Delineating the Bottom of the Aquifer

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DESIGN DOCUMENTS

Design documents are a series of technical papers addressing specific design topics on the Eastern Snake Plain Aquifer Model Enhancement. Each design document will contain the following information: topic of the design document, how that topic fits into the whole project, which design alternatives were considered and which design alternative is proposed. In draft form, design documents are used to present proposed designs to reviewers. Reviewers are encouraged to submit suggested alternatives and comments to the design document. Reviewers include all members of the Eastern Snake Hydrologic Modeling (ESHM) Committee as well as selected experts outside of the committee. The design document author will consider all suggestions from reviewers, update the draft design document, and submit the design document to the SRPAM Model Upgrade Program Manager. The Program Manager will make a final decision regarding the technical design of the described component. The author will modify the design document and publish the document in its final form in .pdf format on the SRPAM Model Upgrade web site.

The goal of a draft design document is to allow all of the technical groups that are interested in the design of the SRPAM Model Upgrade to voice opinions on the upgrade design. The final design document serves the purpose of documenting the final design decision. Once the final design document has been published for a specific topic, that topic will no longer be open for reviewer comment. Many of the topics addressed in design documents are subjective in nature. It is acknowledged that some design decisions will be controversial. The goal of the Program Manager and the modeling team is to deliver a well-documented, defensible model that is as technically representative of the physical system as possible, given the practical constraints of time, funding and manpower. Through the mechanism of design documents, complicated design decisions will be finalized and documented.

Final model documentation will include all of the design documents, edited to ensure that the "as-built" condition is appropriately represented.

Introduction

Hydrogeologists use the bottom of the aquifer when estimating the volume of water in storage within an aquifer, and when determining the thickness of an aquifer. Often a stratigraphic change defines the bottom of the aquifer. For the Snake Plain Aquifer this might be considered the basalt/rhyolite contact. In other cases the aquifer bottom is defined by gradual changes in material properties. An example of this for the Snake Plain Aquifer might be diagenetic alterations within the basalts gradually reducing permeability as the older and deeper basalts age. Given a gradational phenomenon such as this, hydrogeologist may disagree on exactly which horizon defines the base of the aquifer.

Problem Statement

Determining the bottom of the Snake Plain Aquifer is problematic. The bottom may be gradational, or it may coincide with the basalt/rhyolite contact. The aquifer thickness issue is critical because response functions (Drezin and Hamies, 1977; Cosgrove et al 2001) assume that aquifer response is linear. The linear assumption is explicitly true if the aquifer is confined. If the aquifer is unconfined, changes in aquifer thickness must be negligible relative to total aquifer thickness.

Considered Options

The options considered for estimating the elevation of the aquifer bottom include:

1) Most of the flow takes place in the upper 250 ft of the aquifer. This option stipulates a constant 250 ft thick aquifer.
2) The base of the basalt section defines the bottom of the aquifer. This option allows for a variable aquifer thickness.

250 ft thick aquifer

This option assumes a constant 250 ft thick aquifer. Mann (1986) found that hydraulic conductivity decreased with depth in the Snake Plain aquifer and concluded that most of the flow takes place in the upper 250 ft. This finding may or may not extrapolate beyond the well Mann tested. Perhaps the more active portion of the aquifer varies in thickness. If this were the case, we would assume that the aquifer were uniform in thickness when, in fact, thickness varies.

Full basalt thickness aquifer

This option assumes the Eastern Snake Plain aquifer bottom is defined as the base of the basalt column. Whitehead (1986) published basalt thickness maps by estimating basalt thickness based on drill hole observations and inferences from geophysical techniques. These maps appear geologically reasonable with thick basalts along the axis of the Eastern Snake Plain that thin toward the boundaries of the plain (Figure 1). The assumption that Whitehead's maps represent a reasonable proxy for aquifer thickness allows aquifer thickness to vary.

