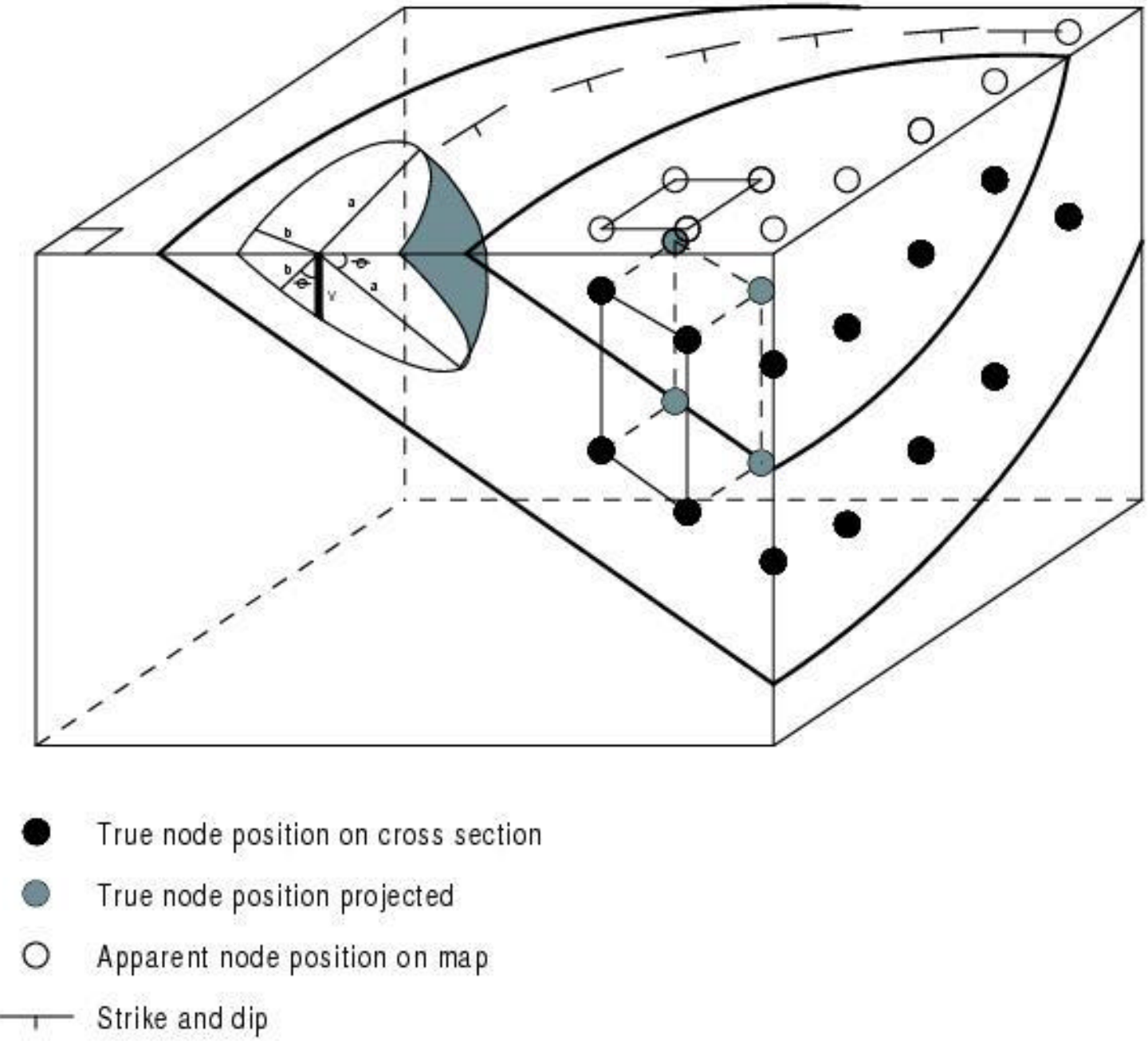
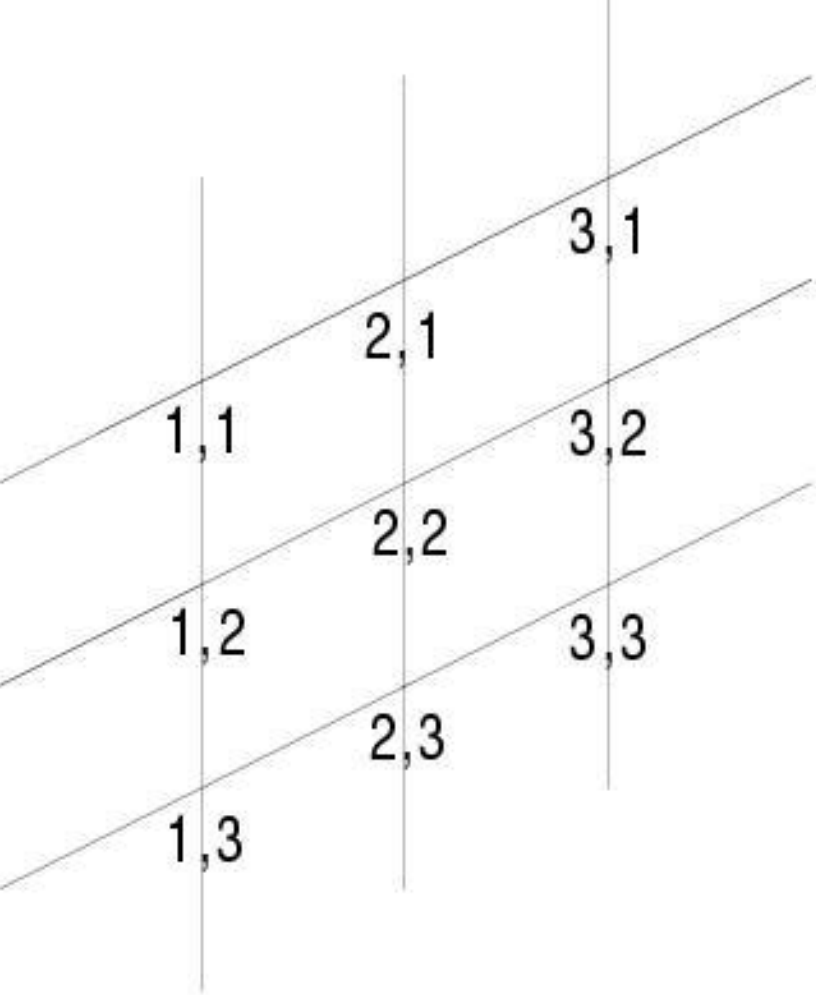
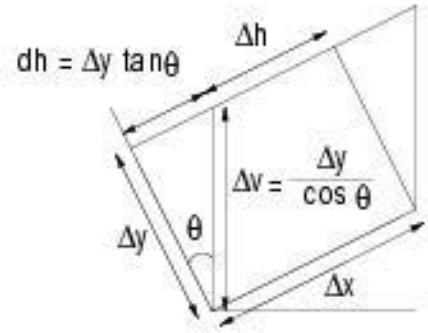
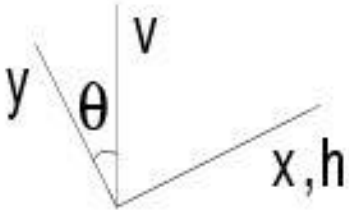


