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Characterization of a Chromium Plume in Groundwater Along the Columbia River Shoreline, Hanford Site, Washington

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CHARACTERIZATION OF A CHROMIUM PLUME IN GROUNDWATER ALONG THE COLUMBIA RIVER SHORELINE, HANFORD SITE, WASHINGTON

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Geosciences, Westinghouse Hanford Company

To Be Presented at the 1992 Fall Meeting of the American Geophysical Union December 7-11, San Francisco, California

SLIDE #1: TITLE, AUTHORS, AND AFFILIATION

SLIDE #2: LOCATION MAP FOR THE HANFORD SITE AND REACTOR AREAS

The Hanford Site was formerly used to produce plutonium for nuclear weapons. So-called "production reactors" located along the Columbia River shoreline created irradiated fuel elements that were subsequently processed chemically to extract plutonium. Large amounts of liquid wastes were generated both at the reactors and the chemical processing plants. Some of these wastes were discharged to the soil column. The production reactors were in active operation during the 1950's and early 1960's. By the mid-1960's, the demand for plutonium decreased and decommissioning of the reactors started. This presentation focuses on one aspect of groundwater contamination at the 100-H reactor Area.

SLIDE #3: LOCATION MAP FOR THE 100-H REACTOR AREA

The six reactor areas were constructed to similar facility configurations. Each had one or two reactors, a water treatment plant to prepare once-through reactor coolant, a coolant water retention basin, and several liquid waste disposal trenches. After decommissioning of the reactor at 100-H Area, part of the water treatment plant was converted to a chemical waste storage facility -- the 183-H Solar Evaporation Basins.

Groundwater monitoring wells are currently in place to monitor waste constituent migration from the 183-H Basins and also to characterize residual contamination from past disposal practices. The objectives of these investigations are to (1) identify the hazardous constituents present in groundwater, (2) describe their concentration and distribution, and (3) determine their rate of movement. This information is then used in making environmental remediation decisions.

SLIDE # 3 cont.

Chemical indicators of hazardous wastes in groundwater include nitrate and chromium. Radiological indicators include gross alpha and gross beta activity levels, the latter caused by uranium and technetium-99, respectively. Of the several hazardous waste constituents still present in groundwater at the 100-H Area, chromium is the most widespread. Chromium occurs at levels above drinking water standards (formerly 50 parts per billion, raised to 100 parts per billion as of July 30, 1992).

Chromium in groundwater has several potential sources, all associated with past-practices activities. Documentation exists for the disposal to the soil column of approximately 3600 kilograms of sodium dichromate in the vicinity of the reactor building and 90 kilograms to the 107-H liquid waste trench. Approximately 750 kilograms of chromium were contained in acid wastes stored in the 183-H Solar Evaporation Basins, some of which leaked to the soil column. Well 199-H4-3 provides the only historical record of chromium levels in groundwater during the period when waste solutions were being handled at that facility.

SLIDE #4: CONCENTRATION OF CHROMIUM IN WELL 199-H4-3

Between 1973 and 1985, supersaturated solutions of nitric acid that had been neutralized with sodium hydroxide were stored in the 183-H basins. The solutions were waste products from the manufacture of nuclear fuel at another facility on the Hanford Site. These solutions contained metals, low levels of radioactivity, and miscellaneous other chemical wastes. As revealed by the concentrations of waste indicators in a single downgradient well adjacent to the Basins, waste solutions were escaping and migrating to groundwater.

Historical data on chromium suggest concentrations approaching 5000 parts per billion during the operational period. Since waste storage ceased in 1985 and cleanup operations were started, concentrations have continued to decrease with time. All chemical wastes have been removed from the facility and decontamination activities are in progress. Current concentrations of chromium in groundwater plume are generally less than 400 parts per billion. Chromium attributable to the 183-H Basins is superimposed on a more widespread chromium plume that has resulted from other sources described earlier.

SLIDE #5: CROSS SECTION SHOWING HYDROSTRATIGRAPHY AT 100-H AREA

The upper part of the unconfined aquifer in the 100-H Area is contained within two stratigraphic units: unconsolidated, poorly sorted sands and gravels resulting from glacial floods ("Hanford gravels") and consolidated silty-sands associated with river floodplain deposition (Ringold Formation). The hydraulic conductivity of the flood gravels is much higher than that of the silty sands. Estimated values for Hanford gravels lie in the range 0.07 to 0.002 meters per second, while estimates for Ringold deposits range from 0.002 to 0.00007 meters per second. An erosional unconformity separates the two units and the water table typically occurs 2 to 6 meters above the contact. To date, contamination has not been verified below the contact, although only three wells are available for sampling. An upward hydraulic gradient is present in the area, which works against downward migration of contamination.

The Columbia River stage fluctuates through a daily range of 2 to 2½ meters and a seasonal range of 2½ to 3 meters. This influence is readily observed in wells that monitor the water table at distances of 300 meters or less from the river. Bank storage of river water during high river stage forms a layer of river water overlying groundwater that is migrating toward the river channel. Some mixing probably occurs as well. Either or both processes reduce the concentrations of waste indicators in groundwater exposed as riverbank seepage during low river stage.

The three-dimensional model created during this investigation of the chromium plume includes the layer of groundwater between the water table and the Hanford gravels/Ringold Formation contact. The model uses the average of monthly water level measurements for 1-year intervals covering 1988, 1990, and 1992. Contouring control for chromium concentrations is less complete, and either average quarterly measurements or estimates extrapolated from historical trends for chromium concentrations were used to characterize the time period.

SLIDE #6: OBJECTIVES OF THE CHROMIUM PLUME CHARACTERIZATION EFFORT

This investigation is being conducted to provide information for two areas of cleanup-related decision making. First, existing data are being used to calculate the volume of groundwater affected by chromium contamination and the total amount of chromium contained in the plume. This information will be used to help design treatment processes, if risk-based decisions conclude that remediation is warranted. Second, there is uncertainty regarding sources for the chromium contamination currently observed. The locations of disposal areas and their period of use are not well documented. By better characterizing changes in the plume characteristics with time, it may be possible to evaluate the potential for currently unidentified continuing sources of chromium.

SLIDE #7: PERSPECTIVE VIEW OF 100-H AREA HYDROSTRATIGRAPHY

Interactive three-dimensional computer graphics are being used to create models of the chromium plume for different time intervals. A Model 4D/35 engineering work station (Silicon Graphics, Inc., Mountain View, California) and GeoDraw 5.0™ software (trademark of Dynamic Graphics, Inc., Alameda, California) were used to create the graphics displayed in the following slides.

Recent topographic mapping of the area has resulted in high resolution maps and digital topography, which has enhanced computer modeling efforts. Contours at 0.5-meter (1.6-foot) intervals reveal land surface modifications associated with past reactor operations, as well as natural topographic features. Selected facilities at which chromium solutions were disposed are superimposed on the surface for reference. The coordinate system used is NAD-83, Washington State South Zone grid. North is towards the upper right in the perspective views.

SLIDE #8: PERSPECTIVE VIEW OF 100-H AREA WATER TABLE: 1988

Twenty-three boreholes penetrate the contact between the Hanford gravels and Ringold Formation, thus providing reasonable control for the bottom surface of the volume of groundwater contaminated by chromium. The upper surface is defined by the average of monthly water level measurements taken between July 1 and June 30 of the following year, for 1988, 1990, and 1992. Flow direction is generally towards the Columbia River, with a downstream component that tends to transport groundwater along the shoreline. Daily river level fluctuations strongly influence water levels observed in wells along the shoreline.

SLIDE #9: PERSPECTIVE VIEW OF 100-H AREA WATER TABLE: 1990

SLIDE #10: PERSPECTIVE VIEW OF 100-H AREA WATER TABLE: 1992

Both 1990 and 1991 were relatively high river stage years. The water table underlying the 100-H Area was frequently higher than normal during parts of these years. Volume calculations for the slab of water containing the chromium plume confirm an increase in the amount of groundwater present between 1988 and 1992. The polygon used in the model was held constant for each of the three years, and volumes of 2,477,176 cubic meters (1988), 2,607,458 cubic meters (1990), and 2,673,335 (1992) were calculated.

