Estimating Depth to the Underlying No-Flow Boundary of Regional and Basin-Scale Ground-Water Flow Models Using Spatial Variations in Earth's Gravitational and Magnetic Fields: the Case for Northern Arizona

James Callegary, Mark Gettings, Kyle Blasch, and D.R. Pool

USGS, Arizona Water Science Center, 520 N Park Ave, Tucson, 85719

The United States Geological Survey is charged with constructing a ground-water flow model for much of Northern Arizona, to include the Verde River, Salt River, Little Colorado River, and Colorado River watersheds (fig. 1). Ground-water flow models require a lower boundary condition which in this case is a no-flow boundary defined by the elevation of Precambrian crystalline bedrock. To determine these elevations, variations in the earth’s magnetic and gravitational fields caused by contrasts in susceptibility for the magnetic field and density for the gravity field were used. The benefit of this approach is that it allows us to extrapolate the elevation of crystalline basement in three dimensions between measured elevations of crystalline bedrock in boreholes and outcrops.

Three approaches including Euler deconvolution, analytic signal amplitude, and horizontal gradient magnitude were used and compared, because each is sensitive to subsurface features of different geometries. The mathematical foundation of the methods is the analysis of the horizontal (and sometimes vertical) derivative of the gravity and magnetic fields. Each method calculates the elevation of a source (elevation of contrast in susceptibility or density) which may be caused by faults or other structures. In the case of the magnetic field, the calculated elevation is typically closer to the portion of the

structure that is closest to the land surface. In the case of gravity, these elevations are influenced by the center of mass of the structure. In both cases, the elevations need to be calibrated by measured elevations of crystalline basement. This helps to correct for errors introduced by the simplifying assumptions used in each method. The results of each approach applied to each data type are being integrated to construct a map of the elevation of crystalline basement (fig. 2).

