Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

REPORT TO
ROCKWELL HANFORD OPERATIONS

PRELIMINARY EVALUATION OF THE ADEQUACY OF PIEZOMETER SEALS

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1. INTRODUCTION

This report presents the results of a preliminary evaluation of the adequacy of piezometer seals in four multilevel standpipe piezometers located in the RRL area of the Cold Creek Syncline on the BWIP Site. This evaluation was based upon a review of water level responses to drilling and testing in boreholes DC-23W and DC-23GR. Available hydrographs from piezometers DC-19C, DC-20C, DC-22C, and DC-23W were studied to help assess the adequacy of the seals in those installations. The results of these studies are summarized in Section 2. Alternatives for future analyses, field tests, and alternative piezometer designs are presented in Sections 3 through 5, respectively. Conclusions and recommendations are presented in Section 6.

Our conclusions are based upon information on historic hydraulic perturbations and monitored responses presented in the following BWIP documents: (1) SD-BWI-TI-313 "Preliminary Evaluation of Piezometer Responses at DC-19, DC-20 and DC-22 During Construction of DC-23W;" (2) Internal Letter 75220-86-114 from F.A. Spane to S.M. Baker; (3) "Cross-Formational Responses at RRL Nested Piezometer Sites DC-19C, DC-20C, and DC-22C" by F.A. Spane; and (4) the data package provided to us by Mary Hartman in support of the DC-23W piezometer response modeling effort.

2. EVALUATION OF WATER LEVEL RESPONSES

Hydrographs of key horizons in the Wanapum and Grande Ronde were taken from document (1) above and are shown in Figures 1 through 3 for DC-19C, DC-20C, and DC-22C, respectively. The perturbation of interest occurred from September 12 to October 3, 1985, during DC-23W drilling, and from October 21 to 25, 1985, during DC-23W development pumping. Weak perturbations are seen through September 28, during the period of mud rotary drilling in the upper Wanapum. It is interesting to note that during this period a perturbation was monitored in the Sentinel Gap flowtop before drilling reached that flowtop. Much stronger perturbations are seen beginning September 29, when drilling resumed with water instead of mud, and beginning October 21, when the composite Wanapum was developed by air-lift pumping. An earlier perturbation occurred in the Grande Ronde in late May and early June, 1985, during removal of a bridge plug in RRL-14. A lack of detailed information on this earlier perturbation prevented it from being studied in the same degree of detail as that from the DC-23W drilling.

Hydrographs from DC-23W presented in Figure 4 show the response of the Rosalia and Sentinel Gap flow tops to pump testing in the Rosalia flow top in nearby DC-23GR. Again, water pressures in the Rosalia and Sentinel Gap are seen to be synchronous before and after the test, and an attenuated perturbation from the pump test is clearly seen in the underlying Sentinel Gap flow top.

The synchronous behavior of water pressures in the Rosalia (Priest Rapids Interflow Zone) and Sentinel Gap flow tops in the upper Wanapum is clearly evident in all piezometers in the forementioned figures, and is strong evidence for efficient hydraulic communication between these horizons. The independent behavior of the Ginkgo and nearly all Grande Ronde flow tops is strong evidence for a lack of efficient hydraulic communication among these deeper horizons. The only exception to this latter statement is the evidence, provided by synchronous behavior, of efficient communication between the Rocky Coulee and Cohassett flow tops

