# 4.0 Groundwater Modeling

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Computer models are used to forecast future groundwater conditions and the movement of contaminants in groundwater. Such predictions are important in planning waste management and cleanup activities for the Hanford Site. Groundwater modeling activities that address problems on a Hanford site-wide scale, such as contaminant movement from the operational areas on the Central Plateau to the Columbia River, have been consolidated under the Groundwater Performance Assessment Project. The consolidation of site-wide modeling eliminates redundancy and promotes consistency of groundwater models (DOE/RL-2000-11). Other groundwater models are used for problems at a local scale (i.e., <~10 kilometers). Local-scale modeling during the past several years has been used to design and evaluate pump-and-treat systems for treatment of local-scale groundwater contaminant plumes, support closure of single-shell tanks, and support waste site remediation decisions. Local-scale models have also been applied to assess groundwater and contaminant movement in the zone of interaction between the unconfined aquifer and the Columbia River (PNNL-13674). Additional information on modeling to support closure of single-shell tanks can be found in DOE/ORP-2003-11.

This chapter summarizes Hanford Site groundwater modeling activities for fiscal year 2003. Section 4.1 reports progress on the continuing development of the consolidated site-wide groundwater model. Section 4.2 describes application of an earlier version of the consolidated model as a component of the System Assessment Capability. Section 4.3 describes local-scale modeling performed to assess groundwater pump-and-treat operations using models other than the consolidated site-wide groundwater model.

***Groundwater flow and transport models based on alternative conceptual models are being developed to improve predictions of contaminant transport and to evaluate uncertainty in model results.***

## 4.1 Site-Wide Groundwater Flow and Transport Model

Groundwater flow and transport models based on alternative conceptual models, as compared to the "base case" model described in PNNL-13447, are being developed to improve predictions of contaminant transport and to evaluate uncertainty in model results. Uncertainty in model conceptualization has been found to be the most significant source of uncertainty in groundwater modeling (NUREG/CR-6805).

### 4.1.1 Development and Calibration of Alternative Conceptual Model 2

Calibration of a site-wide model based on an alternative conceptual model, referred to as Alternative Conceptual Model 2 (ACM-2), was completed during fiscal year 2003 (PNNL-14398). This alternative model used a zone of hydraulic properties within the most important transmissive hydrogeologic units of the model based on geological "facies." Each facies zone delineates a region where hydraulic properties are expected to be similar based on available geologic and hydrologic information. Six facies zones were defined for model Unit 1, the Hanford formation. Seven zones were defined for model Unit 5, which includes Ringold gravel units C and E and upper Ringold sand (BHI-00184). The facies zones defined for ACM-2 model Unit 1 are shown in Figure 4.1-1. Facies zones defined for Unit 5 are shown in Figure 4.1-2. These zones were developed based on textural information in geologic descriptions from well drilling, knowledge of depositional environments, aquifer test information, and hydraulic head responses in wells (PNNL-14398). The 13 facies zones and the remaining 6 hydrogeologic units within the model result in 19 regions of the model that are assigned distinct hydraulic parameters including the hydraulic conductivity, vertical anisotropy, and storage properties of the sediment within that region.

The hydraulic conductivity fields of previous three-dimensional site-wide models have been tied, through scaling factors, to the transmissivity distribution that resulted from an earlier two-dimensional steady-state calibration of the model. ACM-2 also incorporates interaction with the underlying basalt-confined aquifer system, which was included in the site-wide model for the first time as part of ACM-1 (PNNL-13623). Compared the earlier ACM-1 model, the facies-based ACM-2 model resulted in a better fit to measured water level data. The sum of squared residual differences was 9% lower for ACM-2.

***Alternative conceptual model 2 resulted in a better fit to measure water-level data and is more technically defensible than previous conceptual models.***

The facies-zone approach used for ACM-2 is more technically defensible because it is based on a more detailed examination of geological data and removes possible errors from the earlier two-dimensional calibration. It is also more suitable for the application of geostatistical methods to develop a range of probable conceptual models that will produce a range of results and thus quantify model uncertainty. As described in PNNL-14398, geostatistical techniques were applied to develop a large number of alternative conceptual models with equally likely areas for the facies zones within Unit 1 based on the available data. Methods were also developed to generate alternative conceptual models with different, equally likely, distributions of low-permeability mud units (Units 4, 6 and 8). Work is continuing on development of a range of alternative conceptual models to capture uncertainty in the model results. Understanding and quantifying the resulting uncertainty in model predictions will strengthen the technical defensibility of groundwater transport predictions and lead to a better basis for waste-management and cleanup decisions.

