VOLUME II - APPENDICES

HYDROGEOLOGICAL AND GEOCHEMICAL SITE CHARACTERIZATION REPORT

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APPENDIX A

HYDROGEOLOGICAL CHARACTERIZATION WORK PLAN

SOPS

HEALTH AND SAFETY PLAN

APPENDIX B

SUPPLEMENTAL DATA COLLECTION TRIP REPORT

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1.0 INTRODUCTION

Sequoyah Fuels Corporation (SFC) recently submitted new groundwater characterization and modeling data (Shepherd Miller, 2001) to support decommissioning and reclamation of its Gore, Oklahoma facility. As a result of discussions with the Nuclear Regulatory Commission (NRC) regarding these submittals, several issues regarding site conditions characterization and the groundwater modeling have been identified that need further study. These issues include:

- Increasing arsenic concentrations in well MW095A not predicted by, and inconsistent with, the groundwater modeling;
- Anomalous uranium and arsenic water quality values in 005 Drainage not predicted by, and inconsistent with, the groundwater modeling; and
- Concerns with delineation and characterization of the hydrogeologic and geochemical conditions associated with the subsurface Swale near well MW010.

As a result of these issues, SFC initiated a supplemental data collection effort. This effort was performed February 7 through February 13, 2002. The scope and findings of this effort are presented herein, although results of analytical testing (partitioning coefficient testing on terrace, fill and colluvium) and model revisions are pending. This report discusses the field efforts for each of the three areas described above and concludes with recommendations for additional studies for characterization and evaluation of potential groundwater mitigation efforts. Relevant tables, figures and photographs are included.

2.0 WELL MW095A ARSENIC ANOMALY

The objective of the field effort associated with well MW095A (Figure 1) was to better understand the basis for the arsenic anomaly at this location. Partitioning coefficient (K_d) testing for arsenic and transport modeling did not predict the measured concentrations and increasing arsenic concentration trend at this location (Figure 2). Potential controls of arsenic mobility are thought to include local hydrologic conditions that are not representative of the rest of the site and possible chemical complexation of the arsenic with organic compounds found in Pond 2, the probable past local source for arsenic flowing toward well MW095A.

The investigation approach included hydraulic conductivity tests on wells MW095A, MW097A, MW097, MW093A, MW059A (Figure 1), as well as analysis of water samples from selected wells for evidence of arsenic complexation with organic compounds. Based on these data, additional transport modeling will be performed to identify what K_d or hydraulic conductivity conditions might be required to account for the observed anomaly at well MW095A. The following sections discuss the specific field efforts and available preliminary findings.

2.1 Hydraulic Conductivity Testing

Slug tests were performed to see if anomalously high hydraulic conductivity conditions, which could cause locally faster constituent transport rates, were present in this area. The wells tested for hydraulic conductivity include MW095A, MW097A, MW097, MW093A, MW059A (Figure 1), which are proximal to or downgradient from Pond 2, and are near the predicted flow path from Pond 2 to well MW095A. Three of these wells, MW093A, MW95A, and MW97A, are completed in Shale Unit 4. MW059A is completed in both Shale Unit 3 and Shale Unit 4. MW097 is completed in the unconsolidated colluvial material.

The slug tests were performed and analyzed in exactly the same manner as described in SMI, 2001. Table 1 summarizes the calculated hydraulic conductivity for these wells.

Slug test data analyses for this investigation are presented in Attachment A. Prior to this investigation, the hydraulic conductivity of the colluvium was assumed to be 5 feet per day (ft/day), although no test on this material had been performed. MW097 slug test results indicate that the colluvial deposits have a hydraulic conductivity of 39 ft/day, which exceeds the 5 ft/day value used in the model by a factor of eight. The slug test results for the Shale Unit 4 wells indicate a hydraulic conductivity of between 0.93 ft/day and 4.73 ft/day. These values vary from good agreement with the previously modeled value of 0.5 ft/day to an order of magnitude greater than the previously modeled value. The measured hydraulic conductivity for MW059A, 21.38 ft/day, was higher than previously measured formations for either Shale Unit 3 or Shale Unit 4 by one to two orders of magnitude.

The aquifer testing program indicates that some of the hydraulic conductivity values used in the 2001 groundwater model may have been underestimated. The consequence of underestimating the hydraulic conductivity is reduced contaminant transport velocity, all other parameters held equal. However, the underestimation of hydraulic conductivity is likely not sufficient, on its own, to account for the apparent early arrival of arsenic at well MW095A (Figure 2). Changes to the revised groundwater model, which is currently under development, will be implemented to reflect recently acquired data.

2.2 Arsenic Speciation Testing

Materials deposited in the Pond 2 (Unit 18) area included raffinate and sludge by-products, contaminated rock, yellowcake drums, soda ash, anode blades, drum liners, electrolyte sludge and laboratory wastes (SFC, 1998). In addition, SFC personnel have indicated that significant amounts of the organic compounds tributylphosphate ($C_{12}H_{27}PO_4$) and hexane (C_6H_{14}), which were associated with the solvent extraction process, were also deposited in Pond 2. This has led to speculation that the arsenic in Pond 2 may have formed organic-arsenic complexes or possibly ammonium-arsenic complexes that could migrate at a less retarded rate than the un-complexed arsenic. Therefore, analytical testing of water samples for arsenic speciation (As III, As V, mononmethylarsonic acid [MMAs], dimethylarsinic acid [DMAs], thioarsenates, and other organoarsenicals) was undertaken.

Raw water samples were collected from wells in areas thought to be impacted by Pond 2 seepage and associated organic compounds (MW095A, MW057A, MW059A [Figure 1]) and from wells not likely impacted by Pond 2 seepage and associated organic compounds (MW064A, MW035A, MW042A, MW071A [Figure 1]) in an attempt to identify differences in arsenic speciation and transport mobility. The water samples were sent to Frontier Laboratories in Seattle, Washington for analysis.

2.3 Analytical Results

Samples sent to Frontier Geosciences (FG) for arsenic speciation were initially analyzed by ion-chromatography inductively coupled plasma mass-spectrometry (IC-ICP-MS). Using this analytical method, the As species As(III), As(V), MMAs, and DMAs, as well as other unknown As-species are separated by anion-chromatography using a hydroxide eluent. After separation/speciation, the eluent stream is injected into the plasma flame of the ICP-MS and As in the various fractions is quantified by detection of mass/charge75. Total As is then determined by direct introduction of the filtered sample to ICP-MS after acidification with 1 percent HNO_3.

The results of these analyses are presented in Table 2. Interference was observed during As speciation with IC-ICP-MS, peaks were broadened and retention times were shifted with respect to standards (Figure 3). Peaks were observed at retention times unspecific for known As-species. As(V) matrix spikes were not recovered intact, the signal was shifted more than 2 minutes and the approximate recovery is about 180 percent. Due to the peak shifting, it is not possible to determine which species are present with any certainty, and therefore the approximate concentrations are listed by their retention times (Table 2). Dilution did not overcome the interference, and the reason for the strong interference remains unknown. Common interferents (anions and Fe) are not present at concentrations that would explain these results. Therefore, the analyses for As speciation using the IC-ICP-MS analyses are inconclusive and analysis of these waters for individual As species using this analytical method does not appear to achieve reliable results.

Total arsenic (TAs), as determined by IC-ICP-MS (i.e. by addition of all As-species), suggests that As levels ranges from 0.4 μg/L to 5,180 μg/L. Total arsenic levels determined by direct ICP-MS range from 0.58 to 3,940 μg/L, but there is very poor sample-to-sample agreement for As concentrations determined by the two methods. A comparison of the results from these analyses is presented in Table 2. It should be noted that at the conclusion of the IC-ICP-MS analysis the anion exchange column on the IC needed to be recharged. This suggests that an unidentified As species was present and was irreversibly or very tightly bound to the resin, thereby necessitating column regeneration. It is of interest to note that, if present, the interferent was present in all samples and not just those samples thought to be impacted by organic solvents. Given the discrepancies in results and the atypical chromatograms, a second analytical method was used to investigate As speciation.

The second investigative analytical methodology used consisted of hydride generation cryotrapping gas chromatography atomic absorption spectrometry (HG-CT-GC-AAS). The "cryo" method is similar to EPA method 1632. The overall quality of the HG-CT-GC-AAS and ICP-MS data look good; no analytical issues were encountered and all QA measurements were within established control limits (Tables 3 through 6). Sample MW059A exhibited some peak broadening during the As(III) and total inorganic arsenic (TIA) analysis by HG-CT-GC-AAS which might have lead to an overestimation of the As levels in this sample (Figure 4). However, comparing total As determined by ICP-MS to the TIAs detected by HG-CT-GC-AAS (Table 2), it is obvious that the majority of the As is not accounted for in the sum of the inorganic species. TIAs levels determined by HG-CT-GC-AAS ranged from 0.034 to 0.668 μg/L compared to total As levels that ranged from 0.58 to 3940 μg/L via ICP-MS, a difference of almost four orders of magnitude. Thus, either much of the As in the samples were present as non-hydride forming As species and therefore not detected by the cryo-method or total ICP-MS results are biased high due to the presence of an unknown interference. The presence of a non-hydride forming organic As-species cannot be ruled out.

In summary, results from the As speciation analysis are inconclusive. The possibility exists that the total As data obtained by ICP-MS is biased high due to an unknown interference. It is also possible that there are unknown As species present at comparable concentrations that are not amenable to hydride generation and therefore were not detected by the Cryo method, and were not eluted efficiently from the IC column during analysis with IC-ICP-MS, yielding uncertain results. However, total As numbers determined by ICP-MS are in reasonably good agreement with historical sampling values determined by ICP (Figure 3). Because both of these methods are considered very reliable for determination of total As and employ different detection methods it is unlikely that both would error high with a comparable magnitude. Therefore, it seems prudent to assume that the total As numbers that have been determined by ICP-MS and ICP are accurate and represent actual arsenic levels at the site. Because it was not possible to isolate and identify the unknown As species, the geochemical reactivity of these complexes cannot be determined. It is therefore also not reasonable to assume that partition coefficients (K_ds) determined experimentally using and inorganic arsenic species (As(V)) are representative the K_ds of these potentially present unknown species.

As a result of the analytical complexities encountered while investigating As speciation, two actions will be taken to more accurately model As transport. First, the revised ground water flow model will incorporate the recent hydraulic conductivity tests data to more accurately represent measured flow conditions. Second, the transport model will include calibration of As K_d to accurately reproduce the trends of As arrival at well MW095A, as well as As trends in other site wells.

3.0 005 DRAINAGE ANOMALY

Recent sampling of the 005 Drainage surface waters (Figures 5 and 6) indicate elevated levels of uranium and nitrate that were not predicted by, and are inconsistent with, the most recent groundwater modeling. As a result of these new data, monthly sampling of site drainages has been implemented. Due to limited flows during the low rainfall periods, only a few sample locations are amenable to regular and consistent sampling. Figures 5 and 6 illustrate and Table 7 summarizes the recent surface water samples collected for the 005 Drainage, Figure 7 illustrates the 005 Drainage trenching and soil sampling locations of this investigation. It is suspected that when the 005 Sump pump failed, the groundwater flowing above the bedrock through the backfill materials at the head of the drainage migrated past the French drain collection system and into the 005 Drainage surface waters. These waters are typically collected through a French drain system located in the backfill and pumped from the 005 Sump to the Emergency Basin (Figure 5). It is also possible that the French drain collection and pump back system is not intercepting all of the groundwater flow from the backfill materials. Regardless of their source, the current site model did not predict the occurrence of the constituents in the drainage or in the 005 Sump.

The objectives of the field efforts for the 005 Drainage area were to:

- Better characterize the hydrogeologic conditions in the backfill at the head of the 005 Drainage,
- Determine if the measured concentrations in the drainage are caused by impacted groundwater flowing from the backfill area, and
- Determine geochemical properties (e.g., K_d) of native soils and fill materials.

The technical approach for the 005 Drainage study included two components. The first component consisted of excavating a trench in the fill materials at the head of the 005 Drainage between the emergency basin and the existing 005 Sump, south of Fluoride Holding Basin No. 2 (Figure 7); this trench is referred to as 005 Drainage Trench 1. The second component consisted of sampling soils and water from small excavations in the banks of the 005 Drainage at various points along its alignment (Figure 7).

Soil samples were collected from each trench or pit excavated during the investigation. Soil samples were collected with a stainless steel spoon the day after excavation activities concluded. To obtain a fresh sample, six inches of soil were removed prior to sampling. In some instances, hard soils and shale bedrock samples were first broken into smaller sizes using a rock hammer. Composite samples were collected from materials of similar character at three to four separate locations within each pit or trench. Soils were placed into clean 250-mL glass jars for shipment to the laboratory for geochemical analysis and testing. Soil samples were split and subsampled at the lab. One subsample was dried at 38 ^{O}C for percent moisture determinations and digested according to EPA Method 3050 and analyzed for total As, F and U. The other splits were used for adsorption or desorption batch tests designed to provide additional information on contaminant partitioning within these solid materials.

Water samples were collected within 48 hours, once sufficient waters had collected in the respective trenches. No precipitation fell within this period and the samples are considered to be representative of groundwater water quality conditions. Water samples were collected using a Geotech peristaltic pump with an inline 0.45-micron filter. Tubing was replaced or cleaned with deionized water between sampling events. Decontamination of sampling tubing was performed by pumping trench water through the tubing for five minutes prior to sampling. Three samples were collected at each location. One of these samples was left unpreserved, while the other samples were preserved with either trace metal grade nitric acid or phosphoric acid. The samples were analyzed for fluoride, uranium and arsenic, and dissolved organic carbon (DOC) respectively.

3.1 005 Drainage Trench 1: Top of Drainage

The trench located in the fill material near the head of the drainage (005 Drainage Trench 1) was advanced to characterize the hydrogeologic conditions associated with the buried drainage channel and to collect soil and water samples for analysis.

A track hoe was used to excavate down to competent bedrock (Photo 1). The excavation stratigraphy was documented and visually logged by a professional geologist from the top of the trench wall, and digital photographs were taken of the excavation. The end points of the trench were recorded with a hand-held GPS unit. Table 8 summarizes the GPS coordinates of the trench and Table 7 summarizes the samples collected from the trench. Depths of geologic contacts were visually estimated due to the hazards associated with instability of the trench sidewalls. The cross section illustrated in Figure 8 was developed from these field observations.

The buried channel bottom was encountered at approximately six to eight feet deep. Stratigraphy observed in the trench consisted of a hard sandstone unit overlain by one to two feet of clay (Figure 8). Based on its elevation and lateral occurrence, the sandstone is believed to be Sandstone Unit 3 and the overlying clay is interpreted to be weathered remnants of Shale Unit 3. Overlying the clay/weathered shale unit is a one-foot thick layer of gravel with clay. This unit is interpreted to be the basal gravel on which fill or gravelly fill material was placed in the old 005 Drainage bottom. The unit was observed to be producing water in the trench sidewall, although it was not possible to estimate the rate of water production. Visual estimates of the clayey gravel hydraulic conductivity are approximately 30 feet per day based on particle size distribution and professional judgement. Water and soil samples collected from the pit are summarized in Table 7.

The sandstone bedrock unit was observed to gradually rise in the southern portion of the trench, with the clayey gravel unit thinning to the south. The bedrock abruptly rose in the northern portion of the trench due to what is interpreted to be the buried outcrop on the north side of the buried drainage (Figure 8).

The clayey gravel unit was covered with roughly five to six feet of fill material consisting of clay with gravel and sand (Photo 2). The fill material is believed to be re-worked terrace deposits cut from higher portions of the site during facility construction. A layer of 10-mil black plastic was observed below the upper one to two feet of fill. This liner was apparently placed to reduce infiltration into the fill. The one to two feet of fill above the plastic liner was observed to be reddish brown clay that contained a trace of gravel.

SFC personnel indicate that a French drain system was installed within the fill to collect seepage in the buried drainage. Although there are no known drawings of this drain system, it is believed to consist of perforated plastic pipe with a surrounding gravel pack that collects the seepage from the upper portions of the filled drainage and drains it to the 005 Sump, where it is pumped back to the Emergency Basin.

Two portions of the French drain system were exposed during excavation of the trench; one portion near the center of the trench above the deepest section of the buried channel, and one portion near the southern end of the trench (Figure 8 and Photograph 2). The pipes and associated gravel pack were located approximately one to two feet above the clayey gravel unit. The pipe in the southern portion of the trench was observed to produce roughly 0.25 gpm of relatively clear water. Little water was observed from the pipe and gravel pack in the northern portion of the trench.

Waters pooling in the trench were differentiated by color. The northern portion of the trench contained cloudy water, while the southern portion of the trench contained clearer water that may have originated primarily from the pipe and associated gravel pack. The center of the trench appeared to contain a mixture of these two waters. Soil and water samples were collected from the northern and southern portions of the trench (Figure 8). Soil Sample 005-S-01-01 was a composite sample collected from the clay with gravel fill at the northern portion of the trench (Figure 8). Soil Sample 005-S-01-02 was collected from the gravel with clay material on top of the weathered shale near the base of the trench. This sample was collected below the previously discussed sample. Water Sample 005-2 was taken in the bottom of the trench at his location.

Soil Sample 005-S-02-01 was collected from the southern portion of the trench (Figure 8) from the gravely clay fill material. The sample was composited from the excavated spoils pile. Soil Sample 005-S-02-02 was collected from near the bottom of the trench in the gravel material. Water Sample 005-2 was collected slightly north of where the soil samples were collected.

3.2 005 Drainage Test Pits: Drainage Alignment

Small pits were excavated down to sandstone bedrock along the margins of the 005 Drainage using a backhoe (Figure 8). The pits were advanced to evaluate whether or not the uranium and nitrate detected in surface water samples could potentially be coming from the native aquifer materials adjacent to the stream. Soil and groundwater samples were collected, with the groundwater samples collected from the pit excavations after sitting over night to allow sufficient water to accumulate. Pit nomenclature and sampling was based upon three trench lines; each of the three trench lines (3, 4 and 5) consists of a pit N, north of the drainage, a M pit near the middle of the drainage, and a pit S, located south of the drainage. Samples were collected from the colluvial materials and the underlying shale bedrock, where present. If the colluvium was underlain by sandstone, no bedrock sample was collected. Sample designation 1 refers to the colluvial soil sample and a designation of 2 indicates a shale bedrock sample. For example, sample 005-4M-2 was collected in the medial pit of trench line 4 in the bedrock shale. Water samples were collected from all pits except the most downstream northern pit (Pit 005-5N) because no water was present after 48 hours. Table 7 summarizes the samples collected and sample matrix from each trench and pit location. Table 9 summarizes the lithologic characteristics of the material encountered at each trench.

3.3 Sample Analysis

A complete list of solid samples (soil fill or bedrock shale) collected from the 005 Drainage are listed in Table 10 along with the analyses and tests conducted on each sample. Whole rock analysis was done on all samples to provide information on the total concentrations of As, U, and F in the solid matrix. Selected samples were used in absorption and/or batch desorption tests. These tests were undertaken to enhance our understanding of contaminant transport within the fill, colluvium and adjacent bedrock shale. Previous investigations had used batch desorption tests to establish partition coefficients (K_d) as described in SMI 2001. There are numerous methods commonly used for establishing a K_d, each of which is associated with certain advantages and disadvantages. The current transport model under-predicts uranium contamination in the drainage. Low K_d values in the transport model were suspected because the previously established K_d values may not have accurately predicted apparent uranium mobility. Therefore, absorption tests were performed to arrive at K_d values using alternate methods. In addition, batch desorption tests were initiated on colluvium and bedrock samples to provide K_d values that could be compared to those obtained in the previous site investigation. Preliminary results from this analysis are presented in the following section. Adsorption isotherm and batch desorption tests are still in progress.

3.4 Analytical Results and Conclusions

Conceptually, if groundwater contaminant concentrations are determined to be equal or higher in the banks than the stream, the source of the contamination would be inferred to be derived from the bedrock aquifers. Conversely, if concentrations were higher in the stream, the 005 Sump overflow would be considered as the source of contaminants in the drainage. The same concept would be valid for bedrock and unconsolidated sediment uranium concentrations. Analytical results of the groundwater samples are summarized in Figures 9 through 13 and Tables 11 and 12. Groundwater analyses indicate that all constituents are higher in the waters collected in the center pits with one notable exception, fluoride in trench 005-4S is slightly higher (0.8 mg/L) than in trench 005-4M (0.4 mg/L) (see Figure 11). Uranium and arsenic concentrations in all trench lines are greatest in the M or middle pit, indicating the source of the contamination to the drainage is not from the bedrock. Additionally, concentrations of all constituents diminish in a downstream direction indicating a source near the head of the stream.

Analytical results for the bedrock and soil samples are presented in Table 13 and Figures 14 through 18. In general, constituent concentrations for 005 Drainage test pit samples were higher in bedrock than the overlying colluvial soils. The one exception is fluoride in pit 005-4M. Fluoride concentrations were 3.3 mg/kg in bedrock and 3.8 mg/kg in the soils. Laboratory analyses of the unconsolidated material indicate that uranium concentrations increase in a downstream direction. Uranium concentrations increase from 14.5 mg/kg in 005 Drainage Trench 1 to 564 mg/kg in trench 005-5M. Uranium concentrations in shale bedrock generally decrease downstream. Analytical data for Trench 005-3N indicate uranium concentration of 4.69 mg/kg in bedrock whereas 005-5S contained 2.1 mg/kg.

Interpretation of the laboratory results indicate that the groundwater uranium concentrations are greatest in the 005 Drainage Trench 1, especially in the gravel deposit beneath the French drain lines. It is likely that some of the impacted groundwater in the gravel is not being intercepted by the French drain system and ultimately flows down gradient, either within the unconsolidated sediments or as surface water. The unconsolidated sediments appear to contain more uranium than would be suggested by the groundwater uranium concentrations and are likely due to past spills or contaminated solids washed from the site being transported downstream prior to construction of the storm water intercept trench in 1990. Fluoride was below drinking water standards in all water analysis.

4.0 MW010 SWALE AREA

An additional objective of the field investigation was to evaluate the swale suspected near monitoring well MW010A (Figure 19). This swale is essentially a small surface drainage channel that was covered with local fill materials at the time of facility construction and is suspected of being a subsurface feature that significantly influences local groundwater flow. The technical approach to this field effort consisted of excavating a trench and several test pits. Each pit or trench was excavated until sandstone bedrock was encountered with the exception of trench 5, where sandstone was deeper than the maximum possible excavation depth. Geologic mapping of the material encountered in each pit was conducted. In particular, a lens of well-rounded, well-sorted river gravel was encountered just above sandstone bedrock. Soil samples were collected from the gravel and the overlying fill.

A trench (MW010 Trench 1) approximately 130 feet long was excavated perpendicular to the expected slope of the swale in an attempt to establish the extent of the fill material. The excavation stratigraphy was documented and visually logged by a professional geologist from the top of the trench wall, and digital photographs of the excavation were taken. The pit sidewalls were prone to collapse. Therefore only visual estimates of depths were recorded. The end points of the trench were recorded with a hand-held GPS unit. Table 8 summarizes the GPS coordinates of the trench and summarizes the samples collected from the trench. Depths of geologic contacts were visually estimated. The cross section illustrated in Figure 20 was developed from these field observations.

Depth to bedrock (weathered shale or sandstone) was approximately 15 feet. The excavated area was found to be predominantly compacted fill material to bedrock. The fill consisted of basal gravel varying from one to three feet thick. The gravel consisted of well sorted (washed) well rounded, coarse gravels. The presence of this basal gravel caused the excavated trench to be unstable, and sloughing was common. An additional gravel layer was intermittently present at a depth of approximately seven feet. The balance of the fill material consists of clay with varying amounts of gravel.

The trench was excavated eastward until the basal gravel pinched out. Both gravel layers produced water in varying amounts. Figure 20 is a cross-sectional schematic that illustrates lithology and sample locations. Soil and water samples were collected for analysis. Soil and water samples were collected and preserved in the same manner as samples collected for the 005 Drainage sampling.

Four additional smaller pits (MW010 Trench 2, MW010 Trench 3, MW010 Trench 4 and MW010 Trench 5) were excavated to further investigate the gravel fill and to evaluate its extent, if possible (Figure 19). Each pit was excavated to sandstone bedrock and each encountered the gravel fill to some extent. Overall, the depth to bedrock diminished down slope and the gravel layer thinned and contained more fine-grained material. Table 9 summarizes the geologic conditions identified in these smaller trenches.

Groundwater was observed entering MW010 Trench 2, MW010 Trench 3 and MW010 Trench 4 from the south, the direction of the Decorative Pond. A lesser amount of groundwater was observed entering from up slope. After two days, the water levels in the pits and the trench were surveyed to establish the approximate groundwater elevation. Groundwater entering the western-most trench (MW010 Trench 4) was discolored and appeared yellowish, with light foam of a darker yellow color. The color of the trench water changed from yellow to reddish yellow and finally to a reddish brown during the three days the excavation was open. Subsequent laboratory analyses indicate that the water sampled from the trench contained low uranium concentrations (see Table 12).

The MW010A swale appears to be a much broader feature than was originally estimated. The presence of laterally extensive gravels at the base of the fill materials appears to provide a preferential path for groundwater flow. Groundwater elevations collected in surrounding wells and within the trenches indicate that there is a groundwater mound associated with the Decorative Pond, deflecting groundwater flow to the southwest from the southward dip of the swale. Furthermore, the gravel appears to thin in every direction except northward. The northern direction was not investigated because of the proximity to buildings and the weigh station. Future evaluation of pre-operational topographic information will aid in further delineation of the swale and potential distribution of the gravel fill. Results of these evaluations will be documented and incorporated in the revised modeling that is currently being performed.

Gravels encountered during excavation appeared to be washed river gravel that was probably imported to the site during the initial phase of site construction. Hydraulic conductivity was visually estimated to be on the order of 50 feet per day, based on the observed inflow of water into the trenches. The gravel contained few fines and chemical retardation is anticipated to be low. Because of the nature of the fill placement, the gravel is interpreted to thin toward the edges. Clays in the fill appear to cause confining conditions, as observed in the gravel in pits excavated between the trench and the Decorative Pond. Confined conditions are suspected because the surveyed trench water levels and groundwater elevations in surrounding wells indicate a water level above the top of the basal gravel though no water was observed to flow from the overlying clayey fill. Furthermore, the bedrock well MW030A, located nearest to the Decorative Pond and completed in the shallow bedrock system, exhibits confined conditions evidenced by water levels above the ground surface, preventing downward contaminant migration. Water levels in unconsolidated fill materials encountered in the pits, trench and Decorative Pond indicate groundwater flowing in these deposits flow from up slope and from the Decorative Pond. The lowest groundwater elevations were encountered in the pits. Diminished flow velocities are expected as groundwater encounters colluvial deposits and the gravel fill pinches out. Hydrologic data from this evaluation will be incorporated into the revised groundwater model and documented in the associated report.

Soil samples were collected from the excavated spoils pile for analysis. Sample locations and sample matrix are described in Table 8. Samples analyses, as described in Section 3.3 and Tables 12 and 13, will aid in determination of in-situ K_d value to be used in the updated groundwater transport model. Additional adsorption tests will be conducted on selected samples. The sample selection will be based on analytical results.

4.1 Hydraulic Conductivity Testing

Slug tests were performed to see if anomalously high hydraulic conductivity conditions, which could cause locally faster constituent transport rates, were present in this area. The tests were performed and analyzed in exactly the same manner as described in Shepherd Miller (2001). The raw data and analysis of these tests is provided in the Attachment A to this report. Table 1 summarizes the calculated hydraulic conductivity for these wells.

Previous to this investigation, the hydraulic conductivity of the terrace soils in this area was assumed to be 5 ft/day, which is similar to Shale Unit 1. A slug test performed on well MW010 yielded a calculated hydraulic conductivity of 72.6 ft/day, assuming a saturated thickness of approximately 3 feet, based on visual inspections of the MW010 Trench 1 located 15 feet away from MW010. In the trench it was observed that only the basal three feet of gravel fill material was saturated, the balance of the overlying material in the screened interval was a relatively low permeability gravelly clay that did not appear to be producing water indicating semi-confined conditions. Therefore, it was considered appropriate and conservative to calculate the hydraulic conductivity of well MW010 using the 3-foot producing zone as the saturated thickness. With this assumption, the calculated hydraulic conductivity at this well represents an order of magnitude increase in hydraulic conductivity over the current model configuration for this area.

MW010A is completed in Shale Unit 2 and Shale Unit 3. The average hydraulic conductivity used for Shale Unit 2 and Shale Unit 3 in the groundwater model was 1.2 ft/day and 0.1, respectively. The hydraulic conductivity that was established by the MW010A slug test was 1.5 ft/day, which is consistent with the previously modeled value.

The aquifer testing program indicates that the hydraulic conductivity values used in the groundwater model for layers 1 and 2 (Terrace and Shale Unit 1) in the areas investigated may have been underestimated. The consequence of underestimating the hydraulic conductivity is reduced contaminant transport velocity, all other parameters held equal. Changes to the groundwater model to reflect the recently acquired data will be implemented in the future.

4.2 Analytical Results and Conclusions

Groundwater was sampled in MW010 Trench 1, MW010 Trench 2, MW010 Trench 4 and MW010 Trench 5. The analytical results were used in conjunction with nearby monitoring wells in the unconsolidated deposits. Analytical results are presented in Table 12 and the resulting uranium contour map is presented in Figure 21. The results indicate that the contaminant migration is limited to the gravel deposits of the backfilled swale. The localized hydraulic gradient reversal due to the water level in the decorative pond prevents southward migration of the uranium plume.

Uranium analyses for the current MW010 swale investigations combined with the most recent monitoring well analytical results are depicted in Figure 21. Uranium migration in the unconsolidated sediments appears to be limited in extent to the gravel deposits. Uranium groundwater concentrations appear to diminish where more fines are present in the distal edges of the fill material. Further analysis will be performed in the swale area. The interpreted nature and extent of the gravel fill will be incorporated in the groundwater flow and transport model and will presented in the final modeling report.

5.0 TERRACE BACKGROUND SAMPLING

Two pits were excavated into un-impacted terrace materials east of Highway 10 (Background Trench E-1 and Background Trench E-2; Figure 1). Soil and water samples from these locations will be used to develop K_d values for the terrace materials using batch tests. The trenches were excavated to bedrock and the soil and groundwater samples were collected, stored and shipped in the same manner as the samples collected for the 005 and MW010 swale investigations. Twelve liters of water were collected from the southern pit (Background Trench E-2) to use in batch testing. This trench was selected because there was more water available for sampling than in pit E-1. Both soil and groundwater samples were analyzed for U, F, and As. These results are summarized in Tables 12 and 13.

6.0 RECOMMENDATIONS FOR ADDITIONAL STUDY AND FIELD EFFORTS

The recent supplemental field data collection activities are anticipated to resolve many of the outstanding site characterization issues, although some additional studies may be of value to enhance the site characterization and help support potential future groundwater mitigation efforts. A comprehensive list of potential study topics cannot be assembled at this time because all the recent field data results are not yet available. The following presents a brief discussion of potential areas of additional study or effort.

6.1 All Site Drainages

The potential exists for transport of impacted site groundwater along portions of the drainages covered with fill. Monthly surface water sampling of the site drainages has been initiated. Based on the results of this sampling, additional trenching could be considered for those drainages where anomalous water quality is identified.

6.2 005 Drainage Alternatives

Recent surface water sampling data and excavation of fill at the head of the 005 Drainage indicate that the French drain/005 Sump system may not be intercepting all the subsurface waters from the upper portions of the buried 005 Drainage. The following sections present designs for field scale pilot tests of mitigation alternatives. Two alternatives were evaluated. The first approach consists of a hydraulic containment and pump back system. The second approach employs a passive permeable reactive barrier using zero valant iron or similar reductant. SFC has selected the containment/pumpback approach for the 005 Drainage. Installation will be completed in calendar year 2002

6.3 Well MW010/Swale Area

Some questions remain regarding the distribution of basal gravel and fill materials in the Swale and regarding the hydrologic/hydraulic relationship of the Decorative Pond to local groundwater flow. Stratigraphic and hydrologic mapping of the Swale currently being performed will shed light on these issues. However, additional trenching around the Decorative Pond, especially to the southwest and southeast, may be of value to better delineate the extent of gravel, the groundwater quality and flow path, and the influence of the Decorative Pond head. This trenching is planned for later in 2002.

Based on the existing site information, it appears that installing a hydraulic containment and pumpback system (similar to the system described for the 005 Drainage above), could provide an effective way to intercept and treat a significant amount of terrace groundwater potentially flowing from this area. However, revision of the site flow model is best completed before conceptual or detailed design is undertaken.

6.3.1 Hydraulic Collection and Pumpback System

Design of a hydraulic collection and pumpback system is described below. Details and specifications are presented on Figure 22. The existing trench excavated to the top of the uppermost sandstone unit (Sandstone Unit 3, approximately 8 feet deep) would be expanded to have 2H:1V side slopes and a minimum three-foot bottom width over a 100-foot long alignment spanning the deepest portions of the buried drainage. The side slope lay-back is intended to provide sufficient worker safety and trench wall stability during construction. The trench bottom would be cleaned of residual sediment and materials.

A 60-mil HDPE membrane or similar material liner placed between geofabric protection layers would be installed on the down gradient side of the trench and sealed to the sandstone using site clay. A perforated 4-inch to 6-inch drainage collection pipe would be installed on the sandstone outcrop upgradient of the membrane liner and covered with well graded gravel to slightly above the zone producing water or a minimum thickness of at least two feet. The excavation side walls would be brought in to approximate a vertical wall as the gravel and liner are installed.

A 12-inch to 16-inch, standpipe would be placed vertically in the deepest portion of the excavation as a sump into which the perforated drainage collection pipe will drain. The natural slope of the sandstone to the lowest portion of the trench will allow the drainage pipe to convey water to the sump. A submersible pump with automatic controls would be installed in the sump. The pump would be piped to the site water treatment facility. The liner material would be placed over the top surface of the gravel and cover with random fill placed to the elevation of the ground surface. Alternatively, a filter sand layer with a minimum thickness of one foot could be placed on top of the gravel layer and then covered by native fill materials to the ground surface.

The French drain pipes that currently daylight into the existing trench would remain in place. The upgradient pipe ends would be trimmed and remain open to transmit flow. The gravel backfill would be placed to a minimum elevation of one-foot above the invert of the French drain pipes. Pipe ends on the downgradient side would be trimmed, capped and covered by the plastic membrane liner installed on the downgradient side of the trench.

Two 2-inch PVC monitoring wells points would be installed approximately 10 feet and 20 feet downgradient of the collection trench in the deepest portion of the buried drainage to provide performance monitoring. In addition, surface water sampling throughout the 005 Drainage should be performed monthly until it is verified that the uranium-bearing water has been successfully intercepted.

6.3.2 Permeable Reaction Barrier (PRB)

A conceptual design of a PRB using zero valent iron (ZVI or FeO) is described below. Figure 23 illustrates the conceptual design of this alternative. This second alternative could be installed as a field scale pilot test of this approach, following bench scale tests, for long-term passive mitigation of groundwater impacts.

A new trench could be excavated upgradient of the collection trench described above. Similar to the collection trench, the ZVI trench would be excavated to the top of the uppermost sandstone unit approximately 8 feet deep) with 2H:1V side slopes and a minimum five-foot bottom width over a 100-foot long alignment spanning the deepest portions of the buried drainage. The side slope lay back is intended to provide sufficient worker safety and trench wall stability during construction. The trench bottom would be cleaned of residual sediment and materials.

A funnel and gate type system would be installed in the trench, utilizing a low permeability material at the ends of the trench and ZVI in the center of the trench, as shown on Figure 23.

The low permeability material could be a slurry wall, compacted clay or HDPE membrane as described in the collection trench alternative. Conceptually, a 300-foot trench would be excavated, with a 100-foot wide ZVI section flanked by two 45-foot wide low permeability sections. The actual width of each portion of the trench would be dictated by subsurface flow analysis and bench scale permeability testing of the ZVI to ensure adequate flow through the reactive portion of the trench.

The ZVI portion of the trench would be filled in uniform with ZVI using a backhoe bucket and hand shovels to a maximum height of 5 feet. The excavation side walls would be brought in to approximate a vertical wall as the ZVI is installed. If the French drain pipes are intercepted during excavation, the ZVI would be installed up to one foot above the pipe ends in the upgradient side of the trench wall to provide treatment of any flows from these pipes. Pipe ends on the downgradient side would be trimmed, plugged and covered by the low permeability liner installed on the down gradient side of the trench. A one-foot thick layer of filter sand would also be installed on the upgradient side of the ZVI, as well as above the ZVI with clean native fill materials filling the remained of the excavation. Figure 23 presents conceptual details of the ZVI trench.

Two 2-inch PVC monitoring wells points would be installed approximately 10 feet and 20 feet downgradient of the PRB in the deepest portion of the buried drainage to provide performance monitoring. In addition, surface water monitoring throughout the 005 Drainage would be performed monthly.

6.3.2.1 Summary

The hydraulic collection and pumpback system is the most proven and immediate alternative to mitigate impacted groundwater discharge to the 005 drainage. However, testing of a PRB is suggested to provide efficient passive mitigation in the long-term.

7.0 REFERENCES

Shepherd Miller, Inc. (SMI), 2001. Hydrogeological and Geochemical Site Characterization Report. October.

Sequoyah Fuels Corporation (SFC), 1998. "Site Characterization Report."

TABLES

Table 1 Calculated Hydraulic Conductivity Tests

Well Location	Hydrologic Unit	Hydrologic Condition	Borehole Diameter (ft)	Screen Length (ft)	Saturated Thickness (ft)	Hydraulic Conductivity (ft/day)	Storage Coefficient	Analysis Method
MW010	Gravel Backfill	Confined	0.615	~3	~3	72.63	na	Bouwer and Rice (1976)
MW010A	2SH/3SH	Confined	0.500	13.50	14.00	1.52	6.25E-03	Cooper, et. al. (1967)
MW059A	3SH/4SH	Unconfined	0.500	4.71	5.43	21.38	na	Bouwer and Rice (1976)
MW093A	4SH	Unconfined	0.615	16.57	17.09	2.51	na	Bouwer and Rice (1976)
MW095A	4SH	Confined	0.615	5.50	5.50	4.73	na	Bouwer and Rice (1976)
MW097	Colluvium	Unconfined	0.615	0.90	1.55	39.00	na	Bouwer and Rice (1976)
MW097A	4SH	Confined	0.615	17.00	17.00	0.93	na	Bouwer and Rice (1976)

na – data not derived from this test

Hydrologic Unit	Previous Slug Tests (ft/day)				Modeled Value (ft/day)
	no. tests	log mean	max	min	
Alluvium	2	0.334	5.01	0.0223	50.0
shale 1	13	0.0246	0.261	0.00416	0.800
shale 2	4	0.138	1.35	0.0118	1.200
shale 3	3	0.0478	0.488	0.0103	0.100
shale 4	5	0.0314	1.3	0.00466	0.500

Table 2 Results from Arsenic Speciation Analysis

HG-CT-GC-AAS Results						COMPARISON		
Sample ID	As (III)	TIA	*As(V)	TA by ICP-MS		TIA by HG-CT-GC-AAS	TA by ICP-MS	Sum of As Species by IC-ICP-MS
MW071A	0.015	0.275	0.260	0.58		0.275	0.58	558
MW042A	0.250	0.191	ND	670		0.191	670	20
MW064A	2.814	0.668	ND	3940		0.668	3940	1200
MW035A (1:1 diluted)	0.014	0.034	0.020	3		0.034	3	0.7
MW059A	0.988	0.603	ND	1420		0.603	1420	5180
MW095A	0.018	0.089	0.071	52.7		0.089	52.7	0.4
MW057A	0.134	0.258	0.124	3310		0.258	3310	5.0
IC-ICP-MS Results								
	As(III)	As(V)	US-1	US-2	US-3	US-4	US-5	Sum of
Sample ID	(3.7 min)	(14.20 min)	(15.80 min)	(16.80 min)	(17.50 min)	(18.40 min)	(19.50 min)	As Species
MW071A	<1	<1	0.0	<1	557.7	<1	<1	558
MW042A	<1	<1	0.0	<1	<1	19.7	<1	20
MW064A	<10	<10	0.0	<10	1202	<10	<10	1200
MW035A (1:1 diluted)	<0.1	<0.1	0.1	<0.1	0.3	<0.1	<0.1	0.7
MW059A	16	<10	0.0	<10	5183	<10	<10	5180
MW095A	<0.1	<0.1	0.0	<0.1	0.3	<0.1	<0.1	0.4
MW057A	<10	<10	0.0	<10	0.0	<10	<10	5.0
**MW042A MD	<1	<1	0.0	<1	452.6	<1	<1	453
**MW042A MS+500 ppb	354	<1	872.6	<1	<1	<1	<1	873
**MW042A MSD+500 ppb	364	<1	946.7	<1	<1	<1	<1	947

All results in μg/L
TIA = Total Inorganic Arsenic, essentially all As(III) and As(V)
TA = Total Arsenic, regardless of species
ND = not detected
US – Unidentified Species
* Arsenate is calculated by difference: As(V)=TIAs-As(III)
** Matrix Duplicate (MD), Matrix spike (MS) and matrix spike duplicate (MSD) using 500 ppb As(III)
IC-ICP-MS = ion-chromatography inductively coupled plasma mass-spectrometry
ICP-MS = Inductively coupled plasma mass Spectrometry
HG-CT-GC-AAS = hydride generation cryotrapping gas chromatography atomic absorption spectrometry

Table 3 Quality Control Data - Duplicate Report

Analyte (µg/L)	Sample QC'd	Rep. 1	Rep. 2	Mean	RPD
As(III)	SC3-UUI-201	0.207	0.196	0.201	5.3
TIAs	SB-A2	0.850	0.812	0.831	4.6
Tas	MW071A	0.58	0.59	0.58	1.4

Table 4 Quality Control Data - Matrix Spike / Matrix Spike Duplicate Report

Analyte (µg/L)	Sample QC'd	Sample conc.	Spike Level	MS	% Rec.	MSD	% Rec.	RPD
As(III)	SC3-UUI-201	0.207	0.400	0.586	94.7	0.621	103.5	5.8
TIAs	SB-A2	0.850	1.000	1.829	97.9	1.872	102.2	2.3
TAs	MW071A	0.58	20.00	21.43	104.3	19.94	96.8	7.2

MS = matrix spike
MSD = matrix spike duplicate
RPD = relative percent difference

Table 5 Quality Control Data - Preparation Blank Report

Analyte (µg/L)	IBW1	IBW2	IBW3	IBW4	Mean	Std Dev	Est. MDL
As(III) HG-CT-GC-AAS	0.000	0.002	0.000	0.001	0.001	0.0007	0.003
TIAs HG-CT-GC-AAS	0.006	0.002	0.003	0.003	0.003	0.0015	0.005
Tas	-0.03	-0.04	-0.03	0.00	-0.02	0.017	0.060

Std Dev = Standard deviation
Est. MDL = Estimated method detection limit

Table 6 Quality Control Data - Standard Reference Material Report

Analyte (µg/L)	SRM Identity	Cert. Value	Obs. Value	% Rec.
As(III) HG-CT-GC-AAS	not available			
TIAs HG-CT-GC-AAS	NIST1640	26.67	23.83	89.4
Tas	NIST1640	26.67	26.28	98.5

SRM Identity = Standard reference material identity
Obs. Value = Experimental result
Cert. Value = Certified value
% Rec. = Percent recovery

Table 7 Recent Sampling for the 005 Drainage

Trench Line	Sample ID	Matrix	Location
005 Drainage Trench 1	005-1	Water	North end of trench
	005-2	Water	South end of trench
	005-S-01-01	Soil	clay and gravel fill at north end of trench @2.5'
	005-S-01-02	Soil	gravel with clay fill at north end of trench @ 6'
	005-S-02-01	Soil	clay and gravel fill at south end of trench @ 4'
	005-S-02-02	Soil	gravel with clay fill a south end of trench @5.5
005 Drainage Trench 3	005-03N	Water	
	005-03M	Water	
	005-03S	Water	
	005-03N-1	Soil	composite sample
	005-03N-2	Shale	composite sample
	005-03M-1	Soil	composite sample
	005-03S-1	Soil	composite sample
	005-03S-2	Shale	composite sample
005 Drainage Trench 4	005-04N	Water	
	005-04M	Water	
	005-04S	Water	
	005-04N-1	Soil	composite sample
	005-04N-2	Shale	composite sample
	005-04M-1	Soil	composite sample
	005-04M-2	Shale	composite sample
	005-04S-1	Soil	composite sample
	005-04S-2	Shale	composite sample
005 Drainage Trench 5	005-05M	Water	
	005-05S	Water	
	005-05N-1	Soil	composite sample
	005-05M-1	Soil	composite sample
	005-05S-1	Soil	composite sample
MW010 Trench 1	MW010-1	Gravel	Basal gravel @ 12'
	MW010-2	Shale	Weathered shale @ 14'
	MW010-3	Soil	Composite above 12'
	MW010-1W	Water	Collected near exposed pipe
MW010 Trench 2	MW010-2-1	Soil	Composite clay/gravelly clay
	MW010-2-2	Gravel	Basal gravel @ 8'
	MW010-2	Water	
MW010 Trench 4	MW010-4-1	Soil	Composite clay/gravelly clay
	MW010-4-2	Gravel	Basal Gravel @ 6'
	MW010-4	Water	
MW010 Trench 5	MW010-5-1	Soil	Composite clay/gravelly clay
	MW010-5	Water	
Background Trench E1	E1-1	Soil	Terrace Material
	E1	Water	
Background Trench E2	E2-1	Soil	Terrace/Colluvial Material
	E2	Water	
	E2 - background	Water	12 liters for batch tests

Table 8 Summary of GPS Coordinates for the Trenches and Trench Sampling

Waypoint	Northing	Easting	Location
Wpt 001*	196439	2836121	005 10' N of North End of Trench 1
Wpt 002*	196374	2836107	005 West Bank at Bend in Trench 1
Wpt 003*	196337	2836119	005 South End of Trench 1
Wpt 004*	196399	2836055	MW037 Location Check
Wpt 005*	196409	2836117	005 Trench 1 Drainage Bottom - Approx.
Wpt 006*	196412	2836028	005 Trench 3 South Excavation
Wpt 007*	196439	2836022	005 Trench 3 Middle Excavation
Wpt 008*	196449	2836024	005 Trench 3 North Excavation
Wpt 009*	196396	2835849	005 Trench 4 South Excavation
Wpt 010*	196412	2835864	005 Trench 4 Middle Excavation
Wpt 011*	196444	2835858	005 Trench 4 North Excavation
Wpt 012*	196594	2835580	005 Trench 5 South Excavation
Wpt 013*	196631	2835568	005 Trench 5 Middle Excavation
Wpt 014*	196649	2835548	005 Trench 5 North Excavation
Wpt 015*	196667	2835534	MW100B Location Check
Wpt 016*	195492	2837148	MW010 Trench 1 East End
Wpt 017*	195488	2837014	MW010 Trench 1 West End
Wpt 018*	195432	2837034	MW010 Trench 2 Center on South Bank
Wpt 019*	195433	2837056	MW010 Trench 3 Center on South Bank
Wpt 020*	195396	2836979	MW010 Trench 4 Center on South Bank
Wpt 021*	195473	2836974	MW010 Trench 5 Center on South Bank
Wpt 022*	195488	2837035	MW010 Trench 1 Water Sample Location
Wpt 023*	195047	2838179	East of Hwy 10 South Trench (Trench E2)
Wpt 024*	195937	2838356	East of Hwy 10 North Trench (Trench E1)
Wpt 025*	198380	2836248	Drainage North of Plant N of Salt Branch
Wpt 026*	195883	2841887	Outcrop at NE Corner of Old Pond Dam

Table 9 Trench Lithologic Description

Trench	Depth (ft)	Lithology
MW010 Trench 1 (West Side)	0-1	Fill, Topsoil, dark grayish brown, loose moist
	1-2.5	Fill, Gravel, clayey, reddish brown, moist, gravel ~20%, firm
	2.5-3	Fill, Clay, gravelly, tans to light brown, firm, moist, gravel ~20%
	3-6	Fill, Clay, gravelly, dark reddish brown to black, moist, wet in places, gravel ~20%
	6-9	Fill, clay, sandy, trace gravel, some gravel lenes, Reddish brown to black, moist, wt in places, especially in gravel lenses
	9-12	Fill, Gravel, some clay~30%, reddish brown, wet, loose, rounded, gravel moderately well sorted, 1-3 inches, makes good water
	12-15	Clay, weathered shale, light brown to buff, wet, soft, plastic
MW010 Trench 2	0-8	Fill, Interbeds of gravelly clay and clayey gravel, moist moderate brown to yellowish brown, gravel <10%
	8-8.5	Fill, Gravel, wet, rounded river rock, water entering pit predominantly from pond side
	8.5-9.5	Clay, weather shale, light brown, stiff, saturated, plastic
	9.5	Sandstone
MW010 Trench 3	0-6	Fill, Interbeds of clayey gravel and gravelly clay, moist, becomes very gravelly near base
	6-8.5	Clay, weathered shale light brown, stiff, saturated, plastic
	8.5	Sandstone
MW010 Trench 4	0-5	Fill, Interbeds of clayey gravel and gravelly clay, moist, becomes very gravelly near base
	5-6	Gravel, sparse clay, loose, saturated, rounded river rock
	6-8	Clay, weathered shale light brown, stiff, saturated, plastic
	8	Sandstone
MW010 Trench 5	0-1	Topsoil
	1-2	Gravelly clay, light brown to buff, moist
	2-16	gravel with clay and sand. Poorly sorted, Seeps at 6', 8', 12', and 15'
005 Drainage Trench 1	See Figure 8 for approximate depths	Fill, Clay, silty, reddish brown, moist to wet, underlain by 6 mil black plastic
		Clay, with gravel and sand, dark reddish brown to black, poorly sorted, clay~50% gravel 30%, sand 20%, moist to very moist. Contains two French drain pipes that were broken during excavation. Southern pipe flows <5 gpm
		Gravel with clay, reddish brown, very moist to wet. gravel 55%, clay 45%, soft
		Weathered shale, clay, dark brown, wet plastic, firm
		Sandstone, hard well cemented, laminated, dark gray
005 Drainage Trench 3N	0-8	Clay, some sand and gravel, reddish brown
	8-12	sandstone, hard, well cemented, very shaley
005 Drainage Trench 3M	0-3	Sandy, silty, gravelly clay, moist to saturated, moderate brown
	3	Sandstone
005 Drainage Trench 3S	0-3	Overburden, gravelly, sandy clay, reddish brown, moist becomes saturated near bottom
	3-6	sandstone, shaley, wet near top
005 Drainage Trench 3S	0-3	Overburden, gravelly, sandy clay, reddish brown, moist becomes saturated near bottom
	3-6	sandstone, shaley, wet near top

Table 9 Trench Lithologic Description (continued)

Trench	Depth (ft)	Lithology
005 Drainage Trench 3S	0-3	Overburden, gravelly, sandy clay, reddish brown, moist becomes saturated near bottom
	3-6	sandstone, shaley, wet near top
005 Drainage Trench 4N	0-3	Clay, reddish brown
	3-5	shale, saprolitic, black to dark gray with abundant iron stains
	5-8	Same as above but less weathered
005 Drainage Trench 4M	0-1	Sandy clay, moderate brown, moist to wet
	1-6	shale, gray with iron stains
005 Drainage Trench 4S	0-3	clay, reddish brown, soft, moist
	3-8	Clay, weathered shale, dark gray to black, soft moist
	8-12	sandstone, hard, well cemented, 1.5-3" interbeds
005 Drainage Trench 5N	0-2	clay, reddish brown to brown wet, plastic, soft
	2	Sandstone
005 Drainage Trench 5M	0-0.75	Clay, sandy, silty
	0.75	Sandstone
005 Drainage Trench 5S	0-4.5	clay, yellowish brown, saturated at 4'
	4.5	Sandstone
E-2	0-0.75	silty loam, dark brown, moist, soft
	0.75-2	clay, moderate brown to buff
	2	Sandstone
E-1	0-0.5	silty loam, moderate brown, moist
	0.5-4.5	clay, some gravel, moist, saturated at 2.0'
	4.5	Sandstone

Table 10 List of Samples Collected at Sequoyah Fuels Site during February 2002 and a List of Analytical Procedures Performed on Each Sample

Sample ID	Whole Rock 3050	Adsorption Test	Element(s)	Desorption Test	Element(s)
005-03M-1	X				
005-03N-1	X	X	U		
005-03N-2	X	X	U		
005-03S-1	X				
005-03S-2	X				
005-04M-1	X	X	U		
005-04M-2	X				
005-04N-1	X				
005-04N-2	X	X	U, As	X	U, As
005-04S-1	X	X	U, As	X	U, As
005-04S-2	X	X	U, As	X	U, As
005-05M-1	X			X	U, As
005-05N-1	X				
005-05S-1	X				
005-S-01-01	X			X	U, As
005-S-01-02	X			X	U, As
005-S-02-01	X	X	As		
005-S-02-02	X	X	As		
E1-1	X	X	U		
E2-1	X	X	U		
MW-10-1	X				
MW-10-2	X				
MW-10-3	X				
MW010-2-1	X				
MW010-2-2	X				
MW010-4-1	X	X	U		
MW010-4-2	X	X	U		
MW010-5-1	X				

Table 11 Drainage Surface Water Sampling Results

Location	Date	Uranium µg/l	Nitrate mg/l	Arsenic mg/l
2241	1/4/02	60.2	12.4	< 0.009
	2/22/02	40.0	5.0	< 0.009
	3/6/02	35.3	11.9	< 0.009
2242	1/4/02	46.8	15.8	< 0.009
	2/22/02	40.1	8.0	< 0.009
	3/6/02	30.4	262	< 0.009
2243	1/4/02	2.92	1.2	< 0.009
	2/22/02	1.07	< 1	< 0.009
	3/6/02	5.16	< 1	< 0.009
2244	1/4/02	< 1	70.0	0.021
	2/22/02	< 1	39.8	< 0.009
	3/6/02	1.03	38.4	< 0.009
2245	1/4/02	< 1	388	0.027
	2/22/02	< 1	13.9	0.015
	3/6/02	< 1	97.3	< 0.009
2246	1/4/02	34.6	13.0	< 0.009
	2/22/02	4.52	8.7	< 0.009
	3/6/02	4.00	4.9	< 0.009
Drainage 005 Trench 2	12/3/01	49.8	31.8	
Drainage 005 Trench 3	12/3/01	69	34.8	
Drainage 005 Trench 4	12/3/01	66.5	37.4	
Drainage 005 Trench 5	12/3/01	30	46.2	
Drainage 005 Trench 6	12/3/01	58	82.6	
Drainage 005 Trench 7	12/3/01	210	82.6	
Drainage 005 Trench 8	12/3/01	275	310	
005 Sump (2224)	12/3/01	274	309	

Location	Northing	Easting	Description
2241	196799	2835306	005 Drainage ~25' East of COE Boundary Fence
2242	196641	2835501	005 Drainage - Pool near MW100B
2243	197492	2835812	007 Drainage North of North Fluoride Holding Basin Area
2244	195726	2834825	004 Drainage - Pool ~20' East of COE Boundary Fence
2245	195151	2834303	Seep North of Port Road Bridge
2246	195204	2834191	001 Drainage North of Port Road Bridge

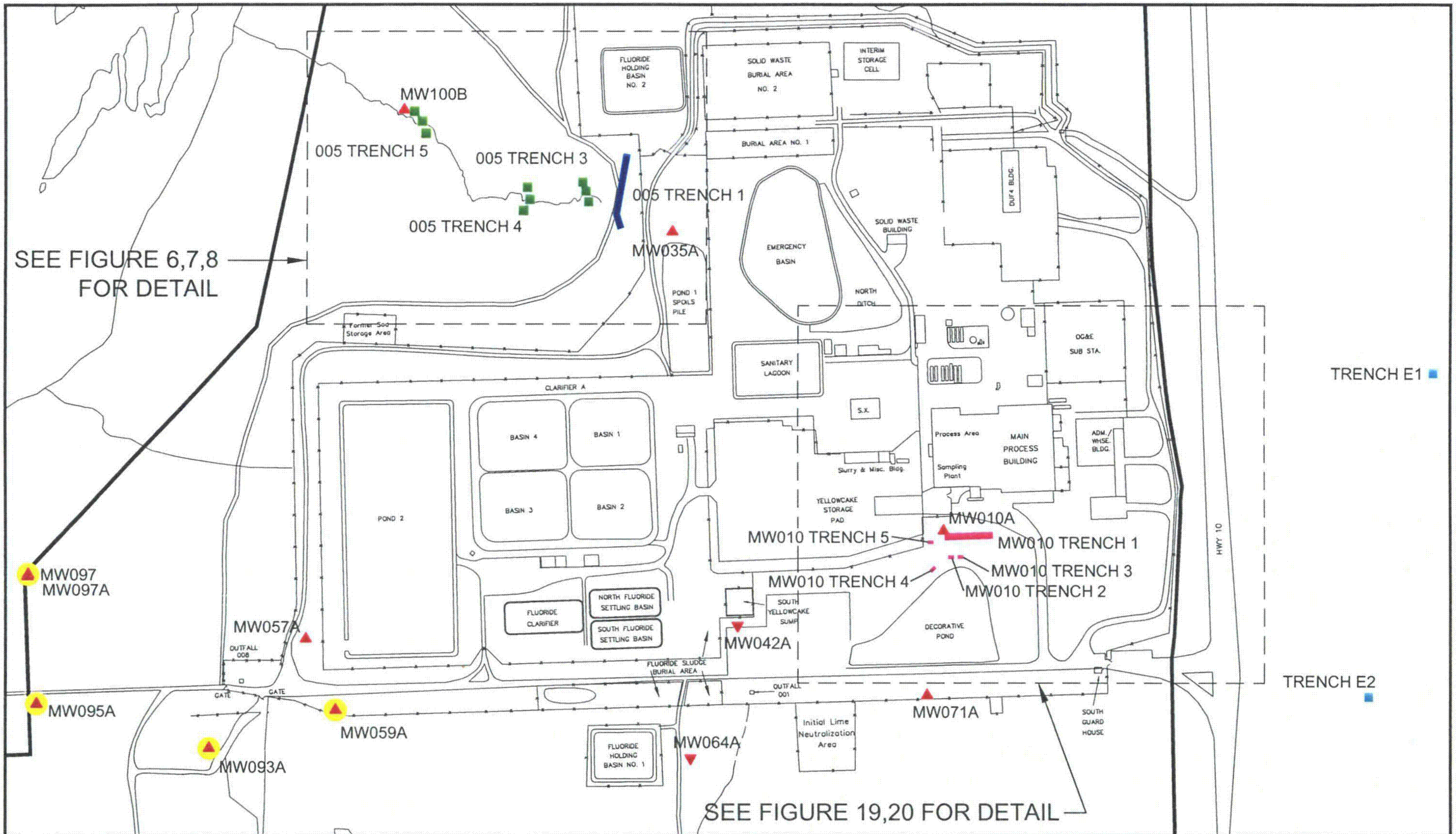
Table 12 2002 Trench Aqueous Sampling Data

Station	Date Sampled	Matrix	Organic Carbon, Dissolved (DOC) (mg/L)	Arsenic (mg/L)	Fluoride (mg/L)	Uranium (mg/L)
005-03M (3)	2/9/02	Aqueous	5.31	0.0044	0.5	0.13
005-03N (3)	2/9/02	Aqueous	4.14	0.002	0.1	0.0007
005-03S (3)	2/9/02	Aqueous	6.07	0.0011	0.2	0.002
005-04M	2/9/02	Aqueous	4.29	0.0029	0.4	0.143
005-04N	2/9/02	Aqueous	5.16	0.001	0.1	0.0077
005-04S	2/9/02	Aqueous	2.41	0.0011	0.8	0.0035
005-05M	2/9/02	Aqueous	4.44	0.001	0.2	0.0317
005-05S	2/9/02	Aqueous	3.96	0.001	0.2	0.0004
005-1	2/9/02	Aqueous	7.84	0.0223	0.6	0.626
005-2	2/9/02	Aqueous	8.32	0.0346	0.3	0.121
E1	2/12/02	Aqueous	19.47	0.0375	0.2	0.0016
E2	2/12/02	Aqueous	7.55	0.0032	0.1	0.0003
MW010-1W (3)	2/9/02	Aqueous	7.81	0.0143	0.3	0.0863
MW010-2 (3)	2/9/02	Aqueous	10.74	0.0121	0.2	0.0085
MW010-4 (3)	2/9/02	Aqueous	22.64	0.0618	0.4	0.0307
MW010-5 (3)	2/9/02	Aqueous	5.34	0.006	0.5	0.108

Table 13 2002 Soil Sampling Data

Station	Date Sampled	Matrix	Moisture %	Arsenic (mg/kg)	Fluoride (mg/kg)	Uranium (mg/kg)
005-03M-1	2/9/02	Soil	14.1	26.3	6.6	66.7
005-03N-1	2/9/02	Soil	14.1	9.74	1.4	9.55
005-03N-2	2/9/02	Soil	4.43	8.52	1.4	4.69
005-03S-1	2/9/02	Soil	15.7	12.6	0.83	7.56
005-03S-2	2/9/02	Soil	4.07	11.4	1.4	1.08
005-04M-1	2/9/02	Soil	20.2	8.25	3.8	396
005-04M-2	2/9/02	Soil	12	4.7	3.3	2.56
005-04N-1	2/9/02	Soil	19.1	37.5	1.4	1.09
005-04N-2	2/9/02	Soil	14.9	6	2.8	1.2
005-04S-1	2/9/02	Soil	19.7	64.5	0.84	1.76
005-04S-2	2/9/02	Soil	11.3	7.12	1.9	1.22
005-05M-1	2/9/02	Soil	36.3	12.7	3.3	564
005-05N-1	2/9/02	Soil	21.6	11	1.9	1.19
005-05S-1	2/9/02	Soil	14.1	10.1	0.73	2.1
005-S-01-01	2/9/02	Soil	18.5	12.5	9.1	18.9
005-S-01-02	2/9/02	Soil	12.6	19.7	7.2	14.5
005-S-02-01	2/9/02	Soil	18.3	8.77	7.9	11
005-S-02-02	2/9/02	Soil	11.1	14	4.6	144
E1-1	2/10/02	Soil	14.3	26	1.7	1.93
E2-2	2/10/02	Soil	18	4.33	1.3	1.39
MW-10-1	2/8/02	Soil	14.6	8.91	3.8	92.4
MW-10-2	2/8/02	Soil	20.3	8.7	3.5	6.15
MW-10-3	2/8/02	Soil	16.2	7.61	2.8	2.14
MW010-2-1	2/9/02	Soil	26.5	14.3	1.7	3.91
MW010-2-2	2/9/02	Soil	12.1	7.02	2.5	1.82
MW010-4-1	2/9/02	Soil	17.4	16.6	12	0.892
MW010-4-2	2/9/02	Soil	15.9	6.11	2.7	3.84
MW010-5-1	2/9/02	Soil	14.5	8.64	3.8	13.6

FIGURES



LEGEND

SLUG TEST LOCATIONS

MONITORING WELL LOCATIONS SAMPLED FOR ARSENIC SPECIATION TESTING

005 DRAINAGE BANK SOIL AND WATER SAMPLE LOCATIONS

NORTH

SCALE IN FEET

0 500

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FIGURE 1
SUPPLEMENTAL DATA COLLECTION LOCATIONS

Date:	APRIL 2002
Project:	100734
File:	TRENCH-01.DWG

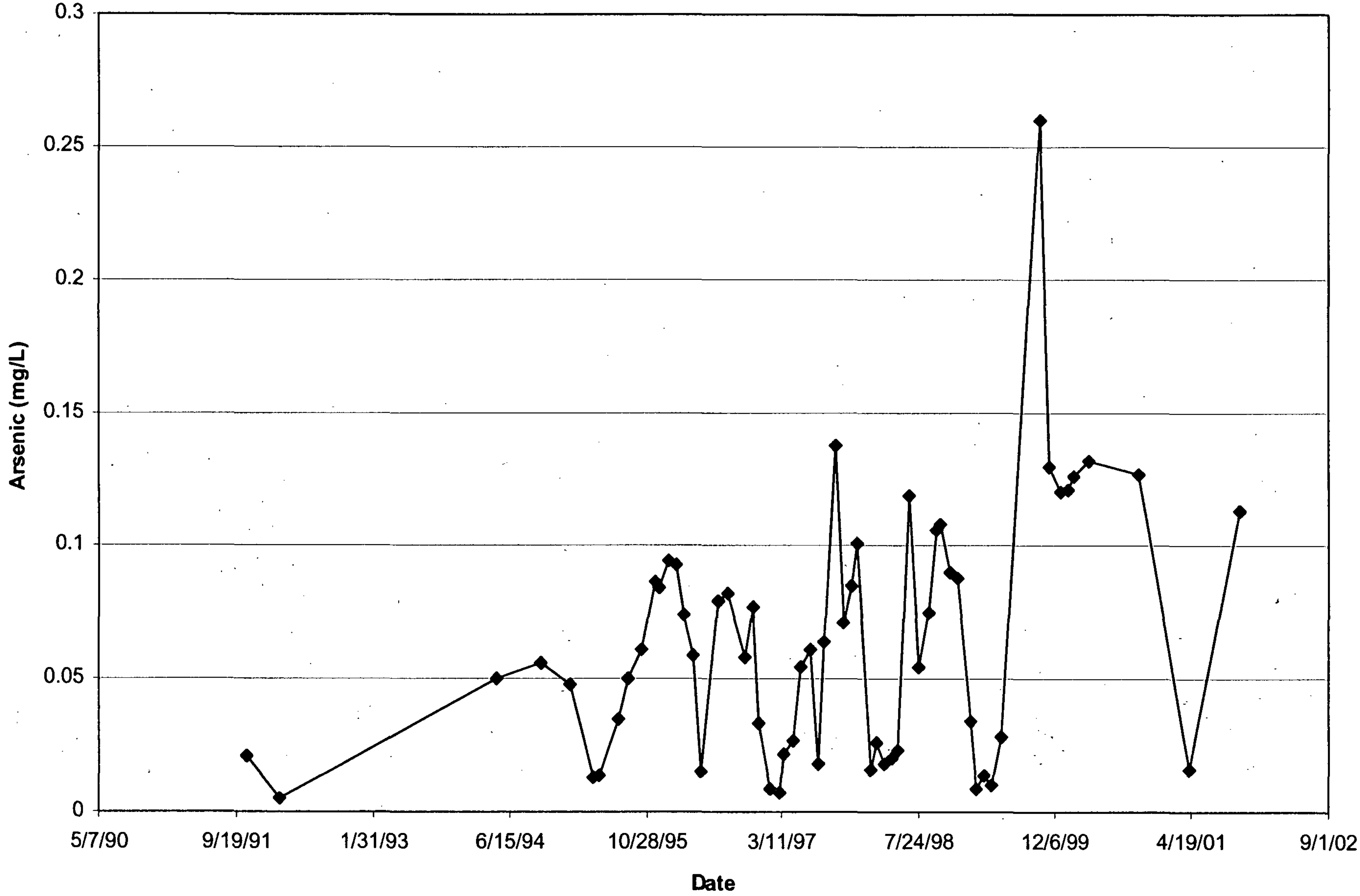

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FIGURE 2
WELL MW095A ARSENIC CONCENTRATIONS

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

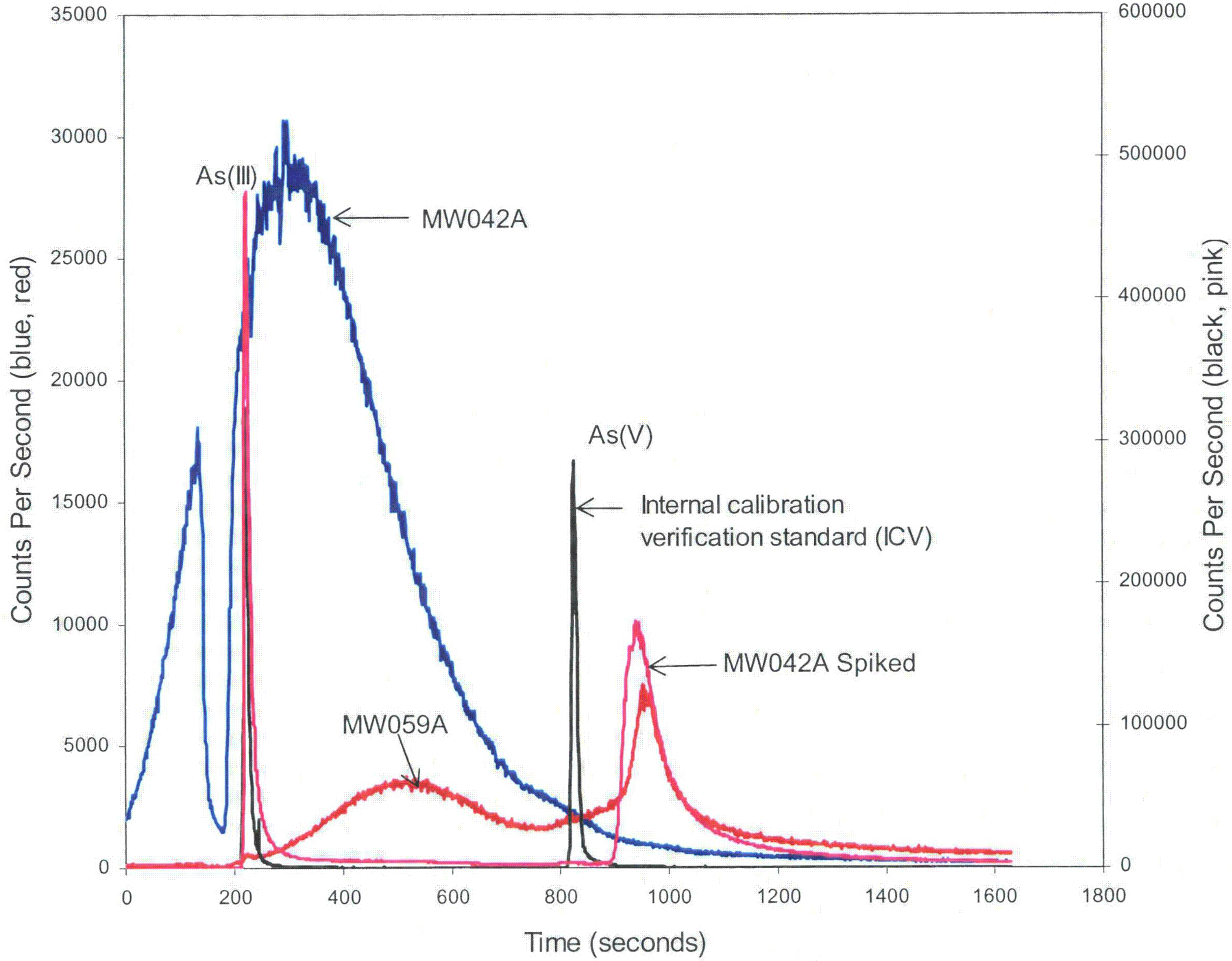

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FIGURE 3
ANALYTICAL RESULTS OF ARSENIC SPECIATION: IC-ICP-MS CHROMATOGRAM

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

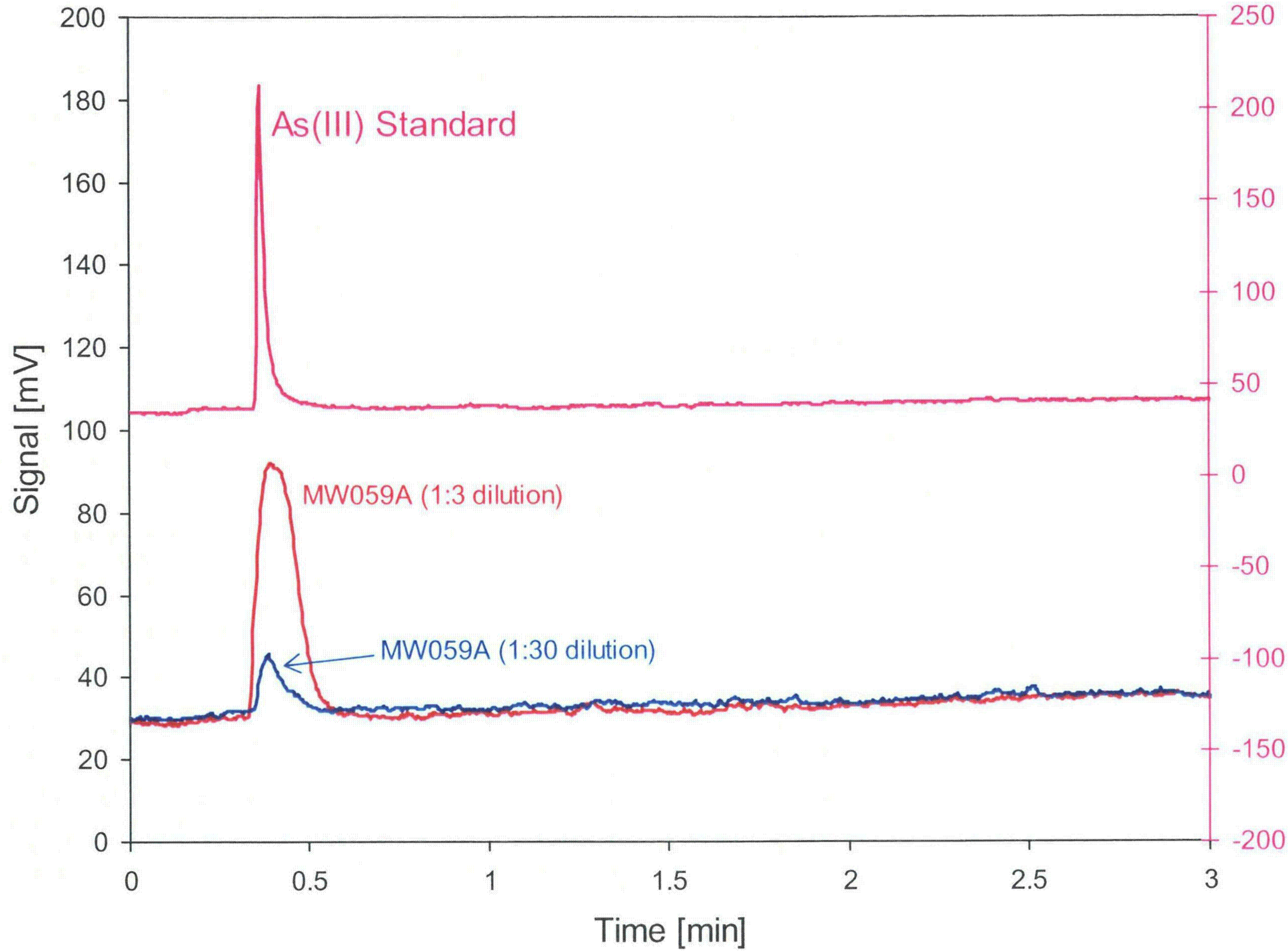

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FIGURE 4
CHROMATOGRAM OBTAINED OF SAMPLE MW059A DURING HG-CT-GC-AAS SPECIATION OF ARSENIC

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

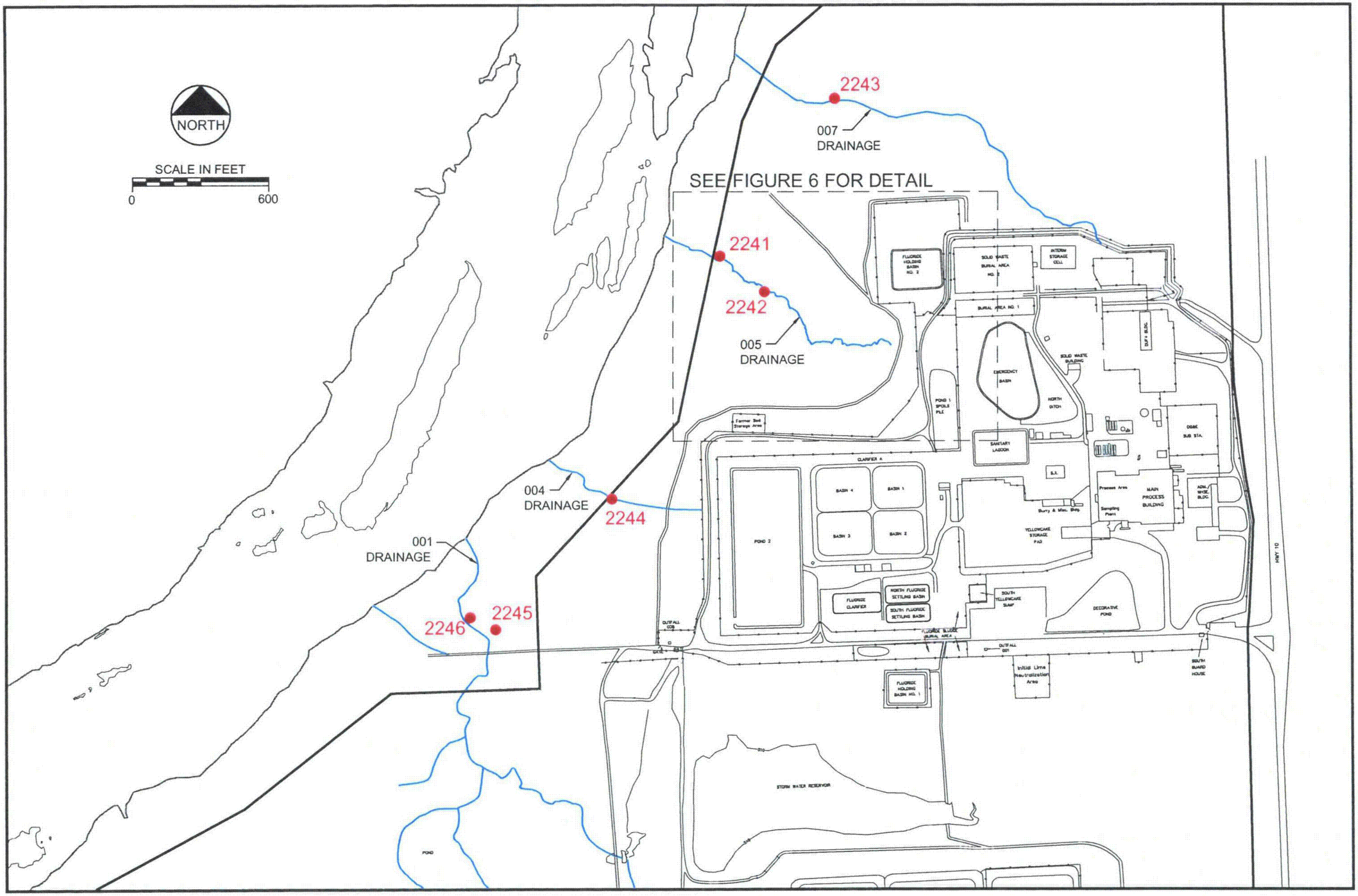

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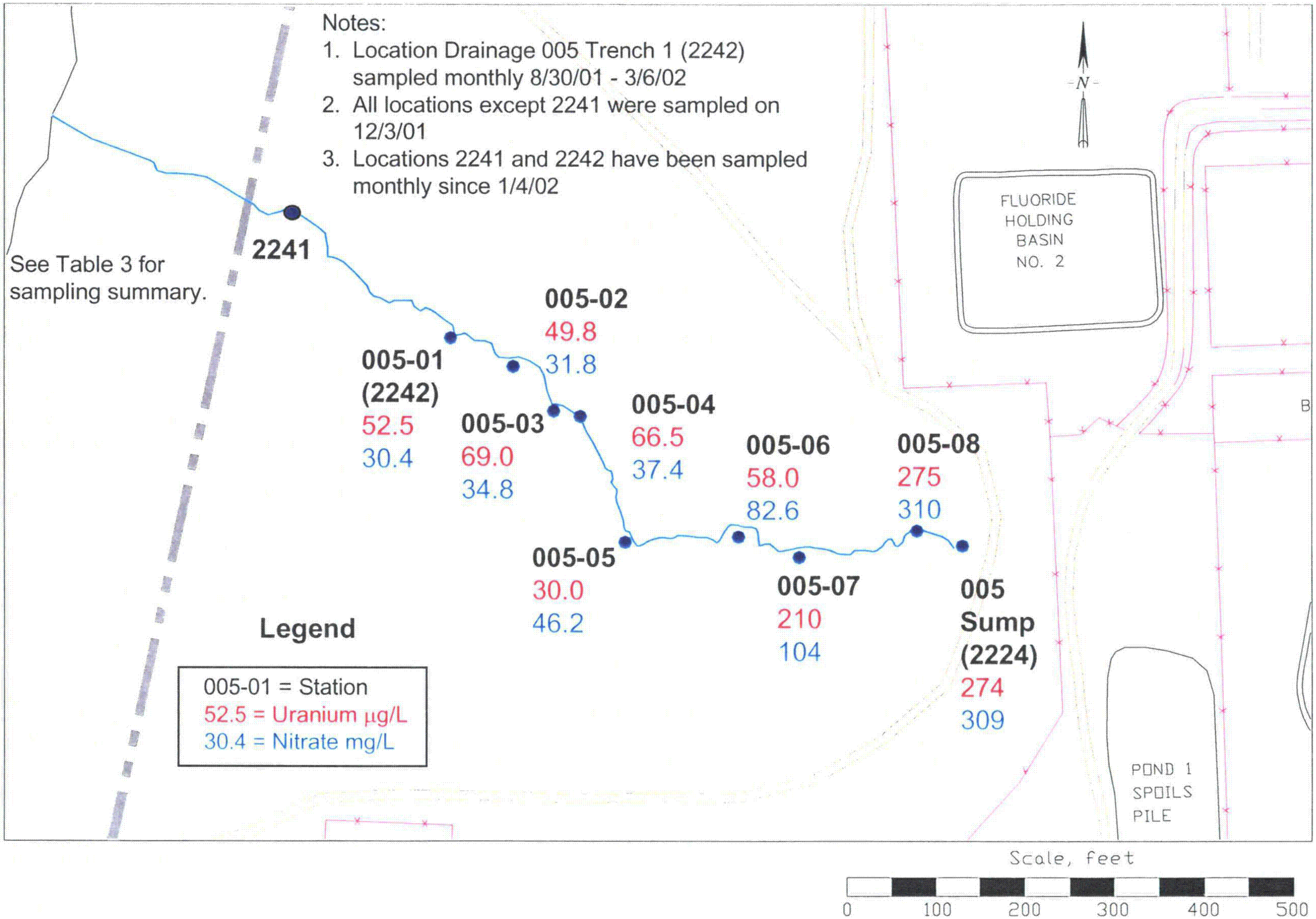
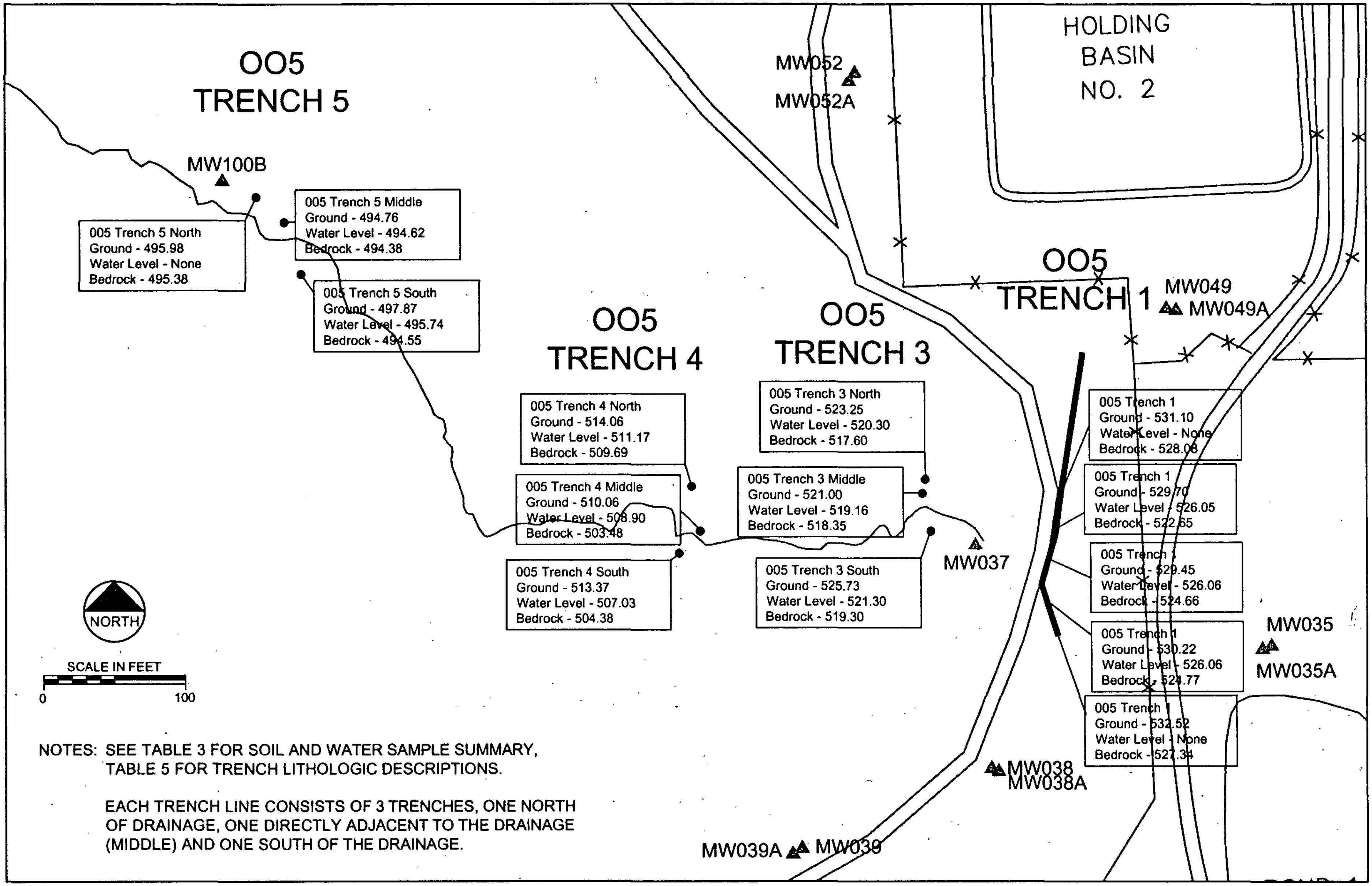
FIGURE 5
SITE DRAINAGES AND SURFACE WATER
SAMPLING LOCATIONS

Date:	APRIL 2002
Project:	100734
File:	DRAINAGESAM....-01



SHEPHERD MILLER	FIGURE 6 005 DRAINAGE SURFACE WATER SAMPLING LOCATIONS	Date: MARCH 2002 Project: P:100734\PRJMGT\ File: TRIPFIGS.ppt



NOTES: SEE TABLE 3 FOR SOIL AND WATER SAMPLE SUMMARY, TABLE 5 FOR TRENCH LITHOLOGIC DESCRIPTIONS.

EACH TRENCH LINE CONSISTS OF 3 TRENCHES, ONE NORTH OF DRAINAGE, ONE DIRECTLY ADJACENT TO THE DRAINAGE (MIDDLE) AND ONE SOUTH OF THE DRAINAGE.

