KERR-McGEE CORPORATION

DECOMMISSIONING PLAN GROUND WATER EVALUATION REPORT

for
Cimarron Corporation's Former
Nuclear Fuel Fabrication Facility
Crescent, Oklahoma

July, 1998

License Number: SNM-928
Docket No. 70-0925

CIMARRON CORPORATION
CRESCENT, OKLAHOMA

CIMARRON DECOMMISSIONING PLAN
GROUNDWATER EVALUATION REPORT
July, 1998

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1.0 INTRODUCTION

The purpose of this report is to provide information regarding groundwater at the Cimarron Facility for inclusion in the Cimarron Decommissioning Plan. This report addresses vicinity and site geology/hydrology, a summary of closure activities for facility areas with groundwater contamination, background and affected area groundwater quality, the trending of environmental data for affected areas and a proposal for additional work at Burial Area #1. The attached Appendix #1 contains the Cimarron Environmental Data for the period June, 1985 through March, 1998. This data was utilized to analyze exposure pathways, a radiological dose assessment for groundwater, the chemical toxicity of the contaminant of concern, a derivation of appropriate groundwater criteria, and a program to address any lingering groundwater levels above the criteria. With the submission of this report, Cimarron believes that it is now appropriate to approve the Cimarron Decommissioning Plan.

Comprehensive background reports previously submitted to the NRC staff addressing groundwater at the Cimarron Facility are cited extensively throughout this document and include:

- Hydrological Information in the Vicinity of the Kerr-McGee Facility, Logan County, Oklahoma, 1973.
- Hydrologic Water Balance, Option Two Burial Site and Vicinity, Cimarron Corporation Facility, Crescent, Oklahoma, 1989.
- Site Investigation Report for the Cimarron Corporation Facility, Logan County, Oklahoma, September, 1989.
- Cimarron Facility Closure Responses to NRC Questions, 1990.
- Cimarron Facility Closure Responses to OSDH Comments, Cimarron Site Investigation Report, 1990.
- Environmental Assessment of a Proposed Disposal of Uranium – Contamination Soil at the Cimarron Uranium Plant, March, 1994.

- Cimarron Radiological Characterization Report, October, 1994.
- Cimarron Decommissioning Plan, April, 1995
- Groundwater and Surface Water Assessment for Cimarron Corporation's Former Nuclear Fuel Fabrication Facility, Crescent, Oklahoma, December, 1996.
- Recharge and Groundwater Quality Study for Cimarron Corporation's Former Nuclear Fuel Fabrication Facility, Crescent, Oklahoma, December, 1996.
- Cimarron Corporation Responses to NRC Staff Comments Dated March 13, 1997, on "Groundwater and Surface Water Assessment" and "Recharge and Groundwater Quality Study", May, 1997.

Cimarron Corporation believes that applicable conditions and criteria for releasing the Cimarron site for unrestricted release can be met as proposed in the Cimarron Decommissioning Plan and in this report. As a result, Cimarron Corporation is requesting that this report become the groundwater assessment part of the Cimarron Decommissioning Plan and be approved so that all remaining activities and final status surveys can be completed, leading ultimately to the termination of License SNM-928.

The Cimarron Facility, located near Crescent, Oklahoma, was operated by Kerr-McGee Corporation (Kerr-McGee) from 1966 to 1975 for the manufacture of enriched uranium and mixed-oxide fuels. Cimarron Corporation is a wholly owned subsidiary Kerr-McGee Corporation (Kerr-McGee).

The Cimarron site was originally licensed under two separate Special Nuclear Material Licenses. Cimarron operated a production facility for the fabrication of mixed oxide (plutonium and uranium) and enriched uranium fuel elements. License SNM-928 was issued in 1965 for the Uranium Plant and License SNM-1174 was issued in 1970 for the Mixed Oxide Fuel Fabrication (MOFF) Plant.

Both facilities operated through 1975, at which time operations were terminated and commencement of characterization/decommissioning efforts began. Since 1976, Cimarron has continued to decontaminate and remove equipment from the facility, dismantle the buildings, and excavate soils under NRC Licenses SNM-928 and SNM-1174. The facility grounds, originally 840 acres, were managed for decommissioning under License SNM-928.

Decommissioning efforts for the MOFF Plant were completed in 1990, at which time Cimarron applied to the NRC for termination of License SNM-1174 (August 20, 1990). The NRC terminated License SNM-1174 for the MOFF Plant on February 5, 1993.

Based upon knowledge of site operations and the characterization and decommissioning work completed at the time, Cimarron prepared and submitted the Cimarron Radiological Characterization Report to the NRC in October of 1994. Cimarron also prepared and submitted the Cimarron Decommissioning Plan to the NRC in April, 1995. As described in these documents, the entire 840-acre site was divided into affected and unaffected areas. The Final Status Survey Plan for the entire Cimarron 840-acre site has been divided into three major areas, which contain both affected and unaffected areas. Each of these three major areas were designated as Phases I, II, and III. These three Phases were then each further subdivided into 5 smaller "Sub-Areas" (i.e. A through E, F through J, and K through O). (See drawing 95MOST-RF3, page 1-7.)

As discussed above, decommissioning efforts involving characterization, decontamination and remediation for the 840-acres, licensed under SNM-928, were initiated in 1976 and are nearing completion. The goal of the Cimarron decommissioning effort is to release the entire 840-acre site for unrestricted use. A small portion of the site will remain active and under the control of Kerr-McGee Chemical LLC, which operates a small-scale Titanium Dioxide pilot plant. The

status of Radiological Decommissioning for Phases I, II, and III is discussed further below:

Phase I

The Final Status Survey Plan for Phase I was submitted to the NRC on October 15, 1994 and was approved by the NRC via letter dated May 1, 1995. The Final Status Survey Report for Phase I was submitted to the NRC on August 1, 1995 and confirmatory sampling was performed by ORISE. The Phase I Area, consisting of unaffected Sub-Areas A, B, C, D, and E, was released for unrestricted use via license amendment #13 on April 23, 1996. License Amendment #13 reduced the licensed acreage from approximately 840 acres to approximately 152 acres. The released acreage was never utilized for any licensed activities.

Phase II

The Phase II area contains both affected and some contiguous adjoining areas and represents approximately 122 of the 152 acres remaining under License SNM-928. The Final Status Survey Plan for Phase II was submitted to the NRC on July 11, 1995 and was approved by the NRC on March 14, 1997. Phase II includes Sub-Areas F, G, H, I and J and includes former Burial Area #1, which was released for backfill and seeding by the NRC in December, 1992. Also included in Phase II are the East and West Sanitary Lagoons, the Emergency Building, the Warehouse Building (Uranium Building #4) and surrounding yard area, as well as numerous natural drainage pathways. Cimarron has substantially completed the remediation of each of the Phase II Sub-Areas and the final status surveys have either been completed or are currently underway. The Final Status Survey Report of Sub-Area "J" was submitted to the NRC in September, 1997, and represents the first Sub-Area of Phase II to

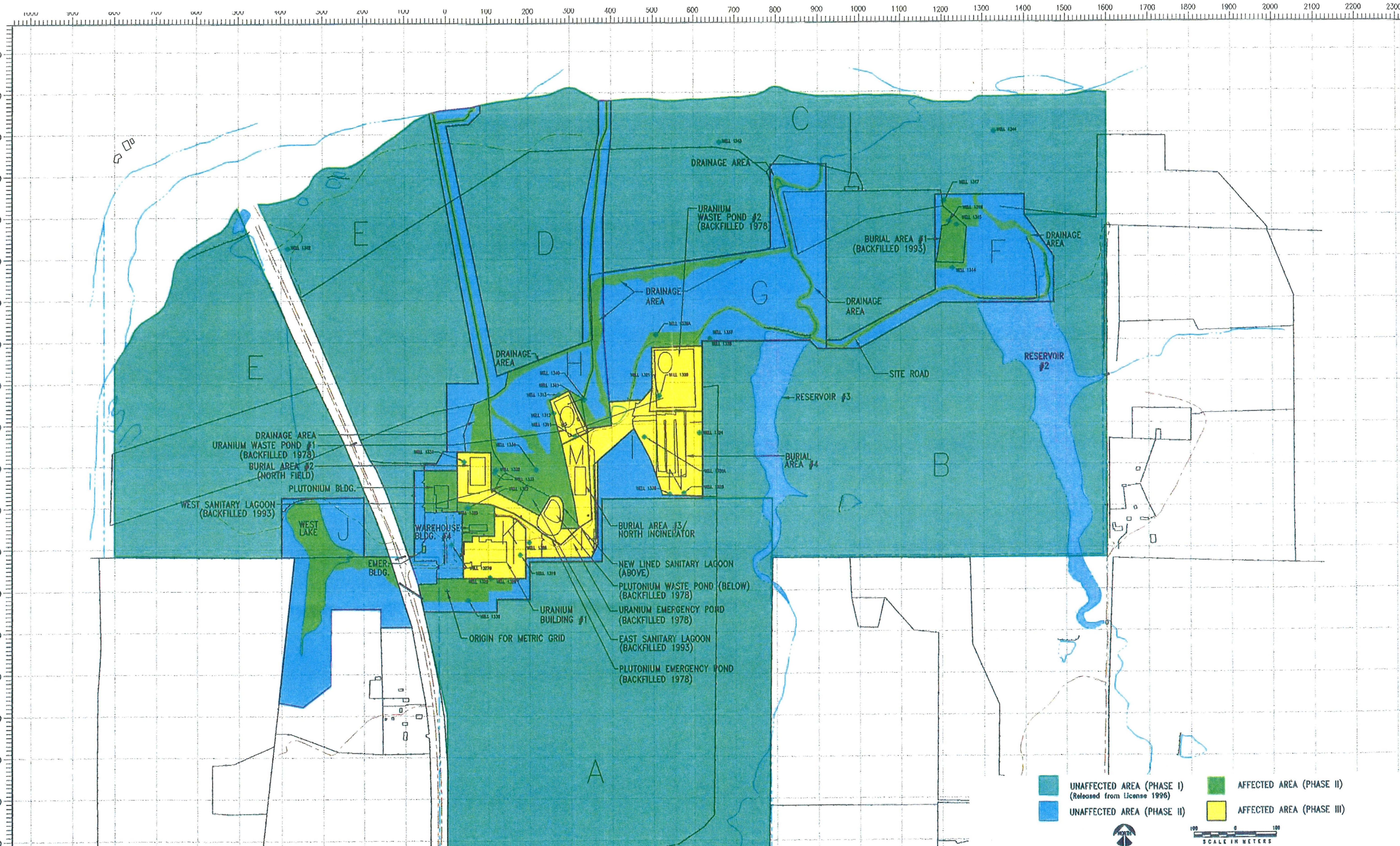
be submitted to the NRC. The NRC provided comments on Sub-Area "J" to Cimarron via letter dated January 9, 1998 and Cimarron responded on May 13, 1998.

Phase III

The Phase III area consists of affected areas only, and represents approximately 30 acres. Phase III includes Sub-areas K, L, M, N, and O. The Final Status Survey Plan for Phase III was submitted to the NRC in June, 1997. The NRC provided comments to Cimarron on the Phase III Final Status Survey Plan via letter dated October 3, 1997 and Cimarron responded to the NRC comments via letter dated December 5, 1997. The NRC provided additional comments to Cimarron on the Phase III Final Status Survey Plan via letter dated February 9, 1998 and Cimarron responded to these comments on June 26, 1998. The Phase III area includes the Uranium Processing Buildings and yard area, Burial Areas #2 and #3, the New Sanitary Lagoon, the BTP Option #2 Disposal Cell (Burial Area #4), and the five former Waste Water Treatment Ponds. These five former ponds consist of Uranium Waste Ponds #1 and #2, the Plutonium Waste Pond, the Plutonium Emergency Pond and the Uranium Emergency Pond.

These five former ponds had been previously released by the NRC in 1978. Waste Ponds #1 and #2 were revisited by the NRC in 1993. As a result, Cimarron Corporation performed further remediation on Waste Ponds #1 and #2 in accordance with the BTP Option #1 criteria and the NRC volumetric averaging guidance. Cimarron is currently awaiting NRC final review and release of Waste Ponds #1 and #2, as detailed in the Sub-Area "O" Final Status Survey Report (Sub-surface).

With the submittal of this Groundwater Evaluation Report, Cimarron has now addressed all of the issues associated with the Cimarron Decommissioning Plan. This report therefore addresses this last remaining issue (i.e., groundwater) required for approval of the Cimarron Decommissioning Plan and eventual license termination.



