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Revision 0

450 mg/L Nitrate Contour Map at Depth for 2010 Annual Report

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

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G. S. Thomas
CH2M HILL Plateau Remediation Company

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Release Approval Date

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Environmental Calculation Cover Page

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1.0 Purpose and Background

The purpose of this environmental calculation is to document the process of constructing a groundwater nitrate contaminant plume map beneath the 216-B-12 Crib for the 200-BP-5 chapter of the *Hanford Site Groundwater Monitoring Report for 2010* (DOE/RL-2011-01). The created map documents a nitrate plume at 10X the drinking water standard that would not be shown in the standard annual report maps.

The reason for investigating the area arose from the *Data Quality Objective Summary Report in Support of the 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study Process* (WMP-28945). In WMP-28945 a decision statement asked if there was enough information on the variability of plume concentrations with depth. The resolution of this decision statement was that there was not enough vertical information regarding the variability of contaminant plumes where the unconfined aquifer was thick. Four depth-discrete groundwater samples were planned adjacent to the 216-B-12 Crib for delineating the vertical contaminant plume as defined in the *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit* (DOE/RL-2007-18).

The highest nitrate concentrations from the depth discrete samples collected near the 216-B-12 Crib were located at a depth of approximately 7.6 meters below the water table during drilling of the new remedial investigation (RI) well, 299-E28-30, in 2010. Because of the depth and method of the sample collection (e.g., during drilling) the data was not portrayed in the annual nitrate plume map for DOE/RL-2011-01. In addition, the 200-BP-5 RI report has been delayed so the information from the drilling was discussed in the annual report and this calculation captures the methodology of the construction of the nitrate plume. The information supporting the contour map may also be used for other purposes (e.g. 200-BP-5 RI/FS report).

The main input for the plume configuration was the depth discrete samples collected at the new RI wells, 299-E28-30 and 299-E29-54. The data is provided in Table 1. Additional existing wells near well 299-E28-30 were also used in generating the cross section plume for Figures 1 and 2 in the back of this calculation. Well 299-E28-9 provided data to the west of well 299-E28-30, well 299-E28-13 provided data to the south, and wells 299-E28-18 and 299-E28-26 provided data to the north. Well 299-E29-54 is east of well 299-E28-30.

No depth discrete samples were collected at the existing wells 299-E28-9, 299-E28-18, and 299-E28-26. Therefore, the nitrate concentrations analyzed from the groundwater collected from these wells was assumed to be an average concentration across the screened interval. Because of the higher concentrations with depth at wells 299-E28-30 and 299-E29-54 it was assumed that higher concentration were at depth in these existing wells. In deriving the nitrate concentration change with depth for these wells two important assumptions were used: 1) nitrate concentrations near the water table were at background concentrations, and 2) the nitrate concentration from existing wells 299-E28-9, 299-E28-18, and 299-E28-26 was an average concentration across the screen interval. The first assumption was based mainly on nitrate concentrations from wells 299-E28-28 and 299-E32-4, located farther northwest of the area of interest, which both have had nitrate concentrations near background levels. The 299-E32-4 well screen only extends 3 meters into the aquifer and is considered cross gradient of the nitrate plume extending northward from beneath the 216-B-12 Crib. Well 299-E28-28 is also considered cross gradient and the well screen only extends approximately 2.5 meters into the aquifer. Therefore, the nitrate concentration at the water table in the monitoring wells 299-E28-9, 299-E28-18, and 299-E28-26 were considered to be at background concentrations taken from *Hanford Site Background: Part 3, Groundwater Background* (DOE/RL-96-61). Because the nitrate values from groundwater sampling at wells 299-E28-9, 299-E28-18, and 299-E28-26 was higher than background and the only apparent source near these wells is the deep nitrate plume beneath the 216-B-12 Crib as explained further in DOE/RL-2011-01 Section 9.1.1.2, some means of deriving the nitrate concentration with depth in these wells was needed to create the cross sections provided in Figures 1 and 2 of this calculation. Thus, the second

assumption, that the nitrate concentrations from these wells is an average concentration from across the well screen was used to derive a linear increase with depth consistent with the concentrations reported for these wells. The calculations are provided in Section 6.0. Also provided in Section 6.0 are figures showing the assumed linear increase with depth.

Once the cross section maps were created then a map view, Figure 3 at the back of this calculation was created for the estimated 450 mg/L concentration contour. The reason for selecting the 450 mg/L contour is because it is ten times the drinking water standard. Some limitations in contouring are shown to the northwest because there were no nearby wells so question marks were added to the 450 mg/L contour map in this area. Note besides the lack of depth discrete samples to the north and west, there is no definitive gradient in this area, so the contours are dashed.

2.0 Methodology

2.1 Data Selection

The following points summarize the process. Sections 3.0 through 5.0 provide additional detail.

- Location: Groundwater near the 216-B-12 Crib.
- Contaminant: nitrate.
- Time range for evaluation: July, 2009 through January, 2011.
- Data Set: Groundwater sampling results from two new RI wells (299-E28-30 and 299-E29-54) and existing monitoring wells (299-E28-9, 299-E28-13, 299-E28-18, and 299-E28-26).
- Data Selection: Selected highest depth discrete nitrate value from well 299-E28-30 and any corresponding value at similar depth from the remaining data set, otherwise use highest result during the time for existing wells.
- Replicates: If more than one data point was available from the sampling window, then the highest concentration was used.
- Exclusions: concentration data flagged as rejected (R) or suspected of errors (Y).
- Determination for Contour line: Use linear to near linear relationships between vertical and horizontal values at select wells to derive cross sections to the north, south, east and west. Where cross sections indicate the 450 mg/L contour extrapolated to map view.

2.2 Map Construction

The following points summarize how maps were constructed. Section 5.0 provides additional detail.

- The 200-BP-5 technical lead downloaded analytical results from HEIS database for the data set and time range discussed above.
- The 200-BP-5 technical lead plotted the depth discrete values from well 299-E28-30 and 299-E29-54 to initiate cross sections in north-south and east-west directions using existing monitoring wells.

