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NIPDR
Pocket 1

Analysis of the Boundary Conditions and

Conductivity Ratios Used in Pasco Basin Modeling

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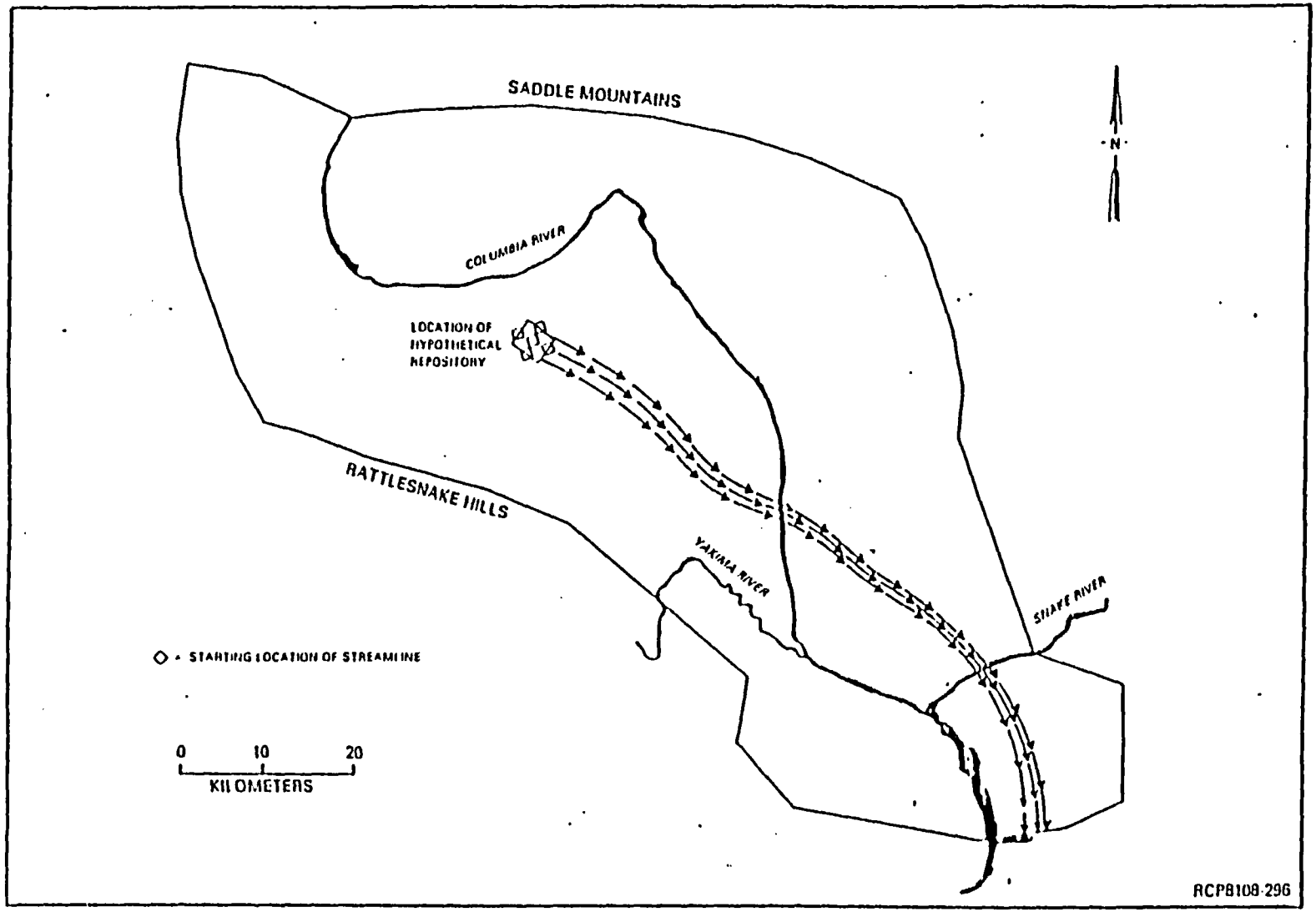


Figure 1. Flow Path Derived From RHO Simulation
(After, RHO-BWI-LD-44)

evaluate the differences between the model setups. A detailed description of these analyses is contained in the Comparion on Models, Lehman and Quinn, 1982. Briefly the principal difference is the choice of boundary conditions. The largest difference is found along the northwestern boundary of the basin while the largest difference in downhole distribution occurs in the southeastern section of the model (Figure 2-4). Less significant differences are present along the northern and eastern sections of the basin (Figures 5 and 6). There are also some differences in the choice of the ratio of vertical to horizontal conductivity used in the models. The above differences are recognized by RHO as important issues to be resolved before site characterization. Workshops are being conducted to resolve the differences in the modeling approaches and to decide on the most reasonable set of boundary conditions given the available data. The consensus building is scheduled for completion in October.

NRC has conducted some preliminary analyses in an attempt to (1) better understand the flow system and (2) gain some insight into the areas which are most important for field testing. The work that has been done is consistent with the plans for BWIP sensitivity analyses (Attachment 1). The two factors of interest are the boundary conditions of the system and the ratio of vertical to horizontal conductivity. The gridding structure and the layering used are shown on Figures 6 and 7.

The runs described are not meant to be a comprehensive sensitivity analysis. For most runs, parameters are varied individually rather than in concert. Similarly, no statistical sampling technique is used to choose parameter values. Parameter choice is based on the need to evaluate particular changes in the system rather than an attempt to

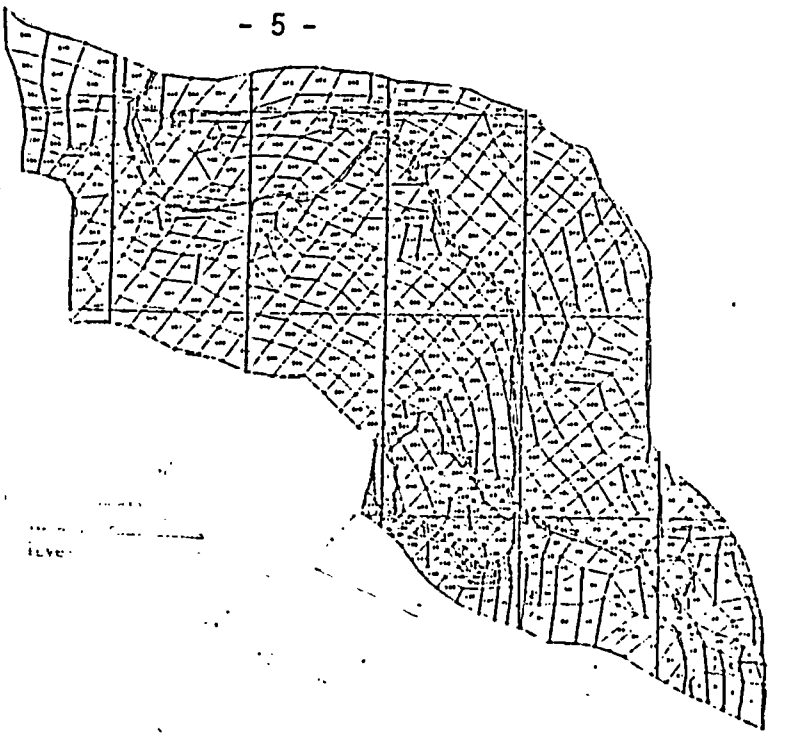


Figure 4. Area of Model Disagreement (Southwest Boundary)

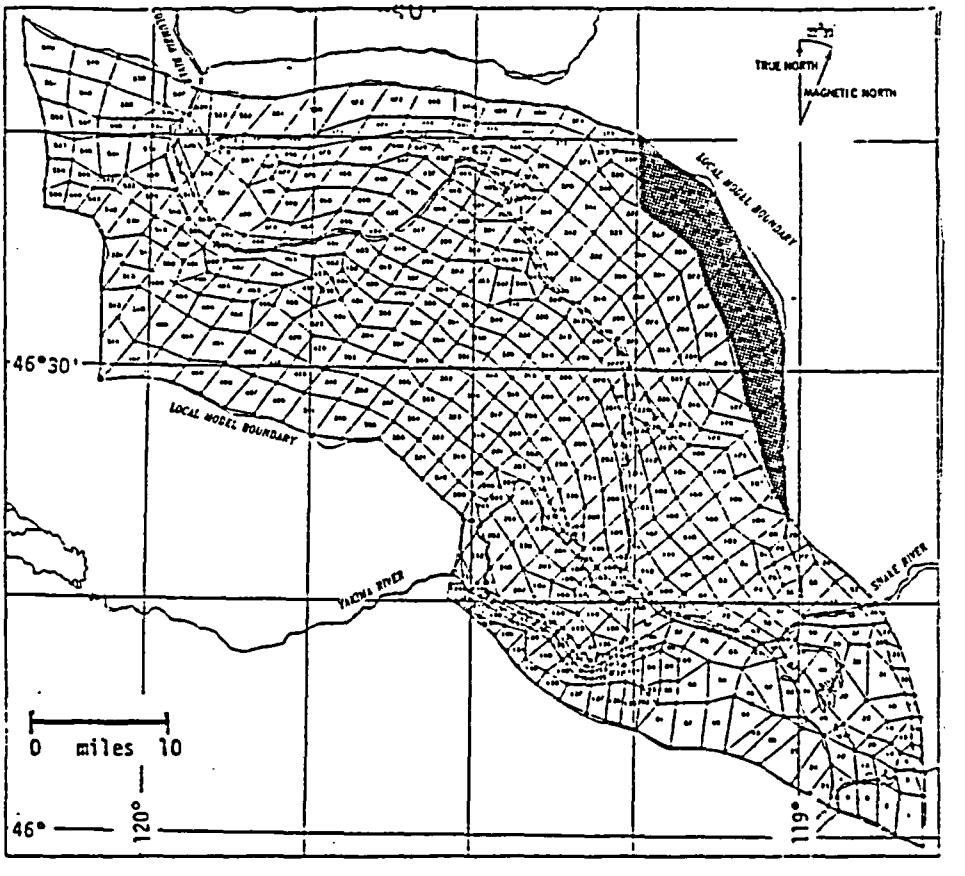


Figure 5. Major Areas of Model Input Disagreement (Southeastern Pasco Basin)

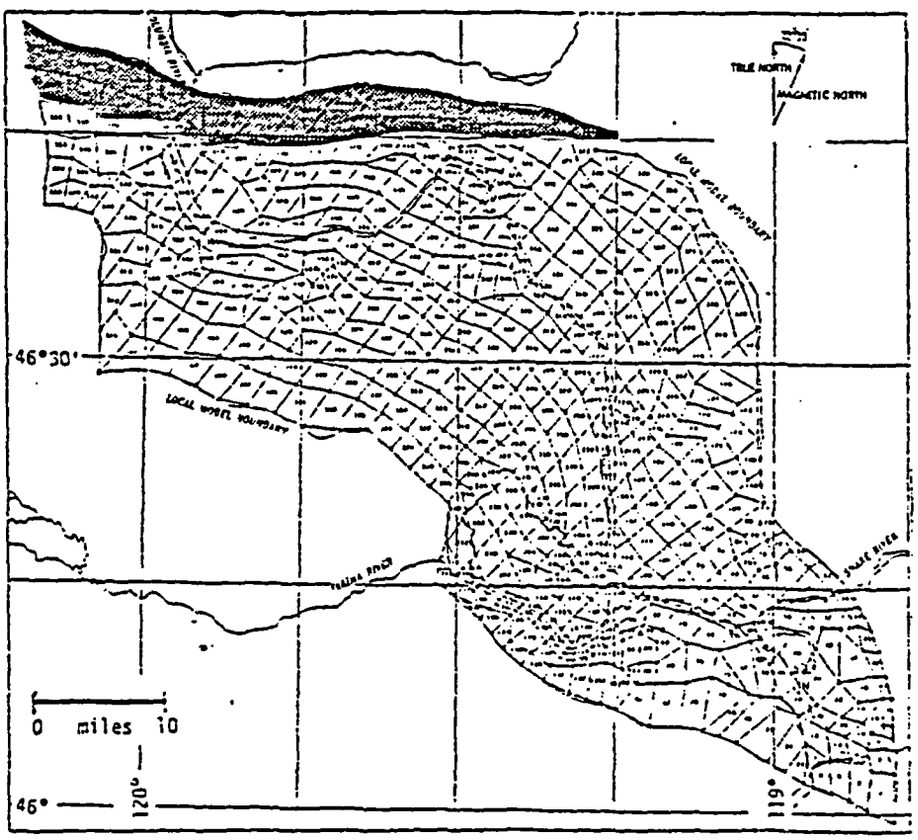


Figure 6: Areas of Model Input Disagreement (Northern Pasco Basin)

