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PITT-10-0-028

October 10, 2000

Project Number 7842

Mr. Tom Bloom
U.S. Environmental Protection Agency
Region 5
77 West Jackson Boulevard
Chicago, Illinois 60604-3590

Reference: CLEAN CONTRACT No. N62467-94-D-0888
Contract Task Order No. 0057

Subject: Groundwater Flow Modeling Report
NIROP Fridley, Fridley Minnesota

Dear Tom:

The Navy, through the USGS, has recently completed a heat pulse flow meter study at NIROP. In addition, during the week of September 18 through 24 the Navy, through TtNUS, conducted a colloidal borescope study at the site. These investigations provide additional information to support the Navy's responses, herein, to EPA's June 30 comments on the subject report.

During the August 2 Partnering Team Meeting, the following decision was agreed to:

> For OU1, an additional well (AT-10) will be put in between 12I and 13I. The extraction well AT-6 will not be put in side the building source area. Once the 'veggie' treatment has been carried out and successful, it will be evaluated along with other remedies (source control) for the hot spot under the building. AT-1 and AT-4 will be shut down. AT-2 will go in with team concurrence. The AT-4 compliance line will be moved to the OU-1 system compliance line.....

This decision impacts many of EPA's comments on the groundwater flow model, and we have identified in our responses where the comments have been overtaken by events. In these cases, we have provided an appropriate response.

In comments, the EPA requests many additional figures be incorporated into the report. We anticipate well over 100 figures would be required, with a large number of these being oversized and/or color. The response to this request, which provides the best utility, is to provide a CD of the model that will include:

- The input and output files of all fourteen model runs
- Figures showing the distribution of residual errors in the calibrated model run
- A table listing the residual errors of all monitoring wells for each of the fourteen model runs
- Input files, output files, and particle track figures for hypothetical extraction well system #6.

We feel that sharing the model directly with EPA provides the most utility because it enables EPA to have access to any output desired whenever they want without needing to request this from the Navy. This should promote the model's usefulness for future Team purposes. More details about the CD are provided in responses to individual comments.

As stated in responses to the AMR and the Anoka Park Field Investigation Report, the Navy anticipates that following review of these responses, the EPA and MPCA will agree the Technical Committee should resolve any remaining issues.

Sincerely,

Mark Sladic P.E.
Task Order Manager

MS/kf
Enclosure

cc: Joel Sanders, SOUTHDIV
John Aubert, NAVSEA
Dave Douglas, MPCA
Richard Harris, RAB Co-Chair
Tim Ruda, UDLP
John Koehnen, Tech Law
Rick Kuhlthau, Tech Law
Keith Henn, TtNUS
Jeff Schubert, TtNUS
Mark Perry/File 7842 TtNUS
Debra Wroblewski, TtNUS (Cover Letter Only)

**GROUNDWATER FLOW MODELING REPORT (Rev. 1)**
**NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT, FRIDLEY, MINNESOTA**
**Responses to EPA comments**

## General Comments

1. **Comment**: Review of the May 2000 Groundwater Modeling Flow Report indicates that significant additional work has been performed to upgrade and improve the groundwater flow model of the NIROP site. The previous model was presented in the November 1999 Groundwater Modeling Flow Report. Significant efforts have been devoted to adjusting boundary conditions and incorporating hydrogeologic data from the recent Anoka County Riverfront Park Investigation. The resulting model is clearly more representative of the groundwater flow system at the NIROP site than the previous model.

   In spite of these improvements, it remains difficult to assess the adequacy of the model for evaluating capture zones based on a series of alternative pumping scenarios. The difficulty lies in part on the failure to provide sufficient analysis of model behavior and performance so that the uncertainty and reliability of the calibrated model can be adequately evaluated. As indicated in the following specific comments, much of the necessary analyses were requested in previous comments provided during the review of the November Groundwater Flow Modeling Report. Agreement with these comments, as well as commitments to provide the requested analyses, was generally included in the response to these comments. However, much of the agreed to analysis has not been provided in the May 2000 Groundwater Modeling Flow Report.