- The 200-BP-5 technical lead plotted the highest nitrate value from existing monitoring wells identified in the data set and within the time frame on the draft nitrate plume cross sections.
- The 200-BP-5 technical lead assumed the nitrate concentration near the water table to be at background concentrations in existing monitoring wells.
- The 200-BP-5 technical lead created various nitrate isopleths extending from well 299-E28-30 to other existing monitoring wells using linear interpolation.
- The 200-BP-5 technical lead made calculations to determine the consistency of the isopleths with the sample results from selected wells as provided in Section 6.0. In these calculations the 200-BP-5 technical lead assumed linear concentration declines from the bottom of the well to the water table if the selected nitrate concentration at an existing well was less than 150 mg/L. If the value was over 150 mg/L and the nitrate isopleths did not appear linear then the vertical concentration profile was normalized for comparison with the analyzed nitrate value from selected existing wells.
- After both the north-south and east-west cross sections were completed and the vertical concentration calculations compared with the nitrate concentration at each existing monitoring well then a contour map was created based on where the derived 450 mg/L contour within the cross section existed.

3.0 Assumptions and Inputs

The groundwater data set was retrieved from the HEIS database for the purposes of creating a 450 mg/L contour at depth within the unconfined aquifer beneath and near the 216-B-12 Crib within the 200-BP-5 OU. The data was retrieved from HEIS on July 27, 2011 for this environmental calculation. The data set and time frame are as described above in Section 2.1. Assumptions used to create the cross sections described in Section 2.2 included the following:

1) The unconfined aquifer is homogeneous and dispersion of the nitrate plume is a linear to nearly linear relationship defined by the sample values collected at the various wells.
2) Nitrate concentration at the water table are considered background (~42 mg/L [DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*]) based on shallow wells (299-E28-28 and 299-E32-4) located in the vicinity.
3) The nitrate sample results from existing wells are an average of the vertical contaminant change within the aquifer at that well location. More specifically the elevated nitrate concentrations at existing monitoring wells near the 216-B-12 Crib (299-E28-9, 299-E28-18, and 299-E28-26) are assumed to be associated with a deep nitrate plume in the aquifer where concentrations decrease as nearing the water table.
4) Depth discrete vertical sample results collected from well 299-E28-30 and 299-E29-54 are reflective of the concentrations at that specific depth. This is because the drill casing extended to the specific depth shown in Table 1, the casing was considered impermeable, and the sample collected represented the groundwater where the casing was open to the aquifer. Note at least one casing volume was purged before sample collection.

4.0 Software Applications

A comma-separated text file was used for downloading data from the Virtual Library. The results were transferred into a Microsoft Excel spreadsheet and are provided in Table 1 following Section 6.0.

Microsoft Excel spreadsheet was used by the 200-BP-5 technical lead to create cross sections in a north-south and east-west direction from the data set discussed in section 2.1. The geographical information system (GIS) team took the Microsoft Excel cross sections and created pdf figure which are provided in Attachment B. The GIS team also created the pdf figure for the contour map also provided in Attachment B.

5.0 Calculation

The following steps describe the process for creating 200-BP-5 nitrate plume map.

1. Queried the data set for the time frame described in section 2.1 from the virtual library for nitrate.
2. Queried to remove any data with a review qualifier of "R" rejected or "Y" suspect (data identified in HEIS as reject or suspect).
3. Nitrate concentrations for each well were rounded to the nearest whole number for mg/L units.
4. The 200-BP-5 technical lead reviewed the resultant data set (Excel file) and selected the appropriate data points in accordance with section 2.1 to create a cross section.
5. Cross sections were initiated with the depth discrete data from well 299-E28-30 at ~8 meters below the water table (btwt) and a corresponding depth discrete sample from well 299-E29-54 at ~8 meters btwt.
6. Existing monitoring wells were added to the cross section using the highest value during the time frame described in section 2.1.
7. Normalizing of the concentration change in the existing wells was completed to verify cross section contour as described in Section 2.2 and shown in Section 6.0.
8. If the normalized value based on the cross section contour was not consistent with the nitrate value for that well then the contours were changed to positions that created consistent results.
9. Upon completion of the cross section contours a map view contour was drawn representing the extent of a 450 mg/L nitrate plume.
10. GIS staff created figures of the cross sections and map results from the Microsoft Excel figures generated by the 200-BP-5 technical lead.

6.0 Results

Table 1 lists the wells within the data set, nitrate values derived from sample analyses collected during the time frame, whether the analytical results were collected via depth discrete sample collection, and the value selected for use in the cross section plume configuration. Following Table 1, two cross section figures (Figures 1 and 2), provide the estimated nitrate contaminant cross section plume in a north-south and east-west direction, respectively. Figure 3 shows the map view of the 450 mg/L nitrate plume based on the cross sections in Figures 1 and 2. Below are calculations for monitoring wells 299-E28-9, 299-E28-18, and 299-E28-26 which show how the interpreted contours align with the well values obtained during sampling using a linear regression approach as described in Section 2.2. Note that no calculation is provided for wells 299-E28-30 or 299-E29-54 based on the assumption in Section 3.0.

Well 299-E28-9

This well as seen in Figure 1 has approximately 37.5' of screen btwt. A linear concentration decline is assumed from approximately 90 mg/L near the bottom of the well (see Table A for estimated regression concentrations and Figure A, below) to background concentrations near the water table (41.72 mg/L). The derived arithmetic mean concentration of 66.6 mg/L by the formula below is consistent with the sample concentration (66.4 mg/L) from this well for the time period as shown in Table 1.