from: Hoaglund, J.R. and D. Pollard, 2003. Dip and anisotropy effects on flow using a vertically skewed model grid. Ground Water, vol. 41, no. 6, p. 841-846.







$$\left\{ \begin{matrix} q_h \\ q_v \end{matrix} \right\} = \begin{bmatrix} K_x \cos^2 q + K_y \sin^2 q & -K_y \tan q \\ -K_y \tan q & \dfrac{K_y}{\cos^2 q} \end{bmatrix} \left\{ \begin{matrix} \dfrac{\partial H}{\partial h} \\ \dfrac{\partial H}{\partial v} \end{matrix} \right\}$$

from: Hoaglund, J.R. and D. Pollard, 2003. Dip and anisotropy effects on flow using a vertically skewed model grid. Ground Water, vol. 41, no. 6, p. 841-846.

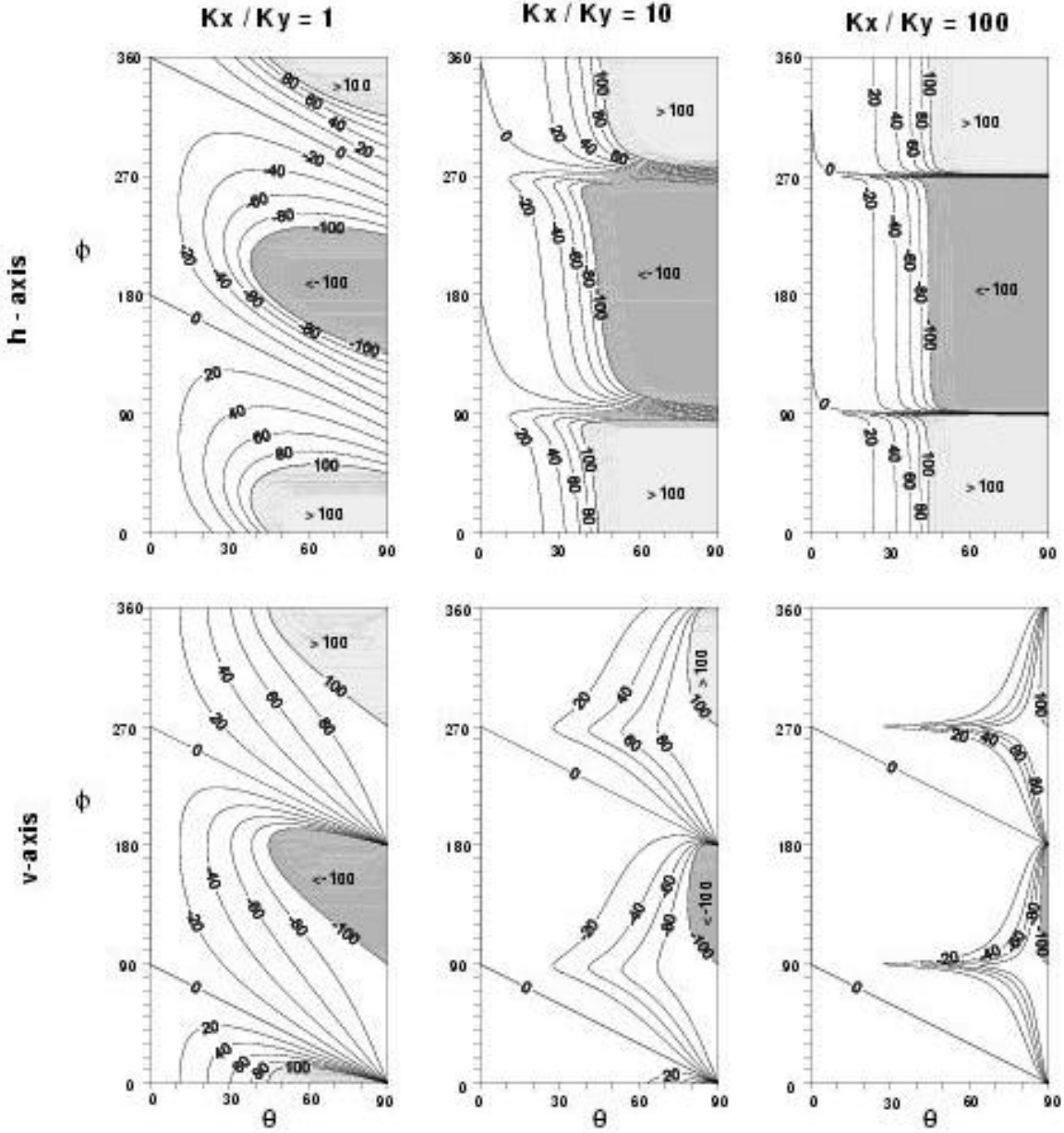


Figure 4. Errors (correct minus incorrect) of the h-axis and v-axis components of flow q_h and q_v in the skewed (h,v) coordinate system, as a percentage of the correct "magnitude" $\sqrt{{q_h}^2 + {q_v}^2}$. This expression represents the average size of q_h and q_v, and is not the physical length of the flow vector (unless $\theta = 0$). Each panel shows the error as a function of structural dip (θ) and orientation of the head gradient measured from bedding (ϕ), with values $< -100\%$ dark shaded and $> 100\%$ light shaded. The upper panels are for the h-axis flow component, and the lower panels are for the v-axis component. The three columns are for different amounts of anisotropy between the bed-parallel (K_x) and bed-orthogonal (K_y) permeabilities.

rom: Hoaglund, J.R. and D. Pollard, 2003. Dip and anisotropy effects on flow using a vertically skewed model grid. Ground Water, vol. 41, no. 6, p. 841-846.