   In addition, review of model predictions indicates that the calibrated model fails to adequately simulate important, currently observed hydraulic behavior in the vicinity of the current extraction well system. The failure to predict this behavior casts further doubt on the ability of the model to adequately evaluate capture zone scenarios.

   Consequently, further analysis and revisions to the model appear necessary before it can be considered a reliable tool for evaluating the capture zones resulting from alternative pumping scenarios. In spite of this apparent lack of reliability, the calibrated model remains a useful tool for evaluating alternative pumping scenarios. However, the predictions of the model must be carefully evaluated against other considerations, including the uncertainty inherent in the parameter estimates resulting from model calibration and the failure of the calibrated model to reproduce the observed hydraulic behavior of the current extraction system.

   **Response**: In the revised model, the match between the measured and the predicted groundwater elevations has been greatly improved around the perimeter of the model area, and has been moderately improved in the central portion of the model area where extraction wells AT-2, AT-3A, AT-5A, and AT-5B are located. Further refinements are limited at this time due to:
   - Fairly deep cones of depression immediately surrounding these extraction wells,
   - Rapid changes in the lateral extent and thicknesses of the different lithologies in this area, and
   - Cell sizes resulting from a grid of 6 layers, 134 rows, and 86 columns of cells.
     Even with the very large number of cells (69,144) in the model domain, it was still necessary to simplify and volume-average the lithologic characteristics and hydraulic properties within individual cells.

   The report acknowledges that resolution of predicted groundwater elevations in several localized regions of the site may not be optimal. However, the Navy believes the model remains largely effective for evaluating well capture zones and overall plume capture efficiency. Recent decisions regarding the placement of new extraction wells at the site were based, in part, on modeling various pumping scenarios. However, the number of new wells and the overall pumping rate of the extraction

system are larger than what the model predicted as being necessary. The Navy believes that the extra capacity designed into the extraction system (i.e., well AT-10) compensates for inherent uncertainties in the capture system analysis.

The Navy believes that diminishing returns would be evident in attempts to further reduce inaccuracies and uncertainties in the model. The Navy agrees that remaining uncertainty in the model can be more thoroughly presented and evaluated. The calibrated model run is currently supported by a verification model run and twelve sensitivity model runs. Each model run has five layers with associated monitoring wells and residual predictive errors, which would result in 70 figures to display all of the residual error distributions for fourteen model runs. To observe the residual errors in adequate detail in the central portion of the model (near the capture wells), additional figures would need to be generated. To address the EPA's data request, the Navy will prepare a compact disk (CD) which will include:

- The input and output files of all fourteen model runs
- Figures showing the distribution of residual errors in the calibrated model run
- A table listing the residual errors of all monitoring wells for each of the fourteen model runs
- Input files, output files, and particle track figures for hypothetical extraction well system #6.

2. **Comment:** The groundwater flow model has been used to evaluate potential extraction well scenarios. This evaluation has been presented in Appendix C of the Groundwater Flow Modeling Report. Based on this analysis a recommended scenario has been identified (scenario 2b). Based on recent discussions, further revisions to this scenario have been proposed to address concerns raised with this scenario. To address this scenario a revised scenario 2c has been proposed and evaluated in a recently distributed Technical Memorandum. This scenario has been evaluated based on simulations using the calibrated model. The results of this analysis are presented in the Technical Memorandum. However, as discussed in Specific Comment No. 17, the analysis presented in the Technical Memorandum is incomplete. More importantly, the calibrated model used to evaluate this scenario has failed to reproduce the hydraulic behavior of the system in the particular area of concern. Thus, the model, as currently formulated and calibrated, may not be able to evaluate this option. Consequently, the pumping option selected to address the concerns in this area may require the most direct and reliable approach to ensure success. Such an approach would likely require the installation of an extraction well directly into the sand and gravel deposit present in the intermediate zone, in the area between extraction well AT-3A and AT-5A (see Specific Comment No. 17 ).

   **Response:** The Navy has agreed to install a new extraction well in the intermediate zone between wells AT-3A and AT-5B (i.e., well AT-10).