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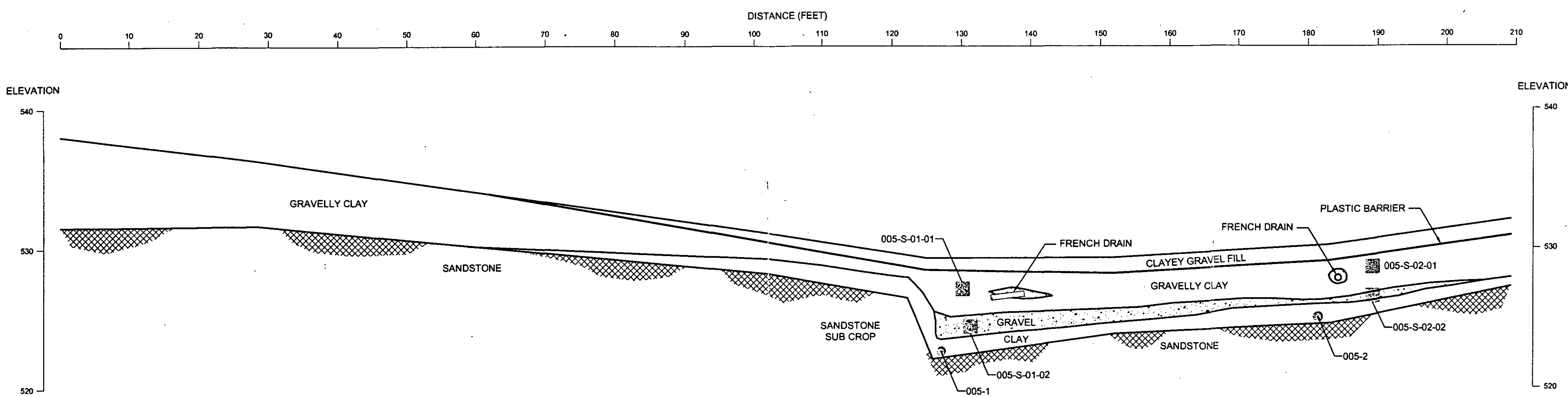
FIGURE 7
005 DRAINAGE TRENCHING AND SOIL/WATER SAMPLING LOCATIONS

Date:	APRIL 2002
Project:	100734
File:	TRENCH-FIGS



LEGEND

SOIL SAMPLE LOCATIONS AND ASSOCIATED SAMPLE NUMBER

WATER SAMPLE LOCATIONS AND ASSOCIATED SAMPLE NUMBER

SEE TABLE 3 FOR SOIL AND WATER SAMPLE SUMMARY

FIGURE 8
CROSS SECTION VIEW OF 005
DRAINAGE TRENCH 1

SHEPHERD MILLER

Date:	APRIL 2002
Project:	100734
File:	PROFILES-01.DWG

Filename: E:\100734\profiles-01.dwg
Date: 04/17/2002
Time: 13:11:41.38

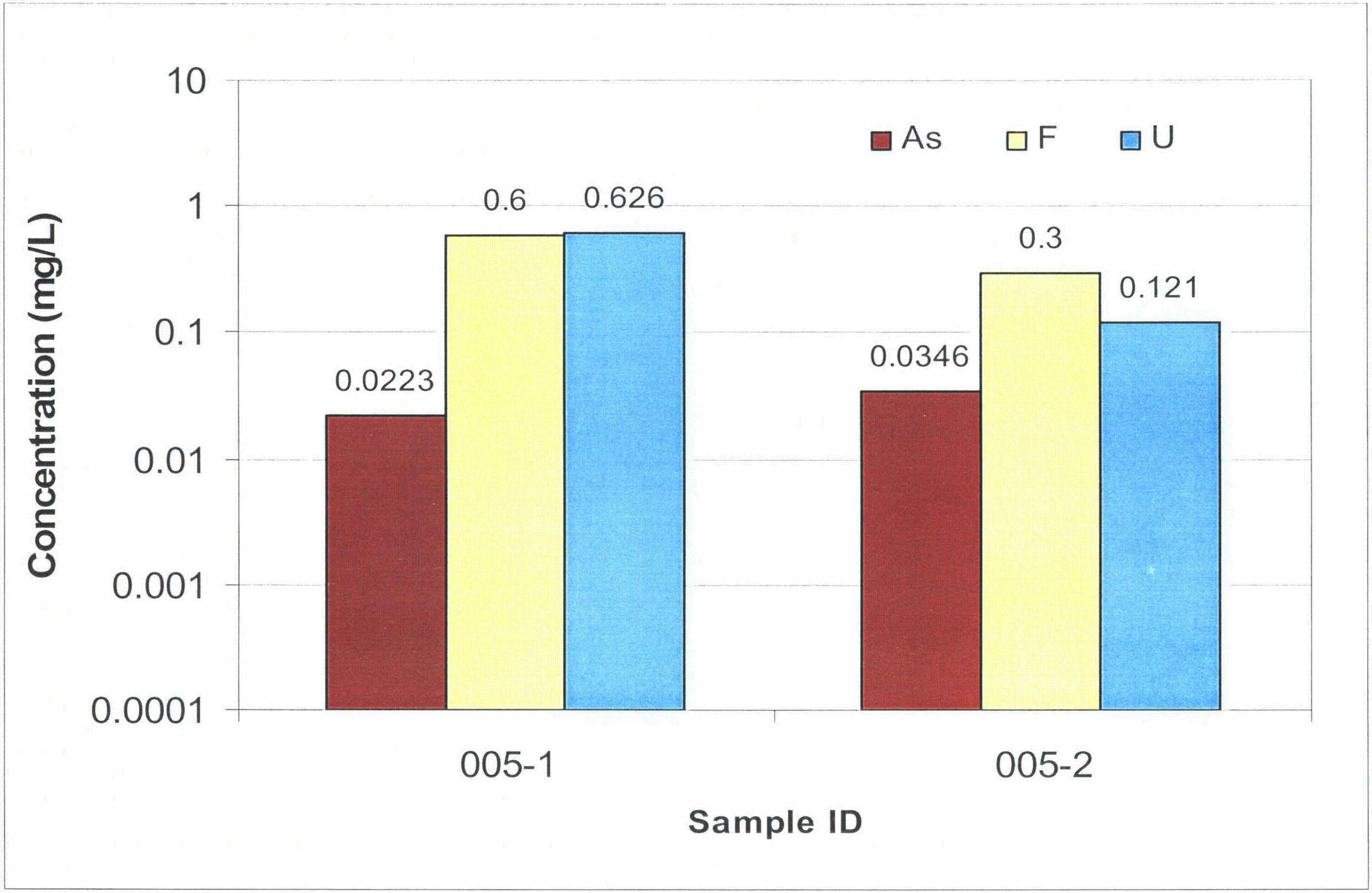


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FIGURE 9
AQUEOUS ANALYTICAL RESULTS FOR 005 DRAINAGE TRENCH 1

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

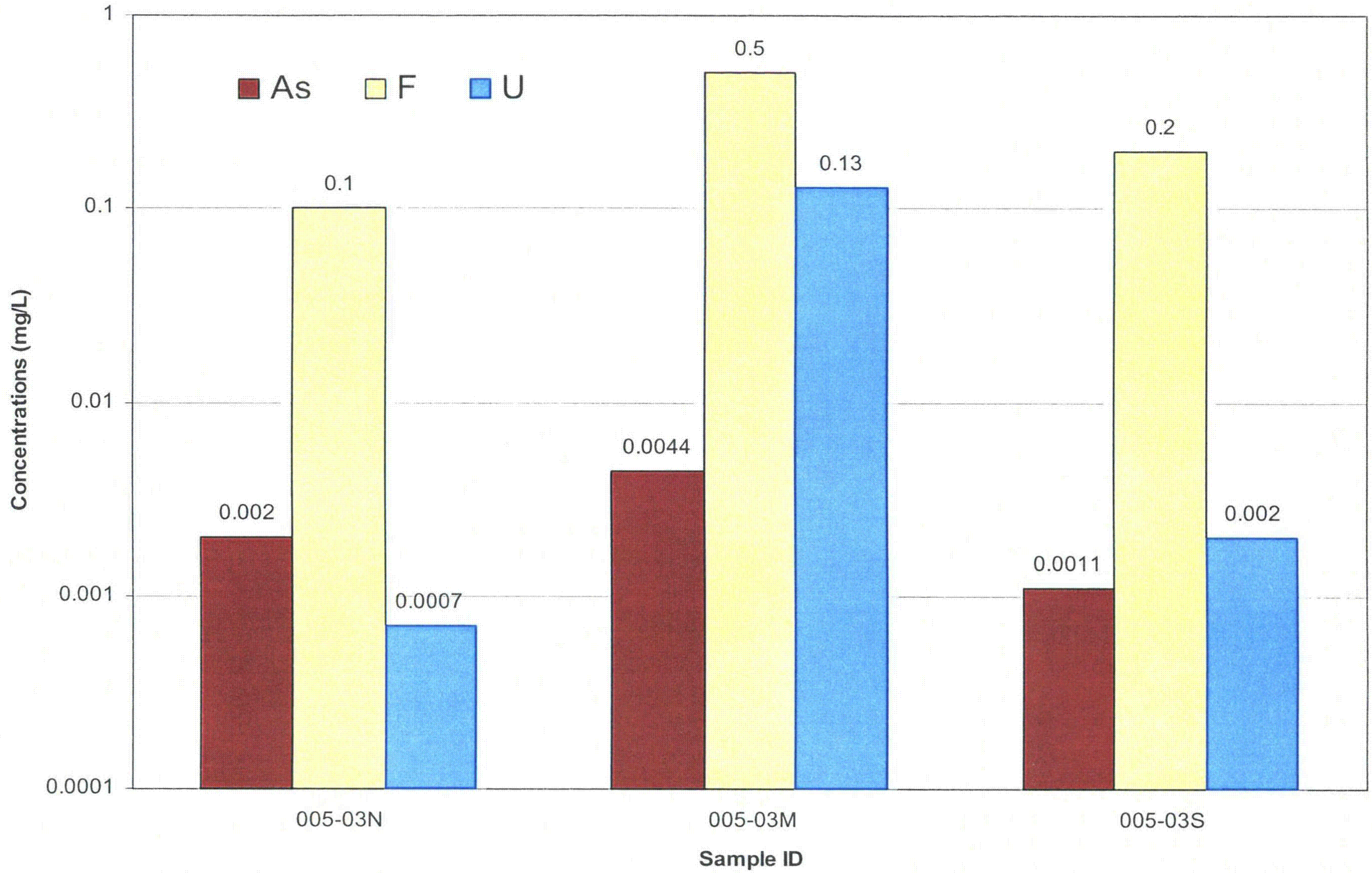

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FIGURE 10
AQUEOUS ANALYTICAL RESULTS FOR 005 DRAINAGE TRENCH 3

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

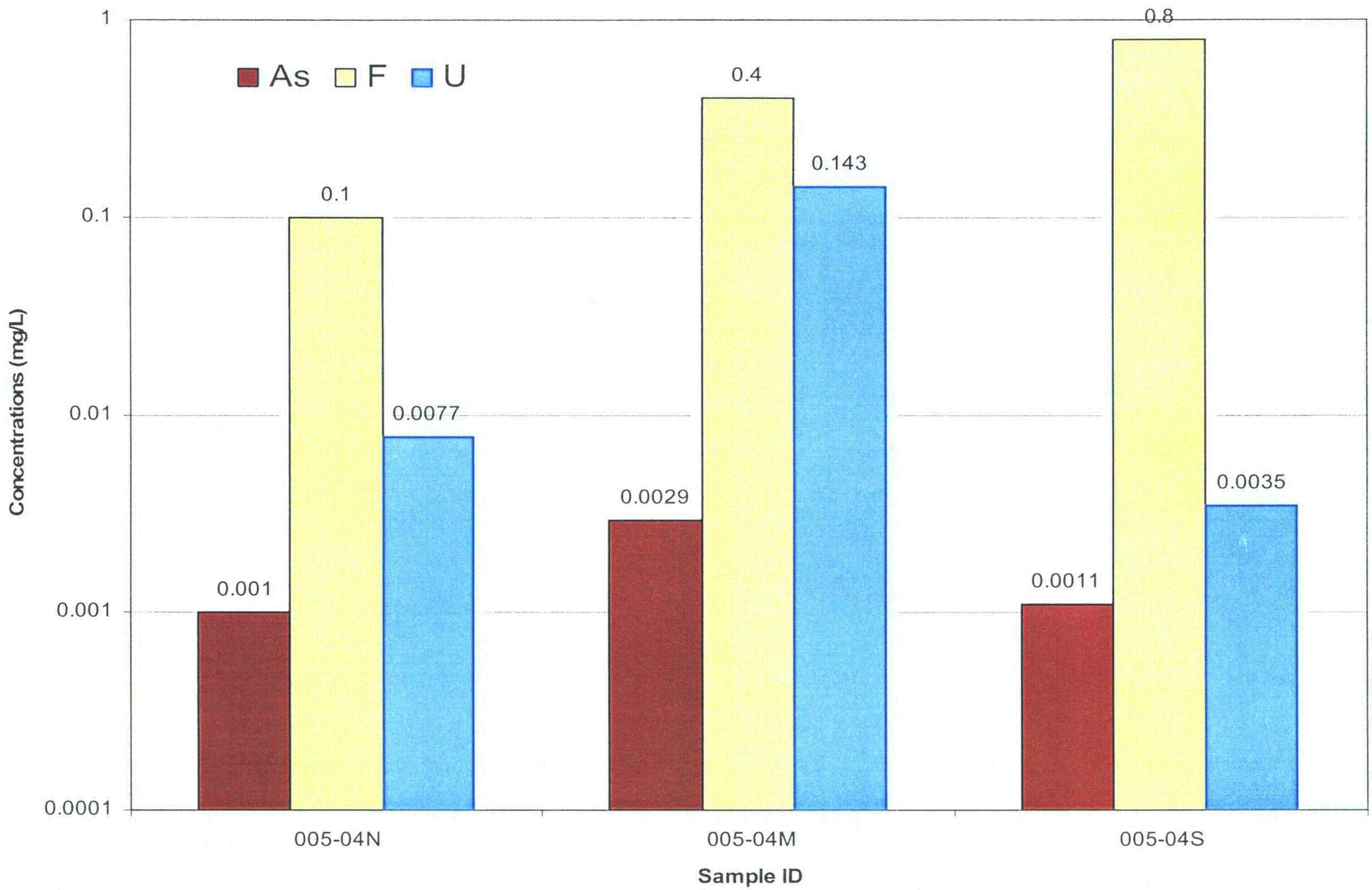

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FIGURE 11
AQUEOUS ANALYTICAL RESULTS FOR 005 DRAINAGE TRENCH 4

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

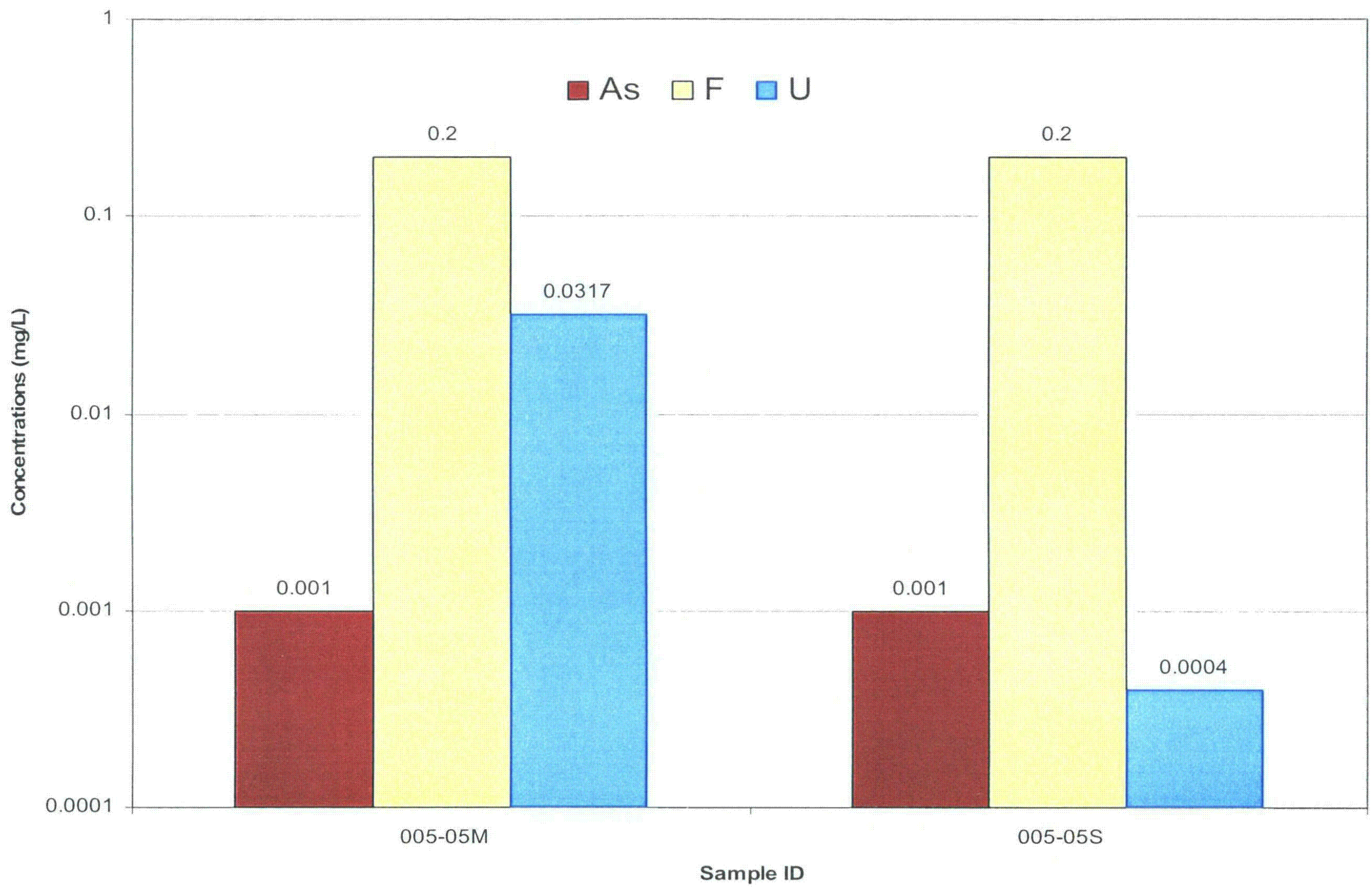

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FIGURE 12
AQUEOUS ANALYTICAL RESULTS FOR 005 DRAINAGE TRENCH 5

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

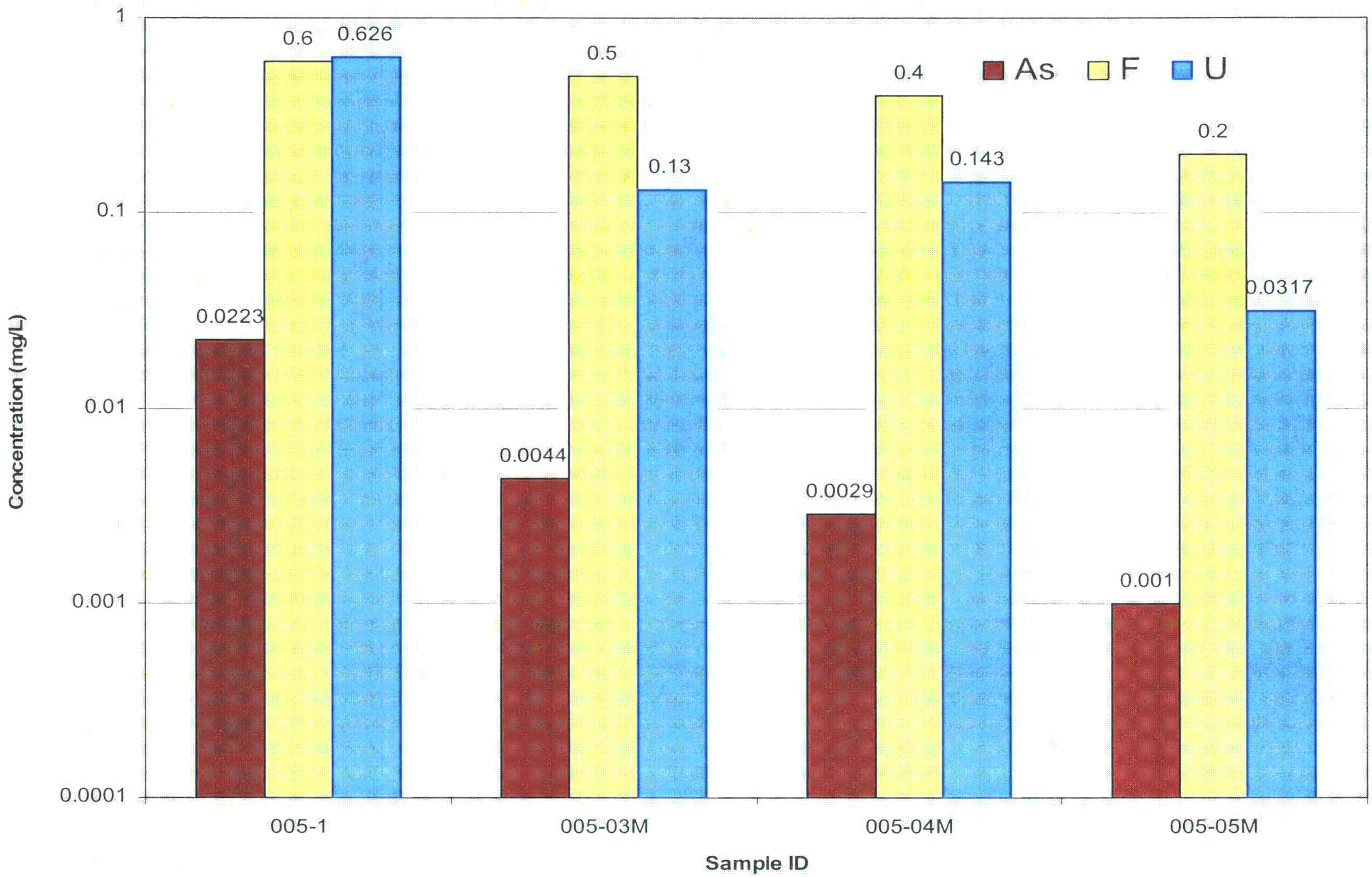

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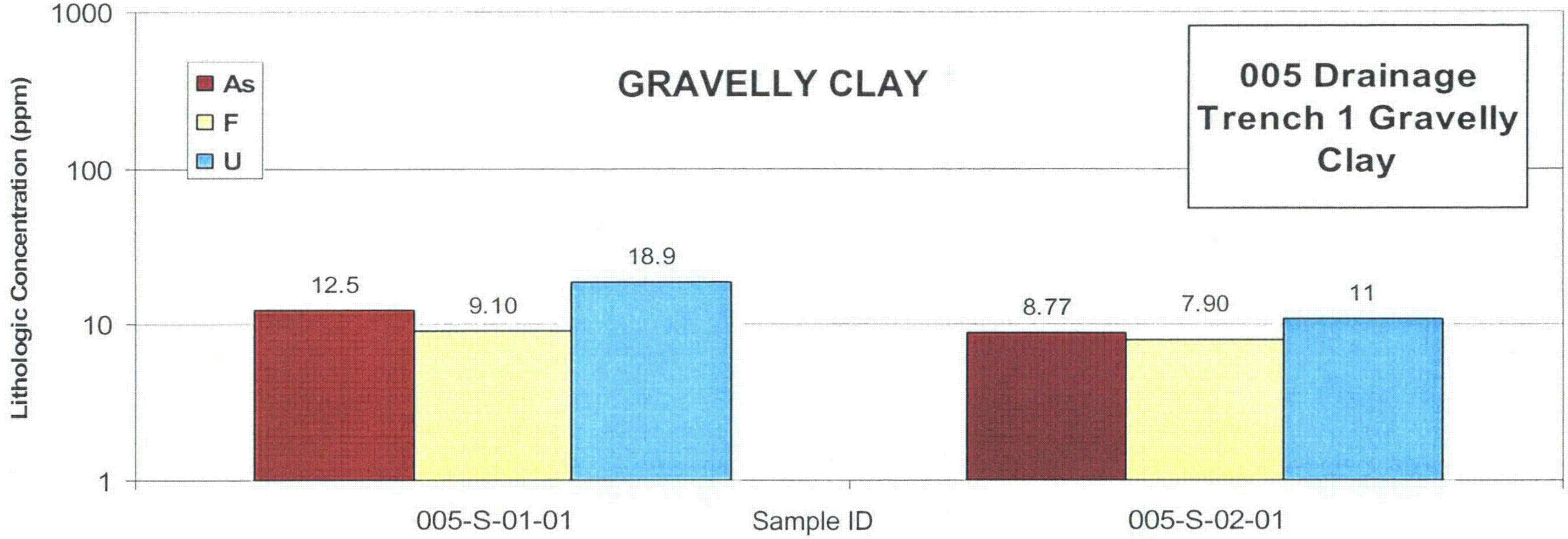
FIGURE 13
AQUEOUS ANALYTICAL RESULTS FOR 005 DRAINAGE FOR DOWNSTREAM THROUGH MIDDLE TRENCH

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt



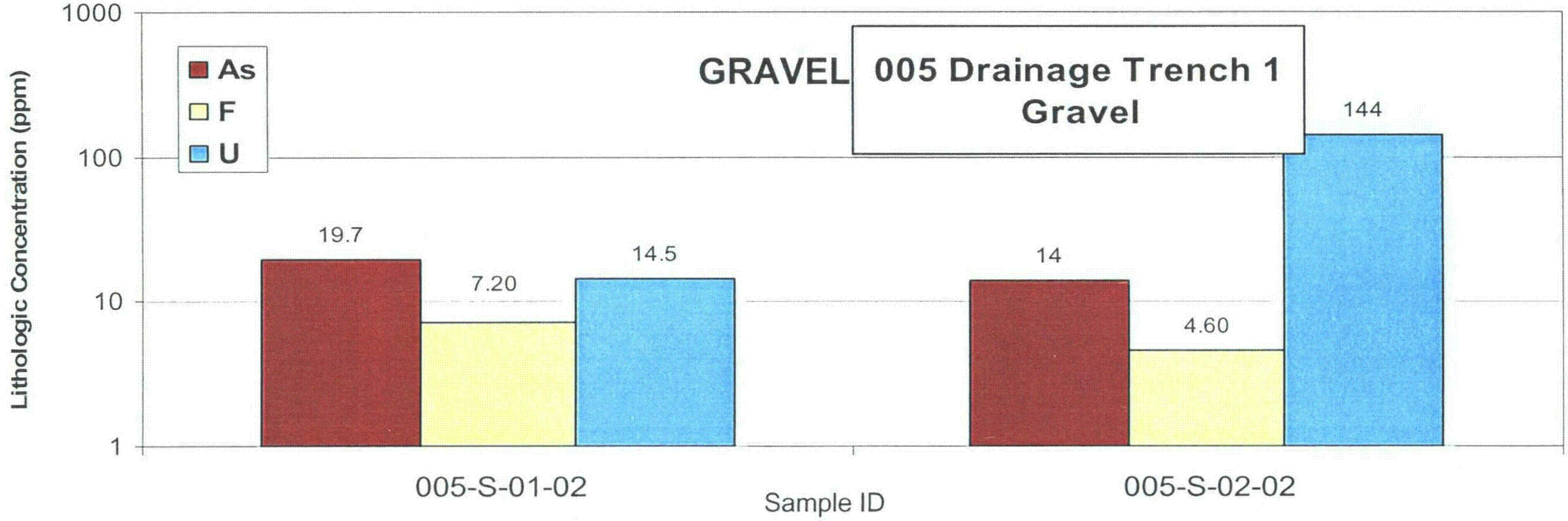


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FIGURE 14
SOLIDS ANALYTICAL RESULTS
DRAINAGE 005 TRENCH 1

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

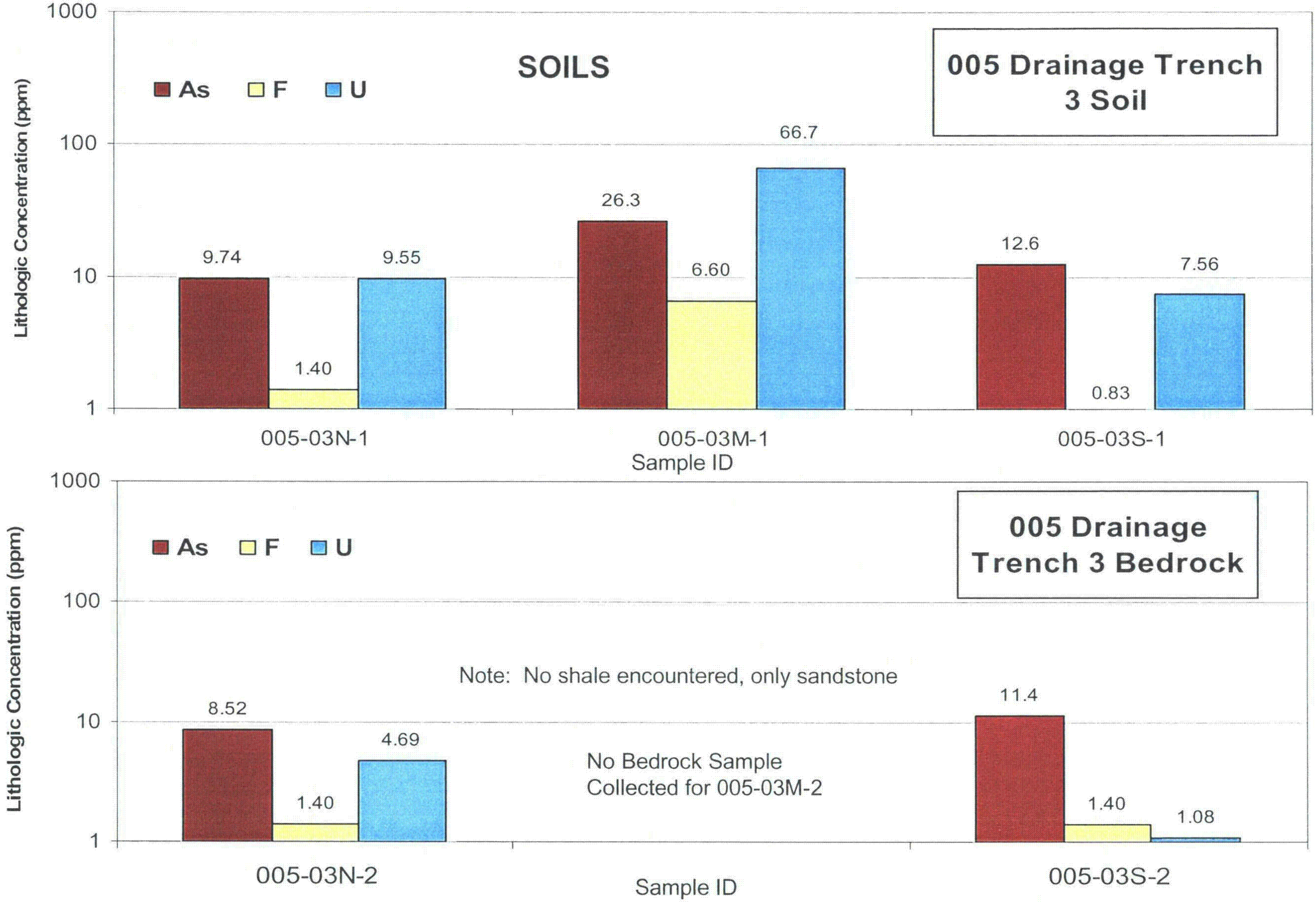

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FIGURE 15
SOLIDS ANALYTICAL RESULTS
DRAINAGE 005 TRENCH 3

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

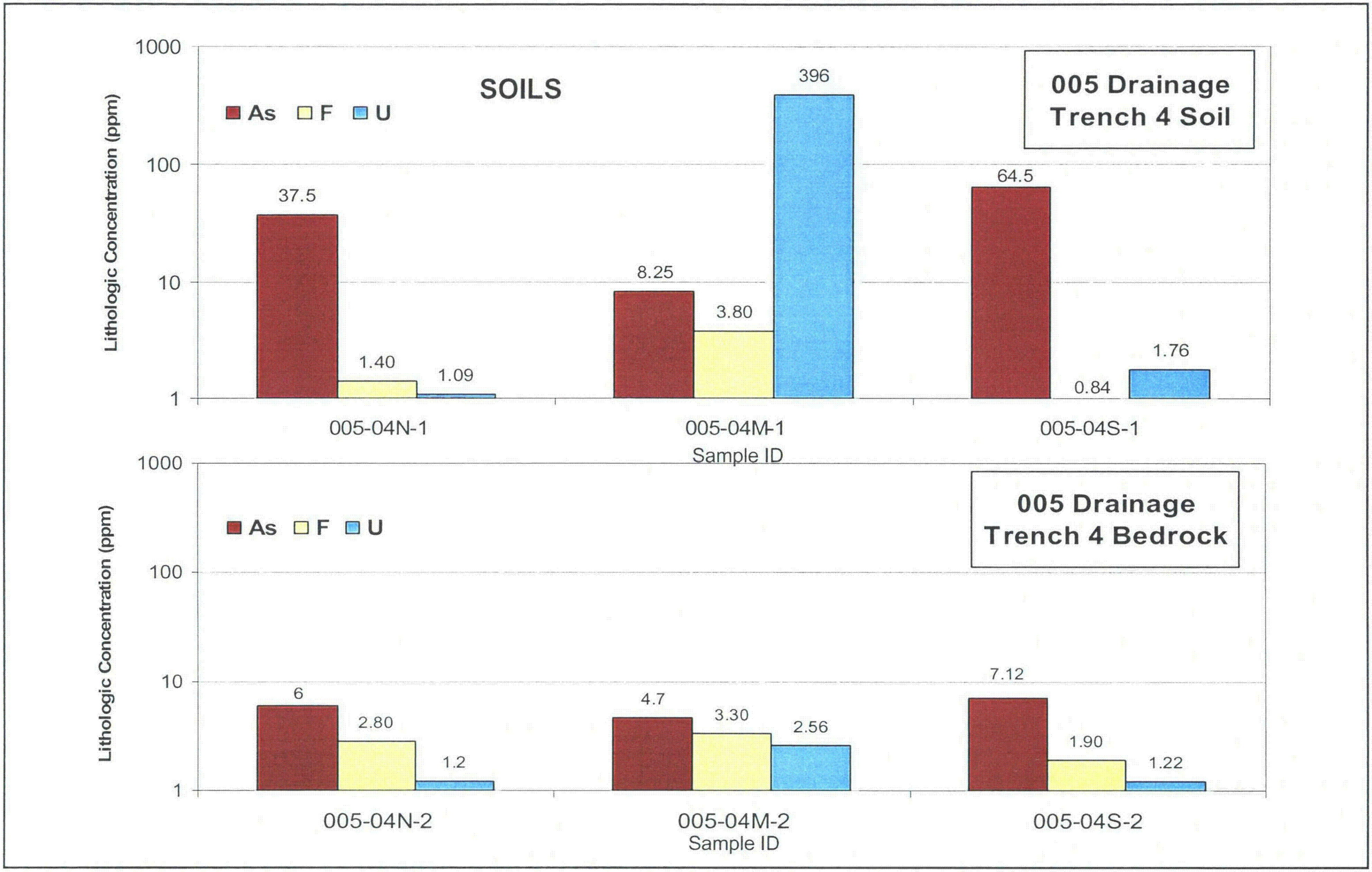

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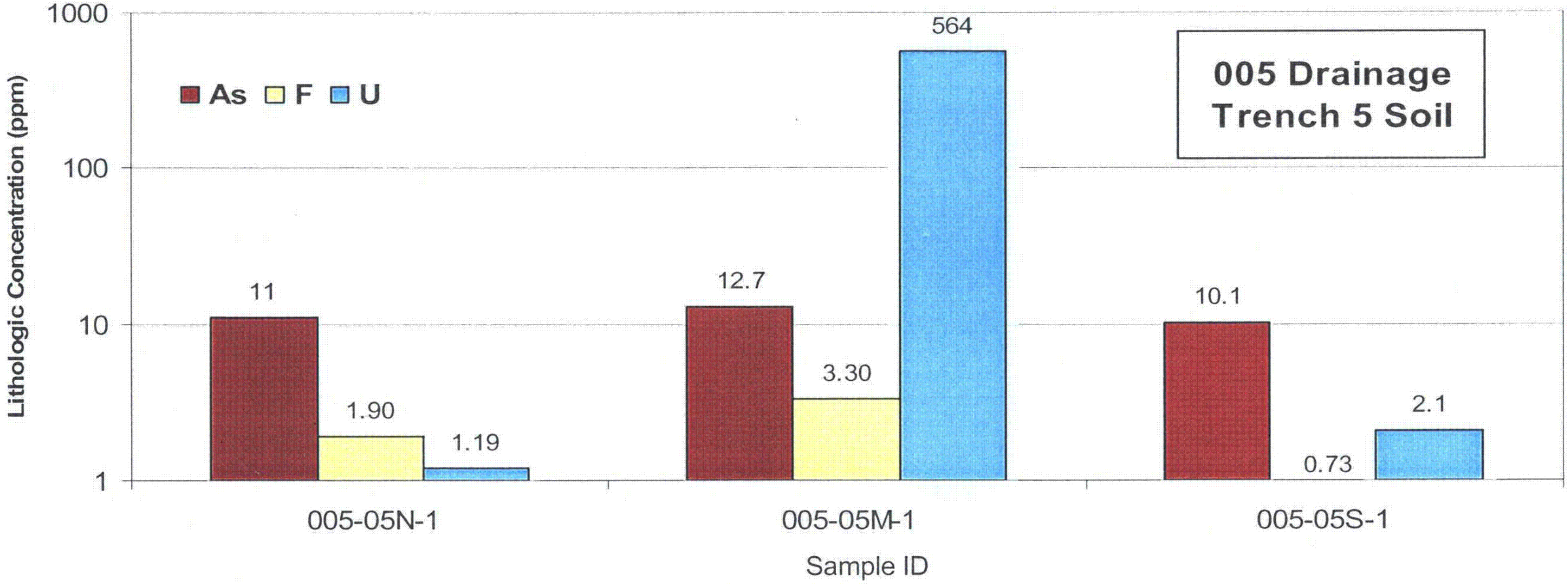
FIGURE 16
SOLIDS ANALYTICAL RESULTS
005 DRAINAGE TRENCH 4

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt



NO BEDROCK SAMPLE | **NO BEDROCK SAMPLE** | **NO BEDROCK SAMPLE**

Note: No bedrock sample, only sandstone present, no shale.

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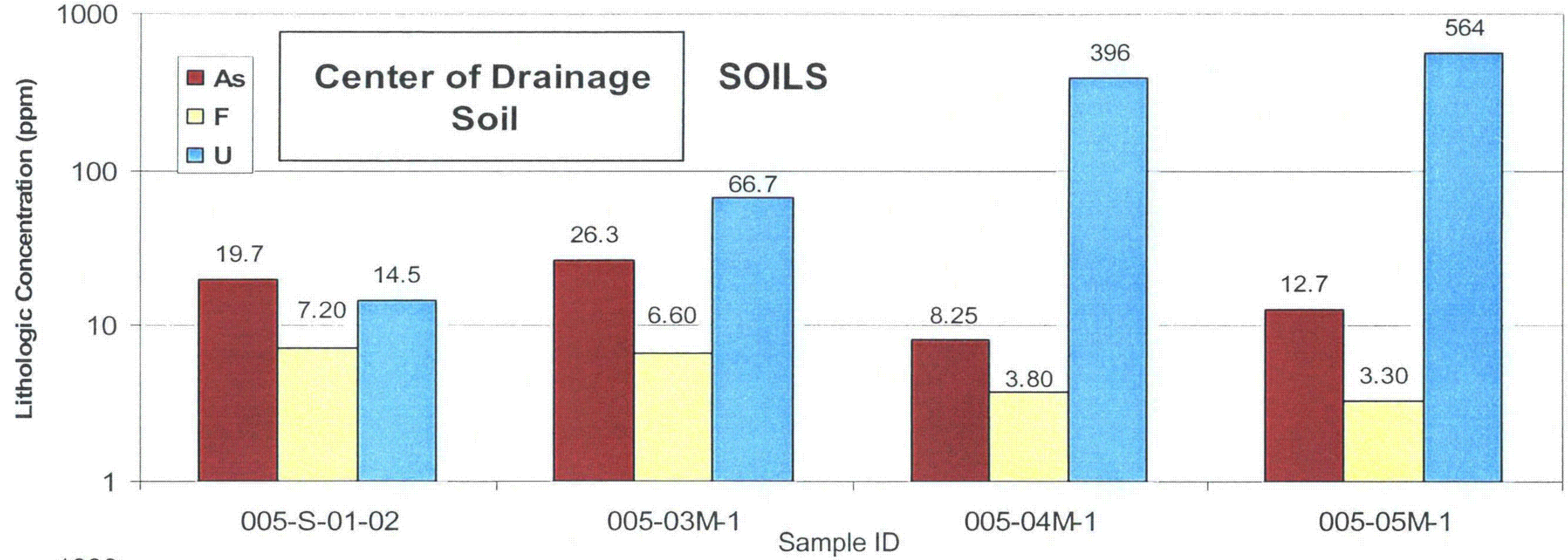
FIGURE 17
SOLIDS ANALYTICAL RESULTS
005 DRAINAGE TRENCH 5

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt



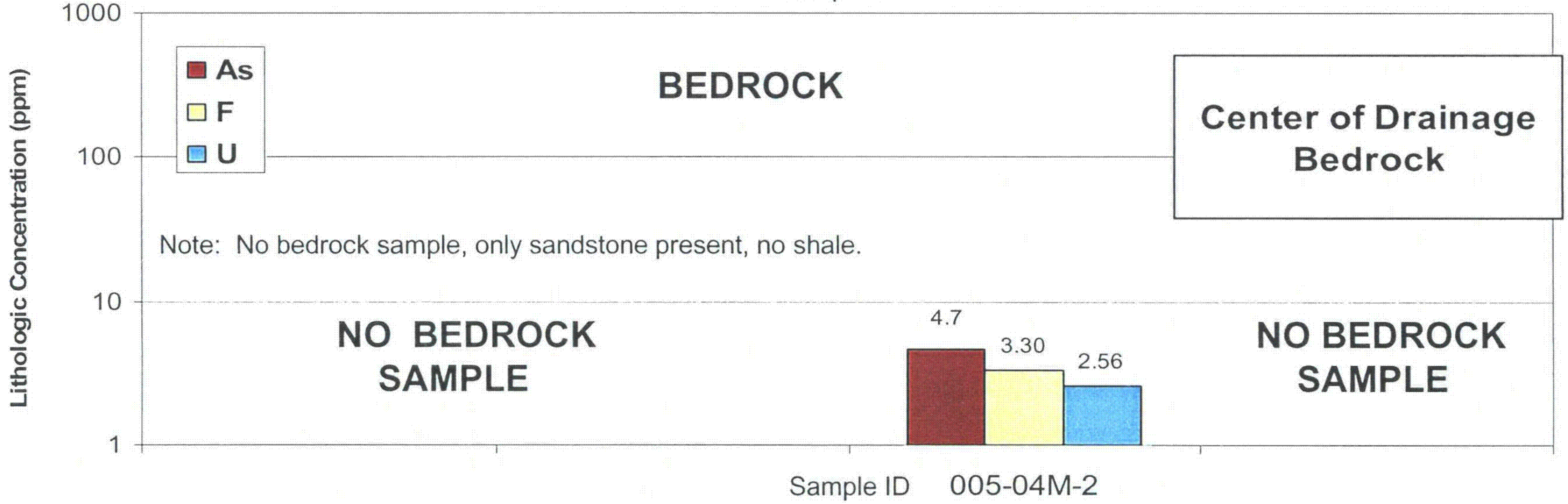


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FIGURE 18
SOLIDS ANALYTICAL RESULTS
DOWNSTREAM THROUGH MIDDLE TRENCH

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

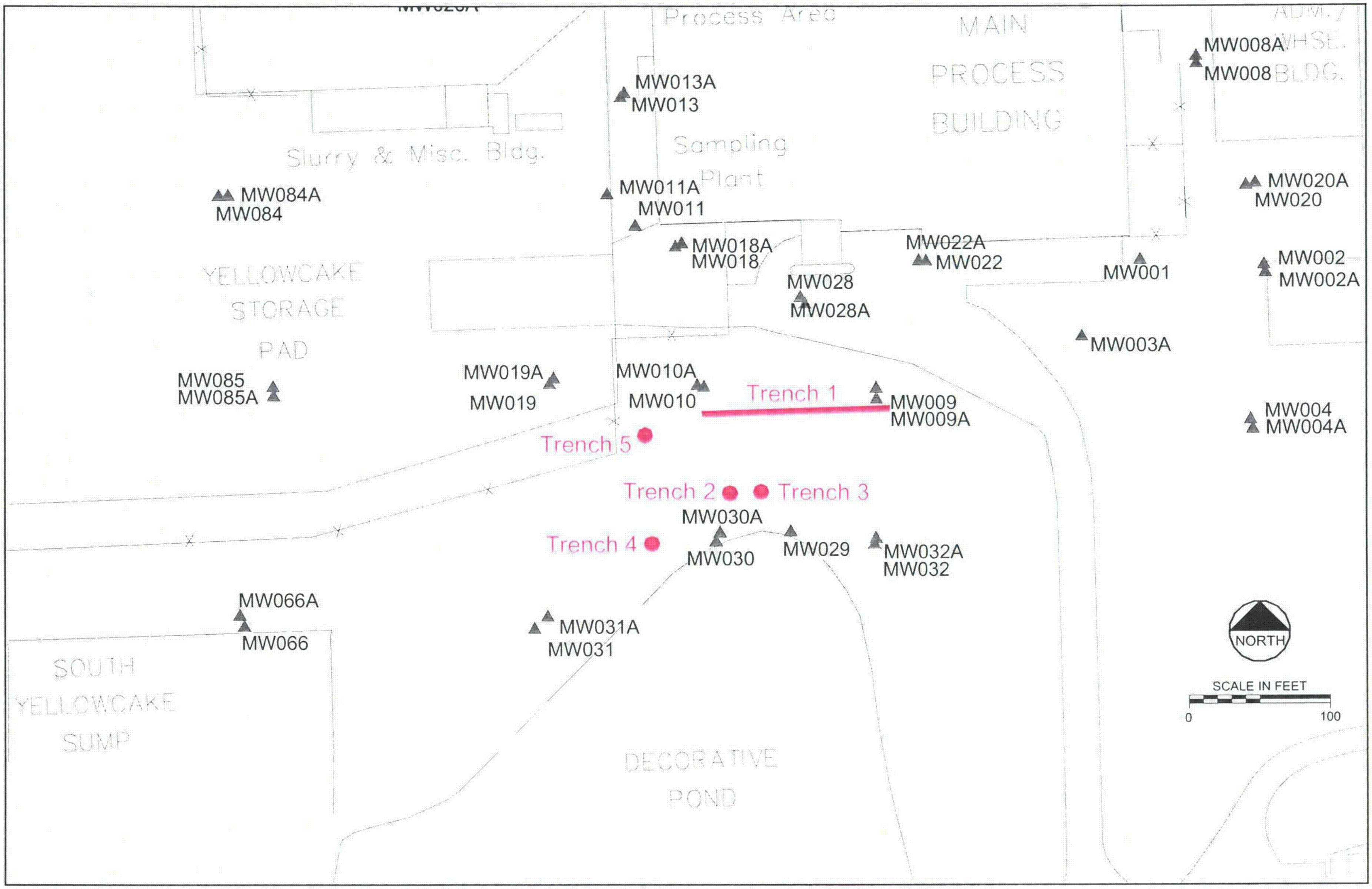

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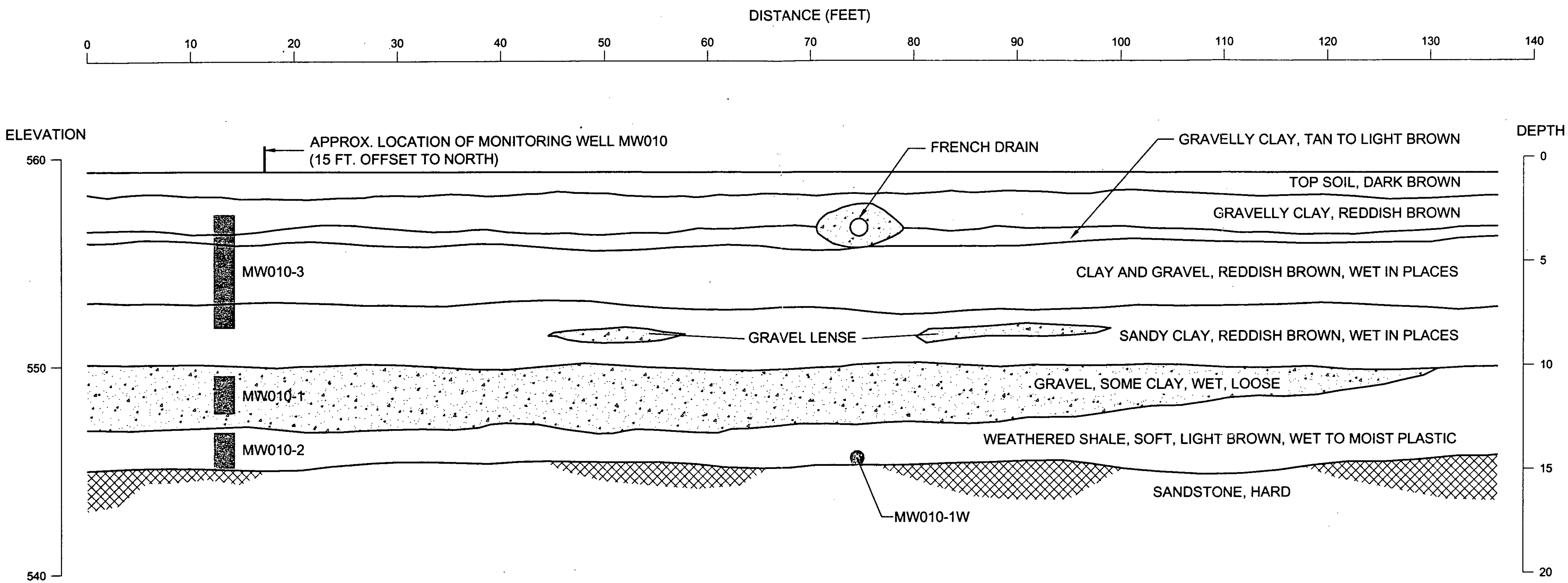
FIGURE 19
MW010 SWALE AREA TRENCH LOCATIONS

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt



LEGEND

SOIL SAMPLE LOCATIONS AND ASSOCIATED SAMPLE NUMBER

WATER SAMPLE LOCATIONS AND ASSOCIATED SAMPLE NUMBER

SEE TABLE 3 FOR SOIL AND WATER SAMPLE SUMMARY

FIGURE 20
CROSS SECTION VIEW OF MW010
AREA TRENCH 1

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Date:	APRIL 2002
Project:	100734
File:	PROFILES-01.DWG

Filename: E:\100734\profiles-01.dwg
Date: 04/25/2002
Time: 10:32:32:11

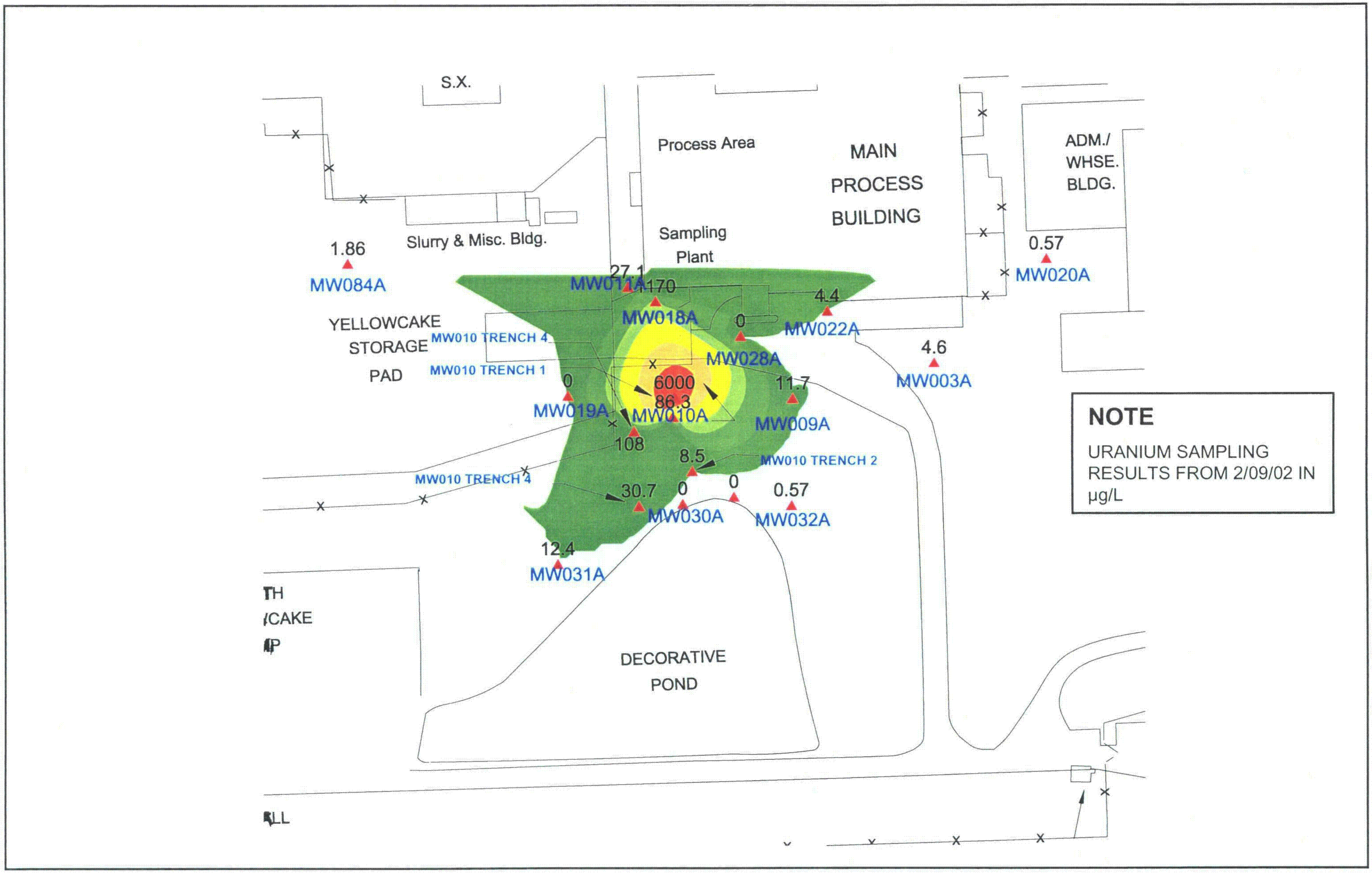

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FIGURE 21
MW010 SWALE URANIUM CONCENTRATIONS
IN GROUNDWATER OF UNCONSOLIDATED MATERIAL

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

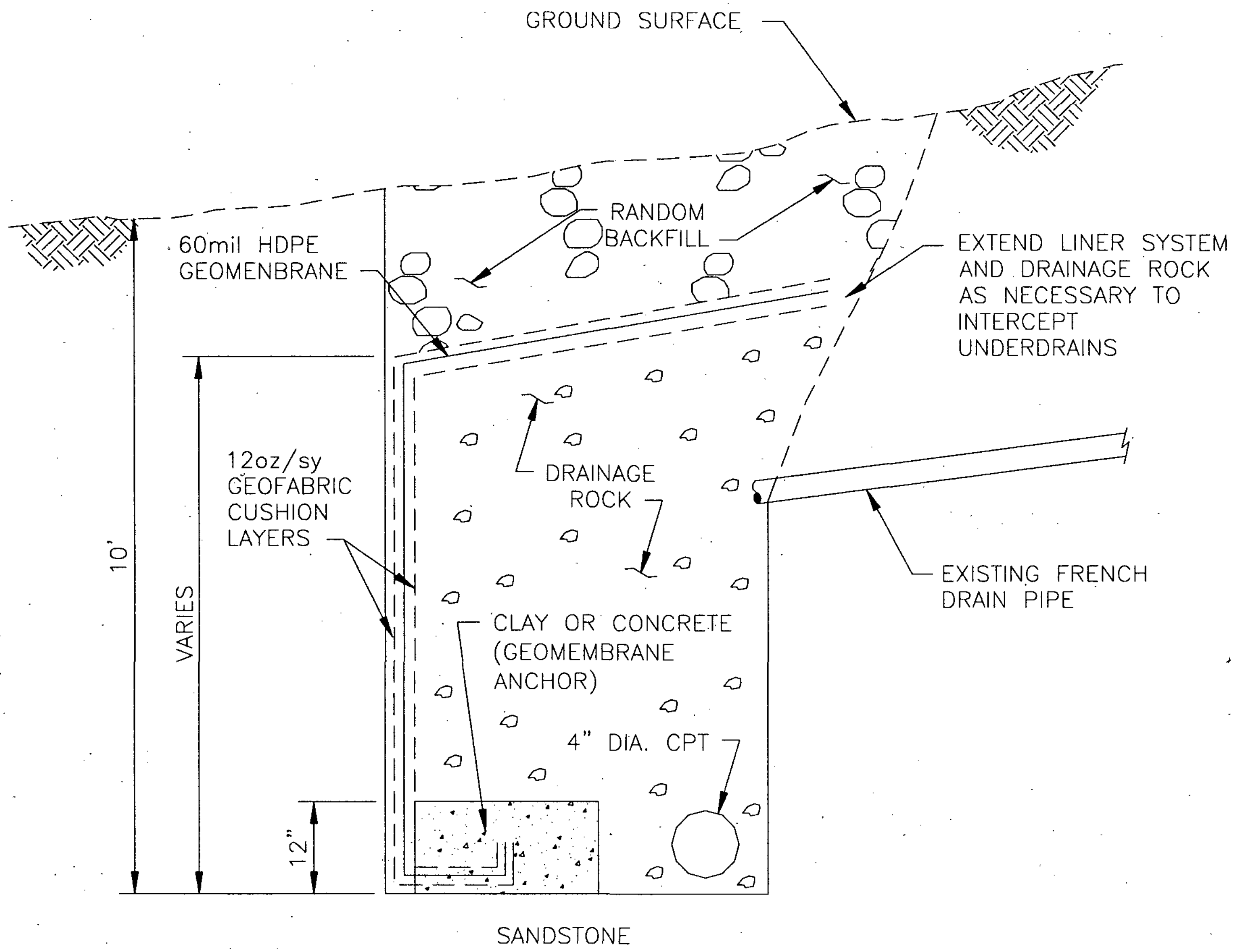

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FIGURE 22
HYDRAULIC CONTAINMENT / PUMP BACK SYSTEM DESIGN

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

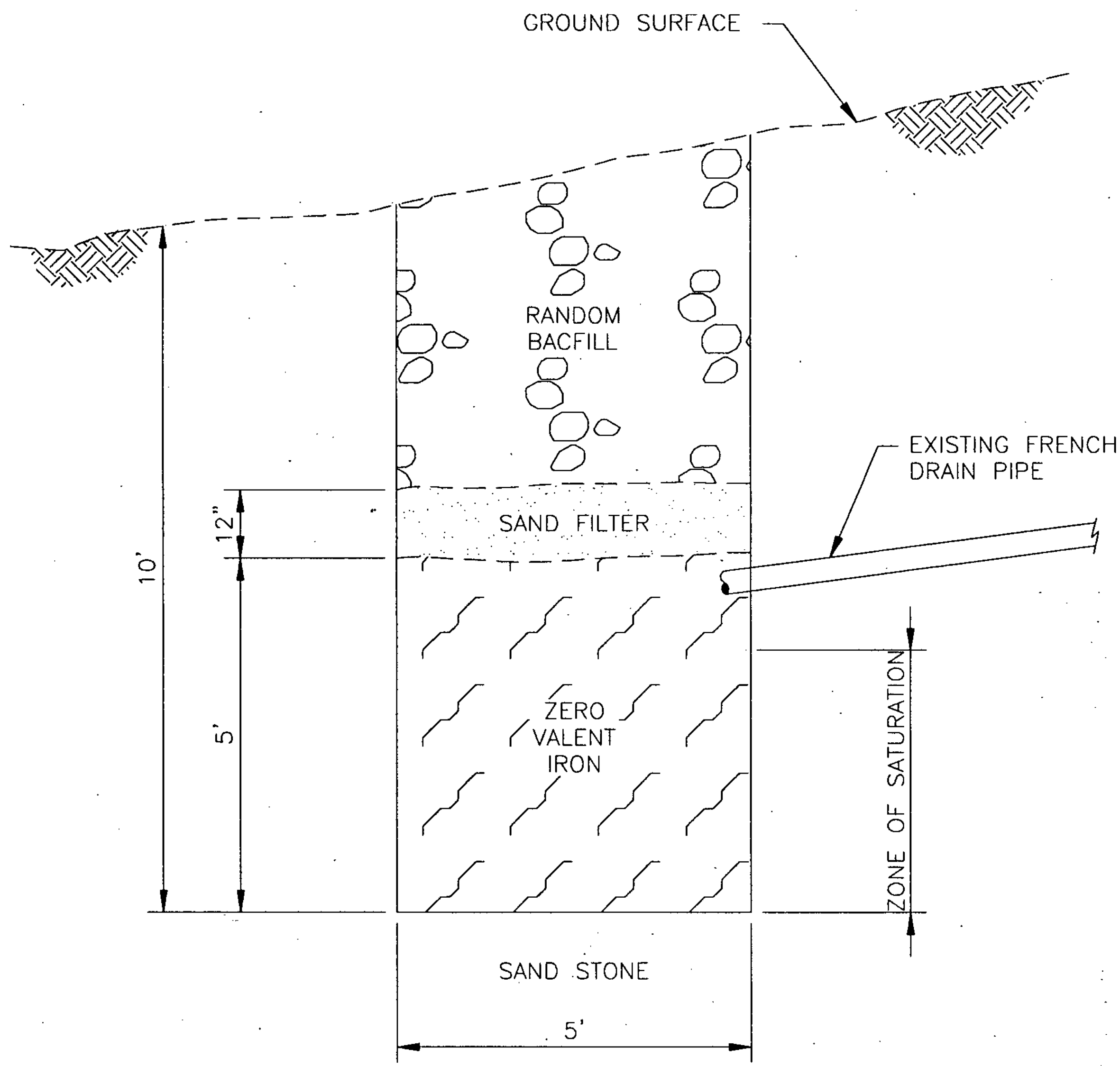

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FIGURE 23
PERMEABLE REACTIVE BARRIER
WITH ZERO VALENT IRON DESIGN

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

PHOTOS

Photo 1 **Excavation of 005 Drainage Trench 1 at Head of Drainage**

Photo 2 **Photograph of 005 Drainage Trench 1 Features, South End**

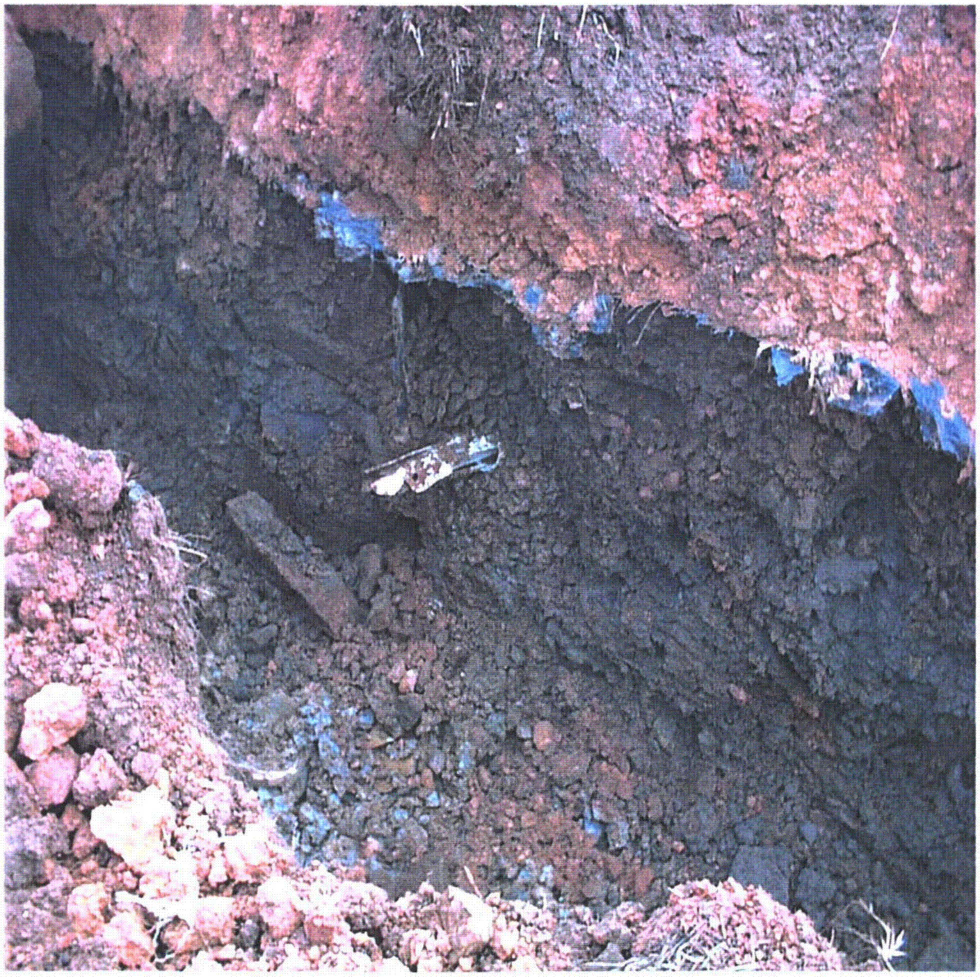

Photo 3 **Photograph of MW010 Trench 1 Features, West End**

Photo 4 Photograph of MW010 Trench 1 Features, South End Bottom

Photo 5 Photograph of MW010 Trench 4 Features

ATTACHMENT A

SLUG TESTS LOCATIONS AND DATA ANALYSIS

SHEPHERD MILLER
Environmental and Engineering Consultants

TECHNICAL MEMORANDUM

DATE: February 27, 2002 **SMI # 180734**

TO: Toby Wright

FROM: Paul Sorek

SUBJECT: Sequoyah Slug Testing

COPY: Micheal Gard

The purpose of this memo is to document the field procedures and analytical methodology relating to the supplemental slug testing at the Sequoyah Fuels Facility (Facility). Slug tests were performed at 7 wells on February 12, 2002. These wells include MW010, MW010A, MW059A, MW093A, MW095A, MW097, and MW097A. MW093A, MW095A, and MW097A are screened in Unit 4 Shale. MW010A and MW059A are both dually completed in Unit 2 Shale/3 Shale and Unit 3 Shale/4 Shale, respectively. MW097 is screened in alluvium, and MW010 is screened in gravel backfill material. The well locations are presented in Figure 1.

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 falling pressure head data at logrhythmic intervals until the water level returned to 95% of the static level, or a maximum of 1 hour. The slug was then removed from the well, and the datalogger collected rising head data. Static water level data are presented in Table 1. The time-drawdown data from the slug tests are attached to this memorandum.

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. These wells include MW059A, MW093A, and MW097. MW010A was tested under confined conditions, and the data were analyzed with Cooper, et. al. (1967) method for unsteady radial flow under confined conditions in a homogeneous and isotropic aquifer. Static water level data at MW010, MW095A, and MW097A suggest that these tests were conducted under confined conditions. However, the time-drawdown data can not be accurately fitted with the Cooper method type curves, indicating that this is not the correct model for these data. It is possible that the hydrogeology at these locations is more accurately described as semi-confined or partially confined. Field observations from a trench located near MW010 support this assumption. Therefore, the Bouwer and Rice method is considered to be the most appropriate solution, and was used to analyze the data from these tests.

For all wells except MW010 and MW097, the rising head data were used in the analyses. Falling head data were analyzed for MW010 and MW097 because sufficient rising head data were not collected. Well construction and borehole lithology data required for the solutions were obtained from well completion reports presented in SFC, 1997. Solution plots for tests are presented in Figures 2 through 8. Table 2 summarizes the input parameters and results for each analysis.

Table 3 presents other estimates of hydraulic conductivity for each unit, including statistics from previous slug tests and values from the SMI flow model (SMI, 2001). It should be noted that the previous test results only include data from wells that are screened in a single hydrologic unit. Overall, hydraulic conductivity values calculated from these tests are greater than average values from previous tests. The results from MW093A, MW095A, and MW097A, all screened in Unit 4 Shale, are significantly greater than the log mean of the previous tests, and are the same order of magnitude as the previously observed maximum. MW010A is dually completed in Unit 2 Shale and 3 Shale. This location also has a hydraulic conductivity greater than the log mean of either shale unit from previous tests, and is consistent with the maximum observed conductivity value for Shale Unit 2 from previous tests (Table 3). The result of the MW097 test, 39.00 ft/day, is significantly greater than previously observed values in the alluvium, but is consistent with the modeled value of 50 ft/day. MW059A is dually completed in Unit 3 Shale and 4 Shale, and has an estimated hydraulic conductivity of 21.38 ft/day. This value is greater than any observed conductivity for the shale units, and is 1-2 orders of magnitude greater than the modeled shale values. MW010 is completed in backfill and the results of this test are therefore not appropriate for comparison with the naturally occurring units.

REFERENCES

Bouwer, H. and R.C. Rice, 1976, A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, v. 12, p. 423-428.

Cooper, H.H., J.D. Bredehoeft, and I.S. Papadopulos, 1967, Response of a finite-diameter well to an instantaneous charge of water, Water Resources Research, v.3, no. 1, p. 263-2

Sequoyah Fuels Corporation (SFC), 1997. "Final RCRA Facility Investigation of the Sequoyah Fuels Uranium Conversion Industrial Facility."

SMI, 2001, Final Hydrogeological and geochemical site characterization report, consultants report, Shepherd Miller, Inc. Fort Collins, Colorado.

Table 1 Static Water Level Data

Well Location	Easting (ft)	Northing (ft)	Measuring Point Elevation (ft msl)	Depth to Groundwater 2/12/02 (ft bmp)	Groundwater Elevation 2/12/02 (ft msl)
MW010	2837016	195508	565.17	11.09	554.08
MW010A	2837011	195509	563.72	10.79	552.93
MW059A	2835336	195016	529.31	19.36	509.95
MW093A	2834987	194911	521.18	25.95	495.23
MW095A	2834517	195032	488.71	11.76	476.95
MW097	2834491	195382	488.88	11.61	477.27
MW097A	2834493	195387	488.93	15.50	473.43

Table 2 Well Data and Results

Well Location	Hydrologic Unit	Hydrologic Condition	Borehole Diameter (ft)	Screen Length (ft)	Saturated Thickness (ft)	Hydraulic Conductivity (ft/day)	Storage Coefficient	Analysis Method
MW010	Gravel Backfill	Confined	0.615	~3	~3	72.63	na	Bouwer and Rice (1976)
MW010A	2SH/3SH	Confined	0.500	13.50	14.00	1.52	6.25E-03	Cooper, et. al. (1967)
MW059A	3SH/4SH	Unconfined	0.500	4.71	5.43	21.38	na	Bouwer and Rice (1976)
MW093A	4SH	Unconfined	0.615	16.57	17.09	2.51	na	Bouwer and Rice (1976)
MW095A	4SH	Confined	0.615	5.50	5.50	4.73	na	Bouwer and Rice (1976)
MW097	Colluvium	Unconfined	0.615	0.90	1.55	39.00	na	Bouwer and Rice (1976)
MW097A	4SH	Confined	0.615	17.00	17.00	0.93	na	Bouwer and Rice (1976)

na – data not derived from this test

Table 3 Other Estimates of Hydraulic Conductivity

Hydrologic Unit	Previous Slug Tests (ft/day)				Modeled Value (ft/day)
	no. tests	log mean	max	min	
Alluvium	2	0.334	5.01	0.0223	50.0
shale 1	13	0.0246	0.261	0.00416	0.800
shale 2	4	0.138	1.35	0.0118	1.200
shale 3	3	0.0478	0.488	0.0103	0.100
shale 4	5	0.0314	1.3	0.00466	0.500

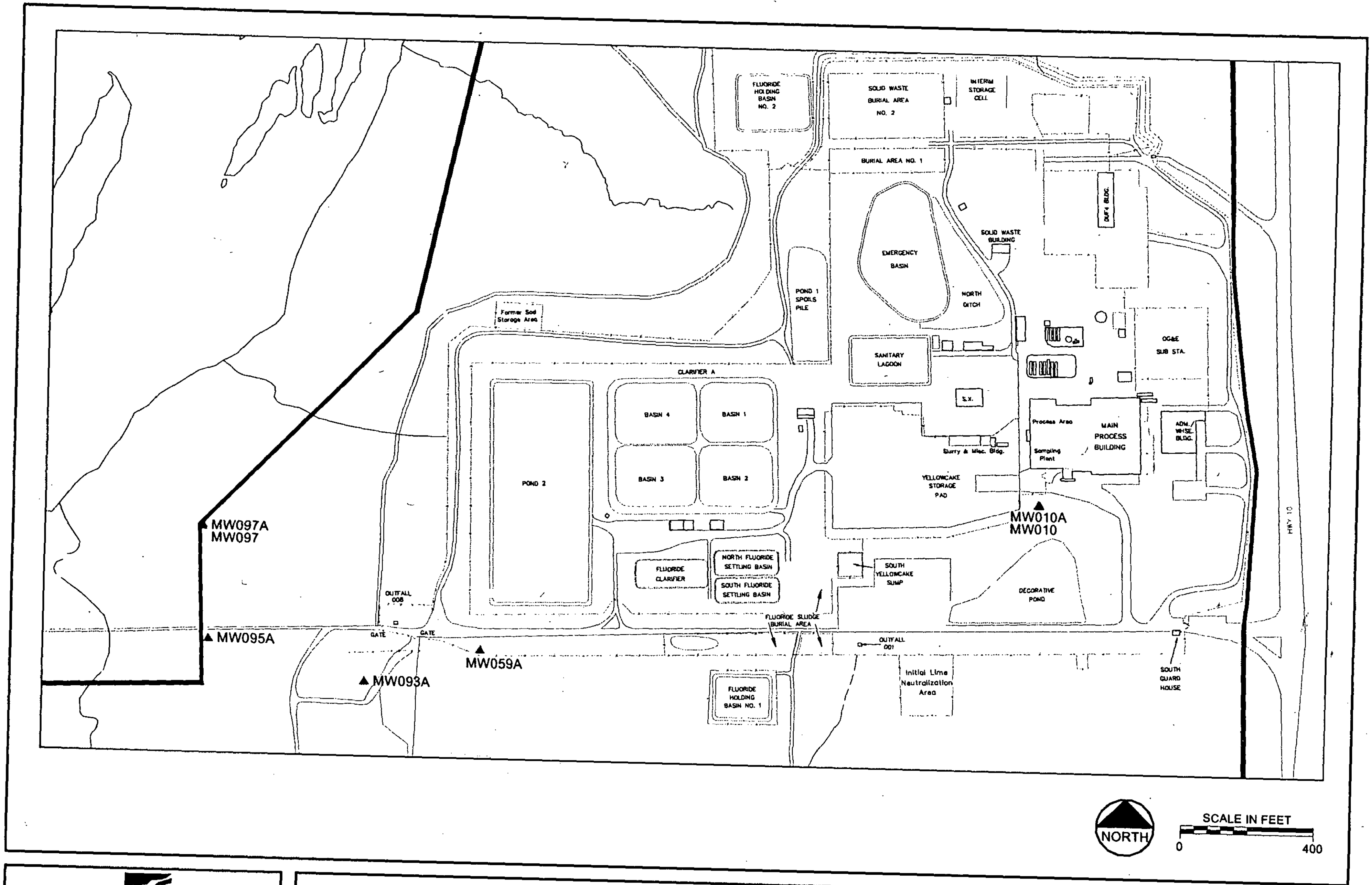

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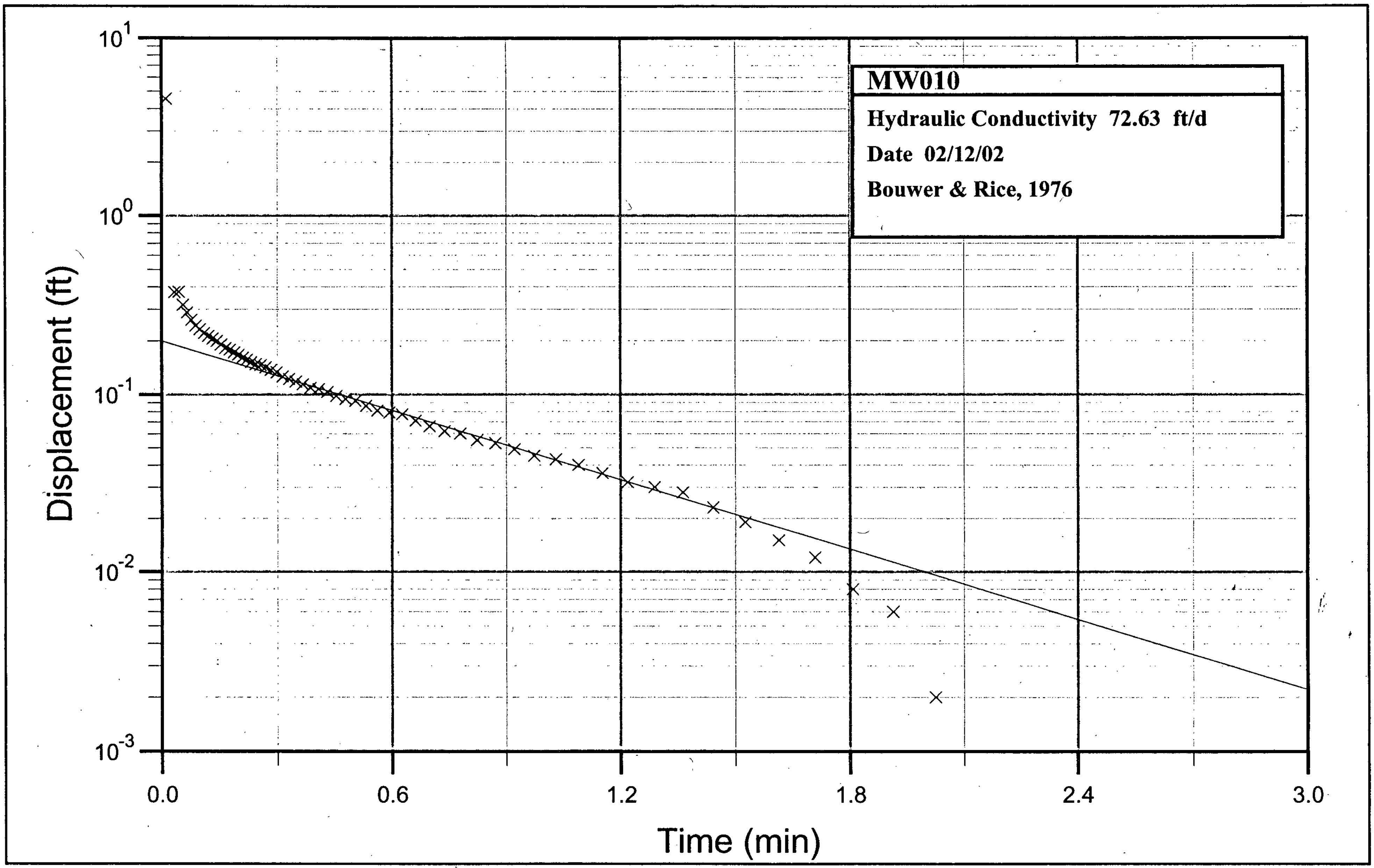
FIGURE 1
SLUG TEST LOCATIONS

Date:	February 2002
Project:	P:\100734/HYDROGE
File:	SLUG TESTS.ppt



SHEPHERD MILLER
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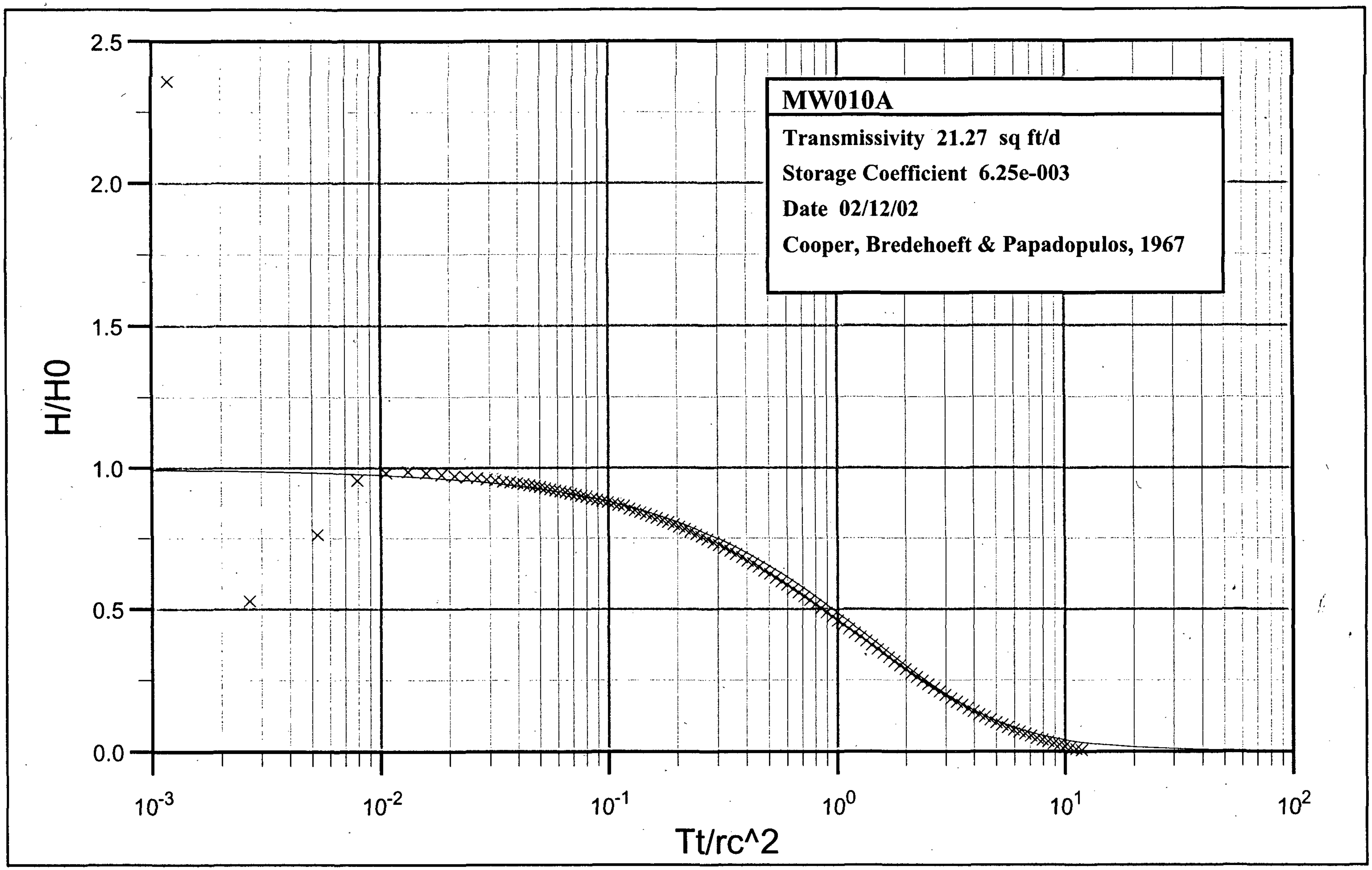
FIGURE 2
MW010 SLUG TEST RESULTS

Date:	February 2002
Project:	P:\100734/HYDROGE
File:	SLUG TESTS.ppt



SHEPHERD MILLER
INCORPORATED

FIGURE 3
MW010A SLUG TEST RESULTS

Date:	February 2002
Project:	P:\100734/HYDROGE
File:	SLUG TESTS.ppt

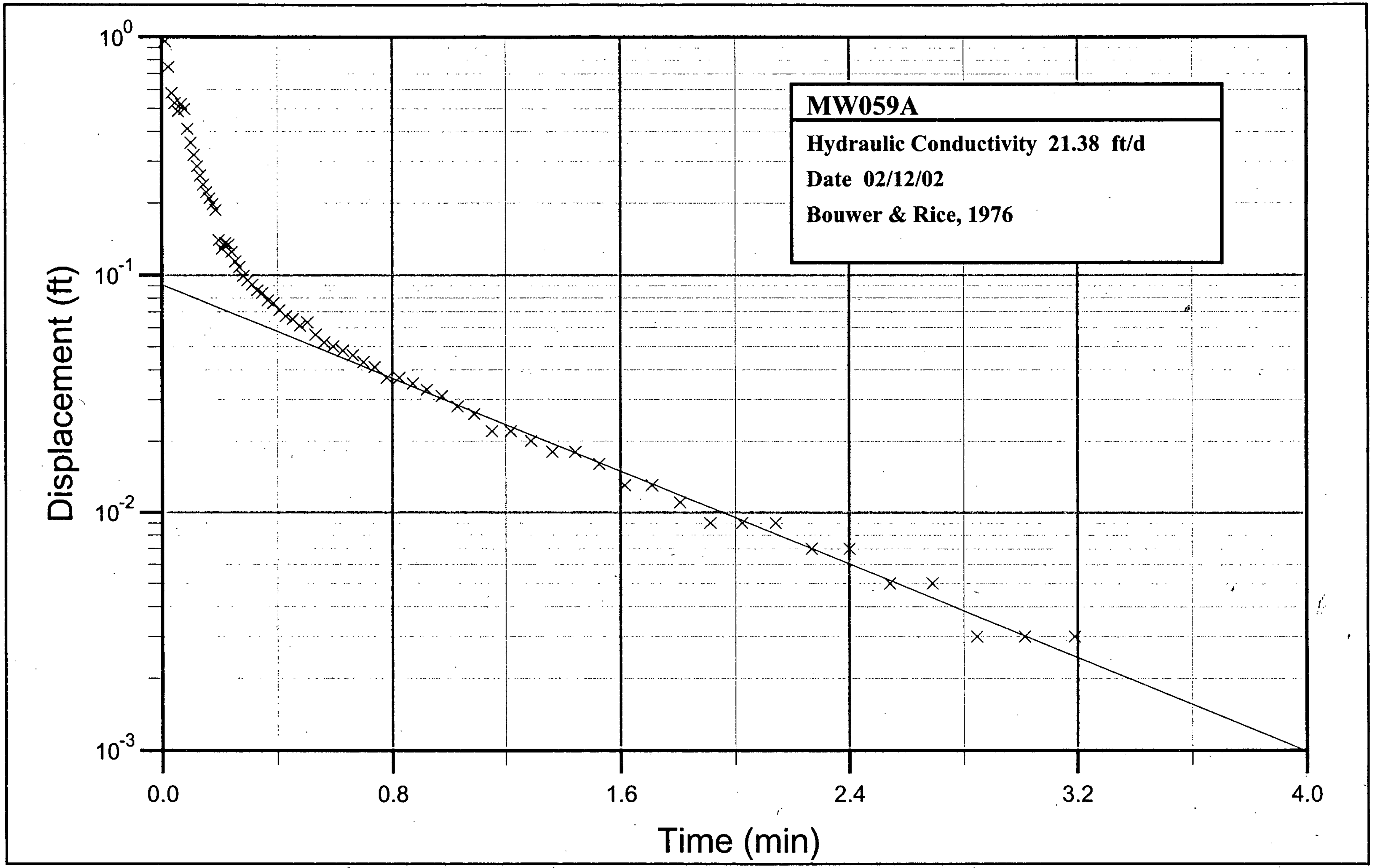


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FIGURE 4
MW059A SLUG TEST RESULTS

Date:	February 2002
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File:	SLUG TESTS.ppt

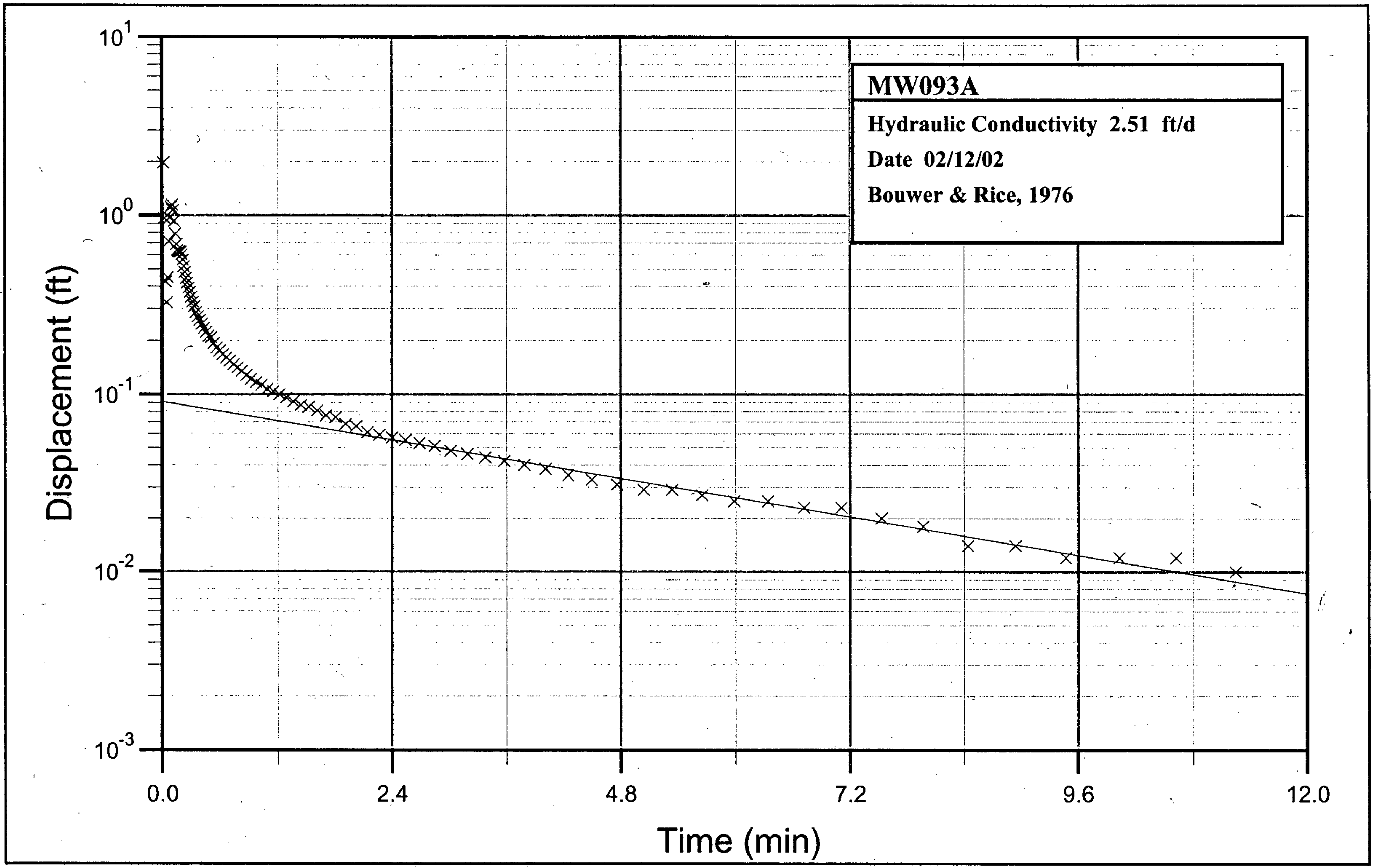

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FIGURE 5
MW093A SLUG TEST RESULTS

Date:	February 2002
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File:	SLUG TESTS.ppt

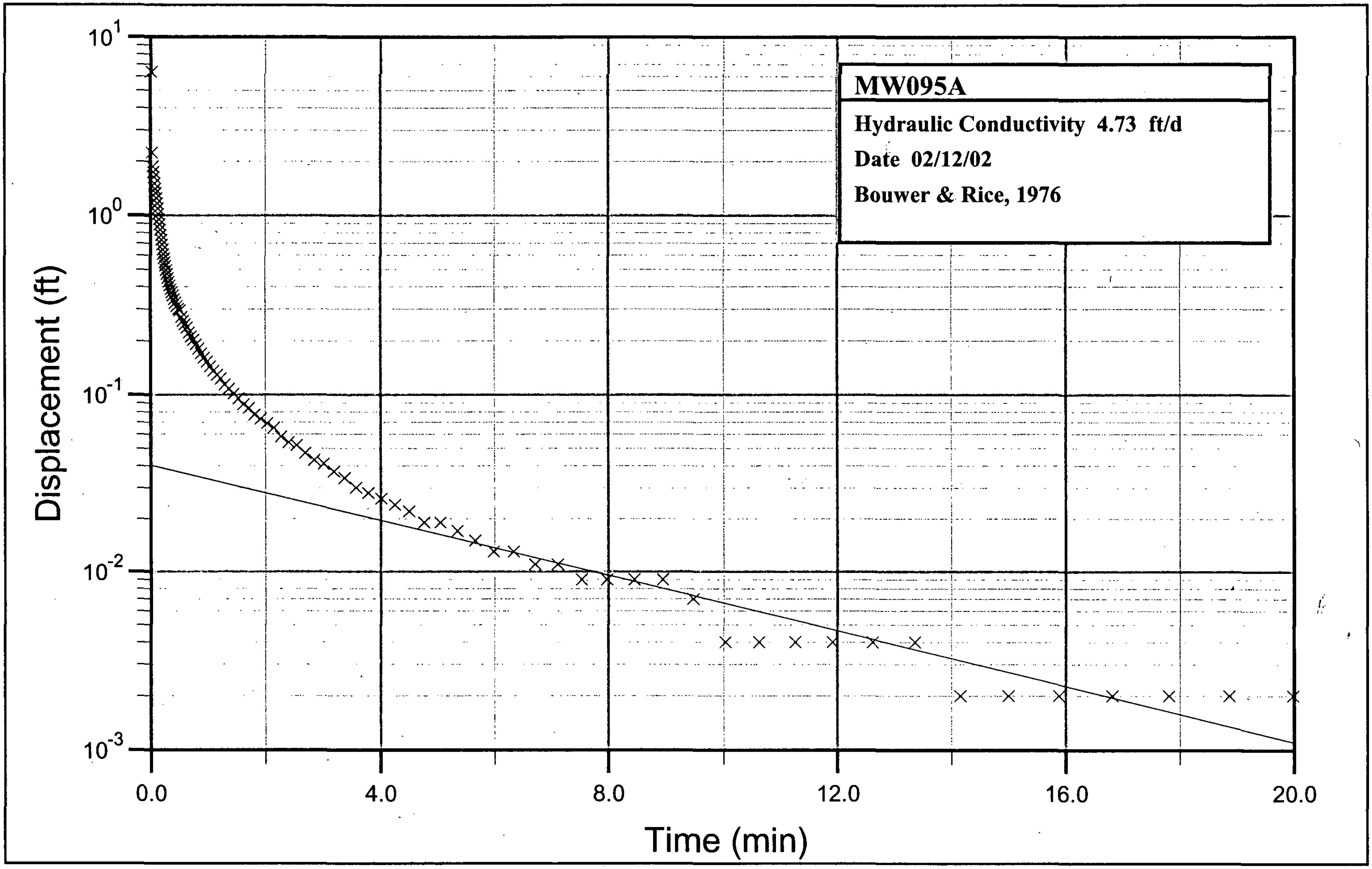

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FIGURE 6
MW095A SLUG TEST RESULTS

Date:	February 2002
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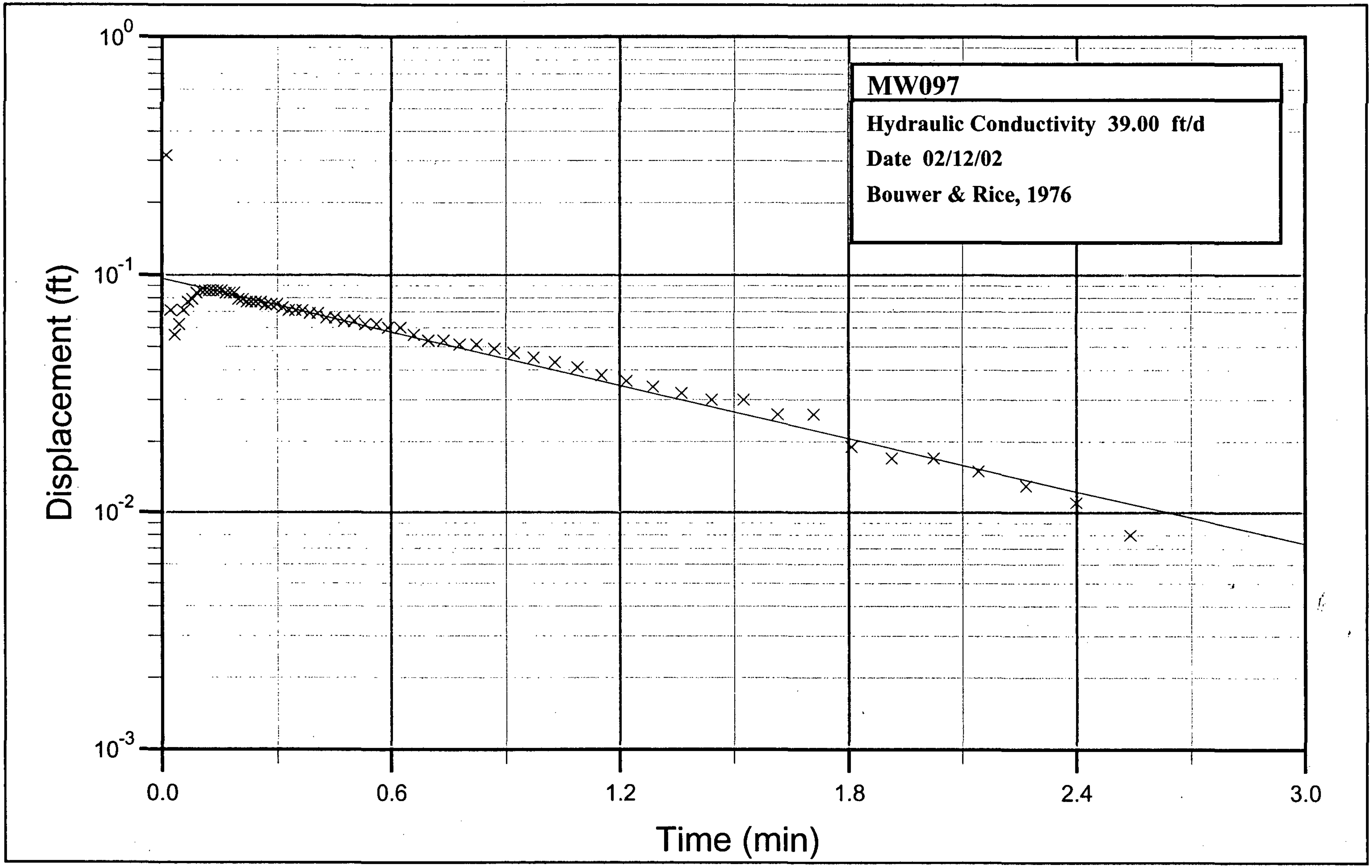

