

## Appendix R - Description of BEM Numerical Models

AAI developed numerical models for Crandall Canyon Mine as early as 1995. Between 1995 and 2004, AAI performed several design/modeling projects using a program called EXPAREA. According to AAI:

*“This program was developed at the University of Minnesota by Dr. S. Crouch and Dr. Starfield (Starfield and Crouch (1973), St. John (1978)). It was initially used for Project Salt Vault in the early days of the Nuclear Waste program. It uses the displacement discontinuity method. The development of the program and later variations such as MULSIM were further developed at the University of Minnesota under funding from the USBM [US Bureau of Mines]. AAI has used the program since 1979 for design of underground thin-seam mines, particularly for coal mines.”*

However, in 2006, AAI elected to use another program, LaModel<sup>5</sup>, to model ground behavior at the mine. According to NIOSH<sup>26</sup>:

*“LAMODEL is software that uses boundary-elements for calculating the stresses and displacements in coal mines or other thin, tabular seams or veins. It can be used to investigate and optimize pillar sizes and layout in relation to pillar stress, multiseam stress, or bump potential (energy release). LAMODEL simulates the overburden as a stack of homogeneous isotropic layers with frictionless interfaces, and with each layer having the identical elastic modulus, Poisson's Ratio, and thickness. This "homogeneous stratification" formulation does not require specific material properties for each individual layer, and yet it still provides a realistic suppleness to the overburden that is not possible with the classic, homogeneous isotropic elastic overburden used in previous boundary element formulations such as MULSIM or BESOL. LAMODEL consists of three separate programs - LAMPRE, LAMODEL, and LAMPLT. You must install all three programs to use LAMODEL:*

*LAMPRE is the pre-processor that facilitates creating the input file for LAMODEL. LAMPRE accepts all of the numerical parameters input for LAMODEL and allows graphical input of the material codes for the seam grids. Also, a "Material Wizard" helps generate reasonable coal properties and appropriate yield zones on coal pillars.*

*LAMODEL calculates the stresses and displacements at the seam level from the user's input file. Model runs can take several minutes to several days depending on the computer speed and model complexity. The output from LAMODEL is stored for subsequent analysis by LAMPLT, the post-processing program.*

*LAMPLT is the post-processor that allows the user to plot and analyze the output from LAMODEL.”*