**Specific Comments**

1. **Comment: 2.5.2 Horizontal Groundwater Flow**
Potentiometric surface contour maps under pumping conditions for the shallow, intermediate, deep and bedrock intervals are presented in Figures 2-9 through 2-12, respectively. Groundwater flow patterns under both pumping and non-pumping conditions are further discussed in Section 2.5.2. Concerns over several aspects of the interpretation of groundwater flow presented in this discussion have been previously identified. These concerns relate primarily to the groundwater mound and nearby depression, particularly as they relate to non-pumping conditions. These concerns are discussed in detail in the Technical Review Comments submitted on the March 2000 1999 Annual Monitoring Report (1999 AMR). The potential alternate interpretations of groundwater flow based on available data should be acknowledged in the Groundwater Flow Modeling Report. In addition, any potential impacts on the modeling effort resulting from the uncertainties in the interpretation of groundwater flow should be identified and discussed in the Groundwater Flow Modeling Report.

**Response:** The Navy partially agrees. As noted in the Navy's response to EPA comment number 1 on the 1999 Annual Monitoring Report (1999 AMR), the Navy acknowledges that other interpretations are certainly plausible, however the Navy believes the contours provided in the modeling report figures best represent the site conditions. The Navy is currently in the process of further analyzing the existing data to provide additional justification for the interpretations provided. The Navy is also in the process of collecting additional data (e.g., borehole flowmeter results) which should assist and support the stated interpretations further. Based upon an agreement in the July 6, 2000 technical meeting (conference call), the Navy will change some of the discussion in the text so that it better describes the site conditions (e.g. use the term "ridge" instead of the word "mound") and acknowledge where multiple interpretations are possible.

2. **Comment: 3.4 DESCRIPTION OF HYDRAULIC CONDUCTIVITIES**
The Groundwater Flow Modeling Report presents a series of figures (Figure 3-2 through Figure 3-12) depicting first, the thickness of each layer and second, the hydraulic conductivity zones established in each layer with hydraulic conductivities assigned to each zone identified. However, it is not clear if the hydraulic conductivities identified on the figures are the initial values assumed prior to calibration or the values resulting from model calibration. Based on the position in the Report and the discussion in the text, these values most likely reflect initial hydraulic conductivity values prior to calibration. This should be confirmed, and text and figure legends modified to clearly indicate whether the hydraulic conductivity values show the initial or final calibrated values.

**Response:** The hydraulic conductivity values shown for model layers 1 through 5 in Figures 3-3, 3-5, 3-7, 3-9, and 3-11 are the values obtained during model calibration (i.e., calibrated model values). Hydraulic conductivity values initially assigned to each zone will be added to these maps with appropriate labels.

3. **Comment: 3.4.6 Layer 6**
The Groundwater Flow Modeling Report (pg. 3-6) indicates that Layer 6 represents the Prairie du Chien dolomites and the Jordan Sandstone. Figure 3-12 is the only figure provided to illustrate the model set up for the Prairie du Chien. The upper surface elevation of the Prairie du Chien is shown on this figure. Based on the discussion in the text, it appears that the thickness established for Layer 6 in the model ranges between 190 and 230 feet. If this is correct, it should be clearly stated in the text. More importantly, no discussion in the text nor figure is provided to identify the number of hydraulic conductivity zones established for Layer 6 and the hydraulic conductivity assigned to each zone. This information should be provided in this section of the Groundwater Flow Modeling Report.

**Response:** Figure 3-12 shows the elevation contours for the upper erosion surface of the Prairie du Chien/Jordan Aquifer. The base of the aquifer is approximately 500 feet above mean sea level (amsl)

(see Section 3.4.6 of the text). The text will be clarified to explain how the base was estimated to be 500 feet, and the fact that the aquifer ranges from 190 to 230 feet thick.