REV.	DESCRIPTION	DRWN BY:	CK'D BY:	APP'D BY:	DATE
10	ADDED WELLS 1342, 1343 & 1344	JE	WR	JL	3/13/98
9	MODIFIED BOUNDARY BETWEEN SUB-AREAS G & H.	JE	WR	JL	1/3/97
8	URANIUM WASTE POND #1 ADDED TO SUB-AREA O.	JE	WR	JK	8/27/97
7	ADDED BURIAL AREA #4/PIT #3 & WELLS 1337 THRU 1341.	JE	WR	JK	5/2/97
6	PHASE II AFFECTED AREA MODIFIED IN SUB-AREA H & BOUNDARY CHANGE TO SUB-AREAS I & N	JE	WR	JK	12/18/96
5	PHASE II AFFECTED AREA MODIFIED TO MATCH GPS SURVEY DATA.	JE	WR	JK	10/11/96
4	DRAWING REFLECTS NEW SURVEY DATA ON FENCE.	JE	WR	JK	6/13/96
3	DRAWING REFLECTS NEW SURVEY DATA ON FENCES AND ROADS.	JE	WR	JK	5/15/96
2	MODIFICATIONS TO PHASE I SUB-AREAS.	JE	WR	JK	11/13/95
1	ADDED PROPERTY SOUTH OF WEST LINE; MODIFIED NORTHERN BOUNDARIES.	JE	WR	JK	7/14/95
0	DRAWING ISSUED.	JE	WR	JK	4/1/95

CIMARRON CORPORATION

CIMARRON FACILITY
FINAL STATUS SURVEY PLAN
PHASES I, II AND III

CLIENT DRAWING NO.

2.0 GEOLOGY

The Cimarron facility lies in the Central Lowlands portion of the Great Plains physiographic province. The local and regional topography is characterized by low, rolling hills and incised rivers, streams, and floodplains. The site elevation ranges from about 940 to 1010 feet above mean sea level. A principal geomorphic feature at the site is the Cimarron River floodplain which is approximately one-half mile in width and trends east-west. The river and floodplain are bordered by a system of low lying cliffs and bluffs that overlook the river. The facility is located in an upland area south adjoining the river and includes portions of the floodplain and the adjoining cliffs and bluffs. The upland elevation of the facility in former operations areas is approximately 980 to 1,000 feet above mean sea level. The elevation of the floodplain is approximately 940 feet. Total relief across the site is approximately 50 to 70 feet. Local drainage is toward the Cimarron River and its floodplain.

Regional and local hydrogeologic features have been described through numerous characterization reports assembled for the Cimarron Facility. (See Introduction). Regional and site geology are described in detail in the Comprehensive Site Characterization Report (Grant, 1989) completed for the application for on-site disposal of Option #2 materials. The Grant report presented results of an extensive site hydrogeologic and geotechnical characterization completed in 1989. Pertinent details from this report and more recent additional investigations are summarized in this section.

2.1 Regional Geology

The regional geology is characterized as a gentle, west-southwest dipping homocline of Permian bedrock. The sediments forming the Permian bedrock were deposited in shallow marine and non-marine deltaic environments. Quaternary-age alluvial and terrace deposits unconformably overlie the erosional surface of the bedrock.

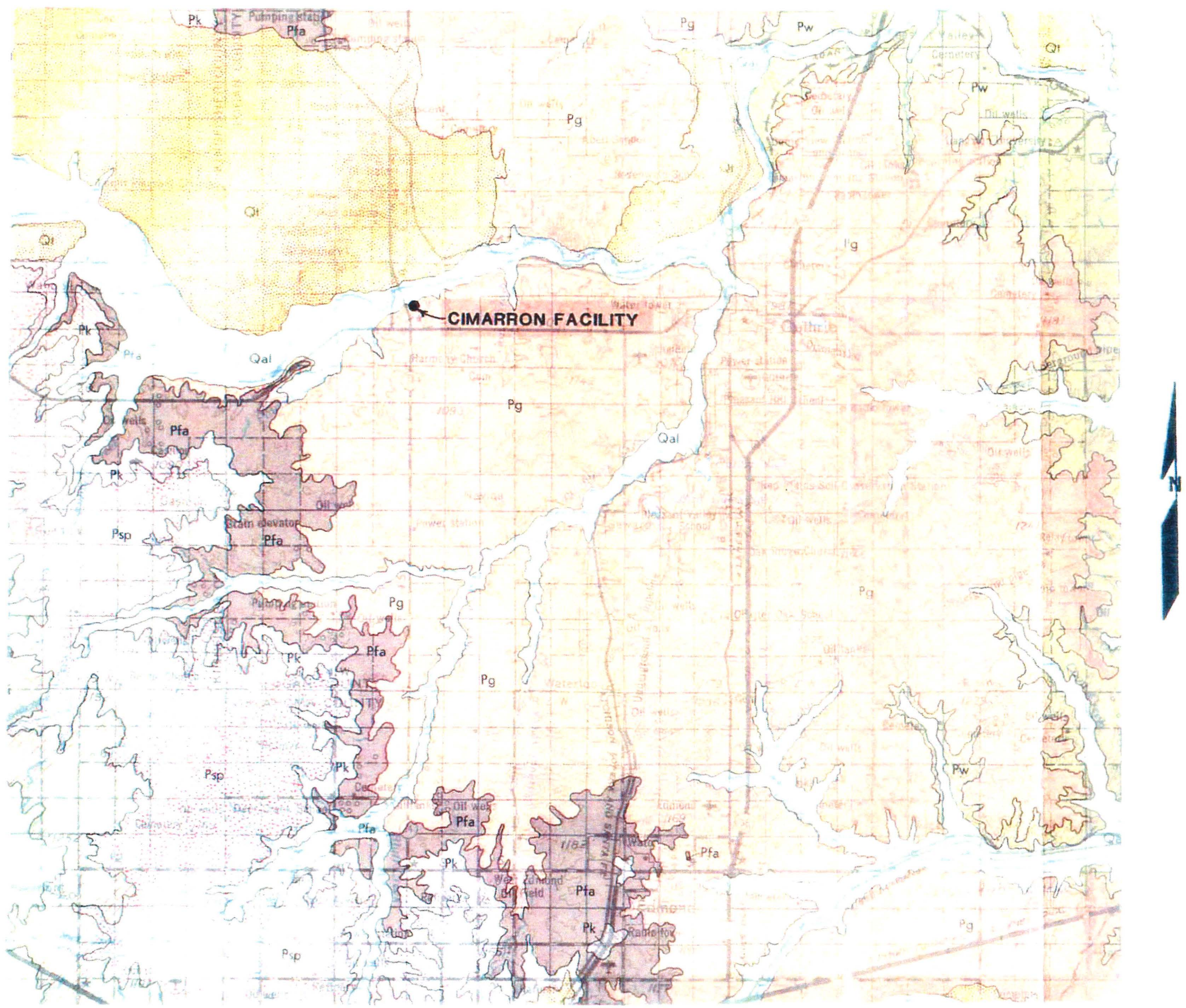
Permian bedrock in the area includes (from younger to older) the Hennessey Shale Formation, the Garber Sandstone and the Wellington Formation. The Hennessey Formation is absent beneath the site, but is present about four miles west of the facility. Regional dip of the Permian beds at the surface is about 20 to 40 feet per mile to the west. A map showing regional geology is included as Figure 2.1.

The Permian-age Garber Sandstone and underlying Wellington Formation include lenticular sandstones interbedded within shales and mudstones. The combined thickness of the Garber Sandstone and the Wellington Formation is about 800 to 1,000 feet. The lithology of both units is similar, consisting of interbedded sandstones, shales and mudstones with an absence of fossils. The water-bearing characteristics of each formation (e.g., hydraulic conductivity and water quality) also are similar. Since the two formations are reportedly not readily distinguishable, they often are considered as a single hydrostratigraphic unit, the Garber-Wellington Aquifer (Wood and Burton, 1968).

The Quaternary deposits overlying the Garber Sandstone include terrace deposits from earlier river channels and alluvium in the modern river channels. The terrace deposits are located on the northern side of the Cimarron River. The alluvium in the river channel floodplain on the south side is unconformably deposited on the Garber Sandstone (Engineering Enterprises, 1973).

2.2 Site Geology

A soil veneer, one to eight feet thick, covers most of the site. The shallow bedrock at the site consists of sandstones and siltstones of the Garber formation (Garber Sandstone). The Garber Sandstone is relatively thick in the facility area and no other formations have been penetrated by drilling conducted during the most recent investigations.



Scale 1:250,000

5 0 5 10 15 20 Statute Miles

5 0 5 10 15 20 25 30 Kilometers

CONTOUR INTERVAL 100 FEET
WITH SUPPLEMENTARY CONTOURS AT 50-FOOT INTERVALS

DATUM MEAN SEA LEVEL

QUATERNARY

Qal — ALLUVIUM

Sand, silt, clay, and lenticular beds of gravel. Thickness ranges from about 30 to 100 feet and probably averages about 50 feet along major streams. Along minor streams, thickness ranges from a few feet to about 50 feet and probably averages about 25 feet. Alluvium is a major aquifer in parts of quadrangle.

Qt — TERRACE DEPOSITS

Lenticular beds of sand, silt, clay, and gravel. Thickness ranges from a few feet to about 100 feet and probably averages about 50 feet along major streams. These deposits are major aquifers along Cimarron, Canadian, and North Canadian Rivers.

PERMIAN

Pd — DUNCAN SANDSTONE

Mainly red-brown to orange-brown fine-grained sandstone, with some mudstone conglomerate and shale; grades northward into Cedar Hills Sandstone and Chickasha Formation. Thickness, 450 feet near Chickasha, 300 feet near Oklahoma City, and 100 feet or more near Okarche.

Pbi — BISON FORMATION

Mostly red-brown shale; grades northward into many thin greenish-gray calcitic siltstones and some orange-brown fine-grained sandstones and siltstones. *Reeding Sandstone Bed* at base. Thickness ranges from 95 feet in south to 120 feet in north.

Psp — SALT PLAINS FORMATION

Red-brown blocky shale and orange-brown siltstone; grades southward into Purcell Sandstone in Norman area. Thickness 200 feet.

Pfa — FAIRMONT SHALE

Red-brown blocky shale; grades into Garber Sandstone at base. Thickness, 30 feet at Oklahoma City, 110 feet near Purcell, and 120 feet near Kingfisher.

Pg — GARBER SANDSTONE

Mostly orange-brown to red-brown fine-grained sandstone irregularly bedded with red-brown shale and some chert and mudstone conglomerate. Thickness ranges from 150 feet in south to 400 feet or more in north. The Garber and underlying Wellington are major aquifers in Cleveland and Oklahoma Counties.

Pw — WELLINGTON FORMATION

Red-brown shale and orange-brown fine-grained sandstone, containing much maroon mudstone conglomerate and chert conglomerate to south. Thickness ranges from about 150 feet in south to 500 feet in north.

SOURCE: BINGHAM AND MOORE, 1975

FIGURE 2.1

GEOLOGIC MAP

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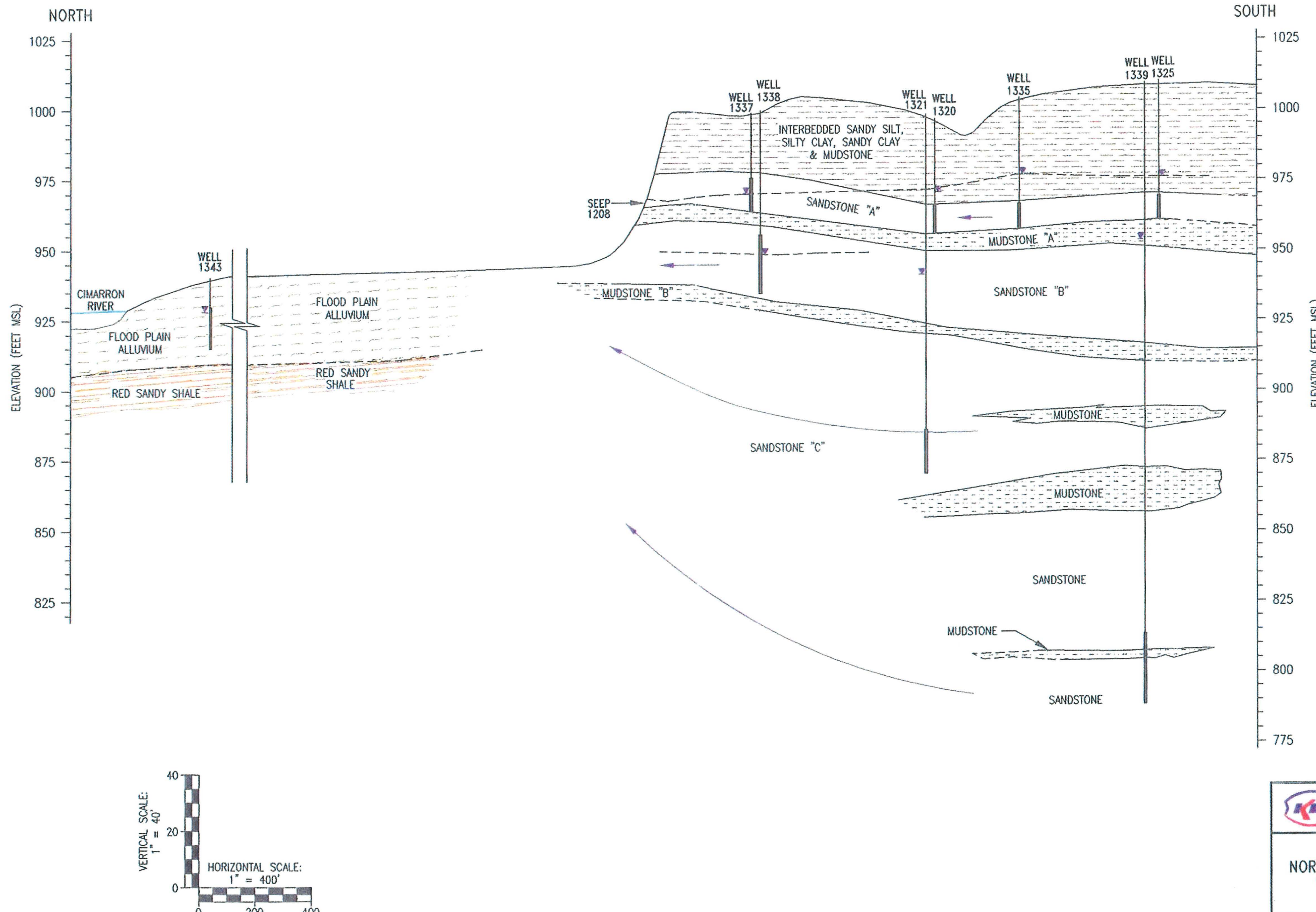
The Quaternary alluvium in the Cimarron River channel consists of sand, silt, clay, and lenticular gravel beds. The alluvium is estimated to range between 30 and 100 feet in thickness along major rivers such as the Cimarron River, with an average thickness of about 50 feet. The depth of alluvium in the vicinity of the site is important because of the extent (vertical) to which the river has cut into the underlying sandstone layers. The intersection of the alluvium with the underlying sandstones creates discharge zones for the sandstones, and controls the lateral movement of groundwater from beneath the site. The intersection of the alluvium with the Garber Sandstone is discussed in more detail in Section 3.0, Site Hydrogeology. Drawing No. 98-XSEC-1 (next page) is a geologic cross section showing the shallow subsurface stratigraphy underlying the center of the site, and schematically extends north to the Cimarron River.