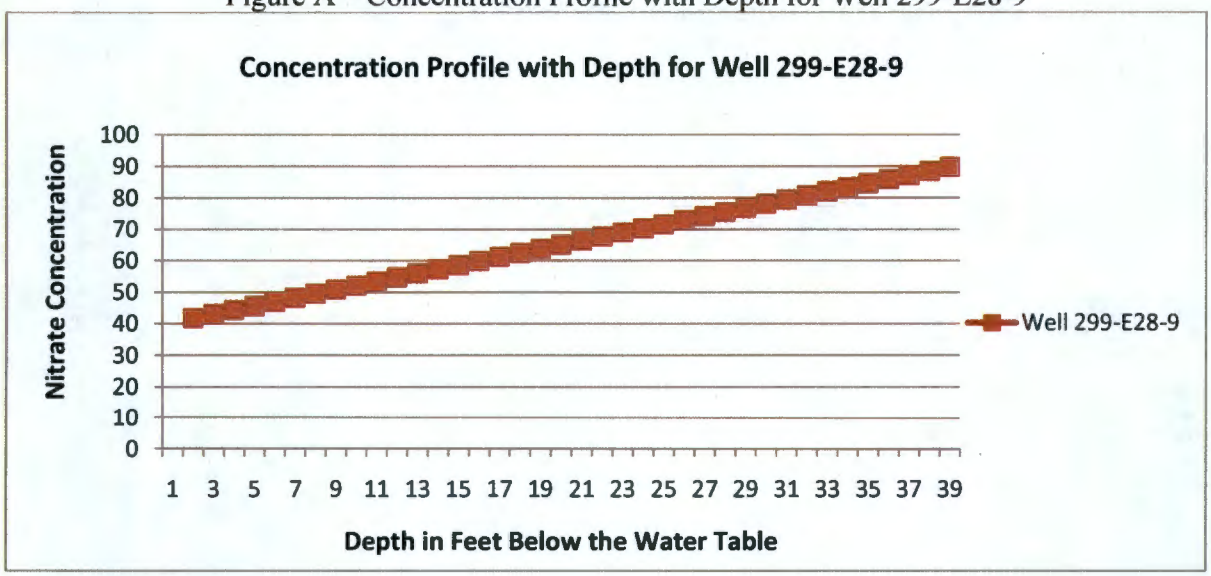
$$\textbf{Mean Value} = 1/n \sum_{i=1}^{n} X_i$$

Table A

1' – 5' btwt	6' – 10' btwt	11' – 15' btwt	16' – 20' btwt	21' – 25' btwt	26' – 30' btwt	31' – 35' btwt	36' – 37.5' btwt
41.72	48.22	54.72	61.22	67.72	74.22	80.72	87.22
43.02	49.52	56.02	62.52	69.02	75.52	82.02	88.52
44.32	50.82	57.32	63.82	70.32	76.82	83.32	89.82
45.62	52.12	58.62	65.12	71.62	78.12	84.62	
46.92	53.42	59.92	66.42	72.92	79.42	85.92	

$n = 37.5$, $\sum_{i=1}^{n} = 2499$, Mean = 66.6 mg/L

Figure A – Concentration Profile with Depth for Well 299-E28-9



Well 299-E28-18

This well as seen in Figure 2 has approximately 20.9' of screen btwt. A nearly linear decline is seen in the cross section from an estimated 440 mg/L near the bottom of the well (see Table E for estimated concentrations at bottom of well, below) to an estimated background concentration (41.72 mg/L - Table B) near the water table. Because of the near linear decline four discrete intervals were averaged and normalized for the total well screen before being divided by the screen length. The normalized nitrate concentration is 178.4 mg/L which appears to be a good approximation to the 190 mg/L value associated with the analyzed sample. Based on the assumptions provided in Section 3.0 the contour positions appear to be a reasonable reflection of the possible nitrate plume near this well. Additional detail on the following calculations is provided in the paragraph below.

Calculations are shown for each of the four intervals in which mean concentrations were derived, starting with the first interval from the water table to approximately 8 feet btwt. Each interval also provides a figure showing the estimated concentration increase with depth. The second interval is from 8 to 13.5 feet btwt. The third interval is from 13.5 to 17 feet btwt. The final interval is 17 to 20.9 feet btwt. The normalization process multiplies the derived mean by the screen length (in feet) for each interval and sums the values together before dividing by the screen length (in feet) to derive a average nitrate concentration across the entire screen interval.

$$\textbf{Mean Value} = 1/n \sum_{i=1}^{n} X_i$$

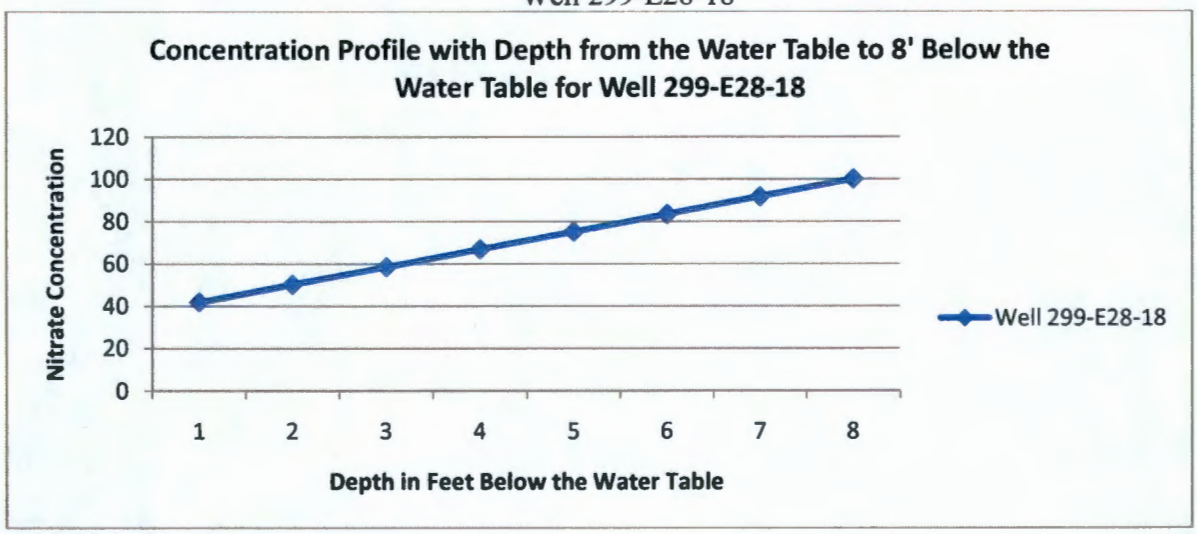
Interval 1 – Assumed Nitrate Concentrations from the Water Table to 8 feet Below the Water Table