4. **Comment: 3.5 VERTICAL LEAKANCE VALUES**
The Groundwater Flow Modeling Report (pg. 3-7) discusses the vertical leakance parameter, and Table 3-2 identifies the range of this parameter value calculated for each model layer. The report similarly indicates that leakance values were computed for each cell in each layer and that leakance zones were established for each layer based on grouping similar leakance values. These zones are depicted for Layer 1 through Layer 4 in figures provide in Appendix B. The Report indicates that the leakance values that were assigned to the zones were approximately equal to the average cell value found in each zone and that leakance values were subsequently adjusted for each zone during the calibration process. Leakance values for each of the zones established for Layer 1 through Layer 4 are also identified in the figures provided in Appendix B. However, it is not clear if these leakance values are the initially assumed values or the values resulting from model calibration. The Report should clearly indicate if the zonal conductance values provided in Appendix B are pre- or post-calibration values. In addition, no figure has been provided in Appendix B showing the leakance zones and values applied to Zone 5. Such a figure should be provided.

**Response:** The values of vertical leakance shown on the maps in Appendix B are the calibrated values. Vertical leakance values initially assigned to each zone will be added to these maps with appropriate labels. In addition, a map will be added showing the initial and calibrated vertical leakance values for Layer 5.

5. **Comment: 3.5 VERTICAL LEAKANCE VALUES**
When discussing the establishment of leakance values, the Groundwater Flow Modeling Report does not indicate clearly how the vertical hydraulic conductivity values used in computing leakance values were arrived at. The degree of anisotropy assumed, if any, when computing vertical hydraulic conductivity values from horizontal hydraulic conductivities values has not been identified and justified. A similar comment was included in review comments previously provided on the November 1999 Groundwater Flow Modeling Report (EPA/TechLaw Comment No. 2). The response to these comments that were attached to the March 1, 2000 Partnering Meeting Minutes (the March 10 Modeling Comment Responses) indicate that a $K_v/K_h$ ratio of 0.2 was used to initially compute the vertical hydraulic conductivity values during the development of the previous version of this model. The value of the $K_v/K_h$ ratio used during the development of the current model should be clearly established in the Report.

If the $K_v/K_h$ ratio of 0.2 was assumed during the development of the current model, it is not clear that such a value is appropriate. The analysis of the pump test data from extraction wells AT-3A and AT-4A indicates that a $K_v/K_h$ ratio of 0.01 may be more appropriate (U.S. Geological Survey, 2000). The Report should clearly identify the $K_v/K_h$ ratio used to develop the initial estimates of the leakance parameters. The Report should similarly provide adequate justification for the ratio used.

**Response:** The initial estimates of horizontal hydraulic conductivity (Kh) for each zone were divided by a factor of 5 to obtain the vertical hydraulic conductivity (Kv) for each individual model zone. The vertical leakance value for each cell was then calculated as a thickness-weighted harmonic mean value between two adjacent layers, according to McDonald and Harbaugh, 1988, p. 5-13, equation 51). A ratio of Kv/Kh for a single lithology is typically estimated to be about 1:5 to 1:20. A ratio of 1:5 was used because some of the thin lenses of silt and clay at NIROP Fridley are discontinuous, which would lead to a low ratio.

The USGS pump tests were analyzed using the entire thickness of the overburden (and including the St. Peter, Prairie du Chien, and Jordan Formations where appropriate) in the saturated thickness to calculate transmissivity, hydraulic conductivity, and Kv/Kh ratios. The test involving well AT-3A used a saturated thickness of 470 feet to calculate the hydraulic parameters. The test involving well AT-4 used a saturated thickness of 110 feet (the entire overburden thickness) to estimate the hydraulic parameters. Thus, the Kv/Kh ratios determined from these tests involve multiple lithologies for each

test. When considering layered strata, the ratios can be quite small. For example, a coarse sand layer overlying a confining clay unit can have a combined Kv/Kh ratio of $10^{-4}$ or less. For the model, however, the Kv/Kh ratios estimated for each model cell pertained only to a single lithology. Therefore, the ratios used in the model can not be compared directly to the ratios used to analyze the pumping test data. The text of section 3.5 will be expanded to clarify how vertical leakance values were estimated.