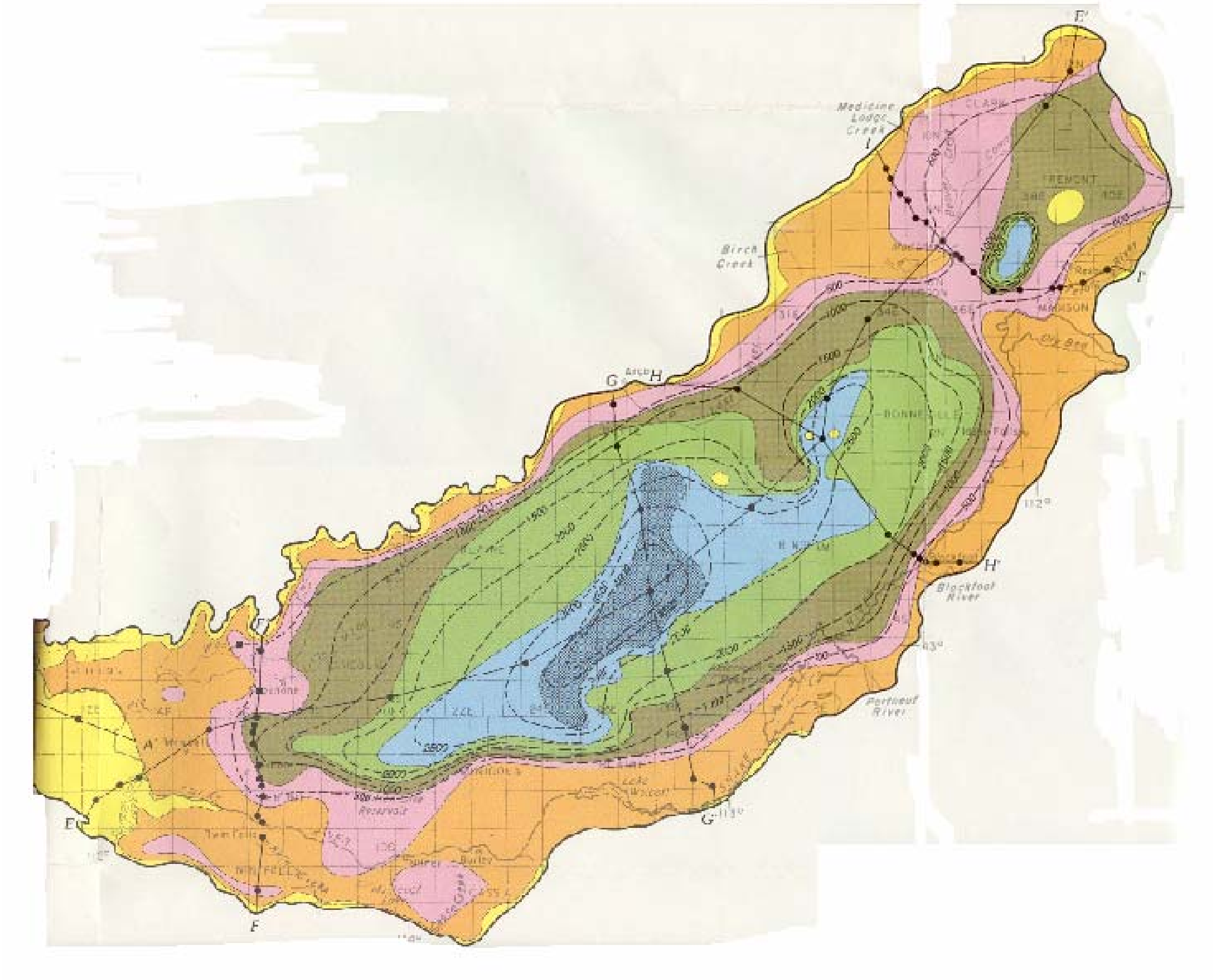

Figure 1. Basalt thickness map from Whitehead (1986).

Effect

Calibration of a ground water flow model scales hydraulic conductivity to obtain an estimate of transmissivity, effectively compensating for any incorrect aquifer thickness estimates. The most likely effect of an incorrect assumption regarding aquifer thickness will manifest itself during response function modeling yielding incorrect aquifer/river interaction results, if in fact aquifer response is not linear (i.e. thickness changes are significant).

Data Availability

No evidence exists indicating that anyone conducted an extensive survey of the active thickness of the Snake Plain Aquifer. Mann (1986) and Smith (Personal communication, 2002) conducted limited studies on the Idaho National Engineering and Environmental Laboratory (INEEL) but no studies exist on an Eastern Snake Plain wide scope. Using Whitehead's data as a proxy for aquifer thickness remains the most viable option.

Figure 2 contains a map constructed by kriging Whitehead's data to interpolate the bottom of the aquifer. The data density will not support a rigorous variogram analysis. In light of the sparse data a spherical variogram with a scale factor of 1.5E+06, a range of 2.0E+05, and an anisotropy of 2 with an angle of 45^{o} was assumed. These kriging parameters resulted in maps similar to Whitehead's (compare Figures 1 and 2).

