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MEMORANDUM FOR: Michael J. Bell, Chief
High-Level Waste Licensing
Management Branch
Division of Waste Management

THRU: Malcolm R. Knapp
High-Level Waste Licensing
Management Branch
Division of Waste Management

FROM: Linda L. Lehman
High-Level Waste Licensing
Management Branch
Division of Waste Management

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SUBJECT: HANFORD TRIP REPORT ON HYDROLOGIC MODELLING

HYDROLOGIC MODELING

INTRODUCTION

Modeling efforts by Rockwell Hanford Operation (RHO) are an attempt to integrate and explain the behavior of the flow systems underlying the Hanford Reservation. The report is limited to the hydrologic models used. Rock mechanics modeling was not addressed at meetings attended by the hydrologic modelers from the NRC group. Also enclosed please find trip reports from Jim Mercer, Geotrans, Inc. which describes the modeling efforts of PNL and the USG's and from Mark Reeves, Intera, which compares and contrasts various approaches and offers suggestions for NRC's approach.

The flow modeling at RHO has been divided into two main categories; (1) far-field modeling and (2) near-field modeling. The far-field effort is confined to the Pasco Basin topographic boundaries, as illustrated in RHO-BWI-ST-5. The far-field effort is further subdivided into a three-dimensional approach and a two-dimentional approach.

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Pasco Basin Three-Dimensional Approach

The three-dimensional approach uses the finite element flow code MAGNUM with three active layers; the Saddle Mountains formation, the Wanapum formation and the Grande Ronde formation. Layering is composited, i.e., very transmissive zones are averaged together with non-transmissive zones to form an equivalent transmissivity. Hydraulic properties are assumed homogeneous and anisotropic in each layer.

Boundary conditions used in this simulation are as follows. The water table is simulated using constant head (Dirichlet) boundaries. Recharge was simulated as; (1) Interbasin flow - from the east and northwest in all layers, and from the southwest in the Grande Ronde. (2) Precipitation - into the Saddle Mountains formation and Wanapum formation in the vicinity of Saddle Mountains and Rattlesnake Hills, and (3) Irrigation - in just one area southeast of the Saddle Mountains, into the Saddle Mountains formation. No-flow boundaries were applied in all layers along; (1) the north side of the Saddle Mountains, (2) the western basin boundary (Rattlesnake Hills), and (3) the southern basin boundary (south of Wallula Gap) in the Wanapum and Saddle Mountains. Discharge was simulated; (1) along the Columbia and Snake Rivers in the Saddle Mountains formation and (2) (supposedly) in the Wallula Gap area in the Wanapum and Grande Ronde formations.

Conclusions drawn from this model study are; (1) flow from the Saddle Mountains formation and possibly from the upper Wanapum formation discharges to the Columbia and Snake Rivers, (2) lower formations may discharge at Wallula Gap or beyond, with no apparent connection with the Columbia River outside of Wallula Gap (This may be due solely to choice of boundary conditions.), and (3) composited layering scheme is not conservative and more layers are needed to accurately calculate travel times. Figure 1 shows the layering scheme proposed for the multilayer model.

Future modeling efforts will include: increasing the vertical permeability beneath structural features such as anticlines and ridges, sensitivity analyses, and further use of the multi-layer model. Some preliminary results of this model will be presented in RHO-BWI-LD-44.

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Pasco Basin Two-Dimensional Approach

The two-dimensional approach consisted of choosing a streamline and pressure boundaries from the three-dimensional model and setting up a cross-section running from the repository to Wallula Gap, crossing under both the Columbia and Snake Rivers (Figure 2). The simulation also uses the MAGNUM finite element flow code. Composite layering was again used, but interest was focused on the Grande Ronde in order to estimate the travel time required of a particle leaving the repository to the accessible environment. Recognizing that the composited layering would yield non-conservative results, RHO increased the horizontal conductivity by a factor of 1000 in a small portion of the upper Grande Ronde formation. This small section was to represent the flow top breccia of the Umtanum flow unit.

The results of this calculation yield a travel time on the order of $>10^5$ years. This figure is much larger than previous calculations performed by RHO, Los Alamos Technical Associates/Intera, and Pacific Northwest Labs. Table 1 and Figure 3 list and compare the results of all the above mentioned studies. RHO maintains that the difference in these calculations is due to new data obtained since 1979. However, a large portion of this difference can be explained by boundary conditions chosen by RHO in the present modeling exercise.

Major Conclusions by RHO

Based on the results of these and previous modeling studies RHO has reached several major conclusions shown below. It should be noted that the NRC does not necessarily share these conclusions. Conclusion number 6 is discussed in more detail in the geochemistry section of the overall trip report (Wright, et al.) The major conclusions are as follows:

1. Discharge areas of the lower aquifers are presently unknown.

2. Hydraulic conductivities (K_h) of 10^{-4} to 10^{-5} m/sec are typical of flow tops and interbeds within the Saddle Mountains and Wanapum formations. Values of 10^{-6} m/sec are characteristic of the Grande Ronde formation.

3. Hydraulic conductivities (K_h) of 10^{-9} m/sec are typical of columnar sections of a basalt flow.

4. Storage coefficients are 10^{-3} to 10^{-6}.

5. The Wanapum and Grande Ronde basalts are characterized by small hydraulic gradients.

6. Major hydrochemical breaks occur suggesting minimal vertical groundwater mixing.

7. Hydrologic modeling studies suggest that the dominant direction of flow and transport are upward from the repository and laterally along flow tops within the Grande Ronde basalt.

NEAR-FIELD MODELING

The near-field modeling also consists of two types: (1) a repository scale model and (2) a heat-transport and travel-time model. The code used for both of these exercises is MAGNUM, utilizing, in this case, heat and flow (porous media, dual porosity and discrete fracture) capability.

Repository Scale Model

The repository scale model is contained within the Umtanum flow unit and is characterized by various rock types which take into account the differences in rock characteristics within the flow and also the backfill materials. The entablature portion of the flow is treated as orthogonal fractures while the colonade is visualized as discreet vertical fractures. The flow top breccia is simulated as a porous/fractured media, using the dual-porosity approach. The canister backfill and room backfill as well as the damaged zone due to construction are treated as porous media. The code used is unique in its ability to treat these various rock types in the same simulation. Most codes are not this flexible. Figure 4 is the conceptual model on which the simulations are based.

This modeling work is preliminary and actual results were not presented nor were calibration procedures or boundary conditions. The model is to be used in determining rates of groundwater ingress into the operational repository. Results are expected to appear in RHO-BWI-LD-44.