SLIDE #11: HISTORICAL CHROMIUM DATA IN WELL 199-H4-18

Well 199-H4-18 is used as an example to demonstrate how chromium concentrations were characterized for each of three time intervals: July 1 to June 30 of the following year for 1988, 1990, and 1992. Data coverage is more complete for 1988 than later intervals, which are limited by data gaps. Characterizing the chromium concentrations for each time interval was subjective by necessity. This has limited the confidence that can be attached to conclusions regarding temporal changes in the plume, particularly for recent years.

During 1992, numerous new groundwater monitoring wells are being installed to support remedial investigations. Analytical results for samples from these wells are starting to become available for interpretation. The new data will enhance definition of the chromium plume and increase the confidence attached to conclusions regarding temporal changes in the plume.

SLIDE #12: PERSPECTIVE VIEW OF 100-H AREA CHROMIUM PLUME: 1988

The area and volume of the unconfined aquifer affected by chromium were calculated for three 1-year time intervals. Successive rings of the plume were defined by 20 parts per billion incremental increases in chromium concentration (the slide shows broader contour intervals for clarity). The elevation of the Hanford/Ringold contact was subtracted from the average water table for each year to determine a ring thickness. Using an assumed total porosity ranging between 10 and 20 percent, the volume of groundwater in the aquifer was calculated. The mass of chromium in this volume was then calculated for each concentration level.

For 1988, the total volume of groundwater affected by chromium in excess of 10 parts per billion is approximately 416,000 cubic meters and the total mass of chromium in the plume is approximately 36 kilograms, assuming a total porosity of 20 per cent. Elevated chromium levels in the region to the northwest of the 100-H Area were not included in the calculations.

SLIDE #13: PERSPECTIVE VIEW OF 100-H AREA CHROMIUM PLUME: 1990

SLIDE #14: PERSPECTIVE VIEW OF 100-H AREA CHROMIUM PLUME: 1992

SLIDE #15: SUMMARY OF VOLUME AND MASS CALCULATIONS

Groundwater volume and chromium mass calculations were made for each successive "ring" formed by concentration contours at 20 parts per billion increments. For the summary table, a total porosity of 20 per cent and the mid-range of each contour interval were used. Results are summarized by year for the plume at levels above 10 parts per billion (nominal detection limit for chromium), above 50 parts per billion (former Environmental Protection Agency drinking water standard), and above 100 parts per billion (revised drinking water standard as of July 30, 1992).

Both the volume of groundwater affected by chromium and the total mass of chromium present appear to be increasing slightly during recent years. To gain some idea of how sensitive these results are to the porosity value use, and to the concentration value assigned to each contour interval "ring," the calculations were run several times.

SLIDE #16: SENSITIVITY TO ASSUMED POROSITY AND CONCENTRATION BOUNDARIES

Chromium mass calculations were run for porosity values ranging from 10 to 20 percent to demonstrate the influence of that variable on the results. The upper value is a conservative estimate to use when planning groundwater remediation activities, although the range 10 to 20 percent is applicable for these Hanford Site sediments.

The influence of the concentration value assigned to the various contour "rings" was also tested. Calculations were run for concentrations assigned to the outer and inner circumferences of the contour rings, and also for the concentration at the mid-point of the contour interval. The effect is not significant for the type of information to be derived from the analysis, and the mid-point of each contour range is appropriate.

[Back to **SLIDE #15: SUMMARY OF VOLUME AND MASS CALCULATIONS**]

Based on the contouring and volumetric calculations performed by the Dynamic Graphics software, there appears to be a slight increase in both the volume of groundwater affected by chromium, and the mass of chromium contained in the plume, between 1988 and 1992. Whether or not the differences are significant and represent actual change in the plume is equivocal, although there appears to be a consistent trend.

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SLIDE #17. SUMMARY OF RESULTS AND CONCLUSIONS

We initially set out to use three-dimensional computer graphics to provide information on two areas that influence cleanup-related decisions. First, we wanted to know how much groundwater is affected by chromium from past disposal practices and how much chromium is currently in the plume. Second, is there any evidence of a chromium source that continues to supply chromium to the groundwater at the 100-H Area?

Given the existing data coverage for the 100-H Area, computer modeling has provided reasonable and consistent estimates for (1) the volume of groundwater involved in the plume and (2) the amount of chromium contained in the plume at various concentration levels. The calculated values provide a starting point for estimating the requirements of remediation activities.

Whether or not a continuing source of chromium is present is less certain. Given a groundwater flow rate in the range of meters per day through the 100-H Area, we expected to see a continuous decline in the volume of the plume and mass of chromium over the 4-year interval. That does not appear to be happening. Since the previously identified liquid waste disposal sites are no longer active (e.g. disposal trenches near the reactor building and the 183-H Basins), there may be other sources to consider, if the trend is real.

One possible source is the withdrawal of chromium held in the soil column above the water table. Residual chromium from past disposal activities may be retained by capillary forces or as soluble residues. A higher than normal seasonal water table might provide a mechanism to remobilize such residues. Both 1990 and 1991 were relatively high water years for the Columbia River and the water table in the 100-H Area.

An as yet unidentified underground source containing mobile chromium is a second alternative. Buried piping and/or underground storage tanks are potential candidates, but we currently have no documented evidence for them.

A third explanation for the slight increase in the plume with time involves migration into the 100-H Area of a chromium-bearing water mass from the west. Limited groundwater monitoring data from upgradient wells suggest another chromium plume, whose leading edge may be starting to influence the wells used in the model for the 100-H Area plume.

[Back to **SLIDE #12: PERSPECTIVE VIEW OF 100-H AREA CHROMIUM PLUME: 1988**]

Background for question and answer period.

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SLIDE #1: TITLE, AUTHORS, AND AFFILIATION.

CHARACTERIZATION OF A CHROMIUM PLUME IN GROUNDWATER ALONG THE COLUMBIA RIVER SHORELINE, HANFORD SITE, WASHINGTON

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Geosciences Group
Westinghouse Hanford Company
Richland, Washington