Flow Model Correction Option 1: Correct Modflow

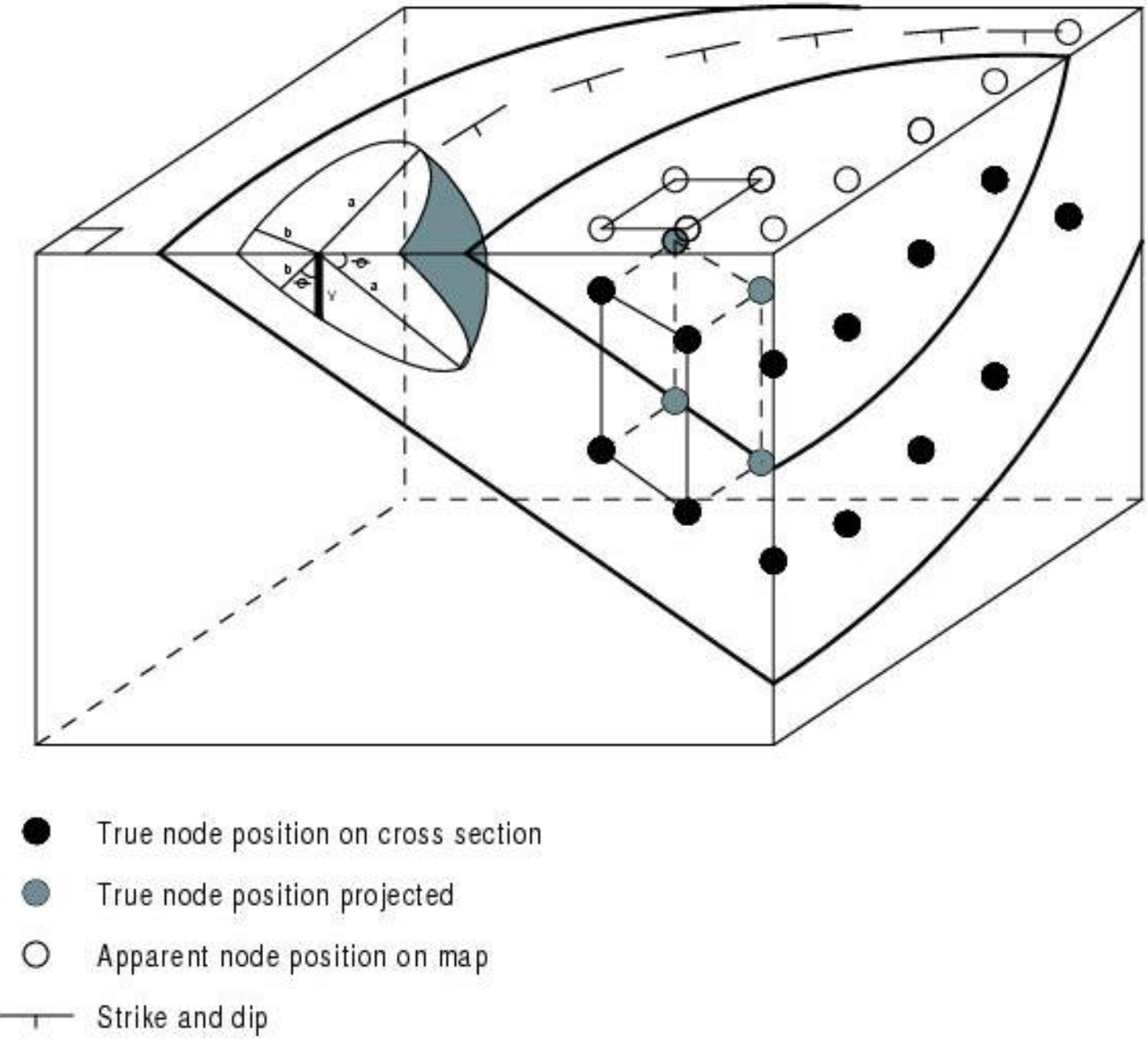
- Weiss (1985) incorporates this correction using curvilinear coordinates. Analyzed isotropic case using Trescott (1976) finite difference model. Derived but did not analyze the anisotropic case.
- Weiss solution for the isotropic case is only stable for dips less than 30°
- Error analysis of Hoaglund and Pollard (2003) shows error only significant for dips greater than 30°

Weiss, E.M., 1985. Evaluating the hydraulic effects of changes in aquifer elevation using curvilinear coordinates. Journal of Hydrology, Vol. 81, p. 253-275.