The deeper stratigraphic units in the area were penetrated by a proposed deep test well that was completed in 1969. This well represents the deepest borehole known to have been drilled in the immediate vicinity of the site. The deep well which was located on the Cimarron facility property near the former uranium plant has been plugged. The depth of the well was 2,078 feet. The well was never permitted or used for injection purposes or other site uses. The top of the geologic unit immediately underlying the Garber Formation, the Wellington Formation, was identified at 200 feet below the ground surface. The Wellington Formation consists of 960 feet of red shale with several thin siltstone beds. The top of the Wolfcampian age Stratford Formation was found at 1,160 feet. It is 870 feet thick and consists of red and gray shale with thin anhydrite beds in the upper part. The lower part of the Stratford Formation is predominately red and gray sandy shale with three porous sandstone members.



CIMARRON CORPORATION

CIMARRON FACILITY
NORTH–SOUTH CROSS SECTION THROUGH
WELLS 1337, 1338, 1321, 1320, 1335, 1339, 1325 & 1343

REV.	DESCRIPTION	DRWN BY:	CK'D BY:	APP'D BY:	DATE
1	WELL 1343 ADDED.	JE	RS	JL	6/18/98
0	DRAWING ISSUED.	JE	RS	JK	3/27/97

DRWN. BY JE	DATE 3/27/97	SCALE AS SHOWN	
JOB NO.	DRAWING NO. 98-XSEC-1		REV. 1

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2.2.1 Geologic Description of the Garber Sandstones/Mudstones Across the site

The Cimarron Facility is directly underlain by the Garber Sandstone and Wellington Formation. These geologic units collectively form the Garber-Wellington Aquifer.

Three major sandstone units and two mudstone units have been identified in borings drilled at the site. These sandstones have been informally classified (from shallow to deep) as the A, B, and C sandstones (and in some site reports as the 1, 2, and 3 sandstones respectively). Thicknesses range from 30 to 55 feet for each of the sandstones.

The two predominant mudstones (the A and B mudstones) are each about six to 14 feet thick, and separate the A sandstone from the B sandstone, and the B sandstone from the C sandstone, respectively. The mudstones generally are massive, with some zones of thin laminations in the upper portions. The mudstones are less permeable than the sandstones, and retard the vertical movement of groundwater. The sandstone and mudstone units are discussed below.

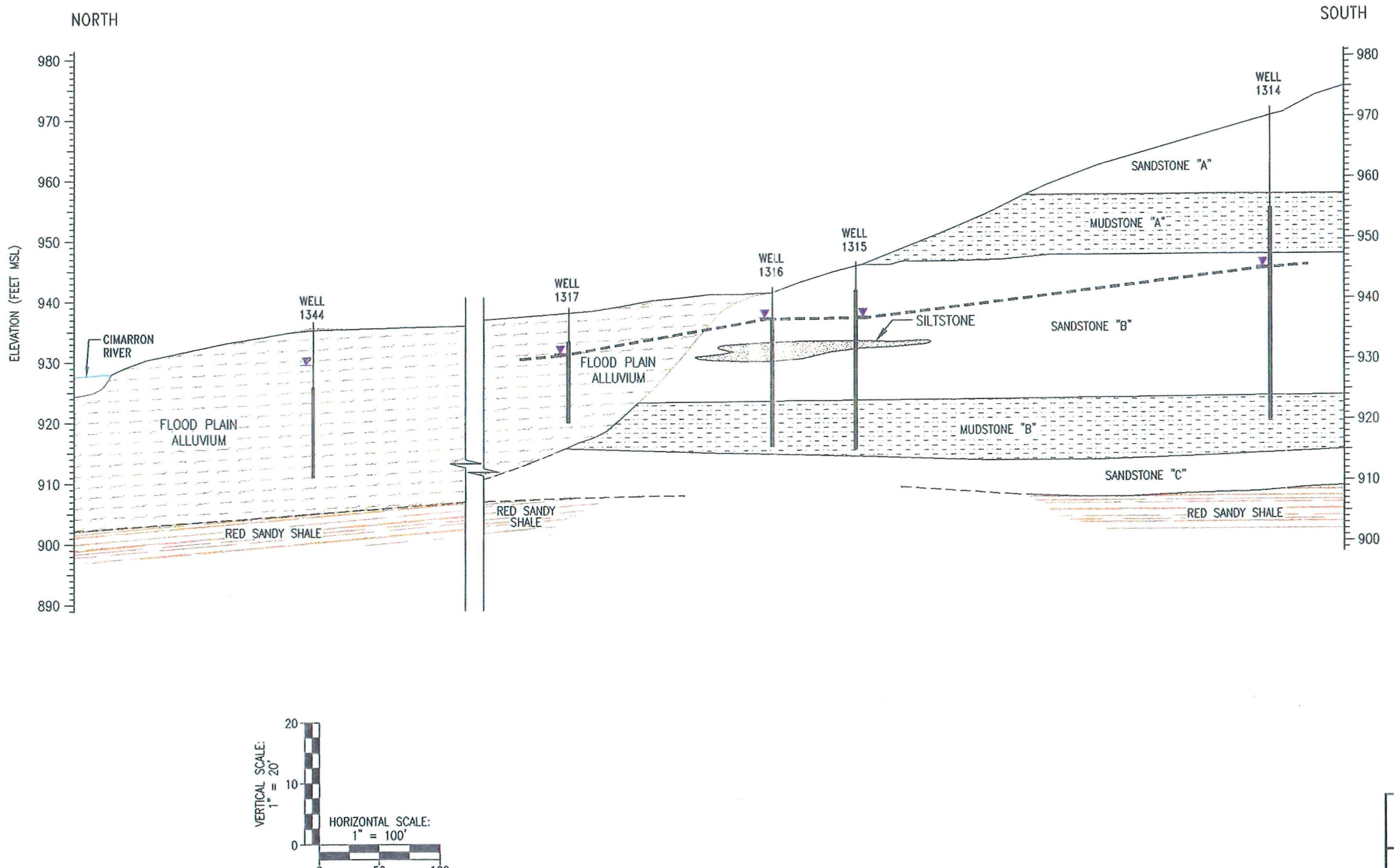
- Sandstone A: As shown by Drawing No. 98-XSEC-1, the first water bearing sandstone encountered at the site is referred to as Sandstone A. This sandstone consists of up to 25 feet of red-to-tan colored sandstone and silty sandstone on the western half of the site. This sandstone may be well or poorly cemented, and is locally cross bedded. Water level data collected from monitor wells show that the sandstone is fully saturated at the southern boundary (upgradient) of the site. The saturated thickness decreases to the north where groundwater discharges as base flow into small, north-flowing tributaries to the Cimarron River, and at seeps where the

sandstone outcrops along the bluff. Well yield data collected during aquifer tests and well development work indicates that Sandstone A will not support a sustained pumping rate greater than approximately one to two gallons per minute. Areas of this horizon that are impacted by past facility operations are near the extreme north of the facility (e.g., around Uranium Waste Ponds No. 1 and No. 2).

- Mudstone A: As shown by Drawing No. 98-XSEC-1, this sequence of mudstone and silty mudstone ranges in thickness from six feet to nearly 20 feet between Sandstone A from the underlying Sandstone B. Water level data from monitor wells show that this mudstone unit hydrologically separates the two sandstones.

- Sandstone B: As shown by Drawing No. 98-XSEC-1, the second, or intermediate, water bearing sandstone encountered at the site is referred to as Sandstone B. This sandstone, which is similar in lithology to Sandstone A, can be up to 30 feet in thickness on the site. At the eastern edge of the site, Sandstone A has been eroded to the extent that Sandstone B is the first water bearing sandstone encountered. The sequences of sandstones and mudstones in this area are shown by Drawing No. 98-XSEC-2 (next page); which represents the shallow subsurface stratigraphy through the area formally occupied by Burial Area #1.

  Water level data collected from monitor wells in this sandstone located at the central and western parts of the site show that the saturated thickness decreases to the north where groundwater discharges to both the alluvium of the Cimarron River and to seeps in cliffs overlooking the river flood plain. At the eastern portion (Burial Area # 1) of the site, Sandstone B generally discharges to



CIMARRON CORPORATION

CIMARRON FACILITY
NORTH–SOUTH CROSS SECTION THROUGH
WELLS 1314, 1315, 1316, 1317 & 1344

REV.	DESCRIPTION	DRWN BY:	CK'D BY:	APP'D BY:	DATE
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0	DRAWING ISSUED.	JE	SL	JK	4/18/97

DRWN. BY	DATE	SCALE
JE	4/17/97	AS SHOWN

JOB NO.	DRAWING NO.	REV.
	98–XSEC–2	1

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the north to the alluvium. Well yield data collected during development work indicates that Sandstone B will not support a sustained pumping greater than approximately one to two gallons per minute. Areas of this horizon that are impacted by past facility operations are near the extreme north of the formation (i.e., around Burial Area No. 1).

- Mudstone B: As shown by Drawing No. 98-XSEC-1, this sequence of mudstones ranges in thickness from six feet to 14 feet between Sandstone B and Sandstone C. Water level and water quality data from monitor wells show that this unit hydrologically separates Sandstone B from Sandstone C.

- Sandstone C: As shown by Drawing No. 98-XSEC-1, all sandstones underlying the Mudstone B confining layer are collectively referred to as Sandstone C. This sequence of interlayered sandstones and mudstones is at least 100 feet in thickness beneath the Cimarron site. The base of the fresh water zone as defined by the USGS, is found within the shallow-most strata of Sandstone C. Water-level data collected from monitor wells constructed at various depths in this horizon show that the sandstone is fully saturated, with pressure heads that increase with increasing depth. Given the elevations of the potentiometric surface, Sandstone C is discharging into the Cimarron River as base flow. The base of the high salinity interface was found in the deeper strata of Sandstone C at a depth of 190 feet below grade.

2.2.2. Description of Sandstones

All three sandstones encountered during the numerous investigations can be described as generally fine to very fine grained with well sorted subangular to rounded grains. Variable silt content was observed in the

sandstones. The estimated silt content ranges from less than 10 up to 50 percent. Where the silt content is high, distinction between sandstone and siltstone is difficult. The sand grains are virtually all quartz, with minor amounts of potassium feldspar and occasional mafic grains such as magnetite. Micas are minor constituents. Intergranular porosity is generally good, though obviously varies with silt content.

The sandstones typically are weakly cemented and friable. The cementing agents appear to be calcite and hematite; however, silt and clay-sized fractions in the matrix may also contribute to cementation. Thin intervals are present occasionally that are well cemented and hard. These intervals are frequently conglomeratic with gypsum and possibly barite providing additional intergranular cement. The sandstones often are cross-stratified with thin, silty laminae. The cross-stratification is planar and is indicative of deposition in a fluvial/deltaic system. Cross stratification was usually found near the middle of the sandstone intervals.

2.2.3 Description of Mudstone

Separating the sandstones are fine-grained, silty and shaley beds. These beds were identified in the field as mudstones, a generic description inferring their origin. Stratification within the mudstones is largely absent and they lack the fissile nature characteristic of shales.

The mudstone units typically are poorly consolidated as indicated by the tendency for core samples to deteriorate rapidly. The mudstone cores have a consistency more like a very stiff to hard sandy silt or clay than rock, even at depths greater than 100 feet below ground.

Encapsulating the mudstone layers were thin, bluish-gray zones or layers that ranged from less than 0.1 inches to over 4 inches in thickness. These layers tentatively were identified in the field as "reduction zones."