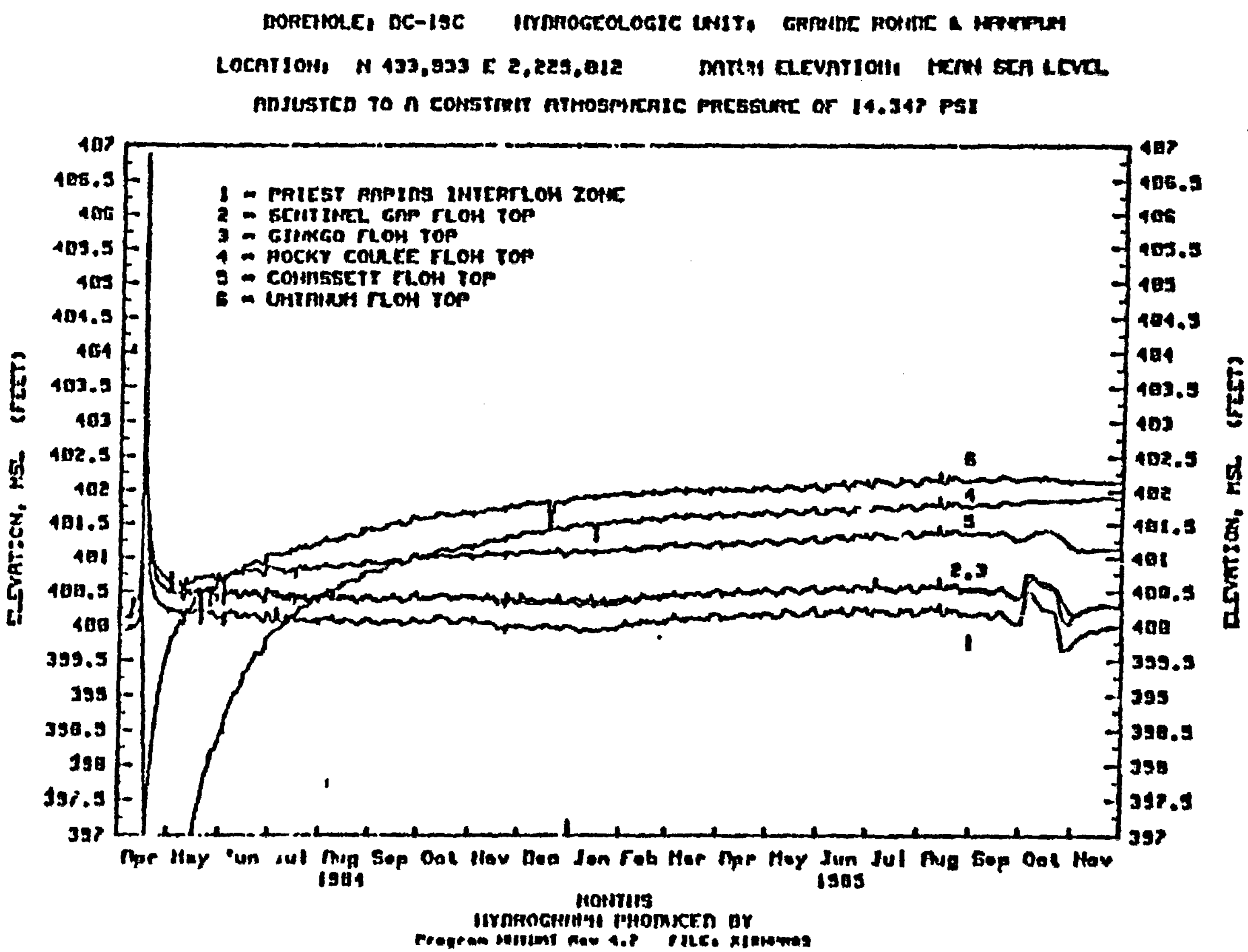

FIGURE 1

HYDROGRAPHS OF WANAPUM AND GRANDE RONDE HORIZONS IN DC-19C

PIEZOMETER SEALS

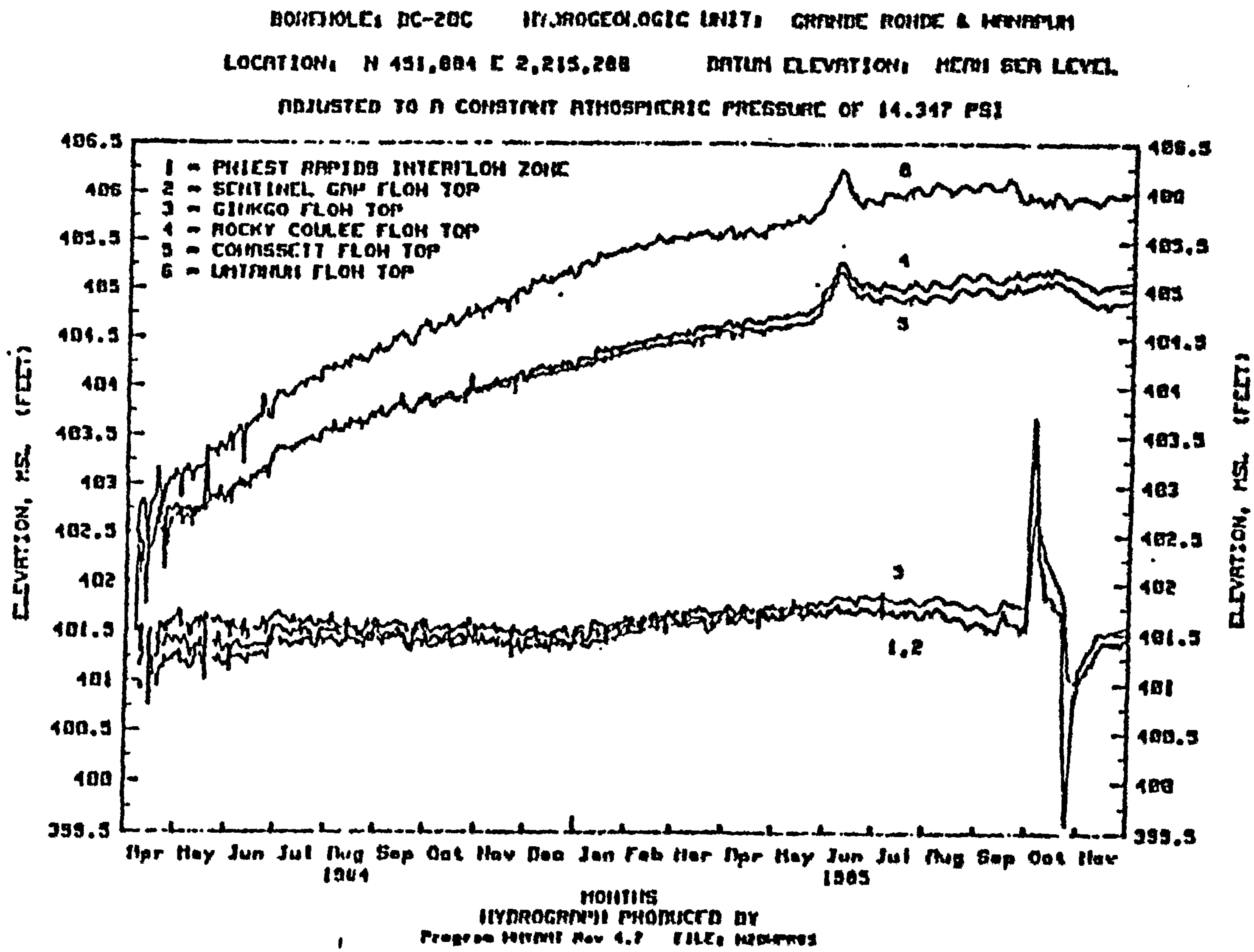

FIGURE **2**

HYDROGRAPHS OF WANAPUM AND GRANDE RONDE HORIZONS IN DC-20C

PIEZOMETER SEALS

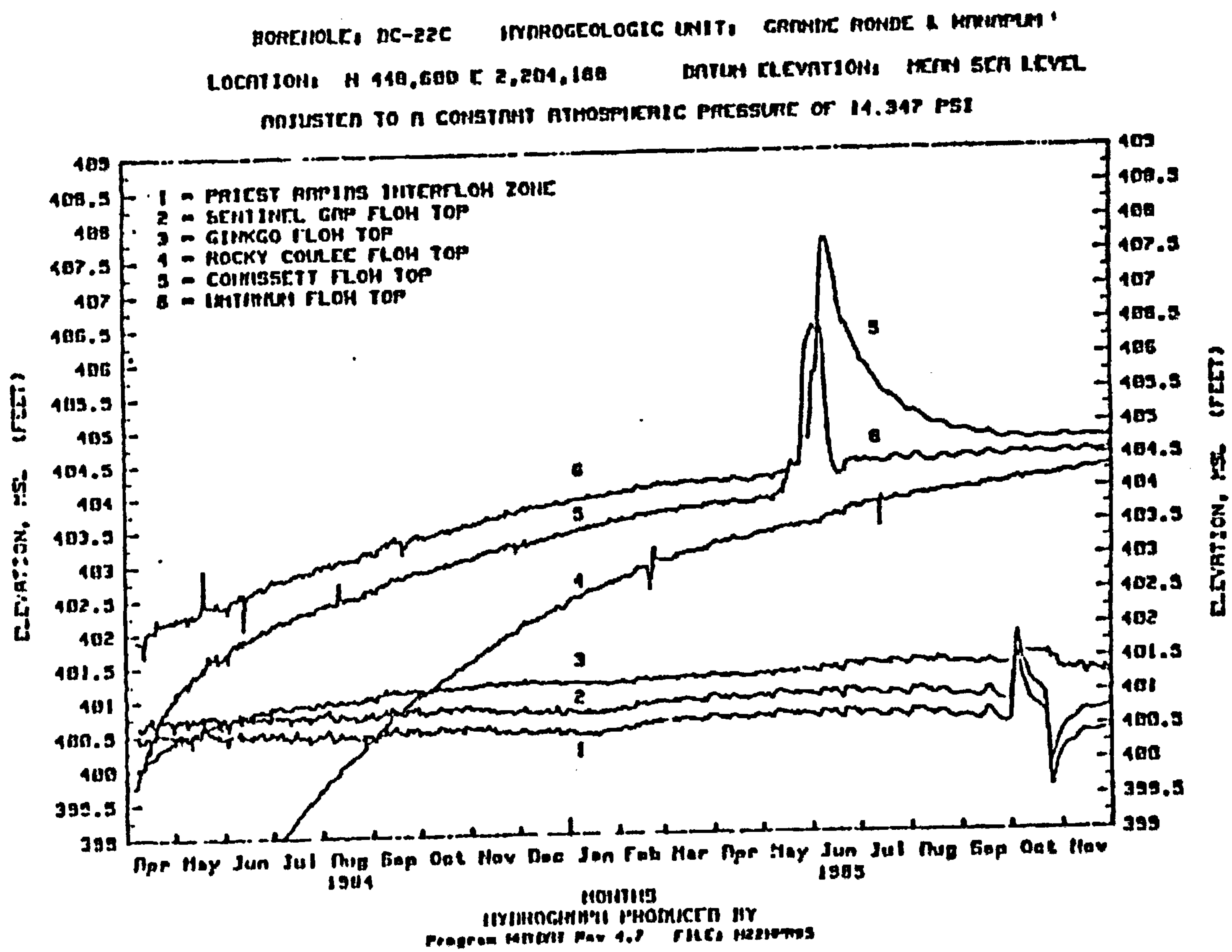

FIGURE 3

HYDROGRAPHS OF WANAPUM AND GRANDE RONDE HORIZONS IN DC-22C

PIEZOMETER SEALS

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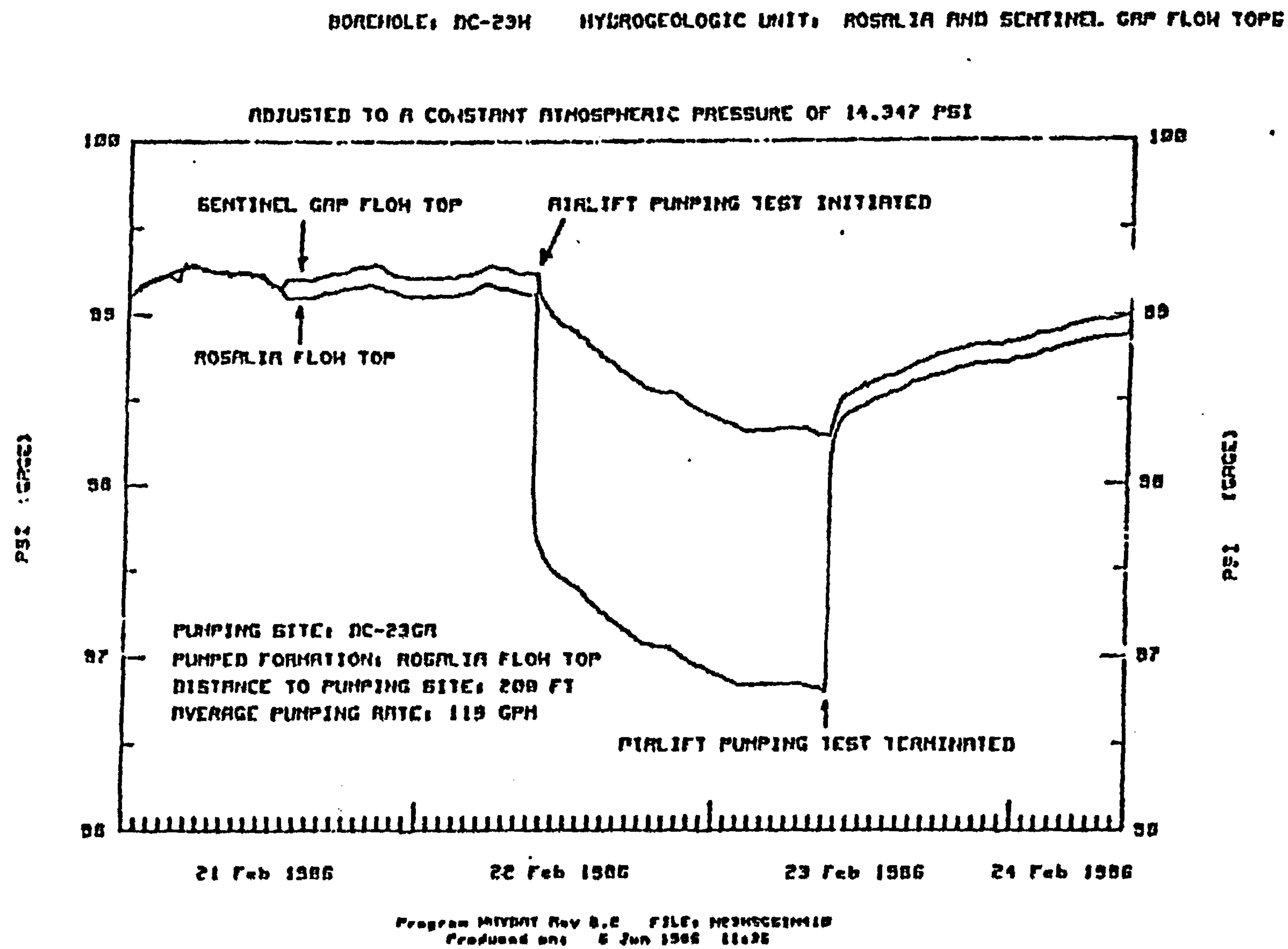