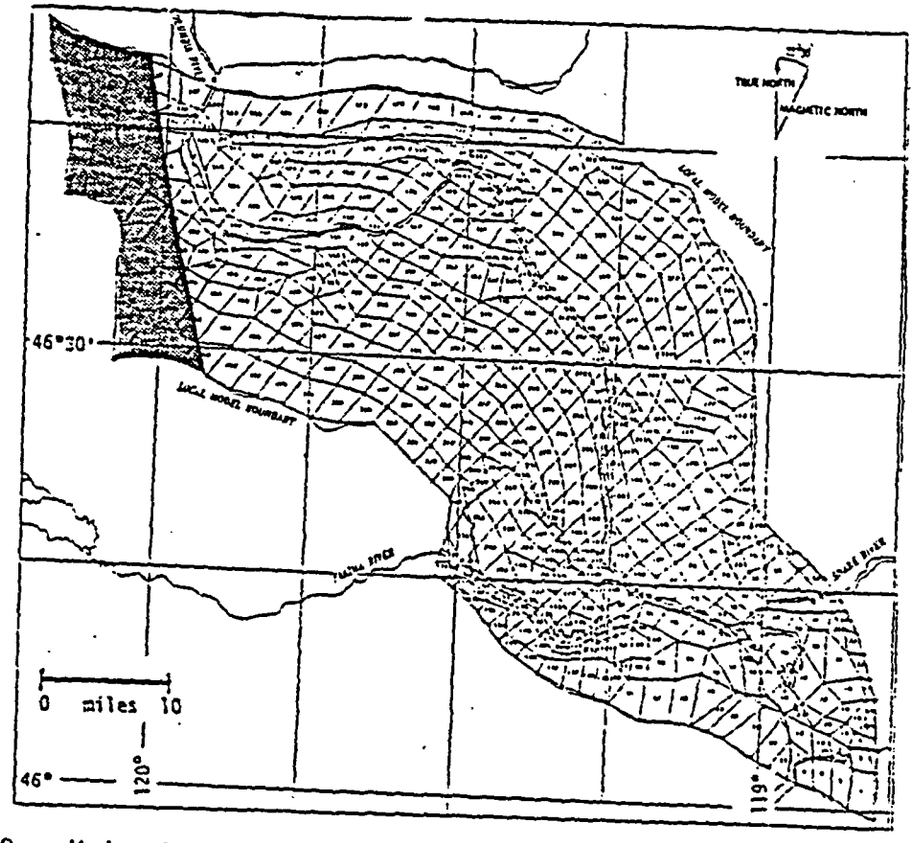


Figure 2. Major Areas of Model Input Disagreement (Northwest Pasco Basin)

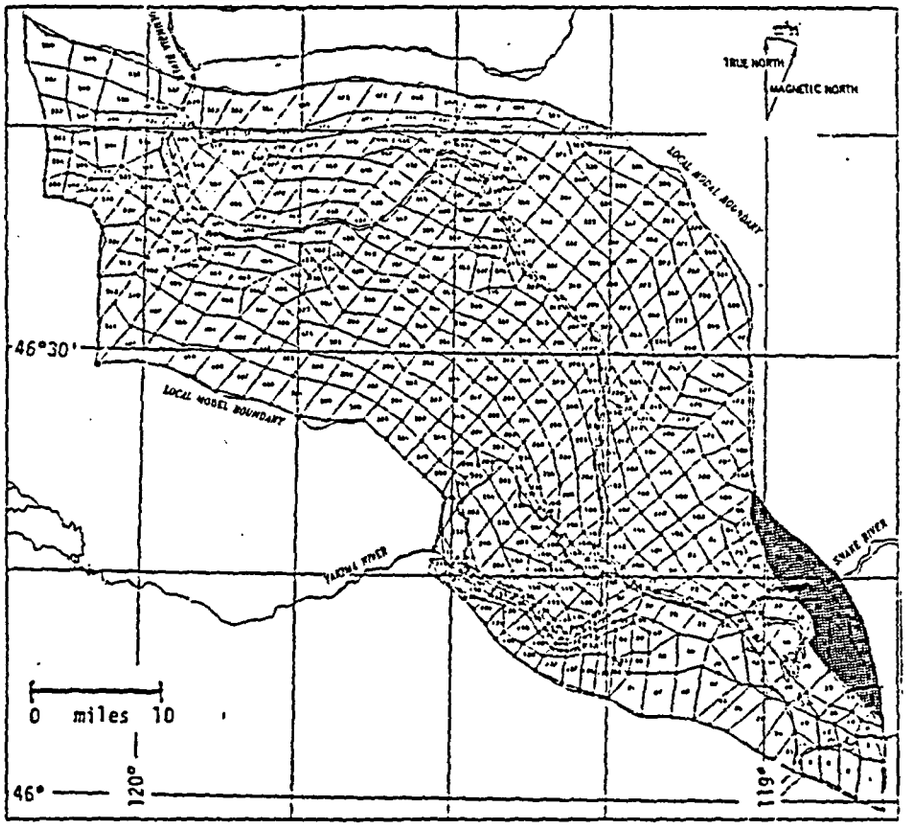
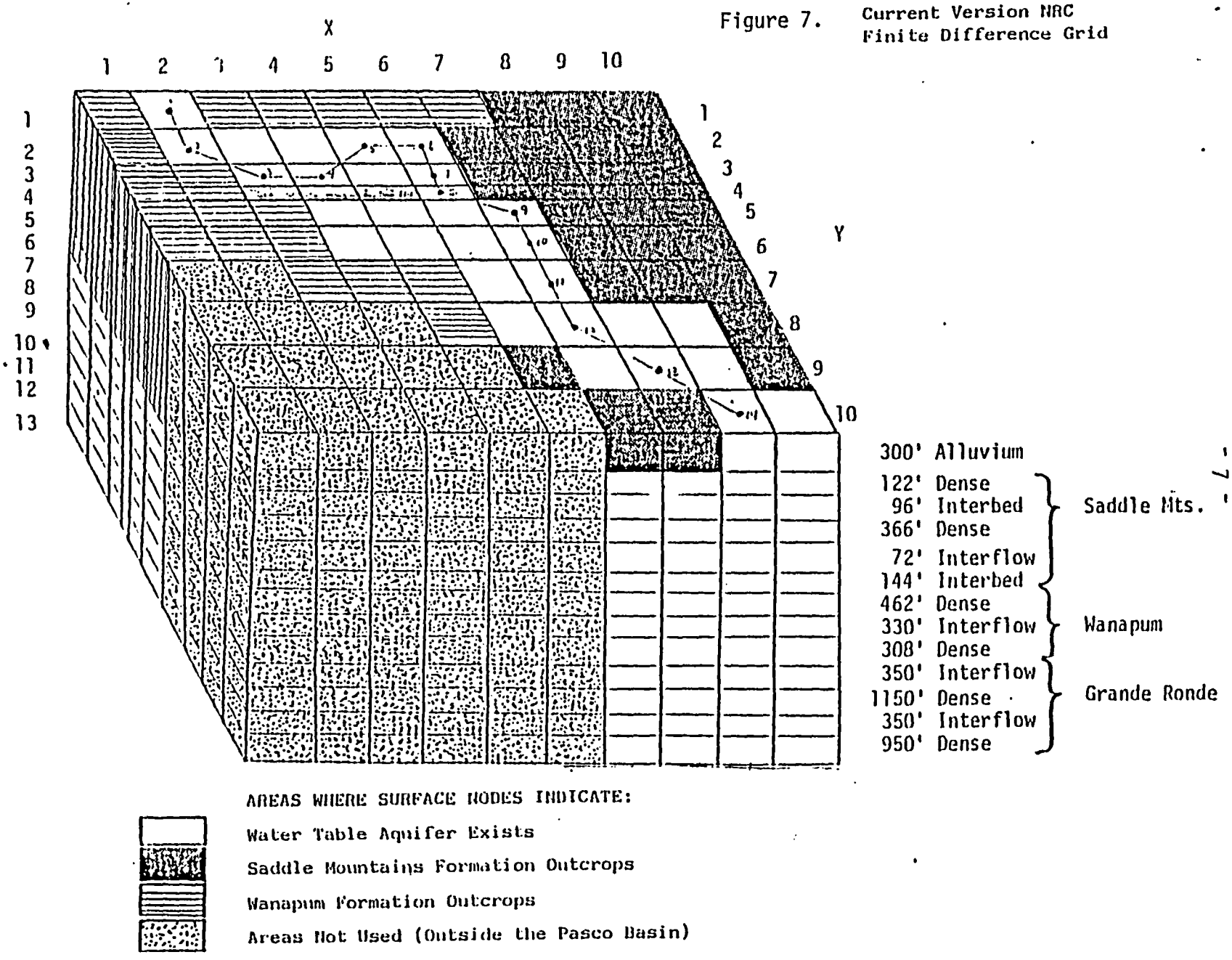


Figure 3. Major Areas of Model Agreement (Southeastern Pasco Basin)

Figure 7. Current Version NRC Finite Difference Grid



AREAS WHERE SURFACE NODES INDICATE:

- Water Table Aquifer Exists
- Saddle Mountains Formation Outcrops
- Wanapum Formation Outcrops
- Areas Not Used (Outside the Pasco Basin)

Figure 8.

Current NRC Layering

Layer 1	Alluvial Water Table Aquifer	300 ft.
Layer 2	Dense Basalt Saddle Mountains Fm.	122 ft.
Layer 3	Interbeds Saddle Mountains Fm.	96 ft.
Layer 4	Dense Basalt Saddle Mountains Fm.	366 ft.
Layer 5	Interflows Saddle Mountains Fm.	72 ft.
Layer 6	Interbeds Saddle Mountains/Wanapum	144 ft.
Layer 7	Dense Basalt Wanapum Fm.	462 ft.
Layer 8	Interflows Wanapum Fm. ,	330 ft.
Layer 9	Dense Basalt Wanapum Fm.	308 ft.
Layer 10	Interflows Grande Ronde Fm.	350 ft.
Layer 11	Dense Basalt (Umtanum included)	1150 ft.
Layer 12	Interflows Grande Ronde Fm.	350 ft.
Layer 13	Dense Basalt Grande Ronde Fm.	950 ft.

prioritize the importance of all variables. All of the runs are performed as steady state analyses.

The standard of measure is also more qualitative than quantitative. Frequently, runs using NWFT compare the results to some known standard of radionuclide discharge such as the draft EPA standard. In these analyses the flow path has been set and the importance of the parameters along that path is the principal concern. However our Pasco Basin analyses are evaluating the sensitivity of the flow path to changes in the system. The basis of comparison then is a significant change in the flow path as viewed in the particle tracking plots or pressure contours.

The groundwater travel times associated with these changes in flow direction should not be considered reliable estimates of groundwater travel time for the site. At the time of this exercise no reported measurements of effective porosity existed for the Hanford site. Since the travel time will be dependent on this parameter, this is one of the constraints on the analysis.

To complete the suite of analyses, sensitivity studies are now being conducted for basalt using NWFT/DVM. Parameter ranges are being chosen and the the Latin Hypercube sampling method will be used to select the input values. These runs will determine the geochemical parameters (solubility limits and Kd values) necessary to meet the EPA Standard. The analyses will also evaluate the importance of borehole and shaft seal failures and their relation to site performance. These analyses will be conducted for operating plan committments 311448 and 311449.

Variations of the Conductivity Ratio

Before discussing the results of the computer simulations, it is useful to review the data base for the analysis. Three layer types with different hydrologic characteristics exist in the section: interbeds, interflows, and dense basalts. The interbeds, sedimentary units deposited between flow episodes, are located in the Saddle Mountain Formation. They comprise approximately 30% of this unit. The interflows, the brecciated flow tops and/or bottoms of the basalt layers, are located throughout the section. They comprise anywhere from 8-14% of each formation. The interflows generally increase in thickness down the section; an approximately 100' thick interflow layer occurs directly above the Umtanum unit (Figure 9). The dense basalt layers are the relatively intact flow centers which occur throughout the section. The Umtanum, a dense basalt unit in the Grande Ronde Formation, is currently being considered as a potential repository horizon.

The values of conductivities used are principally from the tests done in the Rockwell drillholes on the Hanford Reservation. The Rockwell hydrology document, ST5, reports the following ranges for the horizontal conductivities:

1) interbeds - 10^{-1} - 10^{2} ft/day
2) interflows - 10^{-2} - 10^{4} ft/day
3) dense basalts - 10^{-3} - 10^{-8} ft/day

During our recent visit to Hanford for the hydrology workshop (July 21-27), Rockwell identified the base information which was used for selecting conductivity values in the model (Table 1). The majority of the measurements have been taken on the higher permeability zones because these are the major pathways for water movement and because they are more