Table B

Water Table	1' Below Water Table	2' Below Water Table	3' Below Water Table	4' Below Water Table	5' Below Water Table	6' Below Water Table	7' Below Water Table	8' Below Water Table
	41.72	50.046	58.371	66.697	75.023	83.349	91.674	100

$n = 8$, $\sum_{i=1}^{n} = 2499$, Mean = 70.86 mg/L

Figure B – Concentration Profile with Depth from the Water Table to 8' Below the Water Table for Well 299-E28-18



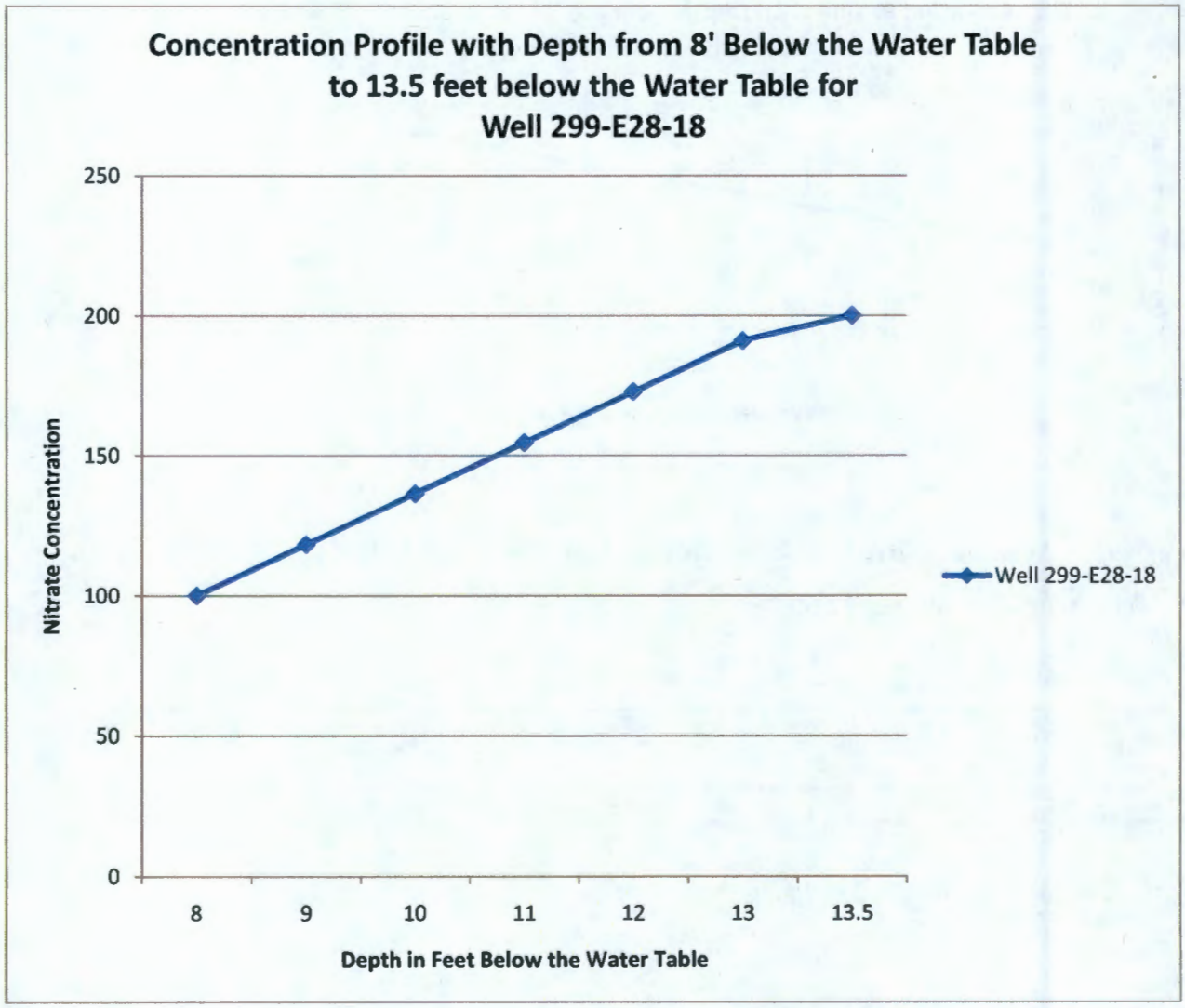
***Interval 2* - Assumed Nitrate Concentrations from the 8 feet below the Water Table to 13.5 feet Below the Water Table**

Table C

8' Below Water Table	9' Below Water Table	10' Below Water Table	11' Below Water Table	12' Below Water Table	13' Below Water Table	13.5' Below Water Table
100	118.18	136.3	154.5	172.73	190.91	200

n = 7, $\sum_{i=1}^{n} = 1072.73$, Mean = 153.25 mg/L

Figure C – Concentration Profile with Depth from 8' Below the Water Table to 13.5 feet below the Water Table for Well 299-E28-18