FIGURE 4
PRESSURE HYDROGRAPH FOR THE ROSALIA AND SENTINEL GAP FLOW TOPS AT DC-23W
PIEZOMETER SEALS

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at DC-20C. While some degree of hydraulic communication may exist among all monitored Wanapum and Grande Ronde horizons, highly efficient communication is evident only between the Rosalia and Sentinel Gap flow tops and between the Rocky Coulee and Cohassett flow tops in the vicinity of DC-22C.

Highly efficient communication between two flowtops suggests the presence of relatively high permeability vertical flow paths. The available information is insufficient to confidently determine whether these flow paths are naturally present or result from flaws in the piezometer seals.

Assuming that the piezometer seals were carefully placed, with appropriate use made of tubing spacers, high density neat grout, and emplacement by pressure injection beneath a rising grout surface, then good seals would be expected. Further, if proper grout emplacement and tubing spacing techniques were used, one would expect flaws to occur randomly and to be relatively independent of the competence of the surrounding rock and the number of tubes in the hole. There is a total of 20 seals between monitored Wanapum and Grande Ronde zones in the four wells. Assuming proper placement techniques, it is not likely that significant flaws would randomly occur in every seal in the four piezometers between the Rosalia and Sentinel Gap, and in none of the seals between virtually every other set of flowtops.

The one questionable seal in the Grande Ronde, between the Rocky Coulee and Cohassett flowtops in DC-20C, is understood to be at a location where the Rocky Coulee dense interior is thin and the rock is of poor quality. This evidence suggests enhanced hydraulic communication through a geologic anomaly rather than a faulty seal.

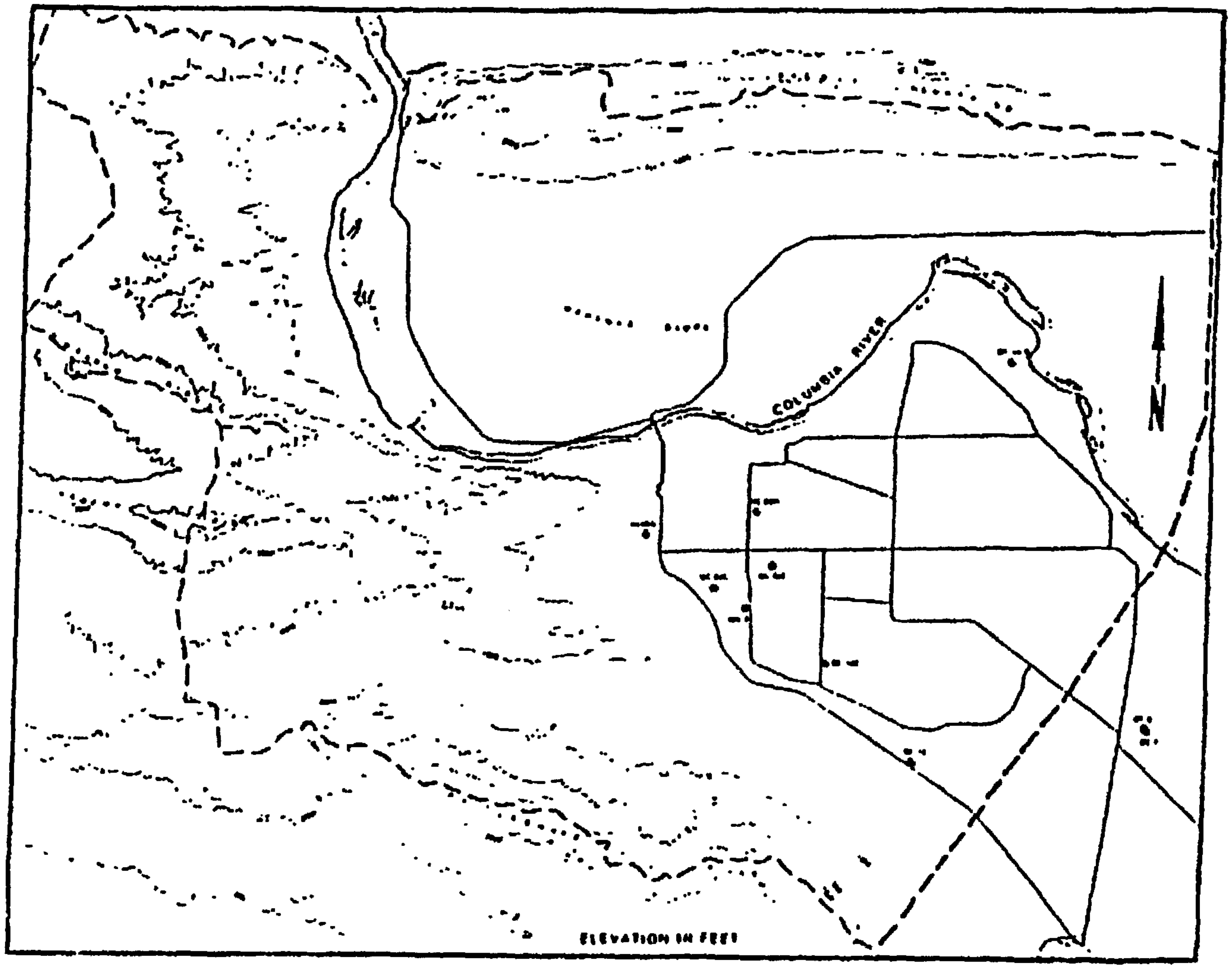
Although the foregoing reasoning suggests that the seals are probably good and that the observed vertical communication is probably a natural phenomenon, it does not provide complete assurance that this conclusion is correct. Additional information regarding the adequacy of the seals can be obtained from more detailed numerical analysis of existing data, and from the results of specifically designed in-situ tests.

3. NUMERICAL ANALYSIS OF AVAILABLE DATA

Hydrologic modeling of the Wanapum basalts would be expected to provide additional information on the possible mechanisms responsible for the observed hydraulic communication between the Rosalia and Sentinel Gap flow tops. This would be accomplished by developing a model with defensible boundary conditions that is calibrated to available head data. This model would then be run in a transient state reproducing the known hydraulic perturbations from drilling and testing, and evaluating the sensitivity of the results to alternative vertical leakage scenarios. The principal scenarios to be considered would include localized vertical leakage at or near the piezometers, uniform vertical leakage through the dense flow interiors, and treatment of the upper Wanapum as a single, homogeneous hydrostratigraphic unit. Variations of these scenarios, such as the locations and sizes of discrete leakage features, could be readily evaluated with the model.

Development of such a model is currently in progress by Golder, in support of BWIP's Site Characterization Plan. The 3-dimensional finite element code FE3DGW is being used. The area covered by the model is shown in Figure 5. The boundaries of the model extend laterally to no-flow boundaries at the edge of the Pasco Basin on the north, west and south, and to known constant head boundaries on the east. The eight deep wells shown on the figure within the model area coincide with model nodes, and any can be modeled as pumping centers. A plan view of the model mesh is shown in Figure 6. The more refined discretization in the RRL will support more detailed analyses in that area. Also, the results of this model are expected to provide supportable local boundary conditions for future highly detailed models of the RRL.

