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Ms. Amy McLaughlin
Remedial Project Manager
U.S. Environmental Protection Agency
Region IV, Superfund North Florida Section
61 Forsyth Street, SW
Atlanta, GA 30303-3104

**Subject:** Transmittal of Beazer's Comments on the GRU Team June 7, 2005 Report entitled "A Critique of the GeoTrans Flow and Transport Model, Koppers Inc. Site, Gainesville, Florida"

Dear Ms. McLaughlin:

On behalf of Beazer East Inc. (Beazer), GeoTrans would like to thank the Gainesville Regional Utilities (GRU), Waterloo Hydrogeologic, Inc. (WHI) and the GRU Expert Panel (GRU Team) for their detailed and thorough review of the October 2004 GeoTrans fate and transport model of the Koppers Inc. site ("Site") in Gainesville, Florida (GeoTrans Model). The GRU Team report was submitted to the United States Environmental Protection Agency (EPA) on June 7, 2005 and is entitled " A Critique of GeoTrans Flow and Transport Model, Koppers Inc. Site, Gainesville, Florida" (the GRU Team Report). This response to the GRU Team Report has been delayed because of our focus on the current field effort to install additional Upper Floridan (UF) Aquifer monitoring wells.

No significant technical issues were identified by the GRU Team Report concerning the GeoTrans' modeling approach and design, although their review did identify some inconsistencies with the GeoTrans Model datasets and draft report. The GRU Team Report provided yet another technical review and quality control check on the GeoTrans Model in addition to previous technical reviews provided by the GRU, EPA, Florida Department of Environmental Protection (FDEP), Alachua County Environmental Protection Division (ACEPD) and their associated consultants (Stakeholder letter comments: U.S. EPA September 8, 2004 and January 2005; ACEPD December 21, 2004; FDEP January 11, 2005). The GRU Team Report offers additional support that the GeoTrans Model is a technically defensible tool for the analysis of constituent fate and transport in the Surficial Aquifer, Hawthorn Group (HG) deposits and UF Aquifer.

This letter provides technical comments addressing the GRU Team model simulations and the effective-porosity analysis in Appendix C of the GRU Team Report (Appendix C). Additionally, GeoTrans would like to correct several misleading statements in the cover letter and select text within the GRU Team Report. The following is a brief summary of our response to the major issues associated with the GRU Team Report and associated GRU Team model simulations. A thorough discussion of our comments on the GRU Team Report is provided in Attachment A of this letter.

1) <u>The effective-porosity value of 15 percent used in the GeoTrans Model is appropriate and is consistent with the modeling approach, scale of the model, and other modeling work in Florida, including the previous GRU model (CH2MHill, 1993).</u> The approach to the analysis of effective-porosity values for the UF Aquifer presented in the GRU Team Report Appendix C was flawed because it failed to account for three-dimensional flow and the scale dependency of the apparent effective matrix-diffusion coefficient. If this scale-dependency effect had been included in the GRU Team analyses, it would have resulted in a larger effective-porosity estimate. The unrealistically low effective-porosity value reported for the Tampa, FL area by Robinson (1995) is a questionable porosity value and not applicable for constituent fate and transport on the scale of 2 miles. The test was performed at a scale smaller than the Representative Elementary Volume (REV) for the UF Aquifer. As a result, Robinson's use of a porous-media model to analyze the test is not valid and the corresponding effective-porosity value reported for this test is not defensible.

2) <u>The treatment of the Upper Transmissive Zone (UTZ) and semi-confining unit combined thickness in the GeoTrans Model is a valid modeling approach and not an error</u>. The GeoTrans Model utilized an implicit approach to simulate vertical flow across the semi-confining unit; however, the thickness of the semi-confining unit was incorporated into the model layer representing both the UTZ and semi-confining unit. This approach was utilized to allow for some lateral flow within the 100-foot thick semi-confining unit. The GRU Team has attempted to portray this modeling approach as an error in the GeoTrans Model, with significant impacts on constituent fate and transport predictions. However, the treatment of the UF Aquifer thickness was deliberate and not an error. As we indicated previously (Beazer, 2005), the GRU Team suggested approach of simulating the units as separate model layer will be adopted in future Site modeling. While the difference in approaches may have minor effects on predicted model results, these impacts are insignificant on fate and transport model simulations.

3) <u>The cover letter for the GRU Team Report provides misleading statements and conclusions of the model simulations performed by the GRU Team.</u> For example, the GRU cover letter to the GRU Team Report misquotes the report by stating that "*Based on running the model with assumptions which are more appropriate for the site the report indicates that predicted travel times for contaminants form [sic] the Koppers site to reach the City of Gainesville's Murphree Wellfield may be as low as 4 to 5 years..*" In fact, the GRU Team fate and transport model predicts that contaminants will never reach the Murphree wellfield in concentrations that exceed either Federal MCLs for drinking water or FDEP cleanup standards.

The GRU cover letter overstates the results of the GRU Team fate and transport simulations using a very conservative, and we believe unrealistic, effective-porosity value. GRU Team produced a simulation in which naphthalene at a concentration of approximately 1 µg/L reaches the wellfield after 10 years (see Figure 10 in GRU Team Report). The letter states the following: "*..Floridan Aquifer contamination below the Koppers site poses a significant threat to the City's water supply.*" A groundwater concentration of 1 µg/L is a factor of 14 times lower than the FDEP cleanup standards and drinking water requirements for this constituent.

4) Site data are inconsistent with the GRU Team model simulation results. If solute transport were as rapid as the GRU Team model simulations suggest, then there should be elevated constituent concentrations downgradient of the Site. Existing Site monitoring data do not show evidence of rapid or wide-spread constituent migration indicating that the GRU Team model assumptions are incorrect and the corresponding model simulations vastly over predict constituent transport rates.

In summary, the GRU Team review, in conjunction with previous reviews by the EPA, FDEP and ACEPD, provides confirmation that the GeoTrans Model is a technically defensible tool for the analysis of constituent fate and transport at the Site. The accuracy of the GeoTrans Model calibration and predictive capabilities is further supported by historical and existing Site data. On the other hand, a number of assumptions made by GRU Team model simulations are incorrect, and produce results that are inconsistent with Site data.

Sincerely,

James R. Erickson　　　　Gaius Roemer

James R. Erickson, P.G.
Principal Hydrogeologist

Gaius Roemer, P.E.
Senior Environmental Engineer

Attachment A

cc:
B. O'Steen, EPA
K. Helton, FDEP
J. Mousa, ACEPD
B. Goodman, GRU
R. Hutton, GRU
M. Slenska, BEI
M. Brourman, BEI
J. Mercer, GeoTrans
L. Paul, KI
P. Salisbury, KI

# Attachment A:
# Comments on GRU Team Report Entitled:
# "A Critique of the GeoTrans Flow and Transport Model, Koppers, Inc. Site, Gainesville, Florida"

GeoTrans developed a three-dimensional fate and transport model for the KI Site (Site) and surrounding areas in Gainesville, Florida. The purpose of this model was to evaluate Site constituent transport in the Surficial Aquifer, Hawthorn Group (HG) deposits and Upper Floridan (UF) Aquifer, and the potential for these constituents to reach the Murphree Wellfield. The following comments are in response to the GRU Team Report entitled "A Critique of GeoTrans Flow and Transport Model, Koppers Inc. Site, Gainesville, Florida".

## General Comments

The first part of the GRU Team Report included an extensive evaluation of GeoTrans' conceptual model, numerical model design, and the properties assigned to hydrostratigraphic units in the model. The model dataset review was performed by incorporating the GeoTrans Model datasets into a graphical user interface software program called Visual MODFLOW, which was utilized to perform a detailed QA/QC check of the GeoTrans Model datasets. It should be noted that no significant errors were identified during this QA/QC review.

The second part of the GRU Team Report described numerous "what-if" GRU Team model simulations that evaluated increased layer discretization and the effects of varying model parameter values. The series of GRU Team model simulations appears to be a systematic approach to adjusting model parameter values, with the apparent objective of determining what parameter values allow Site constituents to reach the Murphree Wellfield. The GRU Team model approach should not be confused with a traditional sensitivity analysis, which tests the model's sensitivity to the adjustments or variance of specific parameter values, as was included in the GeoTrans Model report (GeoTrans, 2004). The GRU Team's "what-if" model simulations finally achieved this apparent objective, but only after an extensive series of parameter adjustments and model simulations.

What goes unstated in the GRU Team Report, but is clearly demonstrated from their model simulations, is just how difficult it is for modeled Site constituents to actually reach the GRU Murphree Wellfield. The GRU Team simulations evaluated numerous model adjustments that have the potential of showing Site constituents reaching the Murphree Wellfield (see Table 5 in GRU Team Report) including: 1) Increasing the number of model layers of key hydrostratigraphic units; 2) Increasing the hydraulic-conductivity values of the Hawthorn Group (HG) clays and UTZ; 3) Decreasing effective porosity; 4) Decreasing dispersivity values; 5) Adding a karst channel that essentially connects the Site to the Murphree Wellfield; 6) Varying constituent retardation factors; and 7) Eliminating biodegradation in UF Aquifer. The only above GRU Team model change that allowed detectable concentrations of naphthalene to actually reach the wellfield was an unrealistically low effective-porosity value. The low concentrations of naphthalene predicted to reach the wellfield (see Figure 10 of GRU Team report) are more than 14 times less than what is considered safe for public consumption by both

State Cleanup standards and Federal MCLs. None of the other GRU Team model changes resulted in Site constituents reaching the wellfield. This fact, in and of itself, demonstrates that it is unlikely that Site constituents have a realistic pathway that will allow them to reach the wellfield. However, we agree that long-term Site monitoring data, consisting of actual groundwater sample collection and analysis, will help to confirm these modeling results.

