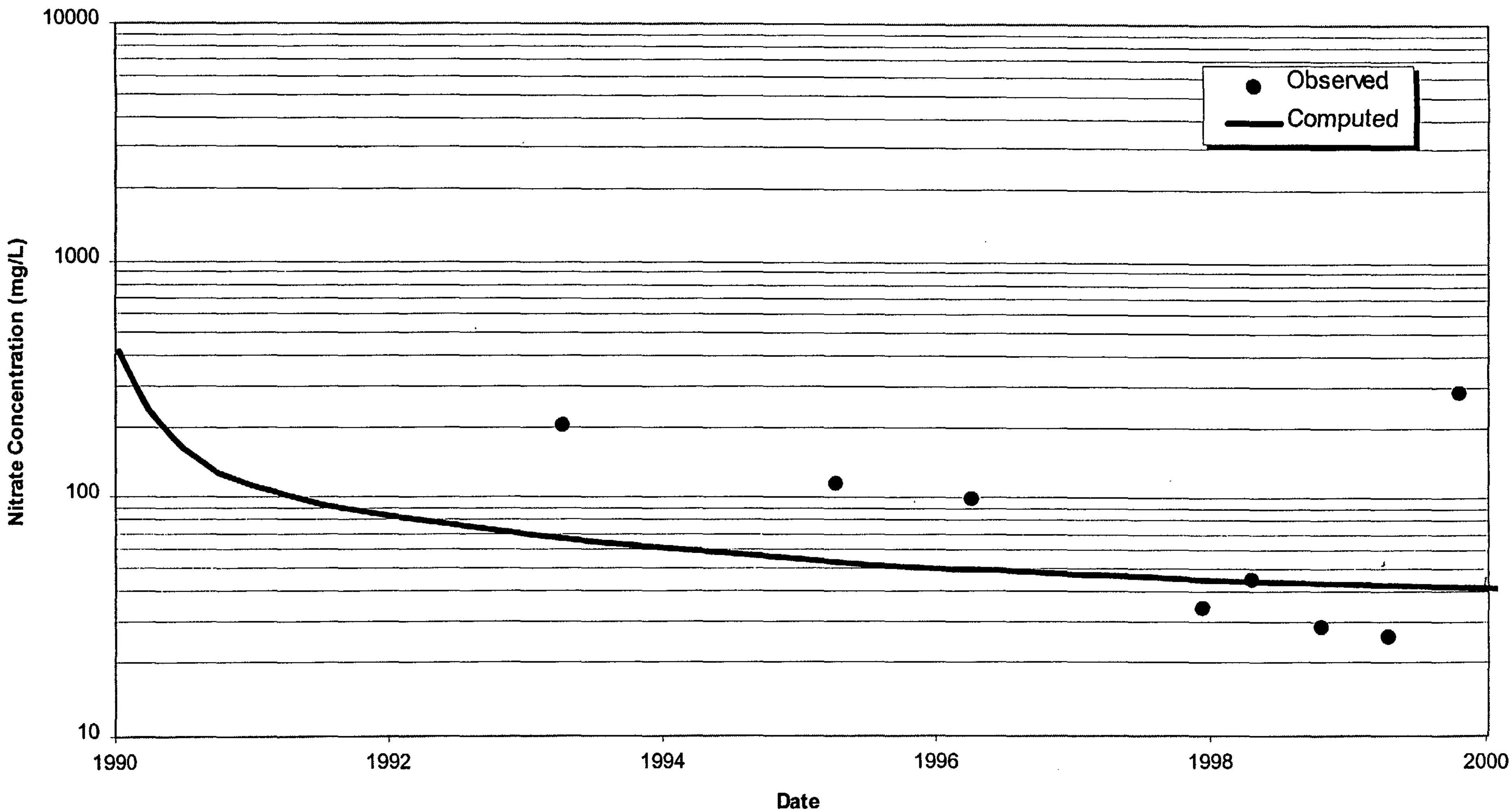


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW055

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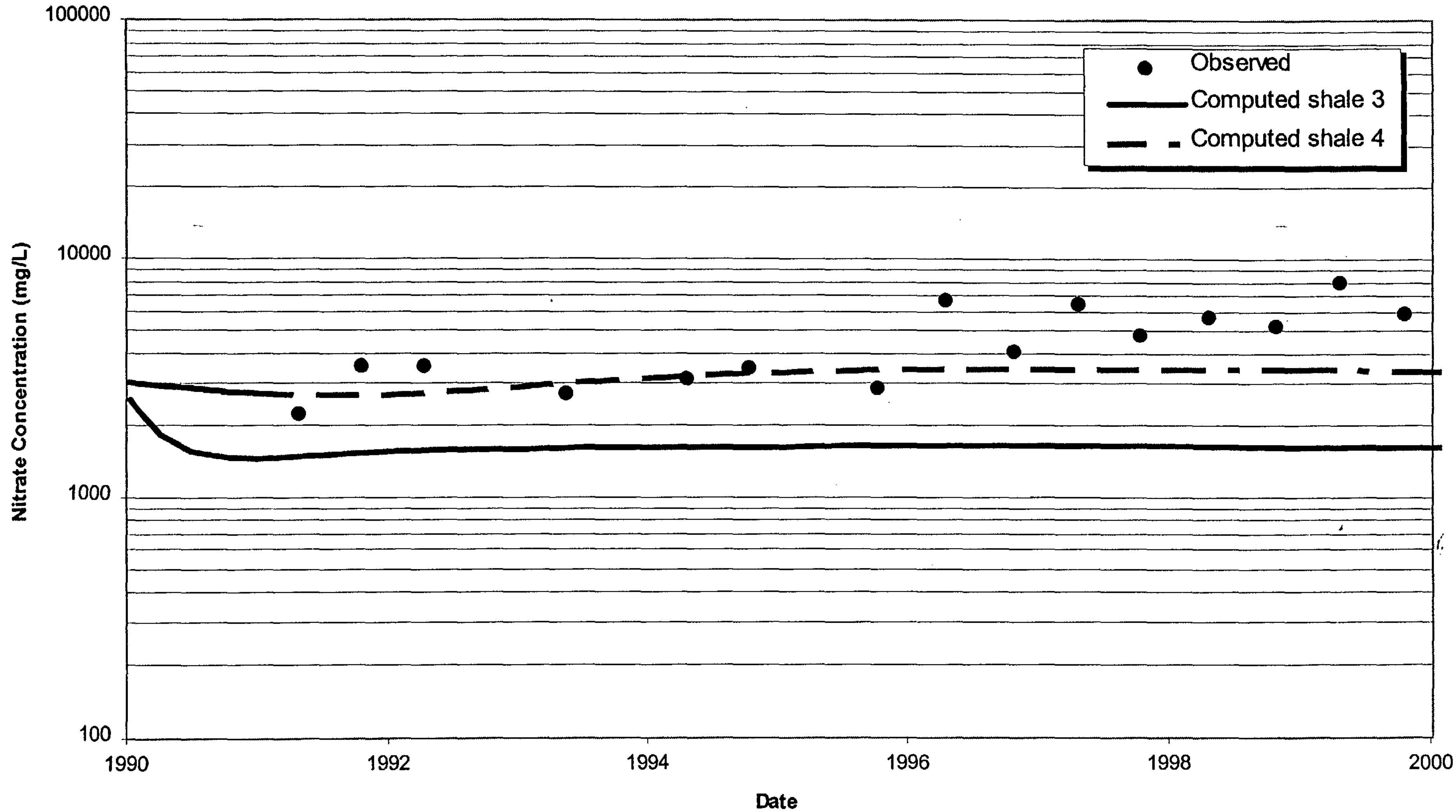


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW057A

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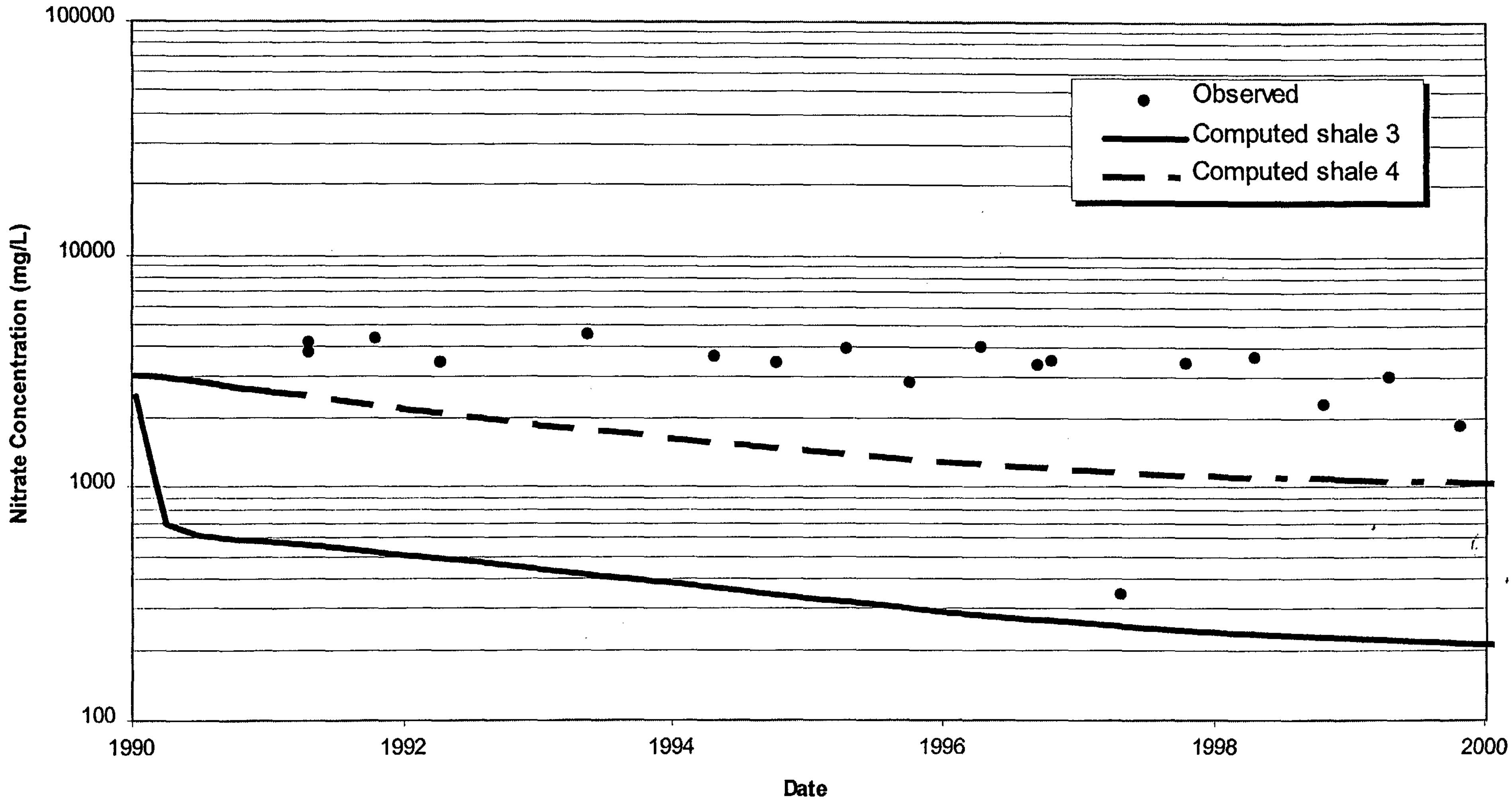


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW058A

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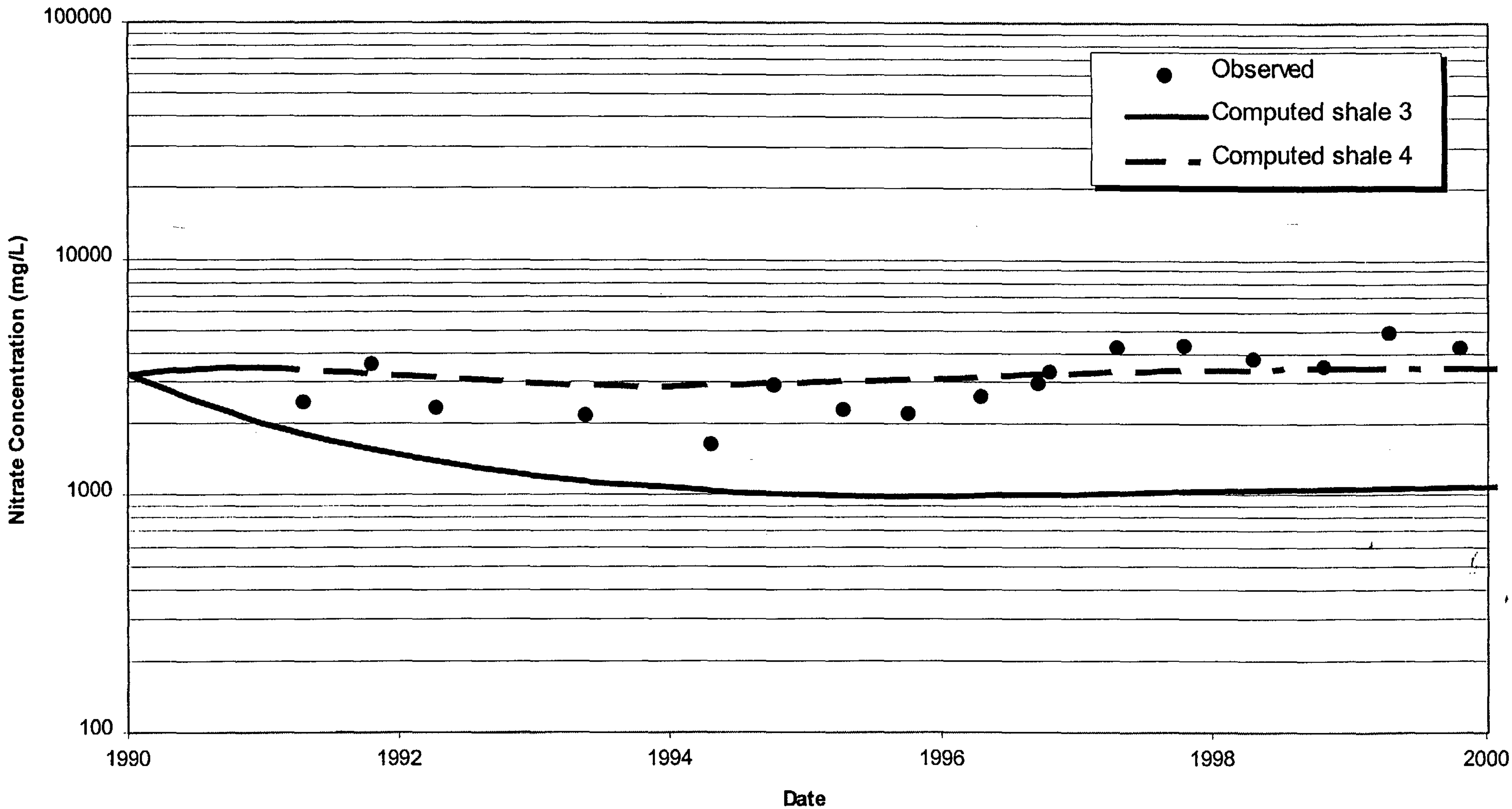


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW059A

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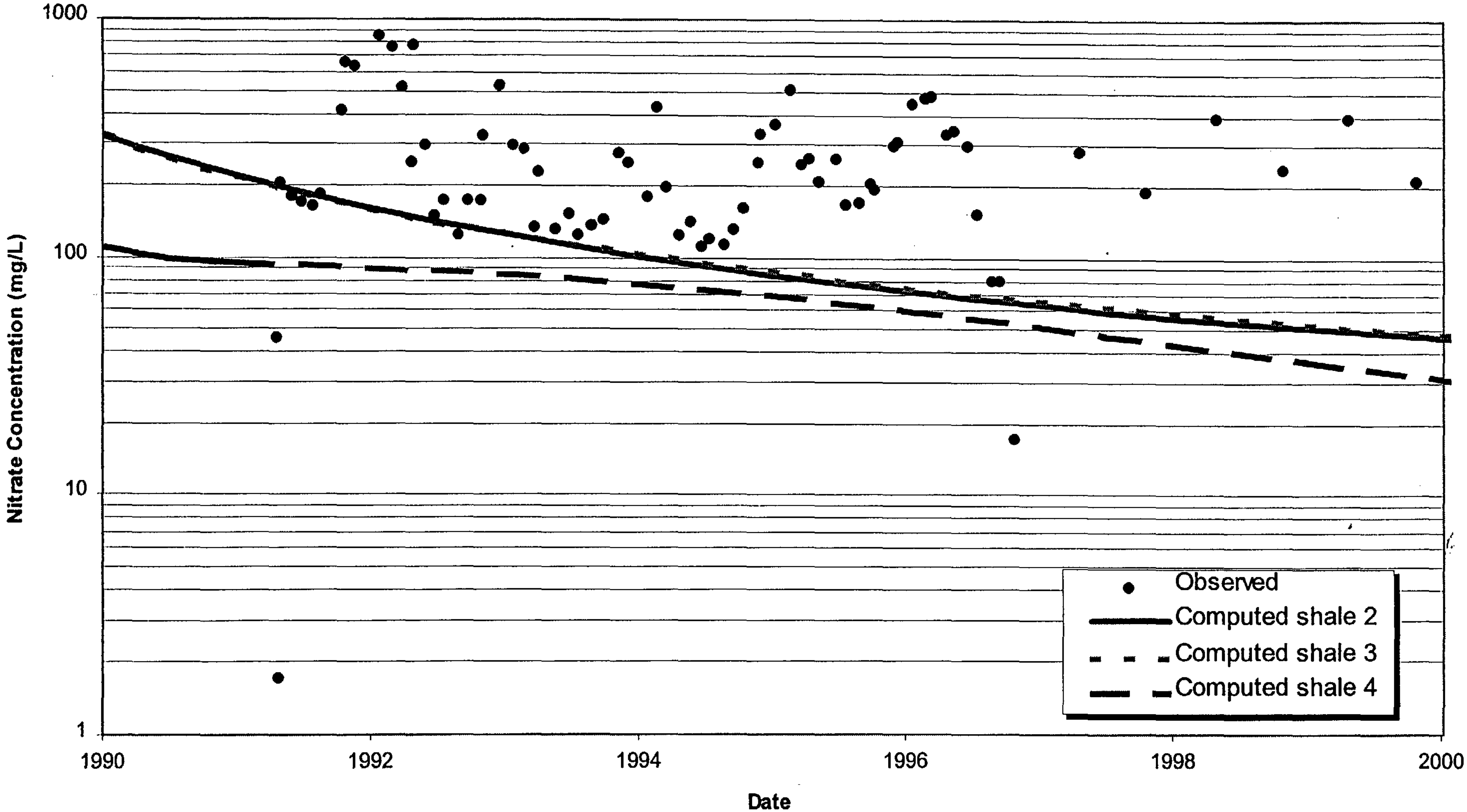


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW082A

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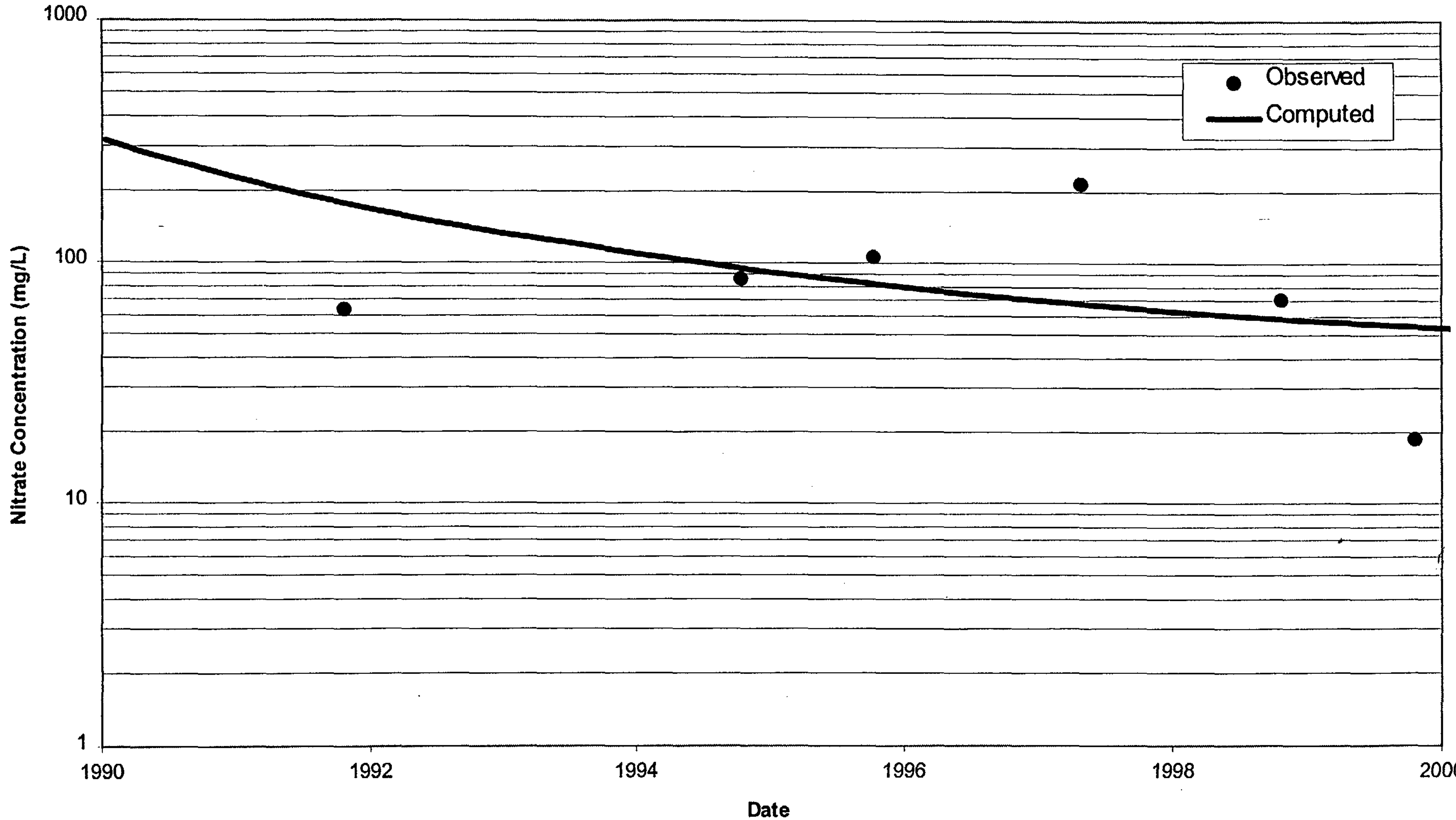


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW082

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Project: P:\100734-2\REV CHAR RPT

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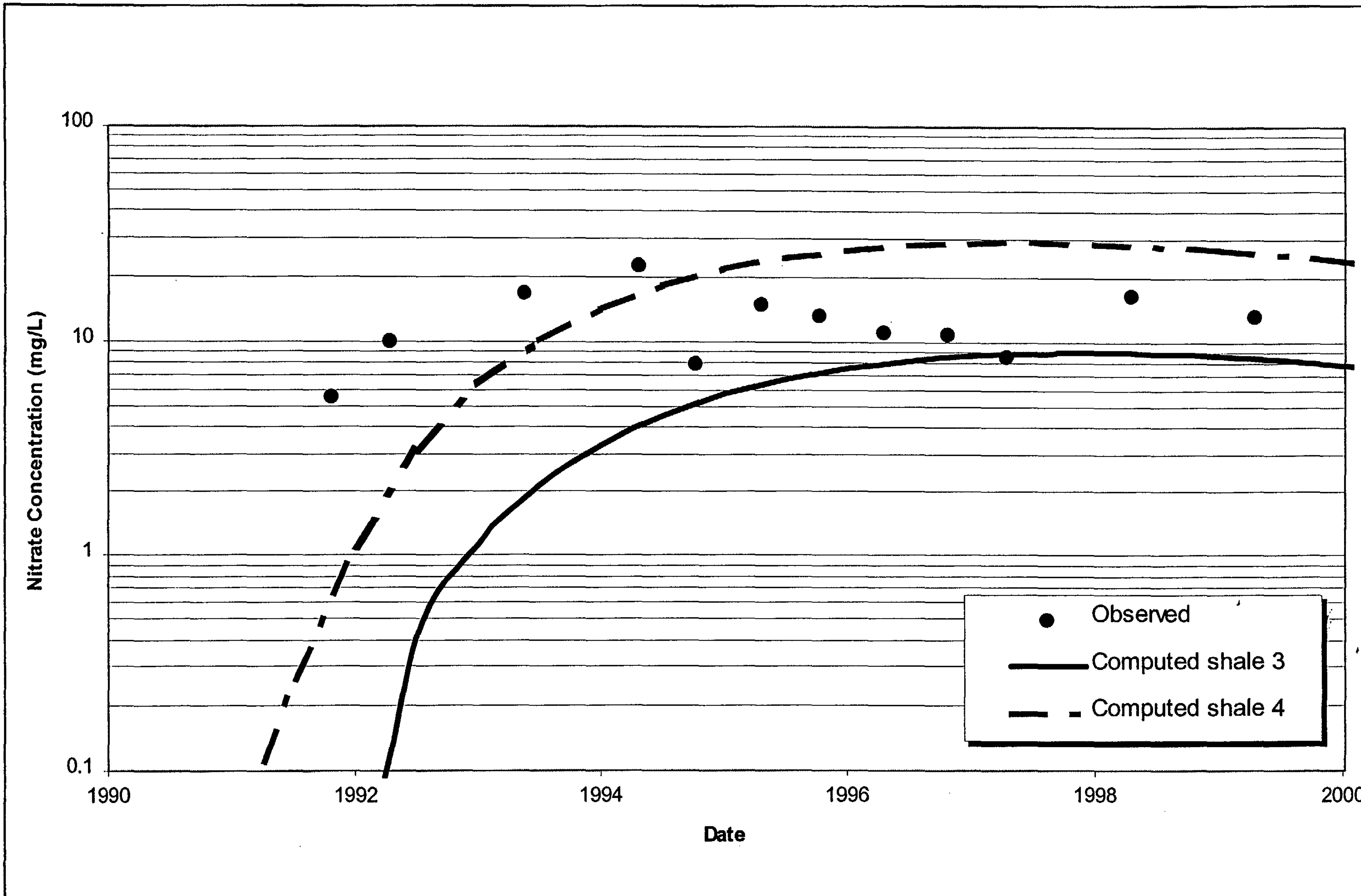


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW094A

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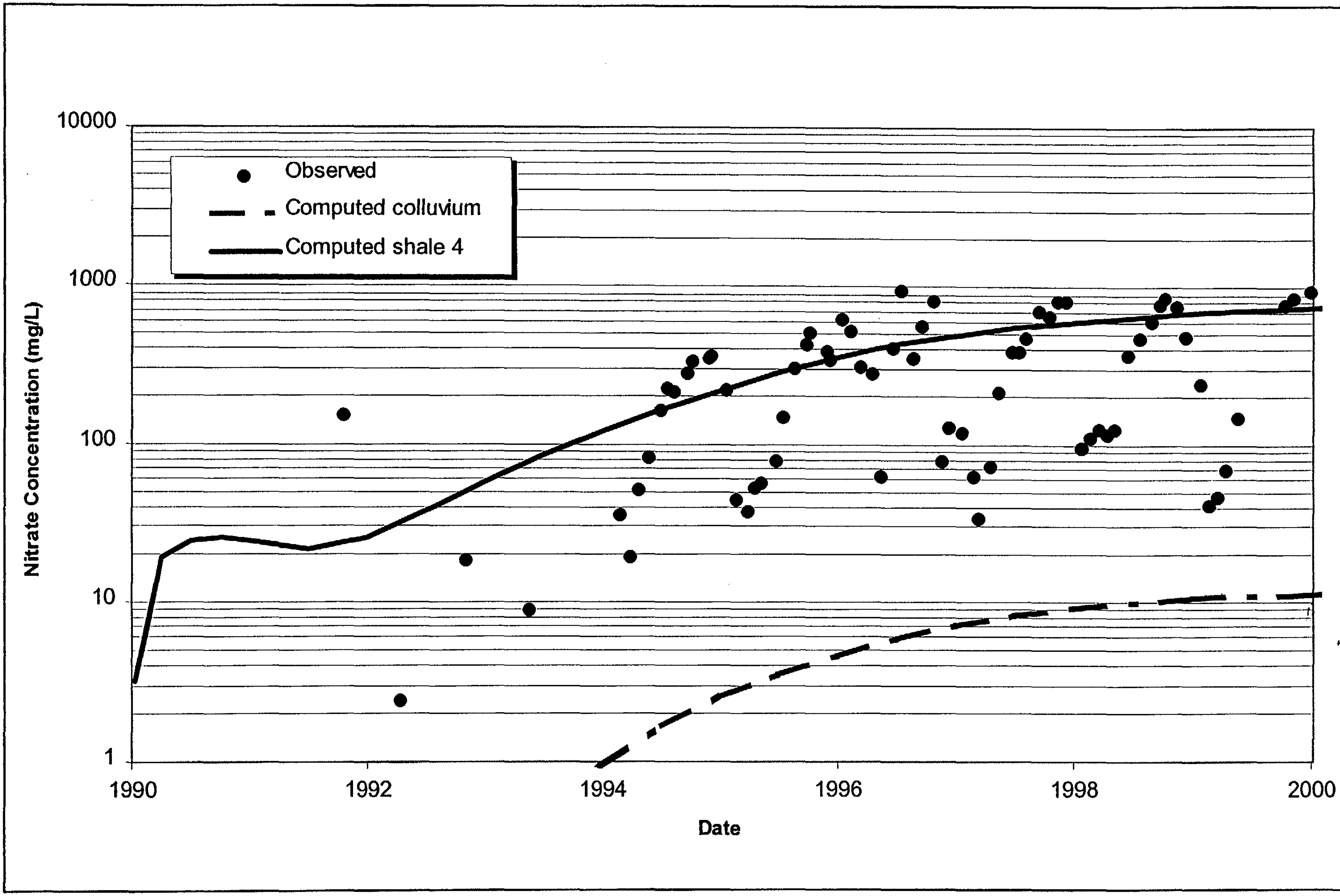


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW095A

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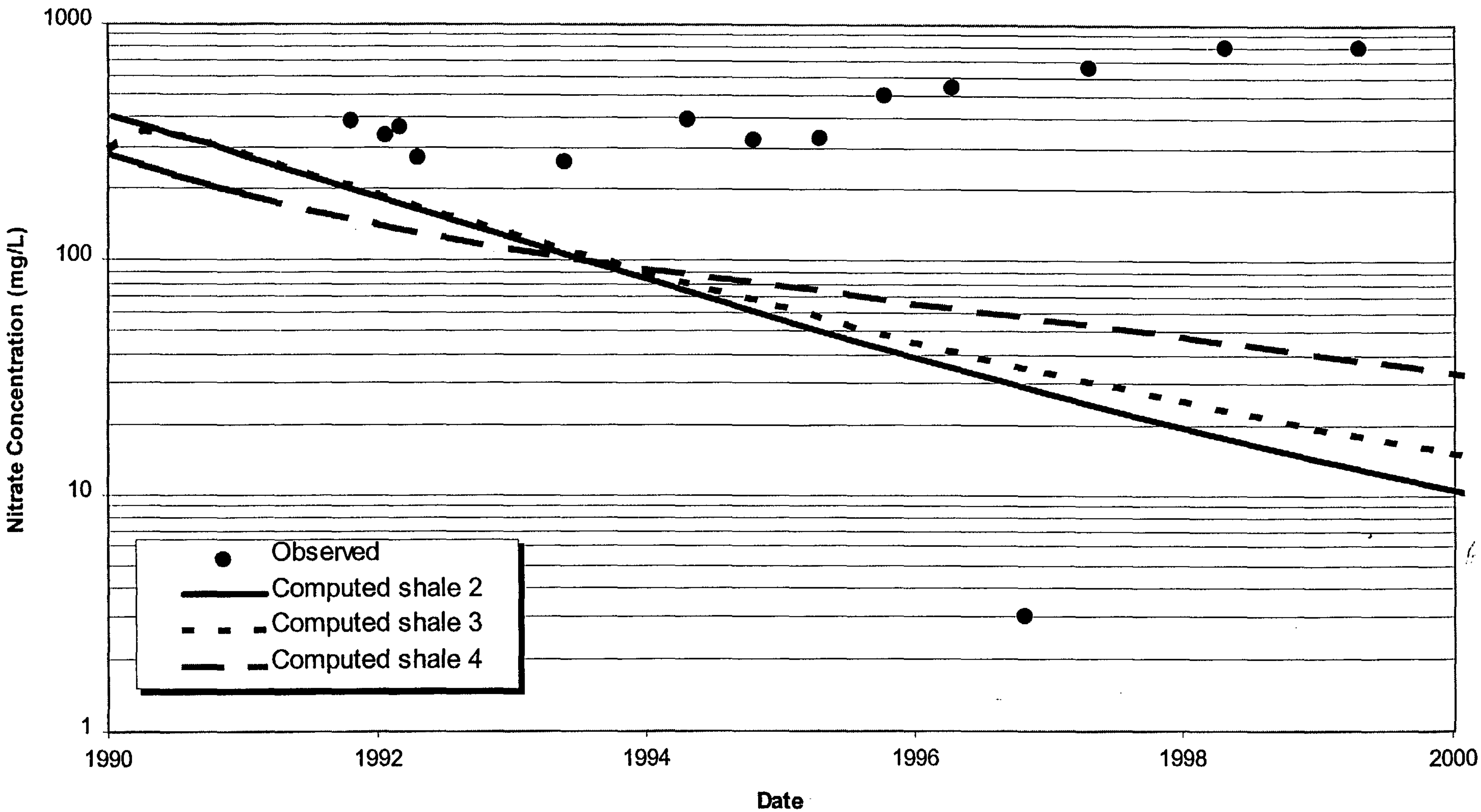


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW103A

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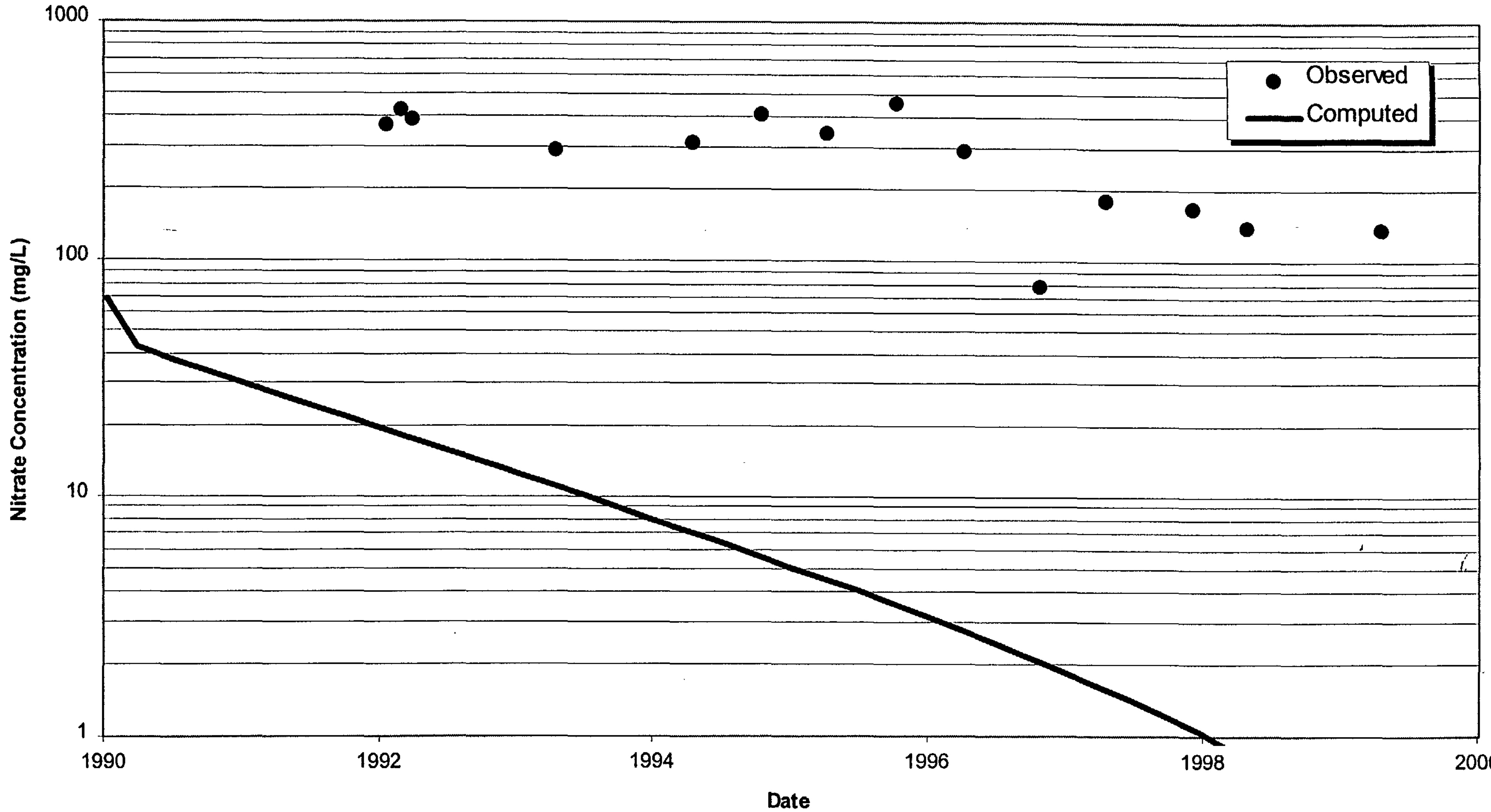


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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW103

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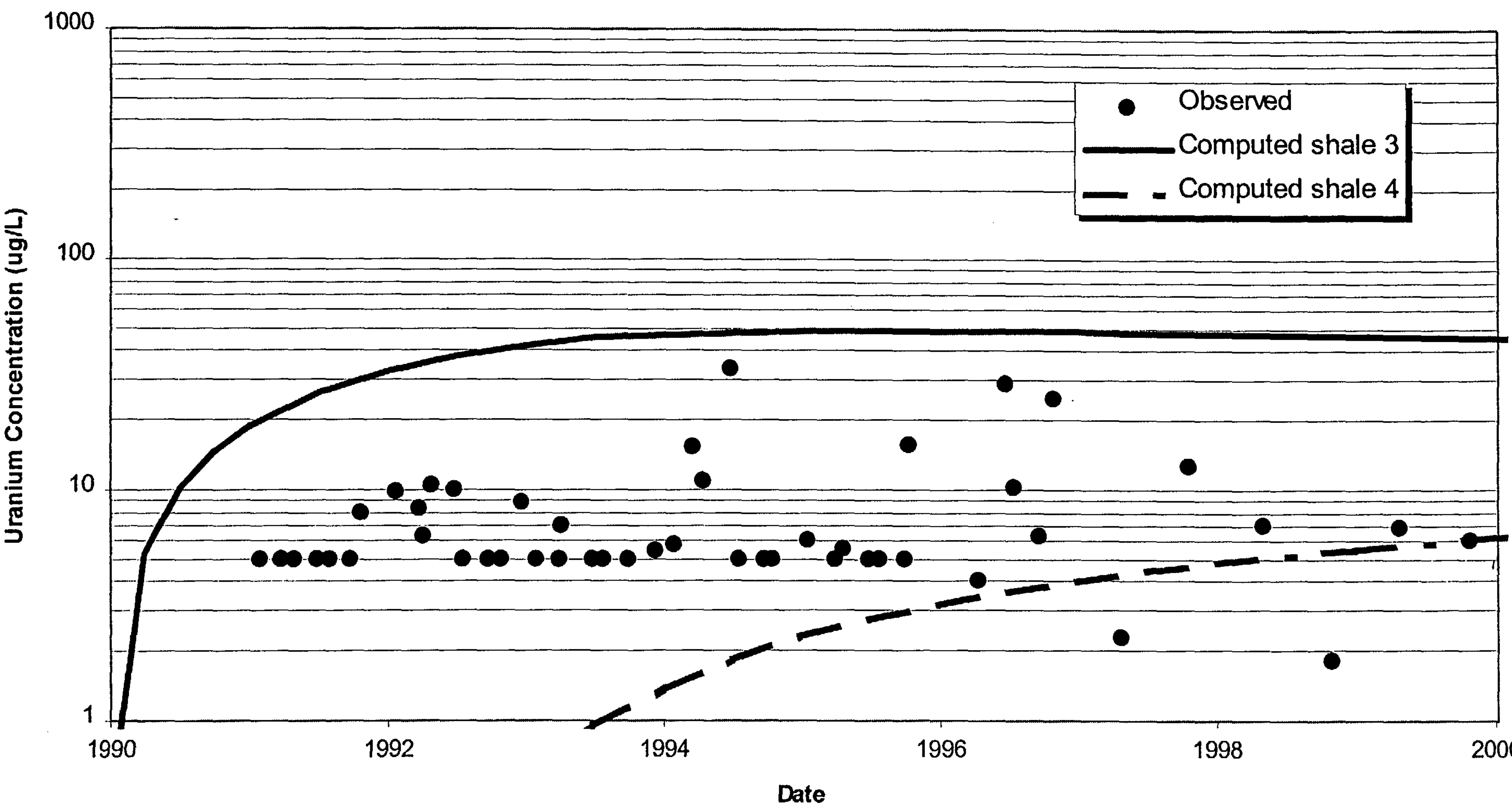


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL 2301A

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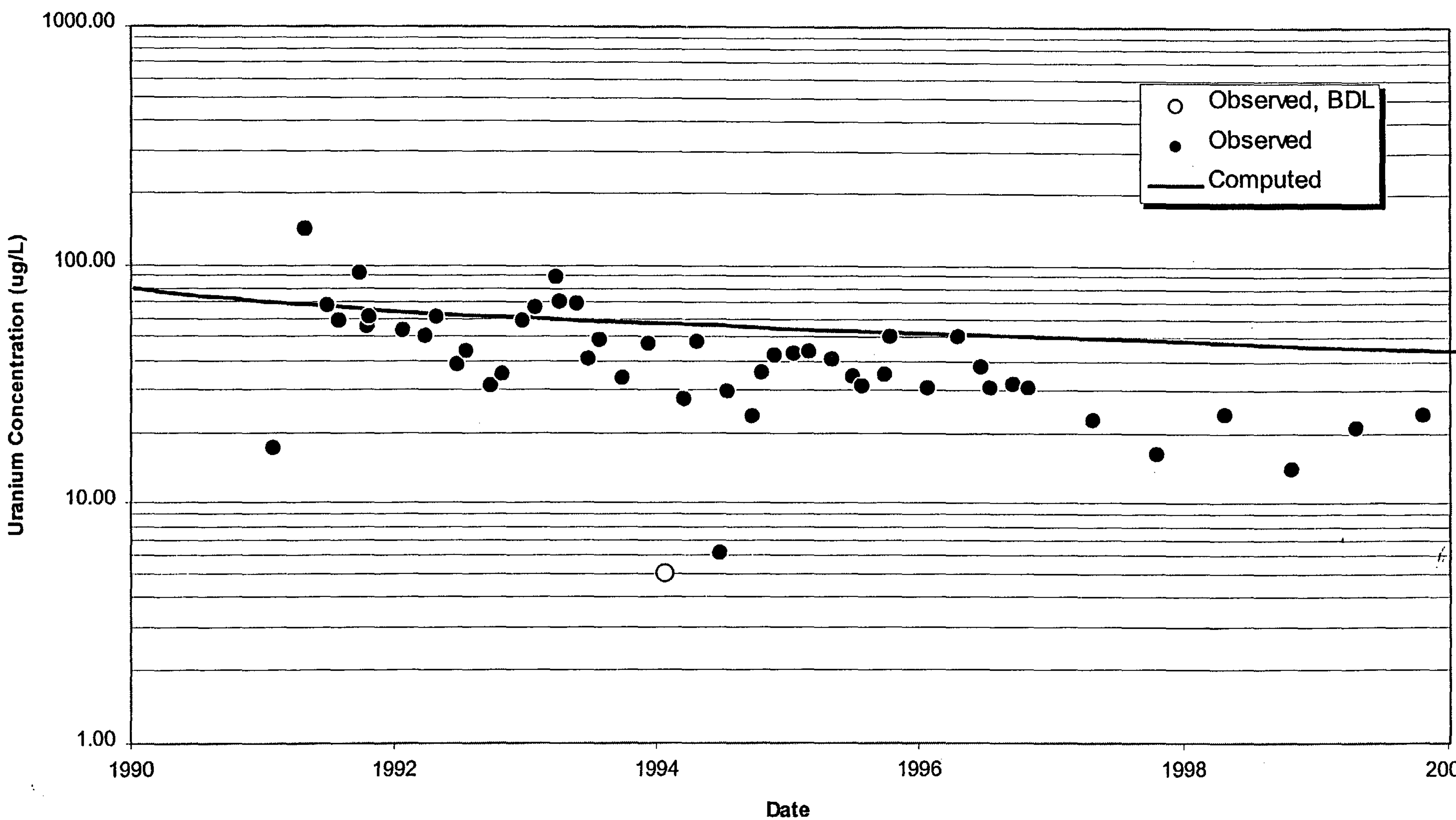


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL 2301B

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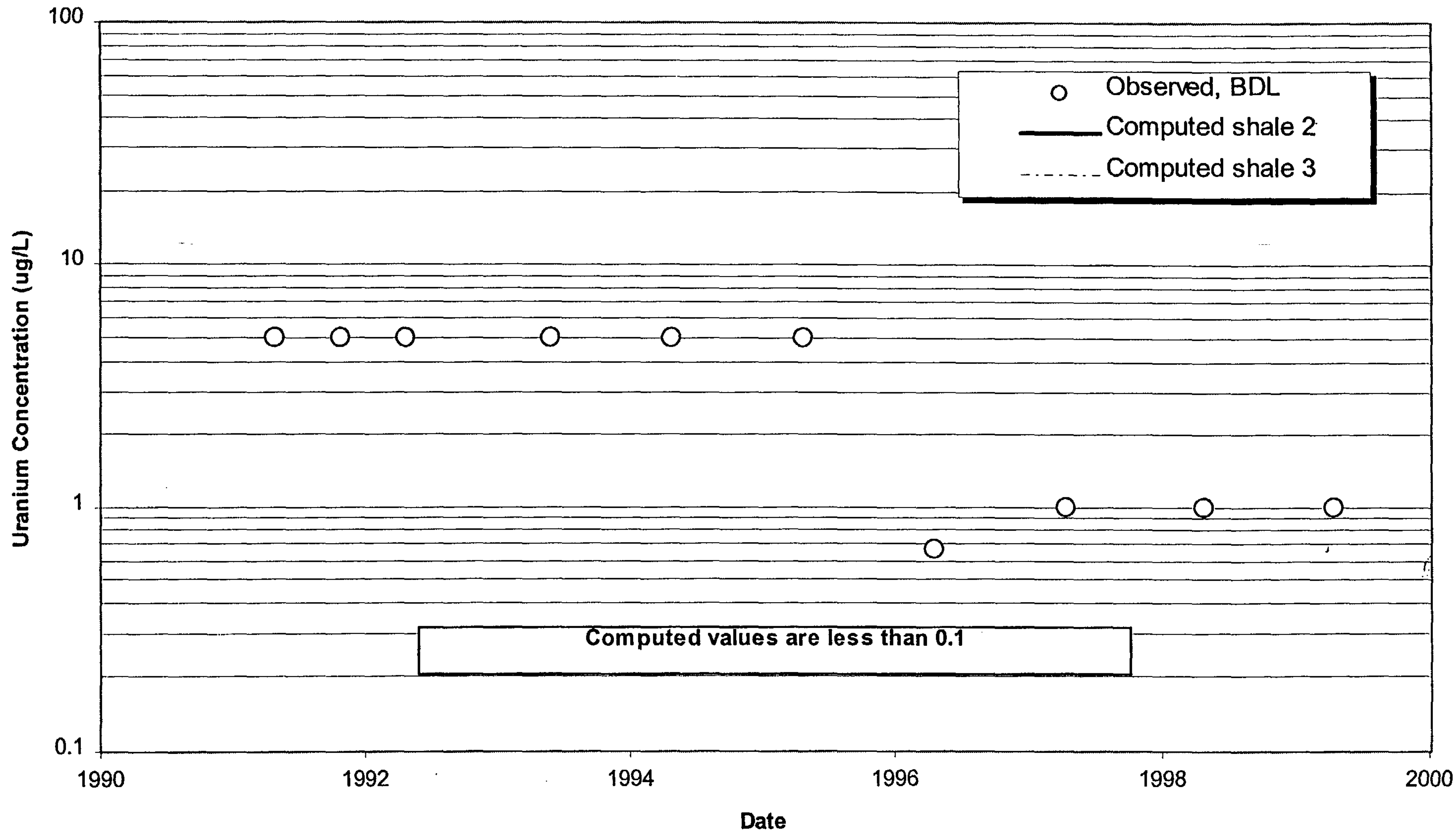


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW003A

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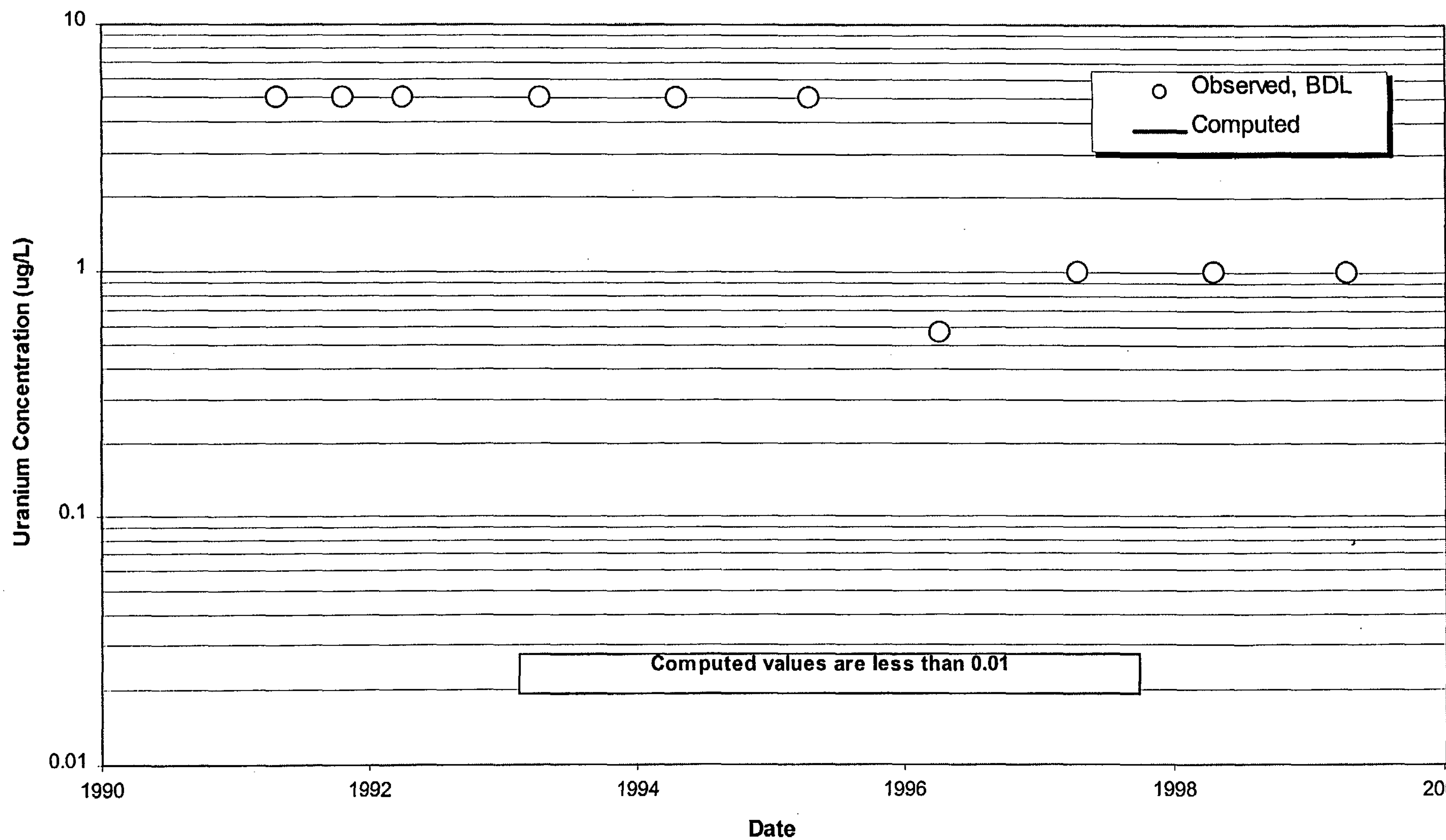