In vertical section, the model divides the Wanapum into seven material layers, consisting of the Rosalia, Sentinel Gap, and Ginkgo flow tops and the four adjacent composite horizons. The Mabton interbed and Rocky Coulee flow top form the upper and lower model boundaries, respectively, and are held at constant head.



Note. Dashed line indicates model boundary

0 5000 10000
Meters

FIGURE 5
LOCATION MAP OF PASCO BASIN SHOWING WANAPUM MODEL BOUNDARY
PIEZOMETER SEALS

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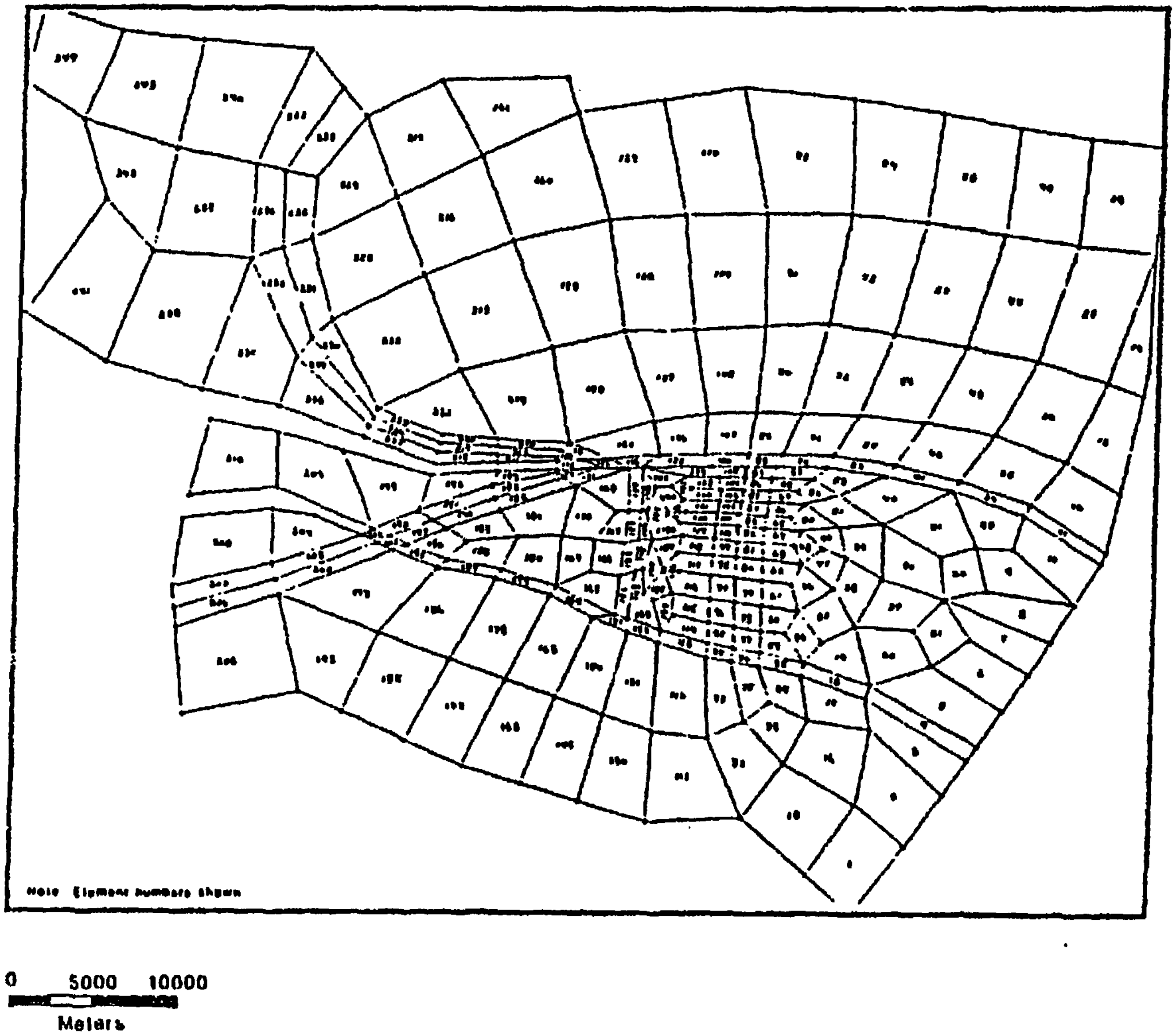

FIGURE 6

WANAPUM MODEL MESH

PIEZOMETER SEALS

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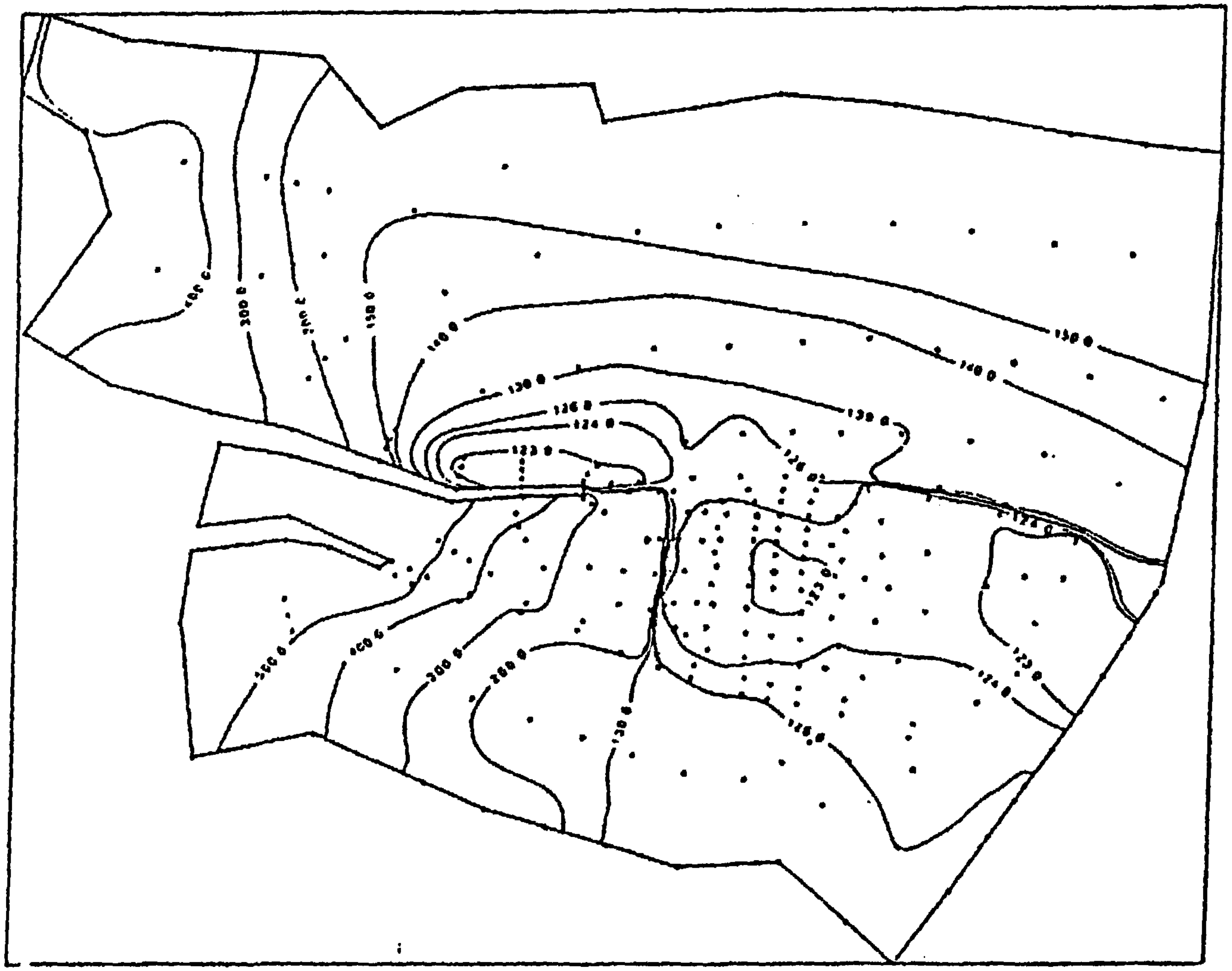
Results from a recent steady state run are shown in Figure 7, where equipotential contours are plotted for the Ginkgo flow top. The predicted heads on this run matched measured heads to within about +/- 2 m., which was slightly improved in our final steady state calibration run. Preparations are now underway to continue into transient simulations of the hydraulic perturbations during DC-23W drilling and development pumping.



