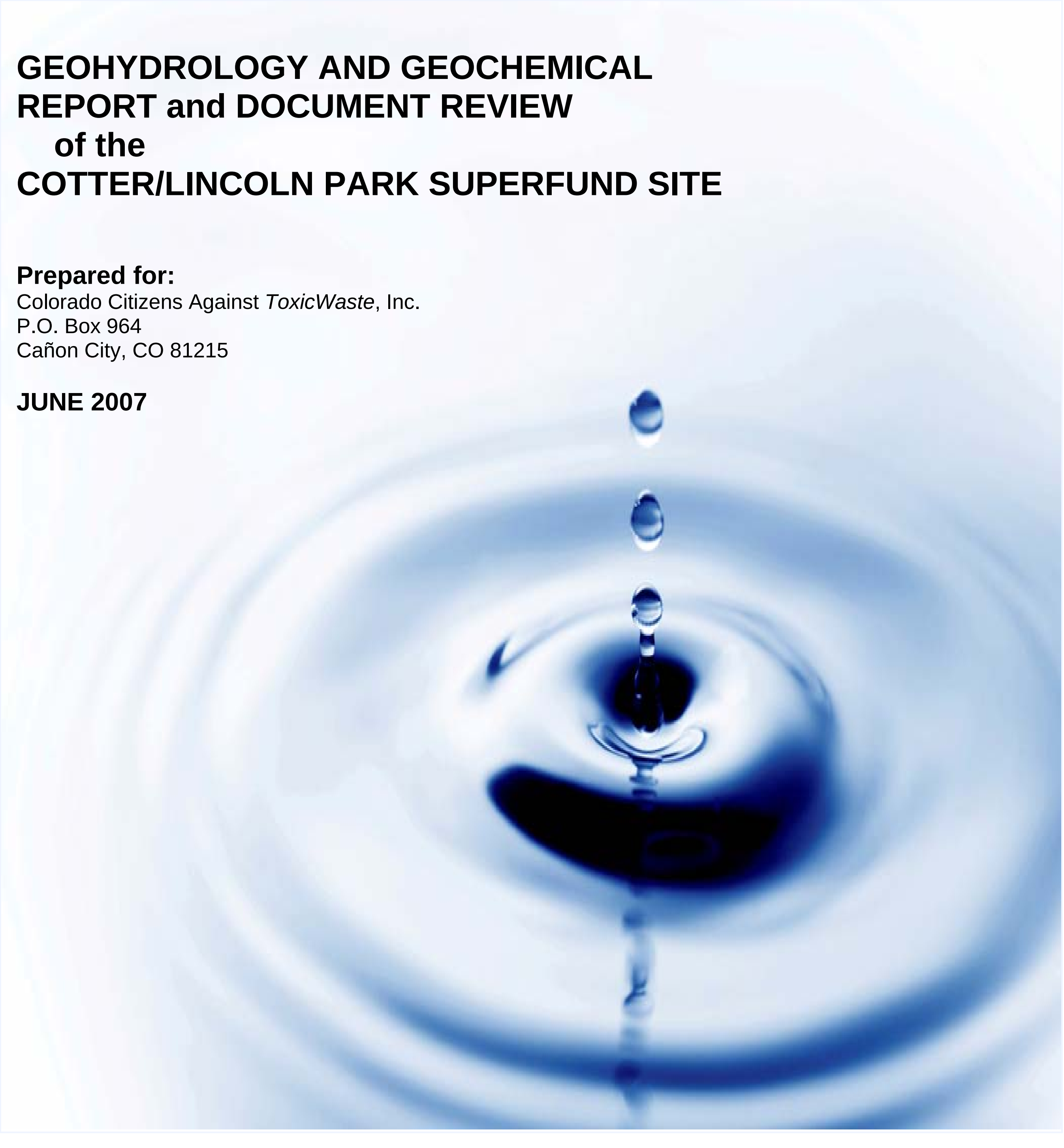
Charles G. Patterson, Ph.D.

P.O. Box 3007
Eldorado Springs, CO 80025



GEOHYDROLOGY AND GEOCHEMICAL REPORT and DOCUMENT REVIEW of the COTTER/LINCOLN PARK SUPERFUND SITE

Prepared for:
Colorado Citizens Against *ToxicWaste*, Inc.
P.O. Box 964
Cañon City, CO 81215

JUNE 2007

Technical Assistance Grants (TAGs)

A Technical Assistance Grant (TAG) provides money for activities that help your community participate in decision making at eligible Superfund sites. An initial grant up to $50,000 is available to qualified community groups so they can contract with independent technical advisors to interpret and help the community understand technical information about their site.

Congress made public involvement in decision making an important part of the Superfund process when the program was established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. Congress wanted to ensure that the people whose lives were affected by abandoned hazardous wastes would have a say in actions to clean them up. The role of community members in the Superfund process was further strengthened in the Superfund Amendments and Reauthorization Act of 1986 (SARA). With SARA, Congress created EPA's TAG Program. TAGs are available at Superfund sites that are on the EPA's National Priorities List (NPL) or proposed for listing on the NPL, and for which a response action has begun. EPA's NPL is a list of the most hazardous waste sites nationwide. Since the first TAG was awarded in 1988, more than $20 million has been awarded directly to community groups.

For more information, visit EPA’s TAG website:

http://www.epa.gov/superfund/community/tag/

GEOHYDROLOGY AND GEOCHEMICAL REPORT and DOCUMENT REVIEW of the COTTER/LINCOLN PARK SUPERFUND SITE

Prepared for:
Colorado Citizens Against *ToxicWaste*, Inc.
P.O. Box 964
Canon City, CO 81215

By:
Charles G. Patterson, Ph.D.
P.O. Box 3007
Eldorado Springs, CO 80025

Under a Technical Assistance Grant from the
U.S. Environmental Protection Agency

June 30, 2007

DISCLAIMER: The writer of this report certifies he has used good faith scientific judgment in its preparation. Following EPA TAG guidelines, the contents were not produced with the intention to be used in, nor to support, litigation. Conclusions drawn in this review were limited by the availability of documents as well as the complexity and obscurity of documents obtained. Therefore, conclusions drawn are informed opinion based on available information.

A complete copy of this report is available at:
Royal Gorge Regional Museum and History Center
Canon City, Colorado

INTRODUCTION

The following are my findings from over three years of work reviewing documents, attending meetings, and interviewing individuals concerning the Cotter/Lincoln Park Superfund Site in Fremont County, Colorado. The work was funded by an EPA Technical Assistance Grant (TAG) obtained by Colorado Citizens Against ToxicWaste, Inc. (CCAT).

The report includes a site history, site characteristics, hydrology, my findings and recommendations, general comments, and conclusions. Appendix A contains selected document reviews. Appendix B contains special studies and answers to community questions (e.g. use of tracers in the impoundment liner leakage investigation, uranium uptake in vegetables, and my Remedial Action Plan comments on proposed changes). I might note that I received no response to my comments on the Remedial Action Plan submitted to CDPHE in 2005. Appendix C is an unpublished newsletter article written for CCAT, and Appendix D is comprised of spreadsheets checking the accuracy of Cotter’s water quality data provided in CY2004 and CY2005 annual environmental reports. Appendix E is my Curriculum Vitae.

My TAG contract asked me to apply my knowledge of hydrogeology, geology and geochemistry to review and analyze existing documents pertaining to stratigraphy, structural features, contaminant pathways, seismology, coal mines under the mill site, the impoundment ponds, water quality, contamination content and migration, water levels, surface and groundwater discharge into the Superfund Site, groundwater well monitoring plans, and remedial actions. Based upon my review, I was asked to identify any outstanding concerns about the site that have not been addressed.

Although the site is regulated under the federal Comprehensive Environmental Recovery, Compensation, and Liability Act of 1980 (CERCLA, otherwise known as "Superfund"), it is supervised by the Colorado Department of Public Health and Environment (CDPHE).

As seen in the Site History section, remediation on the site has been going on for over three decades, with much left to do in the future. An immense, confusing, and often contradictory body of documents and data has been produced over that time. The site is very complex. Much of the data has been presented in ways that make retrieval difficult. Often I would have to go from one many-hundred page document to another in order to put together information I was trying to assemble. Graphs, charts, maps, and diagrams often have important information omitted. Many hours of work time were consumed in searching for illusive pieces of information or data, often to only find that they didn't exist anywhere.

After completion of my contract, using the funds allocated by the grant, I find there is much more that should be done in reviewing this site, both historically and currently.

TABLE OF CONTENTS

Section **Page**

APPENDIX A – Document reviews
APPENDIX B – Special studies providing answers to community questions
APPENDIX C – CCAT newsletter (previously unpublished)
APPENDIX D – Accuracy check of Cotter water quality data
APPENDIX E – C.G. Patterson, Ph.D. – Curriculum Vitae

LIST OF FIGURES

LIST OF FIGURES (cont.)

LIST OF ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
CDPHE	Colorado Department of Public Health and Environment
CDH	Colorado Department of Health (previous name)
CERCLA	Comprehensive Environmental Recovery, Compensation, and Liability Act
CGS	Colorado Geological Survey
DO	Dissolved Oxygen
EC	Electrical Conductivity
DWD	DeWeese-Dye Ditch
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
MCL	Maximum Contaminant Level
mg/l	Milligram per liter (ppm or parts per million)
NEPA	National Environmental Protection Act
NRC	Nuclear Regulatory Commission
OPA	Old Pond Area
OU1	Operational Unit One (Superfund unit – Cotter facility)
OU2	Operational Unit Two (Superfund unit – Lincoln Park area)
PFC	Perfluorocarbons
pH	A measure of acidity or alkalinity
PRB	Permeable Reactive Barrier
PRTW	Permeable Reactive Treatment Wall
RAP	Remedial Action Plan (Clean up plan for Superfund Site)
RI	Remedial Investigation (1986)
ROD	Record of Decision (USEPA decision document 2002)
SCS	Soil Conservation Service (dams)
TAG	Technical Assistance Grant
TDS	Total Dissolved Solids
ug/l	Microgram per liter (ppb or parts per billion)
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WQD	Water Quality Division (CDPHE)
ZVI	Zero-valent Iron

LIST OF ACRONYMS AND ABBREVIATIONS (cont.)

Al	Aluminum
As	Arsenic
Ca	Calcium
Cd	Cadmium
Cl	Chlorine
Co	Cobalt
Cr	Chromium
Cu	Copper
F	Fluorine
Fe	Iron
FM	Formation
Hg	Mercury
K	Potassium
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
Na	Sodium
Pb	Lead
Ra	Radium
Rn	Radon
Se	Selenium
SO_4	Sulfite
Th	Thorium
U	Uranium
U308	Yellowcake
V	Vanadium
W	Tungsten
Zn	Zinc

1.0 SITE HISTORY

The site history is somewhat self-explanatory in the Chronology that follows. However, a good description is found on the CDPHE Cotter Corporation Uranium Mill web page, which states, "The Cotter/Lincoln Park site consists of a uranium processing mill located adjacent to the unincorporated community of Lincoln Park, and is approximately 1 ½ miles south of Cañon City. The entire site is within Fremont County. The mill operated continuously from 1958 until 1979, and intermittently since that time. Operations are regulated primarily by a Colorado Radioactive Materials License. Mill operations have released radioactive materials and metals into the environment. These releases contaminated soil and groundwater around the mill and the Lincoln Park area."

I would add that the Canon City limits and hundreds of new homes now border Cotter's property on the west, and the Lincoln Park community of approximately 4,000 residents borders Cotter on the north. Lincoln Park's southern boundary is less than a mile from the tailings impoundments and mill. A satellite image of the Cotter, Lincoln Park and Canon City area from Google Maps is provided (Fig. 1a), as well as a 1998 oblique air photo of the impoundment ponds and mill from the CDPHE Cotter website (Fig. 1b). A street map of the mill and community is also provided (Fig. 1c), and an undated CDPHE map drawing of the Superfund Site Operational Unit 1 (OU1-Cotter) and Operational Unit 2 (OU2-Lincoln Park), showing soil and water contamination plumes (Fig. 1d).

The CDPHE description also states, "The Cotter/Lincoln Park Site was added to the U.S. Environmental Protection Agency's (EPA) National Priorities List in 1984 (making it a Superfund site). EPA divided the site into two 'operable units,' one being the sources of contamination on the mill site, such as the old ponds area and the other being the Lincoln Park neighborhood (off-site impacts)."

The mill resumed operations in 1999 after being dormant and on standby since around 1985. Cotter again ceased operations and went on Stand Down in Spring of 2006. The community has been told that operations will not resume until State required refurbishments of the mill are completed and a Readiness Review is approved by CDPHE. To the best of my knowledge, the following is a chronology of significant events at this site.

1.1. Chronology:

1908-1950's: Coal mined extensively in area. Approximately 50% of Cotter site is underlain by coal mine workings.

1958: The Cotter mill was constructed (in just 63 days) and began operations refining U ore from western slope and other mines producing "yellowcake" (U_30_8).

1958-1979: Mill wastes, both liquid (raffinate) and solid mill tailings were deposited in a series of unlined ponds (referred to as "old tailings ponds") adjacent to the mill site. Ponds #2, 3, and 10 were lined.

1965: Heavy rainstorm caused tailings to flood down Pine Street and into Lincoln Park.

1968: Contamination from seepage from these ponds was detected in wells in Lincoln Park. U and Mo were designated as contaminants of interest.

~ Bosco cows show symptoms of poisoning. Bosco house and field wells show high concentration of Mo and Se.

~ Colorado becomes “Agreement State”, assuming responsibility for regulating nuclear facilities from the AEC.

1971: CDH requests Cotter make changes in handling of liquid wastes including construction of lined impoundments, to be completed by 1972.

~ Construction of east SCS dam and west SCS dam for flood control.

1975: One lined impoundment completed (pond #2).

~ Wells in Lincoln Park show excessive levels of alpha and beta radiation.

1978: Wolf Park Mine (Littel) shaft plugged.

1979: New mill constructed. Two lined tailings impoundments completed. Design operating life: 20 years. Rips and tears in the liner fabric were documented during construction, as were several ground water springs that were covered over by the impoundment.

~ Gravel-lined trenches constructed upgradient of SCS dam to intercept ground water from Old Pond Area.

1980: CBI issues report accusing Cotter of shoddy safety record and falsification of records.

~ Transfer of 2.5 million cubic yards of old tailings to a 50 acre segregated area of the lined impoundment called the "secondary impoundment".

1983: CDPHE and Colorado Attorney General files $50 million lawsuit against Cotter for damaging natural resources under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA, otherwise known as "Superfund").

~ Cotter pays $11 million in out of court settlement.

1984: Lincoln Park placed on National Priorities List (NPL) and named a Superfund Site as required by CERCLA.

1986: Remedial Investigation/Feasibility Study presented outlining causes and areas of contamination, with recommendations for monitoring and remediation. In the RI, several lines of evidence are presented that the lined impoundments are leaking.

~ Cotter Mill put on "Standby" status due to declining production after peaking in 1981.

1987: USGS report on water quality in the plant site area and Lincoln Park (Hearne and Litke USGSWRI 87-4014). The report contains some original data as well as a compilation of some previous analyses.

1988: Cotter and the State of Colorado reach settlement that Cotter is responsible for cleanup at the site.

~ Low-permeability SCS Hydrologic Barrier constructed just upstream of SCS dam and pump-back system installed to intercept ground water flow from Sand Creek gap.

~ Contaminated soils (unspecified amount) were removed from the OPA and relocated to the lined secondary impoundment.

~ Water distribution pond built November 1988, providing surge capacity for pump back water from the SCS hydrologic barrier, withdrawal wells, and/or flushing extraction wells prior to distribution to mill process, main impoundment, secondary impoundment, etc.

1989: Injection and withdrawal system below berm and 9/16 hydraulic barrier constructed. Both systems designed to restrict raffinate migration downgradient of Cotter mill site.

~ Compliance Wells 019 and 020 constructed and first sampled.

1990: Well 018 constructed to investigate the Wolf Park mine shaft as contaminant pathway. Sampling was discontinued sometime around 2000.

~ SCS Dam to DeWeese-Dye Ditch flushing began in 1990 and stopped in 1996, due to citizen concerns.

1991: Pilot test areas constructed in old tailings pond area for evaluating methods of remediation of soil and ground water contamination. These consisted of injection and withdrawal wells, and collection trenches.

~ First Cancer Study for the area was released covering 1979-87. Data was used from the Colorado Central Cancer Registry which began in 1979. Relocated residents weren't tracked.

~ First Health Risk Assessment submitted by Cotter, rejected by State in 1992, and Cotter required to submit a supplemental assessment using EPA methodologies.

1992-1994: Soil characterization of U and Mo was performed.

~ Clean up of 4th Street Bridge railroad site completed in 1994

1993: Second Cancer study released covering 1979-90; again, relocated residents not tracked.

1997: Flush/Fixation used in Old Tailing Ponds Area to minimize a source of ground water impact from contamination. Canon City water and a chemical (calcium polysufide) were used, but by 1999, the method was found ineffective.

1998: Supplemental Health Risk Assessment submitted, finding that contaminated ground water can pose a health risk.

~ Third Cancer study released covering 1979-95; relocated resident not tracked.

1999: 100,000 cubic yards of contaminated soil removed and placed in primary lined impoundment cell.

~ Facility approved to begin operations again with new Alkaline Leaching after being on standby since 1986.

~ The *Lincoln Park Superfund Site Ecological Risk Assessment* (Stoller & Schaefer, 1998) was released indicating low risk to animals and plants.

2000: A Permeable Reactive Barrier (PRB), also called Permeable Reactive Treatment Wall (PRTW) was constructed somewhere in the vicinity of the SCS dam. No site map is included in the final report. The PRB began to fail after only a few months as Mo concentrations in ground water rose ultimately to levels greater than incoming ground water, apparently as the PRB began releasing Mo that had been previously sequestered. Mounding of ground water upstream of the PRB occurred as it became impermeable due to precipitation of carbonate and sulfate salts in the zero-valent iron barrier (ZVI).

~ Cotter Uranium Mill purchased by General Atomics to become an Affiliate.

~ Completion of 20 acres of evaporation ponds in the west and south areas of the primary impoundment.

2002: Cotter applies for authorization to import approximately 450,000 tons of radioactive waste clean up from a Superfund Site in Maywood, New Jersey, for direct disposal in the impoundments, which was subsequently denied.

~ Record of Decision (ROD) signed by USEPA determining no further action needed for soil remediation in the Lincoln Park (OU2) portion of the Superfund Site. The Cotter Mill portion (OU1) is not the subject of this ROD. The ground-water portion of Lincoln Park will be addressed at a later date.

2005: Geophysical study commissioned by Cotter to investigate seepage from lined impoundments. Survey found high conductivity areas near impoundment indicating possible leakage to me, but the authors suggested that an alternative interpretation are possible which indicates no significant leakage.

~ A feasibility study for the clean up of the Old Tailings Pond Area, *Alternatives Assessment, Old Ponds Area* (EMSI, 2004) was submitted for Cotter. CDPHE approved the alternative of “selective excavation with on-site disposal” in May 2006. The project had not begun as of this writing in 2007.

2006: Facility goes on stand down. Extensive renovation of the mill facility and a *Readiness Review* will be required by CDPHE before resuming operations.

~ Impoundment pond leakage investigation initiated. By early summer 2007, CDPHE determined there is leakage from the impoundment.