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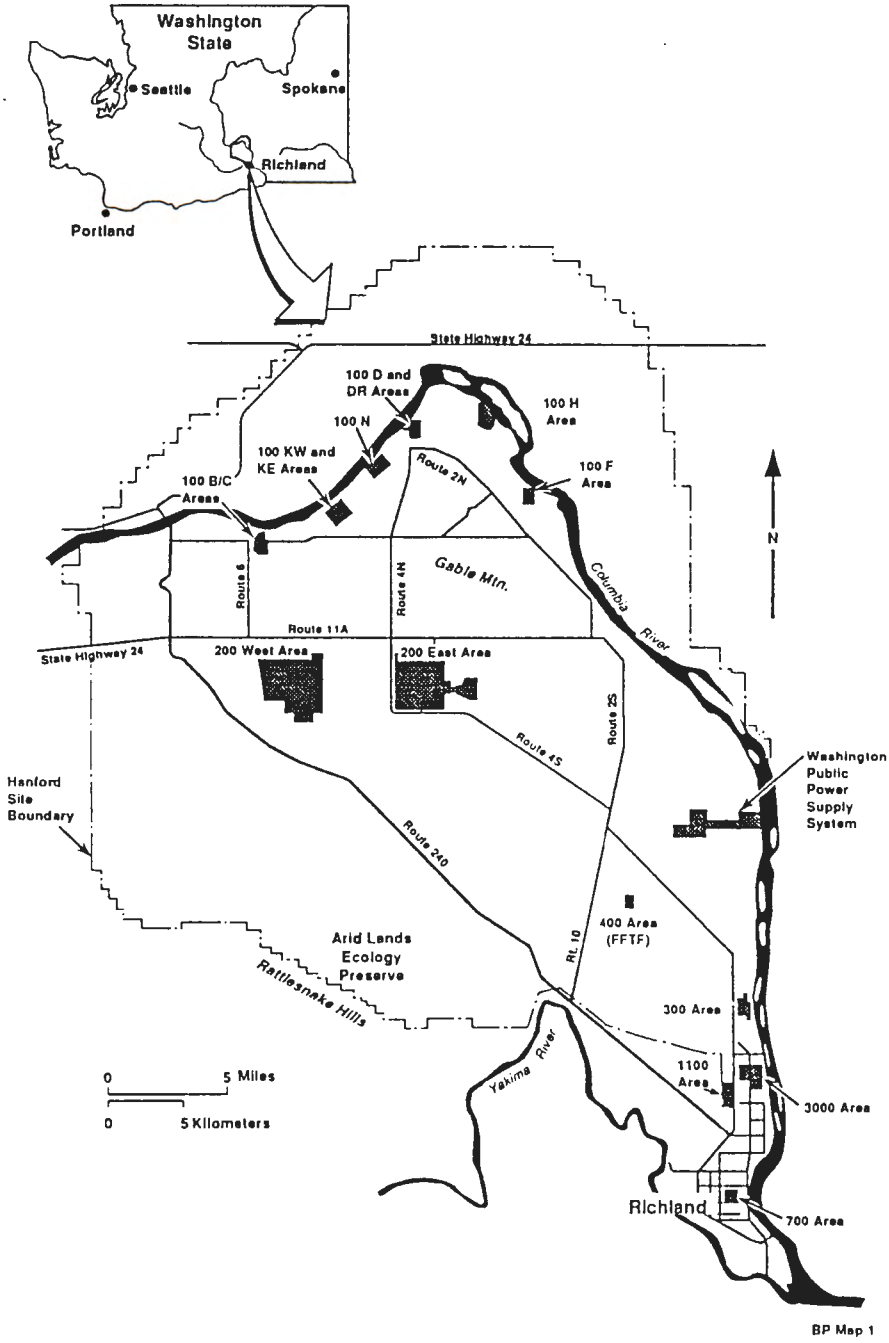
SLIDE #2: LOCATION MAP FOR THE HANFORD SITE AND REACTOR AREAS.