Note: Heads are shown in meters above msl.

0 5000 10000
Meters

FIGURE 7

HEADS IN GINKGO FLOW TOP FROM MODEL CALIBRATION RUN

PIEZOMETER SEALS

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4. FIELD TESTS

A variety of field tests have been conceptualized that may provide additional information regarding the integrity of the questionable piezometer seals. If significant leaks are present, certain of these tests can potentially provide positive evidence for those leaks; however, if the leaks are slight, the degree of confidence that can be placed in the results of most of the tests will rapidly decline. None of these tests can be considered standard, all will require pretest technique development and analysis, and any of these tests may yield inconclusive results.

As will be seen, the list of tests was developed in an unconstrained, "blue-sky" discussion. While each test has certain merit, they have been addressed in a preliminary order of priority because not all are believed to have the same probability of success. The tests are described below in terms of an "upper" monitored flowtop, such as the Rosalia, that directly overlies the questionable seal, and a "lower" monitored flowtop, such as the Sentinel Gap, that directly underlies the questionable seal.

4.1 Radioactive Tracer Test

A steady-state, vertically downward hydraulic gradient would be established by pumping in the lower flowtop, and a short-lived, poorly sorbed gamma emitting radioactive tracer such as $NH_4\ Br^{82}$ would be released in the upper flowtop as shown in Figure 8. Gamma detectors would be placed inside the tubing of the other piezometers at locations within the lower flowtop and between the upper and lower flowtops where the seal is questionable. The tracer would be expected to migrate toward the lower flowtop. If it migrated through a flowpath within the seal, a strong response would be expected to be measured through the

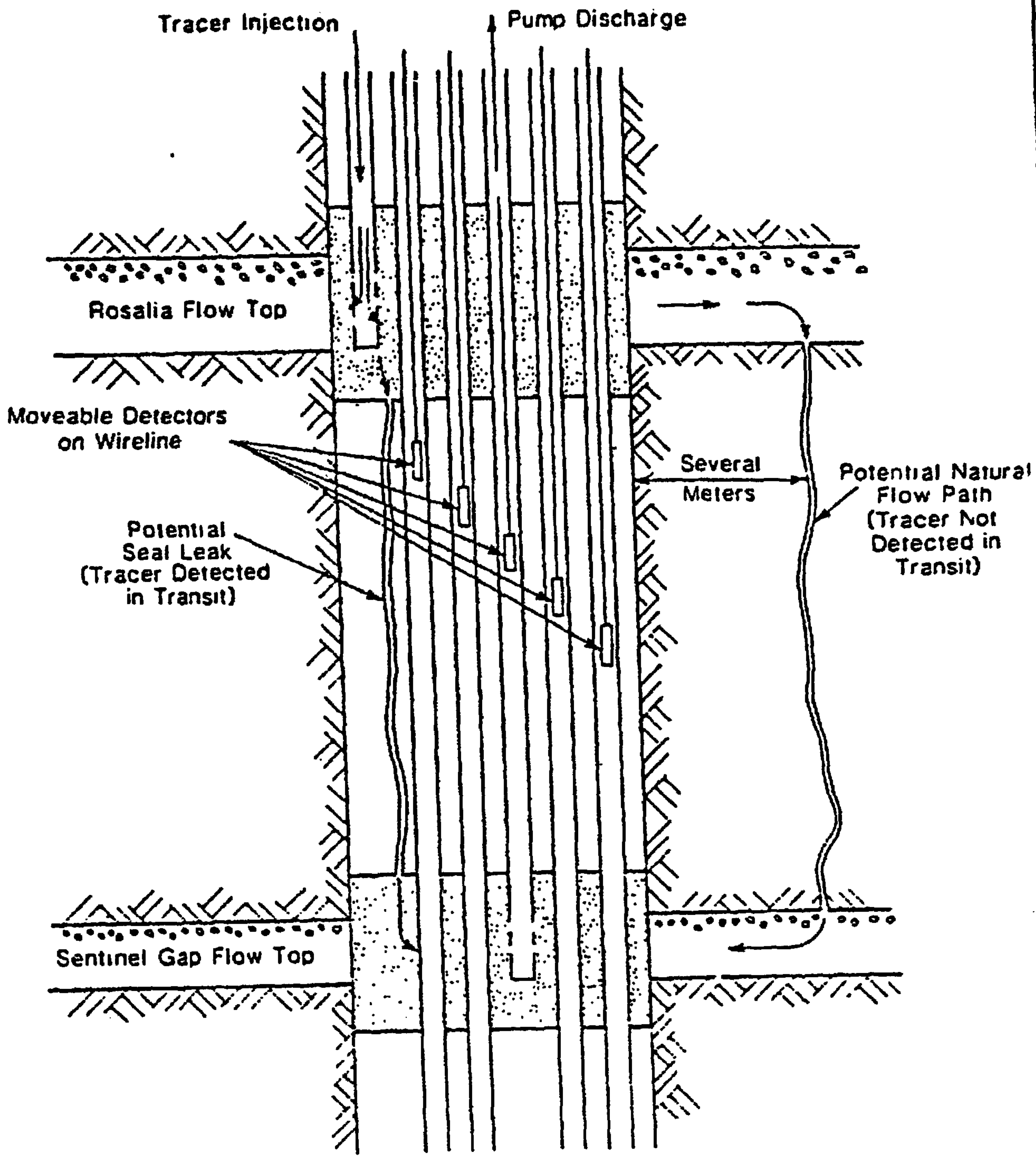

FIGURE 8

SCHEMATIC OF RADIOACTIVE TRACER TEST

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metal tubing. The gamma energy would be rapidly attenuated by the rock, and if the tracer followed a natural flowpath through the rock even a few meters away from the hole, little or no response would be expected to be seen.

The likelihood of success is considered to be higher for this test than for most of the other tests considered. This test may be capable of detecting relatively small seal leaks. Pretest analysis and evaluation of gamma ray attenuation in the basalt, grout and tubing wall would be required. Also, care would be required in handling the radioactive materials, and approval to release such a tracer may be difficult to obtain.

4.2 Trace Constituent Test

A steady-state, vertically downward hydraulic gradient would be established by pumping in the lower flowtop, and a nonsorbing tracer would be released in the upper flowtop as shown in Figure 9. The tracer-laden water would be expected to migrate toward the lower flowtop. Samples would be regularly taken of water issuing from the lower flowtop and subjected to hydrochemical trace analysis. Detection of the tracer would indicate that vertical fluid movement was occurring. If the tracer-laden water had migrated through a flowpath largely within the seal, it may acquire dissolved trace minerals that would be different than if the water had migrated largely along a natural flowpath within the rock.

The likelihood of success for this test is potentially good, but will depend upon the ability of the moving tracer-laden water to dissolve exotic trace minerals from the grout, the ability to detect those minerals, and the ability to distinguish trace minerals dissolved at the grout-sand pack interface from those dissolved along a leakage flowpath.