Reduction spots were also observed. This phenomenon is common in red bed formations and therefore is not considered unique to the site. In the subsurface at the facility, the thickness of the bluish-gray layers is directly proportional to the thickness of the silt and clay-rich layers they bound.

The reduction zones may represent intervals where ferric compounds have been reduced to ferrous compounds. Ferrous iron is much more soluble and more easily removed or transported by ground water. Al-Shaieb (1977), attributed the reduction of ferric iron to a reaction with hydrogen sulfide produced either by the contact of sulfate with hydrocarbons, or hydrogen sulfide released directly from naturally occurring hydrocarbons.

2.2.4 Chemical Environments

The chemical environment underlying the site is characterized by the chemistry of the unsaturated and saturated zones of the A, B, and C sandstones. The unsaturated zone environment will be dominated by the chemistry of the soils and rock strata. The saturated zone will be dominated by the chemistry of the ground water.

Groundwater at the site is oxygenated and slightly alkaline. The strata appear oxidized and have a relatively low cation exchange capacity. The organic content of the strata is negligible.

2.3 References

Al-Shaieb, 1977. Uranium Potential of Permian and Pennsylvania Sandstones in Oklahoma: American Association of Petroleum Geologists Bulletin, Volume 61, 1997.

Engineering Enterprises, 1973. Hydrological Information in the Vicinity of the Kerr-McGee Facility, Logan County, OK.

Grant, James L., 1989. Site Investigation Report for the Cimarron Corporation Facility, Logan County, Oklahoma, September 12, 1989.

Wood and Burton, 1968. Groundwater Resources in Cleveland and Oklahoma Counties, Oklahoma: Oklahoma Geological Survey Circular, 71.

3.0 HYDROLOGY

Exploitable groundwater in the central Oklahoma region occurs principally in the Permian-aged Garber/Wellington Aquifer. The Oklahoma Geological Survey groups the Garber and Wellington formations together as a single hydrologic unit on the basis of similar lithologies and water-bearing characteristics (Bingham and Moore, 1975).

The EPA (40 CFR 270) and the NRC (10 CFR 40, Appendix A) both define an aquifer as "a geologic formation, group of formations, or part of a formation capable of yielding a significant amount of groundwater to wells or springs." This definition, unfortunately, makes no specific reference to water quality, nor does it define the term "significant." Therefore, in areas where a widely used and recognized aquifer is present, other water-bearing zones that may yield lesser amounts of water, or water of poorer quality, become less important, although they may still meet the regulatory definition of aquifer. In such instances where lesser yields are present, important considerations become those of locations of impacts, availability of better sources of water, and potential for habitation. As indicated by a wide range of data, Cimarron believes the shallow and deeper groundwater at the site does not represent a potentially useful, viable or sustainable source of potable water – particularly with regard to consideration of higher quality alternate local sources of water (reservoirs and local water district). Data that supports this position, including information regarding regional and local hydrology, well yields, groundwater and surface water quality, and other sources of water are discussed in the following sections.

3.1 Regional Hydrogeology

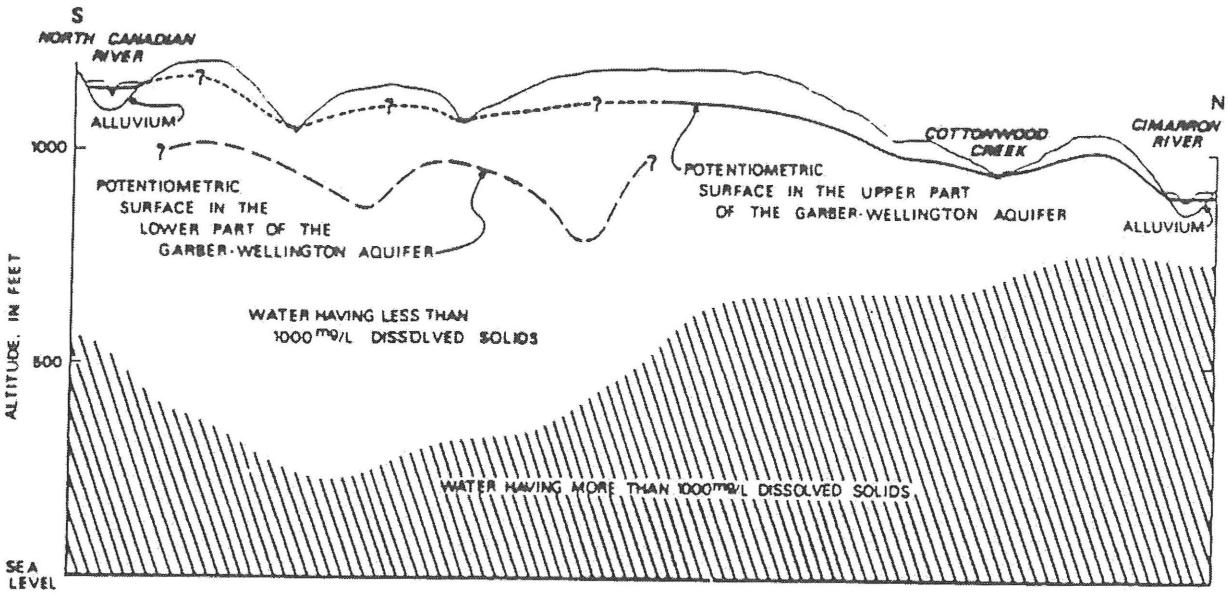
The water-bearing sandstones in the region are fine-grained and friable, with interbedded siltstones, mudstones and shales. North of Oklahoma County and into Logan County (where the site resides), the Garber-Wellington Aquifer thins and becomes more fine-grained. This

characteristic results in low aquifer permeability, resulting in a low amount of water that can be produced from the aquifer.

Generally, the sandstones in the Garber-Wellington are lenticular and thin. Their lenticular nature creates an environment within which water quality and quantity can differ greatly from one location to an another (Engineering Enterprises, 1973). For example, yields from six Garber Sandstone wells near the site ranged from 20 to 90 gallons per minute (gpm), with hardness ranging from 212 to 2,240 parts per million (ppm) and chloride ranging from 26 to 3,155 ppm (Engineering Enterprises, 1973). Monitoring wells on the site show similar ranges of constituent concentrations, but less yield, and are discussed in greater detail in Section 3.2.

3.1.1 Regional Groundwater Movement

The regional groundwater movement in the Garber-Wellington Aquifer depends on the depth of the groundwater. There are two major changes in the groundwater with depth. First, water-table (unconfined to semi-confined) conditions generally exist in the upper 200 feet in the area where the Garber-Wellington Aquifer crops out. Below 200 feet, and where the aquifer is saturated, the groundwater is typically under confined conditions. Second, there is a fresh-water/salt-water interface within the Garber-Wellington Aquifer. The elevation of this interface ranges from about 250 feet above mean sea level (fmsl) in the south to 850 fmsl in the north (near the site). The fresh/saline interface is about 190 feet below the ground surface in the vicinity of the site. This interface is shown on Figure 3.1.



SOURCE: CARR AND MARCHER, 1977

FIGURE 3.1

CONTACT DEPTH OF WATER CONTAINING IN EXCESS OF 1,000 PPM TDS

Groundwater in the shallow portions of the aquifer predominantly flows laterally and discharges to surface drainage pathways formed by the major rivers and streams. Upward flow near the discharge locations has been interpreted from potentiometric surface measurements of shallow groundwater (Carr and Marcher, 1977). This discharge maintains flows in the major rivers and some larger streams, even during dry periods. The movement of groundwater in the terrace and alluvial deposits is toward the surface drainages followed by rivers and streams. At the site, this flow is toward the north, culminating in the Cimarron River.

There are few potentiometric measurements in the lower part of the aquifer; some water-level data are available in the Oklahoma City area, several miles south of the site. Based on these measurements, deep groundwater (e.g., groundwater below that whose flow is influenced by the river channels, or below about 200 feet) movement is believed to be generally down-dip in a west- southwesterly direction.

3.1.2 Regional Groundwater Recharge/Discharge

Groundwater movement is controlled by local and regional recharge and discharge locations. The movement of groundwater in regional and local systems has been examined by Toth (1963) and Freeze and Witherspoon (1967). The local system overlays the regional groundwater system. The large river systems form the regional discharge locations, while local discharges may occur at smaller streams, as well as at the regional discharge locations. One characteristic of a recharge location is that the hydraulic head decreases with depth (downward flow), while in a discharge area, the hydraulic head increases with depth (upward flow).

Regional recharge to the Garber-Wellington Aquifer is primarily by the lateral movement of groundwater from outcrop areas located upgradient and to the east and south of the site. The principal recharge area for

precipitation and infiltration in the outcrop area for the Garber-Wellington has been identified as being north of the Canadian River, south of Guthrie, east of the Canadian County line and west of Shawnee (Johnson, 1983).

Johnson (1983) determined that surrounding the known recharge area is an area termed a "potential recharge area". The potential recharge area is a buffer surrounding the known recharge area, and includes any regions that may recharge to the aquifer that are unknown or not mapped. Johnson indicated that the potential recharge area extends about four miles beyond the recognized recharge area. The Cimarron site is located at the edge of the potential recharge area, and quite possibly beyond the limit of this potential recharge area.

Groundwater recharge has been estimated to be between five and ten percent of annual precipitation (annual precipitation is about 30 to 33 inches per year (in/yr) in the immediate vicinity of the site) (Carr and Marcher, 1977). Annual precipitation in the Oklahoma City quadrangle, which includes the site, ranges between about 28 and 41 in/yr. Actual evapotranspiration is on the order of 24 to 30 in/yr, with runoff ranging between 2.5 and 8 in/yr. Thus, an estimated 1.5 to 3.5 in/yr of precipitation is available for recharge (Bingham and Moore, 1975).

Natural regional discharge from the shallow portions of the Garber-Wellington Aquifer (as defined earlier) in the site area is to the Cimarron River and feeding stream drainages, as indicated by troughs in the potentiometric surface along the valleys of the Deep Fork, Bear Creek, Cottonwood Creek and the Cimarron River. Carr and Marcher (1977) indicate that upward flow occurs in areas where major streams, such as the North Canadian River, are entrenched into the aquifer, and where groundwater discharges to the alluvium. They also indicate that this situation is analogously occurring in the vicinity of the Cimarron River.

The locations of points or areas of discharge from the deeper portions of the Garber Wellington Aquifer are unknown, but are presumed to be outside of the central Oklahoma region (Carr and Marcher, 1977). Discharge from the shallower portions of the aquifer are to the rivers and streams that form the local discharge locations. This difference in discharge characteristics demonstrates a separation of the shallower and deeper flow zones in the Garber-Wellington Aquifer.

3.2 Site Hydrology

Groundwater is found in two types of geologic deposits found at the site including the Quaternary aged alluvial deposits found beneath the river and floodplain of the Cimarron River and in sandstone bedrock units of the Permian-aged Garber Sandstone. The Garber Sandstone contains interbedded sandstones, mudstones, and shales. The Garber Sandstone forms the bedrock formation that outcrops in upland areas bordering the Cimarron River. The alluvium was deposited in a deep channel that was cut into the Permian bedrock.

Groundwater in the Garber Sandstone can be divided into two water bearing zones including a shallow zone which includes groundwater found in Sandstones A and B and a deeper zone associated with Sandstone C. Groundwater in the shallow zone at the site is recharged from upland sources, and from on-site reservoirs and from infiltration from precipitation. Groundwater in the deeper zone is recharged regionally at upland outcrops areas found in areas east of the site.

Shallow groundwater in Sandstones A and B discharges to a series of seeps found in the cliffs and bluffs that are found adjacent to the floodplain of the Cimarron River. Deeper groundwater found in Sandstone C discharges to the alluvium deposits associated with the Cimarron River.

Groundwater found in the lower portions of Sandstones B also discharges to the river alluvium.

These groundwater flow systems are discussed in greater detail in the following sections.