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW003

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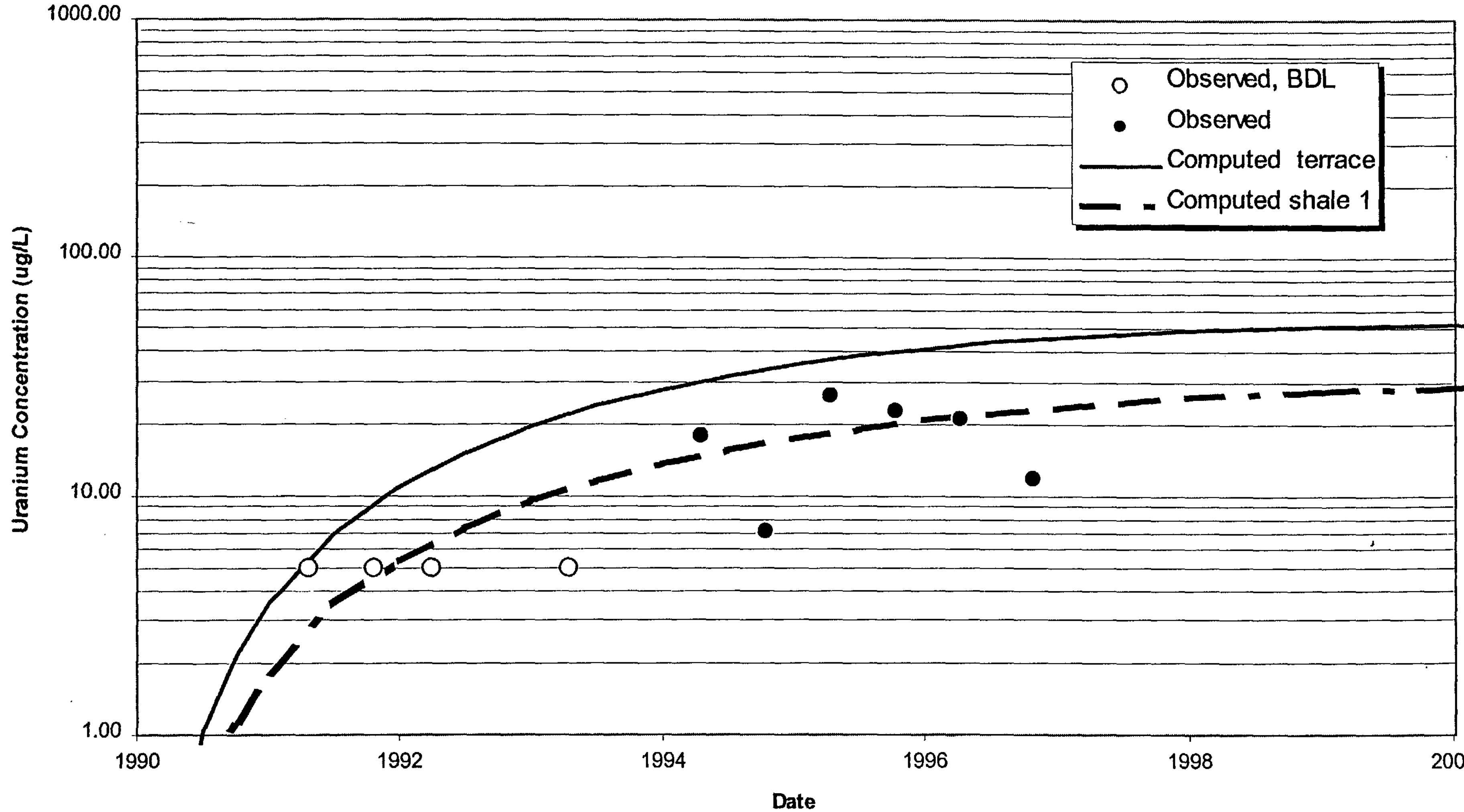


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW009

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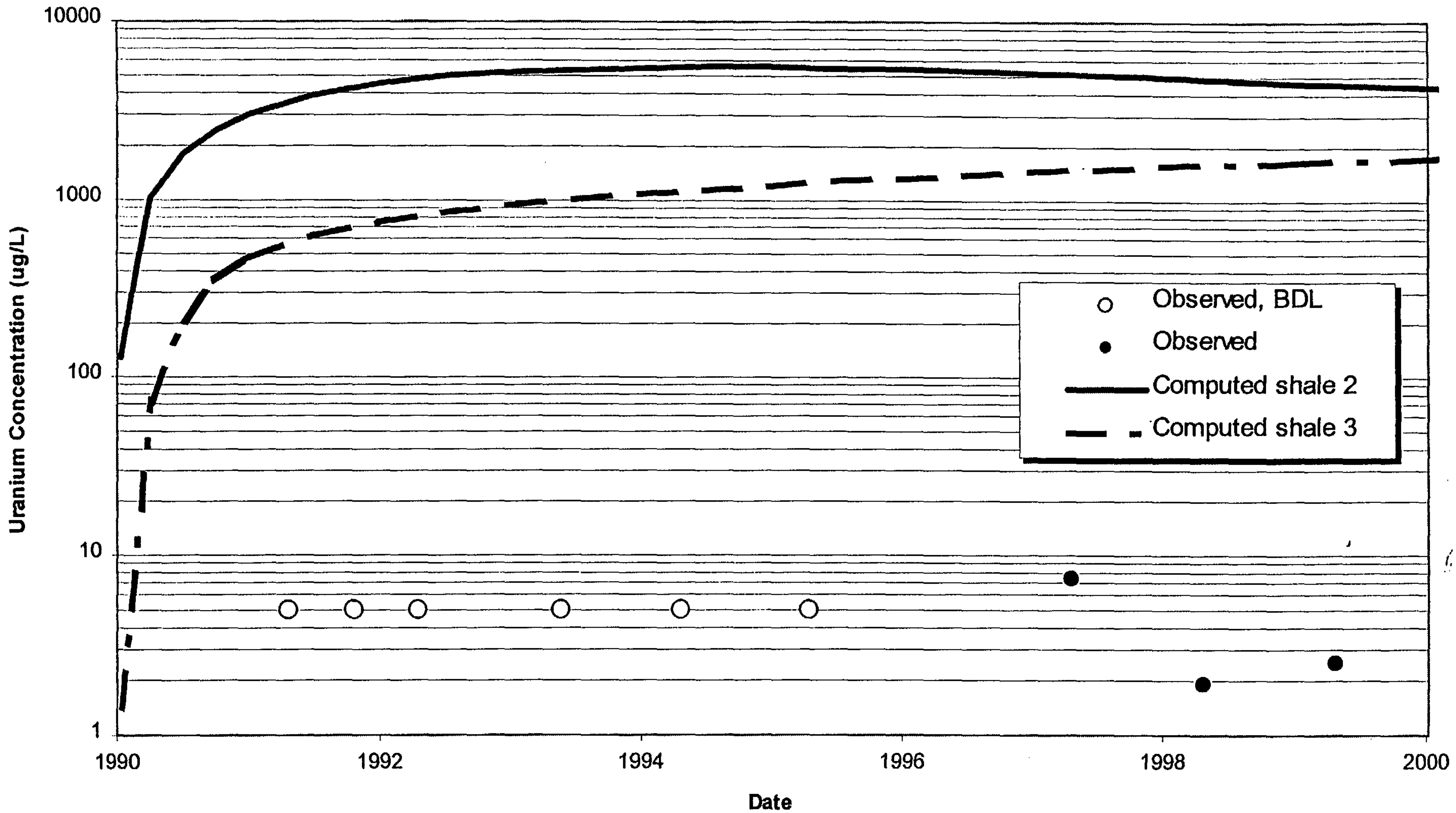


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW010A

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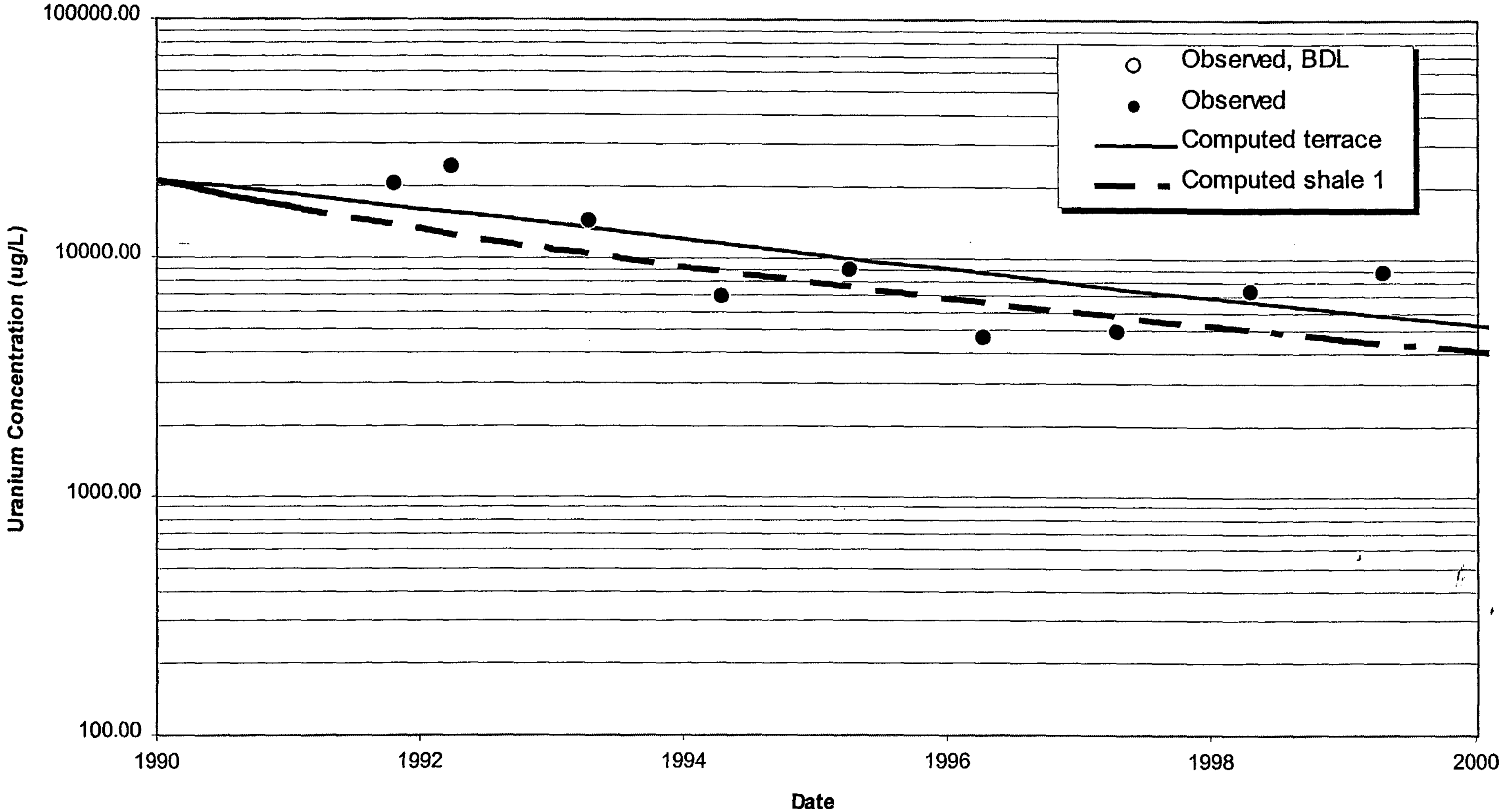


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW010

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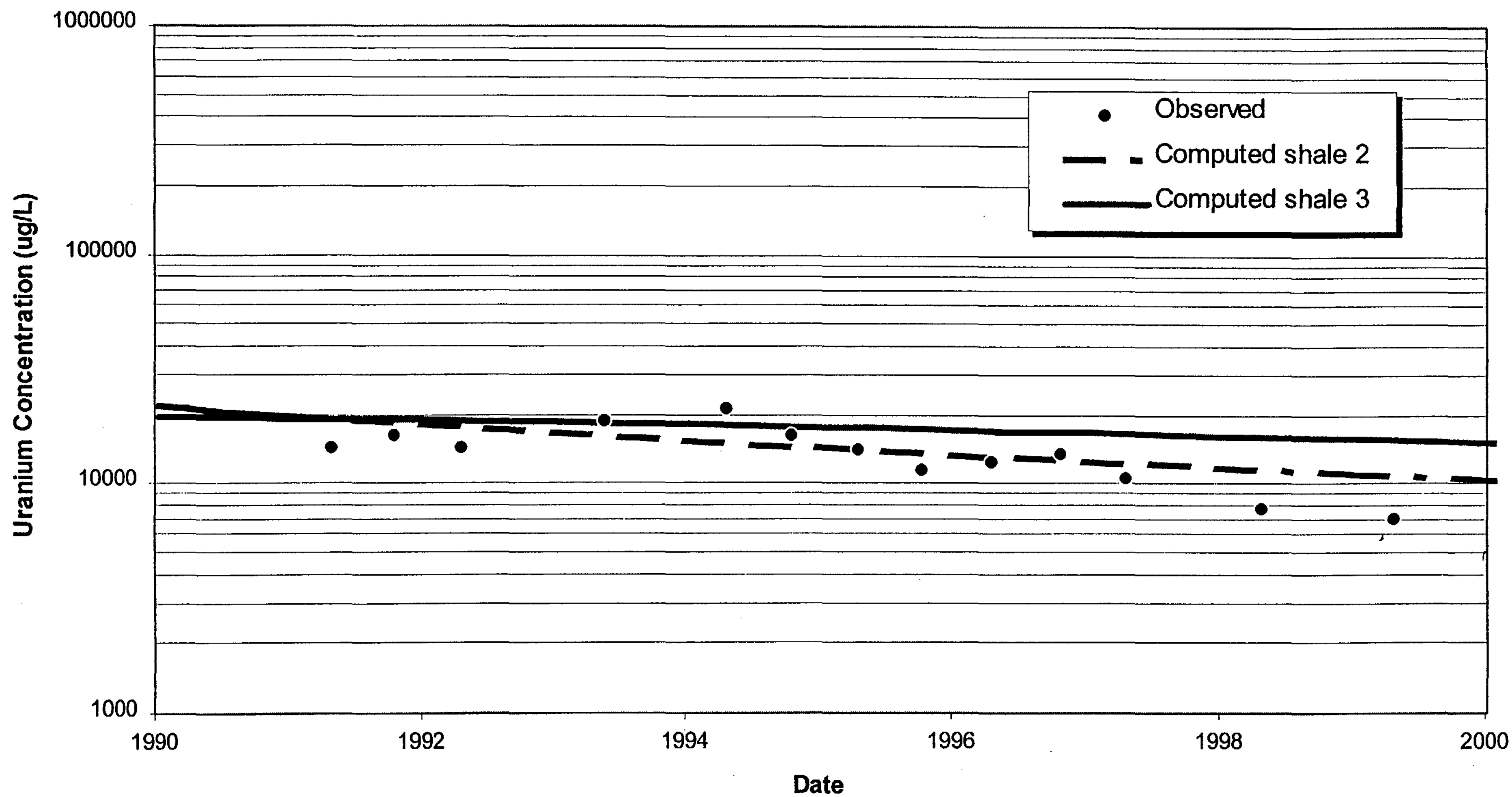


| | | |
|---|---|---|
| MFG consulting scientists and engineers | FIGURE<br>URANIUM TRANSPORT CALIBRATION FOR WELL MW012A | Date: AUGUST 2002<br>Project: V:\Titleblocks\<br>File: MFG TBLK LAND.ppt |

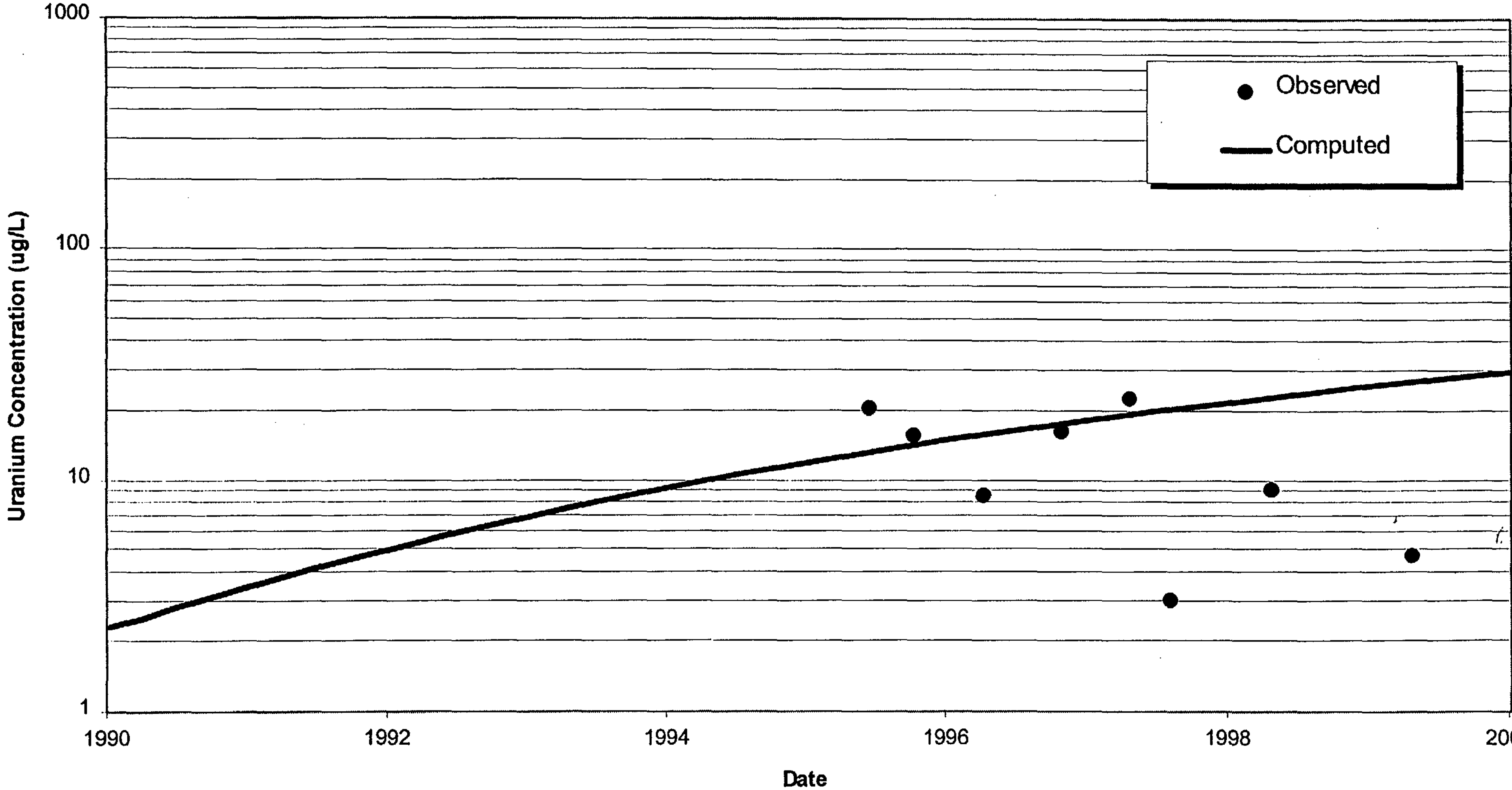


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW012B

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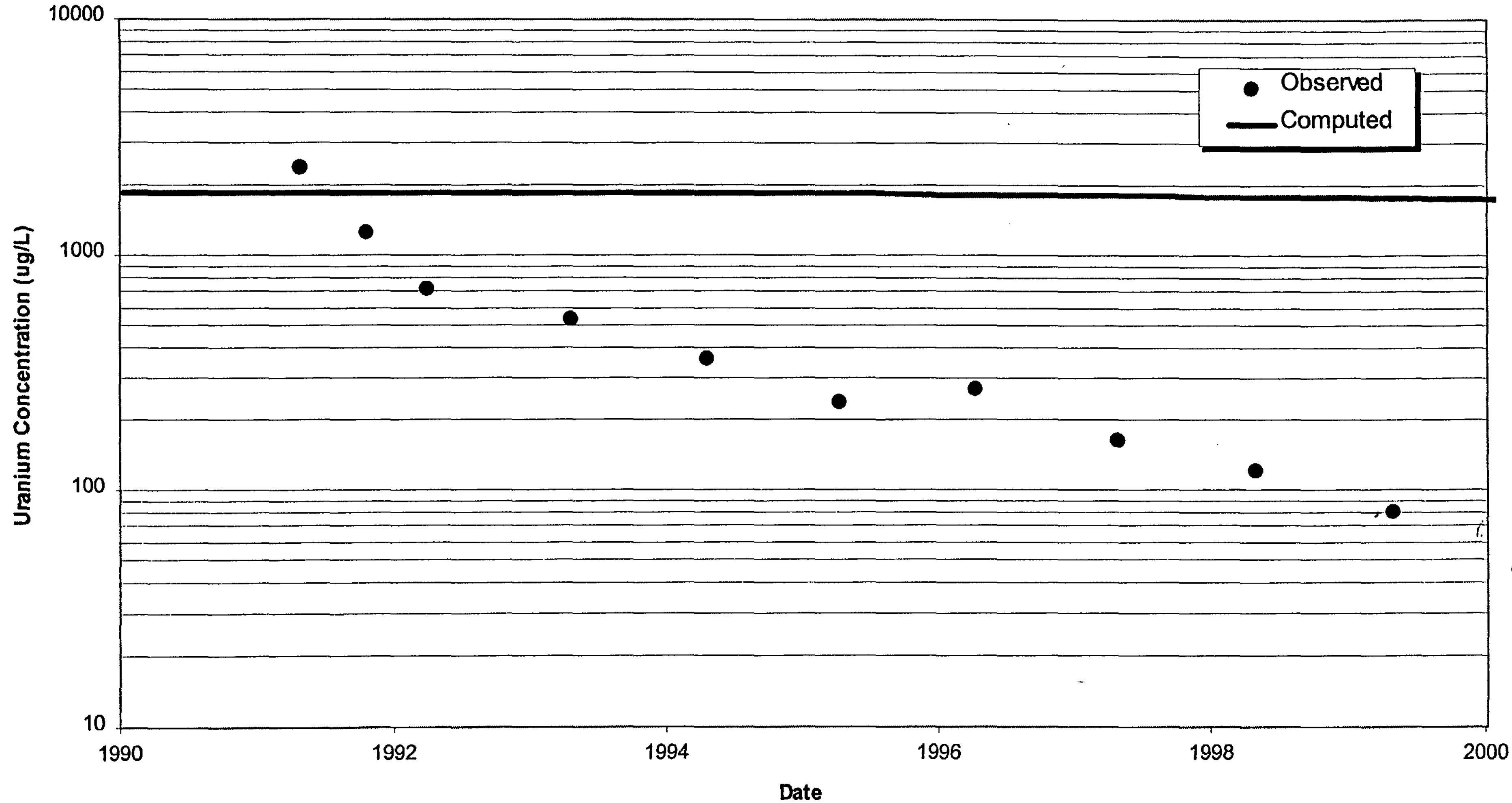


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW012

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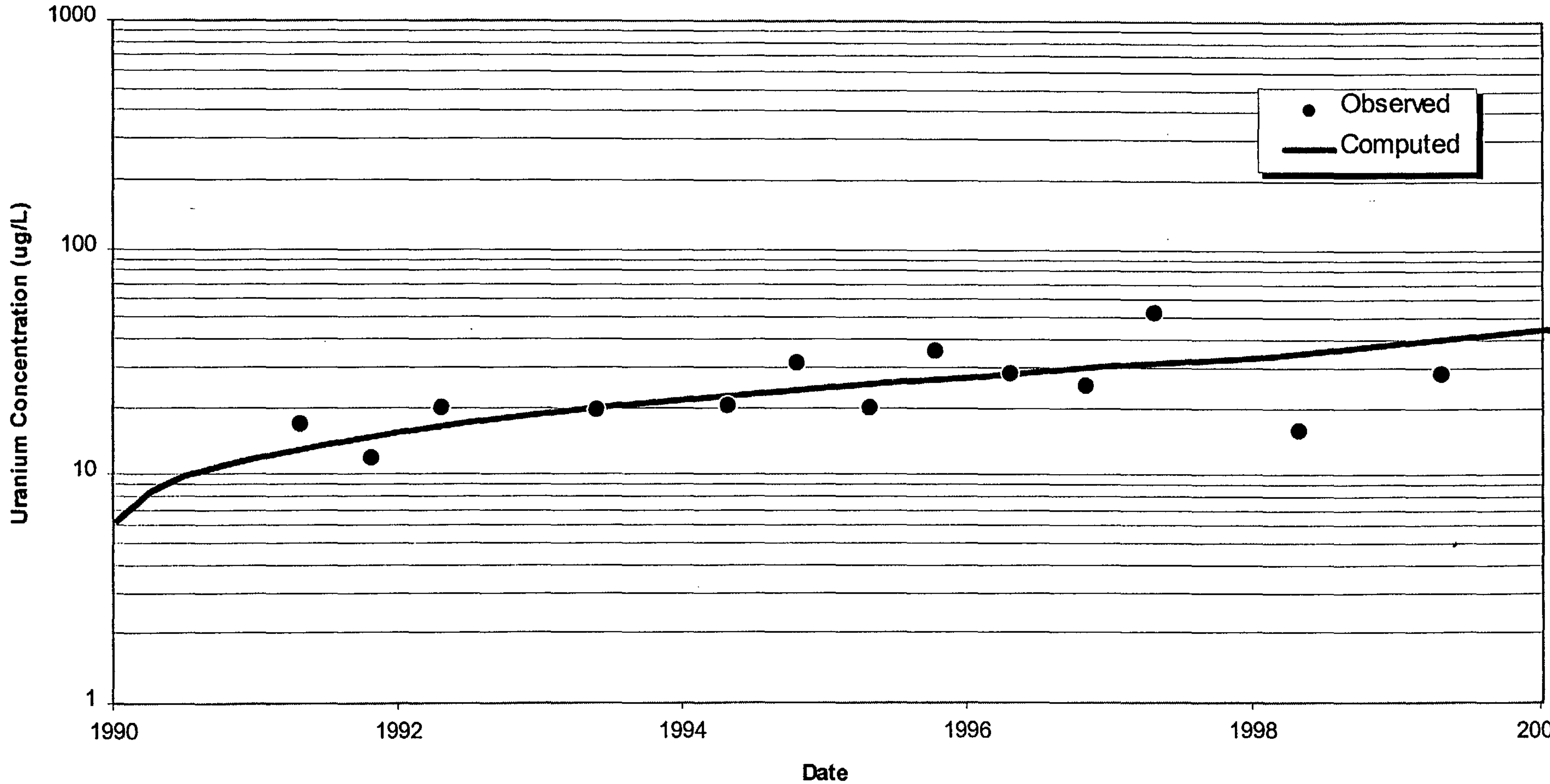


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW013A

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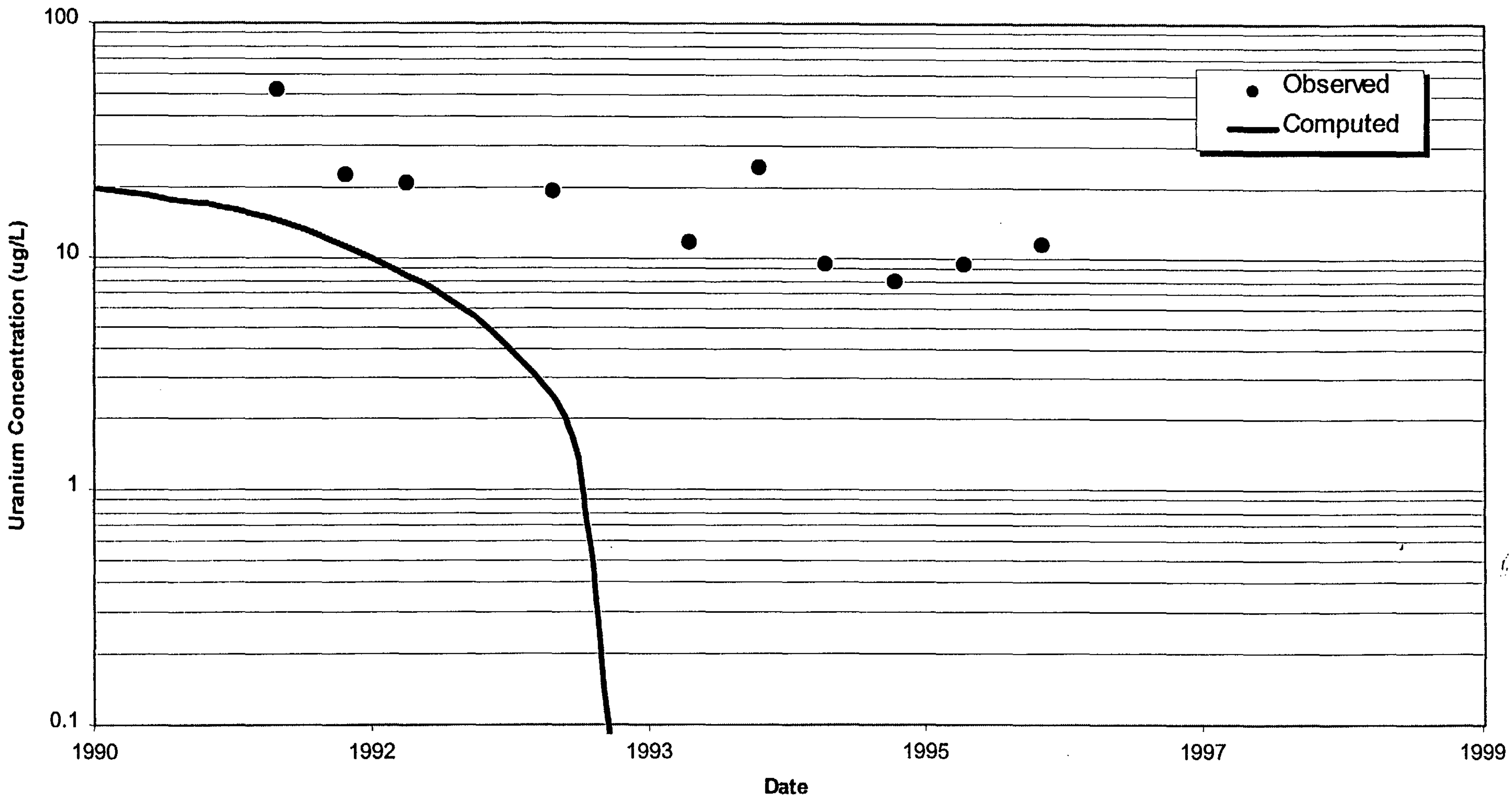


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW013

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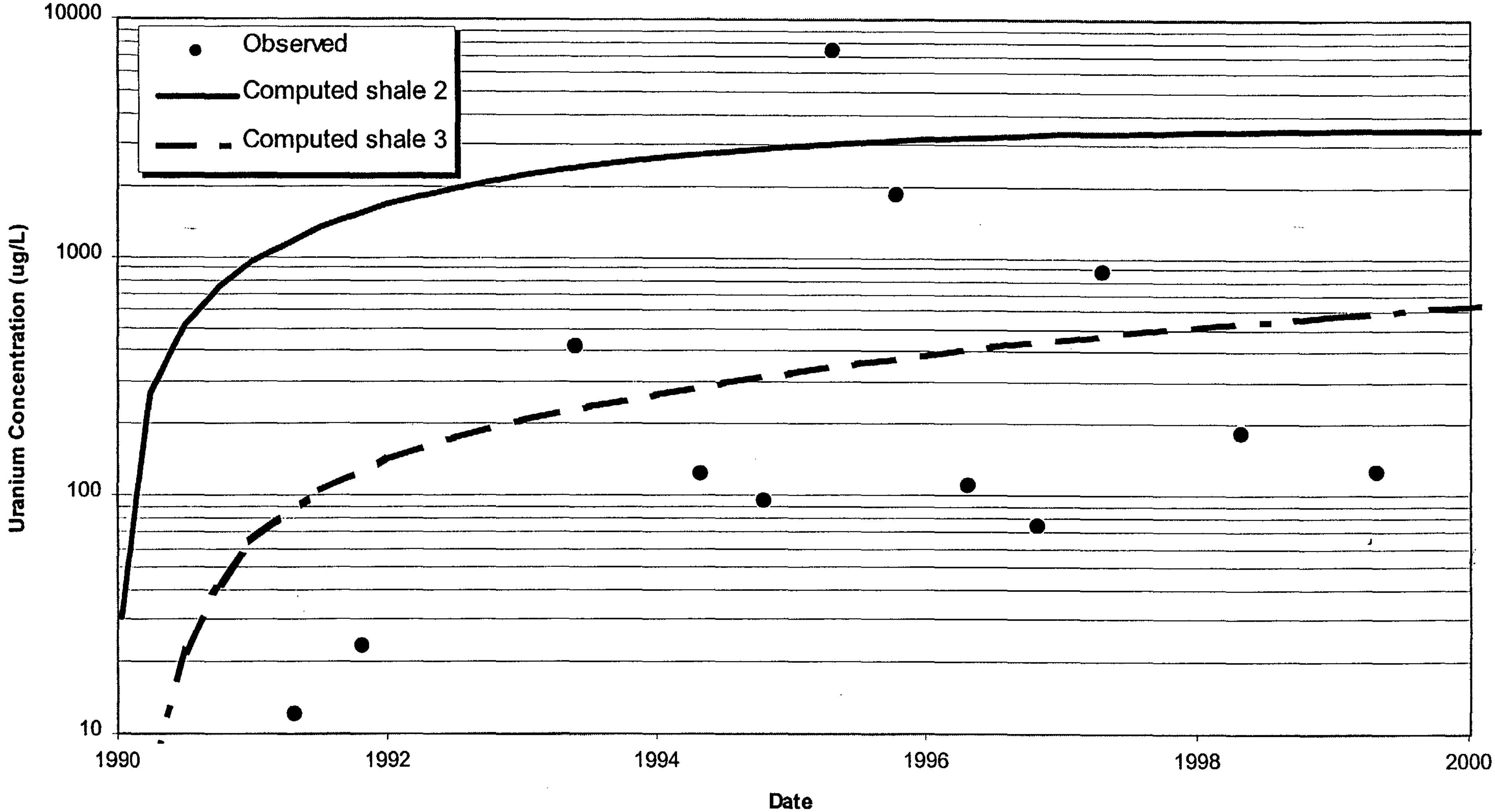


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW014A

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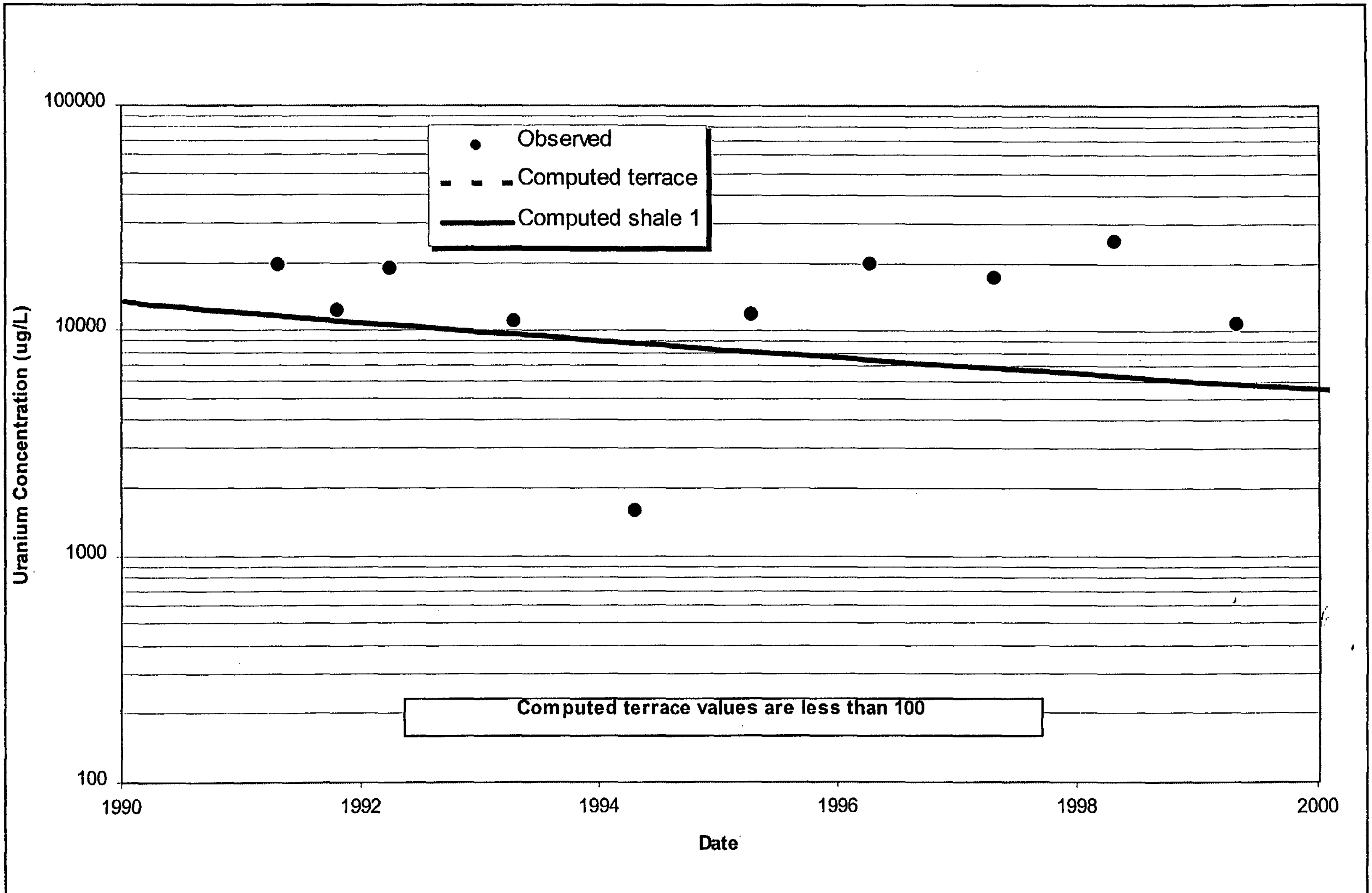


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW014

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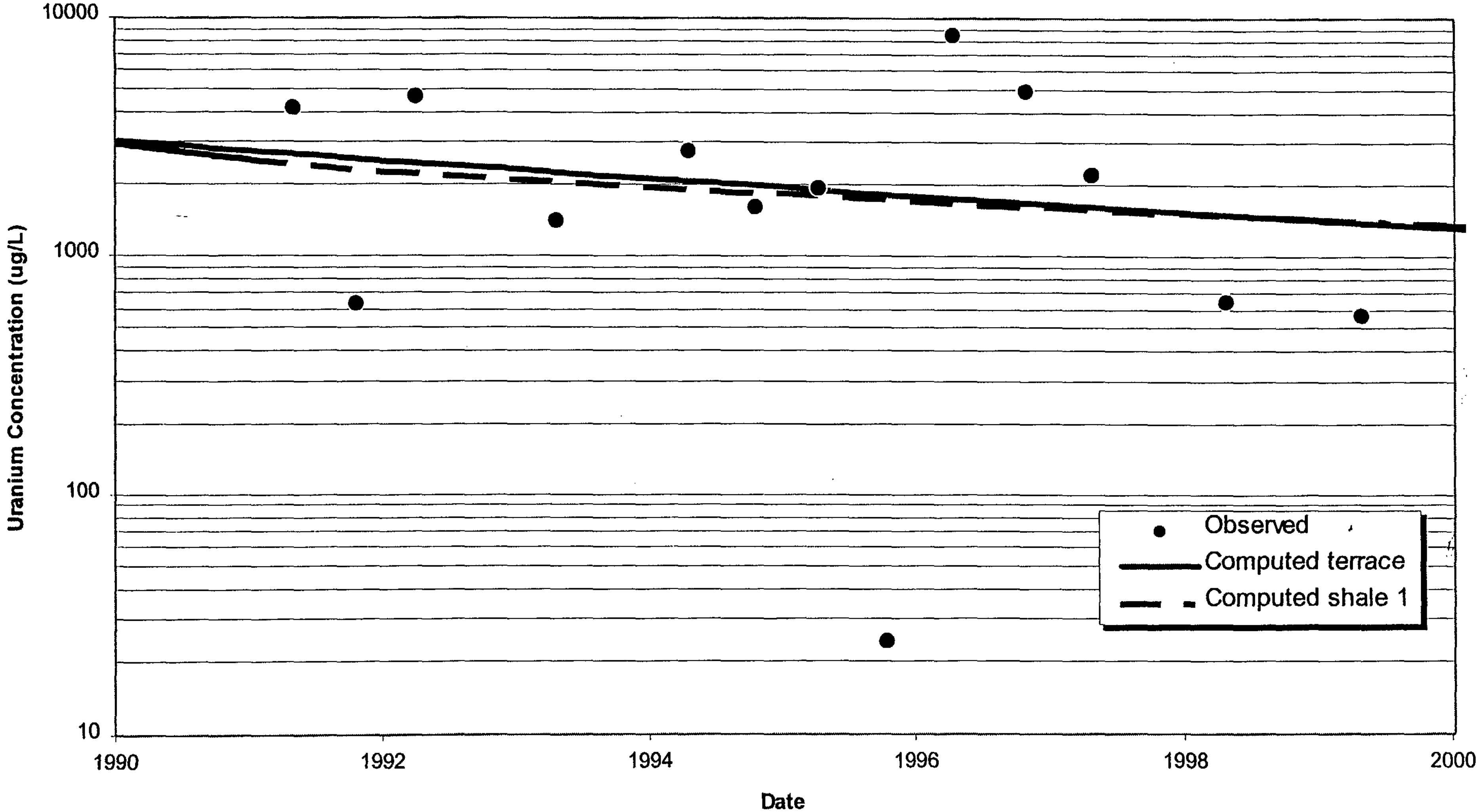


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW018

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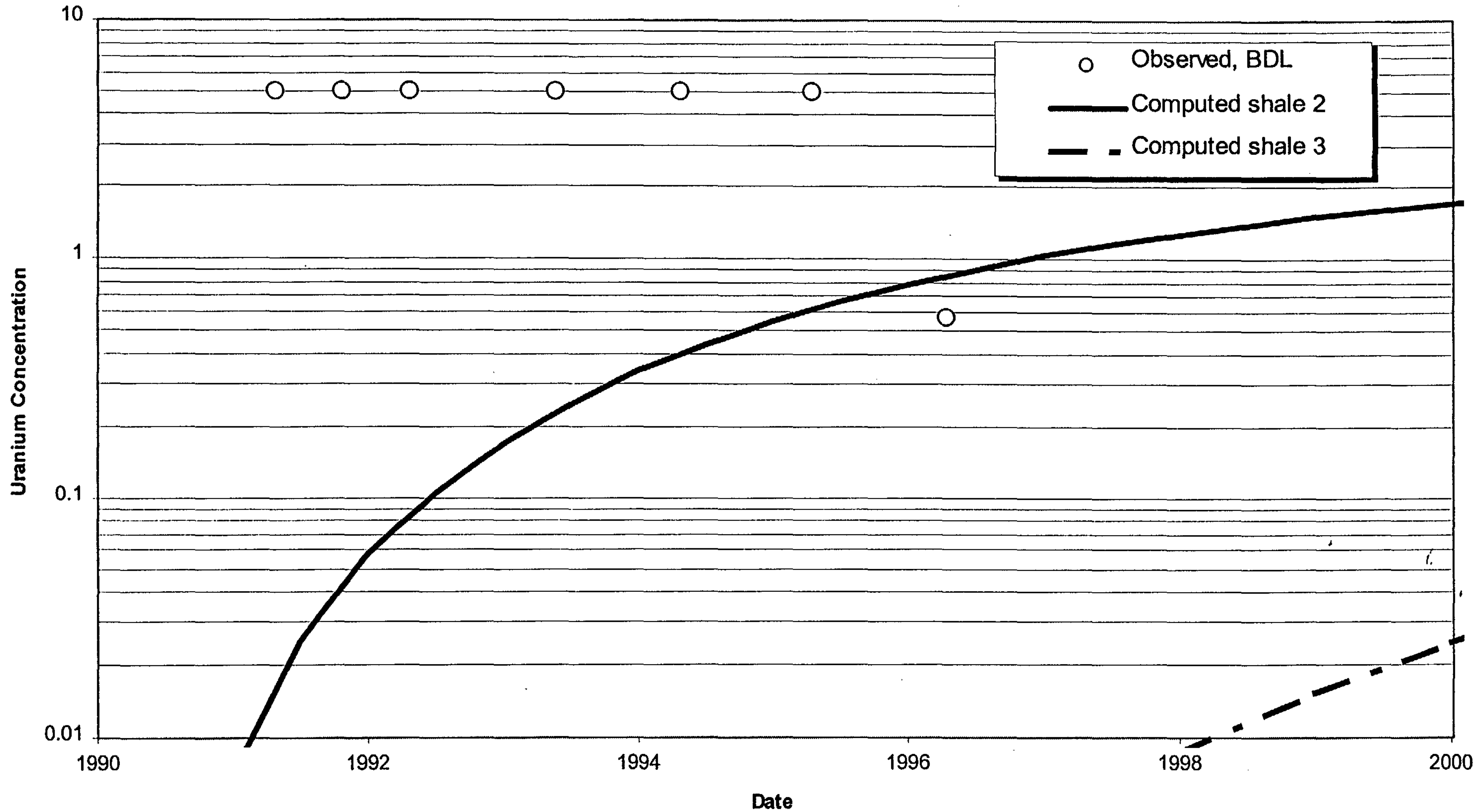


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW022A

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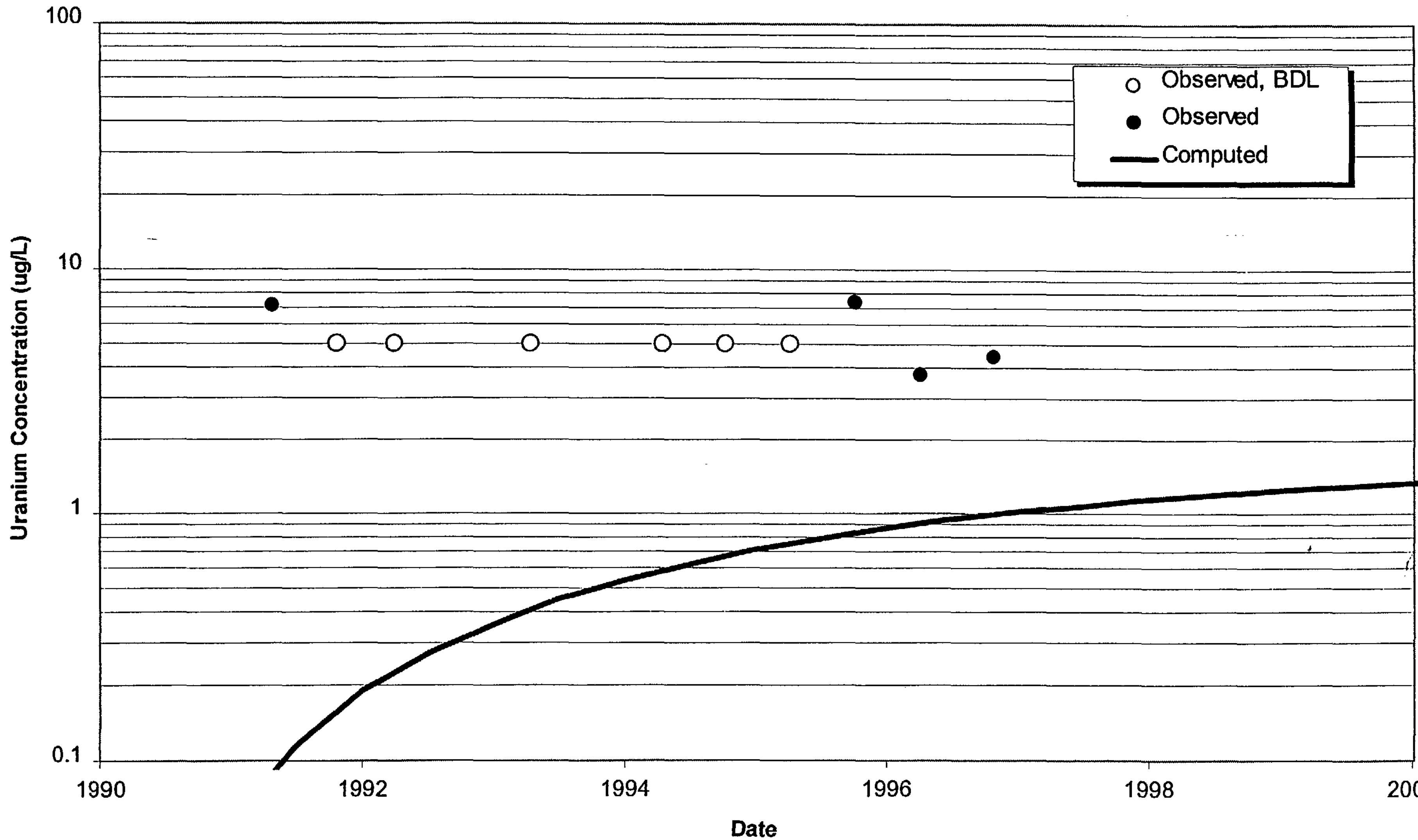


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW022

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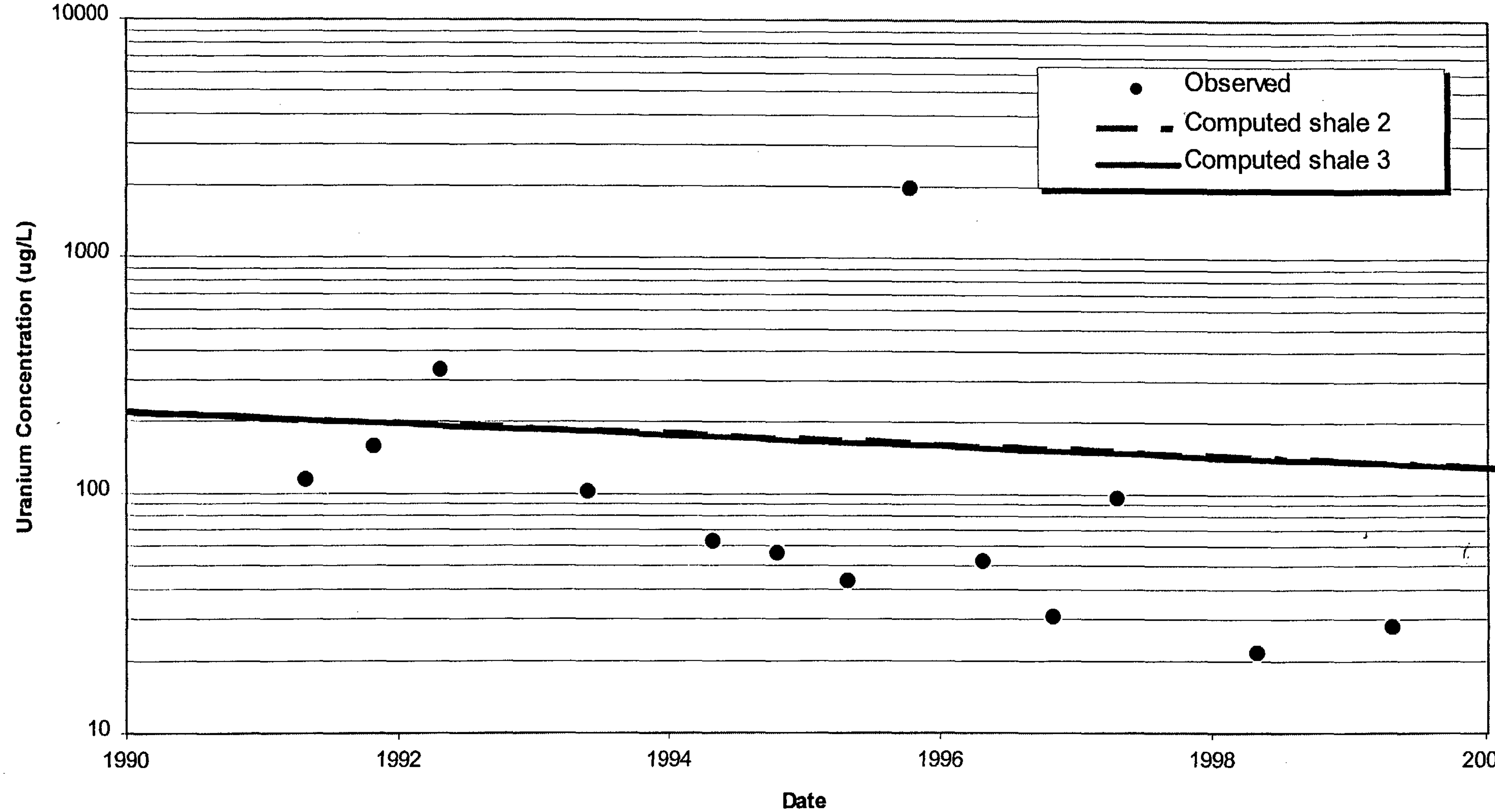


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW024A

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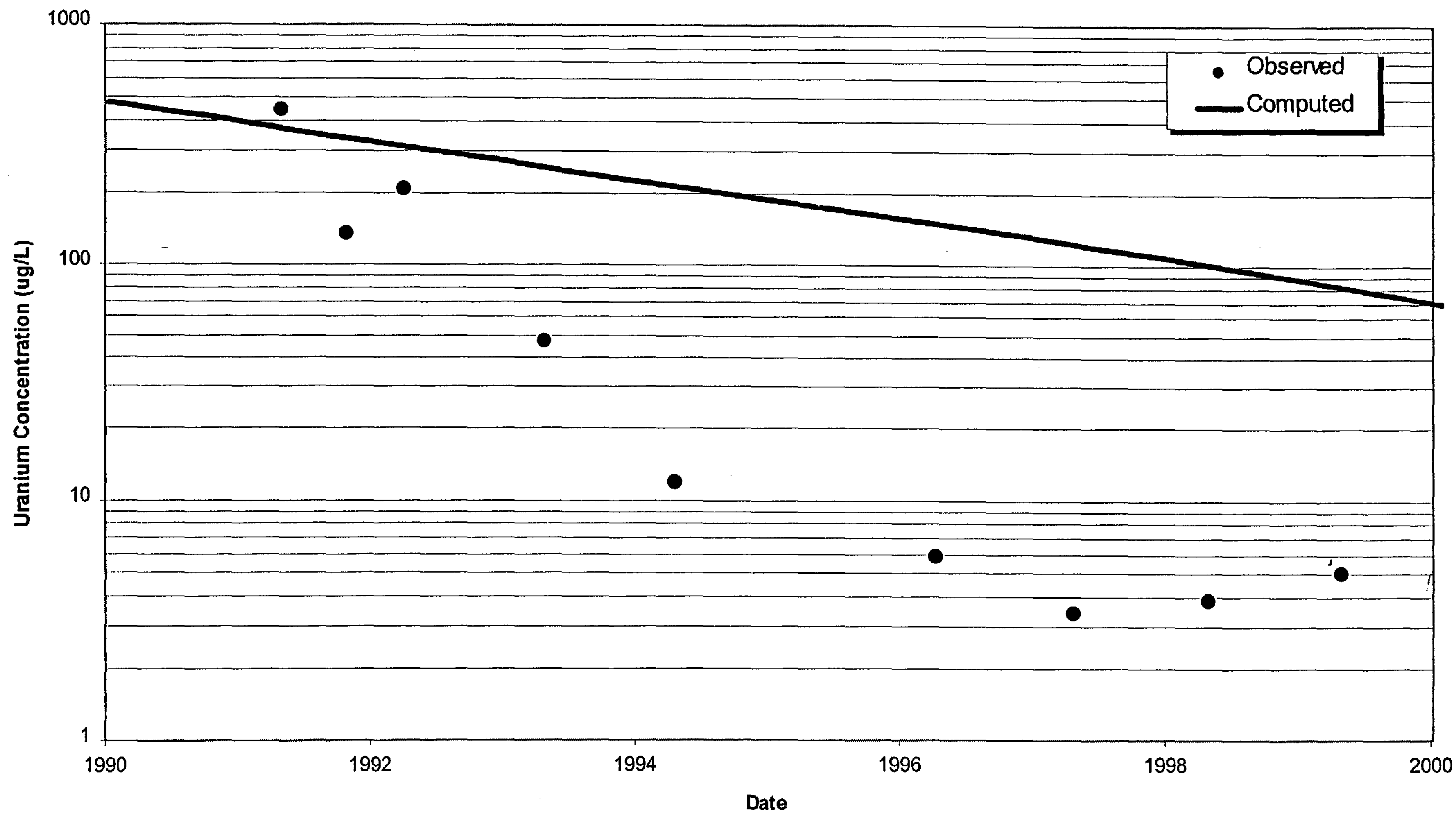