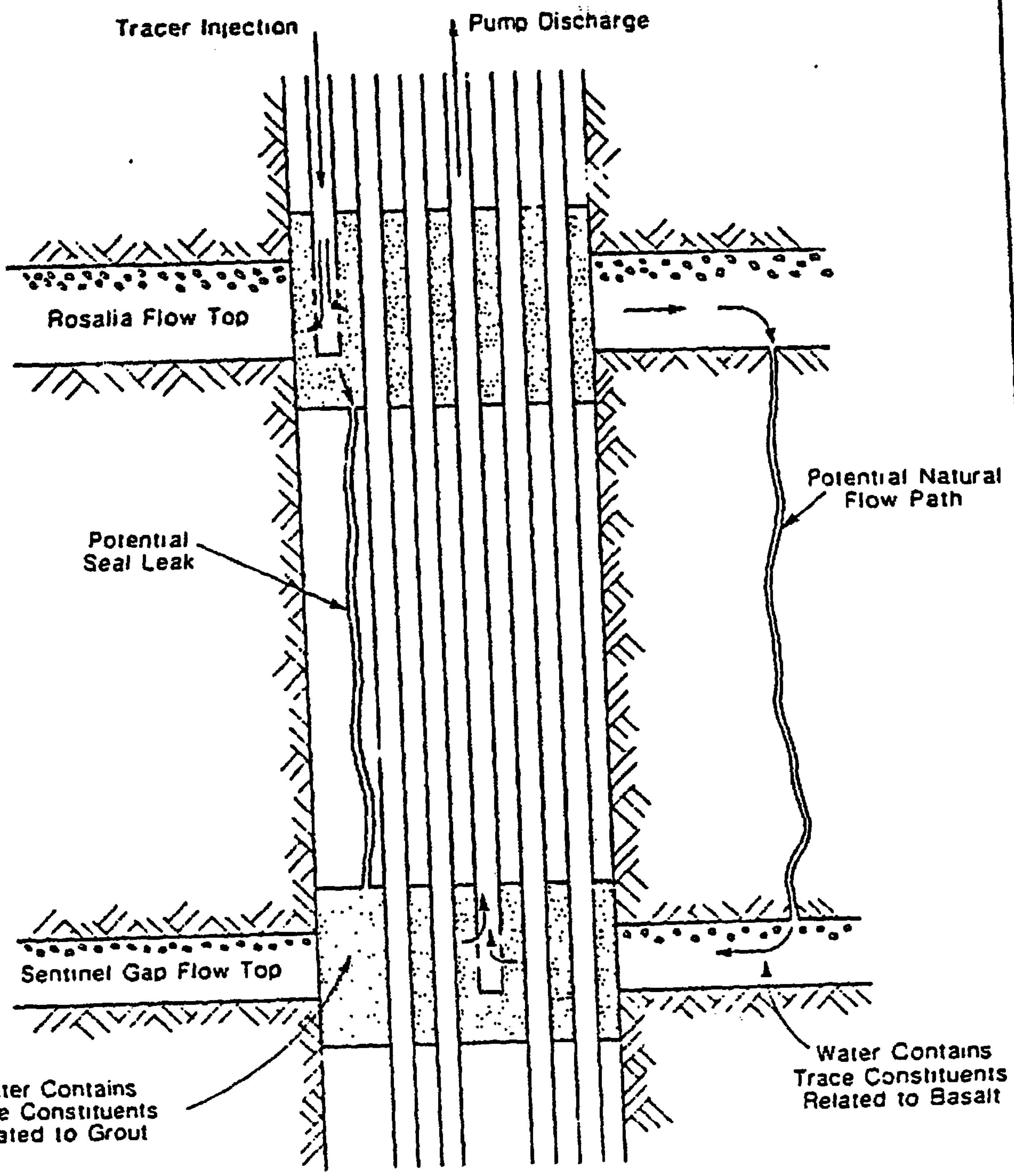

FIGURE 9

SCHEMATIC OF TRACE CONSTITUENT TEST

PIEZOMETER SEALS

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Even if this test provides an indication of a leak, it may not be able to distinguish whether the leak is in the seal above or below the lower flowtop without further refinement. The uncertainties of this test are greater than those of the foregoing tests, and pretest analysis and evaluation of the dynamics of trace mineral pickup from the basalt, grout and tubing walls would be required. The environmental effects of this test are expected to be relatively small.

4.3 Thermal Perturbation Test

A steady-state, vertically downward hydraulic gradient would be established by pumping in the lower flowtop, and heated water would be injected into the upper flowtop as shown in Figure 10. Temperature detectors would be placed inside the tubing of the other piezometers at locations within the lower flowtop and between the upper and lower flowtops where the seal is questionable. The heated water would be expected to migrate toward the lower flowtop. If it migrated through a high conductivity flowpath within the seal, a strong temperature response would be expected to be measured through the metal tubing. The heat would be rapidly attenuated by the rock, and if the heated water followed a natural flowpath through the rock even a few meters away from the hole, a significantly weaker response would be expected to be seen.

If a relatively large leak is present, the likelihood of success for this test is considered to be relatively high. Smaller leaks may not be as easily detected because the rate of heat transfer by conduction may be as rapid as by advection along the flowpath. Under either case the rate of heat loss to the formation is expected to be significant and it may not be possible to track water movement by this approach along the entire distance between the two flow tops. Pretest analysis and evaluation of thermal conduction and heat capacity in the basalt, grout and tubing wall would be required. This test would be fairly easily implemented and its environmental effects are expected to be small.

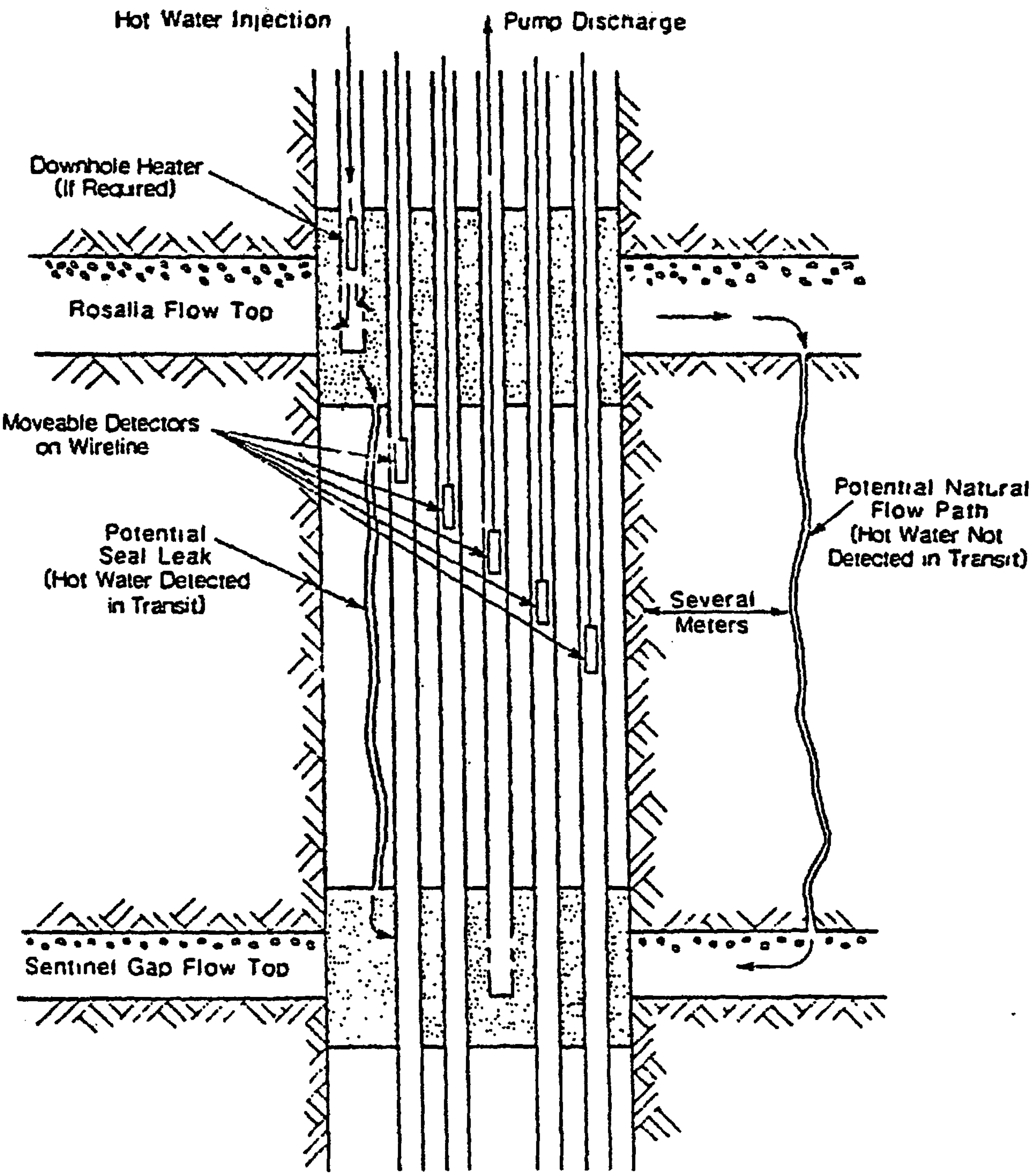

FIGURE 10
SCHEMATIC OF THERMAL PERTURBATION TEST
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4.4 Borehole Geophysical Tests

A number of standard borehole geophysical tests are available which might provide information on the potential for seal leaks. These include density, sonic and resistivity logs. As discussed below, each of these logs has potential benefits but may also have problems related to the presence of multiple piezometers in the same hole.

Standard omnidirectional density logging would not be expected to work because the high density of the multiple steel pipes would be expected to dominate the response such that minor variations resulting from voids in the grout would not be distinguishable. Directional density scanning with a neutron emitting tool could be potentially useful, but could only be directed radially outward away from the center of the hole. This constraint may be significant if flaws from grout emplacement are preferentially related to interference among tubes rather than interference between the tubes and the borehole wall.

Sonic waves can be used to check bonding between the piezometers and grout by testing for reflective fracture surfaces. While they may be useful very near the piezometer tube, multiple reflections would be expected at greater distances from the other standpipes in the hole. Sonic bonding logs may have already been performed in these holes, and should be checked for an initial evaluation of the adequacy of this tool.