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Heat-Transport and Travel-Time Model

The heat-transport and travel-time model also uses MAGNUM. This two-dimensional model simulates an area from just above the Vantage Sandstone to approximately 200 feet below the Umtanum (Figure 5). The layering scheme is homogeneous and anisotropic. Effort is taken not to composite, i.e., interflows and interbeds are separate layers. In this simulation, interflows are assumed to exist immediately above and below the Umtanum with 200 feet of vertical separation.

Conclusions reached as a result of this modeling effort are as follows: Pathline and travel-time calculations done with and without thermal loadings (40KW/acre) indicate that the thermal loading significantly increases the travel-time. This is contrary to what was previously expected. As others studies have shown that an increased heat load would increase both horizontal and vertical hydraulic conductivity thereby decreasing travel times. RHO's explanation for this is that the vertical bouyancy forces become so much larger than the horizontal velocities, that water is driven upward, higher into the section through areas of lower hydraulic conductivity, not allowing horizontal movement until the thermal gradient flattens out. Only then can the flow move horizontally into the more transmissive zones.

Other codes used by RHO to calculate radionuclide concentrations based on the previously mentioned flow calculations are CHAINT and FECTRA. CHAINT is a one dimensional code with the capability of handling multiple radionuclide chains. FECTRA contains a dual porosity transport capability.

OBSERVATIONS

The modeling of the groundwater flow system at Hanford has been handicapped by a lack of deep hydrologic data. The present modeling efforts show that groundwater travel times and flow paths should be considered preliminary and are not adequate to confidently predict these parameters. Future modeling efforts will become more refined and will gain acceptance after calibration by accpeted methods such as history matching and matching present day water table contours. To date, there is no consensus between RHO and PNL regarding important basic concepts, i.e., location of discharge areas.

The Pasco Basin should be viewed as a part of the Columbia Plateau regional flow system and not as a separate entity. The RHO modeling effort could be enhanced by constructive cooperation between RHO and PNL

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or the USGS regarding the regional hydrology of the Columbia Plateau. Regional models developed by both PNL and USGS could provide boundary conditions or other important insights into the more local scale of the Pasco Basin.

RHO supports its conclusions by calibrating the models against observed downhole pressure potentials. As a result, conclusions are strongly dependent on two boreholes, DC-7 and DC-15, which seem to indicate that lateral flow is occuring in the lower units. This lateral tendency may be merely a local phenomenon. It is very likely that local heterogenieties exist which cause flow on a local scale to appear to be in one direction (lateral) but, when viewed on a larger scale, the water may indeed by moving in another direction (vertical). Fine-tuning the models to these variations in downhole potential may not be warranted at this stage of investigation. Rather, calibrating via a free surface to match water table levels may be a more meaningful exercise. Currently the water table configuration is forced by means of constant head boundaries. Further these downhole potential distributions are not taken at a given instant in time. They are acquired as drilling proceeds downhole and there may be as much as 2 years difference from the top to the bottom of the hole.

The modeling studies could be used more effectively in the planning of hydrologic investigations by using sensitivity analyses on input parameters and boundary conditions to determine effects on the flow direction. This information can be used to identify areas were certain data types would be most beneficial.

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MEMORANDUM

To: L. Lehman, NRC

From: J. Mercer, GeoTrans, Inc.

Subject: TRIP REPORT--BWIP Site Visit

Date: September 30, 1981

The purpose of this memorandum is to describe meetings, discussions, and impressions concerning the BWIP Site Visit. This trip report is part of a combined effort, and as such, only the following items are discussed: (1) a September 21, 1981, meeting with Pacific Northwest Laboratories (PNL), (2) a September 28, 1981 meeting with the U.S. Geological Survey, and (3) general comments on the overall trip. Detailed meeting notes are also attached.

The modeling effort of PNL was divided into two parts: (1) a regional model and (2) a Pasco Basin model. The regional model covered 21,000 square miles and had two active layers. The code VTT was used and two-dimensional flow was assumed in the layers, which were connected through the use of transfer coefficients between layers. The Pasco Basin model covered 2,000 square miles. The three-dimensional model, FE3DGW, was used with three active layers. Both models had the following major assumptions: (1) porous flow equivalent of composite transmissive zones and confining zones, and (2) the Grande Ronde Formation is similar hydrologically to the Wanapum Formation. The latter assumption was made because most wells are less than 400 feet in depth and only a few wells penetrate the Grande Ronde Formation.

The major conclusions from the local model include: (1) large scale vertical hydraulic conductivity is of the order 0.001 ft/day; (2) supports vertical upward leakage in the Pasco Basin (what PNL calls distributed discharge); (3) supports ground-water divide for Rattlesnake - Hog Ranch - Table Mountain; (4) supports Saddle-Mountains as only permeability barrier; (5) pathway analysis indicates that radionuclides will move primarily vertically, with average ground-water travel time to the Columbia River calculated as about 15,000 years; and (6) in 10,000 years, only ^{129}I and ^{14}C will reach the accessible environment (1 mile boundary). These radionuclides have distribution coefficients close to zero. Recommended additional data requirements include (1) tests to determine the nature of the vertical permeability; (2) porosity measurements; and (3) deep potential measurements.

The approach taken by PNL, that of using a regional model to help define the local boundaries and boundary conditions, is a good one. Since limited data are available, this modeling effort is considered preliminary, and a simple model with few layers is justified. In fact, because of the scale of the regional model and the limited data, a one layer model probably would have been adequate. This is supported since they had to lump the Saddle Mountains and Wanapum Basalts into one layer, while for the Grande Ronde layer, they had to assume similar hydrologic properties to those of the Wanapum Formation. Why not treat all as one layer with leakage? For the local model, more layers are justified since the goal is to calculate travel times.

Four modeling studies have been or are currently being made by the USGS in the Columbia Plateau. These include: (1) a two-dimensional (areal) modeling study by J.E. Luzier and J.A. Skrivan in the Odessa-Lind area, (2) a three-dimensional coarse grid model of the entire Columbia Plateau, part of which was done by Bill Meyer, (3) a three-dimensional model of the Quincy Basin, Henry Buyer's project, and (4) a three-dimensional model of the Horse Heaven Hills area, Frank Packard's area. In addition to these studies, in 1983, a regional aquifer study is planned to be initialized by the USGS dealing with the entire Columbia Plateau. This is to be a four year study.

initiated

In summary, the U.S.G.S. presents several ideas and observations that are different from those of PNL and/or Rockwell. One important observation is the large amount of pumpage that occurs in the areas surrounding the Hanford location. These are producing drawdowns that average ten feet per year and extend into the Grande Ronde. And, at least in some locations, these drawdowns are thought to cause interbasin flow. The possible long-term effects of this pumpage on a repository need to be evaluated. Second, under pre-man conditions, no interbasin flow is thought to have occurred; discharge is to the low points, i.e., the rivers. Third, flow is structurally controlled. This helps lead to the conclusion that the interbeds control vertical flow and the vertical hydraulic conductivity is generally higher for areas with anticlines. They also feel that considerable vertical flow occurs in the basalts, which is contrary to Rockwell's beliefs. Finally, the main conclusion is that there is not enough data to adequately calibrate most models of the Columbia Plateau.