2.0 SITE CHARACTERISTICS

2.1 GEOGRAPHY: The Cotter site occupies a small basin defined by hogback ridges, in close proximity to agricultural areas and urban development. The site sits at an elevation of about 5600 ft, about 3 miles to the southwest and 300 feet above the Arkansas River. The climate is semi-arid with 12.7 inches of precipitation per year on average; the dominant wind directions are from due west and southeast. Extreme fluctuations of temperature and precipitation occur throughout the year with occasional violent weather.

2.2 GEOLOGY: The geology of the site consists of sedimentary rocks of Cretaceous and Tertiary age that have been folded into a NW-SE trending synclinal (trough like, like a taco shell) structure known as the Chandler Syncline (Scott, 1977).

2.2.1 Stratigraphic (sedimentary rock) units of interest in the study area (Fig. 2c):

Alluvium	(0-60 feet thick). These surface deposits covering the bedrock are all sand and gravel deposited by modern and ancient streams during the Holocene and Pleistocene Epochs (1.6 million years before present). They are unconsolidated with quite high hydraulic conductivity allowing rapid ground water flow. Most ground water flow from the site and in Lincoln Park is through the alluvium layer and the fractured and weathered surface zone of the bedrock immediately below.
Poison Canyon Fm	(0-1,000 feet thick). Consists of claystone, siltstone, and sandstone of Paleocene Age (65 million to 55 million years ago). The Poison Canyon Fm has low hydraulic conductivity except for the fractured and weathered zone at top. (Note, the formation name is from type locality, where formation is described, and it makes no reference to chemical qualities, i.e. it is not poisonous)
Raton Formation	(0-500 feet thick). The Raton is a medium to coarse-grained sandstone of late Cretaceous to early Tertiary age (90-55 million years ago). It is fairly hard and forms a hogback ridge at the surface that encircles the plant site. It has low permeability, and will retard the flow of groundwater.
.	
Vermejo Formation	(0-1,100 feet thick). The Vermejo consists of interbedded shales and sandstones of Cretaceous age (approx. 100 million yrs.) containing many coal seams. Mining has resulted in many water-filled voids. The hydraulic conductivity of the Vermejo is quite variable between the different lithologies and ranges from impermeable (low hydraulic conductivity) to permeable, especially in the fractured coal seams. Because impermeable beds sandwich permeable beds, ground water flow is impeded across the beds, unless penetrated by a mineshaft, but the coal seams may be fairly permeable and allow fairly rapid flow.
Trinidad Formation	(0-90 feet thick). The Trinidad is a fine to medium grained-sandstone of Cretaceous age, and it is probably low in permeability.
Pierre Shale	(3900 feet thick). This thick unit of Cretaceous shale, mudstones, siltstones, and thin sandstones is quite impermeable and underlies more permeable rocks of the Chandler Syncline. Vast areas of Pierre Shale are found East of Canon City and geologically would be a fine bedrock site to house a uranium mill in that the rock is quite impermeable and the clay content binds and sequesters metals.

2.3 STRUCTURAL GEOLOGY: The beds fold down intro a trough, which puts the coal measures of the Vermejo Fm up to 1000+ feet below the surface just below the Cotter site, although they emerge at the surface in the Lincoln Park area. The Poison Canyon Fm is at the surface in the Cotter basin, covered by a thin veneer of alluvium (Fig. 2c, 2eii).

These rocks are folded upward into a structure known as the Chandler Syncline, which forms a northwest trending structural basin bounded topographically by the Raton Sandstone ridge. The Raton Fm is more resistant to erosion than the surrounding units, and erodes to make a "hogback" ridge.

The whole structure rather resembles a double layer taco, with the Raton Fm as the corn tortilla, the Poison Canyon as the ground beef filling in the very center, the Vermejo Formation as the bean layer, and the Trinidad sandstone as the outer flour tortilla.

The syncline is steeper on the SW, and gentler on the NE. The bedrock immediately below the plant consists of the Poison Canyon Fm overlain by up to 40 feet of alluvium along the Sand Creek and two other drainages. Below that is the Raton Sandstone, the coal-bearing Vermejo Fm, the Trinidad Fm, and the Pierre Shale. Coal has been mined from the late 1800's to the 1950's in extensive workings, many of which underlie the plant site and are connected to the surface through several shafts.

The Poison Canyon and the Raton are pierced by several shafts up to over 1000 feet deep leading to coal seams in the Vermejo FM. These shafts are adjacent to the Cotter mill and ponds and have historically received some waste from the mill, either intentionally or unintentionally. Currently, the shafts have been back-filled, preventing further contamination but also denying easy access to sample the mine waters.

2.4 SITE HYDROLOGY: Sand Creek enters and exits the basin through water gaps in the hogback ridge formed by the eroded, upturned edges of the Raton Sandstone. Several other drainages head within the plant site area and exit through low gaps in the Raton ridge. These include, from NW to SE: Unnamed drainage which feeds SCS West dam, Sand Creek, Plum Creek, Spring Creek, Fawn Hollow, and Chandler Creek. The spring at the intersection of Hwy 115 and the Rockvale road is on a branch of Chandler Creek canyon.

Surface drainage on the plant site is mainly from the through-flowing Sand Creek drainage. This stream is perennial in the vicinity of the plant, but emerges at the surface in Lincoln Park as it is fed by ground water. The alluvium of Sand Creek carries the main flow through the plant site in the Chandler Syncline. Other ground water pathways have been proposed. Through the alluvium, there is a north pathway, which runs under the golf course, and a south path, which exits the syncline along a creek. An unknown, but possibly large percentage of the subsurface flow along these drainages is also through the fractured and weathered upper part of the Poison Canyon Fm. The exact orientation of these fractures has never been specified, although they could control, to a certain extent, subsurface migration pathways. The fractures most likely are oriented both NW-SE along the axis of the Chandler Syncline, and possibly a joint set orthogonal to that, at NE-SW, based on the stress field generated by the folding of the syncline.

The ground water table is, in general, about 35 ft +/- 5ft below the surface in the Quaternary alluvium, often depending on the season.

Hydraulic conductivity is generally low in the Poison Canyon Fm, but the top of the formation is heavily weathered and fractured. The fractures are documented by resistivity and air photo studies. They allow rapid and unfiltered ground water movement just below the alluvium layer. These fractures may be vertical or inclined to 45^0 and very likely trend NW-SE, just as the axis of the syncline, and NE-SW, at right angles to the syncline axis.

The Raton Fm is considered an aquitard, impeding ground water flow.

The Vermejo Fm is generally impermeable across the beds unless penetrated by old mine workings. It is more permeable in the sandstones and in some fractured coal beds.

Trinidad Sandstone is felt to have low permeability.

Pierre Shale consists of very impermeable clays that also have a high capacity to adsorb, or trap, heavy metal pollutants.

2.5 CONTAMINATION PATHWAYS AND COMPOSITION: Contamination has entered the ground water by leakage from old unlined waste ponds. There may be a smaller, but significant amount of leakage from the newer, lined tailings ponds. CDPHE recently required Cotter to investigate leakage and contaminant migration directly below the mill facility building complex and CCD tanks.

The contamination consists of "raffinate" fluids, or spent uranium (U) processing liquids and water that has been in contact with tailings. The U processing at Cotter is only 94% efficient, leaving 6% of the U in the ore in the tailings. In addition Mo, V, Al, Cd, Cr, Co, Fe, Mn, Hg, W, Zn, As, Cu, Pb, and Se are found in the raffinate-contaminated ground water.

Cotter has used both "acid" and "alkaline" leaching processes at the plant. These generate waste solutions and tailings with either a very low pH (acidic) or a very high pH (alkaline).

Contamination pathways consist of some known and some conjectural, suspected, but still unproven routes for contamination to leave the plant site. I feel it would be appropriate that CDPHE at least give some effort to researching these pathways, as the disproof of them is at least in part theoretical and conjectural.

2.5.1 Sand Creek Gap (the middle near-surface pathway): This is probably the major path and receives the most attention in the remediation. Ground water containing raffinate-derived components moves rapidly in the shallow, alluvial aquifer down the Sand Creek drainage to Sand Creek Gap, where it flows under the SCS dam, but is intercepted now by a barrier wall and pumped back to a surface pond. This has been the major source of pollution to the Lincoln Park neighborhood. Seasonal leakage from the DeWeese-Dye Ditch dilutes the contamination by up to 10 times, but also spreads the contamination into the ground water below Lincoln Park. Interestingly, contaminant levels are not dropping to background levels. Some wells show slightly increasing values, while others seem to be leveling to a value somewhat above the compliance goal.

2.5.2 The "Deep Path": Since the earliest reports, it has been considered likely that the Littel Shaft of the Wolf Park Mine (Fig. 2c), adjacent to the unlined ponds, allowed raffinates to migrate directly down to great depth, then travel up dip in the Vermejo FM to emerge under Lincoln Park. Nearly every investigator, including earlier USGS reports, has considered this to be a potential path. However, USGS studies in the late 1990's do not support this, but the reasoning is based on theoretical grounds and was not verified by testing or experiment. I still feel that the possibility exists. Cotter back-filled the Litell Shaft, but the monitoring well placed adjacent to continue sampling was a failure. Whatever the levels of contamination and its potential movement in the deep mines is now only a matter of conjecture.

The West and East near-surface pathways are minimized in the USGS reports, but irregularities in the outline of the pollution plumes in Lincoln Park, along with general hydrologic favorability and some suggestive sample analyses, still leave the possibility of these pathways contributing some contamination offsite (Fig. 3a, 3b).

A "back-of-the-envelope" calculation shows that the appearance of a spike in the U values near the mill could be seen several years later in a down-gradient well along the west pathway. Greens and fairway watering from the golf course, which lies astride the suspected west path, may obscure the potential contamination.

2.5.3 Nature of contamination and background values: As previously shown, raffinate-derived fluids contain a wide variety of heavy metals, as well as high levels of sulfate, chloride, bromide, magnesium, calcium, total dissolved solids (TDS, indicated by high electrical conductivity or EC), and low pH (acidic condition).

The search for indicators of raffinate has been unduly slow. Superficial similarities with waters derived from certain formations have obscured the origin of contaminated ground water. In the interim, U and Mo have been designated as the contaminants of concern. The pollution plume is defined by the compliance goal level for these contaminants as measured in monitoring wells.

This has been set by CDPHE as 35 micrograms per liter (35 ug/l), or 0.035 milligrams per liter (0.035 mg/l) for U, and 100 micrograms per liter (100 ug/l) or 0.100 milligrams per liter (0.100 mg/l) for Mo. It is felt by many US authorities, and in many foreign countries, that acceptable values for U in domestic water are set too high for public safety. Some (Finnish) authors suggest as low as 2 micrograms per liter (2 ug/l), a German medical team suggests 10 ug/l, and the World Health Organization recommends 15 ug/l, or less than 1/2 of the Maximum Contaminate Level (MCL) set by CDPHE. Canada's MCL is 20 ug/l, but they do not recommend domestic use of water above 10 ug/l for human consumption. The EPA set an MCL for U in drinking water at 30 ug/l, but only for cost reasons, and actually preferred a level of 20 ug/l. The State of California and the State of Vermont have set MCL levels for U at 20 ug/l, well below Colorado's MCL of 35 ug/l. [Micrograms per liter (ug/l) is equivalent to parts per billion (ppb), and is 1/1000 of a part per million (ppm) or milligrams per liter (mg/l). 35 ug/l of U equals 0.035 mg/l.]

In order to confirm contamination by raffinate, background levels (pre Cotter) for these components have been determined from local wells, but no water sampling data was available from the time period before plant operations (and contamination) began. Nowadays, an Environmental Impact Statement (EIS) would have to be done before any construction could occur. Many authors feel that so many local water sources are contaminated with raffinate that background levels of U and Mo are set too high in the Lincoln Park area.

2.6 MONITORING WELLS: Questions remain as to whether the monitoring well network is adequate to fully identify the extent of pollution and its sources. The sampling network of monitoring wells has been decreased drastically, citing redundancy and costs. An early well survey of the Lincoln Park area found approximately 100 private wells. Today approximately 22 private wells are monitored. Thus far, the CDPHE has not issued a definitive list of the wells that have been dropped from the sampling network or given reasons why each well was dropped. Some wells placed to monitor the leakage from the lined ponds are inadequate in number or incorrectly placed, in my opinion.

The plant itself lies in the recharge zone of the ground water aquifer and of Sand Creek. The lined impoundment ponds intersect the ground water table, which allows direct contact with between mill waste and raffinates and the ground water. Springs were encountered during construction of the new impoundment in 1978-79, and underdrains were then constructed to funnel this spring water away from the impoundment. At a minimum of any requirements for tailings ponds, the base and liner of the pond should be well above any possible intersection with ground water, which is not the case at this site.

2.7 SURFACE WATER CONSIDERATIONS: Flooding and erosion concerns arose after heavy rains in 2004 threatened the impoundment ponds with overtopping (Fig. 5b - photo). For comparison, a photo is provided of the impoundments in 1998 (Fig. 1b).

The drainage basin of Sand Creek above and including the Cotter site is about 9 square miles. A USGS Fremont County 1:50,000 map, Canon City 71/2 minute quadrangle map, is provided (Fig. 5a). If 12" of rain fell in a single storm (100-500 year storm) and if 50% were lost to evapotranspiration and infiltration, that would leave about 14 million cubic feet of water in the basin. The SCS dam would not be overtopped by such a flood, but the berms surrounding the lined impoundments would be threatened. The ponds appear nearly bank full in the photos from 2004. I do not recall the exact amount of precipitation from that storm, but I think it was around 5-6". Surely twice that amount in the same length of time would be more than the ponds could hold. The resultant spill would severely re-contaminate the soils and shallow ground water of the site.

The nature of precipitation in the summer season is of potentially violent and damaging storms that could drop several inches of water on the plant site in a matter of a few hours. The hypothetical 1000-year storm has not been estimated or addressed. As this site needs to remain safe for thousands of years without human assistance, the 1,000 year storm assessment should be done immediately before further wastes are stored at the mill site.

Flooding of the site and contamination of the Arkansas River by surface flow is a remote possibility, but should be modeled in an exhaustive investigation to show whether the site can sustain itself without human maintenance for thousands of years. It is much more likely that the impoundment walls could be overtopped, recontaminating the soil and groundwater.

3.0 FINDINGS AND RECOMMENDATIONS

3.1 THE "DEEP PATH": There still exists probable cause to continue to investigate the possibility of the "Deep Path." This "deep path" is a hypothetical, but long-suspected, hydrologic connection between coal beds in the Littel Shaft of the Wolf Park mine and the ground water of Lincoln Park. The shaft was located adjacent to the unlined ponds that received mill waste for many years. The shaft was subsequently plugged in 1978 to prevent further influx of contaminated surface water, but in such a way as to prevent further sampling. The mine tunnels received wastes from the plant via the Littel shaft (Fig. 2c), wastes which may still be en route to Lincoln Park.

A USGS map (Chafin and Banta, 1999) showing some monitoring wells, subsurface coal mine boundaries and possible migration paths of contamination is also provided (Fig. 1f). Stephens (1993) created an excellent Site Conceptual Model of a cross-section showing the coal bearing Vermejo Fm emerging at the surface in Lincoln Park where Wells 006 and 138 are located (Fig. 2eii). Lehman (1991) provides another cross-section showing the Wolf Park Coal Seam, of which I added the locations of Well 006 and 138 (Fig. 2g).

There are at least two lines of evidence supporting the possibility of a "Deep Path." **First**, test well sampling data provide compelling evidence. A test well of the USGS, Well LP85-1D, in Lincoln Park encountered artesian conditions from a coal seam in the Vermejo Fm (Fig. 2ei). This well was felt to have penetrated the same coal seam as is found in the bottom of Well C138 (now Well 138), which was the "discovery" well of the site, containing high levels of U and Mo (Hearne and Litke, 1987, p. 16). A herd of cattle was rendered ill by water from Well C138 (Runnels, et al, 1977). This coal seam is contacted by Well 006, which carries the highest values of Mo and U in Lincoln Park (Fig. 2e). Chafin and Banta (1999) show a map of the Geology of the study area that clearly shows the Vermejo Fm surfacing from east to west along the southern edge of Lincoln Park (Fig. 2a). I superimposed my estimate of the approximate location of the Wolf Park coal seam and Trinidad Sandstone outcrop/subcrop over that map (Fig. 2b) and over a map from Wahler, 1978, (Fig. 2f).

All of these wells exhibit high levels of U, Mo, and total dissolved solids (TDS). I will offer that at least a portion of this contamination may come from the coal seam, which has been purported to be the Wolf Park Seam by Hearne and Litke (1987) and Stephens (1993). Hearn and Litke suggested (1987, p. 70) that waters migrating through a deep path via the Vermejo Fm would probably reach wells such as 006, and others in that vicinity, very slowly, indicating a need for monitoring far into the future.

Waters characteristic of the Vermejo FM contain mainly sodium with varying proportions of bicarbonate and sulfate, depending on the path the water took and whether or not it encountered reducing conditions. It is noteworthy that the sodium bicarbonate waters related to the Vermejo FM have high U, and the sulfate waters have less U. Uranium travels as the bicarbonate complex in ground water. Vermejo waters may also have moderately high TDS.

In addition, High Fluoride (F) waters were found in Lincoln Park in Wells LP85-6D and LP85-4 (Fig. 2e). In the figure please notice that Well EPA 4 is in fact LP85-4, and that it and Well 006 penetrate the Vermejo Fm according to Stephens (1993). I locate these along the subcrop of the Vermejo Fm. This strongly indicates water from deeper aquifers is affecting Lincoln Park wells. The CDPHE and Cotter no longer report F, so I had to rely on historic data from USGS and others for this information. Fluoride might be a good fingerprint for the "deep path".

The **Second** line of evidence for a “deep path” is that waters observed in a spring on Chandler Creek (SE/4 sec 12 T19S R70W) appeared to have very high concentrations of iron, indicative of coalmine waters. These may flow from the Chandler airshaft. In 1987, Hearne and Litke did find these waters to be high in iron and bicarbonate, but low in U and sulfate, indicating loss of these components by reduction in anoxic zones in the mine. This spring should be sampled as it could indicate off-site transport of Vermejo Fm water through a "Deep Path.”

Water currently flows out of the Chandler airshaft, Well or location 153, which was tested frequently until 1988, and then once more in 1993, when it showed an increase in U and Mo, but hasn’t been sampled (Fig. 3g). It is anecdotally connected hydraulically with the underground workings and with the backfilled Wolf Park Littel Shaft adjacent to the mill. Other investigators, Hearn and Litke of USGS (1987, p.9) and GCA Corporation (1983, p. 5-5) have determined this mine connection (Fig. 2di and 2dii). Compare the boundaries of the coal mines as shown in Chafin and Banta of USGS, 1999 (Fig. 2d) with those of Hearne and Litke and GCA Corporation. Hearne and Litke and GCA show the Chandler mine connected to the Wolf Park mine, while Chafin and Banta later show them unconnected. Anecdotal reports from residents state that miners *could* walk from the Wolf Park to the Chandler mine, and possibly from the Wolf Park to the Rockvale #3 mine. Bob Shukle of CDH concluded the “deep path” was possible, and not improbable (Hart, 1981).

GCA Corporation (1983, p. 4-2) recommended, “…sampling existing wells penetrating the workings and coal seams; construction of other wells to sample other parts of the mines; and sampling discharge from abandoned adits and airshafts.” Geohydrology of the Cotter site was also investigated by L.A. Hershey of Canon City (1977). Hershey presents useful geologic data, maps, many well logs, and many cross-sections of the plant site showing wells. He discusses the coal mine situation and also proposed a "deep path." His ground water table contour map seems to show the "west path" and the "east path" fairly clearly, (Fig. 3di).