Another change to ACM-2 compared to earlier models was the addition of "run-on" recharge from upland areas on the western boundary of the model. The Distributed Hydrology Soil Vegetation Model was applied to calculate expected runoff from the upland areas (PNNL-14398). Three runoff areas were defined including Cold Creek Valley, Dry Creek Valley, and Rattlesnake Mountain. Runoff from these areas was applied to model elements as shown in Figure 4.1-3.

### 4.1.2 Background Information on the Site-Wide Groundwater Model

The site-wide groundwater model is based on a conceptual model of the unconfined aquifer system that consists of features and processes that control groundwater flow and contaminant transport within the aquifer. It was developed from the following information:

- Three-dimensional location and extent of major hydrogeologic units within the aquifer.
- Distribution of textural and lithologic properties of aquifer sediments.
- Spatial distributions of hydraulic and transport properties.
- Aquifer boundary conditions including potential groundwater recharge and discharge.
- Distribution and movement of contaminants.

The model consists of nine separate hydrogeologic units, eight of which exist below the water table. The groundwater flow system is bounded by the Columbia River on the north and east and by the Yakima River and basalt ridges on the south and west, respectively. Additional information on the site-wide groundwater model is presented in PNNL-11801 and PNNL-13641.

The effort to incorporate uncertainty in the site-wide model began in 1999 with recommendations from an external peer review panel to establish a new modeling framework that accepts the inherent uncertainty in model conceptual representations, inputs, and outputs (PNNL-13641). This framework will produce a range of predicted results for future groundwater conditions and contaminant transport based on differences in conceptual model assumptions. As described in PNNL-13641, uncertainty in the site-wide groundwater model is being quantified through sensitivity analysis (e.g., alternative conceptual models and future scenarios) for those aspects of the analysis related to vagueness and through uncertainty analysis for those situations where the uncertainty (e.g., for parameters) can be represented by probability density functions.

## 4.2 System Assessment Capability

The System Assessment Capability is an integrated assessment tool. It includes several linked computer models designed to simulate the movement of contaminants from waste sites through the vadose zone, groundwater, and Columbia River to receptors. It also incorporates modules that calculate the risks to human health and the environment.

Assessments to support the *Optimization Strategy for Central Plateau Closure* (WMP-18061) and the *Final Hanford Site Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement (HSW EIS)* (DOE/EIS-0286F) were performed using the System Assessment Capability during fiscal year 2003. Updates to data sets and software were also made in preparation for performing the 2004 composite analysis. This will be an update of the composite analysis described in PNNL-11800. It is designed to calculate the combined impact of all radiological waste that will be left on the Hanford Site at the time of site closure. The System Assessment Capability software was also modified to allow longer time periods to be simulated so that model runs can be extended to identify the time of peak concentrations that occur up to 10,000 years after site closure.

***During fiscal year 2003, the System Assessment Capability was updated; an atmospheric transport module was added and newer versions of the groundwater flow and transport module were incorporated into the computer model.***

During fiscal year 2003, the System Assessment Capability was updated with the addition of an atmospheric transport module and with newer versions of models including an updated groundwater flow and transport model. The three-dimensional, base case site-wide groundwater model described in PNNL-13447 was used in the initial assessment performed during 2002 (PNNL-14027). In fiscal year 2003, the model grid was refined around the contaminant plume areas. The original model was based on a 750-meter grid spacing. This was refined to a 250-meter spacing in areas of widespread plumes and 83 meters in areas of smaller plumes. The updated grid is shown in Figure 4.2-1. Some minor changes to the geological interpretation and recharge boundaries were also incorporated in the updated model. Hydraulic conductivities were updated based on a calibration using the new grid. These changes were made to support the upcoming 2004 composite analysis.

The System Assessment Capability uses a stochastic analysis, which means that selected parameters are represented by probability distributions from which values are selected. This results in a range of calculated risks that are designed to encompass the uncertainty in the analysis. For the groundwater module, only the sorption coefficients of contaminants are represented stochastically. Other sources of uncertainty in the groundwater model, including conceptual model uncertainty, will eventually be incorporated based on the strategy described in Section 4.1. The groundwater module of the System Assessment Capability receives contaminant flux from the vadose zone module. It simulates contaminant movement through the uppermost aquifer system to the Columbia River and other potential exposure locations such as wells or seeps. The concentration of contaminants in groundwater is then used in the risk module calculations. Background information on design of the initial System Assessment Capability tool is summarized in BHI-01365. Results of an initial assessment performed with the System Assessment Capability are provided in PNNL-14027 and a description of the software is provided in PNNL-13932 and PNNL-13932-Volume 2.