We disagree that the apparent effective porosity for the UF Aquifer is as low as 1 percent. The GRU Team has taken the position that not only is a 1 percent effective-porosity possible for the UF Aquifer, it is also likely. The GRU Team position on this issue not only contradicts an existing model that GRU is using to define wellhead protection in the county (CH2MHILL, 1993), it also contradicts numerous other models and aquifer tests performed by the State and U.S. Geological Survey in Florida (see Beazer letter to EPA dated February 23, 2005).

The GRU Team's basis for assuming a 1-percent effective-porosity value is a small-scale (200 feet) aquifer test analysis performed in the Tampa area, and a single-fracture analytical analysis that is based on the assumption of a single fracture connecting the Site to the Murphree Wellfield. Although, tracer tests can theoretically be used to measure effective porosity in fractured rock, the effects of heterogeneity and the size of the Representative Elementary Volume (REV) make the analytical and numerical methods for the analysis of these tests ambiguous. The analytical equations used to describe groundwater flow employ the concept of a continuum, which applies to a macroscopic volume of aquifer. The continuum approach uses the concept of an REV to define aquifer properties. Conceptually, an REV is the minimum volume of aquifer for which an aquifer property remains approximately constant, as the volume of aquifer for which the property is measured increases. For a homogeneous unconsolidated sand aquifer, the REV can be on the scale of a few feet, whereas for a karst, fracture limestone the REV can be on the scale of 1,000s of feet.

There is an important question as to the applicability of equivalent-porous media theory to rock in which the scale of the experiment is likely considerably smaller than the REV for the transport parameters of interest. The values obtained from small-scale tests may not be representative of the system at a regional scale, and considerably different values may have been obtained with a slightly different test configuration. There are too many other test-specific factors that influence the data from these tests, in addition to the assumptions that makes the analysis of these tests open to multiple interpretations. The Tampa tracer test study resulted in data that did not fit the curve-matching and tracer-dilution analytical method analyses performed by Robinson (1995), because the fractured karst aquifer did not act as an equivalent porous media at the scale of test (200 feet). The multiple arrival times for the tracer and the low tracer recovery for the two tests are indicative of the heterogeneity of the aquifer.

GeoTrans does not agree with the "apparent effective porosity" evaluation and believes the overly simple conceptual model is flawed and overlooked complexities within the UF Aquifer. The evaluation of "apparent effective porosity", included in Appendix C of the GRU Team Report, demonstrates the importance of taking matrix diffusion into account. We concur that the role of matrix diffusion from fractures or solution channels should be considered, but believe that the GRU Team has not fully considered the effects of heterogeneity or the effect that dispersion within a network of fractures and solution channels will have on the surface area across which diffusion will occur. The GRU Team Report analysis is for a single fracture, and does not take into account the effects of heterogeneity, the existence of a fracture network that will cause spreading of the contaminant plume into other fractures, and the concomitant increase in surface area across which diffusion will occur. Thus, considerable attenuation of concentrations will occur that is not accounted for in the one-dimensional analysis. In addition, the hydraulic conductivity of the matrix is high enough that advection through the matrix will retard movement of dissolved constituents. In other words, the diffusion of constituents into the aquifer matrix will act to lower constituent concentration in the fracture and reduce the lateral extent of the plume.

GeoTrans selected a value of apparent effective porosity that we believe is more representative of a three-dimensional regional system. Based on the issues with using a one-dimensional analysis of flow in a single fracture, we believe that the net effect of matrix diffusion on "apparent effective porosity" in a three-dimensional system would produce values greater than a few percent, but less than the matrix porosity, which has been measured in excess of 50 percent in some UF Aquifer samples. Site data that are discussed in the cover letter and below are consistent with this three-dimensional approach.

## Specific Comments

**Comment #1, GRU Team Report Cover Letter**: "*Based on running the model with assumptions which are more appropriate for the site the report indicates that predicted travel times for contaminants from the Koppers site to reach the City of Gainesville's Murphree Wellfield may be as low as 4 to 5 years, and that Floridan Aquifer contamination below the Koppers site poses a significant threat to the City's water supply.*"

**Response:** The above paragraph is misleading by stating that the GRU Team model predicts that contaminants travel from the Site to the wellfield in as little as 4 to 5 years. This statement is contrary to the work described in the GRU Team Report. Page 16 of the GRU Team Report states: "*Low concentrations (0.1 ug/L) reach the Murphree Wellfield after 3804 days (10.4 years) in the simulation containing the four source zones in the HG and the Ocala UTZ. Removing the source zone from the Ocala UTZ results in a groundwater plume of similar extent in the Ocala UTZ albeit of much lower concentrations*." The GRU Team Report shows and states that under the most conservative assumptions used in the GRU Team model, naphthalene never reaches the wellfield in concentrations that exceed Federal MCLs for drinking water or FDEP cleanup standards (14 µg/L), yet the above statement implies that GRU Team model runs indicate that the wellfield would become contaminated in as little as 4 years.

**Comment #2, GRU Team Report, page 3:** *"The Lower Hawthorn Group Clay wells heads plotted in Figure 3-9 of the GeoTrans Report consistently showed lower observed heads when compared with simulated results."*

**Response:** The GRU Team is correct in pointing out that the model simulated heads do not match the two wells completed in the HG lower clay unit. As part of the initial model conceptualization, GeoTrans established that these two wells were not critical calibration points and do not impact the GeoTrans Model predicted constituent distributions. What is critical is that the hydraulic gradient across the clay is accurately simulated by the GeoTrans Model. A detailed discussion of the importance of matching the hydraulic gradient across the lower clay unit is provided in GeoTrans response to "Comment m" (Beazer, 2005) from GDCT Report (GRU, 2005). As stated in the GeoTrans Modeling report (GeoTrans, 2004), it was difficult to match observed hydraulic heads in these wells because of the 90-ft head difference across the 30-ft thick lower clay unit and the fact the lower clay was simulated with one model layer. Thus, there is about a 3-ft head differential for every 1 ft of clay. Ten-foot well screens were installed in the HG lower clay wells (HG-7 and HG-8), resulting in approximately 30 ft of head differential within the interval sampled by the well screen. Therefore, it is difficult to produce an accurate match between simulated and observed heads given that this unit is simulated with one layer and the wells are completed at different depths within this unit. As GeoTrans stated in their earlier response to modeling comments (Beazer, 2005), additional modeling layers will be added to the HG lower clay unit, which will result in a better match of water levels for these wells.

**Comment #3, GRU Team Report, pages 3 and 4**: *" The Surficial Aquifer, Upper and Lower Hawthorn Groups and Ocala UTZ wells show good correlation to simulated head results…Although minor differences may exist between the two models, the overall flow conditions as determined by the GeoTrans Model were matched by the WHI Base Case Model."*

**Response:** The development of a three-dimensional numerical model is a labor-intensive effort requiring many months of data compilation, conceptualization and data entry into model datasets. As such, the process is susceptible to data entry errors and requires extensive quality-assurance and quality-control checks. The GRU Team performed a thorough evaluation of the data sets and did not find any substantial problems with the GeoTrans Model datasets. The fact that they failed to identify significant errors in the datasets supports the conclusion that the GeoTrans Model was accurately constructed and calibrated.

**Comment #4, GRU Team Report, page 3:** *"The model was not calibrated using groundwater flow information, such as discharge to wetlands. This means that the calibration achieved in the GeoTrans model does not consider the interaction between groundwater and surface-water features within the model domain. During groundwater modeling studies there are often different hydraulic conductivity and transmissivity value distributions that can adequately match observed groundwater levels. Completing a calibration to estimated and measured flow rates (to surface water such as wetlands and streams) helps to reduce the nonuniqueness of the calibration to groundwater levels alone. In addition, groundwater flow rates predicted with the groundwater model (inflows and outflows) would typically be part of this analysis as well as matching gradients and observed concentrations at selected locations in the model."*

**Response:** GeoTrans is not aware of any reliable estimates of wetlands discharge for this area. No discharge measurements have been taken in wetlands or nearby creeks, such as Springstead Creek (personal communication, ACEPD, 2004) within the model domain. Both ACEPD and SJRWMD were contacted to obtain these types of data.

Conversely, monthly groundwater withdrawal rate data are available for the Murphree Wellfield. GeoTrans used the Murphree Wellfield groundwater withdrawal data as an integral and critical component of model calibration. In the GeoTrans Model simulations, the Murphree Wellfield groundwater withdrawal is the largest water outflow budget component, and is thus important in estimating aquifer model parameter values for the UF Aquifer.