Electrical methods were given a poor likelihood of success because of the shielding provided by the metal piezometer pipes. Detection of the weak electric current induced by the magnetic field established by moving polar water molecules outside a piezometer tube was considered and may provide some results, but should first be tested under controlled conditions. Detection of variations in resistivity of the fluid outside the piezometers was considered in association with injection of an electrolytic tracer solution, but would also be expected to be shielded by the tubing.

4.5 Tracer Sorption Test

A steady-state, vertically downward hydraulic gradient would be established by pumping in the lower flowtop, and a nonsorbing and sorbing tracer pair would be released in the upper flowtop as shown in Figure 11. The tracer-laden water would be expected to migrate toward the lower flowtop. Samples would be regularly taken of water issuing from the lower flowtop piezometer and subjected to hydrochemical analysis to determine breakthrough characteristics. Retardation of the sorbing tracer would be expected to be greatly enhanced if the tracers traveled uniformly through a quasiporous medium rather than through a discrete fracture flowpath.

While support for such an interpretation of differences in sorptive characteristics may be obtained from the results of the tracer tests performed in DC-7/8, the lack of experience in performing and interpreting such tests at the BWIP Site would necessarily attach considerable uncertainty in assessing their results. Additionally, this test would only be capable of distinguishing high surface area flow paths from low surface area flow paths, and would not be able to distinguish among them. For example, flow through a seal leak and flow through a nearby natural fracture are both low surface area flow paths and could not be distinguished from each other.

The greatest strength of this test may lie in the ease of coupling with the forementioned trace constituent test, to provide additional information on the nature of the flow path. The environmental effects of this test are expected to be relatively small.

4.6 Multiple Well Interference Test

A transient pressure perturbation would be induced by pumping in the upper flowtop, and arrival times of that perturbation would be precisely monitored in the lower flowtop of the pumping well and in the upper and lower flowtops in at least one other well. If the flowtops were hydraulically homogeneous and isotropic, a pressure perturbation traveling uniformly downward would be expected to arrive at the nearest observation point sooner than at a more distant observation point. However, if that perturbation traveled through a discrete, permeable pathway such as an isolated tectonic fracture or a leaky seal, the perturbation would be expected to first appear in the piezometer nearest that pathway. If such a pathway exists, its general proximity might be inferred from sequential pump testing at each of the wells.

The likelihood of success for this test is considered to be poor. Successful analysis of the results will depend strongly upon the extent to which the assumptions of flow top homogeneity and isotropy are valid. Although the need to assume isotropy could be mitigated through direct analysis of tests in three or more wells for this parameter, the presence of significant heterogeneities in the flow tops could in themselves cause results that could not be distinguished from those of discrete leakage features. The effects of flow top heterogeneities will be particularly significant if the contrast between horizontal permeability in the flow tops and vertical permeability in the dense interiors is large.

The test is also inherently weak because it cannot distinguish between leakage within a seal and leakage through a natural feature in the vicinity of a piezometer. Further, this test will work only if significant leaks are present at or near only one of the two wells. If high permeability seal leaks are actually present in all Rosalia-Sentinel Gap seals, then this test will not be capable of distinguishing between uniform vertical flow and vertical flow through those leaks.

The uncertainties of this test are significant, and pretest analysis will be required. The environmental effects of this test are expected to be relatively small.

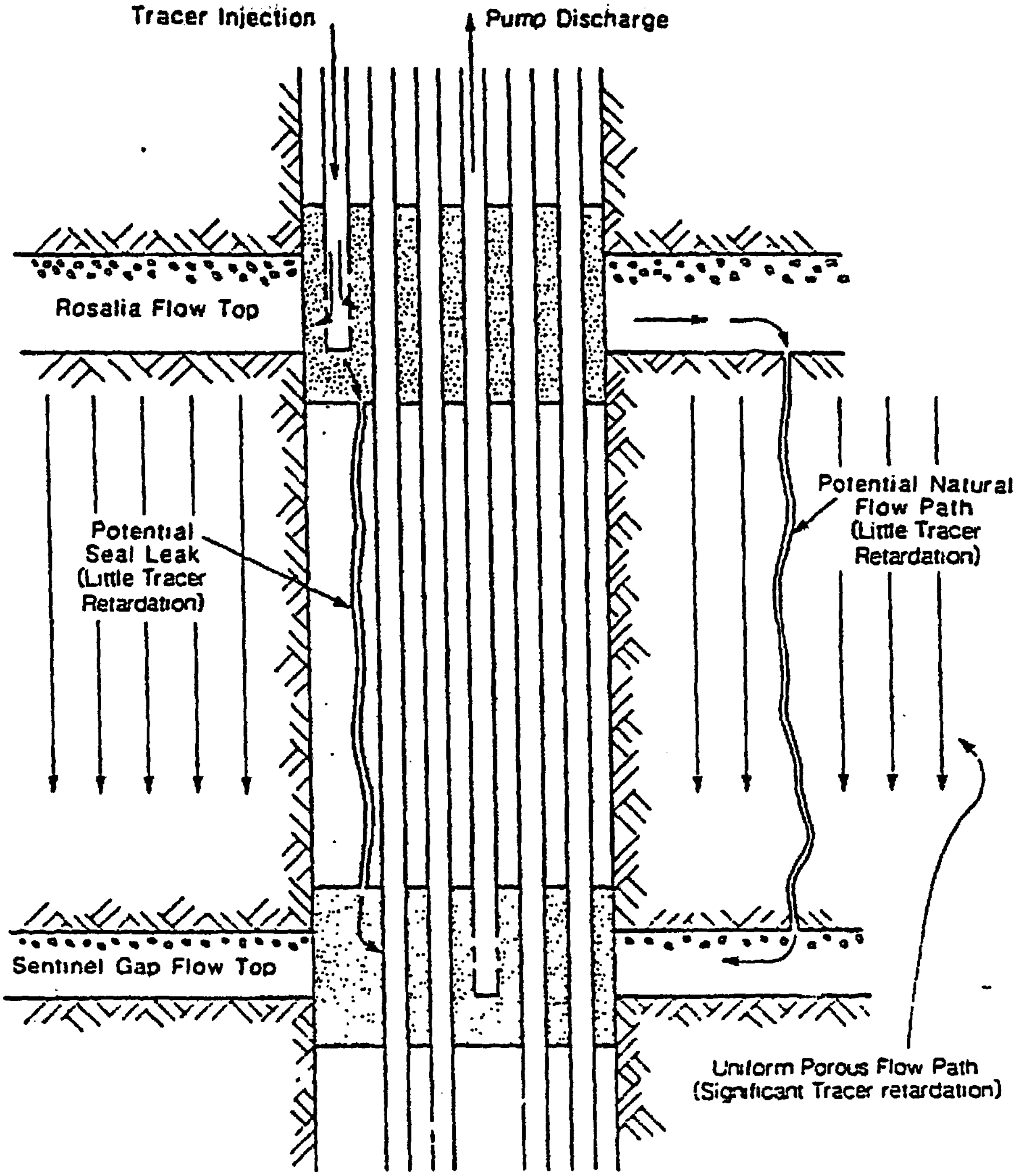

FIGURE 11
SCHEMATIC OF TRACER SORPTION TEST
PIEZOMETER SEALS

5. ALTERNATIVE PIEZOMETER DESIGNS

Alternative piezometer designs may be considered if substantive evidence of seal failure becomes available. Several conceptual alternatives are described below. Each of the major alternative designs has a significant technical or cost problem and further analysis should be performed before pursuing any one of them.

5.1 Single Casing Design

The single casing design would eliminate many of the grout-pipe surface interfaces in the current design that may lead to seal failure, yet retain the simplicity of individual open standpipes. A schematic drawing of this alternative is shown in Figure 12. The concept of the design is to cement one string of casing in the hole, gun-perforate next to monitoring zones, install the piezometer tubes, and isolate the zones within the casing using manufactured seal blocks.

The advantage of this concept is that grouting would be performed in a single operation on a single outer casing, thereby reducing the likelihood of bond failure. A cement bond log could be run prior to installation of the seal blocks to evaluate the quality of the grout bond. The individual piezometer tubes could then be sealed after casing perforation under more readily controlled conditions inside this outer casing. The design of leak-proof inner seal blocks then becomes the focal point of this conceptual approach. Several options exist, including mechanical packers, resin grouting, and plumbed piezometers, which should be evaluated in further studies.

This approach has the disadvantage of being developmental, and the equipment used would have to be specially designed, fabricated and tested. In addition, grout emplacement would necessarily be under considerable pressure which could drive excessive grout into the horizons to be monitored. Although this design is used successfully in the oil industry, its use at the BWIP site is not expected to be acceptable because of potential damage to the monitored horizons. Techniques should be investigated for alternative staged grouting through perforations in the outer casing that would limit grout emplacement to predetermined locations.