Flow Model Correction Option 2: Use Sutra

- Sutra uses finite element mesh consistent with Modflow
- 3D generalized anisotropy tensor can be defined by specifying principal permeability values and the 3D orientation of the maximum principal permeability direction.

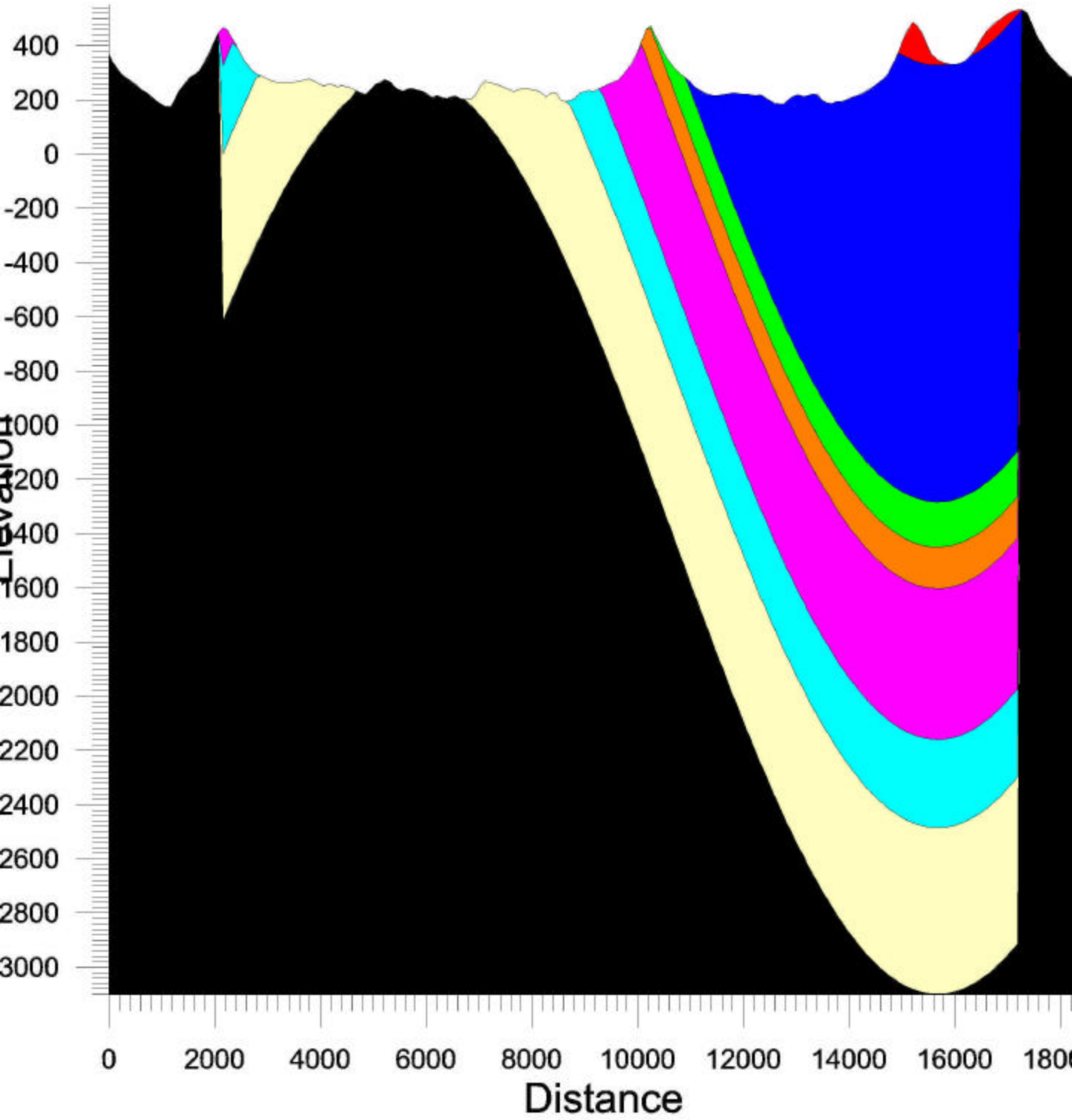
Voss, C USGS



Whether using Modflow or Sutra, correct geometric mesh must be defined!