Other general impressions or comments are included below:

(1) The Columbia Plateau models, by virtue of the data limitations, should be considered preliminary, with results that are likely to be changed or modified, as more data are obtained. Hopefully, the various models will converge to similar results with the acquisition of this data.

(2) As a consequence of the above, obviously more data should be collected to help define the hydraulic system.

(3) More interaction among the various groups performing modeling at the Columbia Plateau is recommended, as well as among the geologists, hydrologists and modelers at the Hanford location.

(4) I suggest that as part of the sensitivity analysis, the Rockwell modeling should allow for a free surface at the top boundary.

(5) Can the different geochemistry of the water near the Columbia River be explained by mixing with water originating east of the river?

(6) The near-field work seems to be lagging behind the far-field work. The field work is considering only thermal-mechanical and ignores flow, while the modeling, at this point, considers only thermal and flow, but no mechanical. To complicate matters even more, certain stresses observed in the field heater experiments cannot be explained. A more integrated approach is needed for this very complicated problem.

(7) In order for the NRC to adequately evaluate modeling work performed at the Hanford location, it is important that all codes and data used be fully documented and incorporated into the quality assurance program.

JWM:dye

cc Nancy Finley, Sandia
Mark Reeves, Intera

DETAILED MEETING NOTES

PLN Meeting

On Monday morning, September 21, 1981, a meeting was held at Pacific Northwest Laboratories (PNL), Richland, Washington to discuss modeling performed by PNL on the Columbia Plateau. In attendance at the meeting were L. Lehman (NRC), N.C. Finley (Sandia), F.B. Nimick (Sandia), M. Reeves (Intera), F.H. Dove (PNL), C. Cole (PNL) and J.W. Mercer (GeoTrans). The meeting consisted of presentations by F.H. Dove and C. Cole. Mr. Dove, manager of the AEGIS Program, gave an overview of the project, while Mr. Cole discussed modeling activities. The remainder of this section will be used to summarize the PNL modeling activities.

The modeling of PNL was divided into two parts: (1) a regional model and (2) a Pasco Basin model. The regional model covered 21,000 square miles and had two active layers. The code VTT was used and two-dimensional flow was assumed in the layers, which were connected through the use of transfer coefficients between layers. The Pasco Basin model covered 2,000 square miles. The three-dimensional model, FE3DGW, was used with three active layers. Both models had the following major assumptions: (1) porous flow equivalent of composite transmissive zones and confining zones, and (2) the Grande Ronde Formation is similar hydrologically to the Wanapum Formation. The latter assumption was made because most wells are less than 400 feet in depth and only a few wells penetrate the Grande Ronde Formation.

The regional model was constructed to estimate flows and boundaries for the local or Pasco Basin model. It is similar to a modeling study performed by the U.S. Geological Survey, known as a coarse grid model that is used to estimate interbasin transfer. The region included in this study is shown in Figure 1. The finite-difference grid of the regional model had two active layers. The lower-most layer represented the Grande Ronde Formation (the Umtanum unit in the middle of this formation is the site of the proposed repository). The next layer represented two formations: the Saddle Mountain Basalts and, primarily, the Wanapum Basalts. An upper third layer was used in the model, but was not active (not part of the solution). Its purpose was to represent the alluvium (Ringold Formation). Where the alluvium was present or