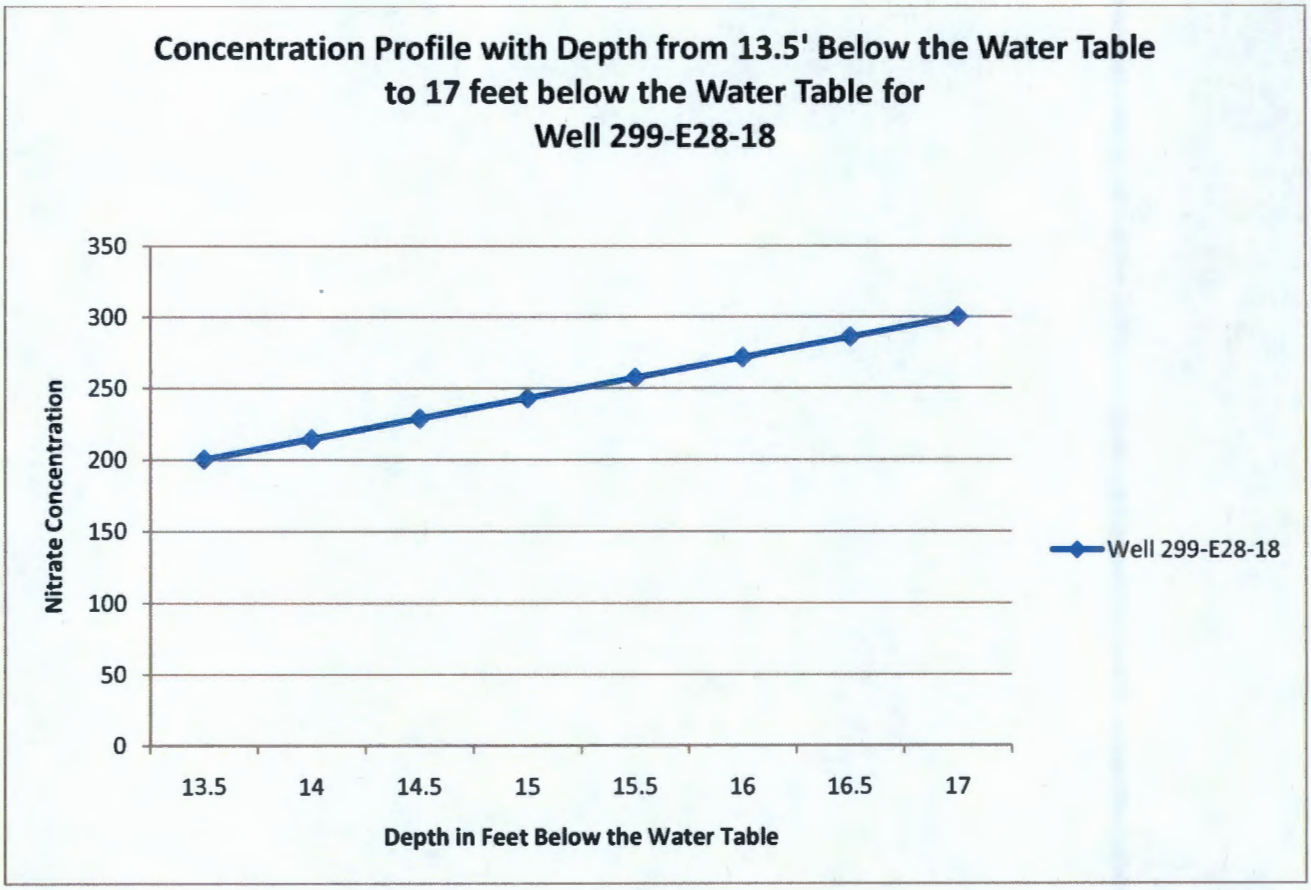
***Interval 3* - Assumed Nitrate Concentrations from the 13.5 feet below the Water Table to 17 feet Below the Water Table**

Table D

13.5' Below Water Table	14.0' Below Water Table	14.5' Below Water Table	15' Below Water Table	15.5' Below Water Table	16' Below Water Table	16.5' Below Water Table	17' Below Water Table
200	214.29	228.57	242.86	257.14	271.43	285.71	300

n = 8, $\sum_{i=1}^{n} = 2000$, Mean = 250 mg/L

Figure D – Concentration Profile with Depth from 13.5' Below the Water Table to 17 feet below the Water Table for Well 299-E28-18



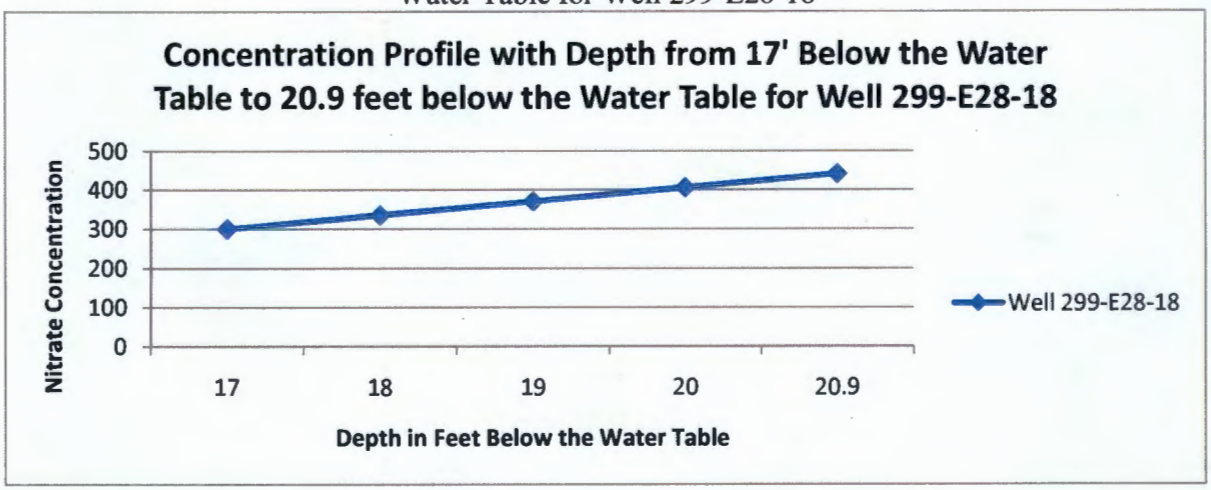
***Interval 4* - Assumed Nitrate Concentrations from the 17 feet below the Water Table to 20.9 feet Below the Water Table**

Table E

17' Below Water Table	18' Below Water Table	19' Below Water Table	20' Below Water Table	20.9' Below Water Table
300	335	370	405	440

$n = 5$, $\sum_{i=1}^{n} = 1850$, Mean = 370 mg/L

Figure E – Concentration Profile with Depth from 17' Below the Water Table to 20.9 feet below the Water Table for Well 299-E28-18