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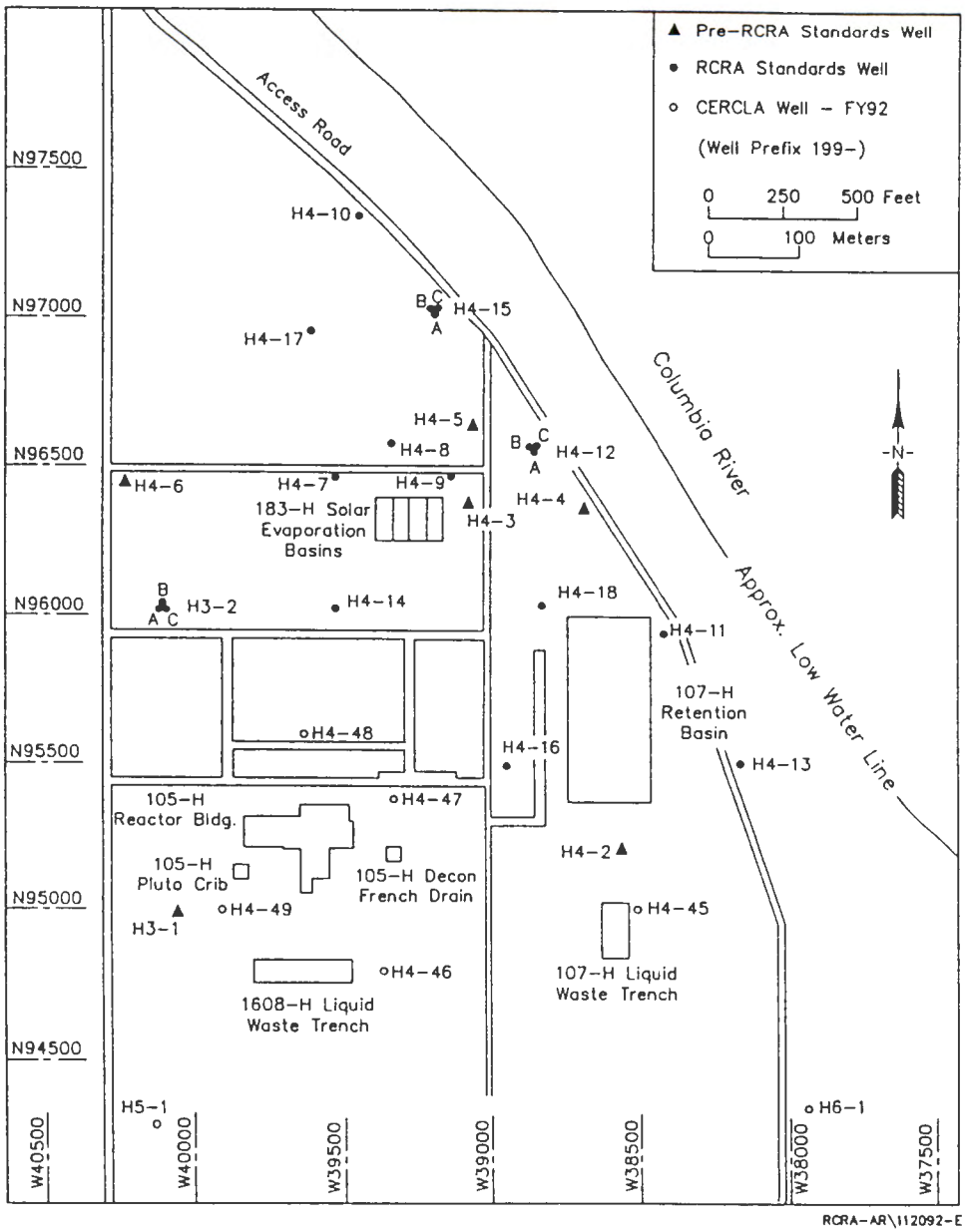
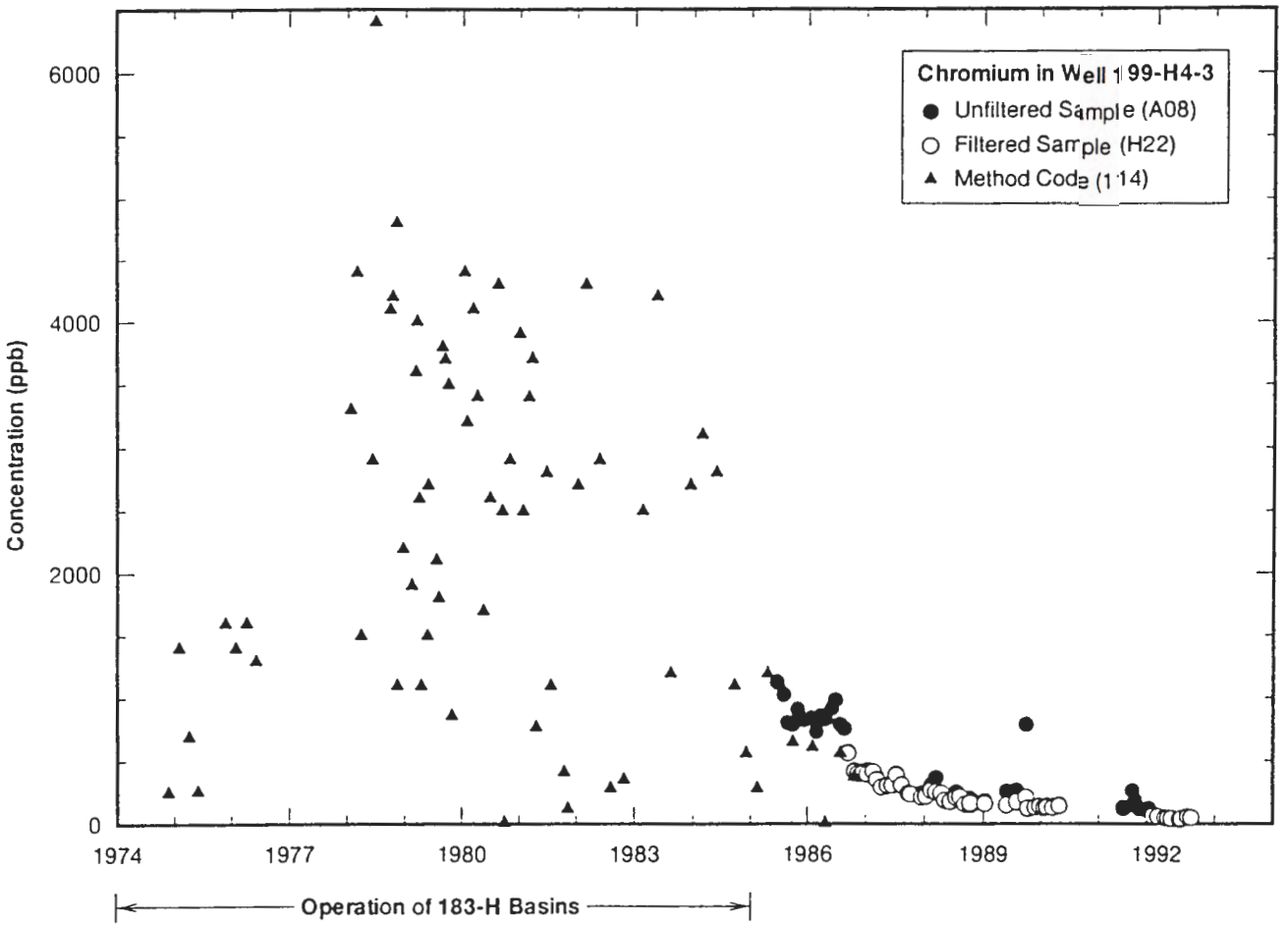
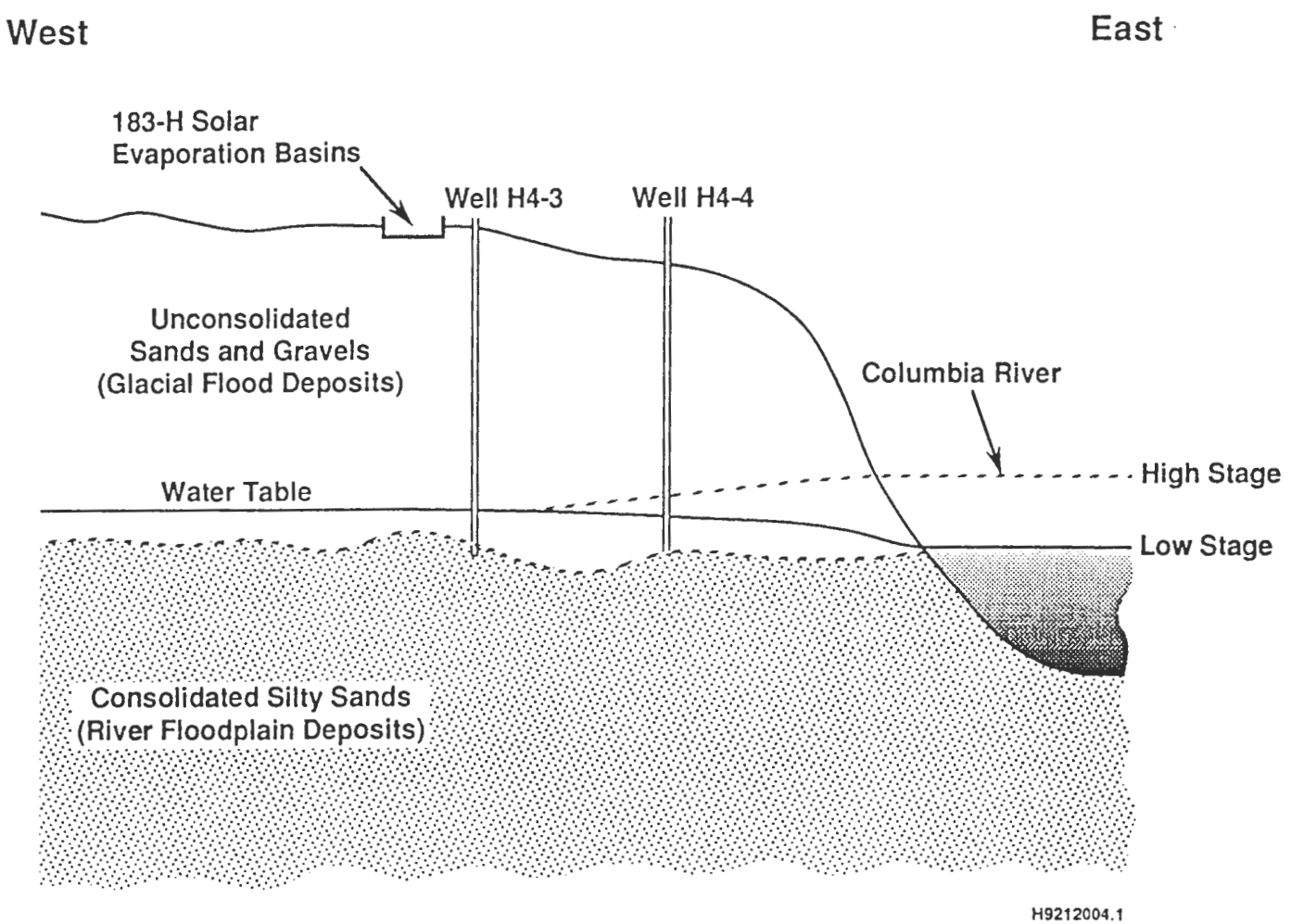
SLIDE #3: LOCATION MAP FOR THE 100-H REACTOR AREA.



SLIDE #4: CONCENTRATION OF CHROMIUM IN WELL 199-H4-3.



SLIDE #5: CROSS SECTION SHOWING HYDROSTRATIGRAPHY AT 100-H AREA.