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW024

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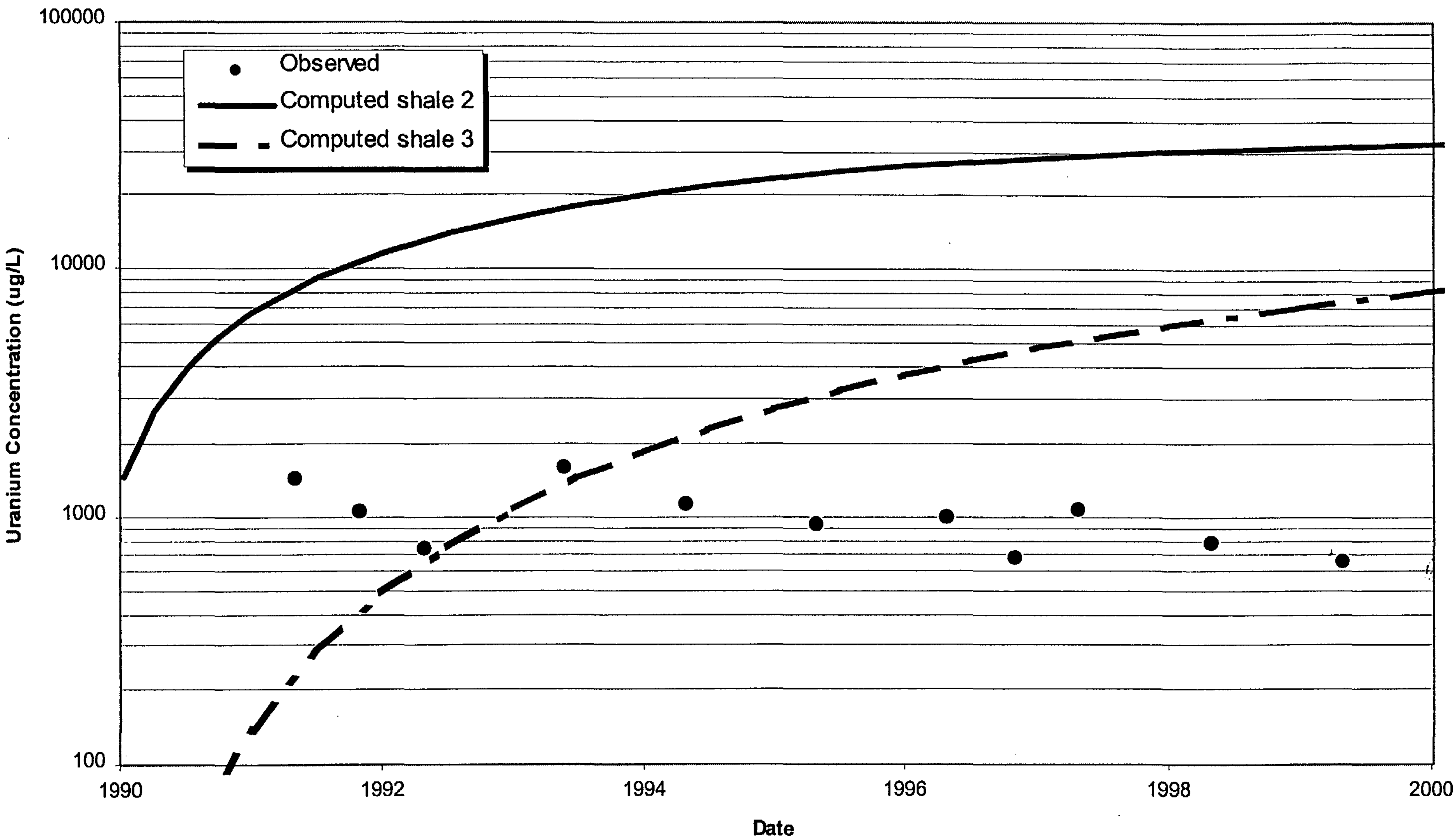


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW025A

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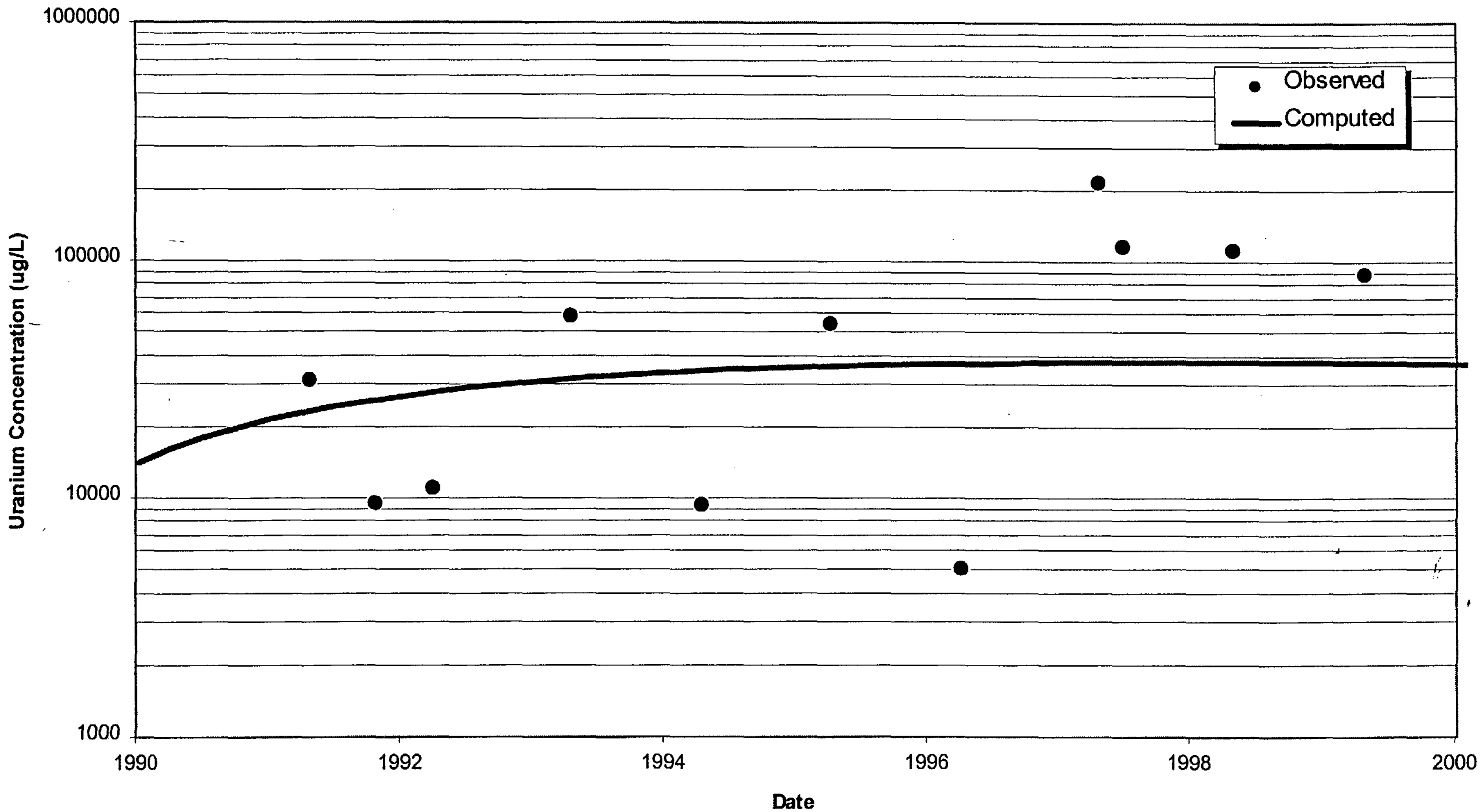


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW025

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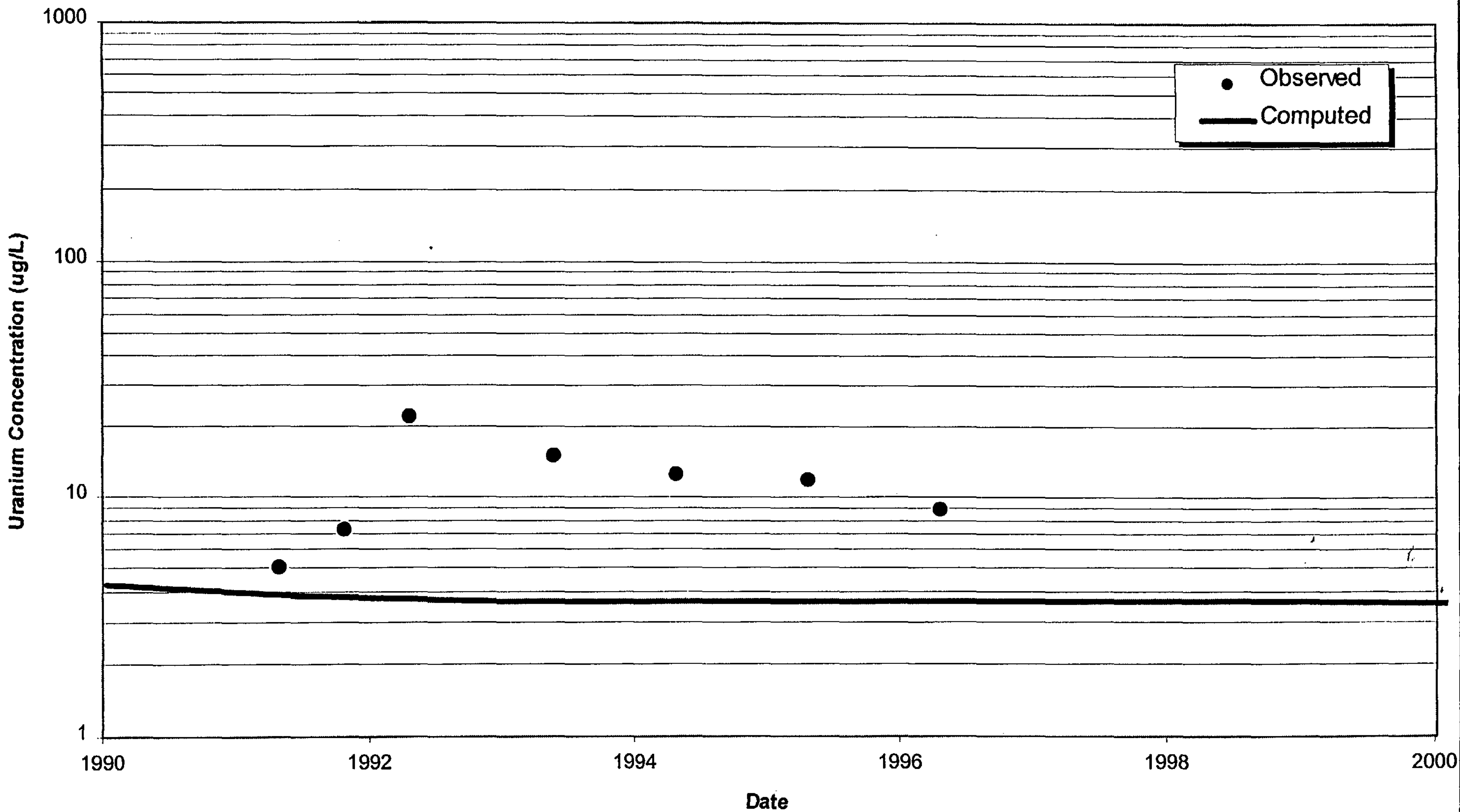


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW026A

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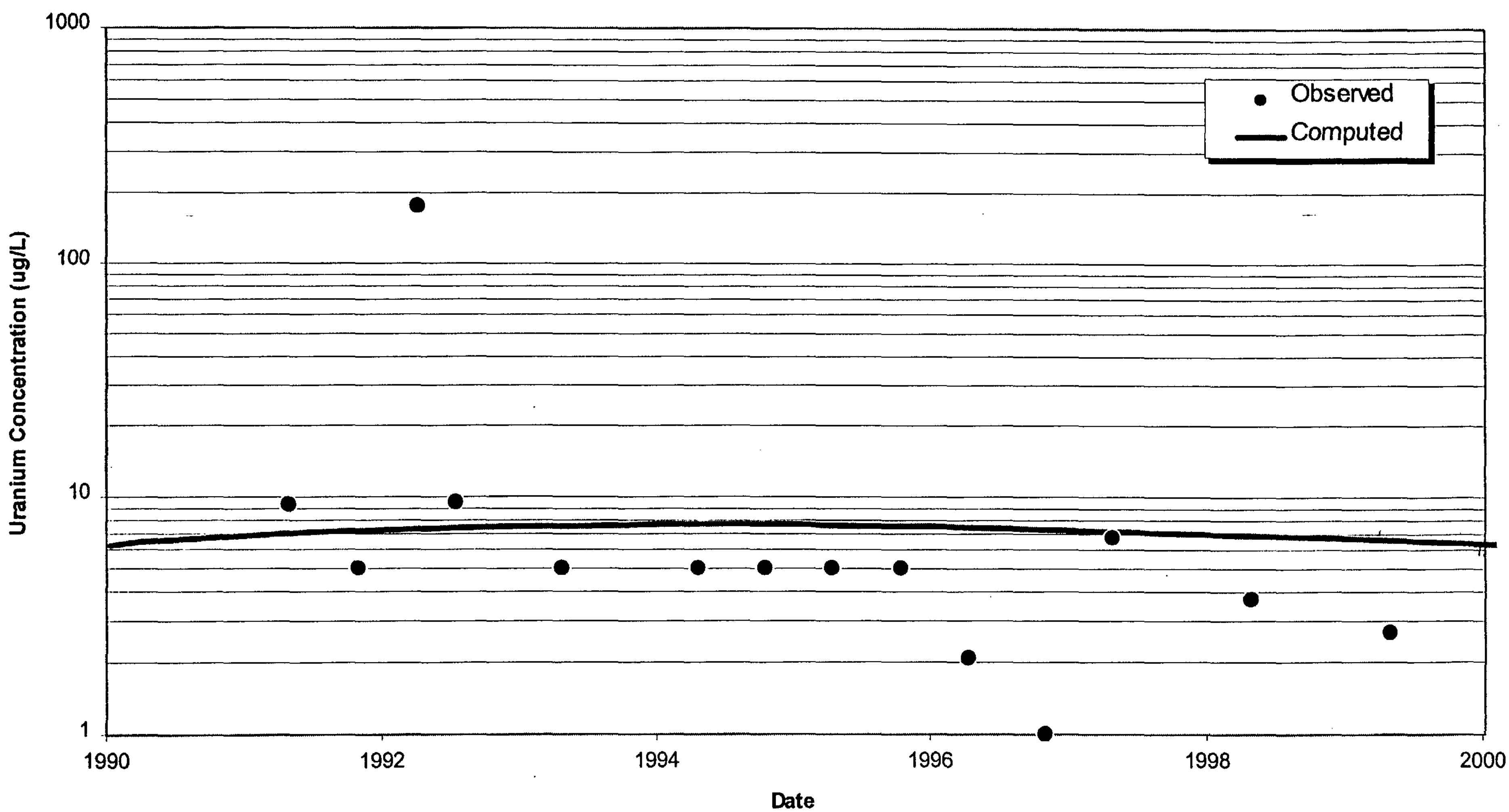


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW026

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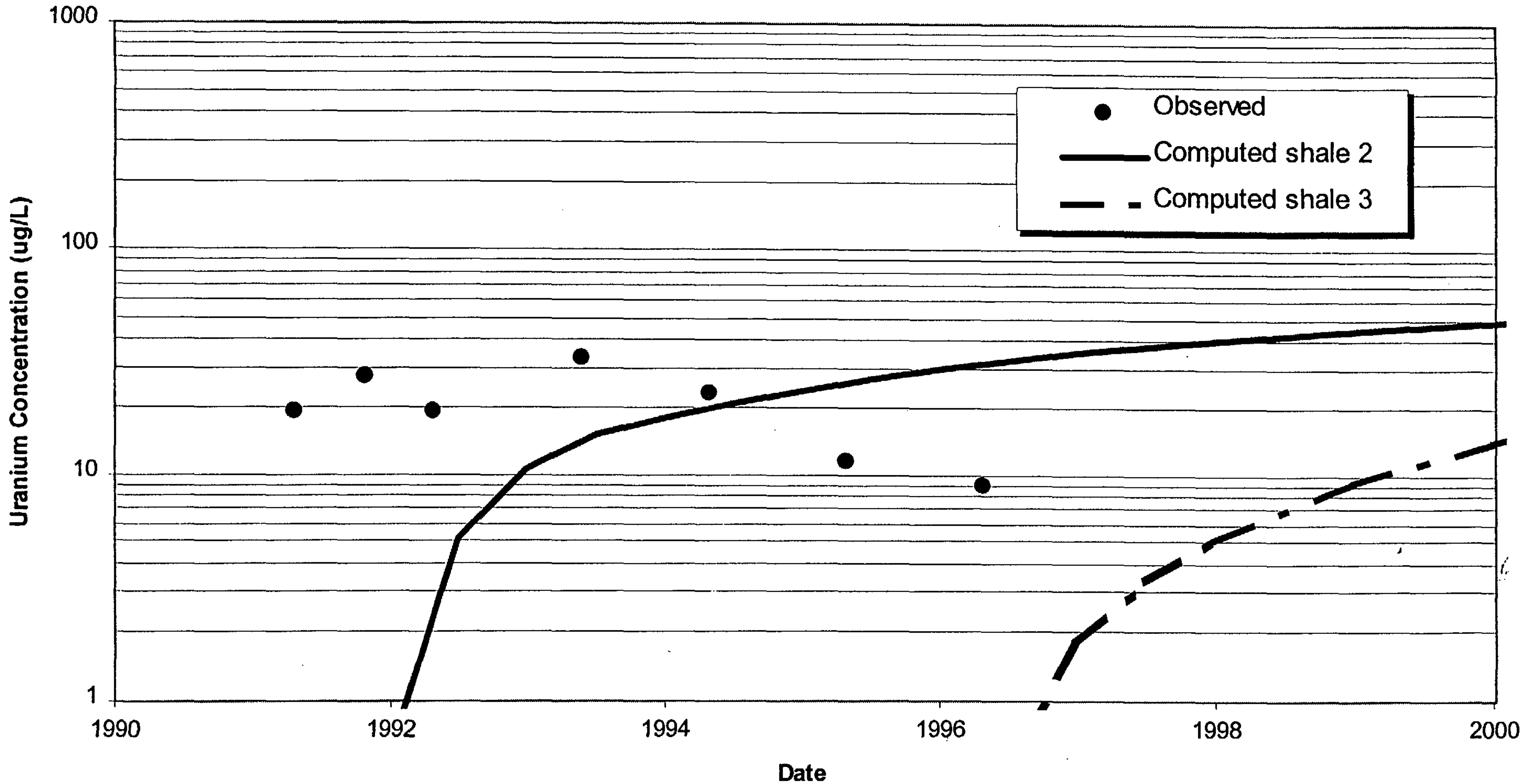


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW027A

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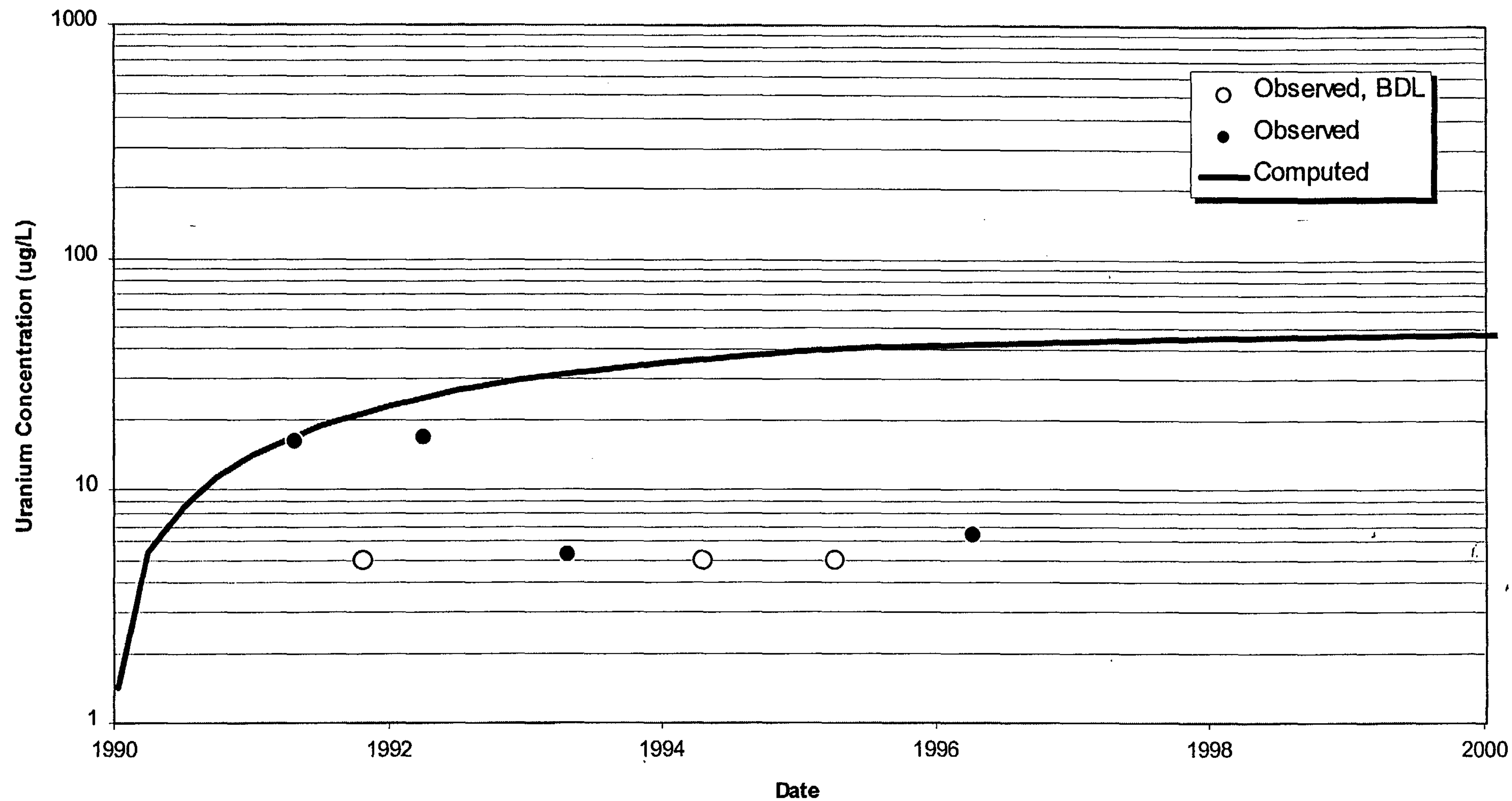


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW027

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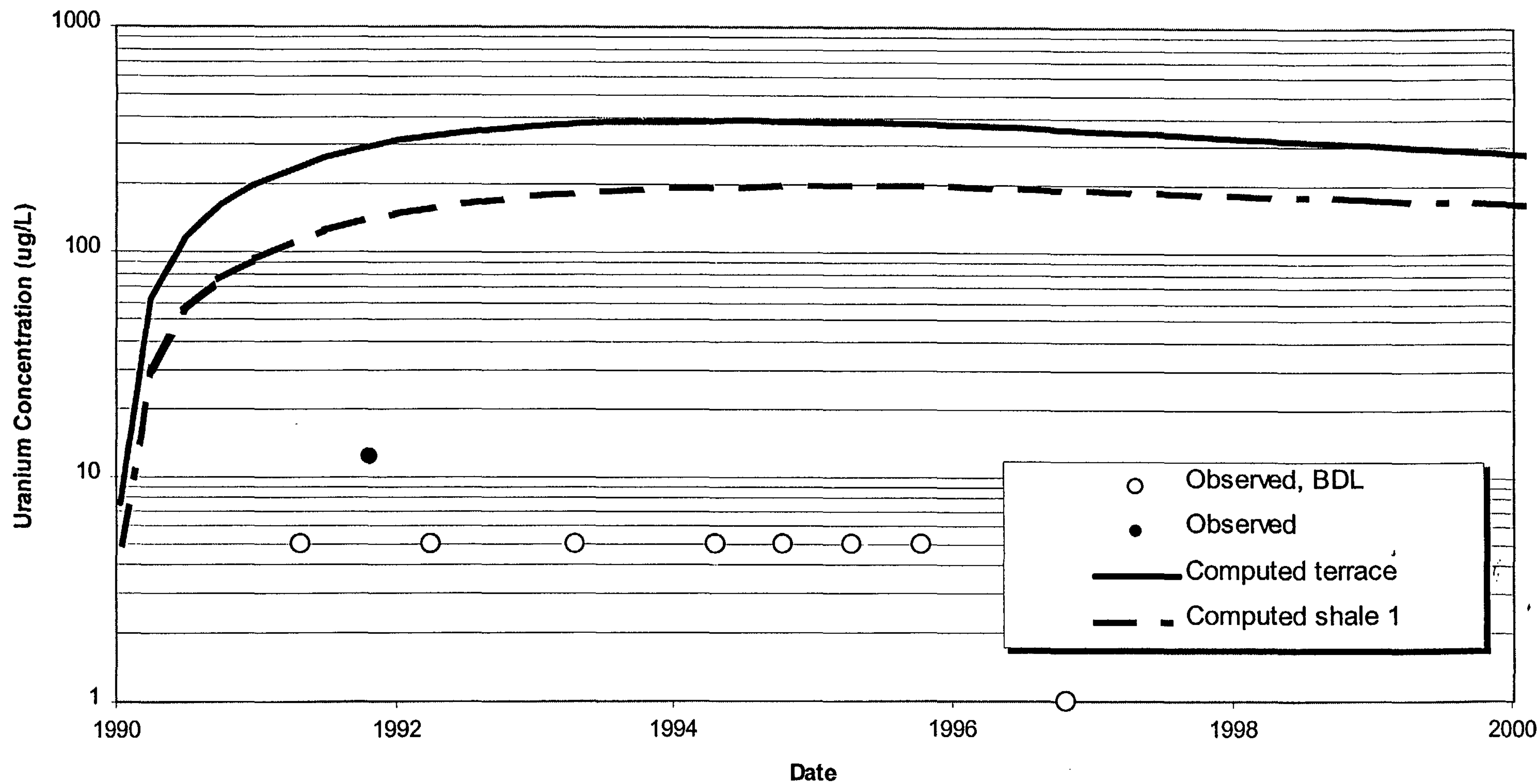


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW028

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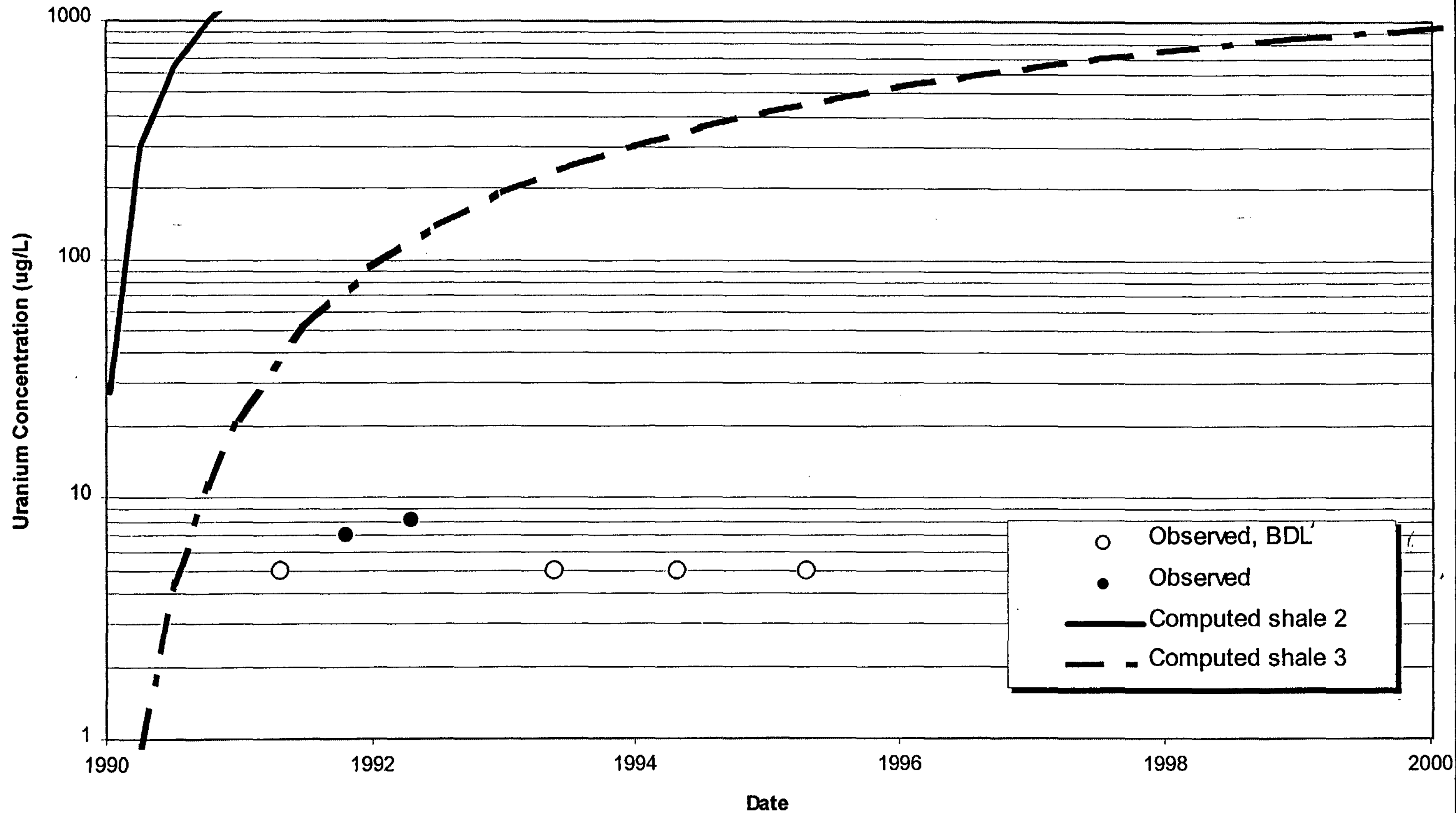


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW030A

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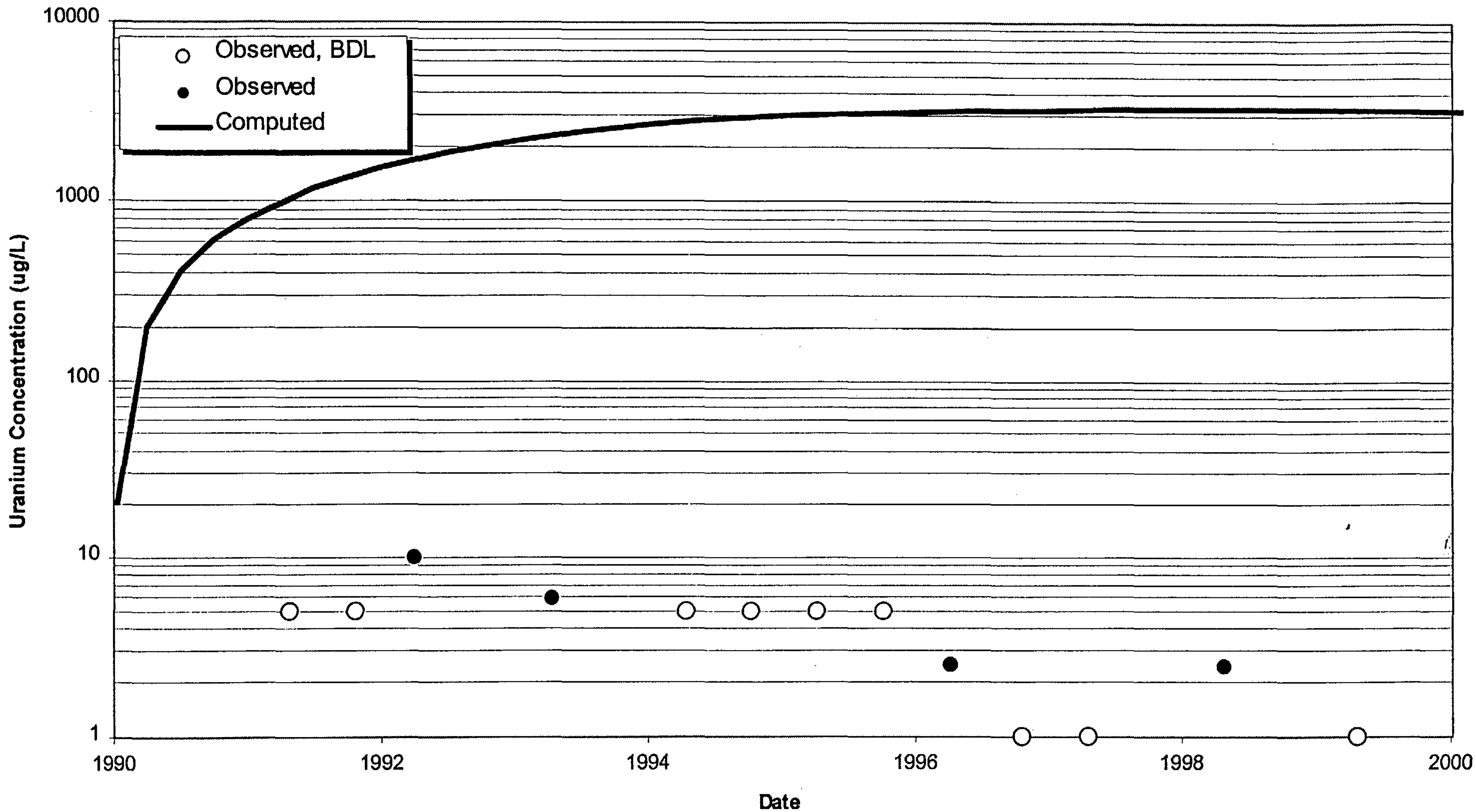


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW030

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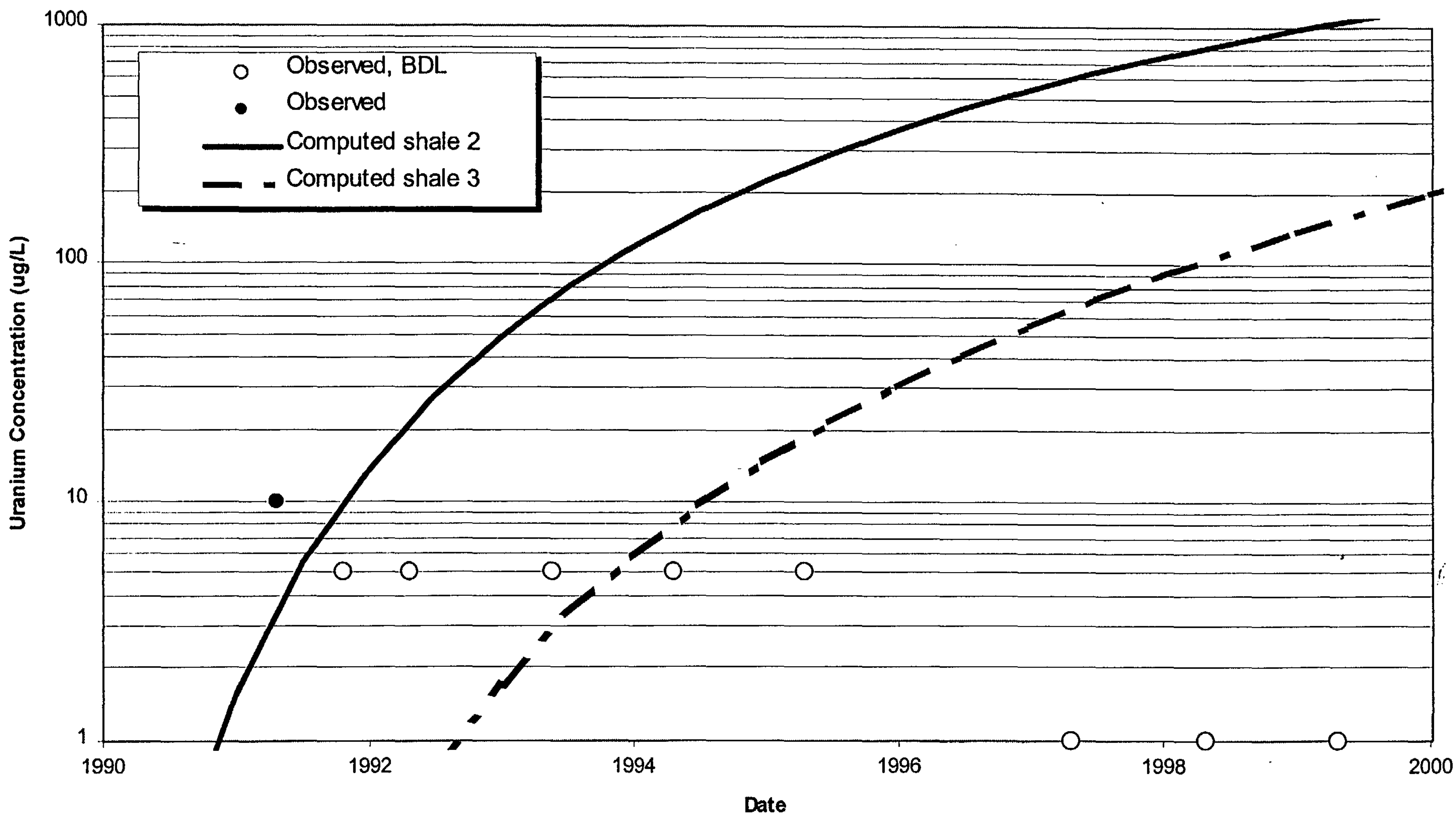


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW031A

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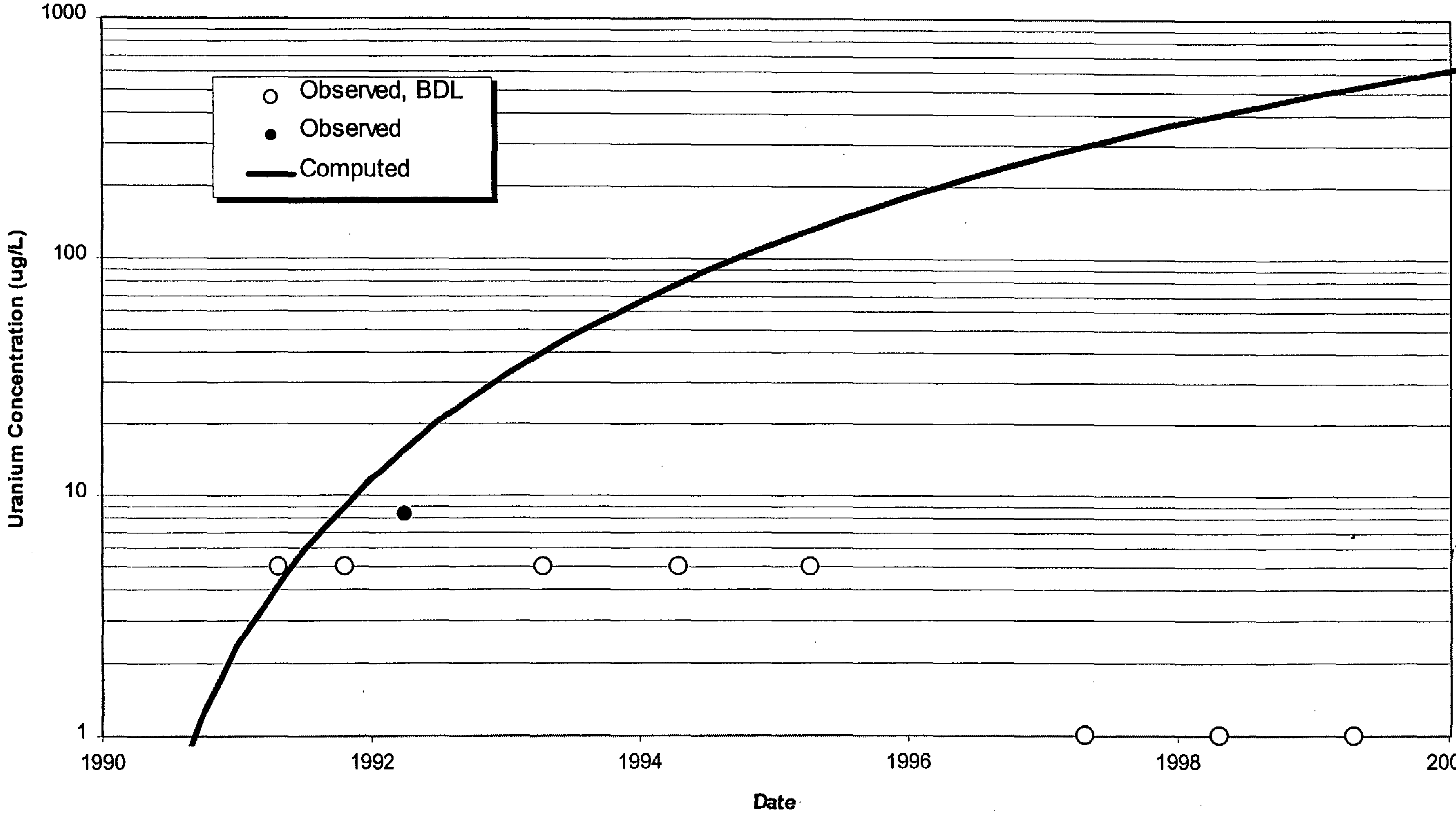


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW031

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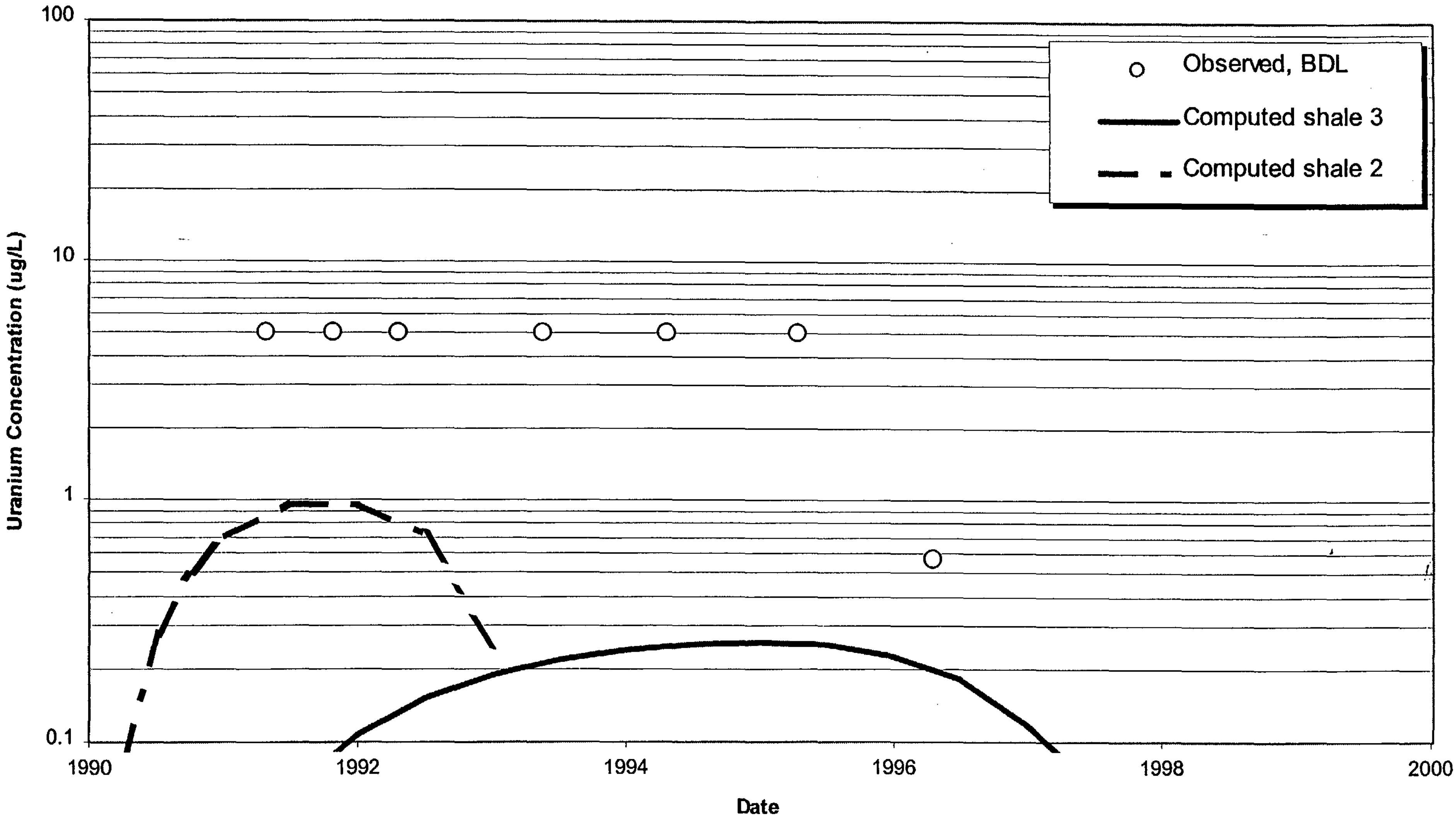


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW032A

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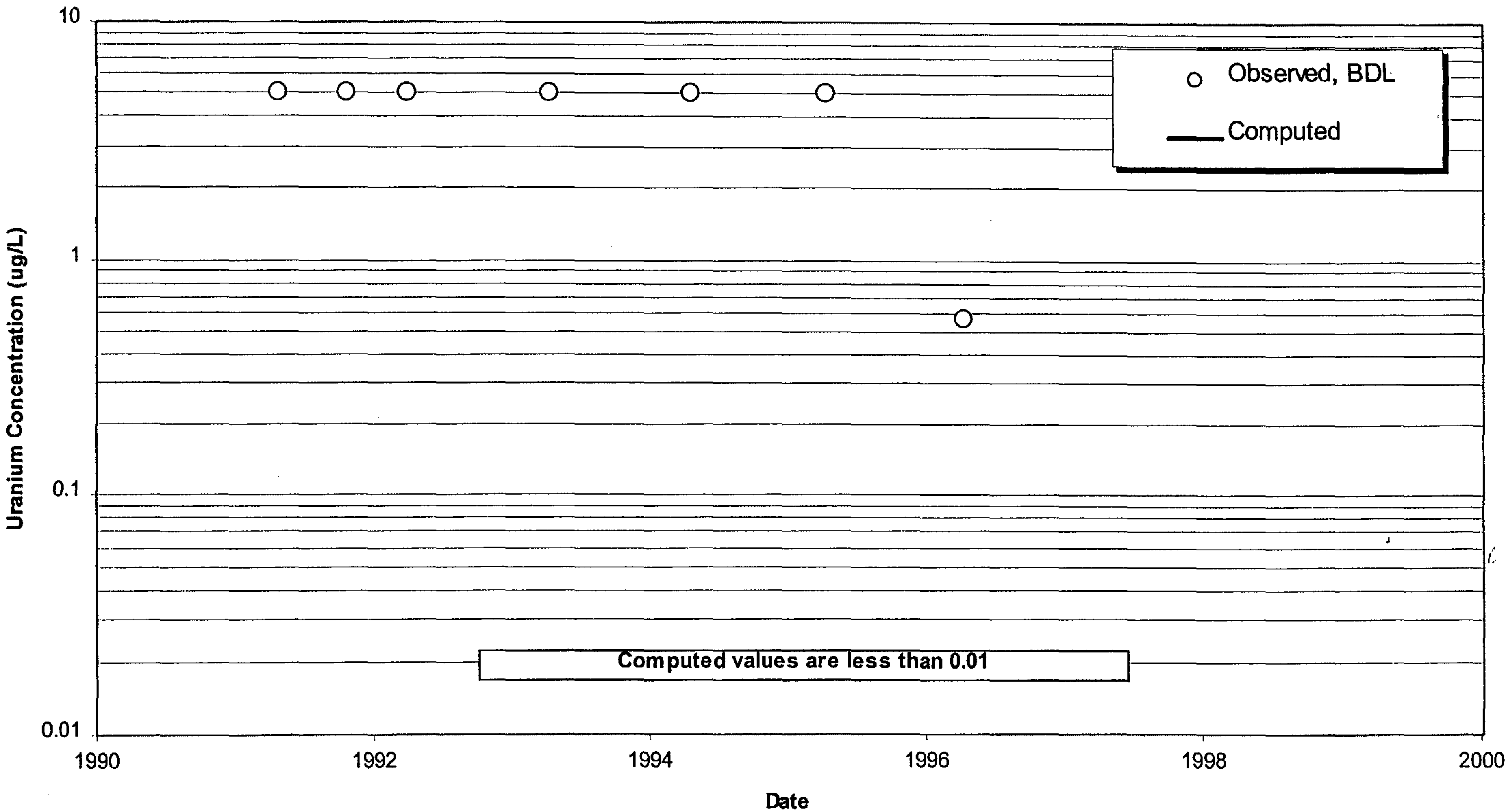


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW032

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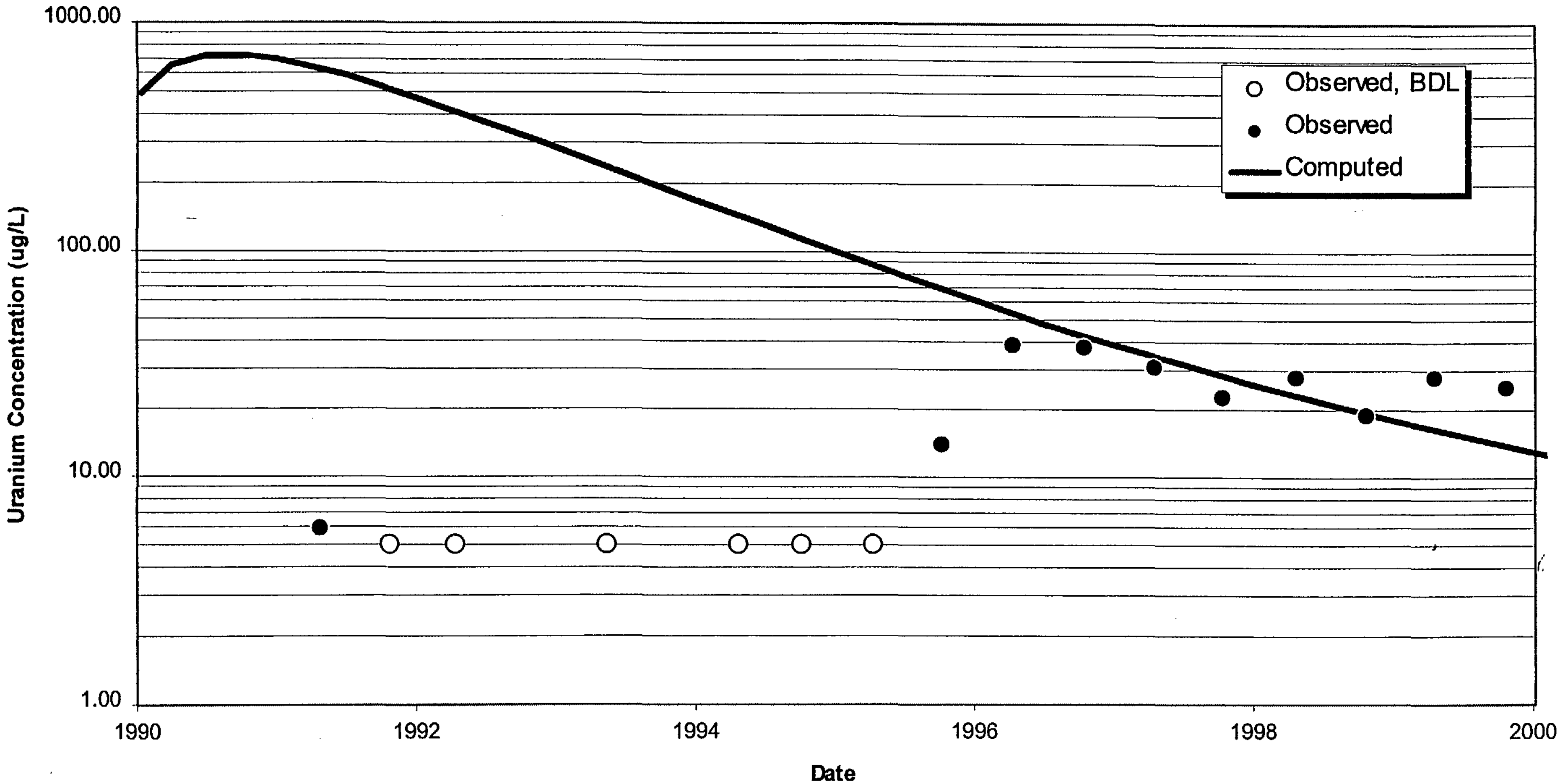