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FIGURE 7
MW097 SLUG TEST RESULTS

Date:	February 2002
Project:	P:\100734/HYDROGE
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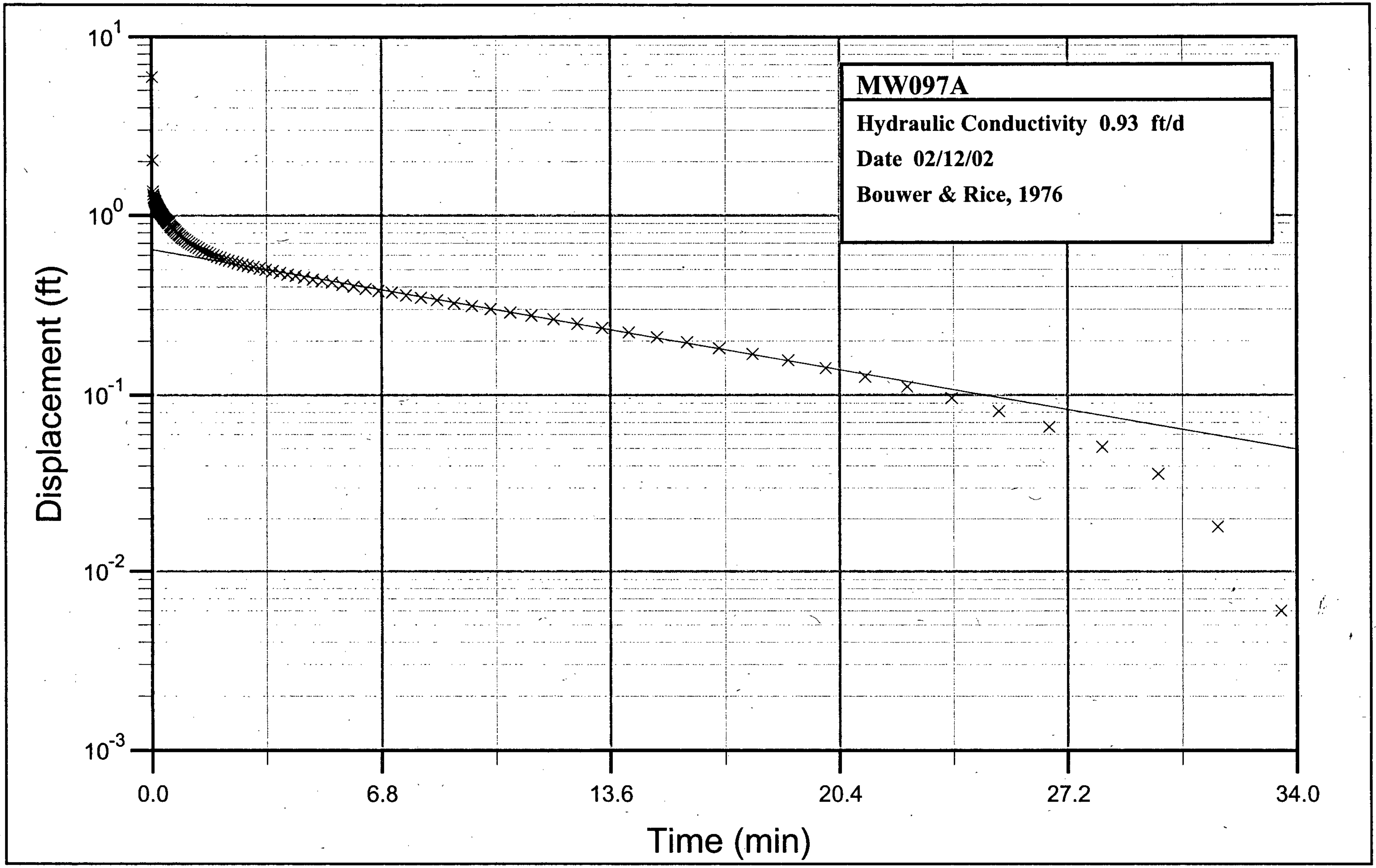

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FIGURE 8
MW097A SLUG TEST RESULTS

Date:	February 2002
Project:	P:\100734/HYDROGE
File:	SLUG TESTS.ppt

SMI Supplemental Slug Test Data 2/12/02

MW010 (falling head)		MW010A (rising head)		MW059A (rising head)		MW093A (rising head)		MW095A (rising head)		MW097 (falling head)		MW097A (rising head)	
Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)
0.011	4.538	0.005	4.481	0.011	0.957	0.011	1.970	0.011	6.348	0.011	0.316	0.011	5.931
0.022	-0.059	0.011	1.005	0.022	0.746	0.022	0.960	0.022	2.232	0.022	0.071	0.022	2.032
0.033	0.374	0.022	1.449	0.033	0.579	0.033	0.425	0.033	1.869	0.033	0.056	0.033	1.360
0.044	0.376	0.034	1.815	0.044	0.527	0.044	0.326	0.044	1.738	0.044	0.062	0.044	1.304
0.055	0.318	0.045	1.864	0.055	0.486	0.055	0.449	0.055	1.626	0.055	0.071	0.055	1.269
0.066	0.288	0.056	1.873	0.066	0.521	0.066	0.714	0.066	1.503	0.066	0.077	0.066	1.241
0.077	0.262	0.067	1.864	0.077	0.497	0.077	0.968	0.077	1.396	0.077	0.079	0.077	1.213
0.088	0.243	0.078	1.853	0.088	0.411	0.088	1.112	0.088	1.327	0.088	0.084	0.088	1.198
0.099	0.232	0.089	1.845	0.099	0.359	0.099	1.143	0.099	1.243	0.099	0.086	0.099	1.192
0.110	0.221	0.101	1.838	0.110	0.319	0.110	1.067	0.110	1.163	0.110	0.086	0.110	1.175
0.121	0.213	0.112	1.832	0.121	0.286	0.121	0.927	0.121	1.088	0.121	0.086	0.121	1.157
0.132	0.206	0.123	1.823	0.132	0.261	0.132	0.789	0.132	1.015	0.132	0.086	0.132	1.147
0.143	0.200	0.134	1.817	0.143	0.239	0.143	0.688	0.143	0.948	0.143	0.086	0.143	1.136
0.154	0.191	0.145	1.808	0.154	0.222	0.154	0.639	0.154	0.886	0.154	0.086	0.154	1.125
0.165	0.182	0.156	1.804	0.165	0.209	0.165	0.626	0.165	0.830	0.165	0.084	0.165	1.117
0.176	0.178	0.168	1.797	0.176	0.198	0.176	0.628	0.176	0.776	0.176	0.084	0.176	1.104
0.187	0.172	0.179	1.791	0.187	0.187	0.187	0.624	0.187	0.729	0.187	0.084	0.187	1.095
0.198	0.167	0.190	1.784	0.198	0.140	0.198	0.602	0.198	0.686	0.198	0.079	0.198	1.084
0.209	0.161	0.201	1.778	0.209	0.129	0.209	0.563	0.209	0.645	0.209	0.079	0.209	1.076
0.220	0.157	0.212	1.772	0.220	0.136	0.220	0.518	0.220	0.609	0.220	0.077	0.220	1.067
0.231	0.152	0.223	1.763	0.231	0.134	0.231	0.481	0.231	0.576	0.231	0.077	0.231	1.058
0.243	0.148	0.235	1.756	0.243	0.125	0.243	0.445	0.243	0.546	0.243	0.077	0.243	1.048
0.255	0.146	0.248	1.748	0.255	0.114	0.255	0.419	0.255	0.523	0.255	0.077	0.255	1.039
0.268	0.142	0.261	1.741	0.268	0.108	0.268	0.393	0.268	0.495	0.268	0.075	0.268	1.030
0.282	0.137	0.275	1.735	0.282	0.099	0.282	0.371	0.282	0.471	0.282	0.075	0.282	1.022
0.297	0.133	0.290	1.726	0.297	0.095	0.297	0.348	0.297	0.447	0.297	0.075	0.297	1.013
0.313	0.126	0.305	1.720	0.313	0.091	0.313	0.328	0.313	0.426	0.313	0.073	0.313	1.002
0.330	0.122	0.322	1.711	0.330	0.086	0.330	0.309	0.330	0.407	0.330	0.071	0.330	0.990
0.347	0.118	0.340	1.705	0.347	0.084	0.347	0.287	0.347	0.387	0.347	0.071	0.347	0.979
0.366	0.114	0.358	1.692	0.366	0.078	0.366	0.272	0.366	0.372	0.366	0.071	0.366	0.968
0.386	0.109	0.378	1.685	0.386	0.076	0.386	0.259	0.386	0.357	0.386	0.069	0.386	0.957
0.407	0.107	0.399	1.677	0.407	0.071	0.407	0.247	0.407	0.340	0.407	0.069	0.407	0.946
0.429	0.103	0.421	1.668	0.429	0.067	0.429	0.234	0.429	0.327	0.429	0.066	0.429	0.931
0.452	0.098	0.445	1.660	0.452	0.065	0.452	0.223	0.452	0.312	0.452	0.066	0.452	0.921
0.477	0.094	0.470	1.649	0.477	0.061	0.477	0.212	0.477	0.301	0.477	0.064	0.477	0.908
0.504	0.092	0.496	1.645	0.504	0.063	0.504	0.208	0.504	0.295	0.504	0.064	0.504	0.903
0.532	0.086	0.524	1.623	0.532	0.056	0.532	0.193	0.532	0.271	0.532	0.062	0.532	0.882
0.561	0.081	0.554	1.612	0.561	0.052	0.561	0.182	0.561	0.258	0.561	0.062	0.561	0.865
0.593	0.079	0.585	1.599	0.593	0.050	0.593	0.175	0.593	0.247	0.593	0.060	0.593	0.854
0.626	0.077	0.618	1.589	0.626	0.048	0.626	0.167	0.626	0.237	0.626	0.060	0.626	0.841
0.661	0.071	0.653	1.573	0.661	0.046	0.661	0.160	0.661	0.222	0.661	0.056	0.661	0.828
0.698	0.066	0.691	1.561	0.698	0.043	0.698	0.154	0.698	0.211	0.698	0.053	0.698	0.813
0.738	0.062	0.730	1.546	0.738	0.041	0.738	0.147	0.738	0.202	0.738	0.053	0.738	0.798

SMI Supplemental Slug Test Data 2/12/02

MW010 (falling head)		MW010A (rising head)		MW059A (rising head)		MW093A (rising head)		MW095A (rising head)		MW097 (falling head)		MW097A (rising head)	
Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)
0.780	0.060	0.772	1.533	0.780	0.037	0.780	0.141	0.780	0.191	0.780	0.051	0.780	0.785
0.824	0.055	0.816	1.518	0.824	0.037	0.824	0.135	0.824	0.181	0.824	0.051	0.824	0.772
0.871	0.053	0.863	1.502	0.871	0.035	0.871	0.128	0.871	0.170	0.871	0.049	0.871	0.757
0.921	0.049	0.913	1.487	0.921	0.033	0.921	0.122	0.921	0.161	0.921	0.047	0.921	0.744
0.973	0.045	0.966	1.470	0.973	0.031	0.973	0.117	0.973	0.153	0.973	0.045	0.973	0.731
1.029	0.043	1.022	1.451	1.029	0.028	1.029	0.113	1.029	0.144	1.029	0.043	1.029	0.718
1.088	0.040	1.081	1.434	1.088	0.026	1.088	0.107	1.088	0.136	1.088	0.041	1.088	0.705
1.151	0.036	1.143	1.418	1.151	0.022	1.151	0.104	1.151	0.129	1.151	0.038	1.151	0.692
1.217	0.032	1.210	1.397	1.217	0.022	1.217	0.100	1.217	0.123	1.217	0.036	1.217	0.682
1.288	0.030	1.280	1.380	1.288	0.020	1.288	0.096	1.288	0.114	1.288	0.034	1.288	0.669
1.362	0.028	1.355	1.360	1.362	0.018	1.362	0.091	1.362	0.108	1.362	0.032	1.362	0.658
1.441	0.023	1.434	1.339	1.441	0.018	1.441	0.087	1.441	0.101	1.441	0.030	1.441	0.643
1.525	0.019	1.517	1.319	1.525	0.016	1.525	0.085	1.525	0.095	1.525	0.030	1.525	0.632
1.613	0.015	1.606	1.298	1.613	0.013	1.613	0.081	1.613	0.088	1.613	0.026	1.613	0.621
1.707	0.012	1.700	1.274	1.707	0.013	1.707	0.076	1.707	0.084	1.707	0.026	1.707	0.611
1.807	0.008	1.799	1.255	1.807	0.011	1.807	0.074	1.807	0.077	1.807	0.019	1.807	0.602
1.912	0.006	1.904	1.233	1.912	0.009	1.912	0.068	1.912	0.073	1.912	0.017	1.912	0.589
2.023	0.002	2.016	1.207	2.023	0.009	2.023	0.066	2.023	0.069	2.023	0.017	2.023	0.580
		2.134	1.186	2.142	0.009	2.142	0.061	2.142	0.065	2.142	0.015	2.142	0.570
		2.259	1.160	2.267	0.007	2.267	0.059	2.267	0.058	2.267	0.013	2.267	0.561
		2.392	1.136	2.399	0.007	2.399	0.057	2.399	0.054	2.399	0.011	2.399	0.552
		2.532	1.113	2.540	0.005	2.540	0.055	2.540	0.052	2.540	0.008	2.540	0.544
		2.681	1.085	2.689	0.005	2.689	0.053	2.689	0.047			2.689	0.533
		2.838	1.061	2.846	0.003	2.846	0.051	2.846	0.043			2.846	0.524
		3.005	1.035	3.013	0.003	3.013	0.048	3.013	0.041			3.013	0.516
		3.182	1.009	3.190	0.003	3.190	0.046	3.190	0.037			3.190	0.507
		3.369	0.981	3.377	0.000	3.377	0.044	3.377	0.034			3.377	0.499
		3.568	0.956	3.575	0.000	3.575	0.042	3.575	0.030			3.575	0.490
		3.778	0.928	3.786	0.000	3.786	0.040	3.786	0.028			3.786	0.479
		4.001	0.900			4.008	0.038	4.008	0.026			4.008	0.468
		4.236	0.872			4.244	0.035	4.244	0.024			4.244	0.460
		4.486	0.846			4.494	0.033	4.494	0.022			4.494	0.451
		4.751	0.818			4.759	0.031	4.759	0.019			4.759	0.440
		5.031	0.790			5.039	0.029	5.039	0.019			5.039	0.432
		5.328	0.764			5.336	0.029	5.336	0.017			5.336	0.423
		5.643	0.736			5.650	0.027	5.650	0.015			5.650	0.410
		5.976	0.708			5.983	0.025	5.983	0.013			5.983	0.402
		6.329	0.680			6.336	0.025	6.336	0.013			6.336	0.391
		6.702	0.654			6.710	0.023	6.710	0.011			6.710	0.380
		7.098	0.626			7.106	0.023	7.106	0.011			7.106	0.372
		7.518	0.598			7.525	0.020	7.525	0.009			7.525	0.359
		7.962	0.572			7.970	0.018	7.970	0.009			7.970	0.348
		8.433	0.546			8.440	0.014	8.440	0.009			8.440	0.337

SMI Supplemental Slug Test Data 2/12/02

MW010 (falling head)		MW010A (rising head)		MW059A (rising head)		MW093A (rising head)		MW095A (rising head)		MW097 (falling head)		MW097A (rising head)	
Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)	Time (min)	Drawdown (feet)
		8.931	0.518			8.939	0.014	8.939	0.009			8.939	0.324
		9.459	0.495			9.467	0.012	9.467	0.007			9.467	0.313
		10.019	0.469			10.026	0.012	10.026	0.004			10.026	0.301
		10.611	0.445			10.619	0.012	10.619	0.004			10.619	0.288
		11.239	0.422			11.246	0.010	11.246	0.004			11.246	0.277
		11.903	0.398					11.911	0.004			11.911	0.264
		12.608	0.374					12.615	0.004			12.615	0.249
		13.353	0.351					13.361	0.004			13.361	0.236
		14.143	0.329					14.151	0.002			14.151	0.223
		14.980	0.310					14.988	0.002			14.988	0.210
		15.867	0.286					15.874	0.002			15.874	0.197
		16.806	0.267					16.813	0.002			16.813	0.182
		17.800	0.245					17.808	0.002			17.808	0.169
		18.854	0.230					18.862	0.002			18.862	0.156
		19.970	0.211					19.978	0.002			19.978	0.141
		21.152	0.191									21.160	0.126
		22.404	0.176									22.412	0.111
		23.731	0.159									23.739	0.096
		25.136	0.142									25.144	0.081
		26.624	0.129									26.632	0.066
		28.201	0.116									28.208	0.051
		29.871	0.103									29.878	0.036
		31.639	0.088									31.647	0.018
		33.513	0.077									33.521	0.006
		35.498	0.066										
		37.600	0.053										
		39.827	0.043										
		42.186	0.034										
		44.684	0.025										
		47.331	0.015										
		50.135	0.008										

APPENDIX C

BORING LOGS AND WELL INSTALLATION DIAGRAMS

APPENDIX D

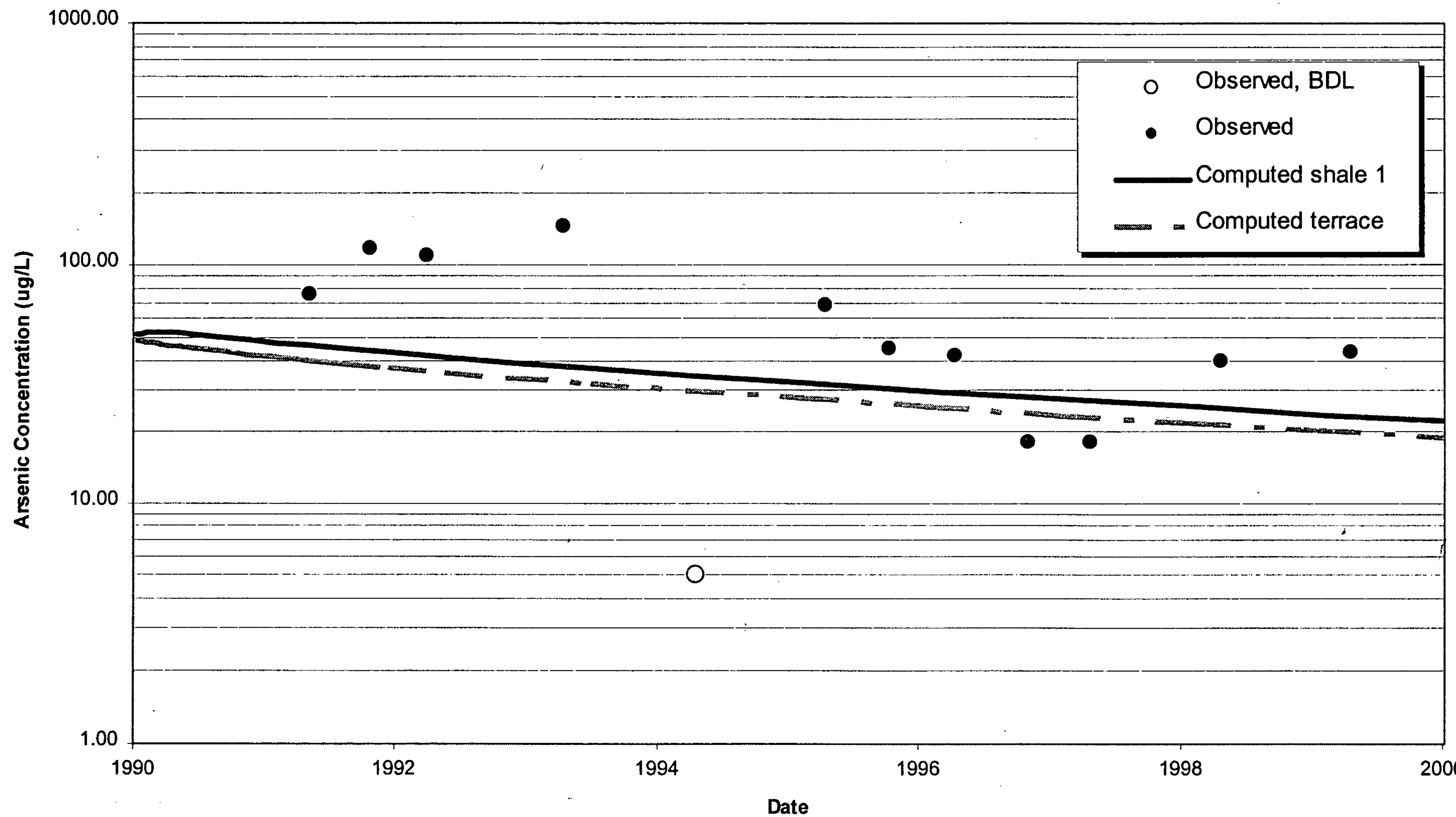
ELECTRICAL RESISTIVITY SURVEY

APPENDIX E

LABORATORY CHEMICAL ANALYSIS REPORT SHEETS

APPENDIX F

TRANSPORT CALIBRATION CHEMOGRAPHS



consulting scientists and engineers

FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW010

Date:	AUGUST 2002
Project:	P:\100734-2\REV CHAR RPT
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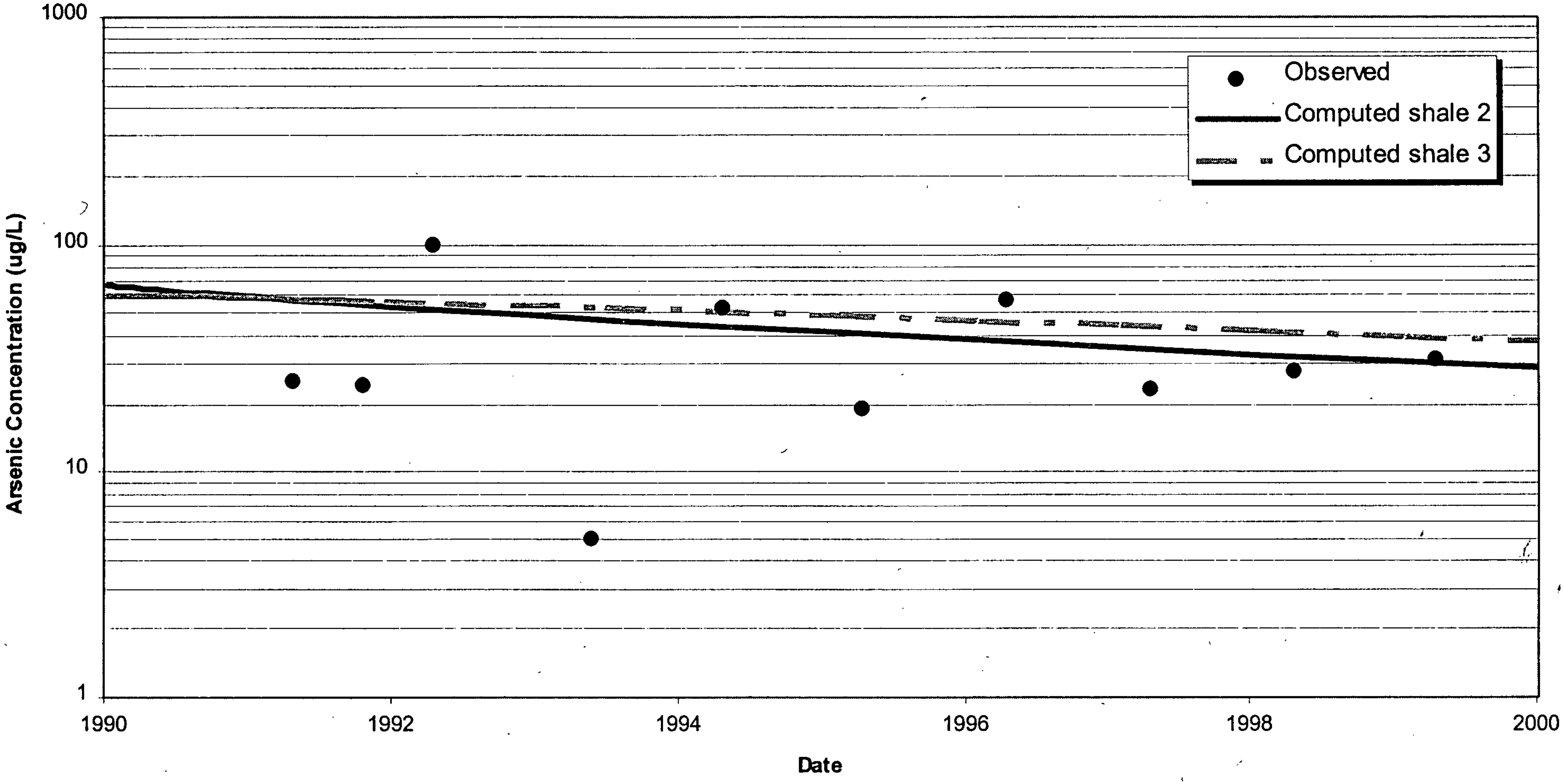

consulting scientists and engineers

FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW010A

Date:	AUGUST 2002
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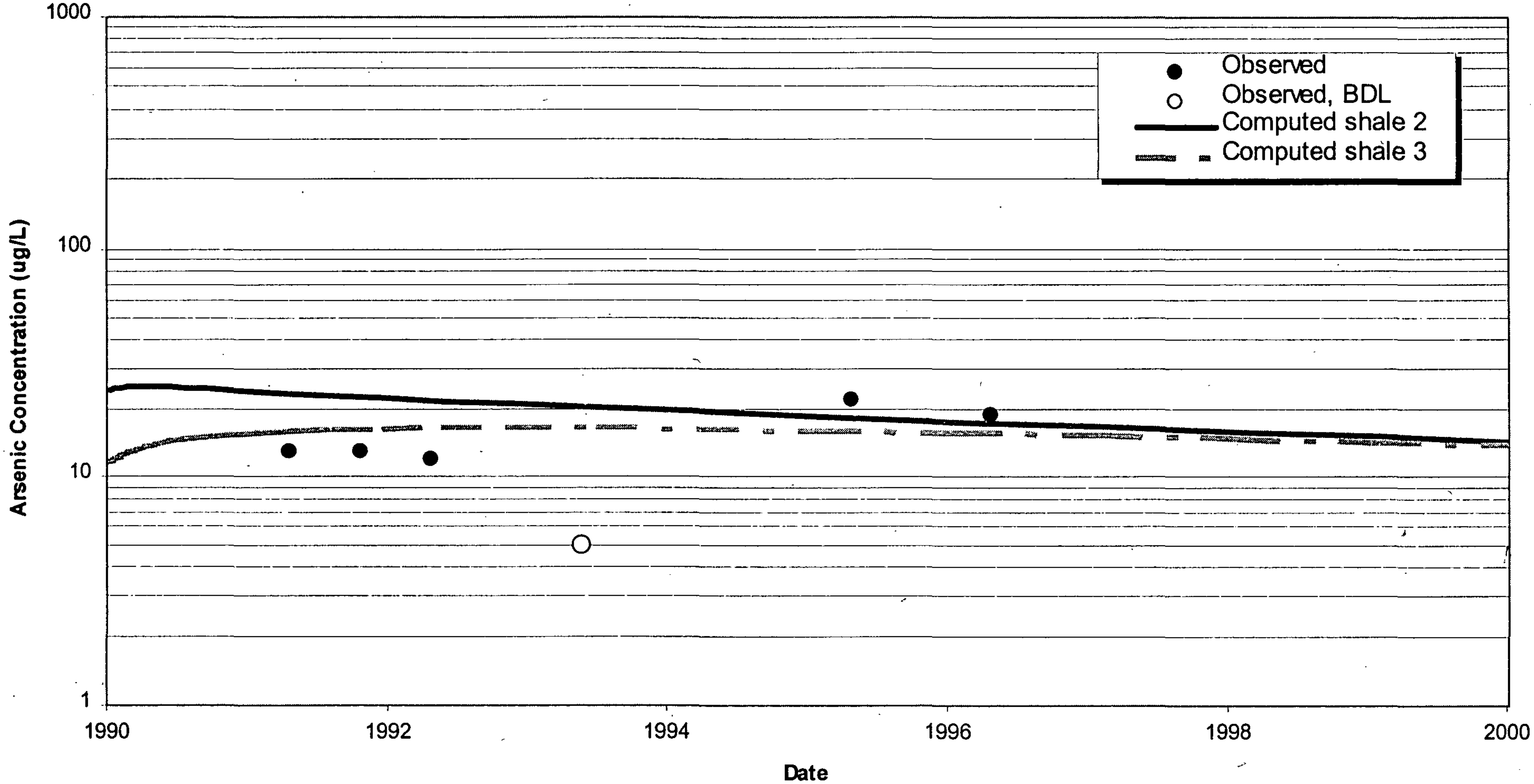

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW011A

Date:	AUGUST 2002
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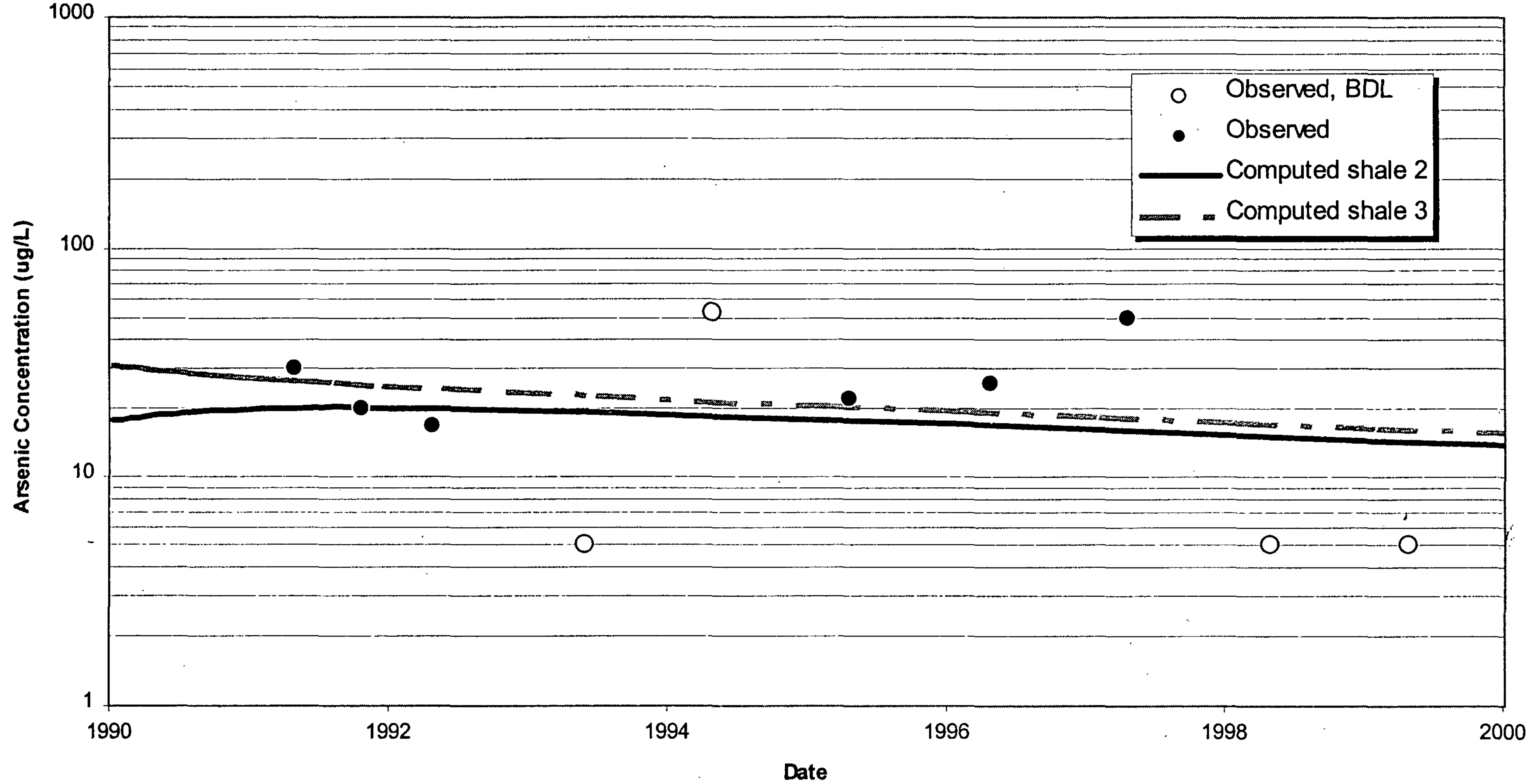

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW012A

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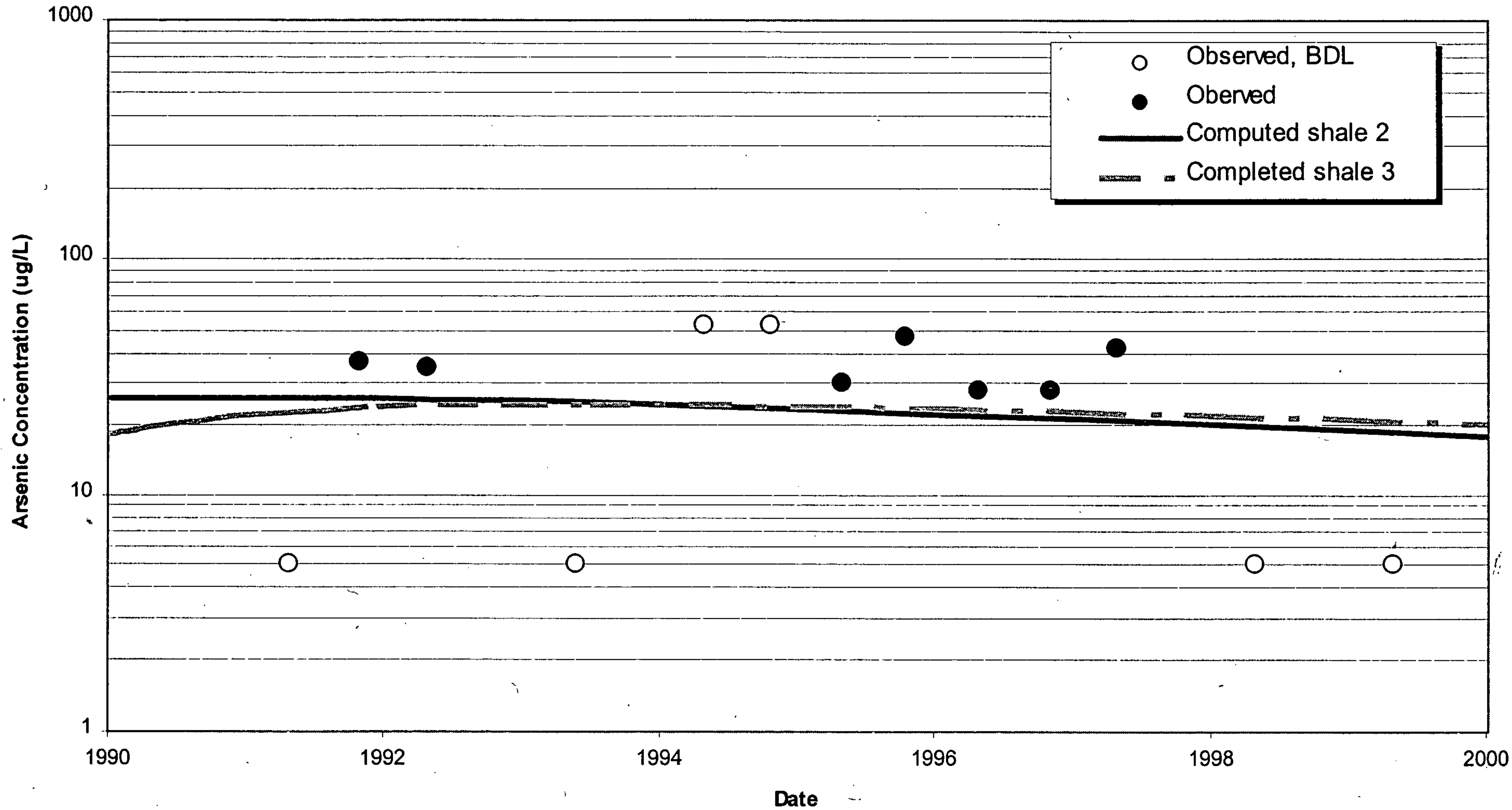

consulting scientists and engineers

FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW024A

Date:	AUGUST 2002
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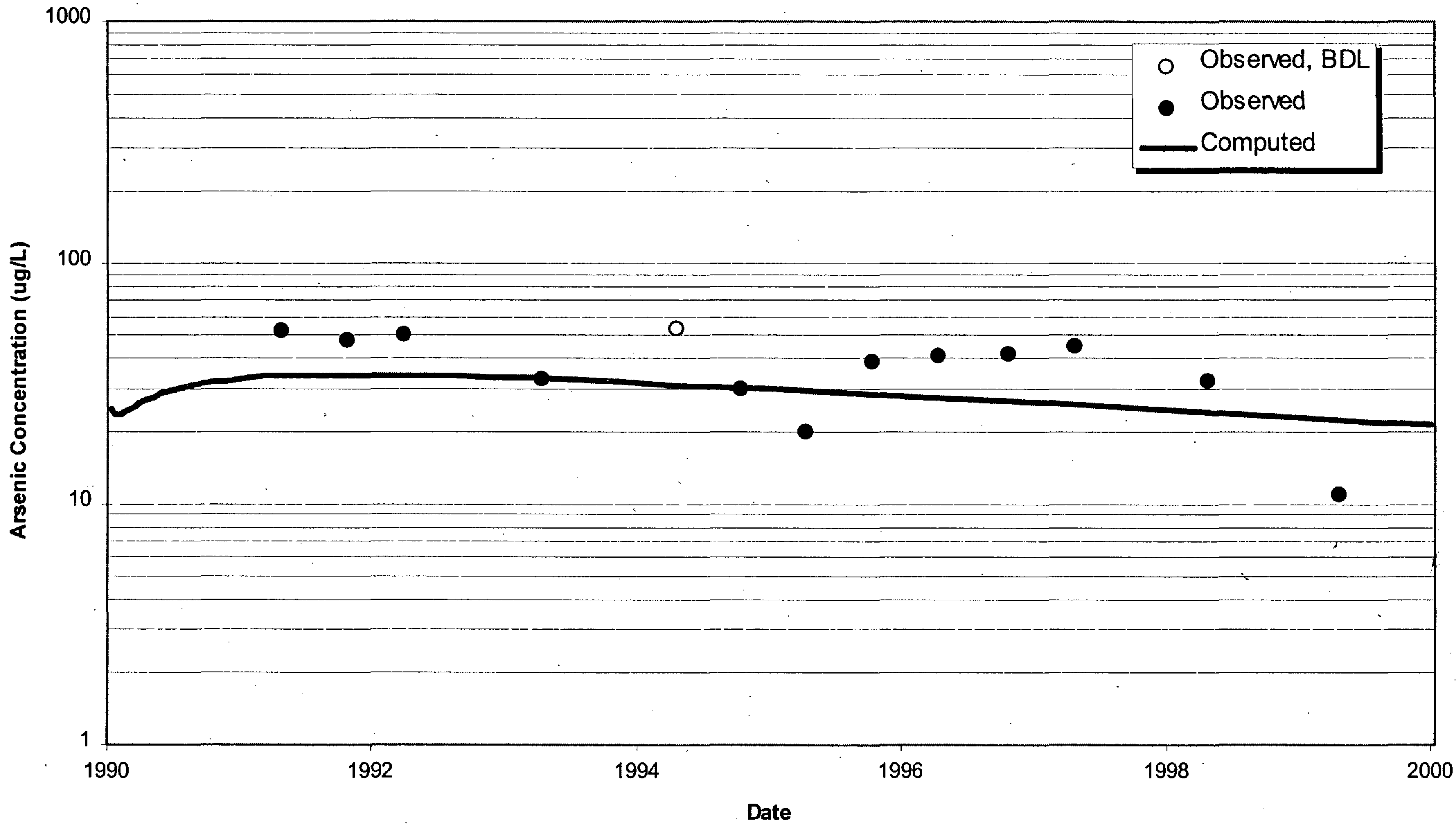

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW030

Date:	AUGUST 2002
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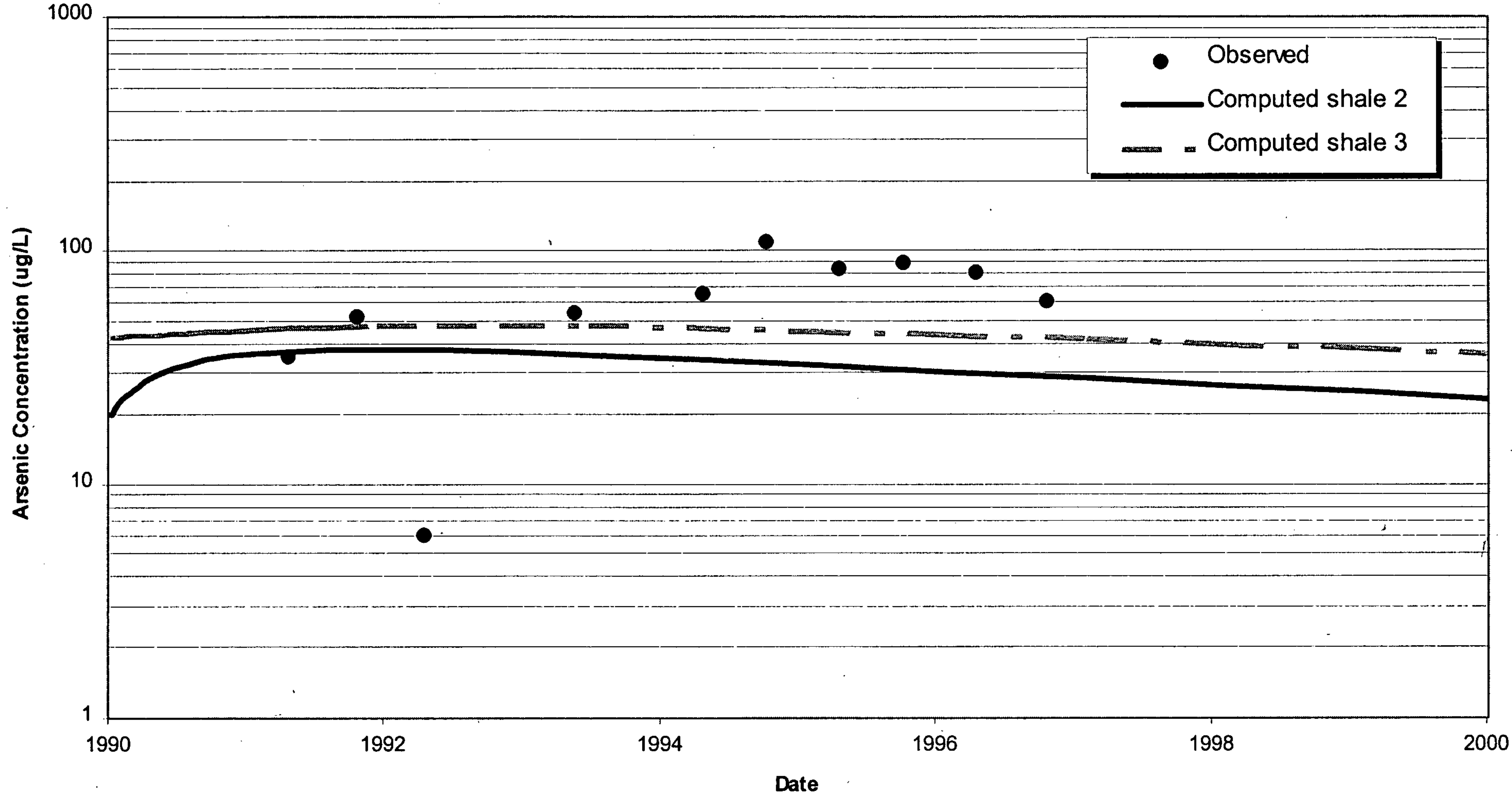

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW030A

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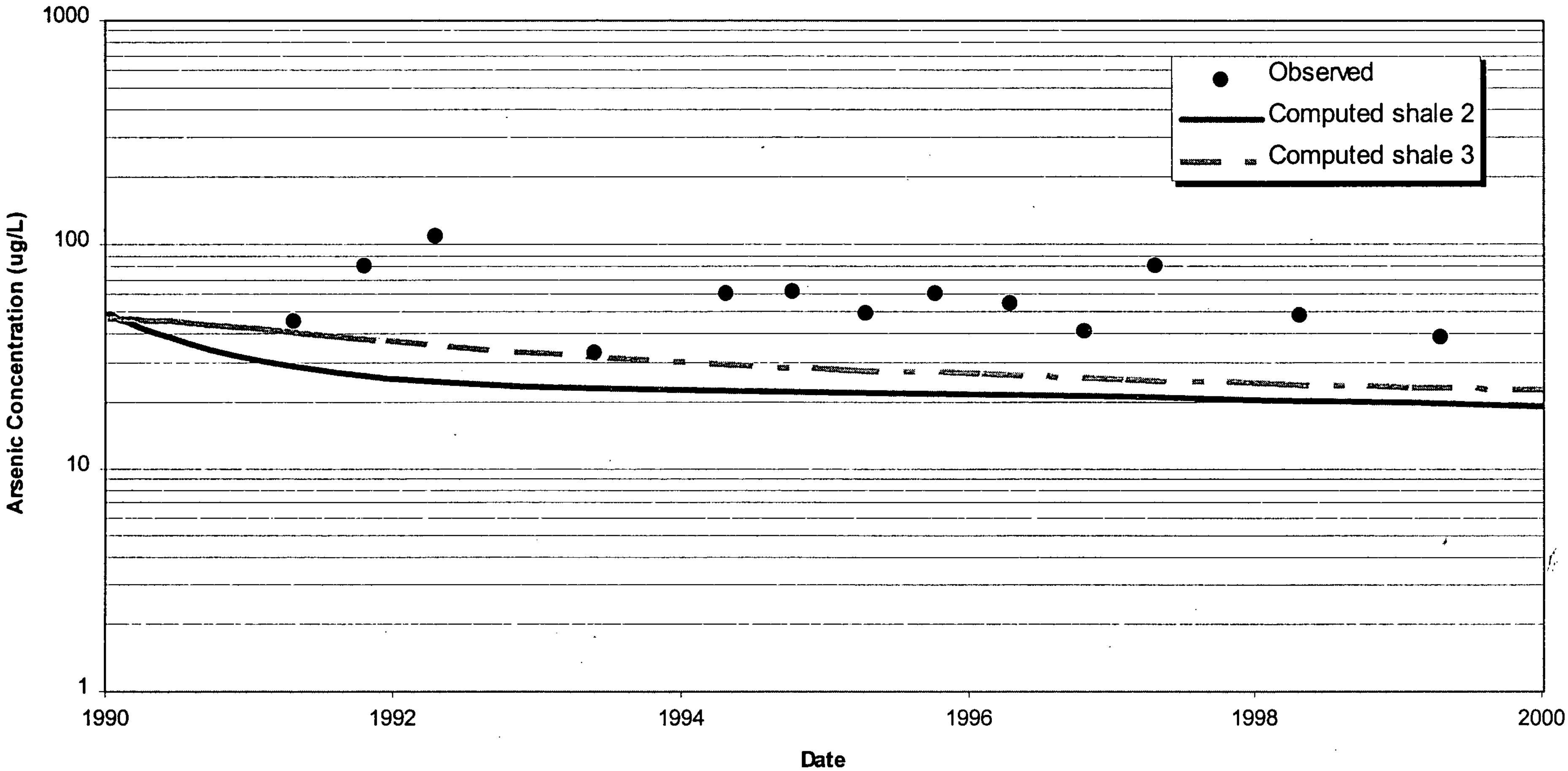

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW031A

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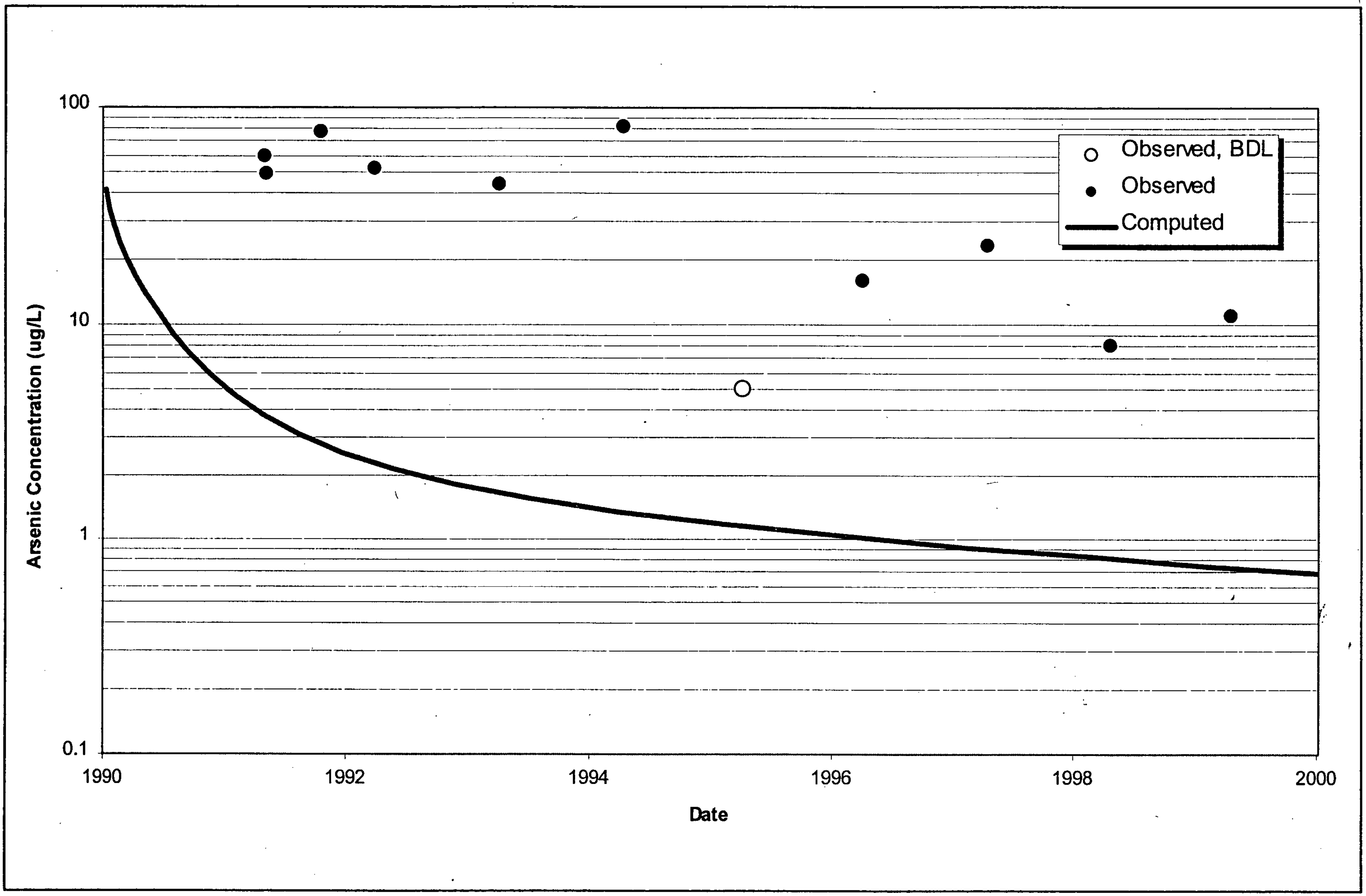

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW035

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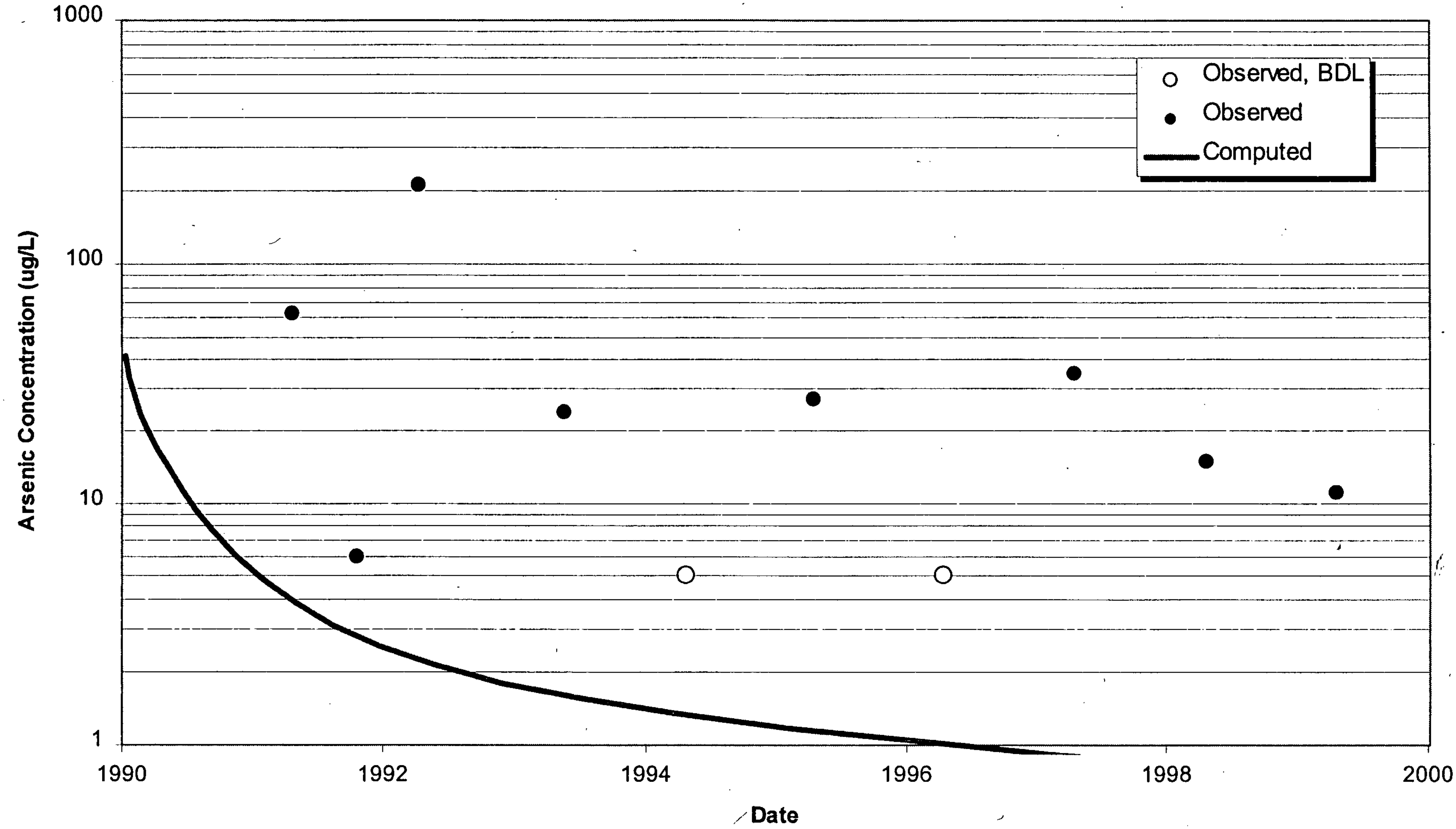

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW035A

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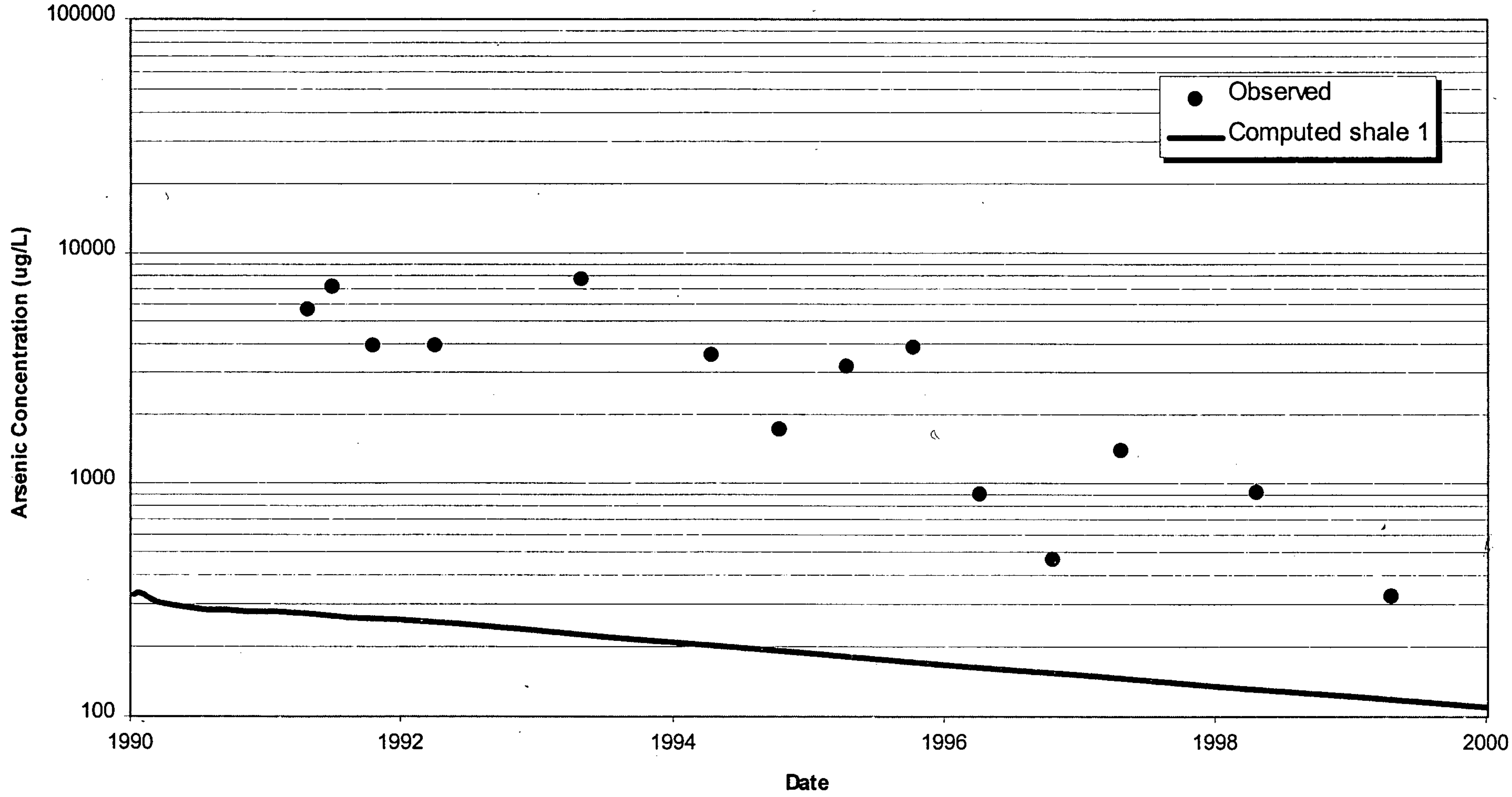

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW042

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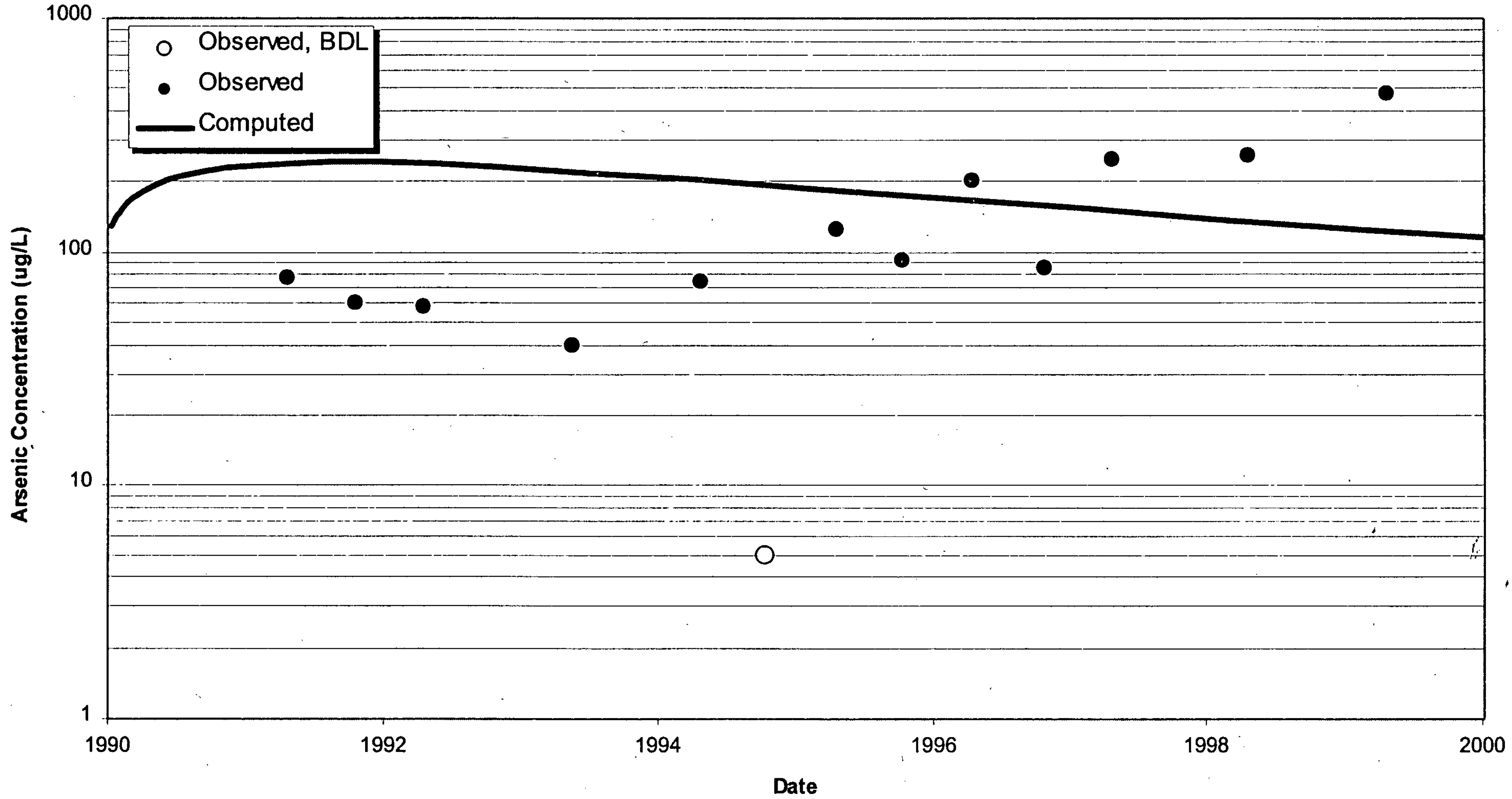

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW042A

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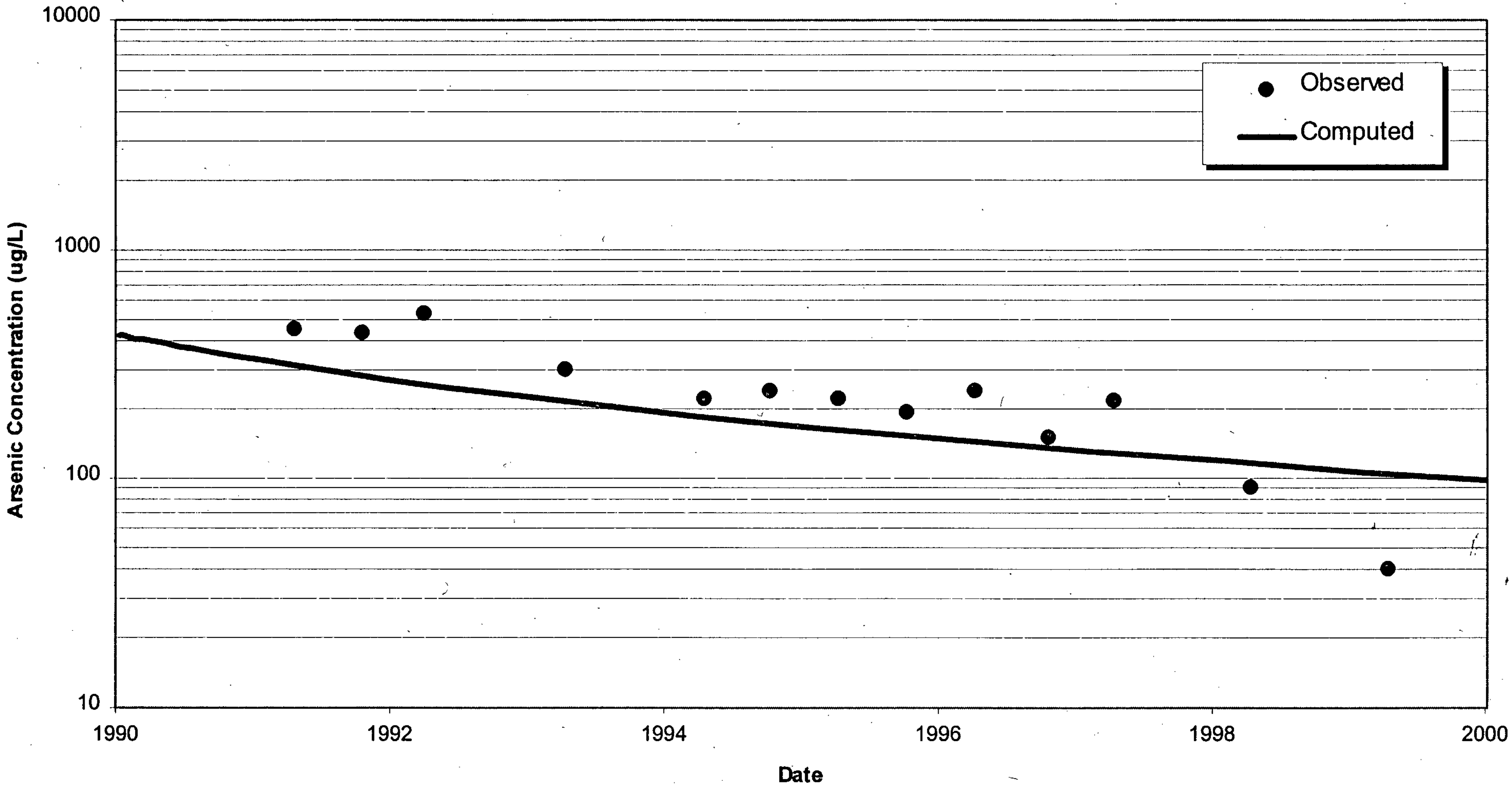

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FIGURE
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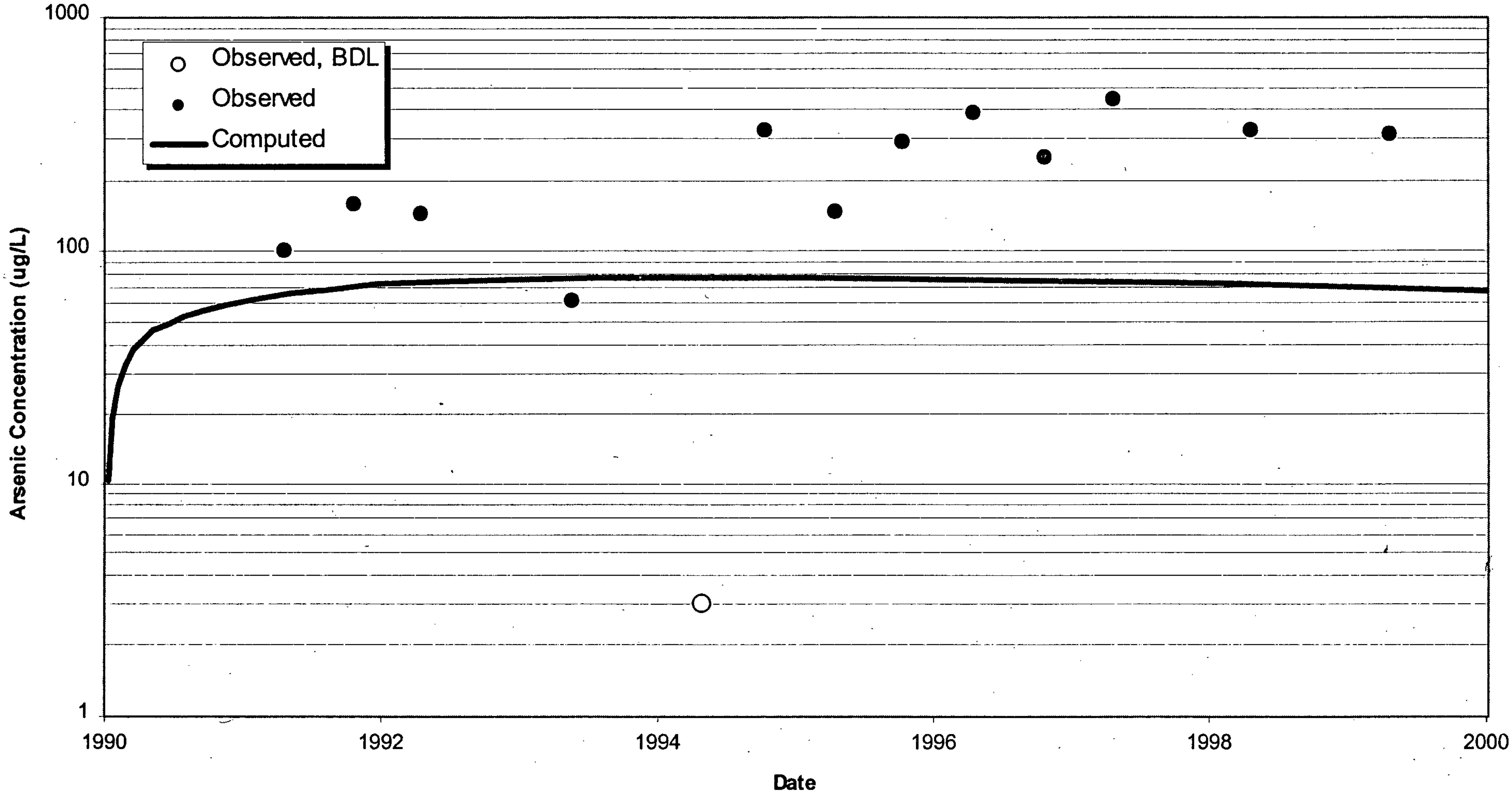

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FIGURE
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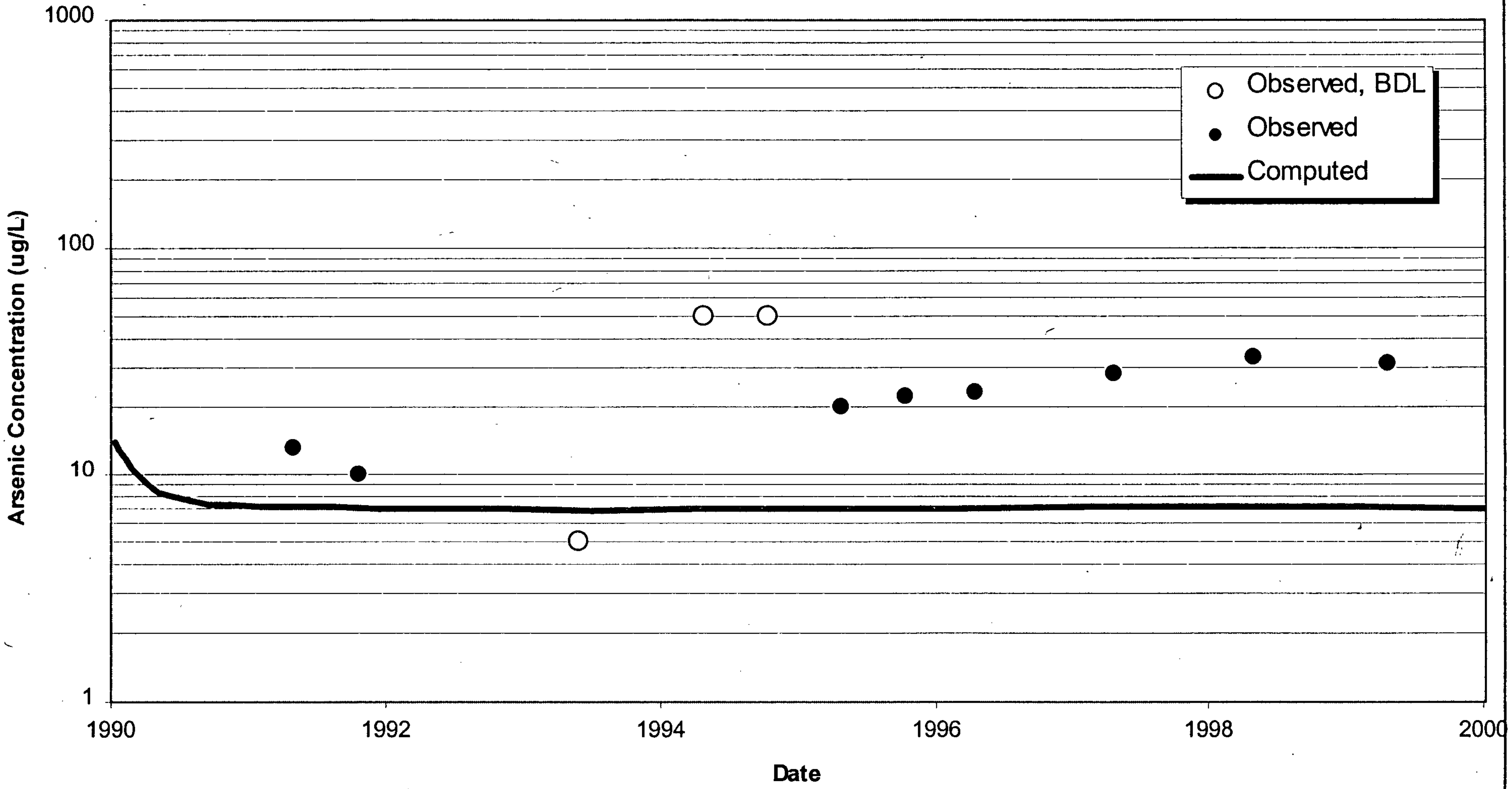

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FIGURE
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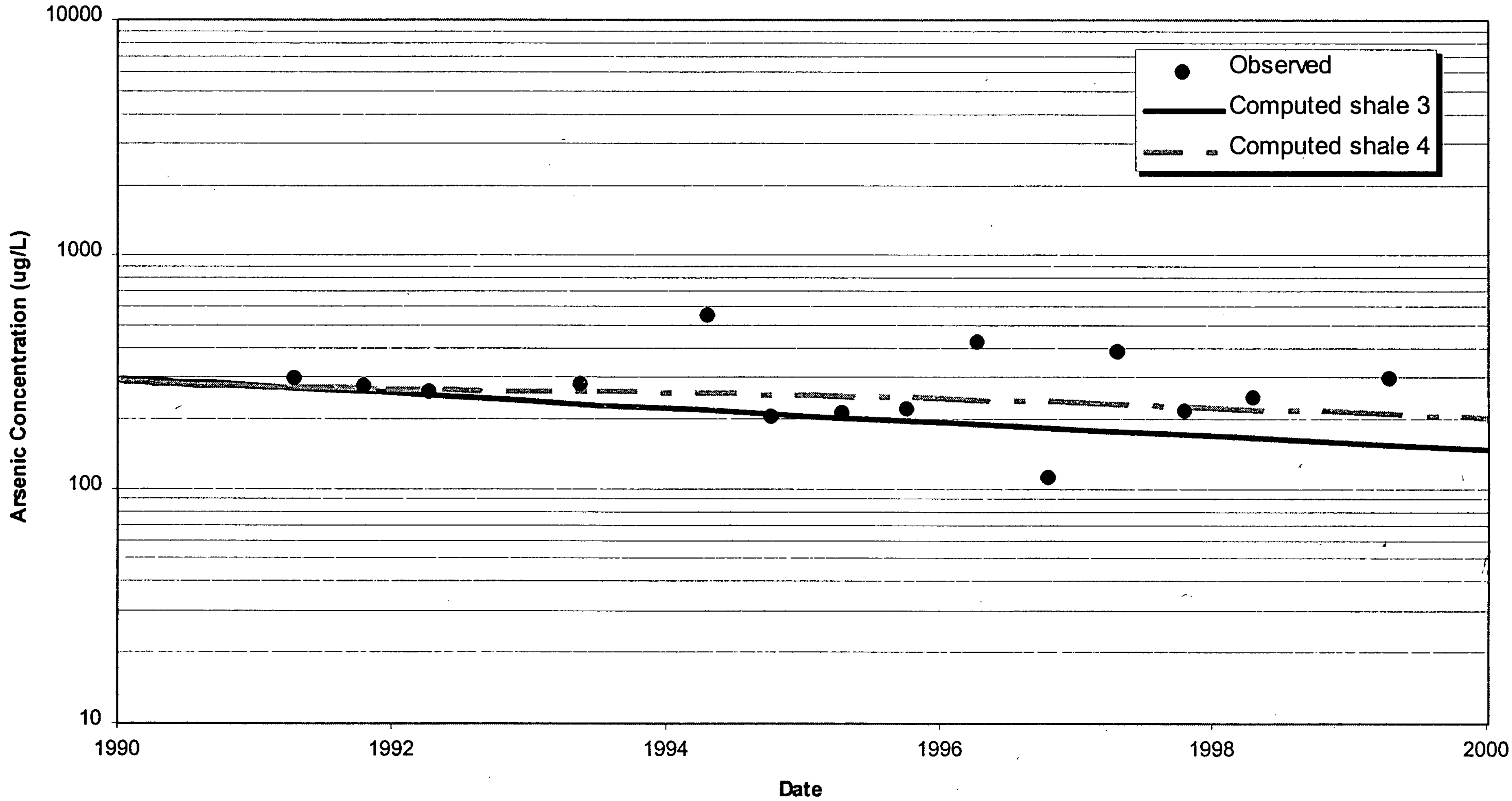

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FIGURE
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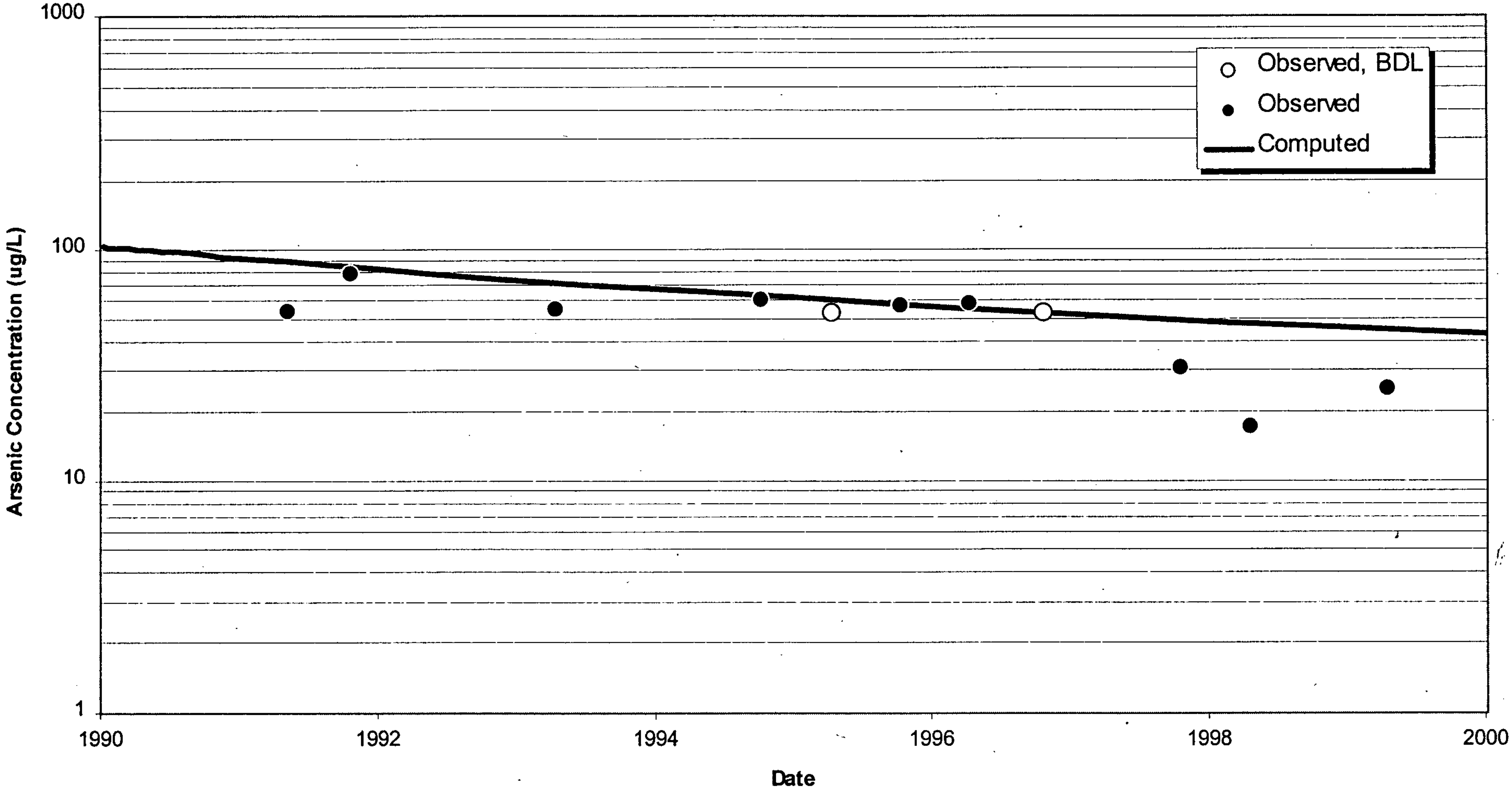

consulting scientists and engineers	FIGURE ARSENIC TRANSPORT CALIBRATION FOR WELL MW055

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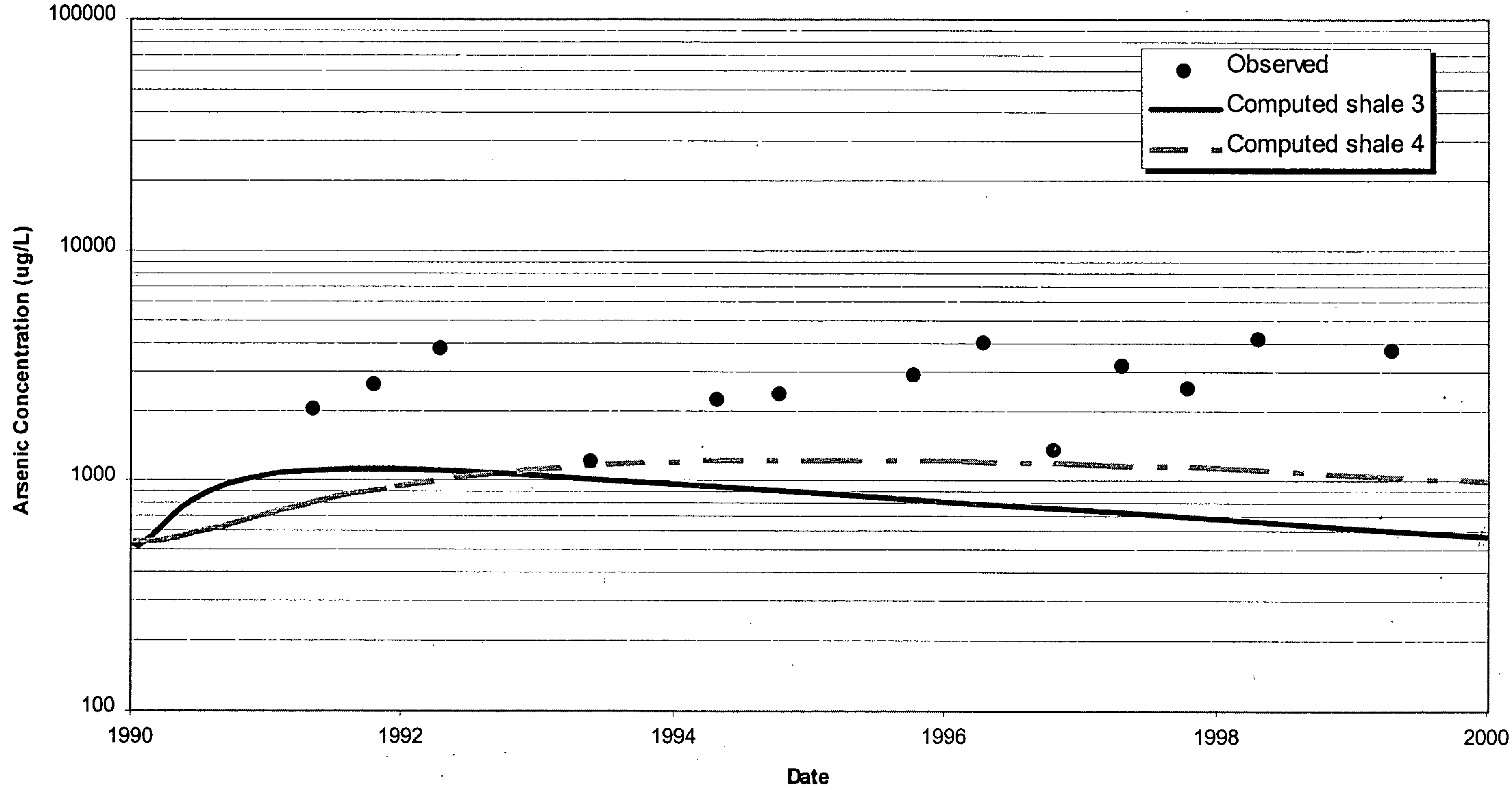

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW057A

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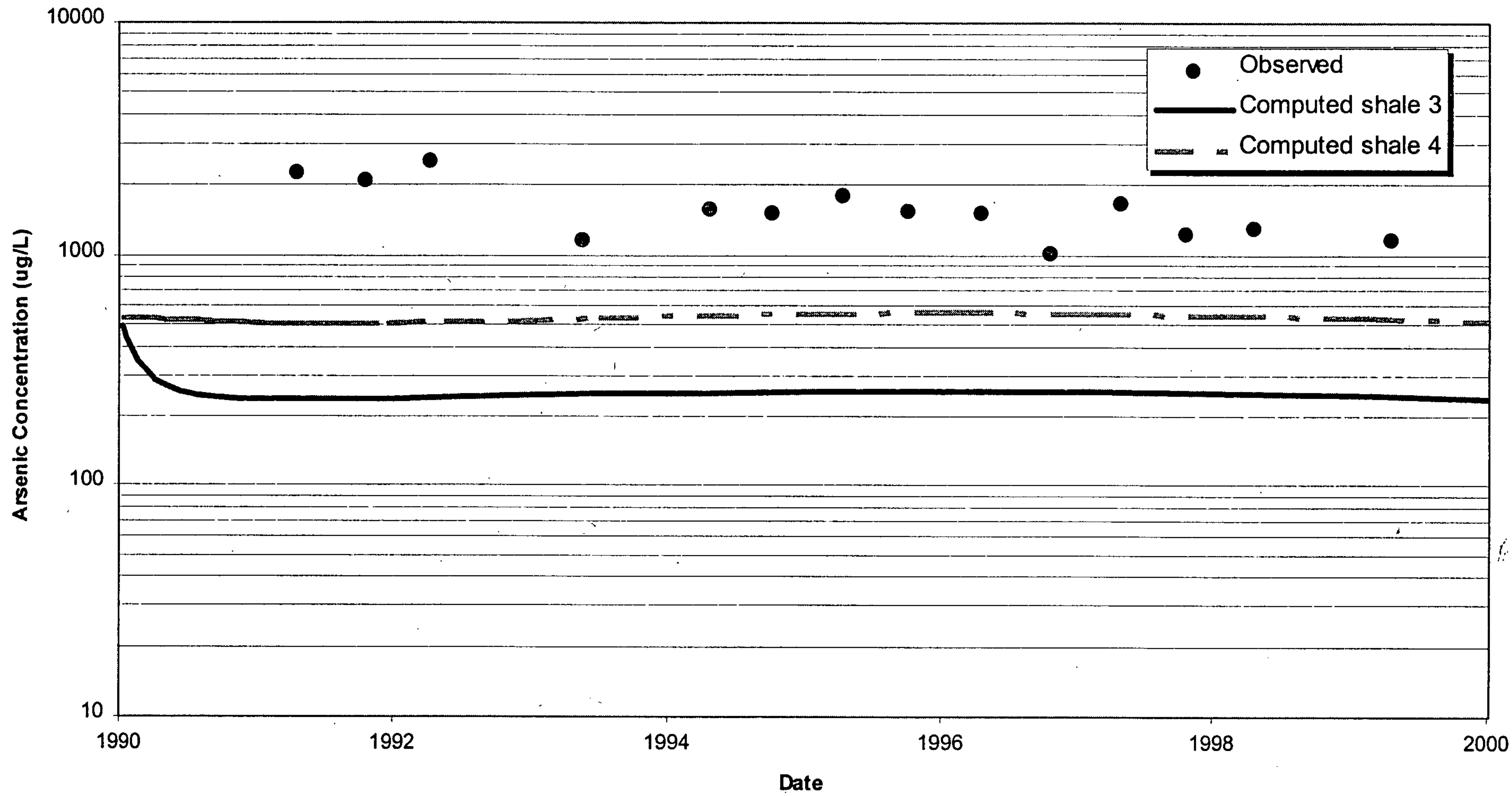