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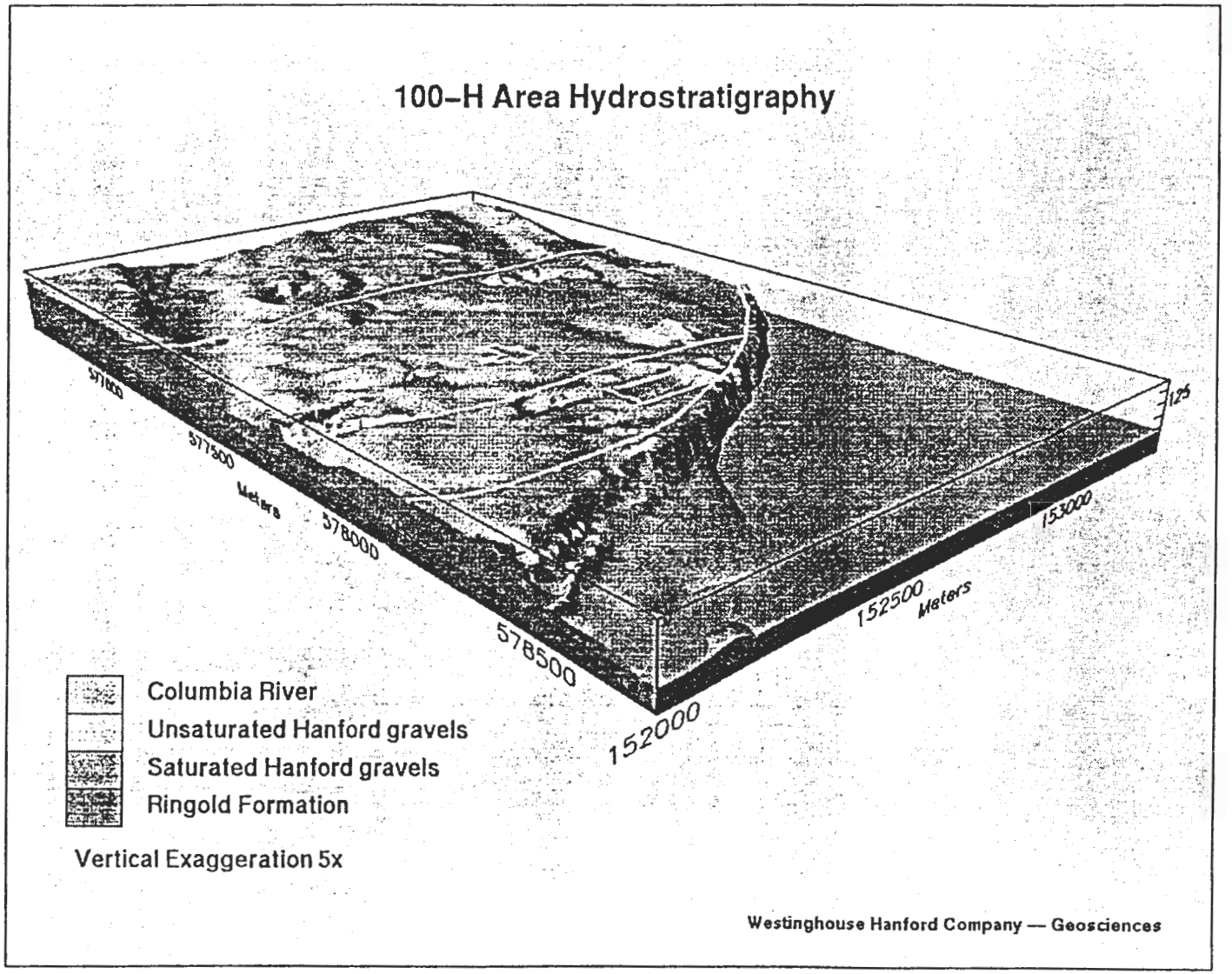
SLIDE #6: OBJECTIVES OF THE CHROMIUM PLUME CHARACTERIZATION EFFORT.

OBJECTIVES OF THE CHROMIUM PLUME CHARACTERIZATION EFFORT

- Estimate the volume of groundwater affected by chromium and the total mass of chromium in the plume, for use in planning remediation activities
- Obtain evidence to better define potential sources for the currently observed plume

SLIDE #7: PERSPECTIVE VIEW OF 100-H AREA HYDROSTRATIGRAPHY.



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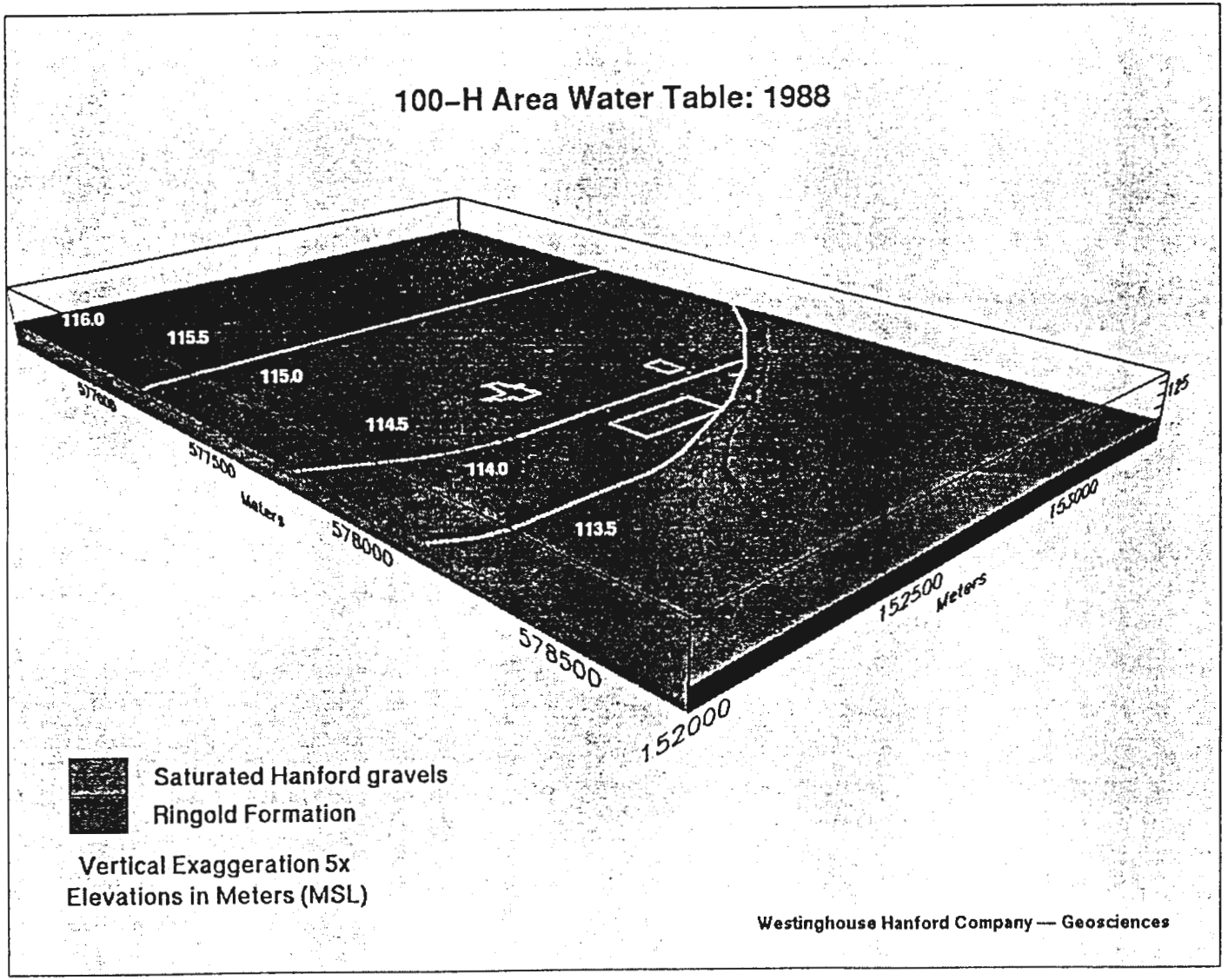
SLIDE #8: PERSPECTIVE VIEW OF 100-H AREA WATER TABLE: 1988.