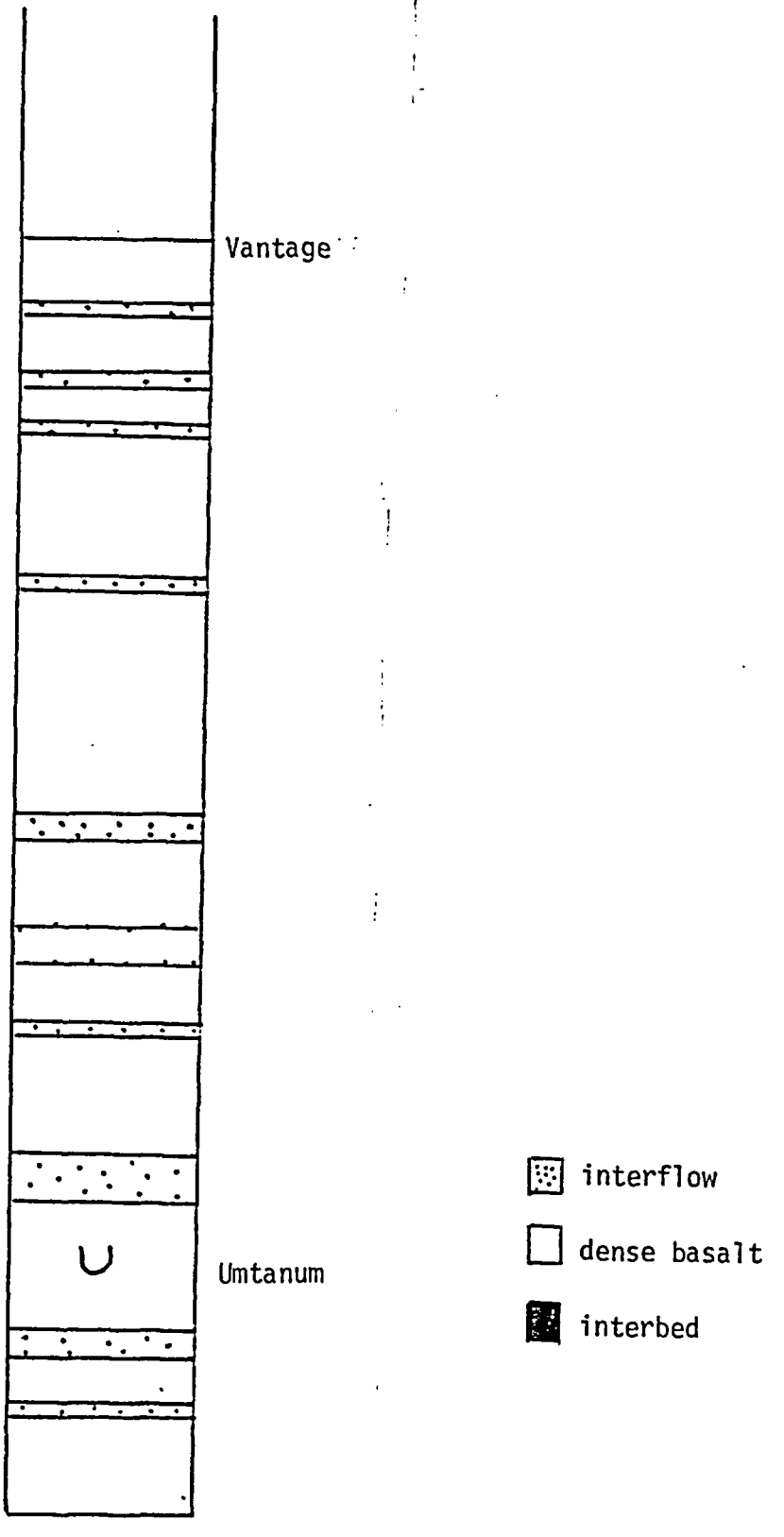


Figure 9. Stratigraphic Column for the Upper Portion of the Grande Ronde Formation (info. taken from DC-4)

Table 1. Basic Test Information From Drill Holes That Exists For Modeling

Drill Hole	Units Tested
DC 12	6 interflow Wanapum 11 interflow Grande Ronde
DC 3	Grande Ronde dense basalt 1 measure
DC 6	interflow GR 6 2 dense basalt Grande Ronde
DC 7/8	5 interflow Grande Ronde
DC 12	6 interflow Wanapum 11 interflow Grande Ronde
DC 14	7 interflow SM 9 interflow Wanapum 11 interflow Grande Ronde
DC 15	6 interflow SM 9 inteflow Wanapum 11 interflow Grande Ronde
DC 16A	4 interflow SM 4 interflow Pinkerton
RRL 2	1 interflow SM 5 interflow Wanapum 2 interflow Grande Ronde
DB Wells	22 interflow SM 14 interflow Wanapum 2 dense basalt Wanapum
Cold Creek	5 interflow Wanapum

Note: 3 dense basalt measures in Grande Ronde, 2 dense basalt in Wanapum measures.

amendable to conventional testing. Note also that all reported values are for horizontal conductivity; no measurements of vertical conductivity have been taken. Since the concern for the flow path is the ratio of vertical to horizontal conductivity, the uncertainty associated with the value is greatly increased.

A commonly used assumption is that the vertical permeability of the dense basalts may be one or two orders of magnitude higher than the horizontal. No substantive argument can be made in favor of, or against this choice. The problem is further complicated by the effect of compositing layers of varied hydrologic character. The choice of a ratio then becomes the result of calibration rather than an attempt to represent the hydrologic properties of the beds.

NRC has already determined that a change in the conductivity ratio could alter the direction of flow (Comparison of Codes, Lehman and Quinn, 1982). Extreme changes such as assigning equal vertical and horizontal conductivities to the sequence cause particles to discharge at the Columbia River. The critical ratio (Kv/Kh) which causes the water path to change from principally horizontal to principally vertical flow appears to be approximately 10^{-3}. The conductivities used for base analyses are shown on Table 2.

The purpose of these additional runs is (1) to test the importance of changing isolated layers in the system; (2) to further define the value which changes the flow direction; and (3) to determine the influence of changes related to structure.

TABLE 2.

HYDRAULIC PROPERTIES USED IN PRELIMINARY MODELS

Rock Unit	K_x	K_y	K_z	Ø
Alluvial Aquifer	10^3	10^3	10^{-1}	.25
Dense Basalt	10^{-6}	10^{-6}	10^{-5}	.05
Interflows	10^{-3}	10^{-3}	10^{-3}	.25
Interbeds	10^1	10^1	10^{-3}	.20

* All conductivity in feet/day

K = hydraulic conductivity
Ø = porosity

The basecase runs, using Rockwell's boundary conditions, show particles leaving the dense basalt layer (Layer 11) and traveling into the lower interflow (Layer 12) (Figures 8 and 10). Increases in conductivity in Layer 11 did not change the flow path just the travel time in that unit. The pathway remains vertically downward through the unit. The effect of changing two units in concert was more pronounced. The vertical conductivities of the Grande Ronde layers were increased by one order of magnitude. Particles leaving the repository layer travel downward through the lower interflow (Layer 12) and into the next dense basalt layer. The flow direction remains vertically downward rather than laterally along the conductive units.

Comparable results can be seen by changing the conductivity of other combinations of layers. Increasing the vertical conductivity by an order of magnitude in the upper Grande Ronde and Wanapum units also causes changes in flow path. The particles move out of the "Umtanum" unit and move upward through the section. Increasing the vertical conductivity by one order of magnitude of all the interbeds and the dense basalts layers in the entire section (conductivity ratio = 3.1×10^{-3}) causes a similar change in pathway (Figure 11).

The difference between vertical and horizontal conductivity chosen for the dense basalt units is large. This was simply the easiest way to change the conductivity ratio given the original set-up. An alternate set of conductivity values was also tested which distributed the variation in hydrologic character more evenly through the section. The dense basalts were kept at the original values; the interbeds were given horizontal conductivities of 10 ft/day and vertical conductivities of 1 ft/day. The interflows were assigned horizontal conductivities of 1

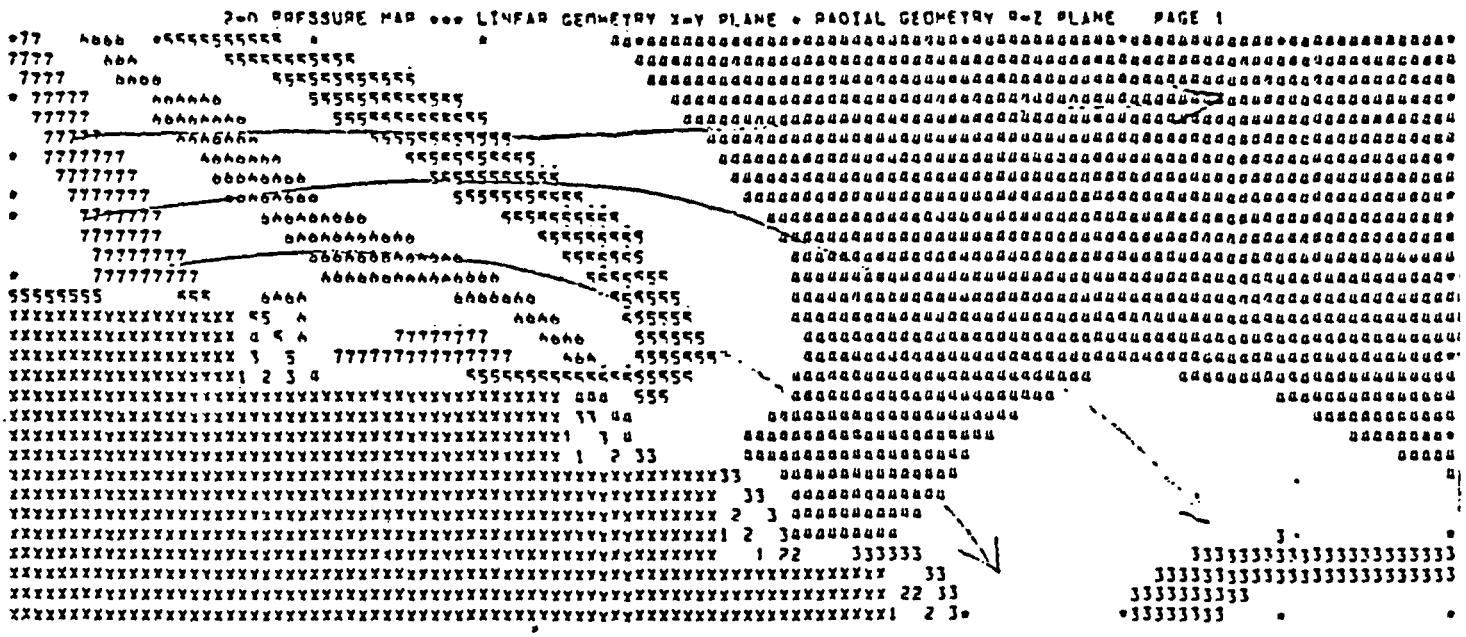


Figure 10. Base Case Flow SWIFT Pressure Plot Layer 11 Plan View (x-z plane)

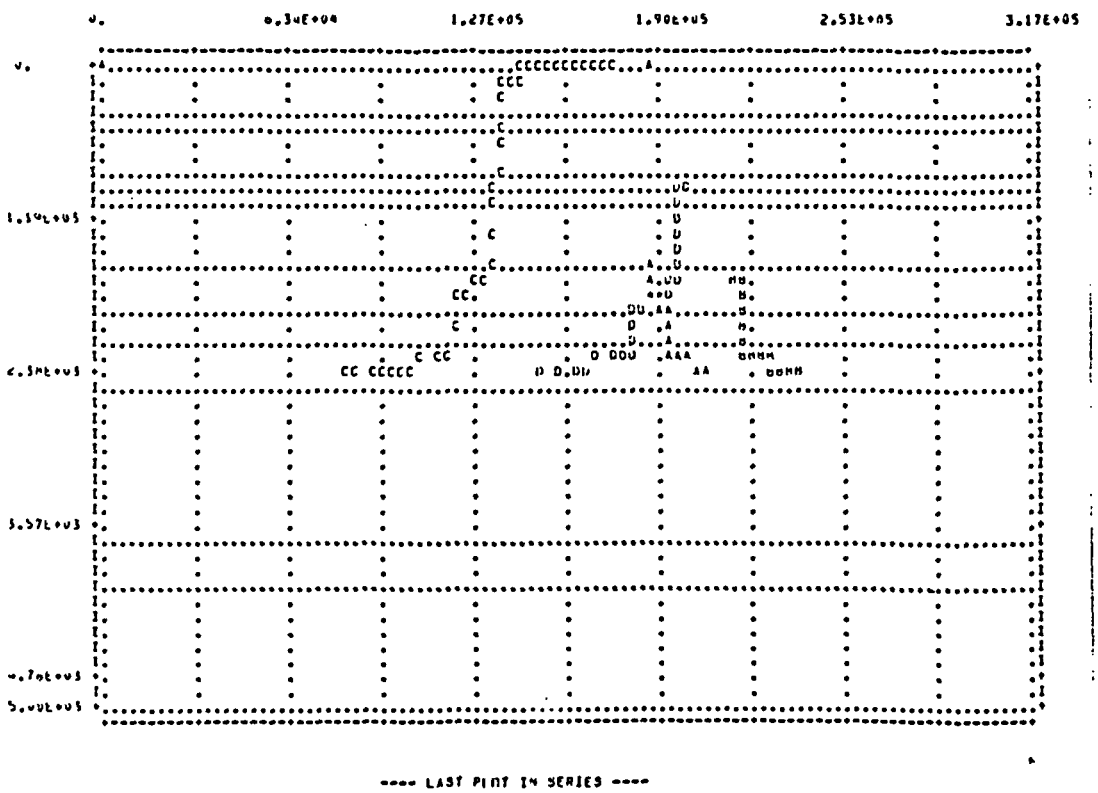


Figure 11. Particle Tracking for Run Using Increased Vertical Conductivity in the Dense Basalts and Interbed Layers

ft/day and vertical conductivities of 10^{-1} ft/day. The horizontal values used in this simulation are within the range quoted by Rockwell. Use of these values resulted in a conductivity ratio of 2.4×10^{-3}. The resulting movement in the system was a stair step pattern of vertical and horizontal flow. The principal discharge point was the Columbia River. These analyses confirm that a reasonable selection of values given the current level of data can cause flow to be changed from principally horizontal to principally vertical flow (Figures 12-14).

The ratio of the conductivity values was also varied to determine the importance of property changes resulting from systematic variation in aquifer properties or from disturbances associated with tectonic fracturing or discontinuities.

The spatially variable conductivity contained in the PNL model was added to the Rockwell set up. PNL attempted to relate the conductivity to the degree of fracturing associated with deformation in the basin. Areas of increased fracturing are assigned vertical conductivities either one or two orders of magnitude higher than base value (Figure 15). The addition of this variable conductivity has no noticable effect on the resulting flow path. The principal areas of conductivity change are along the folded basin margins;the result is to change the rate of flow along the boundaries rather than direction of flow in the basin (Figure 15a).