Finally, Shelton (1978), an engineering geologist for the Colorado Geological Survey, reviewed Wahler’s 1978 *Investigations Related to the Migration of Raffinates* and stated that Wahler made two conclusions: 1). That raffinate contamination has gotten offsite in ground water (no disagreement by Shelton); and 2). That the postulated deep(er) paths don't exist (disputed by Shelton based on a lack of supporting evidence). Shelton’s reasons for disputing this are that key Wells OW-2 and OW-3 are shown to exist, but no discussion of them is in the text. He goes on to state that these wells are critical because of their location and they at least theoretically sample multiple formations at depth. He also notes that the other OW wells are not sufficiently described to know what formations they sample or at what depth, and that the entire series of wells drilled by Hershey & Associates are not discussed, indicating a lack of evidence to omit the "deep path." ***[I thought these wells looked promising to detect deeper contamination]***. Shelton writes, "Although it is generally true that majority of contaminants will flow through the most permeable formation (generally the alluvial deposits), this does not eliminate the possibility of deeper seepage paths through the sandstones of the Poison Canyon, Raton, and Vermejo Fms." He also notes that Wells OW-2 and C12-18 are "absolutely essential" for long-term sampling of this aquifer, and that past values for these wells are not provided, nor are they planned to be used for future monitoring, and that these are serious omissions.

Recommendations: **1.)** Based on the above, I strongly recommend a renewed investigation of the "Deep Path." **2.)** CDPHE or an independent contractor should resume sampling water issuing from the Chandler airshaft. It may represent deep waters underneath the site and may give evidence of a deep path of contamination through the Vermejo Fm. **3.)** The spring by Hwy 115 and Rockvale Road (Fig. 2di) should be sampled as it may represent the Chandler airshaft waters as well, and visually appears to be contaminated as it is precipitating large amounts of iron oxide. **4.)** All wells contacting the Vermejo Fm should continue to be monitored, even if they reach compliance levels, because of the potential for a "deep migration path" that may be slowly making its way towards Lincoln Park. **5.)** I also recommend testing for F in these wells as a fingerprint for the "deep path."

3.2 COMPLIANCE WELLS: Two wells have been chosen in the Lincoln Park study area to determine if ground water has reached compliance with requirements in the Remedial Action Plan of 1988, and they are Wells 019 and 020. I question the use of Wells 019 and 020 as "compliance" wells. The implication is that when levels in these wells are lower than the MCL, the clean up goal has been achieved. This is hardly the case when adjacent wells are still in a much higher mg/l range for U and Mo. It merely points to the complexity in the subsurface aquifer and results from any well will be misleading unless placed in context.

Well 006, discussed earlier, was drilled according to RAP standards to replace Well 138. Well 006 has shown what appears to be increasing levels of U, after a decline in the early 90's. The graph for Mo in Well 006 is omitted in Cotter's CY2005 Environmental Report and ALARA Review (Cotter, 2006), but more recent monitoring data shows that Mo is also well above the MCL and does not appear to be decreasing in Well 006 (Fig. 3f).

Cotter, CDPHE and EPA repeatedly claim that ground water contamination (e.g. U and Mo) continues to decrease off-site in Lincoln Park. This statement is not fully defensible. Wells such as 006 continue to be high and don't appear to be decreasing in Mo and U. The nature of the word "decrease" must be clarified. The implication by Cotter is that the decrease is linear. This would be a straight-line decrease to some low end point at a definable moment. This is incorrect. In a case where there actually is a decrease, the curve must be described as exponential and asymptotic. Which means slowly (in fact more slowly as time goes on) decreasing to a steady-state level.

The steady-state end point may also represent a steady state release from previously contaminated soils and sediments or even slow arrival of U and Mo from deep paths through permeable coal layers in the Vermejo Fm. In either case, levels would take a tremendously long time to achieve background, or never reach it, if long-delayed contamination is surfacing.

Well 006 appears to be increasing in U (Figure 3f) to levels around 0.5 mg/l (500 ug/l). It appeared to be leveling off to a steady-state of around 9.0 mg/l of Mo (9000 ug/l) until sampling in 2006 had a high of between 13 and 14 mg/l of Mo (13,000-14,000 ug/l).

Recommendation: 1.) Well 006 should become a Compliance Well, because it has the highest concentrations of U and Mo in Lincoln Park and is increasing. **2.)** Well 006 should also become a pump back well due to high U and Mo concentrations.

3.3 GROUND WATER MONITORING PROGRAM:

The monitoring network is not sufficient to accurately map the boundaries of the Uranium and Molybdenum plumes. I feel background levels of contaminants in the area could have been set lower using a broader regional picture of natural water chemistry. Certainly, better tracers than simply using regulatory MCL's of U and Mo could be found to identify raffinate-affected water in Lincoln Park wells via plume maps. A USGS map of the groundwater study area boundary and monitoring well locations is provided (Fig. 1e).

Is there a decrease in water contamination? Both Cotter, CDPHE and EPA keep stating that ground water contamination (i.e. U and Mo) continues to decrease off-site in Lincoln Park. This statement is not fully defensible, as explained in the last section. Wells such as 006 and 138 continue to be high in Mo and U (Fig. 3f). The nature of the word "decrease" must be clarified. The implication by Cotter (2005) is that the decrease is linear. This would be a straight-line decrease to some low end point at a definable moment. This is incorrect.

In a case where there actually is a decrease, the curve must be described as exponential and asymptotic, which means slowly (in fact more slowly as time goes on) decreasing to a steady-state level. In order to check the accuracy of Cotter’s reported trends, the confidence level in the "fit" of their trend lines should always be presented. The steady-state end point may also represent a steady state release from previously contaminated soils and sediments or even slow arrival of U and Mo from deep paths through permeable coal layers in the Vermejo Fm. In either case, levels would take a tremendously long time to achieve background, or never reach it, if long-delayed contamination is surfacing.

Adequacy of monitoring well network: The integrity of the well sampling program depends on having an adequate number of wells to show the exact extent of contamination, and to intercept pollution from sources that may have not reached Lincoln Park due to long transit time. The elimination of a well from the sampling network may be acceptable if it can be clearly shown that the well is redundant to the sampling scheme. Affected homeowners are stakeholders in the elimination of wells and every effort should be made to explain and justify elimination of a well in order to alleviate concerns. However, elimination of a well cancels the ability to do comparison of long-term trends. Loss of data may be considerable.

Well 138: I am concerned that Well 138 was dropped from the sampling list, if only for symbolic reasons, as it was the well that first drew attention to contamination by raffinates from the unlined ponds. I feel it should have been retained. I recognize that it was a hand dug well and not specifically designed for sampling. In comparison, Well 122 is still monitored. While providing a useful data point, Well 122 is not nearly so contaminated as Well 138 and does not catch the eye in the same way with milligram levels of U and Mo.

Quantify ground water flow: Noted as early as Hart (1981, p. 4-9), the ground water flows in the shallow alluvium both above and below the SCS Dam have never been quantified. In order to calculate flow velocities, the hydraulic conductivity of the sediments must be measured, and the gradient, or slope of the ground water table must be calculated. Residents of Lincoln Park deserve the best scientific estimate regarding the movement of contaminants in order to evaluate remediation efforts, e.g. PRTW, Dam to Ditch flush, etc., and to estimate arrival of waters in the wells after specific events occur.

Moving Averages: I absolutely disagree with the practice of using "moving averages" to analyze U and Mo data from the "compliance wells" in Cotter's Annual Environmental and ALARA reports. This has a tendency to smooth out the high spikes and the low points which appear in these data. My sense is these mean either there's a lot of variability at this site, or the sampling and analytical methods are inferior, and this should not be obscured by using moving averages.

There is a huge variability in concentration that comes from seasonal irrigation in Lincoln Park. It is truly hard to draw a meaningful trend line through this data. Again, Cotter should always present the confidence level in the "fit" of their trend lines. This enables the reader to evaluate the quality of the trend. After all, if the DeWeese Dye Ditch lined their ditch, concentrations would swing way up in the seepage water. What would also become obvious is how much water Lincoln Park is losing because of the SCS dam and barrier. The water rights issue seems to need renewed investigation or review.

Concentration vs mass of U and Mo: I was dismayed to hear that CDPHE had instructed Cotter to stop reporting mass movement of U and Mo, and just use concentration values. I suggested to CDPHE that Cotter present the data for U and Mo as mass and as concentration. This seems the only way to eliminate the confusing effect of the dilution by the DeWeese Dye ditch. I was told that Cotter used to, but had stopped, and wasn't given a reason. It does serve to lower the "moving average" for concentration levels to below MCL's in some cases, which benefits the Cotter Corporation, giving a false perception of reality.

This also again points out the issue of the focus of this cleanup. Is it just driven by the MCL's for U and Mo, or is raffinate seepage to the ground water system the focus? Once U and Mo are diluted to the point of being non-detectable, the effect of the high TDS waters seeping from the ponds can still be measured.

Other important contaminants: Fluoride (F) characterizes some different water sources, especially the Vermejo Fm, and would be important in determining if these waters are affecting Lincoln Park wells. Unfortunately, F is not currently reported. I have asked the CDPHE for all the fluoride results they have, but have received no response. I have some numbers from the older literature, but even these have been omitted from the CDPHE graphing application website for this Superfund Site.

High F waters were also found in Lincoln Park in Wells LP85-6D and LP85-4. As mentioned before, I locate these along the subcrop of the Vermejo Fm, north of the mill site (Fig. 2b). This strongly indicates water from deeper aquifers is affecting Lincoln Park wells, and might be a good fingerprint for the "deep path". Fluoride is characteristic and obvious, and should be reported. This reduces my confidence in the geochemical reasoning being applied to the management of this site.

Piper Diagrams: In viewing the original literature on Piper diagrams, it is apparent that they were being used incorrectly for analysis in Cotter's CY2004 annual environmental report. Piper Diagrams are a trilinear method of plotting ground water proven useful in depicting water types and mixing between them, but much less so to show mixing of very ***different*** waters. Cations (positively charged dissolved constituents) are plotted on one triangular diagram, and anions (negatively charged dissolved constituents) are plotted on another. These can be combined on a diamond-shaped plot in a central field (Fig. 4a, 4ai). Hearn and Litke created Piper Diagrams for the Vermejo FM water (Fig. 4c), the Lincoln Park alluvium water (Fig. 4ci), and the major-ion composition of Poison Canyon Fm water (Fig. 4cii).

A feature of Piper diagrams that is often overlooked, but very useful, is making the diameter of the plotted analysis point proportional to total dissolved solids (TDS). In the original conception by Piper and others, the TDS of the waters was to be shown by the radius of the data point plotted from the radius of major ions in the water.

As an example, if you were to mix high TDS water with low TDS water, a huge shift would occur with only a small amount of mixing. There is no inherent way on a Piper diagram to show this accurately. In addition, during this mixing, different ions could precipitate and change ratios, notably calcium, magnesium, and sulfate. The TDS values for the comparison wells range from 2200-2500 for up-gradient wells to 11,800 or so for down-gradient wells. This use of the Piper Diagrams is curiously lacking in all literature I have seen relating to the Cotter site, including USGS reports by Banta and Chafin (1999). In fact, there is no reference to TDS. The usefulness of the Piper diagrams is reduced greatly if used in this way.

I see no way water could traverse the plant site from Wells 024 to 372 and 808 and not change more than the data presented show. In Cotter's environmental report, Piper Diagrams (Cotter, 2005, 7-38 to 7-48), using Wells 372 and 808 to determine mixing is not applicable, as these wells are clearly ***different water types*** than Wells 003, 333, and 371. It is not known how these waters started or even where they came from, so it is impossible to tell if they've been mixed or not. Also, I cannot find CY2004 data for Well 710 (underdrain) that Cotter presents as a Piper Diagram in their report or on the CDPHE site. In fact, the sampling for location 710 in 2004 was reported as "no flow." The Piper diagram for CY2004 (Cotter 2005) is based on sampling from 2000-2003, not 2004.

Stiff Diagrams: Another method of expressing water types that incorporates TDS was used very effectively by Hearne and Litke (1987). In this technique, water analyses are expressed on a rectangular plot, with each corner representing an ion or pair of ions. This presents a very readable way of expressing water types as map points. The diagrams and map (Fig. 4b) show how Stiff diagrams are constructed, and their use by Hearne and Litke to portray water types in Lincoln Park. It is easily seen that many water types are present, each representing water from a different source, a mixture of two or more types, or a water representing geochemical modification in some way, such as traveling deep underground or having been subject to evaporation.

Of note is the water type from location C-531, at Sand Creek gap, which theoretically represents the incoming surface water onto the plant site. Interestingly, the analysis shows water from this location to be a sodium-sulfate type, more characteristic of the Vermejo Fm than of the mixed metamorphic and igneous rock of the drainage basin of Sand Creek. Possibly a spring from the Vermejo supplies water at this point, at least at the time of sampling. The expected water type would be a calcium-sodium bicarbonate water type, also characteristic of Arkansas River water, Canon City municipal water, and DeWeese-Dye Ditch water. Knowledge of characteristic water types and how they may mix or evolve is a useful way of sorting out the extremely complicated and confusing ground water chemistry of both the plant site and Lincoln Park.

Accuracy Checks in CY 2004-2005 water monitoring data: I conducted some standard tests to check the accuracy of the water chemistry of the water sampling data (**See Appendix D-Spreadsheets**). The large number of analyses precluded the complete analysis of the data set, but I tried to do at least two for each well or site, and to have them be on approximately the same dates. February and May were chosen as representative months. The Arkansas River values were scrutinized more closely as some inconsistencies were noted.

Tests were done comparing TDS calculations with Lab TDS (arrived at through evaporation and weighing). The method I used added all milligrams of dissolved components (Na, K, Ca, Mg, Cl, HCO3, SO4, and NO3) and compared the totals between TDS and Lab TDS results. If the analytical work is good, these two numbers should be similar with a +/- 10% difference considered acceptable in this field. I was told by CDPHE that a +/- 80% difference was acceptable, and that is not an acceptable practice in my opinion. I found that the numbers varied greatly. Other obvious errors occur, e.g. a decimal point error for site 023 (Secondary Impoundment surface samples) where 15,800 mg/l was entered instead of 158,000 mg/l; and there is a 170% error in Well 144.

Comparing the charge balance or cation/anion ratio is another check on quality of analyses. In a water of any type, the positive charges on the dissolved ions (cations) must match the negative charges (anions), ***as the water must be electrically neutral (+ = -)***. I made a percent of them, also, so you can see how widely variable the data is. This speaks ill of the care taken in analyses, and indicates that a more careful review of Cotter sampling data should be done by the State. If the obvious errors passed through to the final report, in addition to: **1).** the analytical errors indicated by the imbalances in the mass and charge of the analyses; and **2).** the improper use of Piper diagrams, then doubt is cast on the more significant conclusions in the remainder of the Cotter's sampling reports.

I was also really struck by how many even whole numbers were being reported by Cotter. Either some aggressive rounding off of values or really inaccurate and imprecise lab methods were used for so many numbers to be so neat and even in the Annual Environmental and ALARA Reports. Nature isn't that way. I was really amazed to see numbers like 2500 mg/l and 500 mg/l continually reported, which is not realistic at all, and makes it truly difficult to accurately calculate ratios of dissolved ions, like Ca/Mg, as is suggested for leak detection from the lined impoundments.

Reporting total vs. dissolved concentrations: Unless the regulatory standard specifies using "dissolved" concentrations rather than "total" concentrations (e.g. U and Mo, etc.), the "total" number should be calculated and presented. It has been repeatedly shown, notably at Rocky Flats and at Savannah River, that radionuclides will attach to colloids (clays, sesquioxides) in the aquifer and move with the ground water. This was considered impossible until it was demonstrated at those and other sites. There are many supporting references in Fetter (1993, p. 150). Further, "total" concentration was tested at this site in the beginning, and then dropped around 1991. This cancels the ability to do comparison of long-term trends. Loss of useful data for analysis may be considerable.

Background Well 114: This is the background well for Lincoln Park. U values are 12.5 times higher than Well 024, the other background well south of Cotter: U=0.0125 in Well 114 and 0.001 in Well 024, both in mid July, 2004. Mo values are less different in the wells, but Well 114 has nearly the same to nearly double the Mo values in July and April, 2004 (0.009 mg/l for Well 114 vs 0.005 mg/l for 024; and July, 2004, 0.007 mg/l for 114 vs 0.05 mg/l for 024, April, 2004). The graphs on 7-10 and 7-14 (Cotter, 2005) suggest otherwise for Mo in the long-term, but verify the increase in U for 114. **This indicates Well 114 is effected by raffinates, and therefore not a good choice as a background well in Lincoln Park.**

CDPHE graphing application website: The utility is very useful, but many components, such as F, and many critical wells and sites have been omitted, e.g. the Wolf Park (Littel) Mine Shaft sampling location and past data (originally Well 332) are not available on the site. Partly this is due to the information on the graphing application only beginning in 1980, well after much testing and investigation had been done at this site.

Recommendations:

1.) Before declaring there is a decrease in ground water contamination, use methods showing a decrease with a curve that is exponential and asymptotic.

2.) More wells should be included outside the current definition of the U and Mo plumes in Lincoln Park.

3.) A map and report listing the previous sampling network compared to the current sampling network must be presented and distributed by the State, with the decision process for the elimination of any well being clearly stated.

4.) Add Well 138 back to the monitoring program.

5.) I recommend that an accurate ground water flow rate above and below the SCS Dam be calculated and quantified, and documented for reference in the records of this site.

6.) Discontinue the practice of using moving averages to analyze U and Mo data in Cotter's Annual Environmental Report and ALARA Reviews.

7.) Cotter should present the confidence level in the "fit" of their trend lines in reports.

8.) Resume reporting Mass movement of U and Mo.

9.) Water testing should include Fluoride (F).

10.) Piper diagrams should be used to show water types, but not to show mixing of very different waters, and the TDS of the waters should be shown by the radius of the data point plotted from the radius of major ions in the water.

11.) Accuracy checks of water monitoring data should be used comparing TDS with Lab TDS, calculating the cation/anion ratios, with an acceptable difference of +/- 10%, and a serious attempt to find obvious typographical errors and overuse of whole numbers in Cotter's monitoring results.

12.) Resume testing for "total" concentrations as well as "dissolved" concentrations.

13.) Do not report dry wells during sampling as "zero" or non-detect.

14.) Do not use Well 114 as a background well in Lincoln Park.

15.) Add "all" data from ground water locations that have been tested, even those prior to 1980, along with all contaminants, to the CDPHE graphing application website.

3.4 URANIUM AND MOLYBDENUM PLUMES: There are not really enough well data points outside the plume area to actually define the plume as the number of wells sampled in LP has been greatly reduced. Also, the current Uranium plume contour is drawn to a compliance goal of .035 mg/l. The contour should be drawn to .030 mg/l to comply with standards set by the EPA and recommended for use at Superfund Sites. Changing the compliance goal would enlarge the plume contour, and give a more accurate representation of U affecting the domestic use of wells.

Contours of both the U and Mo plumes in Lincoln Park extend from Sand Creek Gap to the NE. Shown most clearly by Chafin and Banta (1999), there are also two patterns of NW-SE extension, making the plume like a lop-sided "T" with two crossbars. One crossbar lies south roughly along the DeWeese-Dye Ditch, and one lies to the north, near the distal (far) end of the plume (Figs 3a and 3b). This configuration appears on diagrams of the contamination plumes for as long as they have been sampled. Various explanations of this phenomenon have been advanced.