Next Slide

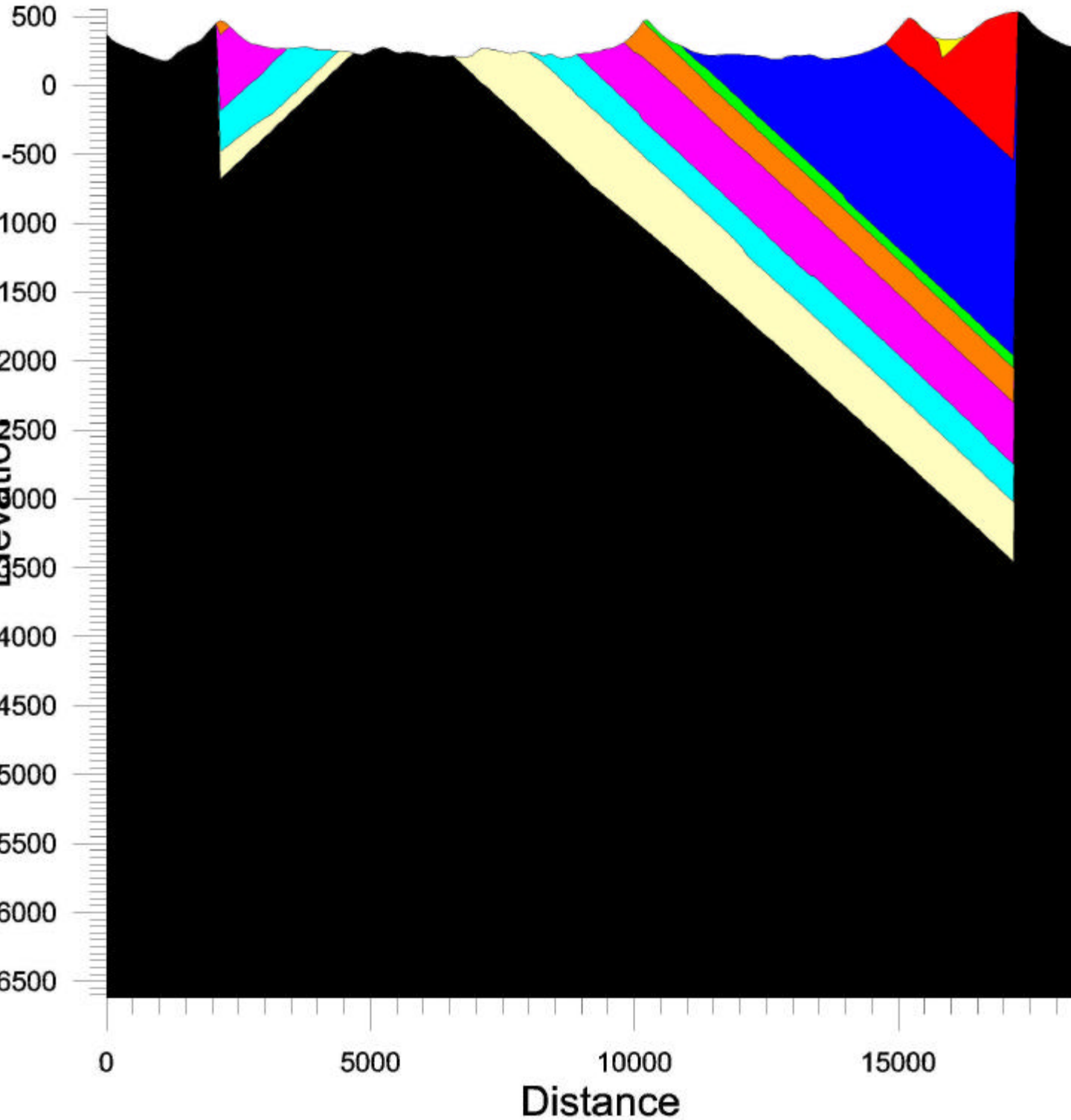
CROSS SECTION FROM ROW 1 COL 139
TO ROW 209 COL 139
ASPECT RATIO (H/V) = 5.13
VERTICAL EXAGGERATION = 5.13x



TO ROW 209 COL 139

ASPECT RATIO (H/V) = 2.61

VERTICAL EXAGGERATION = 2.61x



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