The influence of significant structures in the basin was also evaluated. Two principal changes were made: an increase in conductivity beneath portions of the Columbia River and changes in conductivity under the Gable Mountain-Gable Butte anticline.

New Set Of K Values

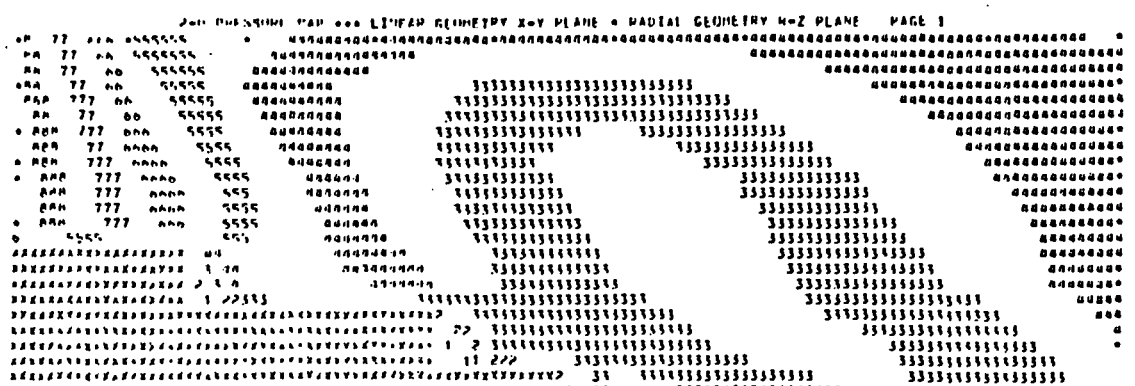


Figure 12. SWIFT Pressure Plot
Layer 11 Plan View (x-z plane)
Alternate Set of Conductivity Values

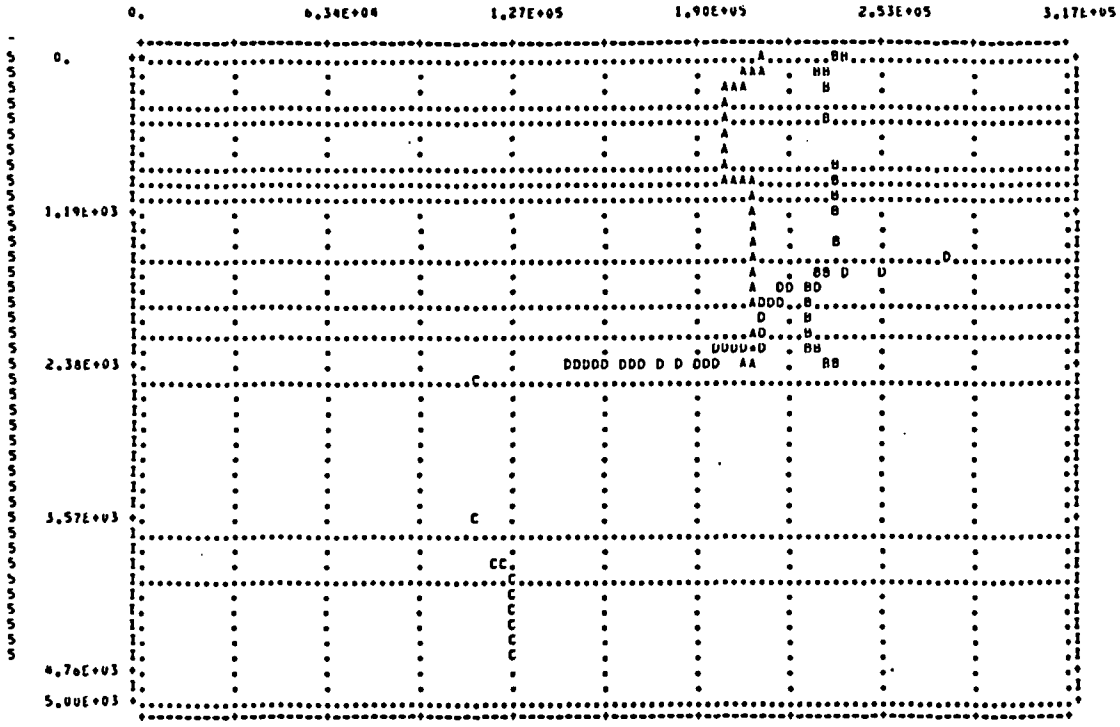


Figure 13. Particle Tracking Using Alternate Set of Conductivity Values (y-z plane)

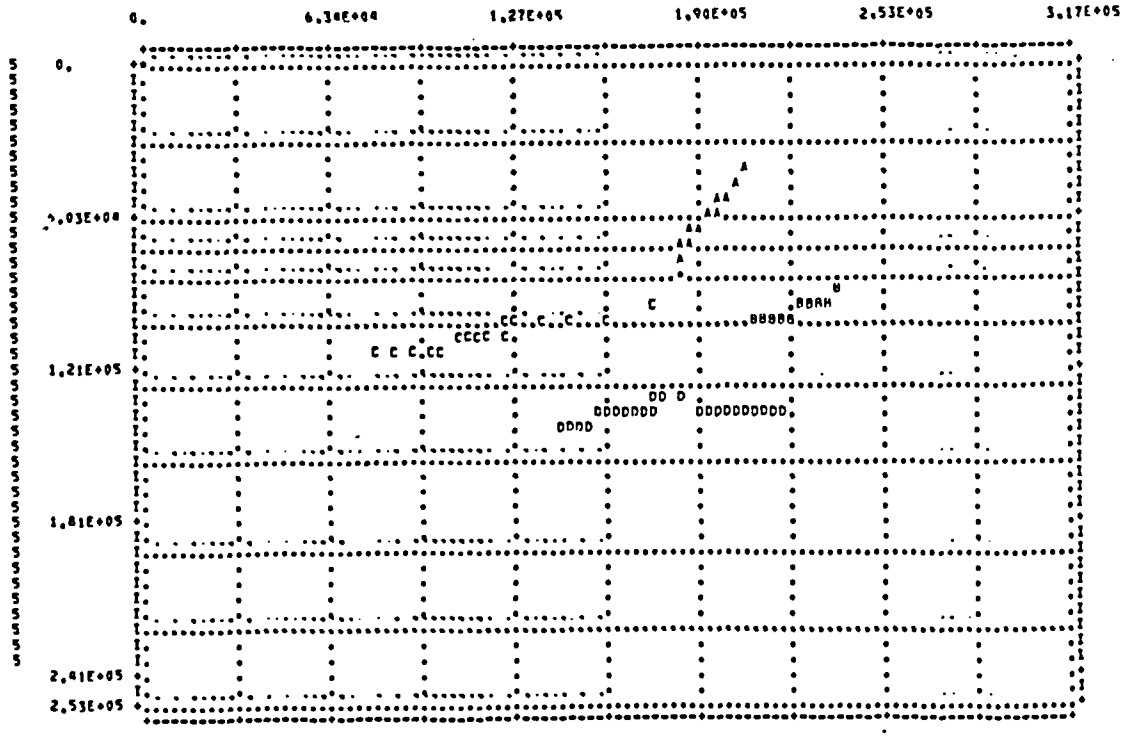


Figure 14. Particle Tracking Using Alternate Set of Conductivity Values (x-y plane)

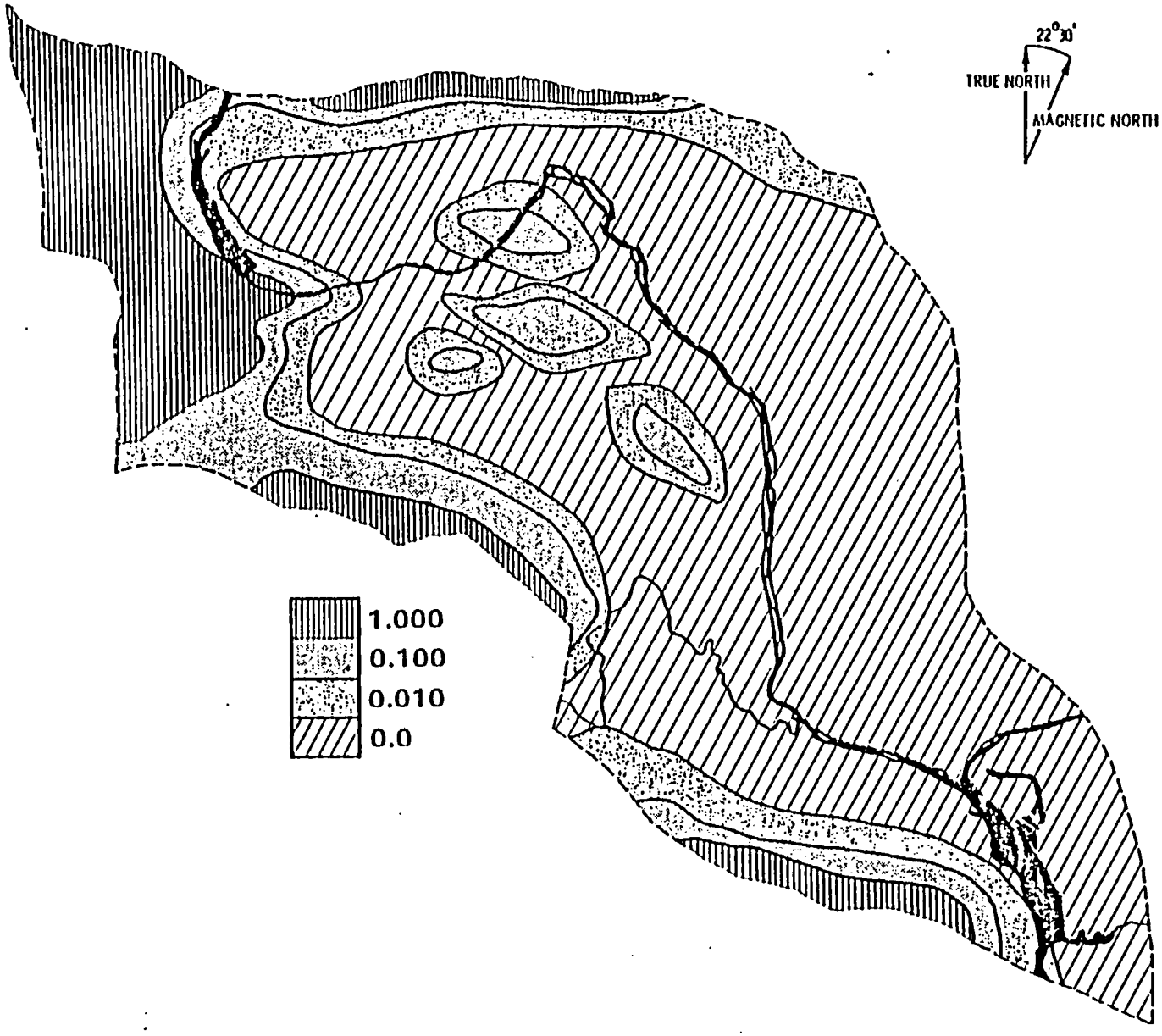


Figure 15. Inferred Zones of Equal Deformation Associated with Both Anticlinal and Synclinal Structures Within the Local Model Area. (Scale is from 0 to 1 with 1 representing areas of greatest inferred deformation.) (after PNL 3632)

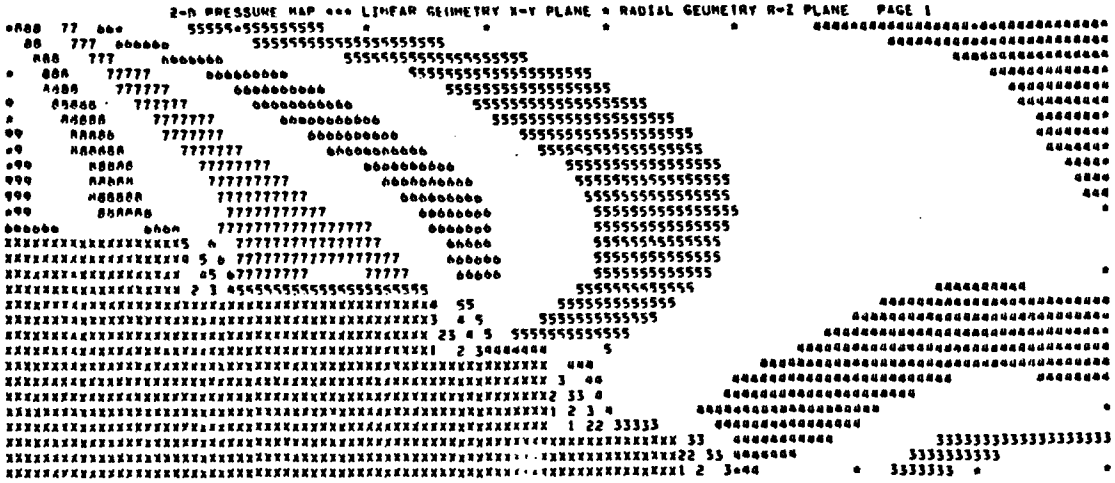


Figure 15a. SWIFT Pressure Plot
Conductivity Increased In Structures
As in PNL Model

The conductivity along the Columbia River was changed in two sections (Figure 16). The vertical conductivity for each section of the river was increased by one and then two orders of magnitude. The changes are made to the individual portions of the river and then in combination. The decision to alter the conductivity along the river is not based on the assumption of faulting along this zone. It is principally an exercise to see the effect of a linear feature with an increased conductivity. The runs also give some useful information about the relative fracturing required to produce upwelling along the river, assuming the validity of the imposed boundaries. Changes of one order of magnitude cause minimal change in the overall flow pattern (Figures 17 and 18). Particles located in the RRL region are not substantially affected by the increase. Neither the general direction of flow nor the number of layers discharging to the river changes. Little effect is seen even if both sections of the river are changed in the same run (Figure 19).