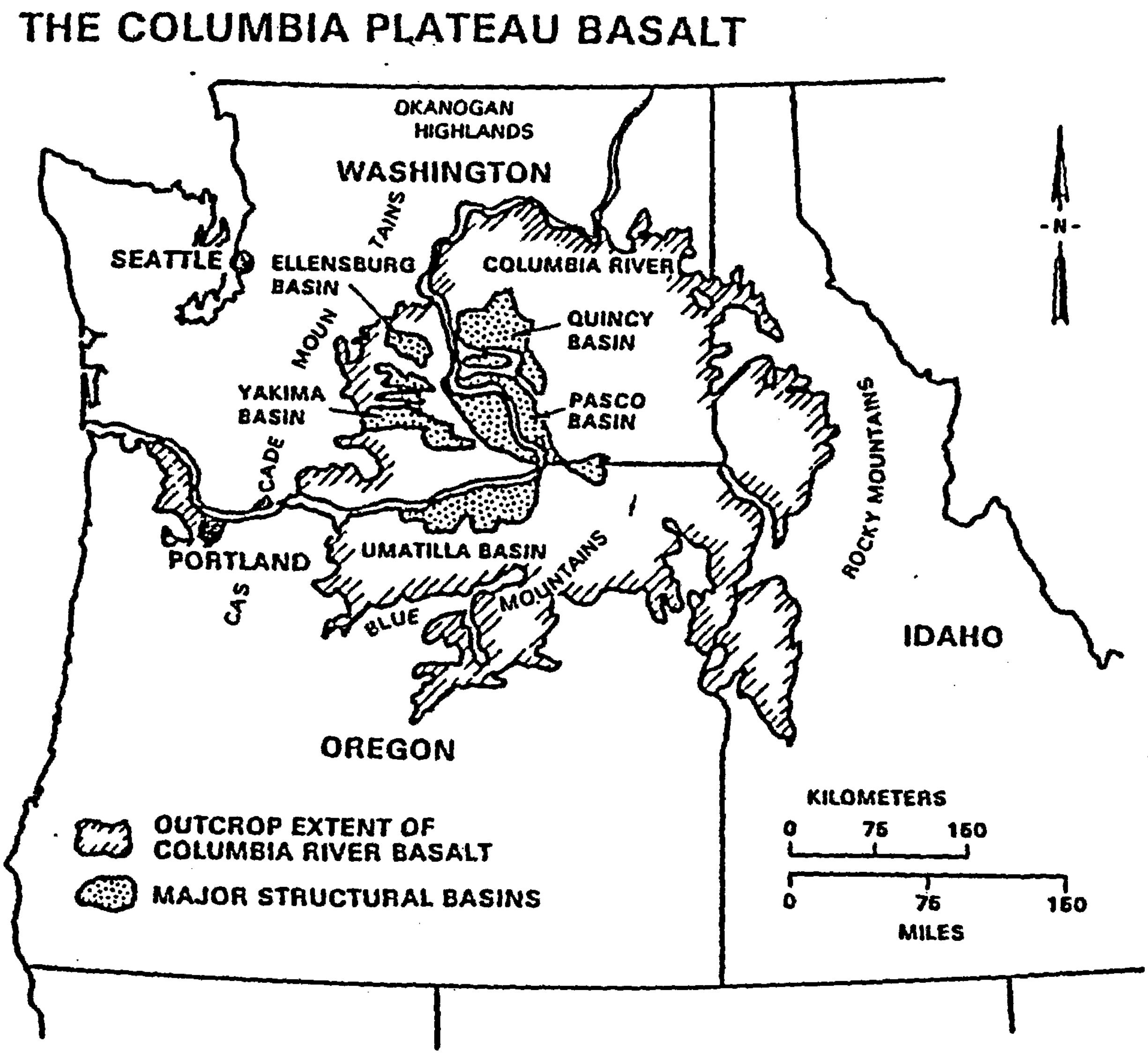

Figure 1. Regional features at the Columbia Plateau (from PNL slides).

where lakes and surface water bodies existed, this layer was considered constant head (a Dirichlet boundary). The lateral boundaries of the regional model were (see Figure 2): toward the north and east, the basalt edge (treated as constant head); toward the south, structural boundaries, such as the Craigmont Monocline, Limkiln Fault, Blue Mountains and Horse Heaven Hills Anticline; and toward the west, structural boundaries, such as Rattlesnake Hills Anticline. These latter boundaries were treated as no-flow because of structural evidence and the evidence of a ground-water divide. The regional model was a steady-state model that included sources and sinks, such as wells, recharge, etc.

There was little data for which to calibrate the model against; this was especially true for vertical characteristics and for the deeper, Grande Ronde Formation. It was also felt that discharge to the rivers was too small to provide a meaningful calibration quantity. This was decided after extensive recharge calculations were made using Land Sat Imagery (see Table 1). The primary observed data that was used for calibration was the potentiometric surface. However, this data was limited to primarily the following units: (1) water table, (2) Rattlesnake Ridge, and (3) Mabton. In order to match this surface, they had to decrease the horizontal permeability and increase the vertical permeability near anticlines. Geologically, this would be expected. Details of the calibration are summarized in Table 2. In general, the Saddle Mountain-Wanapum layer was recharging both the alluvium and the Grande Ronde Formation. An exception to this was the Pasco basin, where the Grande Ronde recharged the Saddle Mountain-Wanapum layer. PNL referred to this as distributed discharge.

The regional model was used to help define the local model of the Pasco Basin. The model used in this case was a three-dimensional finite-element code. There were three active layers, where again, the alluvium was treated as a Dirichlet boundary. The local model boundaries were somewhat arbitrary and are shown in Figure 3. The finite-element grid is shown in Figure 4. The boundary conditions for the boundaries that are common to both the local and regional models are treated as described before in the regional model. For the other boundaries, the Rattlesnake Hills were treated as no-flow (a

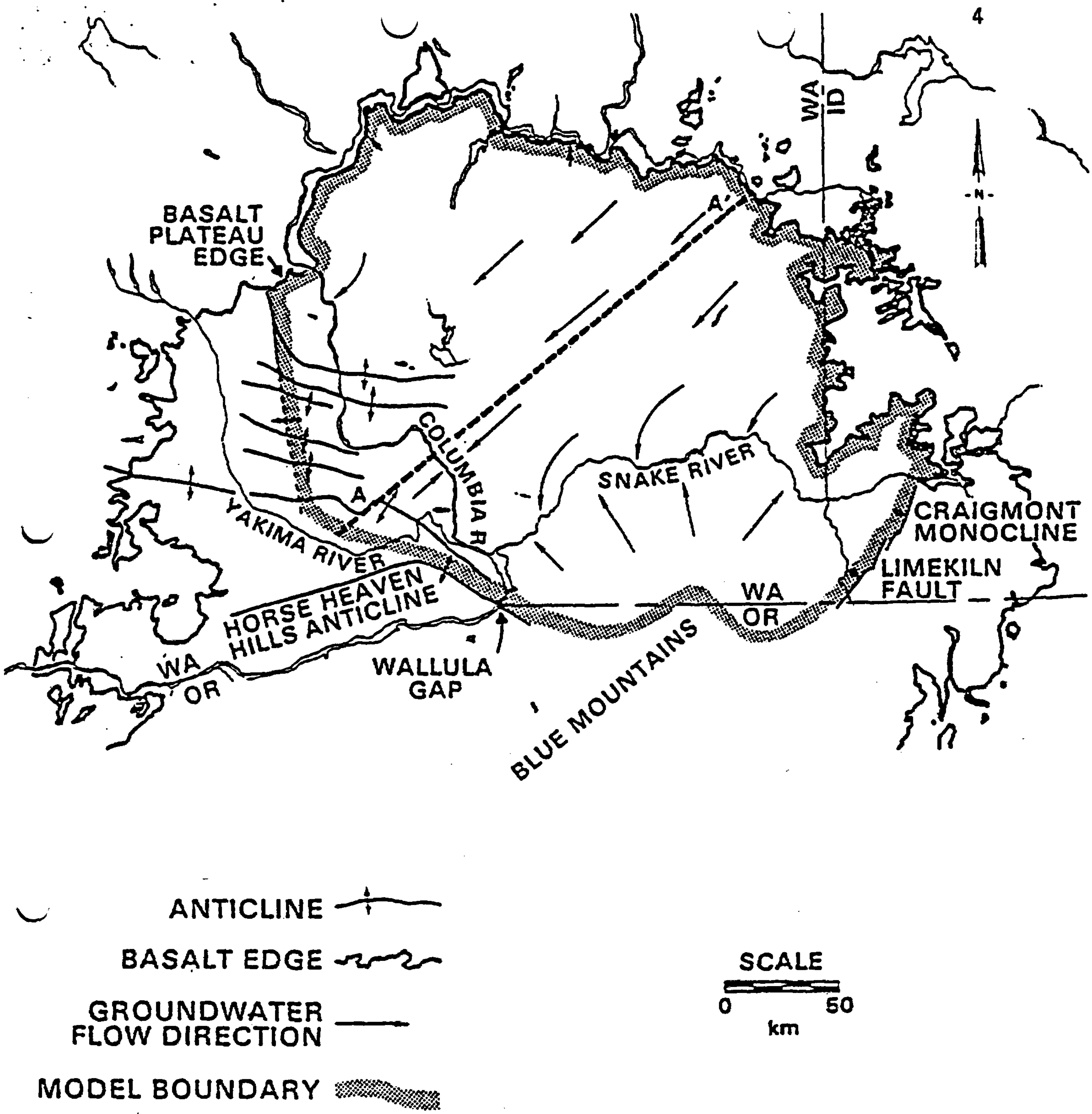

Figure 2. Boundaries of regional model (from PNL slides).