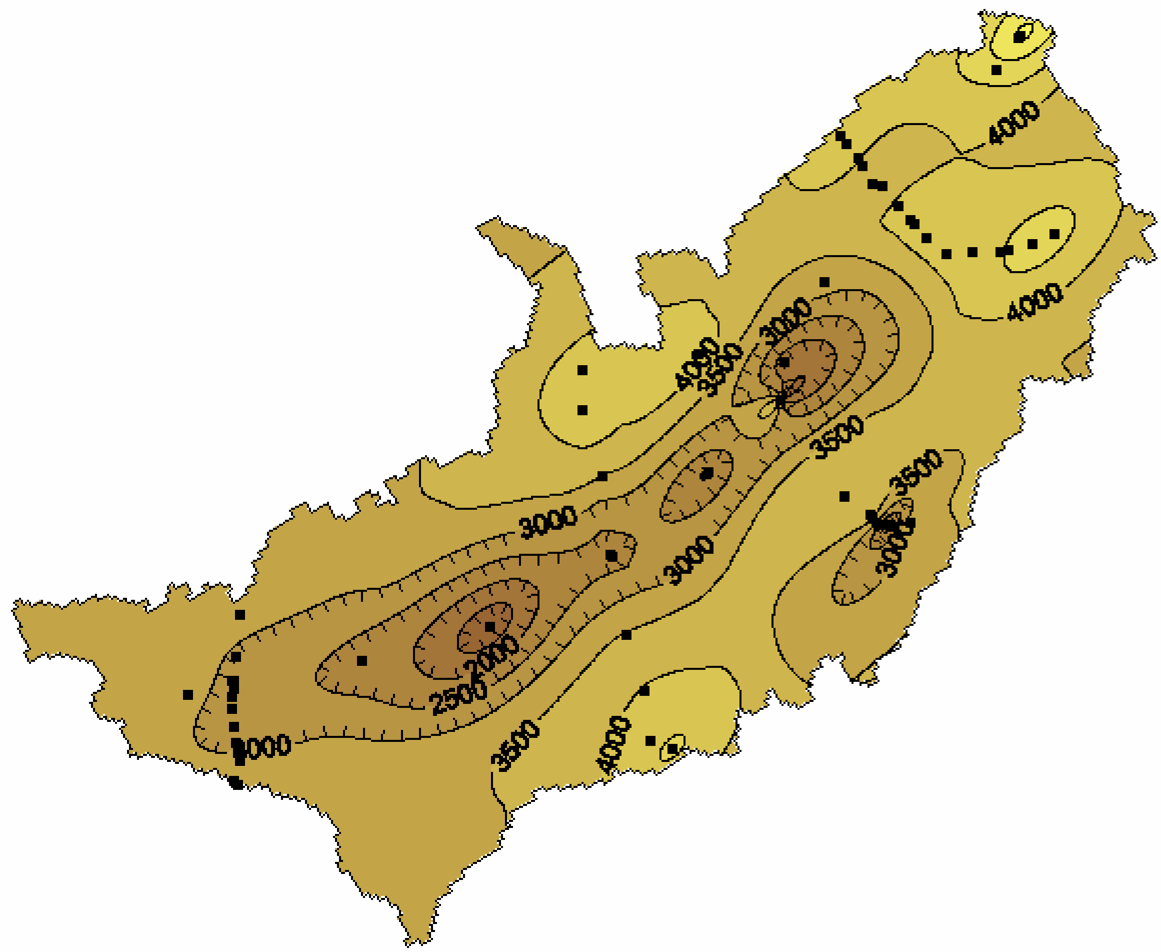

Figure 2. Kriged bottom of the aquifer elevation, dots are data points from Whitehead (1986)

Kriged aquifer bottom elevation estimates were compared against water table estimates to ensure a reasonable thickness at all locations (Figure 3). Obviously the bottom of the aquifer should not exceed the potentiometric surface elevation.