The last sentence of this comment indicates that the model calibration should include a match of "groundwater flow rates, gradients and concentrations." In fact, the GeoTrans Model calibration was performed by quantitatively matching hydraulic gradients and water levels, and qualitatively matching groundwater flow rates and concentrations. The GeoTrans Model was accurately calibrated to water levels and hydraulic gradients at observation wells at the Site. Rarely are quantitative inflow and outflow data available for streams and wetlands for groundwater flow model calibration. However, GeoTrans did perform a qualitative evaluation of model predicted inflows and outflows to discharge areas to ensure that the model predicted discharges are within a reasonable range. In addition, the GeoTrans fate and transport model qualitatively matched concentration distributions at the Site. As discussed our response to Comment # 15 below, an accurate match to concentrations in individual wells at the Site is not technically possible. Hence, the GeoTrans Model calibration is consistent with the calibration approach described by the GRU Team in this comment.

**Comment #5, GRU Team Report, page 4:** *"A well located in the southeastern region of the model was included in the GeoTrans files which were imported by WHI. This well is not pumping so does not affect the flow results."*

**Response:** This well was included in the GeoTrans Model data sets because it was used in sensitivity analyses to evaluate the potential impacts of Tacachale well pumpage on flow at the Site. The Tacachale well is located immediately outside of the model boundary in the southeastern corner of the model. Therefore, a well representing the Tacachale well was placed within the model boundary to evaluate the sensitivity of the model to future groundwater withdrawal in this area.

**Comment #6, GRU Team Report, page 5**: *"Transient specified head boundaries (time-varying constant heads) were used in the model (shown in Figure 2). The model Report recognizes that prescribing constant head boundaries may force the model solution, but states that the low permeability of the Hawthorn Group would make the impact of such boundary conditions minimal. However, the same cannot be said for the highly permeable Ocala Limestone. Due to the relatively small model domain and proximity to user-specified head values, this approach could lead to high parameter correlation, and in consequence, highly non-unique calibration. This means that several combinations of model input parameters can result in equally good 'calibrated' models. Yet, model predictions may be different. In addition, no-flow boundaries were used close to the wellfield, based on an assumption of axi-symmetric behavior of the potentiometric surface surrounding the Murphree Wellfield, which may or may not be correct and may also force the solution. The only way to minimize boundary effects would be to enlarge the model domain."*

**Response:** Because the GeoTrans Model was designed to evaluate fate and transport of Site constituents, a fine grid is required near the Site. In contrast, GRU's previous regional model was designed to evaluate water-resource issues, and had model external boundaries located 8-15 miles from the Murphree Wellfield (CH2MHill, 1993). In the GRU regional model, the simulated drawdown cone resulting from the Murphree Wellfield pumpage intercepted the northern and southern external model boundaries. This is a clear indication that the GRU regional model external boundaries were located too close to the wellfield. To eliminate this effect would require an even larger model domain than the one used by CH2MHill, in addition to finer grid resolution between the Site and the wellfield for fate and transport simulations. As stated in the GeoTrans Modeling report on p. 11, the southern boundary was chosen to approximately coincide with the east-west trending potentiometric surface contours for this area. Using the symmetrical behavior of the potentiometric surface surrounding the Murphree Wellfield as a technical basis for no-flow boundaries is not only reasonable, but justified given the large areal extent of the model domain required to minimize the potential of the drawdown cone intercepting the model boundaries. Note that one of the primary objectives of the GeoTrans Model was to evaluate vertical flow and fate and transport beneath the Site, which was not significantly influenced by the external model boundary conditions. Thus, although it would be theoretically possible to enlarge the model domain, we do not believe that the effort would significantly affect modeling results pertinent to the Site. The inclusion of pumping from the Murphree Wellfield (a major component of the water budget) reduces the parameter correlation and helps to minimize the non-unique nature of the calibration. Furthermore, sensitivity analyses performed on the calibrated parameter values indicate that the fate and transport simulation results are not significantly impacted by 50-100 percent changes to these parameter values.

**Comment #7, GRU Team Report, page 5**: *"GeoTrans used a single layer approach for the Ocala limestone that assumes the entire Ocala UTZ is contaminated, and no vertical variation of concentration occurs. This approach could in principal be conservative, but because of dilution within the entire 100 ft thick aquifer, there could be zones within the aquifer with higher concentrations than those predicted."*

**Response:** The comment is correct in stating that the use of a single-layer approach for the UTZ is conservative; however, the comment is confusing in that the second sentence appears to indicate that the model would have predicted higher concentrations in the UTZ under a multiple-layer approach. This second sentence is incorrect in that both the single-layer approach (GeoTrans Model) and the multiple-layer approach (GRU Team model) demonstrated that the flux of contaminants across the HG lower clay unit is very low. Hence, both models predict low concentration (not measurable) impacts to the UF Aquifer from residual NAPLs in the Surficial and HG deposits.

As a conservative approach to evaluate fate and transport in the UF Aquifer, GeoTrans performed a "what if" simulation that assumed the entire 100-foot thick UTZ beneath the footprint of the former North Lagoon was at a concentration of 1,240 µg/L. This assumption is extremely conservative in that Site data do not indicate wide-spread impacts beneath any of the source areas. Further, the 1,240 µg/L concentration assigned to the UTZ beneath the former North Lagoon was based on an initial concentration measured in FW-6, which is hypothesized to be a result of drilling fluid impacts to the upper 20 feet of the UF Aquifer. If the multiple-layer approach was used to represent the FW-6 impacts beneath the North lagoon, the concentration of 1,240 µg/L would have been assigned to the upper 20 feet rather than the entire UTZ. Thus, concentrations would have attenuated and dispersed more rapidly immediately downgradient from the source.

A recalibration of the model will be performed after data from the new UF wells are available. The recalibration will include up to six additional model layers to represent the UF Aquifer. In addition, actual concentrations measured in the new UF wells will be used to perform future fate and transport simulations rather than the assumption of 1,240 µg/L used in the current model simulations.

**Comment #8, GRU Team Report, page 5**: *"This simplification was used commonly many years ago in MODFLOW simulations (called the Quasi Three-Dimensional Approach) when computer memory was a limiting concern, but is less frequently used today because memory is not a problem and fully three-dimensional representations of aquifer systems is more flexible and accurate. Implicit layers have a number of limitations. They assume fully vertical movement of groundwater and contaminants, as well as no transient storage effects. Contaminant transport and groundwater flow simulation within implicit layers is also not possible."*

**Response:** The implicit layer approach was used to reduce computational time during calibration of the GeoTrans Model and because the fate and transport between the UTZ and LTZ was not considered an important component of the model. Further, it was not the goal of the GeoTrans Model to evaluate transient pumping effects within the UF Aquifer. GeoTrans acknowledged in our response to comments on the draft model report (Beazer, 2005) that this implicit layer would be removed and simulated as a separate series of layers, when the new UF Aquifer data were available. GeoTrans notes that use of implicit layers in a fate and transport model is conservative in that it does not take into account transport times across this layer and corresponding degradation. As GRU Team's model simulations demonstrated, representation of the semi-confining unit with individual model layers further restricts vertical transport into the LTZ of the UF Aquifer.

**Comment #9, GRU Team Report, page 6**: *"Based on matching the GRU Regional Model transmissivities as GeoTrans' report states, there seems to be no justification for using 10 ft/day in the vicinity of the Murphree Wellfield as the lowest value reported in the GRU model near the wellfield is 32 ft/day. In an earlier report by GeoSys (1991) cited in Appendix C, they reported transmissivities in the range of 3,300 to 15,000 ft$^2$/day for the UTZ, which corresponds to hydraulic conductivities from 33 to 150 ft/day (based on a thickness of 100 feet)".*

**Response:** The GeoTrans Modeling report will be corrected to state: "Transmissivity values near the Murphree Wellfield were adjusted to match the proportional decrease of transmissivity values in the GRU regional model." GRU's regional model (CH2MHill, 1993) has a reduction in transmissivity of approximately a factor of 2 to 3 between the Site and the wellfield, which is the same proportional reduction in transmissivity values applied to the GeoTrans Model (4,600 to 2,000 ft$^2$/day). This reduction was necessary in both the GRU regional model and GeoTrans Model to approximately match the hydraulic gradients near the wellfield.

Further, we disagree with the conclusions presented in the GeoSys (2000) report on the hydraulic conductivity of the UTZ as we stated in our response to comments (Beazer, 2005). Our response to "Comment b" from the GDCT Report (2005) provides a discussion of two aquifer tests in the upper 100 ft of the Ocala Limestone that were ignored by GeoSys (2000). Calculating hydraulic conductivities from specific-capacity data from these two tests results in hydraulic-conductivity values of approximately 17 and 72 ft/day, which falls within the range of values used in our model. Also, as stated in our response to "Comment b", "a review of Alachua County aquifer test data indicate that the hydraulic-conductivity value for the UTZ ranges from 0.9 to 86.2 ft/day (see GeoTrans (2004), page 13)." These data were not considered by the GRU Team in this review comment.