6. **Comment: 3.10 EXTRACTION WELLS**
Groundwater Flow Modeling Report (pg. 3-10 and Table 3-3) identifies the extraction wells that are included in the model, including the pumping rates for each well and the layers to which the pumping is assigned. In a number of extraction wells, pumping is assigned to several layers. However, the relative distribution of that pumping amount between the identified model layers and the basis for that distribution have not been identified. This information is critical to evaluating the adequacy of the model, and the discussion of the extraction wells should be enhanced to include this information.

A similar comment was included in the review comments previously provided on the November 1999 Groundwater Flow Modeling Report (EPA/TechLaw Comment No. 5). The March 10 Modeling Comment Responses indicated agreement with this comment and further indicated that the information would be provided in the current report. However, this important information has yet to be included in the current Groundwater Flow Modeling Report.

**Response:** Section 3.10 and Table 3-3 will be amended to show the rate of groundwater pumped from each layer for the extraction wells whose screens penetrate more than one model layer. The extraction rates assigned for each layer were qualitatively estimated based on the saturated thickness and relative hydraulic conductivities of each layer that an individual well penetrated.

7. **Comment: 4.3 RESIDUAL ERRORS OF CALIBRATED MODEL**
Table 4-1 provides a list of the residual errors at each of the target wells. This table also identifies the layer in which each well is located. The table indicates that monitoring wells MW-12IS and MW-13IS are screened in Layer 2. However, Figure 2-4 indicates that these two wells are screened in Layer 3. This apparent discrepancy should be resolved. The impact of this discrepancy on the current model effort should also be assessed.

**Response:** Wells 12-IS and 13-IS were assigned to layer 2 in the model. The lines depicting the model layers in Figure 2-4 are incorrect. The figure will be corrected.

8. **Comment: 4.4 SPATIAL DISTRIBUTION OF RESIDUAL ERRORS**
Table 4.1 presents the residual errors for each target well obtained after model calibration. A discussion of the spatial distribution of the residual errors is provided in Section 4.4. However, figures have not been presented that depict the spatial distribution of residual errors. Figures that identify the residual error at each target well in each model layer would greatly facilitate the evaluation of the overall fit between model results and measured water levels and the identification of any important spatial trends in the residual errors.

This same comment was included in the review comments previously provided on the November 1999 Groundwater Flow Modeling Report (EPA/TechLaw Comment No. 7). The March 10 Modeling Comment Responses indicated agreement with this comment and further indicated that "figures will be added to the revised report that show the distribution of residual errors in each layer." However, these figures have not been included in the current Groundwater Flow Modeling Report. The discussion of the spatial distribution of errors provided in the current Groundwater Flow Modeling Report is not sufficient to study and evaluate model errors in key areas of the model, including the areas adjacent to the extraction wells and the Anoka County Park. The previously requested figures should be provided to allow a more complete evaluation of the adequacy of the calibrated model.

**Response:** As stated in response to general comment No. 1, a CD will be prepared which will present:

- The input and output files of all fourteen model runs
- Figures showing the distribution of residual errors in the calibrated model run
- A table listing the residual errors of all monitoring wells for each of the fourteen model runs
- Input files, output files, and particle track figures for hypothetical extraction well system #6.

In addition, the report text will be expanded in Section 4 to clarify the spatial trends in residual errors of the calibrated model.

9. **Comment: 4.5 MODEL VERIFICATION**
A second set of data based on the measurements taken during a period of non-pumping have been used for model verification. The residual error resulting from the verification run are presented in Table 4-3. A preliminary comparison of the residual errors identified for the calibration and verification runs indicate that the spatial distribution of residual errors may have changed between the two runs. This may provide important insight into the calibration of the model. However, it is difficult to evaluate the differences in the spatial distribution of residual errors without suitable graphics. In addition to the maps of residual error provided for the calibration run (see Specific Comment No. 8), a similar set of maps depicting residual errors should be provided for the verification run. Figures overlaying the predicted and observed potentiometric surfaces for the non-pumping data should also be provided to facilitate the evaluation of the fit between predicted and observed potentiometric surfaces.