## 4.3 Local-Scale Modeling of Pump-and-Treat Systems

The Hanford environmental restoration contractor has performed local-scale modeling during the past several years to design and evaluate pump-and-treat systems for groundwater. The Micro-FEM© code was used to model capture and injection zones of extraction and injection wells, respectively, and to estimate the area affected by the pump-and-treat systems over time. The model was used to evaluate the hydraulic effects of the remedial action sites in several different operational areas.

The following list indicates the operational areas and the contaminants of concern being treated at each area:

- 100-KR-4 Operable Unit (100-K Area) – hexavalent chromium.
- 100-NR-2 Operable Unit (100-N Area – strontium-90.
- 100-HR-3 Operable Unit (includes both 100-D and 100-H Areas) – hexavalent chromium.
- 200-UP-1 Operable Unit (200 West Area) – technetium-99 and uranium.
- 200-ZP-1 Operable Unit (200 West Area) – carbon tetrachloride.

During fiscal year 2003, these models were only updated to reflect the changing water-table elevation in the aquifer and changes in pumping rates. Additional information on these models is provided in DOE/RL-99-79, DOE/RL-2002-67, and DOE/RL-2002-05.

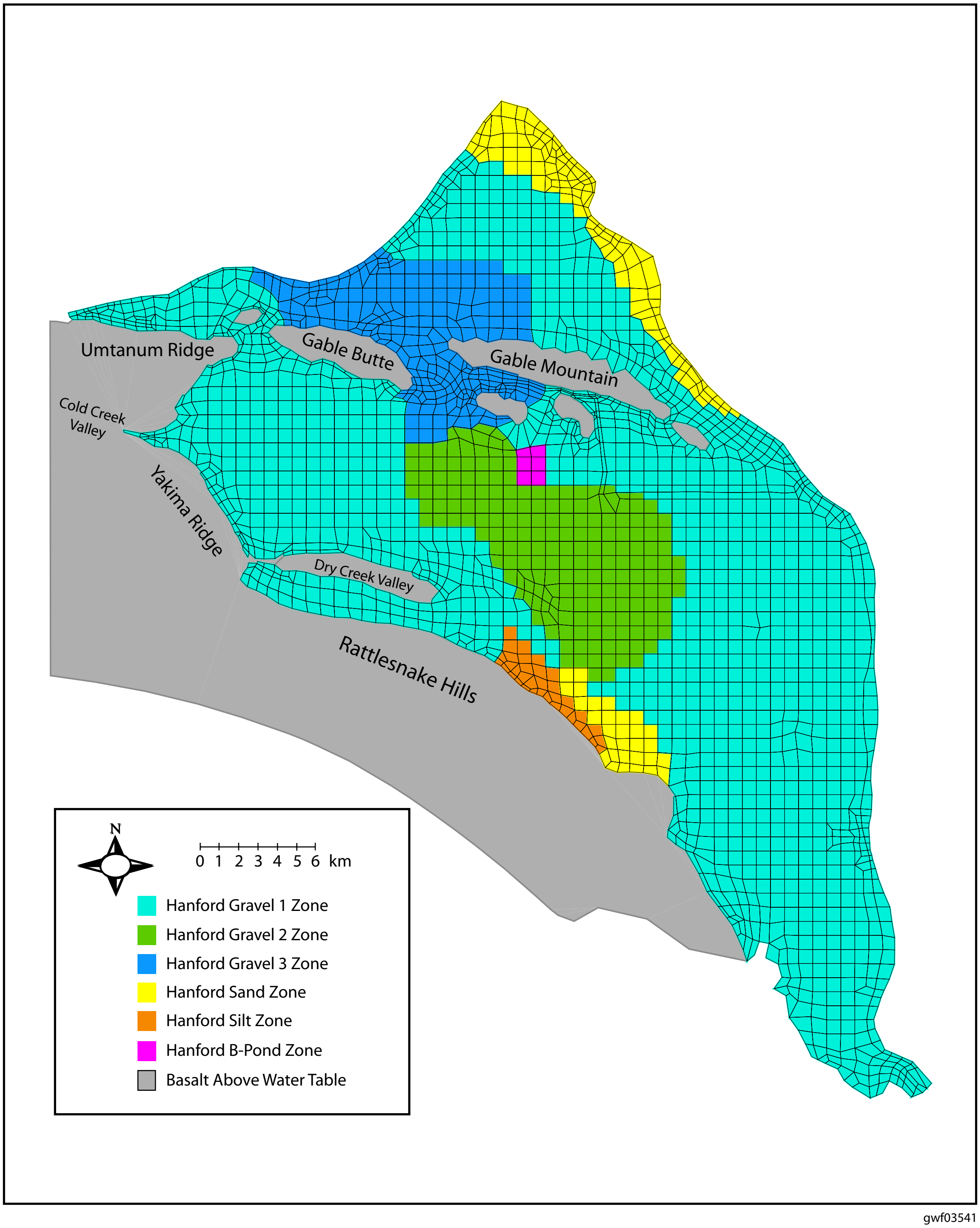


**Figure 4.1-1**. Facies Zones Defined for Alternative Conceptual Model 2, Unit 1

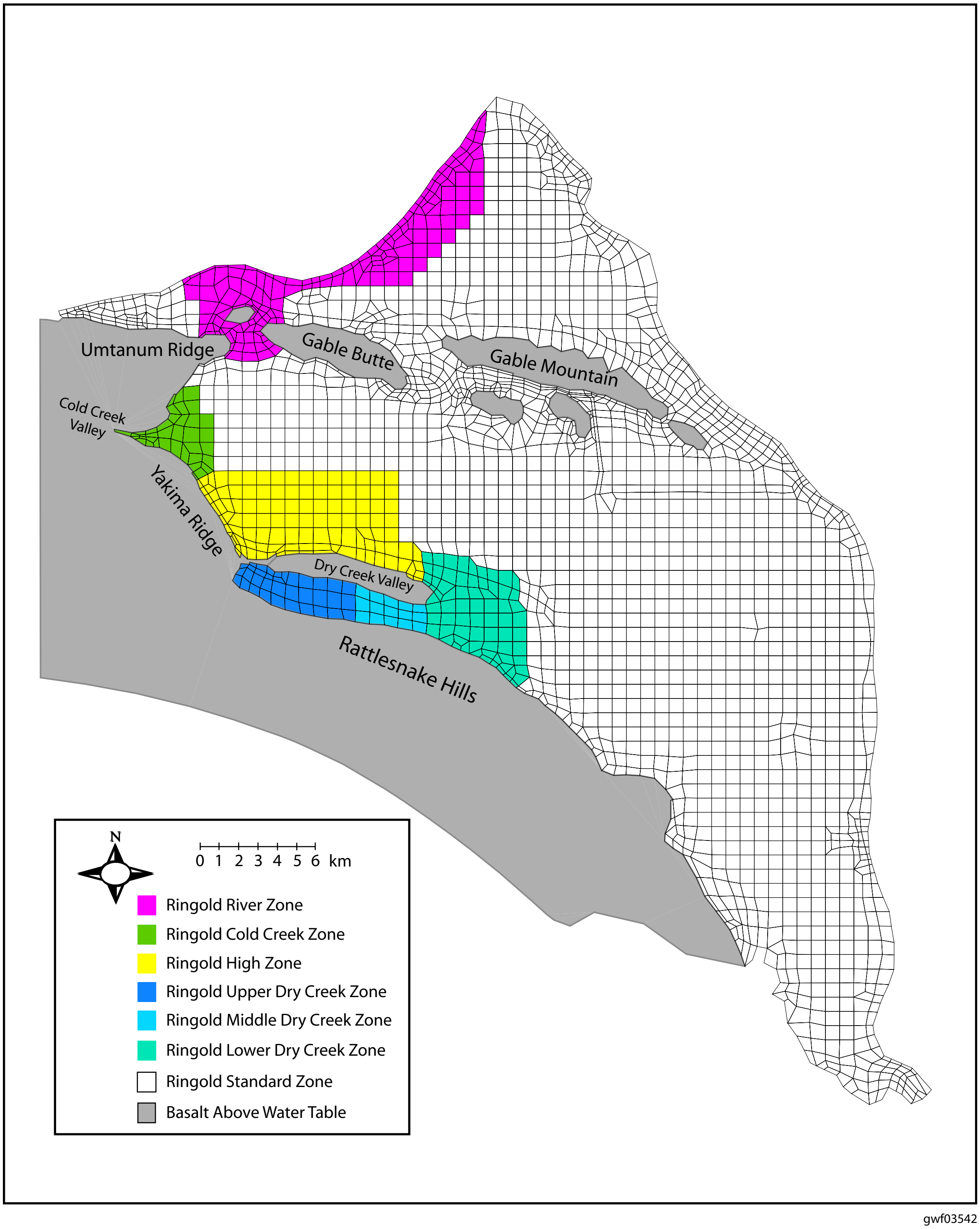


**Figure 4.1-2**. Facies Zones Defined for Alternative Conceptual Model 2, Unit 5

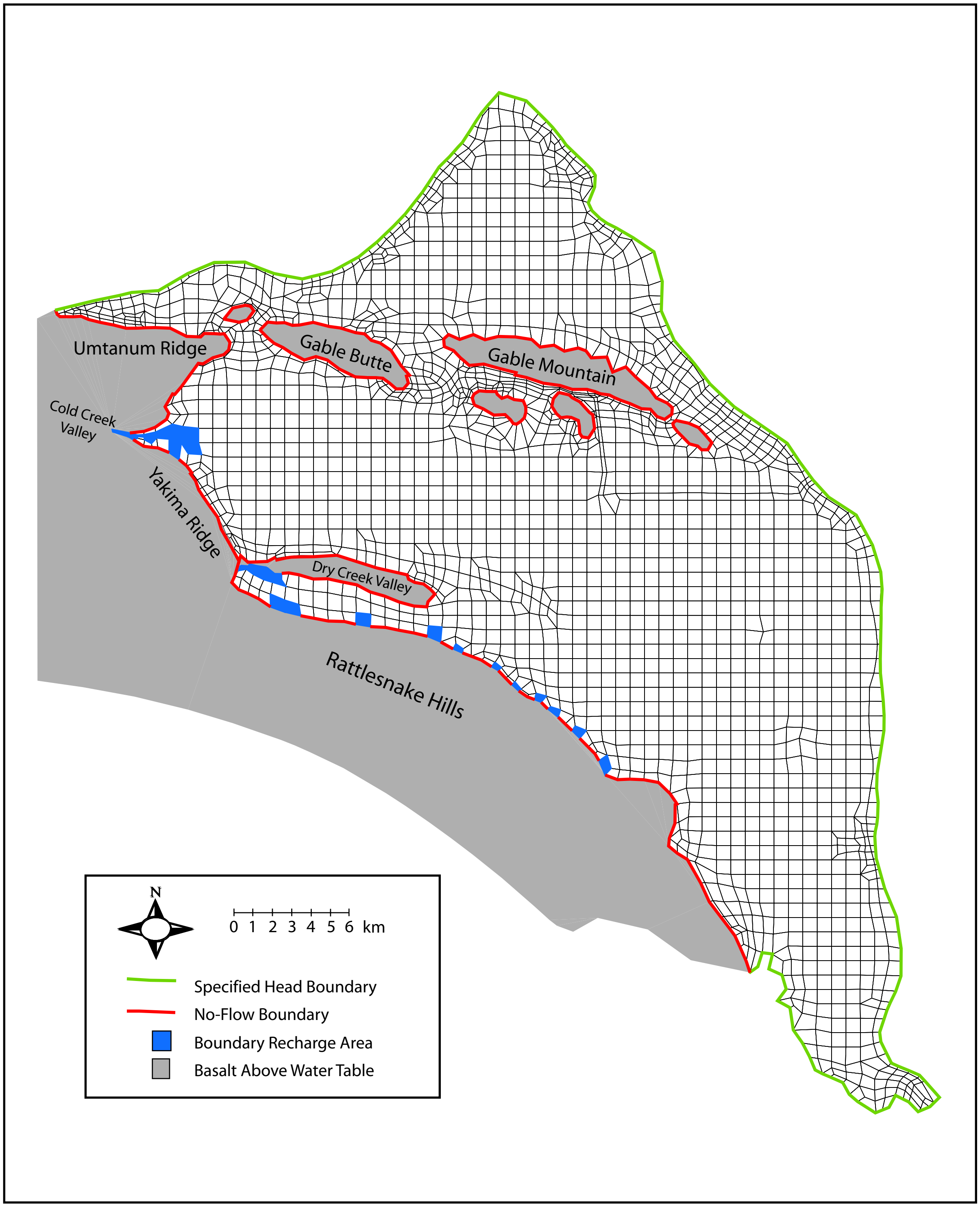


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**Figure 4.1-3**. Runoff Areas (Cold Creek Valley, Dry Creek Valley and Rattlesnake Mountain) Applied to Model Elements Updated System Assessment Capability (SAC) Model Grid