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW058A

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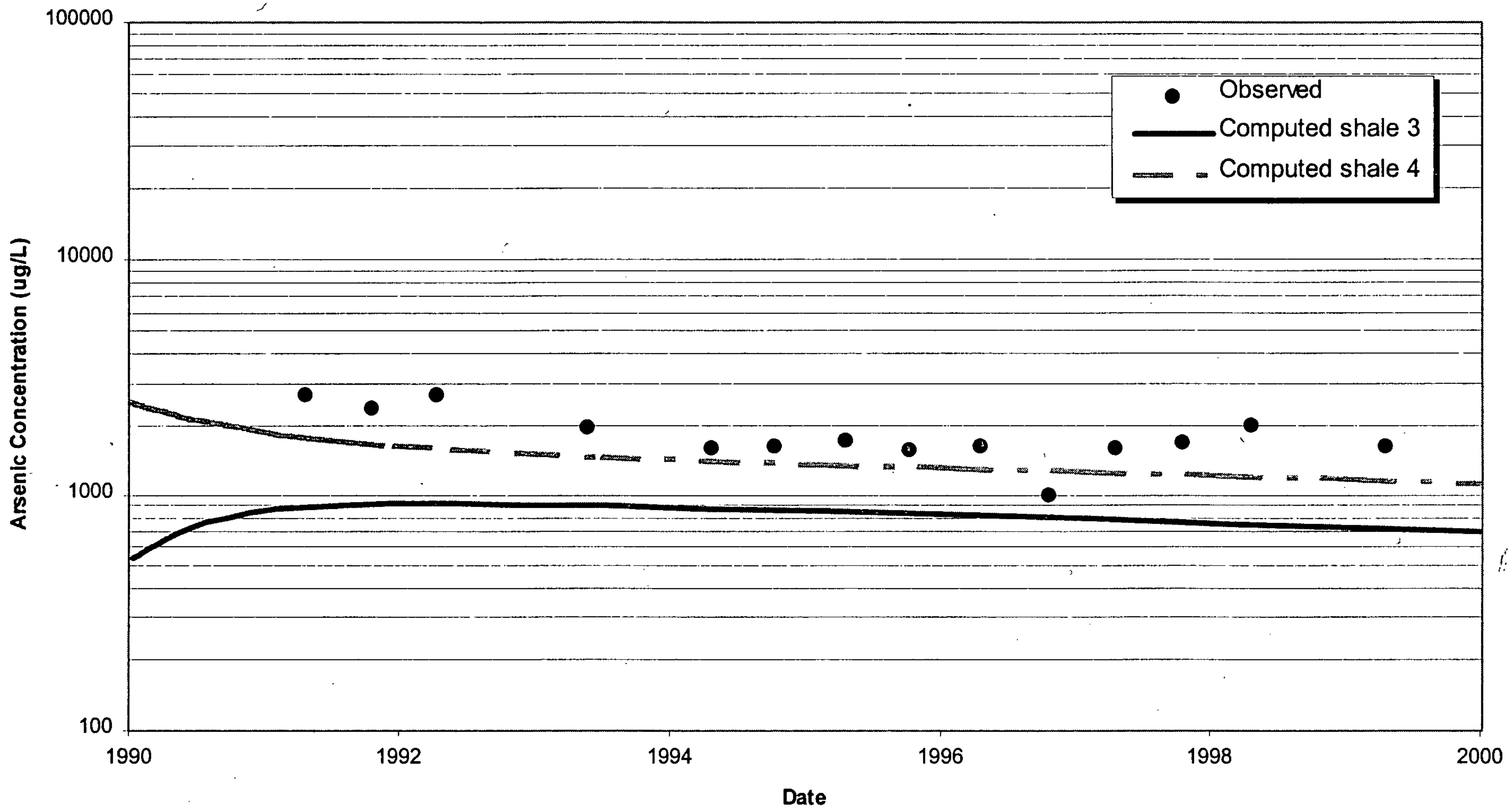

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW059A

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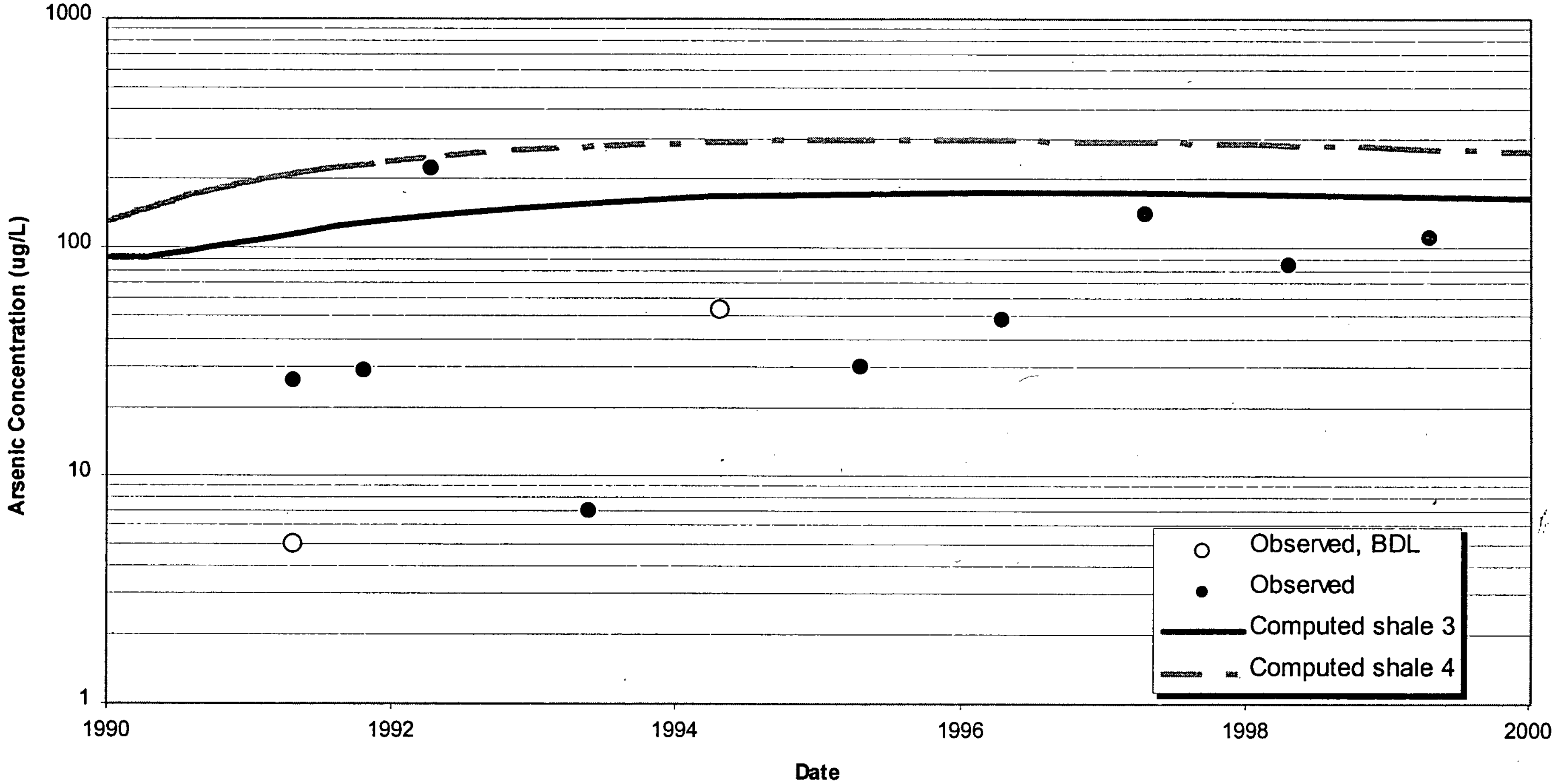

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW060A

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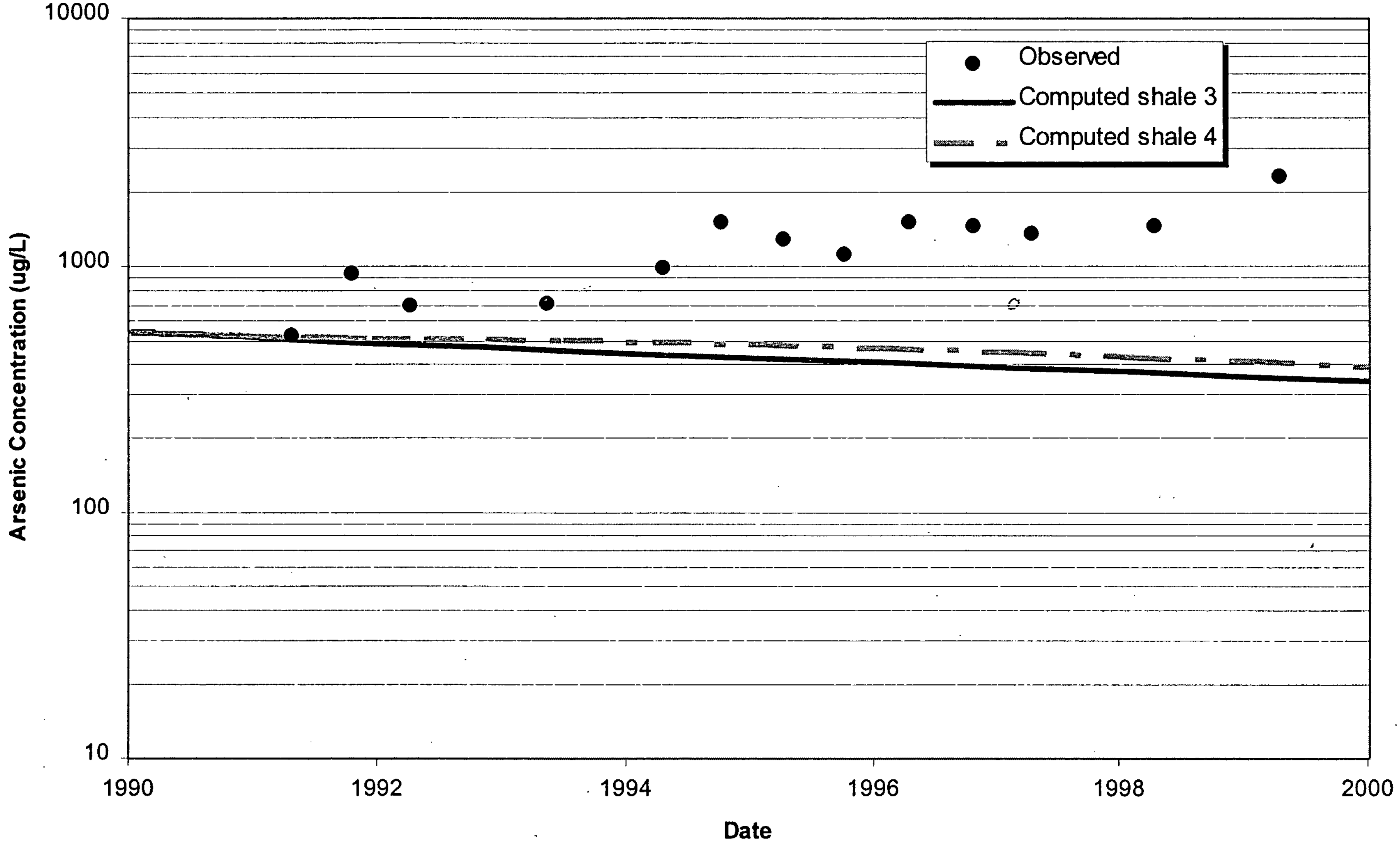

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW061A

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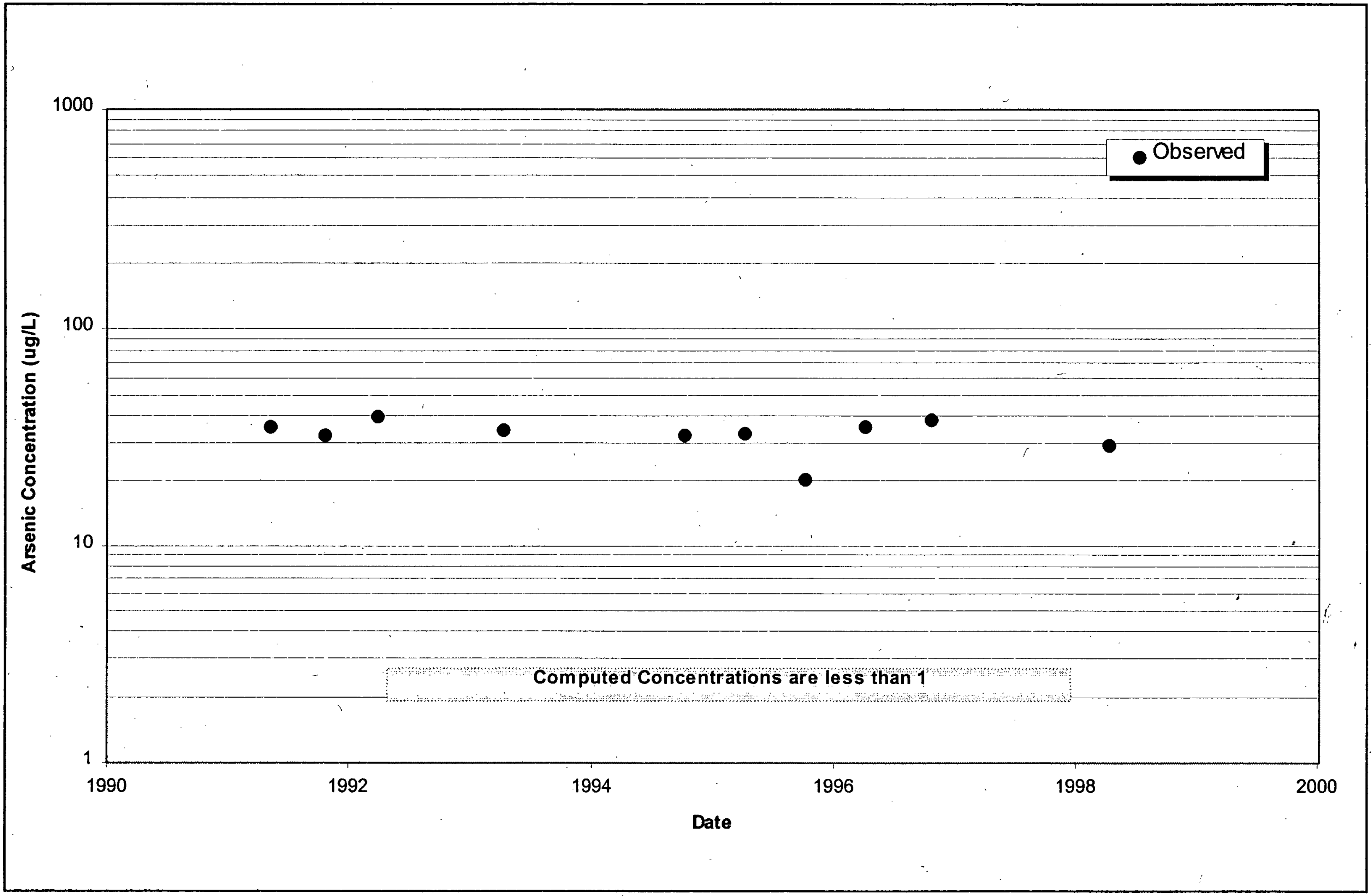

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FIGURE
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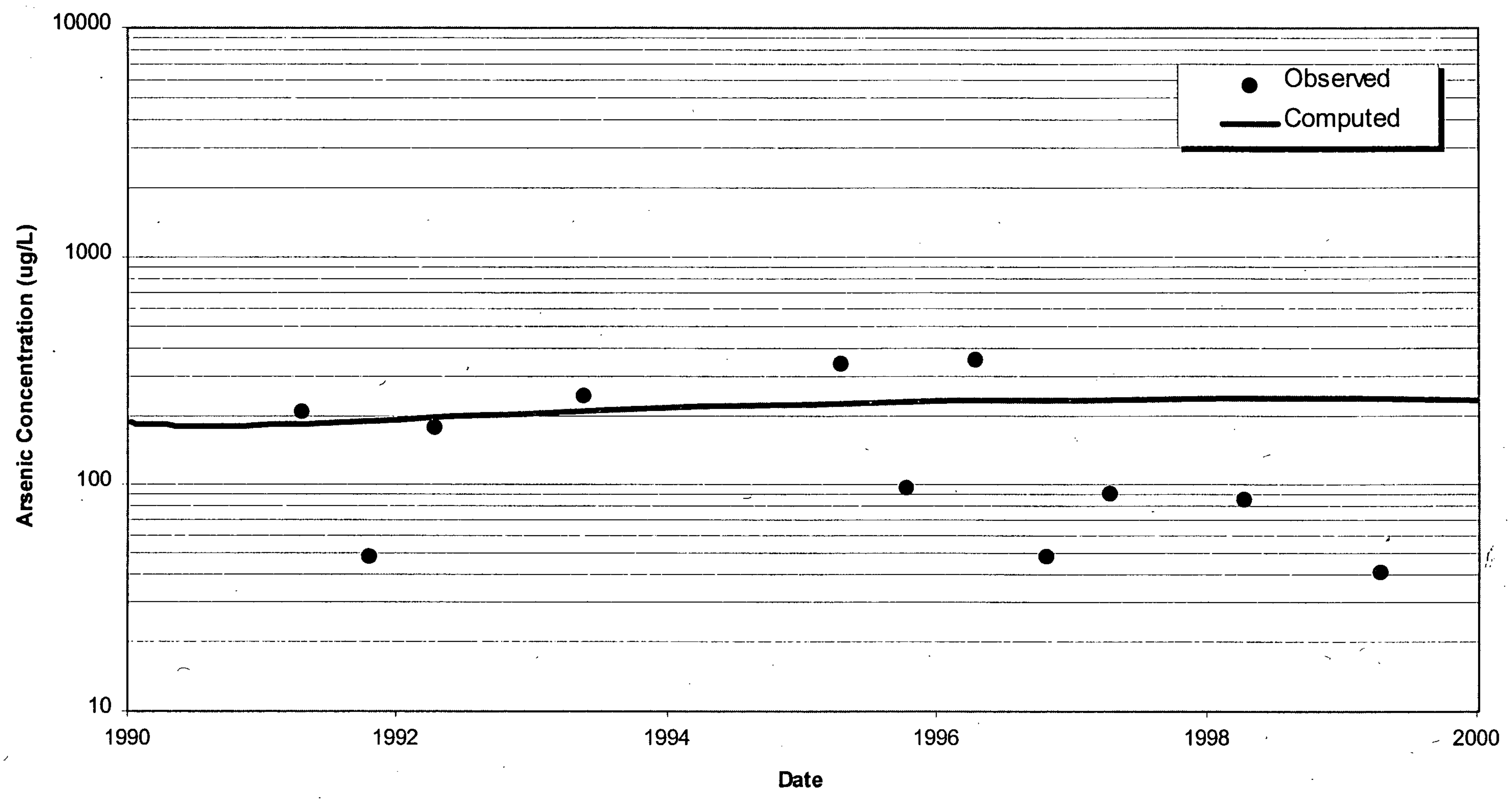

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FIGURE
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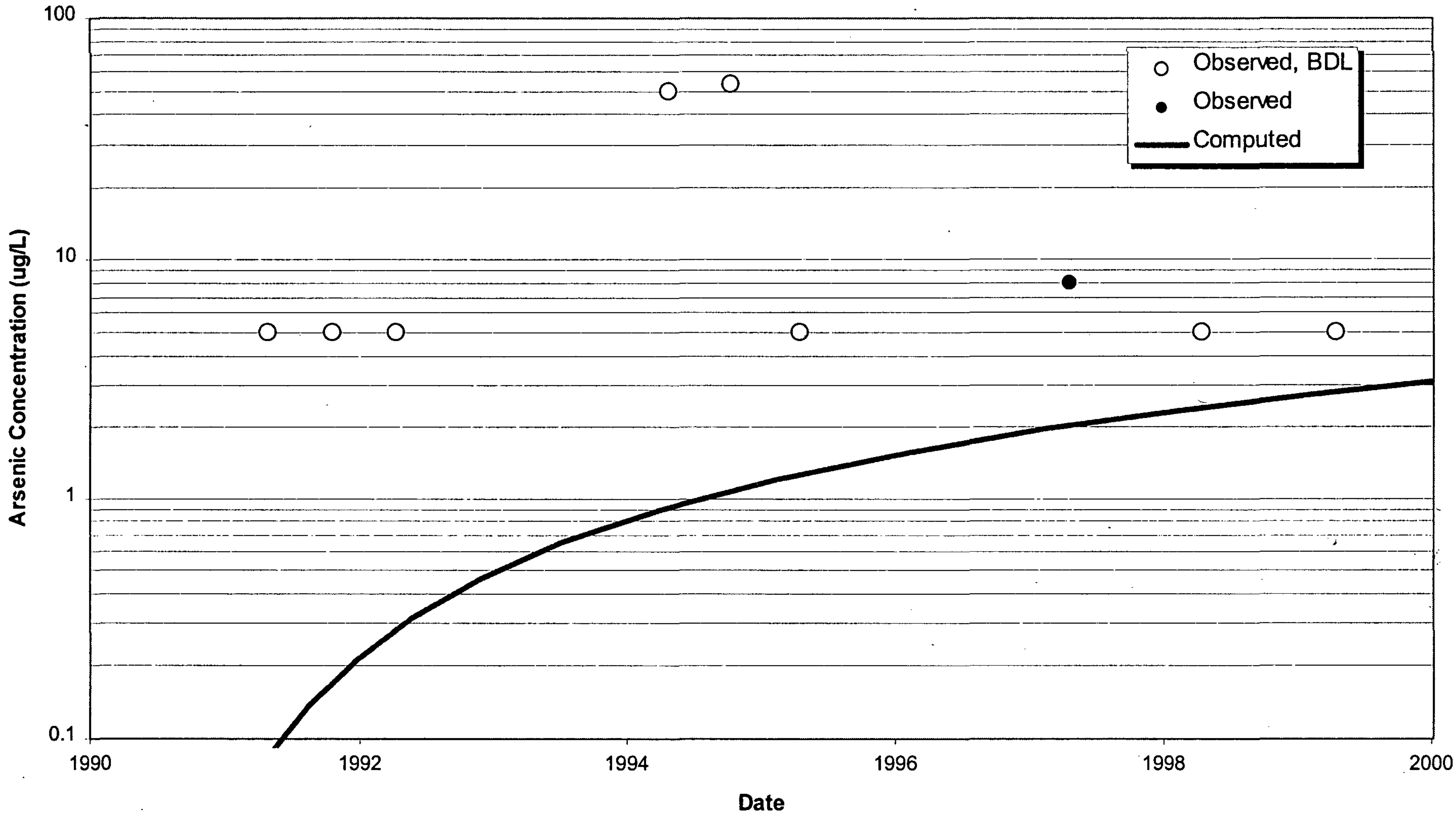

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FIGURE
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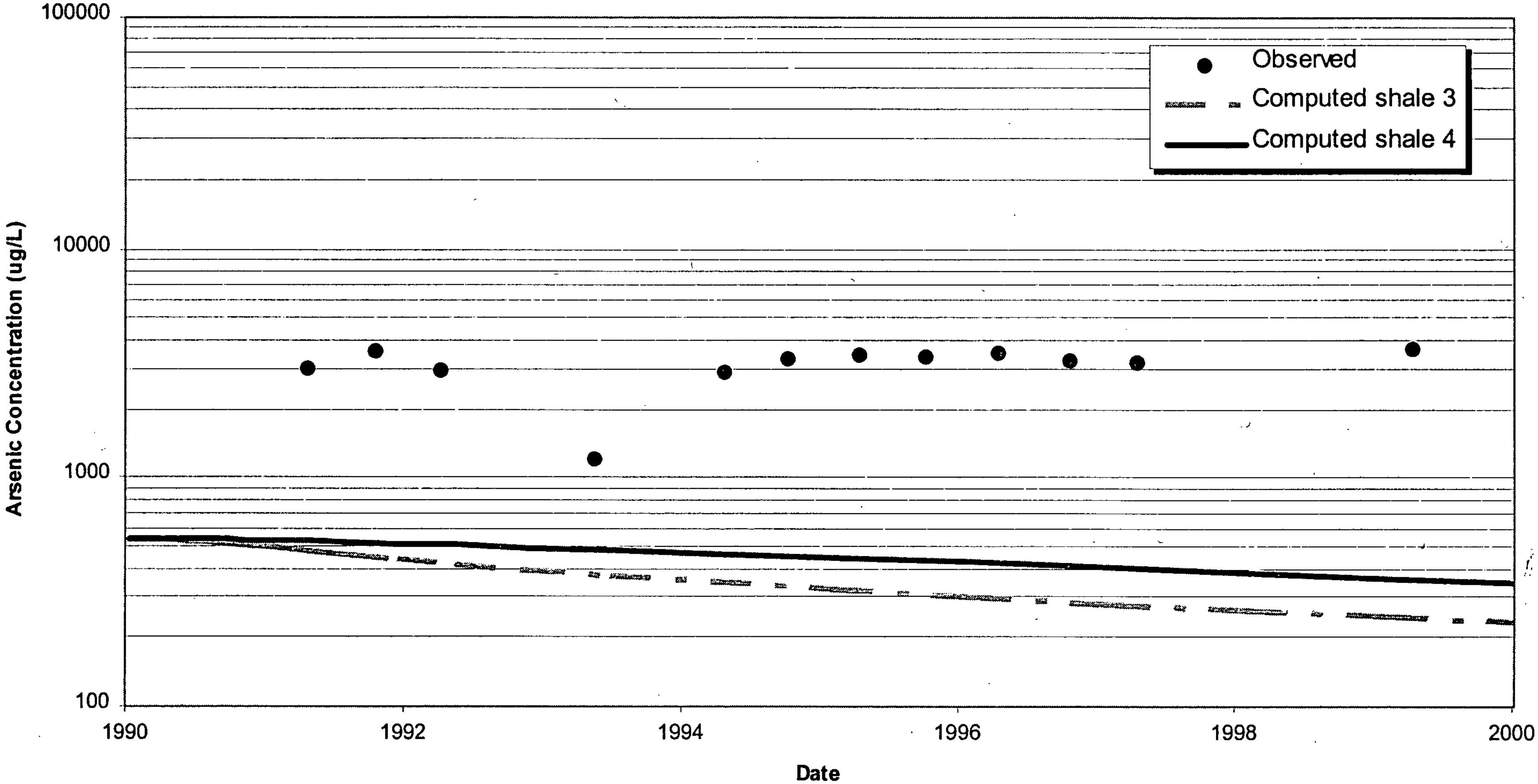

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FIGURE
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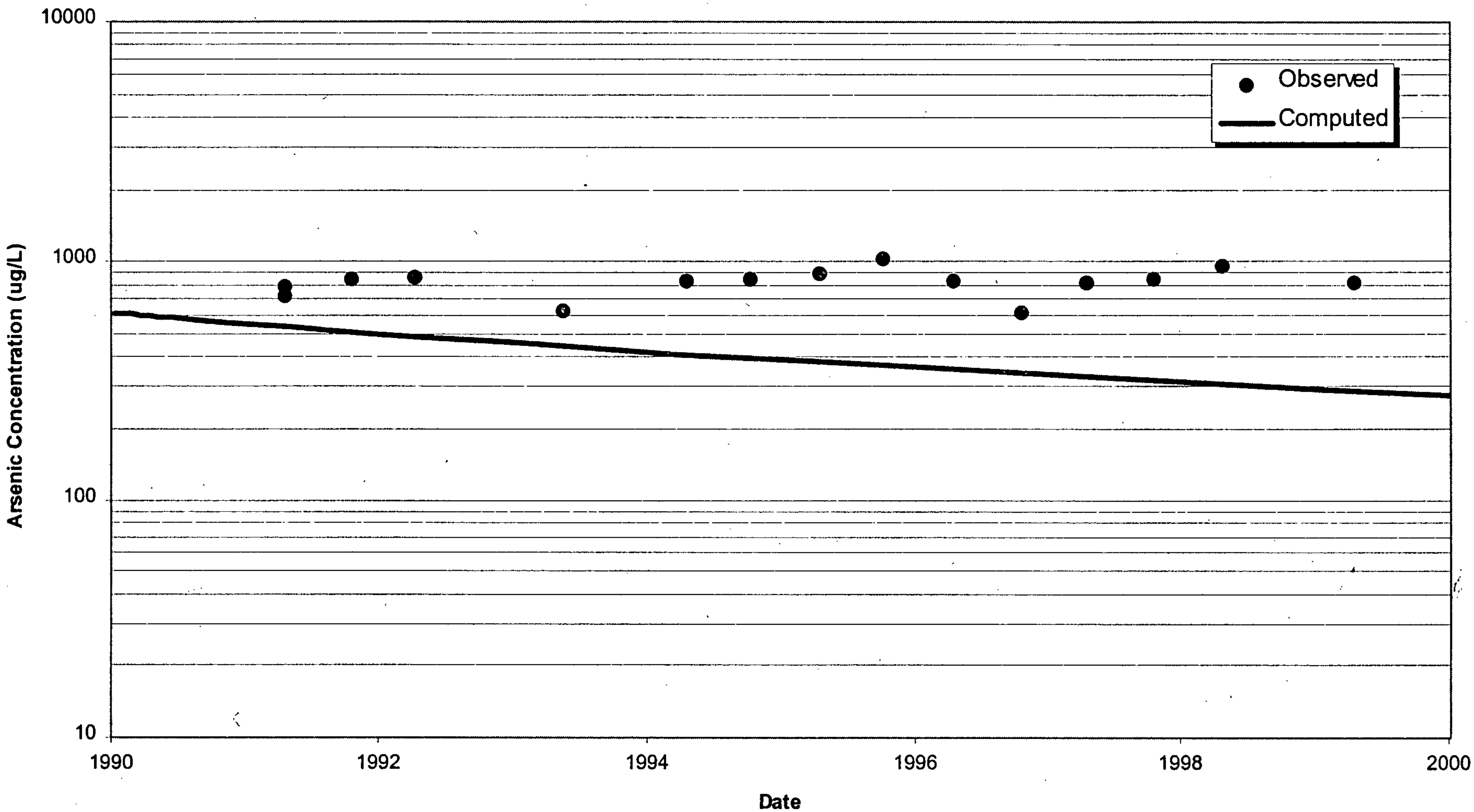

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW065A

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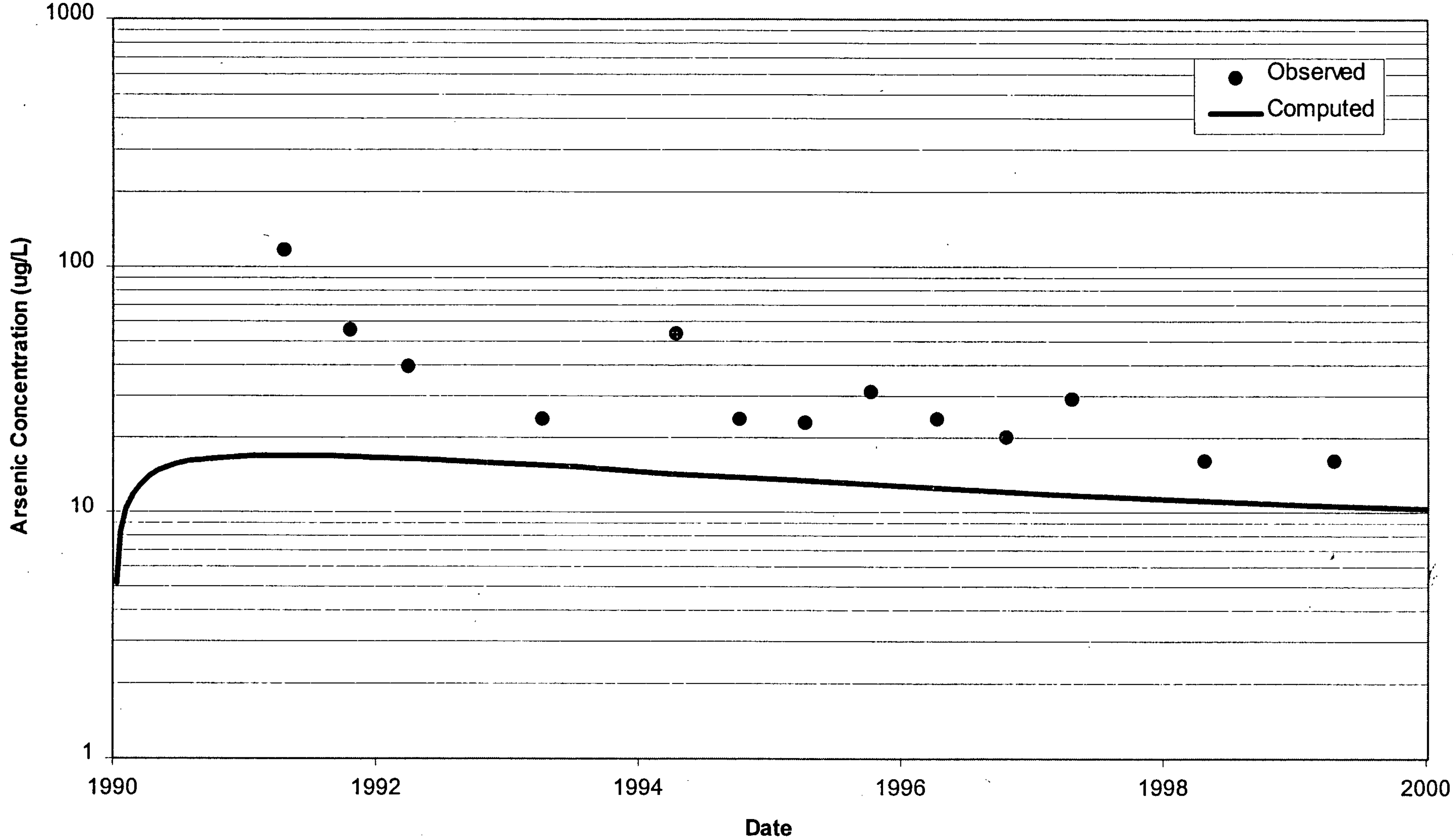

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FIGURE
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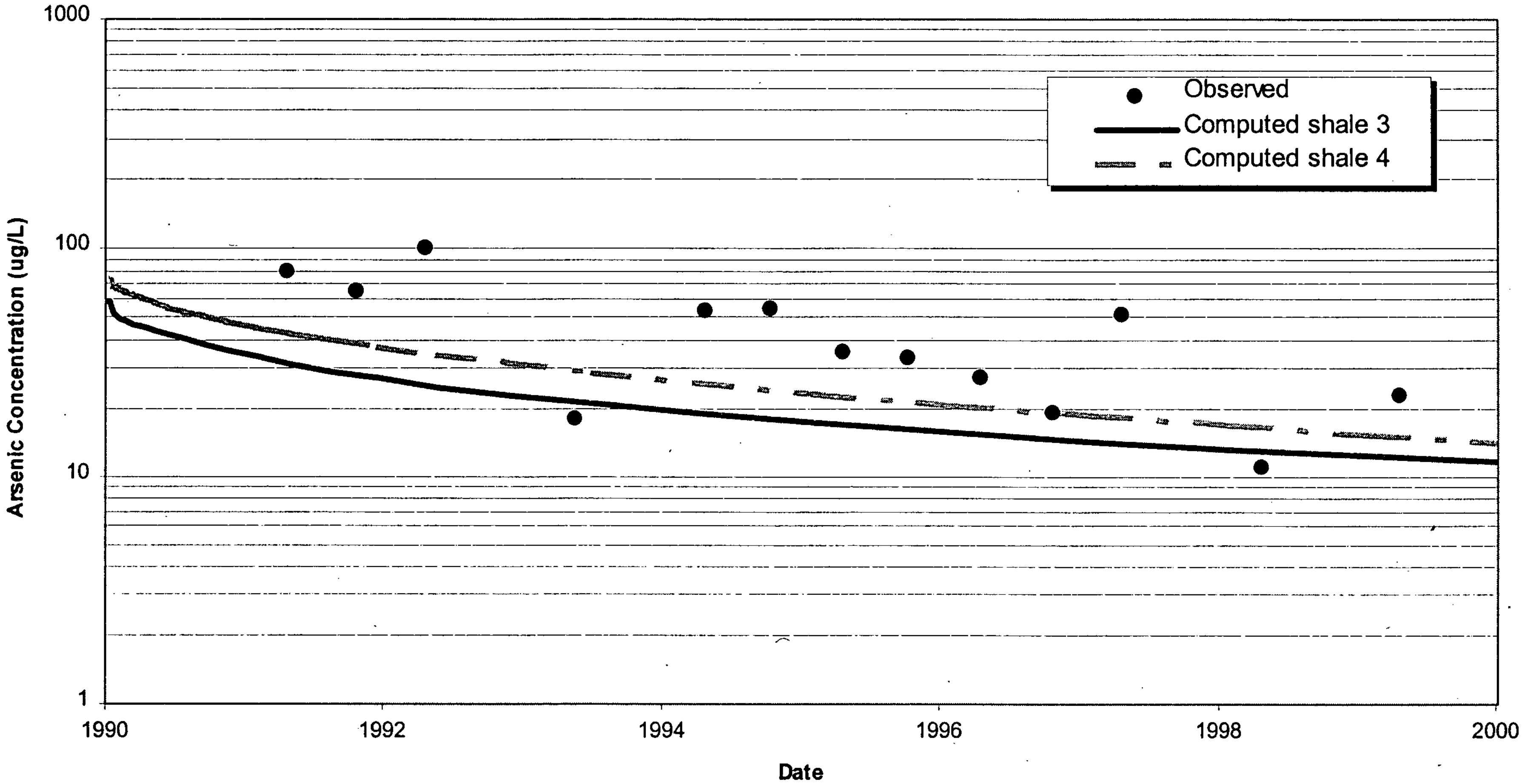

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FIGURE
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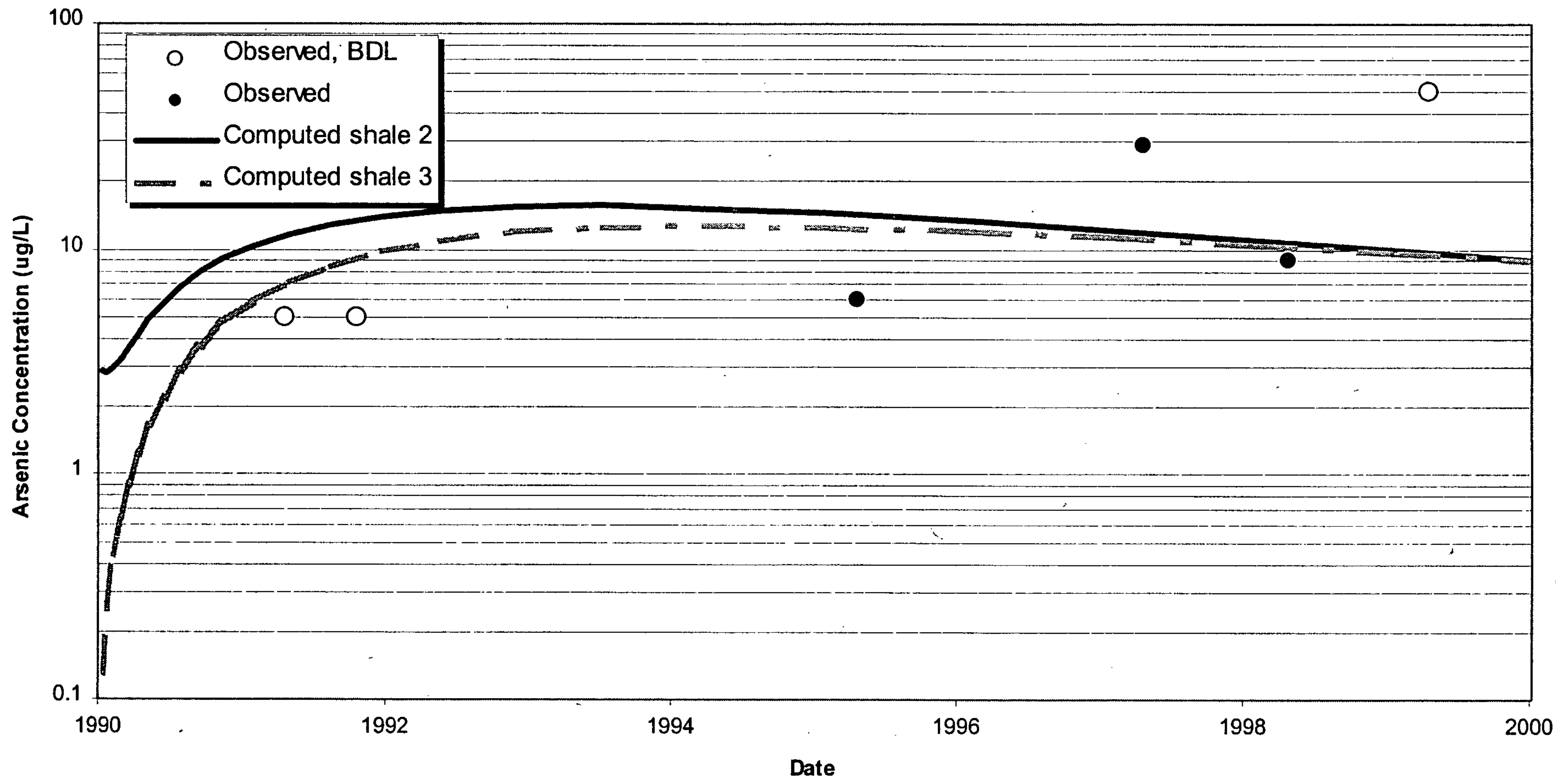

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FIGURE
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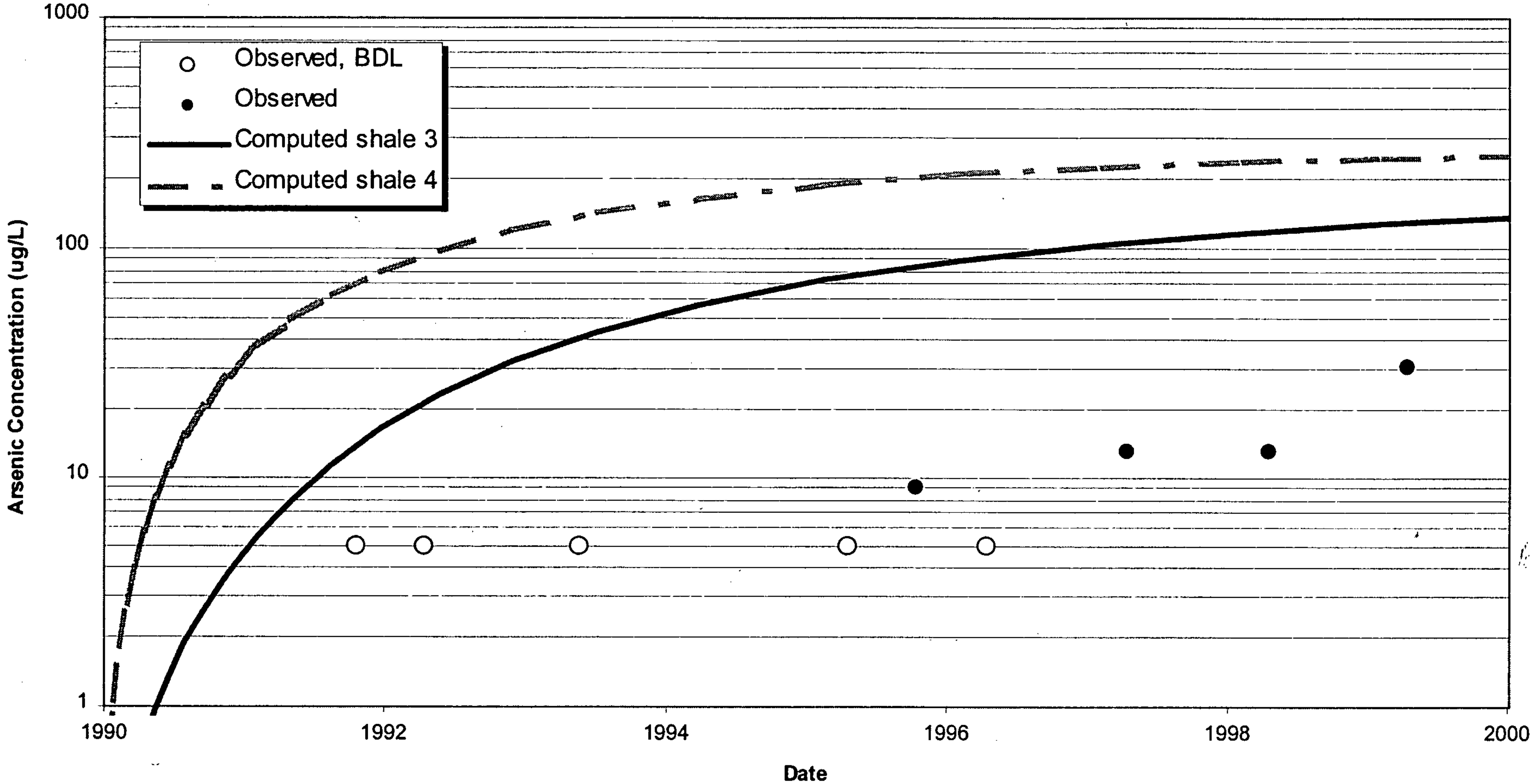

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FIGURE
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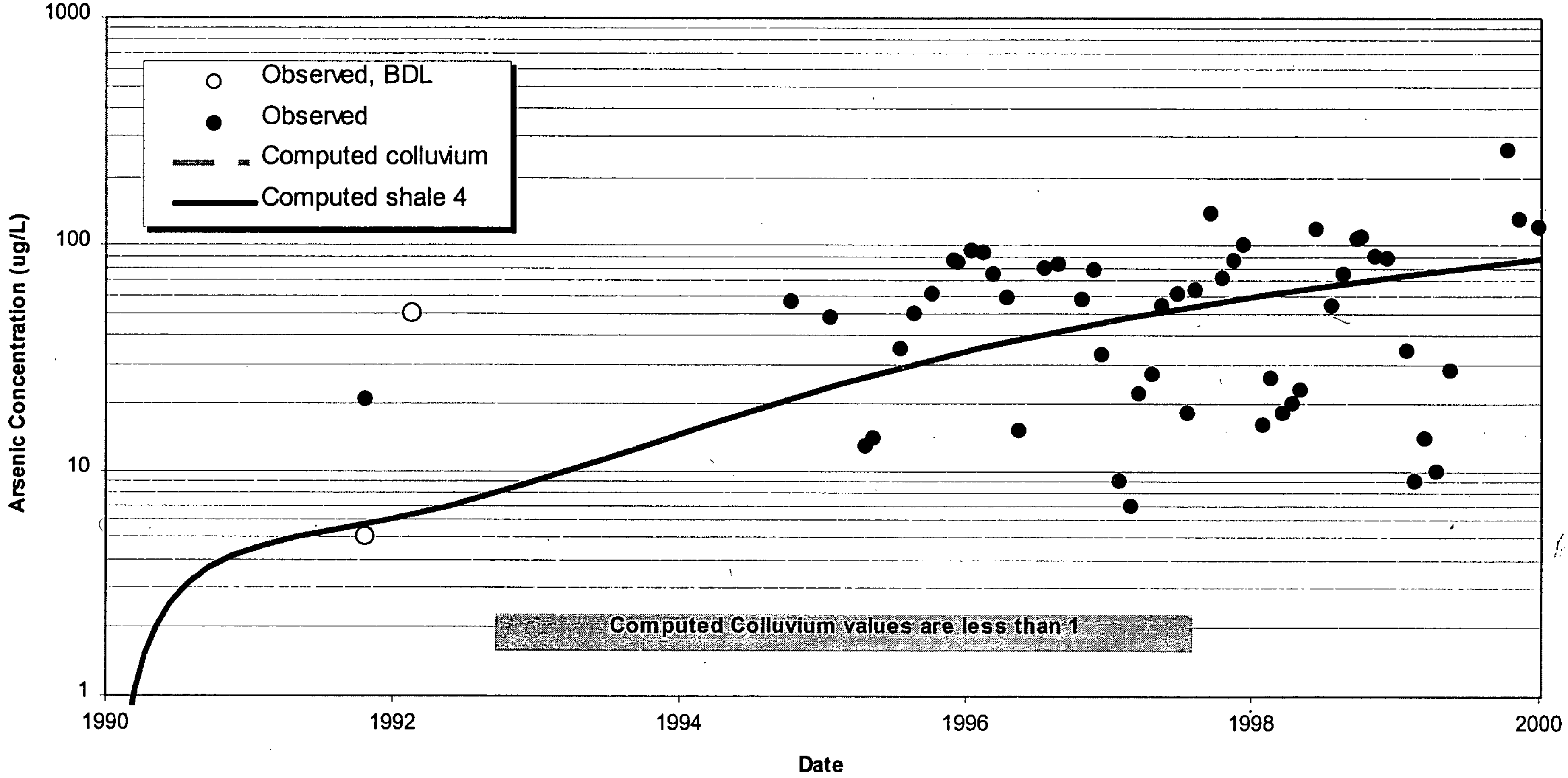

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FIGURE
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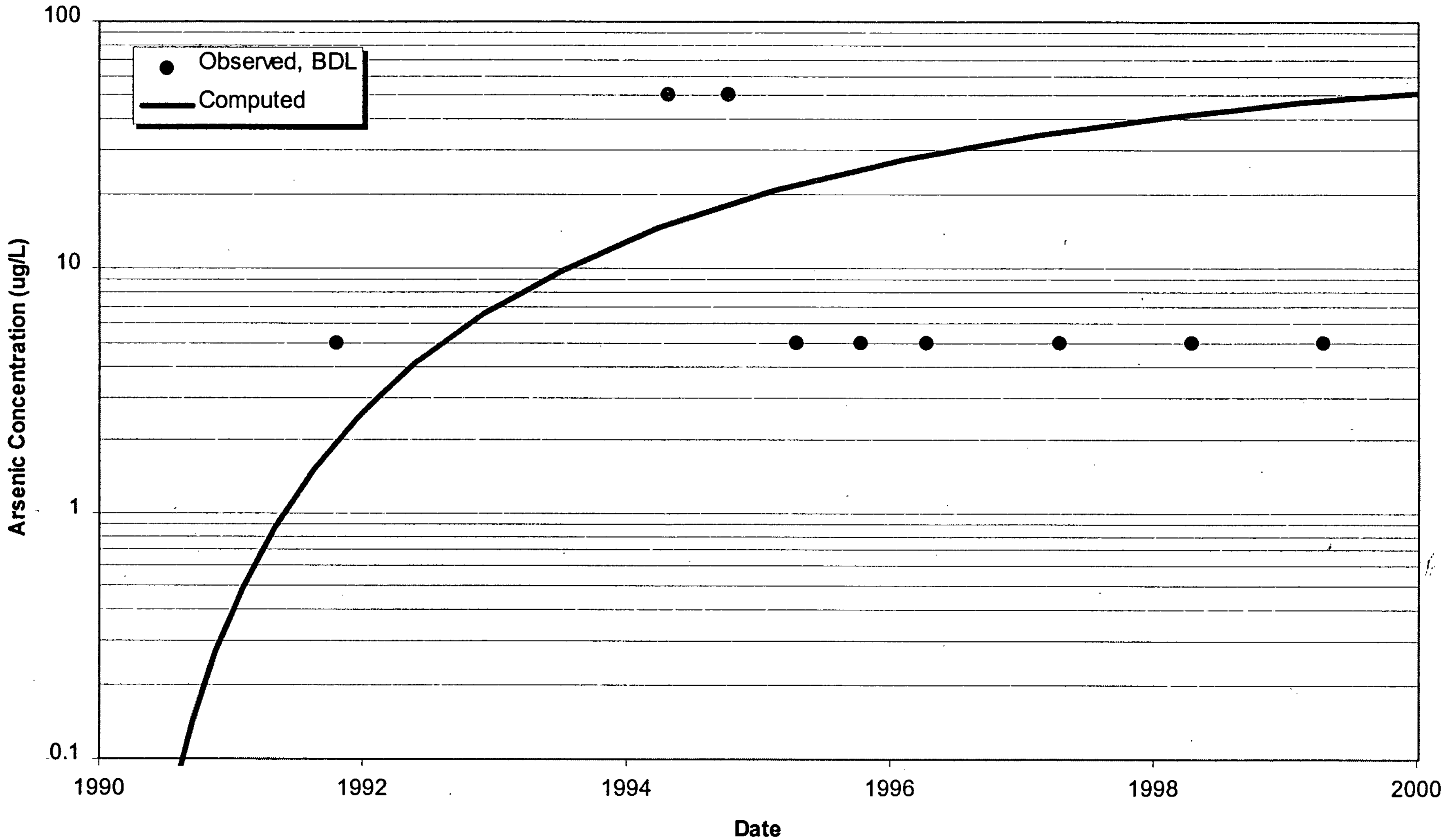

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FIGURE
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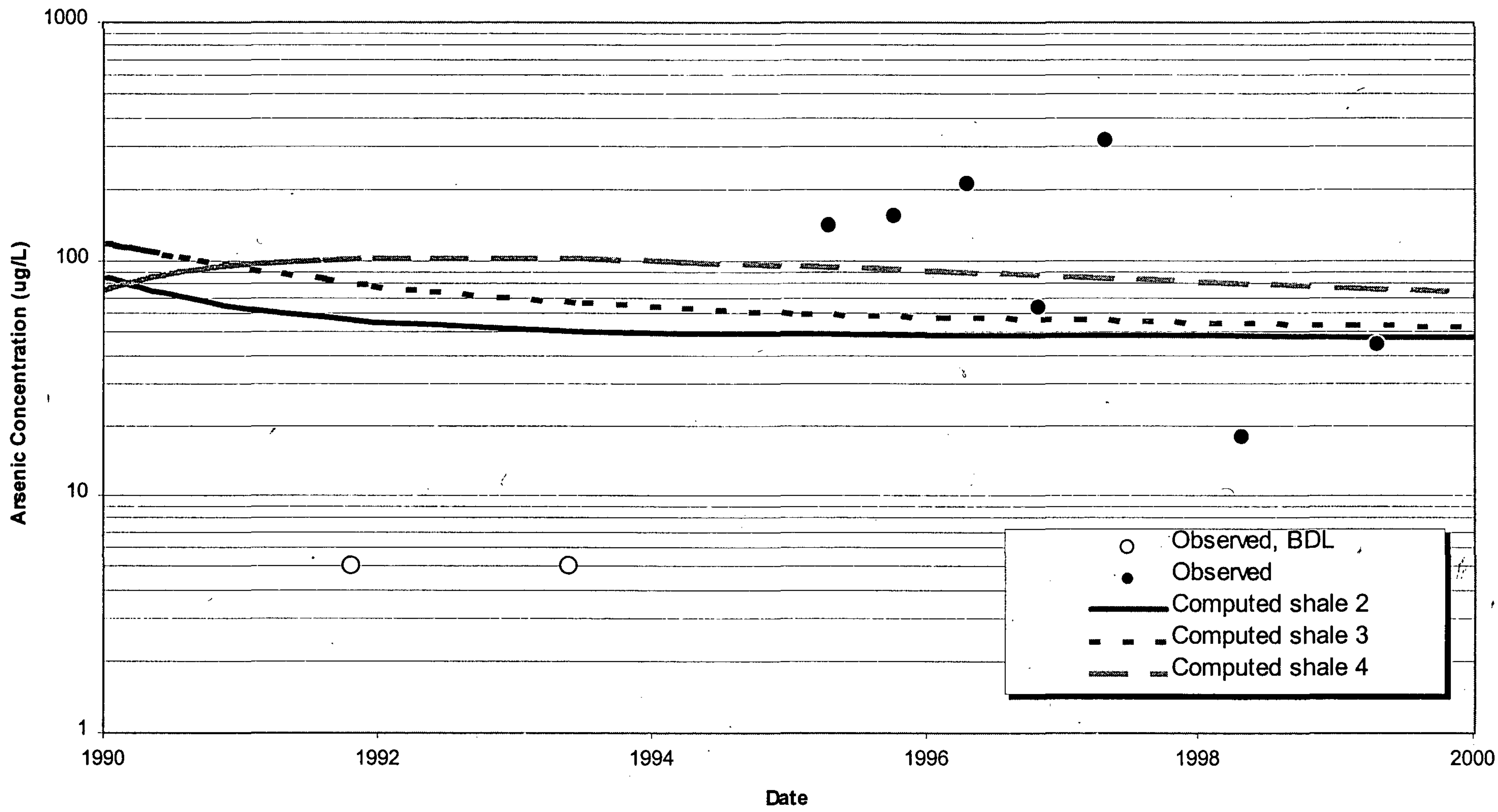

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FIGURE
ARSENIC TRANSPORT CALIBRATION FOR WELL MW102A

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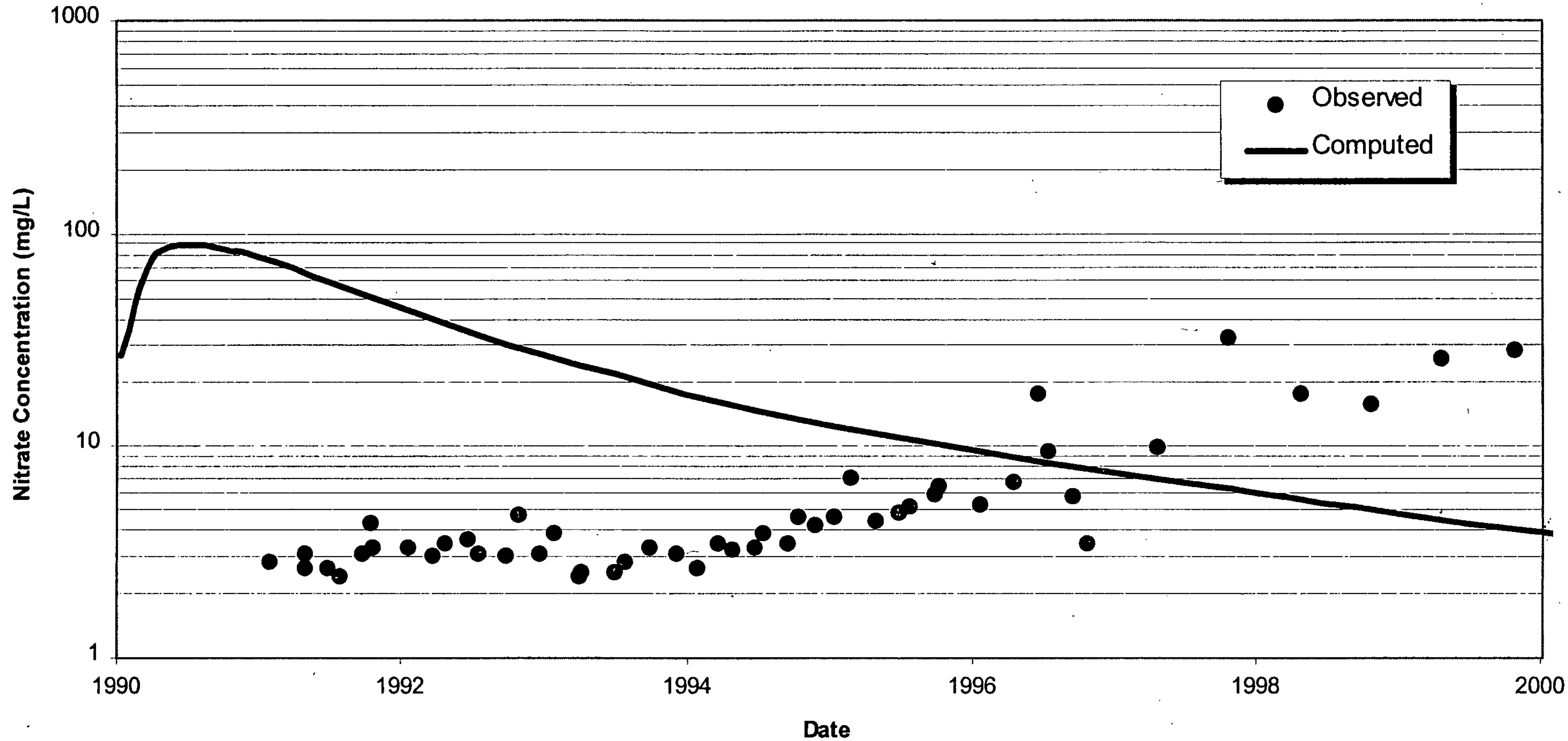

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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2301B

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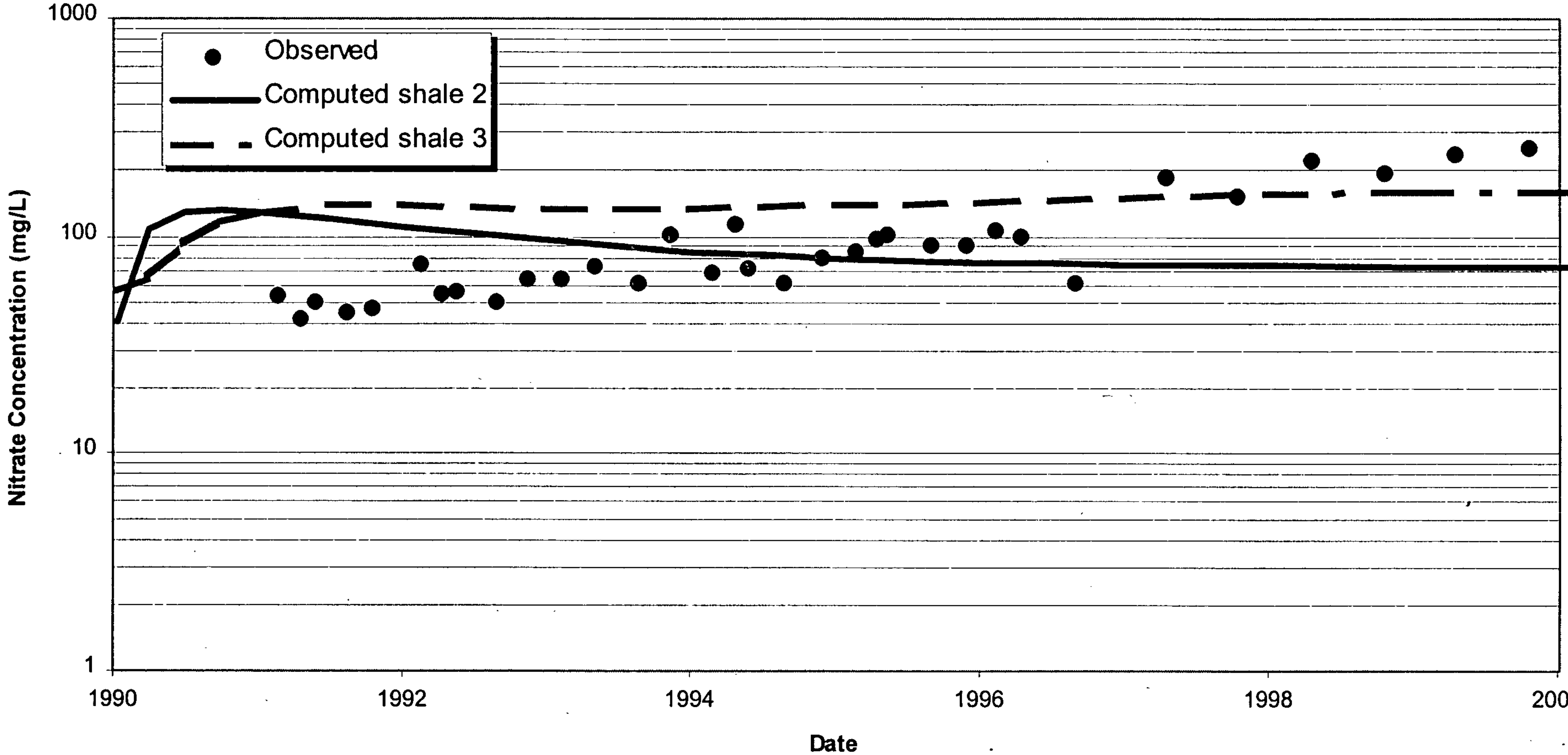

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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2303A

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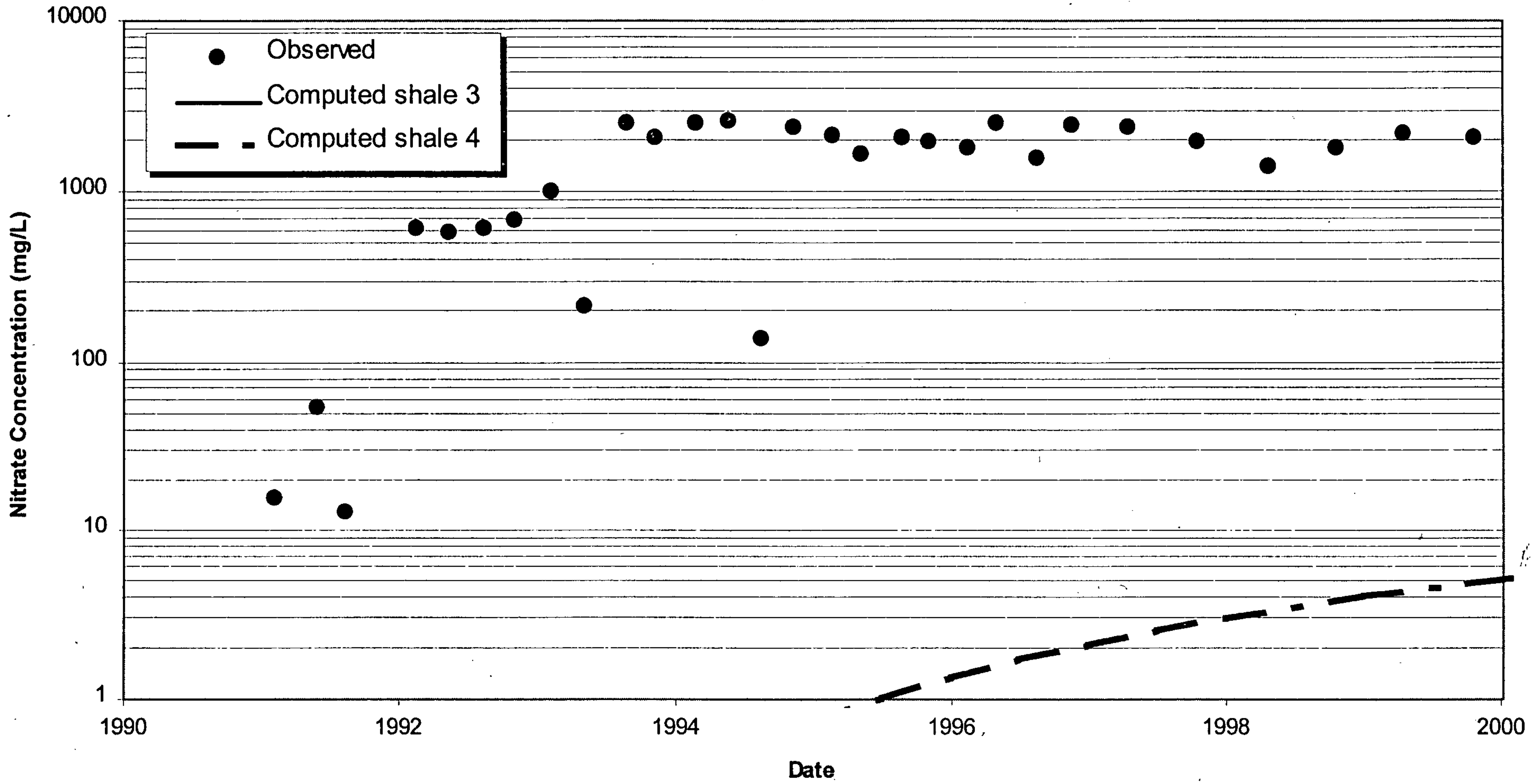

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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2322A

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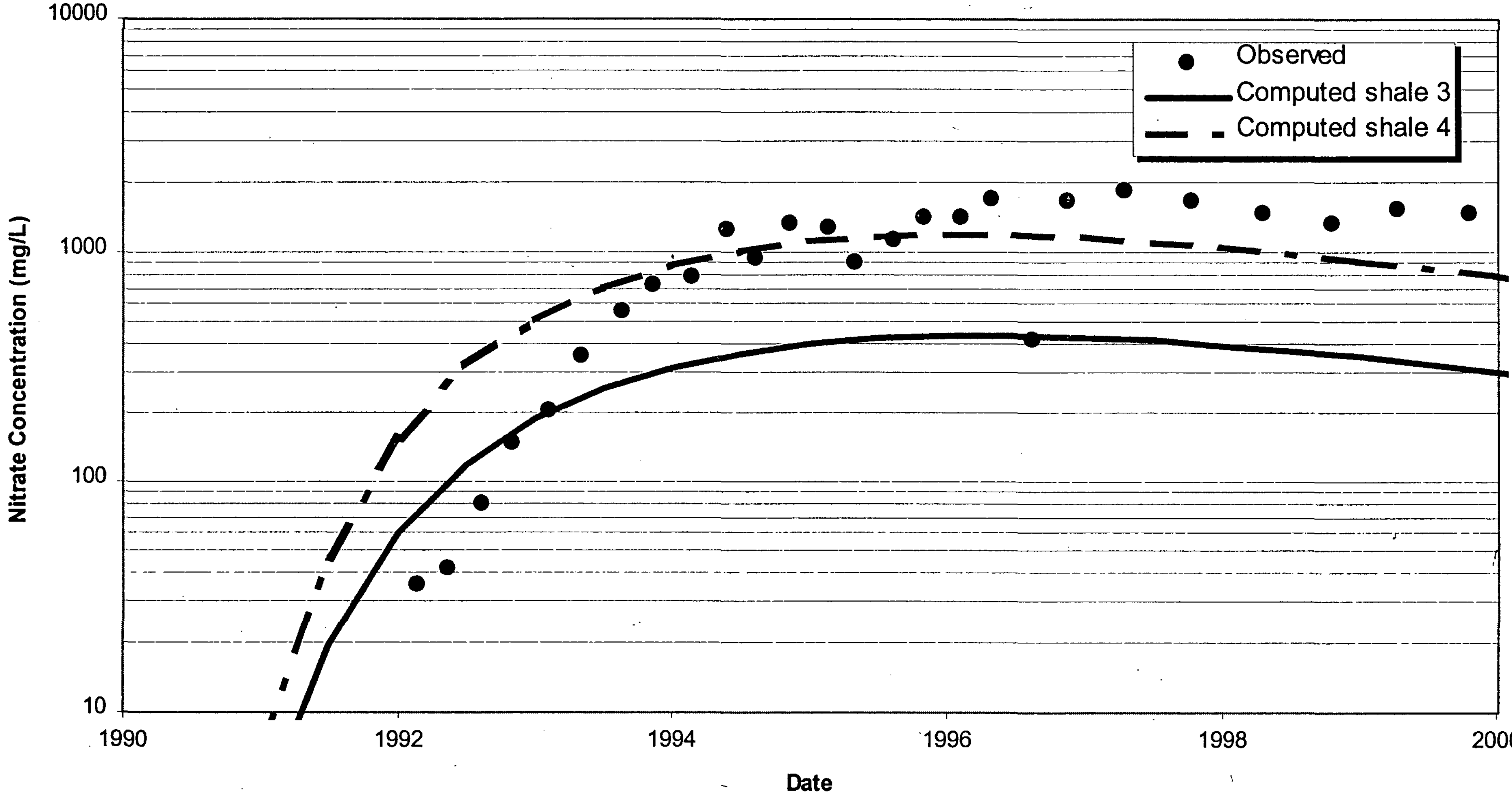

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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2341

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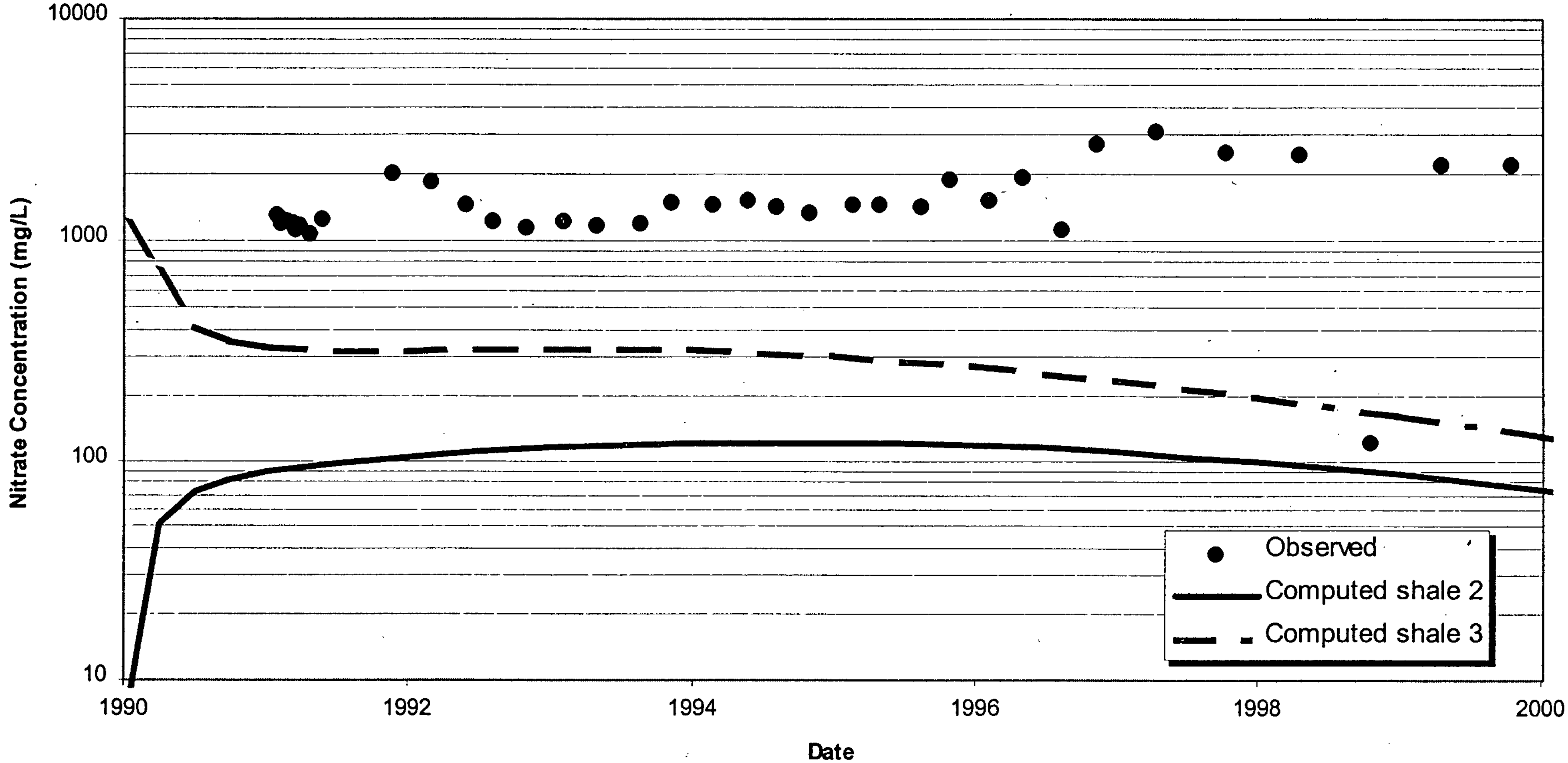

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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2343

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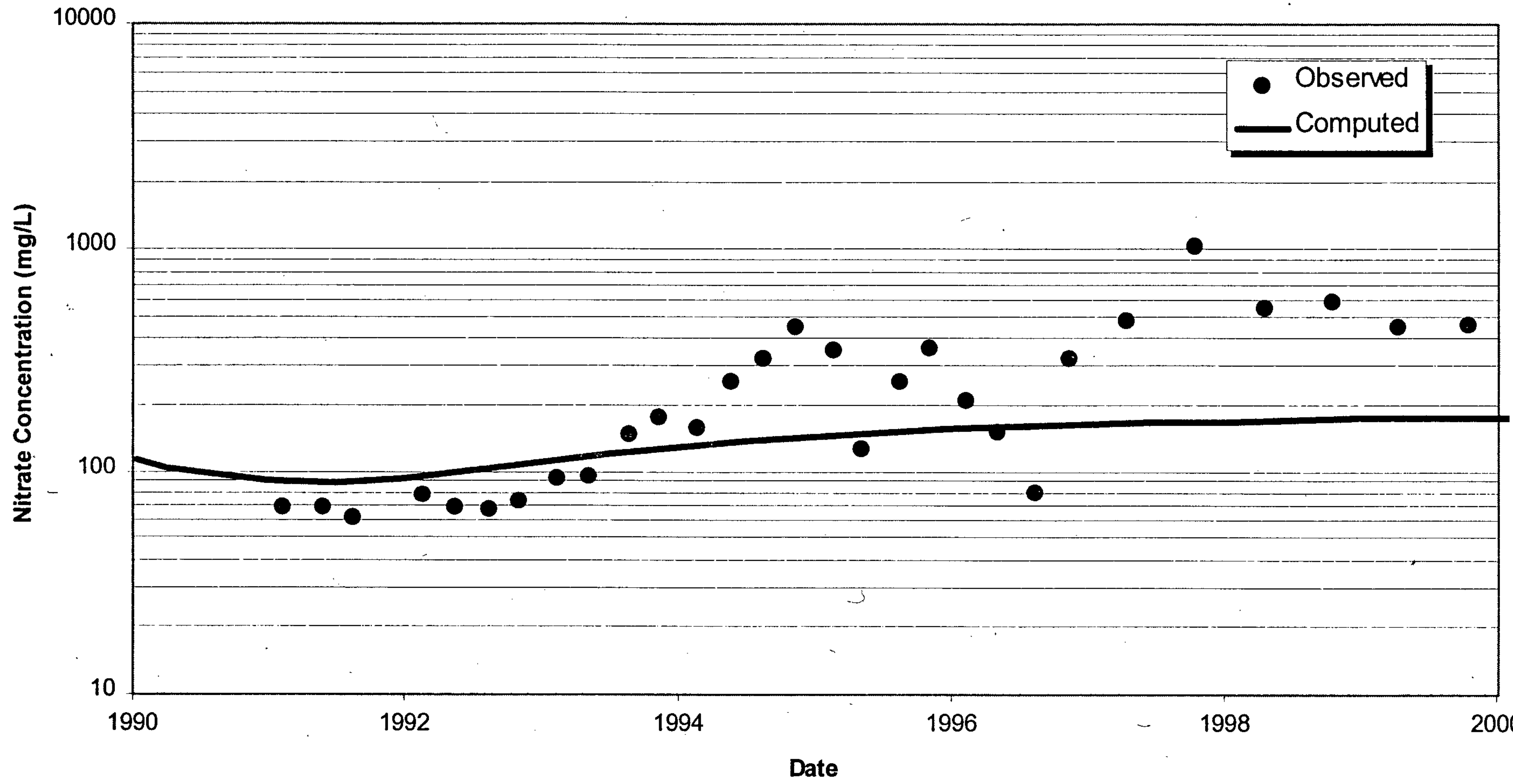

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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2346

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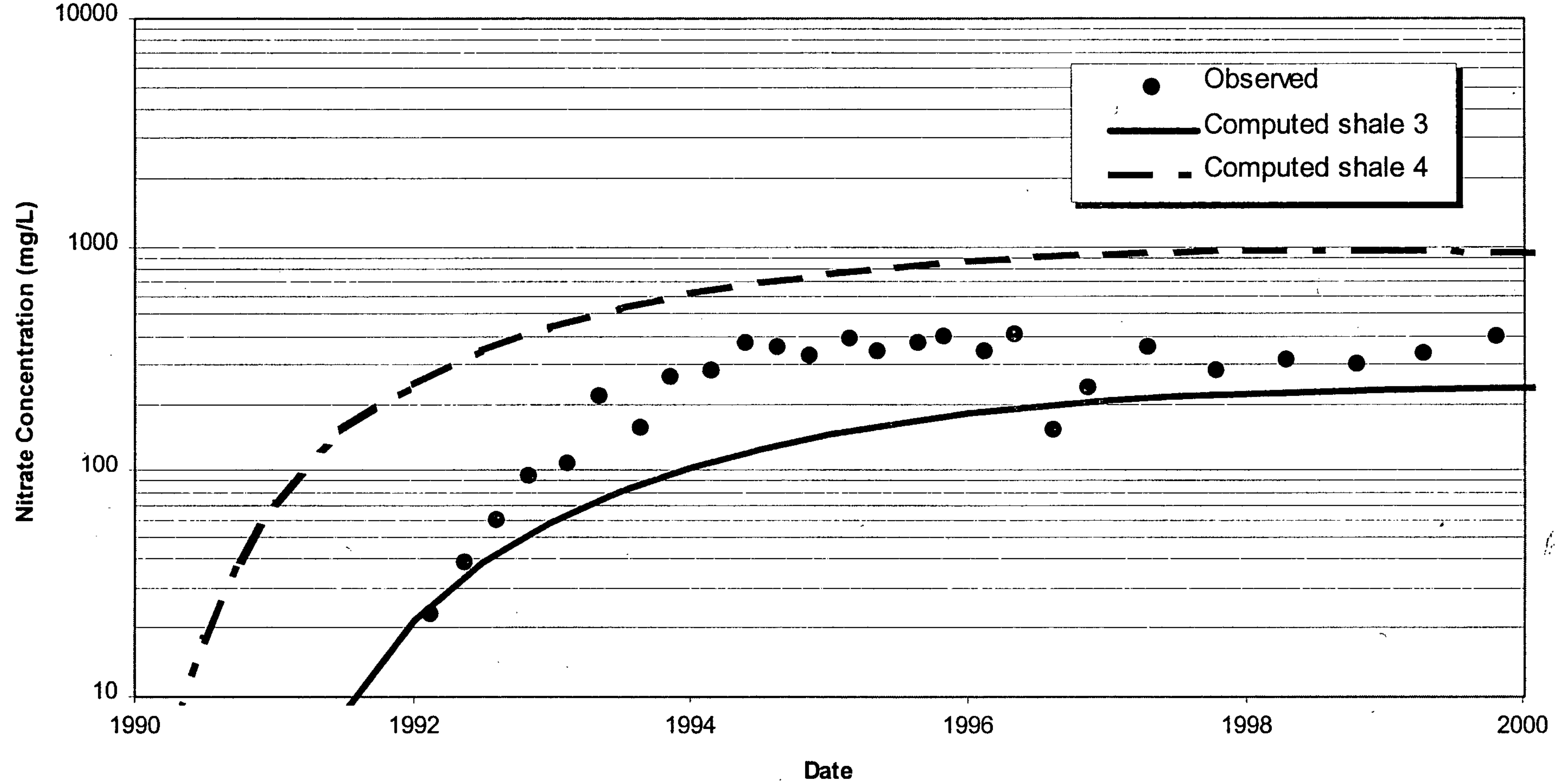

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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2349

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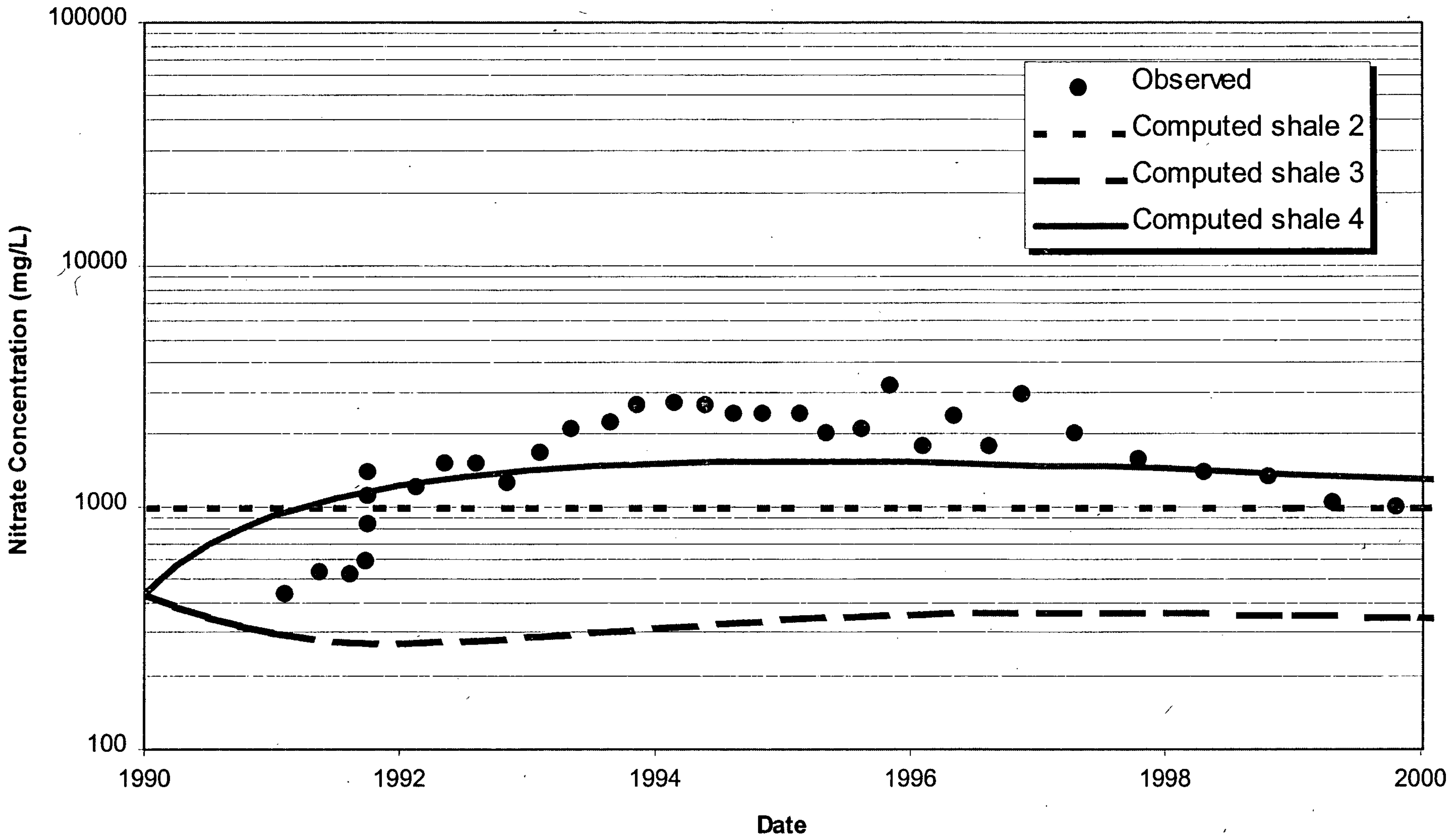

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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2352

Date:	AUGUST 2002
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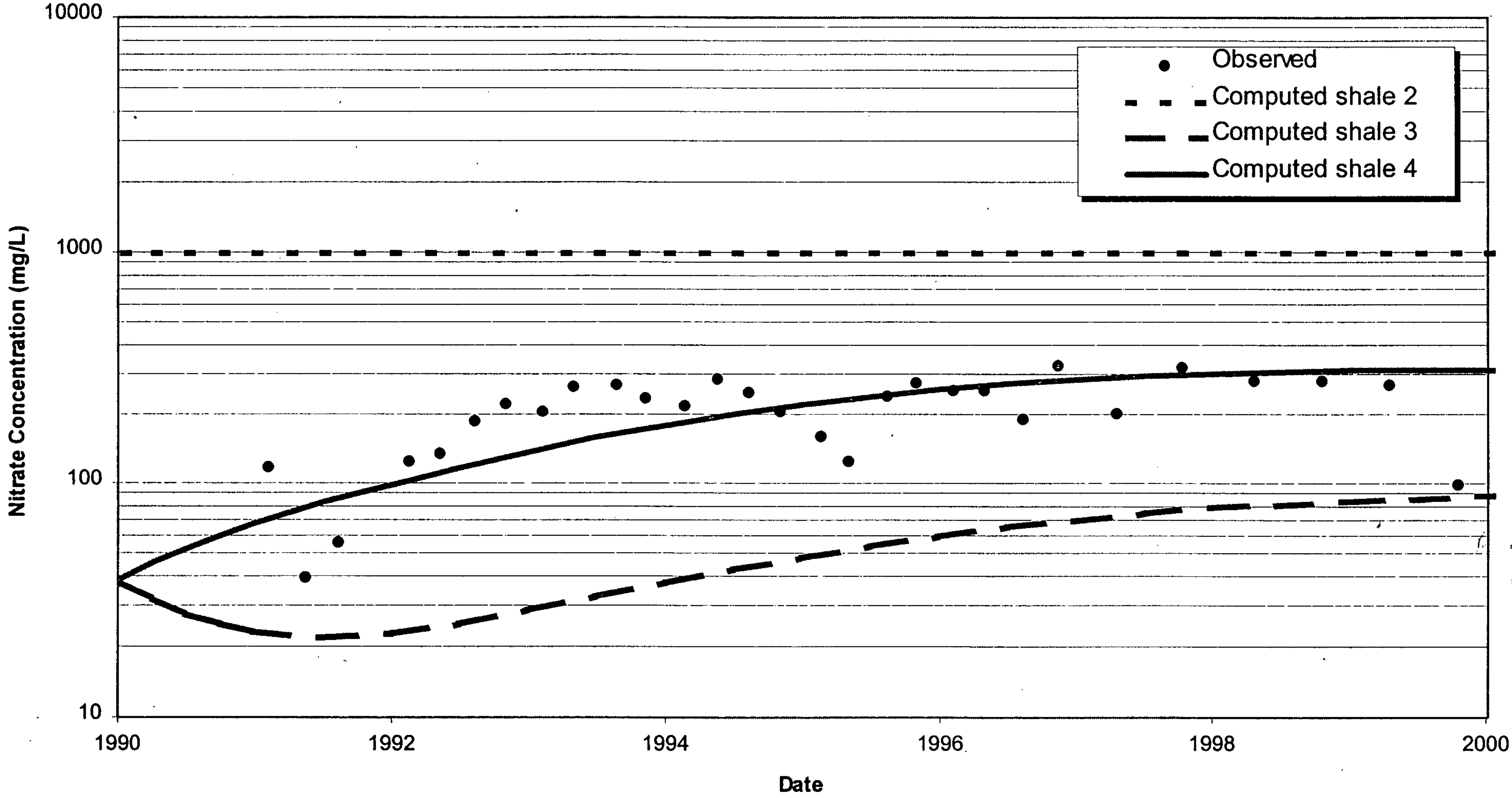

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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2353

Date:	AUGUST 2002
Project:	P:\100734-2\REV CHAR RPT
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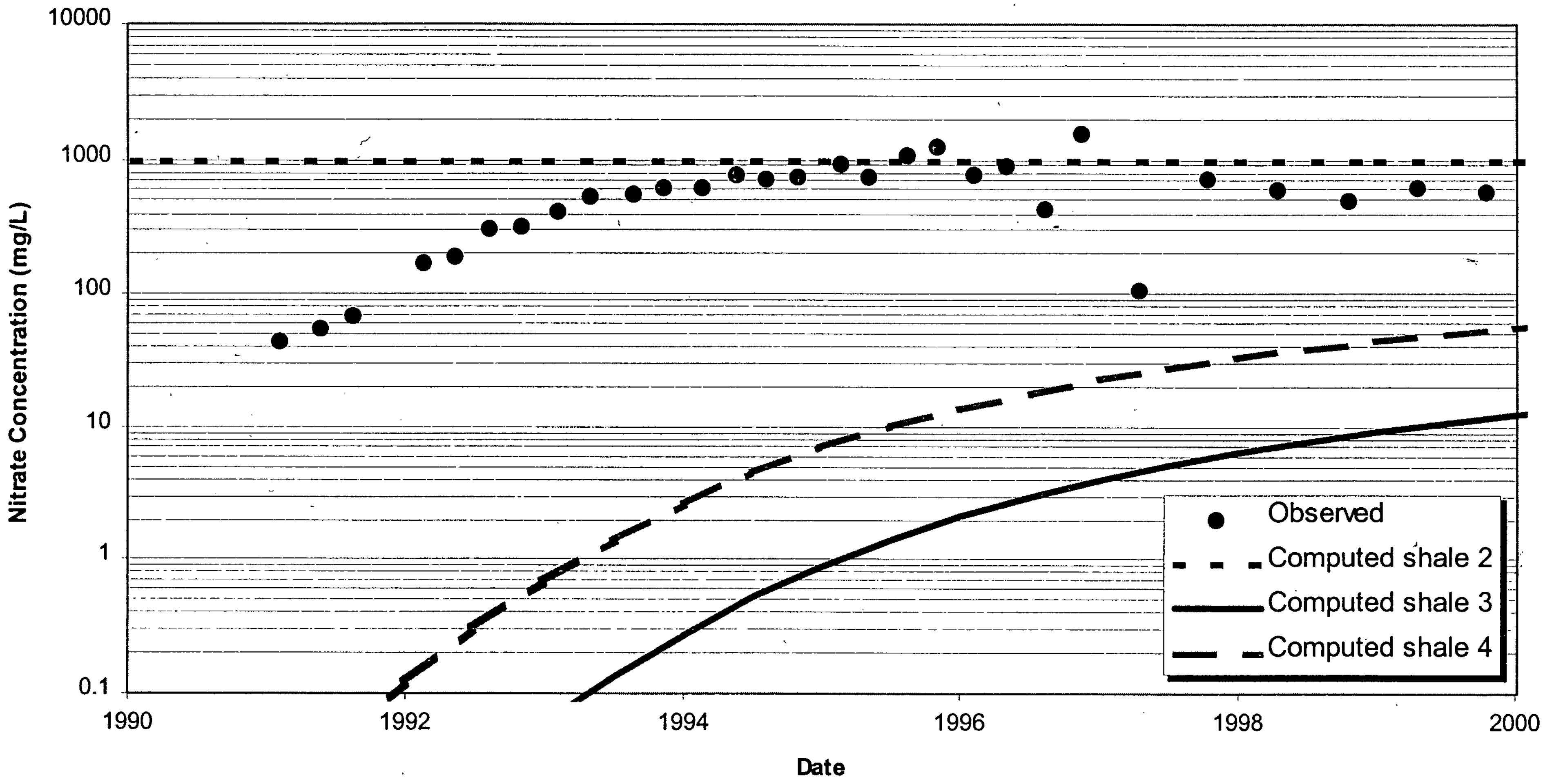