At least theoretically, the plume should emerge from Sand Creek Gap, which acts as a point source and spread from there in a roughly concentric to oval pattern to the NE. Chafin and Banta (1999) propose that the configuration may be because of effects of the DeWeese-Dye Ditch, for the southerly crossbar, and possibly the hypothetical West pathway for the northerly crossbar, and a combination of geological factors in the aquifer or the underlying bedrock surface.

Geohydrology of the Cotter site was investigated by L.A. Hershey (1977). Hershey presents useful geologic data, maps, many well logs, and many cross-sections of the plant site showing wells. He discusses the coal mine situation and proposes the "deep path," and his ground water table contour map seems to show the "west path" and the "east path" fairly clearly (Fig. 3di).

I offer a further refinement of that observation. In the geologic map of the site presented in Chafin and Banta (1999), the subcrop of the Trinidad Sandstone is not shown in Lincoln Park (Fig. 2a). All other authors have included it. This subcrop corresponds fairly closely to the N extension of the plume. A prominent coal bed in the Vermejo, which has been reported to be artesian (Hearne and Litke, 1987), is underneath the S extension of the plume (Fig. 2ei). I modified Chafin and Banta's geologic map to show the outcrop (subcrop where covered by alluvium) of the Trinidad Sandstone and the approximate location of the Wolf Park coal seam in the Vermajo Fm in Lincoln Park (Fig. 2b). A transparency of that modification is provided (Fig. 3c). Place the transparency over Chafin and Banta's plume maps (Fig. 3a and 3b) and you will see how the plume corresponds to the Trinidad subcrop and the Vermejo Fm coal seam. It may seem that geologic factors as well as the DeWeese-Dye Ditch play a factor in shaping the water contaminant plume. This coal seam is also very close to Well 006, which carries the highest values of Mo and U in Lincoln Park (Fig. 2e). I will offer that at least a portion of this contamination may come from the coal seam, which has been purported to be the Wolf Park Seam by Hearne and Litke (1987) and Stephens (1993). I also feel that a case could be made for the existence of the west pathway. Unfortunately, there are insufficient wells in that vicinity to define it.

Calaculating U and Mo Plume Contours: When examining the boundary contours of U (0.035mg/l) and Mo (0.100 mg/l) in Cotter's Annual Environmental Reports, I found that the zone closest to the Sand Creek gap perhaps needs to be re-interpreted (Figs. 3ai, 3aii, 3bi, 3bii).

The plume contours on both U and Mo maps appeared to be hand drawn more or less equidistant between wells with extremely high concentrations of U and Mo and wells with fairly low concentrations. While this may look reasonable to the observer, it does not follow accepted procedure for drawing contours.

Normally, the concentration between adjacent points is expressed as a gradient. It can be calculated how far away from the lower concentration well the MCL contour will be by adding increments of concentration gradient until the value is reached. Note that mg/l is the same as ppm. As an example: Well 331 had 13.175 ppm Mo (an extremely high value) and the next adjacent Well 141, had Mo at 0.005 ppm. The horizontal distance between the wells is 37mm (Fig. 3bi):

a. The concentration gradient between wells is then:

(13.175 - 0.005)/37 = 0.3559 ppm/mm

b. The distance from the Well 141 to the MCL contour (0.1 ppm Mo) is then

Dist = (0.1 - 0.005)/0.3559 = 0.27 mm

Instead of 0.27mm, the contour was placed 25.0 mm away from Well 141 (off by a factor of 10), which considerably reduced the size of the plume visually.

In interpreting this, you must take into account that the Sand Creek gap is essentially a point source for the seepage of contaminants. There is conjectured to be a bedrock channel under the alluvium that contains the plume. I have a certain amount of trouble with this because it should be extremely difficult to maintain a concentration gradient that steep between the pollution plume and the relatively pure water outside of it. My feeling is that rapid diffusion of U and Mo would take place as soon as the contaminant plume left the confines of Sand Creek gap. This is a reasonable conjecture. However, the number of sample locations, especially on the NW side of the plume, is insufficient to define it. I believe it is possible that the plume diffuses and widens immediately after leaving the gap and becomes quite broad. Whether this is true or not could only be substantiated by more sampling.

The plume boundaries farther out in Lincoln Park are fairly accurate, although I see no reason to have an isolated high of U centered around Well 129. This local, isolated high in U could actually be explainable if there was a subsurface (deep path) source for U below Wells 129, 173, 189, etc. The northern E-W extension of the U and Mo plumes seen clearly in USGS maps (Chafin and Banta, 1999) does coincide with the Trinidad Fm (omitted from Banta's maps) and the southern E-W extension corresponds to the base of the Vermejo, where the Wolf Park coal seam is located.

Background values for U and Mo as relates to plume boundaries: Contours of the plume are defined by a clean up level goal, or MCL, rather than definitively showing where raffinates are present in Lincoln Park wells. Many outlying wells and seeps I wanted to investigate, looking for a regional background, are not on the CDPHE Cotter website via the *Cotter Mill Monitoring Application*. I was looking for a regional background that is more reasonable than the current cut-off values of 35 ug/l for U (0.035 mg/l) and 100 ug/l for Mo (0.100 mg/l), which seem unreasonably high when looking farther afield at regional background levels for these elements. Regional levels seem to fall more in the range of 0-5 ug/l for each component. The justification for high cut-off values, that "Canon City is uranium country-it's all over," is not adequate. Even Banta and Chapin (1999) admit that raffinate affected waters may have U and Mo in that low range of 0-5 ug/l.

Recommendations: **1.)** I again recommend that wells be added to the quarterly monitoring program in Lincoln Park in order to further define the plume, especially NW of the plume. **2.)** The MCL or compliance goal for clean up of U in the effected area should be changed to comply with the EPA standard of .030 mg/l (30 ug/l), which would change the contour of the plume by enlarging it (see Sec. 3.5.3-Nature of contamination and background values). **3.)** Further, I recommend a more stringent review and accuracy check by CDPHE and EPA of the plume contour maps presented by Cotter each year. **4.)** The plume map should be contoured down to a regional background level of 5 ug/l for each component for a more accurate picture of actual raffinate contamination present in Lincoln Park wells.

3.5 PERMEABLE REACTIVE TREATMENT WALL (PRTW):

The PRTW is a subsurface barrier composed of iron filings (called ZVI, for "zero-valent iron", i.e. iron metal) placed across the ground water flow below the SCS Dam somewhere near Sand Creek Gap. It was purported to sequester (immobilize and remove) U and Mo from the contaminated ground water flowing through Sand Creek Gap, and touted as a permanent fix for the contamination by utilizing a chemical process to create reducing conditions at the filings layer, which would cause precipitation of the dissolved U and Mo. It began to fail after 8 months, because of clogging by calcium carbonate (calcite) precipitated by the high pH (alkaline condition) that was also generated at the barrier.

I have commented on the PRTW in my comments on the RAP (April 2005), which is included in Appendix B. With the amount of bicarbonate in the water at this site, the PRTW and process was not likely to succeed because of the reduction and sequestration of U and Mo coincided with the high pH values generated by the reaction of the iron filings with acid in the water. It was no surprise that the precipitation of calcium carbonate blocked the pores of the barrier. The well known chemical conditions of the ground water, with high carbonate and calcium, virtually guaranteed that calcium carbonate (calcite) would precipitate and clog the pores of the treatment wall, blocking ground water flow, which then began to mound up behind and flow around the now impermeable barrier. In all, several years were wasted on this experiment.

Since the water chemistry here is unsuitable for "in-situ" electrochemical methods of removing U and Mo from the water because of high carbonate and calcium values, it needs to be treated differently. A “water treatment system” would return clean ground water that has been blocked from Lincoln Park for many years, such as is being done for Leadville, CO. Unfortunately, this is a nuclear site, and the demand for a “water treatment system” for perpetuity is complicated because federal and state radiation regulations do not allow for any remediation systems that require maintenance after closure and decommissioning of the facility. The system needs to keep itself contained on its own.

Since the failure of the PRTW was made public, residents are concerned that water is escaping past the PRTW into Lincoln Park. Even a small amount of seepage is unacceptable. Residents have requested, and been denied, a ground water tracer test to determine if any waters are getting beyond the SCS Dam and PRTW, being told by staff from CDPHE that the rate of flow through the area is unknown making it difficult to set up a time frame for such a test. Quantifying ground water flow above and below the SCS Dam and PRTW would solve the difficulty.

The CDPHE website has a page on PRTW's, but it only has general information about PRTW's in other states and locations, and no information at all about the PRTW at the Cotter Uranium Mill and Superfund Site. This webpage would be an excellent avenue to fulfill the requirement in the Consent Decree of 1988 to provide Remedial Action Plan (RAP) documents to citizen stakeholders within the Lincoln Park/Cotter Superfund Site.

Recommendations: **1.)** For a second reason, ground water flow both above and below the SCS Dam and PRTW should be quantified in order to accurately determine any leakage past the PRTW or SCS Dam. **2.)** I then recommend using a chemical tracer test to determine if any waters are flowing past the PRTW at this time. **3.)** All documented data, analysis, and all information pertaining to Cotter’s PRTW should be placed on the CDPHE website section on PRTWs. **4.)** I recommend that the State of Colorado and federal agencies resolve the current radiation regulation barriers to a “water treatment system,” which would allow the return of clean water once again to the Lincoln Park area and the Arkansas River.

3.6 IMPOUNDMENT LEAK INVESTIGATION:

Since the Remedial Investigation in the mid-1980’s, Cotter was supposed to determine whether the new impoundments were leaking or not. Around 1994, Cotter and regulators devised a method of investigation and declared that there was no evidence of leakage for the next decade. But a new leak investigation was required by CDPHE due to recent reviews of the original impoundment construction reports, and that investigation culminated in a determination in early summer of this year (2007) that the impoundment is leaking. However, CDPHE characterized the leakage as minor, rather than major. Whether minor or major, federal and state regulations for tailings impoundments require that liners “prevent any migration of wastes out of the impoundment to the adjacent subsurface soil, ground water, or surface water,” [10 CFR 40, Appendix A, Criterion 5A(1)].

Geophysical study: A geophysical study of subsurface resistivity was conducted in 2005 as part of that investigation. The study (HydroGeophysicists, Inc., 2005) commissioned by Cotter to determine if there was any leakage from the lined impoundment, and where wells might be placed for further investigation, gave the conclusion that the impoundments were not leaking. However, in the explanatory portion of the text, this conclusion was given equal weight with the possibility of leakage. The choice of one alternative over the other is not warranted by the findings of the study. Further, colors chosen for the subsurface resistivity values differ from colors used at other sites, and give a misleading impression of conditions, at least compared to the examples from other sites shown in the text. Despite this, CDPHE used the study to choose locations for new wells along the edge of the impoundment, where subsequently new Well 379 was found to indicate leakage (Figure 3e). See my special report (**Appendix B, Section 2.0 and 3.0**).

Piper Diagrams and Magnesium as indicator of leakage: Cotter and CDPHE both approve the use of increases in magnesium concentration as a tracer and indicator of leakage from the lined impoundments, but it is not sufficiently justified by site conditions or available chemical data on fluids within the pond sediments. Two objections to this practice immediately appear.

First, few early analyses of deep pore waters from the sediments in the impoundments exist, and the earliest analyses do not include magnesium. The *Remedial Investigation* by GeoTrans (1986, p. 3-9 to 3-10) presents some analyses from 1975-76 of the *old* tailings impoundments, which include both calcium and magnesium, but most do not show magnesium to be in excess of calcium (Fig. 4.e). The single analysis that shows magnesium in excess of calcium is from the old tailings ponds #2 and #4. The other locations show calcium in excess of magnesium. One might ask why magnesium has increased in concentration over calcium so much in the new impoundment ponds, that it is characteristic of the fluids? These fluids were the same as raffinate from the old ponds. I feel at least some explanation of this is necessary. No raffinate fluids from the old ponds area (now excavated and placed into the lined impoundments) show magnesium in excess of calcium. I can think of no reason besides evaporation causing precipitation of gypsum in the surface waters of the ponds that would cause an apparent increase in magnesium, but this would be subject to evaporation, which may vary from year to year.

Secondly, observation of data points of magnesium plotted on a Piper Diagram (Cotter 2006, p 7-46), from 1/29/02 to 12/30/05, actually show magnesium decreasing in the surface waters of the Secondary impoundment at location 023. Measurements should be taken of the chemical composition of fluids from near the base of the sediments in the ponds, near the liner, which would actually represent the first fluids leaking from the pond, if the liner were breached, as has been observed and reported by Bruskin (CDPHE interoffice communication, 2004), and Sentinel (2004). Because of variable seasonality conditions at the surface of the ponds, and a lack of data from deep pore waters in the ponds, magnesium seems a poor choice as a tracer and one not backed by enough solid evidence.

Recommendations: **1.)** Samples of interstitial fluids (deep pore waters) should be taken as part of the regular water monitoring program, and especially during the period of the leak investigation to provide a basis for how the investigation is conducted and how results are interpreted. **2.)** For a third reason, I again recommend that an accurate and definitive flow rate of migrating water be calculated and quantified through this area near the impoundment to be used in interpretation of data from the new wells. **3.)** Determine why magnesium has increased over calcium so much in the impoundment ponds.

3.7 ENVIRONMENTAL IMPACT STATEMENT (EIS): In 1979, as the new impoundments were being finished, the National Wildlife Federation requested an EIS for the Cotter site from the Nuclear Regulatory Commission (NRC). That same year the NRC agreed to perform the study, but it was never done (Hart, 1981, p. 5-14). The *Ecological Risk Assessment* of 1998 (Stoller & Schaefer) was in fact the first environmental study for wildlife, which is usually a part of an EIS.

To date, no complete EIS, per the federal National Environmental Protection Act (NEPA) requirements, has been performed at this site, in spite of the fact that Cotter has changed their operational methods and use of the mill several times. Cotter has changed from Acid processing to Alkaline, and back to Acid. They have processed materials known as Alternate Feed, which came from clean up of nuclear fuel facilities, and even baghouse contents from a power plant in the United Kingdom. Cotter requested authorization to process waste from a Superfund Site at Li Tungsten, in New York. Alternate feeds already processed by Cotter often contained contaminants such as mercury and thorium at concentrations well above what is normally found in uranium/vanadium ore tailings. Fortunately, CDPHE will continue to authorize such materials for processing only on a case-by-case basis. Nevertheless, the tailings produced by this processing are disposed in the impoundment ponds, and are therefore a potential threat to the environment if the impoundments are found to be leaking.

Cotter also requested authority to directly dispose of Superfund waste from The Maywood Chemical Works Superfund Site in New York, using the impoundment for something other than their own ore processing wastes. The unknown factor is how the contents of Alternate Feed tailings and Superfund waste will effect the impoundment's liner, as no EIS has studied this use of the impoundments.

Recommendation: I strongly recommend that a long overdue, complete NEPA review (EIS) be conducted at this site.

3.8 LOCATION AND HYDROGEOLOGICAL FACTORS: As a private consultant, .I also have been involved in the site selection for low-level nuclear waste disposal sites. In reviewing the geology and hydrology of the Cotter site, I was struck by how unsuitable the area is for a uranium milling facility. A manual for site selection called "Hydrogeologic Factors in the Selection of Shallow Land Disposal Sites for the Disposal of Low-Level Radioactive Waste", in U.S. Geological Circular 973 (Fisher, 1986), discusses the major criteria for site selection. Although published in 1986, the guidelines are still valid and constitute standard practice. Though technically Cotter is not authorized to receive "low-level radioactive waste," the waste they are authorized to handle is both low and high in radioactivity, and these siting considerations apply.

The list of hydrogeologic factors to consider in Circular 973 is comprehensive (Fisher, 1986). The considerations are: *Precipitation, amount and type; *Surface drainage, susceptibility to erosion and flooding; *Topography; *Site stability; *Geology; *Thickness of the host soil-rock horizon; *Soil and sediment permeability; *Soil and water chemistry; and *Depth to the water table. In addition, you should also think about: *Meteorology, prevailing winds and storms; *Proximity to built-up areas such as towns, schools, or agricultural areas such as fields, dairy farms, and etc.

How does the Cotter Uranium Mill site stand up to these considerations?

Precipitation.: Rainfall here is low at 12-14"/yr, but it often occurs as violent thunderstorms which may cause flash flooding and erosion, or threaten to overtop tailings impoundments or erode earthen dams, as feared in 2004 when an unusual amount of rain fell in a short period of time.

Surface drainage: The two SCS dams (east and west) offer some protection against offsite flooding, although a breach of the tailings dam would send contaminated tailings over unprotected ground and cause further ground water degradation.

Topography: The site is in a topographic basin, which appears to offer isolation from the surroundings, but is misleading (see Geology, below).

Site stability: There are no active earthquake faults in the area. There is no landslide hazard.

Geology: Here is where things begin to fall apart. As explained earlier, the basin Cotter sits in is a geologic structure called the Chandler Syncline. It is essentially a big taco-like fold with the long axis of the taco pointing E-W. In order, from the surface down, are found first the Poison Canyon Formation. It is claystone to conglomerate-may be fractured-which allows rapid ground water flow. Next down is the Raton Sandstone, which forms the ridge of the basin surrounding the Cotter Mill and tailings impoundments. Below that is the thick Vermejo Formation, mined for coal, which is pierced by mineshafts deeply below the Cotter plant, and emerges at the surface under Lincoln Park. Past studies have established that uranium mill contaminants migrated into the mine. The thin Trinidad Sandstone is below the Vermejo, and below all these rock units sits the Pierre Shale, a 4000 foot thick clay shale.

Extensive mining of coal from the Vermejo Fm has left a vast network of mapped and unmapped mine workings below the Cotter property. Access to surface contamination through the deep mine shafts, "the deep path," has been suspected by many authors, and I am convinced it could exist. Cotter backfilled the Wolf Park shaft, which prevented contaminated surface water influx, but that also prevented further sampling of water in the mine.

The rocks below the plant site are variably permeable with fracture porosity, moderate hydraulic conductivity (granular porosity), and mine openings. My opinion is that this is not a good site geologically because of the very unpredictable ground water flow, which is hard to predict and to control.

Thickness and permeability of the host soil-rock horizon: The plant site is directly underlain by up to 60 feet of hydraulically permeable stream gravels, which allow water to soak in and travel down to bedrock, at which point the water can migrate laterally downgradient towards Lincoln Park and the Arkansas River.

Soil and Water Chemistry: Water entering the plant site is of fairly good agricultural quality, but rather high in carbonate, as is seepage water from any leaks in the liner of the tailings impoundment. As we heard at a Cotter/Lincoln Park Superfund Site Community Advisory Meeting in Spring of 2005, concerning the failure of the PRTW (permeable reactive treatment wall), the main reason for the failure of the "wall" (basically iron filings dumped into a trench) was the precipitation of calcium carbonate, which clogged the pores of the iron filings as the electrochemical reaction with the incoming ground water raised the pH. This clogging began less than one year after installation, rather than the proposed 50-year life of the installation. It is my opinion that this could have been predicted, pre-construction, with a cursory glance at the water chemistry of the site.

The water chemistry here is unsuitable for "in-situ" electrochemical methods of removing U and Mo from the water because of high carbonate and calcium values. It needs to be treated differently, such as with a “water treatment system” that would return clean ground water that has been blocked by Cotter from Lincoln Park for many years. Unfortunately, this is a nuclear site, and the demand for a “water treatment system” for perpetuity is complicated because federal and state radiation regulations do not allow for any remediation systems that require maintenance after decommissioning of the facility. The current pump-back system at the SCS Dam and PRTW, preventing water from leaving the Cotter site and entering Lincoln Park, will present a difficult problem when Cotter can no longer pump contaminated water back to the tailings impoundment.