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW035A

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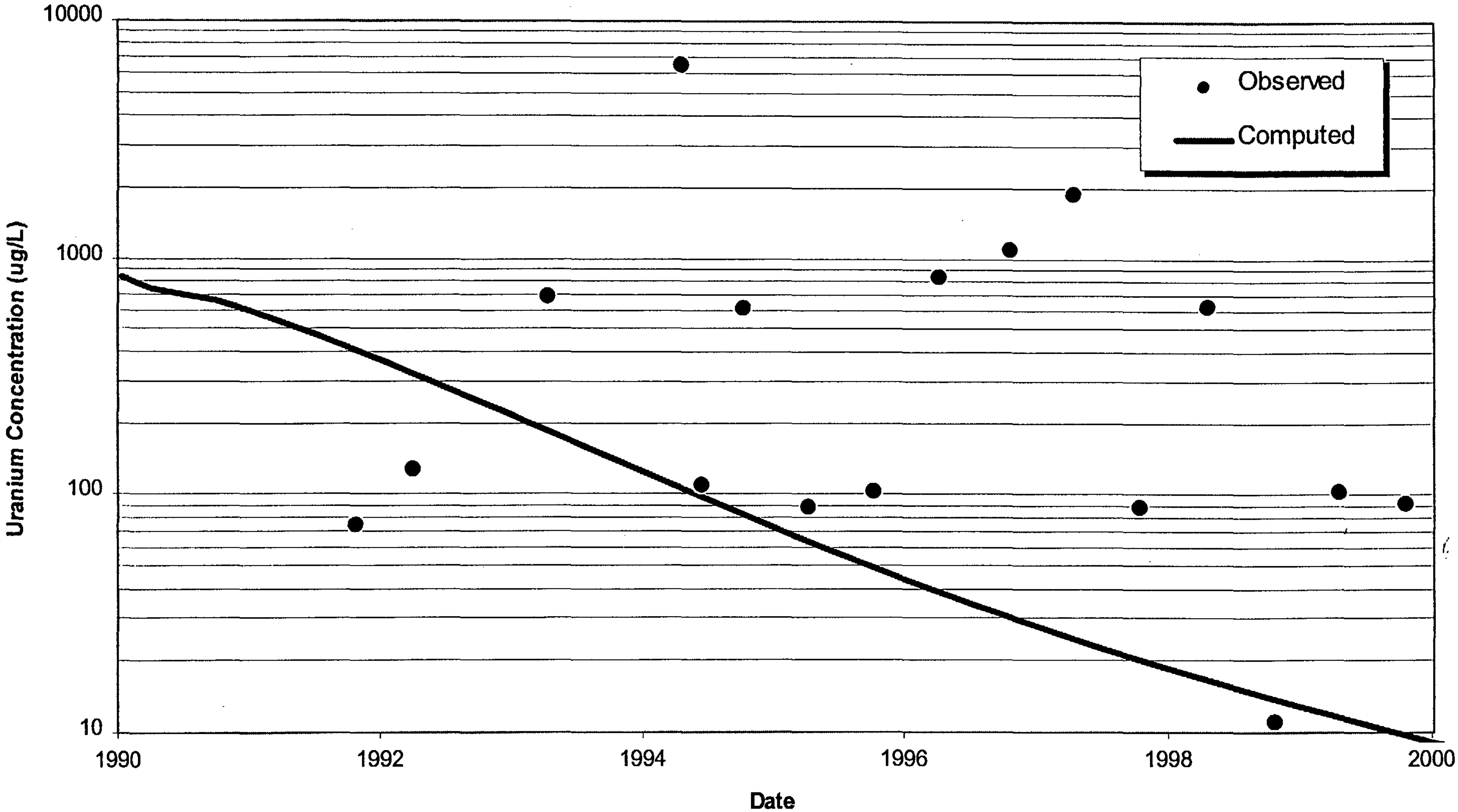


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW035

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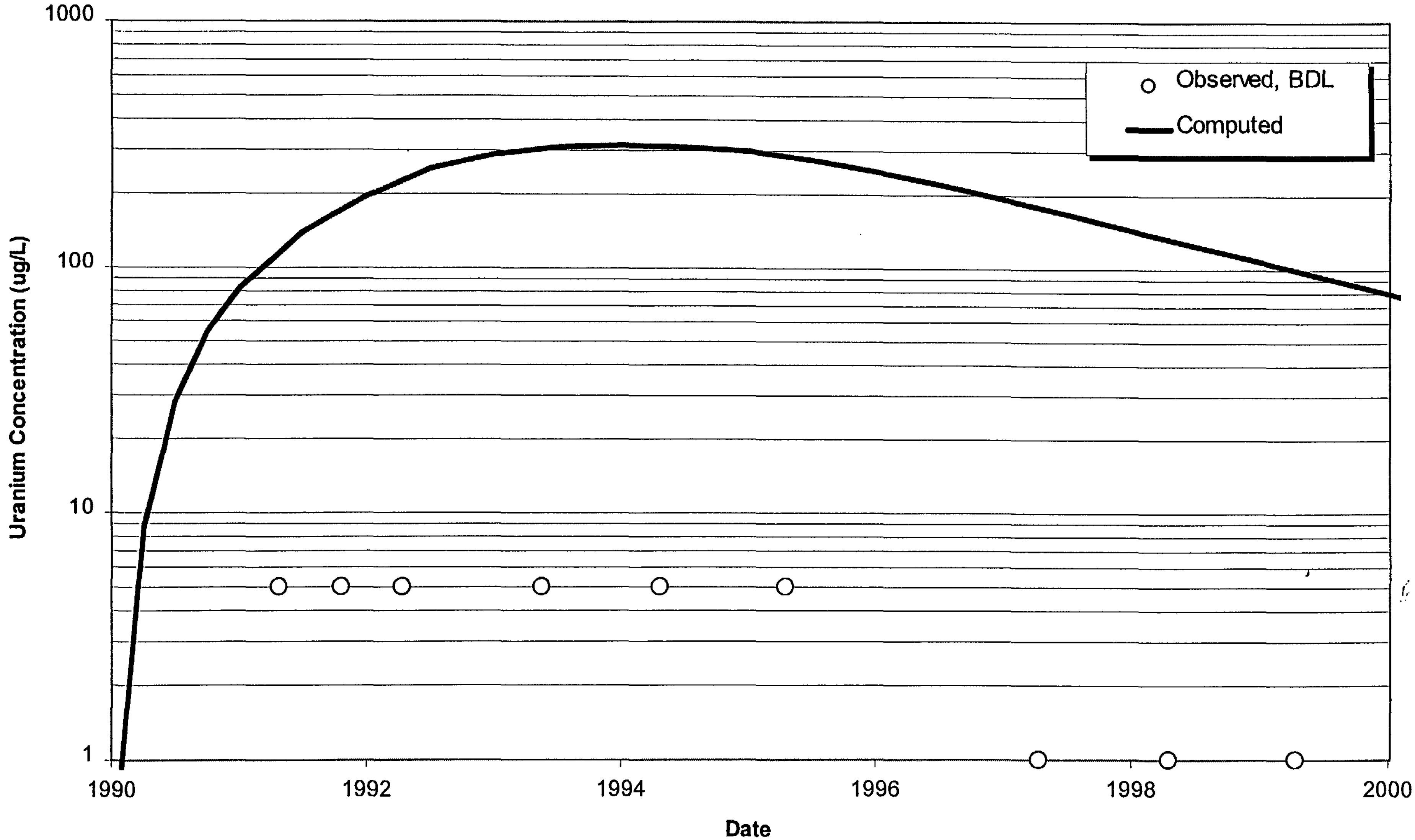


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW037A

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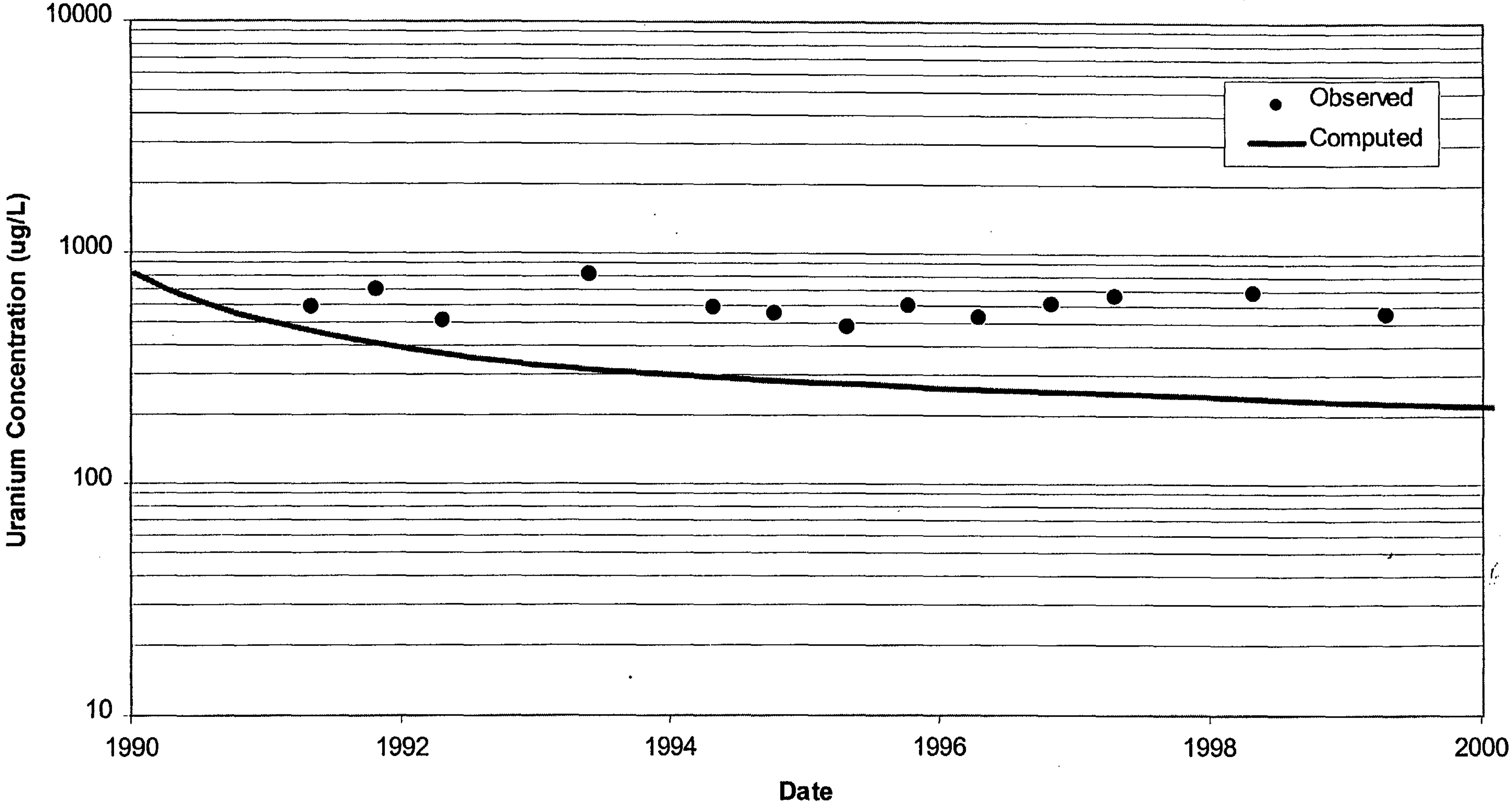


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW050A

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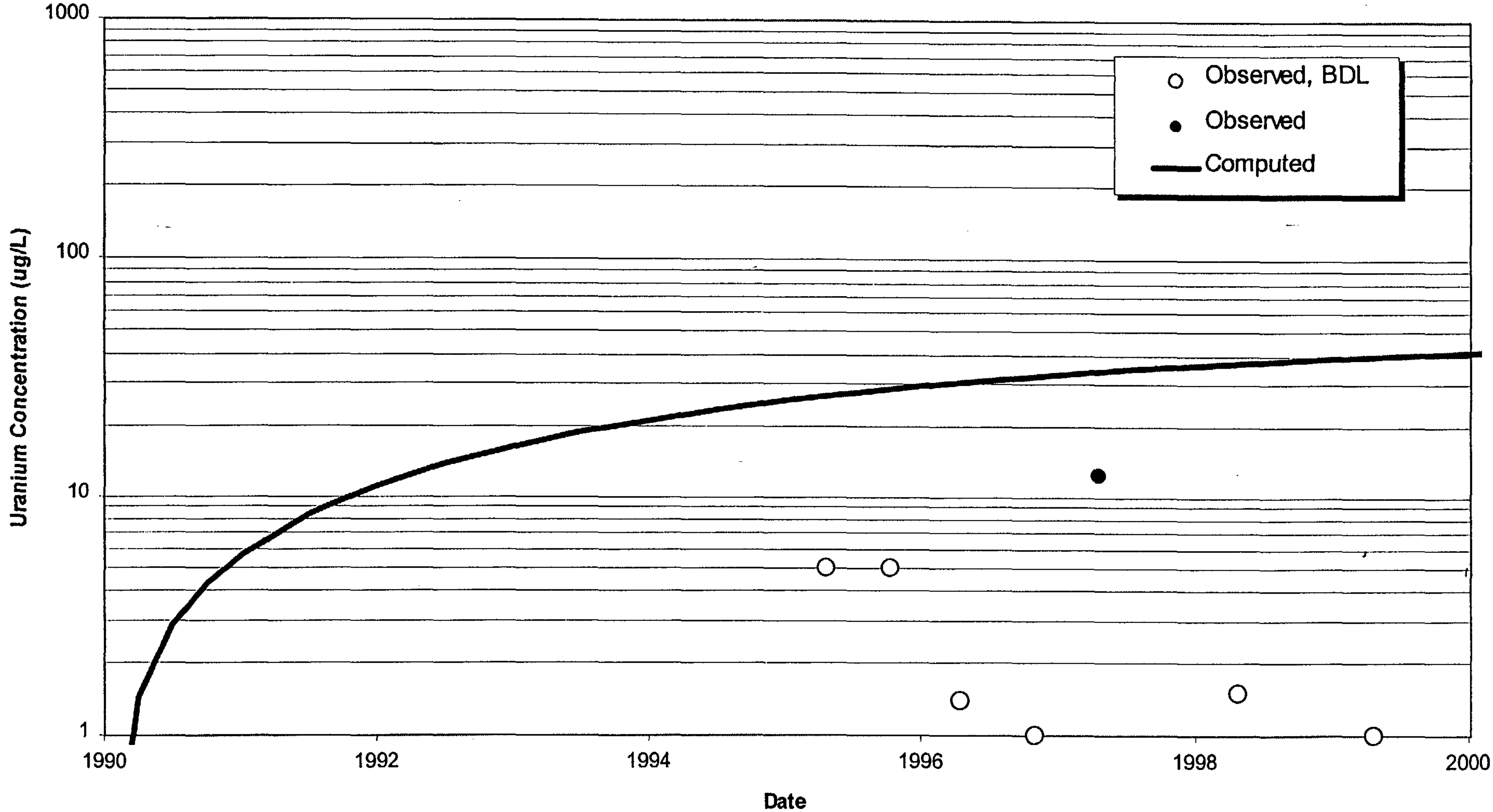


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW050B

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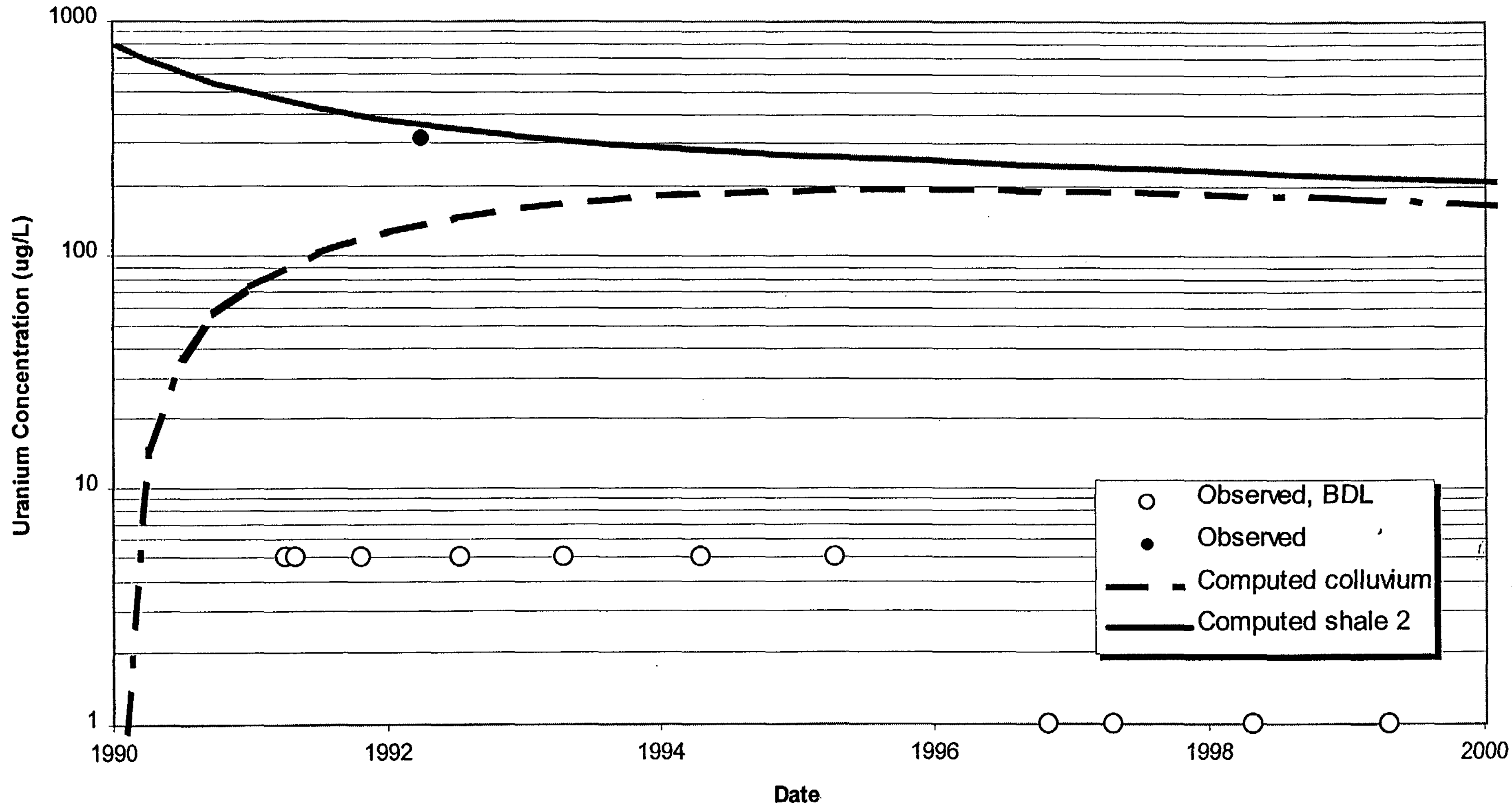


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW050

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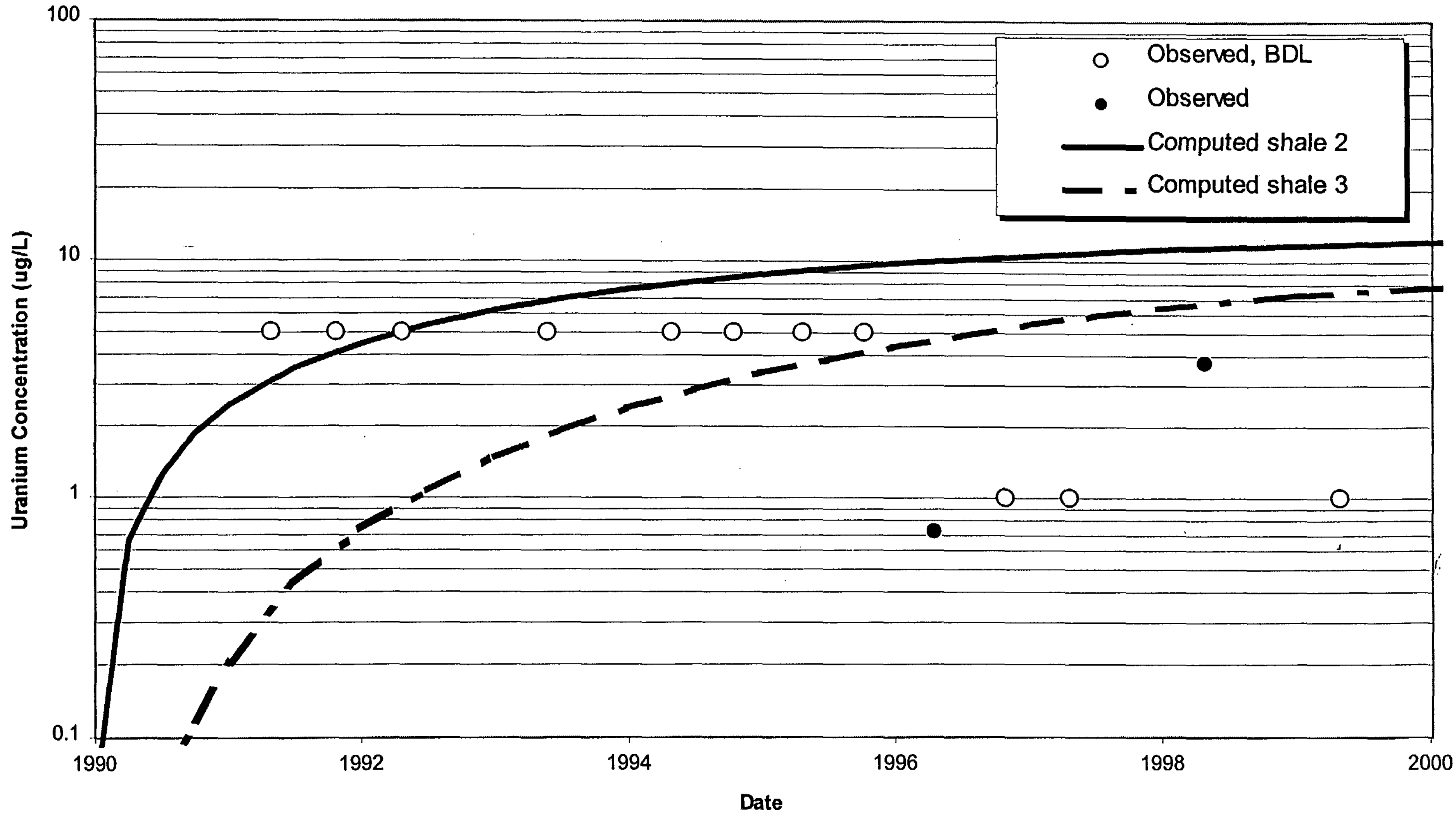


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW053A

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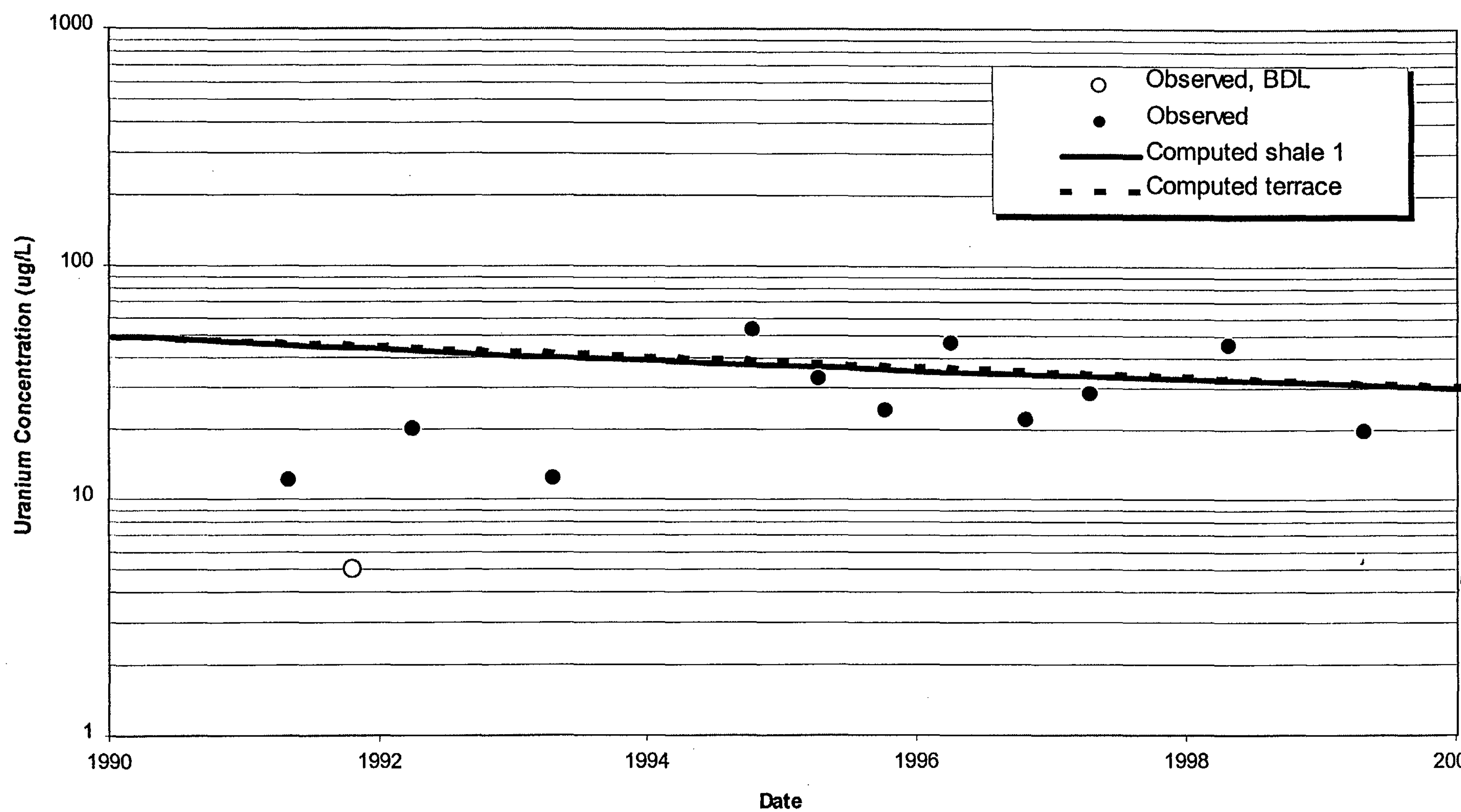


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW053

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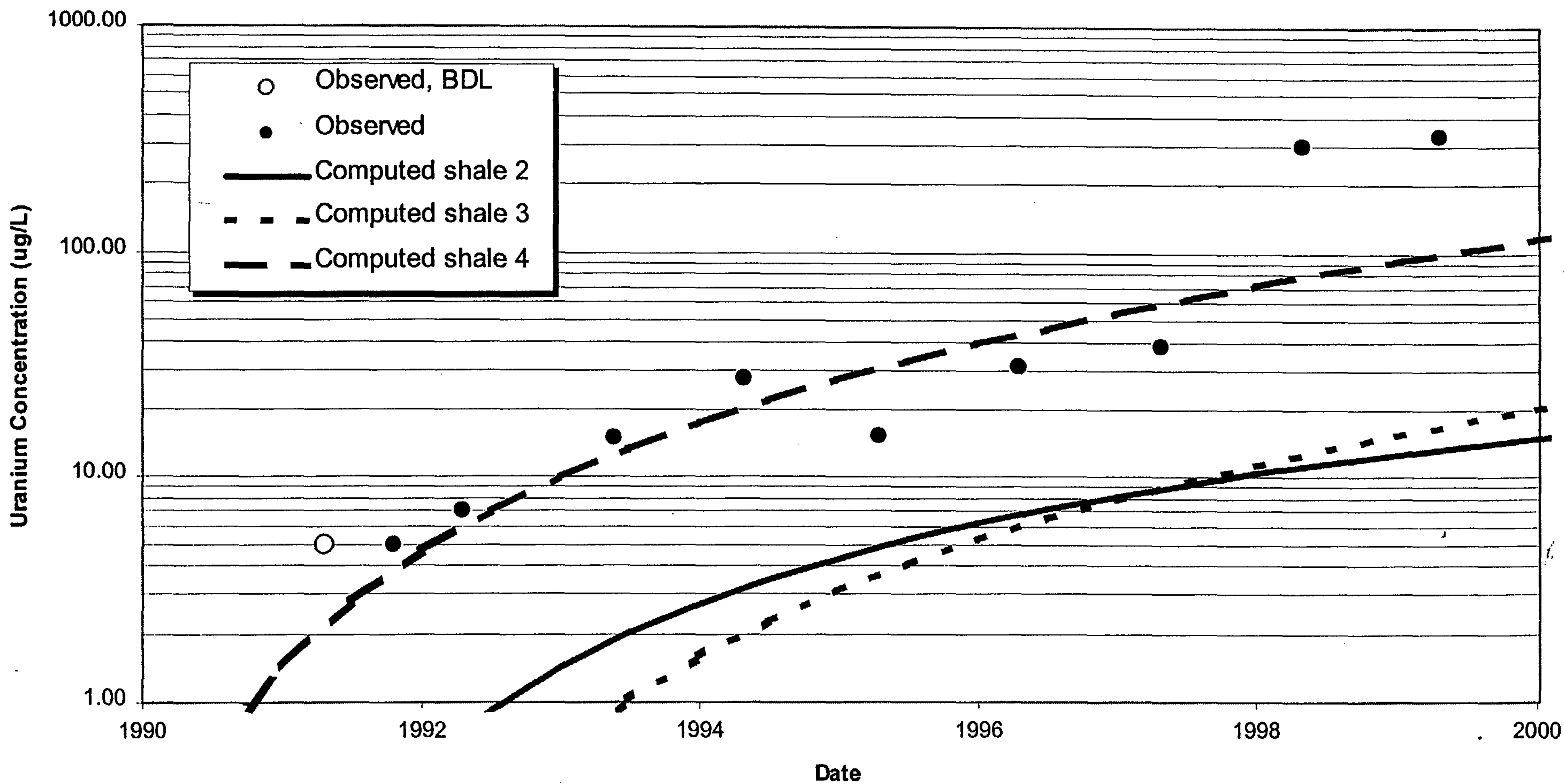


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW067A

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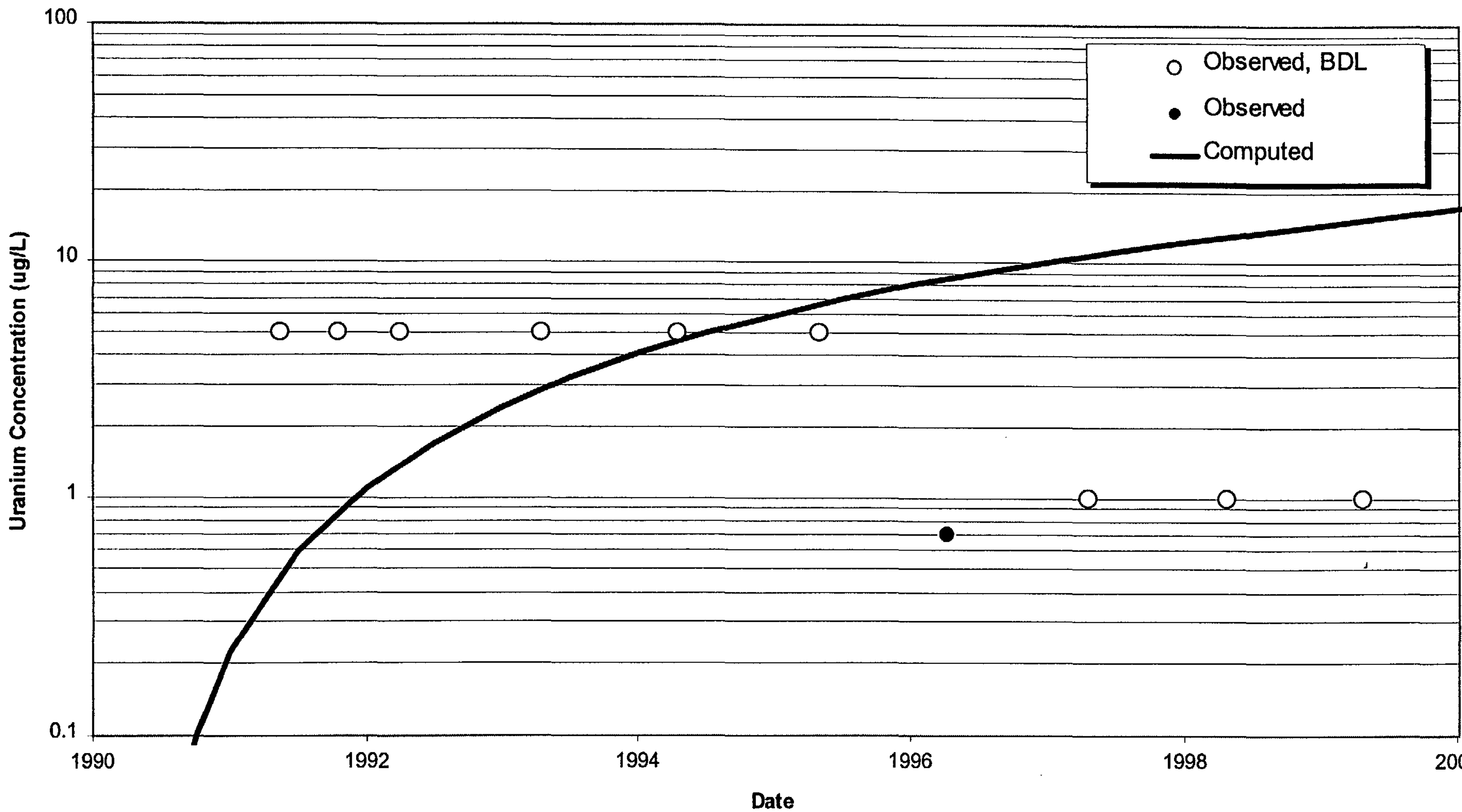


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW067

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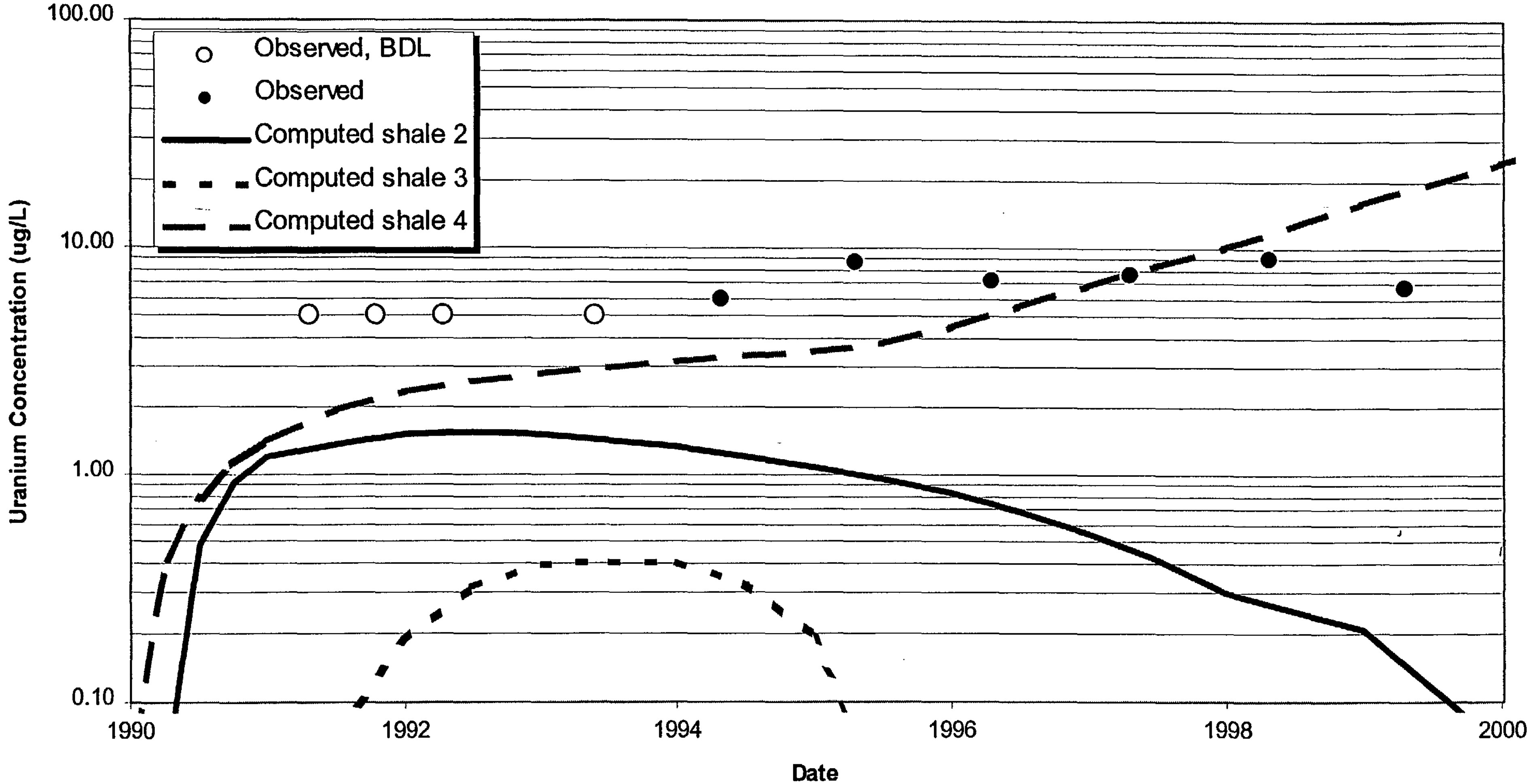


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW068A

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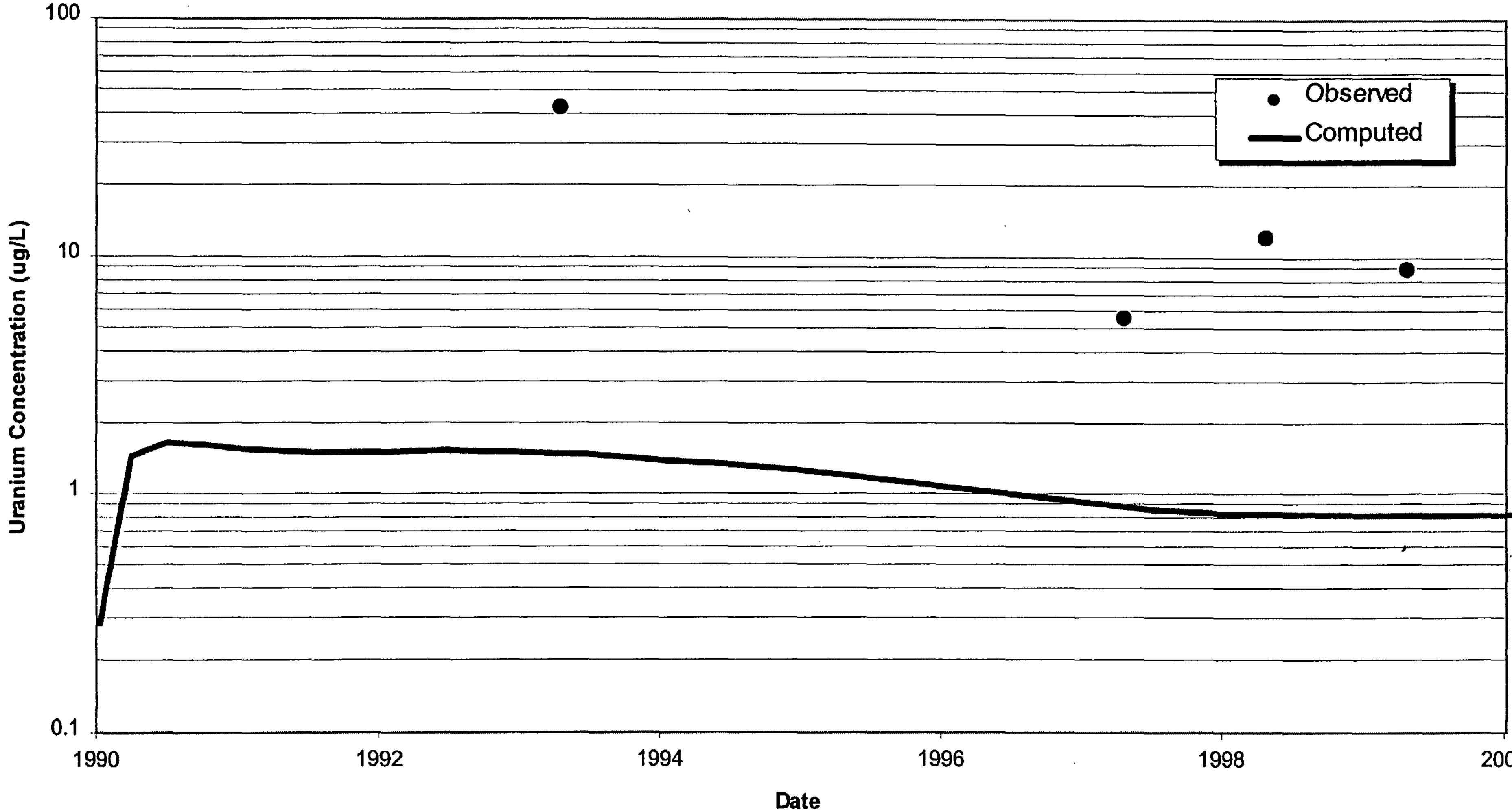


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW068

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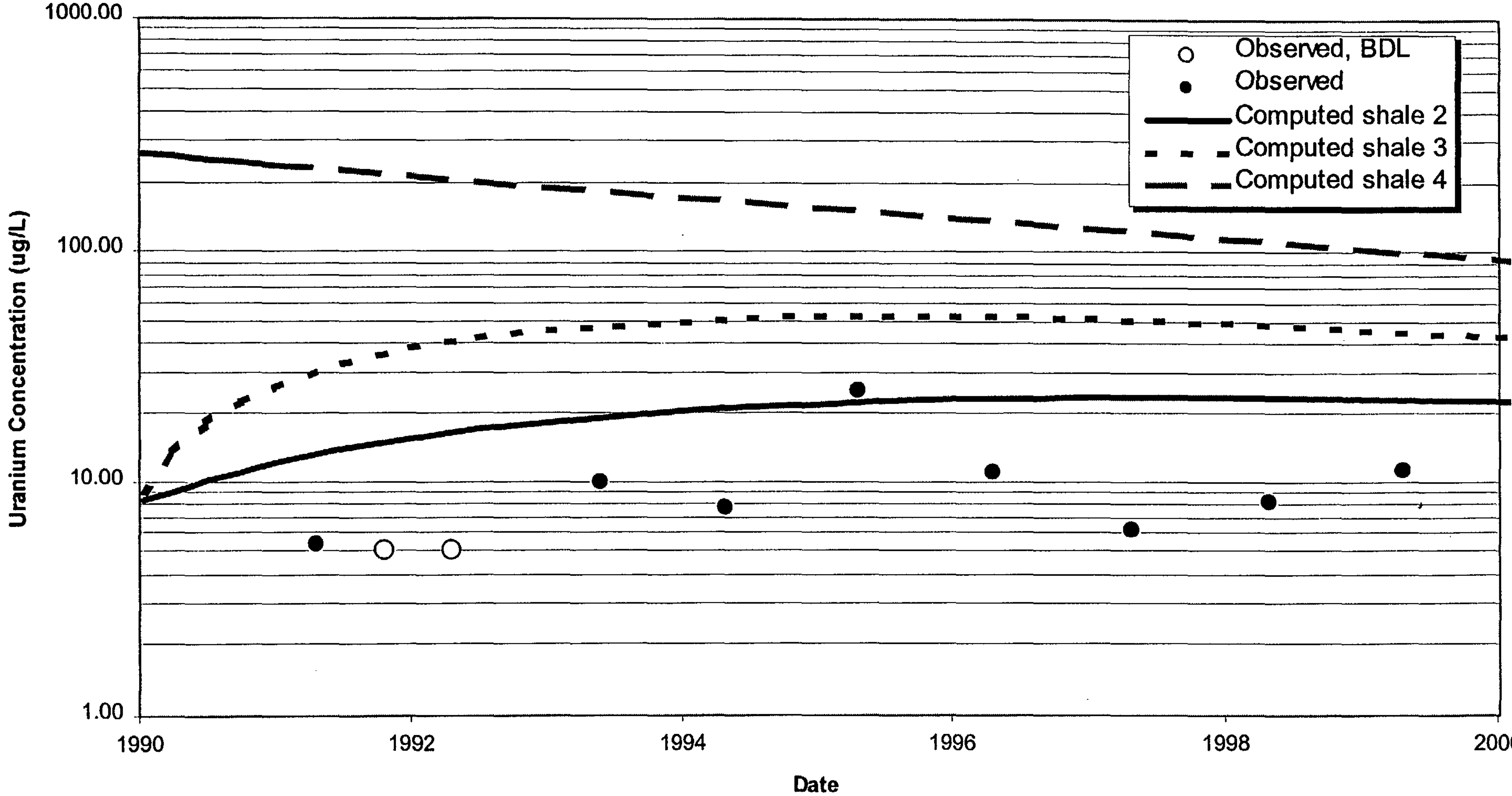


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW078A

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| Project: | V:\Titleblocks\ |
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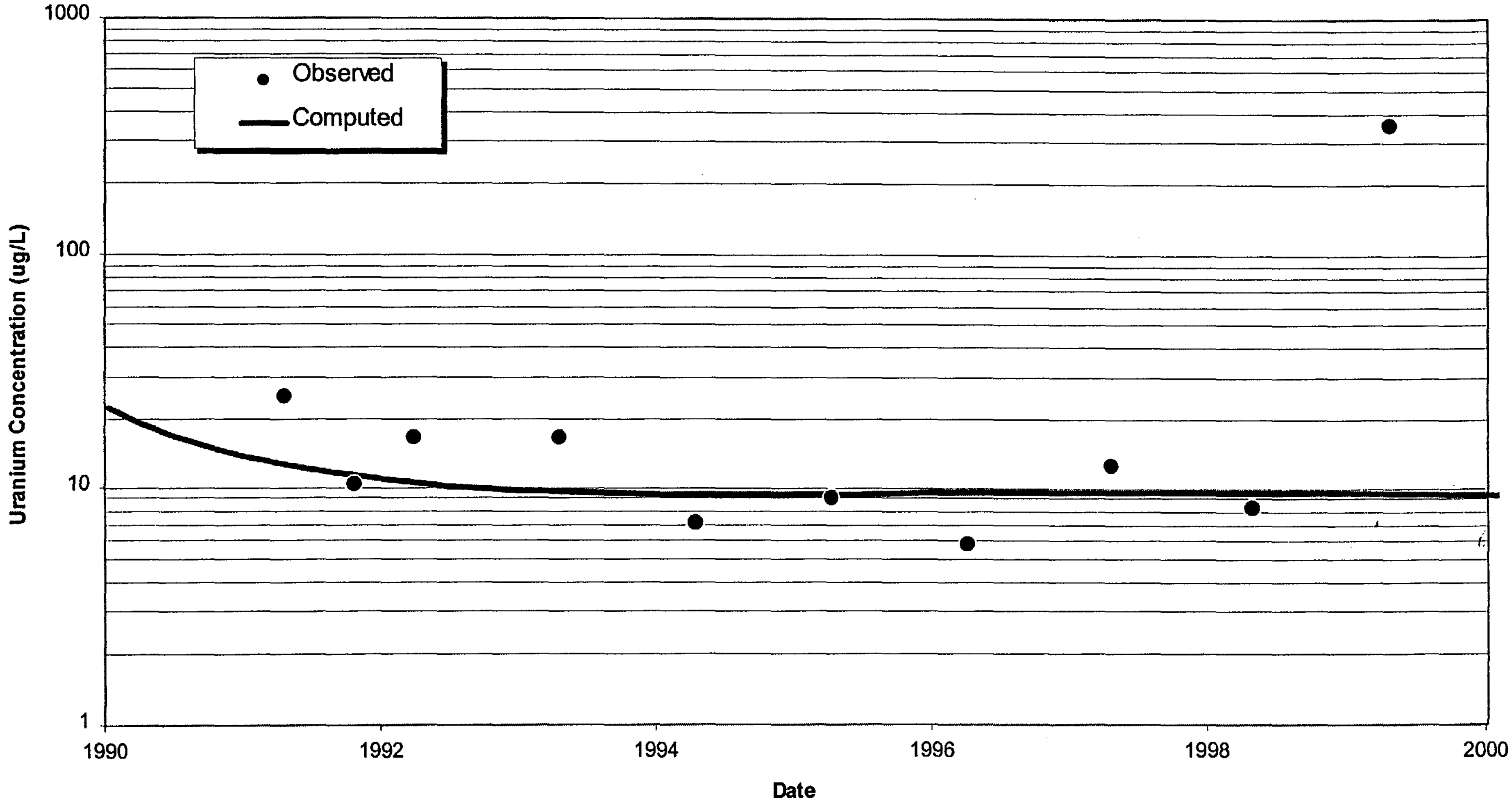


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW078

Date: AUGUST 2002
Project: V:\Titleblocks\
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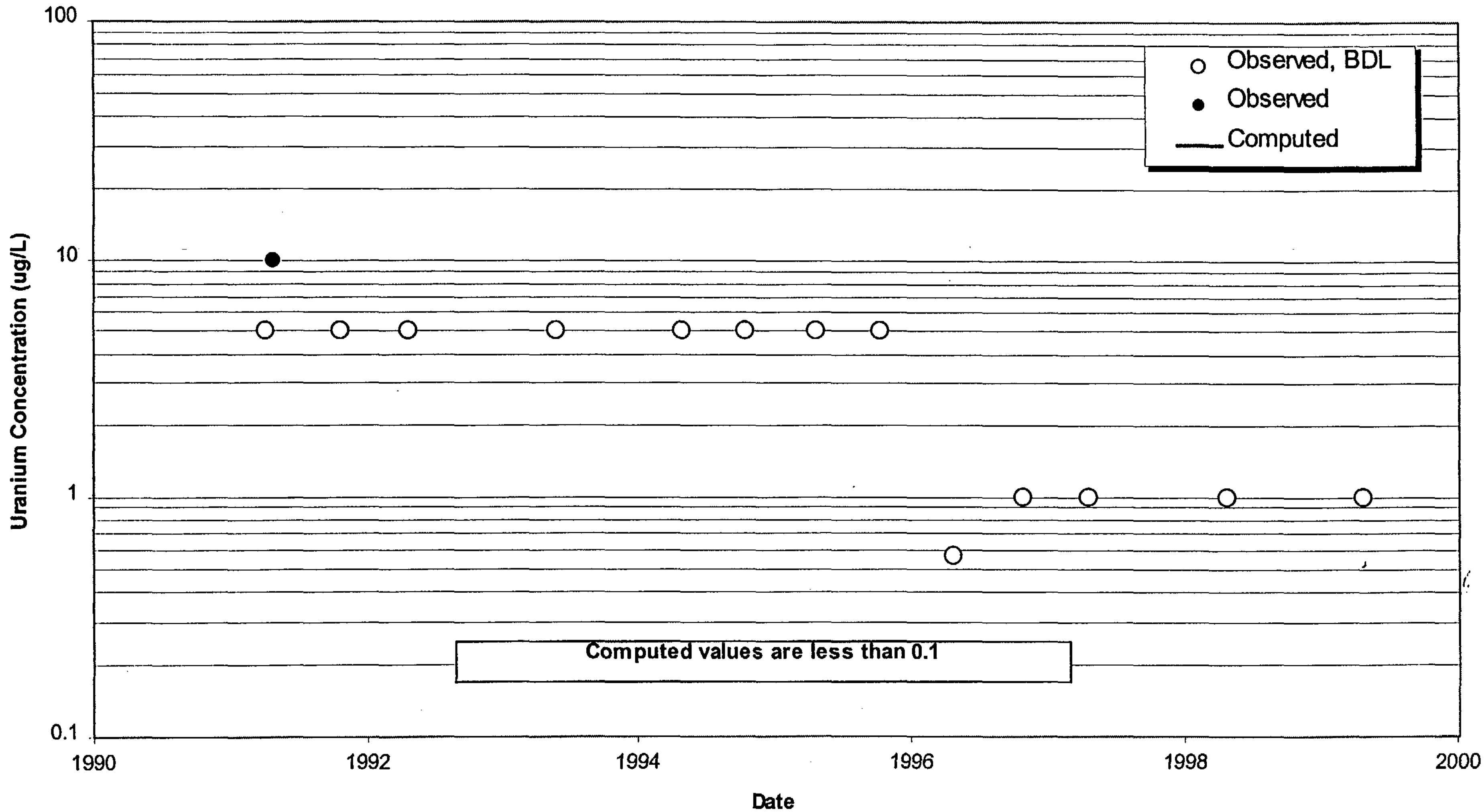


consulting scientists and engineers

FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW084A

| | |
|---|---|
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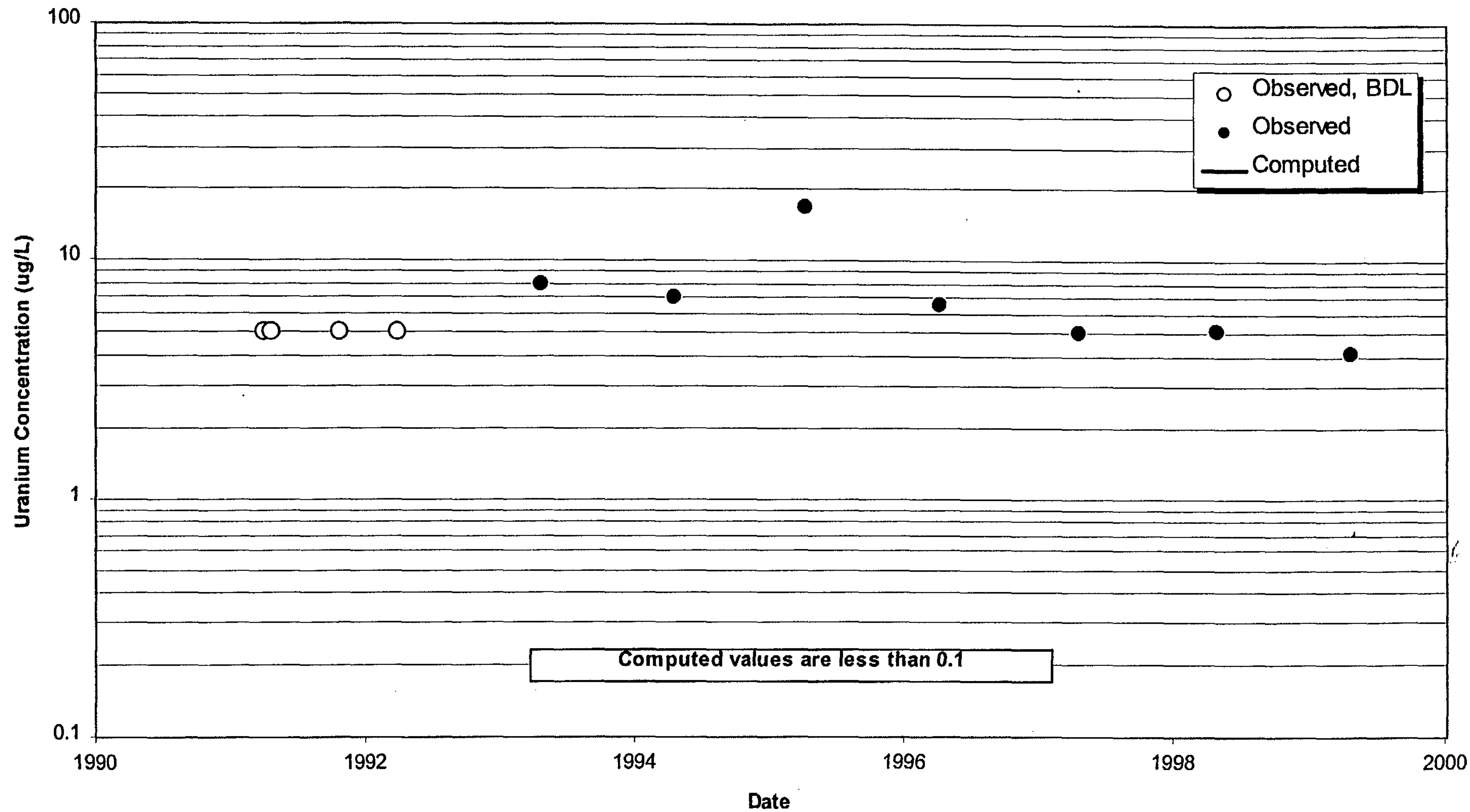


consulting scientists and engineers

FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW084

| | |
|---|---|
| Date: | AUGUST 2002 |
| Project: | V:\Titleblocks\ |
| File: | MFG TBLK LAND.ppt |