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FIGURE
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Date:	AUGUST 2002
Project:	P:\100734-2\REV CHAR RPT
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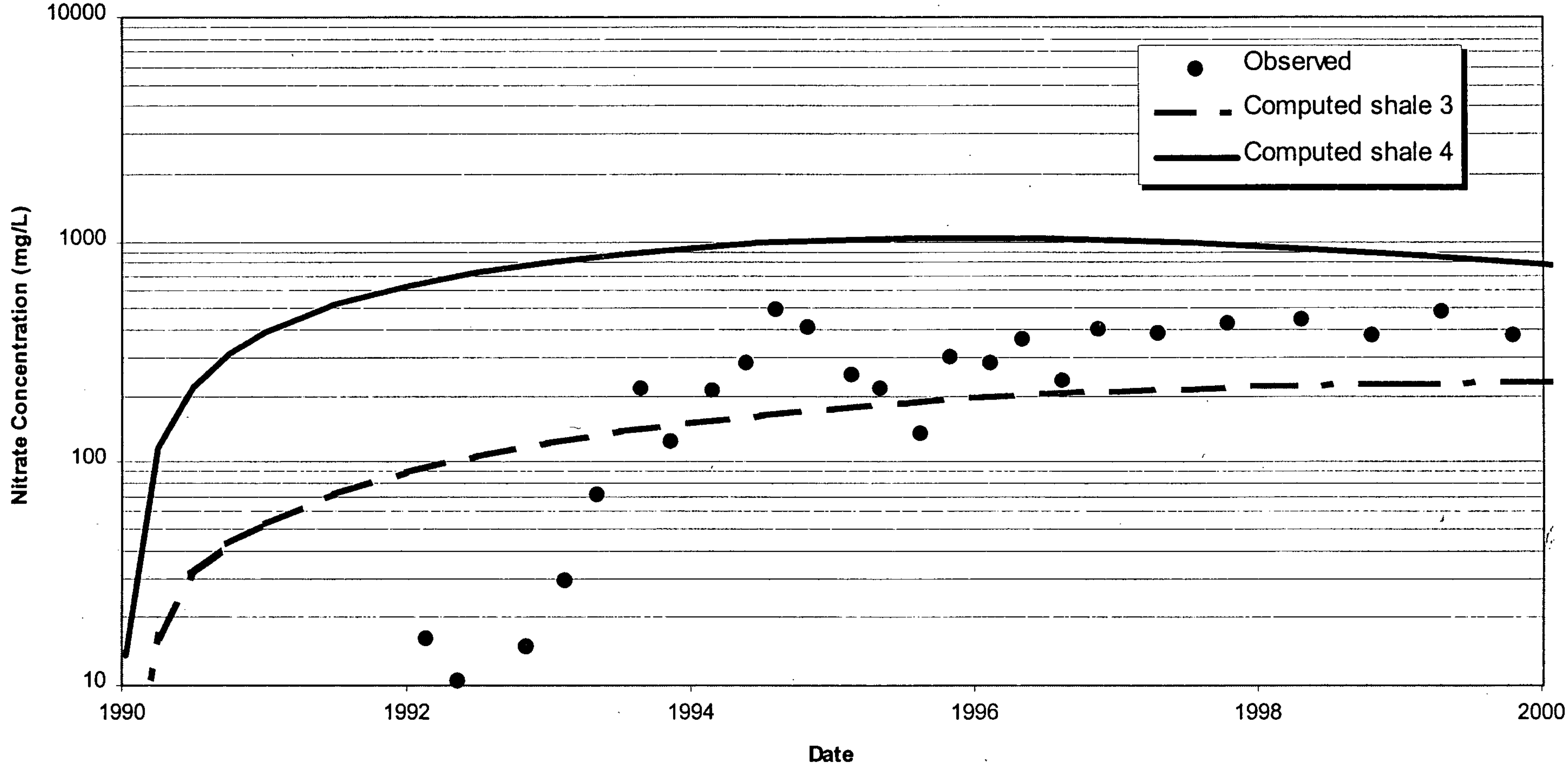

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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2355

Date:	AUGUST 2002
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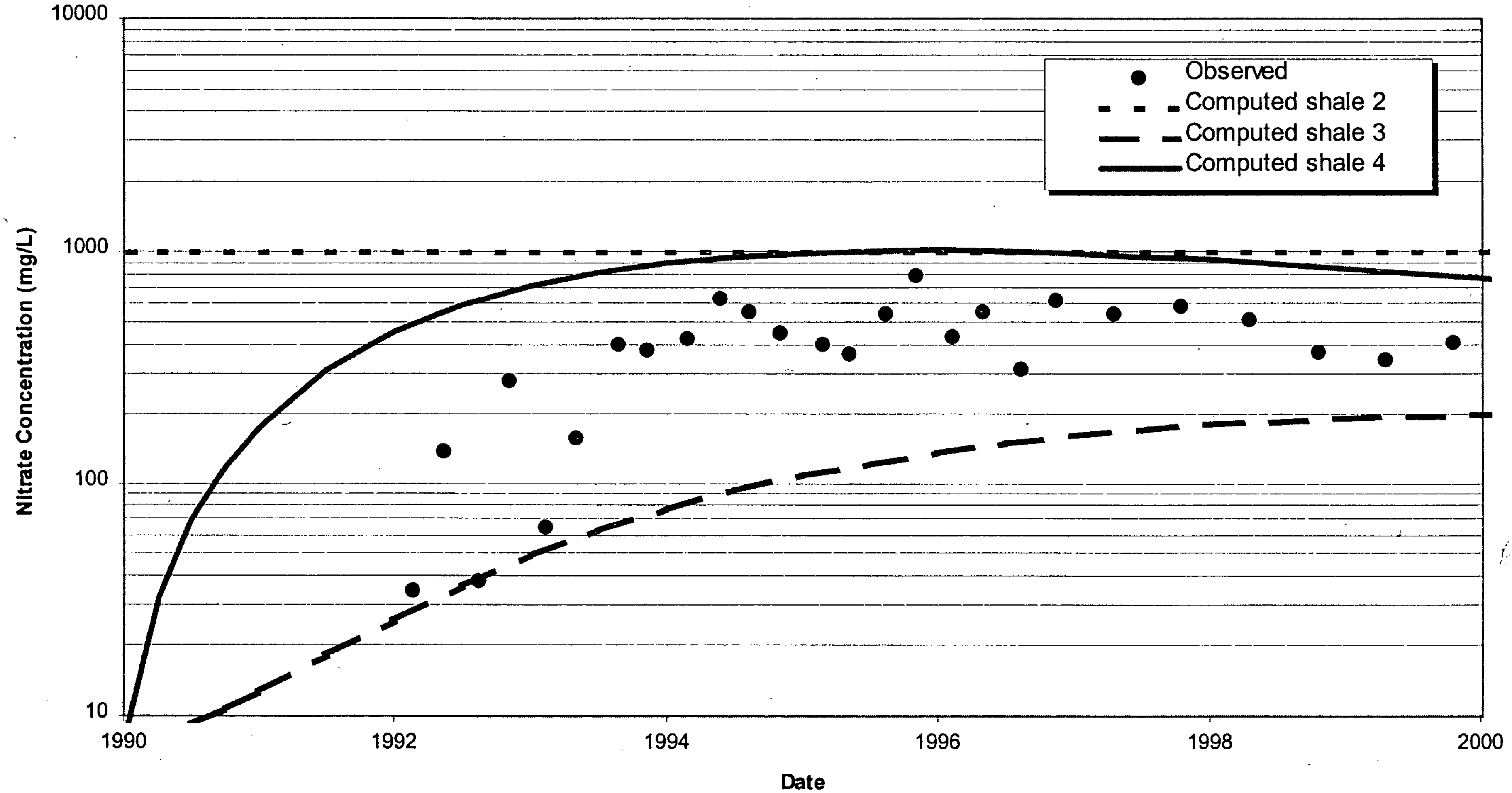

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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL 2356

Date:	AUGUST 2002
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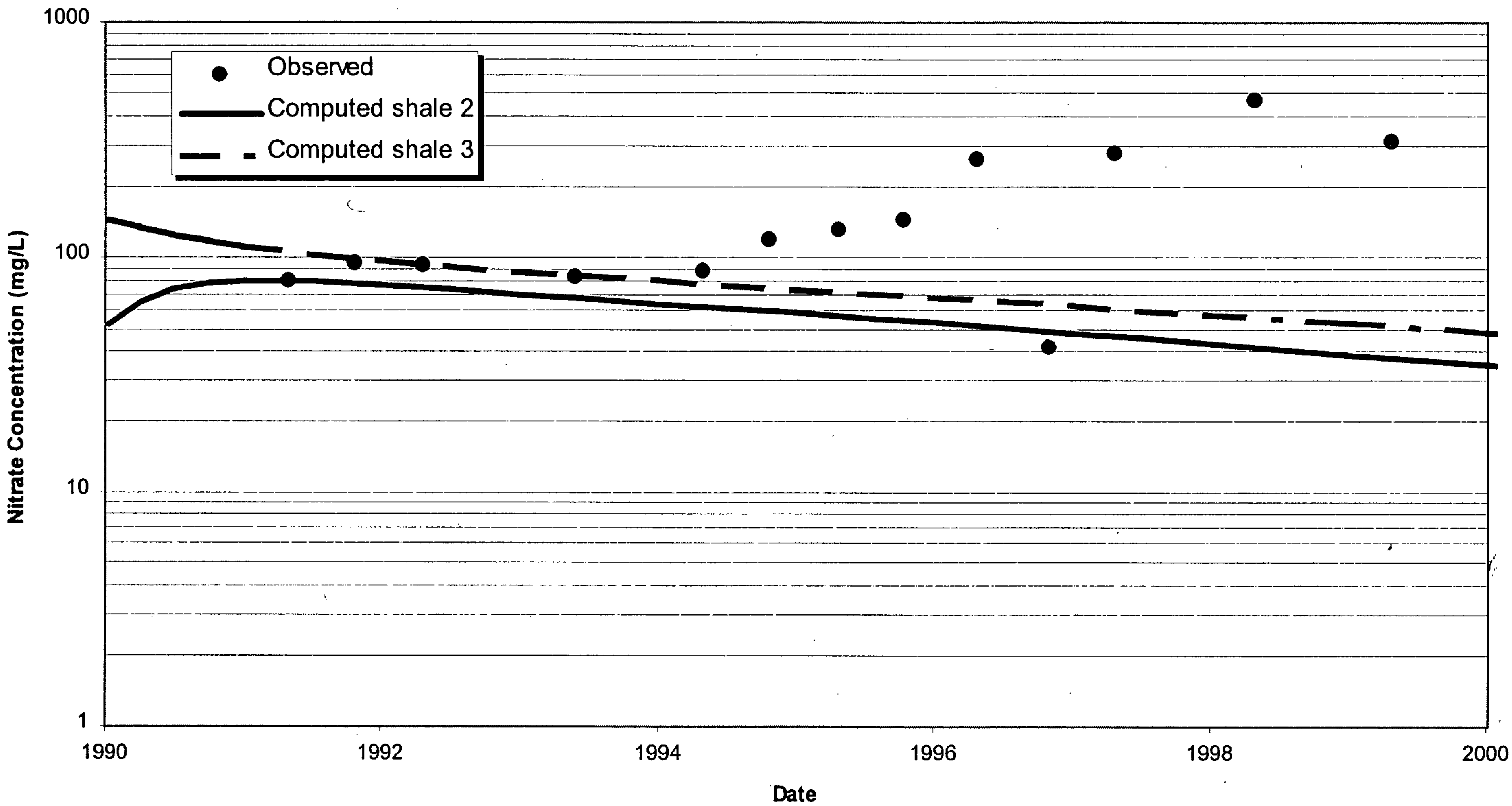

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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW012A

Date:	AUGUST 2002
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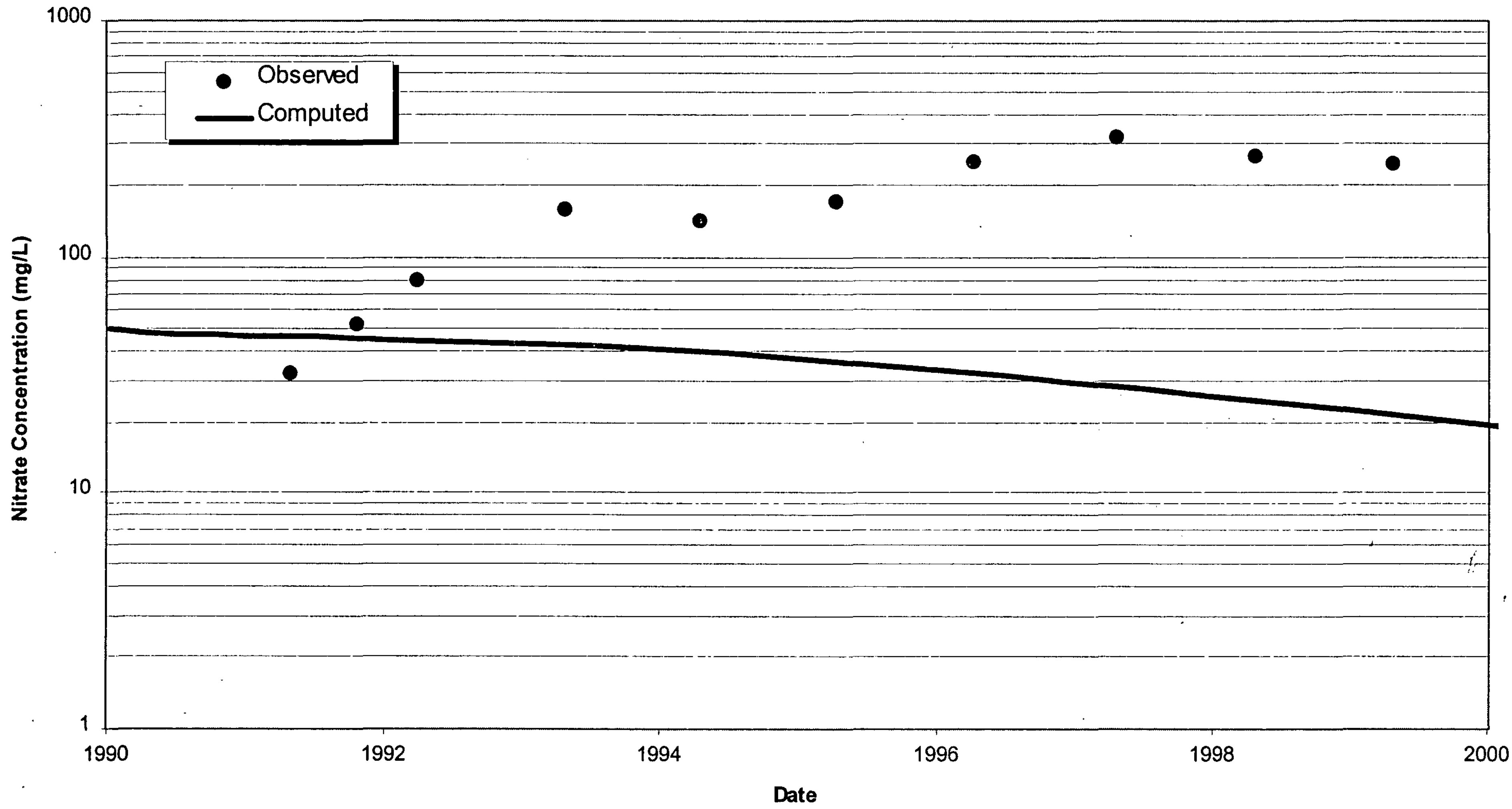

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FIGURE
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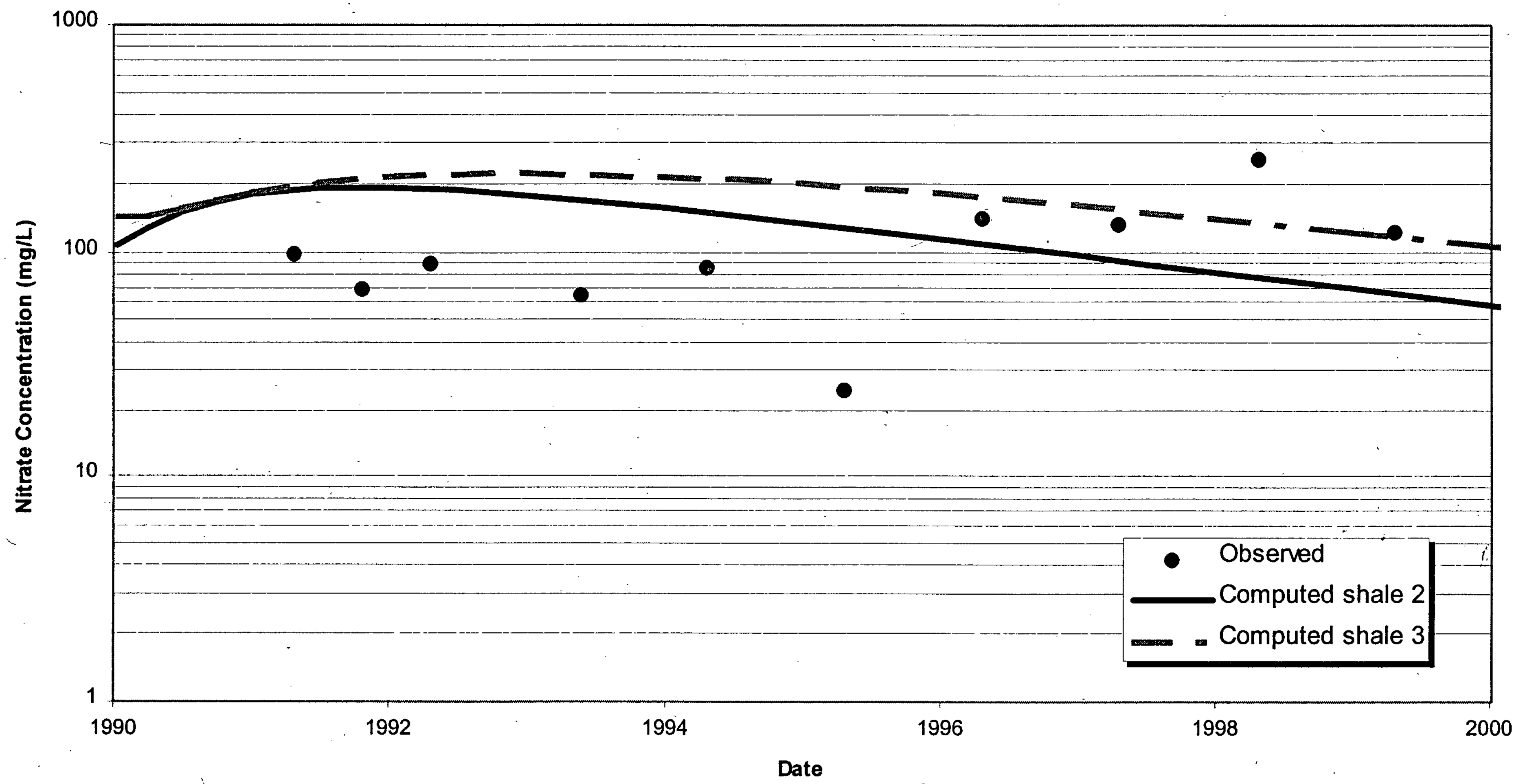

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FIGURE
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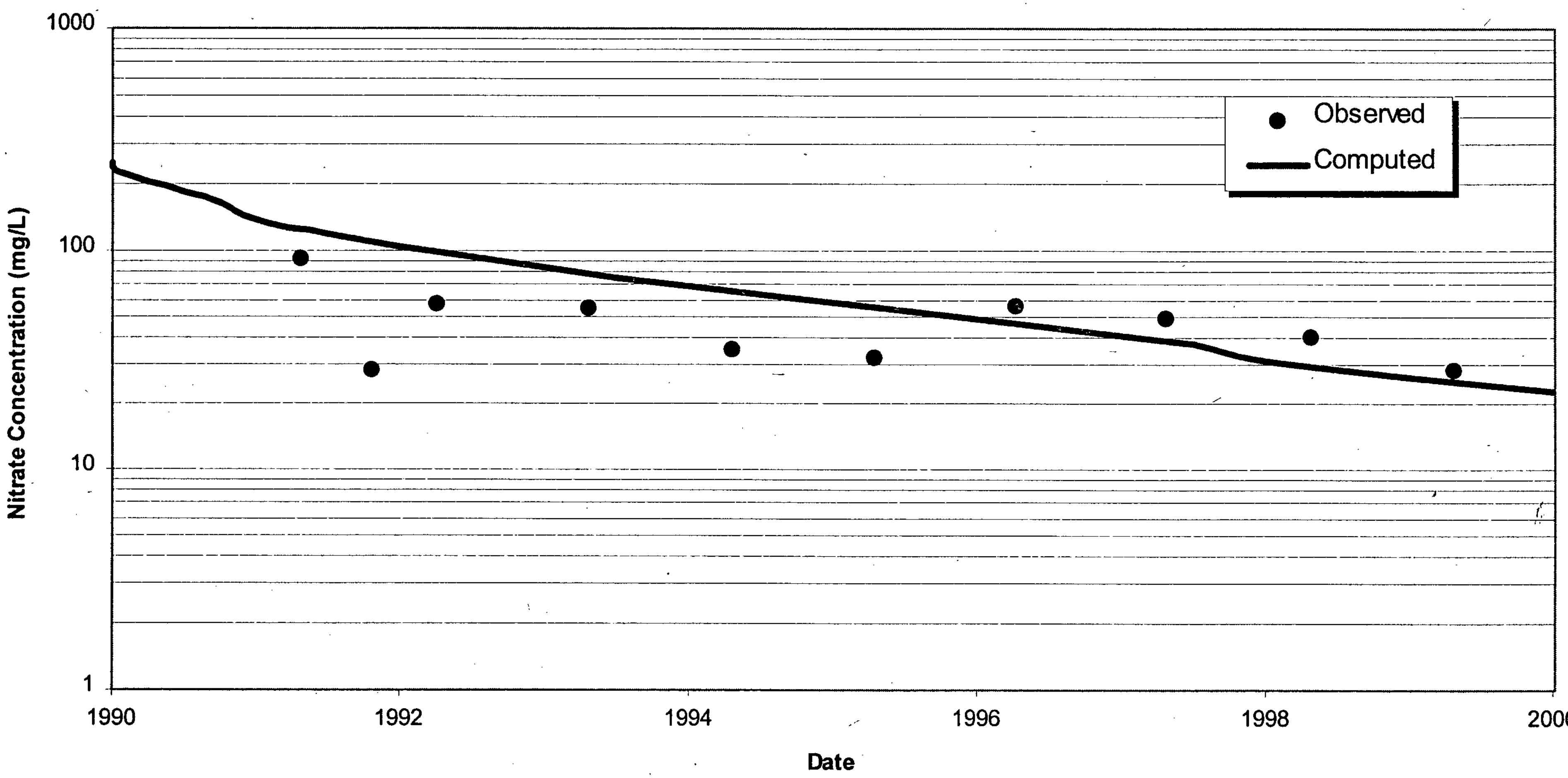

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FIGURE
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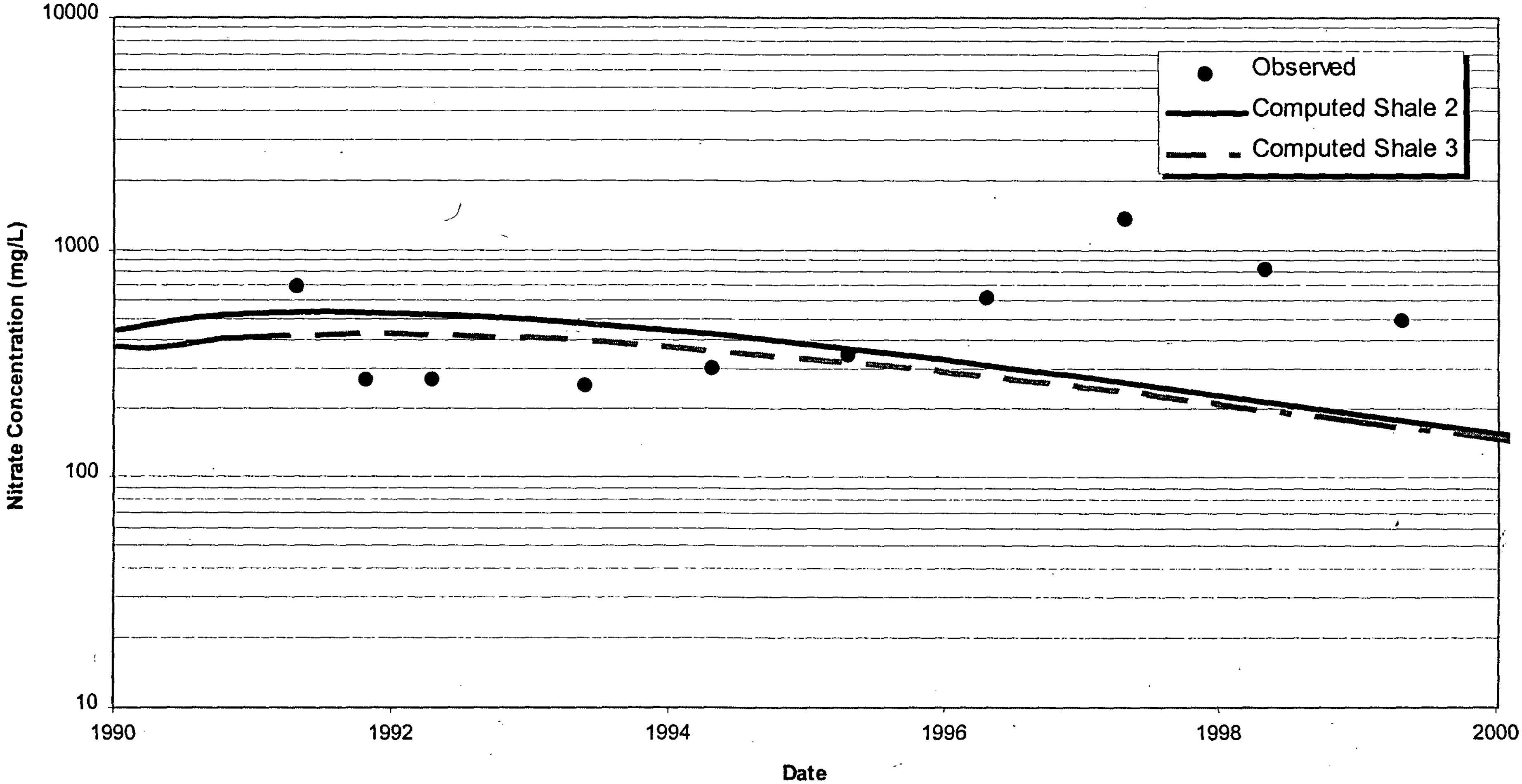

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FIGURE
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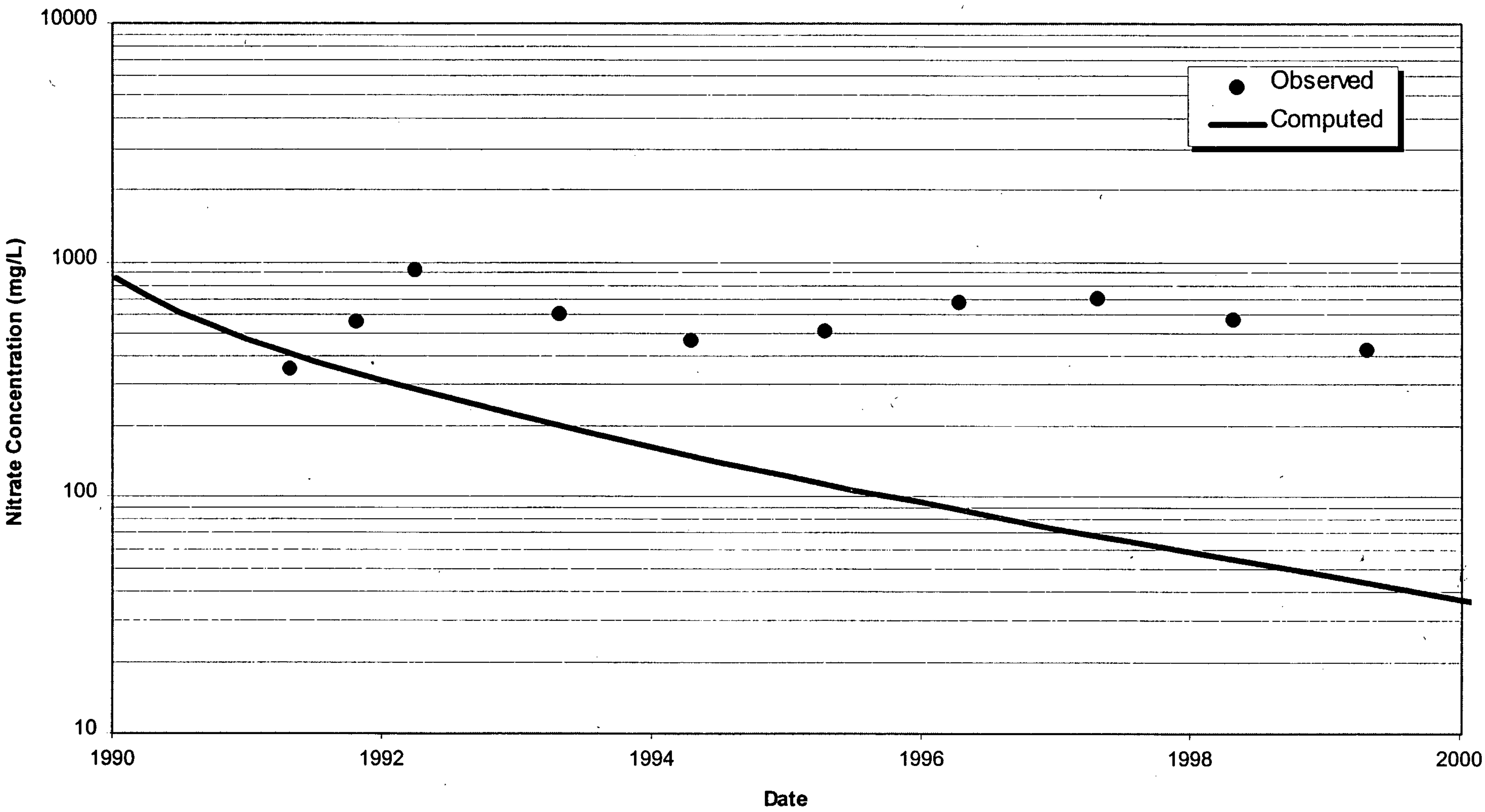

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FIGURE
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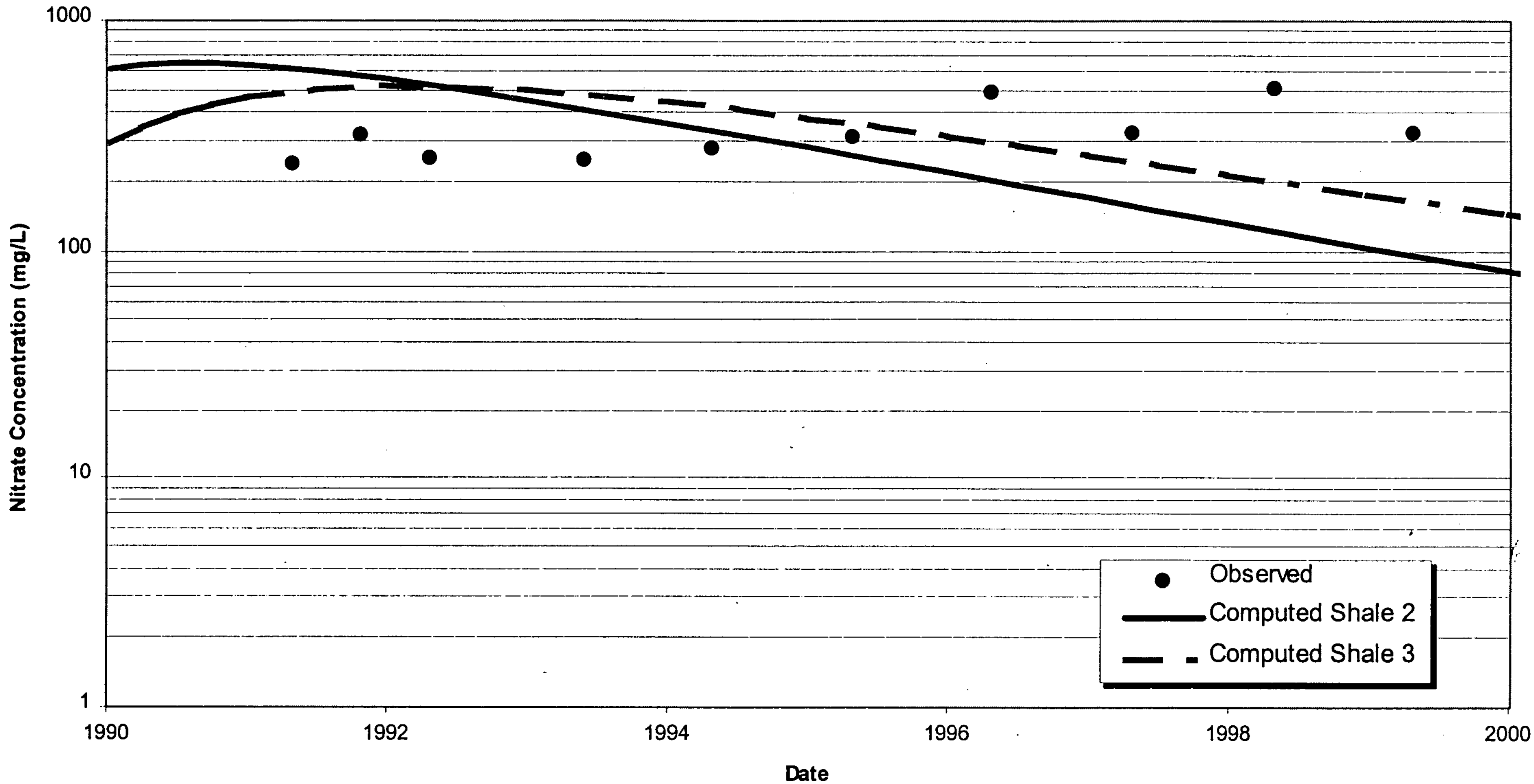

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FIGURE
NITRATE TRANSPORT CALIBRATION FOR WELL MW025A

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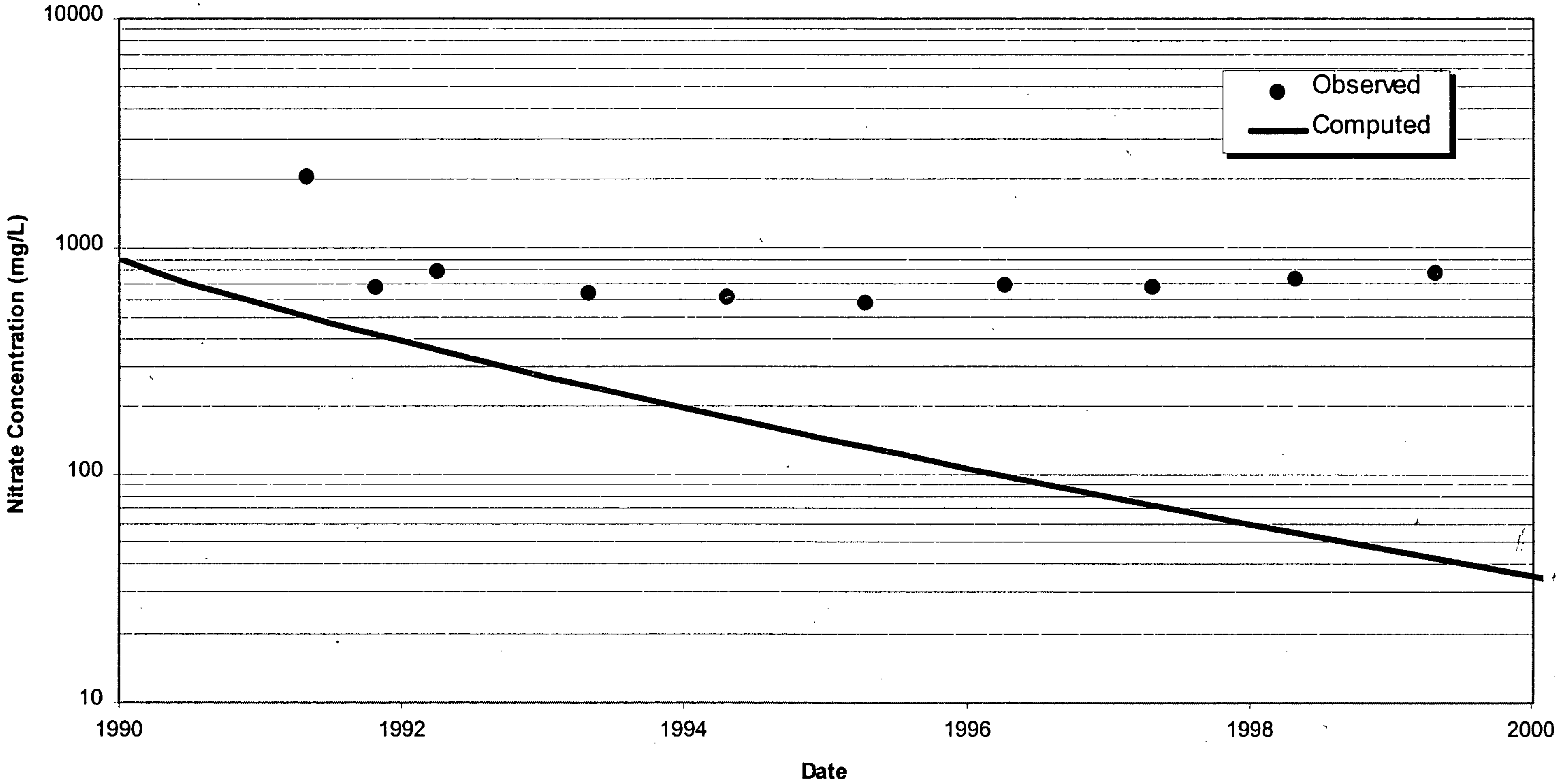

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FIGURE
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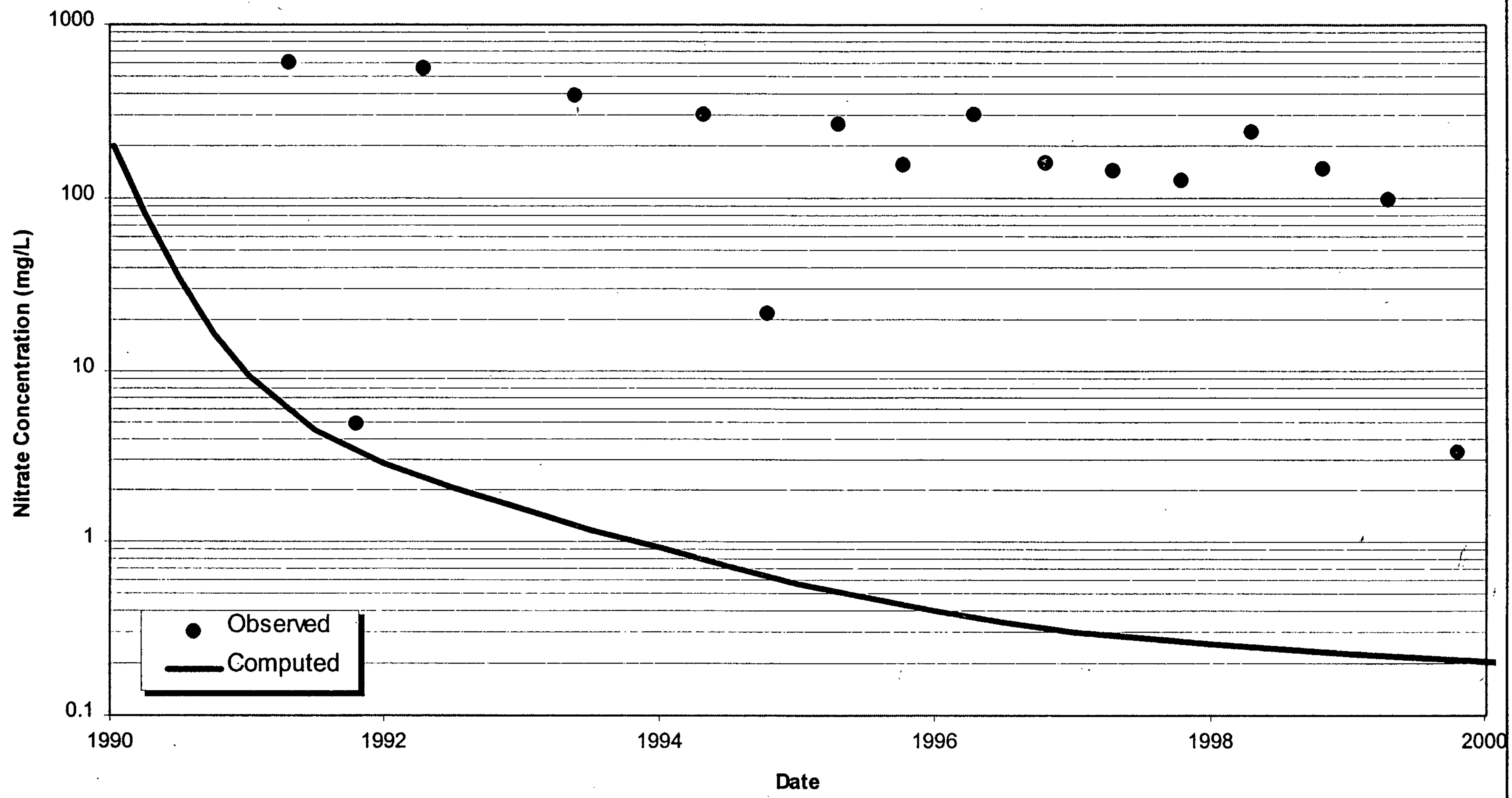

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FIGURE
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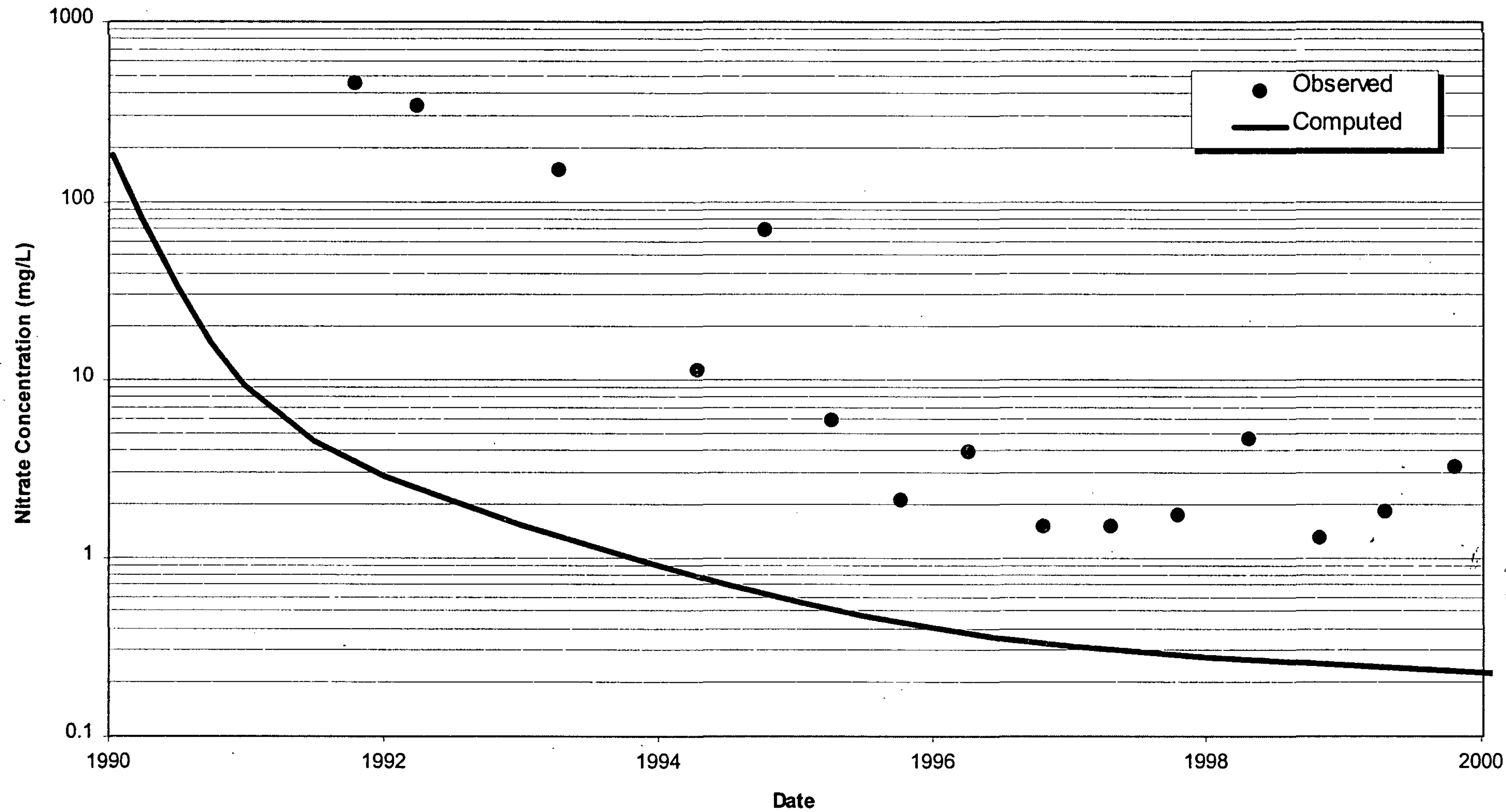

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FIGURE
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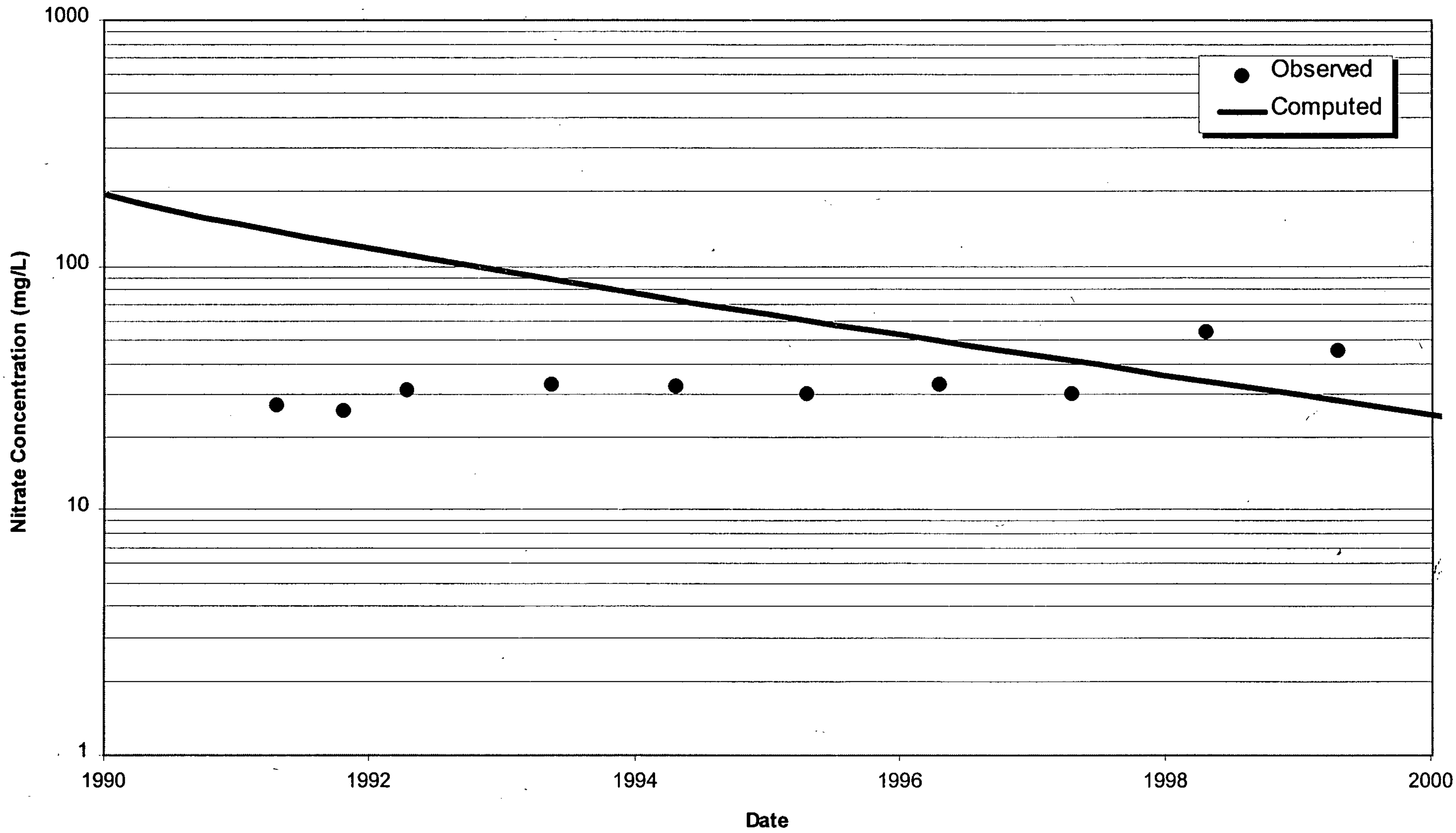

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FIGURE
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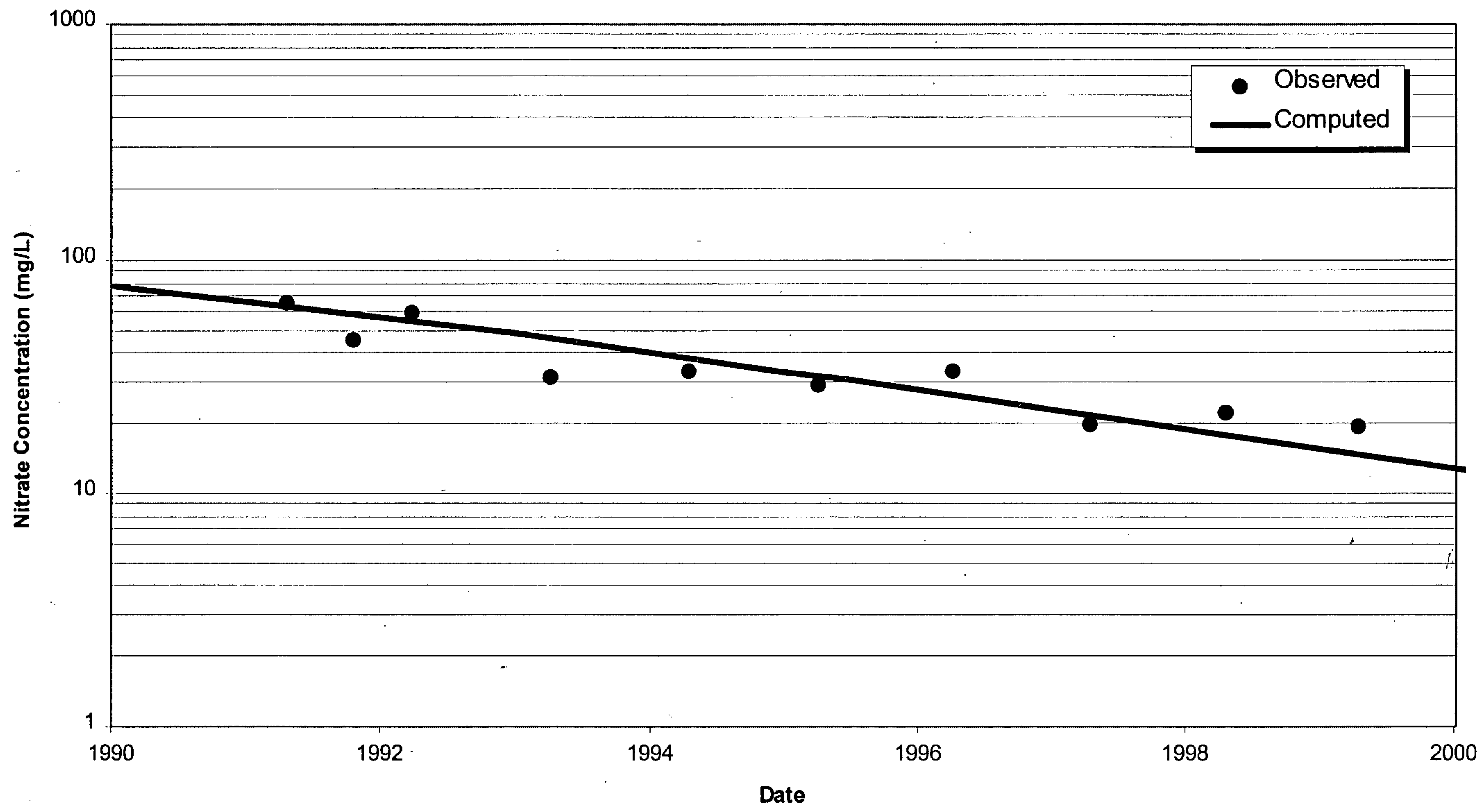

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FIGURE
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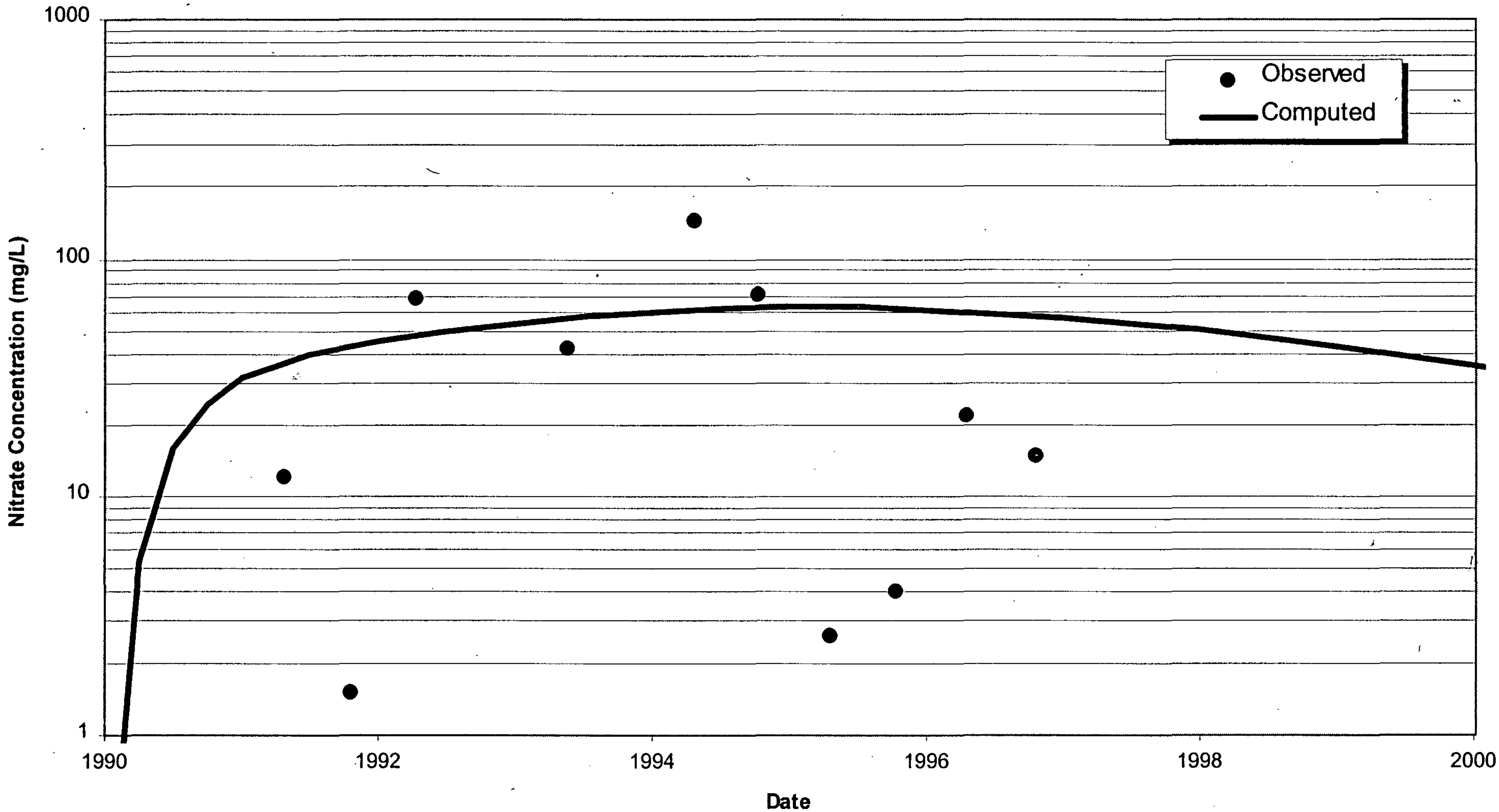

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FIGURE
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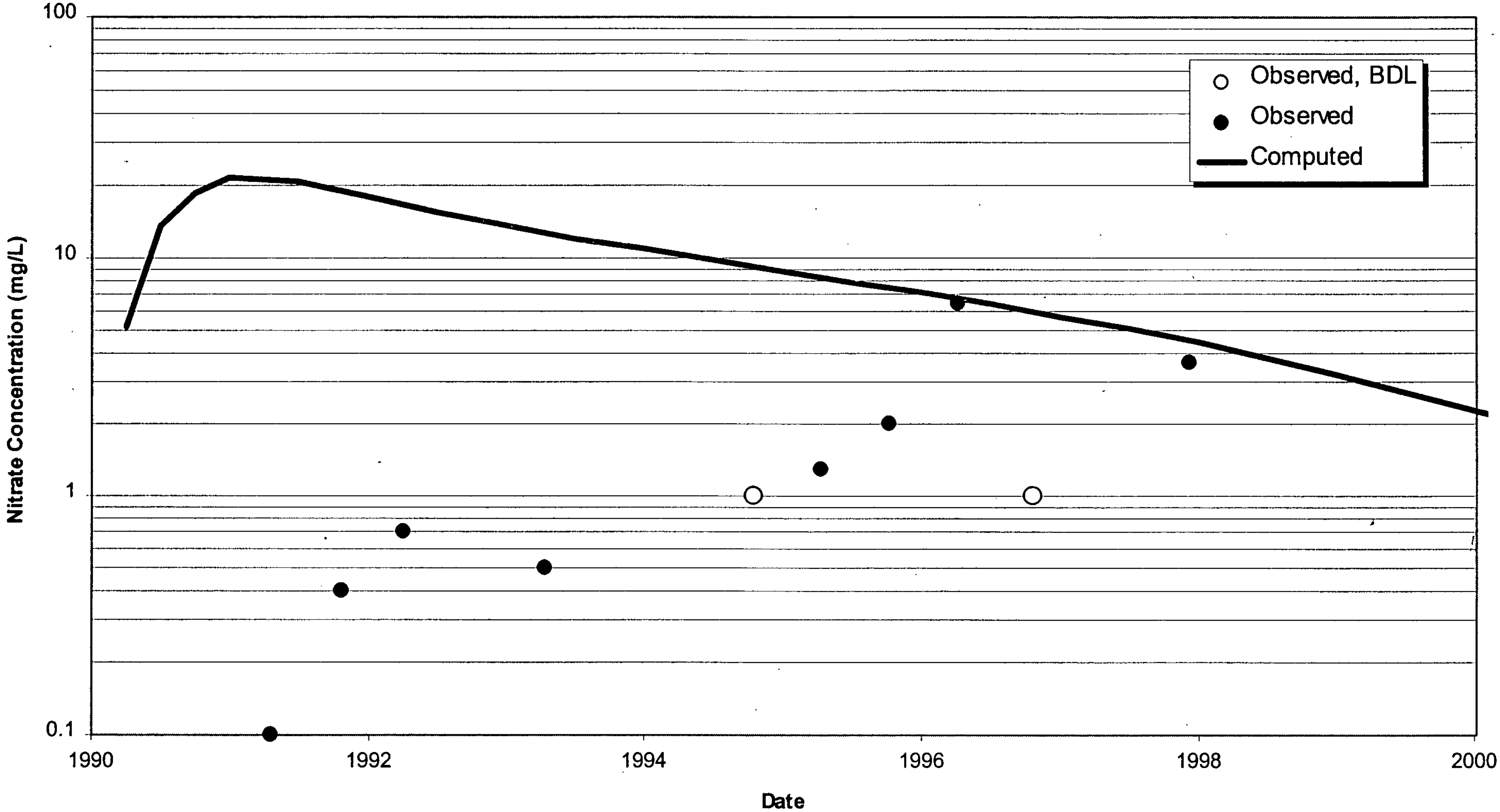

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FIGURE
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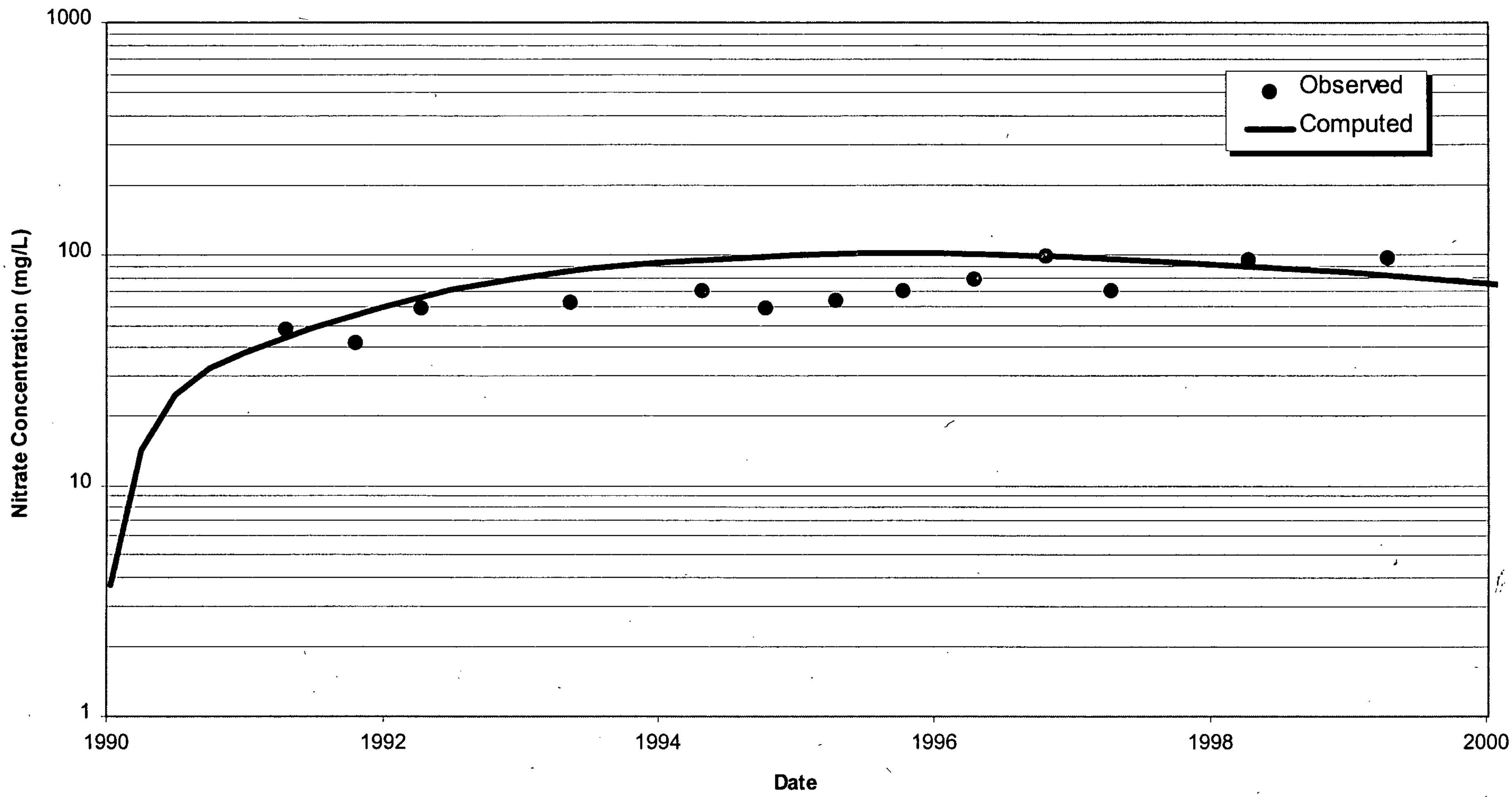

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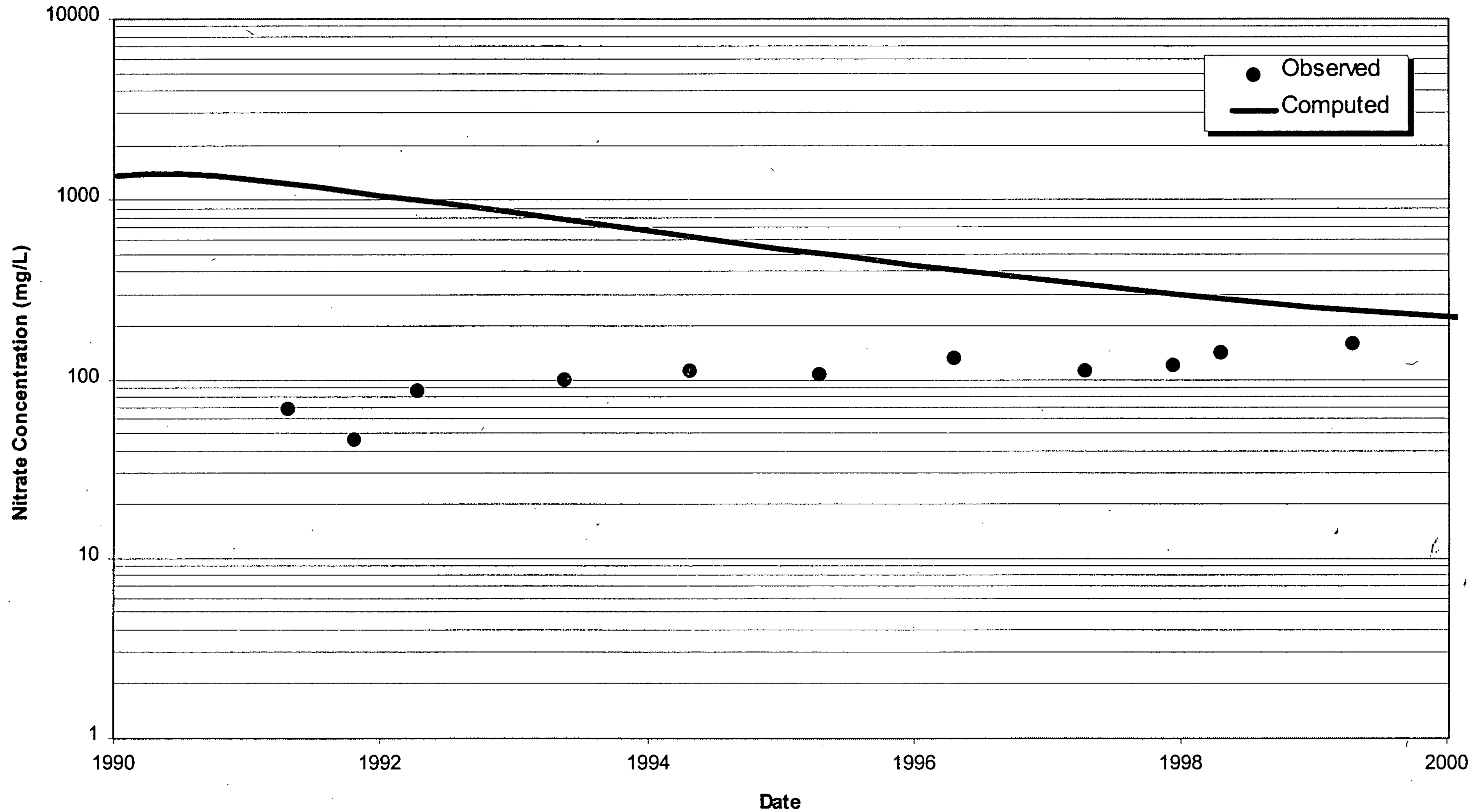

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FIGURE
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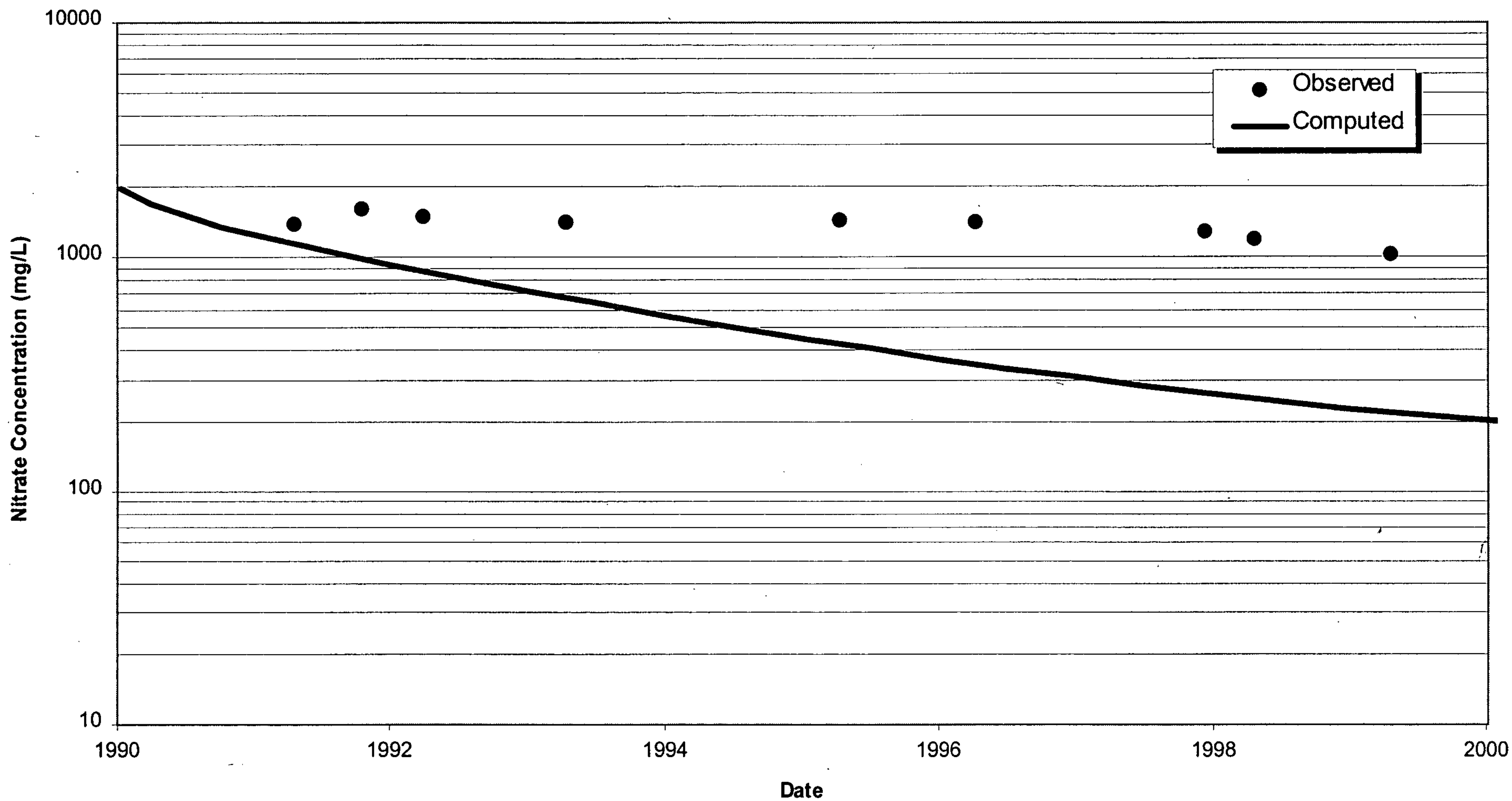

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FIGURE
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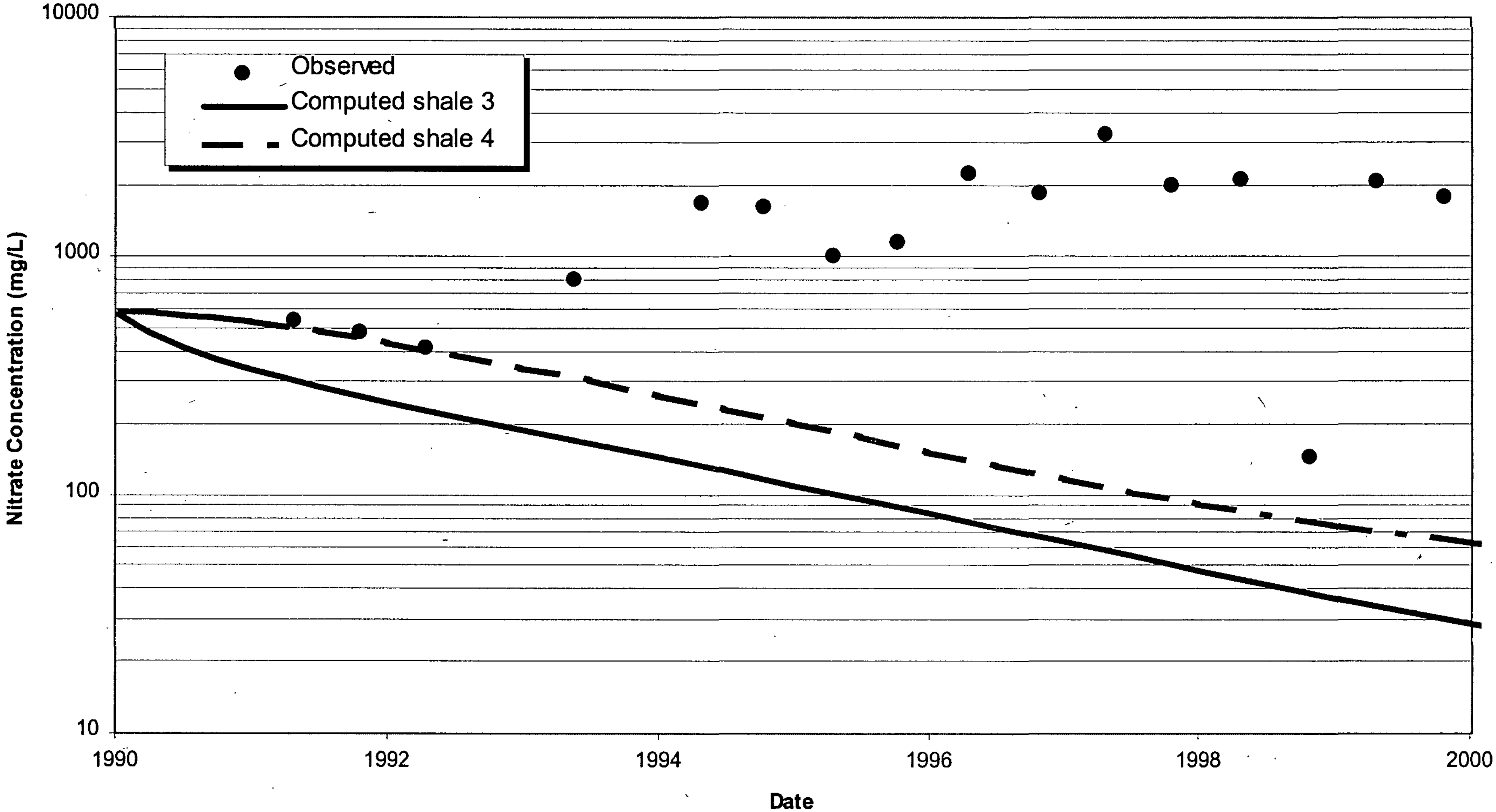

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FIGURE
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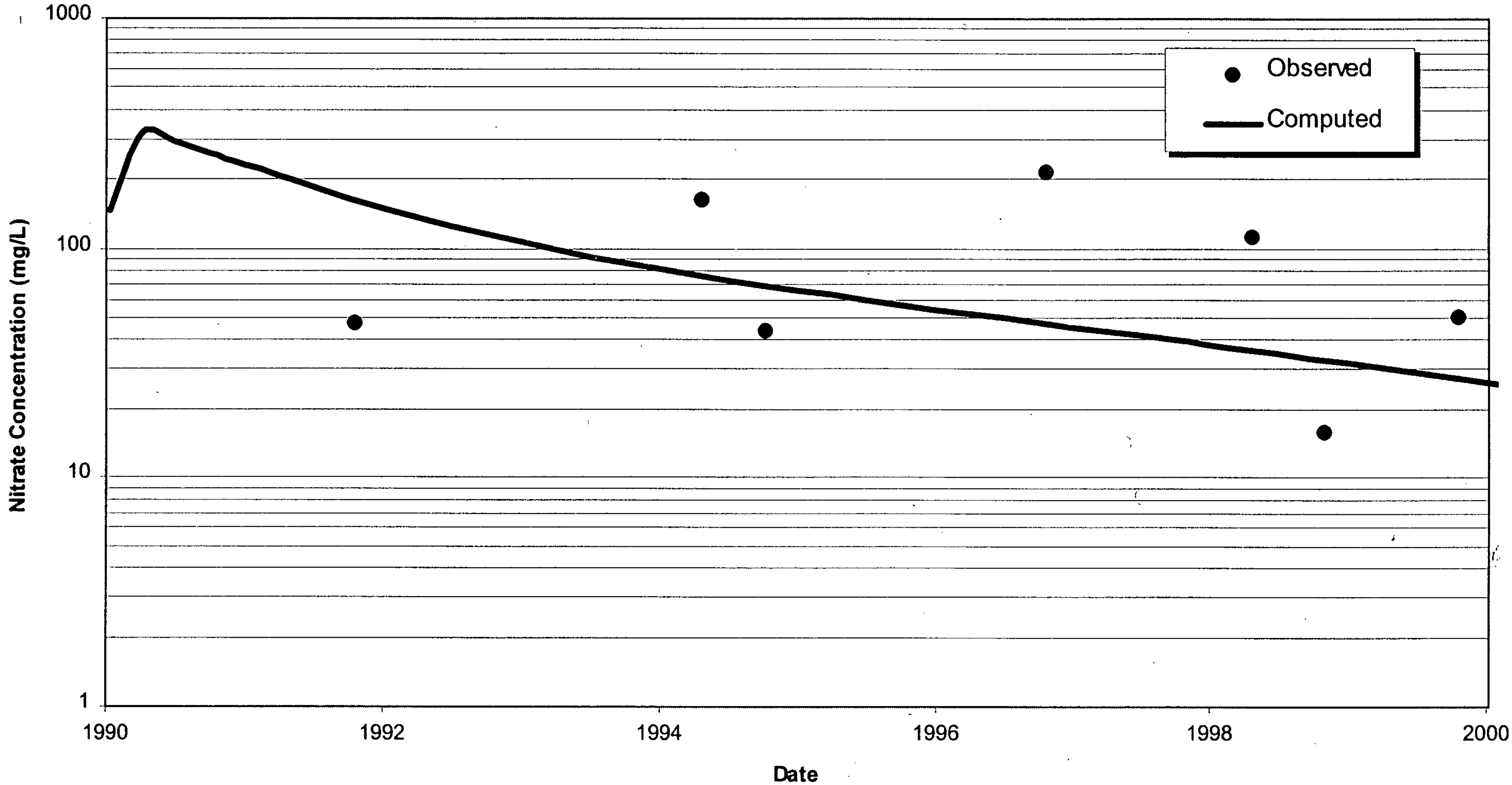

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FIGURE
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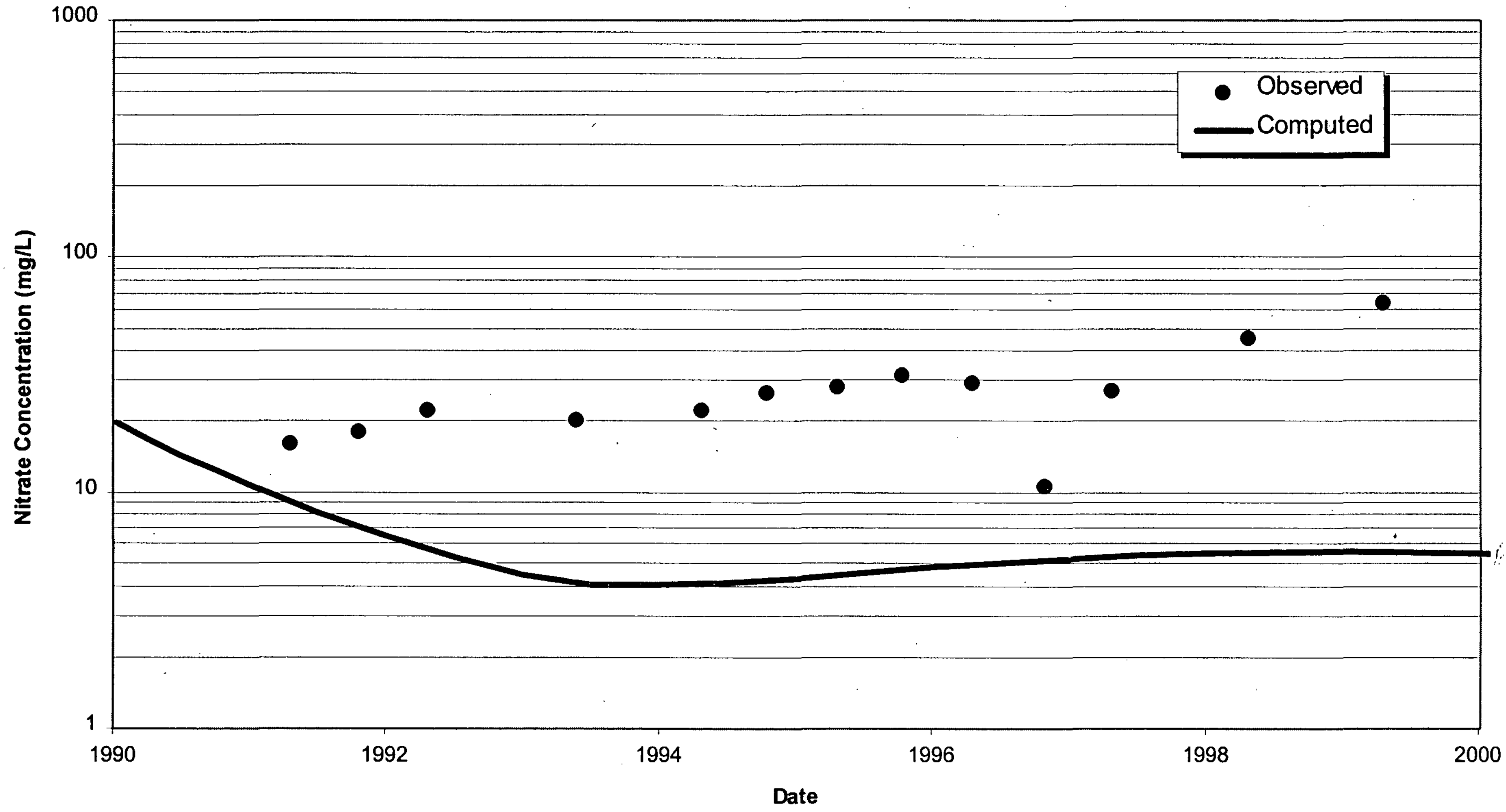

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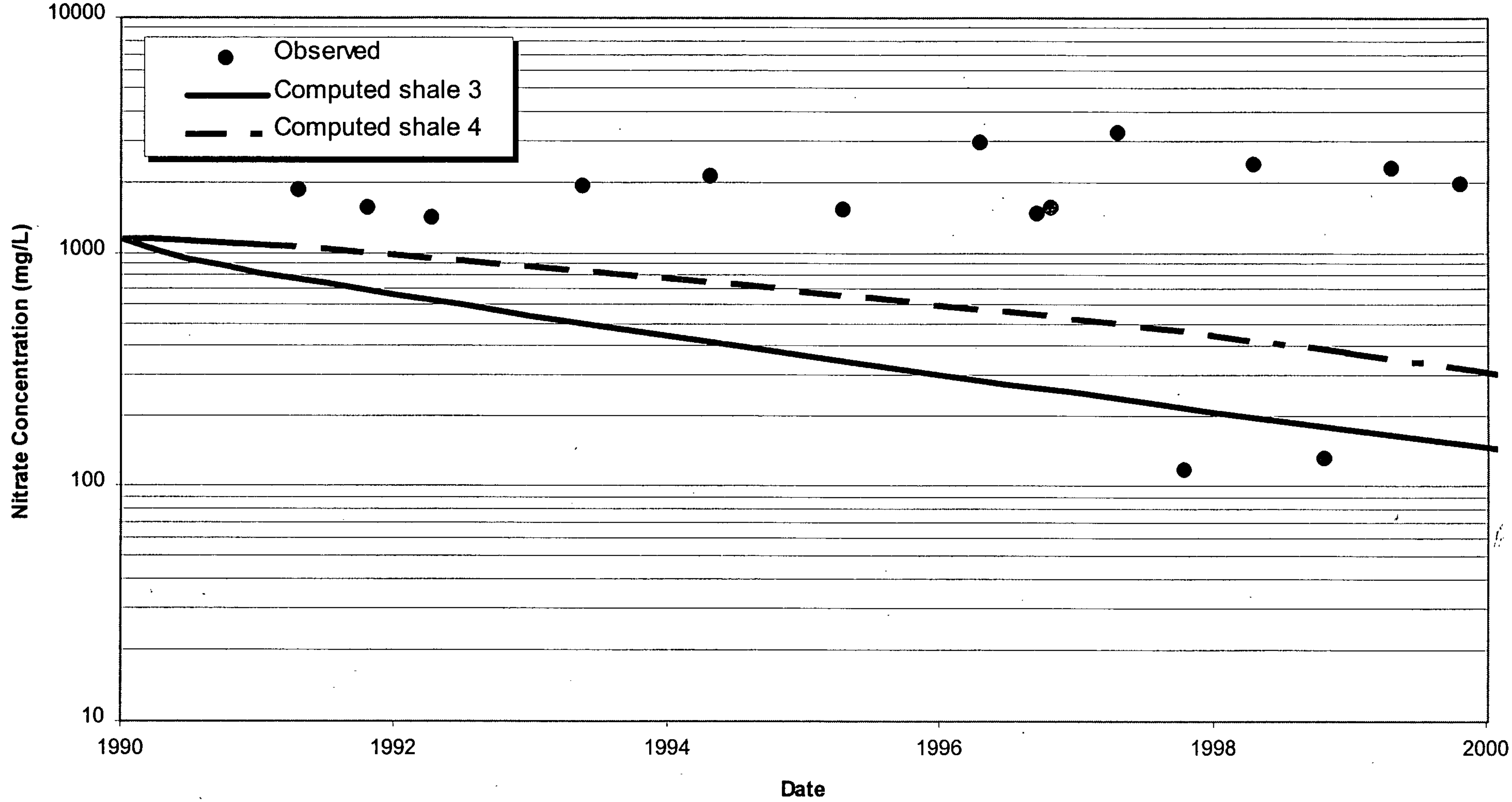

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FIGURE
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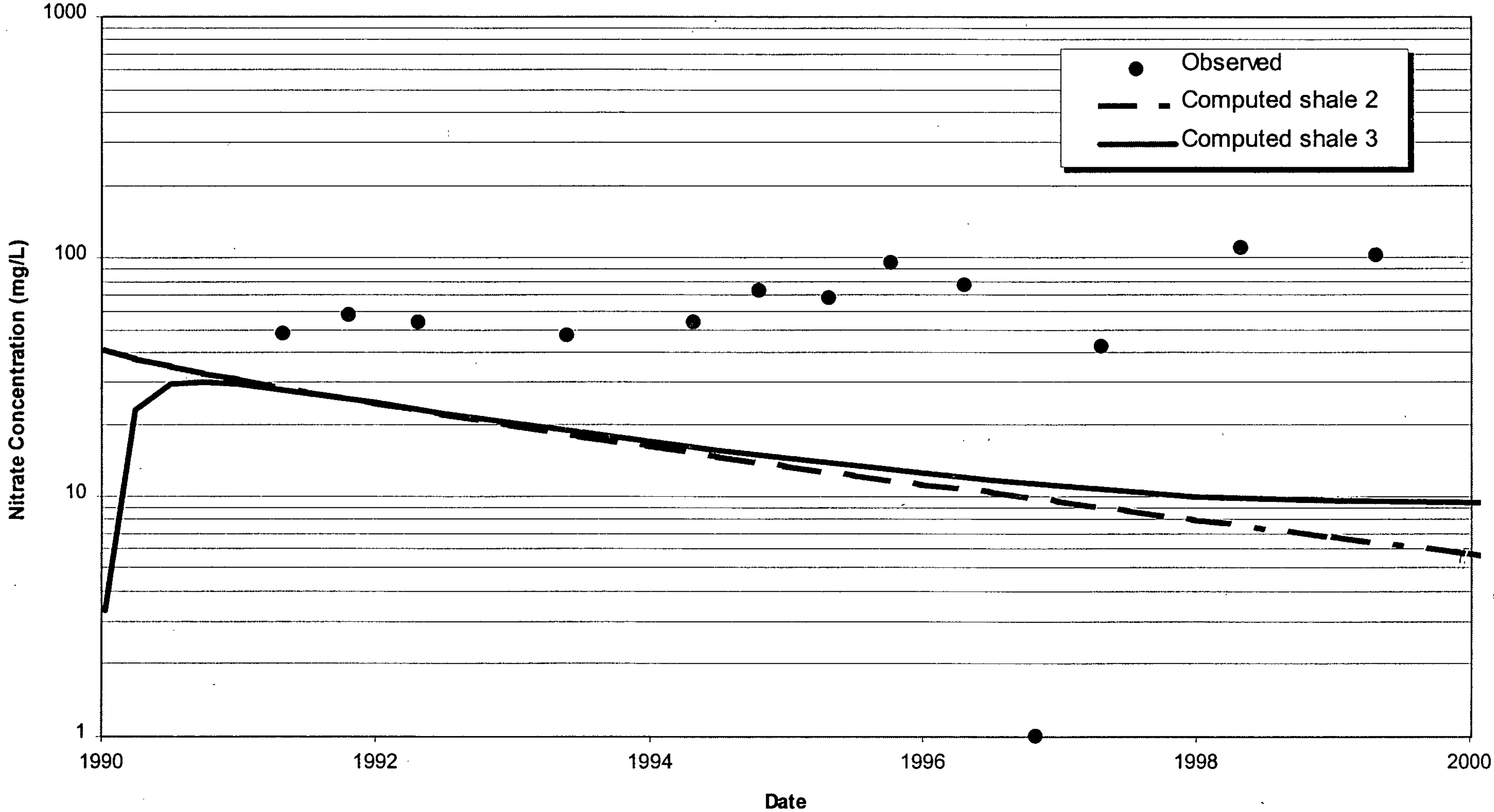