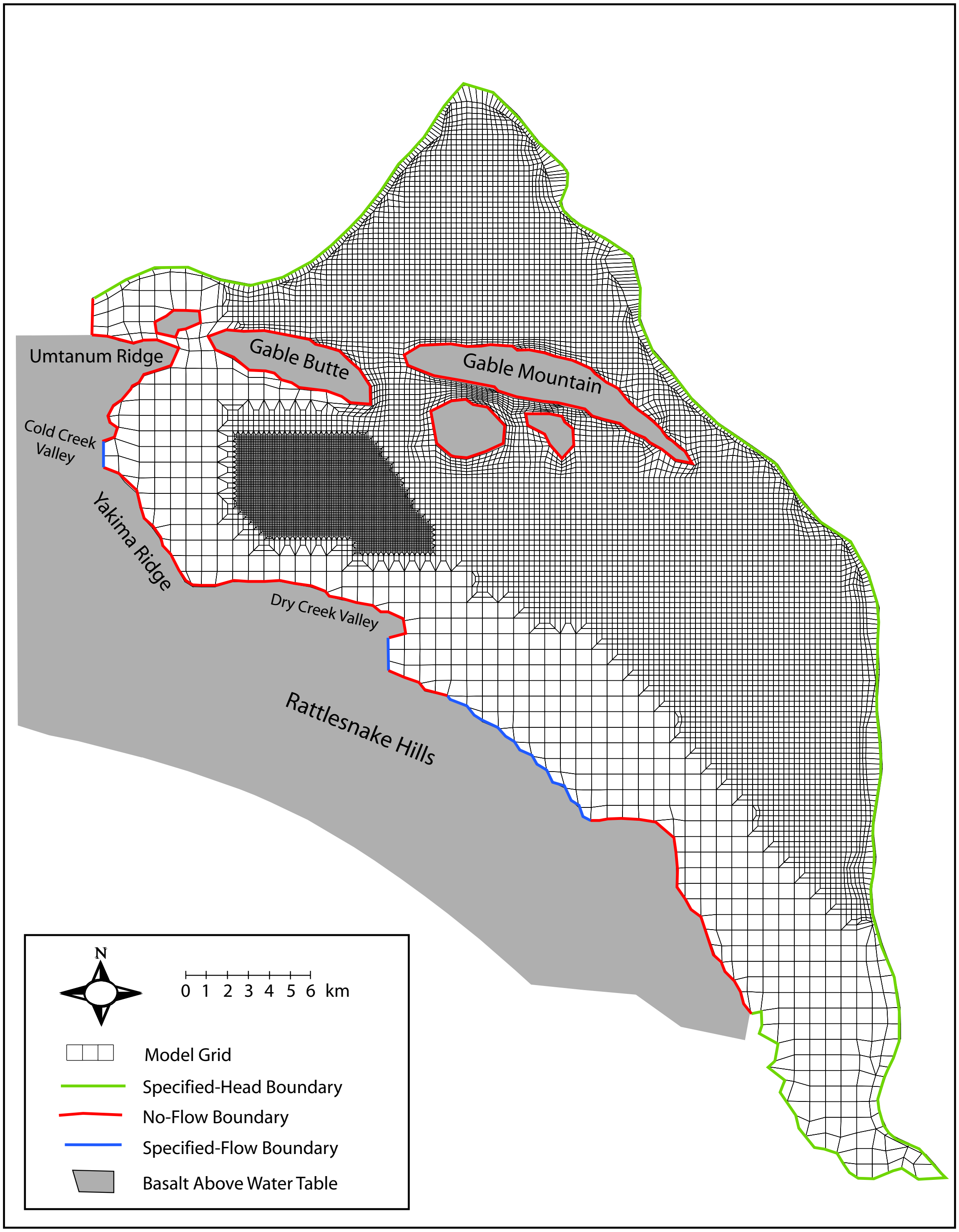


**Figure 4.2-1**. Updated System Assessment Capability (SAC) Model Grid