RECHARGE ESTIMATES MADE ON REGULAR GRIDS.
REGIONAL 3 MILE, 55 X 55, 21,000 SQUARE MILES
LOCAL 1 MILE, 78 X 67, 2,000 SQUARE MILES

GEOSTATISTICAL INTERPLOATION METHOD USED TO FIT PRECIPITATION AND PET DATA FROM WEATHER STATION MEASUREMENTS.

* ACCOUNTS FOR PRECIPATION CORRELATION WITH ELEVATION.
* UNBIASED ESTIMATOR TO DETERMINE OPTIMUM INTERPOLATION PARAMETERS.

REGIONALLY WE MOVE INTO AND OUT OF THE CASCADE RAIN SHADOW AS WE MOVE FROM WEST TO EAST.
PRECIPITATION CORELATION WITH ELEVATION A MORE GLOBAL FUNCTION OF ELEVATION.

* COLFAX IN NARROW VALLEY-PRECIPITATION FUNCTION OF SURROUNDING PLATEAU.

FOUR VEGETATION TYPES:
DRY LAND WHEAT, IRRIGATED, FOREST, SAGE BRUSH-CHEAT GRASS

REGIONAL RUNOFF FROM USDA DATA.

SPRINKLER EFFICENCY AND FALLOWING OF WHEAT ACCOUNTED FOR.

ESTIMATES	REGIONAL	LOCAL
PRECIPITATION	12.2 MAF/YR	772,000 AF/YR
AET	12.2	1,394,000
PUMPING	0.204	27,000
RECHARGE	2.66	287,000 (55,000) PREMAN
	1.22 IRRIGATION	
	0.93 SAGE-CHEAT	
	0.15 FOREST	
	0.36 DRY LAND WHEAT	

Table 2. Parameter for regional model (from PNL slides).

REGIONAL MODEL CALIBRATION
* TRANSMISSIVITY
(INITIAL)FINAL GPD/FT

SM-WP (25,000)-85,000
GR (60,000)-51,000
INCREASE IN CALIBRATED TRANSMISSIVITY NOT UNLIKELY
* INTERAQUIFER TRANSFER
(INITIAL)FINAL FT/DAY
SM-WP TO GR (.001) .00101 MAX.=.007
UPWARD FLUX 0.32 MAF/YR
DOWNWARD FLUX 0.64 MAF/YR (LOSS = 0.32MAF/YR)
ALLUVIUM TO SM-WP (.01) .0069 MAX.=.36
UPWARD FLUX .71MAF/YR
DOWNWARD FLUX 0.11MAF/YR (LOSS = 0.60MAF/YR)

LOSSES TO:	FROM SM-WP	FROM GR
RIVERS	.13MAF/YR	.59MAF/YR
	8.0 CFS/MILE	0.8-5.5 CFS/MILE(COLUMBIA-SNAKE)
LAKES	0.035MAF/YR	0.12MAF/YR
SEEPAGE FACES	0.011MAF/YR	0.015MAF/YR

LAKE LOSSES ABOUT EQUAL TO 40 INCHES/YR

INITIAL COMPARISONS WITH WELLS (UNCALIBRATED)

1958 246, 1968 402, 1978 367, INTERPRETED 701 FINAL INTERPRETED 214

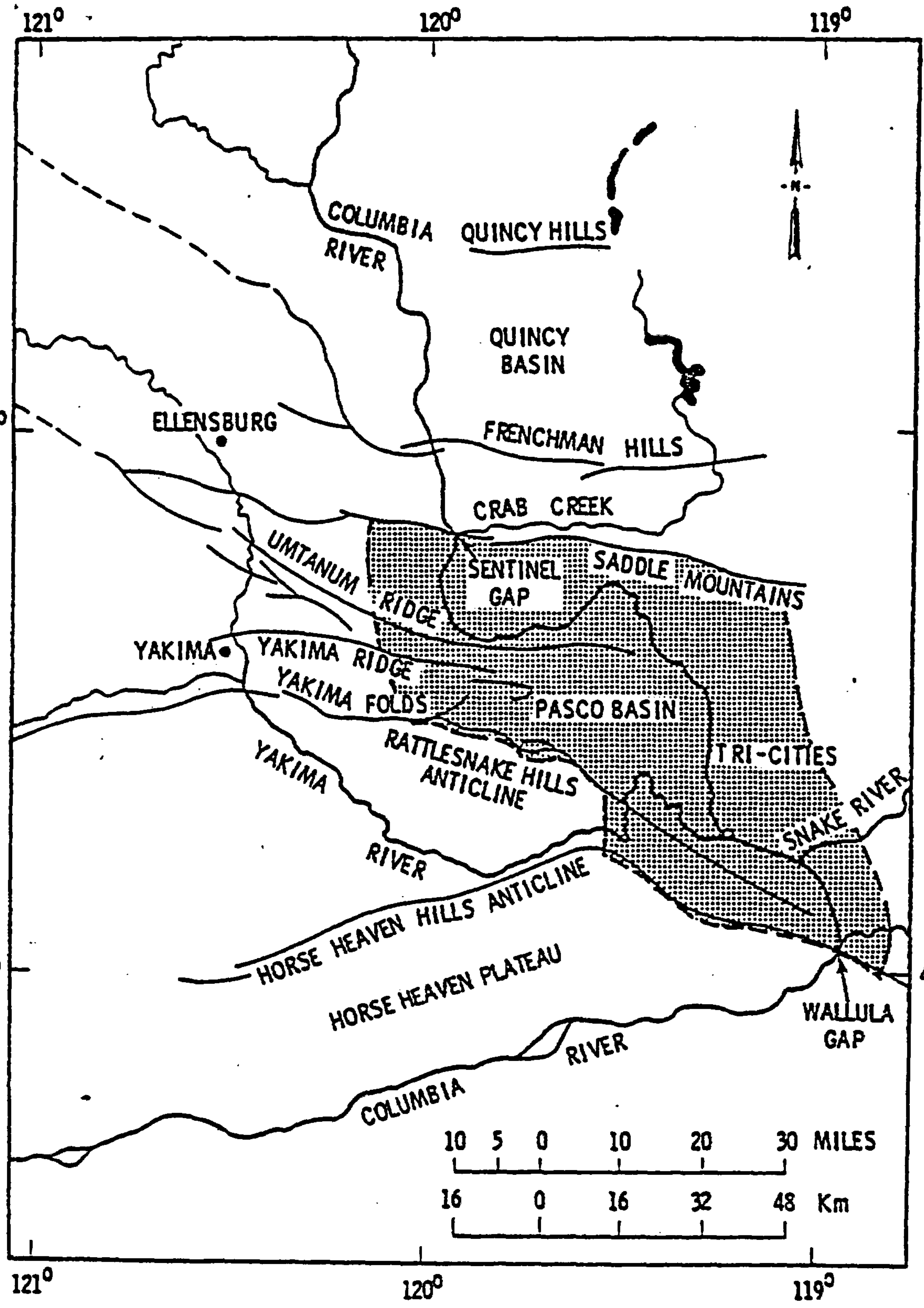

Figure 3. Pasco Basin boundaries (from PNL slides).