Depth to water table: This is variable, but we do know from reports at the time of construction of the lined impoundment, that several springs were encountered in the excavation, which means that the ***ground water table intersects the base of the impoundment pond liner.*** The base of the impoundment liner must be ten's of feet, at least, above the highest possible water table. Ground water contamination is the reason this Superfund Site exists, and should not be allowed to continue. Cotter is currently proposing "selective excavation" of more highly contaminated areas of the old tailings pond area, but this doesn't correct the fact that the liner in the new impoundment was deficient in construction, and has been determine to be leaking. In my opinion, this pond should be abandoned altogether.

Proximity to urban and agricultural areas: In the last decade, when Cotter was dormant, the Canon City limits encroached on the plant site. The city limits now border Cotter property on the West, with hundreds of upscale new homes. The golf course and nearby neighborhoods and farms increase the likelihood of dust and water contamination to residents and livestock.

In summary, the Cotter site fails the U.S. Geological Circular 973 major criteria for site selection in many ways, i.e. ecologically, chemically, and hydrologically. The facility was located during the cold war uranium boom, when people didn't think about these things much, but even early reports express doubts about the suitability of the site, especially when the new impoundments were built in 1978-79 (USEPA, 1978). It would be hard to imagine a worse place for a nuclear facility. Ground water pathways are very vulnerable to contamination. Alluvial gravels which lay directly below the site are highly permeable and subject to contamination by surface spills and impoundment pond leakage. Shallow underlying bedrock is fractured, which allows direct flow. Deeper bedrock levels are pierced by numerous mine workings that may provide egress of contamination outside the topographic basin via a deep path, by allowing communication between the contaminated ground of the Cotter site and the Lincoln Park area outside the topographic barrier of Raton Ridge.

Recommendation: Most of the contamination migration issues could be put to rest by locating a new plant on Pierre Shale. This meets the primary requirement of a radioactive waste site. A site on Pierre Shale, topographically removed from the Arkansas River, geographically removed from population and agriculture centers, could be found in Fremont County. The USGS recommended the best long-term ground water clean up would involve removing the waste piles. As long as Cotter is going to do excavation removing contaminated soil from the Old Tailings Pond Area, why not look for a better site for the plant somewhere in Fremont County. Cotter should consider re-locating.

3.9 COTTER'S ANNUAL ENVIRONMENTAL & ALARA REPORTS:

Please see my full review of Cotter's CY2004 Annual Environmental Report and ALARA Review in the attached appendices (**See Appendix A, Sec. 3.9**). The following are general recommendations for improving future annual reports:

a. **Ground Water Table Map (Sec. 7)**: Include site features (e.g. impoundments, wells, PRTW, and etc.).

b. **Trend lines on graphs:** Cotter should always present the confidence level in the "fit"of their trend lines. This enables the reader to evaluate the quality of the trend.

c. **U and Mo:** I recommend that Cotter present the data for U and Mo as mass, rather than concentration. This seems the only way to eliminate the confusing effect of the dilution by the DeWeese-Dye Ditch. I was told that they used to do this, but had stopped, and I wasn't given a reason as to why. Using concentration does serve to lower the "moving average" to below MCL's in some cases.

d. **Surface water monitoring figures and tables:** The sampling locations for Sand Creek at Ash and at the Arkansas River and DeWeese-Dye Ditch at Cedar Ave are not shown on fig. 7-1. Table 7-1 should be arranged with the upstream site (907) above the downstream site (904). The numbers should be reversed, also, for a more intuitive presentation.

e. **Piper diagrams:** Piper diagrams are useful to show water types, but much less so to show mixing of very different waters. In the original conception by Piper and others, the TDS of the waters was to be shown by the radius of the data point plotted from the radius of major ions in the water. In Cotter's presentation, no reference to TDS is made. The usefulness of the Piper diagrams is reduced greatly if used in this way.

f. **Checks on accuracy of analyses:** I calculated totals of the mass of constituents in each well to see if the analyses were reliable. Generally they were off by a fairly large amount, as has been noticed before in years past. There are two ways of verifying the correctness of an analysis, by 1.) Mass Balance and 2.) Charge Balance. CDPHE and Cotter should be performing these checks. I found errors that could have been caught by 1.) comparing calculated TDS with lab TDS; and 2.) checking to see that charge balance or cation/anion ratios are very close to equal. Included are my spreadsheets checking accuracy of data in this way (**See Appendix D**).

g. **Graphs for Well 006:** There is a significant omission in the text that has actually been carried through for the last few ALARA reports. On p. 7-12, the graph for dissolved Mo in Well 006 is not present and has been replaced by a duplicate of the U graph. This seems more serious as this is the most contaminated well, especially in Mo, off the plant site and was adjacent to Well 138, which was the well that poisoned the livestock originally.

h. Consistency: Be consistent in reporting data. For instance, when reporting water monitoring results by graph, if MCLs or compliance goals are displayed, do the same on all graphs.

i. The hypothetical 1000-year storm: This has not been estimated or addressed as either part of a license renewal environmental application or in an annual environmental report. As this site needs to remain safe for thousands of years without human assistance, the 1,000 year storm assessment should be done immediately before further wastes are stored at the mill site.

4.0 GENERAL COMMENTS: There are two somewhat different but complementary ways to approach a situation like the Lincoln Park/Cotter Superfund Site, from a point of view that is both Wholistic and Reductionist.

The Wholistic approach looks at the entire situation, in all its complexity, and draws conclusions from the overall whole. The Reductionist viewpoint, on the other hand, looks at (sometimes) minute specifics in order to find a deviation from specified standards that might lead to a penalty or reprimand for incorrect procedure. My personal inclination is focused on the Wholistic approach (i.e. the facility location is poor because it is too close to residential areas and the Arkansas River, and there are serious questions regarding the construction and performance of the tailings impoundments).

Reductionist concerns (specific violations of the RAP and other operating statutes and regulations) may also be cited in assessing the site. Unfortunately, in the reductionist arena, the State and Cotter hold the upper hand. They have a big staff that can pour over regulations day by day, diverting attention from the big picture. State workers may come and go, while average citizens trying to keep up with this site are overtaxed with personal life commitments, job responsibilities, and generally just having a life. In a war of attrition, the average citizen is seriously outgunned. The State can direct the argument to specifics quite easily, and divert attention from the fact the situation should not be occurring in the first place. Historically, even though citizens have brought up substantive issues, the State has more often than not ignored the issues and rolled right over the objections.

5.0 CONCLUSIONS

The following conclusions are based on data from available documents related to the site and the work of many other authors. I have also made certain rough calculations based on published data that may contain unforeseen errors. The conclusions and interpretations therefore should be treated as opinions of this author and not statements of fact or accusation. **In my opinion:**

*****The site is in an unsuitable location geographically, geologically, hydrologically, and culturally for an operating uranium ore processing facility or as a storage facility for other sorts of radioactive waste material.

***** There is still some cause, in my opinion, to continue to suspect the "Deep Path" through the Wolf Park mine to locations near Well 006 in Lincoln Park. Although disputed by the USGS, water levels in the Rockvale, the Wolf Park, and the Chandler mines agree with local ground water gradients, implying some connection. Early maps show the Chandler and the Wolf Park connected, and the Chandler air shaft, when last sampled, had the same levels of U as did the Wolf Park. The possibility for contamination arriving at a later date from this pathway should be fully investigated.

***** There is also evidence to suspect the "West Path", under Shadow Hills Golf course, but the calculations are very speculative. Nevertheless, it should be investigated.

***** The lined impoundments, both primary and secondary, should be abandoned, the sediments dewatered and removed to a suitable dry storage location. The liners were observed to be torn in many places during construction, and reports indicate the supporting fill is not uniform. If the fill contains a mixture of grain sizes, it could allow the passage of fluids. The calculations of CDPHE showing excessively long transport times of contaminants from the impoundments were done for water near the surface of the pond, not at the liner level.

***** The current monitoring well network is not sufficient to confidently delineate the ground water plume of U and Mo contamination in Lincoln Park.

***** It is unclear from available studies and data that the concentrations of U and Mo in ground waters of Lincoln Park are actually decreasing to levels below the compliance goals. They appear to be simply asymptotically decreasing to some fairly high level.

***** The use of untreated well water in Lincoln Park for irrigation of food crops or watering of livestock should be strongly discouraged because of deposition of U and Mo salts on vegetation and/or uptake and concentration of U and Mo by certain plants which may later be consumed by animal or human.

***** The use of increases in magnesium concentration as an indicator of leakage from the lined impoundments is not sufficiently justified by site conditions or available chemical data on fluids within the pond sediments. The exact nature of deep interstitial fluids has never been determined (since around 1976). It has never been fully explained why magnesium is in such high concentration in the pond waters in the first place **(See Appendix B, Sec 2.0- 3.0)**.

***** The quality of chemical data from surface locations and from monitoring wells on the site, when subjected to standard tests for data quality (charge balance and mass balance), are shown to be extremely inaccurate in a large number of cases, leaving doubts about the integrity of the entire body of data supporting the remediation and monitoring.

***** The monitoring wells in the vicinity of the lined impoundments are not placed in such a way as to definitively detect leakage from the impoundments.

***** The use of Reactive Treatment Wall technology at this site is not advised because of unsuitable water chemistry that causes calcium carbonate to precipitate in the pores of the wall, clogging it.

***** The geophysical study performed to detect seepage from the lined impoundments was interpreted to indicate no seepage, yet the report admits that other interpretations are possible and equally valid.

6.0 REFERENCES

Banta and Chafin. 1999. *Ground-Water hydrology and simulation of five remediation alternatives for an area affected by uranium-mill effluent near Canon City, Colorado*: U.S. Geological Survey Water-Resources Investigations Report 98-4229.

Bruskin, L. 2004. *Cotter Impoundment Evaluation.* Interoffice Communication, Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division, October 2004.

CDPHE, Ethington, E. 2006. Map showing original and new on-site wells, impoundment leakage investigation. Prepared for Lincoln Park/Cotter Community Advisory Group, Canon City, CO.

Chafin and Banta, 1999. *Migration and geochemical evolution of ground water affected by uranium-mill effluent near Canon City, Colorado*: U.S. Geological Survey Water-Resources Investigations Report 98-4228.

Cotter. 2005. CY*2004 Environmental and occupational performance report, ALARA review, and annual report on remedial action plan activities*, Radioactive Materials License 369-01.

Cotter. 2006. CY*2005 Environmental and occupational performance report, ALARA review, and annual report on remedial action plan activities*, Radioactive Materials License 369-01 Amendment No. 41.

EMSI. 2004. *Alternatives Assessment Old Ponds Area.* Prepared for the Cotter Corporation.

Fetter. 1993. *Contaminant Hydrology.* Macmillan

Fisher, J.N. 1986. *Hydrogeologic Factors in the Selection of Shallow Land Disposal Sites for the Disposal of Low-Level Radioactive Waste.* U.S. Geological Circular 973.

GCA Corporation, Wilder, R.J., etal. 1983. *Assessment of data concerning ground water contamination in the Lincoln Park Section of Canon City, Colorado.* Prepared for the EPA.

Geotrans, Inc., etal. 1986. *Remedial investigation, Cotter Corporation uranium mill site.* Prepared for the State of Colorado Department of Law Office of the Attorney General.

GEOCHEM Division, Terra Vac. 1994. *Clay liner impact evaluation: Primary Impoundment Canon City Mill, Vol. I & II.* Prepared for Cotter Corporation.

Hart, F.C. & Associates. 1981. *Field Investigations of Uncontrolled Hazardous Waste Sites*. Prepared for USEPA, and subcontractor to Ecology and Environment, Inc.

Hearne, G.A., and Litke, D.W. 1987. *Ground-water flow and quality near Canon City, Colorado*: U.S. Geological Survey Water-Resources Investigations Report 87-4014.

Hem, J.D. 1992. *Study and interpretation of the chemical characteristics of natural water*. U.S. Gov. Print. Office, Washington, DC.

Hershey, L.A. 1977. *Geohydrology of the Cotter Mill Environment.* Prepared for NALCO Environmental Sciences.

HydroGeophysics, Inc. 2005. *Geophysical Results for Cotter Corporation, Canon City, Colorado.* Prepared for Cotter Corporation.

REFERENCES (Cont.)

Lehman, L. & Associates. 1991. Letter and report to Law Firm of Waite, Schneider, Bayless & Chesley, Cincinnati, Oh.

NALCO Environmental Sciences. 1975-76. *Environmental Report for the Cotter Uranium Mill, Canon City Colorado.*

Parkhurst, D.L. 1995. *User's Guide to PHREEQC--a Computer Program for Speciation,Reaction-Path, Advective-Transport, and Inverse Geochemical Calculations*, U.S. Geological Survey, Water-Resources Investigations Report (WRI) 95-4227.

Runnels, D.D., etal. 1977. *Geochemistry of molybdenum in Colorado*: The Environmental Trace Substances Research Program, University of Colorado, Boulder.

Scott, G. R. 1977. *Reconnaissance geologic map of the Canon City Quadrangle, Fremont County, Colorado:* U.S. Geological Survey Misc. Field Studies Map MG-892.

Sentinel Consulting Services, LLC. 2004. *Technical Assessment, Waste Containment and Leak Detection Systems for Cotter Corporation Primary and Secondary Impoundments, Canon City, Colorado.* Prepared for CDPHE, December 10, 2004.

Shelton, D.C. 1978. Letter reviewing W.A. Wahler & Associates, 1978, *Investigations related to the migration of raffinates from the existing Cotter tailings impoundments:* Colorado Geological Survey. Prepared for Colorado Department of Health.

Stephens, D.B. & Associates, Inc. 1993. *Assessment of potential seepage iImpacts on ground water, Cotter Uranium Mill, Canon City, Colorado, Volume I, summary of existing hydrogeological data.* Prepared for Colorado Department of Health.

Stoller, S.M Corporation, and Schafer & Associates, Inc. 1998. *Lincoln Park Superfund Site Ecological Risk Assessment.* Prepared for Cotter Corporation.

Wahler, W.A. & Associates. 1978. *Investigations related to the migration of raffinates from the existing Cotter tailings i,mpoundments,* prepared for Cotter Corporation.

USEPA. 1978. Cover letter and EPA comments on *Nalco Environmental Sciences Environmental Report for the Cotter Uranium Mill* and the supplemental tailings impoundment design report. USEPA Record Document ID #296751.

USEPA. No date. *(ORP-LVF) Review on Environment Report for the Cotter Uranium Mill (NALCO ENVIRONMENTAL SCIENCES).* USEPA Document I.D. #296765.