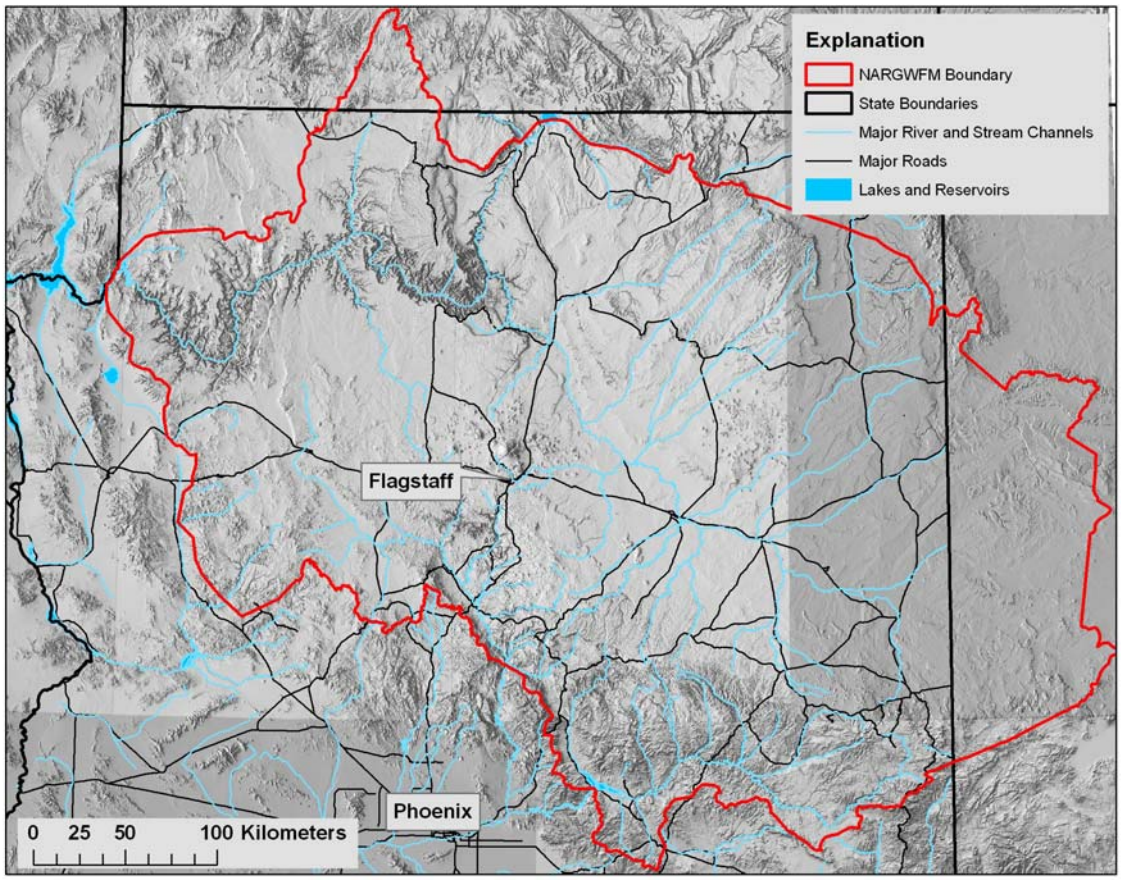

Figure 1. Northern Arizona Ground-Water Flow Model (NARGWFM) Boundary

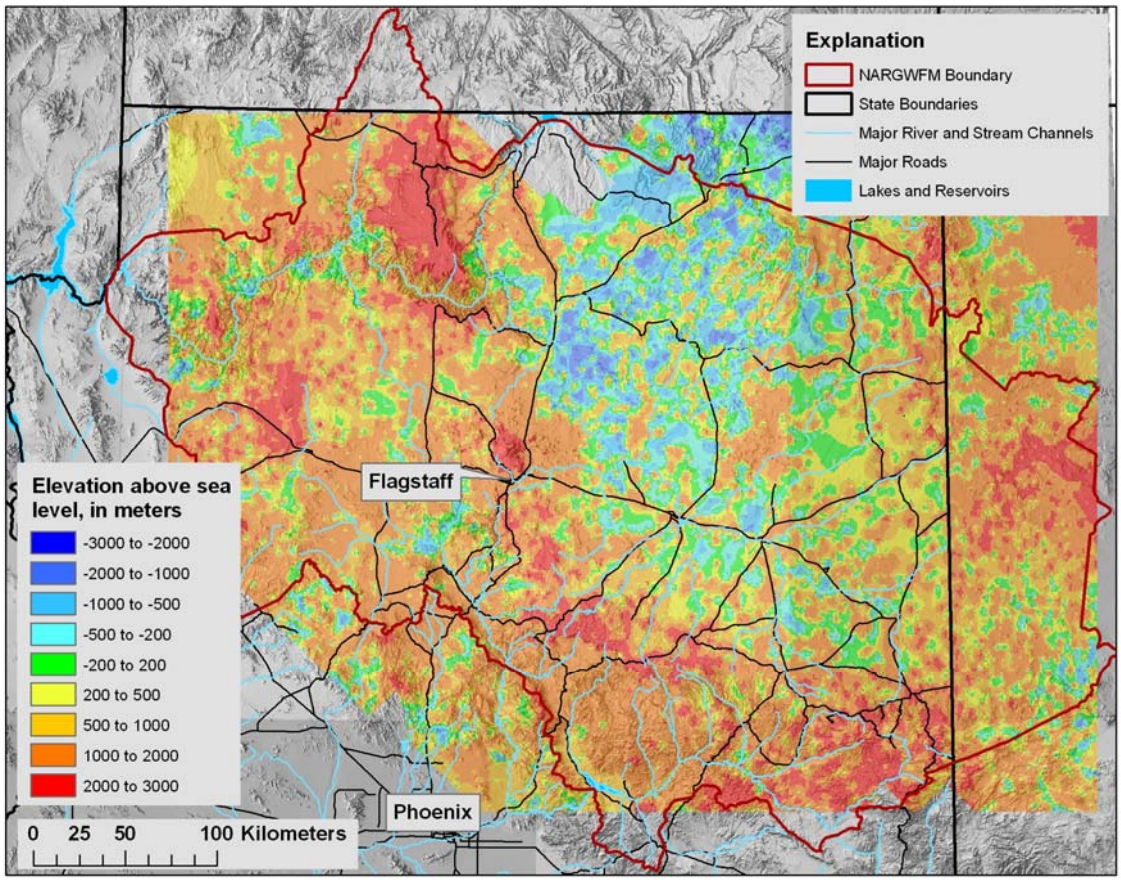

Figure 2. Elevation of crystalline basement (ground-water no-flow boundary) calculated using variations in the gravity field and the analytic signal amplitude method, and calibrated using measured elevations of crystalline basement from boreholes and outcrops.