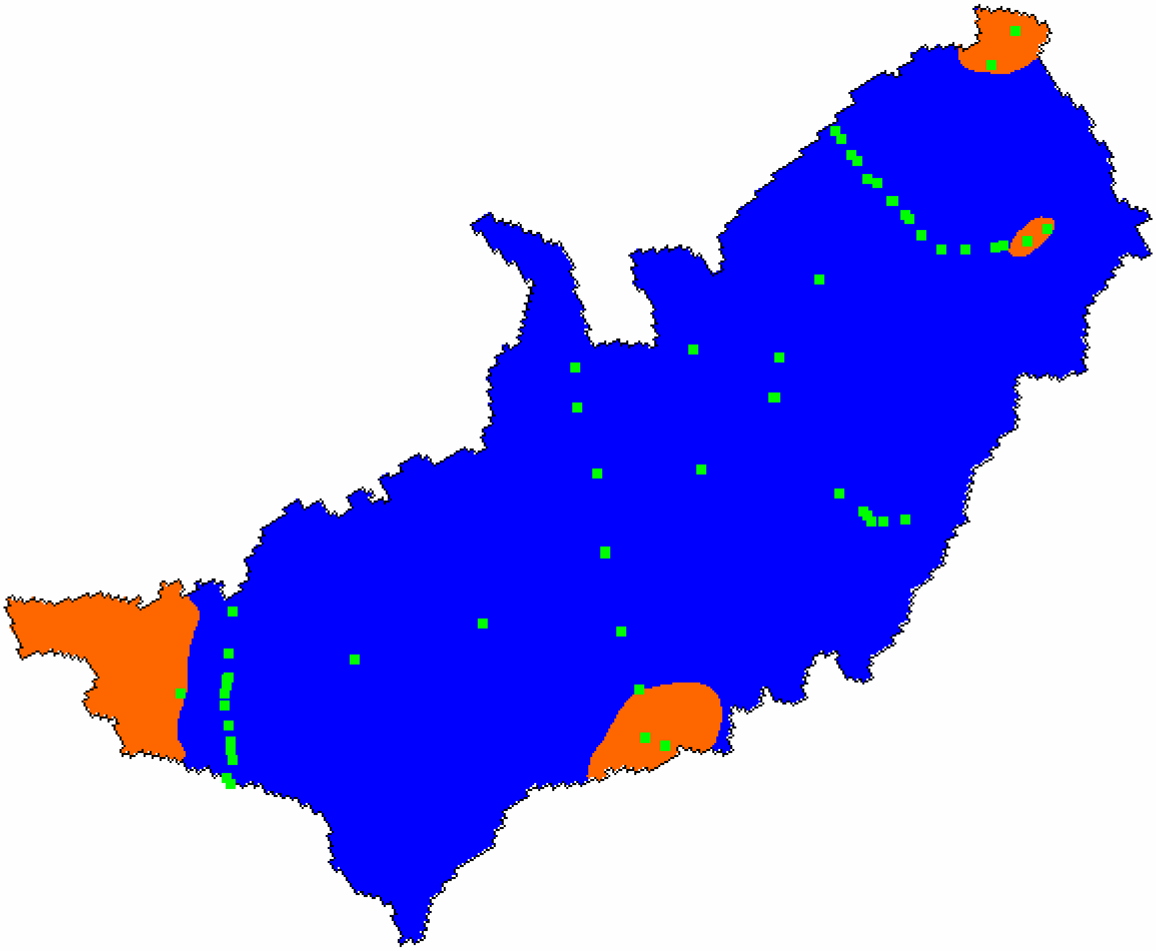

Figure 3. Aquifer bottom elevation subtracted from the aquifer potentiometric surface. Green dots are Whitehead data, orange indicates areas where the aquifer bottom estimate is above the potentiometric surface.

There are four areas, shown in orange in Figure 3, where the estimated aquifer bottom elevation is higher than the potentiometric surface. The area along the southwest edge of the model lacks control. The other areas appear to result from an overestimate of the aquifer bottom elevation. To correct this situation estimated points were added along the southwest edge of the model. Also the Whitehead data in the orange areas were adjusted down to place the aquifer bottom below the potentiometric surface. These adjustments are based on no geophysical or geologic data. There were simply made to bring the surface below the water table. Figure 4 contains an aquifer bottom map constructed using the modified data set. The estimated points are shown in red. Adjusted Whitehead data are green. Table 1 contains the estimates and Table 2 contains the modified Whitehead data