FIGURES

Satellite view of Lincoln Park and Cotter Mill Site June 2005

Available at: http://maps.google.com/

Patterson 2007
Figure 1a

Cotter Corporation Milling Facility, Cañon City, Colorado — May 1998

Patterson 2007

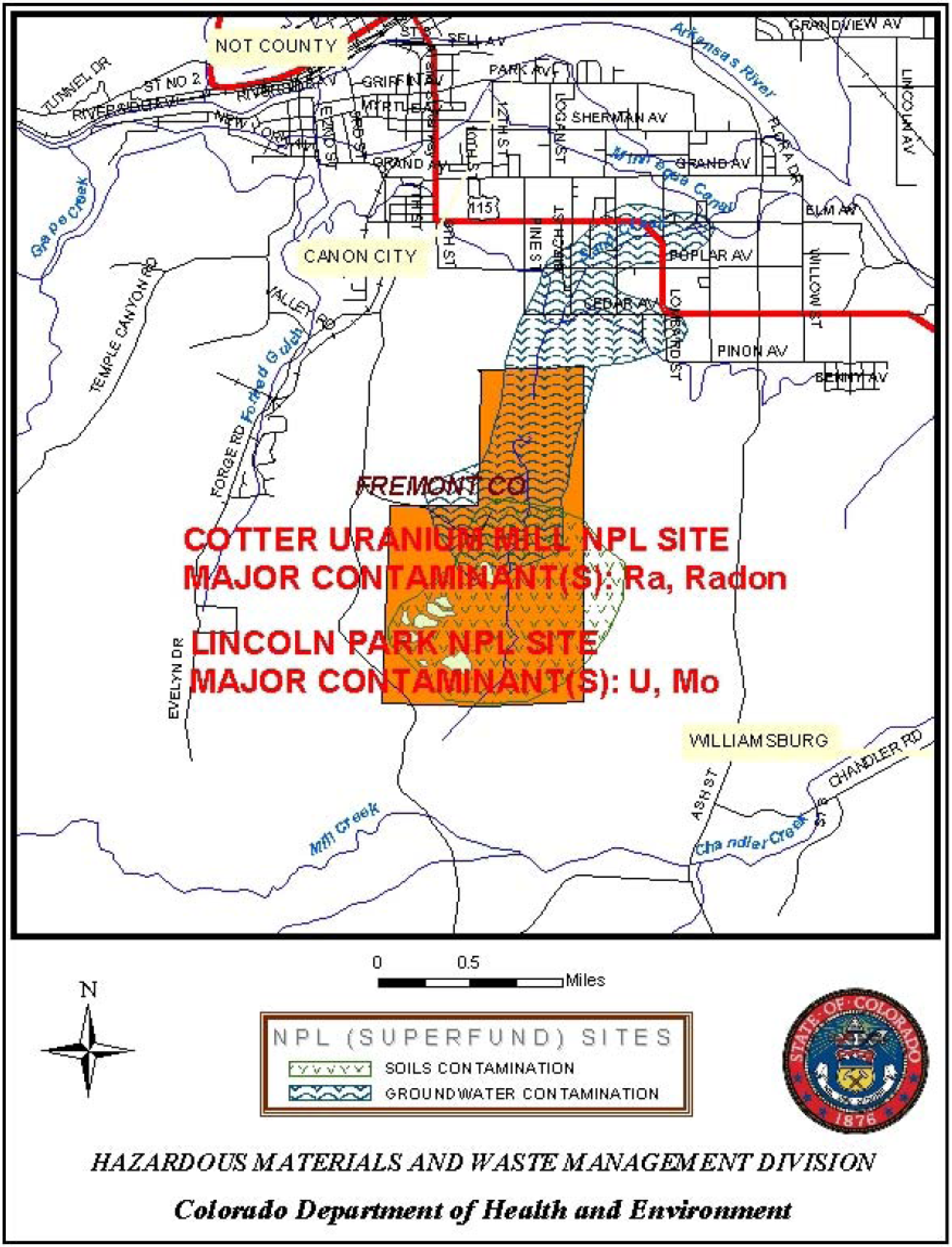
Figure 1b

From CDPHE – COTTER Website: http://www.cdphe.state.co.us/hm/cotter.pdf

Figure 7-1 Location of Arkansas River Sampling Sites

Cotter (2006), p. 7-3

Patterson 2007
Figure 1c



Available at: http://emaps.dphe.state.co.us/hmsitemap/npl/lincolnpark.htm

Patterson 2007
Figure 1d

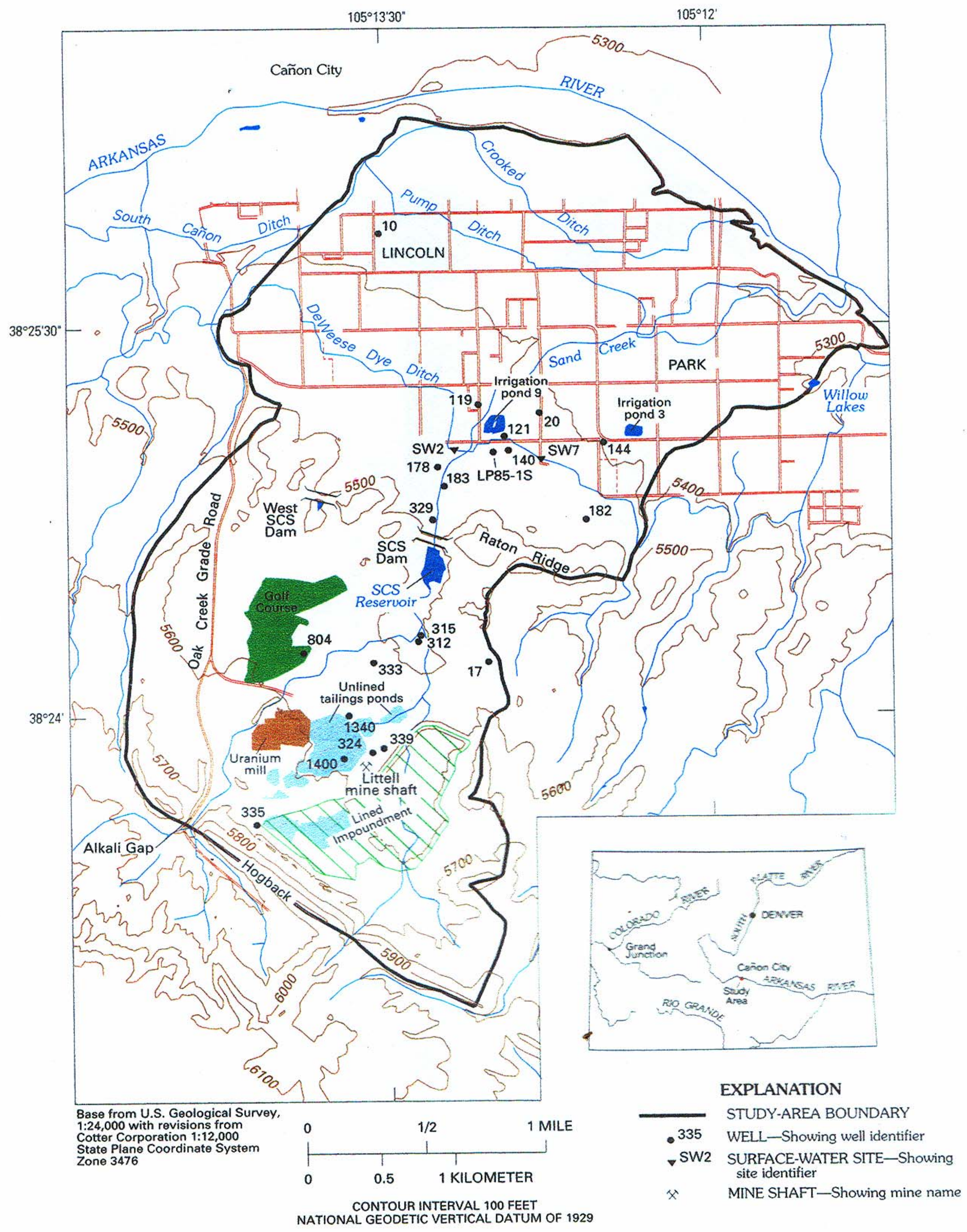


Figure 1. Location of the study area.

Banta & Chafin (1999), p.4

Patterson 2007
Figure 1e

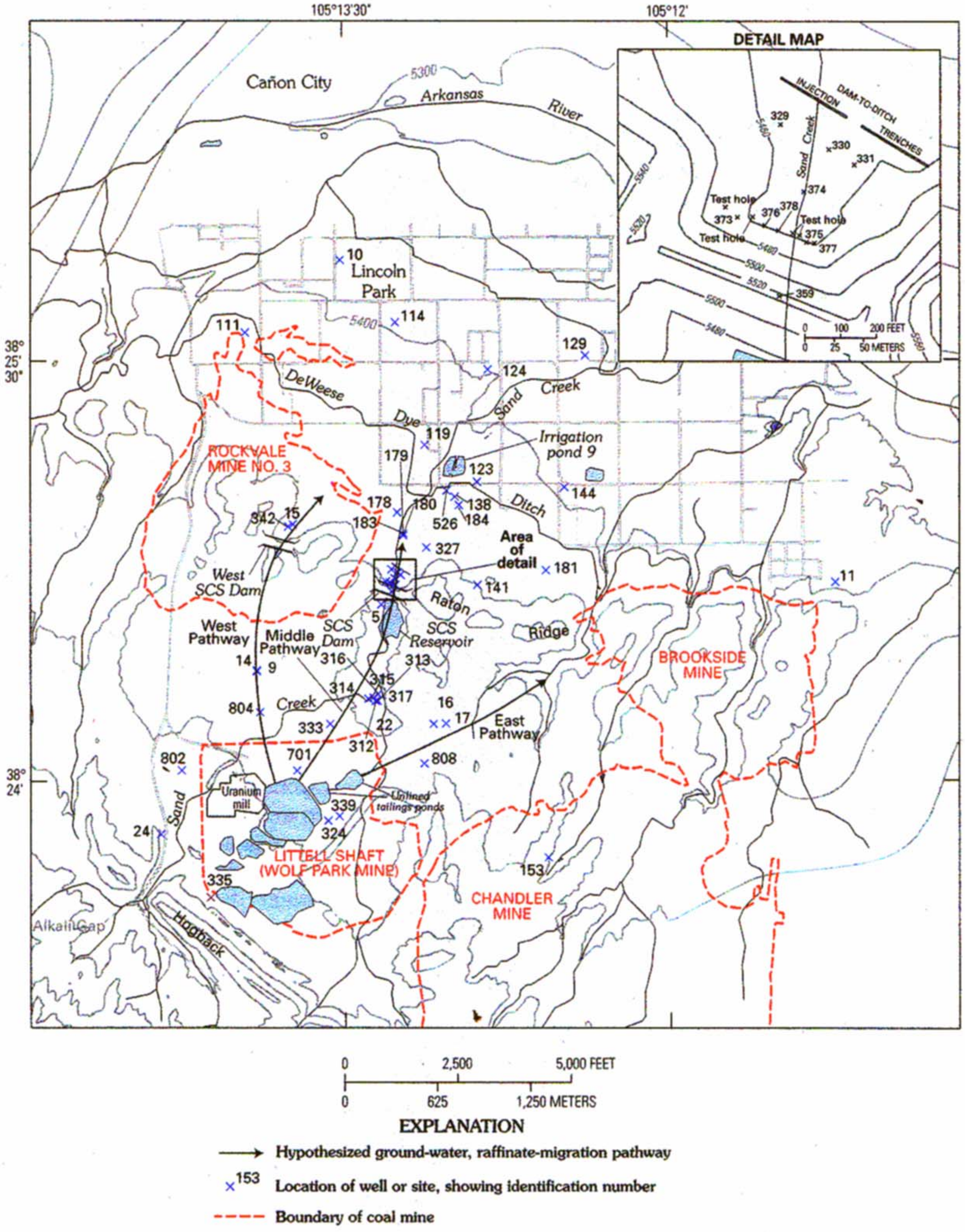
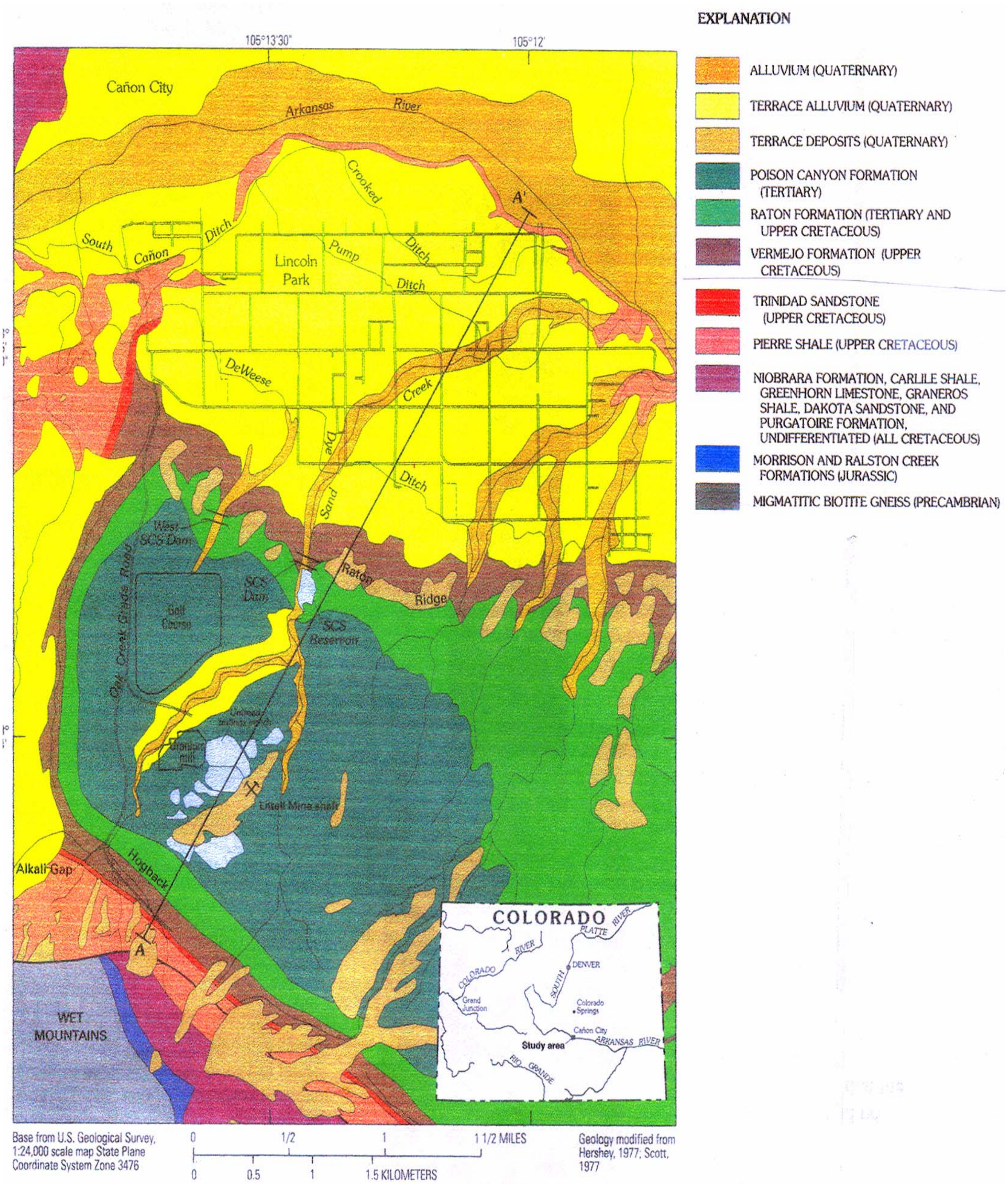


Figure 3 Hypothesized near-surface pathways of contaminant migration and locations of selected ground-water sites.

Chafin & Banta (1999), p. 8

Patterson 2007

Figure 1f



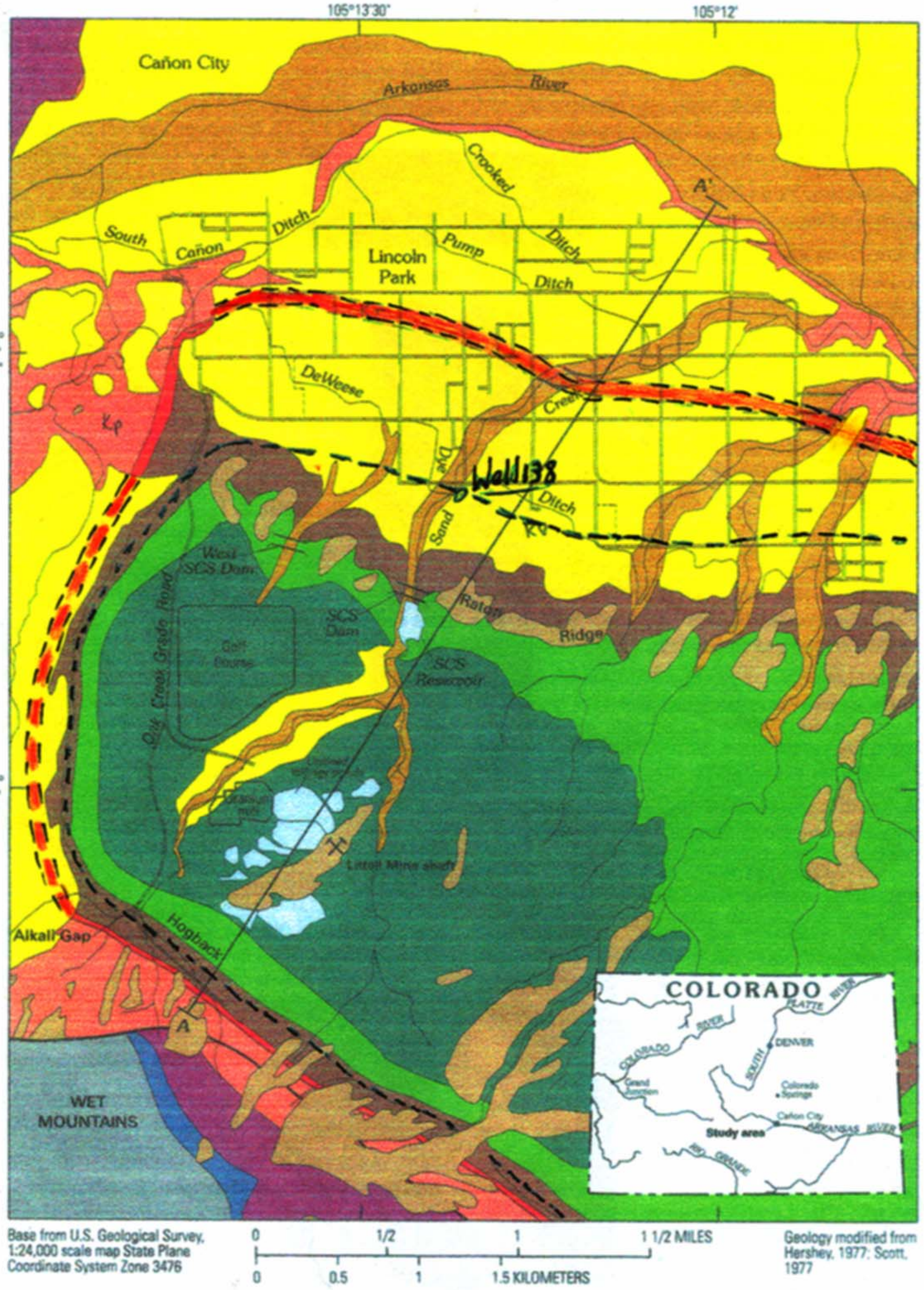
Chafin & Banta (1999), p. 4

Patterson 2007
Figure 2a

(From Chafin & Banta, USGS, 1999, p.4) Modified by Patterson to show outcrop (subcrop where covered by alluvium) of the Trinidad Sandstone and Wolf Park Coal Seam in Lincoln Park.

Wolf Park Coal Seam

Trinidad Sandstone



Base from U.S. Geological Survey, 1:24,000 scale map State Plane Coordinate System Zone 3476

Geology modified from Hershey, 1977; Scott, 1977

Patterson 2007
Figure 2b

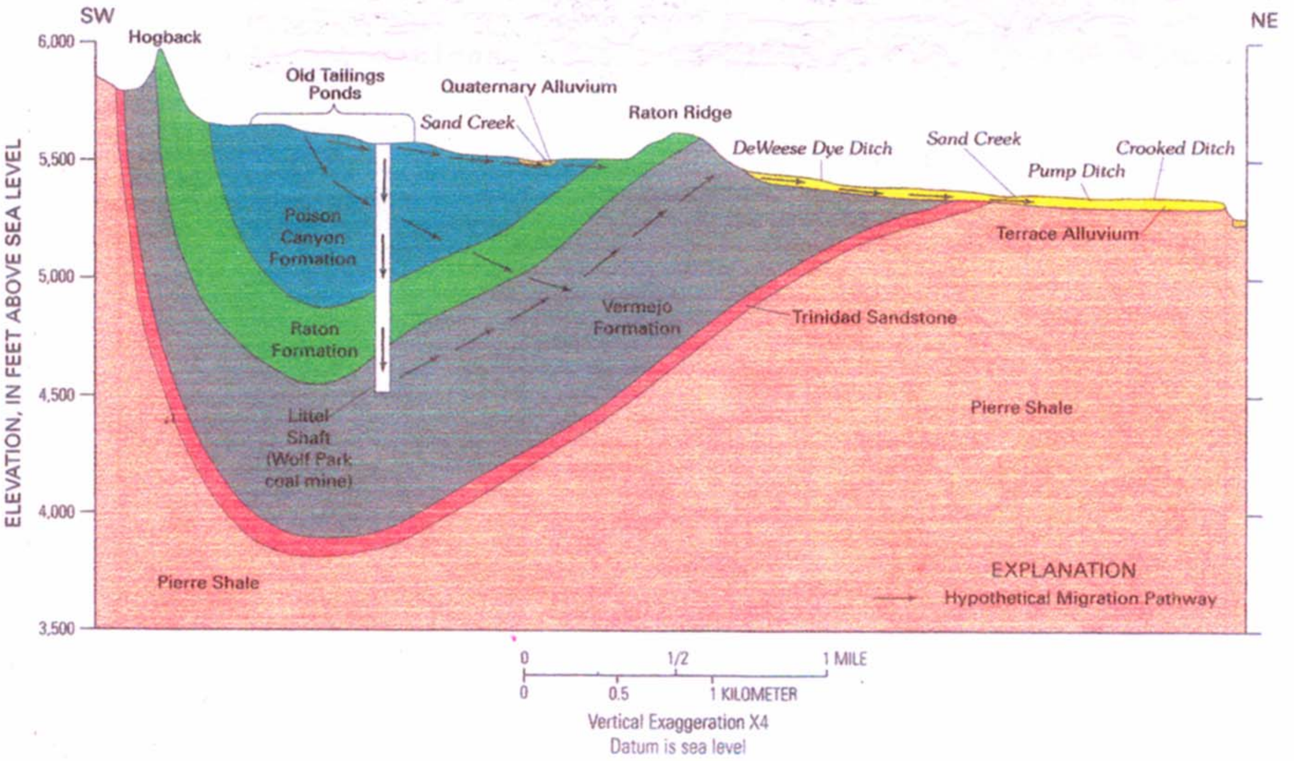
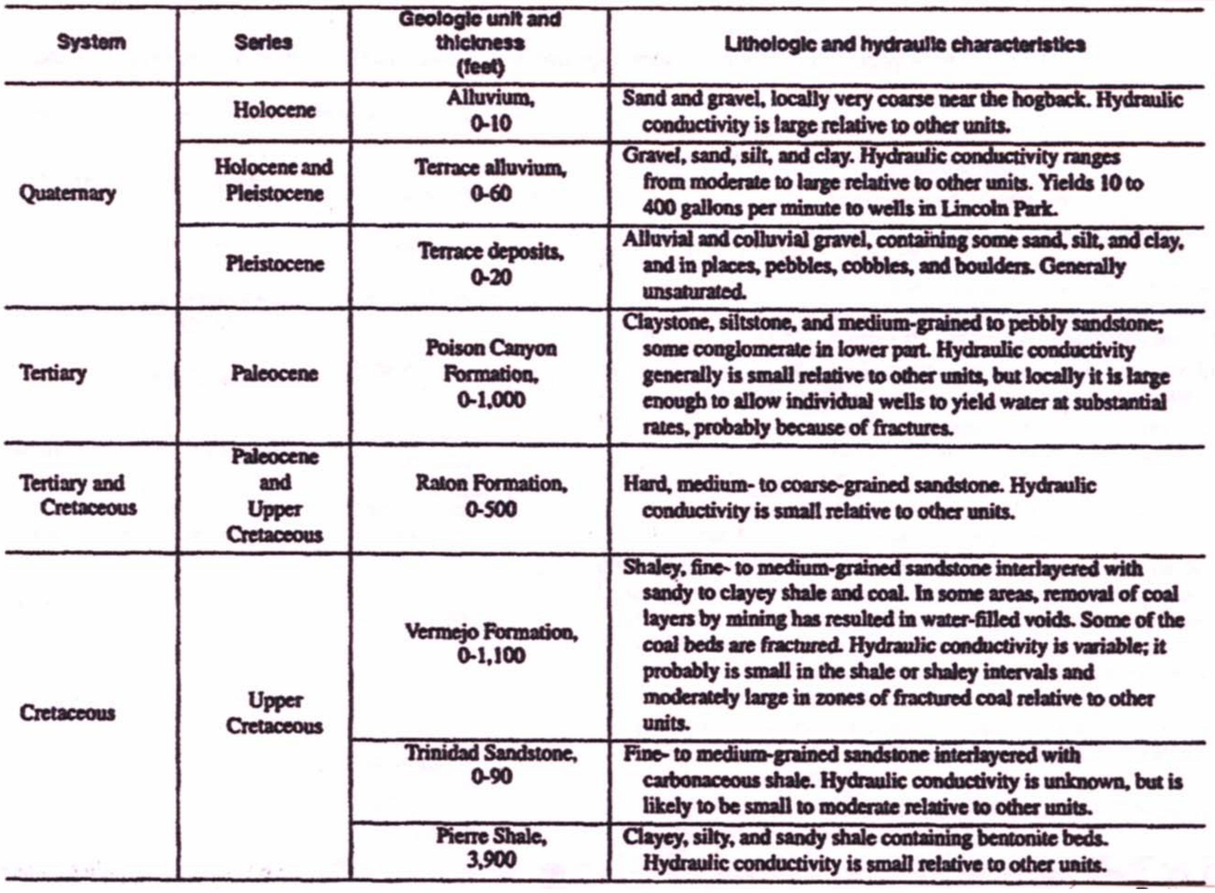


Figure 2. Geologic section of the study area. Location of Littell shaft projected onto line of section (line of section is shown in fig. 1).