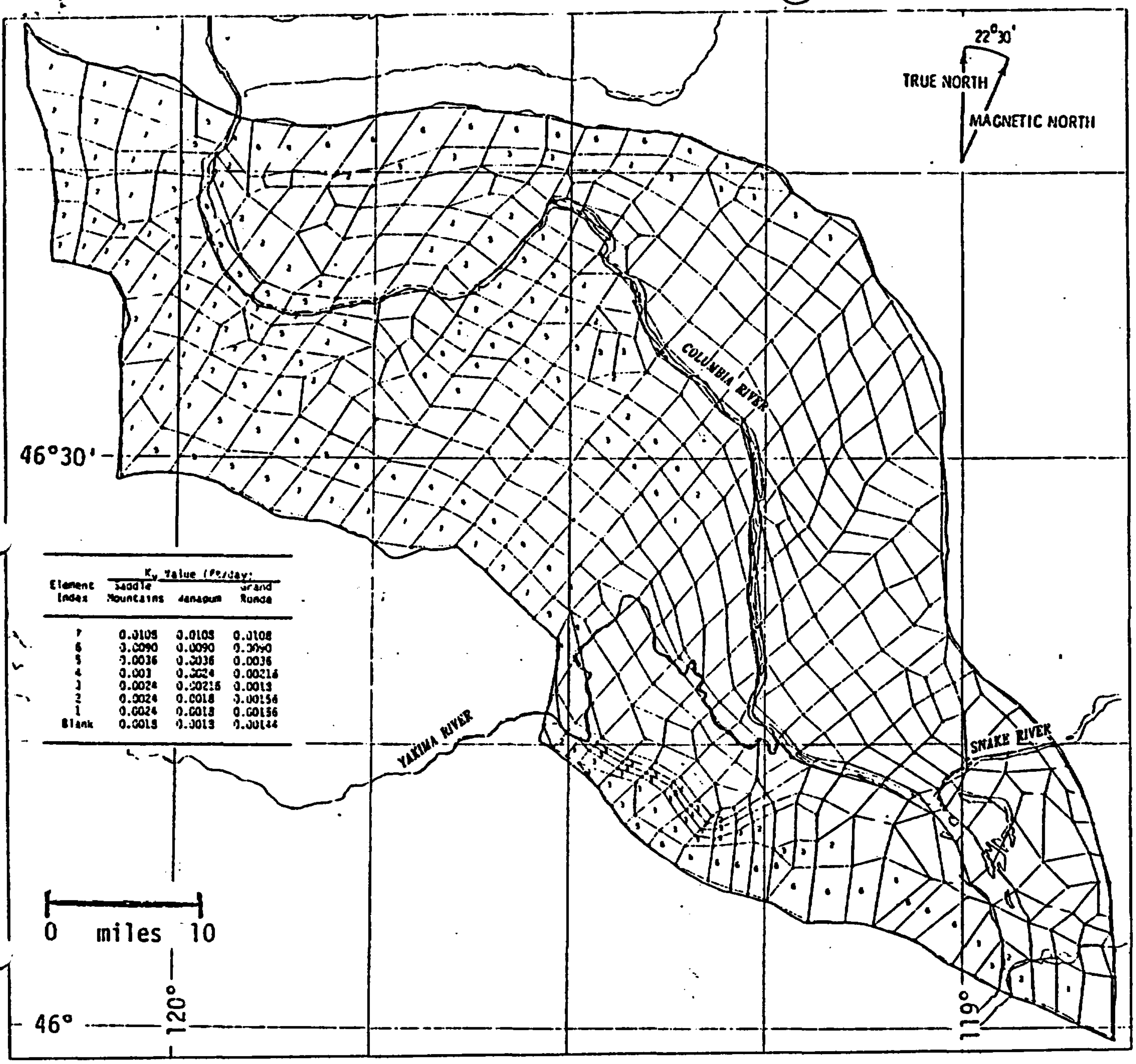

Figure 4. Pasco Basin finite element configuration (from PNL slides).

ground-water divide), whereas the remaining boundary was treated as constant head, determined from the regional model. Since the regional model was a two-layer, finite-difference model, and the local model was a three-layer, finite-element model, some type of extrapolation had to be used to obtain the appropriate head values for the constant head boundaries. Several approximations were used, with all being fairly insensitive to the computed travel time, since the path line was mainly in the vertical. As part of the modeling, anticlines were assigned a higher vertical hydraulic conductivity and a lower horizontal hydraulic conductivity than the surrounding rock. Details of the parameters used in the local model are given in Table 3 and on Figure 4.

The major conclusions from the local model include: (1) large scale vertical hydraulic conductivity is of order 0.001 ft/day; (2) supports vertical upward leakage in the Pasco Basin (what PNL calls distributed discharge); (3) supports ground-water divide for Rattlesnake - Hog Ranch - Table Mountain; (4) supports Saddle-Mountains as only permeability barrier; (5) pathway analysis indicates that radionuclides will move primarily vertically, with average ground-water travel time to the Columbia River calculated as about 15,000 years; and (6) in 10,000 years, only ^{129}I and ^{14}C will reach the accessible environment (1 mile boundary). These radionuclides have distribution coefficients close to zero. Recommended additional data requirements include (1) tests to determine the nature of the vertical permeability; (2) porosity measurements; and (3) deep potential measurements.

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Table 3. Parameter for Pasco Basin model (from PNL slides).