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FIGURE
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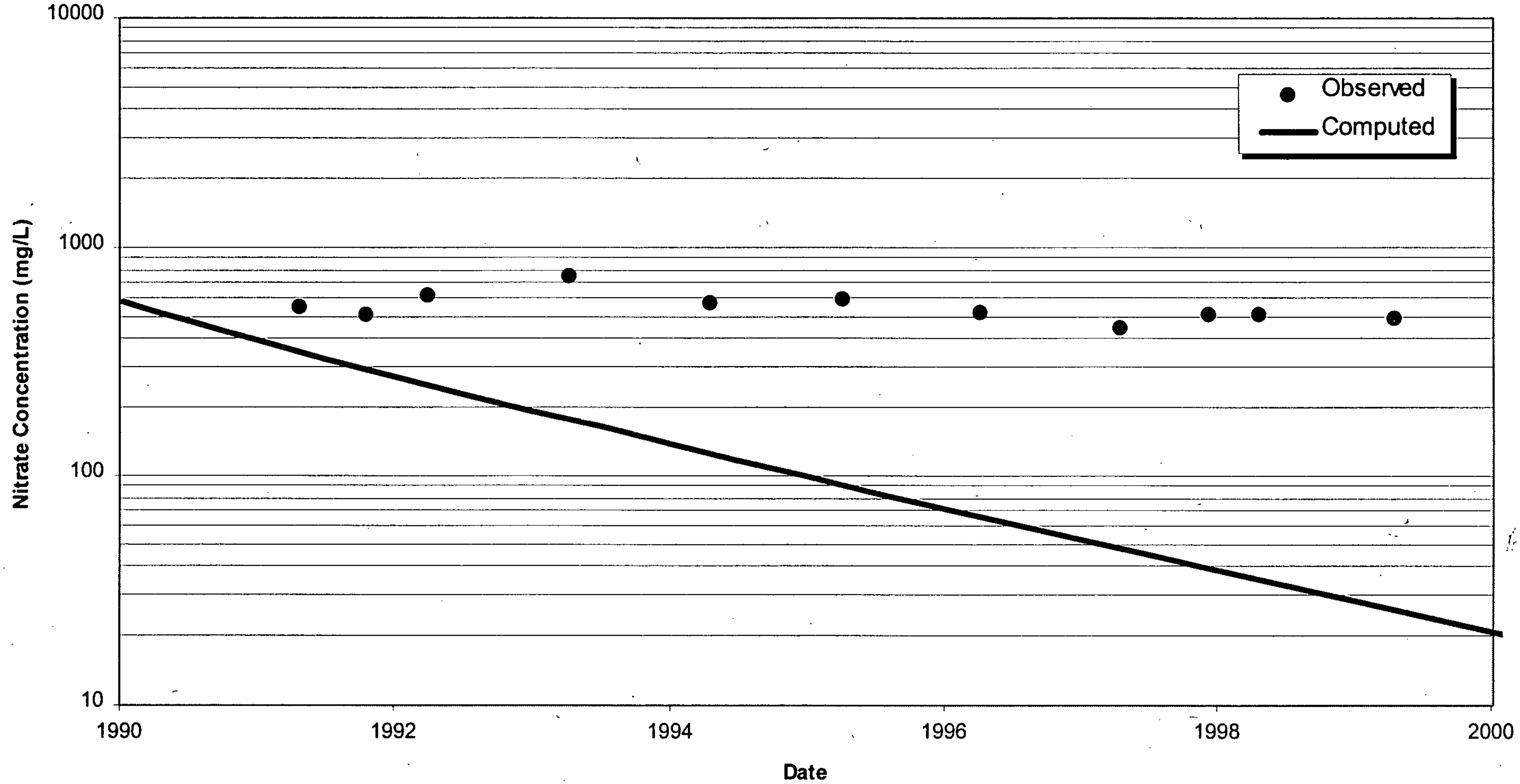

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FIGURE
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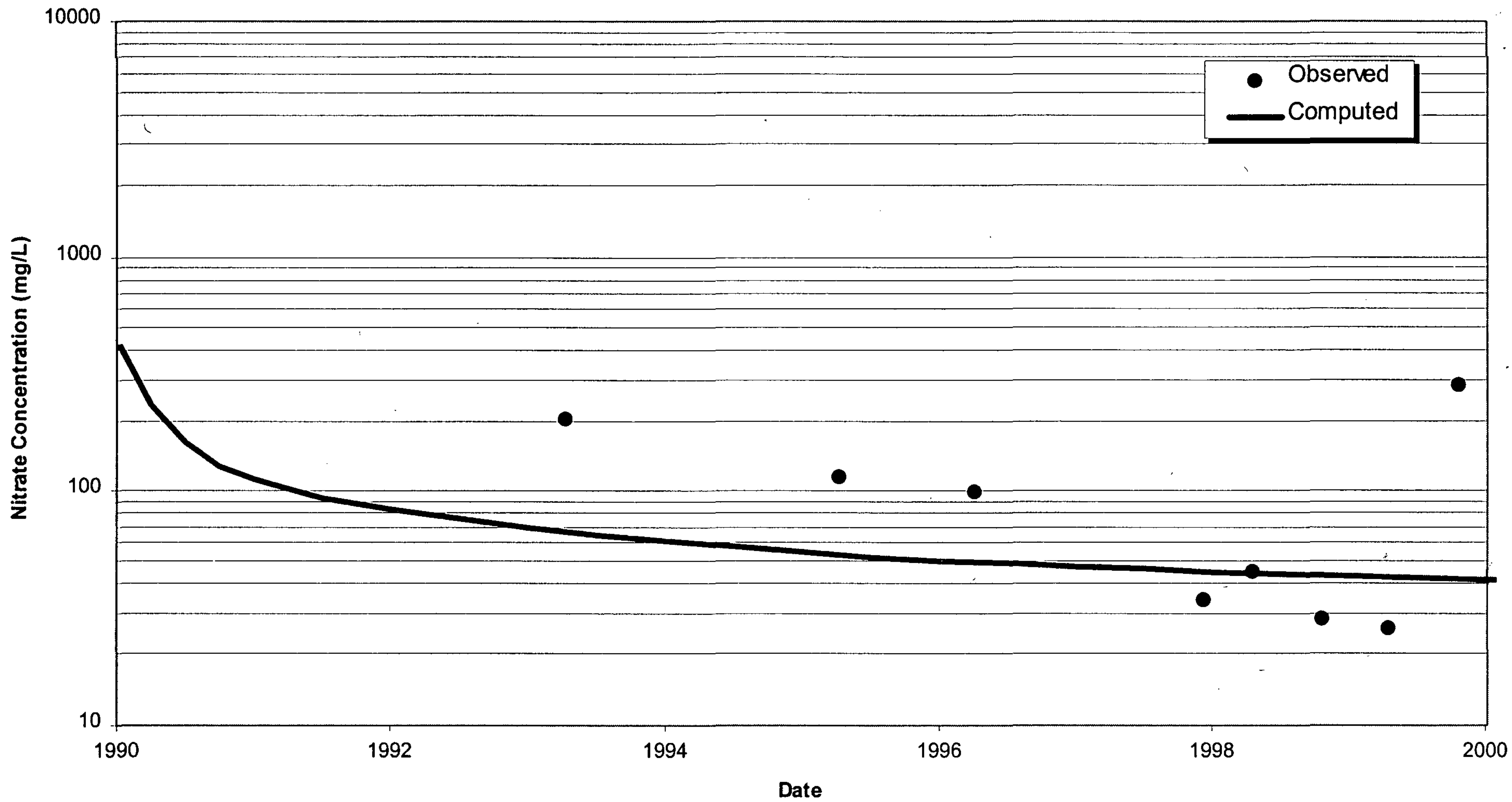

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FIGURE
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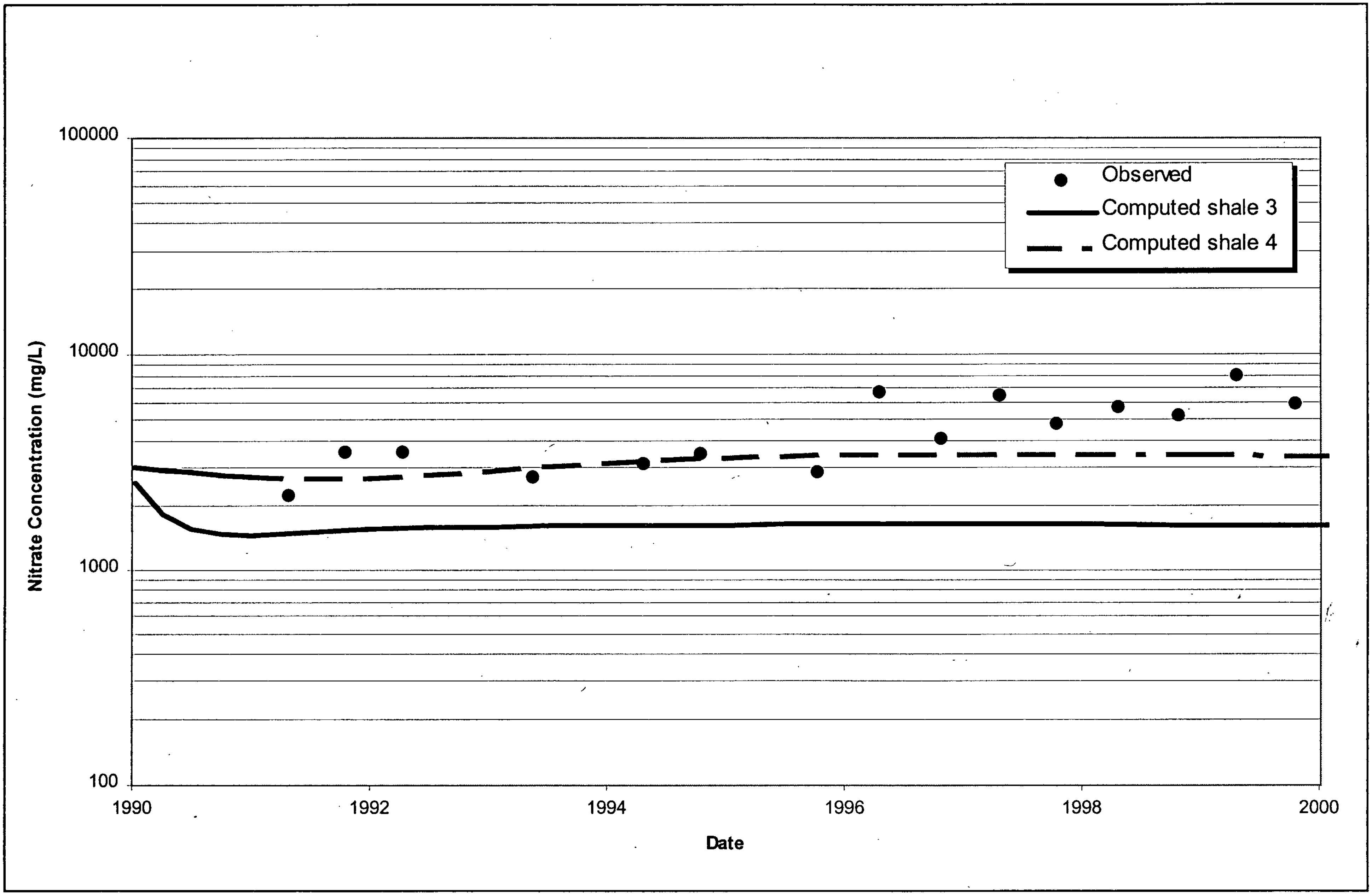

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FIGURE
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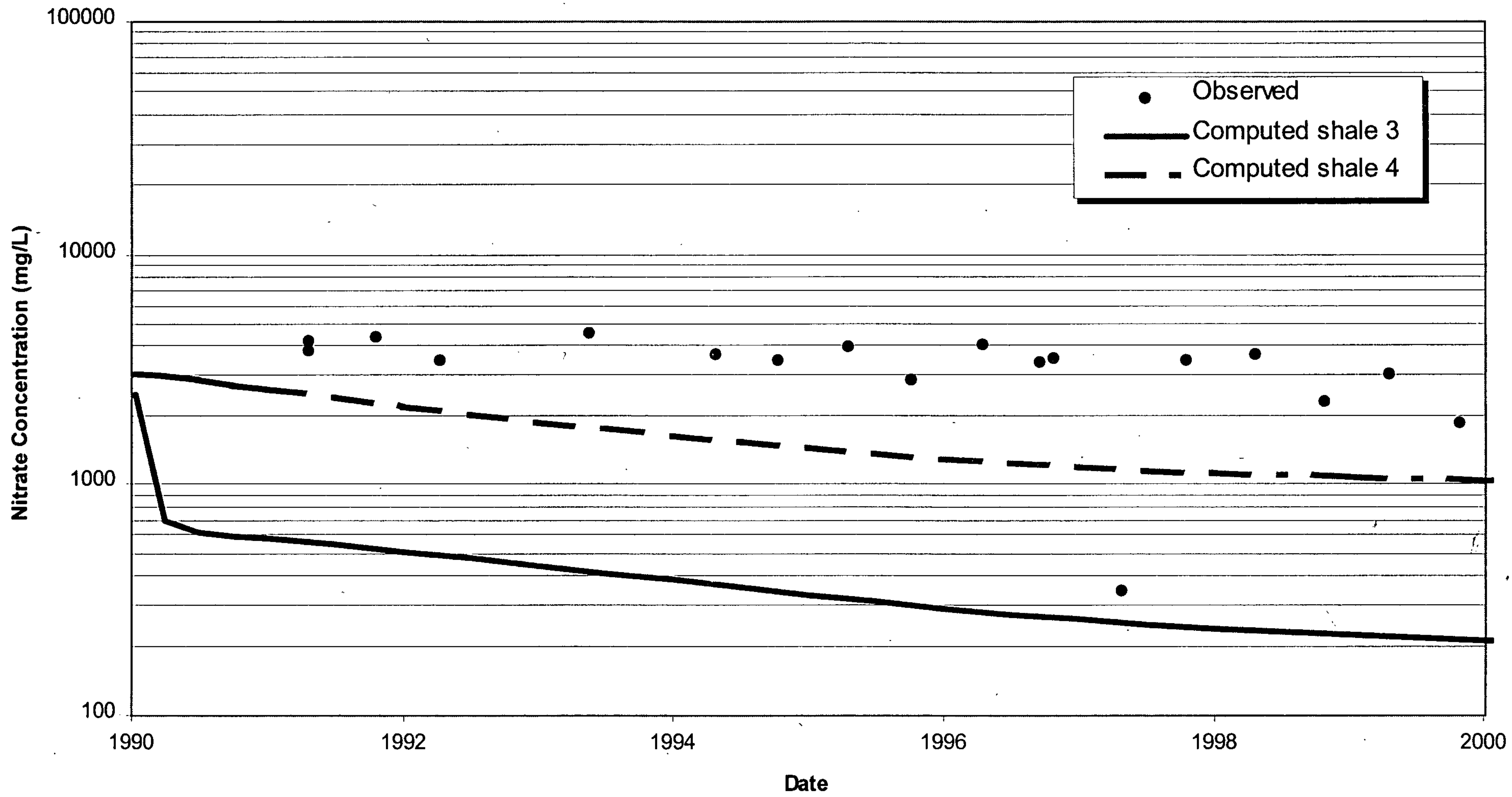

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FIGURE
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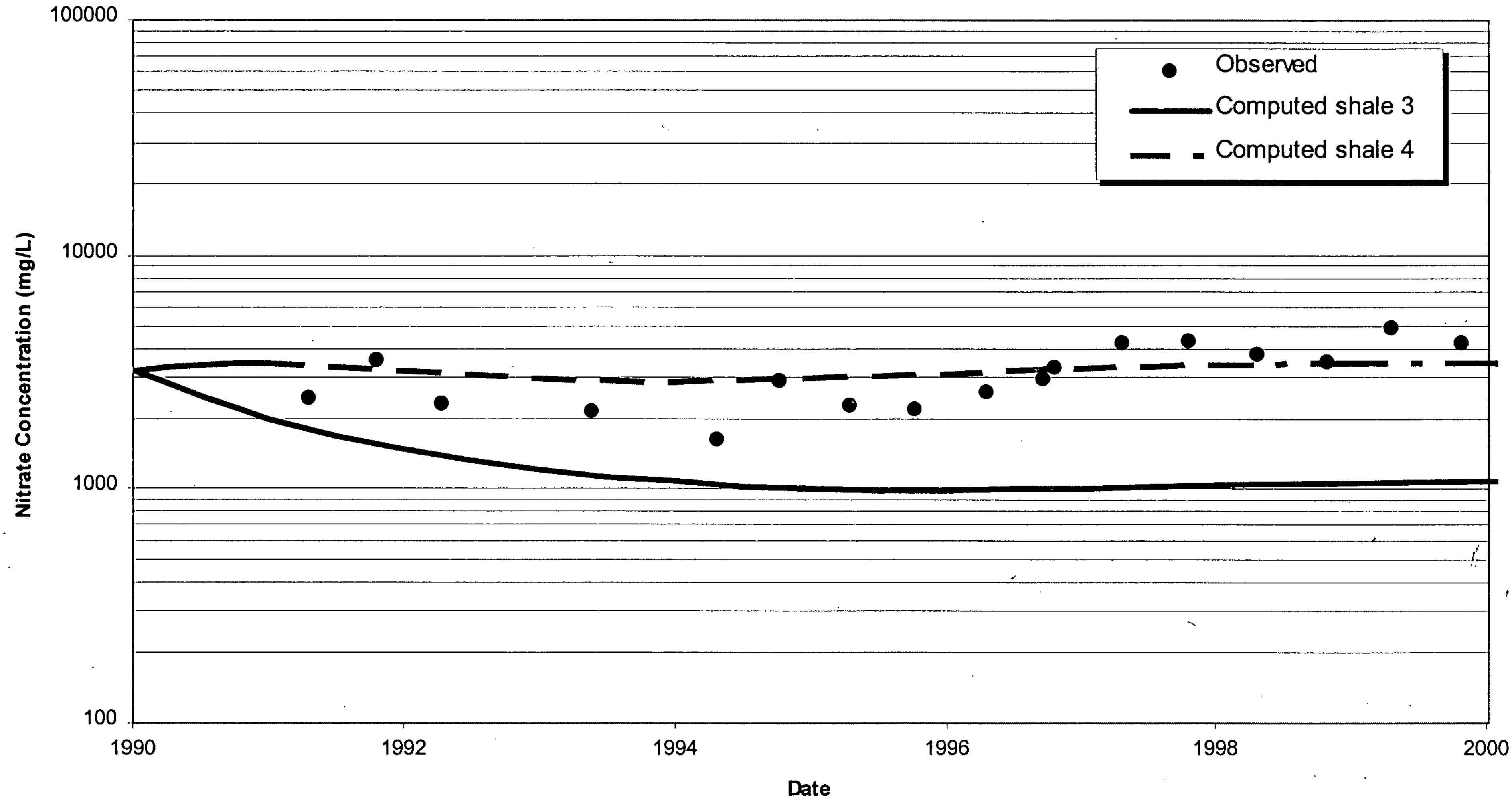

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FIGURE
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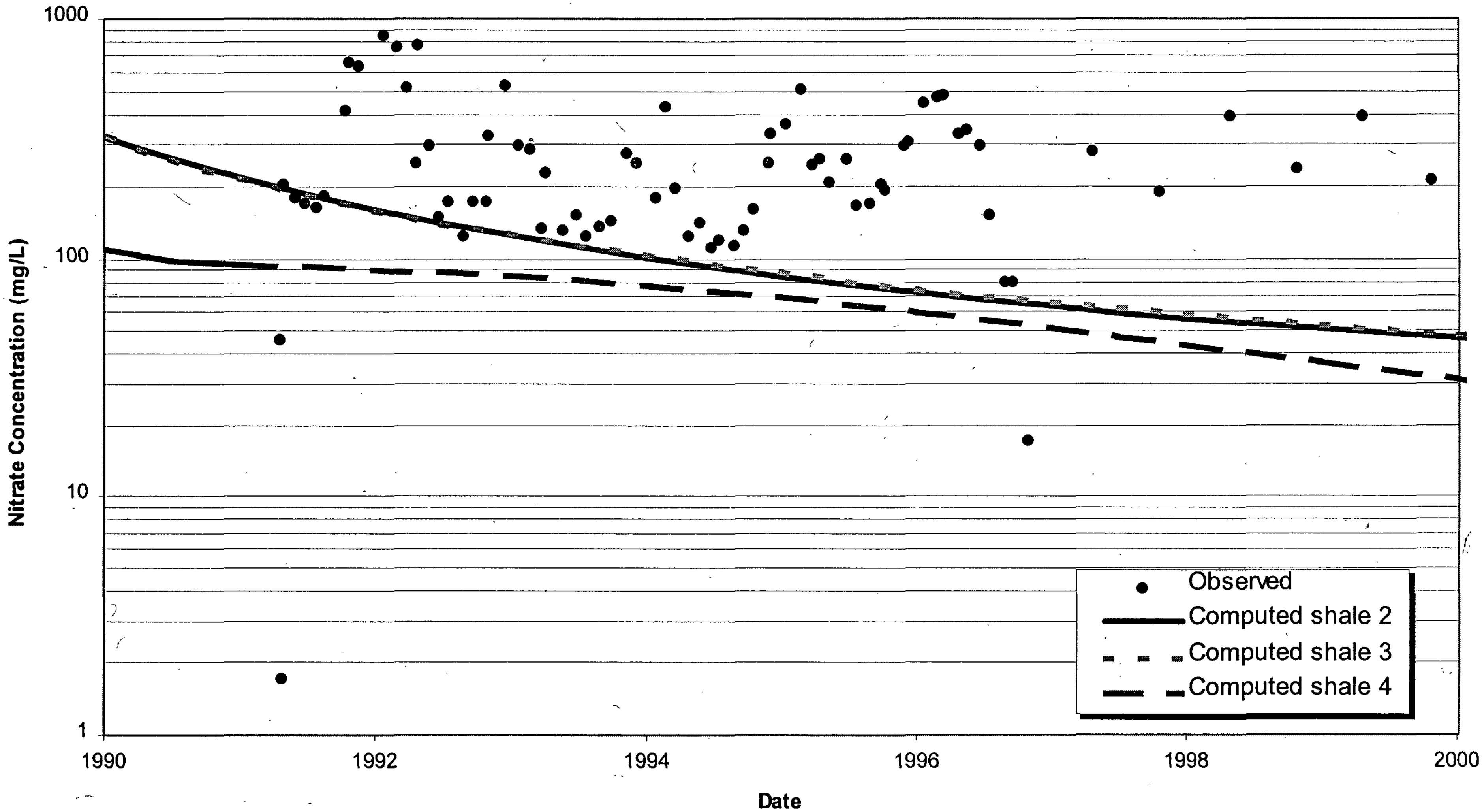

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FIGURE
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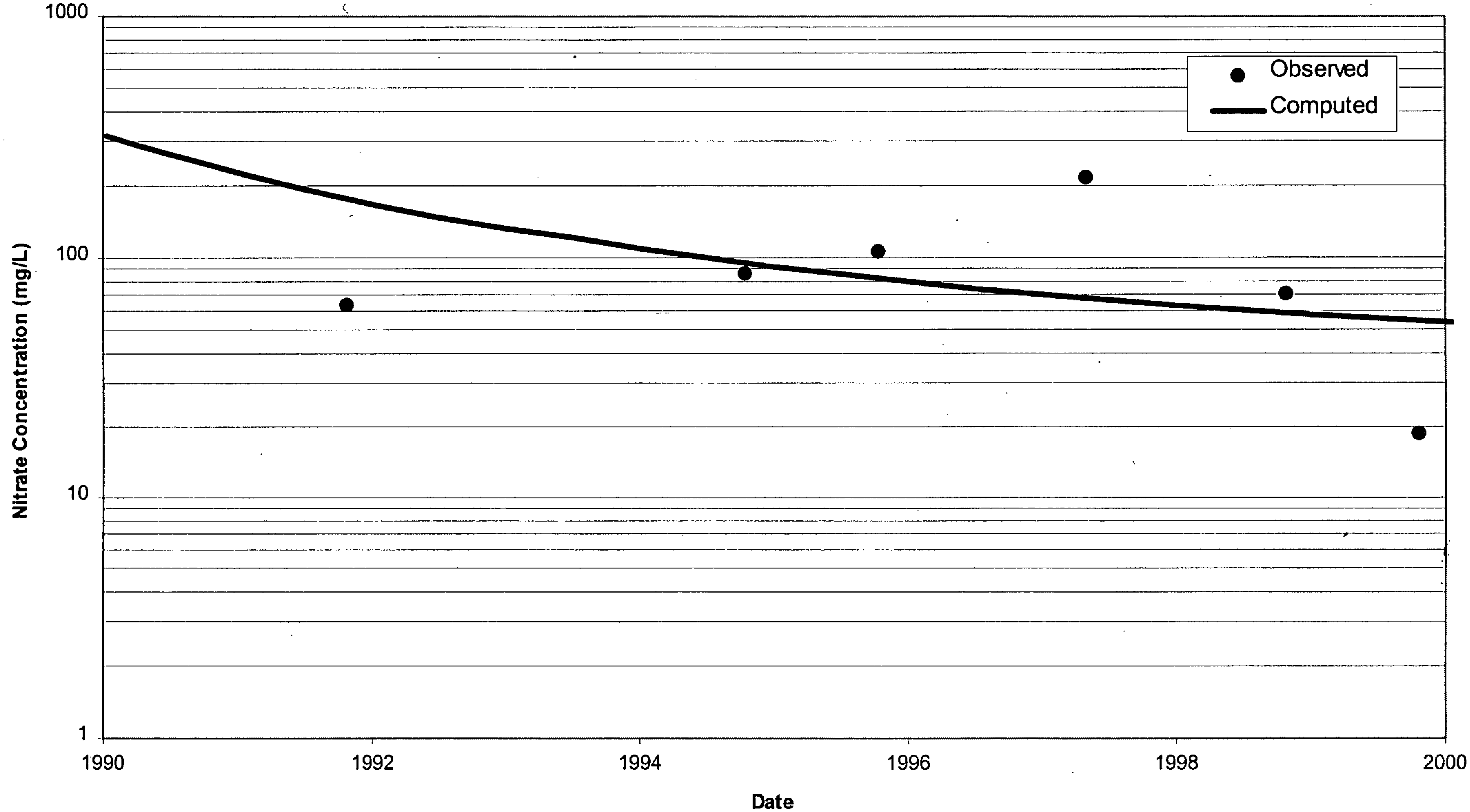

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FIGURE
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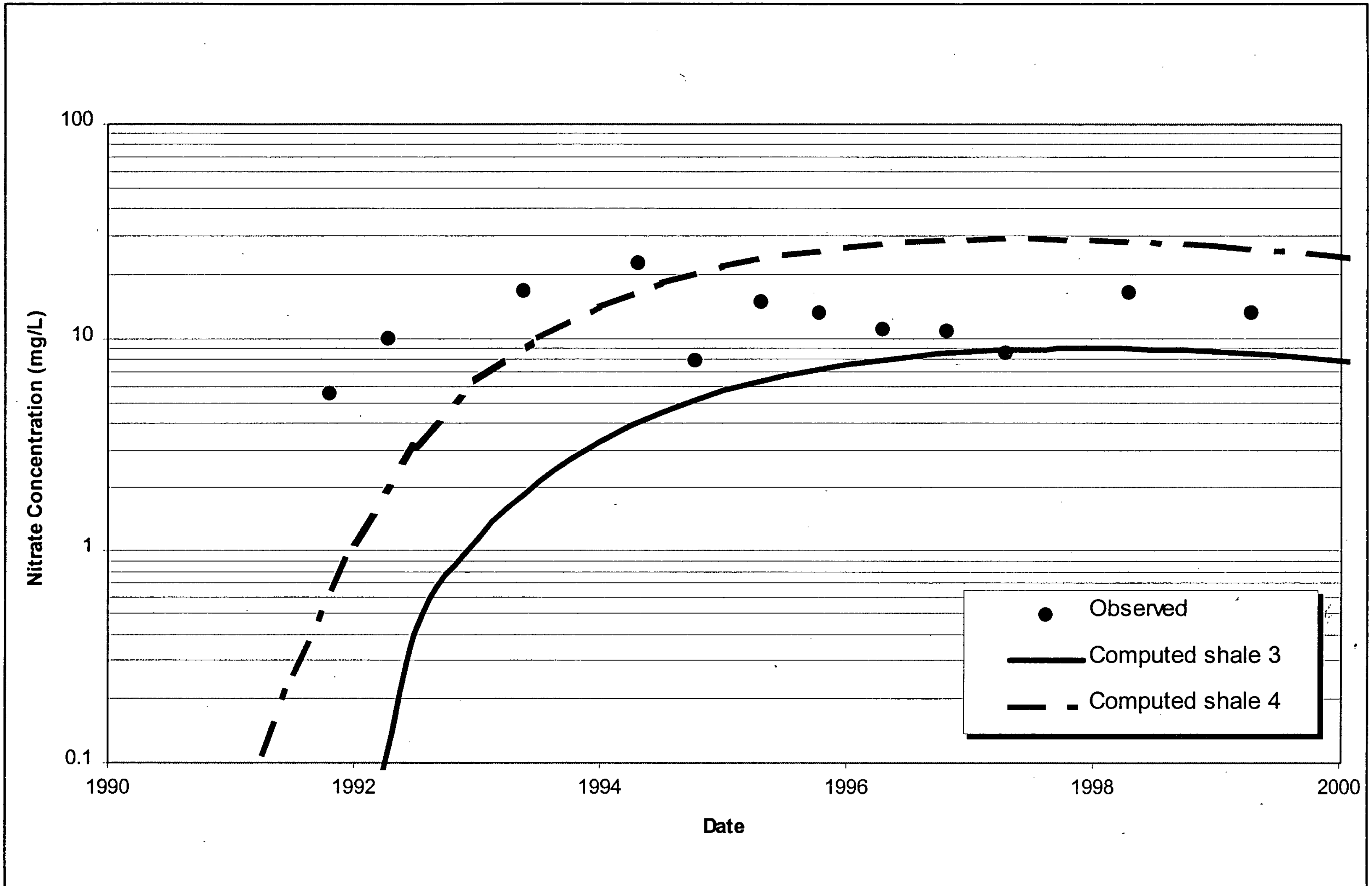

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FIGURE
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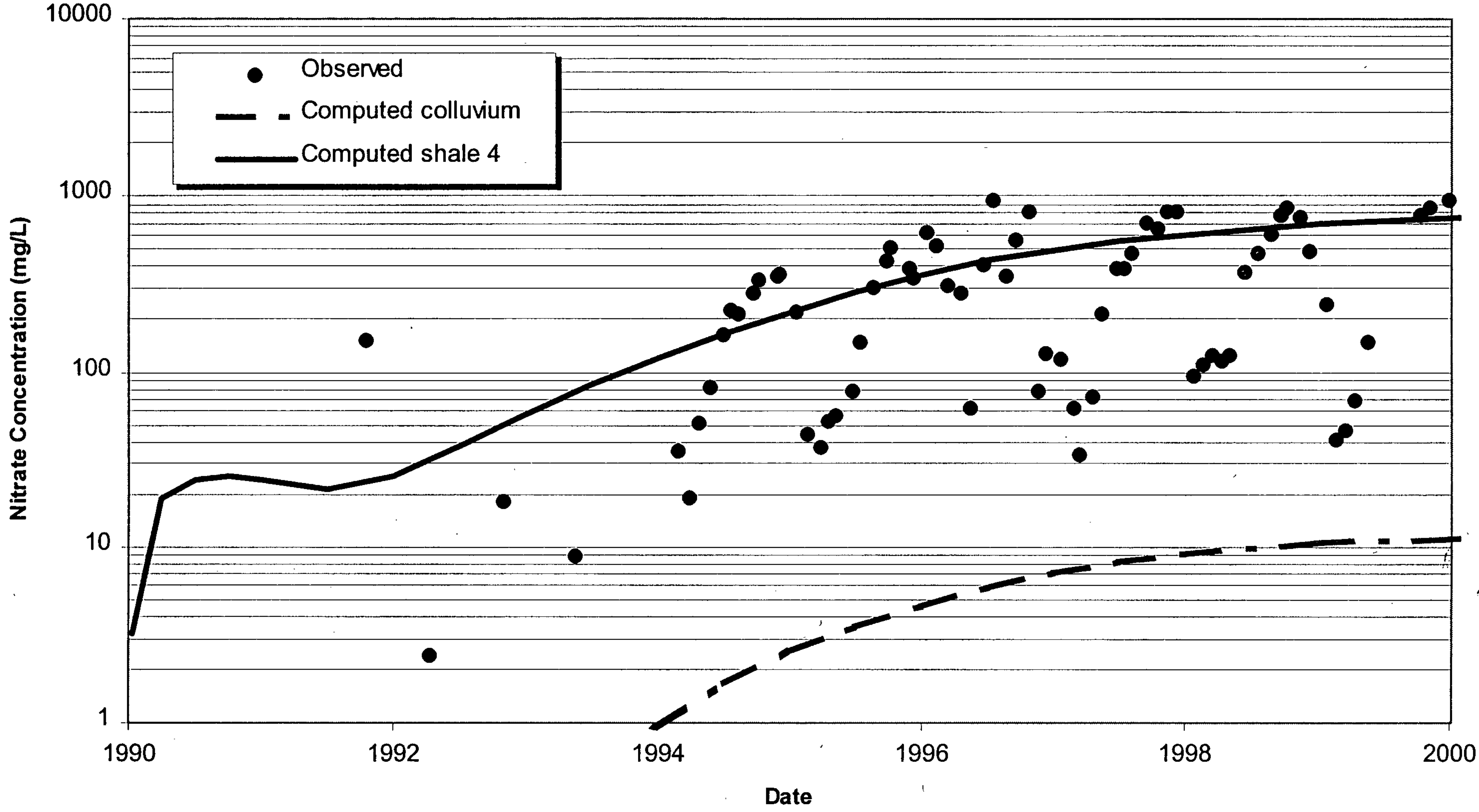

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FIGURE
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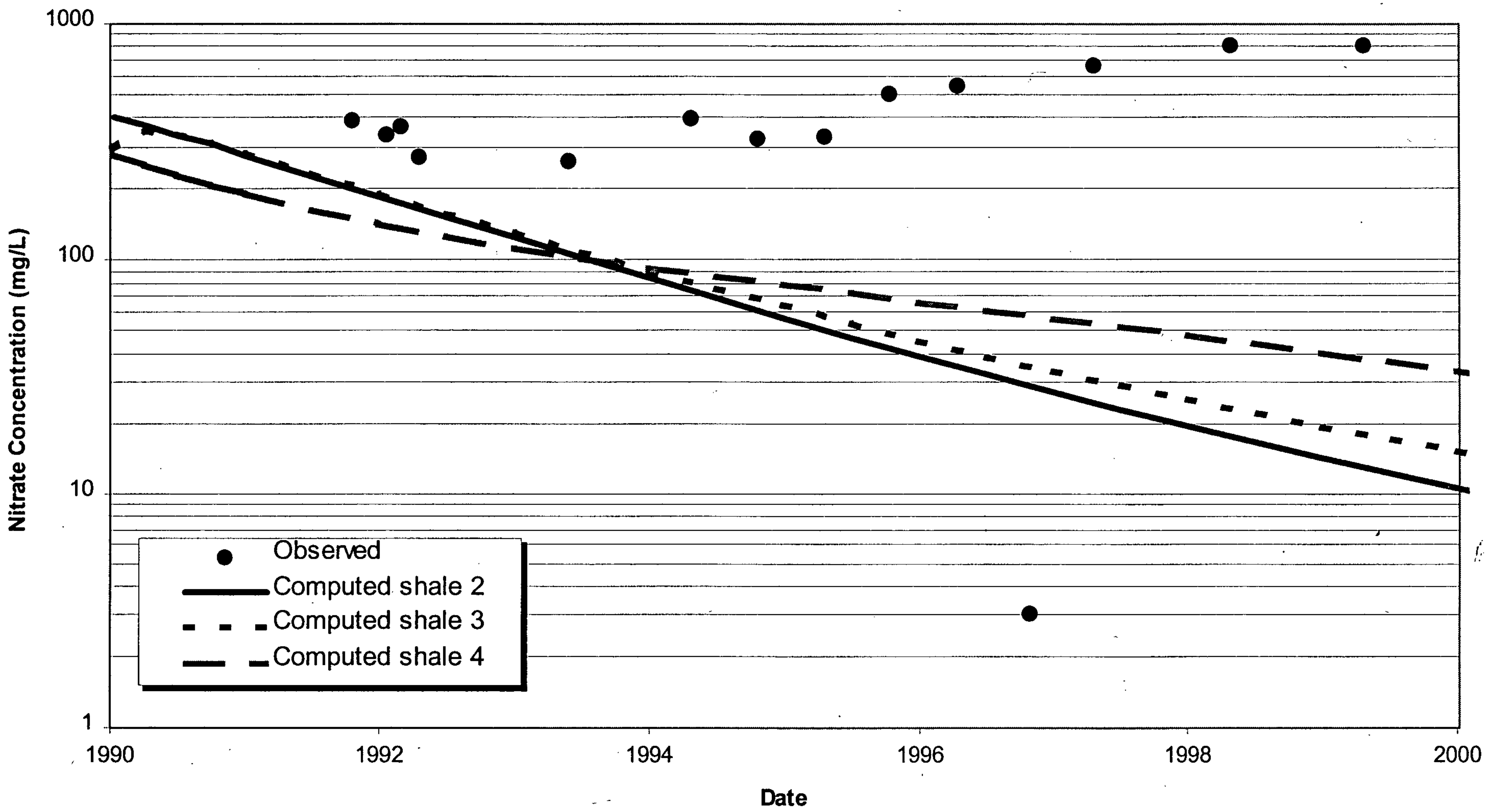

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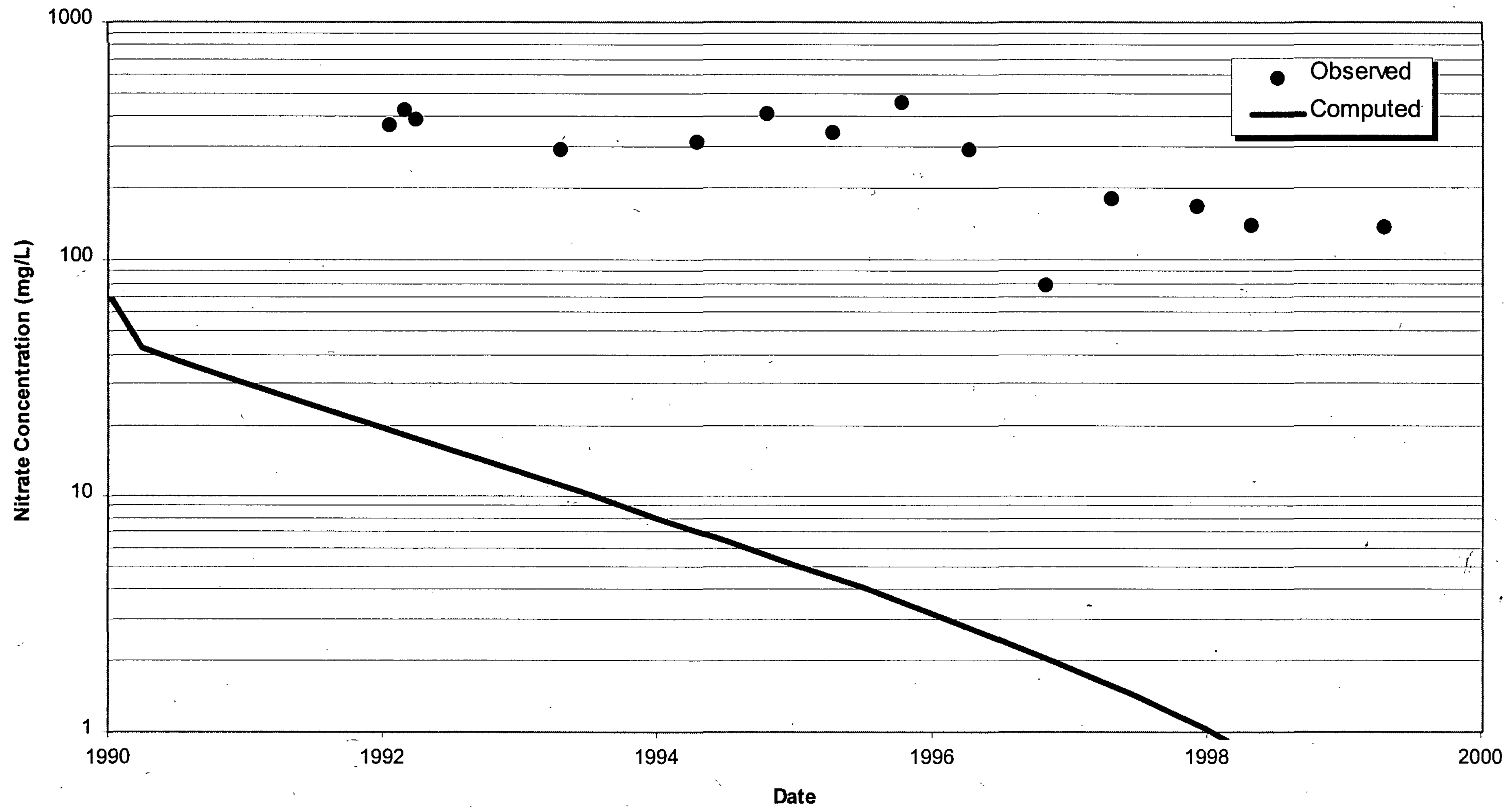

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FIGURE
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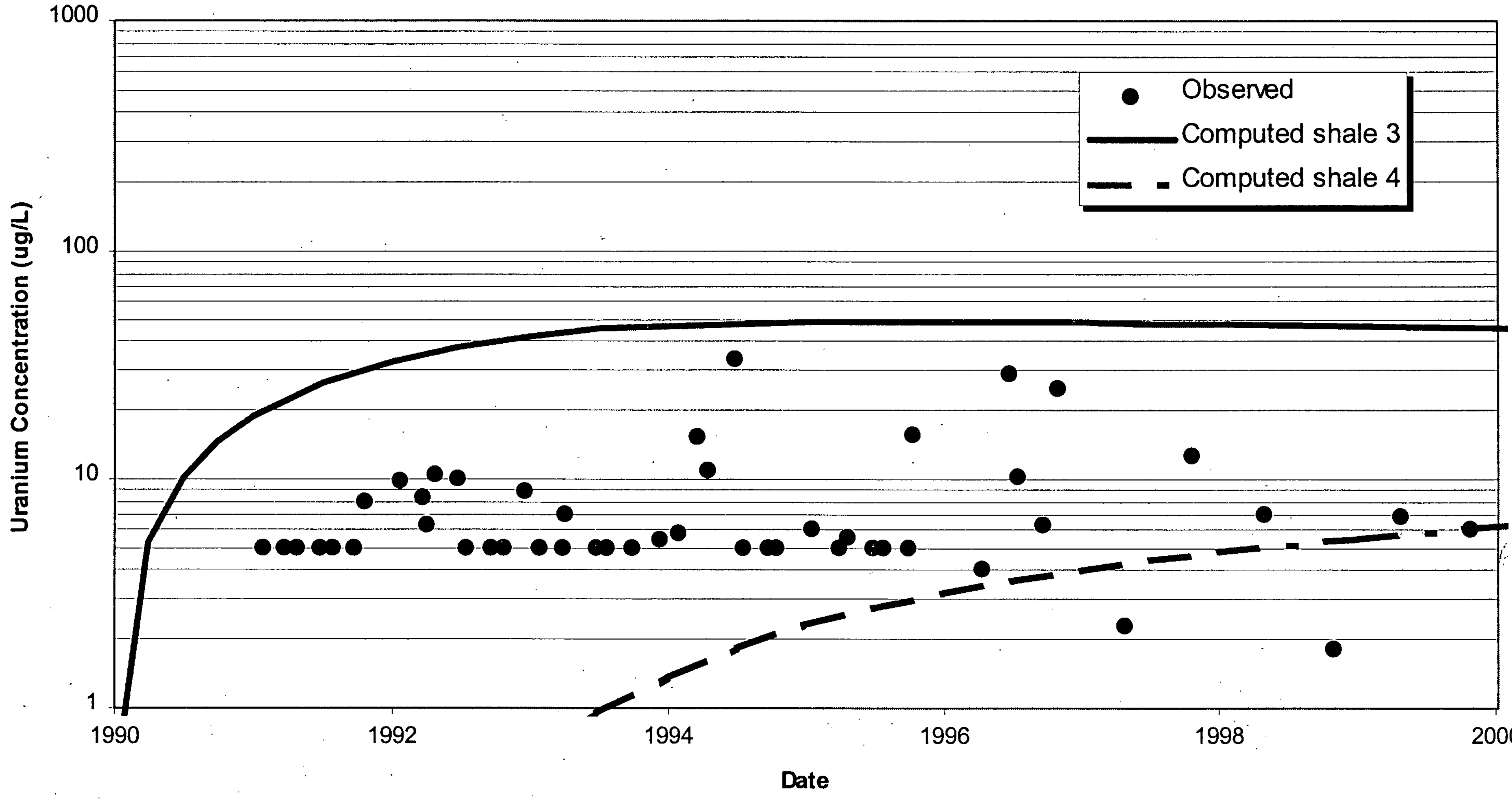

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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL 2301A

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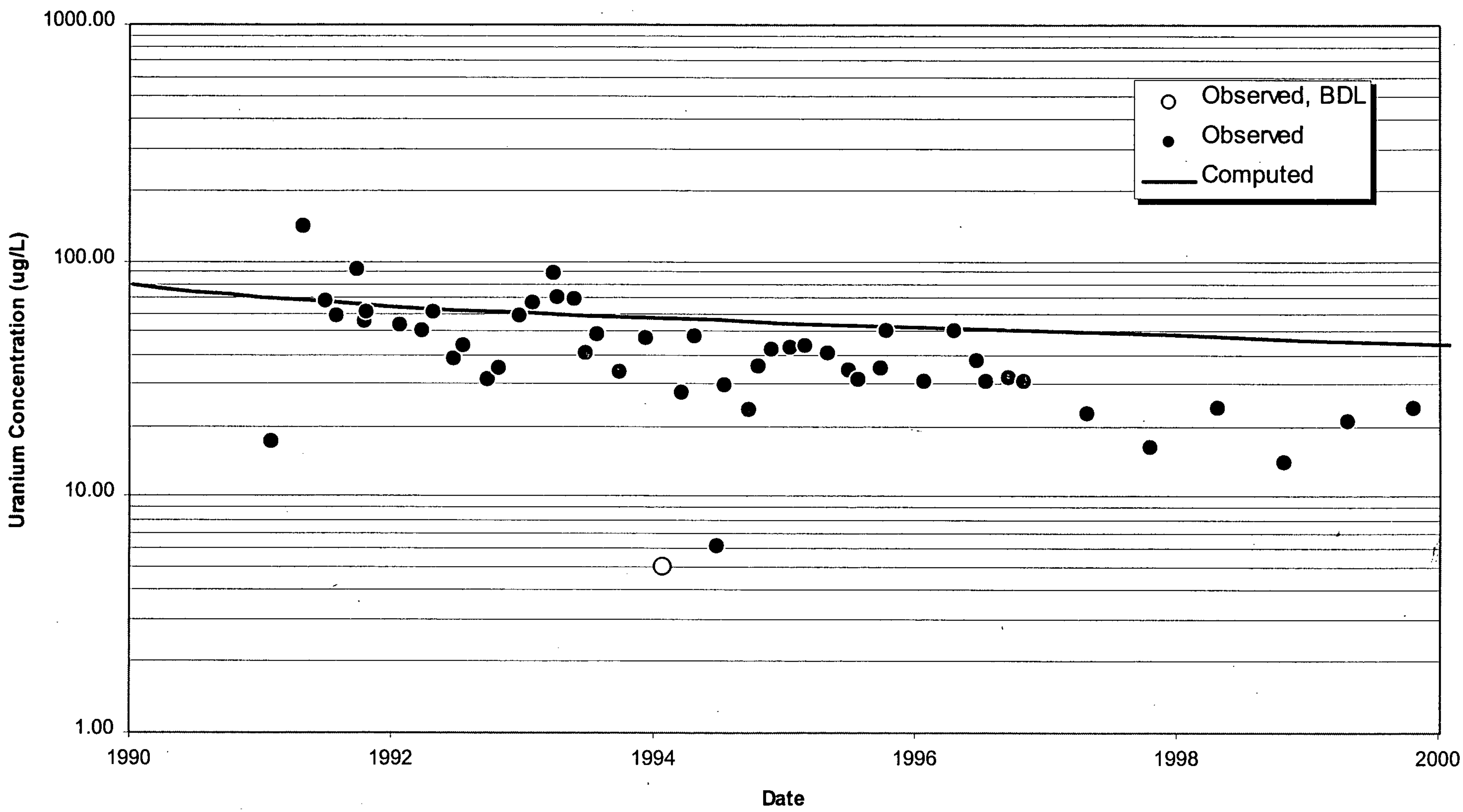

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FIGURE
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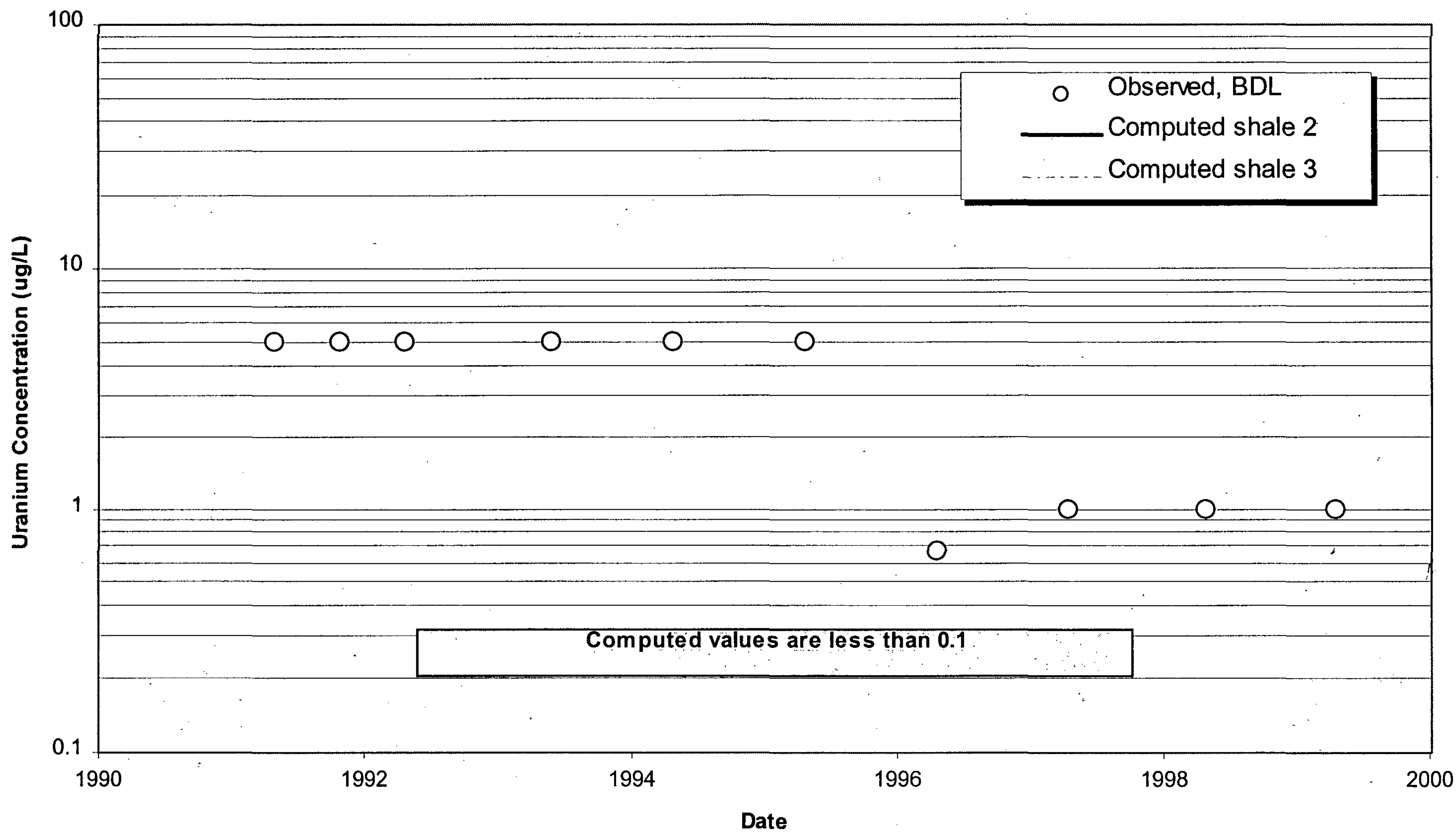

M F G consulting scientists and engineers	FIGURE URANIUM TRANSPORT CALIBRATION FOR WELL MW003A	Date: AUGUST 2002 Project: V:\Titleblocks\ File: MFG TBLK LAND.ppt

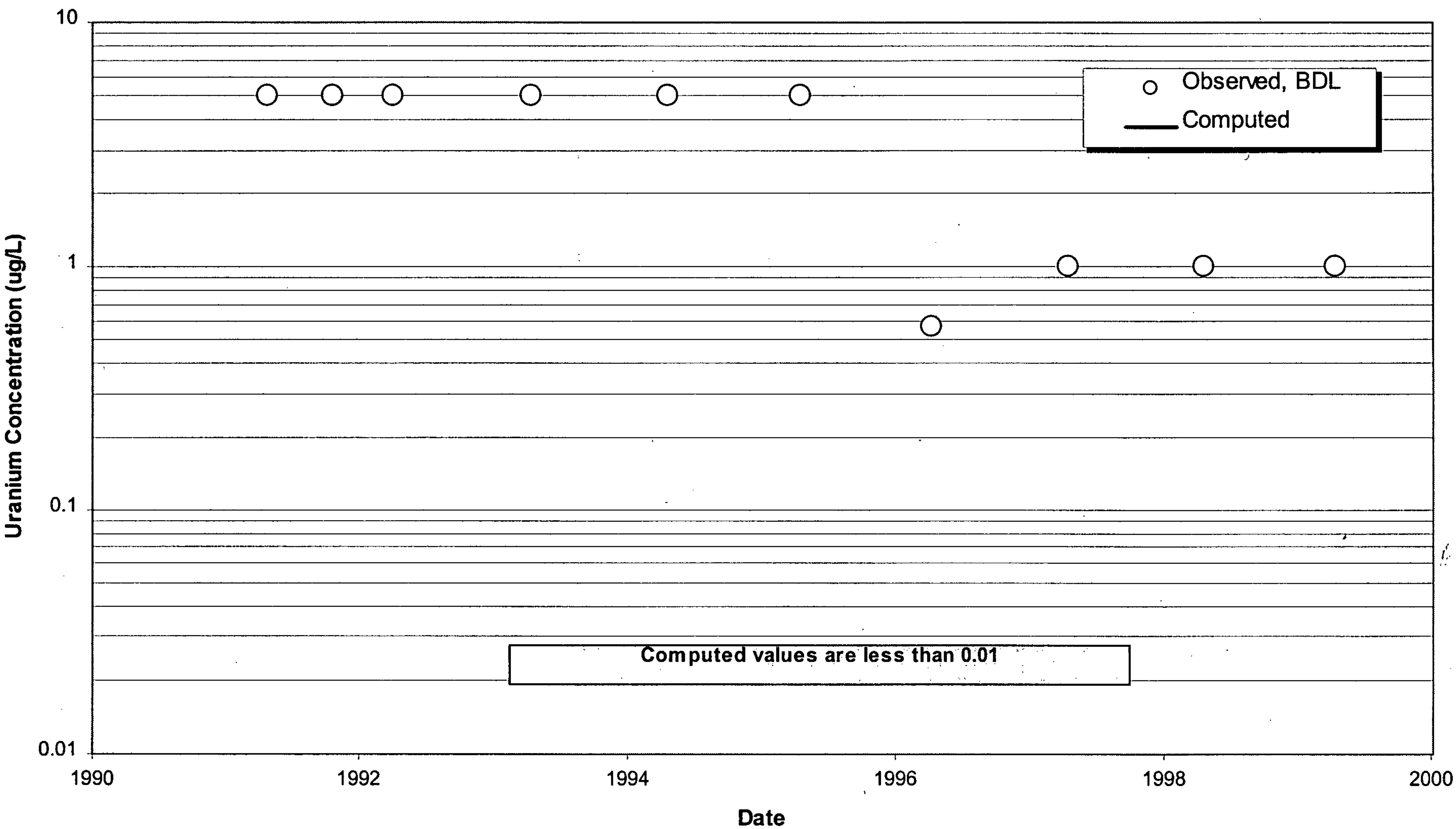

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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW003

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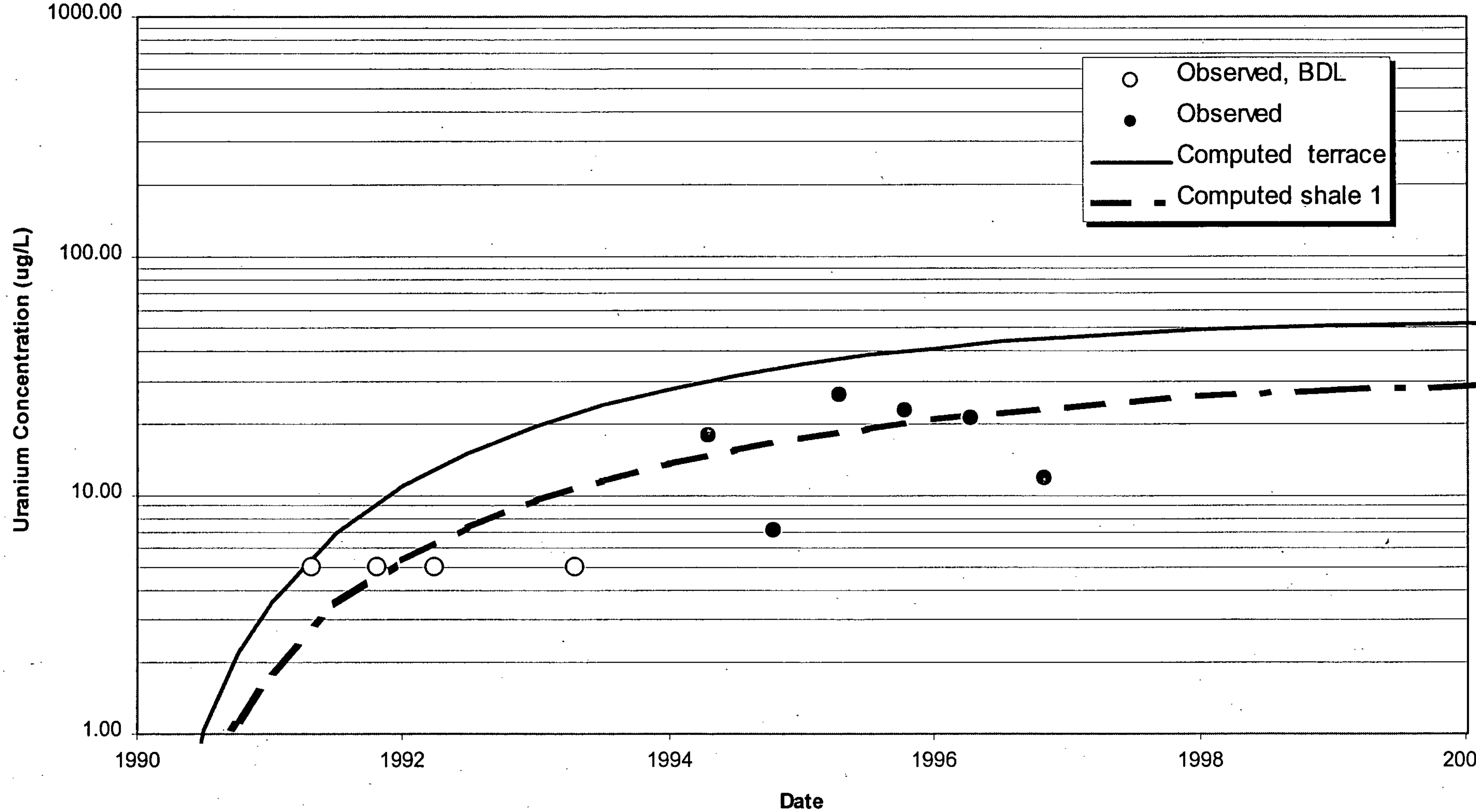

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FIGURE
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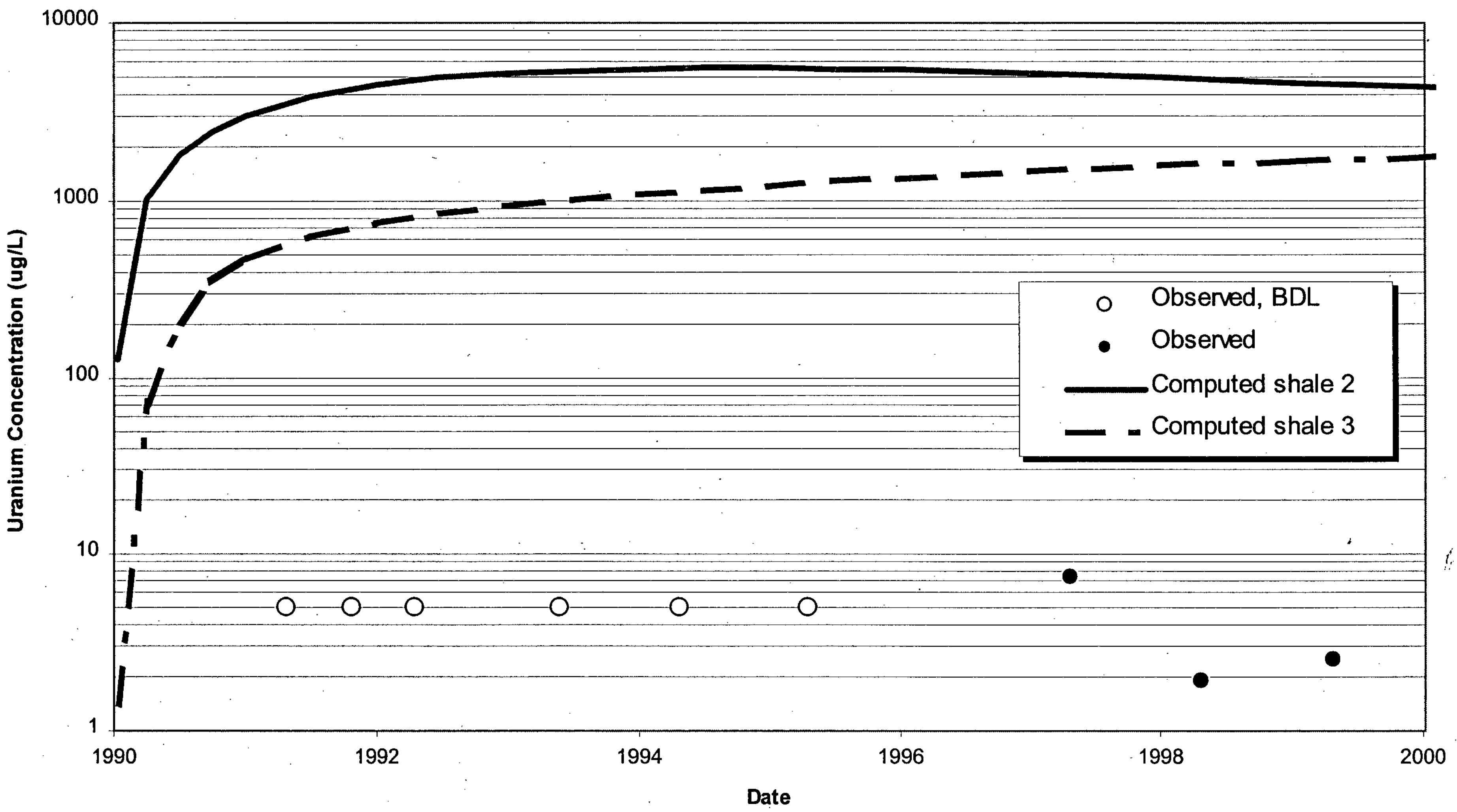

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FIGURE
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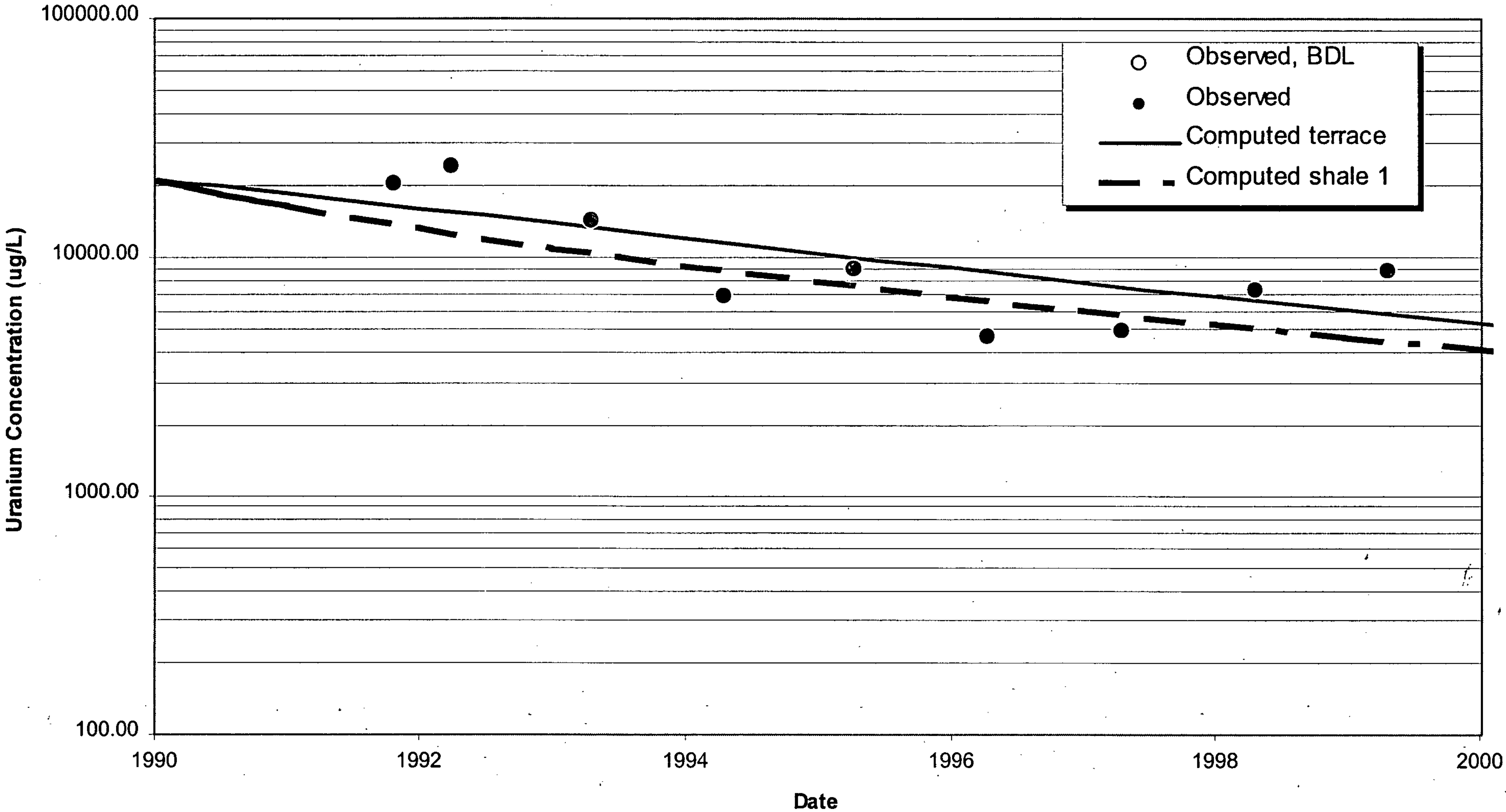

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FIGURE
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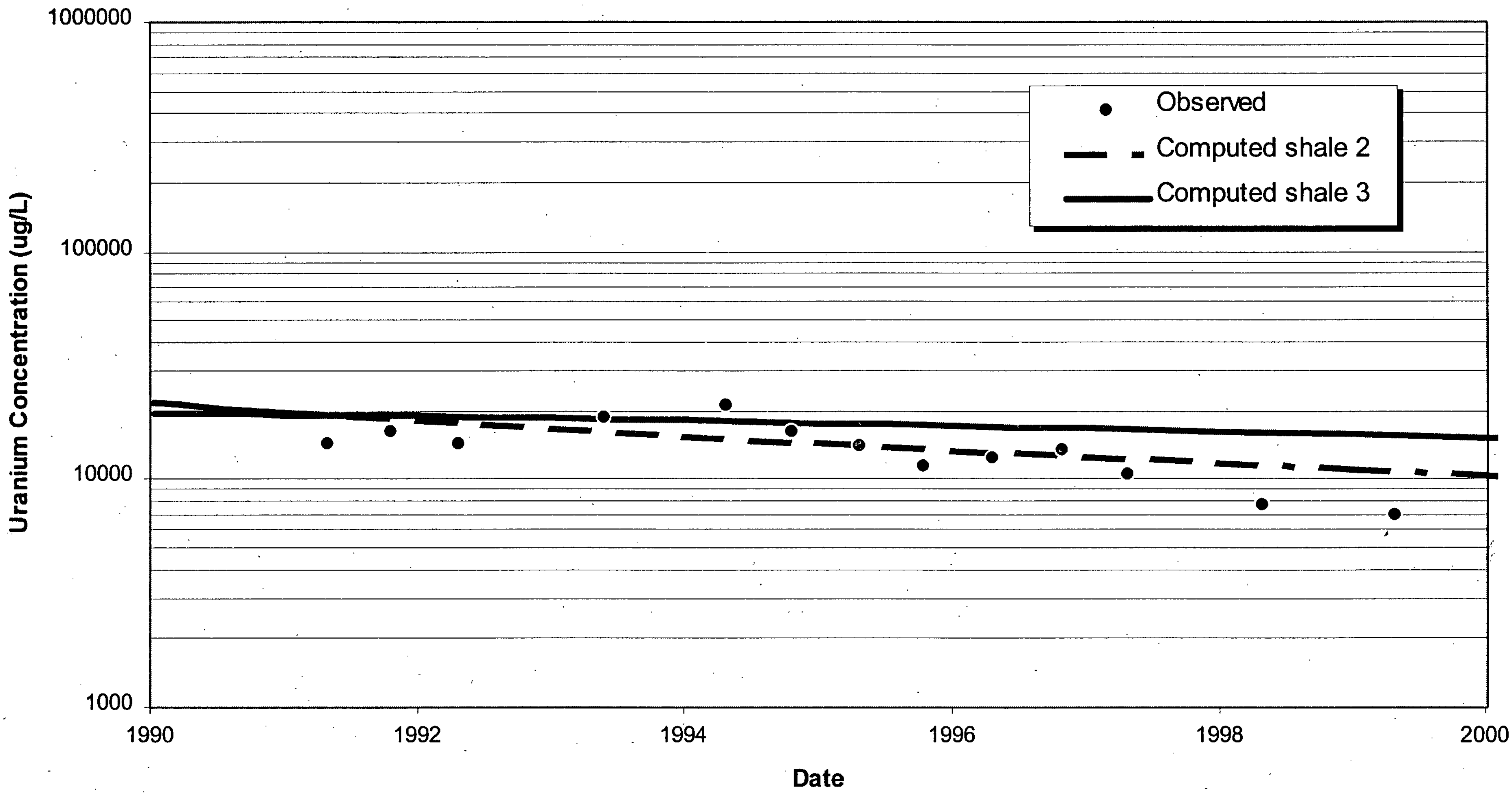

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FIGURE
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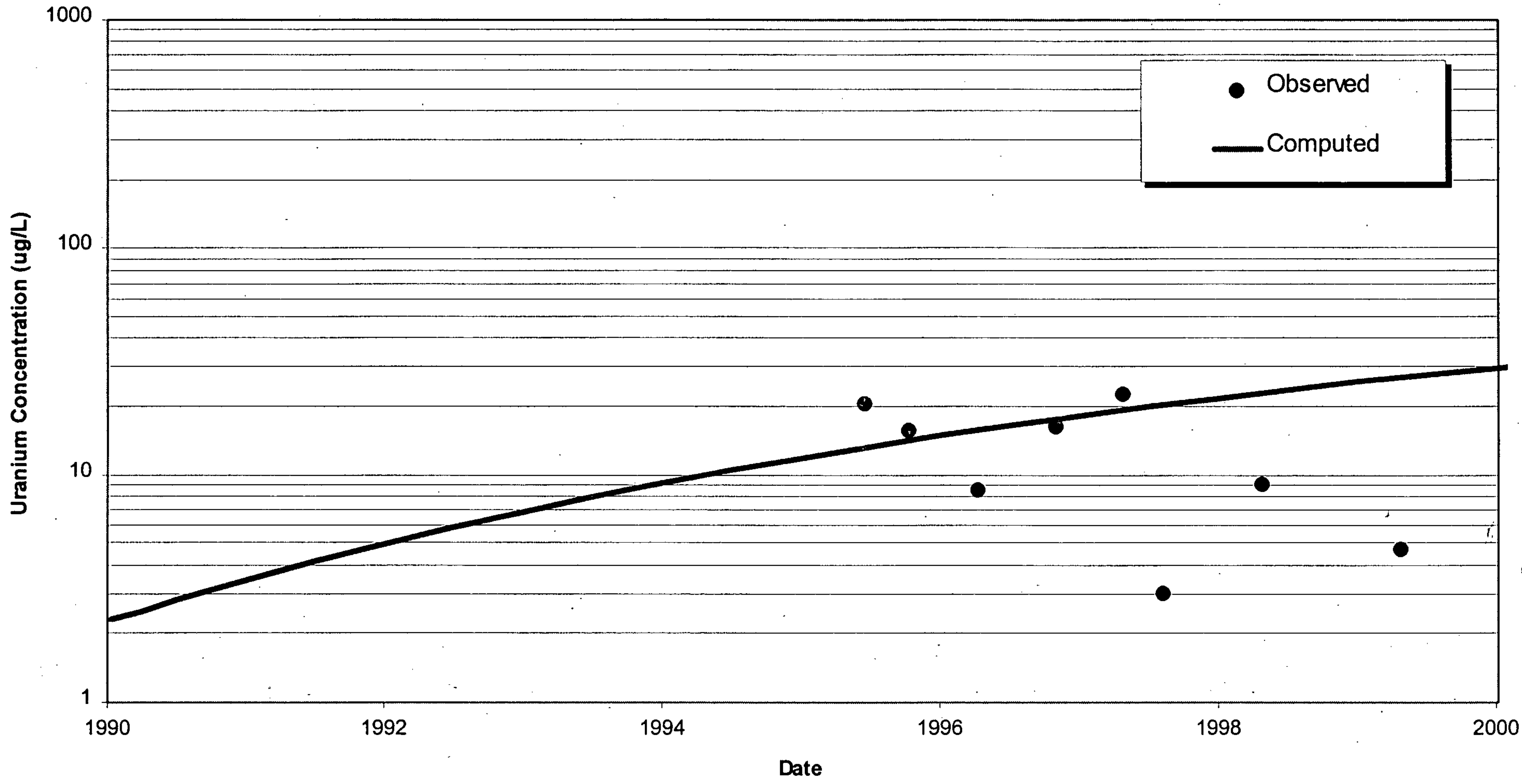

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FIGURE
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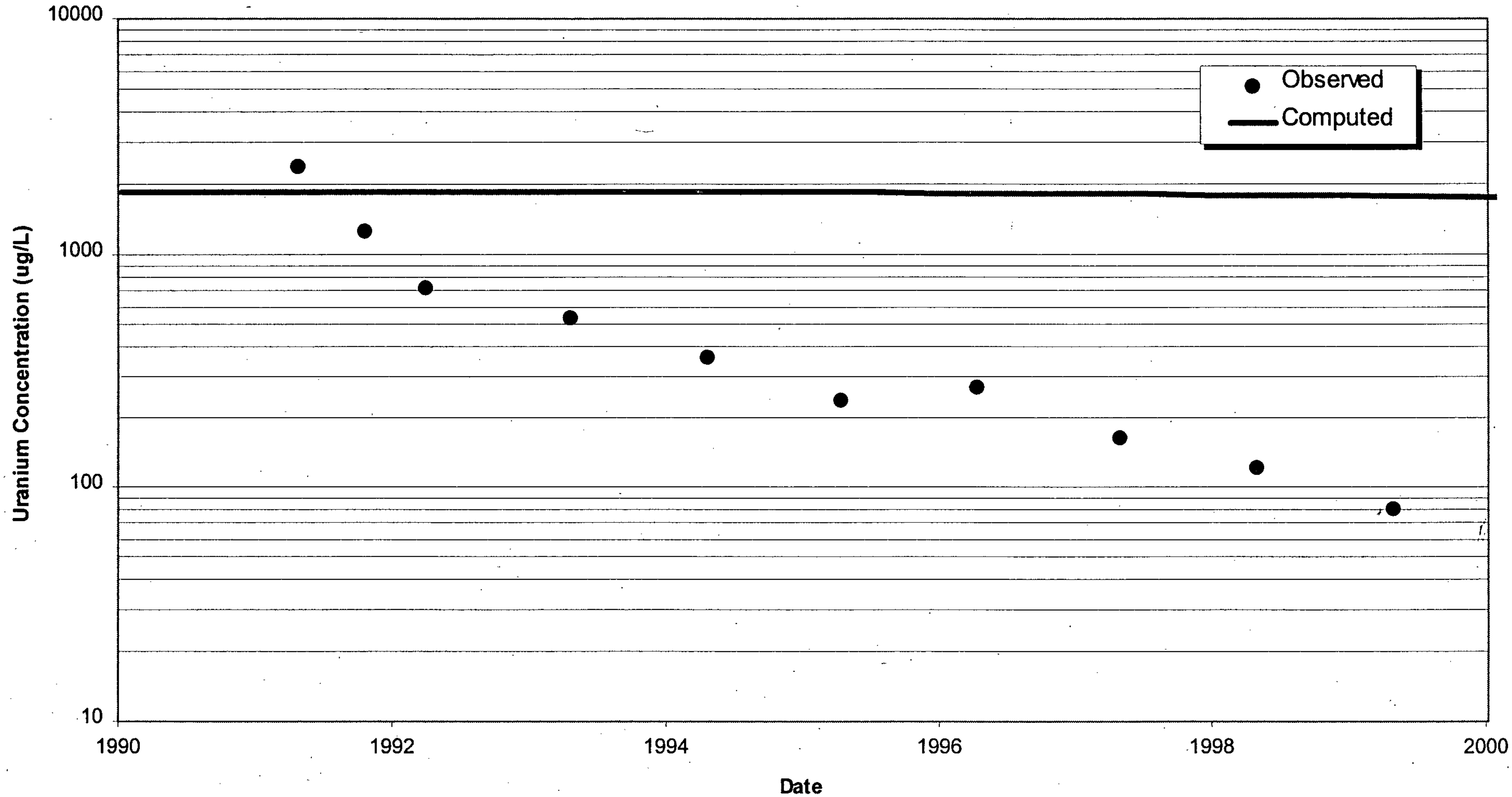

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FIGURE
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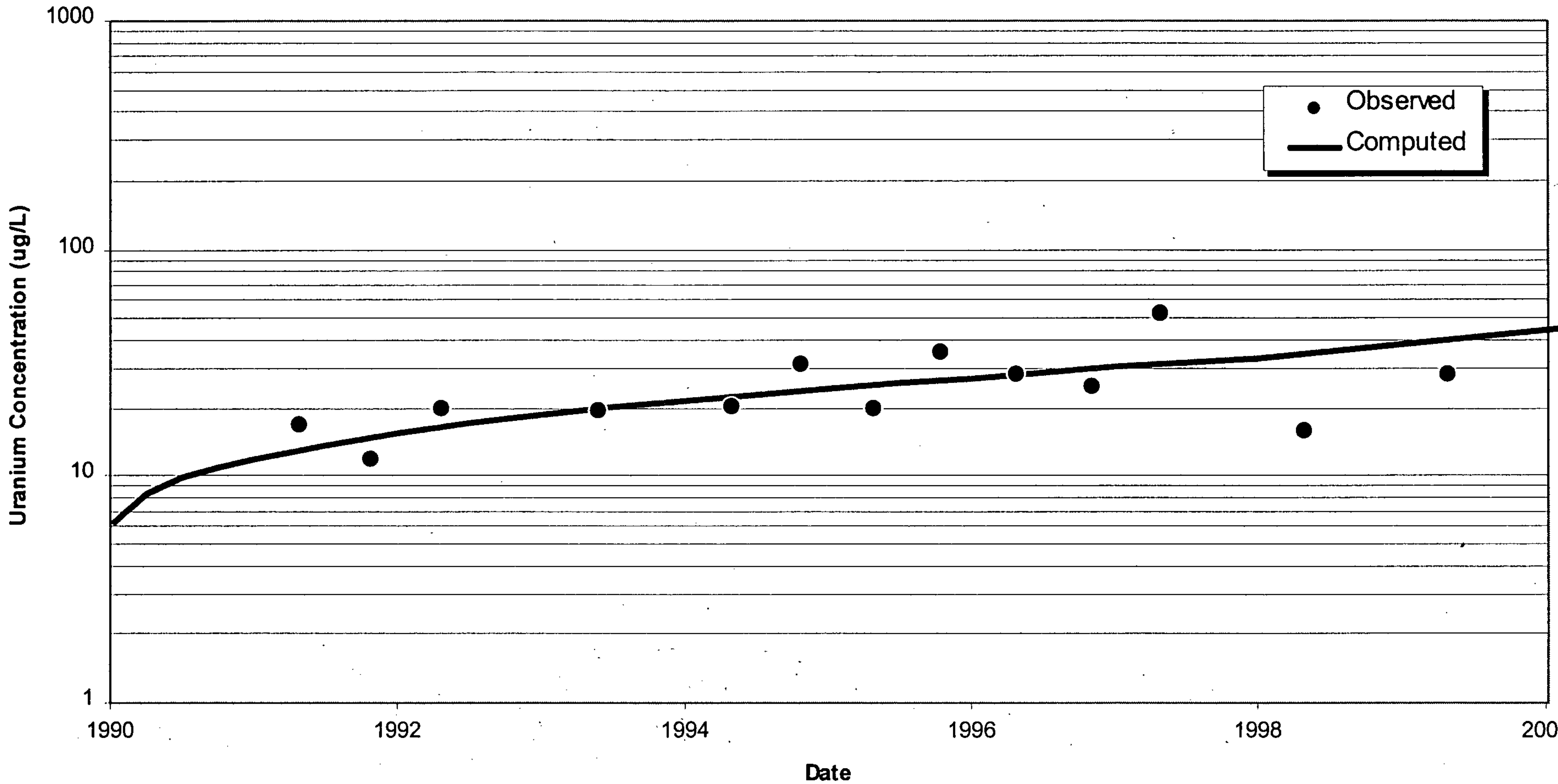

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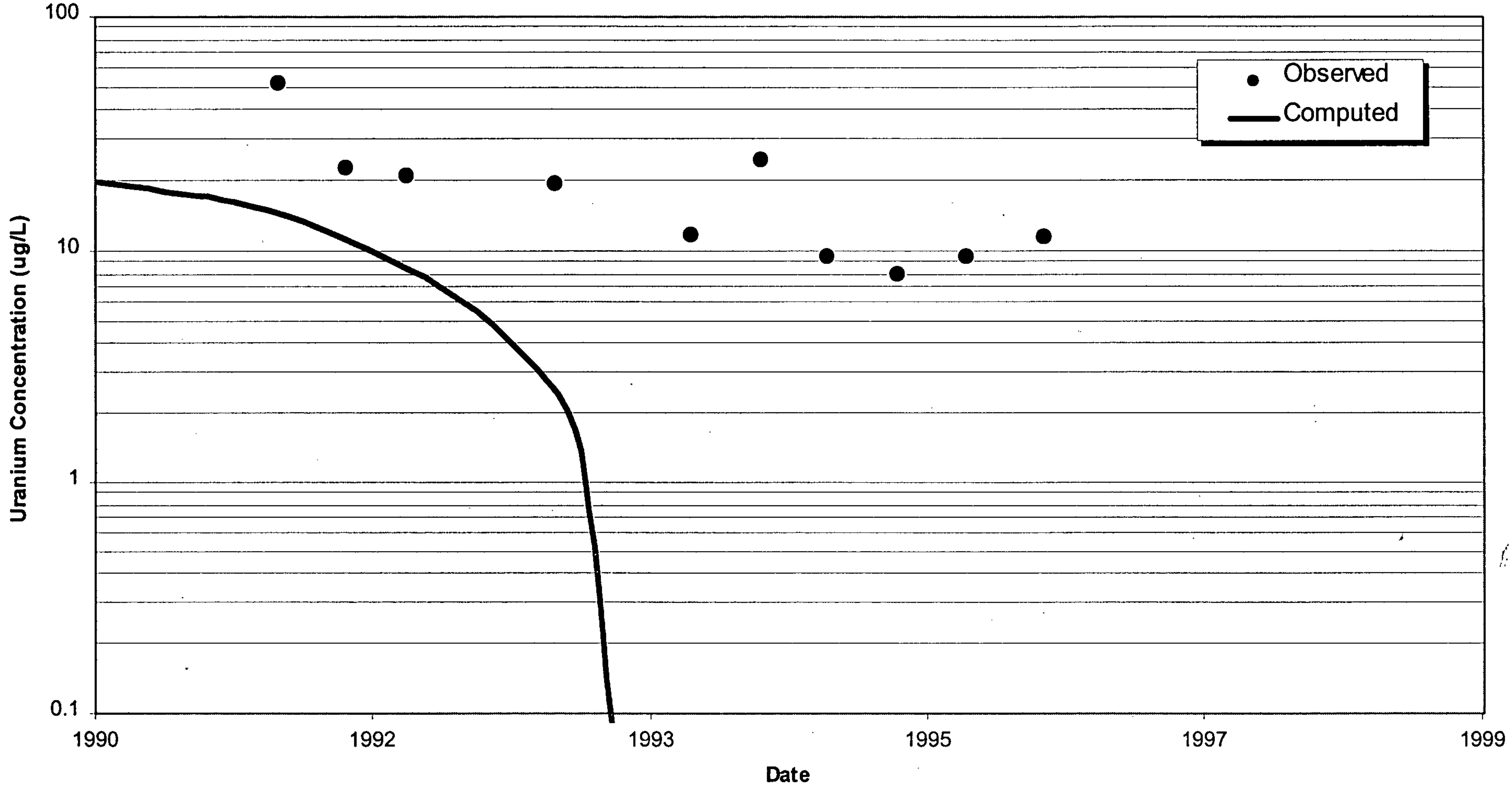

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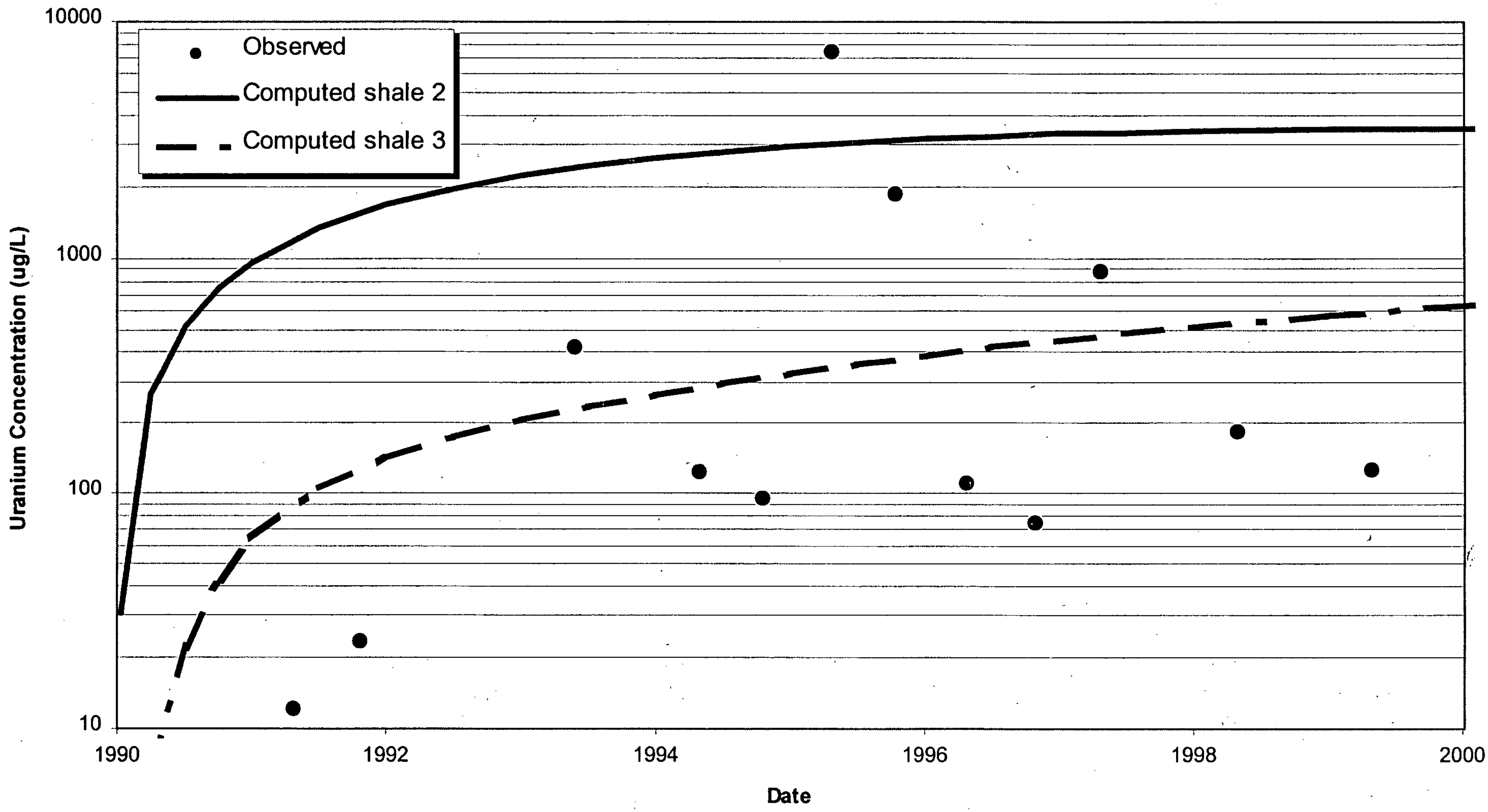

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FIGURE
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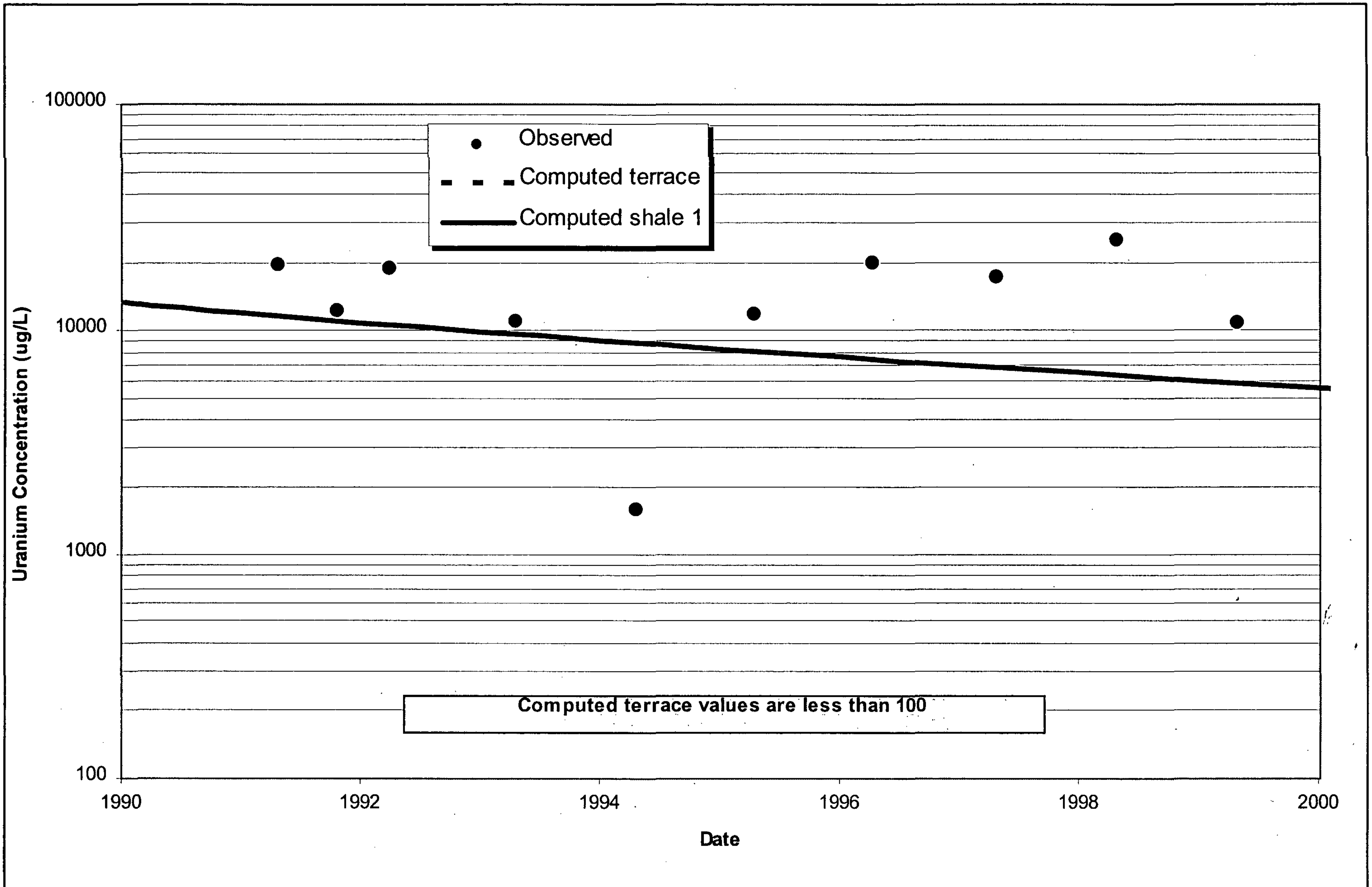