System	Series	Geologic unit and thickness (feet)	Lithologic and hydraulic characteristics
Quaternary	Holocene	Alluvium, 0-10	Sand and gravel, locally very coarse near the hogback. Hydraulic conductivity is large relative to other units.
	Holocene and Pleistocene	Terrace alluvium, 0-60	Gravel, sand, silt, and clay. Hydraulic conductivity ranges from moderate to large relative to other units. Yields 10 to 400 gallons per minute to wells in Lincoln Park.
	Pleistocene	Terrace deposits, 0-20	Alluvial and colluvial gravel, containing some sand, silt, and clay, and in places, pebbles, cobbles, and boulders. Generally unsaturated.
Tertiary	Paleocene	Poison Canyon Formation, 0-1,000	Claystone, siltstone, and medium-grained to pebbly sandstone; some conglomerate in lower part. Hydraulic conductivity generally is small relative to other units, but locally it is large enough to allow individual wells to yield water at substantial rates, probably because of fractures.
Tertiary and Cretaceous	Paleocene and Upper Cretaceous	Raton Formation, 0-500	Hard, medium- to coarse-grained sandstone. Hydraulic conductivity is small relative to other units.
Cretaceous	Upper Cretaceous	Vermejo Formation, 0-1,100	Shaley, fine- to medium-grained sandstone interlayered with sandy to clayey shale and coal. In some areas, removal of coal layers by mining has resulted in water-filled voids. Some of the coal beds are fractured. Hydraulic conductivity is variable; it probably is small in the shale or shaley intervals and moderately large in zones of fractured coal relative to other units.
		Trinidad Sandstone, 0-90	Fine- to medium-grained sandstone interlayered with carbonaceous shale. Hydraulic conductivity is unknown, but is likely to be small to moderate relative to other units.
		Pierre Shale, 3,900	Clayey, silty, and sandy shale containing bentonite beds. Hydraulic conductivity is small relative to other units.

Banta & Chafin (1999), p. 6-7

Patterson 2007
Figure 2c

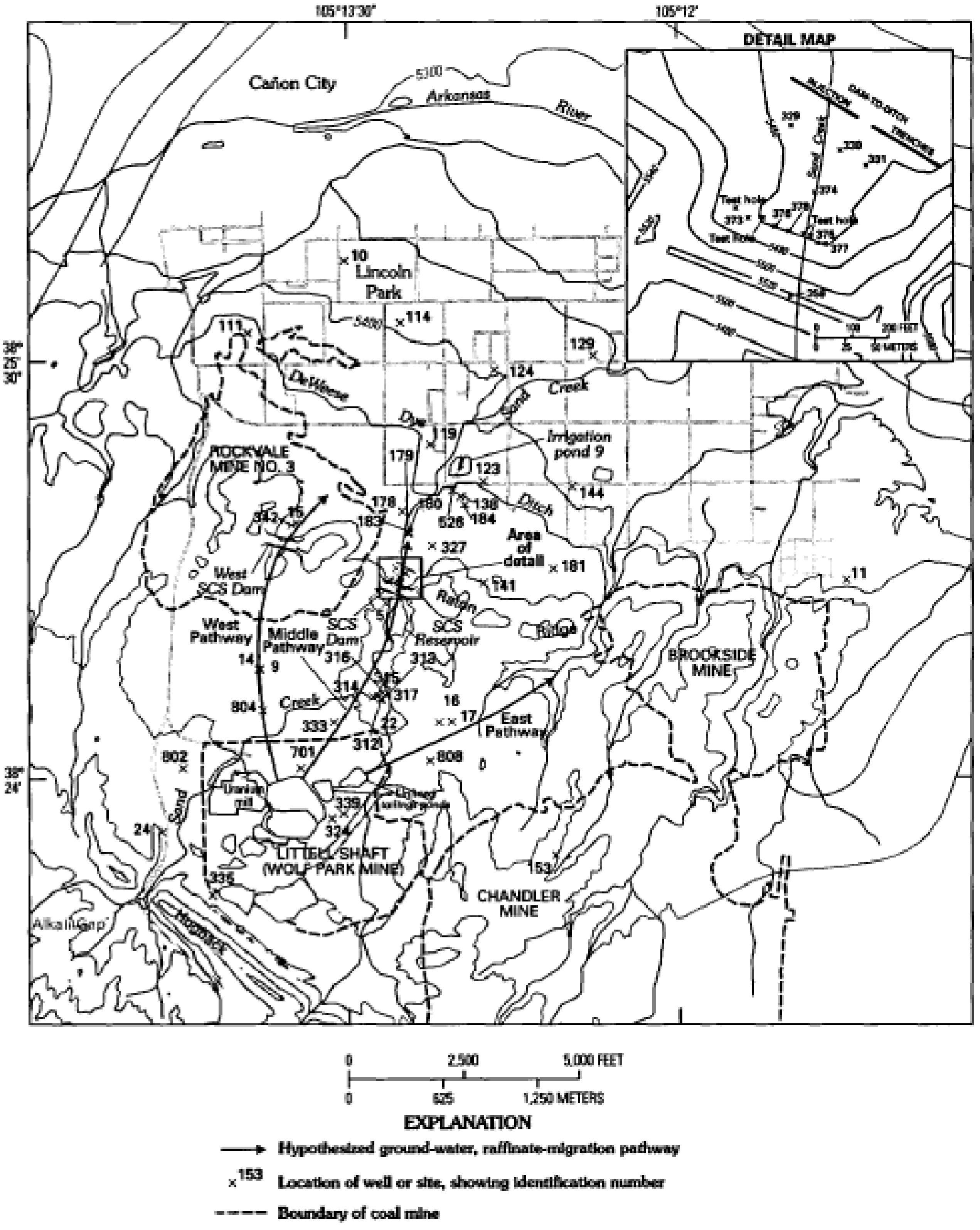
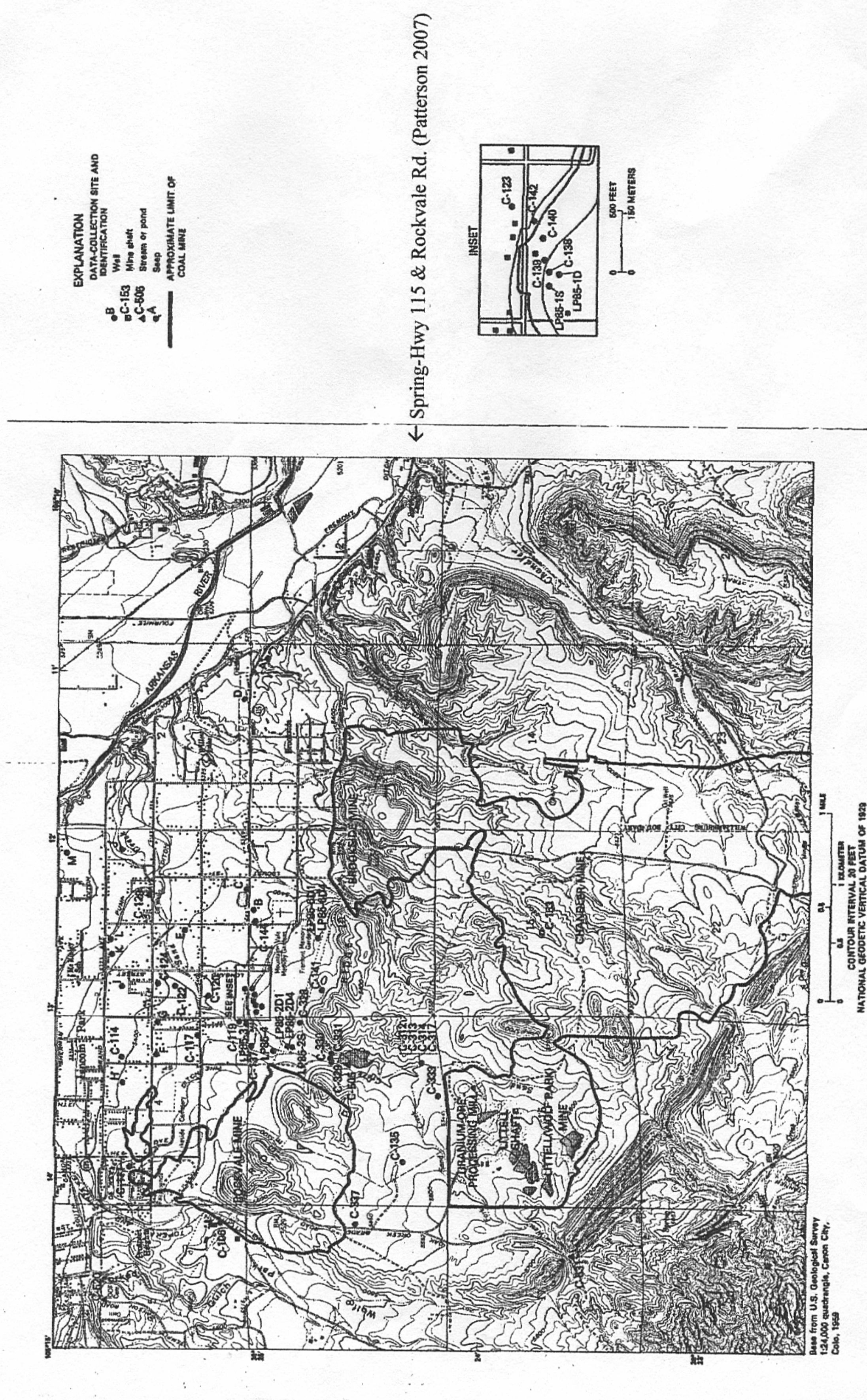


Figure 3. Hypothesized near-surface pathways of contaminant migration and locations of selected ground-water sites.

Chafin & Banta (1999), p. 8

Patterson 2007
Figure 2d



← Spring-Hwy 115 & Rockvale Rd. (Patterson 2007)

Hearne & Litke, 1987, p. 9

Figure 2.--Location of data-collection sites and coal mines.

Patterson 2007

Figure 2di

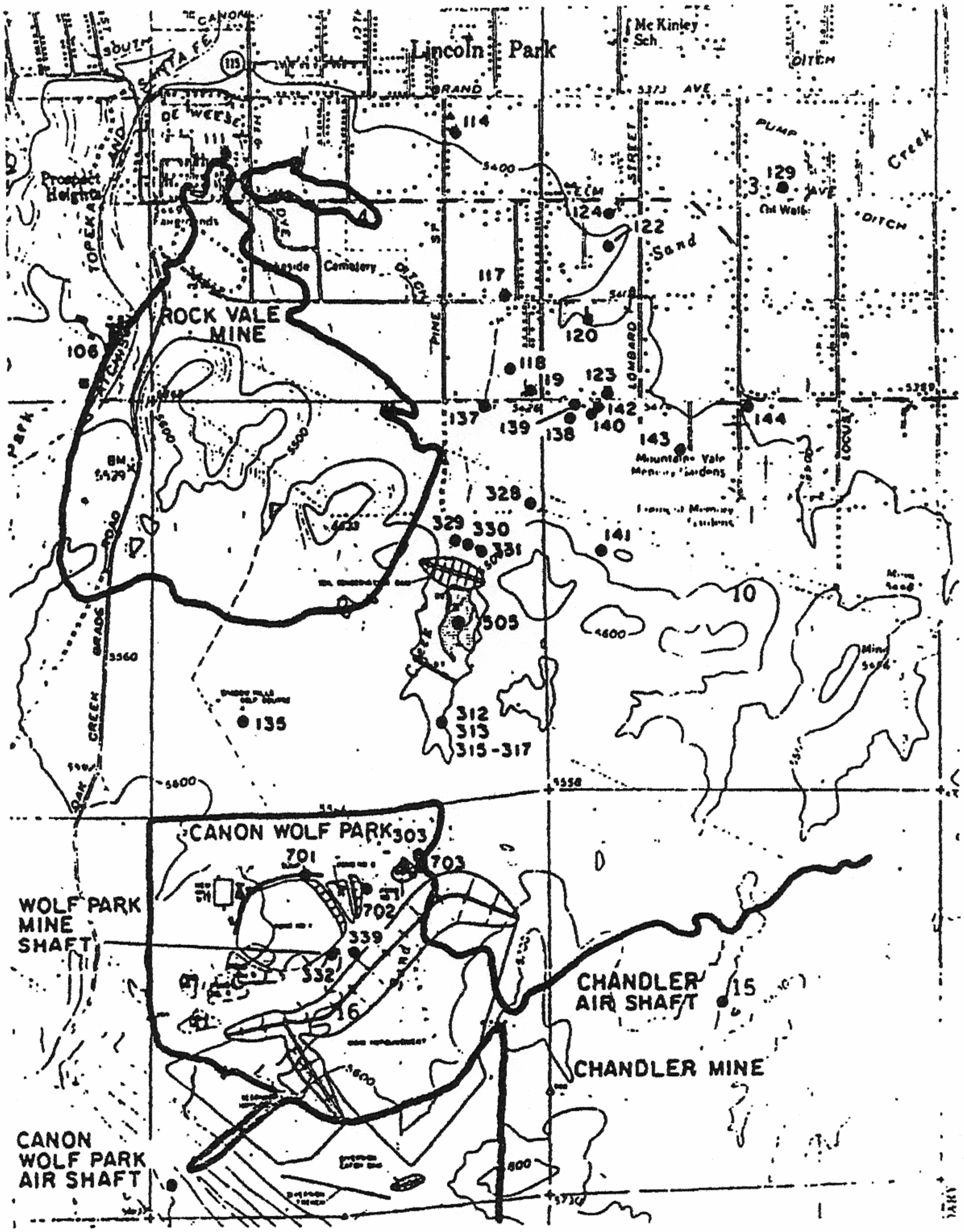
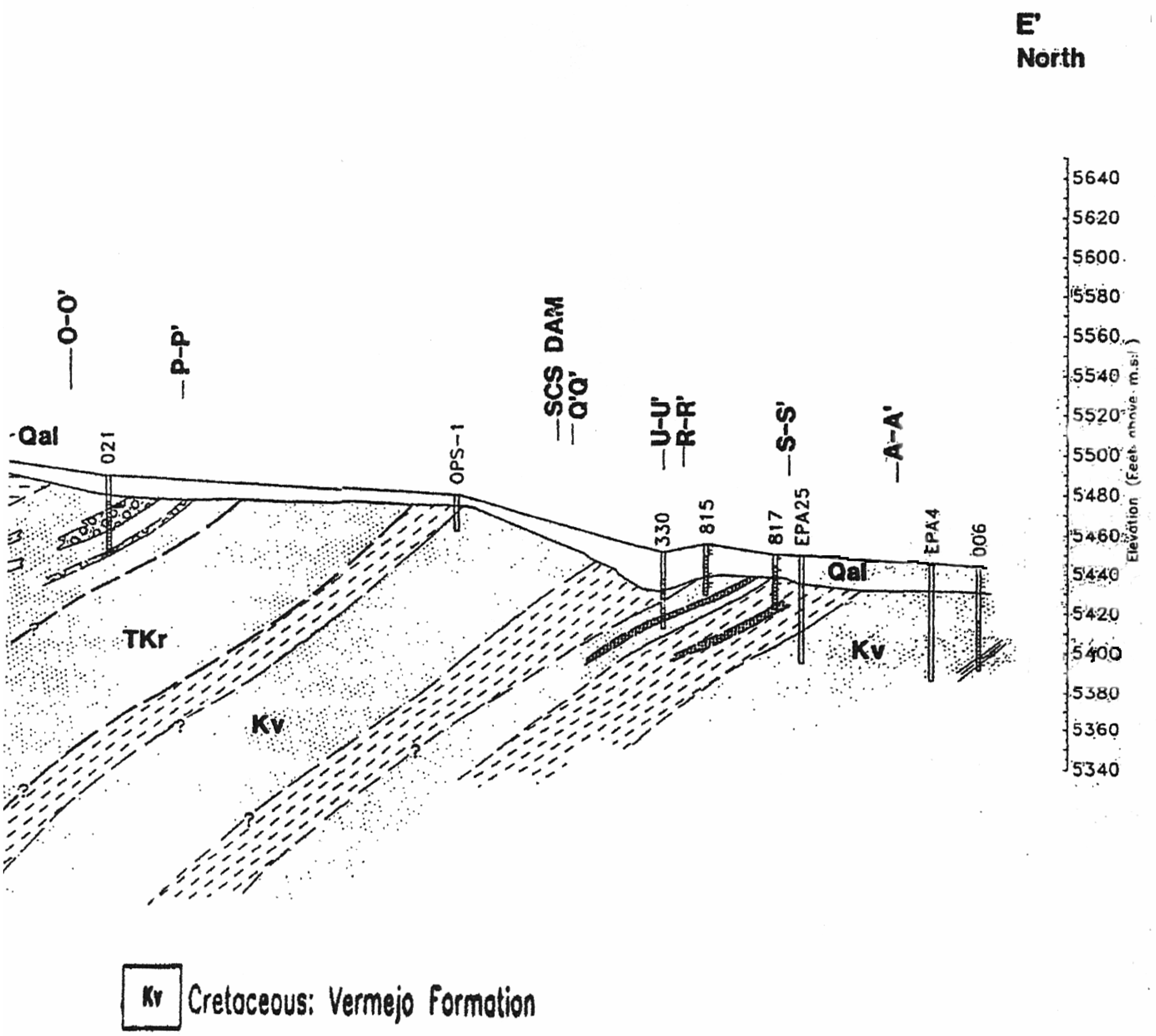


Figure 5-3. Underground coal mine workings in the vicinity of Cotter Corporation and Lincoln Park at Canon City, Colorado (after Fred C. Hart, 1982[102]).