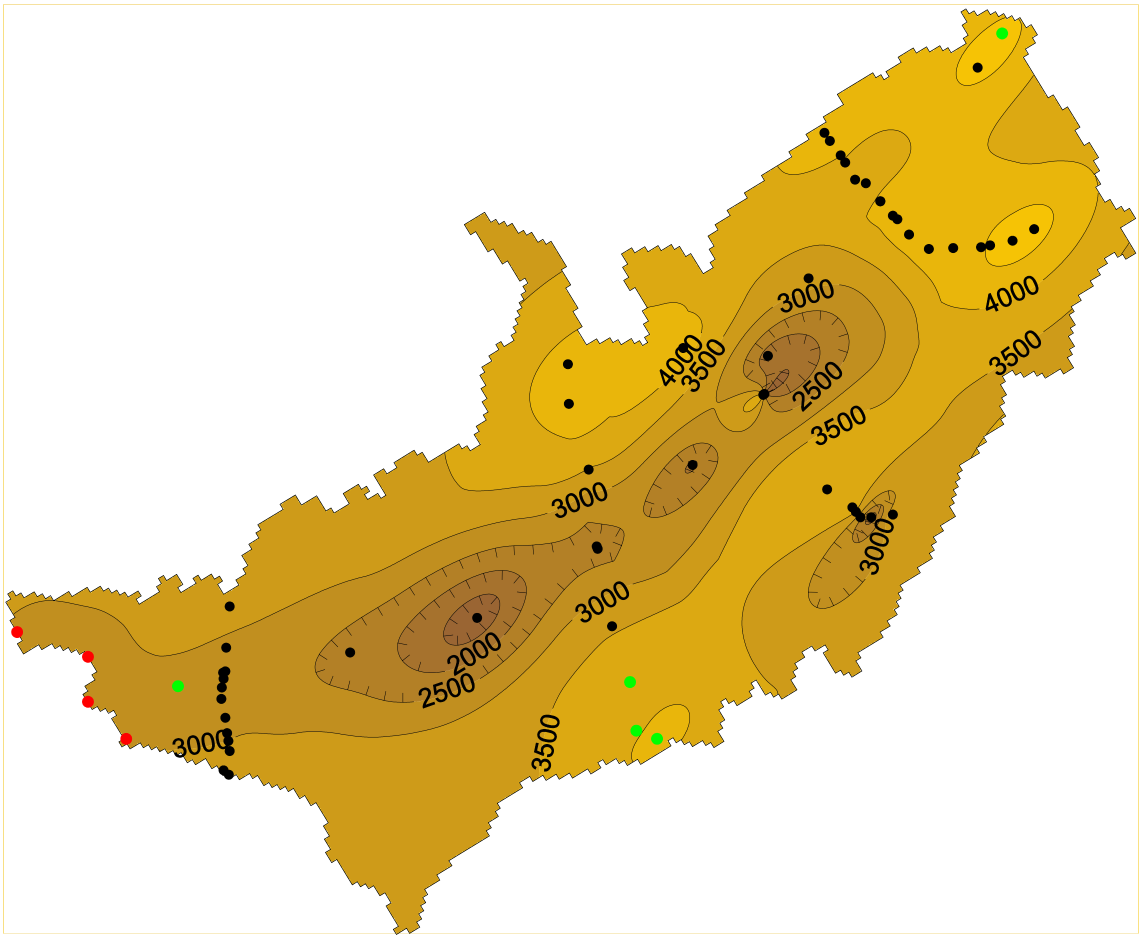

Figure 4. Kriged aquifer bottom elevations with estimated elevation points. Black dots represent Whitehead data, red dots are estimates, and green dots are modified Whitehead data.

Design Decision

Employ a confined aquifer representation during model calibration as outlined by Wylie (2003) and use the adjusted Whitehead data to infer the bottom of the aquifer for post calibration uses, requiring an estimate of the aquifer bottom. The adjusted Whitehead data will be kriged using a spherical variogram with a scale factor of 1.5E+6, a range of 2.0E+5, and an anisotropy of 2 with an angle of 45^{o}. The kriged data will then be used in the model to represent the base of the aquifer. Once the model is calibrated a sensitivity analysis will be conducted to look for evidence of non-linear responses. If the responses are linear then response functions are an appropriate management tool for the Eastern Snake Plain aquifer.

Table 1. Estimated aquifer bottom elevation points.

IDTM Easting ft	IDTM Northing ft	Bottom Estimate	ID
1328195.2	673237.8	2864.9	estimate-1
1391170.30	651251.10	2799.4	estimate-2
1425156.80	578295.30	2937.9	estimate-3
1391170.30	611275.30	2787.6	estimate-4

Table 2. Adjusted Whitehead data points.

IDTM Easting ft	IDTM Northing ft	Bottom Estimate	Adjustment	ID
2203803.86	1205130.97	4700	-1000	E15p
1471206.12	625125.33	2910	-400	E4p
1897020.28	578403.27	4225	-400	G1p
1878619.41	585603.59	3920	-400	G2p
1873019.14	628805.62	3860	-200	G3p

References

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