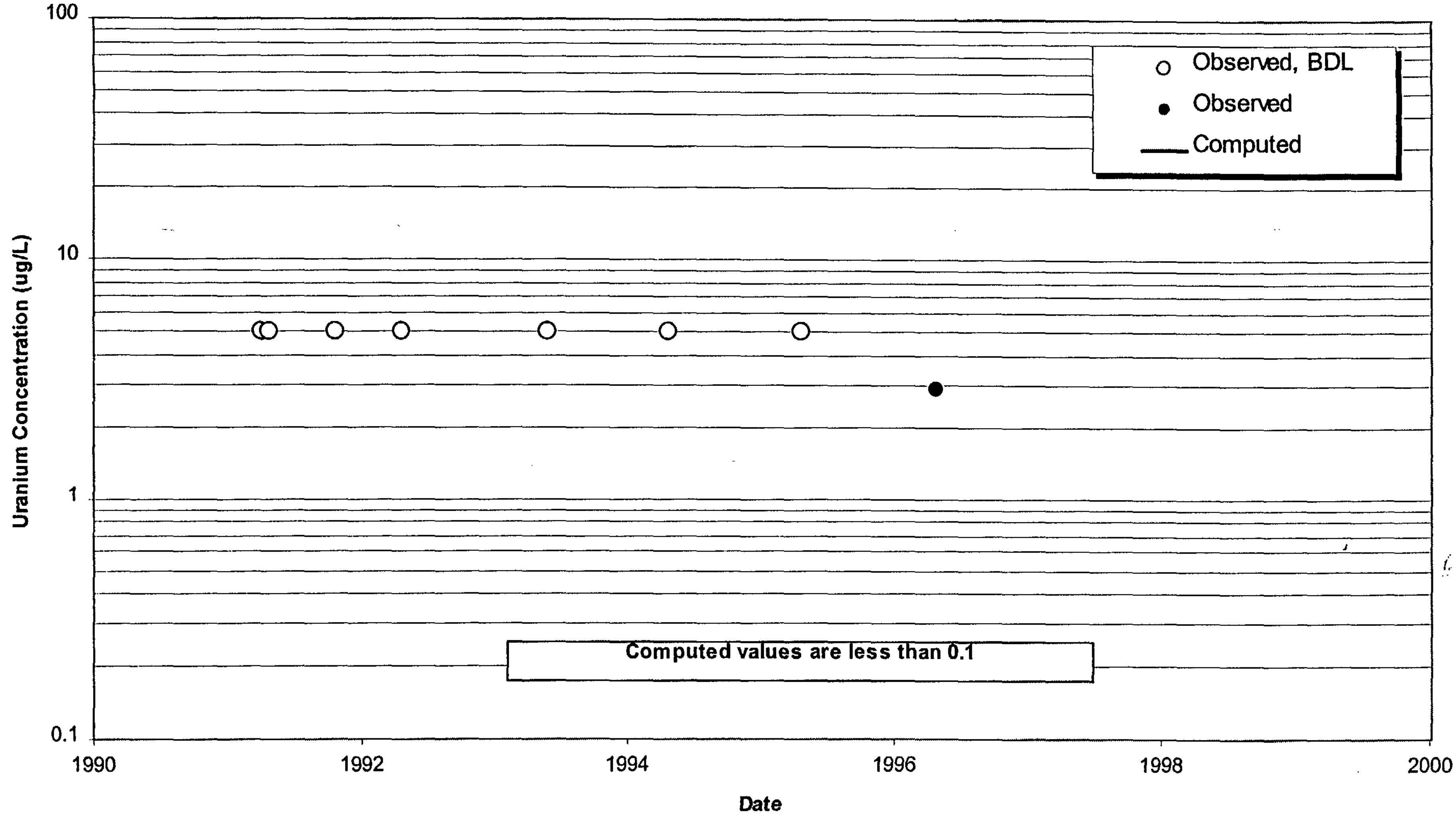


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW085A

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Project: V:\Titleblocks\
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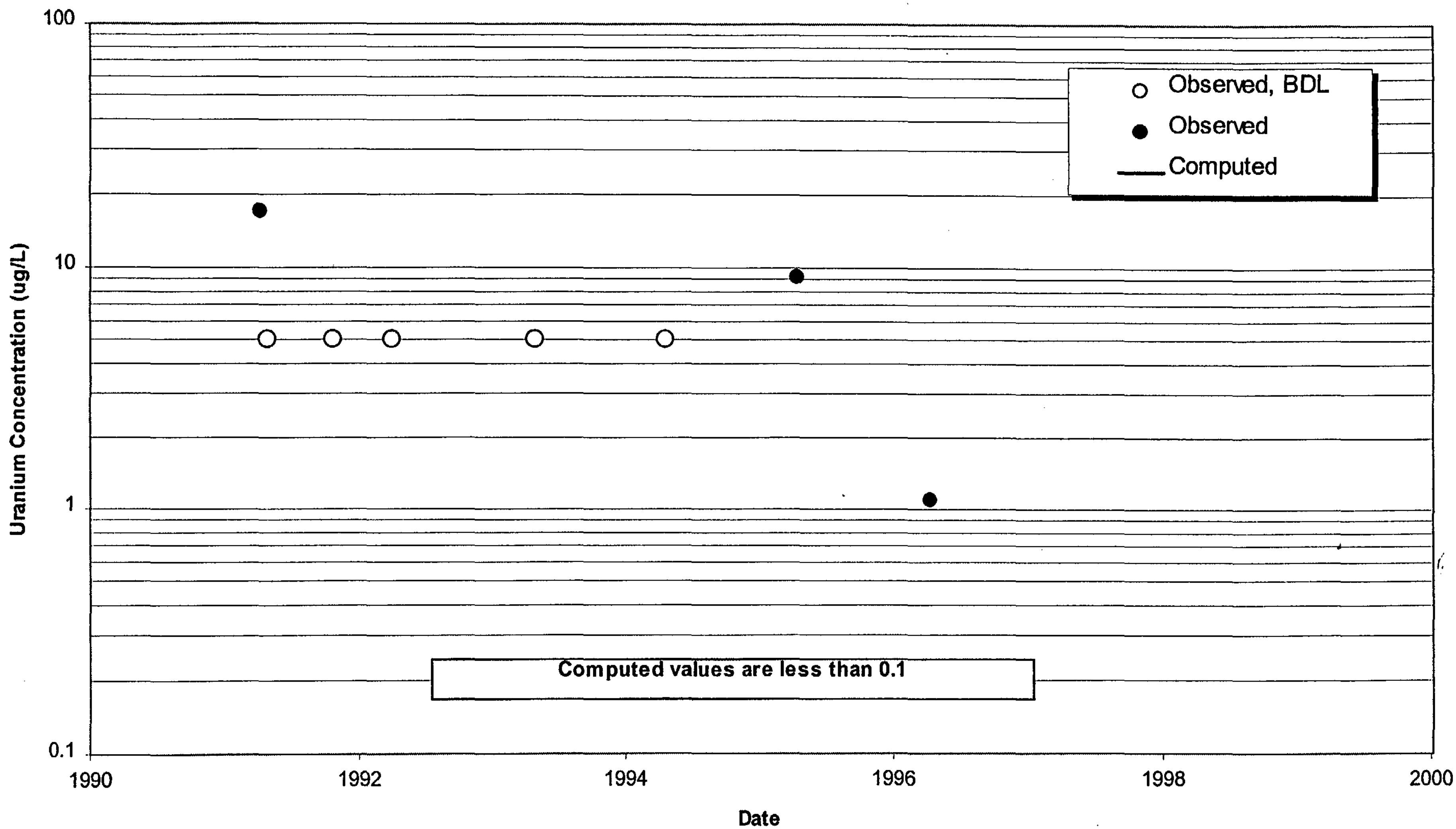


consulting scientists and engineers

FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW085

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|---|---|
| Date: | AUGUST 2002 |
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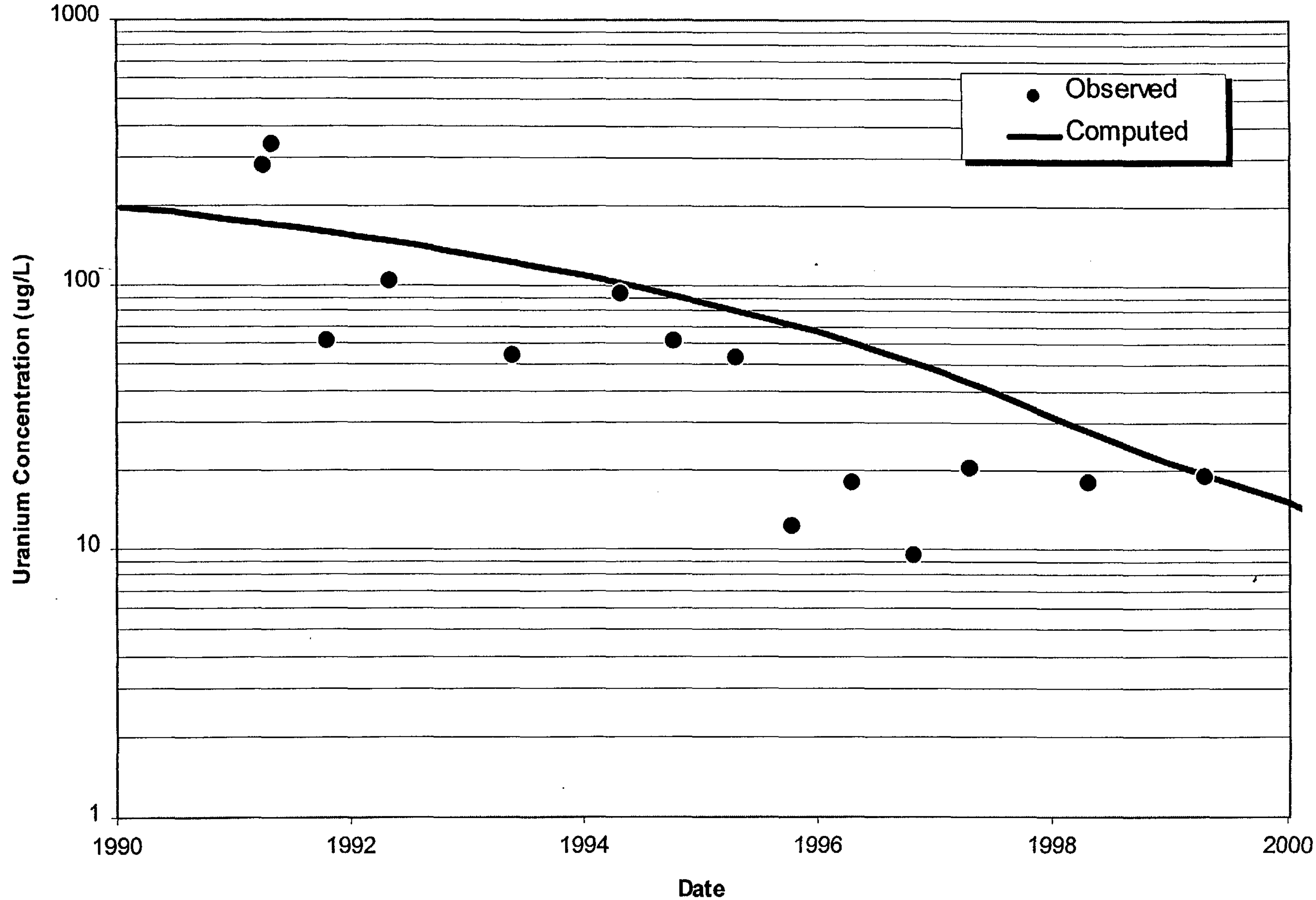
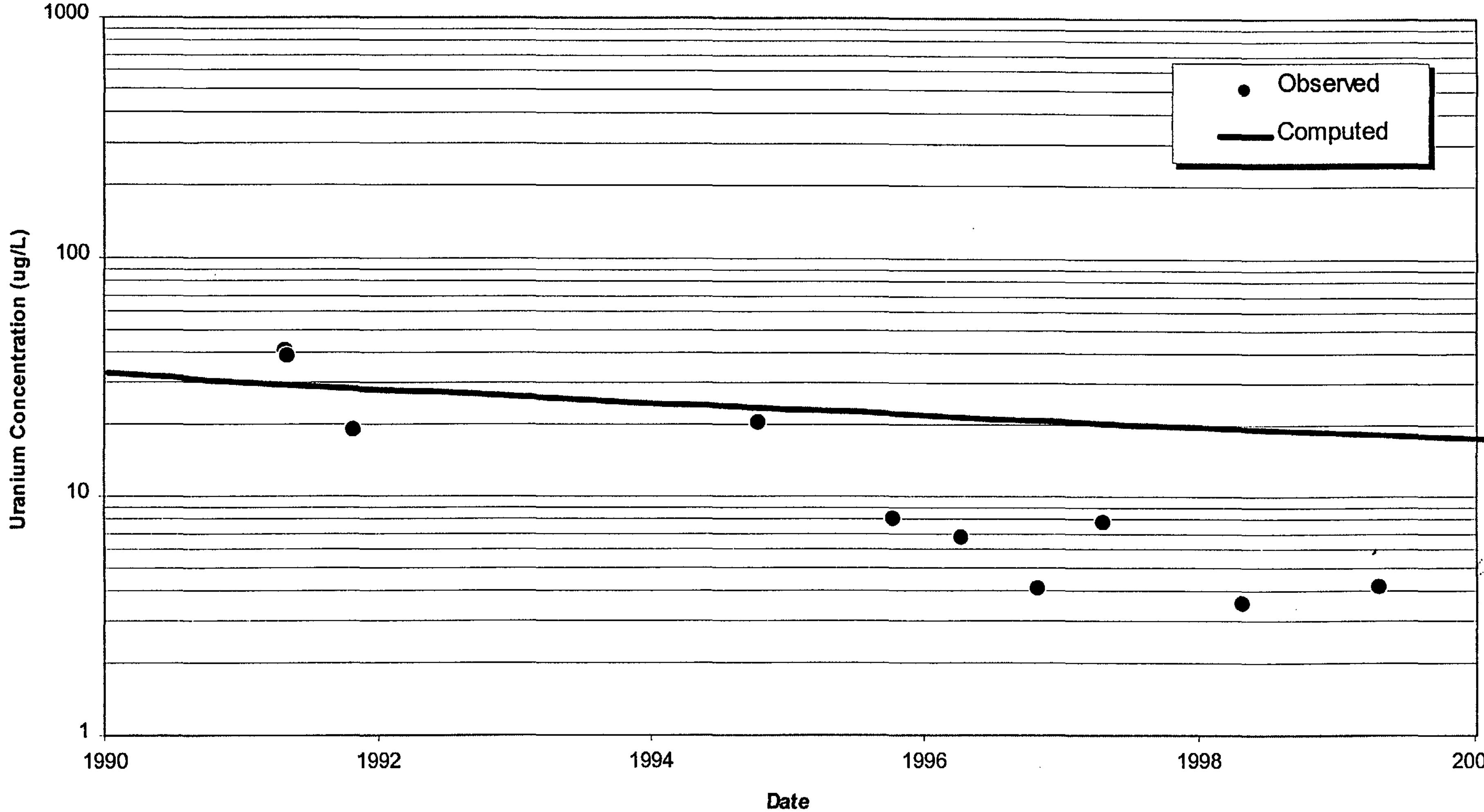



consulting scientists and engineers

FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW087A

| | |
|---|---|
| Date: | AUGUST 2002 |
| Project: | V:\Titleblocks\ |
| File: | MFG TBLK LAND.ppt |




consulting scientists and engineers

FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW087

| | |
|---|---|
| Date: | AUGUST 2002 |
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| File: | MFG TBLK LAND.ppt |

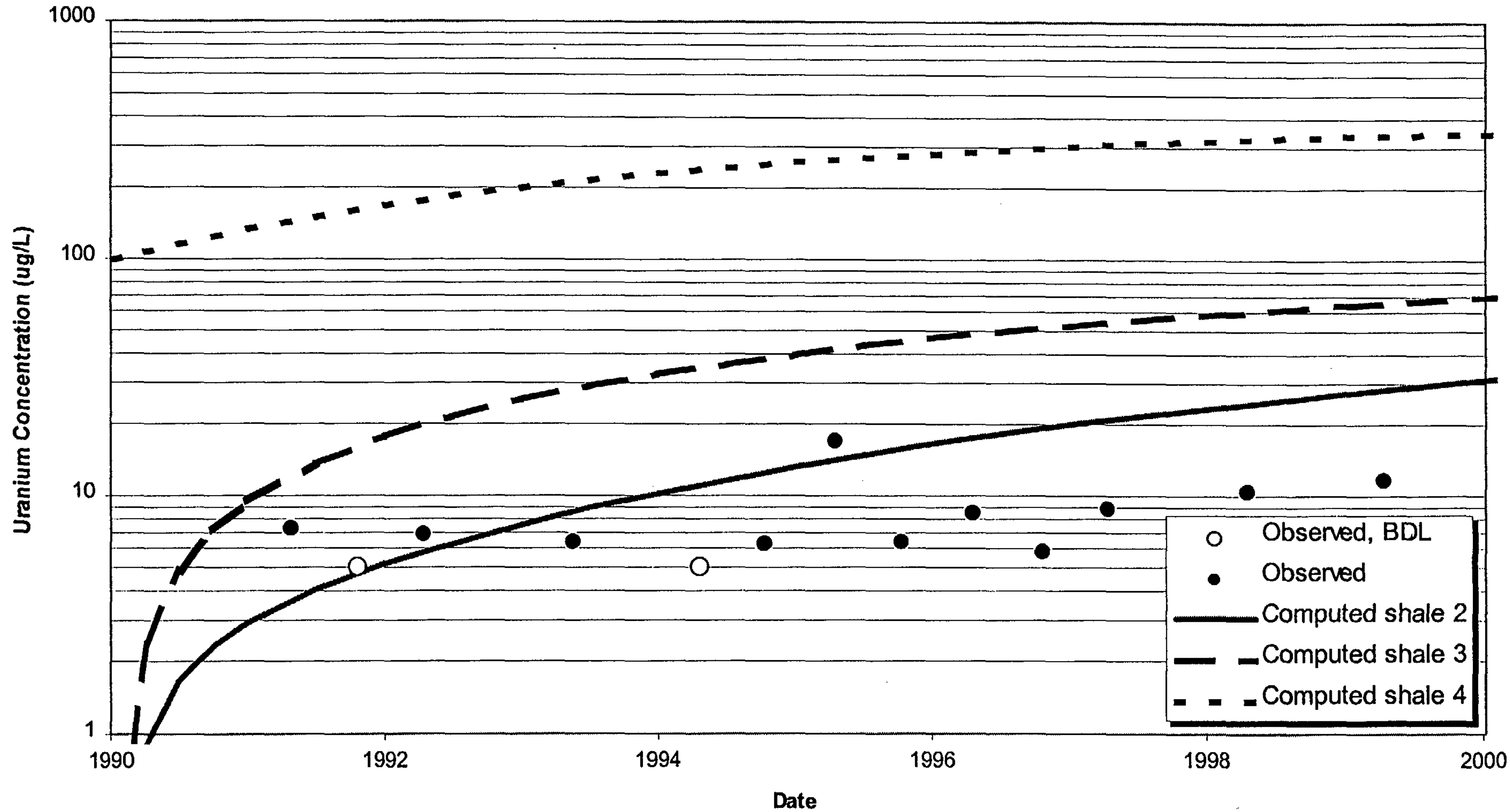


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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW088A

| | |
|---|---|
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| Project: | V:\Titleblocks\ |
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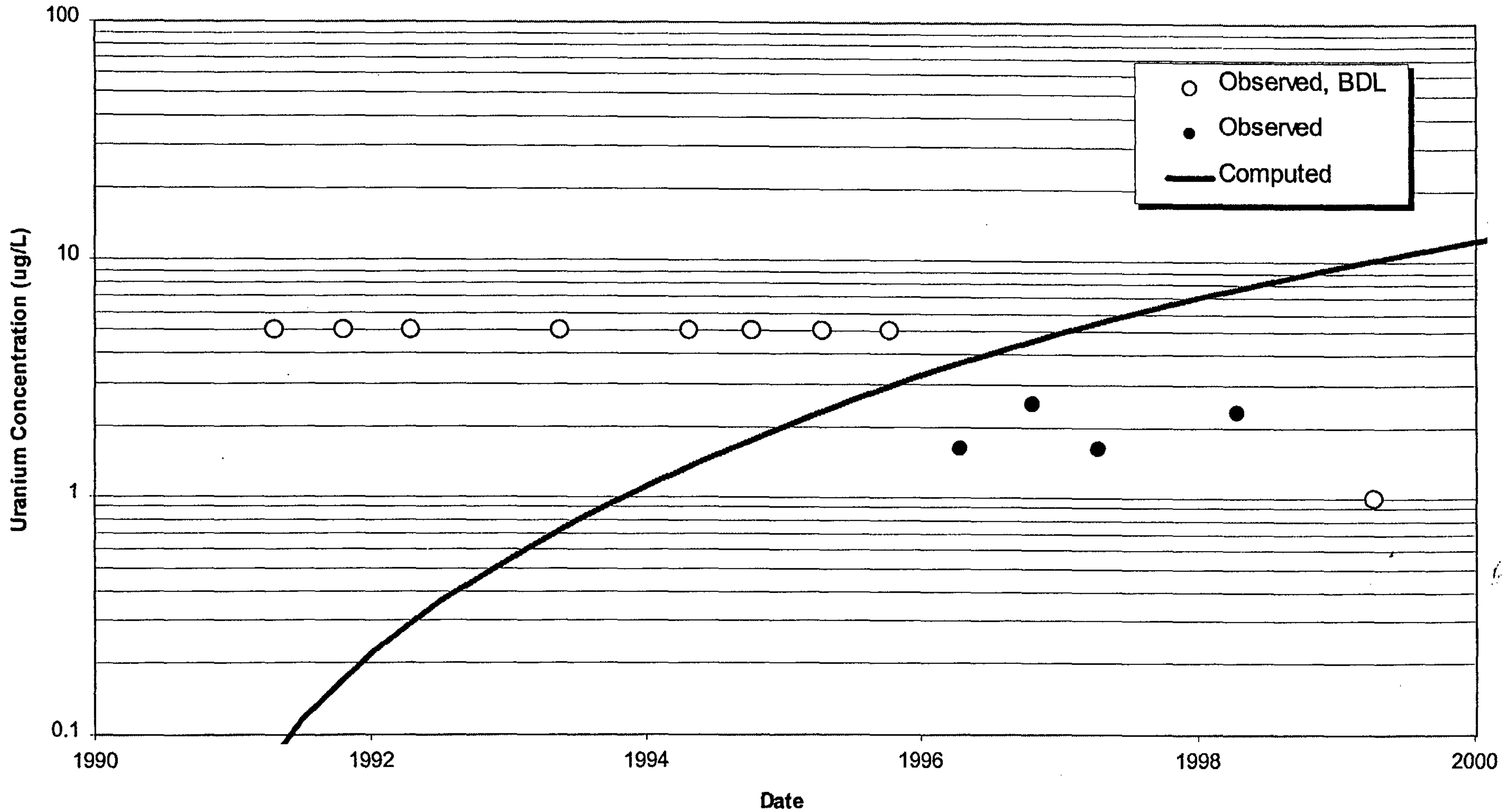




FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW089A

| | |
|---|---|
| Date: | AUGUST 2002 |
| Project: | V:\Titleblocks\ |
| File: | MFG TBLK LAND.ppt |

# APPENDIX G

# BOREHOLE DATA FOR EVS MODEL

## Table 1 Borehole Data for EVS Model

| LOC ID | NORTHING | EASTING | GRND ELEV | TOP TERRACE | TOP COLLUVIUM | TOP ALLUVIUM | TOP 1SH | TOP 1SS | TOP 2SH |
|---|---|---|---|---|---|---|---|---|---|
| 2301B | 196494.4 | 2836451.6 | 549.1 | 549.1 | | | 544.1 | 540.1 | 538.8 |
| 2303A | 195962.7 | 2835903.1 | 547.5 | | 547.5 | | | 541.0 | 538.0 |
| 2322A | 194098.8 | 2835576.2 | 524.9 | | 524.9 | | | 521.7 | 516.1 |
| 2334 | 197935.7 | 2836676.6 | 548.2 | | 548.2 | | | 539.7 | 538.4 |
| 2341 | 193734.5 | 2835035.0 | 494.9 | | 494.9 | | | | |
| 2342 | 193351.8 | 2835321.0 | 505.5 | | 505.5 | | | | 503.5 |
| 2343 | 193402.9 | 2836459.9 | 539.4 | | 539.4 | | | 524.4 | 524.1 |
| 2344 | 193084.9 | 2836495.6 | 522.4 | | 522.4 | | | 515.9 | 515.6 |
| 2346 | 193138.5 | 2836241.6 | 516.9 | | 516.9 | | | | |
| 2347 | 193303.8 | 2837057.6 | 535.5 | | 535.5 | | | 531.5 | 527.0 |
| 2348 | 194115.5 | 2836045.9 | 526.8 | | 526.8 | | | 525.8 | 522.8 |
| 2349 | 194137.5 | 2836525.4 | 533.8 | | 533.8 | | | 531.3 | 530.8 |
| 2350 | 194040.4 | 2837091.0 | 534.7 | 534.7 | | | 533.0 | 530.2 | 527.9 |
| 2351 | 193933.5 | 2836467.2 | 541.0 | | 541.0 | | | 530.7 | 529.8 |
| 2352 | 193750.6 | 2836474.3 | 541.0 | 541.0 | | | 529.5 | 527.5 | 526.8 |
| 2353 | 193918.4 | 2836047.5 | 541.0 | | 541.0 | | | | 523.0 |
| FTP 270-1 | 195929.7 | 2839225.0 | 569.0 | | 569.0 | | | 566.0 | 564.5 |
| FTP 270-2 | 194339.9 | 2839855.0 | 538.0 | | 538.0 | | | 536.7 | 535.0 |
| BH327 | 194737.5 | 2838430.0 | 549.5 | | 549.5 | | | 539.5 | 534.7 |
| BH328 | 193658.4 | 2833793.9 | 479.9 | | | 479.9 | | | |
| BH329 | 192596.3 | 2833765.8 | 482.5 | | | 482.5 | | | |
| BH330 | 195232.2 | 2835268.0 | 538.6 | | 538.6 | | | | |
| BH331 | 192778.6 | 2836051.1 | 501.0 | | 501.0 | | | | |
| BH333 | 195906.4 | 2836846.6 | 564.9 | 564.9 | | | 560.5 | 545.9 | 539.1 |
| BH335 | 194835.1 | 2835602.8 | 525.6 | | 525.6 | | | | |
| BH336 | 194456.4 | 2837511.6 | 539.4 | | 537.4 | | | 533.4 | 531.9 |
| BH337 | 194784.2 | 2836948.6 | 543.2 | | 543.2 | | | 538.2 | 536.2 |
| BH339 | 195204.3 | 2836453.1 | 549.7 | | 549.7 | | | 538.7 | 537.4 |
| FTP-07 | 192192.9 | 2835670.9 | 515.0 | | 515.0 | | | | |
| FTP-10 | 191849.1 | 2835833.5 | 530.0 | | 530.0 | | | | |
| FTP-11 | 191861.1 | 2835144.7 | 530.0 | | 530.0 | | | | |
| FTP-2B | 193408.5 | 2835787.4 | 512.4 | | 512.4 | | | | 509.9 |
| GB042 | 193254.8 | 2836129.7 | 514.0 | | 514.0 | | | | |

## Table 1 Borehole Data for EVS Model

| LOC ID | NORTHING | EASTING | GRND ELEV | TOP TERRACE | TOP COLLUVIUM | TOP ALLUVIUM | TOP 1SH | TOP 1SS | TOP 2SH |
|---|---|---|---|---|---|---|---|---|---|
| GB094 | 197592.9 | 2836929.0 | 548.3 | | 548.3 | | | 545.3 | 542.8 |
| GB096 | 197629.0 | 2837414.3 | 554.4 | | 554.4 | | | 554.2 | 545.4 |
| GB097 | 197345.5 | 2836949.4 | 546.5 | | 545.5 | | | 543.0 | 541.0 |
| GB098 | 197336.0 | 2837198.2 | 556.6 | | 556.6 | | | 551.6 | 548.6 |
| GB099 | 197342.5 | 2837423.2 | 551.9 | | 551.9 | | | 550.4 | 544.9 |
| GB106 | 196861.2 | 2838505.5 | 575.9 | | 575.9 | | | | 570.4 |
| GB108 | 196476.7 | 2838916.6 | 578.2 | | 578.2 | | | 574.0 | 573.1 |
| GB109 | 196463.4 | 2838518.8 | 578.1 | | 578.1 | | | 570.8 | 569.3 |
| GB114 | 195132.8 | 2836219.0 | 548.3 | 548.3 | | | 542.3 | 537.8 | 537.6 |
| GB138 | 194720.8 | 2839381.5 | 541.8 | | 541.8 | | | 539.3 | 539.1 |
| GB156 | 195138.9 | 2838582.9 | 558.0 | | 558.0 | | | 552.9 | 548.5 |
| GB163 | 196204.1 | 2839680.6 | 577.3 | | 577.3 | | | 572.5 | 570.8 |
| GB166 | 195674.5 | 2839073.0 | 560.3 | | 560.3 | | | 556.2 | 555.3 |
| GB169 | 194543.7 | 2838768.1 | 547.5 | | 547.5 | | | | |
| GB170 | 194552.7 | 2836233.6 | 516.7 | | 516.7 | | | | |
| GB172 | 193480.3 | 2837818.1 | 540.0 | | 540.0 | | | 535.5 | 532.8 |
| GB174 | 195191.8 | 2840496.4 | 541.8 | | 541.8 | | | | |
| GB177 | 192662.3 | 2837860.4 | 533.5 | | 533.5 | | | | |
| MW004A | 195478.5 | 2837406.2 | 560.3 | 560.3 | | | 554.5 | 546.3 | 542.3 |
| MW007B | 195843.0 | 2837532.2 | 570.3 | 570.3 | | | 563.3 | 550.3 | 547.9 |
| MW027A | 195859.3 | 2836865.1 | 564.7 | 564.7 | | | 559.7 | 546.7 | 541.2 |
| MW036A | 195953.9 | 2836348.6 | 561.6 | 561.6 | | | 552.1 | 542.1 | 541.0 |
| MW037A | 196408.1 | 2836057.6 | 527.1 | | 527.1 | | | | |
| MW038A | 196241.5 | 2836076.6 | 539.8 | | 539.8 | | | | |
| MW042A | 195238.7 | 2836442.9 | 550.2 | | 549.7 | | | 537.7 | 537.2 |
| MW043 | 194991.0 | 2836516.9 | 537.9 | | 537.3 | | | 535.5 | 535.0 |
| MW045A | 195971.2 | 2835659.7 | 542.0 | 542.0 | | | 537.5 | 536.8 | 532.0 |
| MW047A | 195961.3 | 2835234.5 | 537.2 | | 536.9 | | | | 527.4 |
| MW048A | 195746.6 | 2835231.1 | 528.7 | | 527.7 | | | 525.2 | 522.7 |
| MW050B | 196919.4 | 2836118.1 | 537.5 | | 537.5 | | | 532.0 | 531.0 |
| MW051A | 195543.9 | 2835237.9 | 528.3 | | 528.3 | | | | |
| MW052A | 196733.5 | 2835969.9 | 537.1 | | 537.1 | | | | 531.7 |
| MW053A | 196071.3 | 2836598.2 | 557.3 | 557.3 | | | 546.3 | 543.6 | 539.3 |

**Table 1 Borehole Data for EVS Model**

| LOC ID | NORTHING | EASTING | GRND ELEV | TOP TERRACE | TOP COLLUVIUM | TOP ALLUVIUM | TOP 1SH | TOP 1SS | TOP 2SH |
|---|---|---|---|---|---|---|---|---|---|
| MW056 | 196083.2 | 2835342.2 | 532.2 | | 531.9 | | | 530.7 | 527.2 |
| MW057A | 195211.0 | 2835254.0 | 537.9 | | 537.5 | | | | |
| MW058A | 195013.3 | 2835553.5 | 535.5 | | 535.5 | | | | 531.0 |
| MW063A | 194838.4 | 2836704.5 | 529.9 | | 529.9 | | | 529.4 | 528.9 |
| MW065A | 195136.7 | 2835957.7 | 541.3 | | 541.3 | | | 534.8 | 530.3 |
| MW066A | 195345.9 | 2836684.7 | 556.0 | 556.0 | | | 552.0 | 537.0 | 535.6 |
| MW068A | 196873.7 | 2836615.8 | 549.9 | | 549.9 | | | 542.3 | 539.1 |
| MW069A | 196882.1 | 2836799.4 | 551.6 | | 551.6 | | | 543.1 | 540.6 |
| MW070A | 196542.7 | 2837377.1 | 568.5 | 568.5 | | | 559.5 | 554.2 | 551.1 |
| MW071A | 195056.0 | 2836965.4 | 540.8 | | 540.8 | | | 537.8 | 536.0 |
| MW072B | 196419.8 | 2837549.8 | 574.6 | 574.6 | | | 566.4 | 555.0 | 554.4 |
| MW075A | 196377.7 | 2836756.5 | 558.4 | 558.4 | | | 546.9 | 543.4 | 542.4 |
| MW076A | 195638.9 | 2836450.8 | 565.5 | 565.5 | | | 555.7 | | 541.0 |
| MW081A | 196805.6 | 2837138.3 | 556.7 | | 556.7 | | | 552.0 | 549.7 |
| MW082A | 195347.7 | 2835717.7 | 548.5 | | 548.5 | | | 541.5 | 540.5 |
| MW084A | 195644.2 | 2836676.8 | 566.2 | 566.2 | | | 561.2 | | 541.2 |
| MW086A | 196042.4 | 2836872.3 | 564.0 | 564.0 | | | 552.8 | 548.0 | 546.0 |
| MW087A | 196656.1 | 2836454.5 | 549.2 | 549.2 | | | 543.0 | 541.2 | |
| MW088A | 197047.4 | 2836148.7 | 538.6 | | 538.3 | | | 536.1 | 533.4 |
| MW089A | 196919.5 | 2835979.4 | 535.9 | | 535.5 | | | 532.7 | 530.9 |
| MW090B | 194176.0 | 2834952.0 | 485.3 | | 485.3 | | | | |
| MW091A | 194672.9 | 2835850.2 | 525.0 | | 525.0 | | | | |
| MW092A | 194783.2 | 2835377.5 | 521.6 | | 521.6 | | | | |
| MW093A | 194910.6 | 2834987.2 | 518.6 | | | | | | |
| MW094A | 196390.3 | 2835202.5 | 527.3 | | 527.3 | | | | |
| MW095A | 195032.4 | 2834516.5 | 486.1 | | 486.1 | | | | |
| MW096A | 197285.1 | 2835669.9 | 524.4 | | 524.4 | | | | |
| MW099A | 197252.9 | 2836019.7 | 525.5 | | 525.5 | | | | |
| MW100B | 196661.9 | 2835524.1 | 499.5 | | 499.5 | | | | |
| MW101A | 194547.3 | 2836433.2 | 527.7 | | 527.7 | | | | |
| MW102A | 195436.8 | 2836132.9 | 556.8 | 556.8 | | | 553.3 | 540.8 | 539.8 |
| MW103A | 195584.0 | 2835682.5 | 554.1 | | 554.1 | | | 545.1 | 541.1 |
| MW104B | 193501.4 | 2836317.8 | 524.5 | | 524.5 | | | | 520.6 |

**Table 1 Borehole Data for EVS Model**

| LOC ID | NORTHING | EASTING | GRND ELEV | TOP TERRACE | TOP COLLUVIUM | TOP ALLUVIUM | TOP 1SH | TOP 1SS | TOP 2SH |
|---|---|---|---|---|---|---|---|---|---|
| MW105B | 193728.9 | 2834972.4 | 486.5 | | 486.5 | | | | |
| MW107 | 193291.0 | 2833887.4 | 489.3 | | | 489.3 | | | |
| MW109A | 196970.0 | 2837070.0 | 546.2 | | 546.2 | | | 543.2 | 542.4 |

**Table 1 Borehole Data for EVS Model**

| LOC ID | NORTHING | EASTING | GRND ELEV | TOP 2SS | TOP 3SH | TOP 3SS | TOP 4SH | TOP 4SS | TOP 5SH | TOP 5SS |
|---|---|---|---|---|---|---|---|---|---|---|
| 2301B | 196494.4 | 2836451.6 | 549.1 | 534.6 | | | | | | |
| 2303A | 195962.7 | 2835903.1 | 547.5 | 530.5 | 523.0 | 521.0 | | | | |
| 2322A | 194098.8 | 2835576.2 | 524.9 | 511.4 | 504.5 | 501.4 | 495.1 | | | |
| 2334 | 197935.7 | 2836676.6 | 548.2 | 529.7 | 525.7 | 525.2 | 517.2 | 497.7 | 489.7 | |
| 2341 | 193734.5 | 2835035.0 | 494.9 | | 488.6 | 486.7 | 484.9 | | | |
| 2342 | 193351.8 | 2835321.0 | 505.5 | 493.5 | 486.0 | 483.5 | 477.5 | | | |
| 2343 | 193402.9 | 2836459.9 | 539.4 | 517.4 | 502.9 | | | | | |
| 2344 | 193084.9 | 2836495.6 | 522.4 | 512.2 | 505.1 | 502.4 | | | | |
| 2346 | 193138.5 | 2836241.6 | 516.9 | 508.9 | 501.4 | 498.9 | | | | |
| 2347 | 193303.8 | 2837057.6 | 535.5 | | 519.5 | 516.5 | 513.0 | | | |
| 2348 | 194115.5 | 2836045.9 | 526.8 | 516.3 | 511.8 | 505.8 | 502.8 | | | |
| 2349 | 194137.5 | 2836525.4 | 533.8 | 526.2 | 520.8 | 519.8 | 512.8 | 491.8 | | |
| 2350 | 194040.4 | 2837091.0 | 534.7 | 522.7 | 520.0 | 519.2 | 516.7 | | | |
| 2351 | 193933.5 | 2836467.2 | 541.0 | 521.7 | 514.6 | 511.5 | 505.8 | | | |
| 2352 | 193750.6 | 2836474.3 | 541.0 | 518.7 | 513.5 | 508.9 | 503.0 | | | |
| 2353 | 193918.4 | 2836047.5 | 541.0 | 512.6 | 504.5 | 502.0 | 496.0 | | | |
| FTP 270-1 | 195929.7 | 2839225.0 | 569.0 | 556.0 | 551.0 | 546.4 | 543.3 | 524.0 | 513.0 | |
| FTP 270-2 | 194339.9 | 2839855.0 | 538.0 | 531.3 | 526.8 | 525.7 | 516.5 | | | |
| BH327 | 194737.5 | 2838430.0 | 549.5 | 533.8 | 532.8 | 530.6 | 525.3 | 508.9 | | |
| BH328 | 193658.4 | 2833793.9 | 479.9 | | | | 455.9 | 440.6 | | |
| BH329 | 192596.3 | 2833765.8 | 482.5 | | | | 467.3 | 449.5 | 442.6 | |
| BH330 | 195232.2 | 2835268.0 | 538.6 | 525.6 | 518.2 | 515.6 | 508.9 | | | |
| BH331 | 192778.6 | 2836051.1 | 501.0 | | | 490.0 | 482.0 | | | |
| BH333 | 195906.4 | 2836846.6 | 564.9 | 537.8 | | | | | | |
| BH335 | 194835.1 | 2835602.8 | 525.6 | 524.6 | 512.7 | 512.6 | 509.1 | | | |
| BH336 | 194456.4 | 2837511.6 | 539.4 | 528.4 | 521.1 | | | | | |
| BH337 | 194784.2 | 2836948.6 | 543.2 | 533.2 | | | | | | |
| BH339 | 195204.3 | 2836453.1 | 549.7 | 528.7 | 522.8 | 519.7 | 513.2 | | | |
| FTP-07 | 192192.9 | 2835670.9 | 515.0 | | | 499.0 | 490.8 | | | |
| FTP-10 | 191849.1 | 2835833.5 | 530.0 | | | | 509.6 | | | |
| FTP-11 | 191861.1 | 2835144.7 | 530.0 | | | | 513.7 | | | |
| FTP-2B | 193408.5 | 2835787.4 | 512.4 | 505.9 | 498.9 | 494.4 | 489.4 | | | |
| GB042 | 193254.8 | 2836129.7 | 514.0 | 509.5 | 499.5 | 498.0 | | | | |

## Table 1 Borehole Data for EVS Model

| LOC ID | NORTHING | EASTING | GRND ELEV | TOP 2SS | TOP 3SH | TOP 3SS | TOP 4SH | TOP 4SS | TOP 5SH | TOP 5SS |
|---|---|---|---|---|---|---|---|---|---|---|
| GB094 | 197592.9 | 2836929.0 | 548.3 | 537.3 | | | | | | |
| GB096 | 197629.0 | 2837414.3 | 554.4 | 539.4 | | | | | | |
| GB097 | 197345.5 | 2836949.4 | 546.5 | | | | | | | |
| GB098 | 197336.0 | 2837198.2 | 556.6 | 543.6 | | | | | | |
| GB099 | 197342.5 | 2837423.2 | 551.9 | | | | | | | |
| GB106 | 196861.2 | 2838505.5 | 575.9 | 563.4 | 556.9 | 554.6 | 548.1 | | | |
| GB108 | 196476.7 | 2838916.6 | 578.2 | 564.2 | 559.8 | 558.2 | 552.2 | | | |
| GB109 | 196463.4 | 2838518.8 | 578.1 | 559.5 | 556.1 | 551.3 | | | | |
| GB114 | 195132.8 | 2836219.0 | 548.3 | 529.8 | 523.6 | 520.4 | | | | |
| GB138 | 194720.8 | 2839381.5 | 541.8 | 535.9 | | | | | | |
| GB156 | 195138.9 | 2838582.9 | 558.0 | 543.5 | | | | | | |
| GB163 | 196204.1 | 2839680.6 | 577.3 | 568.8 | 566.7 | 560.8 | | | | |
| GB166 | 195674.5 | 2839073.0 | 560.3 | 552.3 | 546.6 | | | | | |
| GB169 | 194543.7 | 2838768.1 | 547.5 | 541.7 | 539.4 | 537.5 | 530.2 | | | |
| GB170 | 194552.7 | 2836233.6 | 516.7 | | | 516.2 | 512.2 | | | |
| GB172 | 193480.3 | 2837818.1 | 540.0 | 532.0 | 531.4 | 526.0 | 518.4 | | | |
| GB174 | 195191.8 | 2840496.4 | 541.8 | | | 540.8 | 527.4 | 508.4 | 495.8 | |
| GB177 | 192662.3 | 2837860.4 | 533.5 | | | 530.5 | 520.5 | | | |
| MW004A | 195478.5 | 2837406.2 | 560.3 | 538.3 | 530.3 | | | | | |
| MW007B | 195843.0 | 2837532.2 | 570.3 | 546.3 | 544.6 | 540.9 | 525.3 | 509.1 | 499.5 | |
| MW027A | 195859.3 | 2836865.1 | 564.7 | 539.7 | 538.7 | 534.7 | | | | |
| MW036A | 195953.9 | 2836348.6 | 561.6 | 533.6 | | | | | | |
| MW037A | 196408.1 | 2836057.6 | 527.1 | | | 521.6 | 514.1 | 499.1 | | |
| MW038A | 196241.5 | 2836076.6 | 539.8 | 531.5 | 527.3 | 524.8 | 516.8 | 500.3 | | |
| MW042A | 195238.7 | 2836442.9 | 550.2 | 531.2 | | | | | | |
| MW043 | 194991.0 | 2836516.9 | 537.9 | 528.4 | | | | | | |
| MW045A | 195971.2 | 2835659.7 | 542.0 | 527.5 | | | | | | |
| MW047A | 195961.3 | 2835234.5 | 537.2 | 521.7 | | | | | | |
| MW048A | 195746.6 | 2835231.1 | 528.7 | 513.7 | 510.7 | | | | | |
| MW050B | 196919.4 | 2836118.1 | 537.5 | 525.8 | 523.0 | 520.8 | 510.0 | 492.1 | 487.5 | |
| MW051A | 195543.9 | 2835237.9 | 528.3 | 522.5 | 521.8 | 513.3 | 509.3 | | | |
| MW052A | 196733.5 | 2835969.9 | 537.1 | 529.0 | 523.3 | 520.3 | 513.1 | | | |
| MW053A | 196071.3 | 2836598.2 | 557.3 | 532.3 | 529.3 | | | | | |

**Table 1 Borehole Data for EVS Model**

| LOC ID | NORTHING | EASTING | GRND ELEV | TOP 2SS | TOP 3SH | TOP 3SS | TOP 4SH | TOP 4SS | TOP 5SH | TOP 5SS |
|---|---|---|---|---|---|---|---|---|---|---|
| MW056 | 196083.2 | 2835342.2 | 532.2 | | | | | | | |
| MW057A | 195211.0 | 2835254.0 | 537.9 | 525.2 | | 515.9 | 508.4 | | | |
| MW058A | 195013.3 | 2835553.5 | 535.5 | 527.5 | | 519.5 | 513.5 | | | |
| MW063A | 194838.4 | 2836704.5 | 529.9 | 527.3 | | 519.9 | 513.4 | | | |
| MW065A | 195136.7 | 2835957.7 | 541.3 | 524.3 | 518.3 | | | | | |
| MW066A | 195345.9 | 2836684.7 | 556.0 | 530.0 | 523.0 | | | | | |
| MW068A | 196873.7 | 2836615.8 | 549.9 | 532.9 | | 527.9 | 517.9 | | | |
| MW069A | 196882.1 | 2836799.4 | 551.6 | 534.6 | | 529.6 | 518.6 | | | |
| MW070A | 196542.7 | 2837377.1 | 568.5 | 549.5 | 548.5 | 543.0 | 529.5 | | | |
| MW071A | 195056.0 | 2836965.4 | 540.8 | 531.8 | 523.8 | 520.8 | 516.3 | | | |
| MW072B | 196419.8 | 2837549.8 | 574.6 | 550.3 | 549.1 | 546.0 | 530.6 | 514.8 | 505.2 | |
| MW075A | 196377.7 | 2836756.5 | 558.4 | 534.4 | 528.4 | 526.4 | 519.4 | | | |
| MW076A | 195638.9 | 2836450.8 | 565.5 | 536.0 | 535.1 | | | | | |
| MW081A | 196805.6 | 2837138.3 | 556.7 | 542.7 | | 536.7 | 528.2 | | | |
| MW082A | 195347.7 | 2835717.7 | 548.5 | 532.5 | 526.5 | 526.4 | 517.5 | | | |
| MW084A | 195644.2 | 2836676.8 | 566.2 | 539.5 | 538.2 | | 526.7 | | | |
| MW086A | 196042.4 | 2836872.3 | 564.0 | | 541.0 | | 522.5 | | | |
| MW087A | 196656.1 | 2836454.5 | 549.2 | 536.2 | | 525.7 | 517.2 | | | |
| MW088A | 197047.4 | 2836148.7 | 538.6 | 527.6 | | 522.6 | 512.6 | | | |
| MW089A | 196919.5 | 2835979.4 | 535.9 | 525.9 | | 519.9 | 508.9 | | | |
| MW090B | 194176.0 | 2834952.0 | 485.3 | | | | | 469.8 | 453.3 | |
| MW091A | 194672.9 | 2835850.2 | 525.0 | 523.0 | 518.0 | 512.0 | 508.0 | | | |
| MW092A | 194783.2 | 2835377.5 | 521.6 | 520.6 | 514.6 | 509.1 | 504.1 | | | |
| MW093A | 194910.6 | 2834987.2 | 518.6 | 518.6 | 516.6 | 510.1 | 494.6 | | | |
| MW094A | 196390.3 | 2835202.5 | 527.3 | 523.8 | 518.3 | 512.8 | 505.8 | 494.3 | | |
| MW095A | 195032.4 | 2834516.5 | 486.1 | | | | 473.1 | 467.6 | | |
| MW096A | 197285.1 | 2835669.9 | 524.4 | 519.9 | 515.9 | 513.9 | 505.4 | | | |
| MW099A | 197252.9 | 2836019.7 | 525.5 | 524.5 | 517.0 | 515.0 | 506.5 | | | |
| MW100B | 196661.9 | 2835524.1 | 499.5 | | | | | 494.5 | 481.5 | |
| MW101A | 194547.3 | 2836433.2 | 527.7 | 525.9 | 520.7 | 517.2 | 512.7 | | | |
| MW102A | 195436.8 | 2836132.9 | 556.8 | 536.8 | 534.8 | 530.8 | 516.8 | | | |
| MW103A | 195584.0 | 2835682.5 | 554.1 | 536.8 | 534.1 | 534.0 | 518.1 | | | |
| MW104B | 193501.4 | 2836317.8 | 524.5 | 513.8 | 504.3 | 501.5 | 496.4 | 480.3 | 471.7 | |

**Table 1 Borehole Data for EVS Model**

| LOC ID | NORTHING | EASTING | GRND ELEV | TOP 2SS | TOP 3SH | TOP 3SS | TOP 4SH | TOP 4SS | TOP 5SH | TOP 5SS |
|---|---|---|---|---|---|---|---|---|---|---|
| MW105B | 193728.9 | 2834972.4 | 486.5 | | | 484.6 | 481.2 | 463.1 | 448.3 | |
| MW107 | 193291.0 | 2833887.4 | 489.3 | | | | | 468.3 | | |
| MW109A | 196970.0 | 2837070.0 | 546.2 | 535.7 | | 528.2 | 520.2 | | | |