**Response**: See response to specific comment No. 8.

10. **Comment: 5.0 RESULTS OF THE CALIBRATED MODEL**
The discussion of the results of the calibrated model included in the Groundwater Flow Modeling Report focuses on the potentiometric heads predicted by the calibrated model. However, the Report fails to clearly identify and discuss the final parameter sets resulting from calibration. The final hydraulic conductivity and leakance values resulting from the calibration should be clearly identified. In addition, these values should be compared with the initially assumed values. Any significant difference between initial and final values should be identified and discussed. A discussion that demonstrates that these final values are within reasonably expected values should similarly be provided.

**Response**: The final calibrated values of horizontal hydraulic conductivity are shown in Figures 2-9 through 2-12. The final calibrated values of vertical leakance are shown in Appendix B. These figures will be modified to include initial estimated values for each model zone prior to calibration (see Responses to specific comments Nos. 2 and 4). The text will be expanded to discuss differences between initial and calibrated values.

11. **Comment: 5.1 PREDICTED POTENTIOMETRIC SURFACES**
The predicted potentiometric surfaces for each of the model layers have been provided in Figures 5-1 through 5-6. However, no overlays of the predicted with the actual observed water level contours are provided. The text only refers the reader back to Figures 2-9 through 2-12 for comparison between observed and predicted. However, these two sets of figures are difficult to compare because the figures are at different scales and use different layering. The lack of figures that facilitate the comparison between predicted and observed water level contours, combined with the failure to present figures that show the spatial distribution of residual errors (see Specific Comment No. 8), makes it difficult to evaluate the final calibration of the model and to assess the capability of the model for evaluating capture zones of potential pumping scenarios. Figures that overlay predicted and observed potentiometric surfaces should be prepared and included the Report.

A similar comment was included in the review comments previously provided on the November 1999 Groundwater Flow Modeling Report (EPA/TechLaw Comment No. 7). The March 10 Modeling Comment Responses indicated agreement with this comment and further indicated that "figures will also be added which superimpose groundwater elevation contours of both observed and predicted potentiometric surfaces." As noted above, these figures have not been included in the May 2000 Groundwater Flow Modeling Report.

**Response:** The Navy agrees to provide additional figures identifying the spatial distribution of residual errors for each layer of the calibrated model on the CD (see response to general comment No. 1). Due to the large number of data points and contours, the model-predicted contours on top of the measured elevation contours would make Figures 5-1 through 5-6 difficult to evaluate.

12. **Comment: 5.1 PREDICTED POTENTIOMETRIC SURFACES**
Although comparison of predicted with observed potentiometric surfaces is difficult without suitable figures for comparison (see Specific Comment No. 11), comparison of the available graphics and data identify several areas where the predicted potentiometric surfaces do not match well the observed potentiometric surface. Most importantly, the model does not appear to accurately predict the potentiometric contours in the area between extraction wells AT-3A and AT-5A, where monitoring wells MW-12IS and MW-13IS are located. The predicted contours do not appear to adequately represent the elevated pressure ridge that has been observed in the intermediate zone at this location. In addition, Table 4-1 indicates that the residual error at MW-12IS and MW-13IS is -6.49 and -7.60 feet, respectively. Thus, the model significantly under predicts the observed ridge in the potentiometric surface at this depth in this general area. This is likely an area where capture is not achieved with the current system. The failure of the calibrated model to reproduce this observed hydraulic feature raises significant concerns regarding the ability of the calibrated model to reliably evaluate capture in this area.

**Response:** The model does predict a small ridge of elevated groundwater elevations (i.e., a nose) extending southwestward between extraction wells AT-3A and AT-5B in model layers 2 and 3. However, the nose represented in the model is not as pronounced as the field data indicate. The residual errors for wells 12-IS and 13-IS were explicitly acknowledged and discussed in the text (p. 4-5, para. 2; and p. 8-4, para. 2).