**Comment #10, GRU Team Report, page 8**: *"It is important to note that this difference does not change the model predicted heads or flow rates (flow rates are a function of velocity and area available for flow), since the same transmissivity (4600* $ft^2$*/day) is achieved in both cases (23 ft/day * 200 ft = 4600* $ft^2$*/day or 46 ft/day * 100 ft = 4600* $ft^2$*/day). The direct implication of this is that the advective seepage velocity (Darcy flux divided by the effective porosity for flow) should have been twice as high as that predicted by the GeoTrans Model due to the doubling of the hydraulic conductivity. More specifically, the travel times for particles released in the Ocala UTZ to reach the Murphree Wellfield should be a minimum of 51 years (Figure 4b: using GeoTrans' assumption of an effective porosity for flow of 0.15), and not the 110 to 135 years that was predicted by the GeoTrans model (pg. 22, GeoTrans, 2004)."*

**Response:** This statement is confusing and self-contradictory, and needs to be corrected in the GRU Team Report. The GRU Team acknowledges in this comment that the transmissivity values used in both the GeoTrans and GRU Team versions of the model are the same. Hence, by definition the hydraulic gradients for the UF Aquifer have to be the same. Further, they are in contradiction with the earlier statement *" The Surficial Aquifer, Upper and Lower Hawthorn Groups and Ocala UTZ wells show good correlation to simulated head results."*

In addition, we have previously indicated in our response to comments (Beazer, 2005) that the semi-confining layer would be included in future model recalibrations once the new UF wells were installed. The UTZ will be explicitly included in the model, and the thickness of the UTZ will be adjusted based on new hydrogeologic data obtained from the ongoing UF Aquifer Monitoring well installation program. The transmissivity of the UTZ will remain essentially the same as in the current model, resulting in an increase in the hydraulic conductivity of the UTZ.

Further, the GRU Team should refrain from equating water particle travel times to contaminant travel times in that the two are not interchangeable. To continue to do so only serves to further mislead the nontechnical reader into believing that they are the same.

**Comment #11, GRU Team Report, page 8**: *"The likely possibility of horizontal anisotropy occurring in the Upper Floridan Aquifer was not evaluated by GeoTrans."*

**Response:** GeoTrans has previously addressed this issue in our response to comments on our draft model report (Beazer, 2005). Anisotropy was considered but not included in the GeoTrans Model, because the drawdown associated with the Murphree Wellfield suggests that horizontal anisotropy is not significant in the UF Aquifer at this location.

**Comment #12, GRU Team Report, page 9**: *"GeoTrans apparently calculated retardation factors externally using the higher effective porosities stated in their report. Later when they used lower effective porosities in their simulations, they did not recalculate the correct corresponding retardation factors, using instead the ones calculated previously based on higher effective porosities…The correct higher retardation factors will result in slower velocities and longer transport times."*

**Response:** GRU Team is correct in their statement. The error will be corrected in future GeoTrans Model versions. However as stated in the GRU Team comment, the net effect on the model simulations will be "slower contaminant velocities and longer transport times". The net result of these effects will be less lateral and downgradient migration of the plume.

**Comment #13, GRU Team Report, page 10**: *"Naphthalene first-order biodegradation rates were obtained from conservative values from the existing literature. Although this is a highly site-specific value, the values used by GeoTrans are within the range typically used in modeling studies for anaerobic decay of this compound."*

**Response:** GeoTrans used a half life of 3 years that was obtained from measurements on deposits and groundwater at the Site (TRC, 1999). The literature indicates that the half life for naphthalene in an anaerobic environment should be less than 1 year. By using the 3-year half-life, the GeoTrans Model is conservative in the predications of how rapidly constituents biodegrade.

**Comment #14, GRU Team Report, page 10**: *"A more conservative approach for the UTZ source would have been to assume that if DNAPL is found beneath the footprint of the Northern Lagoon, it is likely to occur beneath all other source areas. The impact of such an assumption could be easily implemented in the model."*

**Response:** While this would be more conservative, it would be inconsistent with observations from the Site. DNAPL has never been found in the UTZ beneath the Northern Lagoon or anywhere else in the UF Aquifer beneath the Site. It is well established that DNAPL impacted mud was introduced during the construction of well FW-6 and the elevated concentrations in this well are likely a direct result of this impacted mud. The statement that DNAPL is likely to occur beneath all source areas is inconsistent with the more than 2 years of UF Aquifer monitoring that demonstrates significant impacts are not present in the UF Aquifer beneath the Site. While such statements are consistent with the GRU Team conceptual view, they are inconsistent with extensive investigations and actual Site data. Such statements are incorrect and misleading and should to be deleted from the GRU Team Report.

**Comment #15, GRU Team Report, page 10**: *"The GeoTrans Report states that the modeling effort did not attempt to calibrate the transport model; however, it does believe that the model reproduces the observed concentrations in several wells and implies that this may be the case for other wells. We do not entirely agree with this comment."*

**Response:** This comment is correct in stating that no attempt was made to calibrate the GeoTrans Model fate and transport simulations to observed concentrations at the Site. Rather, GeoTrans chose to concentrate on the groundwater flow model calibration, since advective flow is the primary transport mechanism for dissolved-phase constituents. Attempts to further refine model transport parameter values to better match observed concentrations would be difficult to defend given the inherent non-uniqueness of any fate and transport calibration. In addition, it would be unrealistic to expect any fate and transport model to accurately match concentrations in wells within, immediately adjacent to, and downgradient of source areas. There are too many factors impacting dissolved-phase concentrations and DNAPL dissolution rates to expect an accurate match. Further many of the HG wells listed in Table 4 of the GRU Team Report encountered DNAPL in the cores opposite the screen interval during the installation and five of the wells in this table are currently being used to recover DNAPL in the HG. Hence, the majority of the concentrations reported in Table 4 reflect groundwater samples that are in direct contact with DNAPL in the well and may have included entrained DNAPL droplets in the sample analysis. The majority of the HG well concentrations are not true dissolved-phase groundwater concentrations, but more closely reflect the dissolution concentration from residual DNAPL within and adjacent to the well screen. The extremely high concentrations are hypothesized to reflect DNAPL droplets entrained in the groundwater sample and the lower concentrations are from wells that are not immediately within the residual DNAPL zones. It was from this range of concentrations that an average DNAPL source zone concentration of 10,000 µg/L was determined. It is disingenuous for the reviewers to even suggest that the GeoTrans Model should accurately match all concentrations measured in observation wells at the Site, given the uncertainties associated with subsurface conditions that control dissolved-phase concentrations at any DNAPL site. It is because of the inherent uncertainties that there is no pretense that the GeoTrans Model is calibrated to concentrations measured at the Site. The objective of the fate and transport model was to approximately match dissolved-phase concentrations for the Site, which the GeoTrans Model does a good job of within the Surficial Aquifer, HG deposits, and UF Aquifer.

**Comment #16, GRU Team Report, page 11**: *"An average value of 10,000 µg/L was used to represent source concentrations. However, some monitoring wells positioned within the source areas show concentrations considerably above this (over 20,000 µg/L for the Upper Hawthorn, and some presented concentrations significantly below this value). These differences in assigned source values and what was found may explain the poor correlation between calculated and observed values of concentrations."*

**Response:** We believe that the samples with concentrations greater than 10,000 ug/L contained entrained droplets of DNAPL, and therefore do not represent dissolved phase concentrations. As stated above in Response to Comment #15, many of these groundwater samples were collected in wells that contained DNAPL. The large range of concentrations reflects the variations in subsurface conditions, not a variation in dissolved phase concentrations. It appears from this comment that the reviewers are suggesting that the source zone concentration should be varied to reflect concentration measured in HG wells. While this could have been done to improve the match to measured values, we believe that to have done so would have been incorrect. GeoTrans utilized the HG well concentrations to obtain an average concentration that is representative of dissolved-phase concentrations in groundwater in contact with DNAPL source zones. Based on this evaluation, it was determined that 10,000 µg/L is a representative concentration. In addition, sensitivity analyses were performed varying the source zone concentrations from 10,000 µg/L up to 20,000 µg/L to evaluate the effect on dissolved-phase concentrations. The results of this analysis demonstrated that varying the source zone concentrations had minimal impacts on the overall plume footprint and the predicted concentration distribution downgradient of the Site.

**Comment #17, Section 6.1 Sensitivity of Particle Tracking Results, page 13**. *"Particle tracking simulations representing the pathways a conservative dissolved phase constituent would follow in the WHI Model were performed using MODPATH."*

**Response:** Particle tracking simulations were used by the GRU Team to demonstrate that constituents from the Site have the potential of reaching the Murphree Wellfield. The statement above is a good example of how the GRU Team confuses the non-technical reader with the significance of particle tracking simulations. The important phrase in this sentence is "conservative dissolved-phase constituent". The constituents at the Site are highly nonconservative. Conservative constituents would, theoretically, move at the same speed as water. First, virtually all constituents in groundwater fail to meet this definition because they either adsorb to the aquifer matrix, diffuse into low hydraulic conductivity zones, biologically degrade or they precipitate out in solid form. This definition of conservative only really applies to water itself. It is important to understand the difference between a conservative constituent, and a constituent whose rate of movement is decreased by dispersion, diffusion, sorption, and/or transformation. Hence, the fact that particle tracking simulations predict that groundwater reaches the wellfield in 50 to 100s of years does not translate to Site constituents reaching the wellfield. The organic constituents travel more slowly and are naturally degraded such that virtually all of the model simulations performed by GRU Team predicts that Site constituents will never reach the wellfield. Because naphthalene degrades, a stable configuration of the plume will develop, and naphthalene may never be detectable at the Murphree Wellfield.