LOCAL OR PASCO BASIN MODEL SELECTION
* FE3DGW, 3-D, FINITE ELEMENT, STEADY STATE
* HANDLES MULTIPLE LAYERS AND VERTICAL MOVEMENT
* IRREGULAR SUBDIVISIONS FOR BETTER BOUNDARY DEFINITION
* INHOMOGENEITY AND ANISOTROPY

LOCAL MODEL DATA REQUIREMENTS
* LOCAL BOUNDARY
    - NORTH AND EAST ARE HELD FROM REGIONAL
    - SOUTH AND WEST ARE RECHARGE-STRUCTURAL
      NO FLOW GROUNDWATER DIVIDES (SAMES AS REGIONAL)
* GRID CONSTRUCTION
    - 606 SURFACE NODES
    - 555 SURFACE ELEMENTS
    - 4 LAYERS (ALLUVIUM, SM, WP, GR)
* STRUCTURE TOPS FOR EACH LAYER
* EQUIVALENT POROUS MEDIA K_H, K_V AND POROSITY (SCALE, COMPOSITING, HETEROGENEITY IMPORTANT)
    - INITIAL K_H 4.0 FT/DAY (SM)
    - INITIAL K_V/K_H RATIO 0.1 ALLUVIUM, 0.01 OTHERS
    - INITIAL POROSITY 0.1 AL, 0.095 SM, 0.07 WP, 0.06 GR
* STRESS (RECHARGE-PUMPING)
    - PUMPING 27,000 AF/YR (13000 AF/YR LOW YIELD WELLS IN CIRCLED AREA)
    - RECHARGE 287,000 AF/YR (55,000 PREMAN)
      (DISTRIBUTION OF STRESS IMPORTANT)

USGS Meeting

On Monday afternoon, September 28, 1981, a meeting was held at the U.S. Geological Survey, Tacoma, Washington, to discuss their modeling associated with the Columbia Plateau. In attendance at the meeting were Bob Wright (NRC), Paul Prestholt (NRC), Linda Lehman (NRC), Nancy Finley (Sandia), Fran Nimick(Sandia), Mark Reeves (Intera) Jim Mercer (GeoTrans), Bill Meyer (USGS), Frank Packard (USGS), and Henry Buyer (USGS). Four modeling studies have been or are currently being made by the USGS in the Columbia Plateau. These include: (1) a two-dimensional (areal) modeling study by J.E. Luzier and J.A. Skrivan in the Odessa-Lind area, (2) a three-dimensional coarse grid model of the entire Columbia Plateau, part of which was done by Bill Meyer, (3) a three-dimensional model of the Quincy Basin, Henry Buyer's project, and (4) a three-dimensional model of the Horse Heaven Hills area, Frank Packard's area. In addition to these studies, in 1983, a regional aquifer study is planned to be initialized by the USGS dealing with the entire Columbia Plateau. This is to be a four year study.

The two-dimensional model study of the Odessa-Lind area is the only published study:

Luzier, J.E. and J.A. Skrivan, 1975. Digital-simulation and projection of water-level declines in basalt aquifers of the Odessa-Lind area, east central Washington, Water Supply Paper 2036.

This area was chosen because it is the most developed, in terms of ground-water use, on the Columbia Plateau. This area is northeast of the Hanford site, including parts of Adams, Grant, and Lincoln Counties. The maximum usage of ground water is tending to move south toward the City of Pasco. It is interesting to note that the drawdown in the Grande Ronde/Wanapum combined units was similar to the drawdown in the Wanapum/Saddle Mountain combined units. Also, this rate of drawdown is controlled by state law to be less than ten feet per year.

The coarse grid model study was designed to evaluate data needs. As part of this study, the U.S.G.S. was supposed to evaluate Gupta's model, but because the model did not contain a mass balance, the Survey opted to use its own three-dimensional flow code. The study was terminated prematurely when the U.S.G.S. interpretation of the flow system differed from that of Rockwell; however, a report summarizing the study is in the review process. The coarse grid model simulated steady-state conditions and consisted of two layers. The Saddle Mountain and Wanapum Basalts were lumped into one layer and the second layer consisted of the Grande Ronde Basalt. Calibration was to the potentiometric surface prior to development. This lead to a leakance (K'/ℓ') for the Vantage of 1.3×10^{-11}/s. After considerable sensitivity analysis, the main conclusion was that there was not enough data to adequately calibrate the model. The upper boundary of the U.S.G.S. model was treated similarly to the PNL model, that is, constant head where surface water occurs, recharge elsewhere. It is interesting to note that, unlike PNL, they do not believe that any interbasin flow is occurring (except possibly due to pumpage). The rivers are the lowest points and discharge occurs along them. Data for this model was obtained from the GWSI and subsequently corrected by Lynn Popinka. The final report will be a Washington Department of Ecology report.

The Quincy Basin model is a current project working with one of the subbasins in the Columbia Plateau. The model consists of three layers: (1) the Ringold Formation, (2) Wanapum Basalt, and (3) the Grande Ronde Basalt. The main emphasis of the study is on the shallow system, comprised of the unconsolidated material. In this area, the unconsolidated material is about 300 feet thick and the Wanapum is about 400 feet thick, with the Wanapum considered to have a permeability that is an order of magnitude less than the unconsolidated material. For the Grande Ronde in this subbasin, they believe recharge is from irrigation and discharge is to the Columbia River.

The Horse Heaven Hills study is a current project and actually considers two models: (1) a vertical cross-sectional model and (2) a three-dimensional model. This area is just north of and adjacent to an area in Oregon known as the Columbia Slope, which is also being modeled by the U.S.G.S. They believe that pumpage in Oregon may be causing underflow beneath the Columbia River. The cross-sectional model consisted of five layers: (1) Saddle Mountains, (2) Mabton, (3) Wanapum, (4) Vantage, and (5) Grande Ronde. The two lateral boundaries were associated with an anticline and the Columbia River, and were considered no-flow. The purpose of the model was to examine the vertical connection between layers. They believe that much vertical movement occurs in the basalts, while the interbeds, such as the Mabton and Vantage, offer resistance to vertical flow. Data for the model included the following transmissive data:

Saddle Mountains	$T = 10^{-3} - 10^{-5}$ ft^2/s	(lateral)
Wanapum	$T = 10^{-2} - 10^{-4}$ ft^2/s	(lateral)
Interbeds	$K_v = 10^{-9}$ ft/s	(under river)
	$K_v = 10^{-12}$ ft/s	(under anticline)

Note that, unlike PNL, the vertical hydraulic conductivity associated with the anticline is not the highest. The highest hydraulic conductivity, under the river, is attributed to sand beds found there. Also, from their results, the vertical gradient in hydraulic head in the Grande Ronde was almost negligible. The flow in the Grande Ronde comprised about 25 percent of the flow in the entire sequence modeled in the cross section.