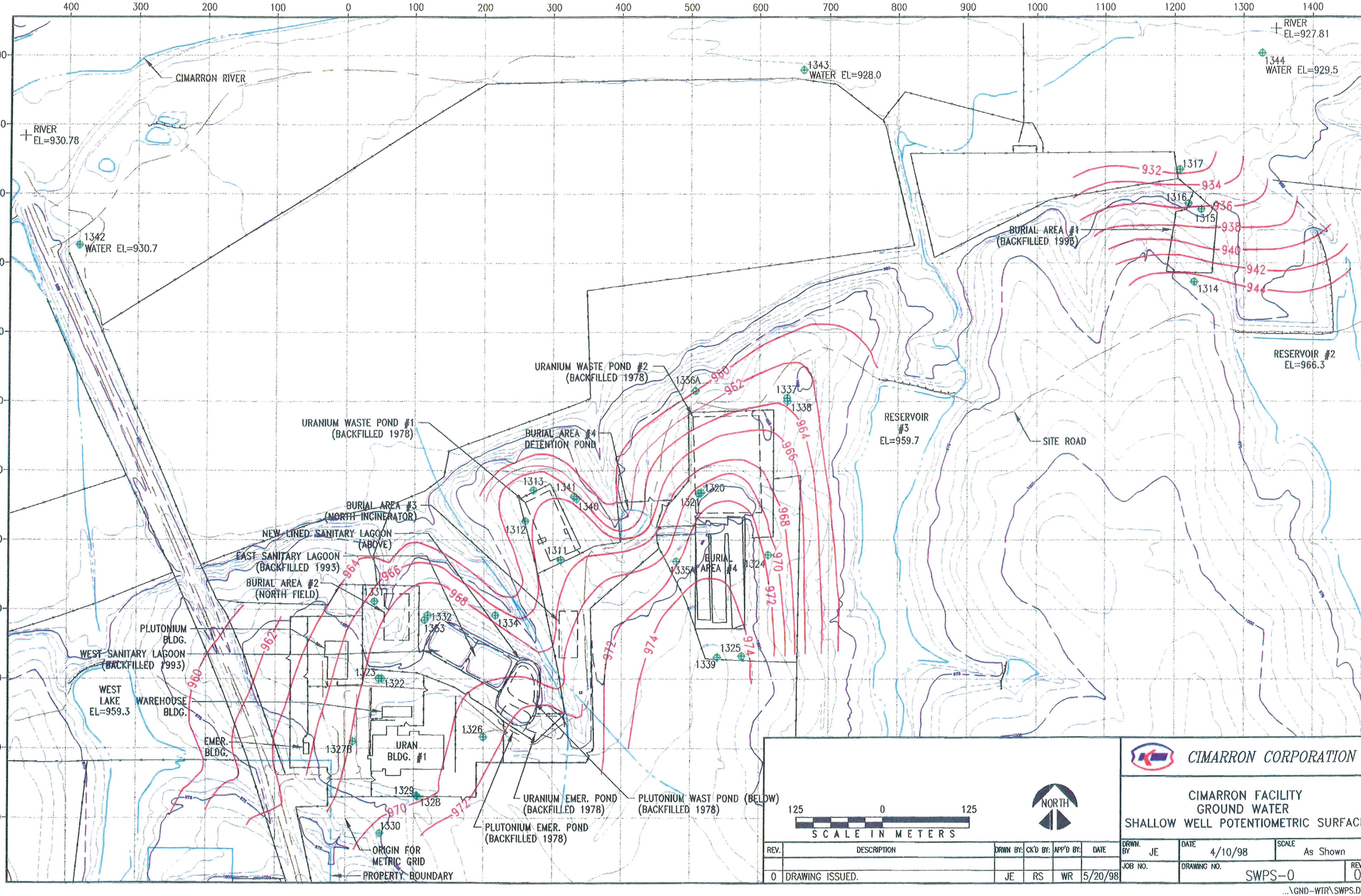
3.2.1 Site Groundwater

Shallow groundwater under the site occurs under water table and partially confined conditions. The depth to water in the shallow wells ranges from about 10 to 40 feet below ground level. Drawing No. SWPS-0 (next page) is a map of the potentiometric surface for the shallow groundwater, and illustrates the general elevations of the groundwater within this zone. The groundwater contours shown for the western portion of the site represent groundwater located within Sandstone A; the contours shown for the eastern area of the site represent groundwater located within Sandstone B.

All the rocks below the shallow water table are saturated. The deep wells were screened in a confined sandstone (Sandstone C) that occurs approximately 100 feet below the ground surface. Drawing No. DWPS-0 (page 3-9) is a map of the potentiometric surface defined by the deep wells, and also illustrates the general elevation of groundwater within this deeper zone.

3.2.1.1 Site Groundwater Movement

Shallow groundwater flow (Sandstones A and B) is influenced by local topography and surface water bodies. Seepage faces are present along the eroded slope found along the south side of the Cimarron River floodplain. In the vicinity of Well 1334 (see Drawing No. SWPS-0), seepage occurs at an elevation of about 964 feet with standing water occurring in a marshy area at an elevation of about 960 feet. The incised


CIMARRON RIVER
RIVER EL=930.78
RIVER EL=927.81
1343 WATER EL=928.0
1344 WATER EL=929.5
1342 WATER EL=930.7
1317
1316
1315
1314
932
934
936
938
940
942
944
BURIAL AREA #1 (BACKFILLED 1993)
RESERVOIR #2 EL=966.3
URANIUM WASTE POND #2 (BACKFILLED 1978)
1336A
1337
1338
960
962
964
966
968
970
972
974
RESERVOIR #3 EL=959.7
SITE ROAD
URANIUM WASTE POND #1 (BACKFILLED 1978)
BURIAL AREA #4 DETENTION POND
1313
1341
1340
1312
1311
1320
1321
BURIAL AREA #3 (NORTH INCINERATOR)
NEW LINED SANITARY LAGOON (ABOVE)
EAST SANITARY LAGOON (BACKFILLED 1993)
BURIAL AREA #2 (NORTH FIELD)
1331
1332
1333
1334
1335A
BURIAL AREA #4
1324
1325
1339
PLUTONIUM BLDG.
WEST SANITARY LAGOON (BACKFILLED 1993)
1323
1322
WEST LAKE EL=959.3
WAREHOUSE BLDG.
EMER. BLDG.
1327B
URAN BLDG. #1
1326
1329
1328
1330
ORIGIN FOR METRIC GRID
PROPERTY BOUNDARY
URANIUM EMER. POND (BACKFILLED 1978)
PLUTONIUM EMER. POND (BACKFILLED 1978)
PLUTONIUM WAST POND (BELOW) (BACKFILLED 1978)
125 0 125
SCALE IN METERS
NORTH
CIMARRON CORPORATION
CIMARRON FACILITY
GROUND WATER
SHALLOW WELL POTENTIOMETRIC SURFACE
REV. | DESCRIPTION | DRWN BY: | CK'D BY: | APP'D BY: | DATE
0 | DRAWING ISSUED. | JE | RS | WR | 5/20/98
DRWN. BY JE
DATE 4/10/98
SCALE As Shown
JOB NO.
DRAWING NO. SWPS-0
REV. 0
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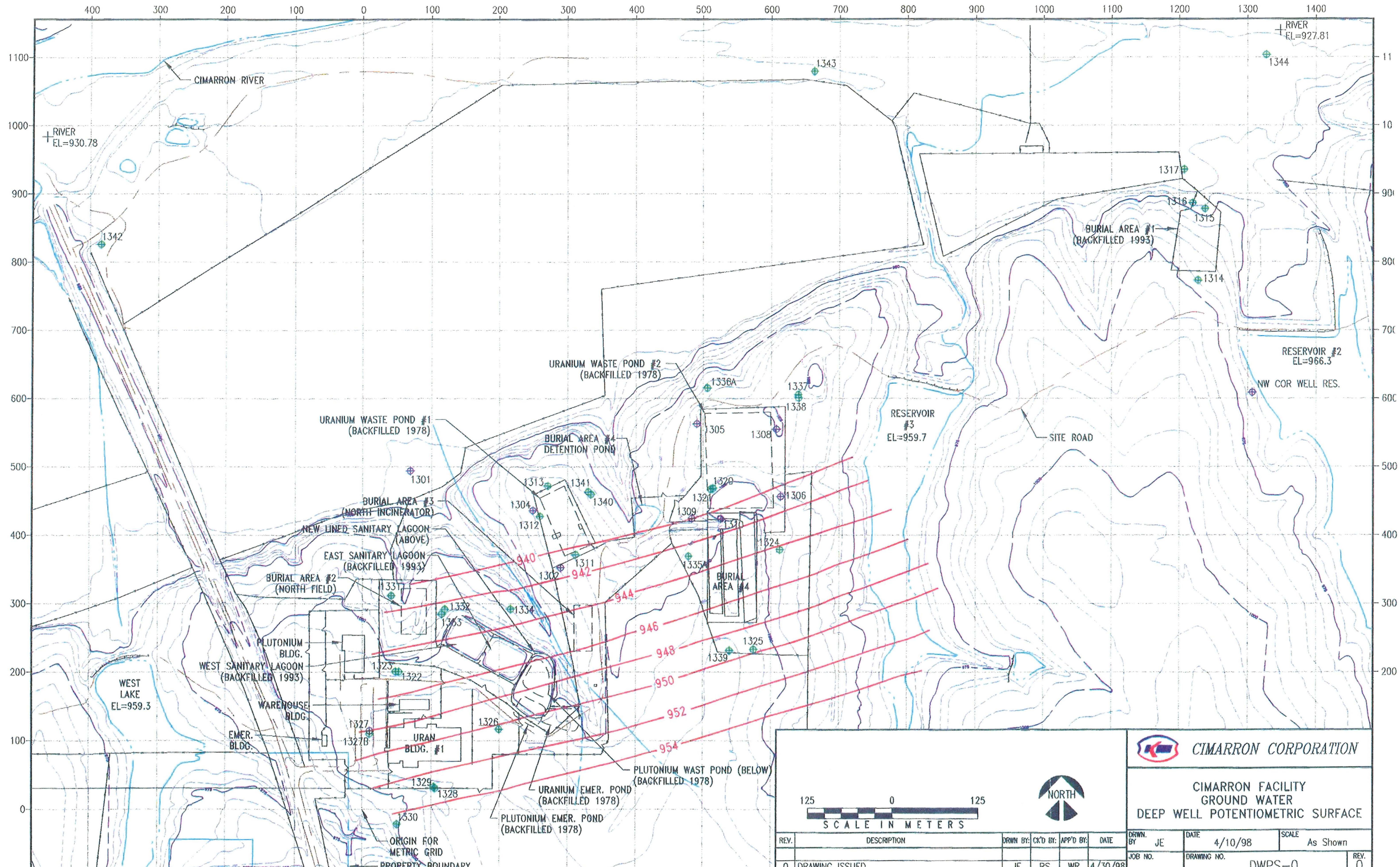


CIMARRON RIVER
RIVER EL=930.78
RIVER EL=927.81
1342
1343
1344
1317
1316
1315
1314
BURIAL AREA #1 (BACKFILLED 1993)
RESERVOIR #2 EL=966.3
NW COR WELL RES.
URANIUM WASTE POND #2 (BACKFILLED 1978)
1336A
1337
1338
1305
1308
RESERVOIR #3 EL=959.7
SITE ROAD
URANIUM WASTE POND #1 (BACKFILLED 1978)
BURIAL AREA #4 DETENTION POND
1301
1313
1341
1340
1320
1306
1304
1312
1309
BURIAL AREA #3 (NORTH INCINERATOR)
NEW LINED SANITARY LAGOON (ABOVE)
EAST SANITARY LAGOON (BACKFILLED 1993)
1324
1311
1302
1335A
BURIAL AREA #2 (NORTH FIELD)
BURIAL AREA #4
1332
1333
1334
PLUTONIUM BLDG.
WEST SANITARY LAGOON (BACKFILLED 1993)
1323
1322
1339
1325
WEST LAKE EL=959.3
WAREHOUSE BLDG.
EMER. BLDG.
1327
1327B
URAN BLDG. #1
1326
1329
1328
1330
ORIGIN FOR METRIC GRID
PROPERTY BOUNDARY
PLUTONIUM WAST POND (BELOW) (BACKFILLED 1978)
URANIUM EMER. POND (BACKFILLED 1978)
PLUTONIUM EMER. POND (BACKFILLED 1978)
940
942
944
946
948
950
952
954
125
0
125
SCALE IN METERS
NORTH
CIMARRON CORPORATION
CIMARRON FACILITY
GROUND WATER
DEEP WELL POTENTIOMETRIC SURFACE
REV.
DESCRIPTION
DRWN BY:
CK'D BY:
APP'D BY:
DATE
0
DRAWING ISSUED.
JE
RS
WR
4/30/98
DRWN. BY JE
DATE 4/10/98
SCALE As Shown
JOB NO.
DRAWING NO. DWPS-0
REV. 0

drainages and bluff overlooking the river's floodplain exert local influences on shallow groundwater flow.

The piezometric surface determined from shallow monitoring wells (represented by Drawing No. SWPS-0) and deep monitoring wells (represented by Drawing No. DWPS-0) indicates groundwater flow in the Garber Sandstone is generally north-northwest toward the Cimarron River. This local condition is contrary to the general regional westward flow direction in the Garber-Wellington Aquifer (as discussed in Section 3.1.1 above). The movement of groundwater from both the shallow (Sandstones A and B) and deeper (Sandstone C) monitored zones beneath the site is toward the Cimarron River. This indicates that both zones monitored at the site are part of a shallow (near-ground surface) groundwater flow regime, and discharge is to the bluffs or to the alluvium north of the site (Cimarron River).

The groundwater gradient for the shallow groundwater zone averages approximately 0.025 (unitless) except where it steepens as a result of proximity to discharge areas. Groundwater from the confined aquifer screened by the deep wells (Sandstone C) flows at a gradient of approximately 0.014. This deeper groundwater interval is at an elevation that indicates it recharges directly to the Cimarron alluvium and contributes to the base flow of the Cimarron River.

