3/25/2013

EPA Questions/Comments on GoldSim Model Review

Comment 1: The technical documentation does not present a step by step derivation of Equation 5-21. As shown in Table 2, review indicates that Equation 5-21 may be incorrect and additional information is needed to confirm its validity.

Table 2: Derivation of Equation 5-21

Governing Equation:

$$h(x) = -\frac{R}{2Kb}x^2 + C_1x + C_2$$

Boundary Conditions:

$h(x=L_A) = h_2$

$h(x=0) = h_1$

The closed form solution (refer to page 66 of N. Kresic, 1977)[1] is:

$$Q(x=L_A) = K\frac{h_1^2 - h_2^2}{2L_A} + \frac{(R)(L_A)}{2} + Q_u$$

Q_u is assumed to be zero. Substituting for hydraulic gradient, i and Q in terms of R, and rearranging:

$$(R)(w)(L_A) = (w)K\frac{(h_1 - h_2)(h_1 + h_2)}{2L_A} + \frac{(w)(R)(L_A)}{2} + 0$$

$$(R)\{(L_A) - \frac{L_A}{2}\} = (K)(-i)\frac{(h_1 + h_2)}{2}$$

$$(R)(L_A) = -(K)(i)(h_1 + h_2)$$

$$\frac{R}{(K)(i)} = \frac{(-h_1 - h_2)}{L_A}$$ Apparently not equivalent to Equation 5-21

[1] *Quantitative Solutions in Hydrogeology and Groundwater Modeling*, Neven Kresic, by Lewis Publishers, CRC Press LL, 461 pages.

Comments 2-7:

Table 3: PolyMet GoldSim Model, Mine Site

Model Location (Container)	Element Name	Comment
\Flowpath_Models	Aquifer_Dims Cell_Sizes	For the mine site, flowpath widths in the GoldSim model range from 240 to 1,735 m. Cell lengths range from 26.2 to 29.8 m. At the upper end, these dimensions result in cells that are 12 acres in size. The following assumptions in the GoldSim model appear to be invalid for such large cells: - well mixed water and contaminant balances, - homogeneous, isoptropic groundwater flow, - singular values for infiltration and runoff, and - uniform geochemical reactions.
N/A	N/A	For the lengthy flowpaths used in the GoldSim model, the equation used to calculate dispersion yields values that are approximately 0.5% of flowpath length. More typically, dispersion is a scale parameter that ranges between 10 and 100% of flowpath length. It appears that dispersion is underestimated in the GoldSim Model.
\Pit_Models\EastPit_Model\EP_MassBal\EPCP_Outflow\EP_PRB_TreatEff	EP_PRB_TreatEff	The equation for eff (%/day) = {Eff(%)/Days * 1/(1 - Eff (%)} is incorrect. The term 1/(1 - Eff (%) should be deleted. Dividing by a fraction has the effect of increasing efficiency beyond the design value.
\Input_Data\Flowpaths\K_Random	K_OSLA	The triangular distribution of the Overburden Storage Area is relatively symmetric around its modal value of 3.58 m/day. Conversely, the triangular distributions for hydraulic conductivity in the other four surficial flowpaths all have positive skew with a tail to the right of the mode. It is not apparent why all five distributions would not have the same shape. Additionally, a plot showing the goodness of fit should be provided to justify the use of a triangular distribution.
\Input_Data\Pit_Hydrology	Wall_RO	Runoff is assumed to be percentage of precipitation and is modeled as a normally distributed variable as shown in Figure 5-9 of the Water Modeling Data Package (*Volume 1, Mine Site, V.12 – pg 96).* Reportedly the variation in this distribution is based upon the coefficient of variation of evapotranspiration. But as can be seen in Figure 5-9, the distribution has very little spread and essentially, in the GoldSim Model, runoff is being treated as a single value of approximately 2.5 in/year. There are two concerns with this approach: 1) Runoff should have higher variability than precipitation and evapotranspiration because it is dependent upon additional variables such as slope, soil texture, moisture content, etc. 2) There are mechanistic models that could be used to estimate the runoff distribution for input to the GoldSim model; similar to the manner in which MODFLOW was used to estimate the probability distribution of hydraulic gradient in the GoldSim model.
\Input_Data\Stockpile_Hydrology	Bare_RO	

Comments 8-11:

Table 4: PolyMet GoldSim Model, Plant Site

Model Location (Container)	Element Name	Comment
\Flowpath_Models	Aquifer_Dims Cell_Sizes	For the plant site, flowpath widths in the GoldSim model range from 1,920 to 2,920 m. Cell lengths range from 34 to 40 m. At the upper end, these dimensions result in cells that are 29 acres in size. The following assumptions in the GoldSim model appear to be invalid for such large cells: - well mixed water and contaminant balances, - homogeneous, isoptropic groundwater flow, - singular values for infiltration and runoff, and - uniform geochemical reactions.
N/A	N/A	For the lengthy flowpaths used in the GoldSim model, the equation used to calculate dispersion yields values that are approximately 0.5% of flowpath length. More typically, dispersion is a scale parameter that ranges between 10 and 100% of flowpath length. It appears that dispersion is underestimated in the GoldSim Model.
\Project\Flowpaths\Flow_Path_Details	Qu_Max	The equation $Q_{u,max} = - K_{surf}*D*w*i_{ave\ max}$ appears to be missing the term $-R*x_c*w$
\Project\Flowpaths\Flow_Path_Details	Recharge	Recharge is assumed to be a triangular distribution with a min, mode and max of 0.3, 0.6 and 1.5. There are two concerns with this approach: 1) It makes recharge independent of precipitation, which is separately modeled with a normal distribution. In reality, years with high precipitation will have high recharge and vice versa. There is a correlation between recharge and precipitation which is not accounted for in the GoldSim model. 2) Triangular distributions are only correct for random processes that have defined values for minimum, maximum and most common values, such as interest rates that cannot fall below zero or exceed 1 and generally have a modal value. Thus, the selection of the triangular distribution to model recharge appears to be arbitrary and could lead to inaccurate results in the GoldSim model.