The Navy has agreed to install a new extraction well (i.e., well AT-10) in the vicinity of monitoring wells 12-IS and 13-IS. The additional pumping capacity in this area is expected to ensure that capture of contaminated groundwater is occurring. Based on the available data, the model predictive abilities in the vicinity of wells 12-IS and 13-IS have been refined to the extent practical.

13. **Comment: 6.0 SENSITIVITY ANALYSIS**
The discussion of the sensitivity analyses performed on the calibrated model indicates that testing of model sensitivity to leakance values involved running a variety of scenarios in which the leakance for Layers 1, 2, 3, and 4 were increased or decreased by 50%. However, as previously indicated (see Specific Comment No. 5), analyses of pumping tests indicate that the values of vertical hydraulic conductivity used to initially compute zonal leakance values may have overestimated vertical hydraulic conductivity by a factor of 10 or more. Although no comparison between calibrated and initially assumed zonal leakance values has been provided (see Specific Comment No. 10), reducing leakance values by 50 % may not be sufficient to adequately gauge the error inherent in the model.

In addition, no sensitivity analysis has been reported for the vertical leakance values established for Layer 5 during model calibration. The vertical leakance values established for Layer 5 involve the vertical hydraulic conductivity for the Prairie du Chien Aquifer. The model has predicted significant flow from the Prairie du Chien Aquifer into the overlying unconsolidated deposits. This flow is controlled, in part, by the vertical hydraulic conductivity in the Prairie du Chien Aquifer. Consequently, the sensitivity of the model to the leakance values assumed in Layer 5 appears to be an important aspect of evaluating the reliability of the model.

Due to its potential influence on groundwater flow patterns and capture zone predictions, the leakance values used in the model should be fully evaluated during sensitivity analysis. A wider range of values that more fully represent the potential error in the parameter should be used in this evaluation, and sensitivity of the model to the calibrated leakance value for Layer 5 should be evaluated.

**Response**: Figures in Appendix B will be modified to show both initial and calibrated values of vertical leakance for each model layer, including Layer 5 (see response to specific comment No. 4). The vertical leakance of model layer 5 was adjusted during model calibration efforts. The report text will be expanded to discuss vertical leakance adjustment and distribution of residual errors associated with the calibration, verification, and sensitivity runs.

14. **Comment: 6.1 RESIDUAL ERRORS**
The discussion of the results of the sensitivity analysis of the calibrated model included in the Groundwater Flow Modeling Report is limited to the presentation of model-wide error statistics in Table 6-1 and a brief discussion of the result in Section 6.1. This discussion provides only limited information on the spatial distribution of residual errors obtained during sensitivity runs. Although a table identifying the residual errors resulting from each sensitivity run at each of the target well locations was included in the previous November, 1999 Groundwater Flow Modeling Report, such a table is not provided in the current Report. Figures depicting the residual error resulting from sensitivity runs at target well locations have similarly not been provided in the current Groundwater Flow Modeling Report, although the response to previous comments on the November, 1999 Groundwater Flow Modeling Report (March 10 Modeling Comment Responses, Comment Response 8) indicated that such residual error maps for specific cases would be produced "where such maps would be useful to make a point or to present information pertinent to the text." Due to the failure to identify and/or map residual errors obtained during sensitivity runs, it is not possible to assess the sensitivity of the model output in key areas, such as adjacent to the extraction system or in Anoka County Park, to changes in key parameters. Without such an assessment, it is difficult to evaluate the reliability of the model, particularly in areas adjacent to and downgradient from the extraction well system.

Previous comments on the November, 1999 Groundwater Flow Modeling Report (EPA/TechLaw Comment No. 9) indicated that "it (did) not appear that consideration (had) been given to the impact of parameter changes in localized areas, particularly in the immediate vicinity of the pumping wells." The March 10 Modeling Comment Responses (Comment Response 9a) indicated agreement with the comment and further indicated that "in addition to the residual error statistics calculated for the entire population of observation well for the whole site, a separate set of residual error statistics will be calculated for a limited set of observation wells adjacent to the capture wells and upgradient of the capture well in the areas of contaminated groundwater." However, this separate set of residual error statistics has not been provided in the current Groundwater Flow Modeling Report.