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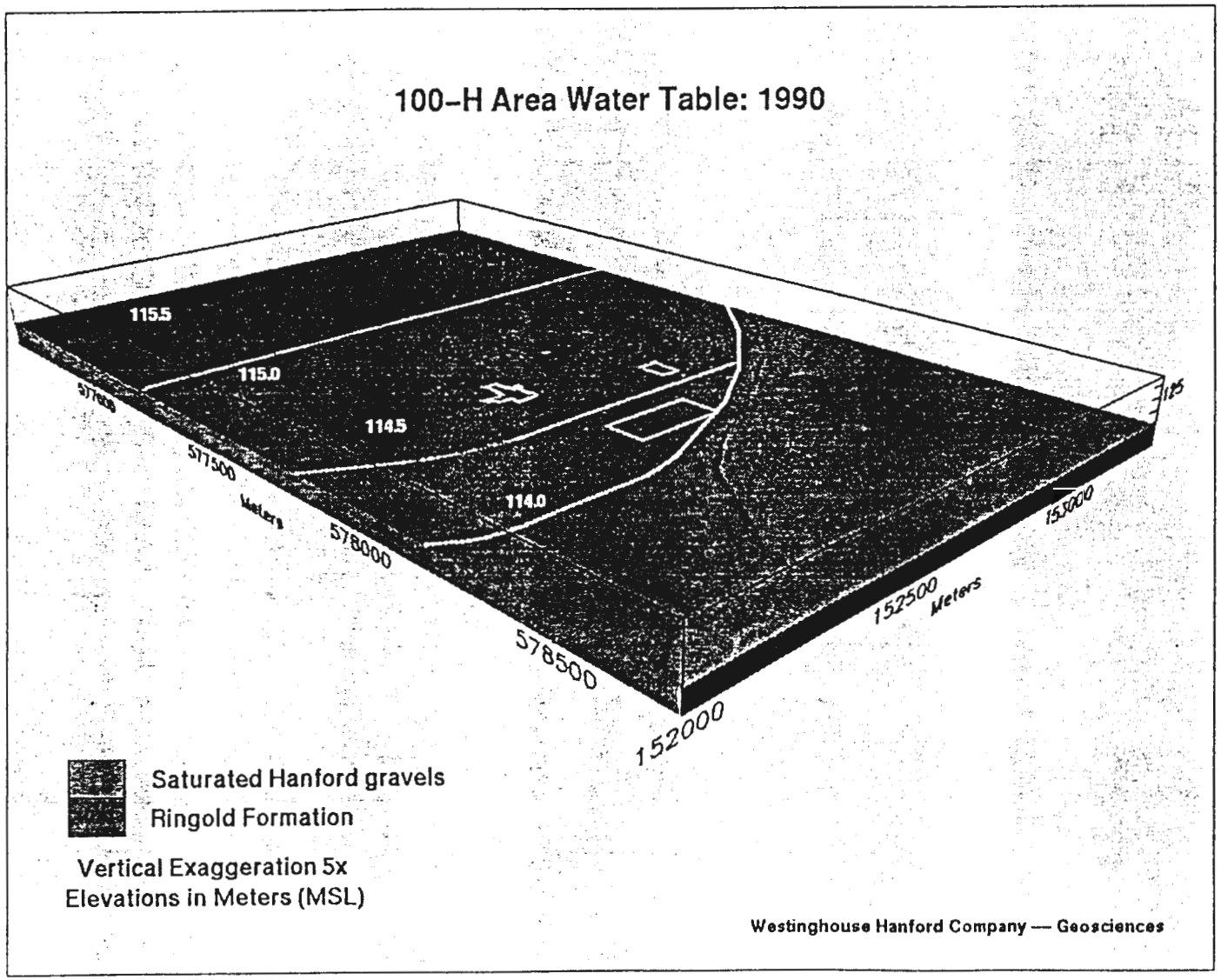
SLIDE #9: PERSPECTIVE VIEW OF 100-H AREA WATER TABLE: 1990.



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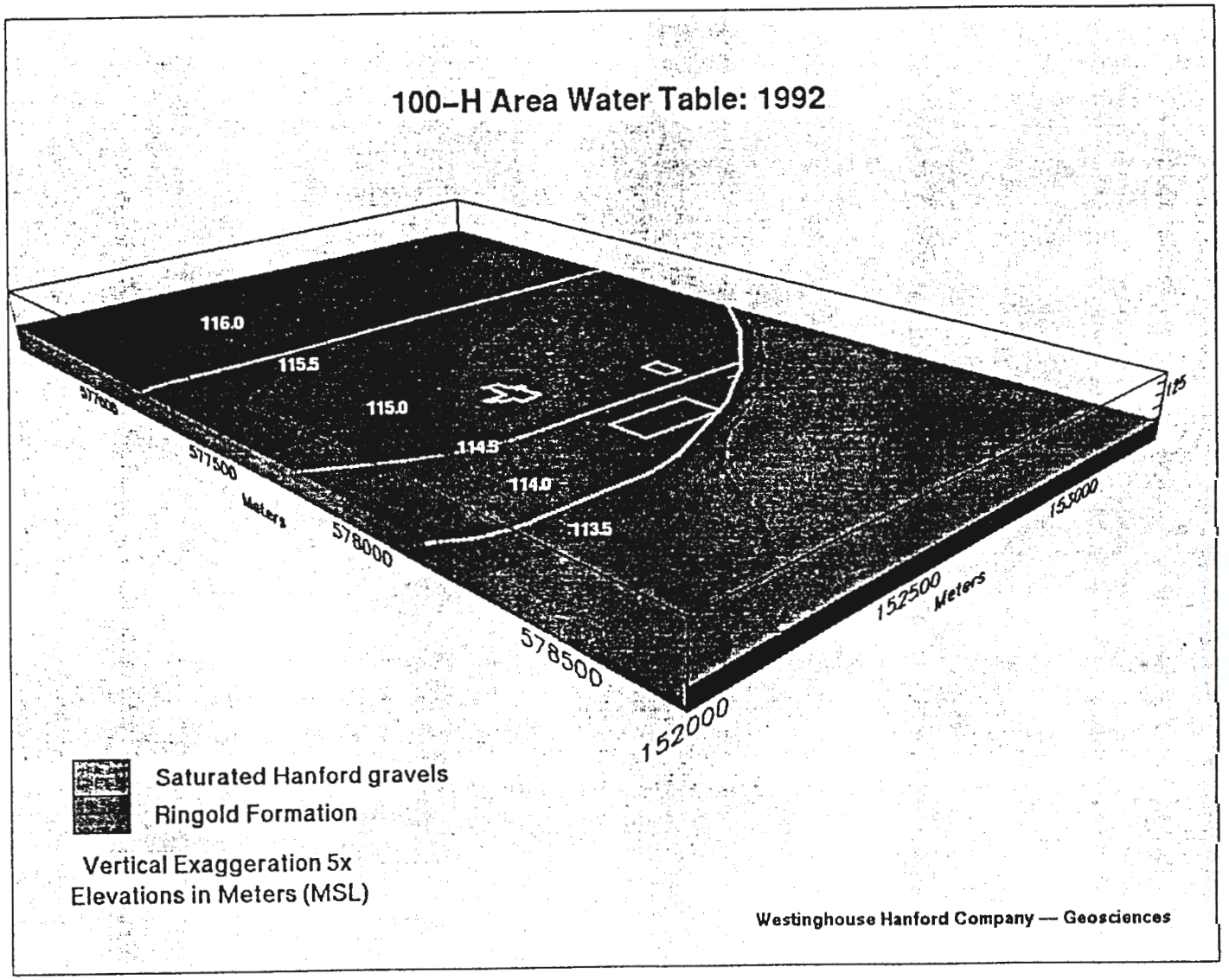
SLIDE #10: PERSPECTIVE VIEW OF 100-H AREA WATER TABLE: 1992.