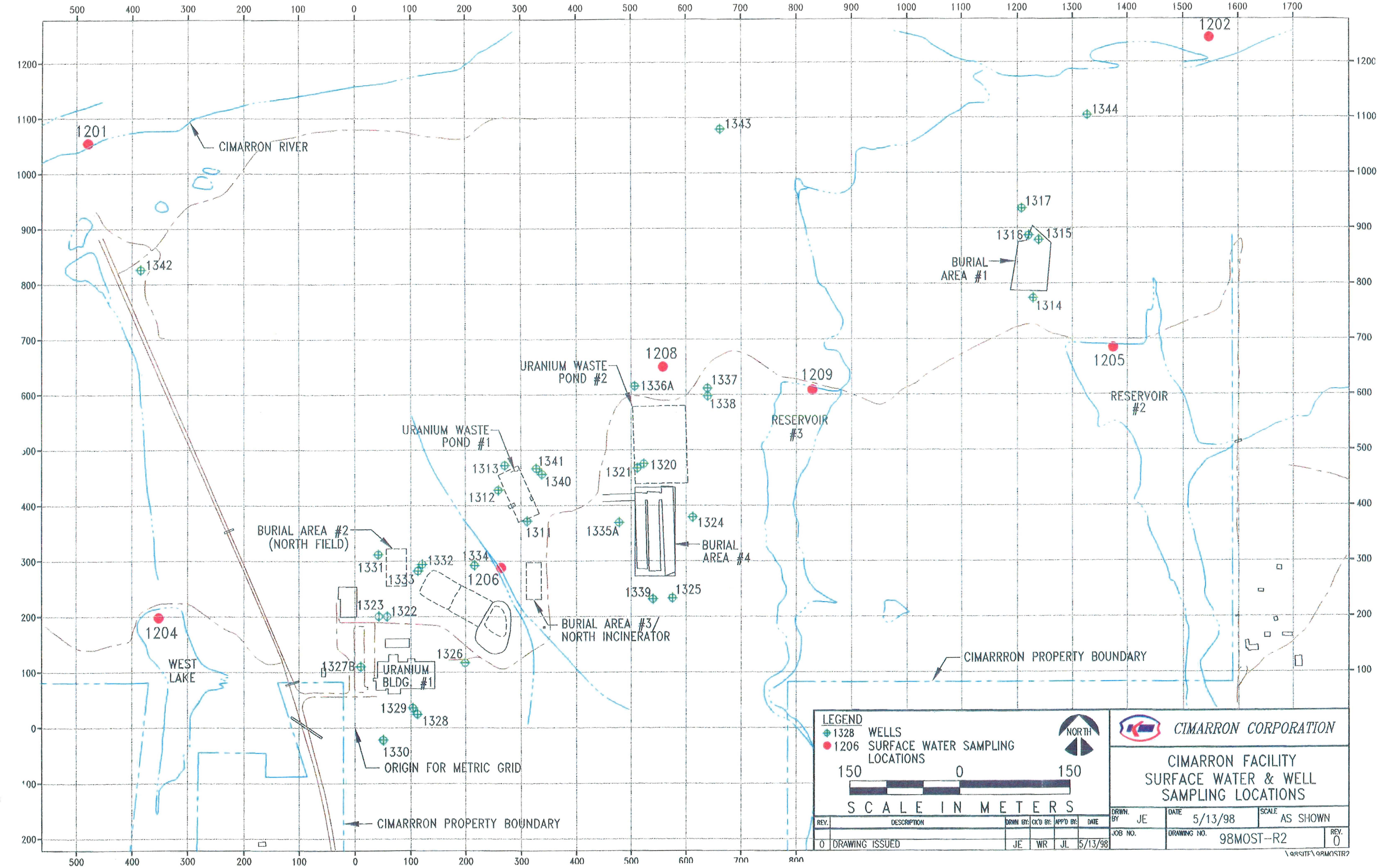
Each of the sandstone units discussed above in Section 2.2.1 contains discontinuous mudstone or siltstone layers that may affect the movement of groundwater through the aquifer. The mudstones typically have a consistency of very stiff to hard sandy silt or clay even at depths greater than 100 feet. As illustrated by the piezometric surface (Drawing No. SWPS-0), there is a net downward vertical potential between the upper water table aquifer and the lower confined units. However, based upon

extensive site borings and investigations, there are significant confining mudstone layers separating the lower confined groundwater zones from the more shallow stratum. These mudstone layers promote lateral flow north toward the seeps and river alluvium. The intersection of the alluvium with the underlying sandstones creates discharge zones for the sandstones and this further influences and controls lateral movement of the groundwater.

Four wells completed in the shallow sandstones confirm that a confining layer exists between Sandstones A and B. Well #1337 (Sandstone A) was installed adjacent to Well #1338 (Sandstone B). For well locations see Drawing No. 98MOST-R2 (next page). Groundwater elevations of 965 MSL verses 942 MSL were noted respectively between the two wells. Similarly, Well #1340 (Sandstone A) and Well #1341 (Sandstone B) show elevations of 961 MSL and 936 MSL respectively. These elevation differences indicate a downward component of flow, but also suggest that Mudstone A acts as a hydrological barrier layer between Sandstones A and B. Also, these elevations provide additional data indicating that groundwater in Sandstone A is unconfined and flows laterally northward, discharging to the bluffs overlooking the south bank of the Cimarron River; and that groundwater in Sandstone B also discharges north to both the bluffs and the Cimarron River alluvium (see Drawing No. 98-XSEC-1, page 2-5).

Groundwater in Sandstone C is confined throughout the site. In addition to the increasing pressure heads with increasing depth, analytical data illustrates that the intervening mudstones act as confining layers. This analytical data is discussed in Section 3.4.2.3.

During installation it was noted that the groundwater level for Well #1339 (completed to a depth of 218 feet in the deeper part of Sandstone C), was


CIMARRON RIVER
1201
1202
1343
1344
1342
1317
1316
1315
BURIAL AREA #1
1314
1205
RESERVOIR #2
1208
URANIUM WASTE POND #2
1336A
1337
1338
1209
RESERVOIR #3
URANIUM WASTE POND #1
1313
1341
1340
1321
1320
1312
1311
1335A
1324
BURIAL AREA #4
BURIAL AREA #2 (NORTH FIELD)
1331
1333
1332
1334
1206
1339
1325
1323
1322
1204
BURIAL AREA #3/ NORTH INCINERATOR
WEST LAKE
1326
1327B
URANIUM BLDG. #1
CIMARRON PROPERTY BOUNDARY
1329
1328
1330
ORIGIN FOR METRIC GRID
CIMARRON PROPERTY BOUNDARY
LEGEND
1328 WELLS
1206 SURFACE WATER SAMPLING LOCATIONS
150 0 150
SCALE IN METERS
NORTH
CIMARRON CORPORATION
CIMARRON FACILITY
SURFACE WATER & WELL
SAMPLING LOCATIONS
DRWN. BY JE
DATE 5/13/98
SCALE AS SHOWN
JOB NO.
DRAWING NO. 98MOST-R2
REV. 0
REV.
DESCRIPTION
DRWN BY:
CK'D BY:
APP'D BY:
DATE
0
DRAWING ISSUED
JE
WR
JL
5/13/98

higher than that recorded in the upper Sandstone C strata. This increased pressure head indicates an upward component of flow, and supports the projections that the Cimarron River is a discharge location for the deeper groundwater. Also, these data show that the discharge pathway of the deeper groundwater (Sandstones C and below) forms a hydraulic barrier to the potential downward migration of the near surface groundwater.

Groundwater quality data for Well #1339 shows that the base of the freshwater interface occurs at a depth of 190 feet below grade surface. Groundwater in this zone (>11,000 mg/L TDS) contributes to the already poor quality of the Cimarron River.

In summary, there are effective confining mudstone strata between each of the groundwater zones of Sandstones A, B, and C. These mudstones influence the lateral flow of groundwater and act to limit the potential downward migration of shallow groundwater found in the A and B sandstone units. Shallow groundwater in the A and B sandstones units generally discharges to the incised drainage pathways and seeps found in the low-lying bluffs and cliffs that border the floodplain of the Cimarron River. Deeper groundwater in both Sandstone B and C discharges to the alluvium deposits that underlie the Cimarron River and the adjoining floodplain. As reported in Section 3.4.2.2, deeper groundwater is of poor quality as a result of high TDS. The water of the Cimarron River is also of poor quality as a result of generally higher TDS.

3.2.1.2 Hydraulic Properties of Water Bearing Strata

Hydraulic conductivities of the Garber Formation sandstones generally are moderate. The sandstones are poorly cemented and show few diagenetic effects. The primary porosity and permeability restrictions are the variable amounts of fines present in the sandstones. Inspection of outcrops at the

site and core samples revealed minimal jointing indicating that the effect of fractures on hydraulic conductivities is expected to be low.

The hydraulic conductivity of the shallow aquifer (Sandstones A and B) ranges from 2.3 x 10-4 cm/sec to 3.0 x 10-3 cm/sec. The mean of the measured values is 1.01 x 10-3 cm/sec. The transmissivity of this aquifer ranges from 9.9 ft sq/day to 108 ft sq/day.

The hydraulic conductivity of the deep aquifer (Sandstones C) ranges from 2.0 x 10-5 cm/sec to 1.0 x 10-3 cm/sec, with a mean of 4.4 x 10-4 cm/sec. The transmissivity ranges from 4.6 ft sq/day to 254 ft sq/day.

3.2.2 Site Groundwater Recharge/Discharge

Aquifer tests indicate that there is no significant hydraulic connection between Garber sandstone layers that are separated by shale layers (Wood and Burton, 1968). This hydraulic separation between water-bearing sandstones has been confirmed at the site as described earlier. During unusually heavy precipitation in 1985, there was no noticeable impact upon water levels in site monitoring wells completed in shallow sandstones separated by mudstones (Sequoyah, 1985). Bingham and Moore (1975) attribute the poor response to precipitation changes shown by well hydrographs to the poor communication of the sandstones with the surface or the recharge areas being a considerable distance from the well.

The site is located upgradient of a system of low-lying bluffs located adjacent to the Cimarron River. As discussed in Section 3.2.1.1, the bluff that borders the river floodplain influences the movement of shallow groundwater at the site. An evaluation of the shallow and deeper potentiometric surface maps for the site indicates that the groundwater flow direction for both is toward the Cimarron River. The lowest potentiometric elevation in the shallow monitoring well (Sandstone A)

nearest to the river is about 960 fmsl (see Drawing No. SWPS-0). The lowest potentiometric elevation in the deeper monitoring wells nearest to the river is about 940 fmsl (see Drawing No. DWPS-0). The elevation of the Cimarron River at normal flow is 927 to 930 fmsl near the site. The elevation of the floodplain is about 940 fmsl (Engineering Enterprises, 1973). Seepage faces are present along the bluffs just above the Cimarron River floodplain (NRC, 1994). Seeps and standing water similarly are reported at elevations between 960 and 964 fmsl (NRC, 1994). The river stage is lower than the potentiometric surface for the shallow and deep monitoring wells at the site. This finding suggests that groundwater in both Sandstones B and C are hydraulically linked to the river and groundwater in these units discharges to the floodplain alluvium and the river. Whereas, groundwater in Sandstone A and the upper portion of Sandstone B discharges to a series of seeps found along the bluff just south of the river.

A hydrologic water balance has been performed for the site. The analysis followed the procedures presented in EPA/530/SW-168. The study focused on the soil types that comprise the surface at the site, and whether those soils contributed to rapid runoff or allowed percolation. Three soil types were identified at the site, the compositions of which typically generate high runoff and preclude rapid infiltration. Water availability was represented by total precipitation, while water loss was represented by evapotranspiration, surface runoff, and soil moisture storage. The average recharge of shallow groundwater to underlying strata is estimated to be low (5 to 10 percent of annual precipitation). Significantly, evaluation of potential recharge at the site suggests that no significant seepage occurs in years of average precipitation, but seepage could occur in years of above-average precipitation (Lower, 1989).

Additionally, the analyses by Toth (1963), Freeze and Witherspoon (1967), support the interpretation of local discharge to seeps and to the Cimarron River. Groundwater in the shallow Garber sandstones underlying the site, and surface water that infiltrates through the site moves laterally toward the Cimarron River, and does not become part of the recharge to the deeper Garber-Wellington Aquifer.

3.3 Surface Water Hydrology

The principal surface-water bodies at the site are the three reservoirs indicated on the site map and the Cimarron River (see Drawing No. SWPS-0).

3.3.1 Local Surface-Water Bodies – Reservoirs

The water elevation of the three reservoirs was determined at the time the monitoring wells were surveyed in 1989. The water elevations (i.e., spill way elevations) for Reservoirs 1, 2, and 3 at that time were 959.3, 966.3, and 959.7 feet above mean sea level, respectively.

The three reservoirs appear to influence shallow groundwater flow at the site. Reservoirs 1 and 3 have water levels significantly below the water table in the nearest wells indicating that shallow groundwater maintains the water level of these reservoirs and hence provides the base flow for the streams that exit the reservoirs.

3.3.2 Cimarron River

As discussed in Section 3.2.1.1, groundwater contained in the confined Sandstones located under the site (i.e., Sandstone B and C) and the deeper high salinity groundwater discharges to the Cimarron River as base flow. The groundwater elevations show that the discharge pathways of the deeper groundwater (Sandstone C and below) forms a hydraulic

barrier to the potential downward migration of the near surface groundwater.