Increasing the vertical conductivity by two orders of magnitude above the base value results in more significant changes to flow. Along the northern section of the river, the effect is fairly localized (Figure 20). Flow in the adjacent grid blocks is directed toward this portion of the river; in the vertical the effect extends throughout the entire section. A similar change along the southern section has a much more extensive influence on the system (Figure 21). Flow throughout the Cold Creek syncline is directed toward the river. When both areas are assigned increased conductivity values, the lower portion of the river still dominates the flow (Figure 22). One possible explanation is that this lower portion dominates because of its larger extent and its relatively greater distance from the influence of boundaries.

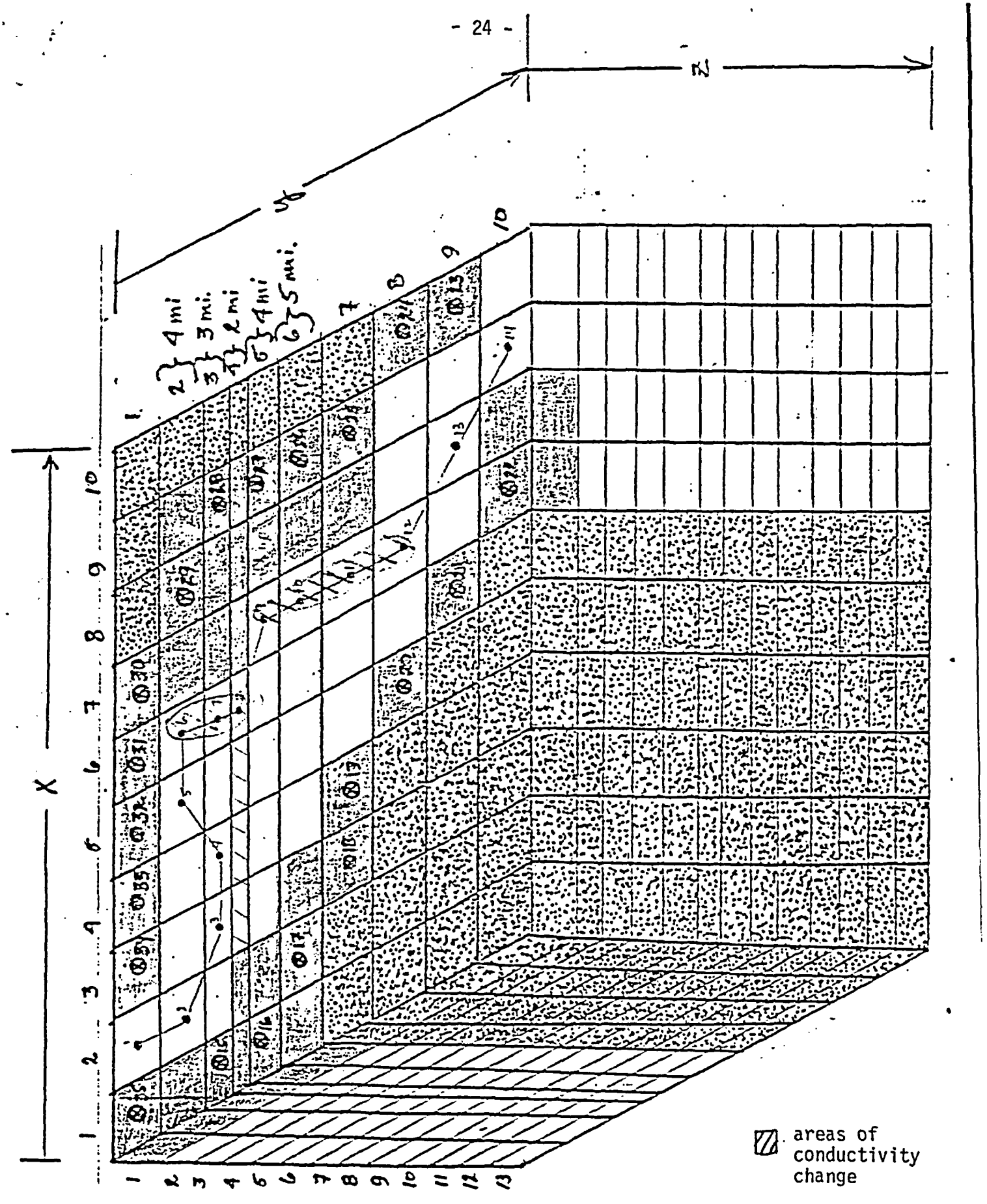


Figure 16. Gridding System Including Areas of Conductivity Change

Figure 17. SWIFT Pressure Plot
Increase of One Order of Magnitude in Vertical
Conductivity Along Northern Part of River

Figure 18. SWIFT Pressure Plot
Increase Of One Order of Magnitude in Vertical
Conductivity Along Lower Portion of River

Figure 19. SWIFT Pressure Plot
Increase of 10x in K Along Both Sections
of the River

Figure 20. SWIFT Pressure Plot
Increase of 2 Orders of Magnitude
in Vertical Conductivity Along the
Northern Part of the River

Figure 21. SWIFT Pressure Plot
Increase in Vertical Conductivity
by 2 Orders of Magnitude Along
Southern Portion of the River

Figure 22. SWIFT Pressure Plot
Increase of 2 Orders of Magnitude Along
Both Sections of the River

The second structure evaluated was the Gable Mountain-Gable Butte anticline. The character of this structure, located directly north of the reference repository area, is still open to question. Alternate suggestions are that these folded and faulted beds would be impediments to flow or that they would provide increased conductivity in the horizontal and/or vertical direction. The character of this structure is important because of its location next to the reference repository location and its position between the Cold Creek Syncline and the Columbia River, a potential discharge location.

Several runs were made where the character of this structure was altered. The structure was: (1) given increases in vertical conductivity 10 - 100 times over the base value, (2) given increases in horizontal conductivity 10-100 times over the base value and (3) treated as a no flow boundary. A one order of magnitude increase in the vertical conductivity did not significantly change the flow pattern. Particles in the RRL region still traveled along a horizontal flow path toward Wallula Gap. The increase in conductivity did not divert particles toward the anticline or up into the section. A two order of magnitude did alter the flow path. Particles adjacent to the anticline were diverted upward into the structure but the effect did not extend far beyond the structure.

Changes in flow path are visible when the horizontal conductivity is increased in the structure. The pressure contours show water being diverted toward the structure for increases in horizontal conductivity of either one or two orders of magnitude (Figure 23). Particles in the RRL region would now be changed from predominantly eastern movement to a more northern direction of flow. Treating the structure as a zone of decreased conductivity or as a no flow boundary separates the area into

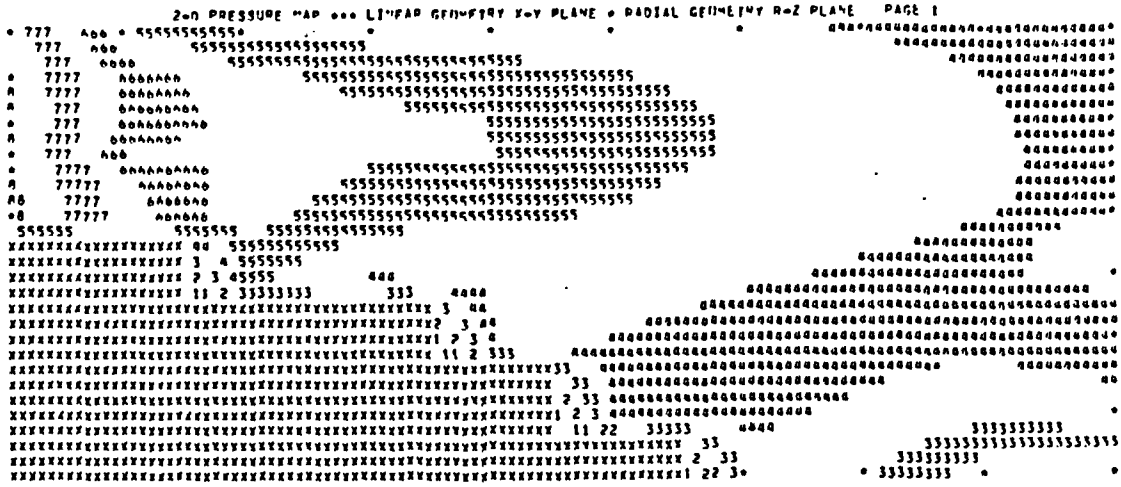


Figure 23. SWIFT Pressure Plot
Increase in Horizontal Conductivity by 50
Around Gable Mountain-Gable Butte Anticline

Figure 24. SWIFT Pressure Plot
Gable Mountain-Gable Butte Anticline
Treated as a Noflow Boundary

two flow systems (Figure 24). Particles in the lower units north of the river travel horizontally until they reach the end of the structure. Within the two regions, the flow patterns are similar to those under original conditions; particles in the RRL region maintain the flow path seen in the base case runs.

One structure which has not been evaluated during this exercise is the lineament west of the RRL area. The structure has been identified in satellite images and has been recognized as a barrier to flow in the upper units in the section. The structure was not included because of the uncertainty about its location, extent and character. However, as additional information about the structure becomes available, this will need to be included in the grid and evaluated (Figure 24a).

Variation of Boundary Conditions

Because of the uncertainty generally associated with selection of boundaries in a large scale model, some analyses of these bounds were attempted. Most values used were intermediate between the choices of RHO & PNL. The reader is referred to Comparison of Codes, Lehman and Quinn, 1982 for a detailed description of boundary differences. The head values used by the two groups are shown in Figures 25 and 26. Isolated extreme boundary choices were considered to substantiate expected results. The following variations are considered:

1) NW boundary decreased by 25%
2) NW boundary decreased by 40%
3) NW boundary decreased by 60%