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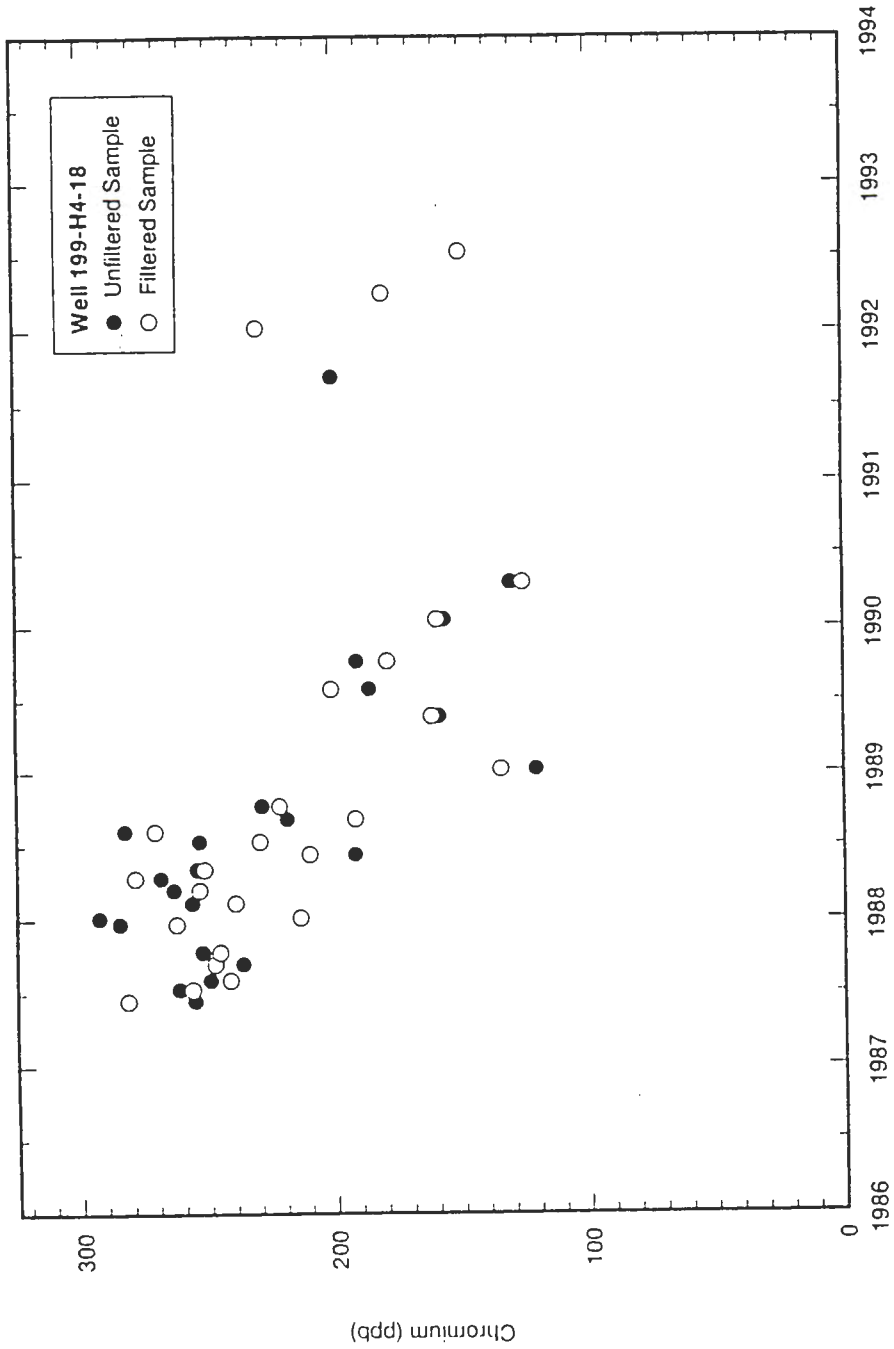
SLIDE #11: HISTORICAL CHROMIUM DATA IN WELL 199-H4-18.



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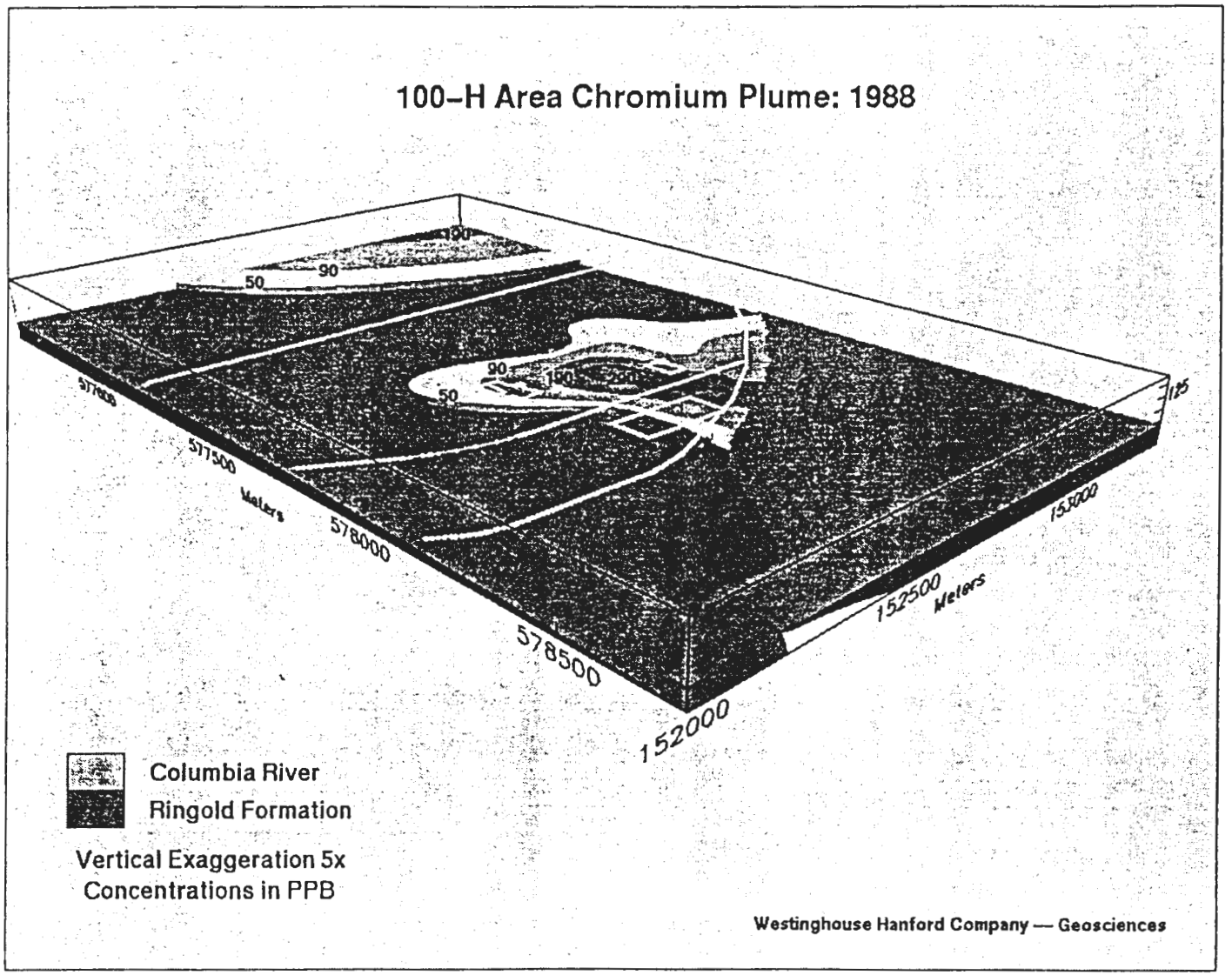
SLIDE #12: PERSPECTIVE VIEW OF 100-H AREA CHROMIUM PLUME: 1988.