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FIGURE
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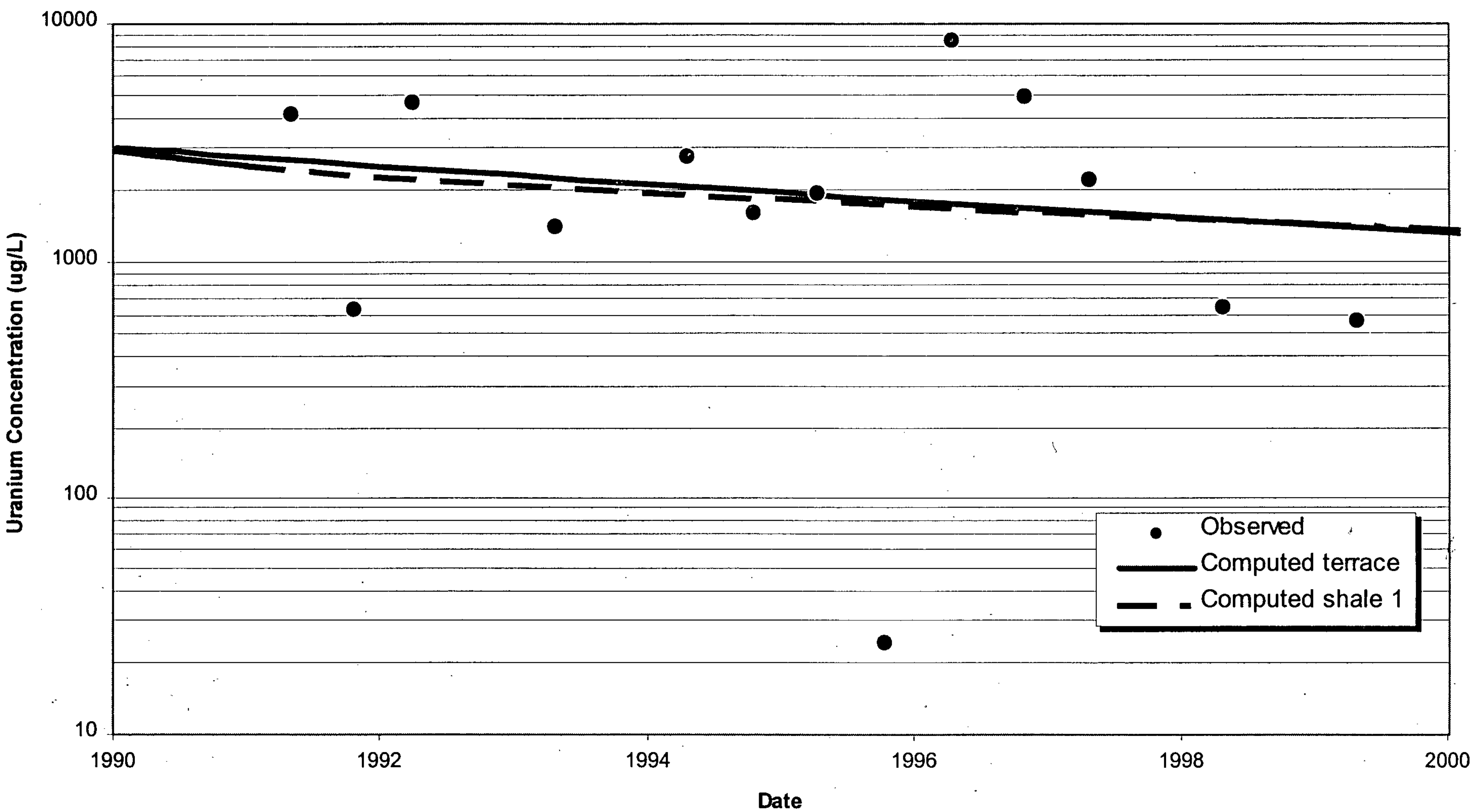

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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW018

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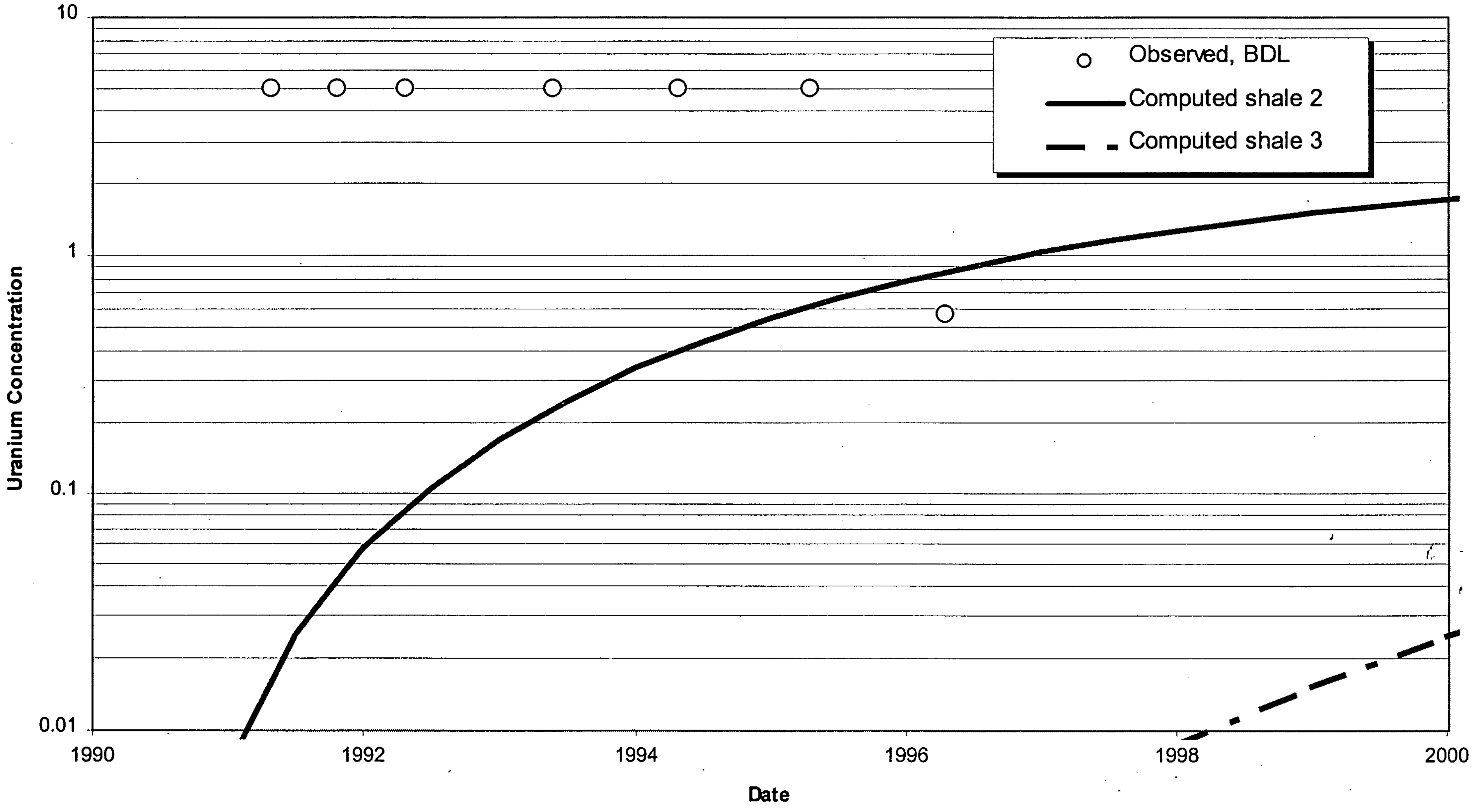

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FIGURE
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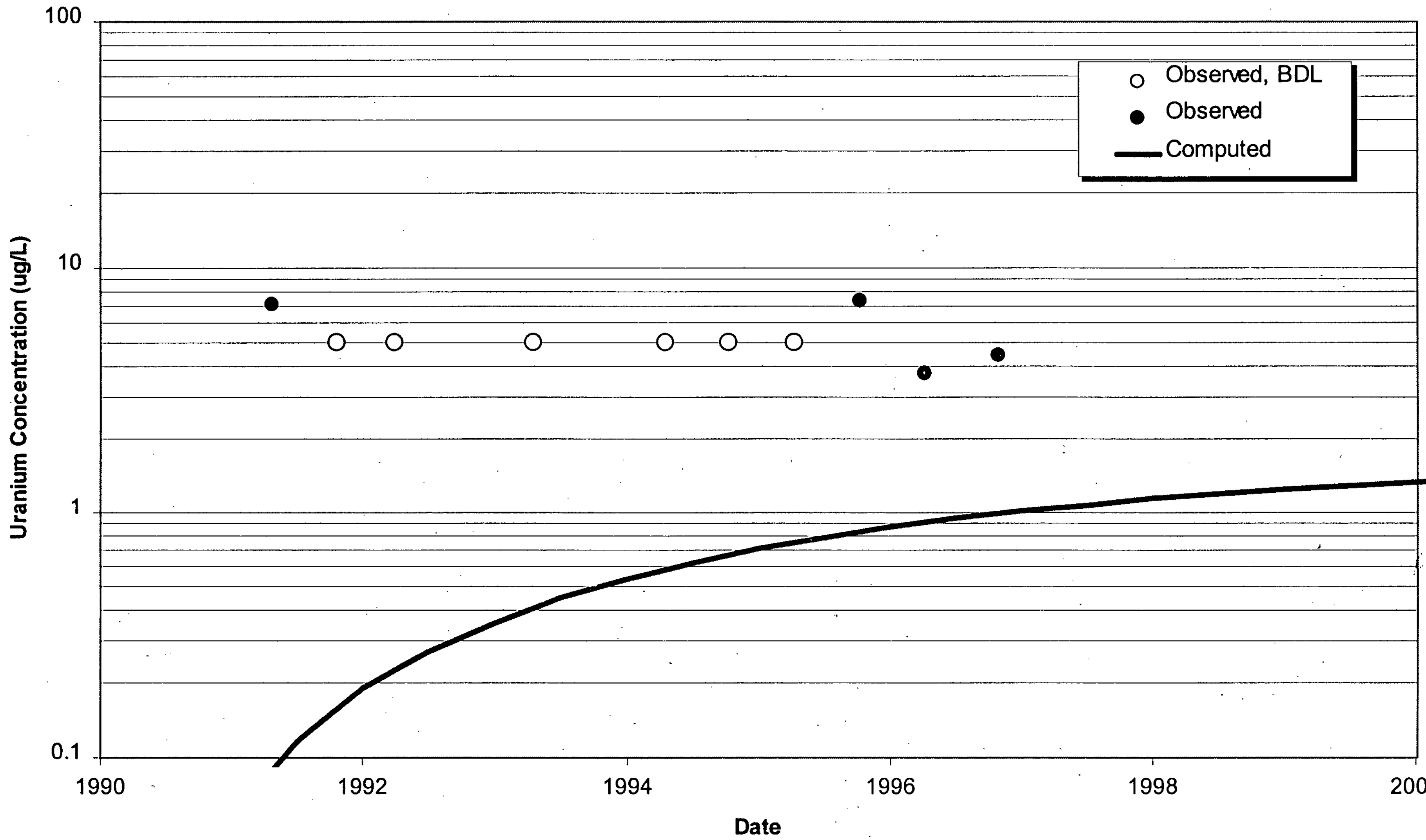

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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW022

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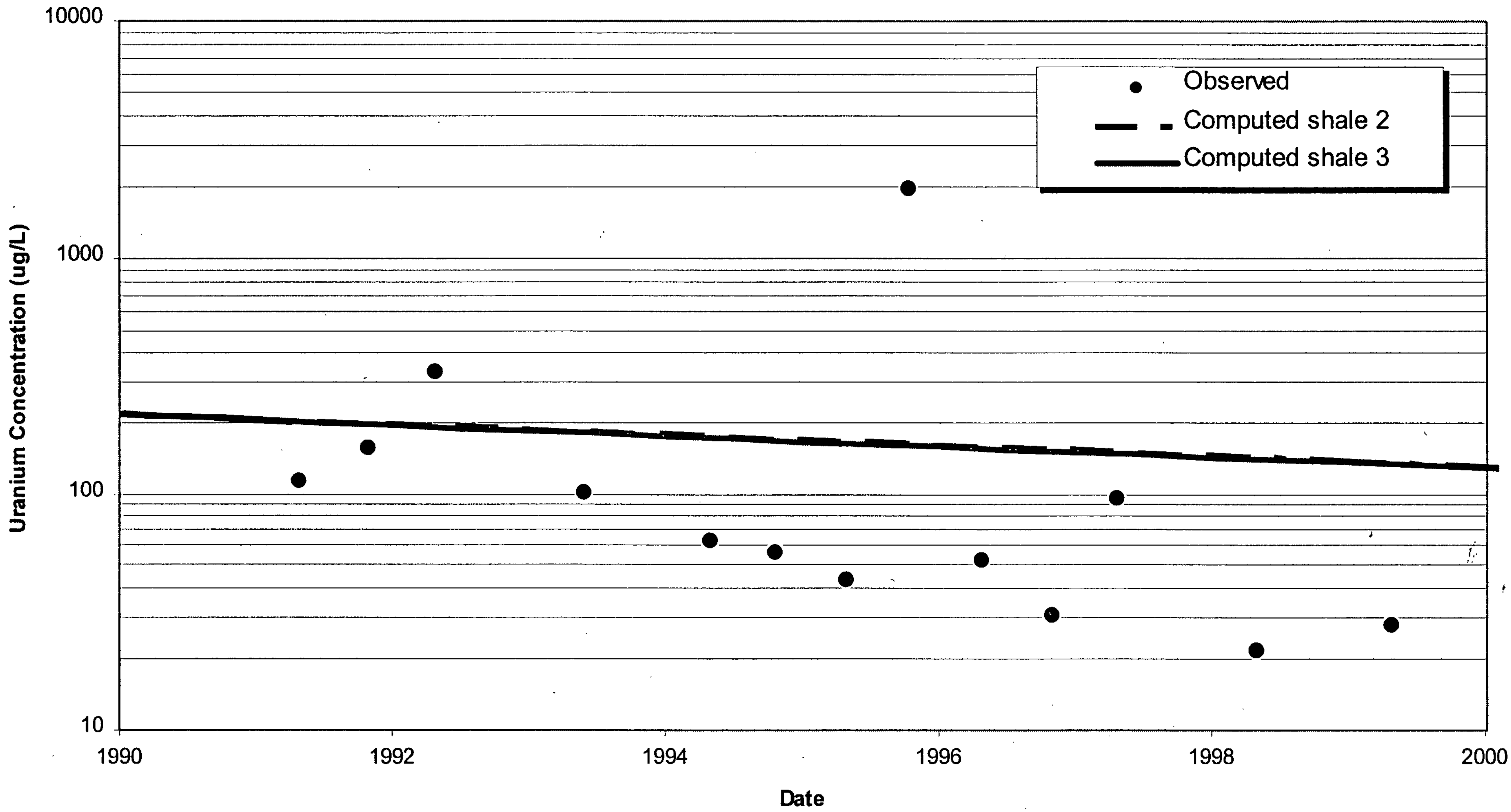

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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW024A

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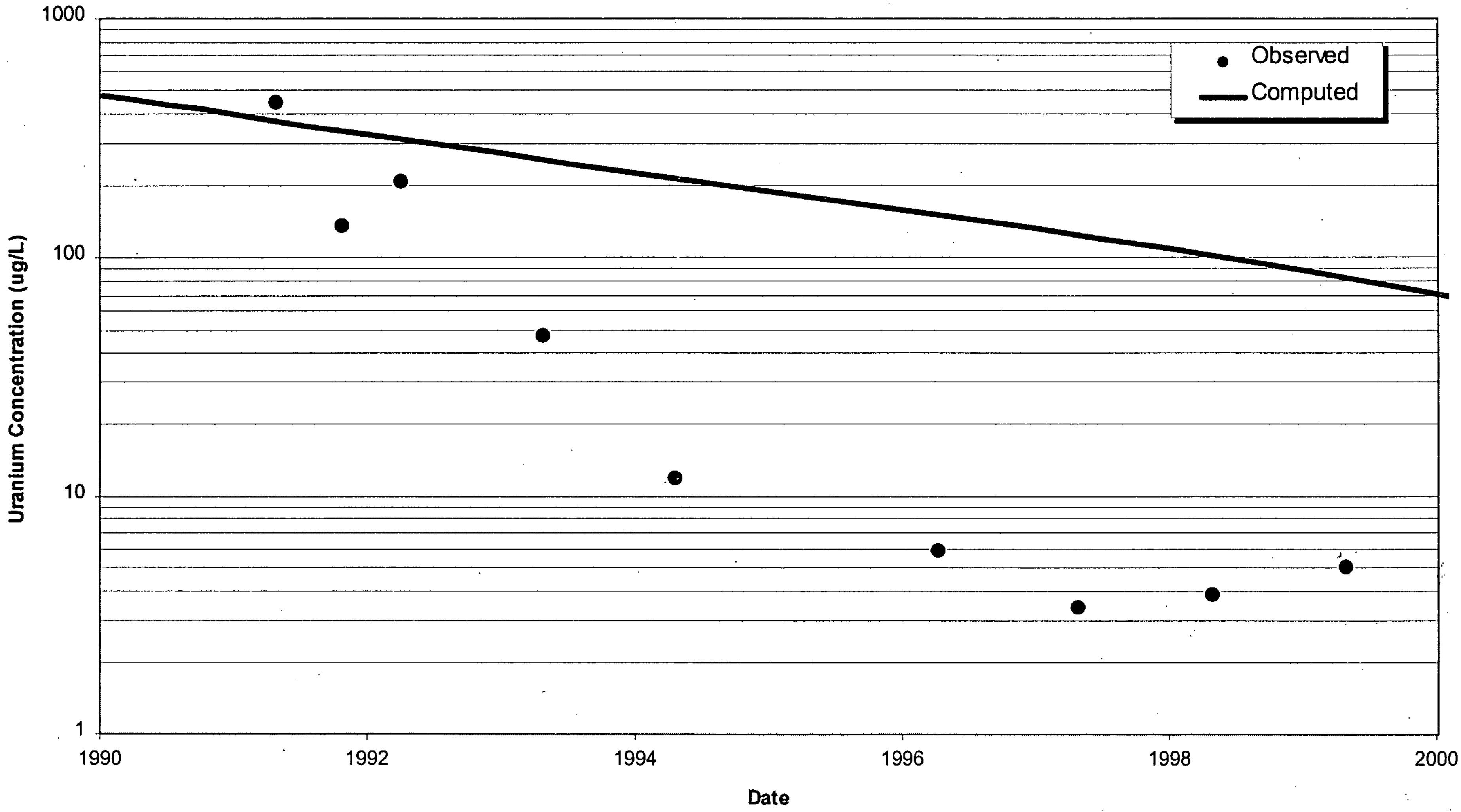

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FIGURE
URANIUM TRANSPORT CALIBRATION FOR WELL MW024

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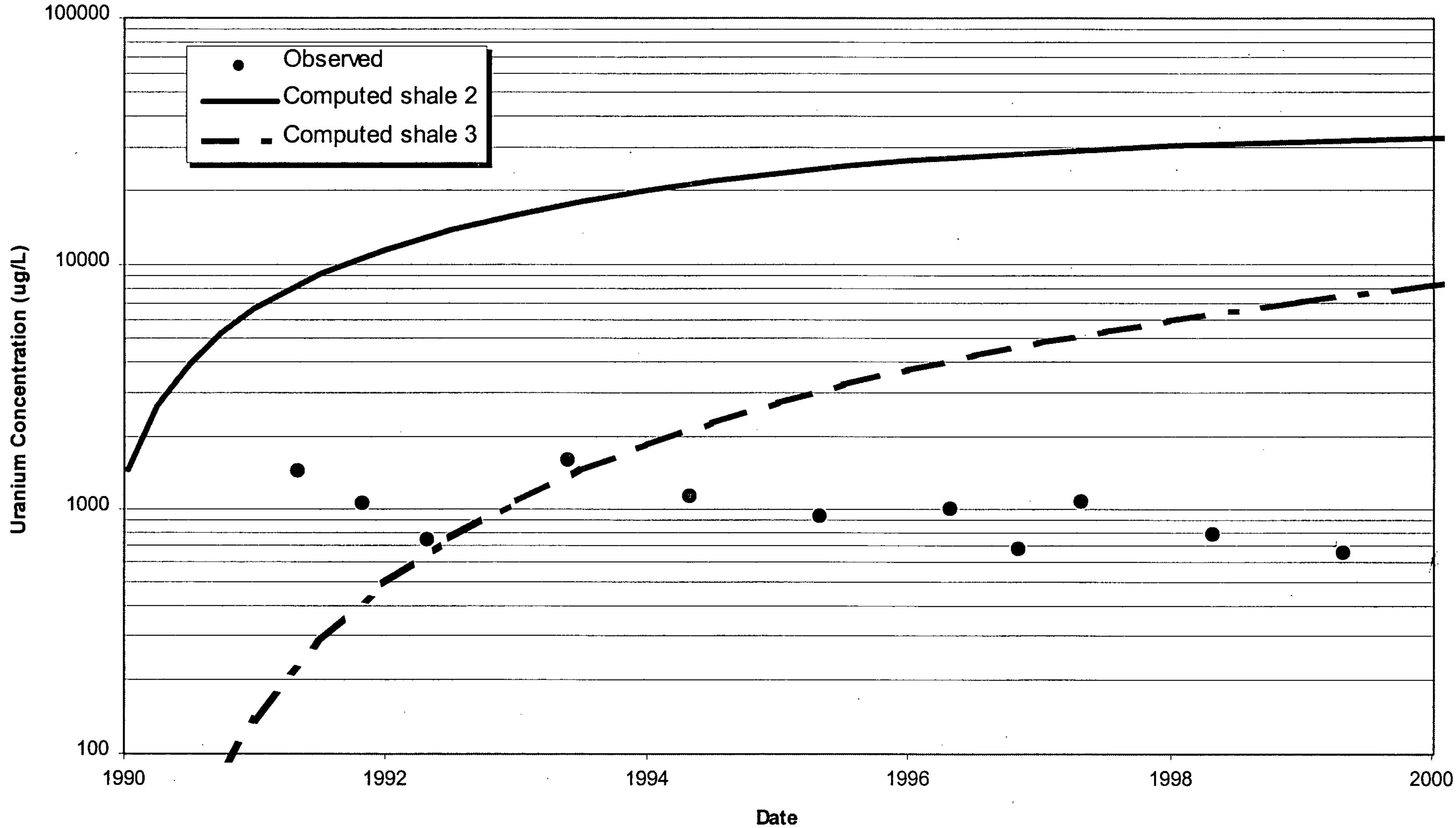

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FIGURE
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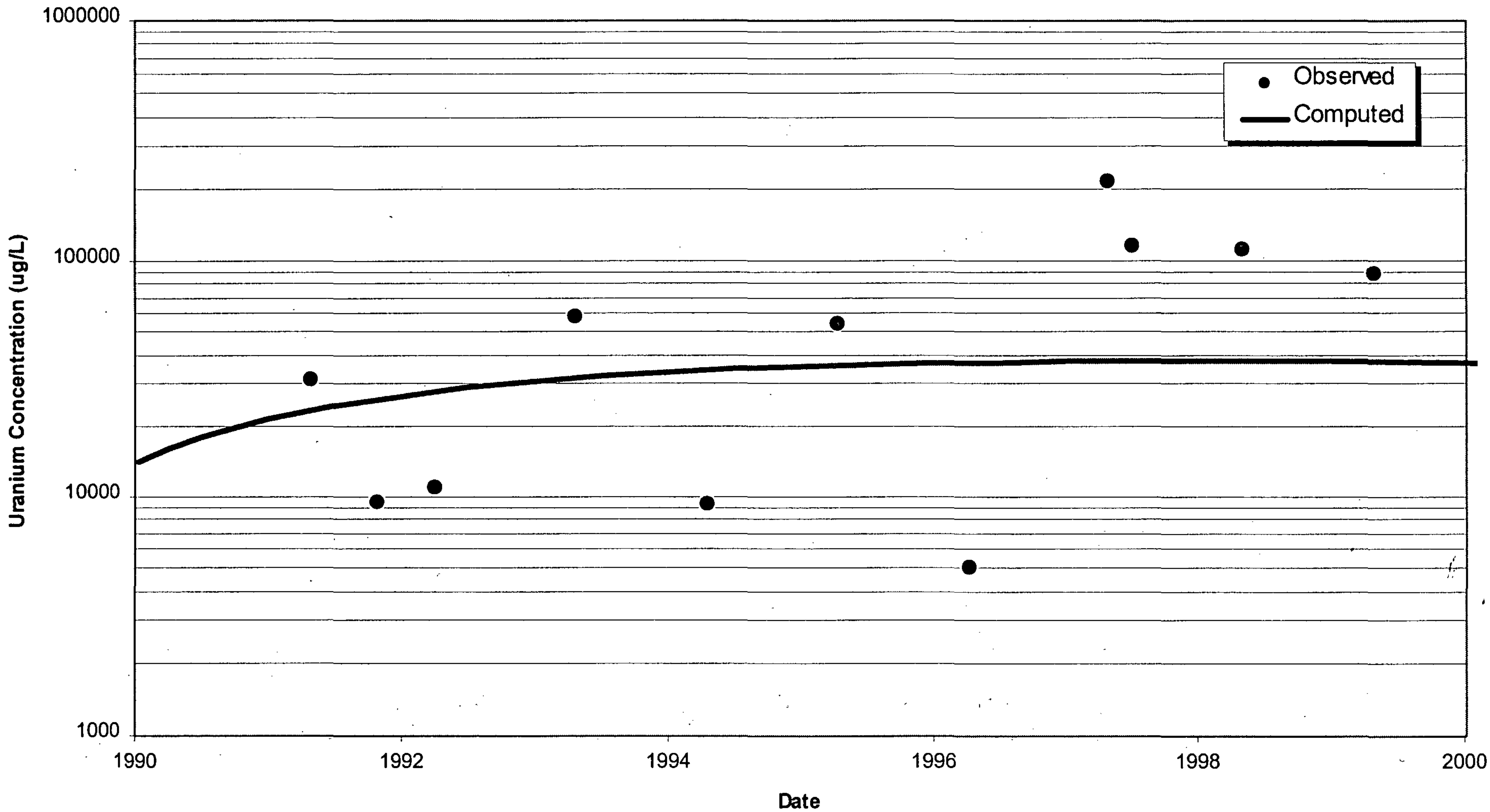

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FIGURE
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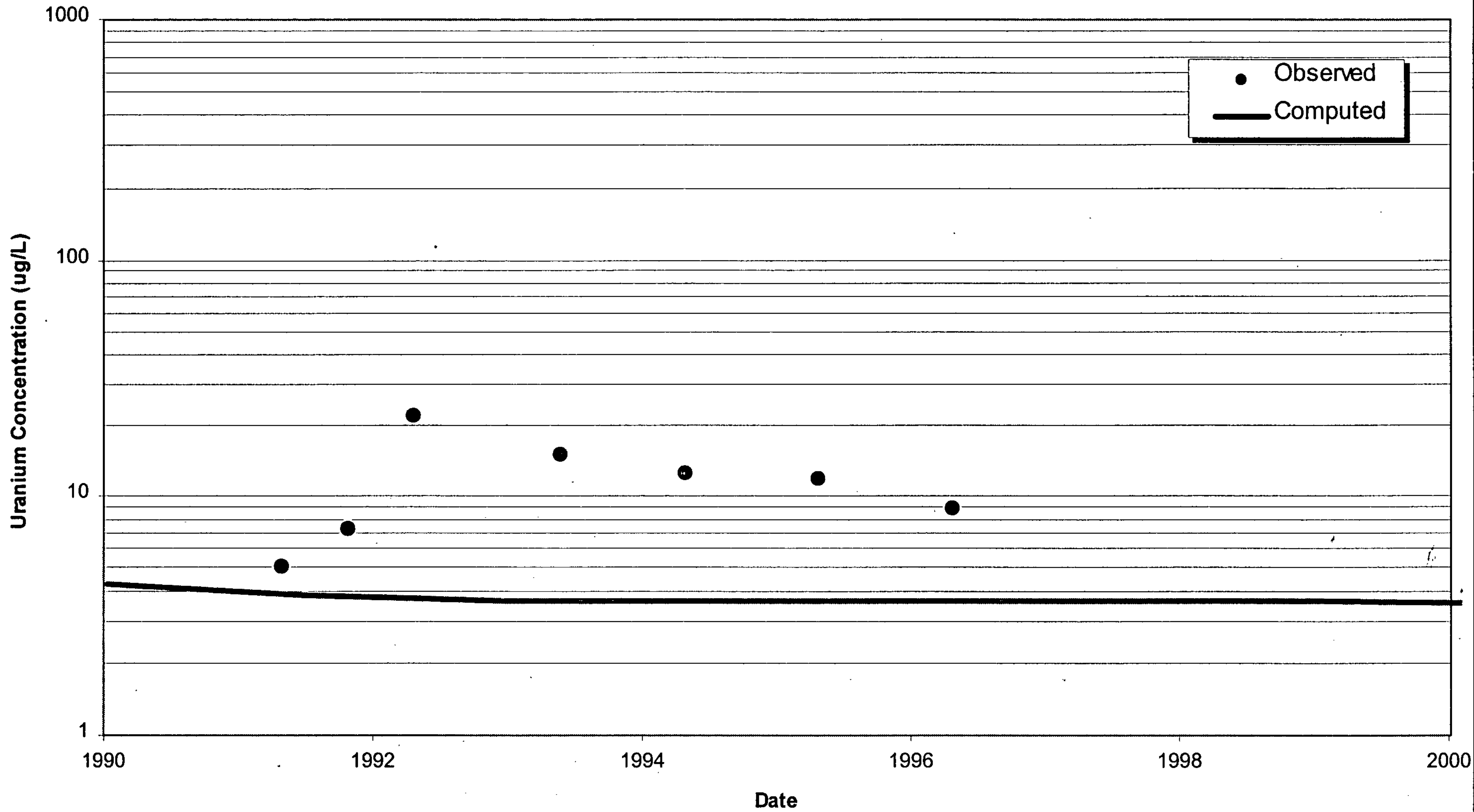

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FIGURE
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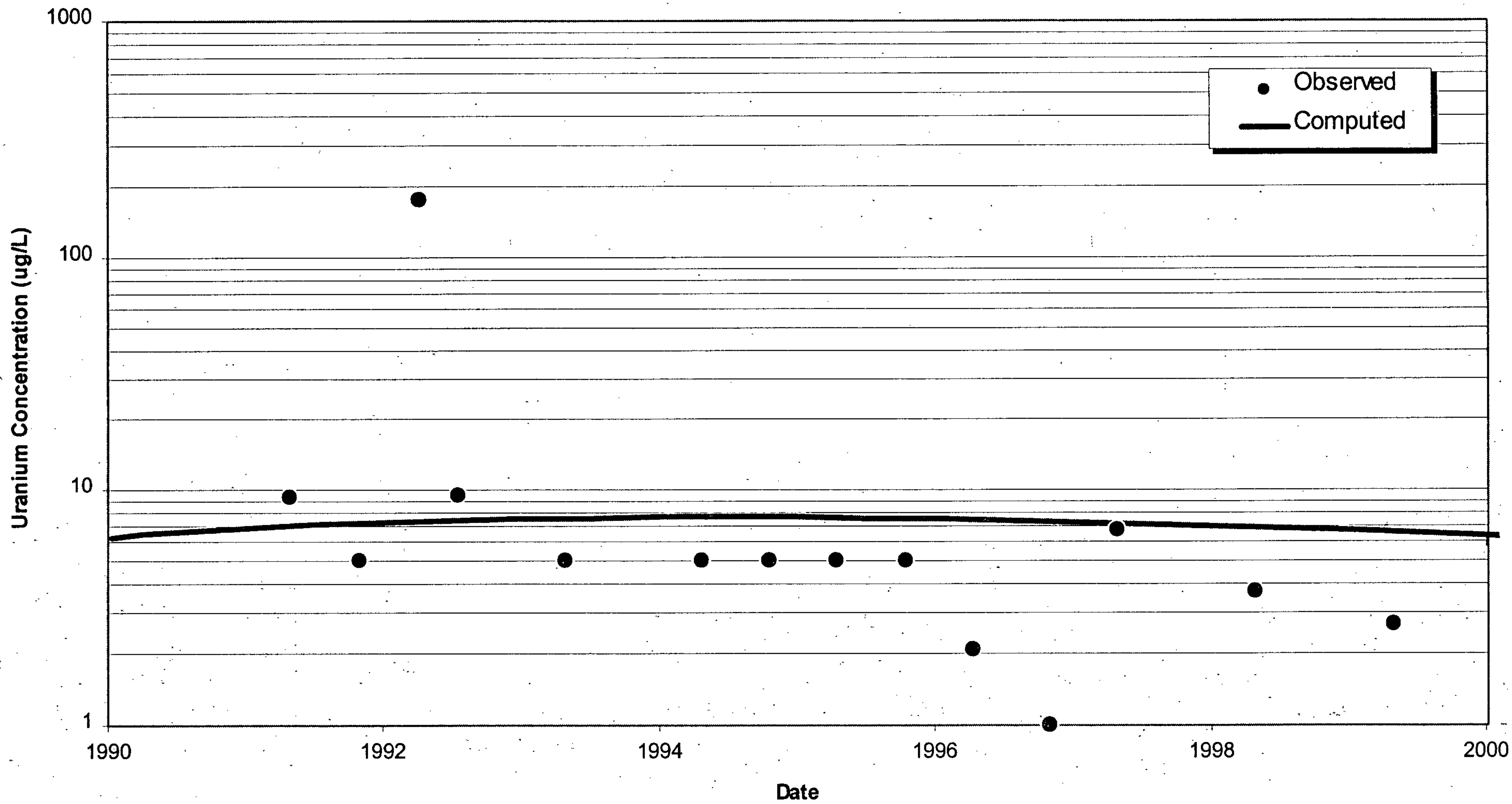

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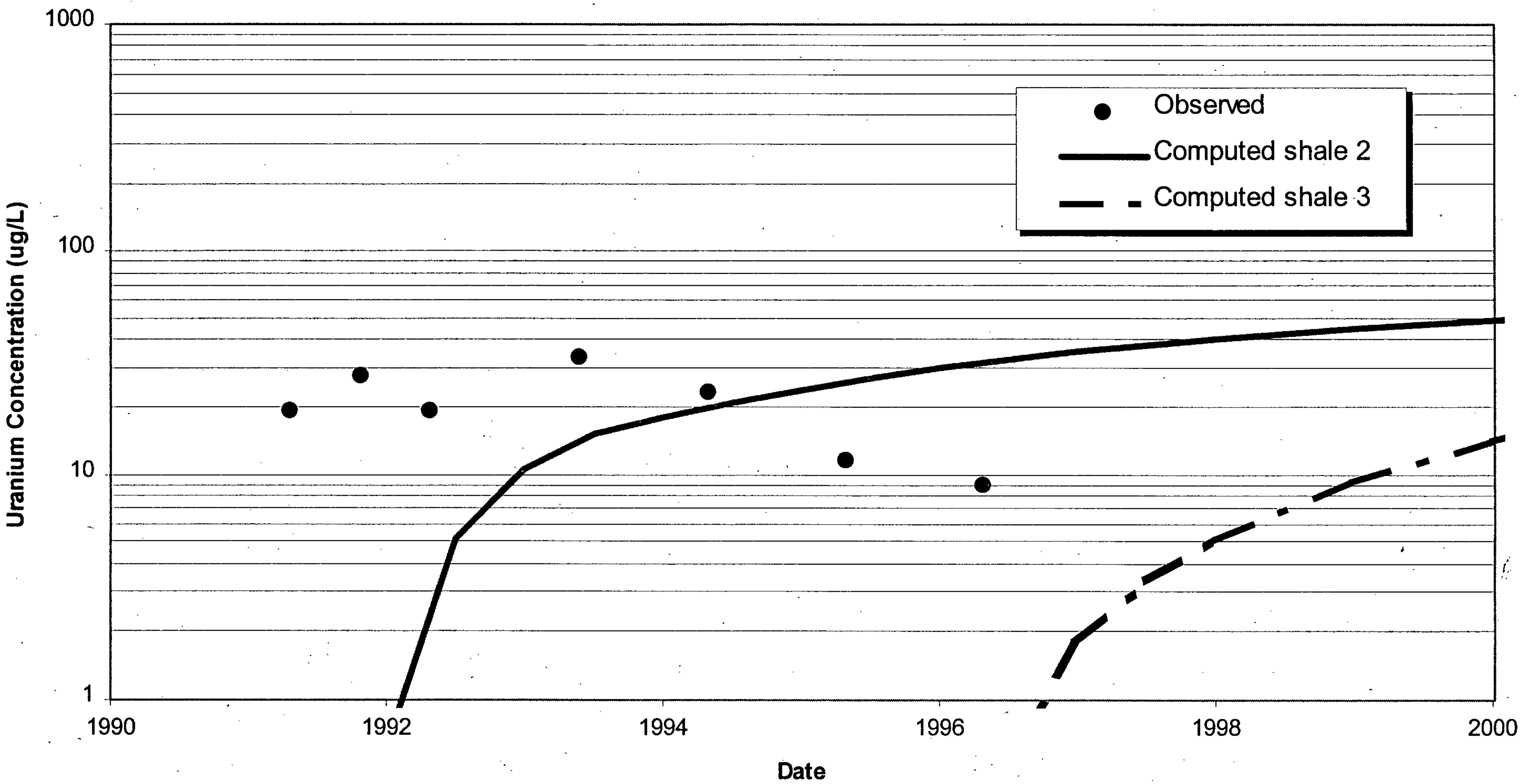

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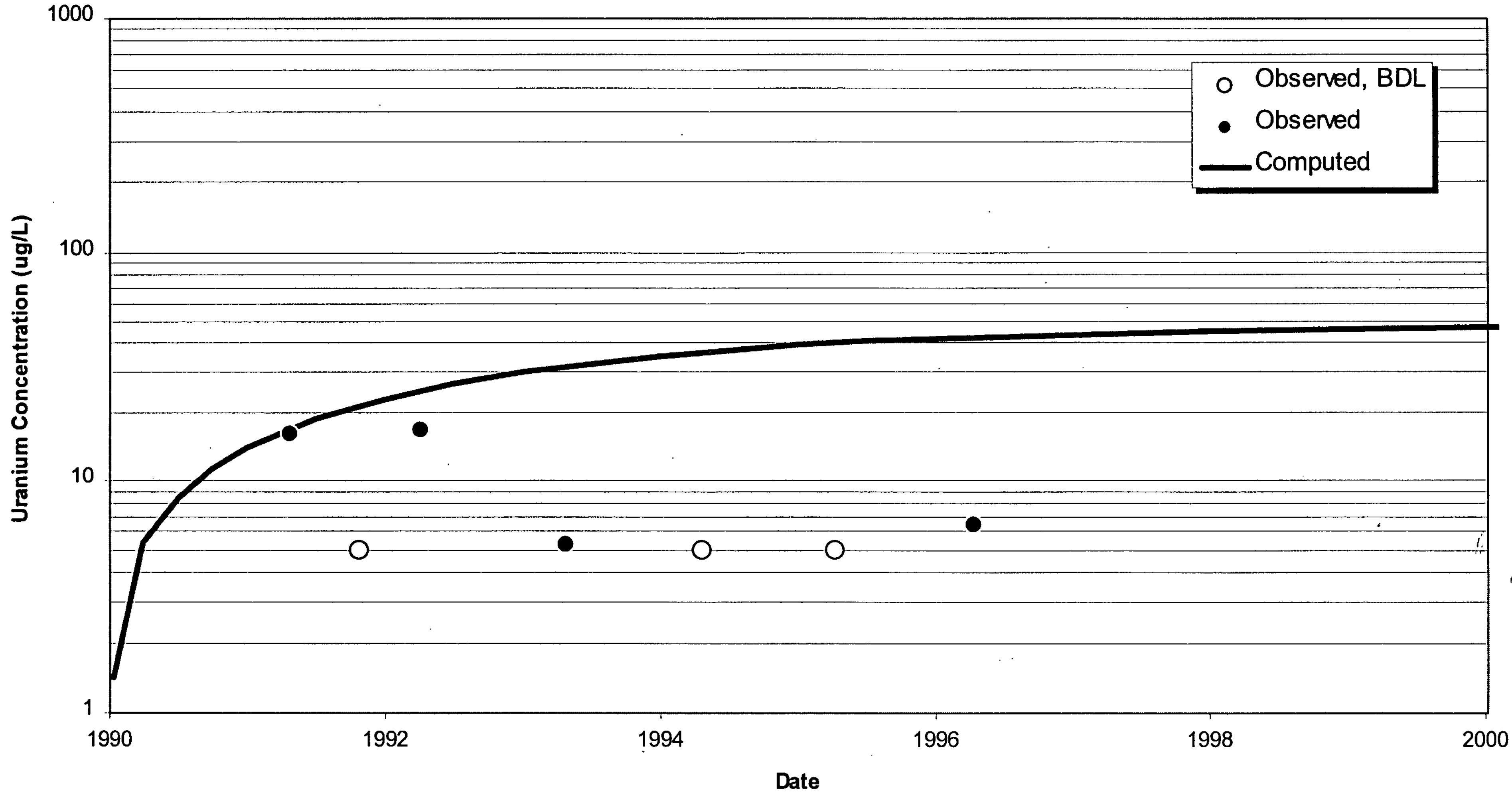

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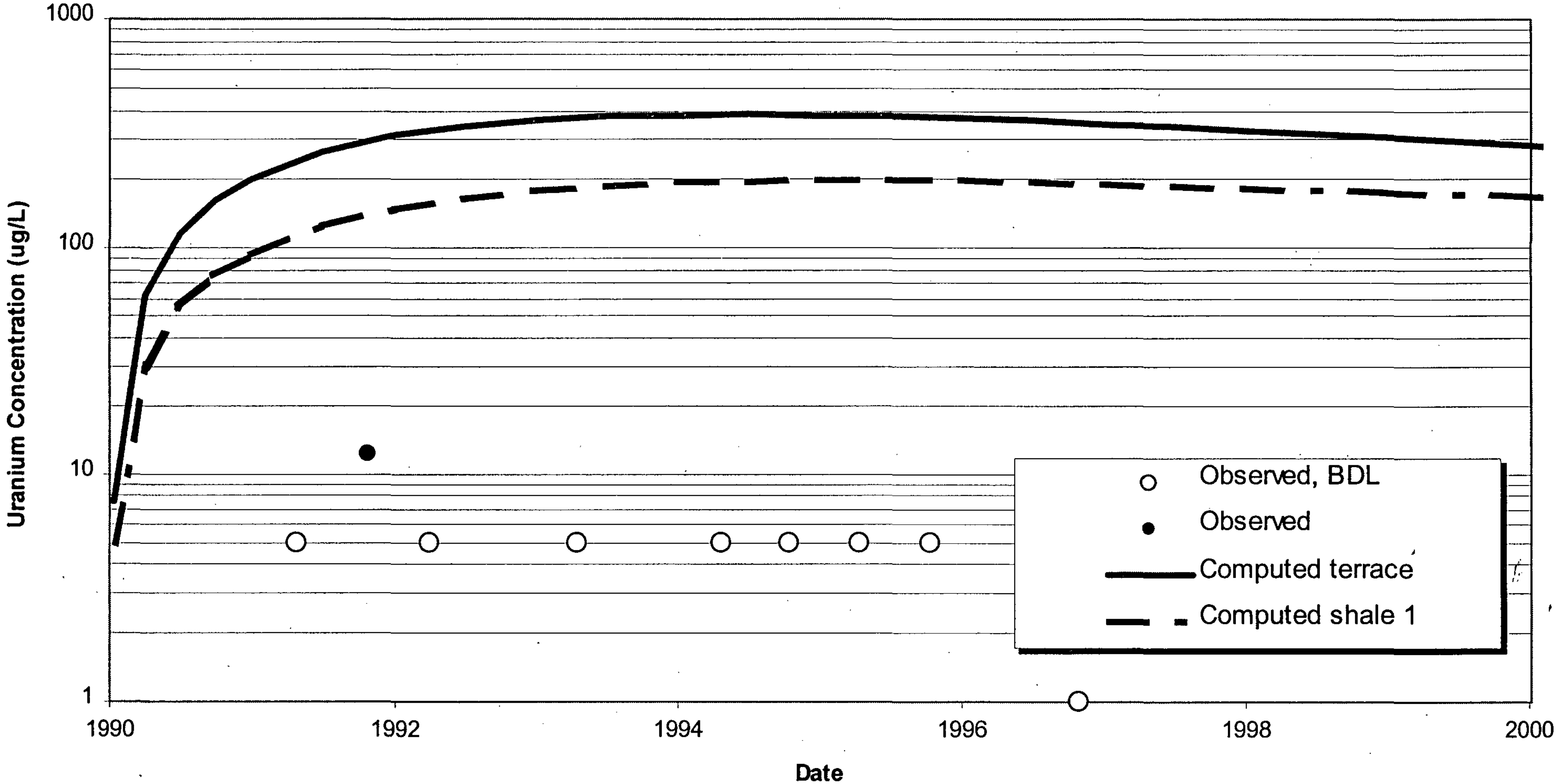

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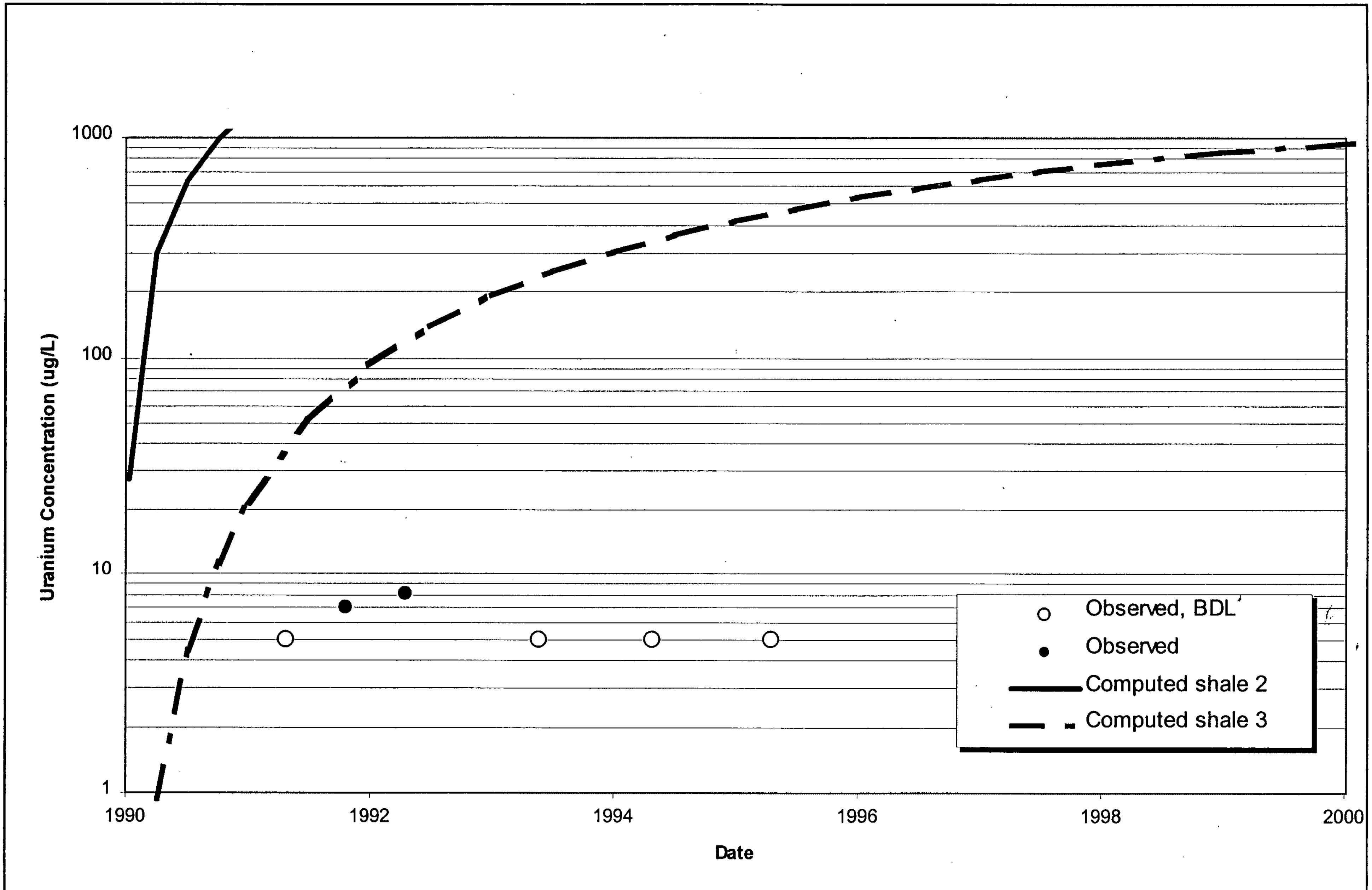

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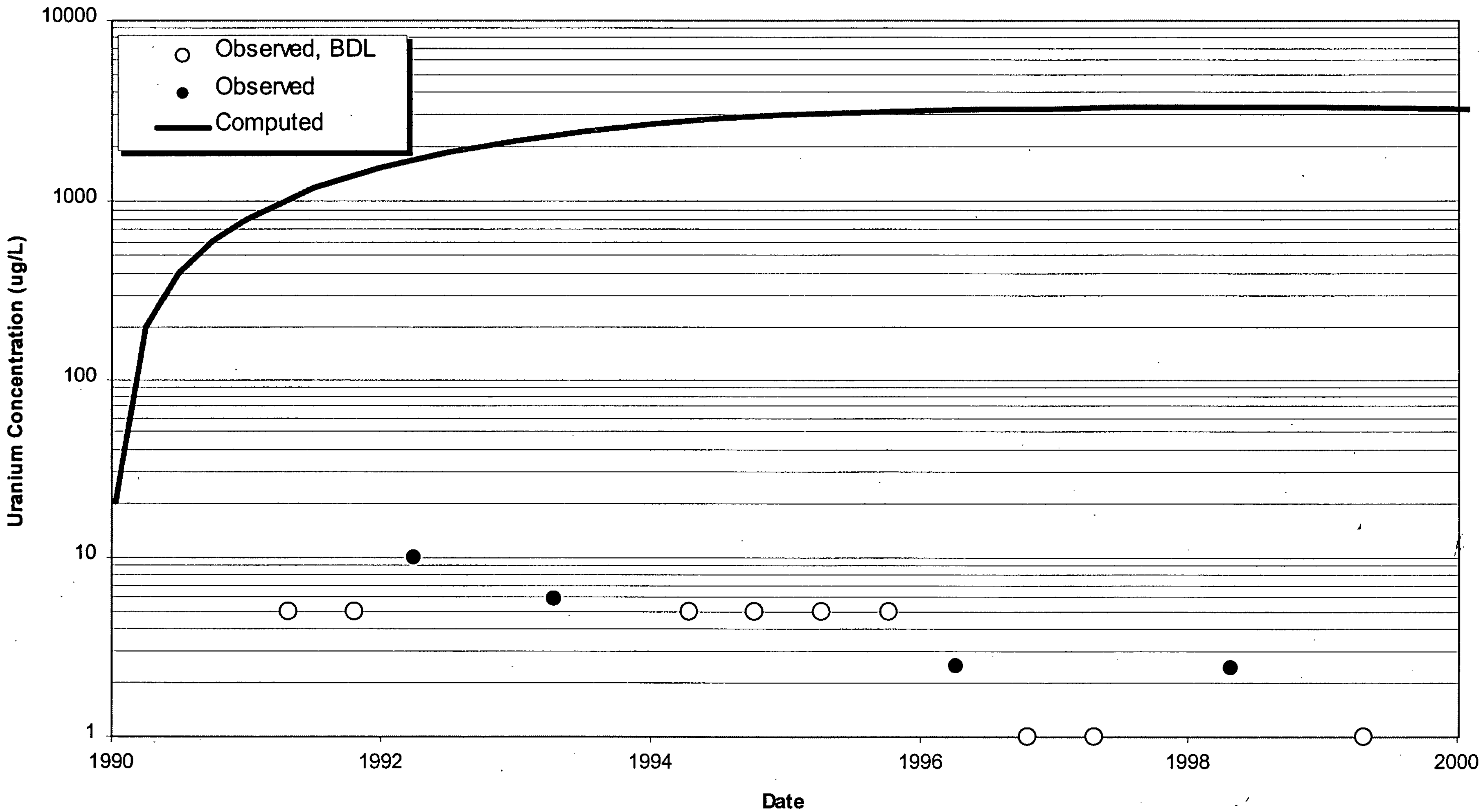

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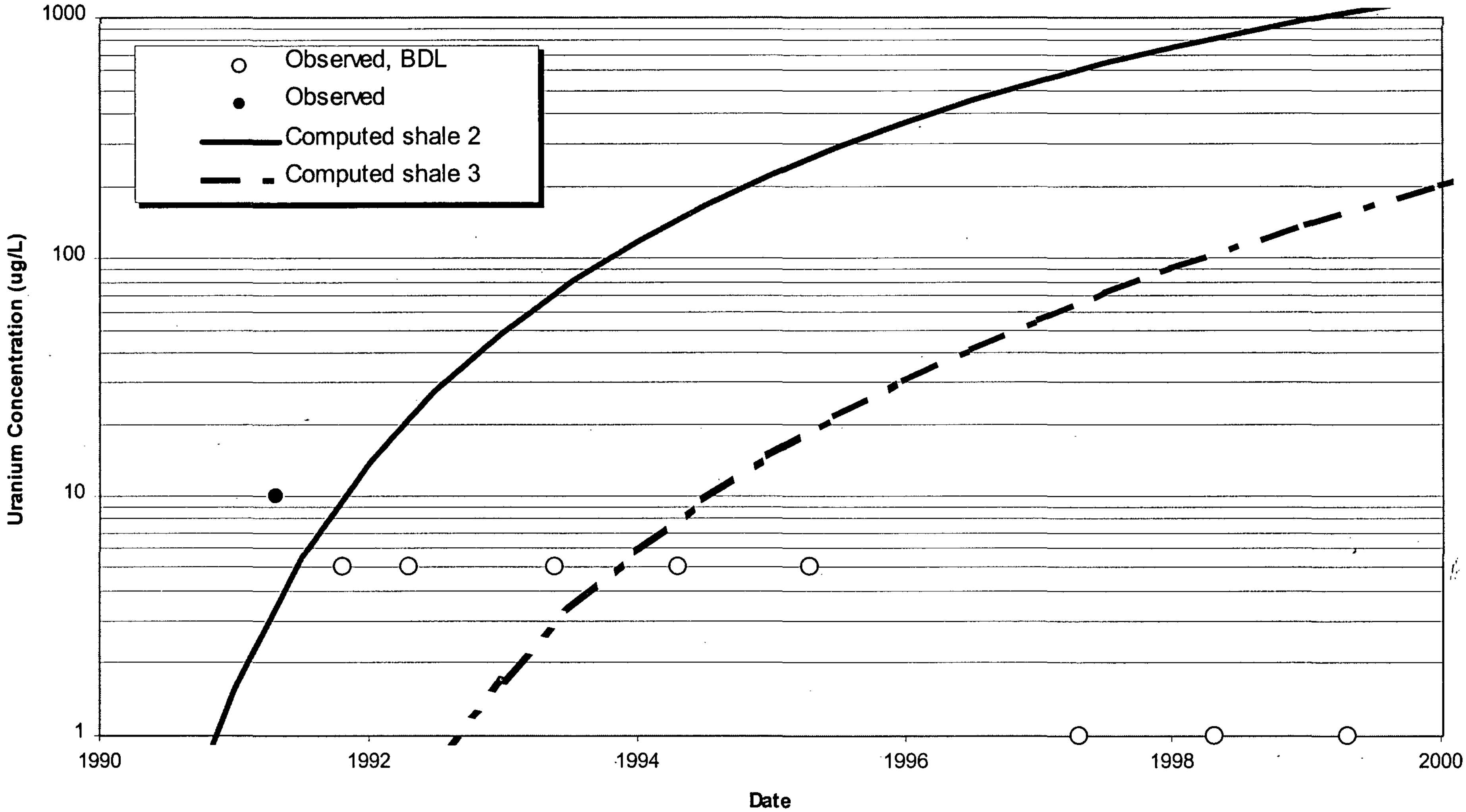

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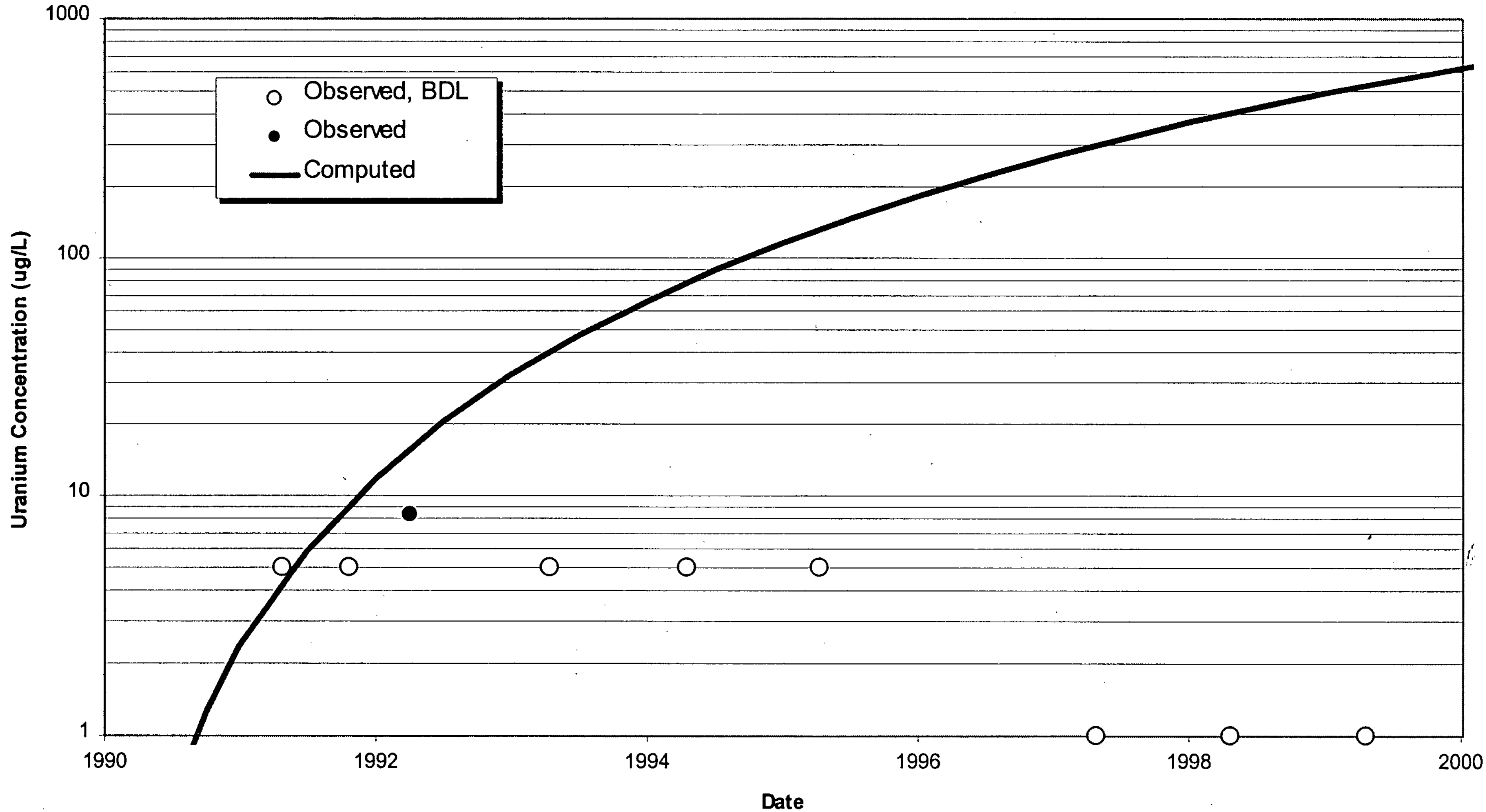

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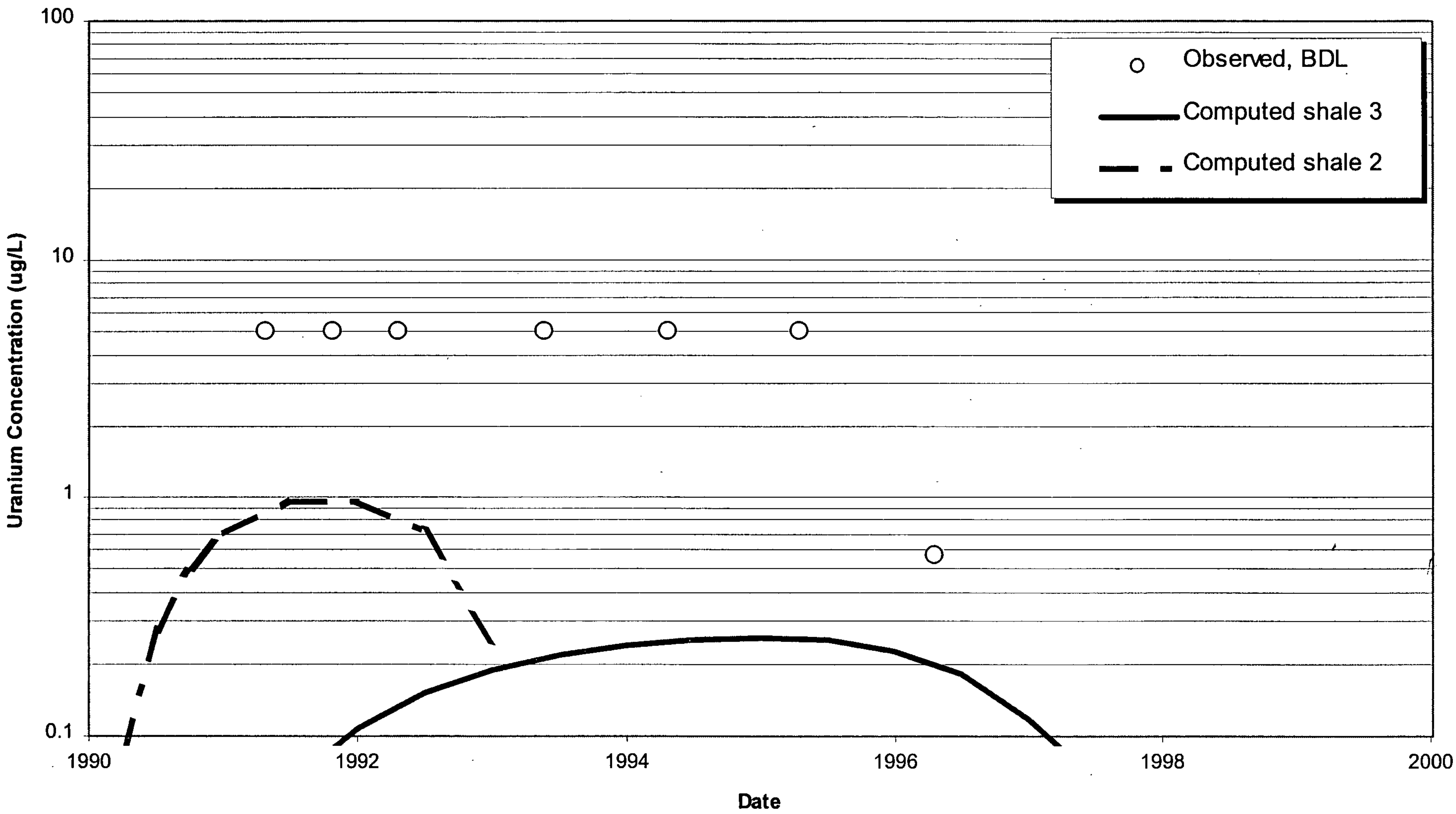

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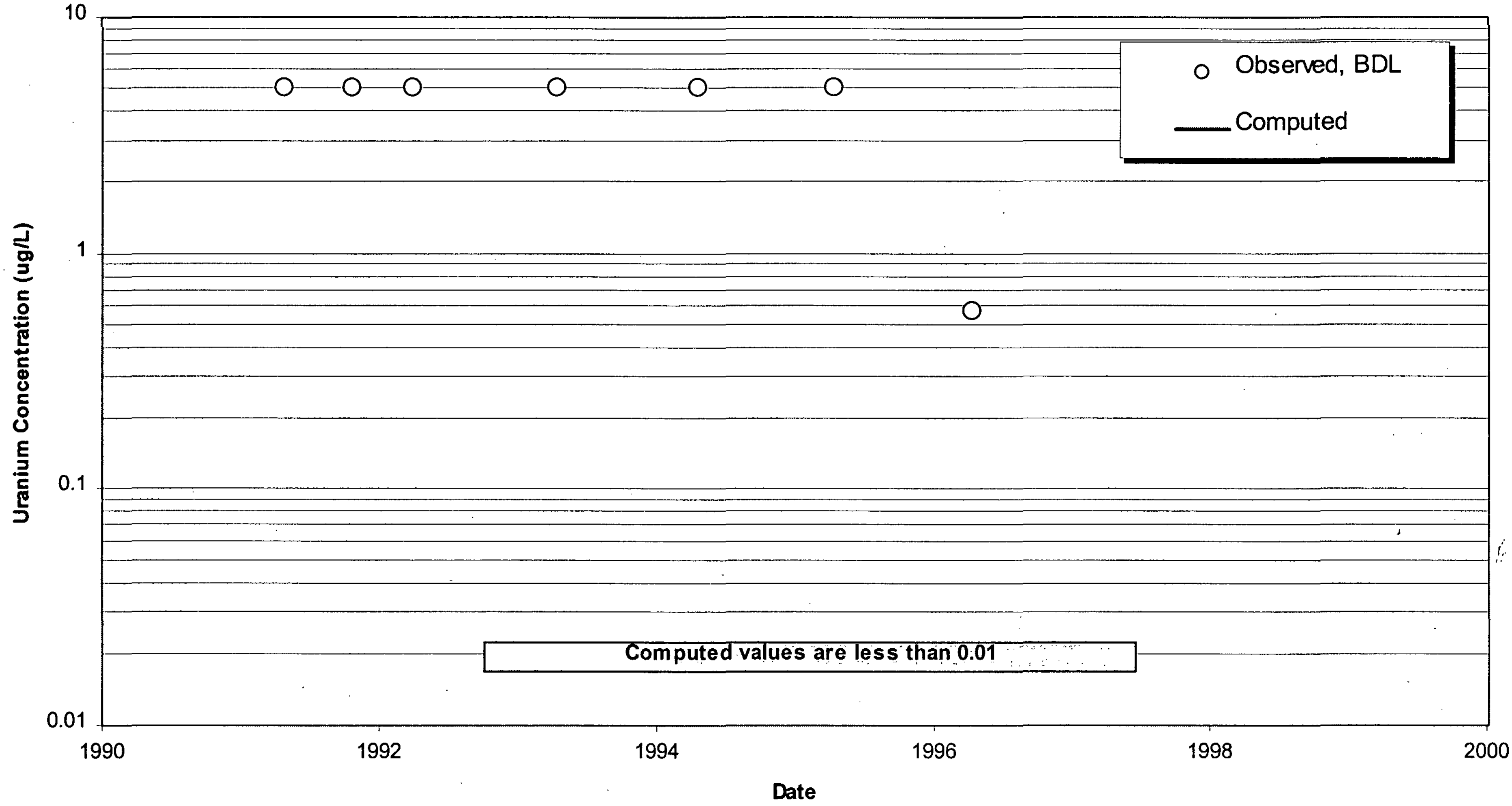

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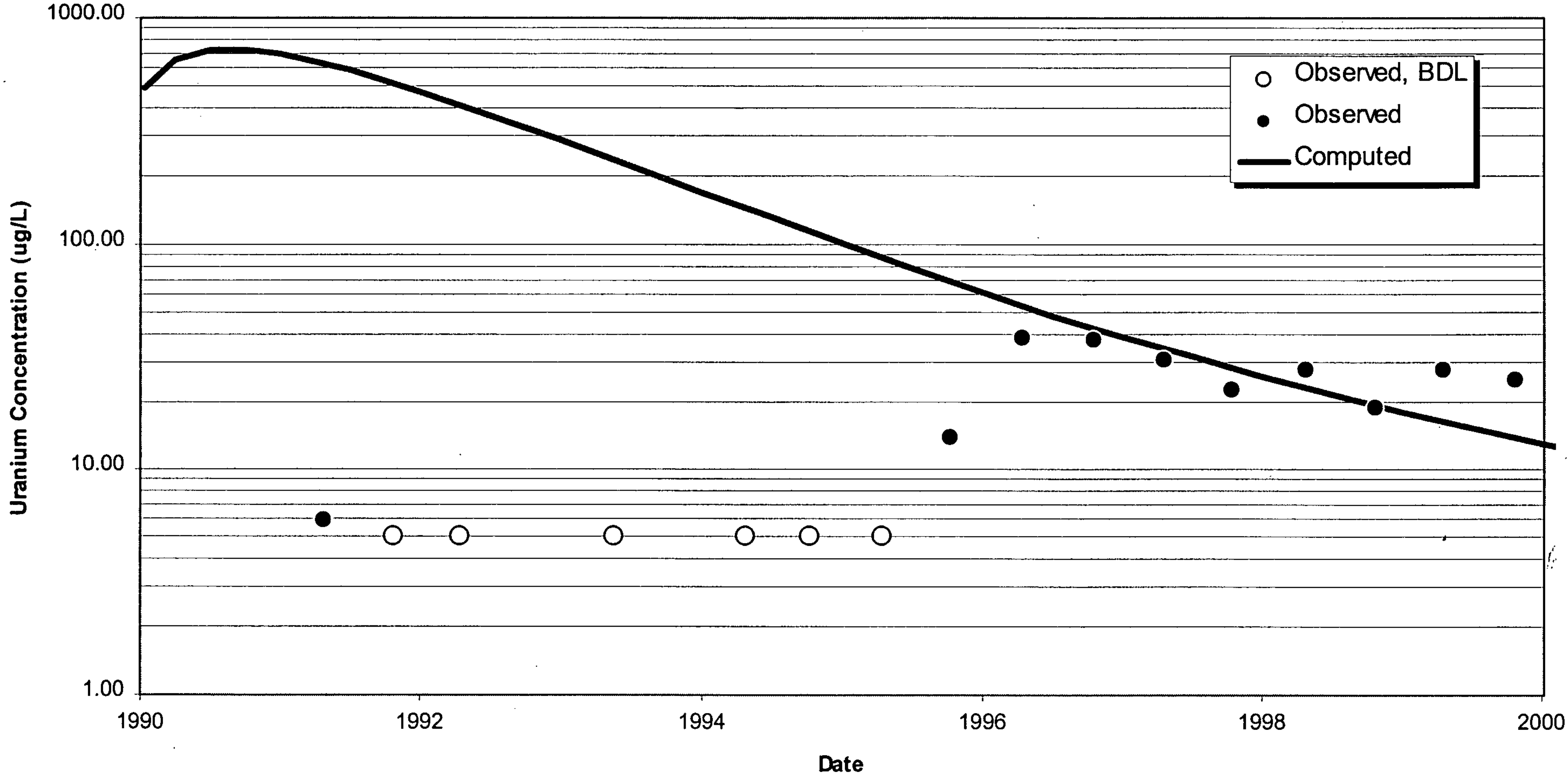

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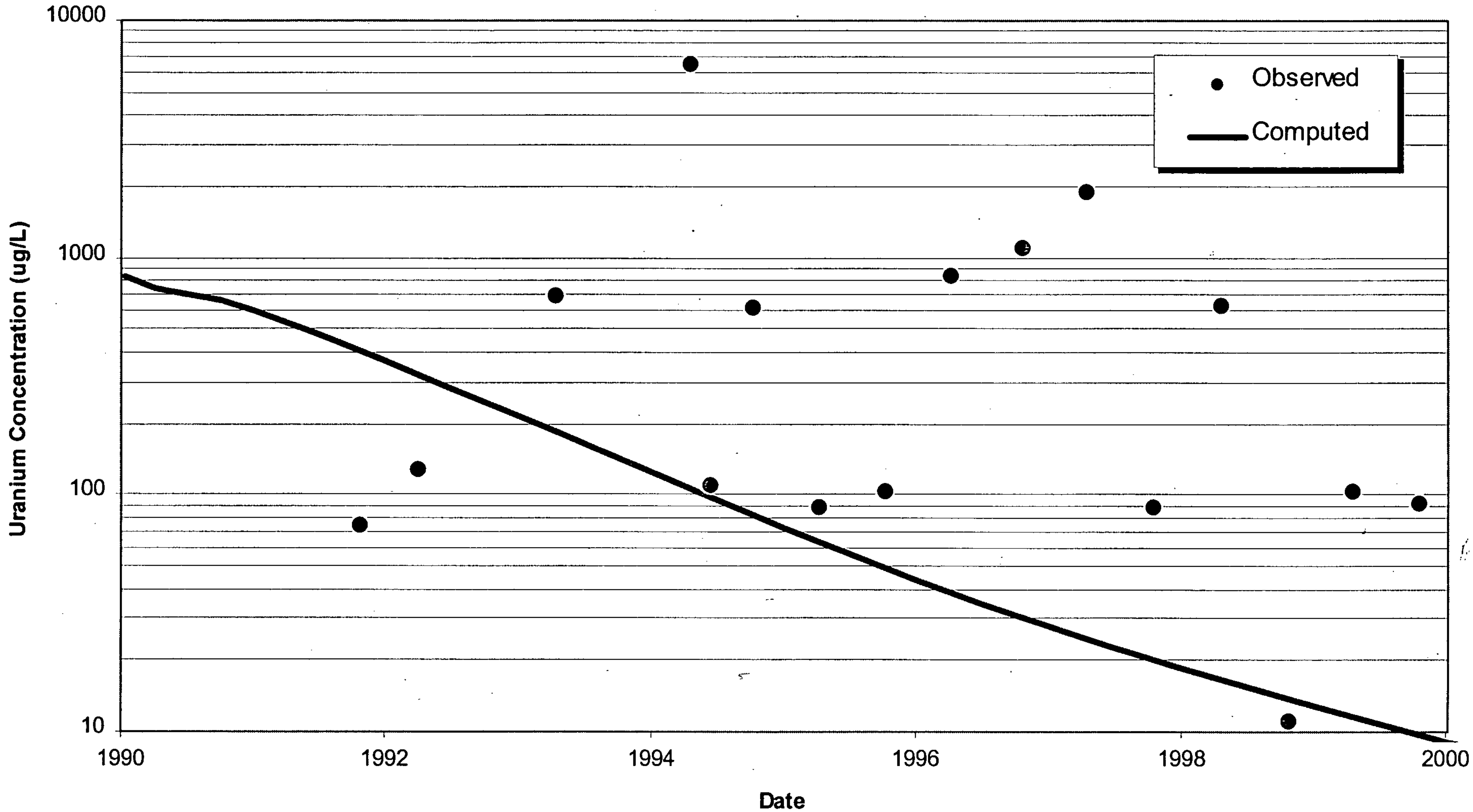

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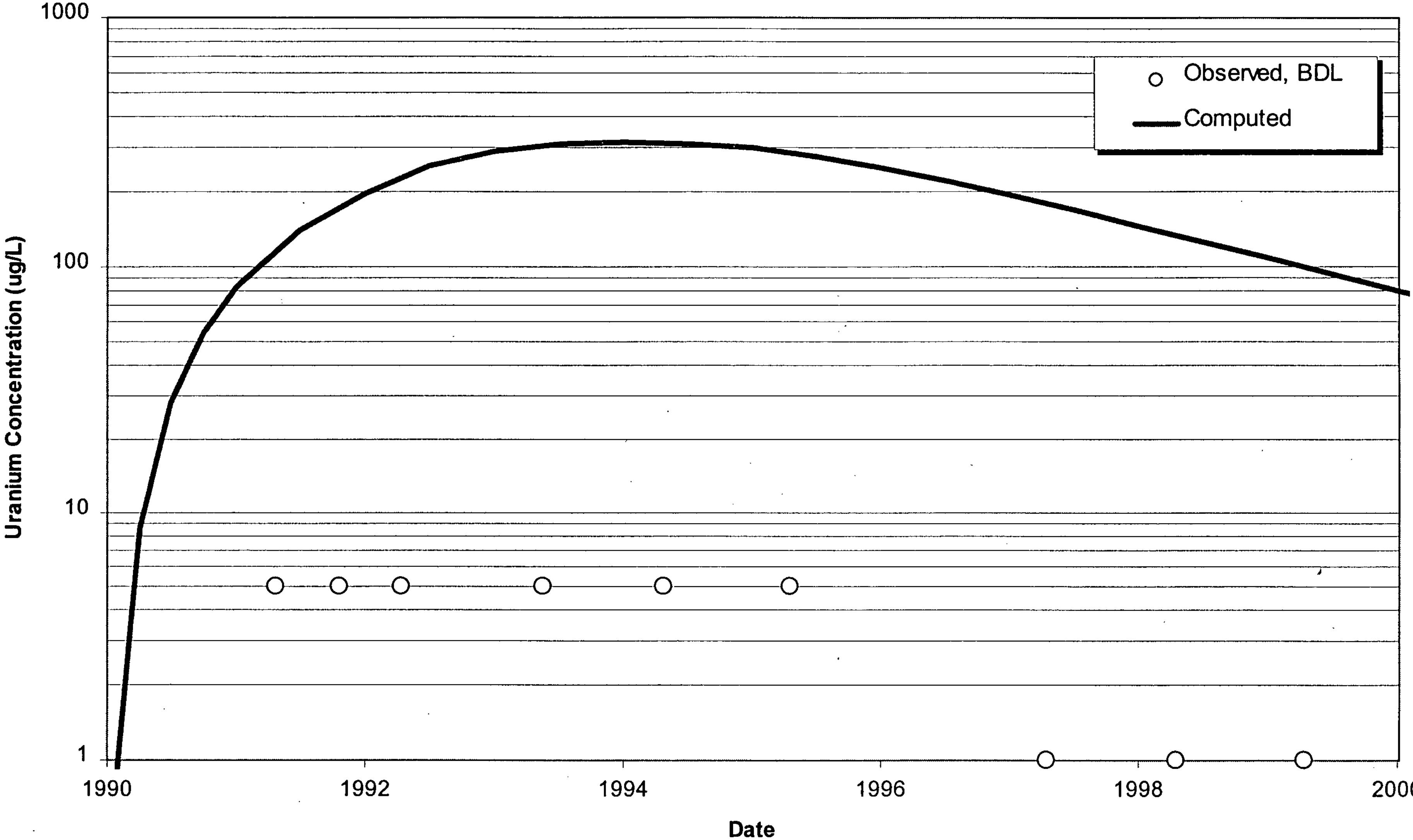

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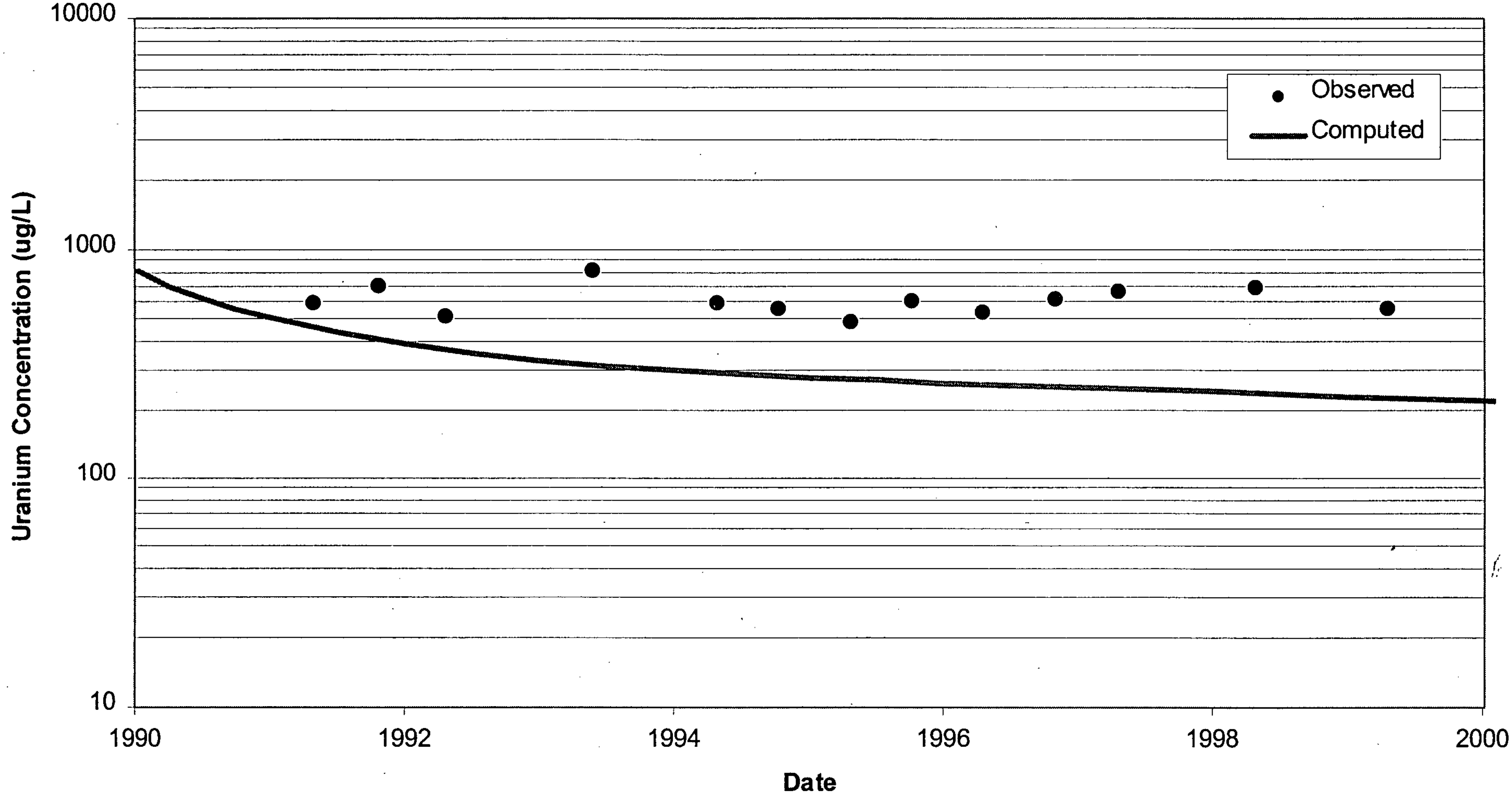

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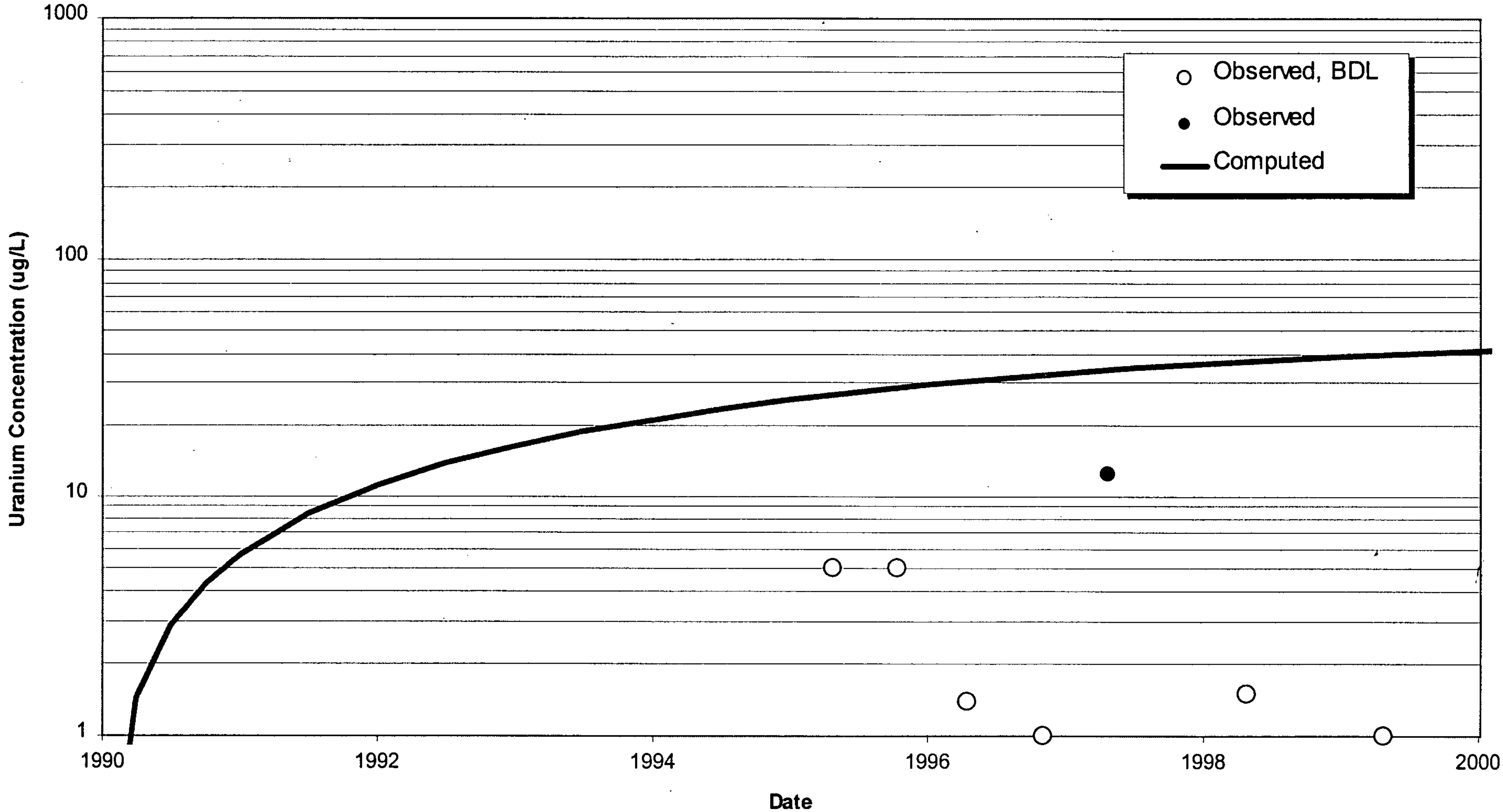

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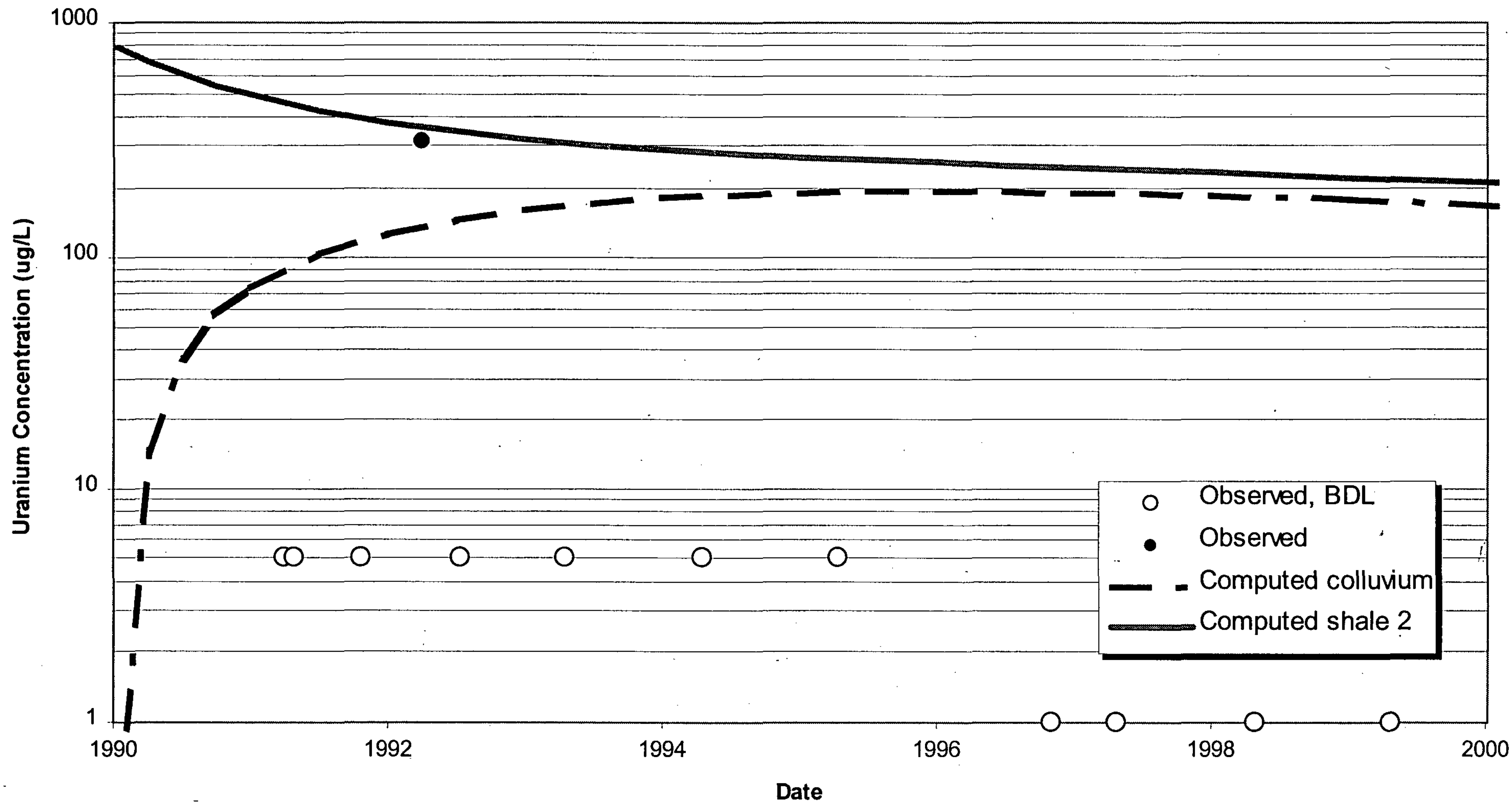

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FIGURE
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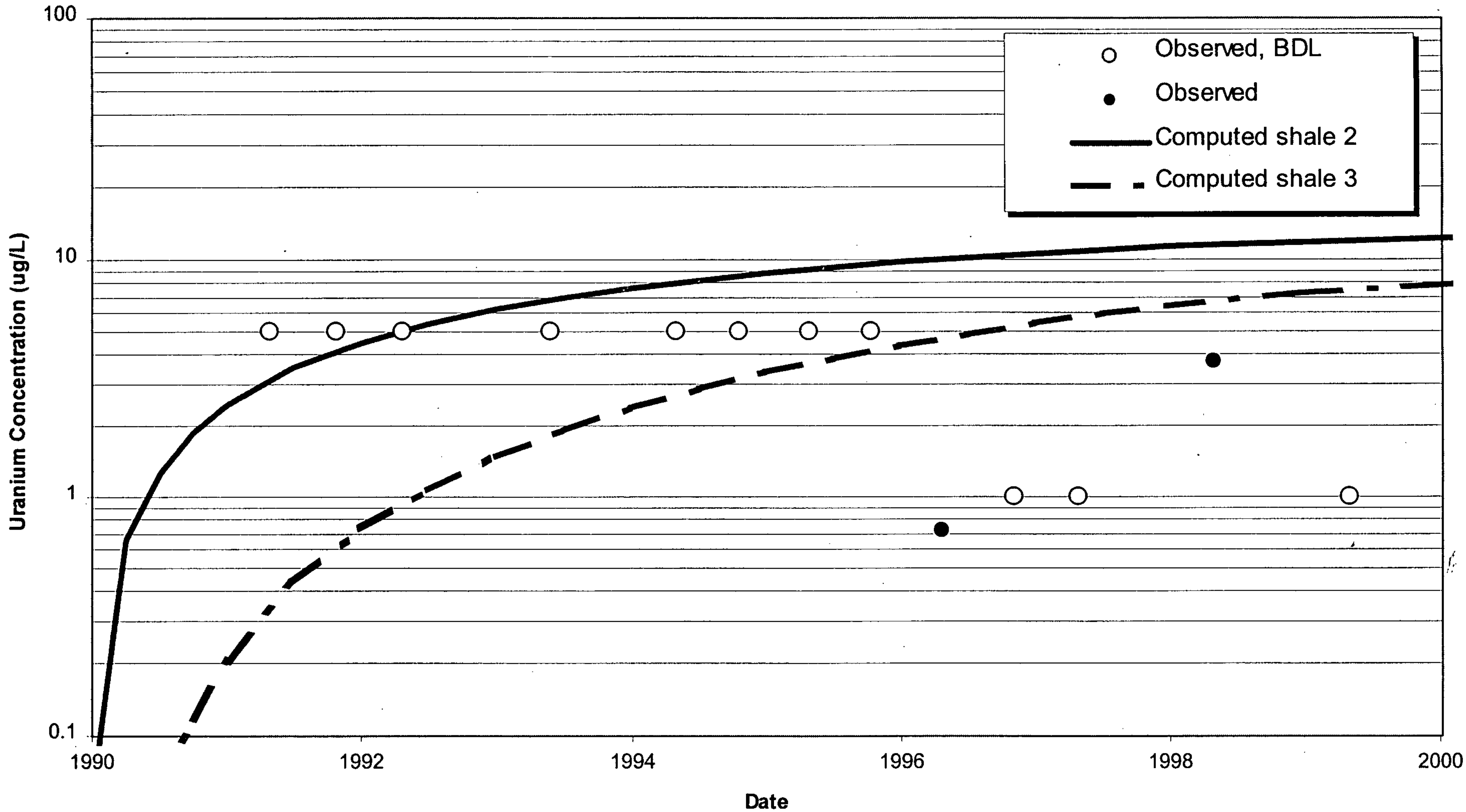