Section 6.1 and Table 6 of the GRU Team Report are misleading to the nontechnical reader in that they lead the reader to believe that the travel times presented in this section reflects Site constituent travel times when in fact there is no correlation. They mask this fact in their use of the technical terms such as "conservative" and the technical phrase "by advective flow only, no retardation or decay" (see page 14 of the GRU Team Report). Particle tracking is only a measure of the average groundwater travel time; it is not a measure of contaminant travel times. Organic constituents at the Site are both retarded (i.e., adsorbs to aquifer material) and decay (i.e., microbes degrade the organics), such that this assumption is not valid (see our response to Comment #1 above).

**Comment #18, GRU Team Report, page 14**: *"Reducing the effective porosity in the Ocala UTZ can result in substantially reduced travel times. Particle pathlines from the Site to the Murphree Wellfield are shown in plan view and cross-section in Figures 4a (using GeoTrans' value of 200 feet thick for the Ocala UTZ) and 4b (using the correct value of 100 feet thick for the Ocala UTZ). Also shown are the minimum and maximum travel times for particles to reach the wellfield. Specifically, for an effective porosity of 0.15, particles originating in the Ocala*

*UTZ reach the wellfield in 51 to 63 years.* ***For an effective porosity of 0.01, particles reach the wellfield in 4.3 to 5.0 years (by advective flow only, no retardation or decay).****"*

**Response:** We agree that travel times for a molecule of water would be reduced from approximately 115 years to 60 years because of the greater detail in the stratigraphic discretization. However, the objective of the GeoTrans fate and transport modeling is to evaluate contaminant migration, not that of water or conservative tracers. Further, we disagree with use of an effective-porosity value of 1 percent in GRU Team's simulations, for reasons provided above under our earlier section entitled General Comments, and below in the section entitled "GeoTrans Comments on Appendix C". The GRU Team incorrectly uses the information in the bolded sentence as the definitive conclusion from the GRU Team Report in its cover letter and other EPA correspondence, even though GRU Team later states (p. 16), "*Low concentrations (0.1 μg/L) reach the Murphree Wellfield after 3804 days (10.4 years) in the simulation containing the four source zones in the Hawthorn Group and the Ocala UTZ."* This low concentration is a factor of more than 100 times below FDEP Cleanup Standards (14 μg/L). The GRU Team ignores this statement in their correspondence (see our response to Comment #1 above).

**Comment #19, GRU Team Report, pages 15 and 16**: *"Refinement of the layers while maintaining the original source zones does not result in significant differences in transport results within the model. This is due to the presence of a constant concentration source over the entire thickness of the model layer, particularly in the Ocala UTZ. The majority of the contaminant movement is vertical. As the number of model layers increases, vertical movement of the contaminant is somewhat slower at early times, but over the 3841 days of the simulation, the concentration distribution is similar (Figure 5). Laterally, the differences do not appear to be significant.*

*Horizontal movement of the contaminant is significantly increased in the case where the Ocala UTZ thickness is reduced (Scenarios 15 to 28). As previously presented, the required increase in hydraulic conductivity (to maintain the same calibrated transmissivity with a smaller layer thickness) produces higher advective velocities by a factor of two. This results in a predicted plume footprint that is considerably larger than in other cases. Similar results were also obtained using the TVD (Total-Variation-Diminishing) transport solver (all other simulations used Upstream Finite Difference) (Figure 7)."*

**Response:** Conceptually, the increase in the number of HG model layers would slow the simulated transport of dissolved-phase constituents by reducing numerical artifacts pertaining to dispersion, such that it would make it more difficult for constituents to reach the UF Aquifer. This concept is demonstrated by the GRU Team model simulations numbers 7-14 where the Lower Hawthorn and Ocala UTZ were discretized into two, four, and eight layers and shows no change in groundwater travel times from the GRU Team Base Case Model, but they do not discuss the effect of vertical discretization in the HG on naphthalene F&T. A discussion of these GRU Team fate and transport simulations should be included in the GRU Team Report, to present a more complete picture of the model review and sensitivity of the model to increased layer discretization.

We agree that the predicted plume footprint for the UF Aquifer would increase slightly in size with a higher hydraulic-conductivity value for the UTZ, but Figure 7 shows that naphthalene would still not reach well MWTP-MW1 (approximately 1,000 feet downgradient of the Site) or the Murphree Wellfield (approximately 2 miles downgradient of the Site) above FDEP cleanup standards.

**Comment #20, GRU Team Report, page 16**: *"Figure 9 shows the effect of increasing hydraulic conductivity in a specified region in the Ocala UTZ to create a karst channel northeast of the Site. The result in this case is an elongated plume."*

**Response:** With the exception of some cave networks, there are no reported karst channels in the Floridan Aquifer that are miles in length. The GRU Team analysis in Appendix C uses a distance of approximately 10 miles for a one-dimensional discrete fracture model. Photos from Appendix D do not show continuous karst channels even over a few hundred feet. We assume the point of this simulation was to make some correlation with the analysis in Appendix C, but there is no information provided.

**Comment #21, GRU Team Report, page 16**: *"Similarly, removing the decay constant of 0.0006 day*$^{-1}$ *results in a much larger plume footprint (not shown)."*

**Response:** The GeoTrans Modeling results are sensitive to the degradation rates. To be conservative, GeoTrans used a half-life value of 3 years (equivalent decay constant of 0.0006 day$^{-1}$) that was measured at the Site. The literature suggests that the half life would be expected to be less than 1 year, which would decrease the plume size even more than is predicted with the use of a 3-year half life. Hence, the model is conservative in the value used for the decay constant.

**Comment #22, GRU Team Report, page 16**: *"The hydraulic gradient in the Ocala UTZ, determined using data collected November 15-17, 2004, is 0.00045 (RETEC, 2005). The average hydraulic gradient calculated for the Site area in the GeoTrans Model and WHI Base Case Model is 0.0012 (outlined in green in Figure 11). The minimum gradient evaluated in the WHI scenarios presented previously resulted when* $K_x$ *and* $K_y$ *was increased to 115 ft/d (Scenarios 25) yielding a hydraulic gradient value of 0.0006. The value of 0.00045 determined using observed data was impossible to reproduce with the GeoTrans Model without modifying model boundary conditions and was not achieved in any of the WHI scenarios."*

**Response:** The hydraulic gradient varies based on pumping at the Murphree Wellfield and recharge to the unconfined UF Aquifer southwest of the Site. The GeoTrans Model was calibrated to all pertinent data that were available at the start of the model development. Data for the UF Aquifer were only available through July 2004 when the GeoTrans model was calibrated. The GRU Team comment references November 2004 UF Aquifer water-level measurements, which were not available during the calibration of the GeoTrans Model. Based on historic UF Aquifer water-level data, the hydraulic gradient can vary by a factor to 2 to 3. Thus, as the GRU Team alludes to in the last sentence, constant head boundaries were varied temporally in the GeoTrans Model to account for the temporal variations in hydraulic gradient within the model.

Once the new UF well data are available, the GeoTrans Model will be modified and recalibrated to water-level data collected since July 2004.

**Comment #23, GRU Team Report, page 18**: *"Feenstra points out that no tracer tests have been performed in the Gainesville area to determine the effective porosity of the Ocala Formation. He notes that the United States Geological Survey has performed two tracer tests in the Ocala Formation at the Old Tampa Well Field (Robinson, 1995). At this location, the geologic description, hydraulic conductivity and matrix porosity of the limestone are comparable to the Ocala Formation in the Gainesville area. The effective porosity determined from tests conducted over a distance of 200 feet was determined to be 0.3 to 1.5%. This is the only quantitative measurement of the effective porosity for the Ocala Formation found in the published literature (Feenstra, Appendix C)."*

**Response:** This comment incorrectly states that the tracer tests were performed in the Ocala Limestone. In reality, the tracer tests from Robinson (1995) were conducted primarily in the Suwannee Limestone and the injection/observation wells were packered off above the permeable zone of the Ocala Limestone. Porosity values of the rock core for the Suwannee Limestone and Ocala Limestone at the Old Tampa Well Field were 21 and 46 percent, respectively. Therefore, there appears to be a significant difference between the porosity of limestones within these two formations.