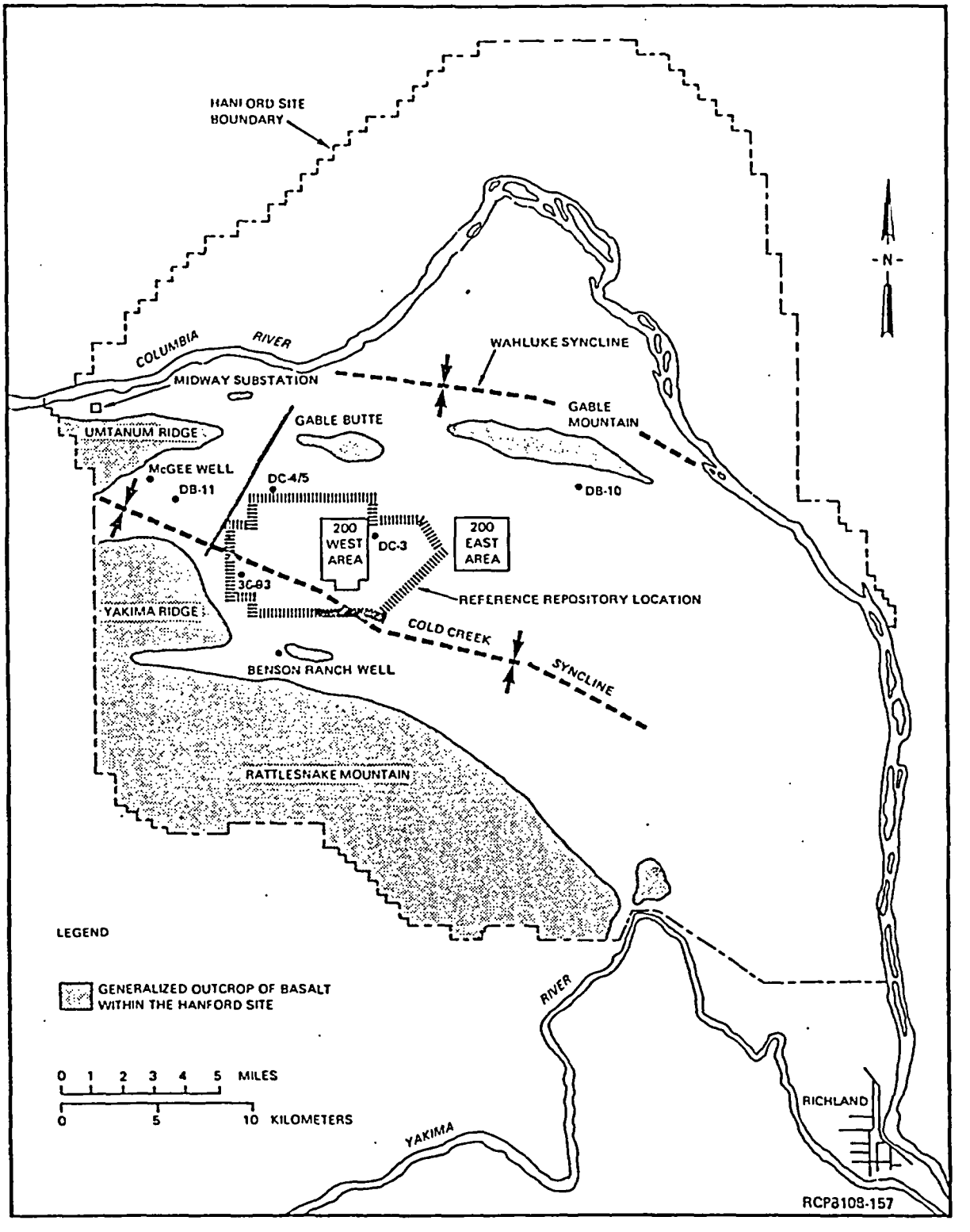
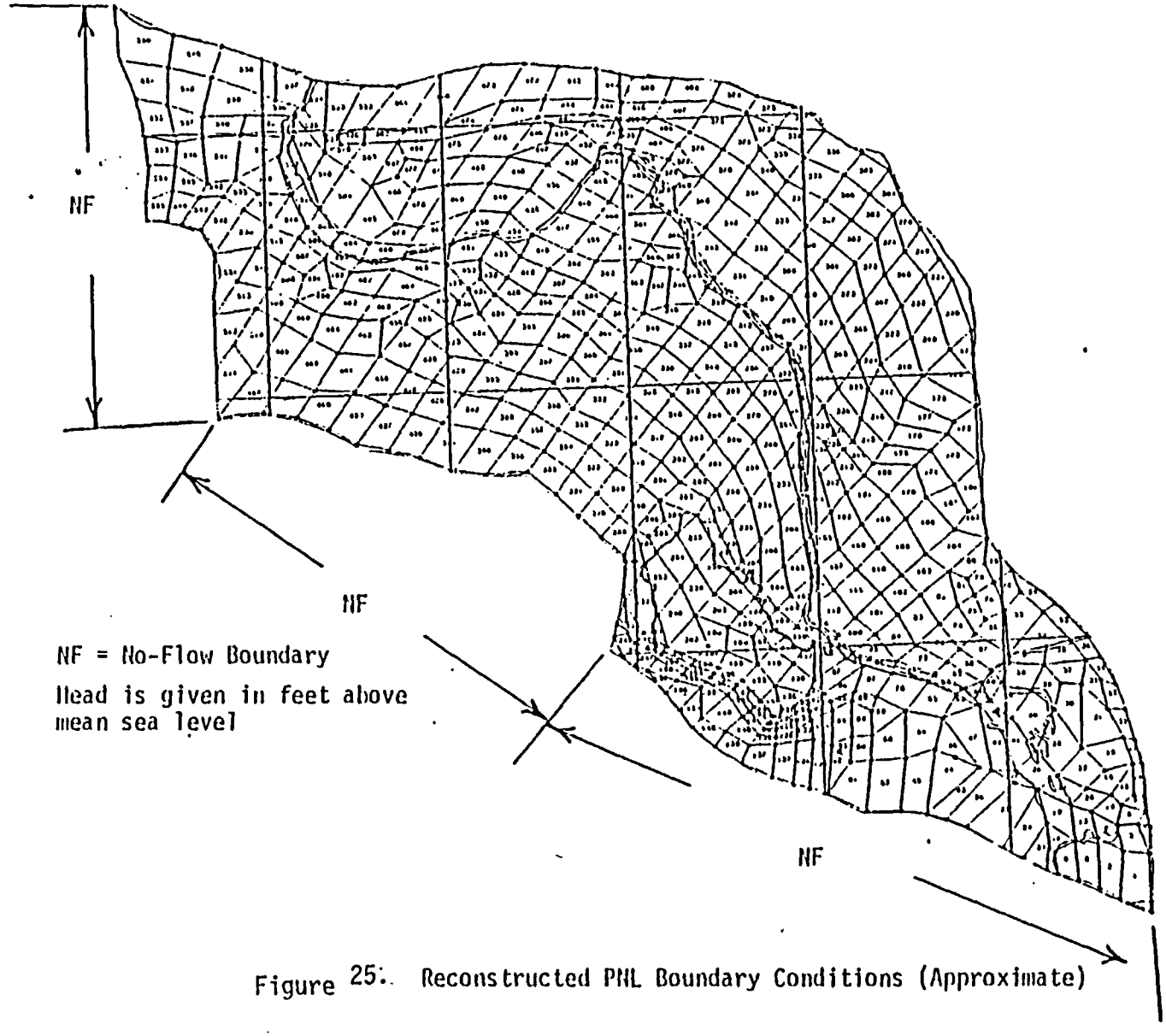


Figure 24a. Location Map Showing Approximate Location of N 96 to N 84 Linear

TSM	NF	NF	NF	NF	NF	NF	NF	817	882	882
TWP	675	675	720	782	749	710	783	817	882	882
TGR	676	678	724	786	759	734	783	817	882	882
BGR	678	691	737	798	790	793	800	823	855	855



TSM TWP	TGR BGR
817 817	817 828
882 882	882 855
926 916	875 790
917 917	917 840
731 731	731 700
630 630	630 606
489 489	489 492
358 358	424 539
437 437	535 657

Figure 25. Reconstructed PNL Boundary Conditions (Approximate)

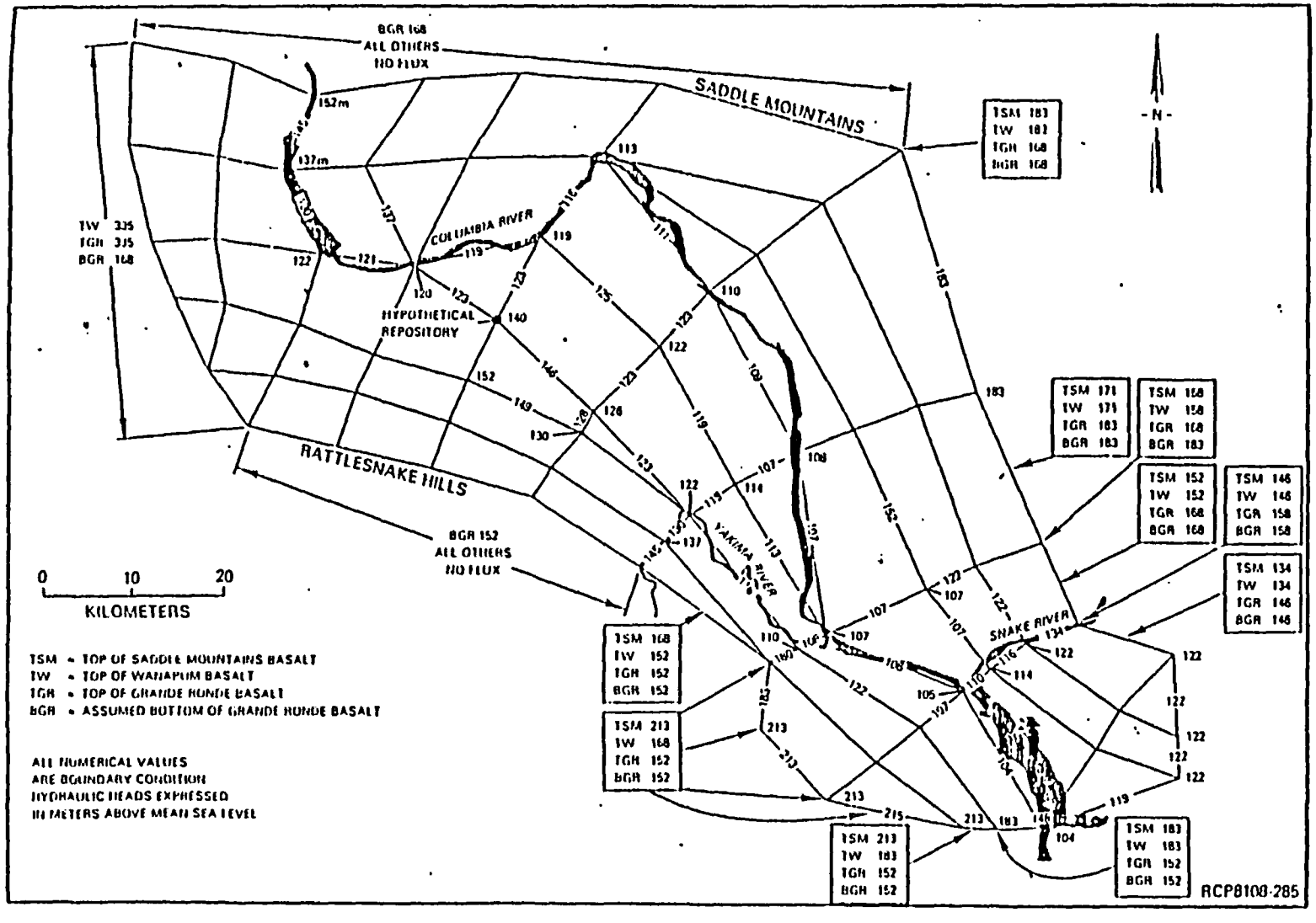


Figure 26. Plan View of Pasco Basin Rockwell Finite Element Grid
(After, RHO-BWI-LD-44)

4) NW boundary no flow
5) SW boundary no flow
6) decrease in NW bound by 25% and decrease in SW by 50 ft
7) NW and SW no flow
8) SE boundary given PNL values
9) Eastern boundary given PNL values
10) Northern boundary given PNL values

Figure 27 shows the areas described by abbreviated boundary descriptions.

The values on the NW boundary were gradually decreased to see the effect on the flow path. A decrease of approximately 25% in the value, bringing the head to 800 ft in the groundwater units* shows no change in the flow path (Figure 28). Similarly a 40% decrease in head along the boundary does not substantially alter the flow path (Figure 29). A particle in the RRL area still moves vertically through the dense basalt and into the interflow. The particle then remains in the interflow and moves horizontally toward Wallula Gap. A decrease of 60% in the head causes flow to leave the

*The head distribution assumed down the hole was not changed. The values were uniformly decreased by approximately 25%.

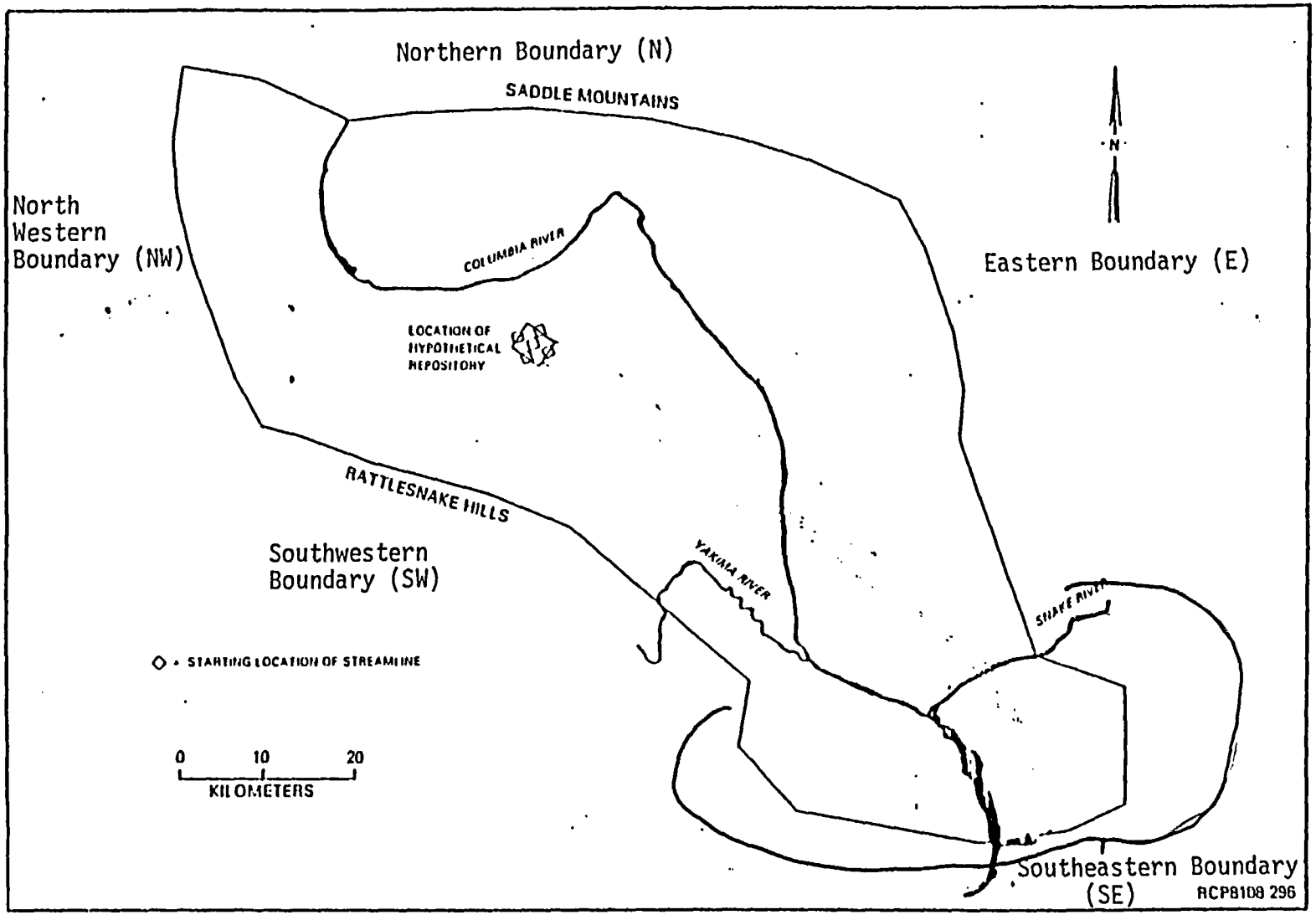


Figure 27. Definition of Boundaries.