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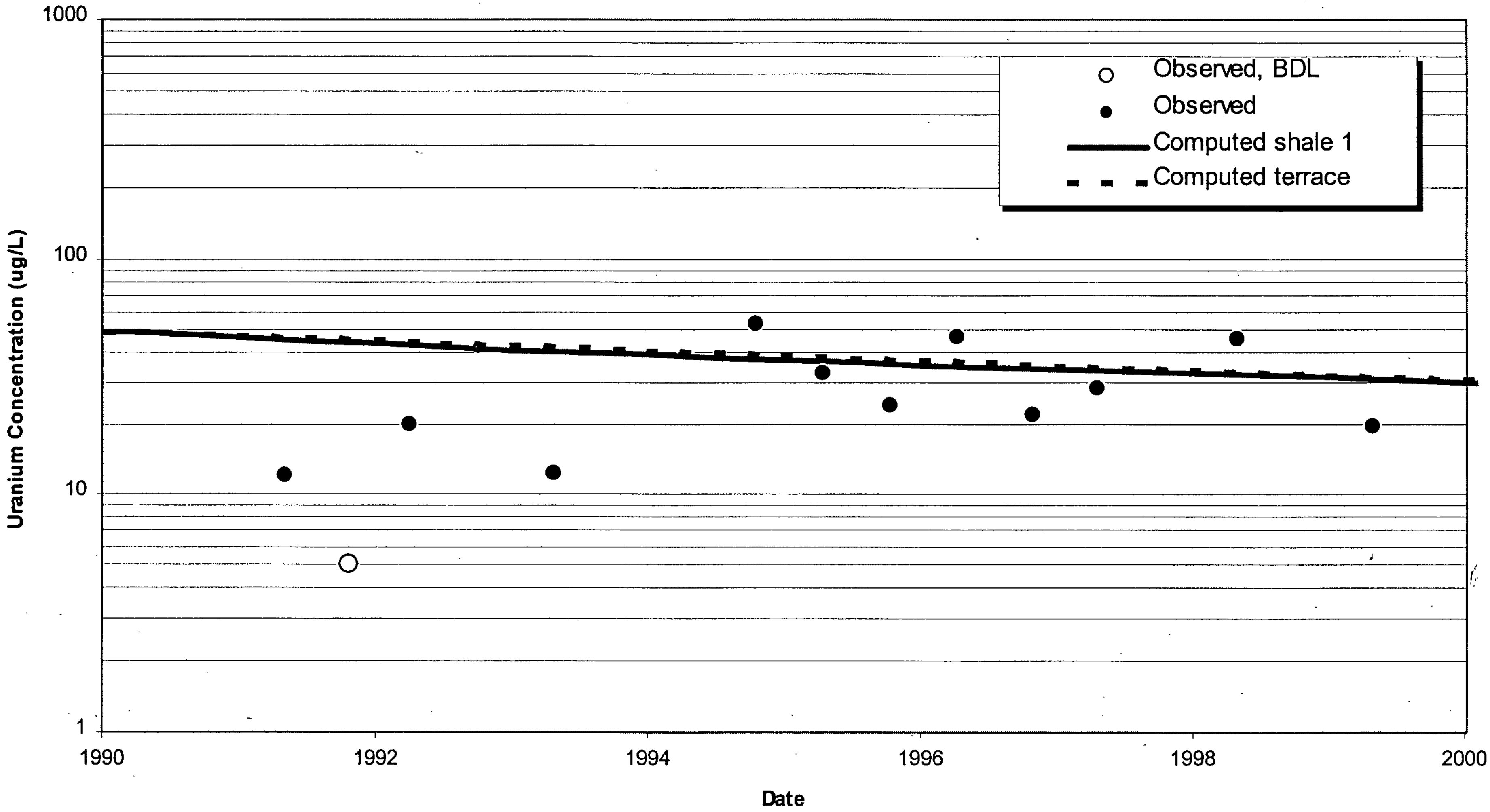

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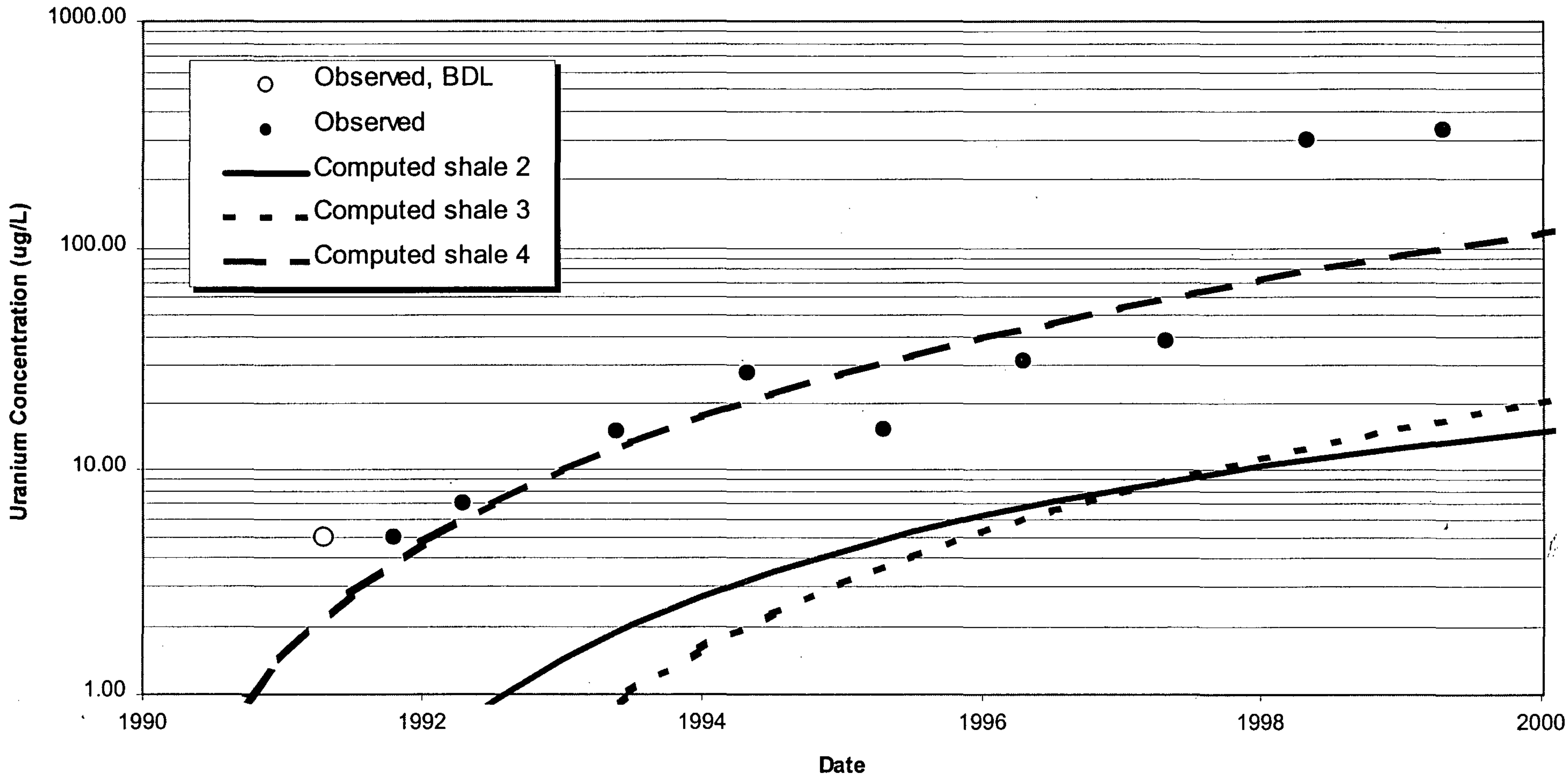

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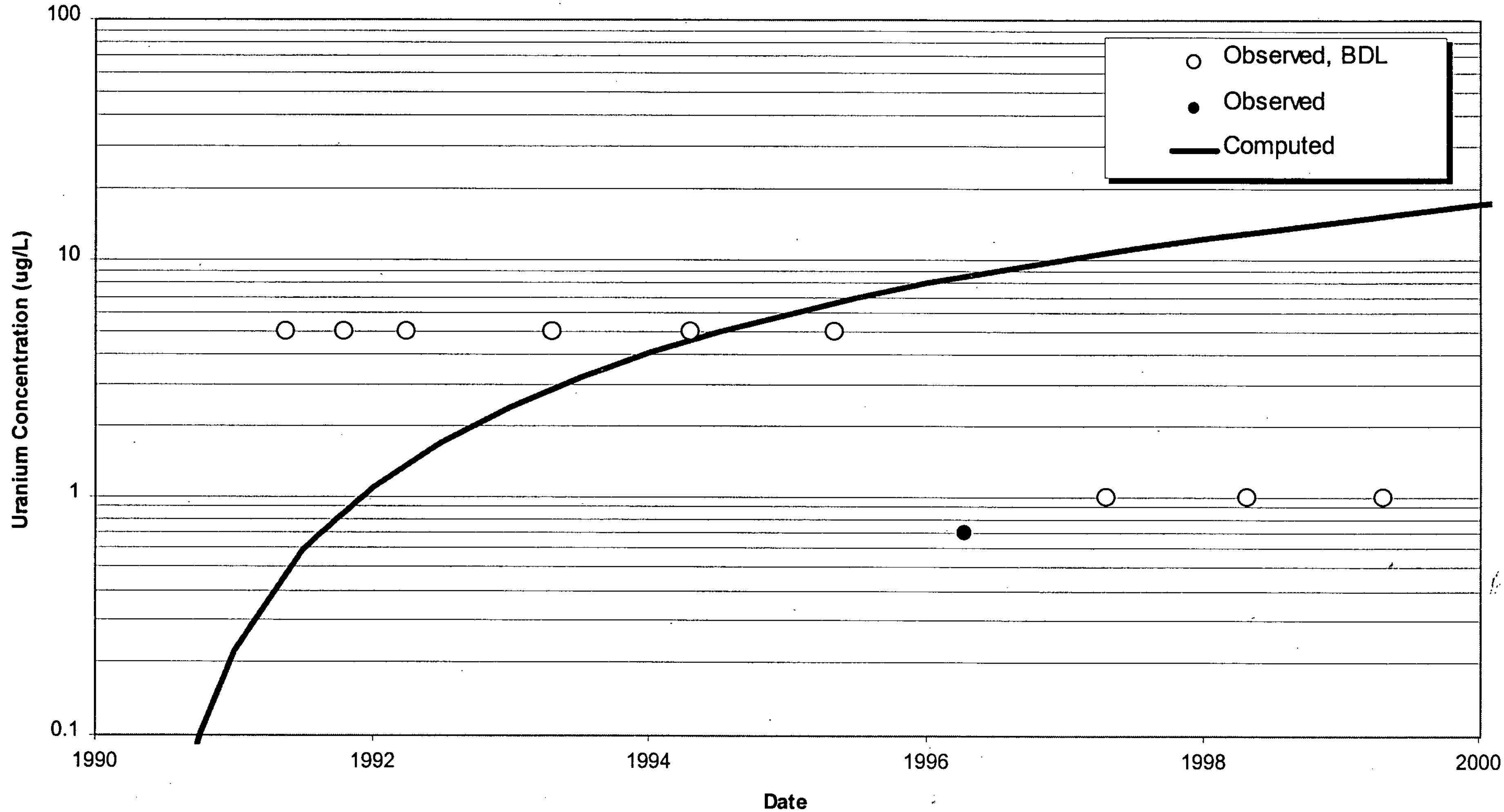

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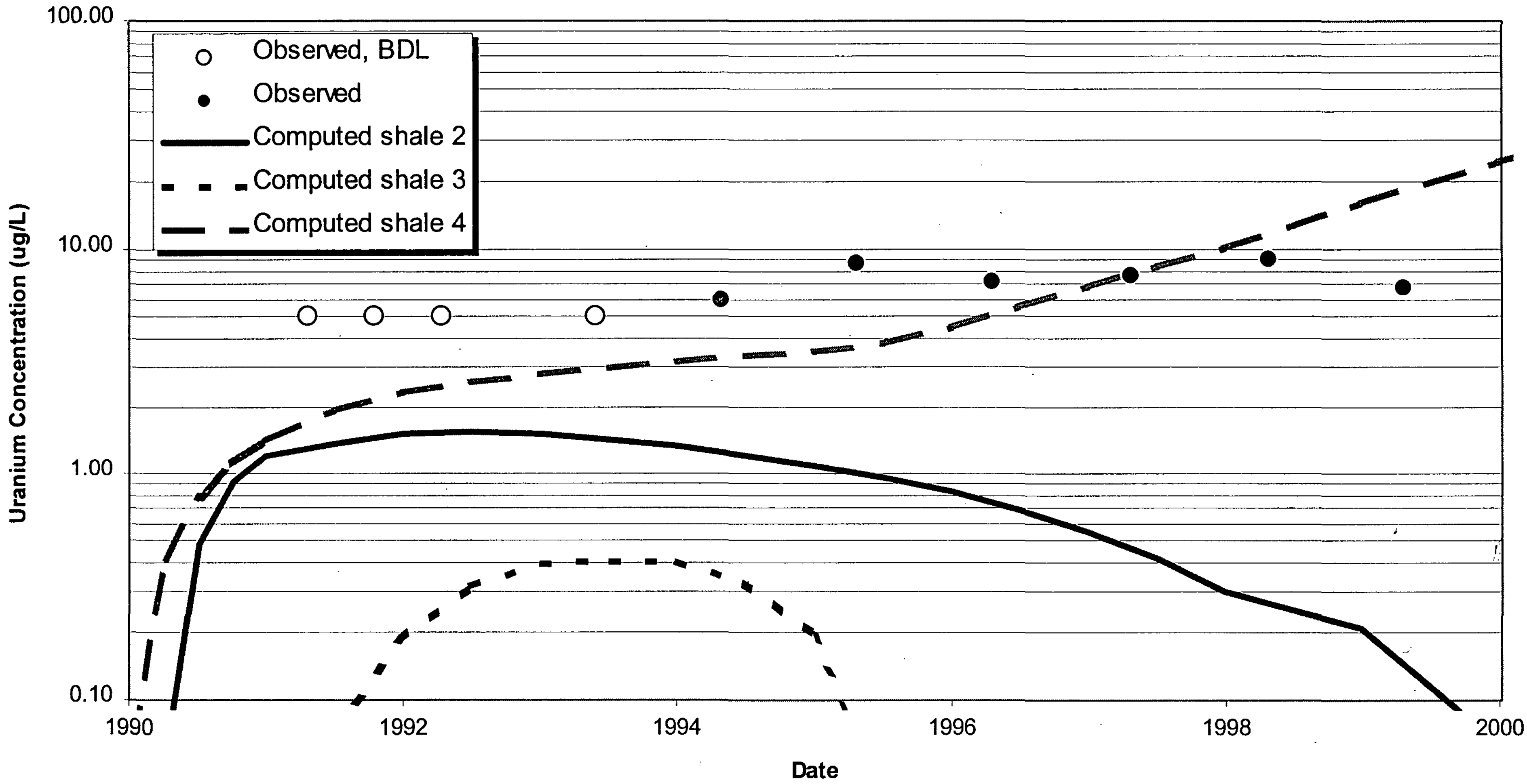

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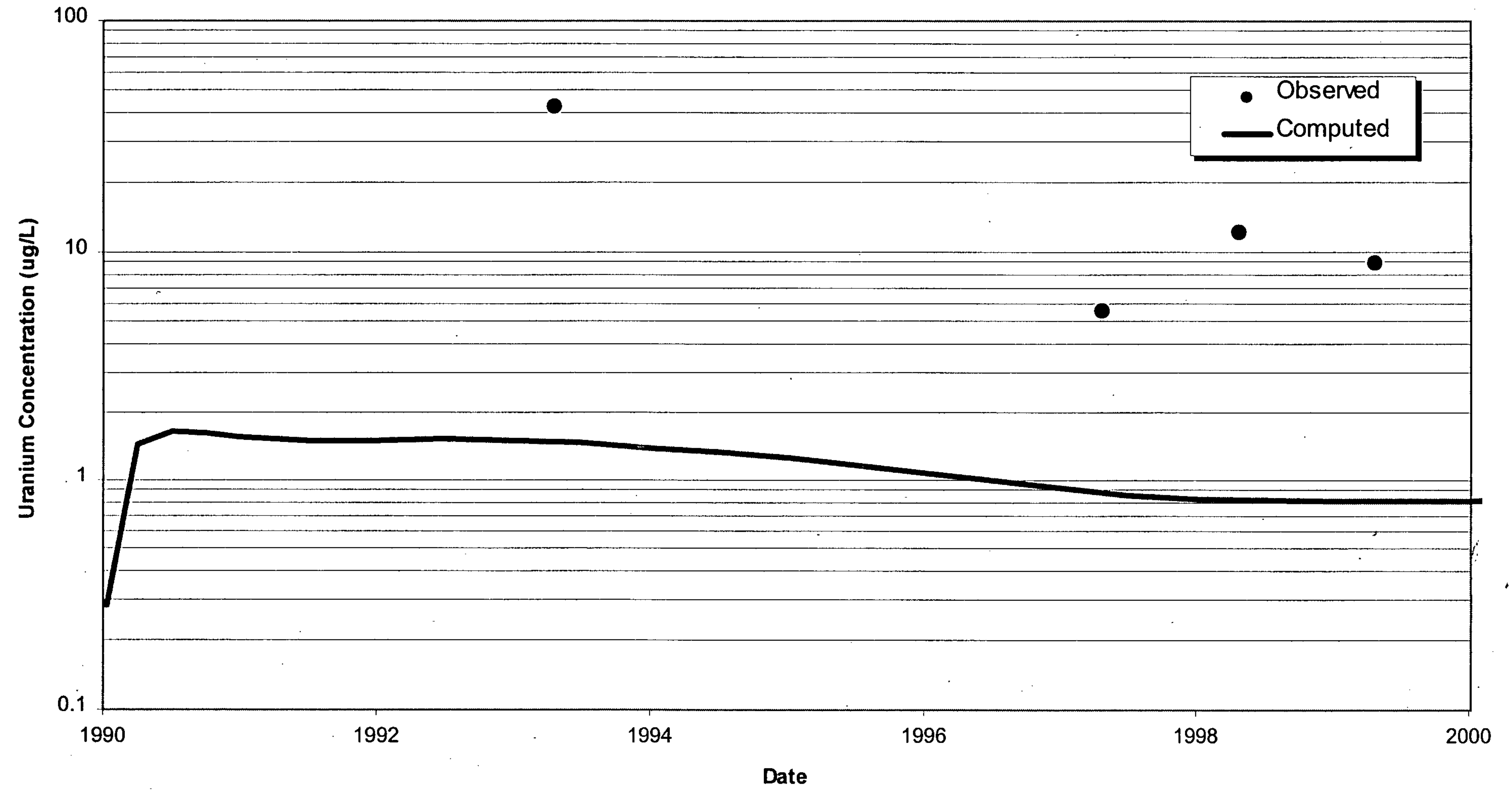

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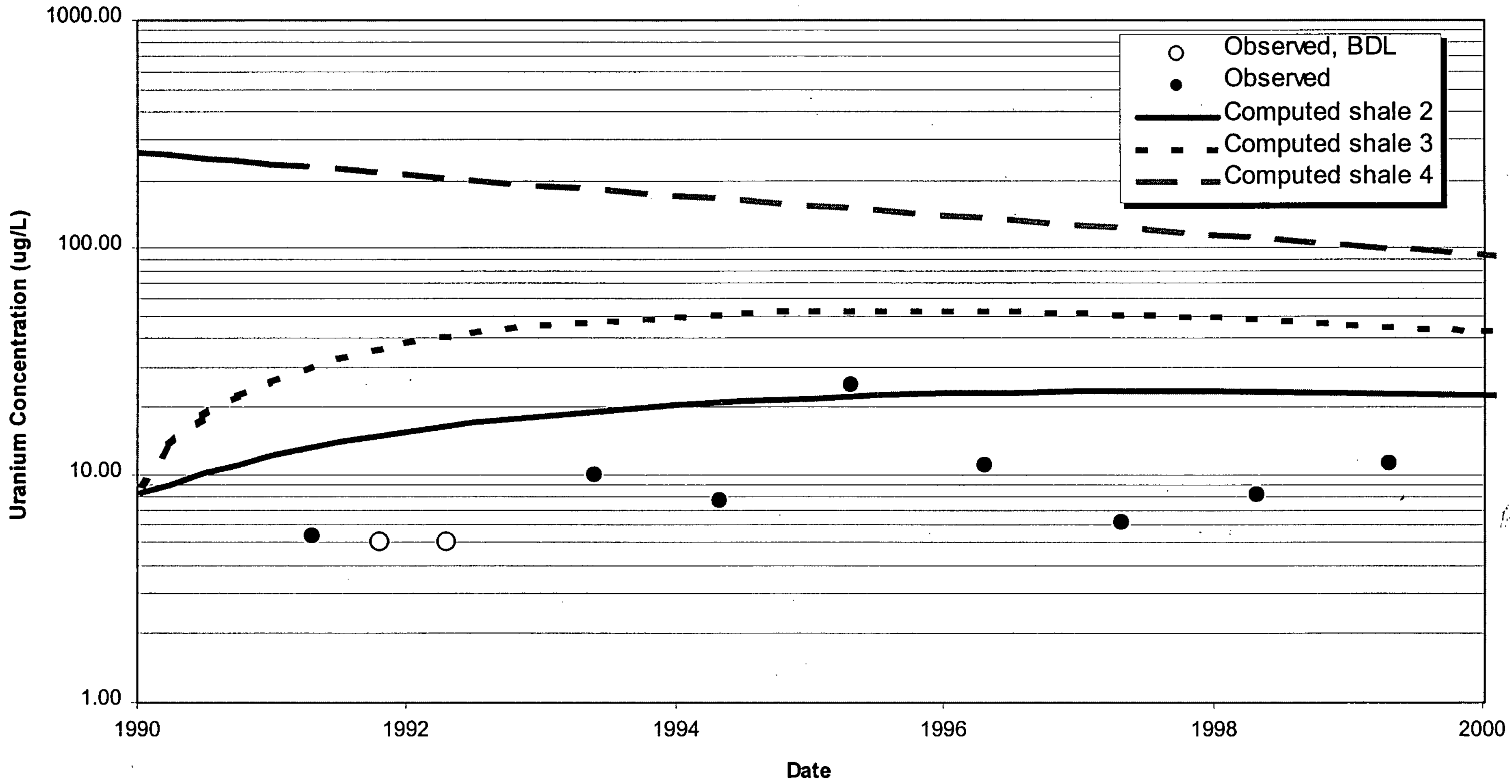

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FIGURE
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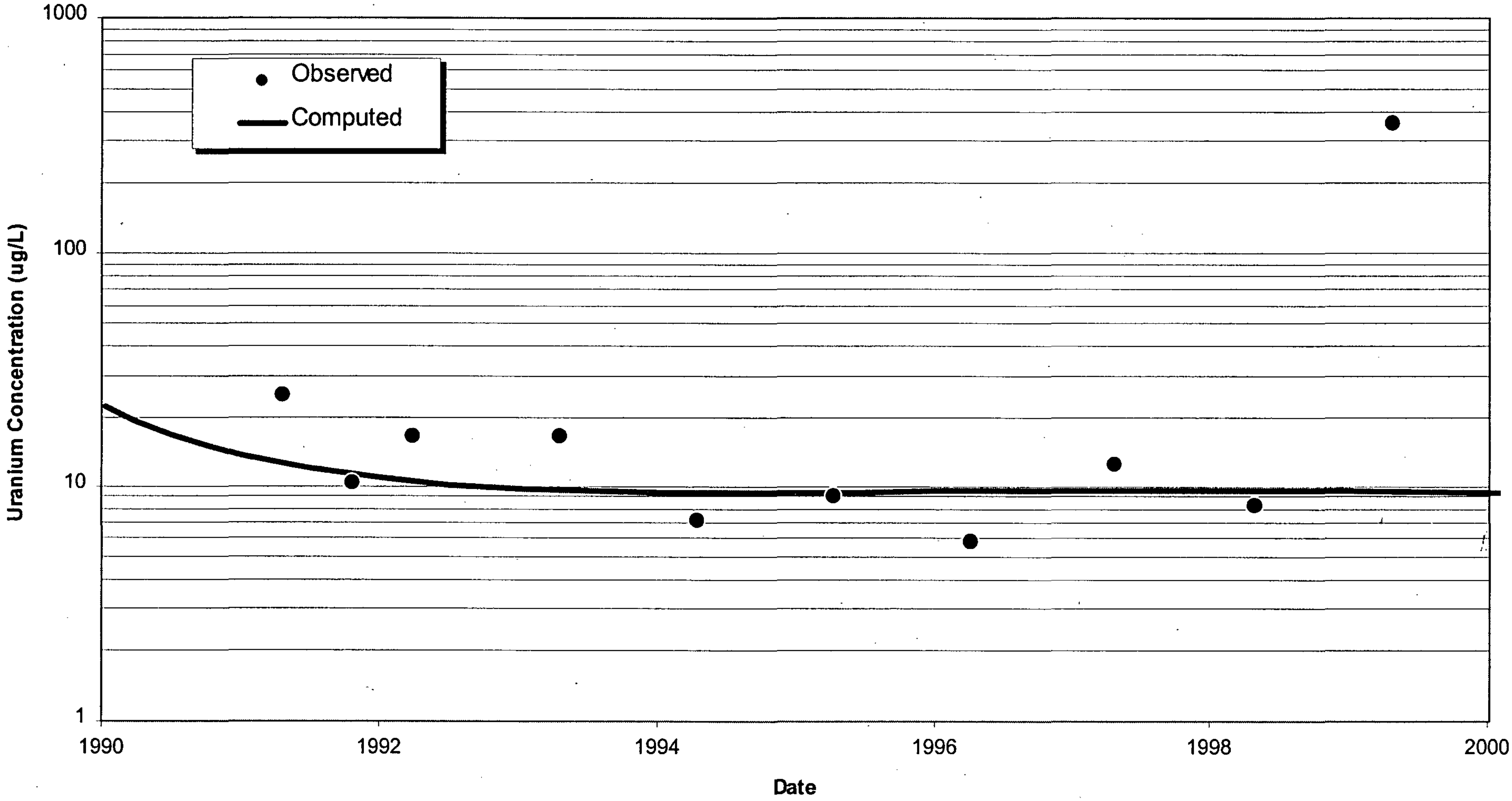

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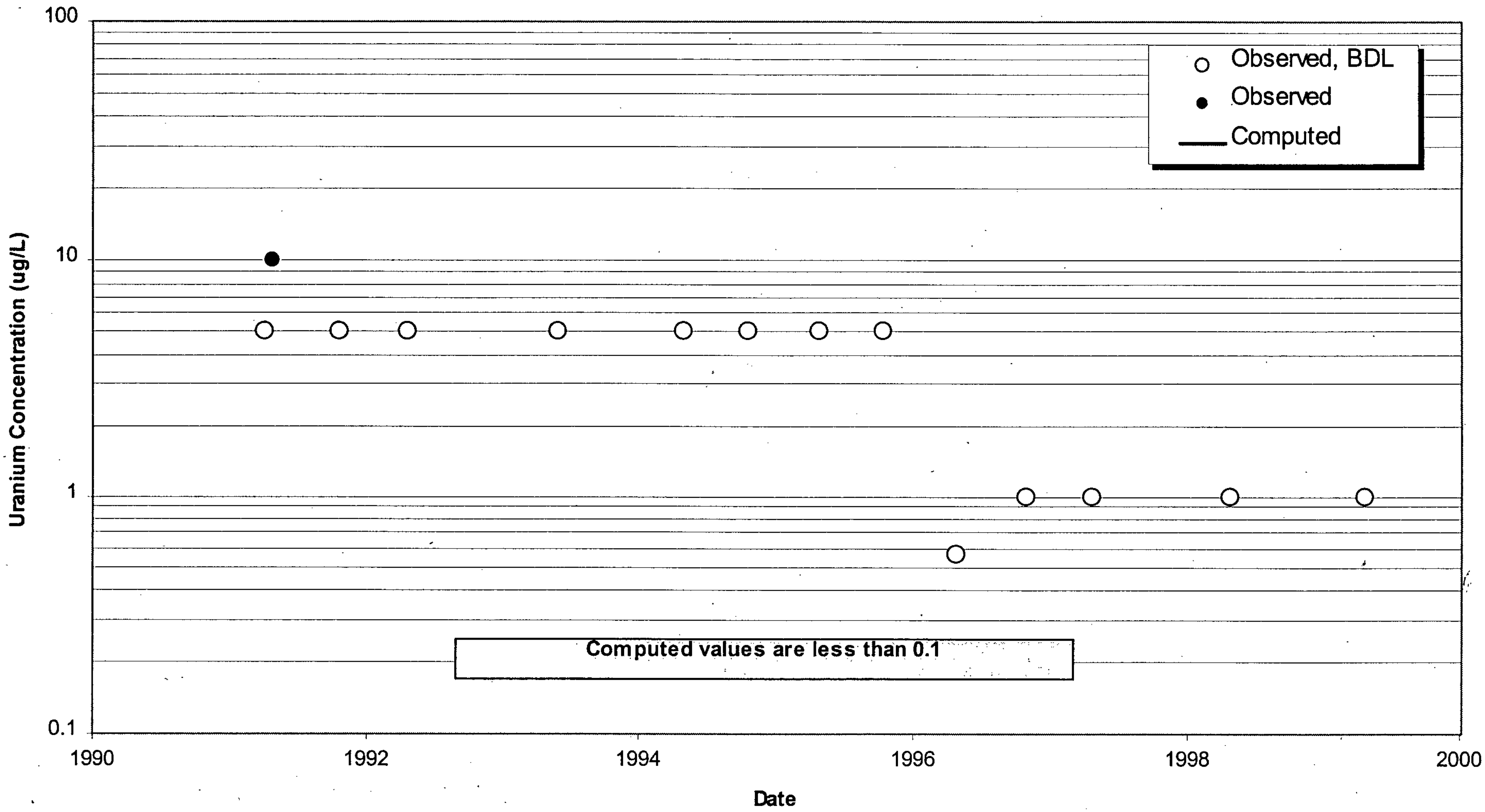

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FIGURE
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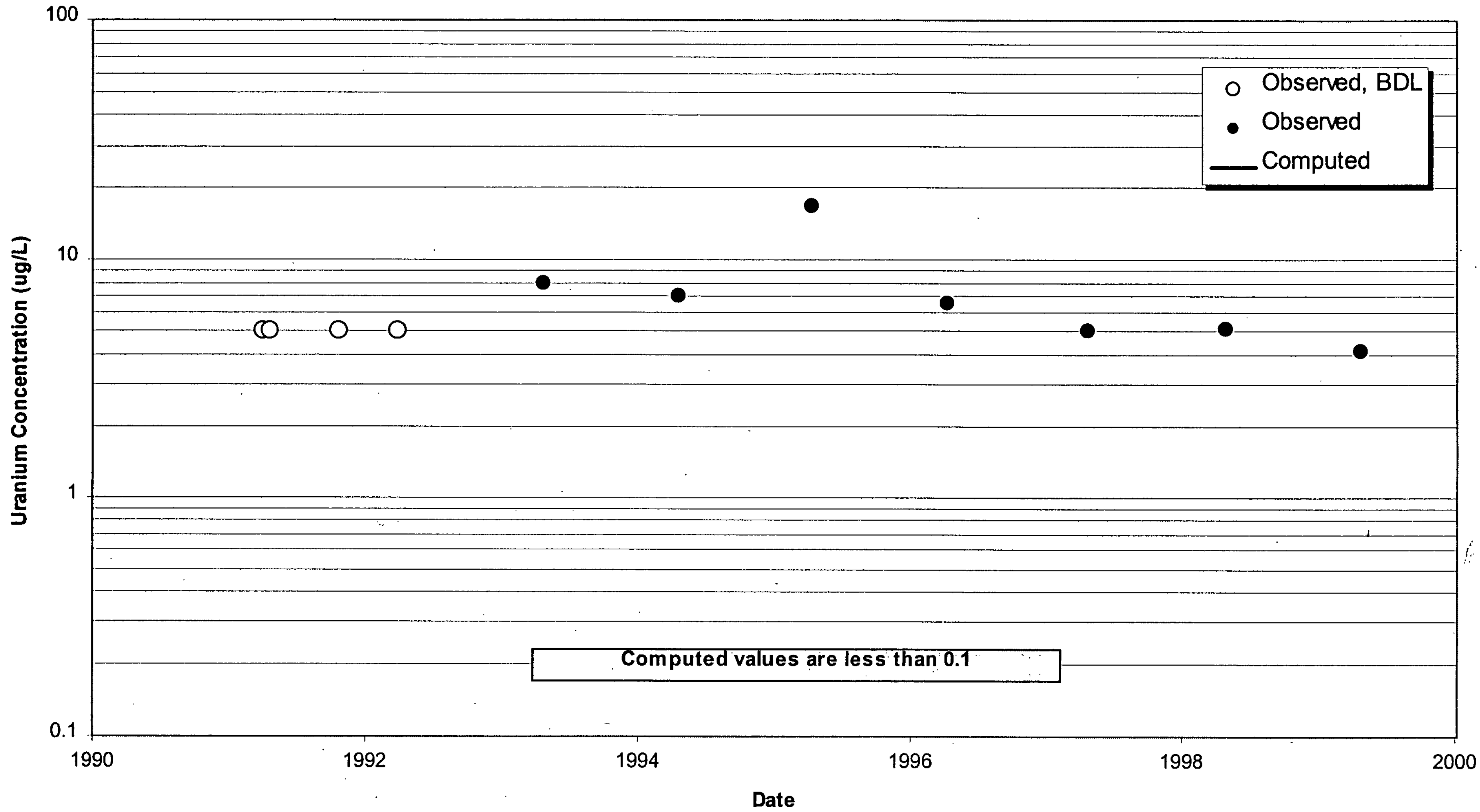

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FIGURE
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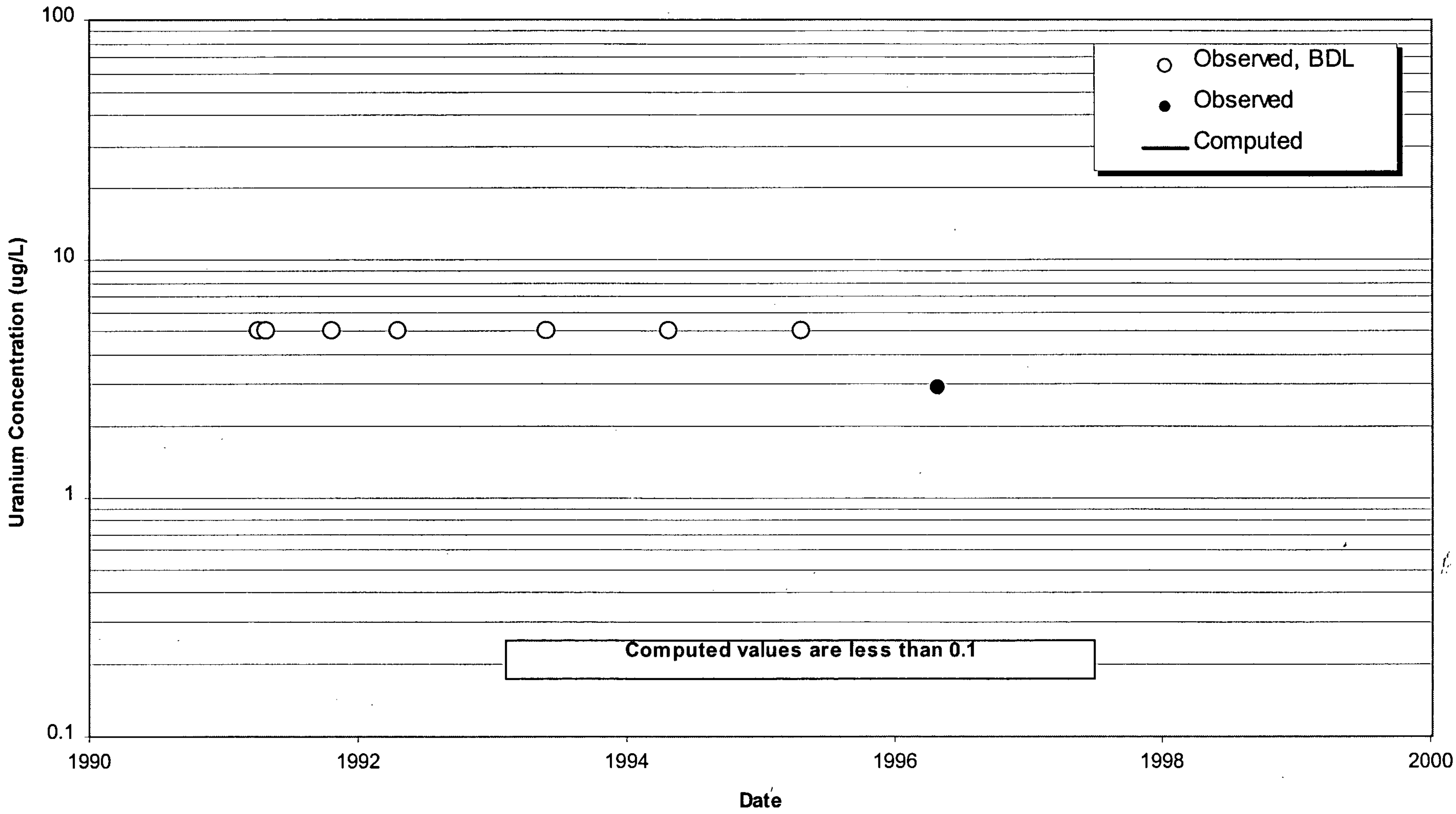

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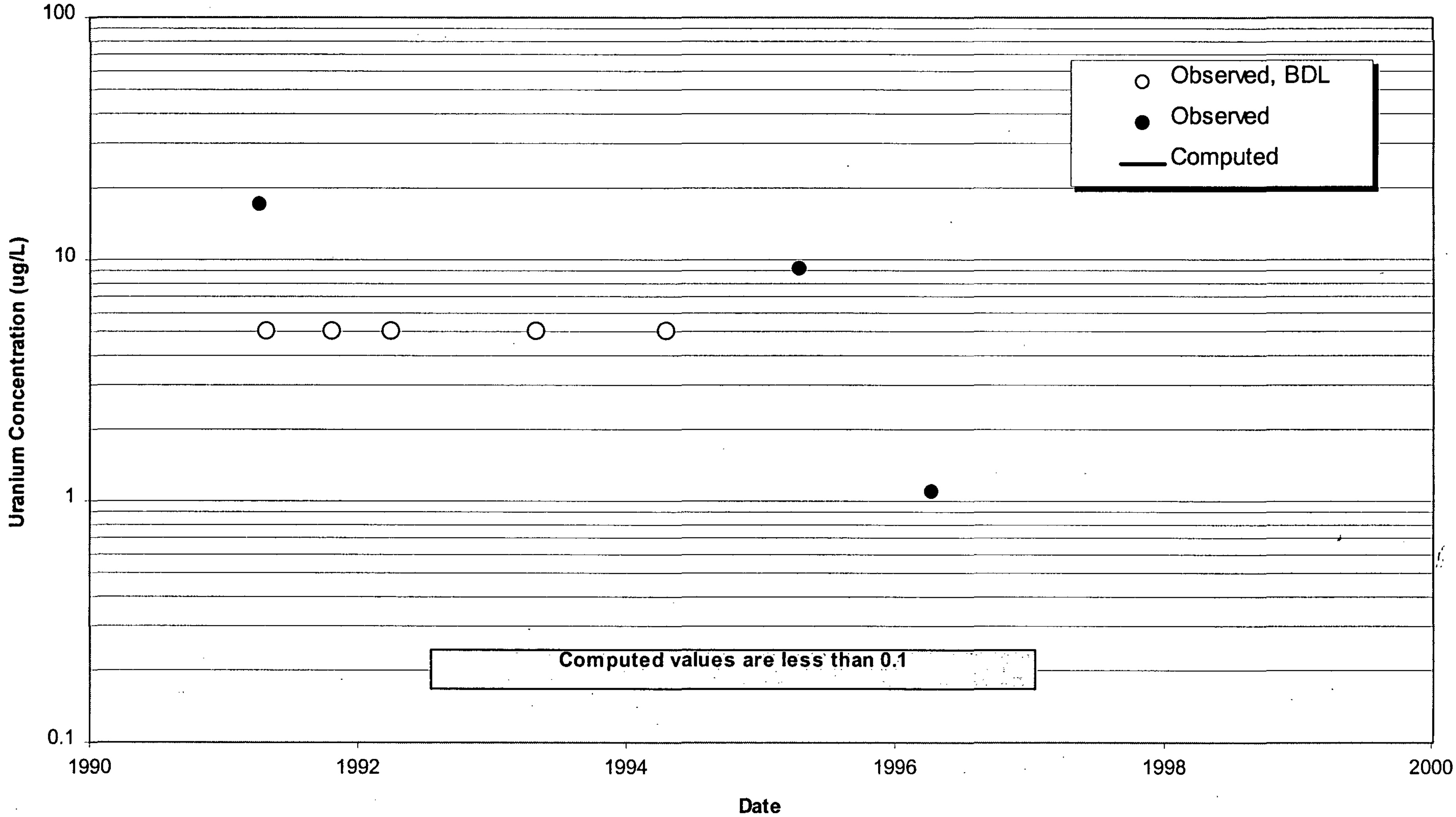

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FIGURE
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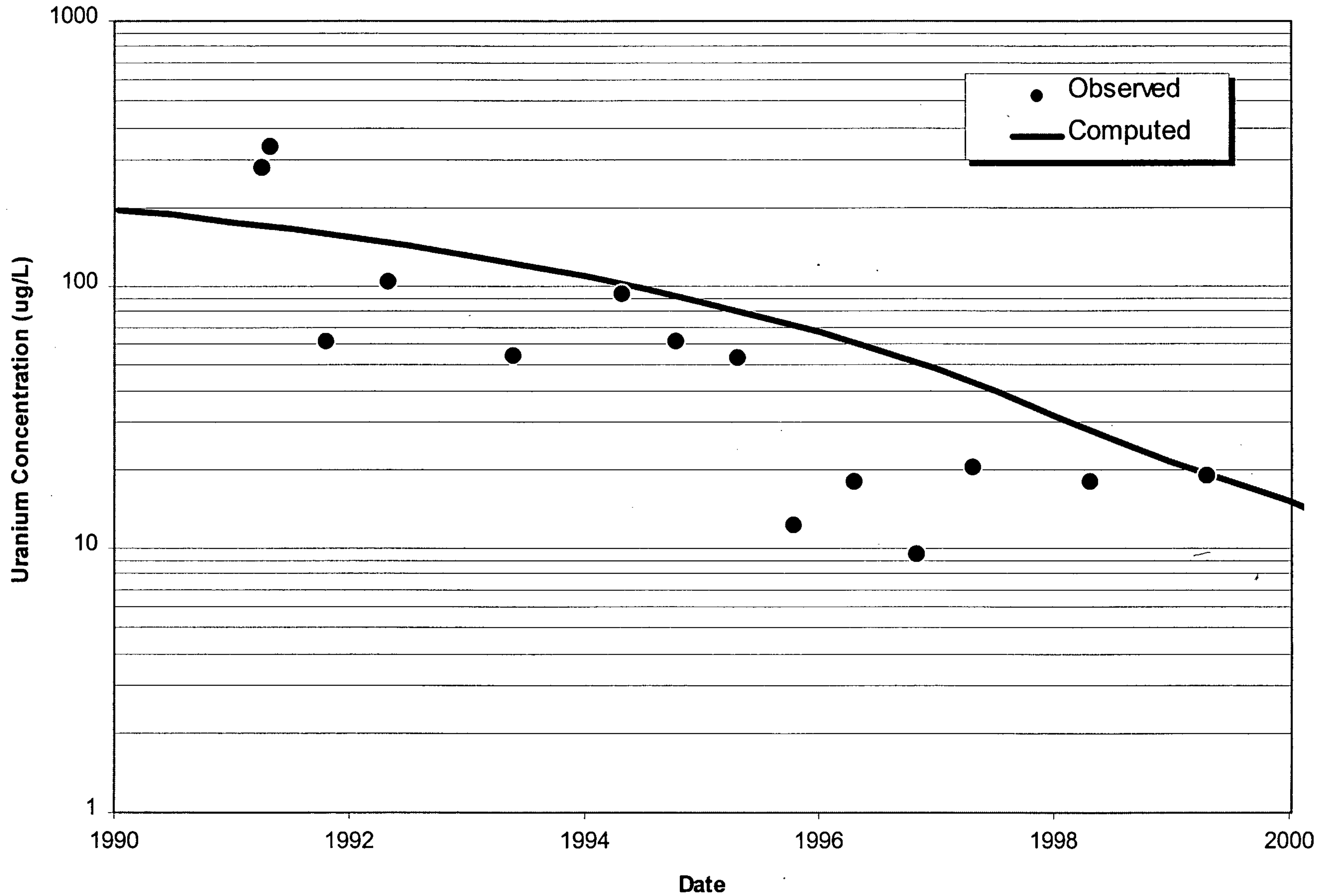

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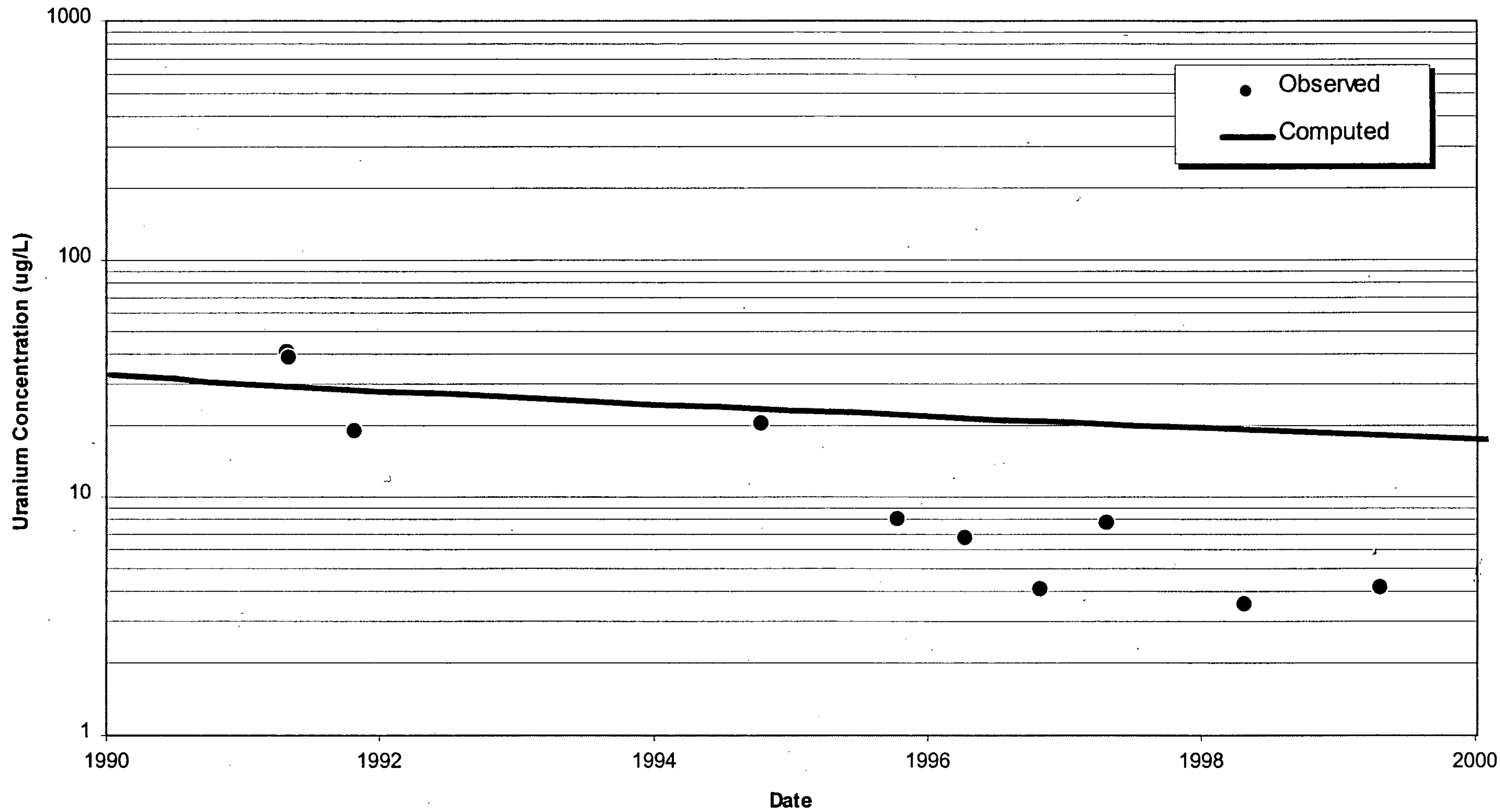

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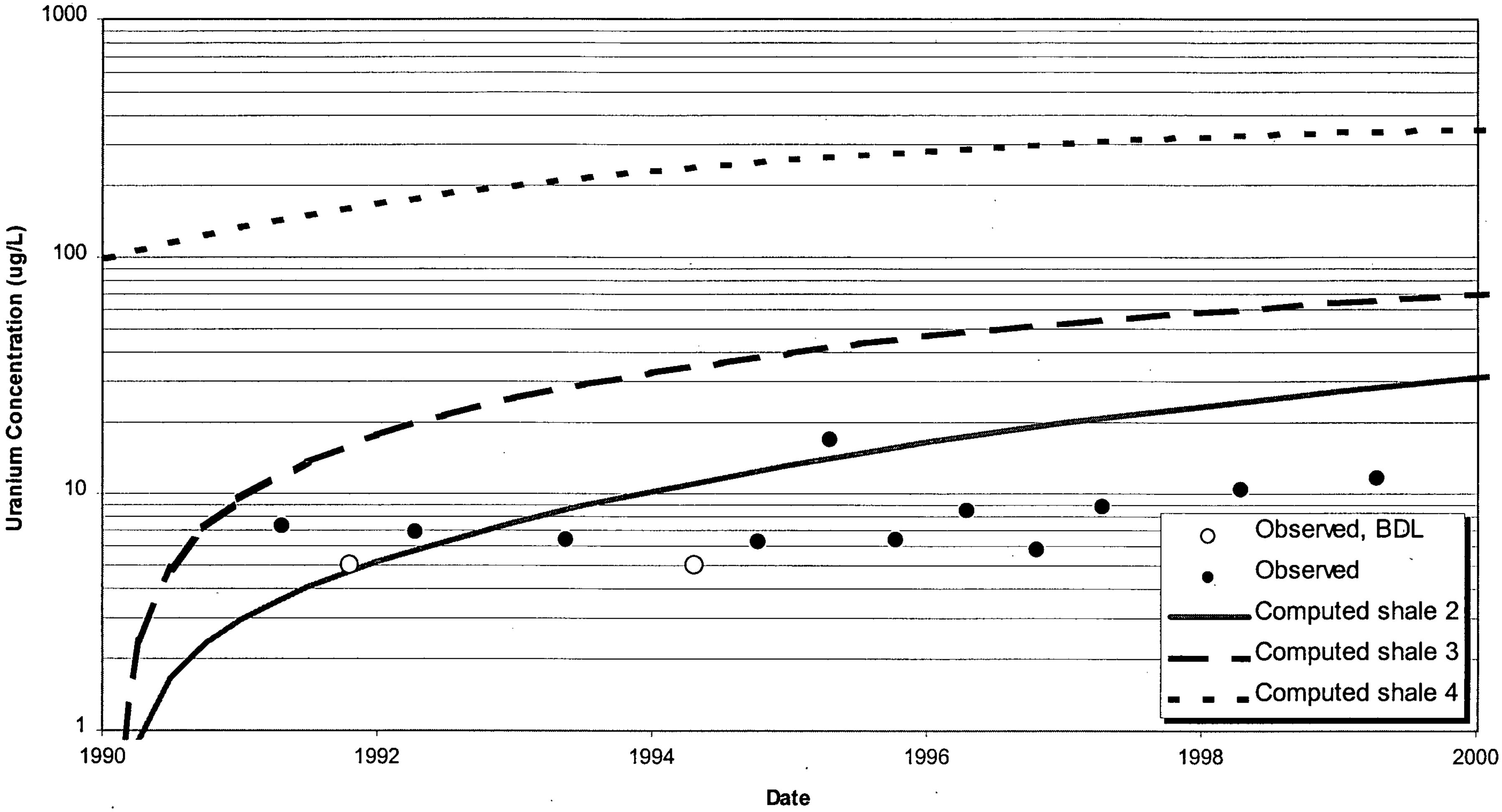

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FIGURE
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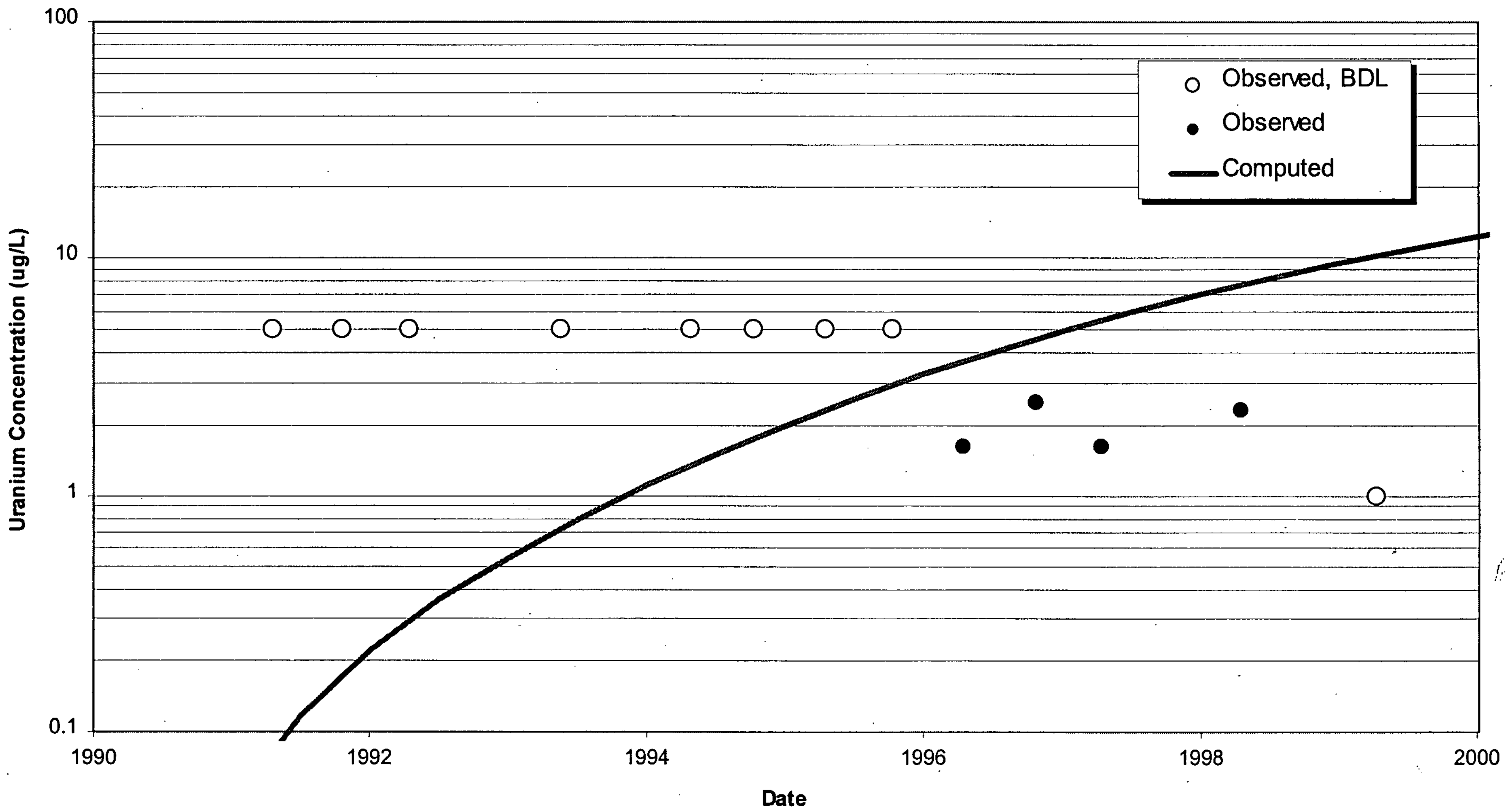

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FIGURE
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APPENDIX G

BOREHOLE DATA FOR EVS MODEL

APPENDIX H

EVSTRIM.EXE

APPENDIX I

VEGETATION WATER BALANCE ESTIMATES FOR SEQUOYAH SITE

APPENDIX J

HYDROLOGIC TEST DATA

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):

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

Solving for r_e yields:

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

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:

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

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

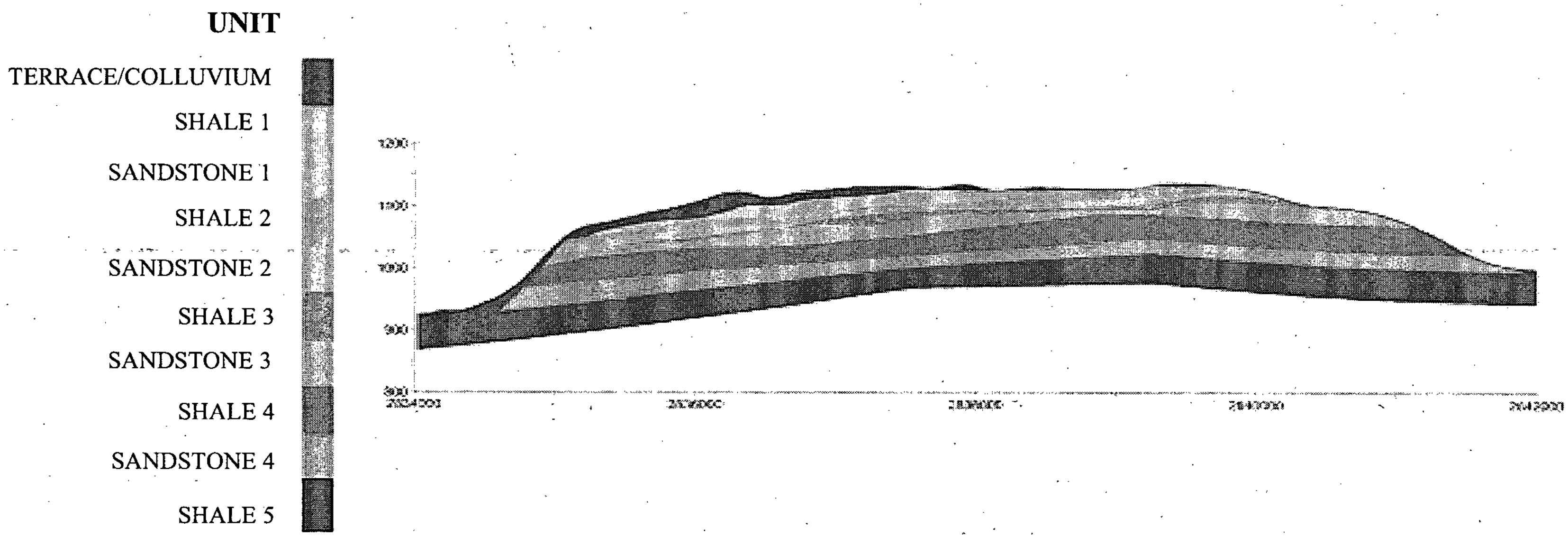
Table 2. Water Levels from Selected Well Sites (continued)

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-)



SHE[illegible]RD MILLER [illegible]RPORATED	FIGURE 1. TYPICAL GEOLOGIC CROSS SECTION

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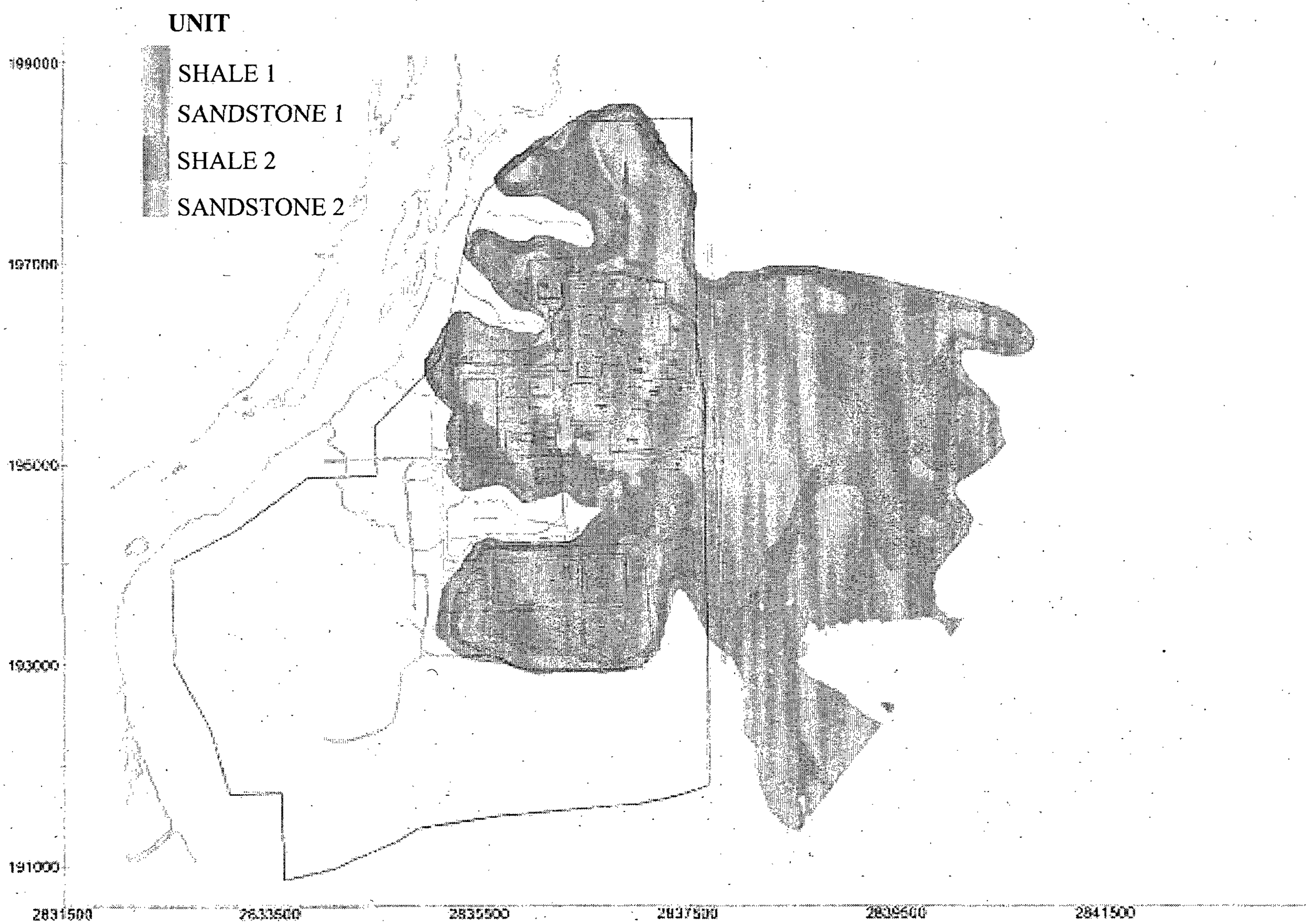

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FIGURE 2. AREAL EXTENT OF UNITS 1 SHALE, 1 SANDSTONE, 2 SHALE, and 2 SANDSTONE

Date:	AUG 2001
Project:	100734
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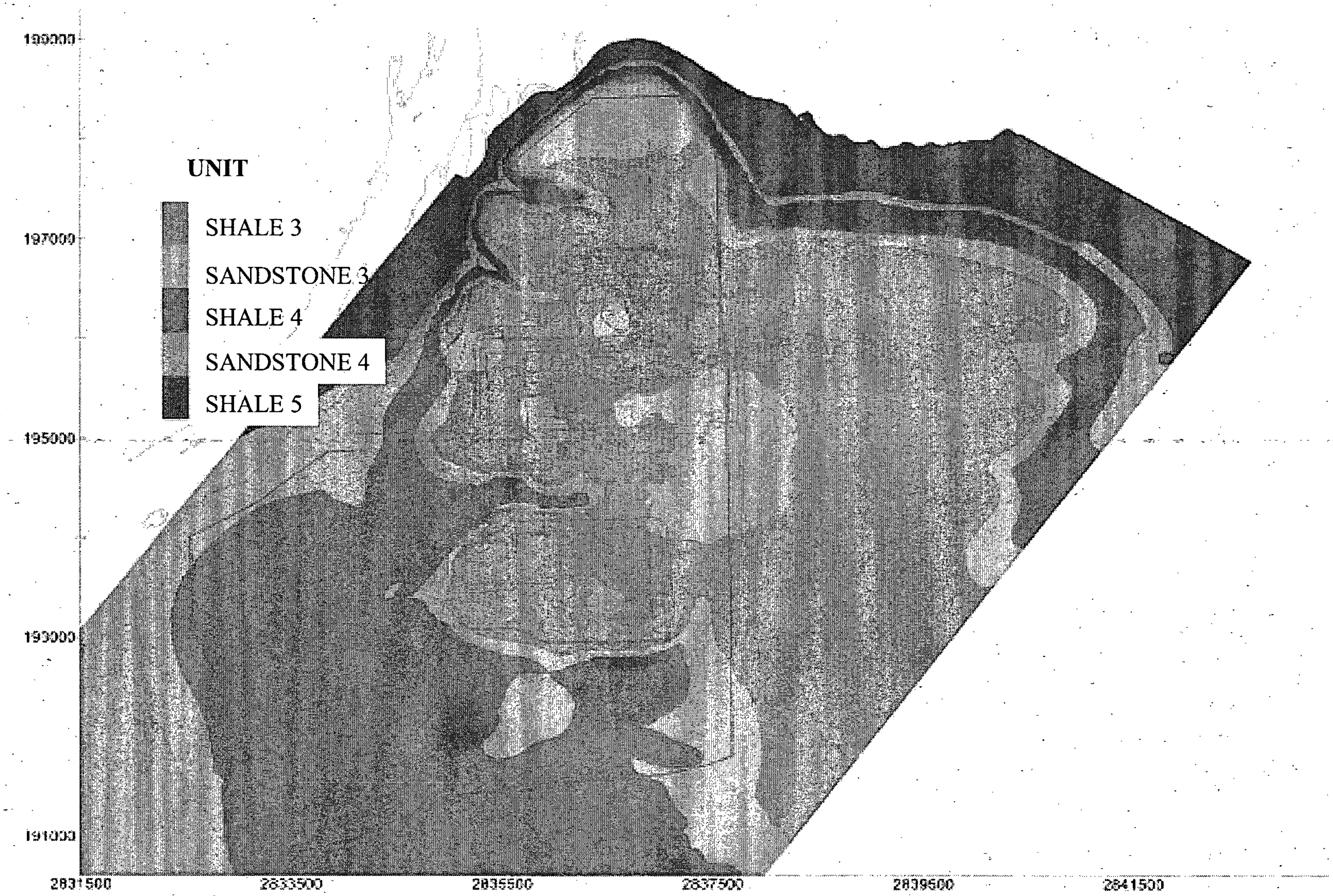

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FIGURE 3. AREAL EXTENT OF UNIT 3 SHALE, 3 SANDSTONE, 4 SHALE, UNIT 4 SANDS[illegible]NE, AND UNIT 5 SHALE

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Project:	100734
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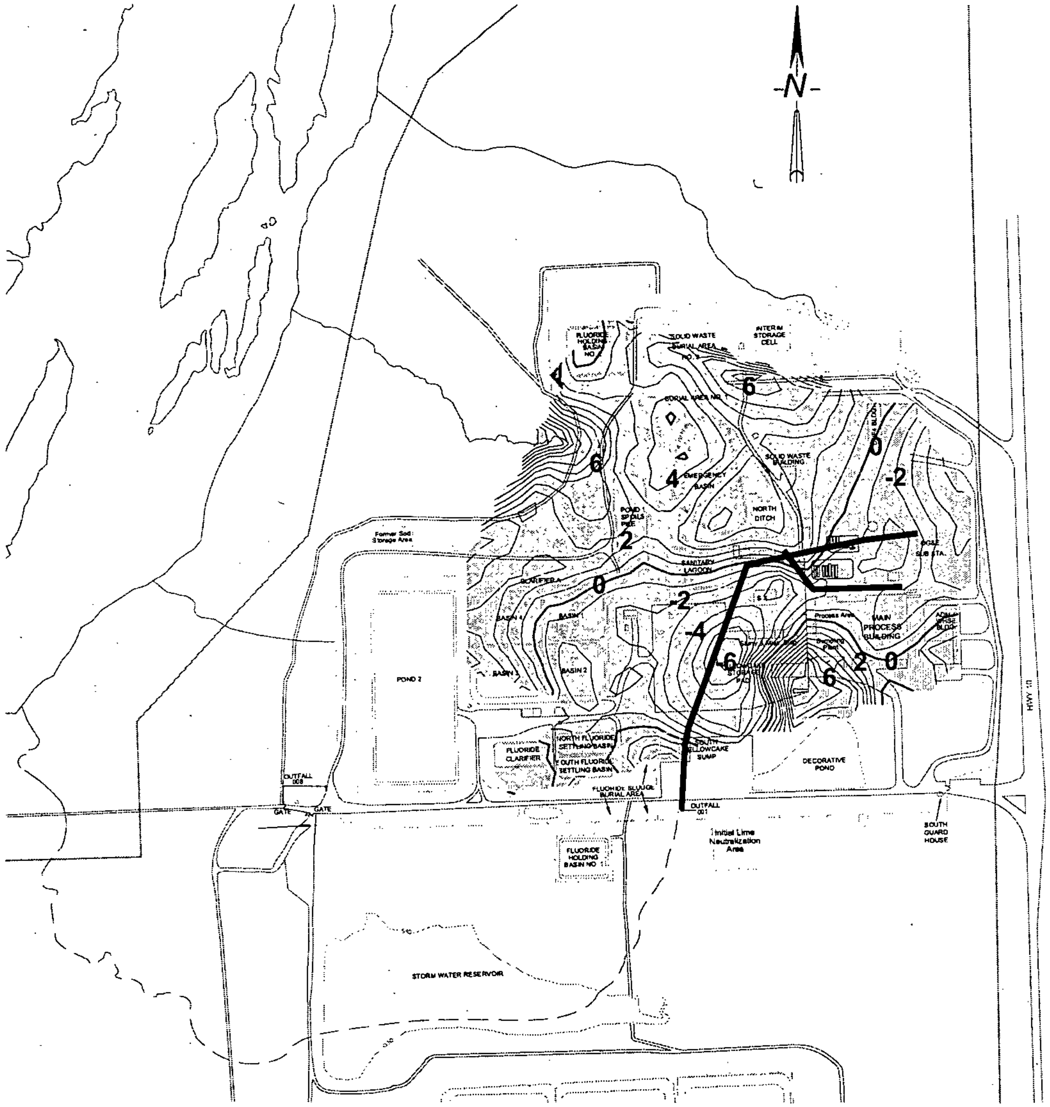

-2 Water level below contact between terrace deposits and Unit 1 Shale

2 Water level above contact between terrace deposits and Unit 1 Shale

Stream drain pipe

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

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Project:	100734
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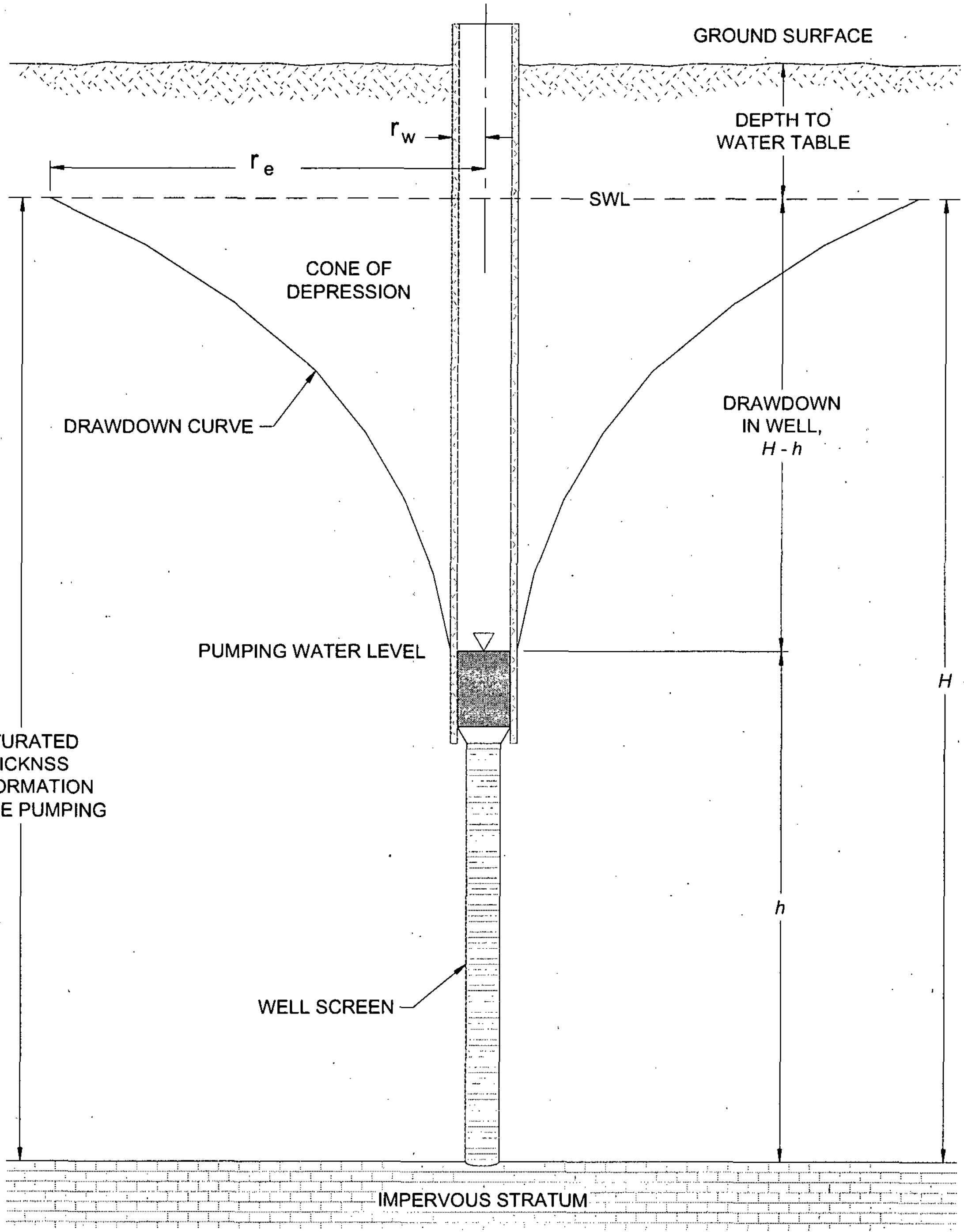

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FIGURE 5
PARAMETERS FOR THIEMS EQUATION

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Project:	100734
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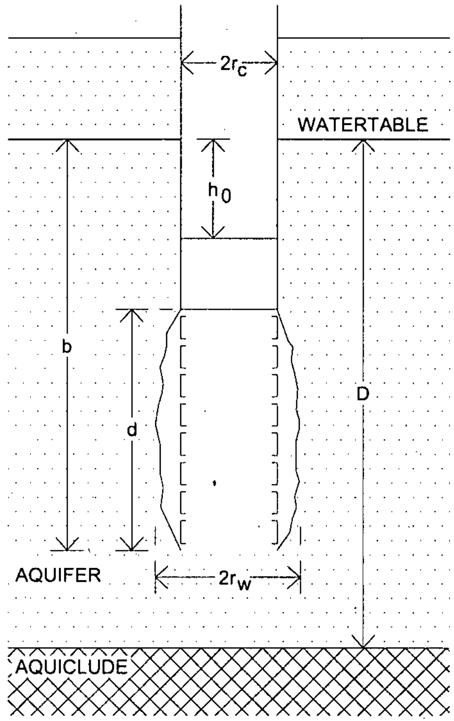

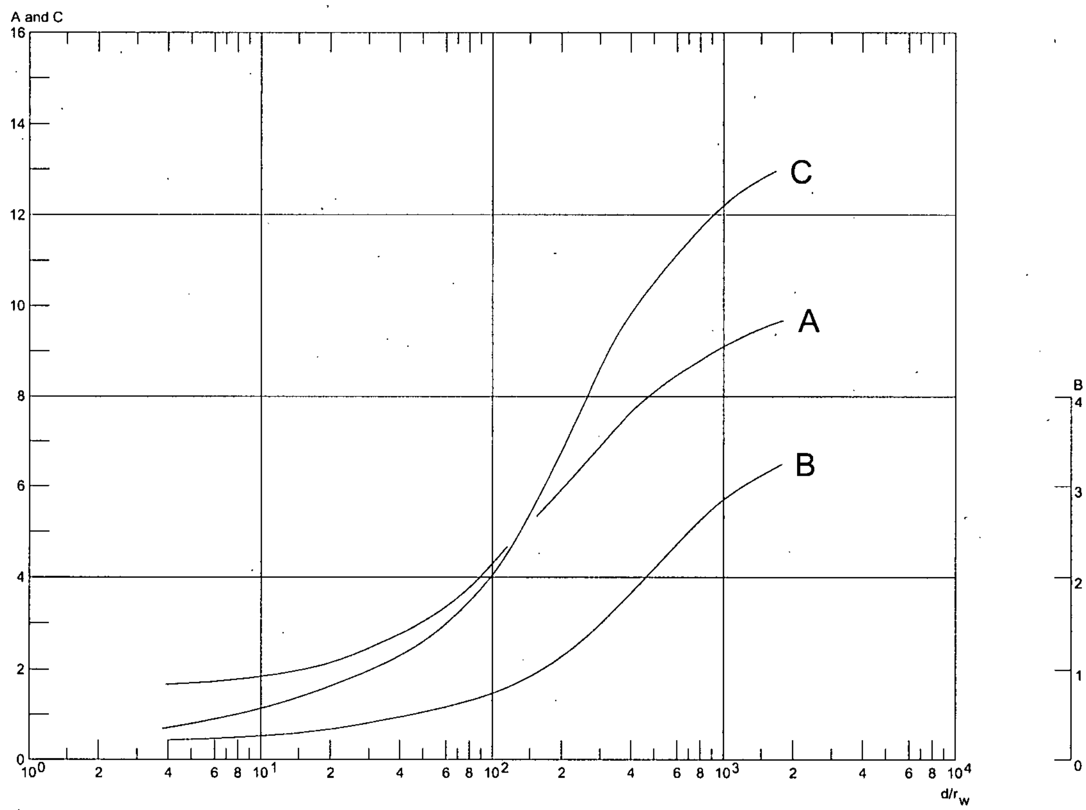

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FIGURE 6
UNCONFINED AQUIFER

BOUWER AND RICE CURVES

Date:	AUG 2001
Project:	100734
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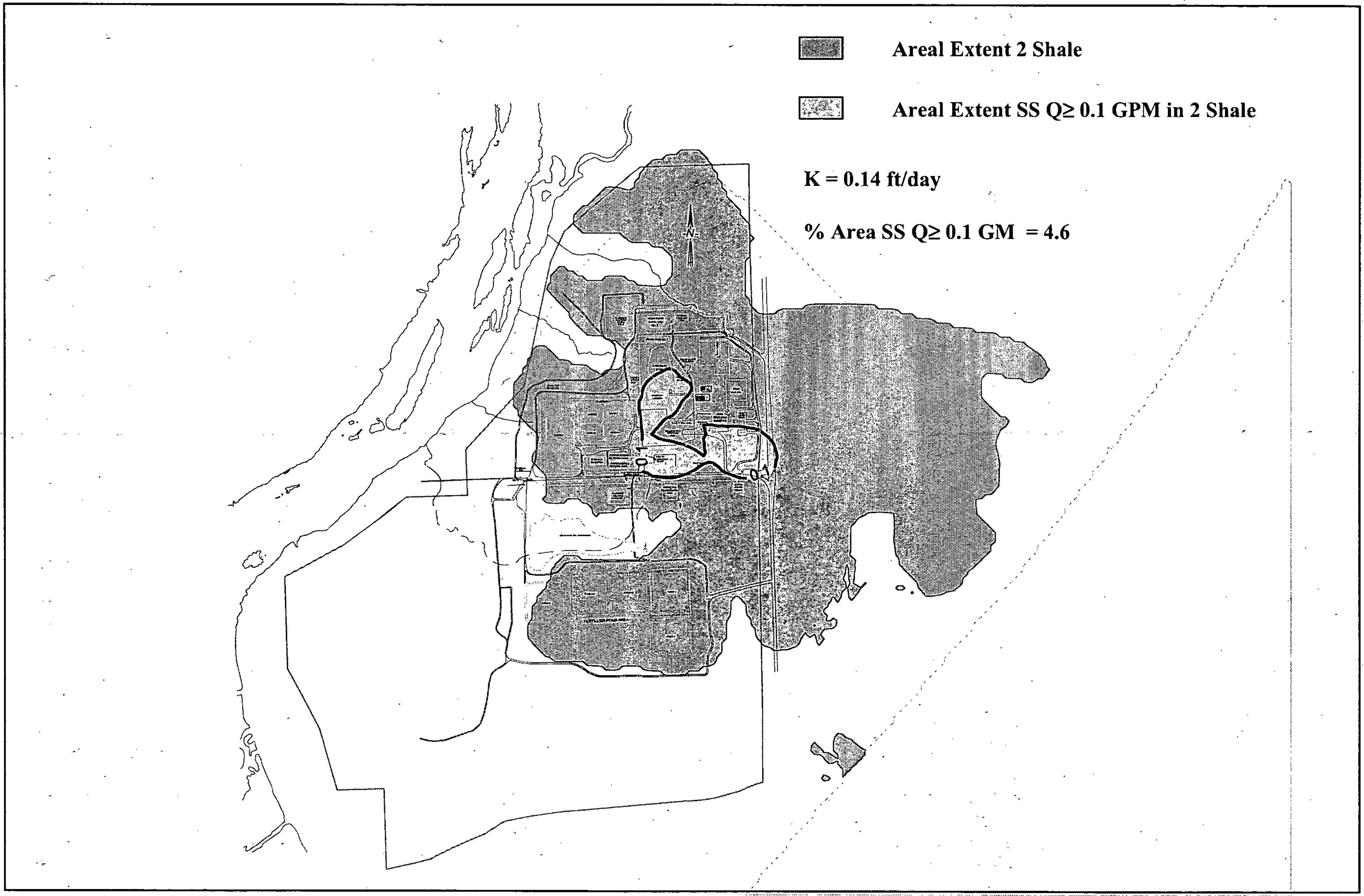

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FIGURE 7. AREAL EXTENT UNIT 2 SHALE AND STEADY STATE YIELD GREATER T[illegible]N 0.1 GPM

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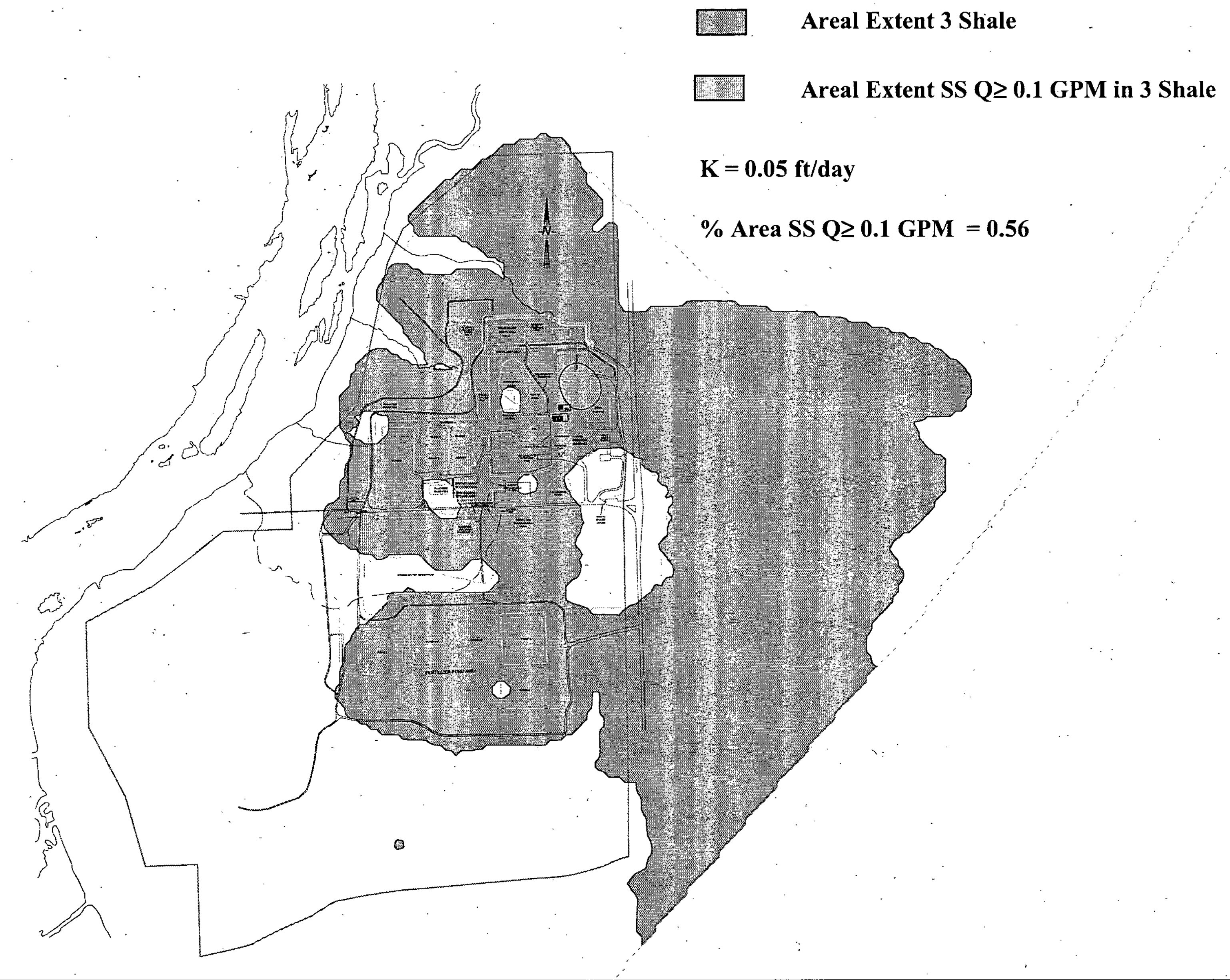

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FIGURE 8. AREAL EXTENT UNIT 3 SHALE AND STEADY STATE YIELD GREATER THAN 0.1 GPM

Date:	AUG 2001
Project:	100734
File:	FIGURES.PPT

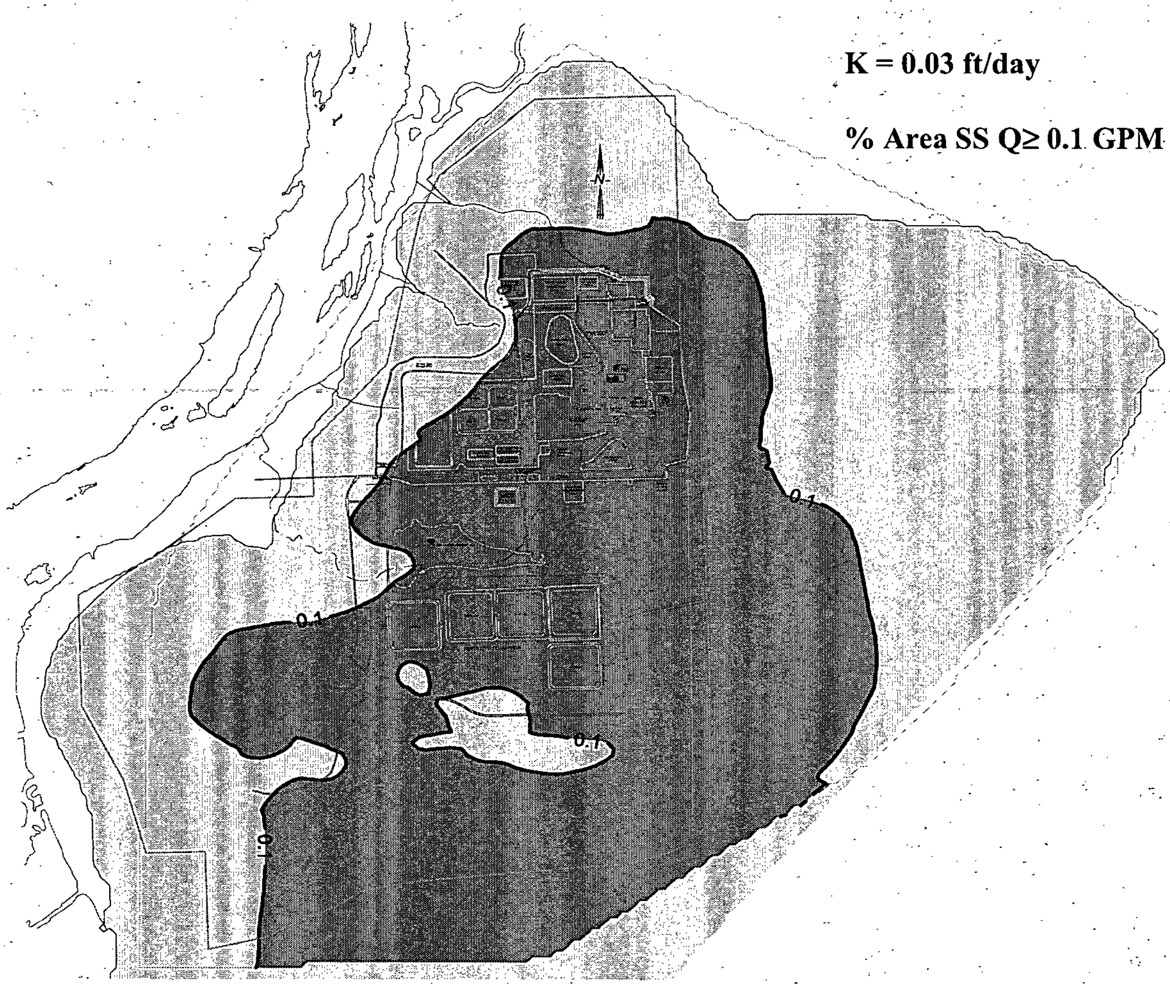

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FIGURE 9. AREAL EXTENT UNIT 4 SHALE AND STEADY STATE YIELD GREATER T[illegible]N 0.1 GPM

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Project:	100734
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