Procedures used to establish probability distributions of background groundwater concentrations are described through documentation in *Water Modeling Data Package, Volume 1, Mine Site, V.9 – pgs 55-57* and in *Calibration of the Existing Natural Watershed at the Mine Site, June 2012 – pgs 2-4.*

PolyMet separated existing groundwater data into two separate sample groupings. One is the data collected from surficial aquifer wells located on the PolyMet site. The other is the regional groundwater monitoring data reported by the USGS and MPCA. PolyMet assumed that in both samples all data are random and independent so that they could be pooled and used to calculate sample means. Sample means for each of the two samples were compared and either combined or kept separate in order to maximize the value used going forward for sample mean. Once maximum mean values were selected, PolyMet used the Normal distribution of the sample means to represent uncertainty in background groundwater concentrations. A log transformation was used, apparently to eliminate the possibility of negative numbers. However, the log transformation of the sample mean has essentially removed the tails from the distributions of background groundwater concentrations that have been observed at this site. There are several other concerns with this approach as follows:

Comment 12:

Given common trends and spatial and temporal correlations found in groundwater data, it seems unlikely that the groundwater sample concentrations are independent. A listing of the data used in these calculations should be provided. Plots and appropriate statistical tests should be performed to demonstrate the validity of this assumption.

Comment 13:

PolyMet is pooling data from several surficial aquifer wells to calculate mean concentrations of groundwater for use in the GoldSim model. However, if the number of the wells are too few to provide an accurate sample of overall groundwater conditions or the wells are located near specific features for the purpose of identifying the groundwater concentration associated with those features, then the resulting means could be biased and not representative of background concentrations. A map of the wells used in this analysis should be provided and an analysis performed to demonstrate the mean concentrations are representative of background conditions.

Comment 14:

Plots comparing the groundwater sampling data and the normal distribution of the sample means are shown in Figures 2 through 28 of *Calibration of the Existing Natural Watershed at the Mine Site, June 2012*. For many of these plots, there is very little variation in the normal distribution. Essentially the distribution reduces to a single value. This observation leads to our next comment.

Comment 15:

It is not clear why the decision was made to use the sample means in lieu of the complete sample. More commonly, upper confidence limits are calculated and used to represent the uncertainty in groundwater sampling data. It seems that upper confidence limits could have been calculated and used similar to the regulatory standard values listed for ground water and surface water. The procedures for calculating upper confidence limits are well established and easy to follow. They may be a more appropriate approach for this project.

Comment 16:

If it is necessary to calculate probability distributions for background groundwater concentrations, it is suggested that PolyMet use the triangular distribution with zero being the minimum value and highest observed value being the maximum value. It may be necessary to remove outliers before the maximum is selected. Modal values could be selected by plotting histograms of the data. For parameters such as manganese, iron and alkalinity where the minimum values are significantly greater than zero, a log normal distribution may be more appropriate than the triangular distribution. We believe that triangular and log normal distributions of the complete data sets would provide a more accurate characterization of the distribution of background groundwater concentrations for this site.

Comment 17:

The Site Conceptual Model assumed the bedrock would behave as a porous medium, or a series of interconnected pore spaces within the bedrock aquifer. Based on the bedrock geology, groundwater flow is within secondary porosity features, such as fractures. This assumption simplifies the modeling process and allows the use of MODFLOW. An alternative to this simplification would be completing a fractured bedrock groundwater flow model; however, this would require much more detailed data on the abundance, orientation, and interconnectedness of the fractures. As explained in RS22, Appendix B, Draft-03, Section 2.4, it was assumed that based on the relatively large scale of the model domain, the fractured bedrock can be assumed to be sufficiently interconnected to behave as a porous medium, thus possible to use MODFLOW to achieve the modeling objectives. It is agreed that this model simplification and assumption is appropriate within this context.

Comment 18:

General Comment: A model objective was not to evaluate groundwater drawdown adjacent to the Mine Site as a result of pit dewatering. On Page 3 of *Attachment C, Updates to Mine Site MODFLOW Model Calibration and Predictive Simulations*, it is stated, "Large areas of drawdown within the unconsolidated deposits are not observed adjacent to other dewatered mine pits in the area, and, in some cases, wetland areas are present within very close proximity of these pits." While not knowing more details of this empirical information, it is suggested that these observations from nearby taconite mine pits could be a more useful methodology to evaluate potential groundwater drawdown impacts as a result of dewatering the NorthMet Mine Site.

Comment 19:

Attachment C, Page3, 2nd paragraph: The model layers were represented and assumed to be confined. As stated on Page 3, "Modeling unconfined aquifers as confined layers with appropriate layer thickness is a recommended approach for reducing model run times (Hill, 1998). As long as the model layer thicknesses are consistent with the saturated thickness of the aquifer layers, the confined model is a reasonable approximation of the unconfined system." We did not review the Hill (1998) reference, but this model simplification is also justified in Faunt et al. (2011).[2]

[2] Faunt, Claudia C.; Provost, Alden M.; Hill, Mary C.; and Belcher, Wayne R., "Comment on ''*An unconfined groundwater model of the Death Valley Regional Flow System and a comparison to its confined predecessor*'' by R.W.H. Carroll, G.M. Pohll and R.L. Hershey [*Journal of Hydrology* 373/3–4, pp. 316–328]" (2011). *USGS Staff -- Published Research.* Paper 394. http://digitalcommons.unl.edu/usgsstaffpub/394.