The movement of groundwater through the Garber-Wellington Aquifer is dependent upon depth and location. As shown on Figure 3.1 (page 3-3), the principle component of groundwater movement in the shallow sand-bearing units of the Garber-Wellington Aquifer is lateral from recharge areas along surface outcrops to points of discharge along exposures in stream valleys. Figure 3.1 shows that the ultimate point of discharge for the shallow groundwater in the vicinity of the Cimarron Facility is the Cimarron River. The movement of groundwater in the deepest portions of the Garber-Wellington Aquifer is thought to be down dip toward the southwest.

3.4 Background Groundwater Quality

As discussed in the previous sections, there are two main occurrences of groundwater in the area of this site south of the Cimarron River. Groundwater is present both in the Garber sandstone and the floodplain alluvium adjacent to the Cimarron River. These occurrences are discussed separately.

3.4.1 Regional Groundwater Quality

The primary groundwater occurrence in the vicinity of the Cimarron facility is within the Garber Sandstone and Wellington Formation. The water-bearing portions of these formations are collectively known as the Garber-Wellington Aquifer. These formations were deposited by streams in a delta that occupied central Oklahoma during the Permian Age.

Figure 3.1 (page 3-3) shows the base of fresh water/salt water interface in the Garber-Wellington Aquifer, which is defined by the U. S. Geological Survey as groundwater having a total dissolved solids (TDS) of more than

1,000 mg/L. The source of the fresh water is meteoric water derived from the infiltration of precipitation, while the salt water is derived from connate water trapped in deeper sediments deposited in a marine environment. The base of the fresh water/salt water interface is deepest beneath Oklahoma County, where much of the recharge occurs, rising to a more shallow depth (about 190 ft below grade) to the north where recharge is less and the Garber-Wellington Aquifer discharges into the Cimarron River.

3.4.2 Site Groundwater Quality

Background groundwater quality has been addressed by two reports (Chase, 1996 and Cimarron 1997) previously submitted to the NRC; these reports demonstrate that water quality varies substantially across the site and with depths on site. Historical groundwater analytical data are discussed in the following sections.

3.4.2.1 Shallow Groundwater Quality

The shallow groundwater zones, identified as Sandstones A and B, contain groundwater from local recharge that flows predominantly laterally north toward the Cimarron River and to the sandstone outcrops located along the northern bluffs. The water quality within these zones is generally fair because they have been influenced by local precipitation and surface water recharge. The ranges of onsite background groundwater quality data for Sandstones A and B are shown in Table 3.1. Wells #1314 (Sandstone B) and #1325 (Sandstone A) are located upgradient from past site operations, and are considered background wells.

Although not included in Table 3.1, background isotopic total uranium concentrations can be determined from historic data. Total isotopic uranium for Well #1314 has ranged from 1.4 pCi/L to 2.3 pCi/L with an

average of 2.0 pCi/L. Total isotopic uranium for Well #1325 has ranged from 1.7 pCi/L to 2.5 pCi/L with an average of 2.3 pCi/L. These average values would indicate that background uranium is similar for both Sandstone A and B.

TABLE 3.1
RANGE OF VALUES FOR SELECT
CONSTITUENTS FOR BACKGROUND WATER QUALITY
SANDSTONES A AND B

Background Water Quality	Shallow Wells #1314 and #1325	
	Grant Data 1989	1996 Data
Hardness (mg/L)	253 - 284	228 - 522
Calcium (mg/L)	65 - 74	55 - 120
Magnesium (mg/L)	22 - 24	22 - 54
Sodium (mg/L)	16 - 22	21 - 44
Bicarbonate (mg/L)	336 - 402	200 - 230
Chloride (mg/L)	8 - 16	7 - 16
Sulfate (mg/L)	8 - 10	8 - 11
Fluoride (mg/L)	1.0	0.31 - 0.64
Nitrate/Nitrite (mg/L)	9 - 14	1.80 - 9.30
Specific Conductance (μmho/cm)	900	500-600

Additionally, Sandstone A Wells #1324 and #1335 can be included in the background water quality data set because, historically, they have been upgradient of the BTP Option #2 cell established in early 1995. Total isotopic uranium for Wells #1324 and #1335 have averaged 1.5 pCi/L and 2.3 pCi/L respectively (with a range of 0.7 pCi/L to 3.7 pCi/L), which are indicative of background uranium concentrations noted in the other Sandstone A and B wells.

3.4.2.2 Deeper Groundwater Quality

Well #1328, which is completed in Sandstone C, can be considered an upgradient well; it monitors the deeper groundwater zones which are not

considered impacted by prior site operations. Background water quality data for this well is shown in Table 3.2. Analytical results from three other deep wells completed in Sandstone C also are included in Table 3.2.

Although not included in Table 3.2, the historical total isotopic uranium concentrations have remained fairly constant. Total isotopic uranium for Well #1328 has averaged 34.0 pCi/L during the period of 1989 to 1997 with a range of 27 to 44 pCi/L.

TABLE 3.2
GROUNDWATER ANALYTICAL RESULTS FOR
SELECTED CONSTITUENTS SANDSTONE C WELLS

	Well Numbers			
	MW1321	MW 1323	MW 1328	MW 1332
Depth (ft.)	122	127	135	116
Hardness (mg/L)	1,698	1,641	1,634	1,751
Calcium (mg/L)	550	530	500	550
Magnesium (mg/L)	78.9	77.1	93.5	91.8
Sodium (mg/L)	65.2	244	127	300
Bicarbonate (mg/L)	223	149	149	137
Chloride (mg/L)	42.0	180	135	400
Sulfate (mg/L)	1,920	2,480	2,310	2,500
Fluoride (mg/L)	0.2	0.2	0.2	0.2
Nitrate/Nitrite (mg/L)	1.01	1.77	2.14	1.82
Spec. Cond. (mho/cm)	2550	3,700	3,440	44,260
TDS (mg/L)	2,660	3,490	3,270	4,090

Well #1321 has averaged 18 pCi/L, and Well #1320 (adjacent to Well #1321 and completed in Sandstone A) has remained fairly constant at an average of 3.7 pCi/L. Likewise, fluorides in Well #1321 have remained, in general, fairly constant at background levels (<1 mg/L) further indicating that this deeper zone has not been impacted by prior site operations and that the intervening mudstones act as confining layers.

Total isotopic uranium for both wells (i.e., #1321 and #1328) has ranged from 11 pCi/L to 44 pCi/L, which is considered within background variances for this deeper sandstone layer.

3.4.2.3 Water Quality Varies With Depth

As discussed in the previous sections, the shallow groundwater zones represent the part of the aquifer that carries modern recharge, while the deeper zones contains saltier formation (connate) water remaining from the original depositional environment. Changes in water quality with depth are discussed in this section.

The total isotopic uranium concentrations for the two shallow Sandstone A and B background wells, and the five deeper Sandstone C wells, are summarized in Table 3.3. The monitoring well data indicates that background groundwater total uranium concentrations increase with depth.

TABLE 3.3
TOTAL ISOTOPIC URANIUM CONCENTRATIONS

Well Location	Total Uranium Concentrations (pCi/L)
Sandstone A	
Well #1325	1.7 – 2.5
Sandstone B	
Well #1314	1.4 – 2.3
Sandstone C	
Well #1321	10.5 – 23.7
Well #1323	27.2 – 40.7
Well #1328	27.7 – 43.7
Well #1332	17.6 – 38.4
Well #1339	14.9

Additionally, analytical data shows that background groundwater quality for certain other constituents, other than uranium, becomes poor with

depth indicating a hydraulic disconnect between the sandstone layers (i.e., A/B and C). For example, sulfates in Well #1325 (Sandstone A) are 11 mg/L, whereas in #1321 (Sandstone C) it is 1,900 mg/L. Well #1339 (depth 218 feet), shows sulfates at 3,560 mg/L. Well #1339 is located upgradient to former Uranium Waste Pond #2 (U-Pond #2).

The four wells completed in shallow Sandstone C, in general, showed elevated dissolved solids concentrations (TDS) greater than 1,000 mg/L. The TDS ranged from 2,660 mg/L to 4,090 mg/L. Concentrations of sulfates for the four shallow Sandstone C wells ranged from 1,920 mg/L to 2,500 mg/L. The hardness of the water calculated from the sum of the magnesium and calcium ranged from 1,641 mg/L to 1,751 mg/L. These results indicate very hard water. For these four wells, chloride ranged from 43 mg/L to 400 mg/L. The deeper Sandstone C well, Well #1339, which was completed to a depth of 218 feet below grade, has a TDS exceeding 11,000 mg/L, with chlorides exceeding 3,700 mg/L. The elevated concentration of TDS, chlorides, and sulfates in these wells attest to the low infiltration rate of fresh water into Sandstone C from the upper sandstone layers.

Nitrates also demonstrate that constituents in Sandstone C are at background levels. Since June 1989, nitrates in Well #1321 have historically been approximately 1 mg/L; whereas in Well #1320 concentrations have ranged from 15 to 30 mg/L. Low nitrate concentrations are also found in deep Wells #1323, #1328 and #1332, averaging 1.5, 1.7, and 1.9 mg/L respectively similar to the value found in Well #1321. This is not true for the shallower horizon where nitrates have shown substantial variances across the site and adjacent to the site in the shallowest groundwater zones. The greatest impact to nitrates in the upper zones is attributed to the agricultural activities that have occurred for several years uninterrupted as noted in the next section .

3.4.2.4 Quality of Groundwater Adjacent to Site

Several wells located adjacent to and upgradient of the site have shown influence from local farming. Wells #1307 and #1303, which are located south (i.e., upgradient) of the operational areas, both near Highway #33, were sampled during the 1970's, 1980's and early 1990's as part of the Cimarron environmental monitoring program. For Well #1307, nitrates/nitrites ranged from 0.3 ppm (0.3 mg/L) to 270 ppm (270 mg/L) from 1971 through 1977. From 1978 through 1991, the results were reported in units of mg/L and varied from 1.0 to 104 mg/L. Well #1303 had concentrations of nitrate/nitrite of 0.98 ppm (0.98 mg/L) to 430 ppm (430 mg/L) from 1971 through 1977. From 1978 through 1986, the results were reported at <1 mg/L to 53 mg/L. The elevated nitrates are believed to be a result of nitrogen fertilizers being used on agricultural fields. Extensive site acreage were used for farming, most typically wheat crops.

The nitrate concentration in Well #1330 has ranged from 172 mg/L down to 35 mg/L (the analytical result of <0.5 mg/L in 1993 was considered erroneous data). This well is located near the edge of a cultivated wheat field and upgradient of any prior production facility operations.

3.4.3 Water Quality of the Cimarron River and Floodplain

The Cimarron River located north of the Cimarron site, flows toward the east. A considerable thickness of alluvium has accumulated within the flood plain. These alluvial sediments generally consist of sand, silt and gravel.

The Cimarron River, carries large amounts of chlorides from the Big Salt plains area approximately 100 miles upstream from the site. A USGS study (Blaz, 1995) completed for the Cimarron River near Guthrie over a fourteen year period from 1949 to 1963 showed chlorides varying from 136 mg/L to 16,500 mg/L. Another USGS study reviewed all data

collected from the Guthrie sample station up through 1978. For the samples analyzed, 98% of the hardness values were greater than 180 mg/L and the average hardness concentration was 710 mg/L. These concentrations result in a hardness classification for the river water as very hard.

The Cimarron Facility environmental monitoring program includes collecting and analyzing samples from upstream and downstream locations. The river was last sampled in June 1997 and showed total uranium concentrations of 8.1 pCi/L for the upstream location (i.e., sample location #1201) and 7.3 pCi/L for the downstream location (i.e., sample location #1202).

3.4.4 Justification for Well Locations On-Site

The Cimarron facility established an extensive and continuous environmental monitoring program to determine the impact of facility activities on the environment. This program consists of routinely collecting and analyzing air, surface water, ground water, soil and vegetation samples from the site and adjacent areas.

The environmental program includes many monitoring wells installed throughout the facility area for collection of groundwater samples from the shallow, unconfined aquifer which occurs at depths less than 50 feet below ground surface. Well #1311 through #1317 shown by Drawing No. 98MOST-R2 were installed during a site investigation in 1985. Boring logs and well completion information for these wells, hydrologic and geologic data, and analyses of groundwater collection from these wells were utilized by Grant (1989) for planning the 1989 characterization investigation.

Grant's 1989 investigation was conducted to supplement the previous site characterization. A total of eighteen (18) Wells (#1320 through #1336) were installed during the 1989 field investigation. Wells were completed in Sandstone A, Sandstone B, and Sandstone C groundwater zones. Data gathered during this 1989 characterization was utilized to:

- characterize the stratigraphy and lithology of the soils and bedrock strata at the site;
- characterize the aquifer properties including hydraulic conductivity, groundwater flow direction and gradient;
- characterize the groundwater quality and determination of the effects that facility operations may have had on groundwater quality; and
- determine the mobility of radionuclides, particularly uranium, in the subsurface and the ability of subsurface materials to retard migration.

The 1989 Characterization Report (Grant, 1989) was completed as part of Cimarron's application for on-site disposal of NRC Branch Technical Position (NRC, 1981) Option #2 soils. The Report included a presentation of groundwater flow direction for both the shallow and deep groundwater zones.