The three-dimensional model of the Horse Heaven Hills area extended south to approximately the Columbia River, east to Wallula Gap, north to the Yakima River, and west to several deeply entrenched streams. The enclosed area included an anticline and two large pumping centers. The model consisted of three layers: (1) Saddle Mountain, (2) Wanapum, the main aquifer, and (3) the Grande Ronde. These were connected through leakance coefficients. Even though the Grande Ronde was included as an active layer, only two wells penetrate the Grande Ronde in this study area, and they were drilled by the Department of Ecology. The model is considered preliminary and again, the purpose was to determined data availability and adequacy. They feel that the hydrology is structurally controlled. For example, the interbeds are believed to control the vertical flow. The Mabton interbed, an ash fall, is thick in synclines and thin on anticlines. Therefore, leakance associated with anticlines should be higher than that of the surrounding area. As pointed out earlier, this rule is violated in this area because of the sand beds under the river. They expect the Vantage to behave similarly to the Mabton. Other observations on this study include: (1) the wells are cased such that good head data are obtained, as opposed to composite heads (this is generally not the case), (2) the Saddle Mountain Basalt generally has a permeability that is an order of magnitude less than that in the Wanapum Basalt, and (3) the rate of drawdown within the Wanapum is about 10-15 feet per year.

In summary, the U.S.G.S. presents several ideas and observations that are different from those of PNL and/or Rockwell. One important observation is the large amount of pumpage that occurs in the areas surrounding the Hanford location. These are producing drawdowns that average ten feet per year and extend into the Grande Ronde. And, at least in some locations, these drawdowns are thought to cause interbasin flow. The possible long-term effects of this pumpage on a repository need to be evaluated. Second, under pre-man conditions, no interbasin flow is thought to have occurred; discharge is to the low points, i.e., the rivers. Third, flow is structurally controlled. This helps lead to the conclusion that the interbeds control vertical flow and the vertical hydraulic conductivity is generally higher for areas with anticlines. They also feel that considerable vertical flow occurs in the basalts, which is contrary to Rockwell's beliefs. Finally, the main conclusion is that there is not enough data to adequately calibrate most models of the Columbia Plateau.

11.0 Trip Report by M. Reeves (INTERA) on Various Modeling Efforts

FROM: Mark Reeves
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TO: Nancy C. Finley and R. M. Cranwell
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SUBJECT: Visits to PNL and RHO (Richland) and to USGS (Tacoma), 8/21 - 28/81.

The purpose of this report is to compare and contrast three different approaches to hydrologic modeling of the Pasco Basin. These approaches represent several years of effort by staff members of Pacific Northwest Laboratories (PNL) and Rockwell-Hanford Operations (RHO) at Richland and the U.S. Geological Survey (USGS) at Tacoma. The ultimate objective, of course, is to use the above-mentioned studies as a basis for formulating our own modeling approach to the far-field modeling of basalt. The latter is appropriate for reference-repository definition and for alternate-media methodology development, and perhaps, also for site-specific analyses.

There are several scales of resolution from which a repository site may be analysed. On this trip, three of them were examined, namely the repository near field, the basin and the region. The near-field analysis done only by RHO consisted of a two-dimensional analysis of flow and heat in the vicinity of the reference repository. Colonnades were assumed to have vertical fractures and entablatures were assumed to have both vertical and horizontal fractures. A discrete-fracture model was used in each case. Flow tops were characterized as having a dual porosity. Coupled heat and flow calculations were presented. One result was that travel times were longer for the coupled heat and flow calculations than for flow alone. Most likely this curious circumstance resulted from the assumed boundary conditions which admittedly were not consistent with the far-field simulation. However, the near-field simulation was examined only superficially since the major interest was in analysis at the larger scales.

Probably the most important calculation to be performed in the far-field modeling is that of travel time (T) and flow path for a tracer particle originating within the reference repository location (RRL) and traveling to the biosphere-discharge point. At present such a determination is uncertain due to a lack of calibration data. Consequently results differ widely. PNL obtains travel time of the order $T = 10^4$y with a flow path taking the most direct water to the Columbia River. RHO, on the other hand, obtains a travel time which they "conservatively" report as being of the order $T = 10^5$y. However their actual results would be more like $T = 10^6$y, since their reference particle is still within the Grande Ronde as it exits the simulated system beneath Wallula Gap and shows no indication of rising.

Why the difference? RHO says that PNL did not have sufficient data with which to calibrate. However, RHO may have used data from only DC-14 (located in the horn of the river) in addition to that used by PNL. Further, RHO says that PNL's vertical head gradients are too high relative to the data. However, such a circumstance could be rectified by simply increasing vertical permeabilities, thereby further reducing PNL's travel times. Vertical permeabilities are already an order-of-magnitude higher in PNL's calculation than in RHO's calculation. Perhaps they should be increased still farther.

Boundary conditions strongly influence flow within the basin. For example, RHO's side boundary conditions, in and of themselves, indicate a flow path from the RRL toward Wallula Gap with a swing east under the Snake River. Further, the side boundary conditions indicate that <u>recharge</u> is occurring in the vicinity of Wallula Gap. Hence a fluid particle in the Grande Ronde Formation cannot possibly rise to be discharged into Lake Wallula. It must be discharged through the southeast side of the basin. The point here is that the flow path determined by Rockwell was predetermined by their side boundary conditions. Rockwell claims that their boundary conditions were used as adjustable parameters to fit the available head data. However, there is only one well, DC-15, in the area which penetrates the Grande Ronde and it has a slight upward gradient rather than the downward gradients used in the nearby boundary conditions. Further, it would appear from the presentation that data from DC-15 was not used in this analysis. To say the least, Rockwell's side boundary conditions are suspect, particularly in the vicinity of Wallula Gap.

PNL, on the other hand, uses a regional model to fix boundary conditions. This procedure is not completely error-free, however. As concluded by USGS from their coarse-grid study, there is insufficient data for calibration of a regional model of the Columbia Plateau. However, such a procedure does bring the regional flow dynamics, as well as it is known, to bear on boundary-condition determination. In this sense use is made of available regional data from wells, lake and river elevations. To me such a procedure is much more defensible than Rockwell's procedure.

In addition to the coarse-grid model for most of the Columbia Plateau, the USGS is also constructing models of the Quincy Basin and the Horse Heaven Hills. In both cases discharge goes directly to the Columbia River, in sharp contrast to Rockwell's work.

In summary, then, I think that the PNL model of the Pasco Basin is the best constructed to date and is an acceptable starting point for the NRC modeling. The NRC model should be refined both by including more of the features of the USGS conceptual model in the regional simulation and by adjusting vertical permeabilities for consistency with RHO's data in the Pasco Basin simulation. Further, important interbeds and interflows should be included explicitly. This will facilitate both the comparison with data and the analysis of transport from the RRL.