Normalization of all Intervals

Table F

0 - 8' Below Water Table	8' – 13.5' Below Water Table	13.5' – 17' Below Water Table	17' – 20.9' Below Water Table
Mean = 70.86 mg/L	Mean = 153.25 mg/L	Mean = 250 mg/L	Mean = 370 mg/L
Sum of Interval 0-8'	Sum of Interval 8-13.5'	Sum of Interval 13.5 - 17'	Sum of Interval 17-20.9'
566.9	842.9	875	1443

n = 20.9, $\sum_{i=1}^{n} = 3727.8$, **Mean = 178.4 mg/L**

Well 299-E28-26

This well as seen in Figure 1 has approximately 10' of screen btwt. A linear decline is assumed from approximately 107 mg/L near the bottom of the well (see Table G for estimated regression concentrations and Figure F, below) to background concentrations near the water table (41.72 mg/L). The derived arithmetic mean concentration of 74.4 mg/L by the formula below is consistent with the selected result from Table 1 for this well (74.5 mg/L).

$$\textbf{Mean Value} = 1/n \sum_{i=1}^{n} X_i$$

Table G

1' btwt	2' btwt	3' btwt	4' btwt	5' btwt	6' btwt	7' btwt	8' btwt	9' btwt	10' btwt
41.72	48.97	56.23	63.48	70.73	77.99	85.24	92.49	99.75	107

n = 10, $\sum_{i=1}^{n} = 743.6$, Mean = 74.4 mg/L

Figure F – Concentration Profile with Depth for Well 299-E28-26

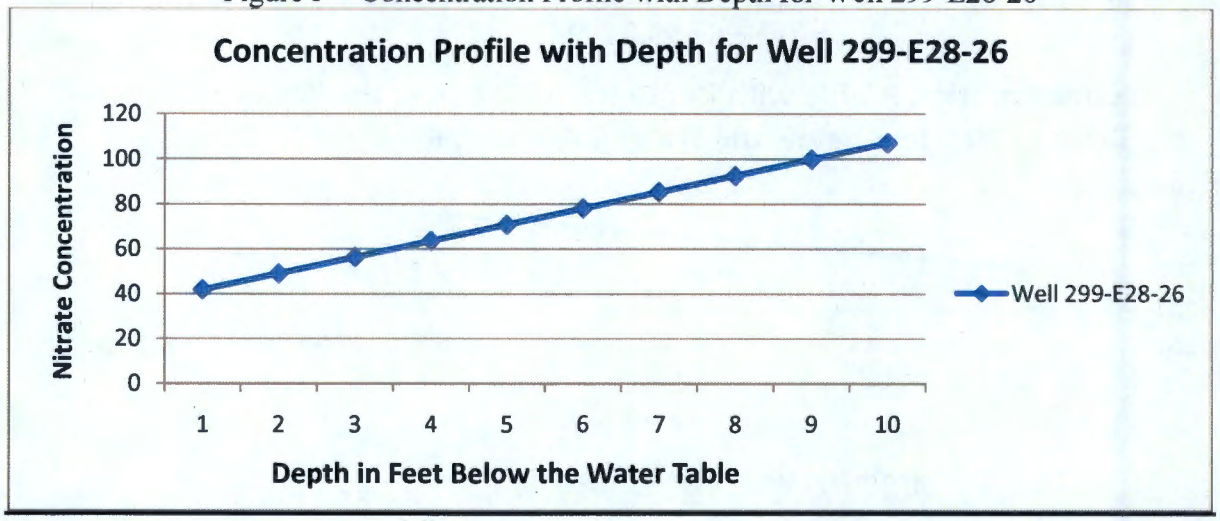


Table 1 200-BP-5 Groundwater Results

Constituent	Well	Sample Date	Sample Depth	Result	Units	Filtered	Lab Q	Rvw Q	Map	Comment
Nitrate	299-E28-9	1/18/2011	NA	66.4	mg/L	N	D		Value used for cross section	Collected from existing monitoring well
Nitrate	299-E28-13	6/29/2010	NA	66.8	mg/L	N	D			Collected from existing monitoring well
Nitrate	299-E28-18	7/7/2009	NA	190	mg/L	N	D		Value used for cross section	Collected from existing monitoring well
Nitrate	299-E28-26	1/6/2010	NA	55.8	mg/L	N	D			Collected from existing monitoring well
Nitrate	299-E28-26	6/29/2010	NA	64.6	mg/L	N	D			Collected from existing monitoring well
Nitrate	299-E28-26	12/29/2010	NA	74.8	mg/L	N	D		Value used for cross section	Collected from existing monitoring well
Nitrate	299-E28-30	2/9/2010	~11 feet btwt	142	mg/L	N	D		Value used for cross section	Depth discrete sample collected during drilling
Nitrate	299-E28-30	2/12/2010	~25 feet btwt	815	mg/L	N	D			Depth discrete sample collected during drilling
Nitrate	299-E28-30	2/12/2010	~25 feet btwt	828	mg/L	N	D		Value used for cross section	Depth discrete sample collected during drilling
Nitrate	299-E28-30	2/22/2010	~51 feet btwt	549	mg/L	N	D		Value used for cross section	Depth discrete sample collected during drilling
Nitrate	299-E28-30	2/25/2010	~70 feet btwt	181	mg/L	N			Value used for cross section	Depth discrete sample collected during drilling
Nitrate	299-E28-30	1/11/2011		55.8	mg/L	N	D			Collected after well construction and development in the upper part of aquifer
Nitrate	299-E29-54	1/7/2010	~7 feet btwt	69.1	mg/L	N	D		Value used for cross section	Depth discrete sample collected during drilling

Table 1 200-BP-5 Groundwater Results

Constituent	Well	Sample Date	Sample Depth	Result	Units	Filtered	Lab Q	Rvw Q	Map	Comment
Nitrate	299-E29-54	1/18/2010	~21 feet btwt	109	mg/L	N	D		Value used for cross section	Depth discrete sample collected during drilling
Nitrate	299-E29-54	1/18/2010	~21 feet btwt	108	mg/L	N	D			Depth discrete sample collected during drilling
Nitrate	299-E29-54	2/3/2010	~41 feet btwt	75.3	mg/L	N	D N		Value used for cross section	Depth discrete sample collected during drilling
Nitrate	299-E29-54	2/11/2010	~63 feet btwt	1310	mg/L	N			Value used for cross section	Depth discrete sample collected during drilling

N/A = Routine sample from existing monitoring well
Filt: N = unfiltered; Y = filtered
LabQ (laboratory data qualifiers): D = Analyte was identified in an analysis at a secondary dilution factor (i.e., dilution factor different than 1.0); N = Spike sample recovery is outside control limits.
Map: If blank, not used for map.