With the completion of the 1989 well installations, groundwater monitoring wells located upgradient, near, or downgradient to former waste management areas and the uranium plant were in place. This system of wells constitutes the facility's groundwater monitoring program.

In early 1997, five additional wells were installed at the site to further characterize the three designated sandstone layers. Four of the wells completed in Sandstones A and B confirmed that a confining layer exists

between Sandstones A and B. Well #1337 (Sandstone A) was installed adjacent to Well #1338 (Sandstone B), with groundwater elevations of 965 MSL versus 942 MSL respectively. Similarly, Well #1340 (Sandstone A) and Well #1341 (Sandstone B) show elevations of 961 MSL and 936 MSL respectively. These elevations confirm that Mudstone A acts as a confining layer between Sandstones A and B. Also, these well elevations provide further evidence that groundwater in Sandstone A discharges to the cliff north of the site and groundwater in Sandstone B discharges to both the cliff and the Cimarron River alluvium. Groundwater discharging from the cliff north of Uranium Waste Pond #2 is monitored by surface water location #1208.

The fifth Well #1339, completed at a depth of 218 feet, confirmed the thickness of Sandstone C, the depth of the freshwater-saltwater interface, and showed that pressure heads increase with increasing depth. Groundwater in this zone, starting at a depth of 190 feet, shows very high salinity (>11,000 mg/L TDS). Groundwater in this zone contributes to the poor quality of the Cimarrron River.

Finally, in late 1997, three shallow wells were installed in the river alluvium next to the Cimarron River. These Wells #1342, #1343, and #1344 were installed to a depth of approximately 25 feet. Data from a separate boring was used to locate the depth of the alluvium deposits.

A review of the potentiometric surface drawings (i.e., Drawing Nos. SWPS-0 and DWPS-0) for the shallow and deep groundwater zones demonstrates the direction of groundwater flow. Based upon the numerous wells installed at the Cimarron site, shallow groundwater was verified to move downgradient in a northerly direction and discharge to the surface as seeps or in the subsurface to the Cimarron River alluvium. Monitoring wells located downgradient from all former waste management

areas are monitoring any shallow groundwater zones that may have been impacted by prior site operations. This system is adequate for continued tracking of the overall progress of site decommissioning and evaluation of residual remaining impacts.

As discussed in Section 3.4.2.2 and 3.4.2.3, environmental monitoring data verifies that groundwater within the deeper sandstone (Sandstone C) has not been impacted by prior site operations. Continued monitoring of this zone is not necessary.

3.5 Groundwater Quantity

At the site, three major sandstone units and two mudstone units have been identified in borings drilled at the site. These sandstones have different hydrologic properties, including the thickness of the saturated material penetrated (see Drawing No. 98-XSEC-1 for illustration).

As discussed in Section 2.0, the mudstones generally are massive, with some zones of thin laminations in the upper portions. The mudstones are less permeable than the sandstones, retard the vertical movement of groundwater, and promote lateral movement toward the sandstone outcrops in the bluffs north of the site (Sandstones A and B), and towards the alluvium of the Cimarron River (Sandstones B and C). The location and thickness of these mudstones have been confirmed by several investigations completed on site.

All three sandstones encountered during the numerous site investigations can be described as generally fine-to very-fine grained with well sorted subangular to rounded grains. Variable silt content was observed in the sandstones. The estimated silt content ranges from less than 10 to up to 50 percent. The sandstones are poorly to well cemented. The primary porosity restrictions are the variable amounts of fines present in the

sandstones. Inspections of outcrops at the site and core samples revealed minimal jointing indicating that the effect of fractures on hydraulic conductivities is expected to be low.

Water generally moves very slowly through fine-grained rocks such as siltstone and mudstone because the openings between the particles are too small to transmit water freely; thus, yields of wells penetrating these lithologic units are small. The substantial silt in the shallow sandstones on-site are reflected by the low transmissivities and low yields measured in the on-site wells.

Sandstone layers in the Garber-Wellington Aquifer to the east and south of the site are fine-to medium-grained, and wells completed in this formation produce greater amounts of water.

3.5.1 Potential Groundwater Withdrawal Rate from Wells On Site

A 24-hour pumping test was performed at the site in 1996 on Well #1325. This well is an upgradient, Sandstone A well. Pre-test analysis of available hydrogeologic data (e.g., hydraulic conductivity, saturated thickness, and lithology) was used to estimate a maximum sustainable pumping rate that could be maintained during the test. Well #1325 was selected for the test because it was expected to be able to sustain a test of 24-hour duration. The predicted pumping rate was on the order of one to two gpm. A Theis analysis (Grant, 1996) predicted a drawdown of about 6.3 feet within 24-hours.

The field results matched postulated results. A sustained pumping rate of 1.2 gpm yielded 6.5 feet of drawdown during the 24-hour test. The data were analyzed using the Jacobs straight-line approximation to the Theis solution. The recovery data from the test also were analyzed using the

Theis recovery solution. These analyses yield similar results, with transmissivity values of about 42 ft^2/day.

A reduction in transmissivity was observed in the data after 480 minutes of recovery, and yielded a transmissivity value of about 28 ft^2/day. This reduction in transmissivity is believed to be a result of the lenticular structure in the Garber Sandstone. This suggests that long-term sustainable pumping rates would be less than the 1.2 gpm rate used in the pumping test.

Two additional wells (Wells # 1338 and #1341), which were completed in Sandstone B, indicated from their development that this sandstone also yields relatively little groundwater. Both wells were pumped in an attempt to establish a sustained pumping rate. Well #1338 yielded a rate of approximately 1 gpm, whereas Well #1341 yielded a slightly higher rate of 2-3 gpm. These rates indicate a low transmissivity formation that would probably yield very little water under long-term sustained pumping.

The bluffs overlooking the Cimarron River represents a large discharge zone that continually drains Sandstones A and B. The upper sandstones are no longer saturated as they approach the bluffs. Any water supply wells located in these areas would experience a declining water level because they would be pumping from an already partially dewatered zone.

3.6 Alternate Source of Water

Cimarron believes that an individual (intruder or even a potential resident) would not likely incur the cost to drill a shallow well (or multiple wells) and install a treatment system (to reduce hardness) when there are numerous alternate sources of better quality water and greater volumes readily available. Alternate sources are (1) the established rural water system that presently supplies water to the site and (2) the two large unaffected

reservoirs located on site. The unaffected reservoirs are recharged from shallow groundwater which is upgradient from impacted areas on site. The two reservoirs (Reservoirs #2 and #3) were originally constructed as sources of process/drinking water during site operations in lieu of groundwater which did not provide an adequate supply. The reservoirs were used as the site water supply until the rural water system became available. Of further importance is the belief on Kerr-McGee's part that the governmental system and its associated infrastructure will not fail for any foreseeable future.

3.7 References

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4.0 HISTORY OF REMEDIAL ACTIONS/CLOSURES FOR BURIAL AREAS #1 AND #2, AND WASTE PONDS #1 AND #2

These areas are discussed below in detail due to the fact that groundwater in these distinct areas has been impacted from previous site operations.

4.1 Burial Area #1

Burial Area #1 was constructed in 1965 and was opened in 1966 for disposal of radioactive material in accordance with 10 CFR 20.302. Radioactive waste material buried in this area included drummed thorium contaminated waste from the Kerr-McGee Cushing, Oklahoma Facility in addition to materials from the Cimarron facility operations. Burial Area #1 was closed and capped in 1970. The site burial records reveal that approximately 1,303 kg of depleted uranium, 148 kg of enriched uranium, and 5,555 kg of natural thorium were buried in Burial Area #1 (Cimarron Corporation, October, 1994). Due to soil settling over the Burial Area #1 trenches, an investigation was initiated in 1984 to establish an appropriate remedial action.

In February of 1985, several monitoring wells were installed in the vicinity of Burial Area #1 (i.e. Monitoring Wells #1314 through #1317). In May of 1985, a number of soil samples from nine boreholes around the perimeter of this area were obtained to a maximum depth of twelve feet. In 1986, a borehole gamma scan was completed on the four trenches contained within Burial Area #1 and the immediate area surrounding Burial Area #1. Based upon the sample/survey data and the continued slumping within Burial Area #1, the decision was made to excavate Burial Area #1 and ship the materials to an off-site low-level radioactive waste disposal facility.

From 1986 through 1988, the Burial Area #1 trenches were excavated and all excavated waste was packaged and shipped off-site to a commercial low-level radioactive waste disposal facility. Waste shipment records indicated that approximately 65,000 ft^3 of drummed waste was shipped off-site. Approximately 16,000 ft^3 of contaminated soil (Option #2 concentrations) was also removed and stockpiled in the East U-Yard Area. These contaminated soils were subsequently placed in the NRC approved on-site BTP Option #2 Disposal Cell (ORISE, November 1, 1994).

ORAU performed interim confirmatory surveying and sampling of remediated Burial Area #1 in August of 1988 and highlighted eight (8) locations that required further remediation (ORISE, January 31, 1989). Cimarron Corporation performed additional remediation in these locations. After this additional excavation of Burial Area #1, soil samples were taken from 0 to 4 feet below the excavated depth of Burial Area #1 on a 10-meter by 10-meter grid. This grid sampling/surveying revealed several areas requiring further remediation. An additional 14,000 ft^3 of contaminated soil (Option #2 concentrations) was removed and added to the previously stockpiled contaminated soil (i.e. 16,000 ft^3) located in the East U-Yard Area. After this remediation was completed, additional soil samples were taken from 0 to 4 feet below the re-excavated depth of Burial Area #1 on a 10-meter by 10-meter grid. These sample results confirmed that Burial Area #1 had been remediated and that any remaining contaminated soils met the BTP Option #1 criteria.

ORAU again performed confirmatory surveying and sampling for Burial Area #1 in December of 1991 and confirmed that Burial Area #1 had been remediated in accordance with the BTP Option #1 criteria (ORISE, January 7, 1991 and ORISE, November 18, 1991). The ORAU Final Report for Burial Area #1 was issued in July of 1992 (ORISE, July 22,

1992). Based upon the ORAU Final Report, the NRC released Burial Area #1 for backfilling with clean soil via License Amendment #9 to SNM-928 (December 28, 1992).

During the period March through July 1993, clean soil was transported and placed in the excavated Burial Area #1. Final grading of Burial Area #1 was completed in July of 1993. Random surface soil sampling of the final graded surface was completed in August of 1993. Detailed information regarding the remediation and closure of Burial Area #1 can be found in Section 7.0 of the Cimarron Radiological Characterization Report (Cimarron Corporation, October, 1994).

4.2 Burial Area #2

Burial Area #2 was utilized in the early 1970's for the disposal of on-site generated industrial solid waste from Cimarron site activities. During an investigation of this area in 1990, there were indications that radioactive waste materials were present in the waste materials in Burial Area #2. Remediation of Burial Area #2 was initiated in 1991.

Remediation and characterization efforts for Burial Area #2 resulted in the identification and excavation of all BTP Option #2 and Option #4 soils from Burial Area #2. Excavated Option #2 soils were stockpiled and sampled in accordance with the NRC approved in-situ sampling protocol prior to being placed in the on-site BTP Option #2 Disposal Cell. All Option #4 soils were packaged and shipped off-site for disposal to a commercial low-level radioactive waste disposal facility. Industrial waste removed from Burial Area #2 was also packaged and shipped off-site for disposal to a commercial low-level radioactive waste disposal facility. Soils from unaffected areas were utilized to backfill the excavations and were also sampled and analyzed. Additional information regarding Burial Area #2 can be found in Section 8.0 of the Cimarron Characterization

Report (Cimarron Corporation, October, 1994) and in the FSSR for Sub-Area "L" - Subsurface (Cimarron Corporation, May, 1996).

Soil samples were collected in May of 1990 on a 10-meter by 10-meter grid at depths from 0 to 4 feet, in one-foot intervals. Additional soil sampling was performed in 1991, 1994 and 1995 to increase the frequency of sampling to correspond to a 5-meter by 5-meter grid. In addition, samples were also obtained in some areas to depths of up to 6 feet, in one-foot increments, and composited.

Approximately 20,000 cubic feet of Option #4 waste, with an average activity of 300 pCi/g uranium, was excavated and shipped off-site for disposal to a commercial low-level radioactive waste disposal facility. Burial Area #2 was remediated such that all remaining soils were at or below the BTP Option #1 criteria.

The NRC Staff supervised a confirmatory sub-surface sampling effort for Burial Area #2 on October 30, 1996. Based upon the results of this confirmatory sampling effort, the NRC staff approved of backfilling Burial Area #2. During the period January 7-14, 1997, Burial Area #2 was backfilled with clean soil and final grading was completed. Burial Area #2 was remediated such that all remaining soils were at or below the BTP Option #1 criteria.

4.3 Uranium Waste Pond #1

Uranium Waste Pond #1 was built in September of 1970 and was an asphalt pitch, felt-paper and pea-gravel-lined evaporation pond that was rectangular in shape. Axis measurements along the centerline to the top of the dike were approximately 300 feet by 110 feet. The bottom area was approximately 23,000 ft^3 in size and the capacity was approximately