5.2 Single Piezometer Installation

The single piezometer installation design also eliminates many of the grout-pipe surface interfaces in the current design that may lead to seal failure, yet retains the simplicity of individual open standpipes. This relatively obvious solution would place only one piezometer in each borehole, and would use the technology developed for the existing piezometers. The disadvantage of this approach is the high cost of drilling a separate hole for each individual installation.

5.3 Multiport Piezometer Installation

The multiport piezometer monitors a number of separate horizons using a traveling probe within a single tube. An example of this type of piezometer is the Westbay System which was installed in RRL-2. We understand that this system failed because of packer leaks. The approach has the advantage of permitting many individual horizons to be monitored from a single relatively small diameter borehole, but the disadvantage of being mechanically more complex and more developmental than the standard grouting process presently being used. Additional development work appears to be required to successfully implement this alternative.

5.4 Downhole Remote Nonretrievable Sensing

This conceptual alternative would involve permanent emplacement of downhole pressure sensors which could be read remotely at a surface location. It is considered highly developmental because (1) the sensor would have to be capable of functioning remotely for the life of the facility (some 10 to 20 years), and (2) the readout system from the

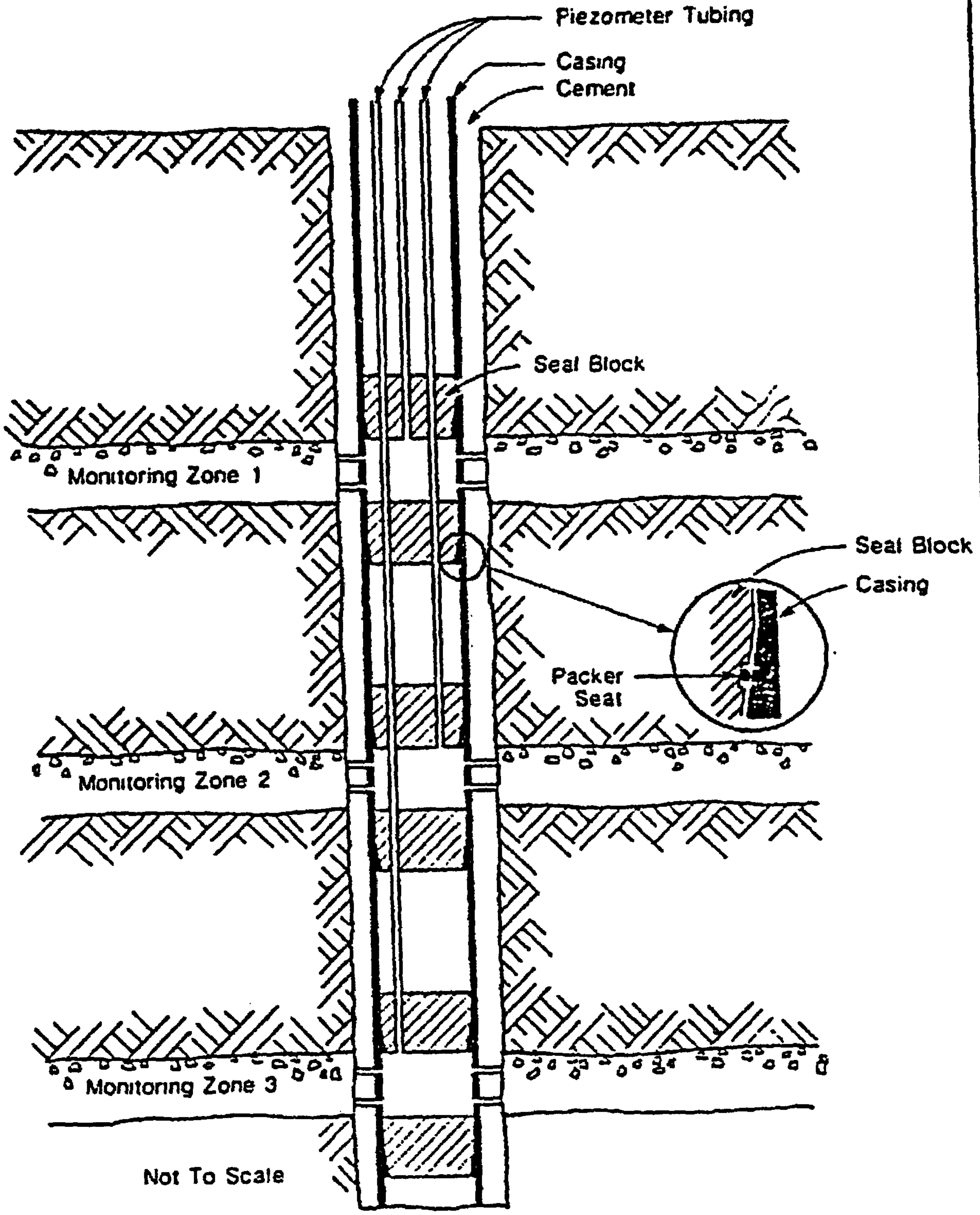

FIGURE 12

SCHEMATIC OF ALTERNATIVE SINGLE CASING DESIGN

PIEZOMETER SEALS

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sensor (for example, an electric wire or optical fiber) would have to be more amenable to sealing than the piezometer tubes now being used. Meeting the first criterion is expected to be very difficult to achieve and would require significant development work.

5.5 Refinement of Present Techniques

Several aspects of the present piezometer installation and grout emplacement techniques may be amenable to improvement. These would include potential modification of the grout mix, hole cleaning and development practices, piezometer spacing techniques, and grout emplacement practices. An independent evaluation of existing techniques would be required before recommendations for refinements could be prepared.

6. CONCLUSIONS AND RECOMMENDATIONS

The synchronous behavior of water pressures between several monitored flowtops is strong evidence for efficient vertical hydraulic communication, and the pattern of such behavior suggests that this communication is through naturally occurring flowpaths. However, the available information is not sufficient to assure that this conclusion is correct. The present uncertainty associated with the integrity of piezometer seals is not considered to be of overriding significance to the site characterization effort to date because all but one of the questionable seals is in the upper Wanapum far from the reference repository horizon, and the one remaining seal that is near the repository horizon is in a zone of poor rock thought to be relatively permeable. However, the issue is significant to future installations because of the importance of avoiding seal failures in the Grande Ronde.

Because the available information suggests that the seals are not likely to be the cause of the observed synchronous behavior, it would not be prudent to embark on an ambitious field testing program to evaluate leakage paths without further information. It is recommended that a stepwise investigation be adopted, as follows:

(1) Perform short term analytical and numerical modeling studies to develop additional insight into the nature and hydrologic implications of the observed field responses. Such studies are already underway and can provide additional information within one to two months. These studies should include a comprehensive review of present piezometer installation and grout emplacement practices at BWIP.

(2) Develop conceptual designs for the most promising field tests and evaluate their likelihood of success. Such studies could be performed concurrent with the foregoing modeling studies, and their early initiation would recognize the likelihood that some field testing will ultimately be required before the issue of leakage can be finally put to rest. Such testing capability will ultimately also be required to demonstrate the adequacy of final borehole sealing techniques at the time of repository closure.

(3) If the additional information provided by the modeling suggests that seal failure is a reasonable possibility and if the conceptual design studies suggest that the piezometer seals can be successfully tested insitu, then proceed to develop final designs and implement field testing.

(4) If seal failure is found to be likely based on the results of the foregoing, proceed to develop alternative piezometer designs.

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/Coleman

CA-988

February 6, 1987

Our ref: 863-1049.005
RSC/094

Rockwell Hanford Operations
P.O. Box 800
Richland, WA 99352

ATTENTION: Mr. P.M. Rogers

RE: CA-988 PRELIMINARY EVALUATION OF THE ADEQUACY OF PIEZOMETER SEALS

Dear Mr. Rogers:

I am pleased to transmit our draft report "Preliminary Evaluation of the Adequacy of Piezometer Seals." This report documents the results of a brief overview of the available piezometric data in the RRL area to provide a preliminary evaluation of the apparent adequacy of the piezometer seals. Also included are recommendations for future analyses, field tests, and a discussion of alternative piezometer designs.

If the potential exists for using information contained in this report in support of licensing, I recommend that it be returned with your comments and formalized as a final Golder report in accordance with our QA procedures.

The concepts presented were developed by Larry Rollins, David South, Dick Bielefeld and myself. Please contact me if you have any questions or would like further elaboration on the ideas presented.

Sincerely,

GOLDER ASSOCIATES

Charles R. Wilson

Charles R. Wilson

CRW/ah
Enclosure

~~cc: L. Cheshire, Rockwell~~