Figure 1. South-North Nitrate Plume Cross Section beneath the 216-B-12 Cribs and Extending Towards LLWMA-1

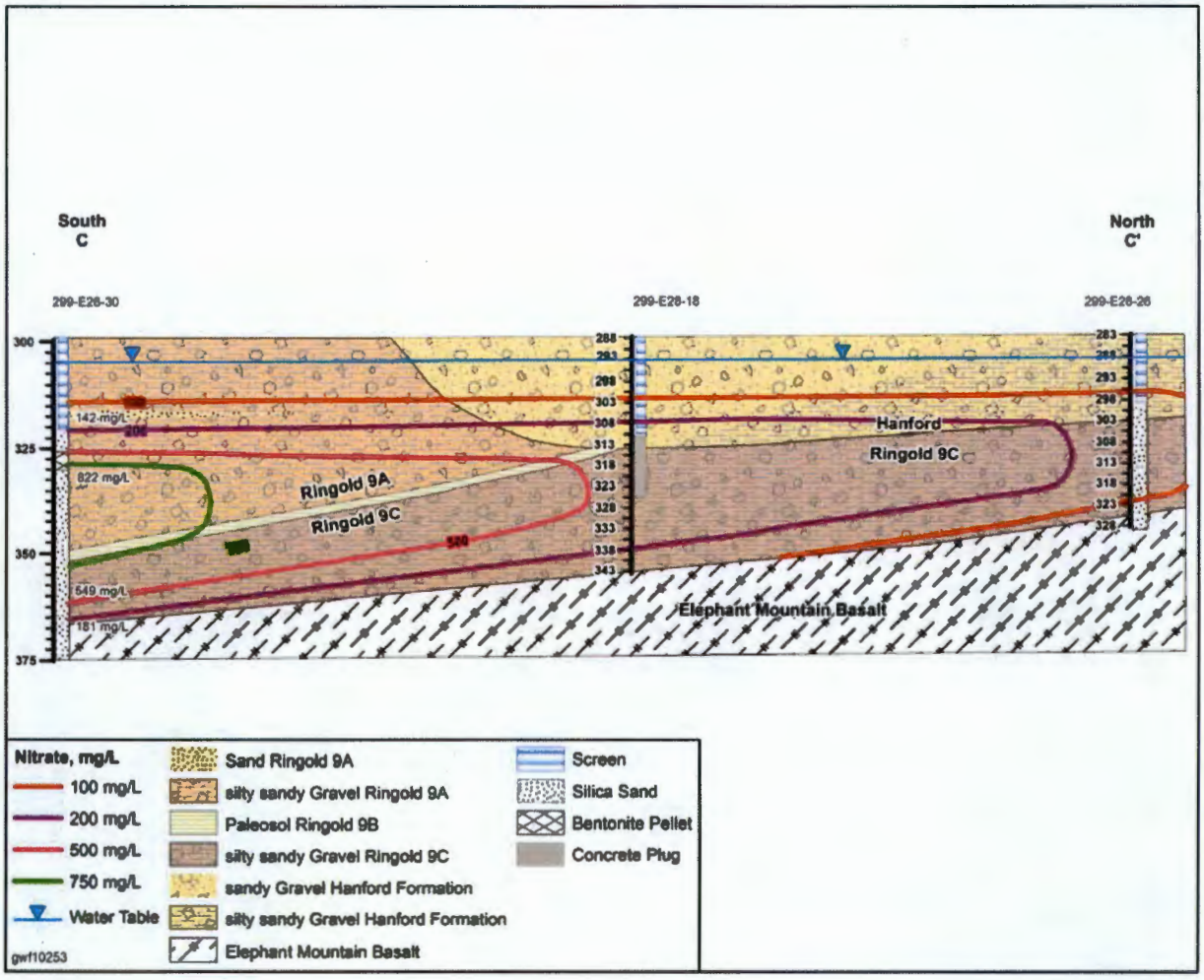


Figure 2. West-East Nitrate Plume Cross Section beneath the 216-B-12 Cribs and Extending Towards B Plant