Robinson ran two tracer tests of different intervals in wells located 200 feet apart. In both tests, the breakthrough curves were characterized by early initial breakthrough at low concentrations, multiple arrivals of tracer into the production well, and significant tracer loss. These results are indicative of heterogeneity in a rock with fractures or solution openings. Only a very small percentage of the tracer appeared in the initial breakthrough. The results were very different than would be expected from a conceptual model of a set of parallel fractures of equal aperture extending from the injection well to the production well, which is the model used in Appendix C. A set of parallel fractures extending from the Site to the Murphree Wellfield is also very unlikely. Further, the scale of interest in Gainesville is not on the order of hundreds of feet, but miles, and upscaling of the results will be difficult. These tracer tests are discussed in more detail in our response to comments on Appendix C, found below.

## GeoTrans' Comments on GRU Team Report Appendix C

The GRU Team approach to estimating an effective-porosity value for modeling constituent transport at the Site is based on hydraulic calculations of fracture aperture using assumed values of fracture spacing, bulk hydraulic conductivity, and matrix hydraulic conductivity. In these calculations, the fracture spacing affects the fracture to matrix proportions; the smaller the fracture spacing, the smaller the fracture aperture. Because the one-dimensional transport solution used by the GRU Team for the fracture/matrix interactions assumes that the fracture blocks are infinite, the fracture spacing only affects the transport calculations through the effect on fracture aperture. The infinite matrix block assumption would tend to overestimate the retardation resulting from matrix diffusion over long timeframes. However, because the calculations are performed for a constituent that biodegrades, the distance over which the constituent diffuses into the matrix is limited to a few feet. Thus, the effect of the infinite block assumption will be minor for the fracture spacings larger than a few feet. If sorption of the solute occurs in the matrix, the diffusion distance can be greatly reduced.

The GRU Team transport calculations were performed using a dual-porosity model in which the solute moves by advection within the fracture and by molecular diffusion within the pores of the rock matrix. The results were then compared with results from a conventional single-porosity advection-dispersion equation using the same values for bulk hydraulic conductivity, hydraulic gradient, dispersivity, and $K_d$ (matrix only). The value for effective porosity was then adjusted in the single-porosity model until the results from the single-porosity and dual-porosity models were similar. The assumption was then made that this value for effective porosity could be used in a conventional single-porosity transport model. The results show that the two models are very similar at times when the diffusion profile reaches an approximate steady state. At shorter times, the two models produce different results. Also, if the model parameters are modified, the apparent effective porosity in the single-porosity model must also be adjusted to achieve similar model outputs.

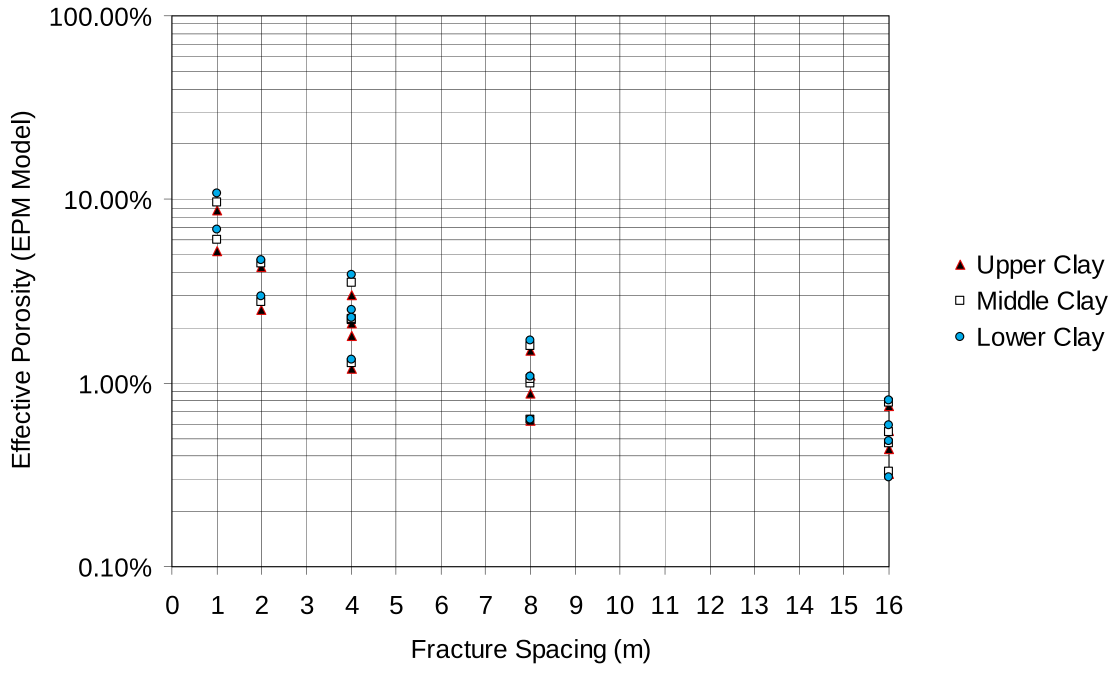
The GRU Team applied the approach to both the HG clays and the Ocala Limestone. Because these are distinctly different lithologies with different modeling issues, our comments regarding the validity of the approach are grouped accordingly.

### Hawthorn Group clays

The three clays in the HG have different hydraulic gradients across them, an indication that their hydraulic conductivity values are different. If the flux across each of these is equal, then the upper clay is the most conductive, and the lowest clay is the least. Further, these clays are separated by sandy and sandy clayey units, which the GRU Team does not address. These intervening sandy units are an important component of the HG and slow the movement of Site constituents through the HG. The GRU Team has ignored this concept/process in their analysis, which has lead to an underestimate of travel times through the HG.

Several errors were detected in the spreadsheets that were assembled for the HG calculations. It appears that the spreadsheets were started for calculating transport with a bulk hydraulic conductivity of $1x10^{-7}$ cm/s and a hydraulic gradient of 1. In several instances, the values were adjusted to $3x10^{-7}$ cm/s for hydraulic conductivity and/or a hydraulic gradient of 3 in the worksheet for the dual-porosity model, but not in the worksheet for the single-porosity model. As a result, the effective porosities in the single-porosity worksheet were adjusted to values that were incorrect either by a value of 1/3 or 1/9, depending on whether 1 or 2 parameter values were incorrect. The corrected figure is provided below, and has a smaller range of values than in Appendix C. Typically, it was the lower values of effective porosity that are corrected to higher values.

Effective porosity values determined from DFM-EPM comparative modeling for the clay units of the Hawthorn Formation.



[Note: The spreadsheets prepared by the GRU Team were reviewed to determine if the solutions to the transport equations were correctly implemented. Only a small error in the programming was detected. In the calculation of the complementary error function, one of the coefficients differs slightly from the value provided in Abramowitz and Stegun (1970). This error is small and will have insignificant impact on the results.]

The GRU Team modeled the three HG clays with hydraulic gradients across the clays of 0.2, 2, and 3. These hydraulic gradients values range over an order of magnitude and approximate values measured at the Site. The bulk hydraulic-conductivity values for the HG clays that were evaluated in the GRU Team analysis ranged over a factor of 3. Conversely, the calibrated values for these same clays used in the GeoTrans Model varied over a factor of 10, with the upper clay having the highest hydraulic-conductivity value and the lower clay having the lowest value. The GeoTrans modeled vertical hydraulic-conductivity values for the clays matched the hydraulic-head data reasonably well and resulted in a flux that was approximately the same across each of the HG clay units. The GeoTrans Model indicated that lateral flow of groundwater into and out of the Site within the HG deposits was minor; hence, the vertical flux of groundwater across each of the clay units should be approximately equal. In contrast, the values used by the GRU Team resulted in a flux that was nonuniform across the clays, with the flux across the upper clay being a factor of 5 less than the flux across the lower clay. The GRU Team one-dimensional flow analysis appears to violate Site data and the fundamental conservation of mass principle for the HG deposits where the flux across the HG upper clay should be approximately equal to the flux across the HG lower clay. This error should be corrected in the GRU Team Report.

One of the assumptions in using comparison of the models to determine an apparent effective porosity is that all other parameters are constant and uniform. In particular, the approach assumes that the retardation is constant. A relatively small change in the retardation value for the dual-porosity model results in a significant change in the apparent effective porosity derived from the single-porosity model. This sensitivity illustrates a disadvantage in using the GRU Team approach.