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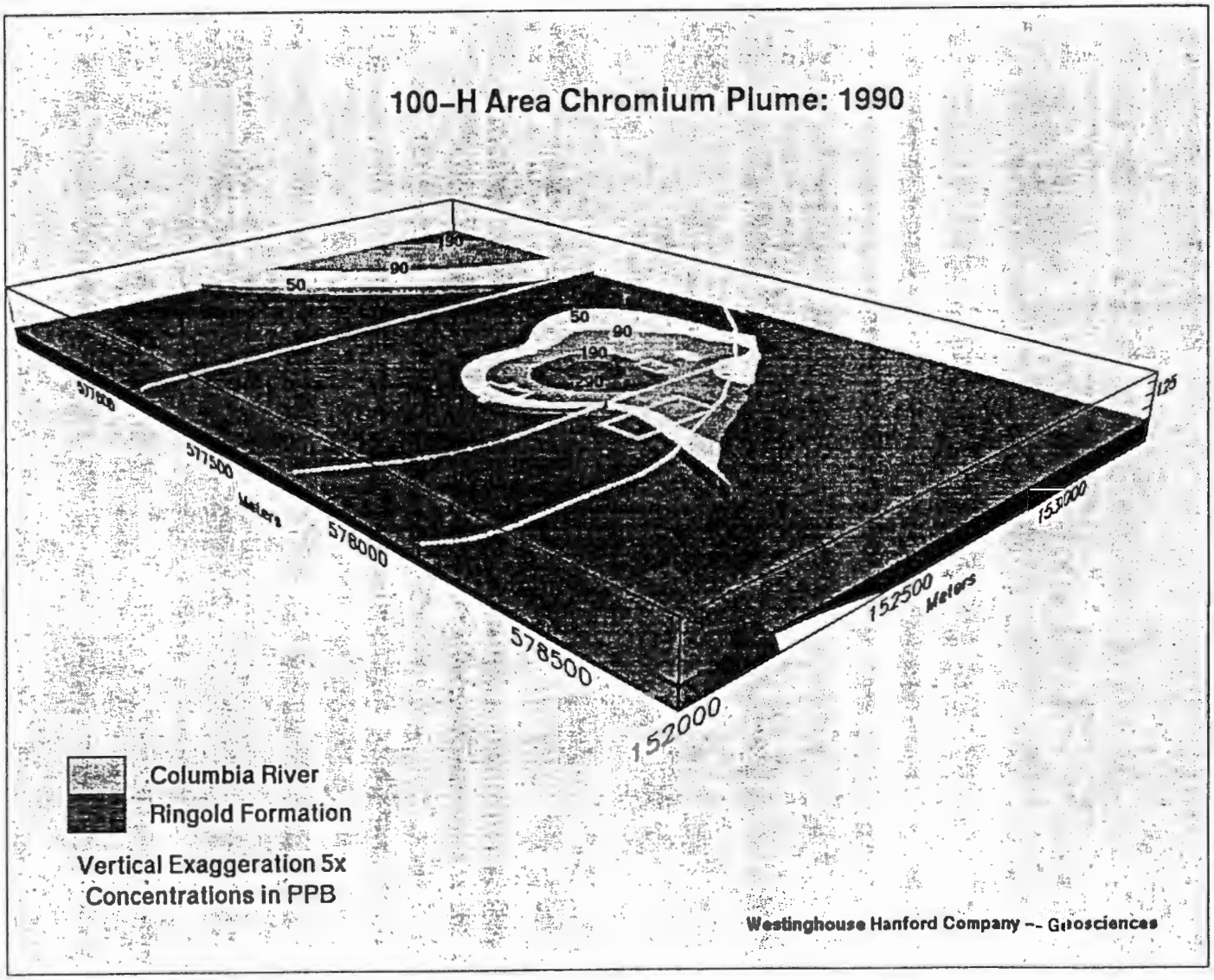
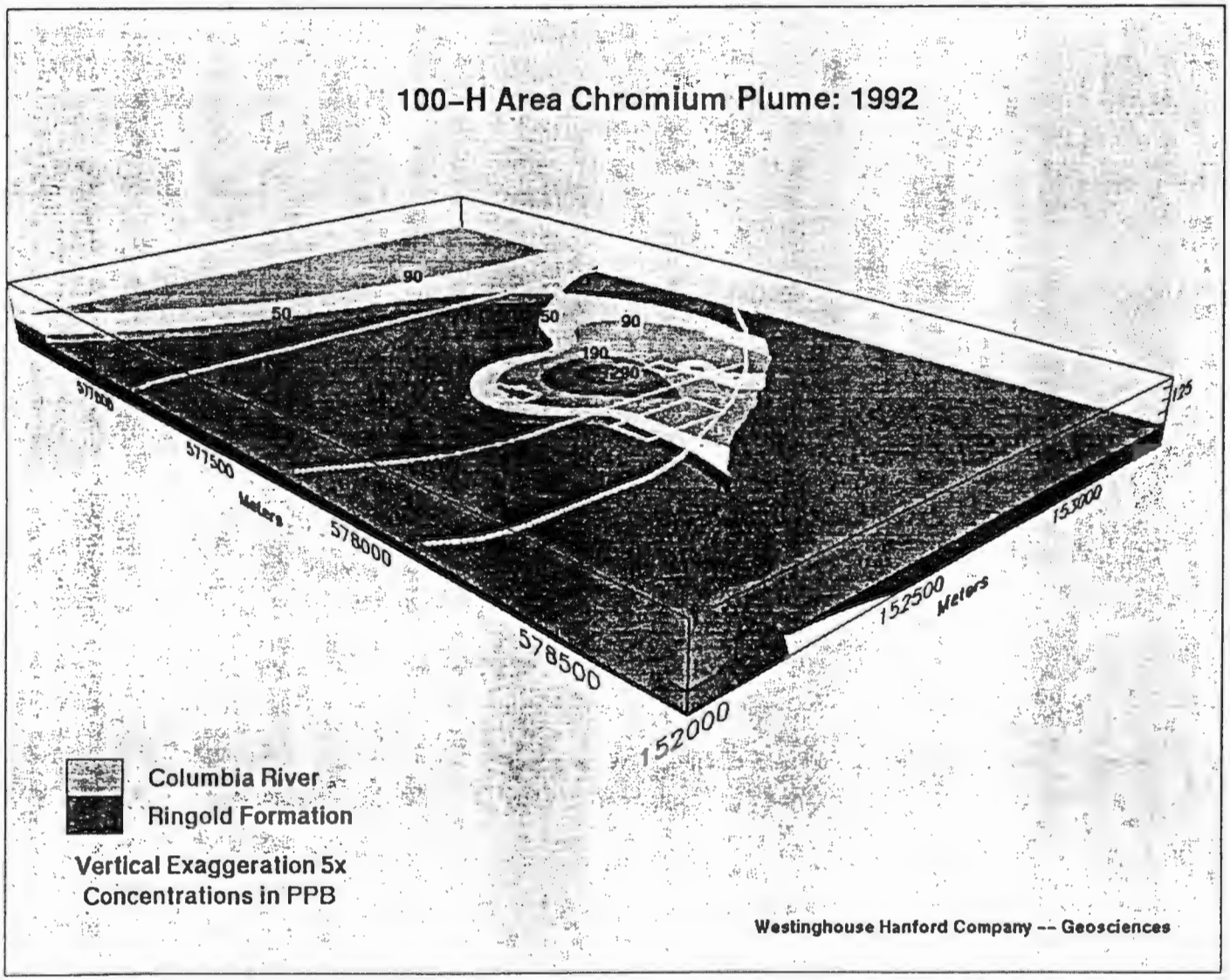
SLIDE #13: PERSPECTIVE VIEW OF 100-H AREA CHROMIUM PLUME: 1990.



SLIDE #14: PERSPECTIVE VIEW OF 100-H AREA CHROMIUM PLUME: 1992.



SLIDE #15: SUMMARY OF VOLUME AND MASS CALCULATIONS.

Summary of Volume and Mass Calculations

(Assumes 20% Porosity and Mid-Range of Contour Interval)

Year	Volume of Groundwater (m^3):		
	>10 ppb	>50 ppb	>100 ppb
1988	416,067	227,218	137,980
1990	513,270	274,748	154,101
1992	520,472	309,924	177,946

Year	Mass of Chromium (kg):		
	>10 ppb	>50 ppb	>100 ppb
1988	35.8	30.7	24.6
1990	39.2	32.0	23.5
1992	41.5	35.5	26.4

SLIDE #16: SENSITIVITY TO ASSUMED POROSITY AND CONCENTRATION BOUNDARIES.

Sensitivity to Assumed Porosity and Concentration Boundaries:

Chromium Mass Above 10 ppb (kg)

Year	Total Porosity:		
	10%	15%	*20%
1988	17.9	26.8	35.8
1990	19.6	29.4	39.2
1992	20.7	31.1	41.5

Year	Concentration For Contour Interval:		
	Low Range	*Mid-Range	High Range
1988	31.6	35.8	40.0
1990	34.0	39.2	44.3
1992	36.3	41.5	46.7

* Preferred Values

SLIDE #17: SUMMARY OF RESULTS AND CONCLUSIONS.

SUMMARY OF RESULTS AND CONCLUSIONS

- Reasonable and consistent estimates for the volume of groundwater affected by chromium and the mass of chromium contained in the plume were obtained

- A trend was revealed that might be indicative of a continuing or new source of chromium:

  ? Withdrawal of chromium retained on soil column

  ? Unidentified buried pipes and storage tanks

  ? Influx of another chromium-bearing water mass

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