Figure 28. SWIFT Pressure Plot Pressures Resulting From an Approximately 25% Decrease in Head Values Along the Northwestern Boundary

Figure 29. SWIFT Pressure Plot Pressures Resulting From an Approximately 40% Decrease in Head Values Along the Northwestern Boundary

region along this boundary (Figure 30). At this point the water level is well below that of the other areas. Given the water levels assigned to the rest of the system, and the geologic character of this north western region it is not likely that such low values would exist.

Decreasing the head by 50 feet along the southwestern boundary also did not change the direction of flow in the RRL area. The relatively minor effects of changing these boundaries seemed suprising; changes within reasonable limits did not affect the flow path from the RRL. The importance of this boundary becomes evident when one reviews the extreme difference in boundary choices of RHO and PNL. When both the northwest and the southwest boundaries are changed to no flow bounds the conditions used by PNL, the water path turns toward the vertical (Figures 31 and 32). The effect is not as visible when only one area is turned into a no flow region (Figures 33 and 34).

The other boundary of major significance is the SE boundary. When the PNL head distribution is assigned to this corner particles again appear to discharge in the system. In addition particles no longer curve along the long flow path. Those which do not discharge along the river go horizontally through the boundary (Figures 35 and 36).

Changes in the northern boundary have less effect on the particle in the reference repository location. This is due to two reasons: the distance from the repository area and the lack of major differences between the RHO and PNL boundary choices. Addition of the PNL bound does "flatten" the pressure contours; particles in the northern section of the basin particles no longer exit along the northern boundary (Figure 37). The principal direction of flow is to the southeast. Assigning the eastern

Figure 30. SWIFT Pressure Plot
Pressures Resulting From an Approximately 60% Decrease in Head Values Along the Northwestern Boundary

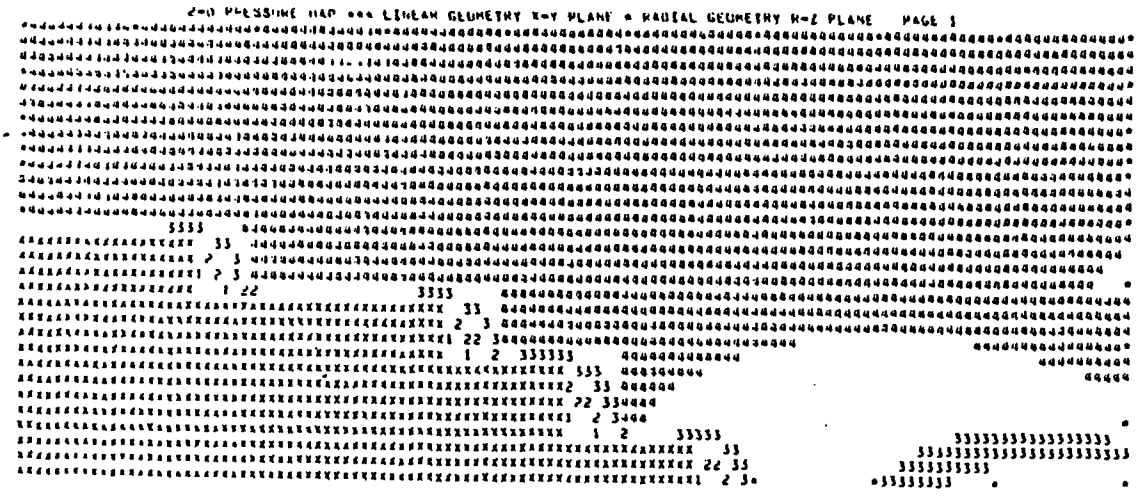


Figure 31. SWIFT Pressure Plot
Northwestern and Southwestern Boundaries
Given No Flow Condition

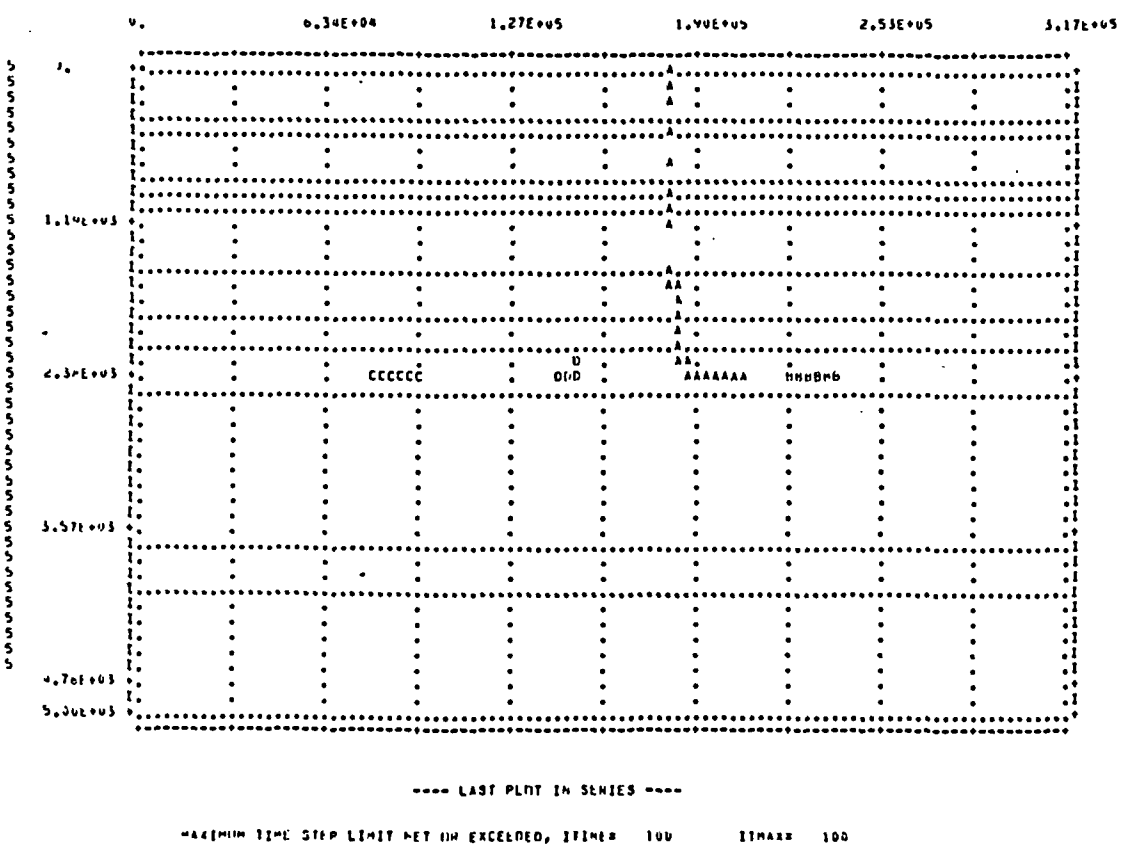


Figure 32. Particle Tracking Northwestern and
Southwestern Boundaries Given
No Flow Conditions

Figure 33. SWIFT Pressure Plot
No Flow Conditions Assigned to
the Southwestern Boundary

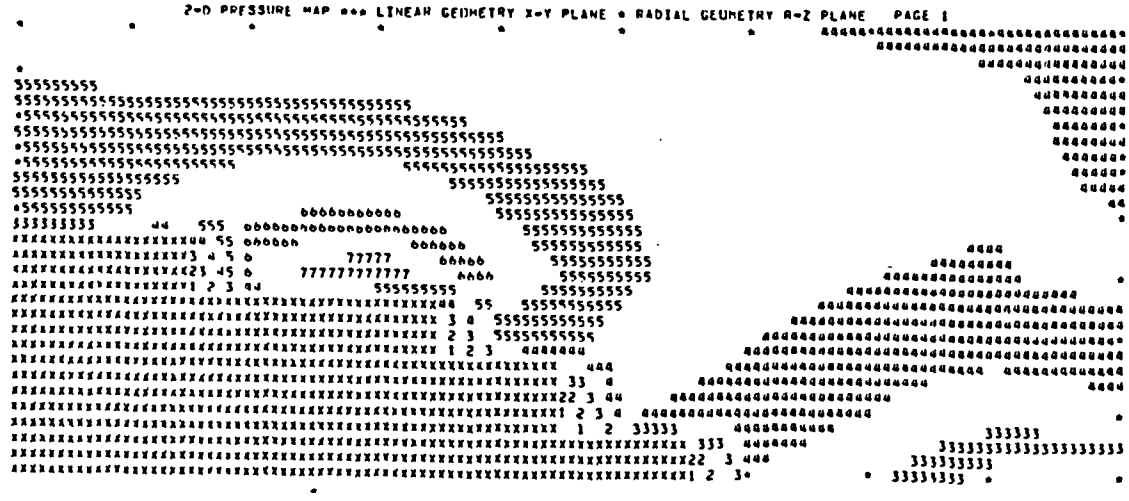


Figure 34. SWIFT Pressure Plot
No Flow Conditions Assigned to
the Northwestern Boundary

Figure 35. SWIFT Pressure Plot
PNL Boundary Conditions Assigned to
the Southeastern Portion of the Model

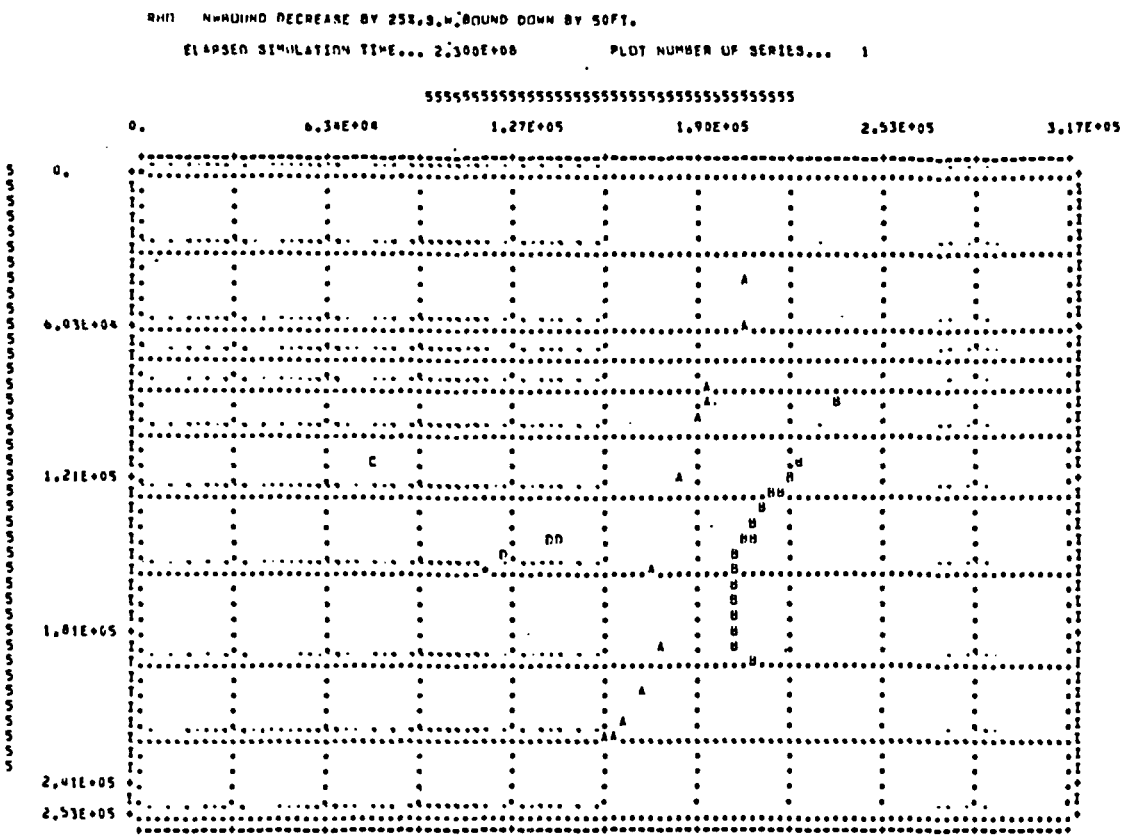


Figure 36. Particle Tracking for PNL Boundary
Condition Along the Southeastern
Portion of the Model

Figure 37. SWIFT Pressure Plot
PNL Northern Boundary
Assigned to the Model

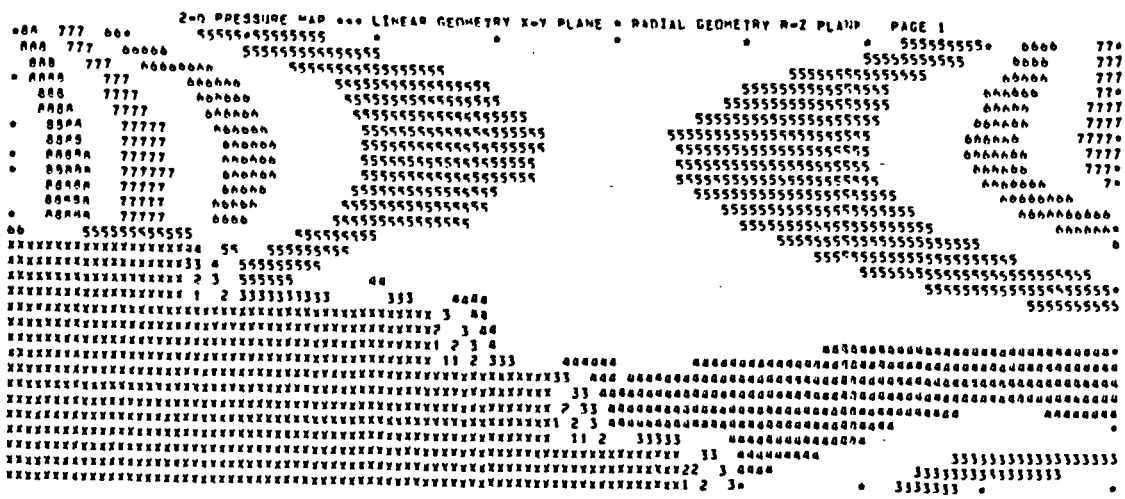


Figure 38. SWIFT Pressure Plot
PNL Eastern Boundary
Assigned to the Model

boundary the PNL values changes the flow path of the lower units on the eastern side of the boundary substantially. Particles no longer exist along the eastern boundary. Instead, movement in all layers is westward toward the river (Figure 38).