Additional data and analyses regarding the spatial distribution of residual errors during sensitivity runs are necessary to evaluate the sensitivity of the model predictions in key model areas to changes in parameter values. Such data and analysis are important to evaluating the reliability of the model for purposes of assessing contaminant plume capture.

**Response**: See responses to general comment No. 1 and specific comments Nos. 8 and 13.

15. **Comment: APPENDIX C - PREDICTIVE GROUNDWATER EXTRACTION WELL SCENARIOS**
Appendix C contains scenarios which include the installation of well AT-6 in the source area beneath the building. Table C-1 indicates that this well will extract water from model layers 1, 2, and 3. However, the distribution of pumpage between these layers during model runs has not been provided. The actual distribution between layers during model simulation may be important to the capture zones created not only by AT-6, but also by downgradient extraction wells during model simulations. Consequently, the assigned distribution of pumpage between layers should be clearly identified. Adequate justification for that distribution should similarly be provided.

It should also be noted that, if at this location there is significant stratification of subsurface material with varying permeabilities, it may be difficult to effectively remove contaminants using a single well. This would be particularly true if high levels of contamination are present in lower permeability materials (relative to other material present). In such a case, water removal could be concentrated in the more permeable material, with potentially insufficient water removed from the more contaminated,

lower permeability strata. Under such circumstances, it will likely to be more effective to screen separate wells in each material so that groundwater extraction can be concentrated at depths that are most useful.

**Response:** The Navy agrees. However, based on subsequent Partnering Team decisions, AT-6 will not be installed at this time. Thus, the items requested by EPA/TechLaw will not be completed. The Navy will modify Appendix C to summarize the planned modifications to the extraction system.

16. **Comment: 1.3 The Groundwater Flow Modeling Report**
Appendix C has identified scenario 2b as "the most cost-effective in capturing contaminated groundwater flowing under the NIROP plant and the southeast side of the NIROP." The analysis presented in this Appendix focuses entirely on hydraulic effectiveness. No discussion of relative costs have been provided. Additional analysis should be provided if the intention of the analysis is to identify the most 'cost-effective' approach.

**Response:** Based on the agreed extraction well network upgrades from the August 2000 Partnering Team Meeting, discussions regarding cost-effectiveness of particular scenarios are no longer relevant and will be eliminated.

17. **Comment: 1.3 The Groundwater Flow Modeling Report**
Appendix C has identified scenario 2b as the preferred approach to modify the existing extraction well system. However, several concerns have been identified regarding this option. Most importantly, it is not clear that effective hydraulic control is achieved by this option in the intermediate zone between extraction wells AT-3A and AT-5A. This is an area in which the model does not appear to reproduce observed water level data well (see Specific Comment No. 12). Consequently the model may not evaluate capture adequately in this area. Potentially, highly permeable sand and gravel deposits have been located in this area. These deposits may represent a significant channel for contaminant migration past the extraction system. Existing potentiometric and contaminant distribution data strongly suggests that this is the case.

In response to these concerns, an alternative 2c is being considered to address these concerns. This alternative involves plugging back extraction well AT-3A in attempt to draw more water from the intermediate zone rather than the deeper zone and the Prairie du Chien aquifer. A Technical Memorandum has recently been circulated to evaluate this option. However, this Technical Memorandum provides no capture zone analysis using the model. Moreover, such an analysis would rely on the currently calibrated model which does not appear to accurately reproduce the groundwater flow system in this area. Consequently, it is very difficult to conclude with much certainty that plugging back AT-3A will result in the effective hydraulic control of groundwater flow in the intermediate zone in this area. A more reliable approach may be to screen an additional extraction well in these sand and gravel deposits in an attempt to more effectively control groundwater flow through these deposits.

**Response:** Based on the agreed extraction well network upgrades from the August 2000 Partnering Team Meeting, the Navy has agreed to install a new extraction well in the intermediate zone between wells AT-3A and AT-5B (i.e., well AT-10).