## APPENDIX H

## EVSTRIM.EXE

PROGRAM EVSTRIM.FOR

```
      real x,y,z(10),ox,oy,rot,ZT(10),xt,yt,otx,oty
      character*80 ending*4,infile2,gvgans*1,geoans*1
      character*80 inline,infile1,outfile,unit*2,root*4,num(20)
      integer znum,nrow,ncol,ztnum
      data num /'01','02','03','04','05','06','07','08','09','10','11',
     +      '12','13','14','15','16','17','18','19','20'/

C     READ THE FILE NAMES AND OPEN THEM

      write(*,*)' Enter gvg multi layer input file name > '
      read(*,*)infile1
      open(10,infile1)
      write(*,*)' Enter number of z values in file > '
      read(*,*)znum

      write(*,*)' Enter gvg truncating surface input file name > '
      read(*,*)infile2
      open(50,infile2)

      write(*,*)' Enter number of z values in file > '
      read(*,*)ztnum

      write(*,*)'do you want to make a gvg file (y/n) '
      read(*,*)gvgans
      if(gvgans.eq.'y')then
            write(*,*)' Enter output file name > '
            read(*,*)infile2
            open(51,infile2)
      end if
      write(*,*)'do you want to make a geo file (y/n) '
      read(*,*)geoans
      if(geoans.eq.'y')then
            write(*,*)' Enter output data file name > '
            read(*,*)infile2
            open(52,infile2)
      end if
      write(*,*)'Enter minimum thickness '
      read(*,*)thick
      read(50,*)inline
      read(50,*)inline
      read(50,*)nrow,ncol,otx,oty,rot
      read(50,*)inline
      read(10,'(a80)')inline
      if(gvgans.eq.'y')write(51,*)inline
      read(10,'(a80)')inline
      if(gvgans.eq.'y')write(51,*)inline
      read(10,*)nrow,ncol,ox,oy,rot
      if(gvgans.eq.'y')write(51,*)nrow,ncol,ox,oy,rot
      read(10,'(a80)')inline
      if(gvgans.eq.'y')write(51,*)inline
```

```fortran
      do i=1,10000000
            read(50,*,end=999)xt,yt,(zT(j),j=1,ztnum)
            xt=otx+xt
            yt=oty+yt
            read(10,*,end=888)x,y,(z(j),j=1,znum)
            x=ox+x
            y=oy+y
c           write(*,*)xt,yt,x,y
C     trim the geo file
            if((xt.eq.x).and.(yt.eq.y))then
                  do j=znum,2,-1
                        if(zt(ztnum).le.z(j))z(j)=zt(ztnum)-(j-1)*thick
                  end do
                  do j=znum,2,-1
                        IF(Z(J).GE.Z(J-1))Z(J)=Z(J-1)-thick
                  END DO
c     double check
                  if(geoans.eq.'y')write(52,'(25f14.4)')x,y,
     +                  (ZT(l),l=1,ztnum),(z(j),j=2,znum)
                  if(gvgans.eq.'y')then
                  x=x-ox
                  y=y-oy

      write(51,'(25f14.4)')x,y,(ZT(l),l=1,ztnum),(z(j),j=2,znum)
                  end if
            else
                  write(*,*)'coordinates do not match',znum,i
                  write(*,*)'rewinding file'
                  close (10)
                  open(10,infile1)
                  do k=1,10000000
                  read(10,*)x,y,(z(j),j=1,znum)
                  if((xt.eq.x).and.(yt.eq.y))write(*,*)' found'
                  end do

            end if
      end do
888   write(*,*)'Matching point not found'
999   end
```

# APPENDIX I

# VEGETATION WATER BALANCE ESTIMATES FOR SEQUOYAH SITE

## VEGETATION WATER BALANCE ESTIMATES FOR SEQUOYAH SITE

Location: Sequoyah County, Oklahoma

Three vegetation types:

1. Oak woodland
2. Bluestem prairie
3. Bermudagrass pasture

Assumptions:

| Vegetation Type | Annual Production | | Water-use Efficiency |
|---|---|---|---|
| Oak woodland | 900 $g/m^2$ | ( 8,000 lbs/ac) | 1624 |
| Bluestem prairie | 450 $g/m^2$ | ( 4,000 lbs/ac) | 1634 |
| Bermudagrass pasture | 1200 $g/m^2$ | (10,600 lbs/ac) | 2238 |

Production References:

| | |
|---|---|
| woodland | Whittaker (1975) |
| prairie | Fick (1994) |
| pasture | 75% of annual average for coastal bermudagrass in Georgia, fertilized with 200 lbs N/ac/year (Burton 1962) |

WUE References:

| | |
|---|---|
| woodland | Mean of oak shrubland (Tenhunen 1990) + 1.6(average of 2 oak species): McCarthy et al. 1990, Lindroth et al. 1994) |
| prairie | Mean of Berg and Sims 1984 (Oklahoma midgrass prairie), Sims and Singh 1978 (Kansas mixed prairie), and Weaver 1941 (bluestem prairie) |
| pasture | Mean of shortgrass pasture (Liang et al. 1989) + 1.6(average of 4 grasses): KR bluestem (Coyne 1986), blue grama (Weaver 1941), tobosa (Dwyer and Degarmo 1970), weeping lovegrass (Masters et al. 1990) |

## Maximum reported rooting depths

| | cm | in | |
|---|---|---|---|
| Oak | | | |
| white oak | 2300 | 906 | Kozlowski and Scholtes (1948) |
| California scrub oak | 853 | 336 | Hellmers et al. (1955) |
| bur oak | 500 | 197 | Herman (1977) |
| Little bluestem | 244 | 96 | Weaver and Fitzpatrick (1934) |
| Bermudagrass | | | |
| purple threeawn | 182 | 72 | Albertson (1937) |
| KR bluestem | 240 | 94 | Coyne and Bradford (1986) |
| blue grama | 213 | 84 | Hopkins (1953) |
| buffalograss | 216 | 85 | Weaver and Clements (1938) |
| tobosa | 150 | 59 | Cottle (1931) |
| Assumption: Evaporation from soil surface in winter months equals 10% of pan evaporation. | | | |

## Monthly water balance (monthly average values): oak woodland

| | Precipitation | | Pan Evaporation | | Production | | ET | | Balance | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month | (in) | (cm) | (in) | (cm) | rate | g/m$^2$ | (in) | (cm) | (in) | (cm) |
| Jan | 1.75 | 4.44 | 1.63 | 4.10 | 0.00 | 0 | 0.16 | 0.41 | 1.59 | 4.04 |
| Feb | 2.38 | 6.05 | 2.14 | 5.40 | 0.00 | 0 | 0.21 | 0.54 | 2.17 | 5.51 |
| Mar | 3.61 | 9.17 | 4.36 | 11.10 | 0.40 | 60 | 3.83 | 9.74 | -0.21 | - 0.54 |
| Apr | 4.58 | 11.63 | 5.87 | 14.90 | 0.80 | 120 | 7.67 | 19.49 | -3.09 | - 7.86 |
| May | 5.48 | 13.92 | 6.21 | 15.80 | 1.00 | 150 | 9.59 | 24.36 | -4.09 | -10.38 |
| Jun | 4.57 | 11.60 | 7.31 | 18.60 | 1.00 | 150 | 9.59 | 24.36 | -5.02 | -12.76 |
| Jul | 3.44 | 8.74 | 8.59 | 21.80 | 1.00 | 150 | 9.59 | 24.36 | -6.15 | -15.62 |
| Aug | 3.19 | 8.10 | 8.06 | 20.50 | 1.00 | 150 | 9.59 | 24.36 | -6.40 | -16.26 |
| Sep | 4.49 | 11.40 | 5.72 | 14.50 | 0.60 | 90 | 5.75 | 14.61 | -1.26 | - 3.21 |
| Oct | 3.39 | 8.61 | 4.33 | 11.00 | 0.20 | 30 | 1.92 | 4.87 | 1.47 | 3.74 |
| Nov | 2.75 | 6.99 | 2.66 | 6.80 | 0.00 | 0 | 0.27 | 0.68 | 2.48 | 6.31 |
| Dec | 2.38 | 6.05 | 1.65 | 4.20 | 0.00 | 0 | 0.17 | 0.42 | 2.21 | 5.63 |
| Annual | 42.01 | 106.70 | 58.53 | 148.70 | 6.00 | 900 | 58.34 | 148.20 | -16.31 | -41.40 |

## Monthly water balance (monthly average values): bluestem prairie

| | Precipitation | | Pan Evaporation | | Production | | ET | | Balance | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month | (in) | (cm) | (in) | (cm) | rate | g/m² | (in) | (cm) | (in) | (cm) |
| Jan | 1.75 | 4.44 | 1.63 | 4.10 | 0.00 | 0 | 0.16 | 0.41 | 1.59 | 4.04 |
| Feb | 2.38 | 6.05 | 2.14 | 5.40 | 0.00 | 0 | 0.21 | 0.54 | 2.17 | 5.51 |
| Mar | 3.61 | 9.17 | 4.36 | 11.10 | 0.40 | 30 | 1.93 | 4.87 | 1.68 | 4.30 |
| Apr | 4.58 | 11.63 | 5.87 | 14.90 | 0.80 | 60 | 3.84 | 9.75 | 0.72 | 1.88 |
| May | 5.48 | 13.92 | 6.21 | 15.80 | 1.00 | 75 | 4.80 | 12.18 | 0.68 | 1.74 |
| Jun | 4.57 | 11.60 | 7.31 | 18.60 | 1.00 | 75 | 4.80 | 12.18 | -0.23 | -0.58 |
| Jul | 3.44 | 8.74 | 8.59 | 21.80 | 1.00 | 75 | 4.80 | 12.18 | -1.36 | -3.44 |
| Aug | 3.19 | 8.10 | 8.06 | 20.50 | 1.00 | 75 | 4.80 | 12.18 | -1.61 | -4.08 |
| Sep | 4.49 | 11.40 | 5.72 | 14.50 | 0.60 | 45 | 2.88 | 7.31 | 1.61 | 4.09 |
| Oct | 3.39 | 8.61 | 4.33 | 11.00 | 0.20 | 15 | 0.96 | 2.44 | 2.43 | 6.17 |
| Nov | 2.75 | 6.99 | 2.66 | 6.80 | 0.00 | 0 | 0.27 | 0.68 | 2.48 | 6.31 |
| Dec | 2.38 | 6.05 | 1.65 | 4.20 | 0.00 | 0 | 0.17 | 0.42 | 2.21 | 5.63 |
| Annual | 42.01 | 106.70 | 58.53 | 148.70 | 6.00 | 450 | 29.49 | 75.14 | 12.37 | 31.57 |

## Monthly water balance (monthly average values): bermudagrass pasture

| | Precipitation | | Pan Evaporation | | Production | | ET | | Balance | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month | (in) | (cm) | (in) | (cm) | Rate | g/m² | (in) | (cm) | (in) | (cm) |
| Jan | 1.75 | 4.44 | 1.63 | 4.10 | 0.00 | 0 | 0.16 | 0.41 | 1.59 | 4.04 |
| Feb | 2.38 | 6.05 | 2.14 | 5.40 | 0.00 | 0 | 0.21 | 0.54 | 2.17 | 5.51 |
| Mar | 3.61 | 9.17 | 4.36 | 11.10 | 0.40 | 80 | 7.05 | 17.90 | - 3.42 | - 8.70 |
| Apr | 4.58 | 11.63 | 5.87 | 14.90 | 0.80 | 160 | 14.10 | 35.81 | - 9.53 | -24.21 |
| May | 5.48 | 13.92 | 6.21 | 15.80 | 1.00 | 200 | 17.62 | 44.76 | -12.15 | -30.86 |
| Jun | 4.57 | 11.60 | 7.31 | 18.60 | 1.00 | 200 | 17.62 | 44.76 | -13.05 | -33.16 |
| Jul | 3.44 | 8.74 | 8.59 | 21.80 | 1.00 | 200 | 17.62 | 44.76 | -14.18 | -36.02 |
| Aug | 3.19 | 8.10 | 8.06 | 20.50 | 1.00 | 200 | 17.62 | 44.76 | -14.43 | -36.52 |
| Sep | 4.49 | 11.40 | 5.72 | 14.50 | 0.60 | 120 | 10.57 | 26.86 | - 6.09 | -15.46 |
| Oct | 3.39 | 8.61 | 4.33 | 11.00 | 0.20 | 40 | 3.52 | 8.95 | - 0.14 | - 0.35 |
| Nov | 2.75 | 6.99 | 2.66 | 6.80 | 0.00 | 0 | 0.27 | 0.68 | 2.48 | 6.31 |
| Dec | 2.38 | 6.05 | 1.65 | 4.20 | 0.00 | 0 | 0.17 | 0.42 | 2.21 | 5.63 |
| Annual | 42.01 | 106.70 | 58.53 | 148.70 | 6.00 | 1200 | 106.53 | 270.61 | -64.54 | -163.79 |

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# APPENDIX J

# HYDROLOGIC TEST DATA

SHEPHERD MILLER, INC.
*Environmental and Engineering Consultants*

# TECHNICAL MEMORANDUM

**DATE:** **July 9, 2001** **SMI # 100734**

**TO:** **Toby Wright**

**FROM:** **Paul Sorek**

**SUBJECT:** **Sequoyah Hydrologic Testing**

**COPY:**

The purpose of this memo is to document the field procedures and analytical methodology relating to the hydrologic testing program conducted at the Sequoyah Fuels Facility (Facility), located near Gore, Oklahoma. The objective of the program is to evaluate the hydrologic properties and conditions of each of the primary hydrologic units in the shallow bedrock system. These units include the alluvium, terrace/shale 1, and shale units 2, 3, and 4. The program consisted of the conduct of slug tests and measurement of water levels in wells screened in a single shale unit at the Facility.

## Slug Tests

Slug tests were performed on 20 existing and newly installed wells to develop representative estimates of hydraulic conductivity for each of the hydrologic units. Table 1 presents the wells that were tested, as well as their completion data. Location of the slug tests is presented in Figure 1. A number of wells that were initially included in the testing program were not tested because they were dry or had an insufficient volume of water in the well casing. These wells include MW047A, MW0636, MW089A, MW115, MW116, MW118, and MW119.

For each test, a 10 psi pressure transducer connected to an Insitu Hermit 3K datalogger was placed at the appropriate depth in the well, and a reference head was determined with and electronic water level indicator. The wells were then allowed to re-equilibrate to static conditions for approximately 1 hour before the slug test was conducted. At which point, a 1-inch diameter PVC slug was submerged in the well. The length of the slug varied between wells depending on the column of water in the well. The datalogger collected pressure head data at logrhythmic intervals until the water level returned to 95% of the static level, or a maximum of 1 hour.


*3801 Automation Way, Suite 100, Fort Collins, Colorado 80525 • Telephone (970) 223-9600 / FAX (970) 23-7171*

Two methods were utilized to analyze the data. Data from wells under unconfined conditions were analyzed with the Bouwer and Rice (1976) method, which models unsteady, unconfined flow from a partially penetrating well in a homogeneous and isotropic aquifer. Data from wells under confined conditions were analyzed with Cooper, et. al. (1967) method for unsteady radial flow under confined conditions in a homogeneous and isotropic aquifer. The solution plots are presented in Figures 2-21.

Table 2 summarizes the slug test results. Estimates of hydraulic conductivity range from 5.01 ft/day to 0.0042 ft/day. Estimates of hydraulic conductivity range from up to 3 orders of magnitude in a single unit. The variability in conductivity does not appear to represent any geospatial patterns, nor do values appear to relate to any geological features at the Facility.

## Potentiometric Surface

Potentiometric data were collected with an electronic water level indicator from 66 wells across the Facility. These wells represent all of the wells at the Facility that have been identified as being screened in only one hydrologic unit. The water level data are presented in Table 3. Potentiometric surface maps for the hydrologic units are presented in Figures 23-27.

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**Table 1 Tested Wells and Compiled Data**

| WELL | EASTING (FT) | NORTHING (FT) | MEASURE POINT ELEVATION (FT MSL) | HYDROLOGIC UNIT | TOTAL DEPTH (FT BGS) | DEPTH TO WATER (FT BMP) |
|---|---|---|---|---|---|---|
| MW117 | 2834786 | 194357 | 491.25 | ALLUVIUM | 15.53 | 12.14 |
| MW120 | 2833803 | 193645 | 482.76 | ALLUVIUM | 24.00 | 14.99 |
| MW008 | 2837366 | 195738 | 564.67 | SHALE 1 | 17.39 | 10.92 |
| MW016 | 2837147 | 195993 | 564.82 | SHALE 1 | 16.68 | 6.29 |
| MW026 | 2836802 | 195792 | 567.86 | SHALE 1 | 21.49 | 11.57 |
| MW073 | 2837577 | 196158 | 582.85 | SHALE 1 | 27.00 | 22.31 |
| MW076 | 2836444 | 195639 | 565.15 | SHALE 1 | 18.20 | 13.30 |
| MW102 | 2836127 | 195438 | 559.10 | SHALE 1 | 11.00 | 6.00 |
| MW035A | 2836264 | 196329 | 543.38 | SHALE 2 | 19.90 | 8.66 |
| MW040A | 2836110 | 195956 | 551.65 | SHALE 2 | 18.60 | 8.39 |
| MW042A | 2836443 | 195239 | 549.87 | SHALE 2 | 25.30 | 7.13 |
| MW085A | 2836709 | 195501 | 565.04 | SHALE 2 | 34.87 | 14.48 |
| 2346 | 2836242 | 193139 | 519.20 | SHALE 3 | 23.00 | 9.67 |
| MW037A | 2836058 | 196408 | 529.00 | SHALE 3 | 28.89 | 17.01 |
| MW084A | 2836677 | 195644 | 565.92 | SHALE 3 | 41.12 | 18.21 |
| MW110A | 2838413 | 194735 | 554.93 | SHALE 4 | 45.00 | 19.40 |
| MW111A | 2833803 | 193655 | 483.10 | SHALE 4 | 38.50 | 15.17 |
| MW112A | 2833775 | 192595 | 485.71 | SHALE 4 | 32.40 | 17.11 |
| MW113A | 2836050 | 192792 | 504.50 | SHALE 4 | 41.20 | 2.80 |
| MW114A | 2833805 | 193666 | 483.02 | SHALE 4 | 38.95 | 15.34 |

**Table 2 Slug Test Results**

| WELL | DATE | HYDROLOGIC UNIT | SATURATED THICKNESS (FT) | HYDRAULIC CONDUCTIVITY (FT/DAY) | TRANSMISSIVITY (FT2/DAY) | METHOD |
|---|---|---|---|---|---|---|
| MW117 | 06/12/01 | ALLUVIUM | 3.9 | 0.0223 | 0.0870 | BOUWER-RICE, 1976 (UNCONFINED) |
| MW120 | 06/16/01 | ALLUVIUM | 17.9 | 5.01 | 89.7 | BOUWER-RICE, 1976 (UNCONFINED) |
| MW008 | 06/15/01 | SHALE 1 | 6.8 | 0.0134 | 0.0900 | BOUWER-RICE, 1976 (UNCONFINED) |
| MW016 | 06/15/01 | SHALE 1 | 11.8 | 0.0129 | 0.150 | BOUWER-RICE, 1976 (UNCONFINED) |
| MW026 | 06/15/01 | SHALE 1 | 10.7 | 0.0310 | 0.330 | BOUWER-RICE, 1976 (UNCONFINED) |
| MW073 | 06/13/01 | SHALE 1 | 7.4 | 0.261 | 1.90 | BOUWER-RICE, 1976 (UNCONFINED) |
| MW076 | 06/15/01 | SHALE 1 | 15.9 | 0.00416 | 0.0660 | BOUWER-RICE, 1976 (UNCONFINED) |
| MW102 | 06/14/01 | SHALE 1 | 11.5 | 0.0297 | 0.342 | CBP, 1967 (CONFINED) |
| MW035A | 06/13/01 | SHALE 2 | 3.0 | 1.35 | 4.05 | CBP, 1967 (CONFINED) |
| MW040A | 06/13/01 | SHALE 2 | 8.6 | 0.327 | 2.81 | CBP, 1967 (CONFINED) |
| MW042A | 06/13/01 | SHALE 2 | 6.0 | 0.0318 | 0.191 | CBP, 1967 (CONFINED) |
| MW085A | 06/15/01 | SHALE 2 | 3.5* | 0.0700 | 0.245 | CBP, 1967 (CONFINED) |
| 2346 | 06/12/01 | SHALE 3 | 2.5 | 0.489 | 1.22 | CBP, 1967 (CONFINED) |
| MW037A | 06/13/01 | SHALE 3 | 12.9 | 0.0103 | 0.130 | BOUWER-RICE, 1976 (UNCONFINED) |
| MW084A | 06/14/01 | SHALE 3 | 3.5* | 0.0217 | 0.0759 | CBP, 1967 (CONFINED) |
| MW110 | 06/13/01 | SHALE 4 | 16.4 | 0.0343 | 0.562 | CBP, 1967 (CONFINED) |
| MW111 | 06/15/01 | SHALE 4 | 12.3 | 0.0482 | 0.600 | BOUWER-RICE, 1976 (UNCONFINED) |
| MW112 | 06/12/01 | SHALE 4 | 17.8 | 1.30 | 23.0 | BOUWER-RICE, 1976 (UNCONFINED) |
| MW113 | 06/12/01 | SHALE 4 | 22.0 | 0.0073 | 0.161 | CBP, 1967 (CONFINED) |
| MW114 | 06/16/01 | SHALE 4 | 12.3 | 0.00466 | 0.0570 | BOUWER-RICE, 1976 (UNCONFINED) |

*estimated

**Table 3 Water Level Data**

| WELL | WATER DEPTH (FT) | DATE | COMMENT |
|---|---|---|---|
| 2344 | 11.40 | 06/12/01 | |
| 2346 | 9.67 | 06/12/01 | |
| MW003 | 4.61 | 06/15/01 | |
| MW007 | 11.46 | 06/15/01 | |
| MW007B | 38.13 | 06/15/01 | |
| MW008 | 10.92 | 06/15/01 | |
| MW012 | 8.82 | 06/15/01 | |
| MW012B | | 06/15/01 | no static, sampled on 6/14/01 |
| MW013 | 9.40 | 06/15/01 | |
| MW015 | 7.25 | 06/15/01 | |
| MW016 | 6.29 | 06/15/01 | |
| MW017 | 4.86 | 06/15/01 | |
| MW021 | 4.11 | 06/15/01 | |
| MW022 | 4.10 | 06/15/01 | |
| MW023 | | 06/15/01 | dry |
| MW024 | 12.35 | 06/15/01 | |
| MW025 | | 06/14/01 | no static, sampled on 6/13/01 |
| MW026 | | 06/15/01 | no static, sampled on 6/13/01 |
| MW027 | 11.16 | 06/15/01 | |
| MW035A | 8.66 | 06/13/01 | |
| MW036A | 13.96 | 06/15/01 | |
| MW037A | 17.01 | 06/13/01 | |
| MW038A | 19.46 | 06/15/01 | |
| MW039A | 13.96 | 06/15/01 | |
| MW040A | 8.39 | 06/13/01 | |
| MW042A | 7.13 | 06/13/01 | |
| MW045A | | 06/13/01 | dry |
| MW046 | | 06/13/01 | dry |
| MW047A | 22.96 | 06/13/01 | |
| MW048 | 7.25 | 06/13/01 | |
| MW049A | 15.49 | 06/15/01 | |
| MW050A | 23.57 | 06/15/01 | |
| MW050B | 28.95 | 06/15/01 | |
| MW052 | | 06/15/01 | dry |
| MW059B | 26.90 | 06/13/01 | |
| MW062A | 20.88 | 06/16/01 | |
| MW062B | 24.23 | 06/16/01 | |
| MW063 | | 06/16/01 | dry |
| MW063A | 6.38 | 06/16/01 | |
| MW065A | 19.36 | 06/13/01 | |
| MW066 | 4.32 | 06/16/01 | |
| MW070 | 11.05 | 06/13/01 | |
| MW072B | 39.49 | 06/13/01 | |
| MW073 | 27.31 | 06/13/01 | |
| MW074 | 6.05 | 06/16/01 | dry |
| MW076 | 13.30 | 06/15/01 | |
| MW079 | 7.86 | 06/15/01 | |

**Table 3 Water Level Data**

| WELL | WATER DEPTH (FT) | DATE | COMMENT |
|---|---|---|---|
| MW083 | 11.06 | 06/15/01 | |
| MW083A | 13.11 | 06/15/01 | |
| MW084 | 12.81 | 06/15/01 | |
| MW084A | 18.21 | 06/14/01 | |
| MW085 | 11.40 | 06/15/01 | |
| MW085A | 14.48 | 06/14/01 | |
| MW086A | 8.60 | 06/15/01 | |
| MW087A | 18.32 | 06/15/01 | |
| MW089A | 25.41 | 06/13/01 | |
| MW090B | | 06/12/01 | artesian, casing overflowing |
| MW093A | 26.51 | 06/15/01 | |
| MW096A | 26.98 | 06/15/01 | |
| MW097A | 16.36 | 06/15/01 | |
| MW098B | 17.12 | 06/15/01 | |
| MW099A | 17.78 | 06/15/01 | |
| MW100B | 17.70 | 06/15/01 | |
| MW102 | 6.00 | 06/14/01 | |
| MW104B | 14.75 | 06/15/01 | |
| MW105B | 4.44 | 06/12/01 | |
| MW109A | 24.15 | 06/15/01 | |
| MW110A | 19.40 | 06/13/01 | |
| MW111A | 15.17 | 06/15/01 | |
| MW112A | 17.11 | 06/12/01 | |
| MW113A | 2.80 | 06/12/01 | |
| MW114A | 15.34 | 06/15/01 | |
| MW115A | | 06/16/01 | dry |
| MW116A | | 06/13/01 | dry |
| MW117 | 12.14 | 06/12/01 | |
| MW118A | | 06/13/01 | dry |
| MW119A | | 06/16/01 | dry |
| MW120 | 14.99 | 06/15/01 | |

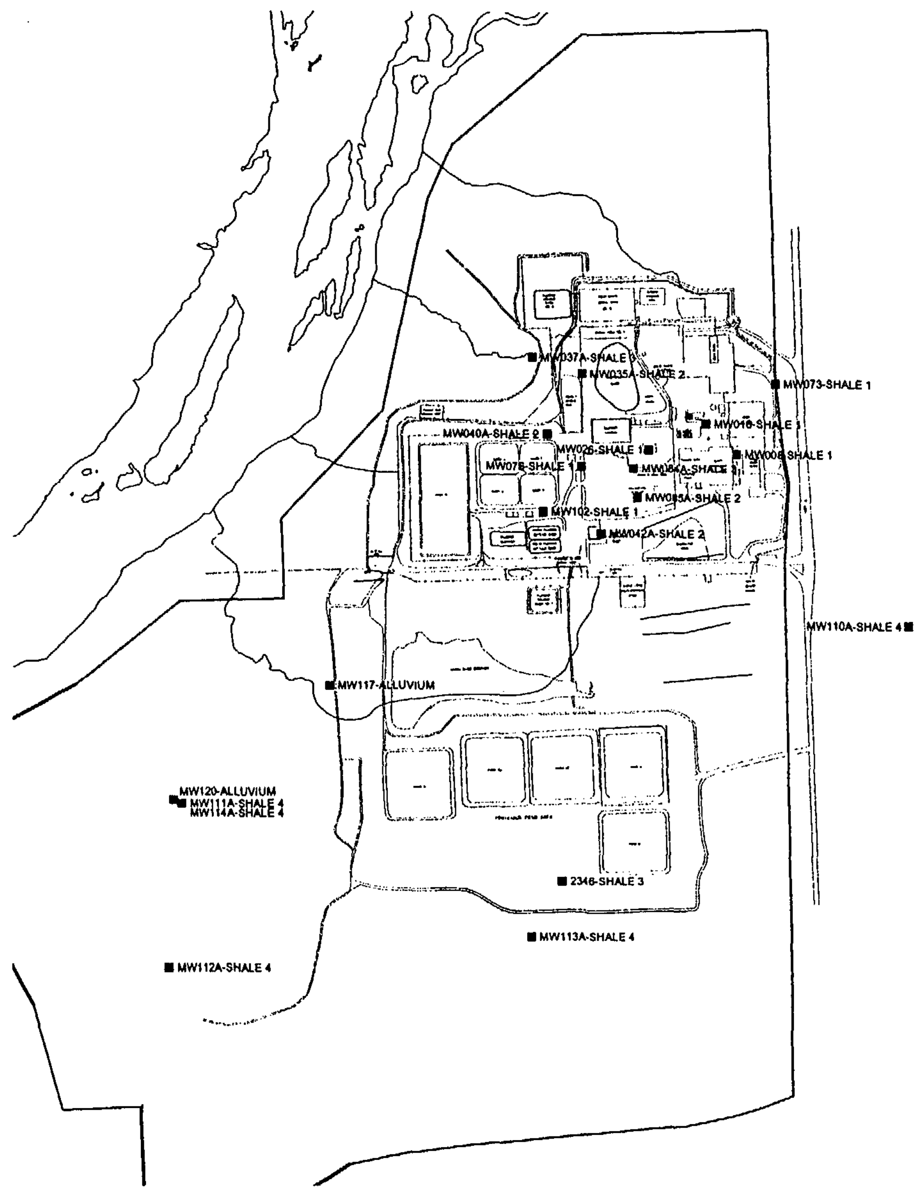


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FIGURE 1
SLUG TEST LOCATIONS

| | |
|---|---|
| Date: | JULY 2001 |
| Project: | P:\100734 |
| File: | HYDROTEST.ppt |

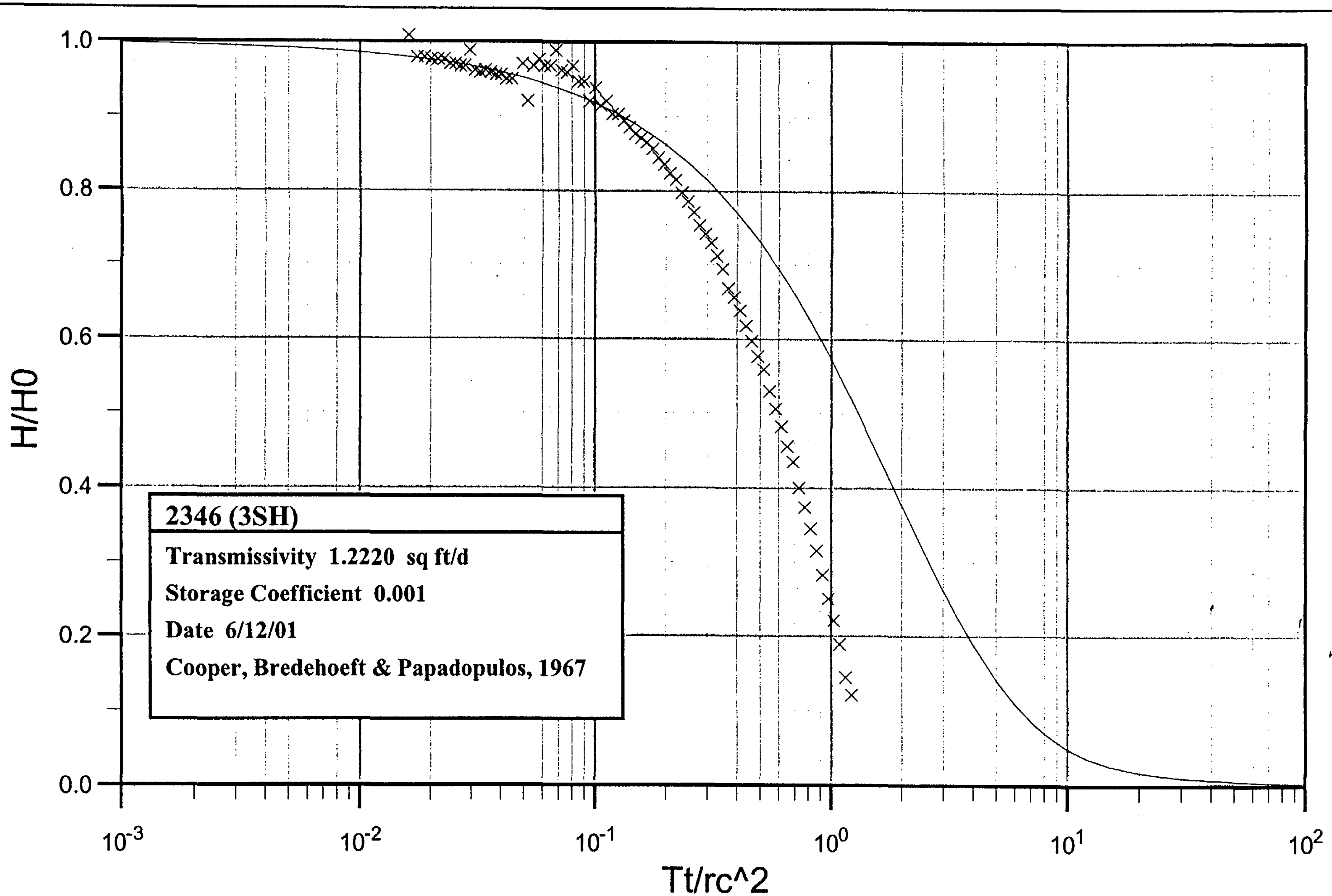


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FIGURE 2
2346 SLUG TEST RESULTS

| | |
|---|---|
| Date: | JULY 2001 |
| Project: | P:\100734 |
| File: | HYDROTEST.ppt |

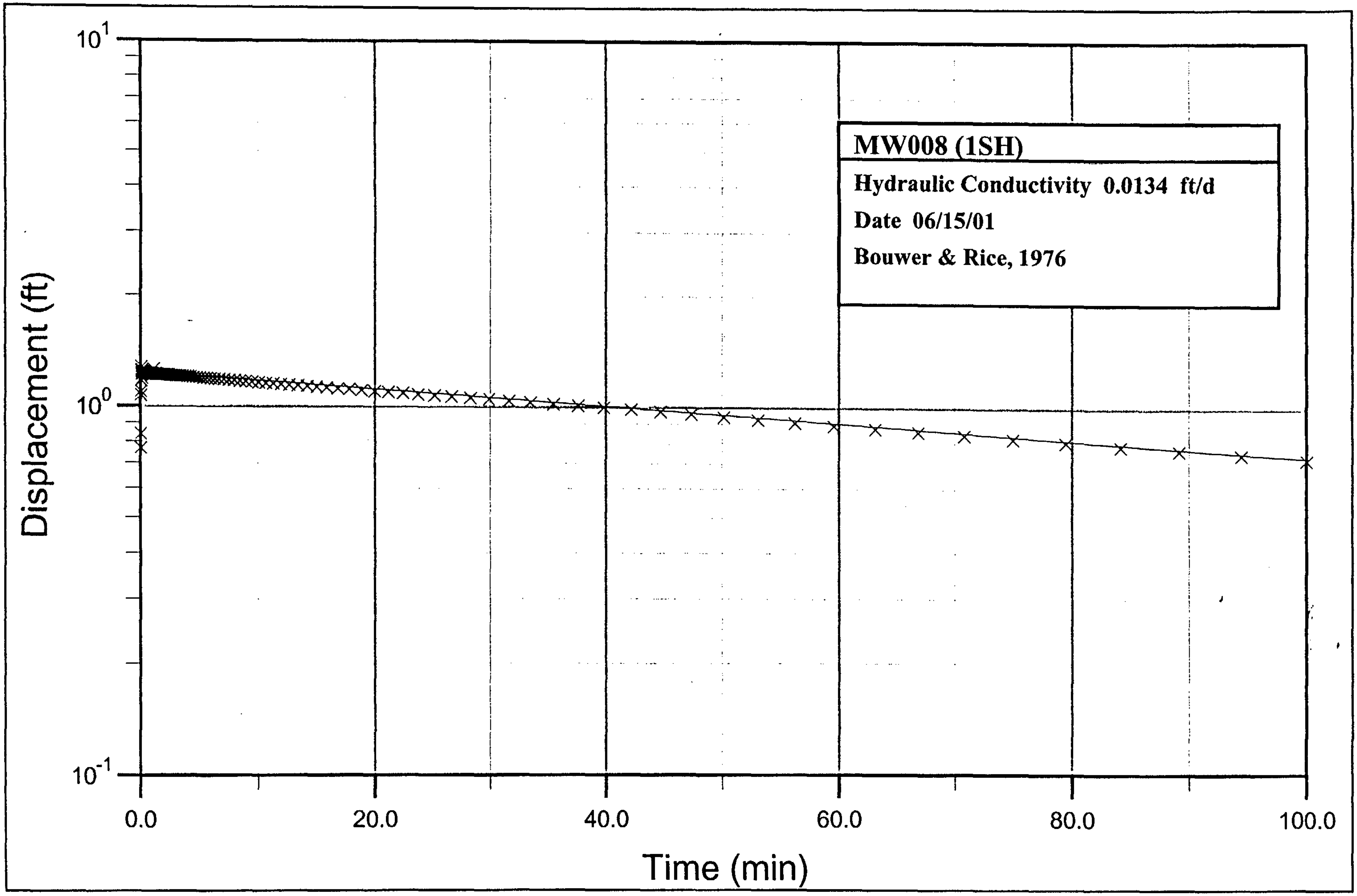


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FIGURE 3
MW008 SLUG TEST RESULTS

| | |
|---|---|
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| File: | HYDROTEST.ppt |

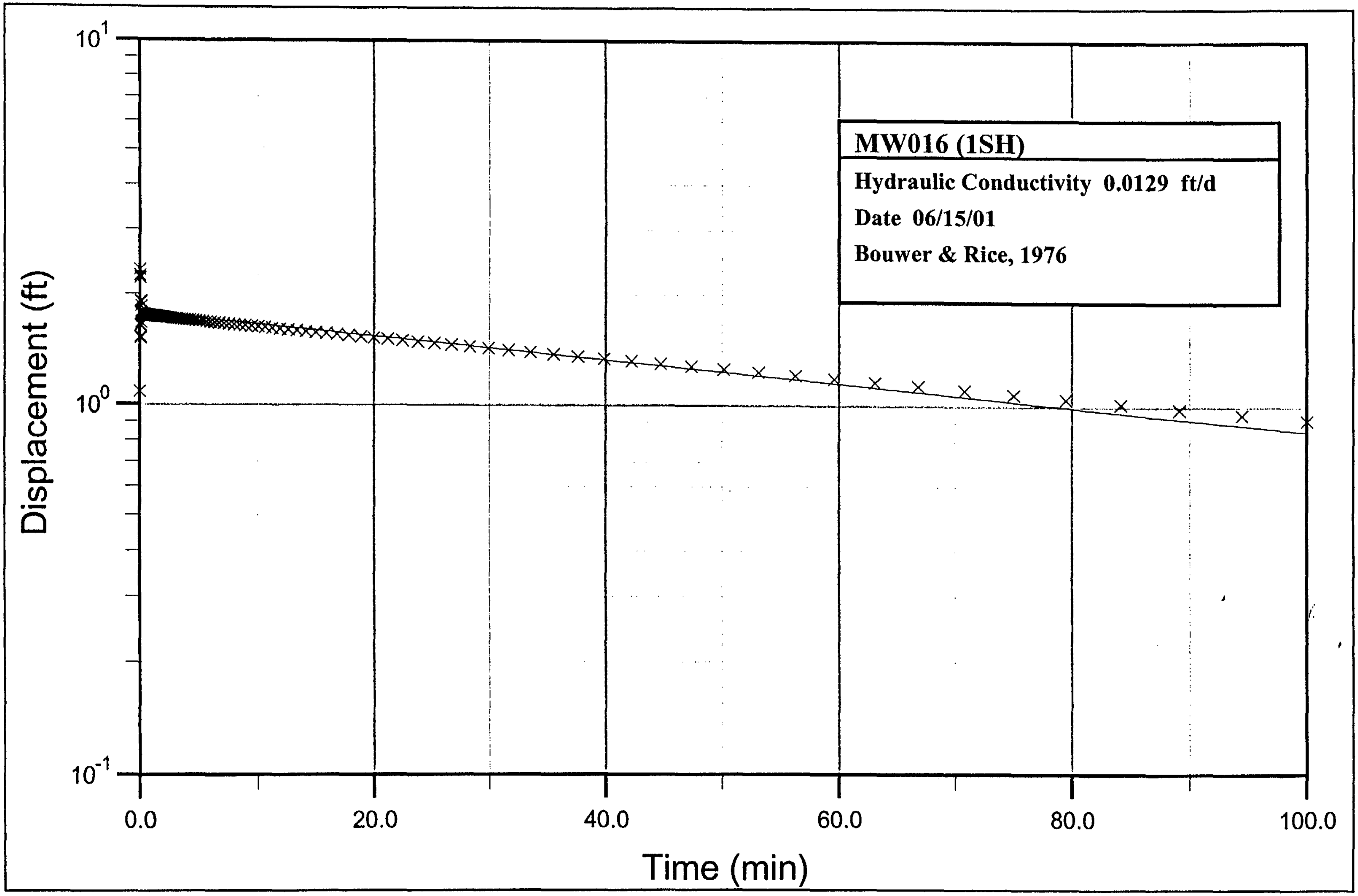


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FIGURE 4
MW016 SLUG TEST RESULTS

| | |
|---|---|
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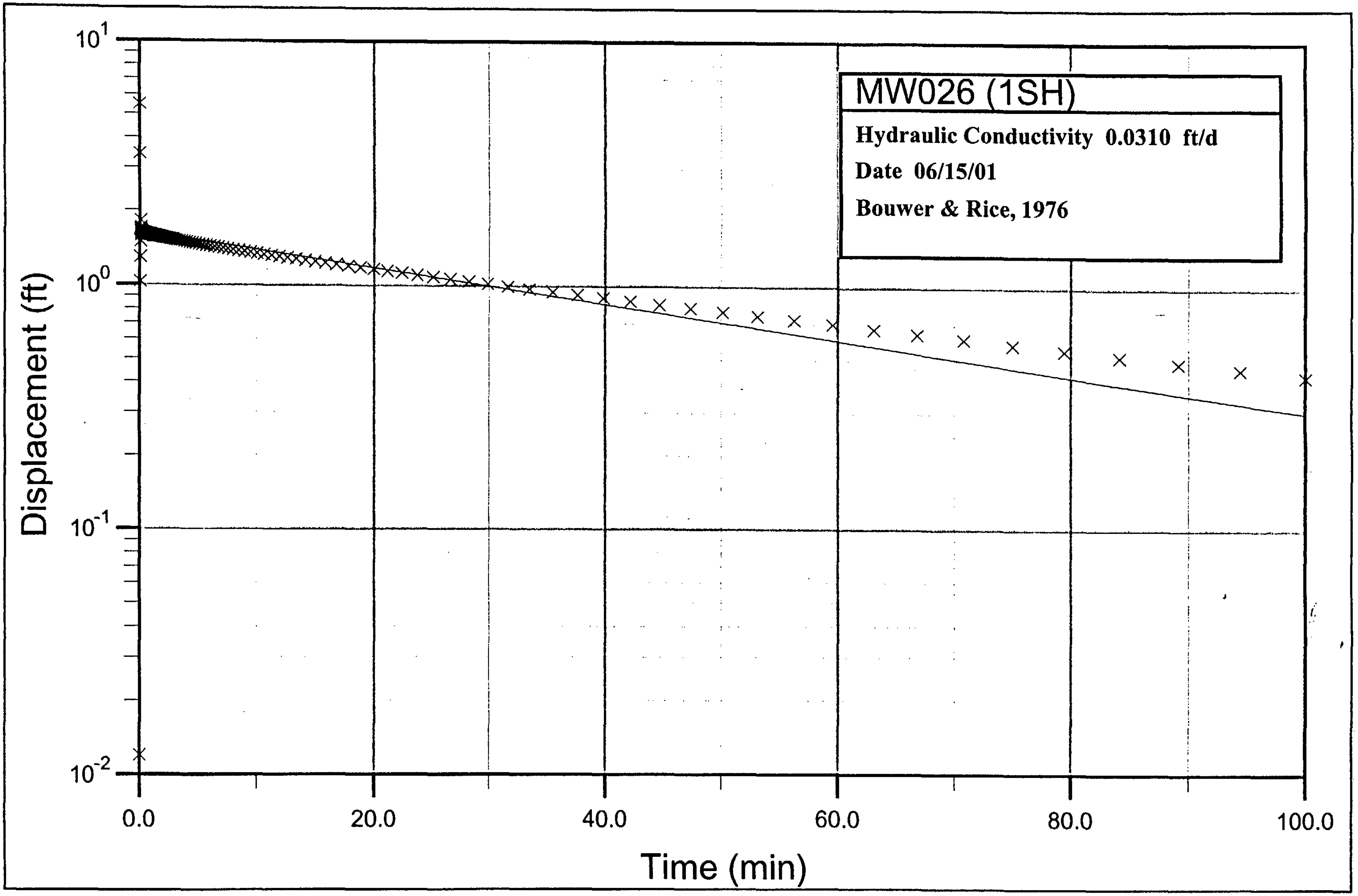
| File: | HYDROTEST.ppt |

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INCORPORATED

FIGURE 5
MW026 SLUG TEST RESULTS

| | |
|---|---|
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| File: | HYDROTEST.ppt |

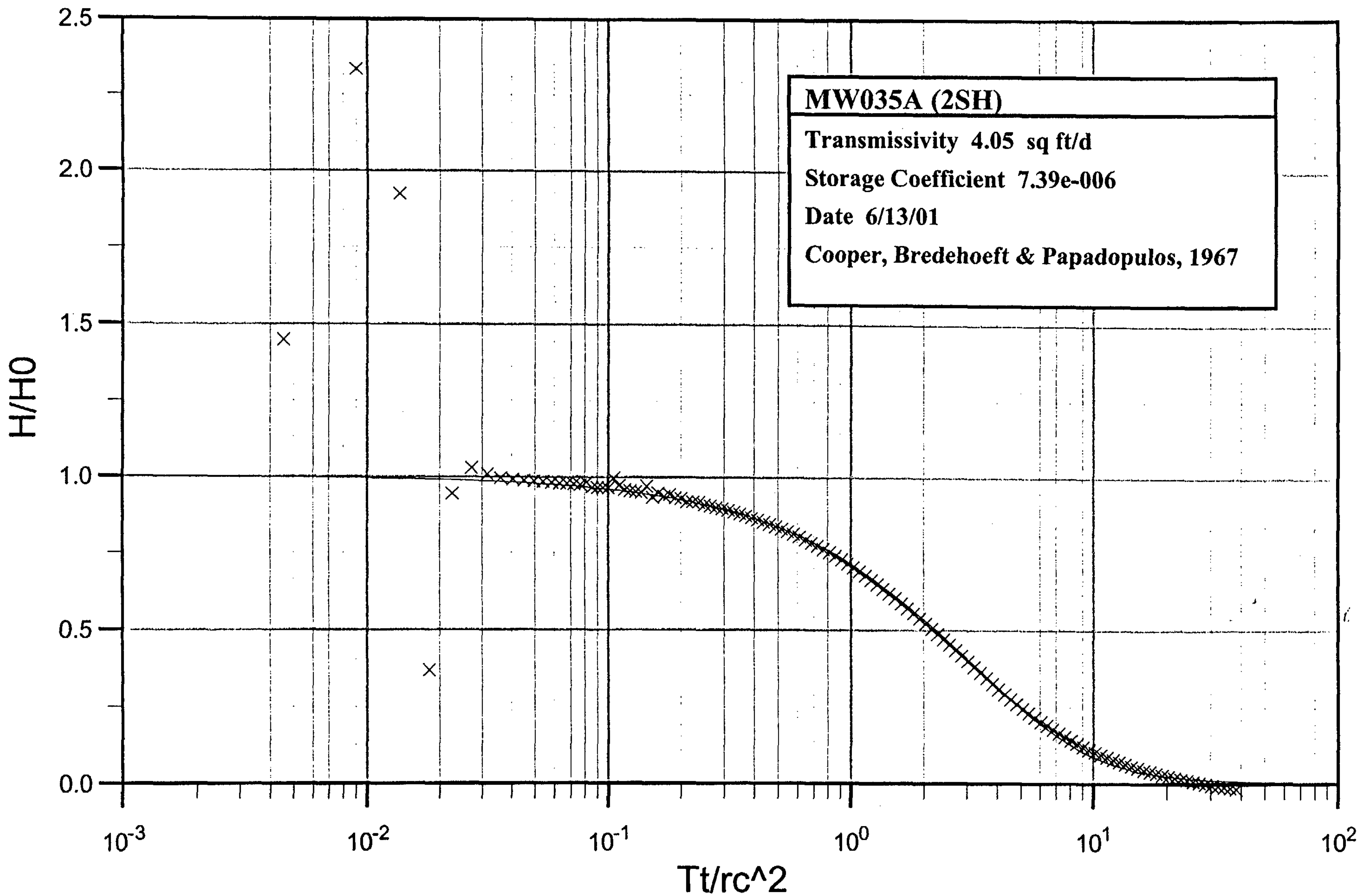


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FIGURE 6
MW026 SLUG TEST RESULTS

| | |
|---|---|
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| File: | HYDROTEST.ppt |

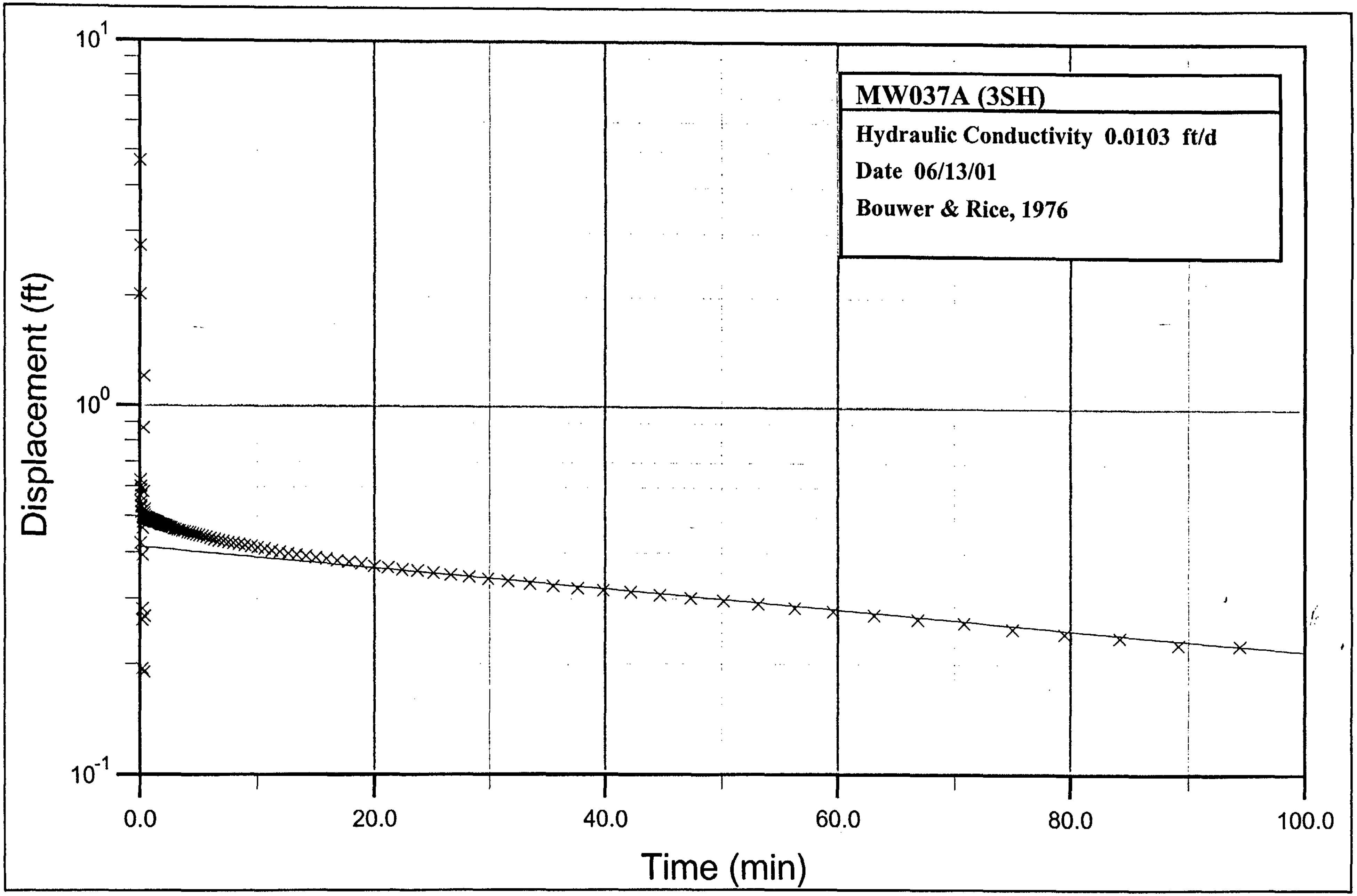


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FIGURE 7
MW037A SLUG TEST RESULTS

| | |
|---|---|
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| File: | HYDROTEST.ppt |

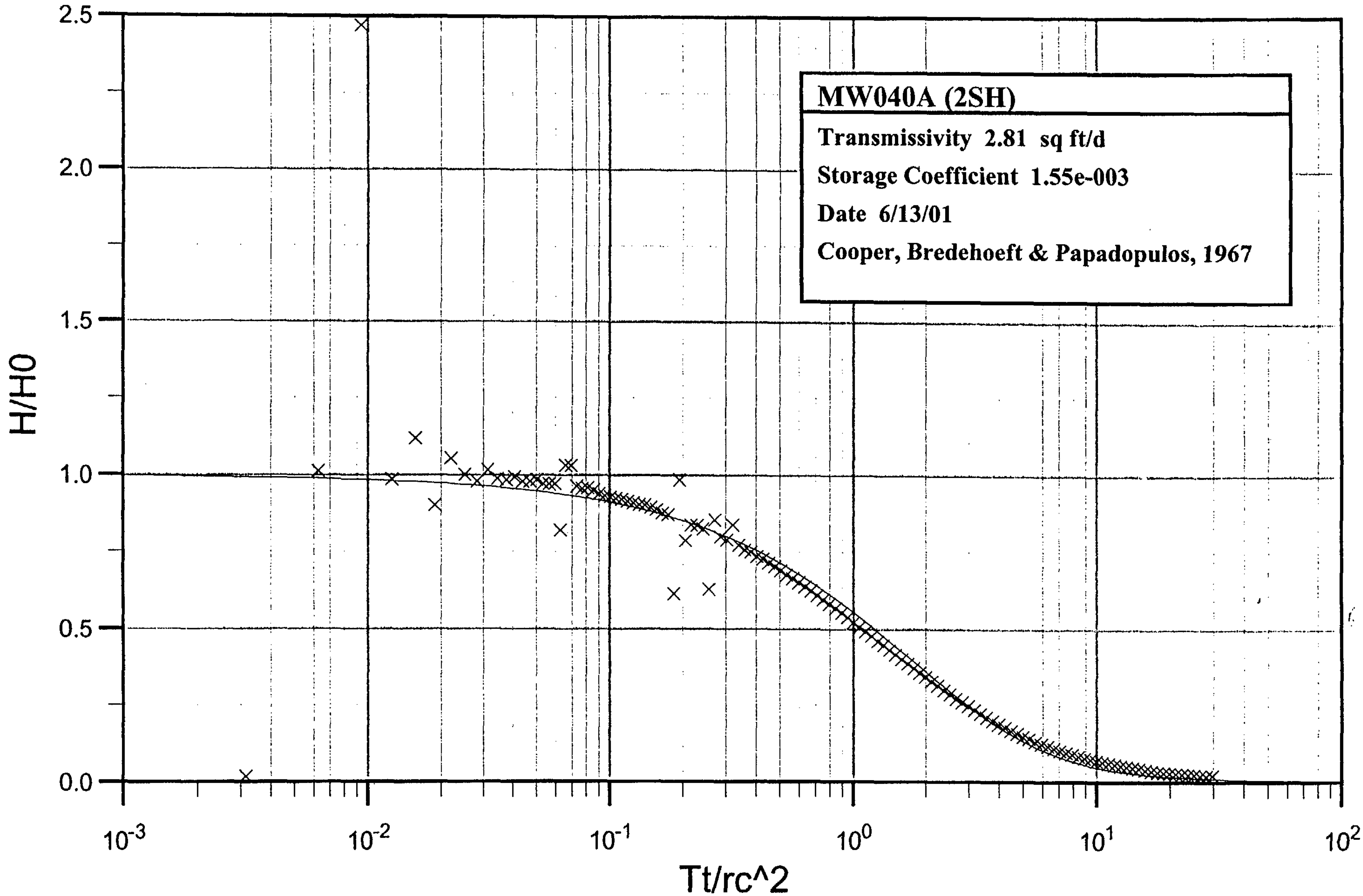


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FIGURE 8
MW040A SLUG TEST RESULTS

| | |
|---|---|
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| File: | HYDROTEST.ppt |