Although data on the bulk hydraulic conductivity of the clay units are unavailable, and thus the importance of fracture flow through these units is conjectural, the GRU Team has shown that <u>if</u> fracture flow is important, the effective porosity of the HG clays is likely to be a few percent. The impact of this is explored in the following table. Emphasis has been placed in Appendix C on the apparent effective porosity of the HG clays. However, a significant part of the HG is composed of sands and sandy clays within which fracture flow is likely to be insignificant. The low hydraulic conductivity of the clays limits the flux through the HG, including the sands and clayey sands. The following table evaluates the impact of using smaller values for the effective porosity of the clays than used in the GeoTrans Model. The Darcy flux through the HG was calculated based on the estimated flux through the lower clay, based on a hydraulic gradient of 3 and a bulk hydraulic conductivity of $1.4 \times 10^{-7}$ cm/s.

| | | GeoTrans Model | | Revised Values | |
|---|---|---|---|---|---|
| Subunit | Thickness (ft) | Eff. Por. | Advective travel time (d) | Eff. Por. | Advective travel time (d) |
| Upper HG clay | 5 | 0.15 | 625.5 | 0.01 | 41.7 |
| Upper clayey sand | 25 | 0.15 | 3127.4 | 0.15 | 3127.4 |
| Middle HG clay | 10 | 0.15 | 1251.0 | 0.01 | 83.4 |
| Lower clayey sand/sand | 30 | 0.15 | 3752.9 | 0.15 | 3752.9 |
| Lower HG clay | 20 | 0.15 | 2501.9 | 0.01 | 166.8 |
| | Sum (days) | | 11258.7 | | 7172.2 |
| | (years) | | **30.8** | | **19.6** |

This table uses conservative values for the thicknesses of the units. The low flux (resulting from the low hydraulic conductivity of the clays) through the sandy units, together with their higher effective porosity, results in an advective travel time through the HG that is many times the half life of naphthalene (3 years or less). Approximately 2/3 of the total travel time through the HG occurs in the two sandy units.

In summary, while GeoTrans used a value for effective porosity for the HG clays that is higher than the GRU Team's estimate of effective porosity, the net effect on transport of dissolved-phase naphthalene within the HG would be inconsequential, especially if biodegradation is considered. The GRU Team's HG analysis ignores the non-clay layers within the HG that will attenuate solute migration due to their higher effective porosities.

Upper Floridan Aquifer

For computational and data reasons, small-scale heterogeneity is not incorporated in site-scale and regional-scale models. This creates an effect in which model parameters are scale dependent. Although ignored by the GRU Team, this scale dependency is recognized by many modelers, including Bush and Johnston (1988) who prepared a regional model of the Floridan Aquifer. Bush and Johnston (p. C6) point out that carbonate aquifers can be characterized as having either diffuse flow or conduit flow. This classification is tied to scale and to the question concerning hydraulic properties -- can they be treated as porous-media properties or fractured-media properties? Bush and Johnston (p. C7) continue the discussion of an appropriate REV and conclude that in karst areas where very large cavernous openings occur, the REV will be very large. However, they point out that in more typical Floridan terrain, where diffuse flow occurs, the REV could be the size of a field-scale test (e.g., an aquifer test). They point out that many aquifer tests in the Floridan Aquifer conform to porous-media assumptions and conclude "At that scale (tens to hundreds of feet), then, the assumption of a porous-media continuum appears reasonable." They further conclude that (p. C7),

> *"On a regional scale, diffuse flow predominates and the porous media continuum approach is probably justified. On a local scale (close to springs and pumping wells), discrete openings and conduit flow predominate and the porous media continuum approach is probably invalid."*

However, it is important to recognize that the size of the REV is different for different parameters, and the assumption about being able to use an equivalent porous-media approach may be valid for flow problems, but not for transport problems. The REV for transport may be considerably larger than the REV for flow.

The literature contains a number of references to measurements of effective porosity on core samples collected from the UF Aquifer. These measurements are not representative of the REV for constituent transport on the scale of miles and should not be confused with an effective-porosity value for a dual-porosity system such as the UF Aquifer. Although these values have been reported as effective porosity, they are more representative of the aquifer matrix porosity. Examples of effective-porosity values reported for core include: 1) Knochmenus and Robinson (1996) laboratory measurement of effective-porosity values for the Ocala Limestone that ranged from 17 to 49 percent and the Avon Park Formation that ranged from 2 to 25 percent; and 2) Hutchinson (2003) measurement of an effective-porosity value of 25.8 percent for the Ocala Limestone.

Just as the effective-porosity values reported for core samples are not representative of an aquifer REV, tracer tests on the scale of 100s of feet are also not representative of the aquifer REV. As demonstrated in the Robinson (1995) tracer test, a single, site-specific, secondary-dissolution feature dominated the tracer arrival time in the observation well; however, as the scale of the transport problem increases to that of the GeoTrans Model, the combined effect of numerous, individual site-specific features likely behave as an equivalent porous media. This observation was also demonstrated in the Renken et al., (2005) tracer tests conducted in the

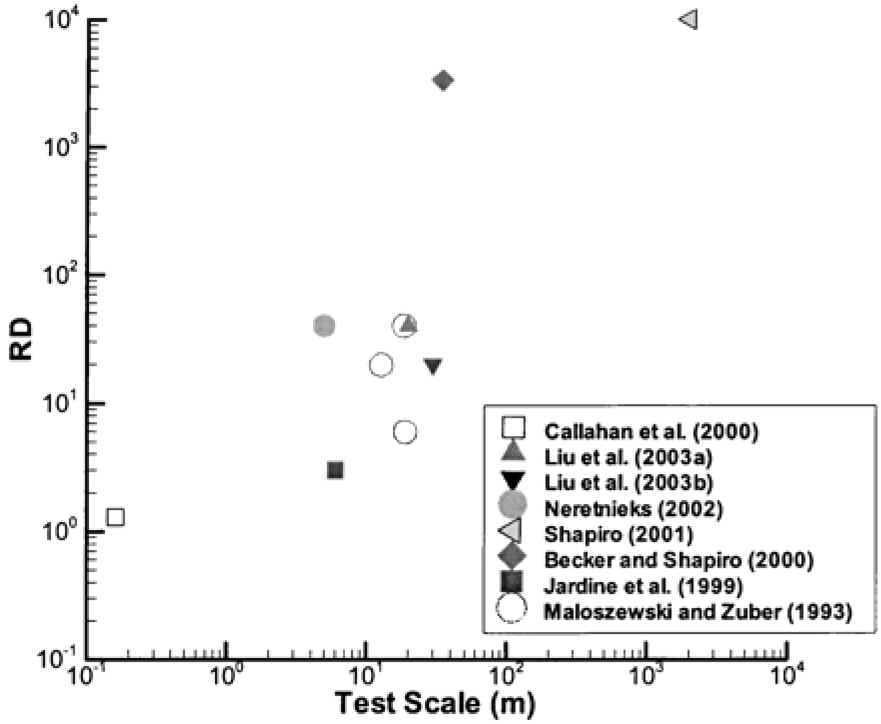
Biscayne aquifer in southeast Florida. Vuggy, stratified flow zones dominate the tracer arrival time in the observation well 328 ft away. The authors reference multiple groundwater flow models of the Biscayne aquifer where an effective-porosity value of 20 percent was used for regional scale applications (Renken, R. A. et al., 2005, p. 326). Hence, small-scale measurements of effective-porosity values on cores and in-situ tracer tests in dual-porosity carbonate aquifers are not representative or appropriate for most model applications.

Because parameters, such as effective porosity, will have different values at the regional scale versus the local scale, modelers at the Murphree Wellfield and other sites in central Florida have all used effective-porosity values for the Floridan Aquifer on the order of 15 to 20 percent. Floridan Aquifer models developed by O'Reilly (1998) and Knowles (2002) used an effective-porosity value of 20 percent. The previous GRU Model (CH2MHill, 1993) used an effective-porosity value of 15 percent. In addition, literature values of limestone effective porosity reported by Wiedemeier et al. (1996) vary from 1 to 24 percent; however, these values are for other areas of the U.S. and not for the Floridan Aquifer system. In a separate study by the City of Gainesville (2001) of the Lake Santa Fe region, the travel time from this region to the Murphree Wellfield was estimated to be approximately 1,000 years; this travel time requires an effective porosity of approximately 23 percent. Based on previous measurements and estimates of effective-porosity values for the Floridan Aquifer system, the GeoTrans Model's effective-porosity value of 15 percent for the Ocala Limestone is both conservative and technically defensible.

The conceptual approach used in Appendix C is not consistent with conditions in the UF Aquifer. The GRU Team used a one-dimensional model by Tang et al. (1981) for the UF Aquifer, an aquifer that is more complex than a one-dimensional flow system. Tang et al. state that their model is a "convenient way to study fracture-matrix transport [is] within the context of a single fracture." The UF Aquifer, however, is not a single-fracture aquifer as illustrated by the GRU Team, who has estimated fracture spacings for the multiple fractures observed in outcrops and rock core. The UF Aquifer has solution features that do not even resemble a smooth fracture or set of fractures, as illustrated in the photographs in Appendix D of the GRU Team Report. Lipson et al. (2005), who used a parallel-plate, discrete fracture solute transport model cautioned that the model approximates conditions where the "bedrock is dominated by bedding plane fractures" (their application was to fractured sandstone). In their general discussion on effective porosity, Pankow and Cherry (1996, p. 357) purposely exclude "solution-channelled or karstic limestones or dolomites". These idealized fracture-matrix (i.e., dual-porosity) diffusion models have mainly been applied to fractured clay, fractured sandstone and fractured granite; these models generally have not been applied to karstic limestones. Consequently, results from the application of a single-fracture model to the UF Aquifer are suspect as the solution features in the UF Aquifer are overly simplified.

There is a related issue of the use of a single-fracture model, in which the surface area available for diffusive transfer of solute from the fracture into the matrix is determined by the fracture length. The single-fracture model is ill suited for the UF Aquifer system in which tortuous pathways along multiple intersecting pathways (fractures or dissolution features) cause transverse spreading, and thus an increase in the available diffusive surface area. Little work has been done on upscaling of diffusion parameters measured at the laboratory scale to field settings.