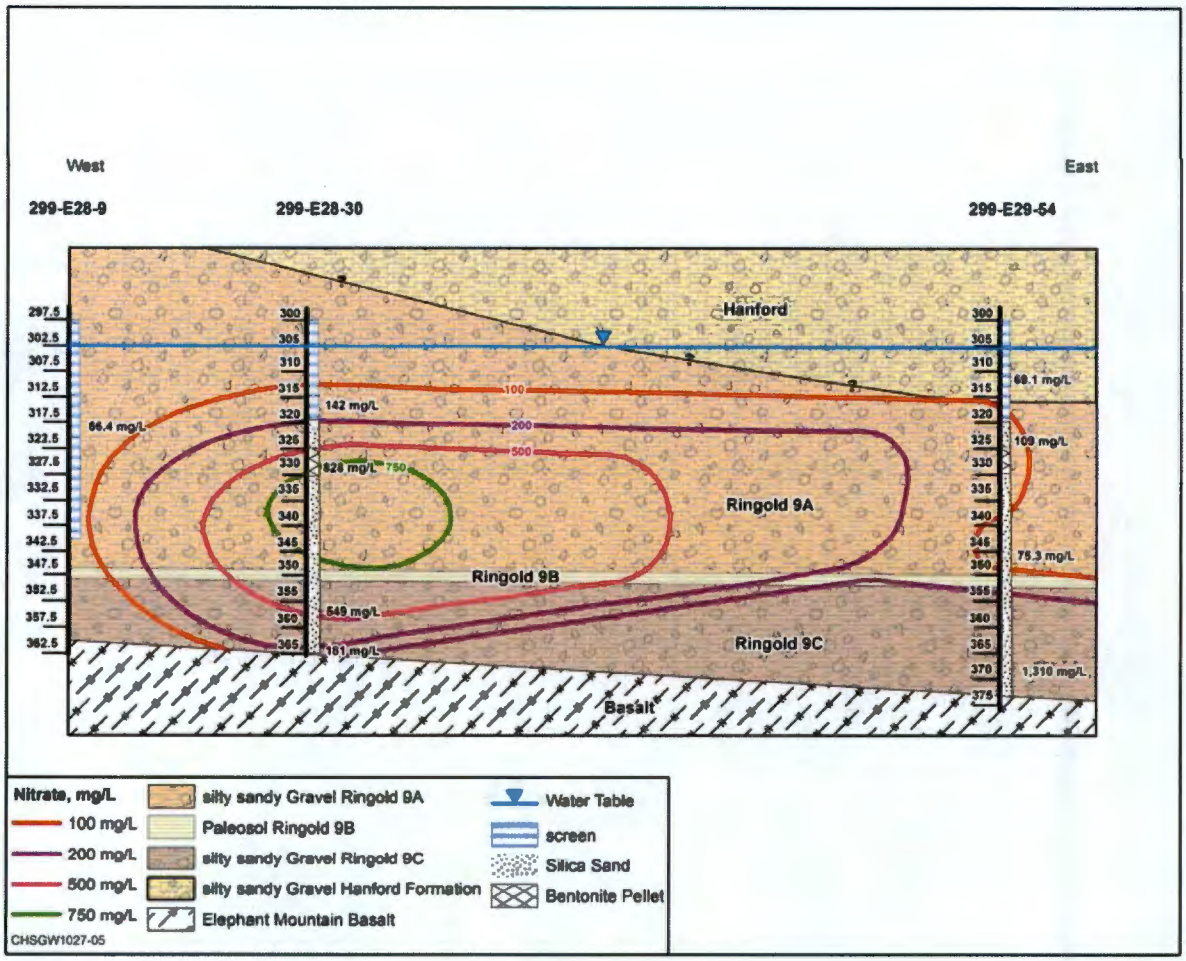
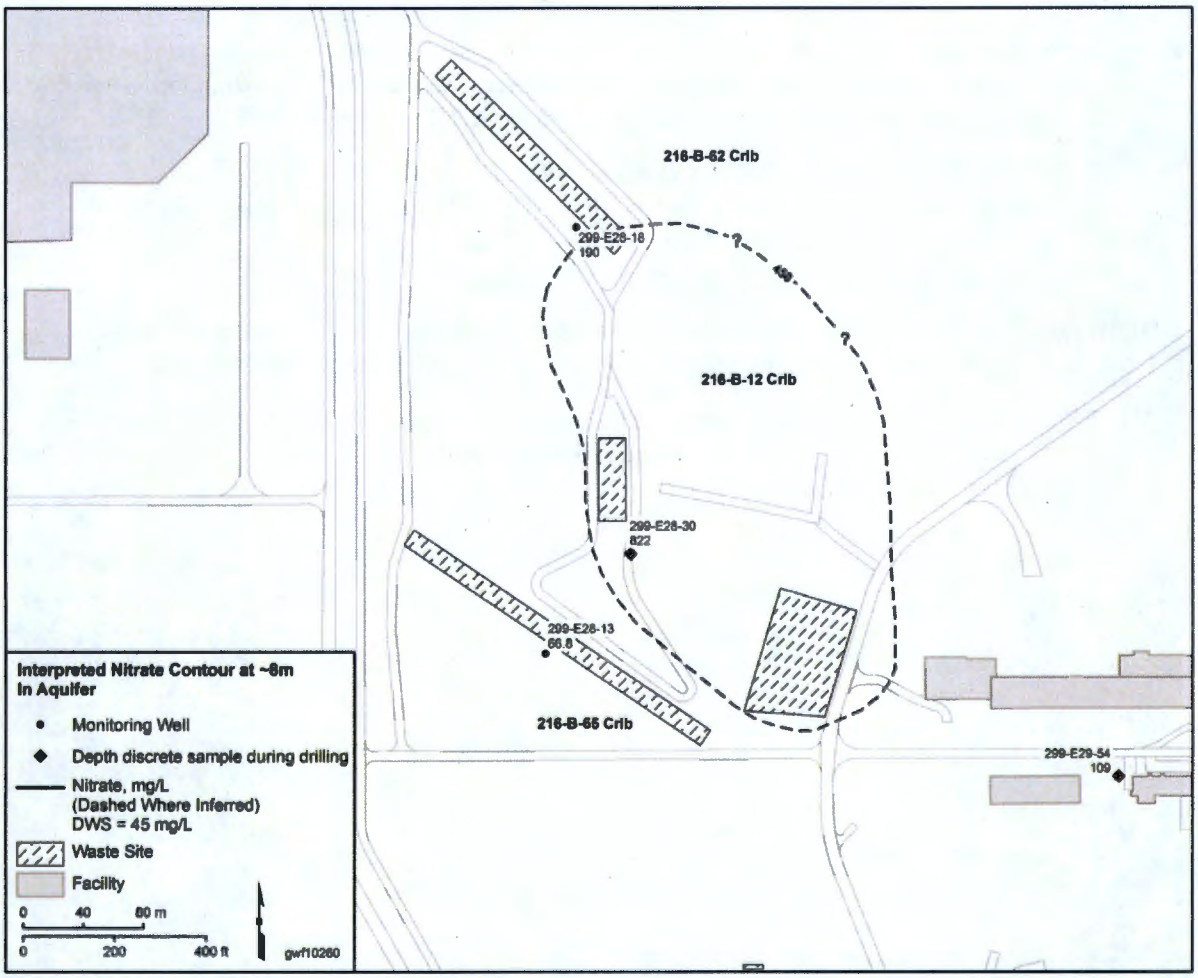


Figure 3. Apparent 450 mg/L Nitrate Plume Extent Near the 216 B-12 Crib.



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