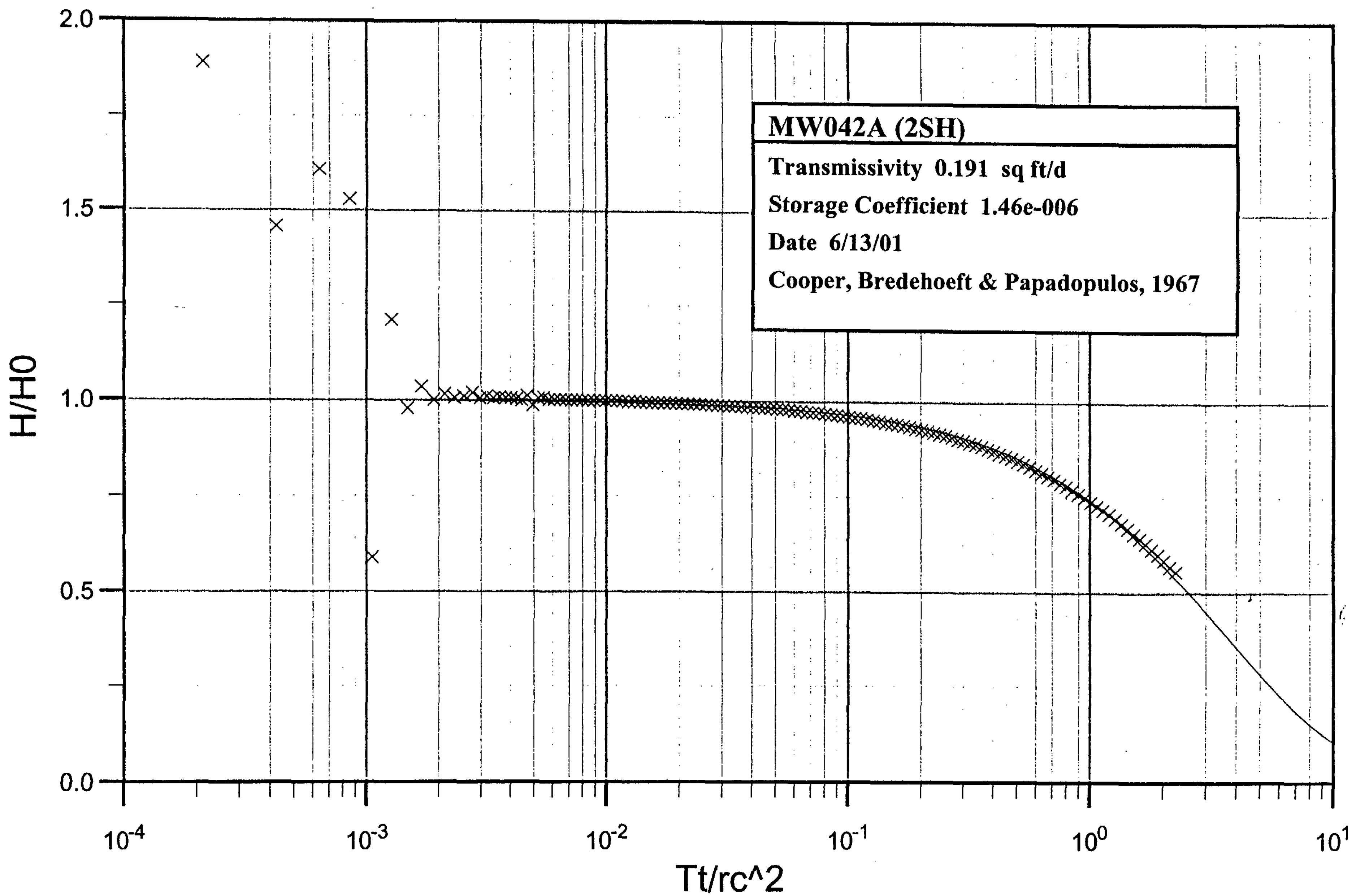


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FIGURE 9
MW042A SLUG TEST RESULTS

| | |
|---|---|
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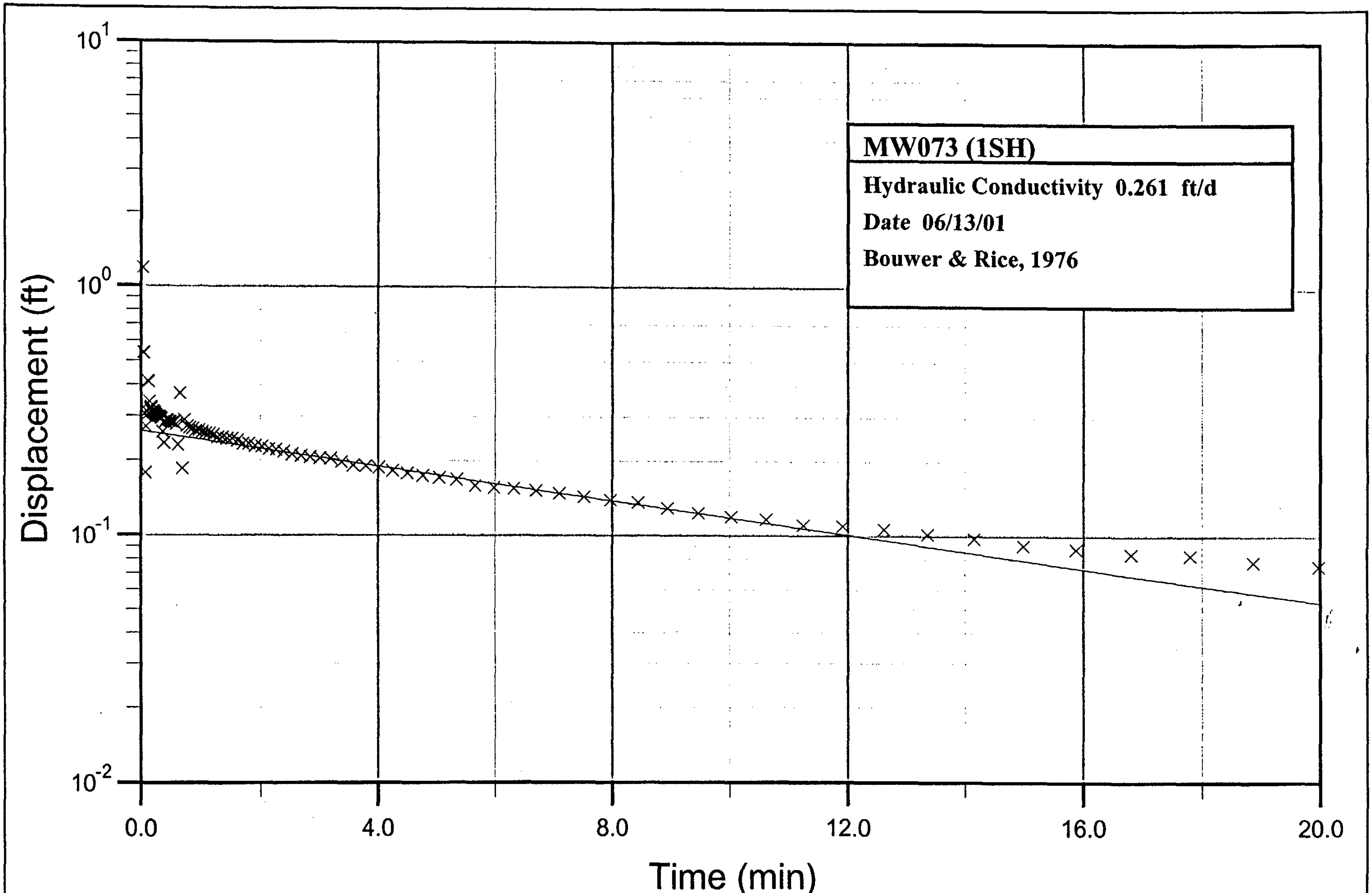


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FIGURE 10
MW073 SLUG TEST RESULTS

| | |
|---|---|
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| File: | HYDROTEST.ppt |

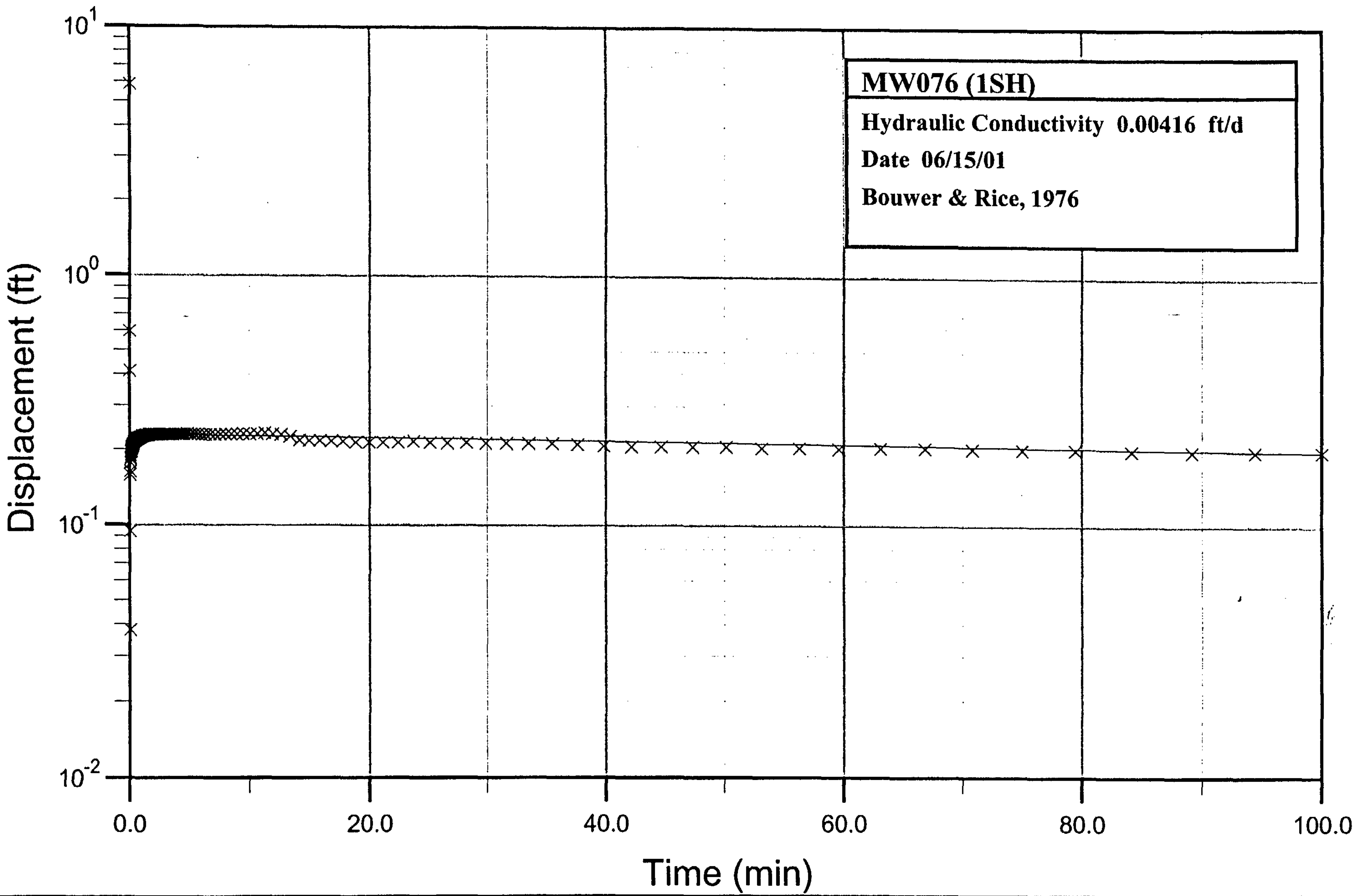


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FIGURE 11
MW076 SLUG TEST RESULTS

| | |
|---|---|
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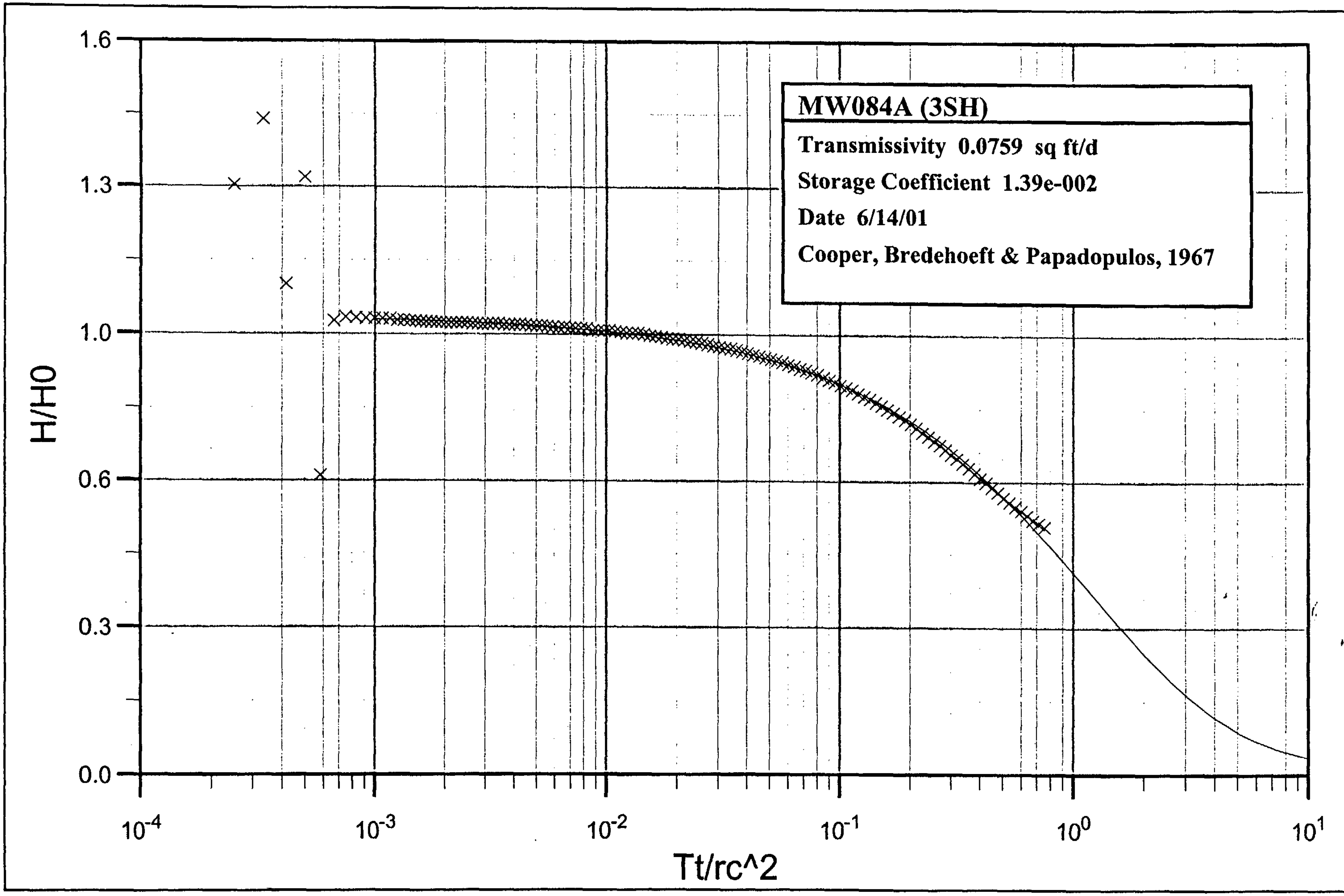
| File: | HYDROTEST.ppt |




SHEPHERD MILLER INCORPORATED

FIGURE 12
MW084A SLUG TEST RESULTS

| | |
|---|---|
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| Project: | P:\100734 |
| File: | HYDROTEST.ppt |

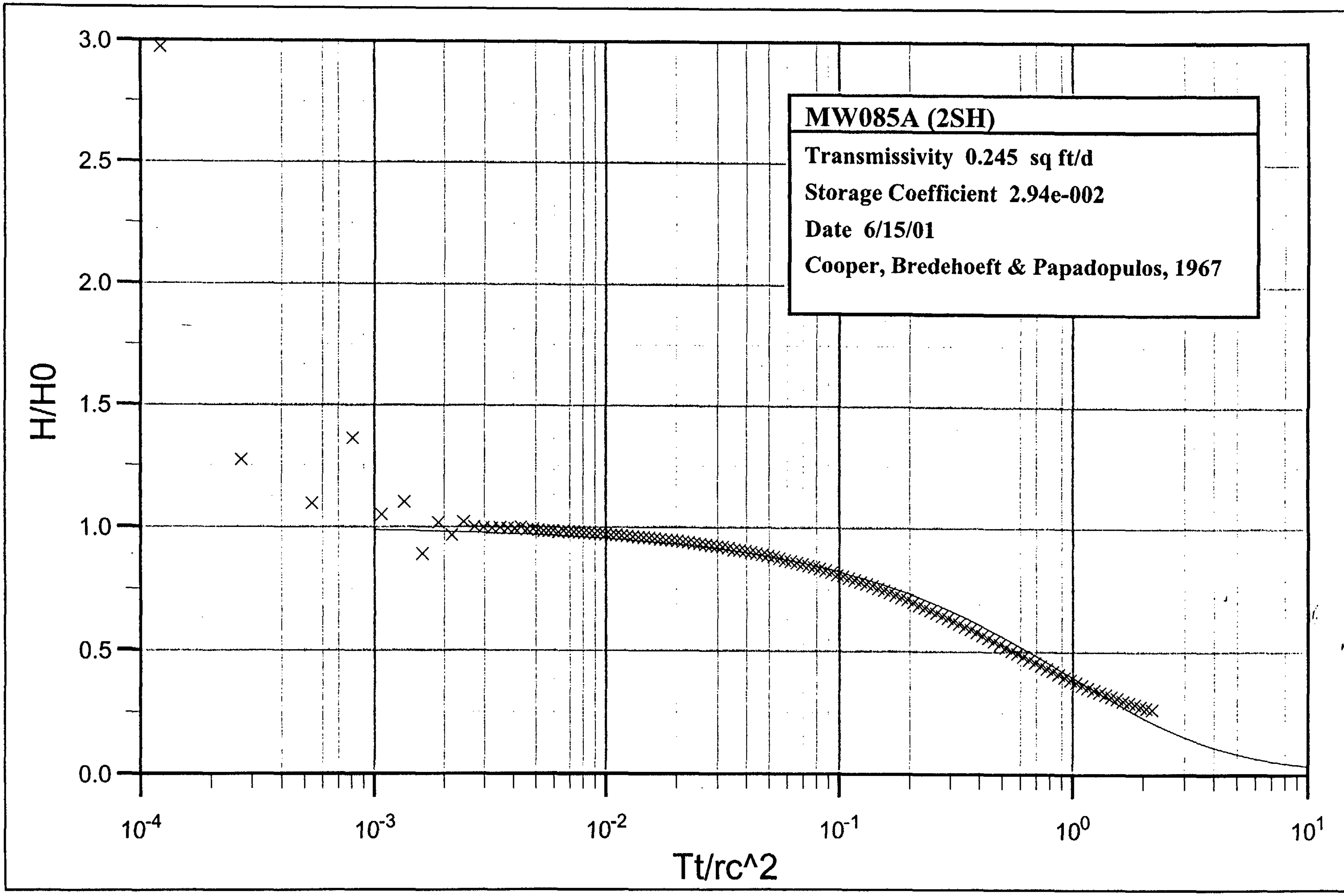


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FIGURE 13
MW085A SLUG TEST RESULTS

| | |
|---|---|
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| Project: | P:\100734 |
| File: | HYDROTEST.ppt |

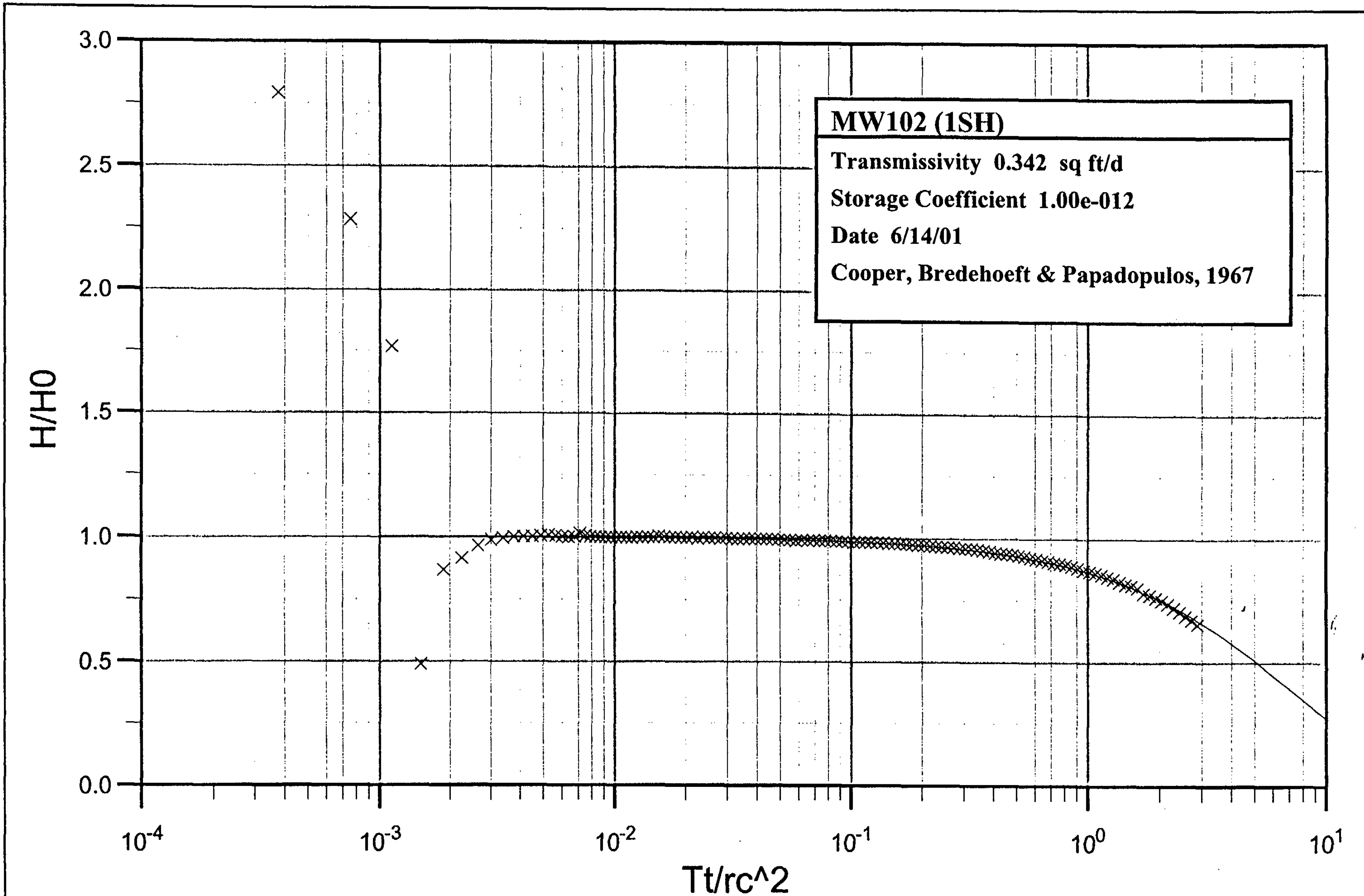


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FIGURE 14
MW102 SLUG TEST RESULTS

| | |
|---|---|
| Date: | JULY 2001 |
| Project: | P:\100734 |
| File: | HYDROTEST.ppt |

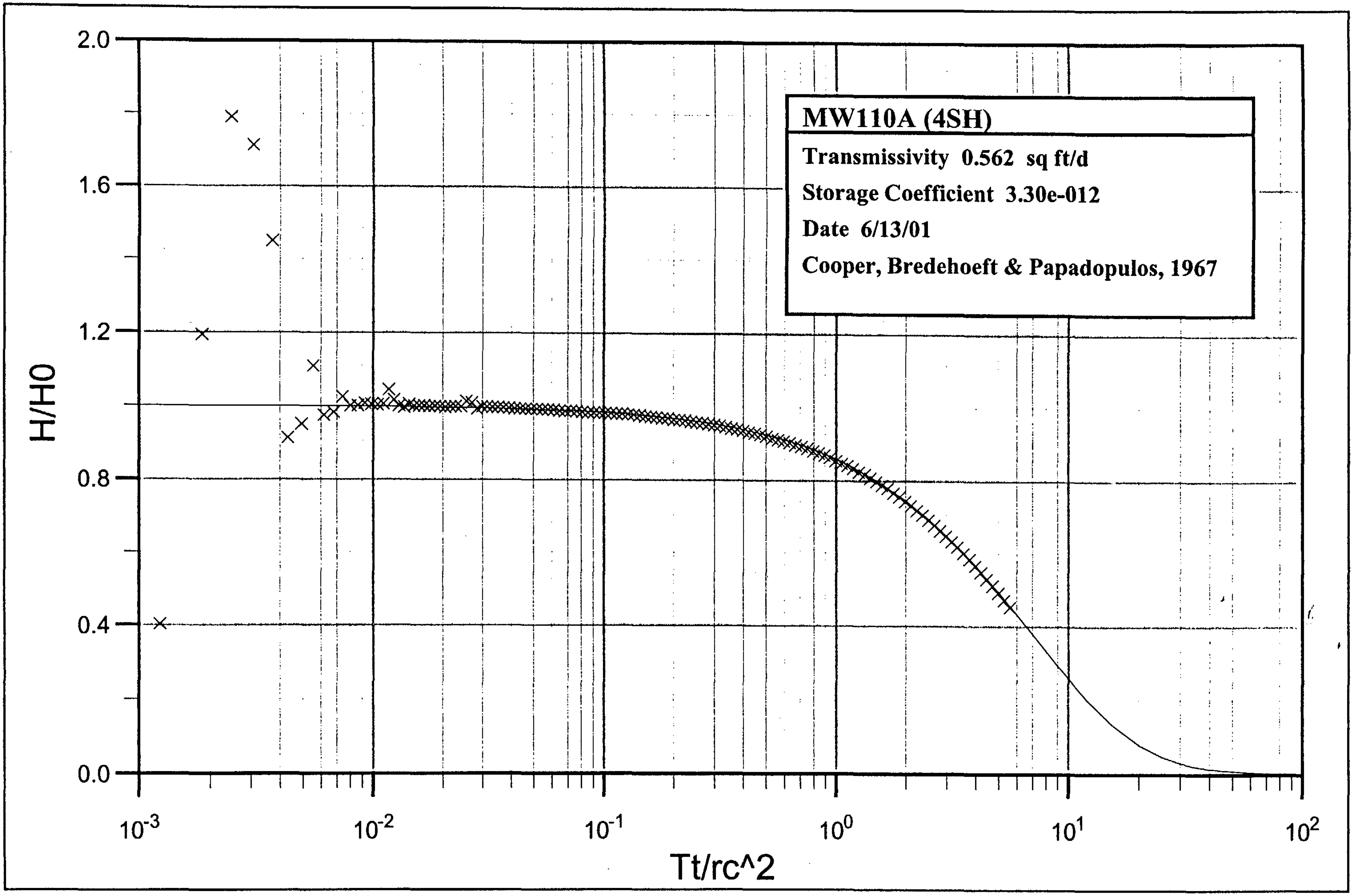


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FIGURE 15
MW110A SLUG TEST RESULTS

| | |
|---|---|
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| Project: | P:\100734 |
| File: | HYDROTEST.ppt |

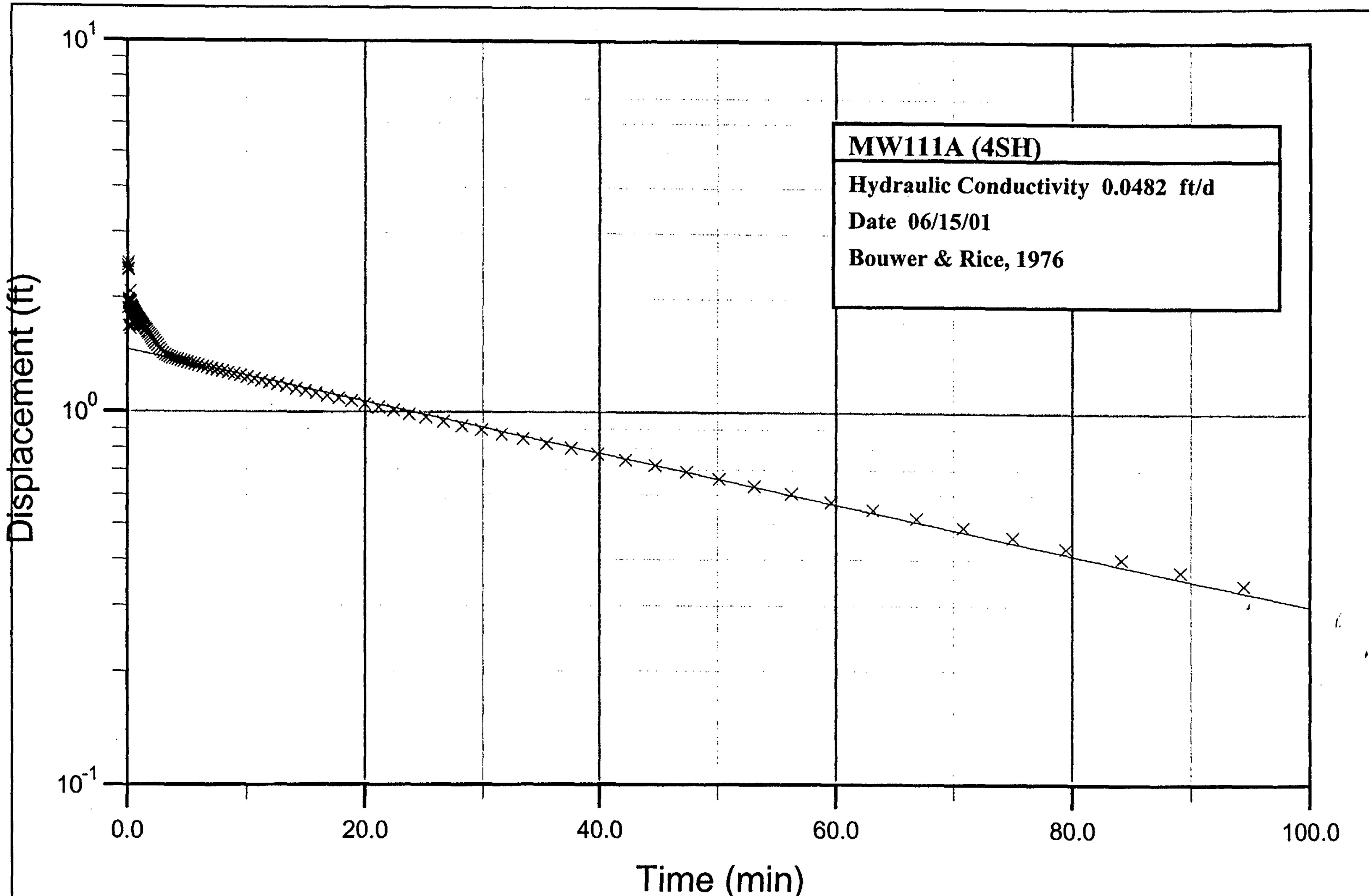


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FIGURE 16
MW111A SLUG TEST RESULTS

| | |
|---|---|
| Date: | JULY 2001 |
| Project: | P:\100734 |
| File: | HYDROTEST.ppt |

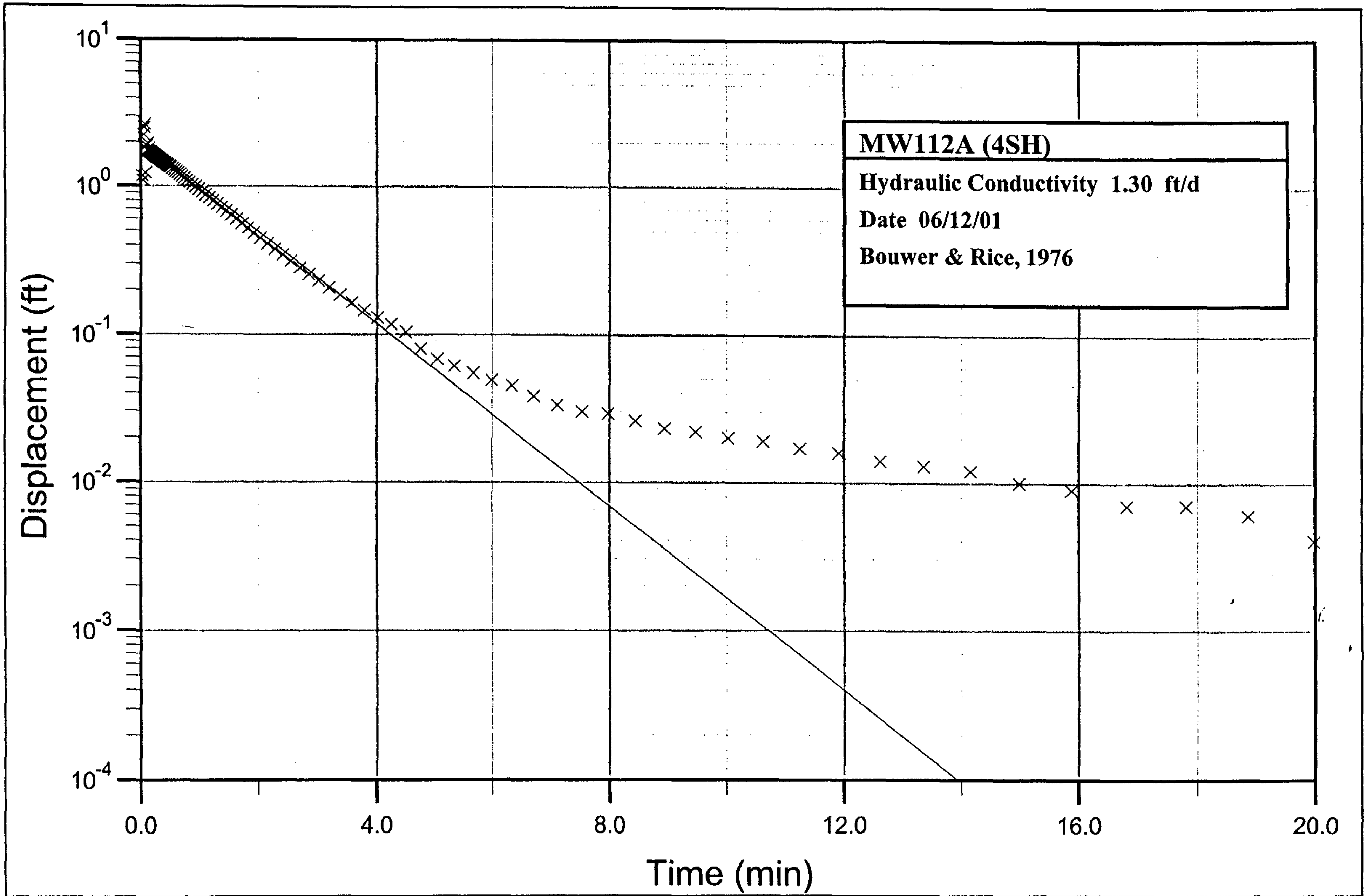


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FIGURE 17
MW112A SLUG TEST RESULTS

| | |
|---|---|
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| Project: | P:\100734 |
| File: | HYDROTEST.ppt |

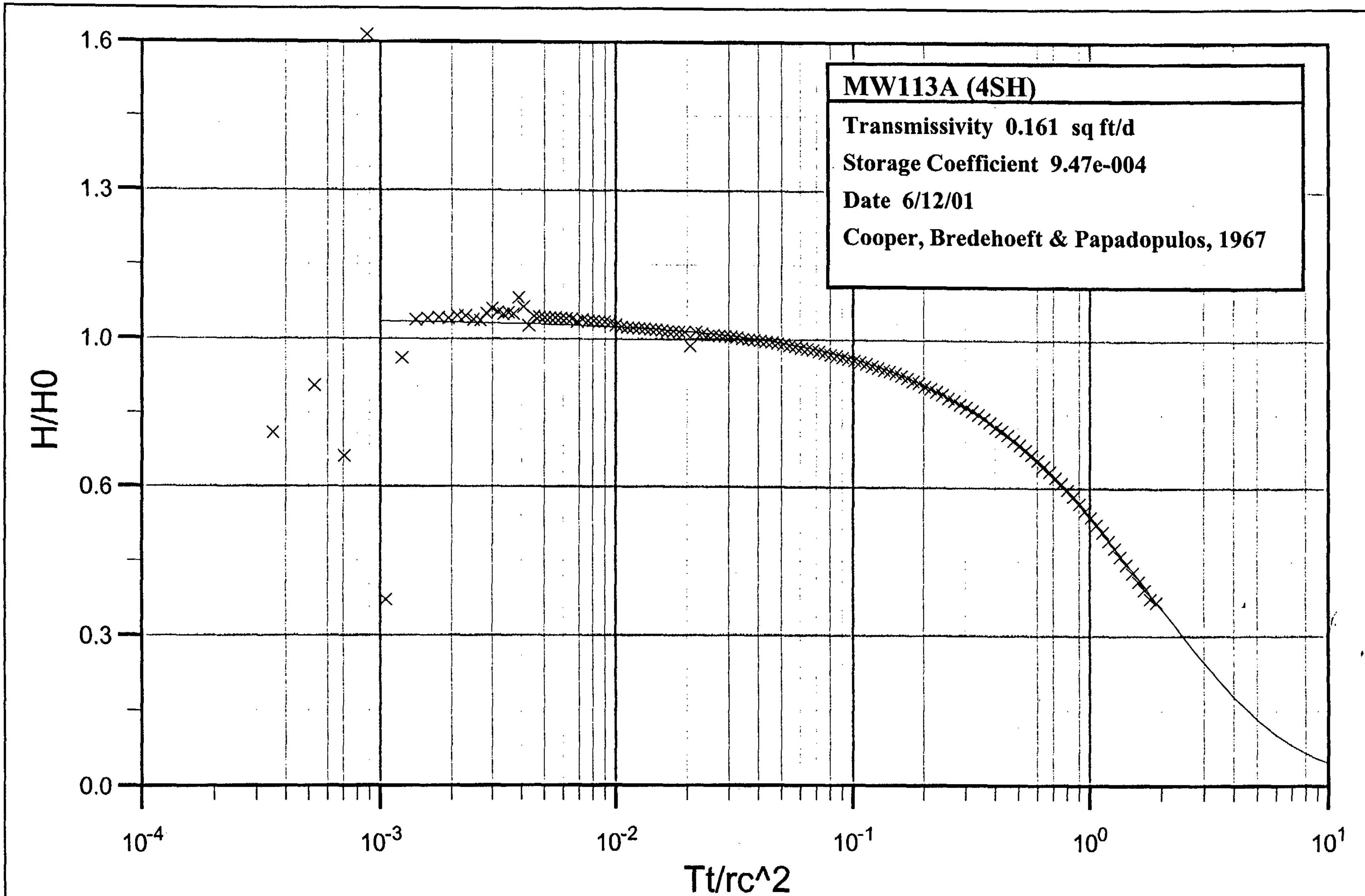


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FIGURE 18
MW113A SLUG TEST RESULTS

| | |
|---|---|
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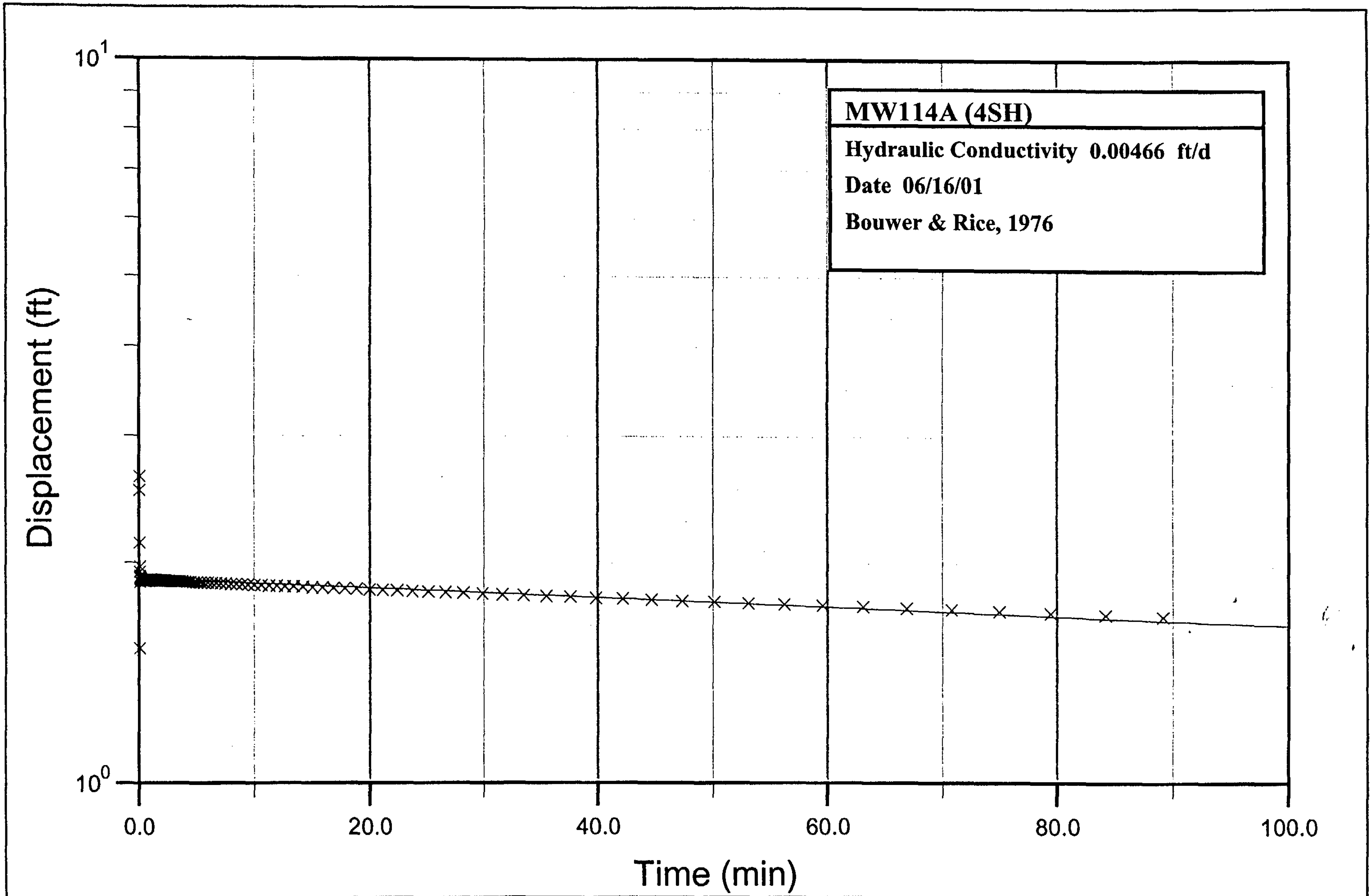


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FIGURE 19
MW114A SLUG TEST RESULTS

| | |
|---|---|
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| File: | HYDROTEST.ppt |

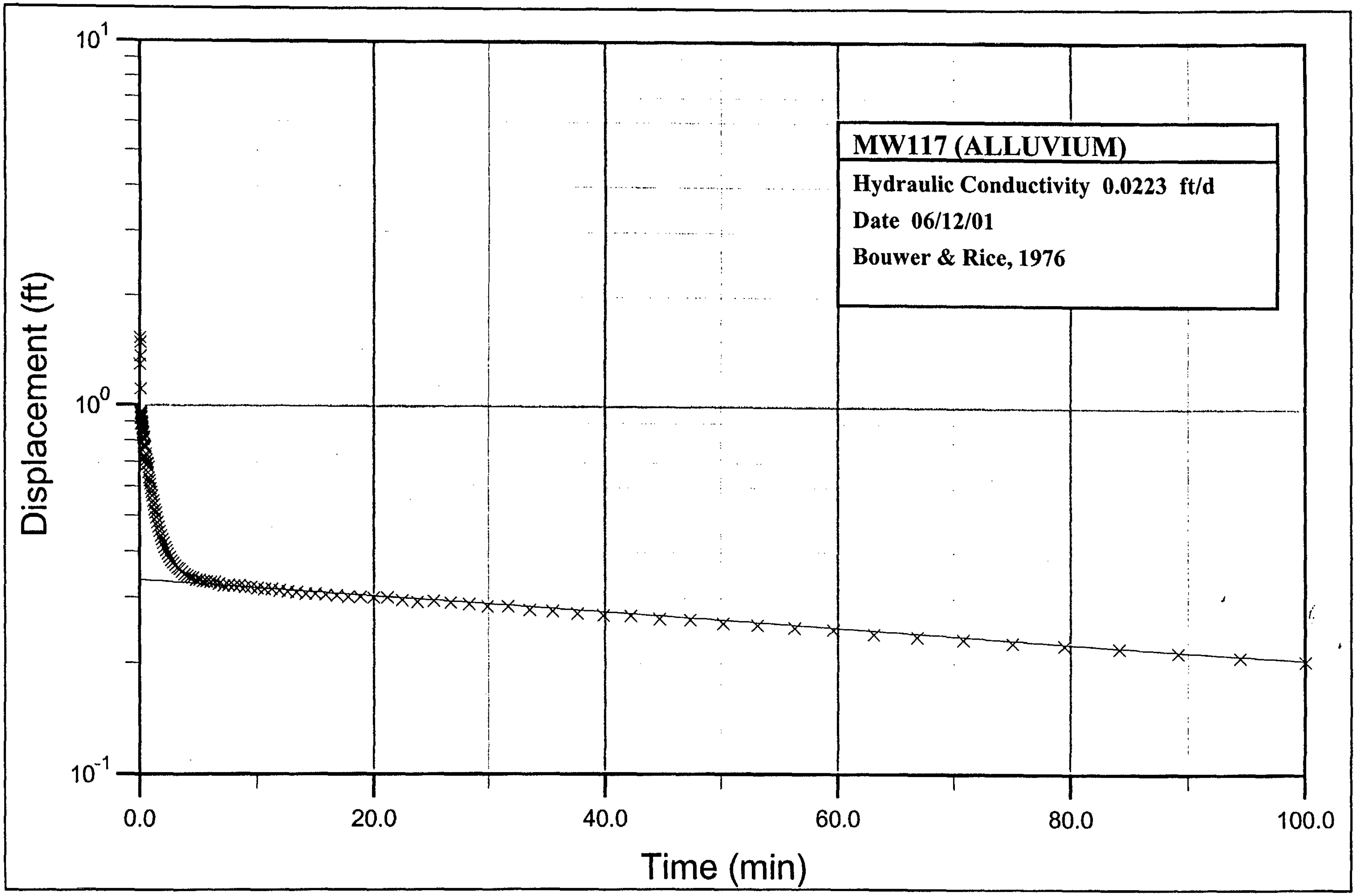


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FIGURE 20
MW117 SLUG TEST RESULTS

| | |
|---|---|
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| Project: | P:\100734 |
| File: | HYDROTEST.ppt |

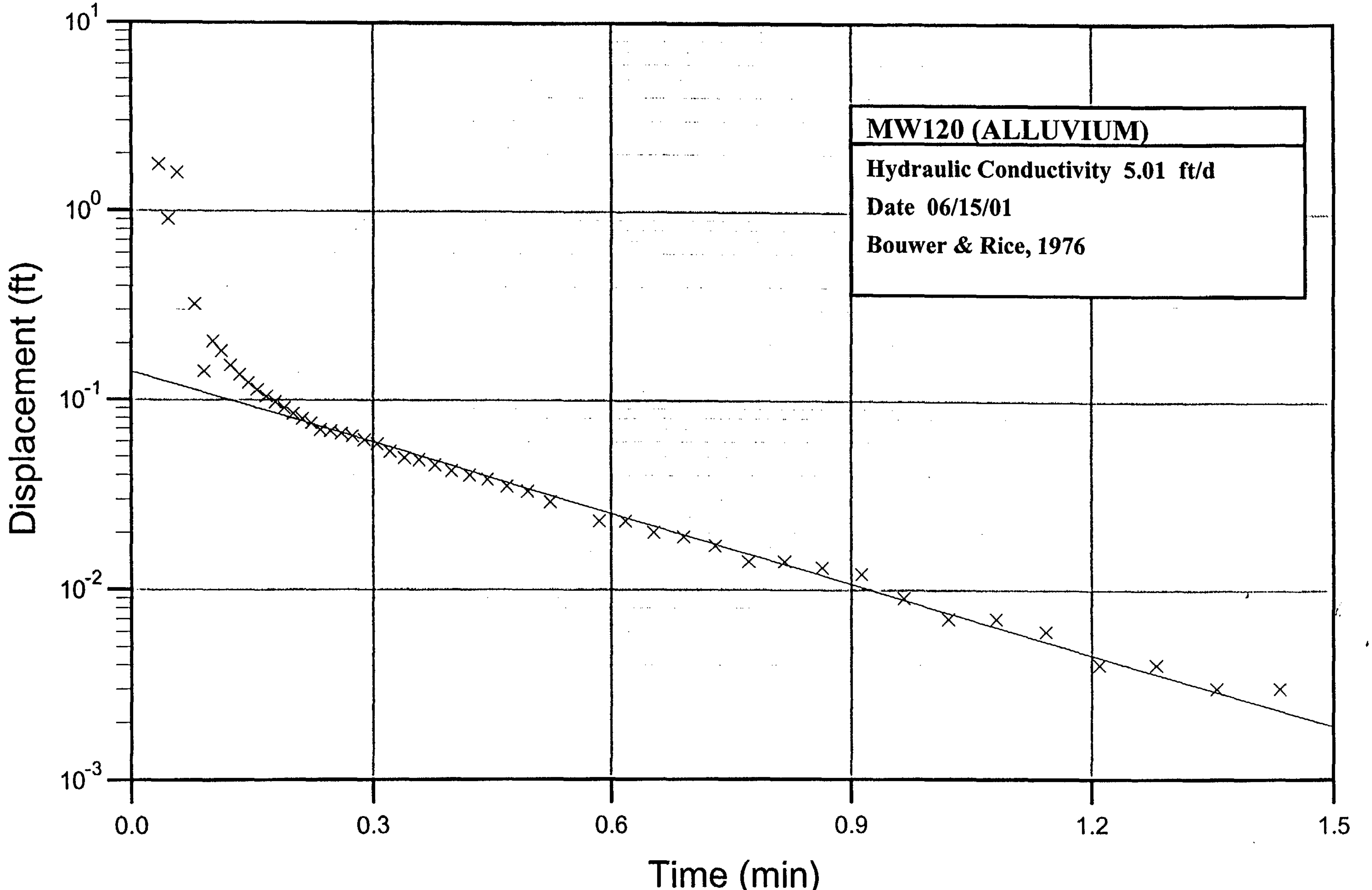


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FIGURE 21
MW120 SLUG TEST RESULTS

| | |
|---|---|
| Date: | JULY 2001 |
| Project: | P:\100734 |
| File: | HYDROTEST.ppt |

## APPENDIX K

## SUFFICIENT YIELD MEMO

SHEPHERD MILLER, INC.
*Environmental and Engineering Consultants*

# TECHNICAL MEMORANDUM

**DATE:** **August 24, 2001** **SMI # 100734**

**TO:** **Craig Harlin**

**FROM:** **Toby Wright**

**SUBJECT:** **Sufficient Yield**

**COPY:**

## INTRODUCTION

Potential human exposure to site-derived groundwater constituents at the Sequoyah Fuels Company (SFC) facility may be an issue to resolve for final site closure, should trespassing on the site occur after closure. In order to evaluate the site conditions at the SFC Site (Site), this technical memorandum compares the Site hydrogeologic conditions to federal criteria for aquifer classifications. The Final Draft EPA Guidelines for Ground-Water Classification under the EPA Ground-Water Protection Strategy (EPA, 1986) presents technical guidelines for implementing a groundwater classification system and processes for determining if an area meets the requirements for classification as a potential future drinking water source.

This memorandum focuses on evaluating whether or not the individual geologic units at the Site have the ability to provide sufficient yield to be considered a potential future drinking water source. This memo also considers other factors to determine if a reasonable assurance exists that there is no direct drinking water pathway to Site-derived constituents in the groundwater at the Sequoyah Fuels Facility. It should be noted that these geologic units, members of the Akota Formation, historically have not and are not currently used as a drinking water source at the Site or in the area/region adjacent to the Site. Evaluation of the Hydrologic Atlas 1, Reconnaissance of the Weber Resources of the Fort Smith Quadrangle, East – Central Oklahoma (Marcher, 1969) indicates that the bedrock and terrace groundwater is classified as least favorable for groundwater supplies. The document describes the Atoka formation as: "Yields limited amounts of water of poor quality."