Liu et al. (2004) argue that the upscaled value can be many times larger than the laboratory value (see figure below; RD is the ratio of the field scale effective diffusion coefficient to the laboratory scale parameter). They attribute this to an increase in the diffusive surface area because of tortuosity in the flow path. Shapiro (2001) also noted an increase in the "effective matrix diffusion" coefficient (to a value greater than 1 $m^2/y$), when the distributions of tritium and CFC-12 were modeled with a simple model. He attributed the increase to advective movement between high-permeability and low-permeability fractures, which appears as an increase in apparent diffusion in a simple model. Thus, one would expect that transport would be much more limited than would be predicted by a model based on a laboratory-scale value. It needs to be recognized that the diffusion parameter does not actually change, but that our limitations on modeling the process in a heterogeneous environment causes the apparent value to increase with increasing scale. The GRU Team's approach ignores scale-dependent heterogeneities that will increase the surface area available for diffusion, and thus, their approach underestimates an apparent effective porosity.



Concerning the work presented in Robinson (1995), several observations are made that question the validity of the GRU Team's use of an effective-porosity value from this study. First, the injection well (well 20) was packed off at a depth of 322 feet (Robinson, 1995, Appendix), whereas the depth to the top of the Ocala Limestone ranged from 300-310 feet (Robinson, 1995, Table 4). Consequently, the tracer test was conducted primarily in the Suwannee Limestone, a different limestone than the Ocala Limestone that underlies Gainesville, FL. Therefore, use of data obtained in the Tampa area in the Suwannee Limestone for the Ocala Limestone in the Gainesville area should be done with caution and clearly noted, which was not done by the GRU Team.

Second, as shown in Figure 10 of Robinson, discrete porosity is made up of both fracture porosity and vug porosity. Robinson (1995, p. 10) describes fracture porosity as “cracks in the rock that are caused by tectonic deformation” and vug porosity as “pores that are large enough to be seen in a borehole television survey.” The GRU Team, using a smooth-wall, single-fracture model, has ignored or incorrectly characterized vug porosity as fracture porosity.

Third and most important, the scale of the tracer test conducted by Robinson (1995) has little to do with flow systems at a more regional scale. In the Appendix (Robinson, 1995), the log for the pumped well (well 15) indicates a large cavity between a depth of 165-169 feet. At this same approximate depth interval (plus or minus 10 feet), logs for the injection well (well 20) and two intervening wells (wells 11 and 15A) exhibit small to medium vugs. This suggests a direct connection existed between the injection and extraction wells, explaining the early arrival of tracer in the production well. Based on the peak arrival of the tracer, a solute velocity of 320 ft/day is obtained. However, it is important to note other features of the breakthrough curve. First, only a small fraction of the injected tracer mass was recovered. Breakthrough concentrations are less than 100,000th of the injection concentration. Second, there were multiple arrival peaks occurring over the length of the tests. The poor tracer recovery may be attributable to significant non-reversible or non-equilibrium sorption of the tracer, diffusion of the tracer into the matrix or advection into lower permeability pathways, or injection into pathways not captured by the production well. A porous medium model with homogeneous properties cannot reasonably match the Robinson (1995) test results. Thus, the analysis of these data with a porous-media approach is questionable, and extreme caution should be used in attempting to upscale this effective-porosity value to a regional value for utilization in a fate and transport model.

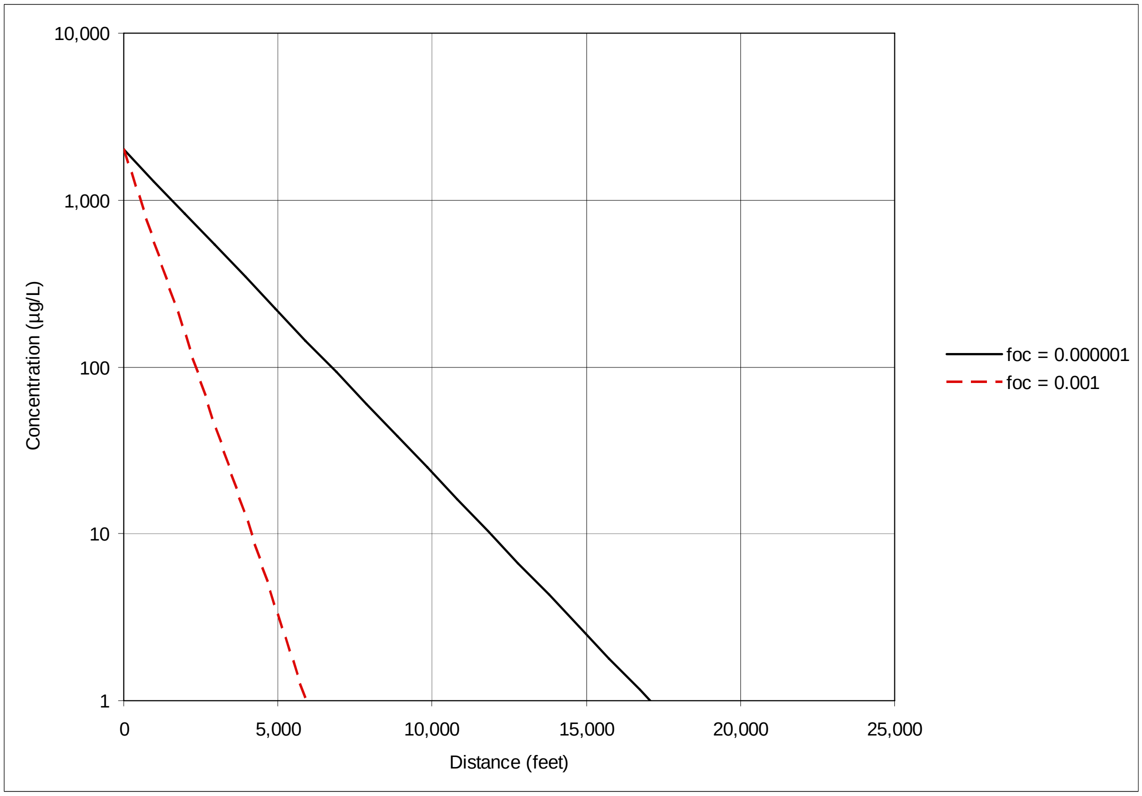
GeoTrans modeled the movement of naphthalene using an effective porosity of 15 percent and a retardation factor of 1 (no sorption). However, even minor sorption of naphthalene is likely to occur. The commonly used relationship to calculate the distribution coefficient ($K_d$) used in estimating retardation is the following (Karickhoff et al., 1979):

$$K_d = Kow * foc$$

$K_d$ is the distribution coefficient, ($L^3/M$)
Kow is the n-octanol/water partition coefficient, (dimensionless) and
foc is the fraction of naturally occurring organic carbon in soils, (dimensionless).

This relationship is not considered valid below foc values less than 0.001 because sorption onto mineral surfaces becomes dominant over sorption onto organic carbon, and the equation underpredicts $K_d$ at low foc. Thus, GeoTrans used a conservative assumption that there was no sorption of naphthalene in the limestone.

There has been relatively little research on sorption processes within limestones. A study by Witthuser et al. (2003) evaluated naphthalene sorption onto two chalks from Israel. These samples varied in their foc values. Batch sorption experiments [$K_d$ values of 1.18 (foc = 0.00047) and 31.4 L/kg (foc = 0.00642)] indicate that some sorption occurs even at low foc values. To illustrate the impact of even minor sorption (see figure below), the value of foc was set to 0.001, yielding a $K_d$ of 1.19 ml/g, in the GRU Team dual-porosity model which used a half life of 3 years, bulk hydraulic-conductivity value of 23 ft/d and fracture spacing of 4 m. Results indicate a reduction in transport of naphthalene by a factor of approximately 1/3.



In summary, the GRU Team Appendix C evaluation of the apparent effective porosity in the Ocala Limestone is flawed. The GRU Team's effective-porosity analysis assumes an incorrect conceptual model, and ignores the scale-dependence of the effective diffusion coefficient and effective porosity. In addition, although slight, naphthalene will sorb, further reducing the distance of transport. Sorption, thus far, has not been incorporated into any of the Site models.

Therefore, the calculation of apparent effective porosity by the GRU Team is unrealistic, because it does not consider that transport would occur in a network of fractures and secondary permeability channels, in which the surface area available for diffusion increases at a rate faster than in the single-fracture model.

The effective-porosity value of 15 percent used in the GeoTrans Model is conservative and consistent with porosity values found in the literature for the State of Florida, and numerous other models developed for the UF Aquifer, including the previous GRU model (CH2MHill, 1993). It is clear that the vast majority of the published porosity data support the use of an effective-porosity value in the range of 15 to 20 percent in regional-scale models. In addition, the GeoTrans Model conservatively assumed that no sorption occurs in the UF Aquifer; consideration of even very minor sorption results in significant reduction of predicted transport.

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