The previous analysis shows that the principal sensitivity is to distribution of head in the southeast and large, basically conceptual differences on the western bounds. This analysis has not included any runs where the effect of changing several variables is evaluated. As an example of the changes resulting from varying several parameters, the following run was conducted. Changes were made to three parameters: the head values along the northwestern and southwestern boundaries and the ratio of vertical and horizontal conductivity. The head values along the northwestern boundary were decreased to 800 feet and the head values along the southwestern boundary were lowered by 50 feet. The conductivity ratio was decreased to approximately 10^{-3}. It was felt that all of the changes were within the uncertainty limits for the original values. With these changes particles assumed a vertical exit path from Layer 11. Although this is a very limited result the run does indicate that, within reasonable error ranges in the system, the water can be redirected from principally horizontal to principally vertical flow.

Porosity Changes

Several runs were conducted where the porosity of the dense basalt unit (Layer 11) which includes the Umtanum unit was changed. Base case runs had assumed a porosity of 5%. The range tested event from from .05% to 10%. The following table shows the movement of particles after one time step (10 years).

	Distance Traveled (ft)	Porosity
Particle A	60.38	.1%
Particle A	14.37	1%
Particle A	31.7	.5%
Particle A	2.87	10%
Particle A	2.87	7%
Particle A	120.78	.05%
Particle A	8.62	2%

	Distance Traveled (ft)	Porosity
Particle B	31.63	.1%
Particle B	8.62	1%
Particle B	12.3	.5%
Particle B	0	10%
Particle B	0	7%
Particle B	63.25	.05%

The results show that as expected the the travel time varies as a function of the porosity chosen. In terms of an accessible environment the distance traveled over 9,900 years varies from*:

.05%	29,690 ft	
.5%	28,270 ft	
.1%	28,270 ft	
1%	15,530 ft	
2%	33,990 ft	30,000 yrs
5%	17,320 ft	30,000 yrs
7%	285 ft	
10%	285 ft	

*For the lower porosity values particles will have left Layer 11, the layer with the porosity change. The difference in distance traveled for the lower porosity runs will be less distinct for longer time periods.

The choice of porosity value is not important in determining the regional groundwater pattern. However, even these simple analyses show that it will be a critical parameter in determining travel time.

Model Recommendations

1) The model has been shown to be very sensitive to changes in boundary conditions and conductivity ratios. Changes which are within the ranges of uncertainty for the variables can cause significant variation in the expected flow path. Because of the uncertainty associated with the flow path, NRC should strongly emphasize the need for Rockwell to perform sensitivity analyses before effort is concentrated on scenario analysis. Unless the response of the system is well documented, it will be difficult to have confidence in scenario results. In addition, the results of the sensitivity analyses could be used to direct field activities. Once the tolerance of the model for current uncertainty ranges has been established, more streamlined data collection programs can be developed.

2) The choice of the western boundaries will have to be justified conceptually. Although all the boundaries vary from those of PNL, the location of these boundaries and the extreme differences in the values makes them important in flow path analysis. Changes in these boundaries have been shown to alter the flow path. The choice of bounds along southern portions of the basin should be similarly reevaluated.

3) Important structures, such as the Gable Mountain-Gable Butte Anticline and the N 96 to N 84 lineament need to be included in the large scale model. Their effect on the flow pattern needs to be determined both from field investigations and modeling exercises.

Field Recommendations:

1) The analyses further support the need for determination of vertical conductivity. While measurements in the Umtanum are the most important, the vertical measures are important on a Pasco Basin scale. In addition since the Umtanum has been chosen as a potential repository horizon because of its unique characteristics, the vertical conductivity measures obtained from this unit may not be considered representive of average values.

   At a minimum, the testing should include some estimate of the vertical conductivity in other dense basalt units to provide reasonable confidence in estimates of regional vertical conductivity values. Such estimates could be obtained from the large scale pump tests which have been recommended by NRC.

2) Porosity measurements will be needed since the travel time changes with this parameter. Because the value, by definition, will not vary over the same range as conductivity, it will be less important to determine the parameters on a regional scale. The need for this parameter has been recognized by Rockwell and tracer tests are planned. However, it is not known what units Rockwell plans to investigate.

3) The modeling results support the need to test around the important structures. Both the character of the structures and the extent of their influence needs to be determined.

4) Rockwell's current plans for drill hole exploration are concentrated around the RRL facility. While this distribution appears to give adequate coverage of this area, the information will not be as useful for calibration of a far field model. The uncertainty in the original flow path predictions has been demonstrated in these sensitivity analyses. Given these drilling plans, much reliance will need to be placed on sensitivity analysis and initial parameter review to support the chosen flow path.

Attachment 1

STRATEGY FOR SENSITIVITY ANALYSIS ON THE HANFORD SITE

One of the proposed tasks for the performance assessment staff during the next six months is a sensitivity analysis on hydrologic parameters at BWIP. The purpose of the work is two-fold: to fulfill our obligations for review of the performance assessment section of the SCR, and to aid the BWIP team in evaluating the validity of the proposed flow field. Also, the use of sensitivity analysis will provide further understanding of the potential for flow from deep basalt units to discharge to the Columbia River.

In order to explain the need for the work and the choice of parameters, a brief explanation of the work done to date and its relation to the BWIP team is necessary. Work done by the performance assessment staff has concentrated on an analysis of groundwater flow patterns at the basalt site. This has included developing a three-dimensional finite difference grid for the Pasco Basin and then comparing the boundary conditions of Rockwell Hanford (RHO) and Pacific Northwest Laboratories (PNL). For a description of these analyses, the reader is referred to the report: Comparison of Model Studies - The Hanford Reservation, Lehman and Quinn, April 1982. The results of the studies have shown several areas where additional work is necessary to define the system. The work has also provided input to the development of the site issues discussed in the BWIP trip reports. The modeling studies will continue to be used in the analysis of the BWIP site suitability issues outlined for site characterization review.

The work will provide a study of the model's sensitivity to changes in the vertical to horizontal conductivity ratio and to the boundary conditions. This portion of the work will be done on the current three-dimensional gridding system. The effect of varying radionuclide transport parameters will be determined using a simplified pipe flow model.

The plans for this work are similar to recommendations of Rockwell given in their most recent modeling study - Pasco Basin modeling and Far Field Radionuclide Migration Potential - RHO-BWI-LD-44. In this document they recommend that a sensitivity and parametric analysis be conducted at a Pasco Basin scale. This analysis would include a sensitivity analysis of hydraulic conductivity (including anisotropic ratios), effective porosity and boundary conditions.

By conducting these analyses, we should be paralleling the Rockwell effort while maintaining an independent capacity to conduct the investigations.

Ratio of Vertical to Horizontal Conductivity

An important parameter to consider in the sensitivity anlaysis is the ratio of horizontal to vertical permeability. Currently, there are ranges of horizontal conductivity values for various portions of the stratigraphic section. Although the ranges are large (greater than 4 orders of magnitude), they do provide some bound for expected values of the interbeds, interflows and dense basalts in the three formations.

In contrast, there are no measurements of vertical conductivity for any of the beds. Some estimates have been used, but no reliance can be placed on these values without some field verification. The columnar fracturing of the dense basalts could produce significant amounts of vertical flow but the amount has not been quantified. There is also disagreement between the PNL modeling assumptions and the RHO modeling work on their choice of ratio. RHO uses an overall ratio of 10^{-4} although they note that 10^{-3} might be more consistent with field information. PNL varies the ratio spatially depending on the structures, suspected degree of fracturing and information from transmissivity maps.

The analysis of the K_v/K_h ratio will have several aspects. First, the ratios in the three formations will be varied by formations to see the effect on the flow field. This work will be done using both PNL and RHO boundary conditions, although the effort will be concentrated on RHO values. One useful measure of comparison will be to show what ratio would be necessary to redirect flow to the river. Some preliminary analysis (Comparison of Models, Lehman and Quinn) do show flow going toward the river in the K_v/K_h ratio is increased.

The second phase will be varying the ratios by hydrostatigraphic unit. The current NRC layering system divides the formations into the various hydrostratigraphic units interflows, interbeds, and dense basalts. The dense basalt units appear to contain most of the vertical flow. By varying the ratio in the different layer types individually, we will gain some understanding about the reasonableness of the composite K_v/K_h. We will not get a unique solution in the system: if K_v for the Umtanum unit is a certain value then flow must go to the river. However, we will gain

some range of values which, under the qualifying assumptions, would give such a flow path.

Finally, the ratio will be varied spatially to reflect the structures and suspected degree of fracturing. This has already been included in analysis of PNL's work since a spatially variable ratio was an initial assumption on their model. However, these changes were not included in the RHO analysis. One portion of this work will include changing the ratio in the river node blocks. This will allow simulation of the proposed fault or structural weakness along the river (Geochemical Interpretations of Groundwater Flow Systems in the Central Columbia Plateau, Lehman & Quinn, February, 1982).

The results of this task will be particularly useful in the issue analysis at the BWIP site. The need to determine the vertical conductivity of the dense basalt units has been stated by many groups including: NRC, PNL and the RHO Hydrology Overview Committee. This value is important because it affects not only the travel time but the direction of flow. However, no studies have determined the effect of changing the conductivity values on Rockwell's flow path. By determining the changes in flow direction, we can quantify the importance of the parameters and determine the value range which would be acceptable.

Analysis of Boundary Conditions

The choice of boundary conditions is a principal area of disagreement between the RHO and PNL modeling studies. Major differences in the choice of pressure head occur in the northern and northwest section of the Pasco Basin. Differences in downhole pressure distribution occur

along the eastern and southeastern boundaries. The largest difference occurs along the northwest boundary where RHO has assigned 1099 feet of pressure head while PNL assumes a no flow boundary. At present we feel these high pressures combined with the constant gradient in the southeastern section of the flowpath control the particle streamlines.

Although we would not expect identical boundary conditions for the two models, the ranges seen in the two simulations are unreasonably large. One method of testing these values would be to develop a regional model to predict the head measurements at the boundary of the Pasco Basin. However, given the time and information constraints we do not feel an in house development of this work is justified.

To refine our understanding of the system we will vary the pressures at the boundaries. All the changes will be intermediate between the two proposed flow systems. This analysis will help determine which portions of the model have large uncertainties and appear to be controlling flow. The analysis will also show how much change in the boundaries is required to significantly divert the flow path.

Both the changes in conductivities and the changes in ratios will be performed as a steady-state three-dimensional analysis. This is to allow evaluation of changes in flow path. Use of a two-dimensional model for this work would not allow as thorough an analysis of flow path changes.

The proposed analyses do not contain the random selection of input variables associated with sensitivity studies. For example, the Latin Hypercube sampling program will not be used. This reflects the site specific nature of the current study. Random selection of parameters or

endless repetitive runs are not necessary when our problem areas are already well defined.

Two-Dimensional Analysis

Some sensitivity analysis will be performed using NWFT/DVM to obtain a preliminary understanding of the effect of various transport factors including Kd, solubility limit, dispersivity, porosity and leach time. This work serves a dual function since it is also being performed to evaluate the relationship of the EPA standard to the requirements of 10 CFR Part 60. The flow path for this analysis will not be varied; it is assumed that the nuclides will travel vertically to an aquifer and then travel horizontally to the discharge point. The horizontal pathlength to the discharge point is 1 mile. The composite layering used will be consistent with that provided in the Sandia draft report - "Technical Assistance for Regulatory Development: A Simplified Repository Analysis in a Reference Basalt Site," Pepping, Chu and Siegel, 1982.

The variables will be input as distributions. The values for the runs will be chosen randomly through use of the Latin hypercube sampling technique. These vectors will then be run in NWFT/DVM to simulate flow through the basalts to the discharge location. Output will be given in terms of discharge rate and EPA release fraction. This work will not be an evaluation of the site against the EPA standard. It is intended to show the relative importance of various transport parameters.

Products of the Sensitivity Analysis

I. Summary of the results of the K_v/K_h analysis.

II. Summary of the results of the boundary condition analysis.

III. Summary of the results of the two-dimensional analysis.

All work is expected to be completed before receipt of the Site Characterization Report for BWIP. The exact completion dates will depend on the staff commitments required to fulfill the other analyses outlined in the performance assessment plans for site characterization analyses (March 2, 1982 memo) and requested by the WMHT branch.