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## PHYSICAL SETTING

The geologic units that directly underlie the Site facilities are a series of alternating shale and sandstone units of the Atoka Formation. Figure 1 illustrates a typical geologic cross section through the Site. Locally, the geologic units have been named, in order of descending elevation, Shale 1, Sandstone 1, Shale 2, Sandstone 2, Shale 3, Sandstone 3, Shale 4, Sandstone 4, and Shale 5. Clay and silt-rich sediments overlying Shale 1 are hereby referred to as Terrace deposits, and the Terrace deposits and Shale 1 are treated as a single hydrologic entity. Previous studies have identified the shale units to be the primary water bearing units, while the sandstone units act as aquicludes or aquitards to vertical groundwater flow. Site-derived constituents have been identified in Shale units 1 through 4 at concentrations that could pose a potential future health hazard if used as a long-term domestic drinking water source. Site-derived constituents have not migrated past Shale 4 into underlying shale (i.e. Shale 5), and are blocked from doing so by a laterally pervasive, thick massive sandstone aquiclude (Sandstone 4). The Site Characterization Report, submitted to the NRC by SFC (1998), presents a more detailed treatment of the geologic site conditions.

## TECHNICAL APPROACH

The hydrologic conditions of the shale units at the Site are compared to EPA criteria for sufficient yield to be considered a potential drinking water source. Through this comparison, the geologic units and portions of geologic units at the Site that do and do not meet the EPA criteria as a potential drinking water source based on calculated yield are identified.

The EPA groundwater classification system (EPA, 1986) identifies three broad groundwater classes, Class I (Special groundwater), Class II (Groundwater currently and potentially a source of drinking water), Class III (Groundwater not a source of drinking water). Class III groundwater units are divided into two subgroups. The Class IIIa subgroup encompasses groundwater units that are not potential sources of drinking water due to high to moderate interconnection with surface water systems or groundwater units of a higher class and have a total dissolved solids concentration of greater than 10,000 mg/L or are untreatable, or have insufficient yield to reasonably support that use. The EPA guidance indicates that two conditions must be met for a geologic unit to be considered as Class IIIa due to insufficient yield. These conditions are:

1. There are no wells or springs used as a source of drinking water regardless of well yield.

2. All water-bearing units meet the insufficient yield criterion.

No wells or springs are currently used as a drinking water source at the SFC facility or in the adjacent area/region. The criterion of 150 gallons-per-day (0.1 gallons per minute [gpm]) is given as the cutoff for sufficiency and is considered to be a conservatively low yield below which it is unlikely or impractical to support basic household needs (EPA, 1986; Section 3.6.2; p.45).

In order to determine the yield of the geologic units at the Site, the steady-state pumping rates for each unit have been calculated using the average hydraulic conductivity values for each unit and the available groundwater drawdown in the units. The hydraulic conductivity data collected from previous Site studies have been compiled by shale unit and are summarized in Table 1.

The available groundwater drawdown of each individual shale unit is calculated as the elevation difference between the bottom of the individual shale unit and the piezometric surface for that unit. Due to the variation in elevation between these two surfaces, the available drawdown varies across the Site. To calculate the available drawdown for each unit, the physical extent and thickness of each geologic unit has been determined from drilling data collected from the previous site studies and contoured using Environmental Visualization Software (EVS; CTECH Corp. Version 5) (Figures 2 and 3). Water levels collected from selected site wells completed in the individual shale units are presented in Table 2 and have been modeled using EVS to determine the piezometric surface in each shale unit. Once these surfaces have been defined for each geologic unit, the gridded data from EVS are exported to an Excel spreadsheet where the available drawdown and aquifer thickness is calculated for each grid node.

Figure 4 shows the relationship between water levels in wells and the contact of the Terrace deposits and the Unit 1 Shale. Positive numbers represent higher water levels that are within the Terrace deposits, and negative numbers represent lower water levels that are within the Unit 1 Shale. Also shown are the locations of the drainpipes. The drains are located near the base of the Unit 1 Shale and transport various discharges of the Industrial Area to Outfall 001, acting as a large sump system in the southeastern part of the Industrial Area. Previous pumping, along with continuing gravity draining of the system has effectively drained water from the Terrace deposits adjacent to the stream drain system. This suggests there is significant hydrologic communication between the terrace deposits and the Unit 1 Shale. Therefore, for the purpose of this investigation, the Terrace deposits and the Unit 1 Shale will be considered to be a single hydrologic unit.

Given the available drawdown, the yield for the Terrace/Shale 1 Unit and each of the underlying shales were calculated using the Thiems Equation (1906):

$$Q = 2\pi\ K\ D(\text{available drawdown}) / \ln\ (r_e/r_w) \qquad \text{(Eq. 1)}$$

Where K is the hydraulic conductivity in feet per day, D is the aquifer thickness in feet, $r_w$ is the radius of the well filterpack in feet and $r_e$ is the effective radius in feet, the distance at which the drawdown of the piezometric surface is essentially zero. Figure 5 illustrates these parameters.

The effective radius ($r_e$) is defined, as the greatest distance from the pumping well a resulting cone of depression will reach. The effective radius is dependant on the well radius ($r_w$) and the

screen length (d) and the well penetration (b) and can be calculated based on the following equation developed by Bouwer and Rice (1976):

$$\ln r_e/r_w = [(1.1/\ln(b/r_w)) + C/(d/r_w)]^{-1} \quad \text{(Eq. 2)}$$

Solving for $r_e$ yields:

$$r_e = (e^{[(1.1/\ln(b/r_w)) + C/(d/r_w)]^{-1}}) \times r_w \quad \text{(Eq. 3)}$$

Figure 6 illustrates the range of values for the dimensionless parameter C taken from Bouwer and Rice. It is conservatively assumed that the values for well penetration (b) and screen length (d) are equal to the available drawdown of the shale unit being considered. In other words, the wells are assumed to fully screened and fully penetrating.

The wells were assumed to be 4-inch diameter installed in an 8-inch boring, making the well radius ($r_w$) 0.3 feet. The values for the ratio $d/r_w$ ranges from essentially zero, where the shales are nearly dry and there is no available drawdown, to roughly 100 where the available drawdown is as great as 30 feet. The range of the dimensionless parameter C is therefore between zero and 4. A representative value for C of 2.5 has been assumed. However, the calculated estimate of $r_e$ is not highly sensitive to the value of C.

The geometric mean K value for each shale unit was determined from slug tests performed on several wells from each shale unit. It has not been feasible to perform pumping tests on the installed wells to extremely low well yields. Table 1 summarizes the K values from each test and the geometric mean for each geologic unit. The geometric mean K value for each shale unit was calculated according to the following equation:

$$\text{Geometric Mean} = 10^{(\Sigma(\log(K))/n)} \quad \text{(Eq. 4)}$$

Where K is the hydraulic conductivity in feet per day and n is the number of K values for each shale unit.

The Excel spreadsheet was used to estimate the value of $r_e$ for the sufficient yield calculations. An Excel spreadsheet was also used to calculate the potential steady state pumping rate at each

grid node. Figures 7 through 9 illustrate the calculated steady-state pumping rate, or yield, for each shale unit.

The analysis developed in this memorandum conservatively estimates decreases (well loss) in potential well yield due to converging flow and well inefficiencies at 80 percent and overestimates the average yield by the conservative assumption that all of the available drawdown could be used to produce well yield.

## RESULTS

Figures 7 through 9 illustrate the extent of each shale unit and the portions of those units that are calculated to yield more than 0.1 gpm. The Terrace/Shale 1 Unit has no calculated yield greater than 0.1 gpm, and is not illustrated here. This analysis indicates that the Terrace/Shale 1 Unit, Shale Unit 2, and Shale Unit 3 have essentially no ability to yield sufficient quantities of water to reasonably be considered as a potential source of drinking water and, therefore, do not meet the EPA criteria.

These analyses indicate that Shale 4 may have the limited potential to yield 0.1 gpm. However, as shown in Figure 9, less than half is capable of producing 0.1 gpm and less than two percent of the extent of Shale 4 has the ability to yield more than 0.2 gpm. This analysis indicates that the saturated portions of Shale Unit 4 are only marginally above the conservative criteria for sufficiency. In addition, most of the area with the potential to yield more than 0.1 gpm is located away from the area of site impacts to groundwater and would pose no hazard if inappropriately accessed in the future. Most wells drilled at the site cannot be sampled the same day they are purged due to excessively slow recharge rates. In addition, it has not been possible to perform pumping tests on site wells to evaluate specific unit hydraulic properties due to insufficient recharge rates to the test wells, requiring slug tests to be the sole form of hydraulic testing at the site. The small margin of potential groundwater yield above the 0.1 gpm criteria makes the potential future use of this water as potential future drinking water source highly unlikely.

In addition, there are several other factors which make it highly unlikely that groundwater at the Site would be accessed as a drinking water source, should trespass occur and institutional record keeping and law enforcement of the trespass fail in the future. First, there is a readily available and abundant source of water easily accessed from the adjacent Illinois River. This water could be pumped to an illegal home site at the Sequoyah Fuels Facility as easily or more easily than from a well completed on site. Second, one would have to drill through several very hard sandstone layers before reaching a unit with any potential to yield sufficient quantities of water for drinking water, which is unlikely given the abundant and easily accessed surface water nearby. Third, the background water quality of the first shale unit with any potential to yield sufficient quantities of water (Shale 4) is so poor that no one would use it. Table 3 summarizes the background water quality from Shale unit 4 as determined from the June 5, 2001 sampling of newly installed well MW-110. These data demonstrate that Shale Unit 4 has a background sulfate concentration of 1,750 mg/L and a total dissolved solids concentration of over 3,100 mg/L. These concentrations exceed the current Class III criteria of the Oklahoma State Water

Resources Board guidelines for suitability of water for livestock and irrigation uses (Oklahoma Water Resources Board, 2000). Should anyone access this water for drinking water they would discard it immediately due to its taste.

In summary, this analysis indicates that the Terrace/Shale 1 Unit, Shale Unit 2, and Shale Unit 3 have essentially no ability to yield sufficient quantities of water to reasonably be considered as a potential source of water for drinking water. Therefore, the Terrace/Shale 1 Unit and Shale Units 2 and 3 do not meet the EPA criteria for consideration as a potential drinking water source. Though Shale Unit 4 may have very limited potential to yield groundwater slightly greater than the 0.1 gpm EPA criteria, the background water quality of this formation is of such a poor quality that it would not reasonably be used for any domestic purpose. Also, there exists an abundant and more easily accessed alternate water supply that would make drilling to substantial depths through the hard sandstone units impractical and highly improbable. Therefore, there exists a reasonable assurance that there is no direct drinking water pathway to Site-derived constituents in the groundwater at the Sequoyah Fuels Facility.

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**Table 1. Hydraulic Conductivity at Test Wells and of Geologic Units**

| WELL | DATE | HYDROLOGIC UNIT | HYDRAULIC CONDUCTIVITY (FT/DAY) | K | | UNIT | GEOMETRIC MEAN (FT/DAY) |
|---|---|---|---|---|---|---|---|
| MW008 | 12/04/90 | SHALE 1 | 0.0156 | 0.0145 | | Terrace/shale 1 | 0.0246 |
| MW008 | 06/15/01 | SHALE 1 | 0.0134 | | | shale 2 | 0.1382 |
| MW012 | 12/06/90 | SHALE 1 | 0.00556 | 0.00556 | | shale 3 | 0.0478 |
| MW013 | 12/06/90 | SHALE 1 | 0.0110 | 0.011 | | shale 4 | 0.0314 |
| MW016 | 12/06/90 | SHALE 1 | 0.0382 | 0.033033 | | | |
| MW016 | 12/09/90 | SHALE 1 | 0.0480 | | | | |
| MW016 | 06/15/01 | SHALE 1 | 0.0129 | | | | |
| MW017 | 12/06/90 | SHALE 1 | 0.0311 | 0.07855 | | | |
| MW017 | 12/06/90 | SHALE 1 | 0.126 | | | | |
| MW026 | 06/15/01 | SHALE 1 | 0.0310 | 0.031 | | | |
| MW073 | 06/13/01 | SHALE 1 | 0.261 | 0.261 | | | |
| MW076 | 06/15/01 | SHALE 1 | 0.00416 | 0.00416 | | | |
| MW102 | 06/14/01 | SHALE 1 | 0.0297 | 0.0297 | | | |
| MW035 A | 06/13/01 | SHALE 2 | 1.35 | 1.35 | | | |
| MW040 A | 06/13/01 | SHALE 2 | 0.327 | 0.327 | | | |
| MW042 A | 06/13/01 | SHALE 2 | 0.0118 | 0.0118 | | | |
| MW085 A | 06/15/01 | SHALE 2 | 0.07 | 0.07 | | | |
| 2346 | 06/12/01 | SHALE 3 | 0.488 | 0.488 | | | |
| MW037 A | 06/13/01 | SHALE 3 | 0.0103 | 0.0103 | | | |
| MW084 A | 06/14/01 | SHALE 3 | 0.0217 | 0.0217 | | | |
| MW110 | 06/13/01 | SHALE 4 | 0.0143 | 0.0143 | | | |
| MW111 | 06/15/01 | SHALE 4 | 0.0482 | 0.0482 | | | |
| MW112 | 06/12/01 | SHALE 4 | 1.30 | 1.3 | | | |
| MW113 | 06/12/01 | SHALE 4 | 0.00732 | 0.00732 | | | |
| MW114 | 06/16/01 | SHALE 4 | 0.00466 | 0.00466 | | | |

**Table 2. Water Levels from Selected Well Sites**

| LOC ID | WATER DEPTH | DATE SAMPLED | UNIT | COMMENT |
|---|---|---|---|---|
| 2344 | 11.4 | 6/12/01 | 3SH | |
| 2346 | 9.67 | 6/12/01 | 3SH | |
| MW003 | 4.61 | 6/15/01 | 1SH | |
| MW007 | 11.46 | 6/15/01 | 1SH | |
| MW007B | 38.13 | 6/15/01 | 5SH | |
| MW008 | 10.92 | 6/15/01 | 1SH | |
| MW012 | 8.82 | 6/15/01 | 1SH | |
| MW013 | 9.4 | 6/15/01 | 1SH | |
| MW015 | 7.25 | 6/15/01 | 1SH | |
| MW016 | 6.29 | 6/15/01 | 1SH | |
| MW017 | 4.86 | 6/15/01 | 1SH | |
| MW021 | 4.11 | 6/15/01 | 1SH | |
| MW022 | 4.1 | 6/15/01 | 1SH | |
| MW023 | | 6/15/01 | 1SH | Dry |
| MW024 | 12.35 | 6/15/01 | 1SH | |
| MW025 | | 6/14/01 | 1SH | |
| MW027 | 11.16 | 6/15/01 | 1SH | |
| MW035A | 8.66 | 6/13/01 | 2SH | |
| MW036A | 13.96 | 6/15/01 | 2SH | |
| MW037A | 17.01 | 6/13/01 | 3SH | |
| MW038A | 19.46 | 6/15/01 | 3SH | |
| MW039A | 13.96 | 6/15/01 | 3SH | |
| MW040A | 8.39 | 6/13/01 | 2SH | |
| MW042A | 7.13 | 6/13/01 | 2SH | |
| MW045A | | 6/13/01 | 2SH | Dry |
| MW046 | | 6/13/01 | 2SH | Dry |
| MW047A | 22.96 | 6/13/01 | 2SH | |
| MW048 | 7.25 | 6/13/01 | 2SH | |
| MW049A | 15.49 | 6/15/01 | 3SH | |
| MW050A | 23.57 | 6/15/01 | 2SS | |
| MW050B | 28.95 | 6/15/01 | 5SH | |
| MW052 | | 6/15/01 | 1SH | Dry |
| MW059B | 26.9 | 6/13/01 | 5SH | |
| MW062A | 20.88 | 6/16/01 | 4SH | |
| MW062B | 24.23 | 6/16/01 | 5SH | |
| MW063 | | 6/16/01 | 3SS | Dry |
| MW063A | 6.38 | 6/16/01 | 4SH | |
| MW065A | 19.36 | 6/13/01 | 4SH | |
| MW066 | 4.32 | 6/16/01 | 2SH | |
| MW070 | 11.05 | 6/13/01 | 1SH | |
| MW072B | 39.49 | 6/13/01 | 5SH | |
| MW073 | 27.31 | 6/13/01 | 1SH | |
| MW074 | 6.05 | 6/16/01 | 2SS | Dry |

Table 2. Water Levels from Selected Well Sites (continued)

| LOC ID | WATER DEPTH | DATE SAMPLED | UNIT | COMMENT |
|---|---|---|---|---|
| MW076 | 13.3 | 6/15/01 | 1SH | |
| MW079 | 7.86 | 6/15/01 | 1SH | |
| MW083 | 11.06 | 6/15/01 | 1SH | |
| MW083A | 13.11 | 6/15/01 | 4SH | |
| MW084 | 12.81 | 6/15/01 | 1SH | |
| MW084A | 18.21 | 6/14/01 | 3SH | |
| MW085 | 11.4 | 6/15/01 | 1SH | |
| MW085A | 14.48 | 6/14/01 | 2SH | |
| MW086A | 8.6 | 6/15/01 | 3SH | |
| MW087A | 18.32 | 6/15/01 | 4SH | |
| MW089A | 25.41 | 6/13/01 | 3SH | |
| MW093A | 26.51 | 6/15/01 | 4SH | |
| MW096A | 26.98 | 6/15/01 | 4SH | |
| MW097A | 16.36 | 6/15/01 | 4SH | |
| MW098B | 17.12 | 6/15/01 | 5SH | |
| MW099A | 17.78 | 6/15/01 | 4SH | |
| MW100B | 17.7 | 6/15/01 | 5SH | |
| MW102 | 6 | 6/14/01 | 1SH | |
| MW104B | 14.75 | 6/15/01 | 5SH | |
| MW105B | 4.44 | 6/12/01 | 5SH | |
| MW109A | 24.15 | 6/15/01 | 4SH | |
| MW110A | 19.4 | 6/13/01 | 4SH | |
| MW111A | 15.17 | 6/15/01 | 4SH | |
| MW112A | 17.11 | 6/12/01 | 4SH | |
| MW113A | 2.8 | 6/12/01 | 4SH | |
| MW114A | 15.34 | 6/15/01 | 4SH | |
| MW115A | | 6/16/01 | 3SH | Dry |
| MW116A | | 6/13/01 | 2SH | Dry |
| MW119A | | 6/16/01 | 2SH | Dry |

## Table 3. Summary of Shale Unit 4 Background Water Quality (Well 110, sampled 6/5/01)

| Constituent | Concentration (mg/L) |
|---|---|
| Aluminum | <0.1 |
| Arsenic | 0.001 |
| Bicarbonate | 415 |
| Calcium | 110 |
| Carbonate | <1.0 |
| Chloride | 9.4 |
| Iron | <0.03 |
| Magnesium | 45.9 |
| Phosphorus | <1.0 |
| Potassium | 2.9 |
| Sodium | 849 |
| Silica | 9.1 |
| Sulfate | 1,750 |
| Uranium | 0.0024 |
| Vanadium | <0.1 |
| Total Dissolved Solids* | 3,182 |

* Sum of all major ions (Ca, K, Mg, Na, CO32-, HCO3-, Cl, SO42-)

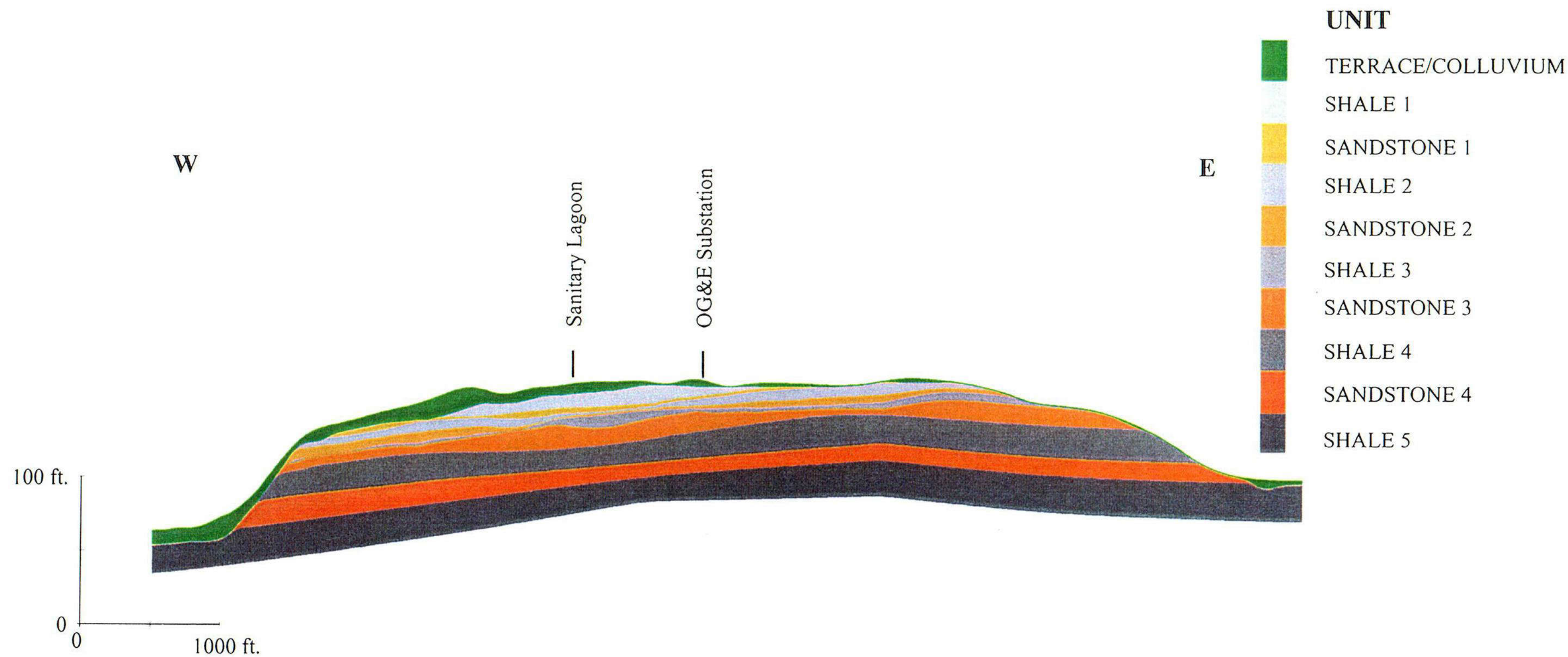


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FIGURE 1. TYPICAL GEOLOGIC CROSS SECTION

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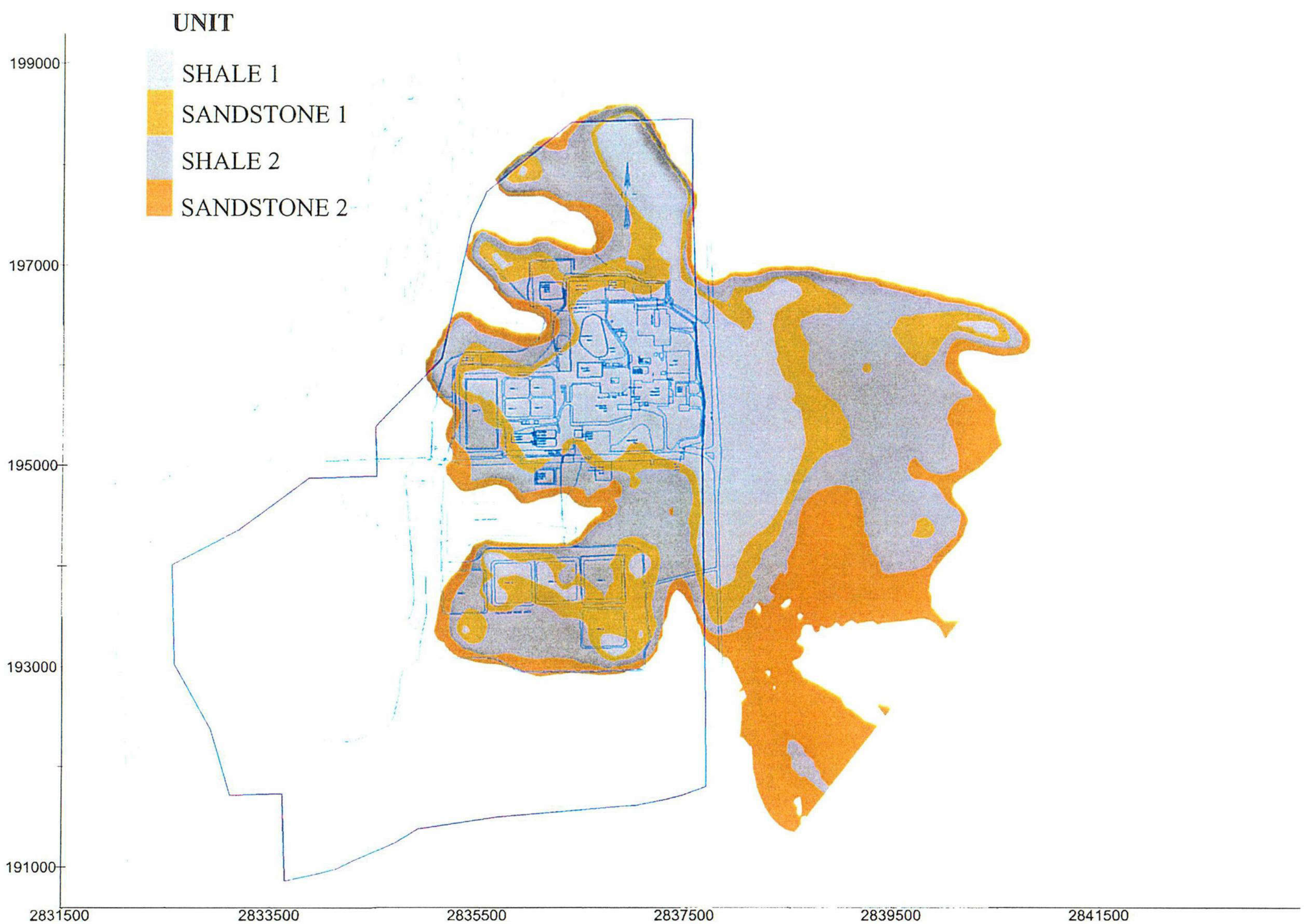


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FIGURE 2. AREAL EXTENT OF UNITS 1 SHALE, 1 SANDSTONE, 2 SHALE, and 2 SANDSTONE

| | |
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C02

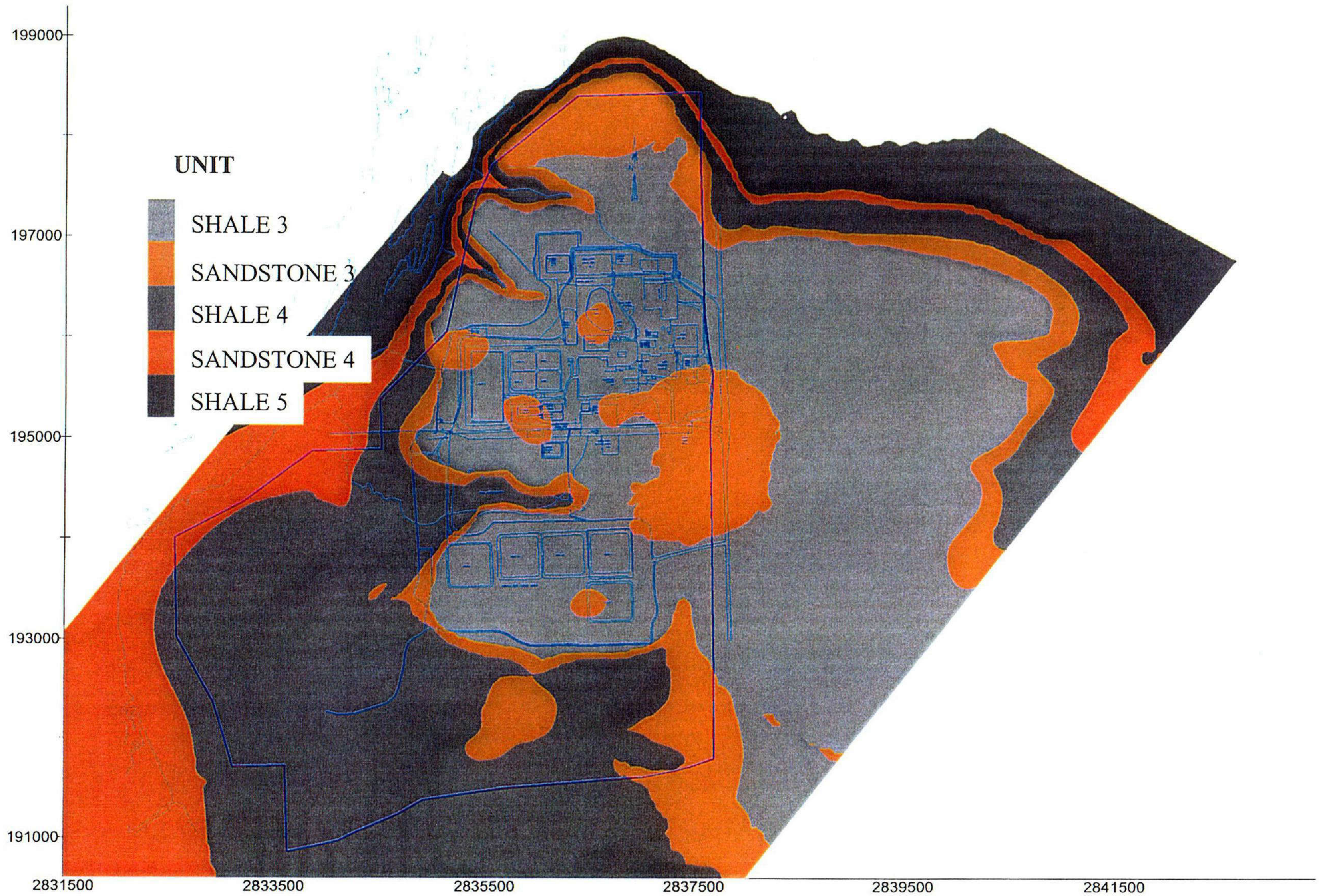


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FIGURE 3. AREAL EXTENT OF UNIT 3 SHALE, 3 SANDSTONE, 4 SHALE, UNIT 4 SANDSTONE, AND UNIT 5 SHALE

| | |
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C03

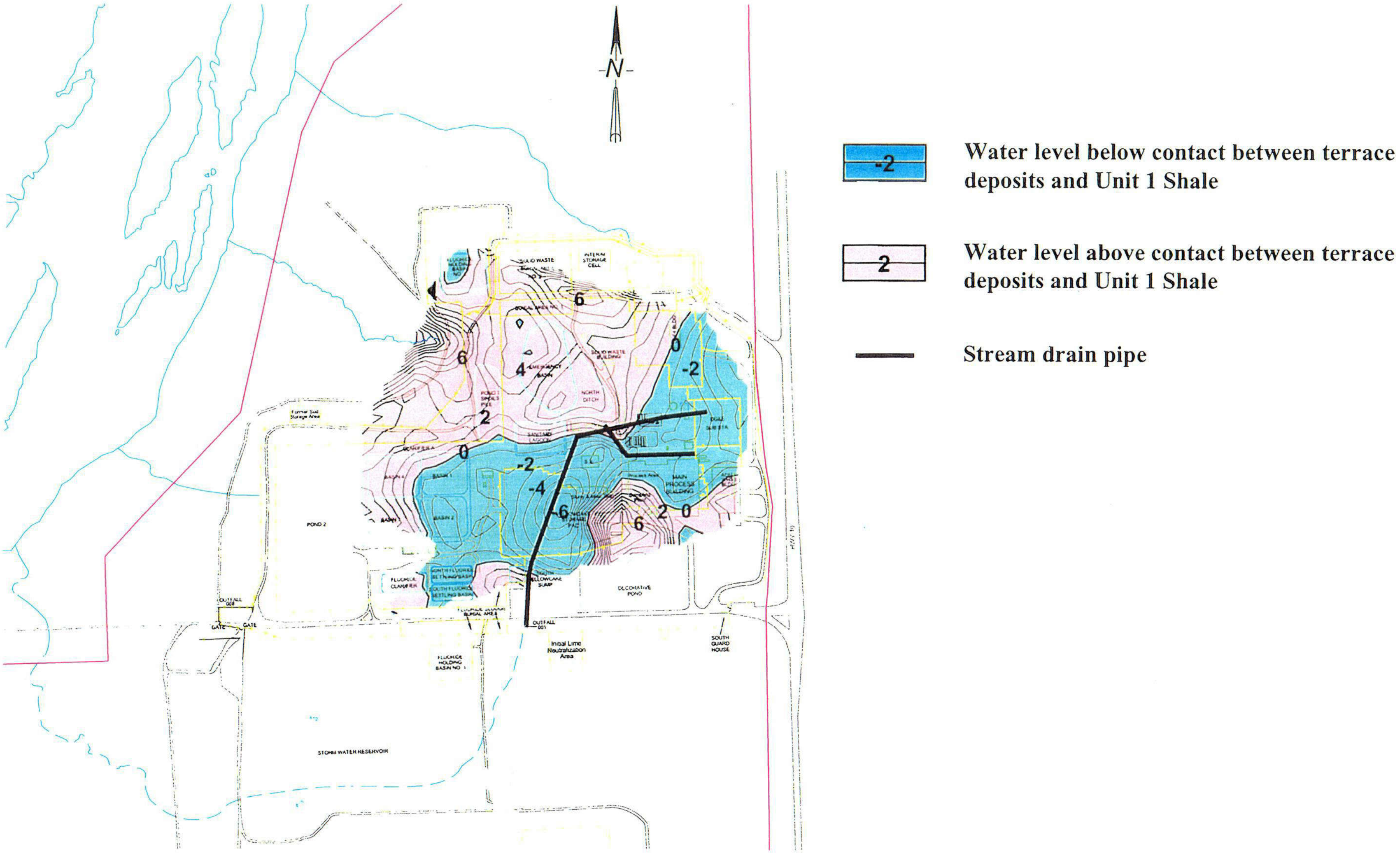


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FIGURE 4. WATER LEVEL IN WELLS IN RELATION TO TERRACE/SHALE 1 CONTACT

| | |
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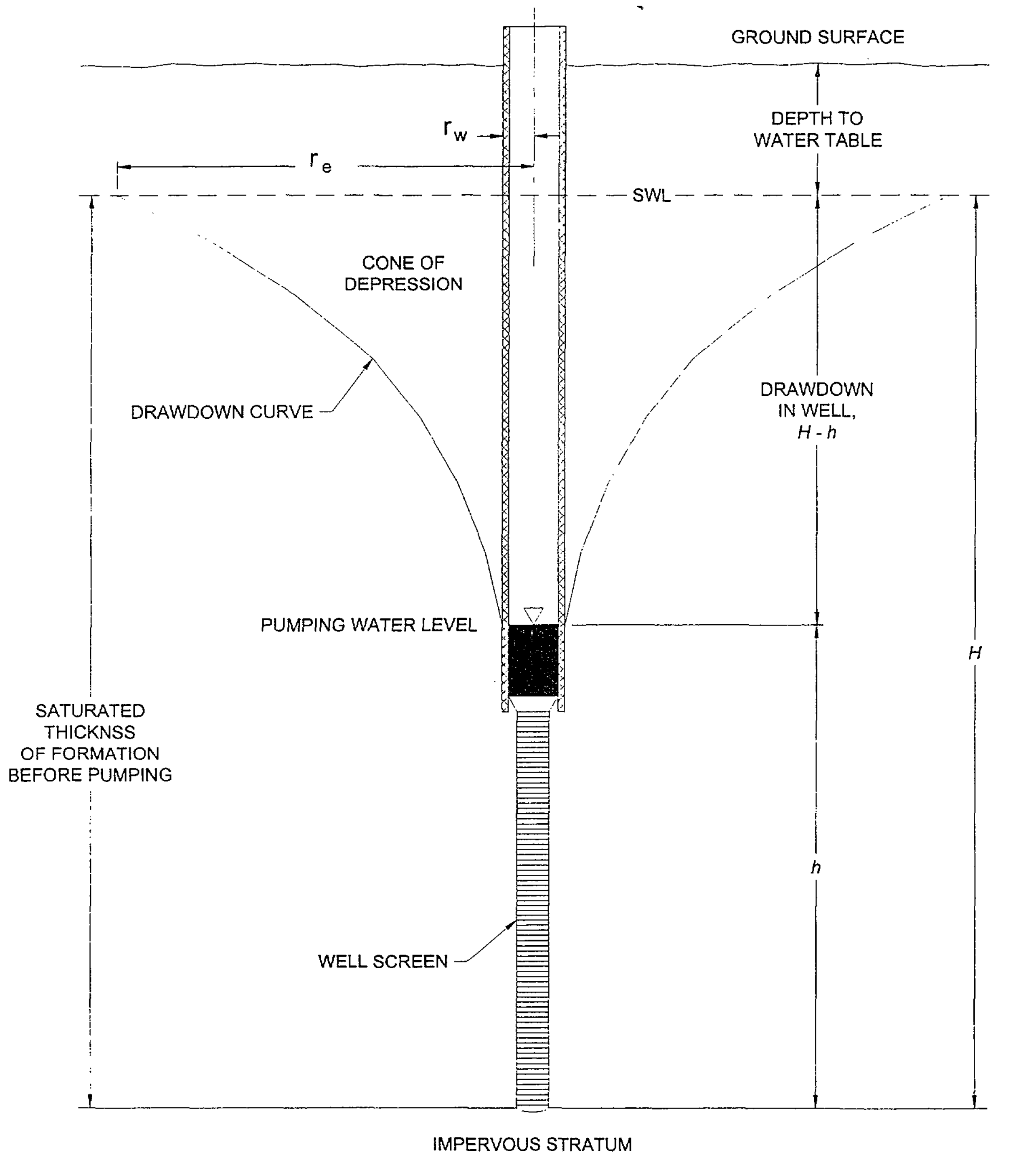


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FIGURE 5
PARAMETERS FOR THIEMS EQUATION

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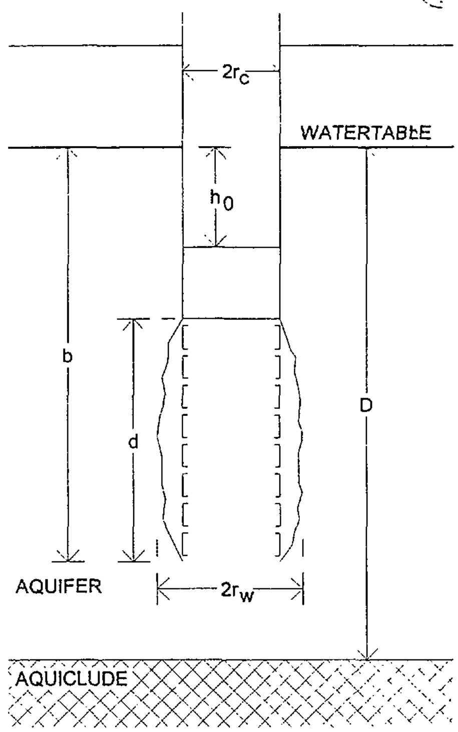


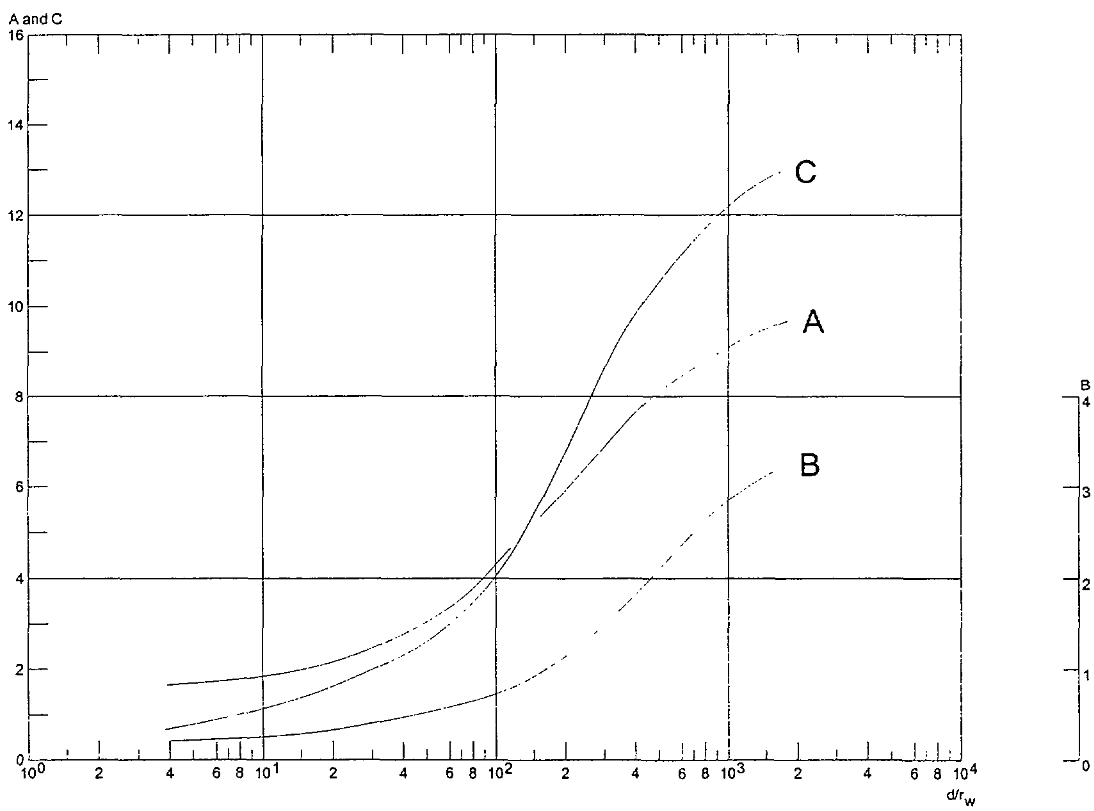


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FIGURE 6
UNCONFINED AQUIFER

BOUWER AND RICE CURVES

| | |
|---|---|
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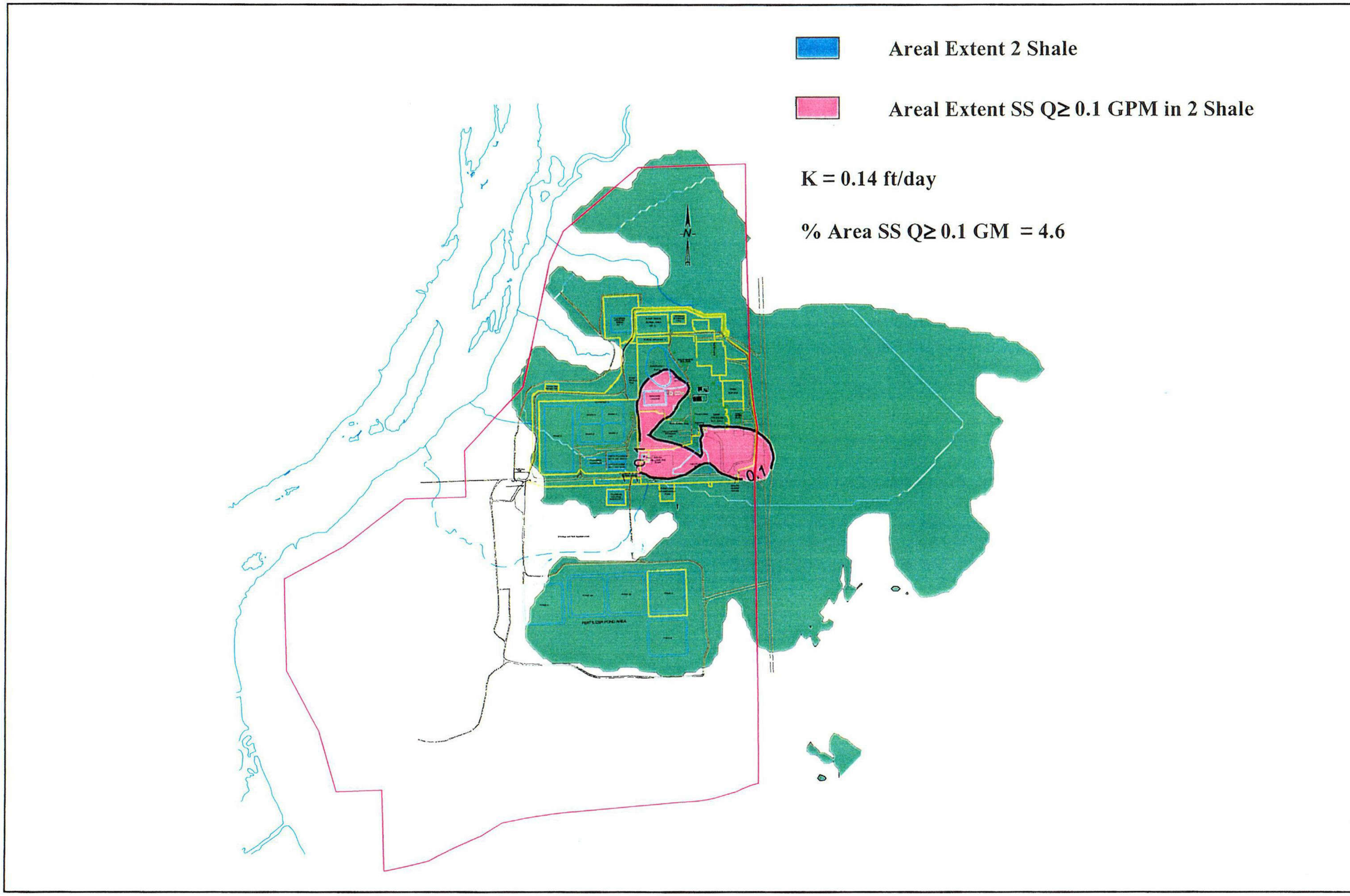


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FIGURE 7. AREAL EXTENT UNIT 2 SHALE AND STEADY STATE YIELD GREATER THAN 0.1 GPM

| | |
|---|---|
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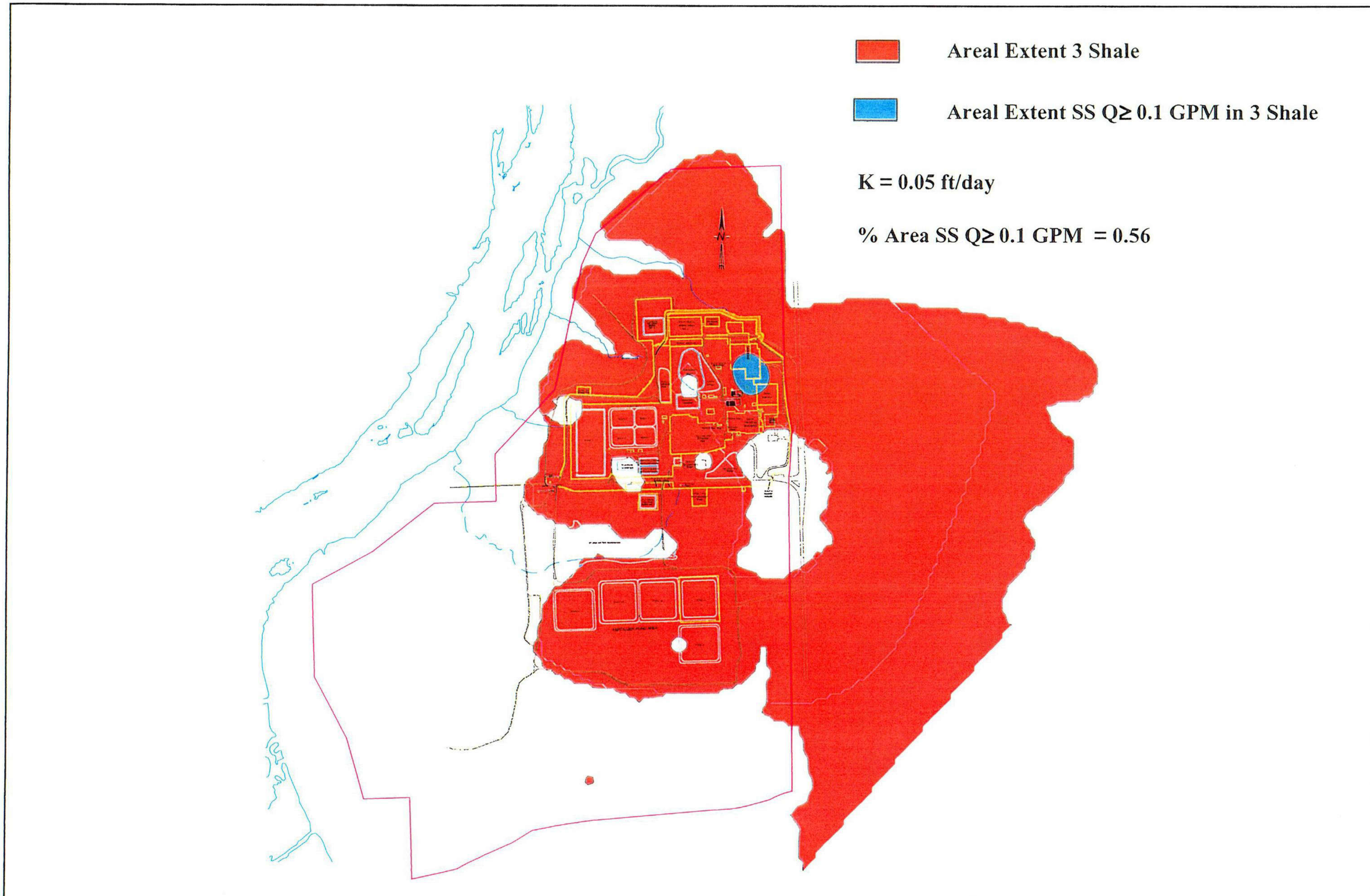


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FIGURE 8. AREAL EXTENT UNIT 3 SHALE AND STEADY STATE YIELD GREATER THAN 0.1 GPM

| | |
|---|---|
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| Project: | 100734 |
| File: | FIGURES.PPT |

C06

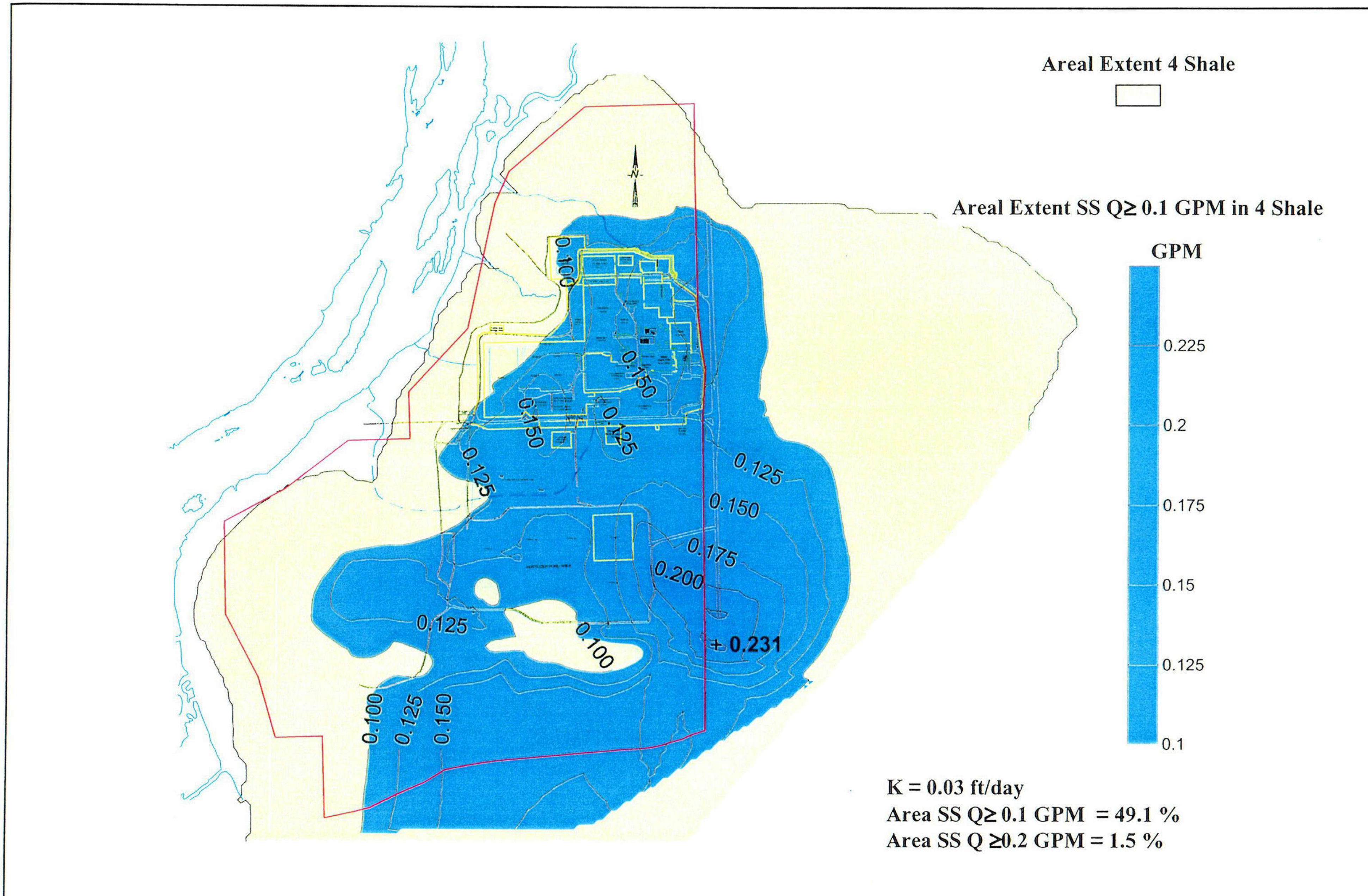


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FIGURE 9. AREAL EXTENT UNIT 4 SHALE AND STEADY STATE YIELD GREATER THAN 0.1 GPM

| | |
|---|---|
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| Project: | 100734 |
| File: | FIGURES.PPT |