GCA Corporation (1983), p. 5-5 Patterson 2007

Figure 2dii



Stephens, 1993. (Figure 7, *Geologic Cross-Section E-E'*)

[Note: EPA4 = LP85-4]

Patterson 2007
Figure 2e

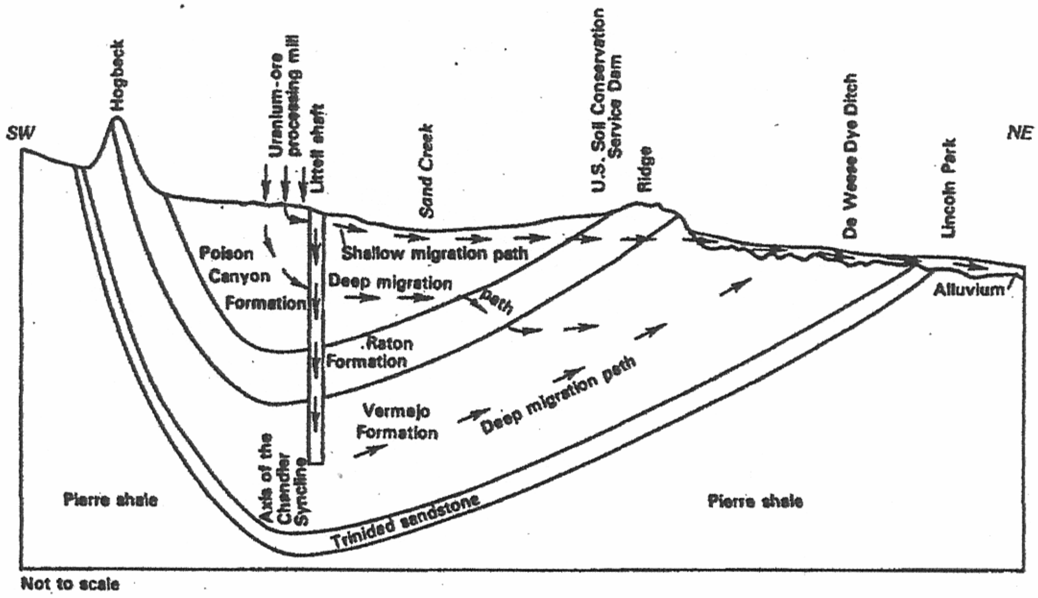
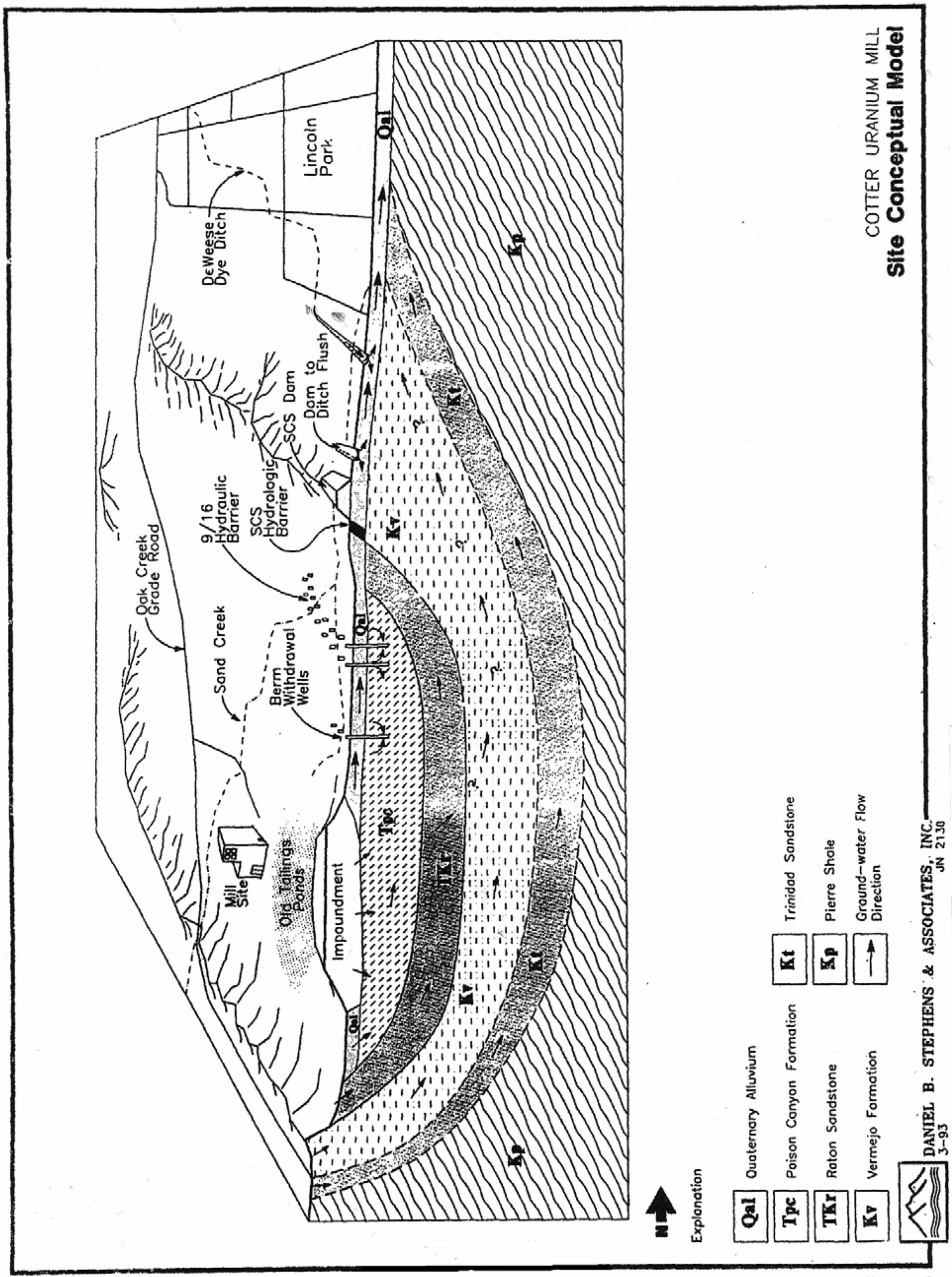


Figure 3.--Generalized geologic section normal to the Chandler syncline showing potential ground-water migration paths from the uranium-ore processing mill to Lincoln Park.

"Test well LP85-1D (fig. 5) was drilled with air through 10 ft of unsaturated alluvium and 78 ft into the Vermejo Formation (total depth 88 ft), encountering water under artesian pressure in a coal seam at a depth of 83 ft. The test well is 165 ft south of well C-138. Assuming an eastward strike and a dip of about 5° south, the coal penetrated by test well LP85-1D would be near the bottom of well C-138," (p.16).

Hearne and Litke (1987), Figure 3, p. 11; Text p. 16

Patterson 2007
Figure 2ei



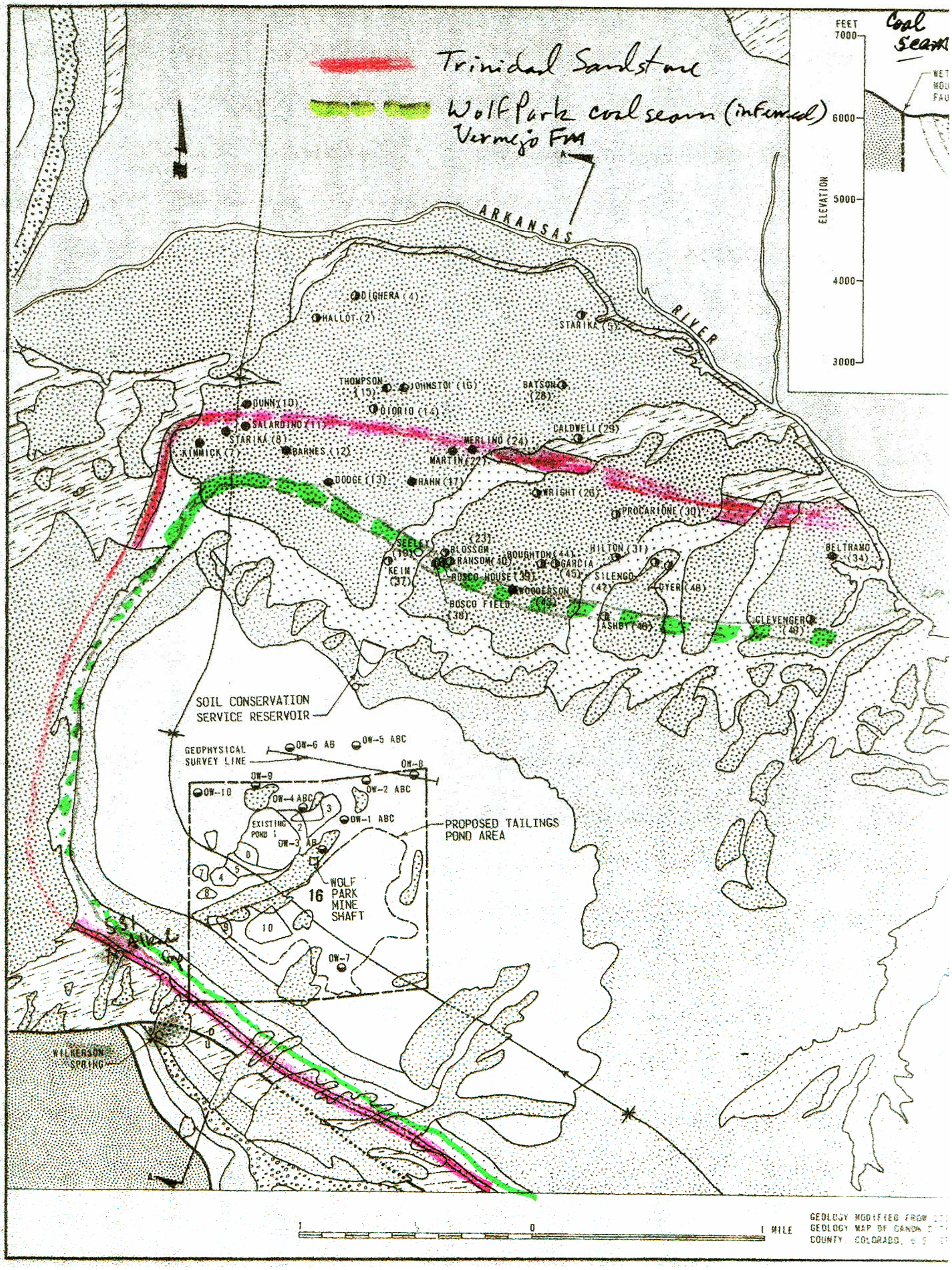
Stephens, D.B. & Associates, Inc. (1993), Figure 2, Vol III

Figure 2

Patterson 2007

Figure 2eii

Wahler, W.A. & Associates. 1978. *Investigations Related to the Migration of Raffinates from the Existing Cotter Tailings Impoundments.* For Cotter Corporation. (following p. II-3)



Patterson 2007

Figure 2f

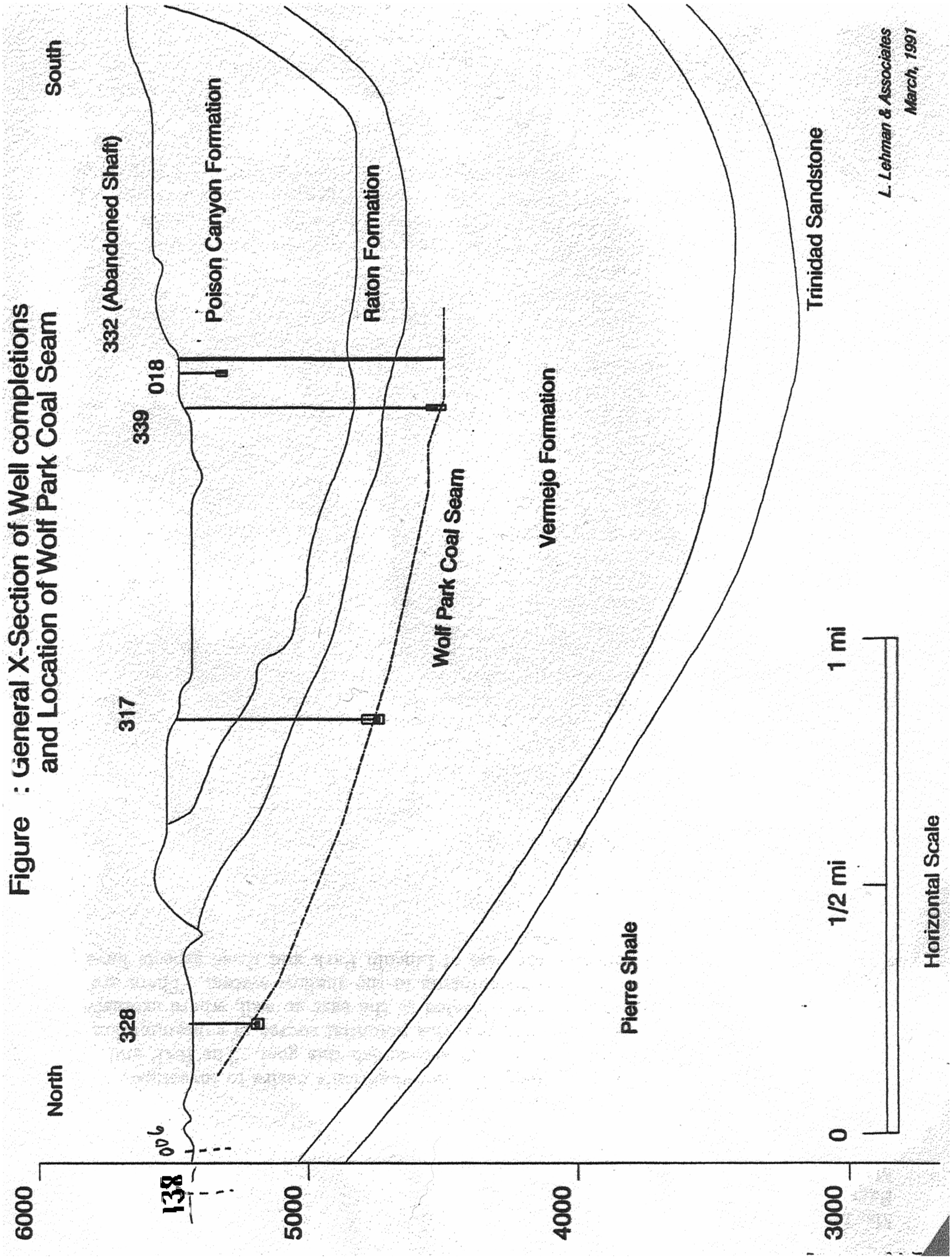


Figure : General X-Section of Well completions and Location of Wolf Park Coal Seam

Patterson 2007
Figure 2g

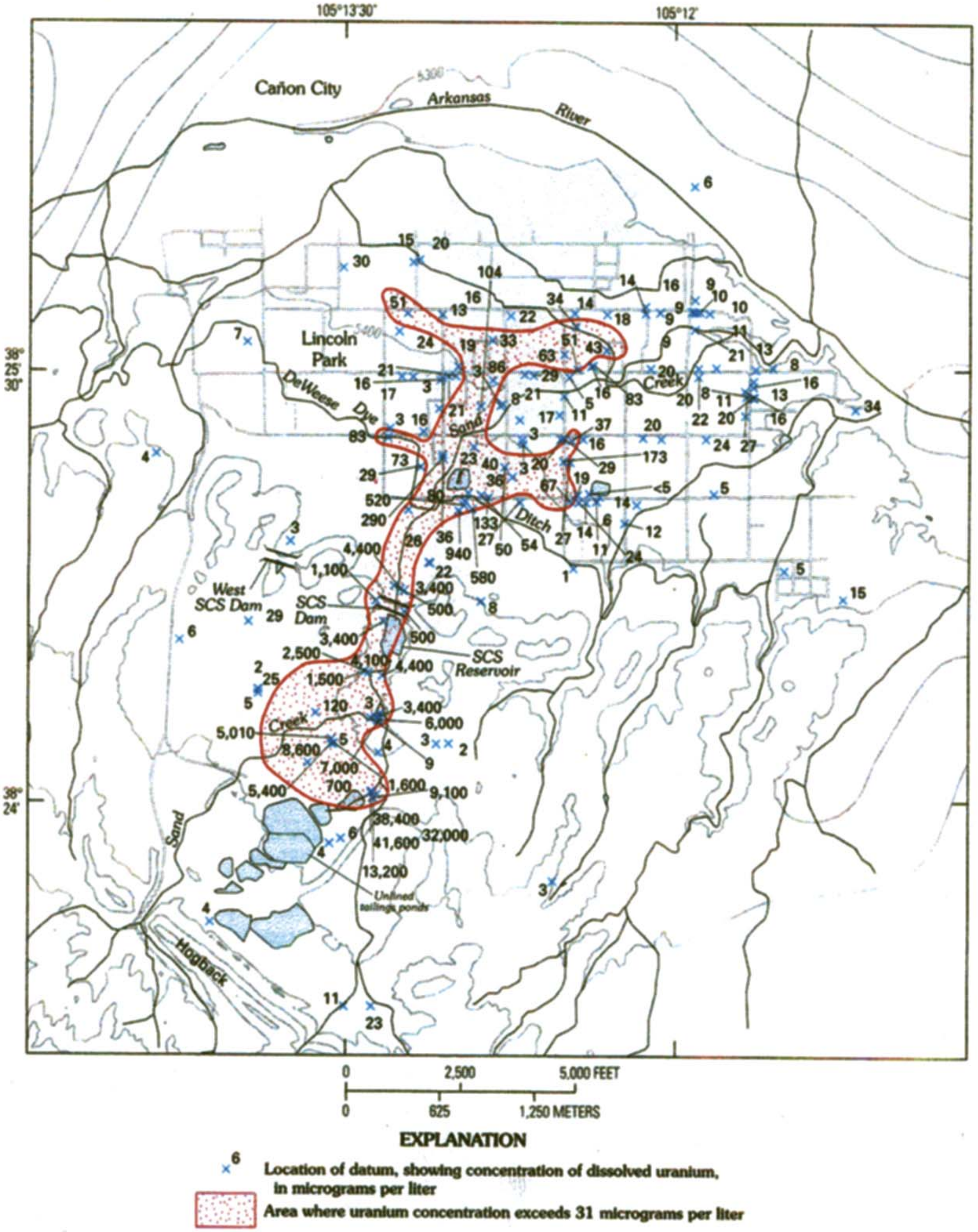
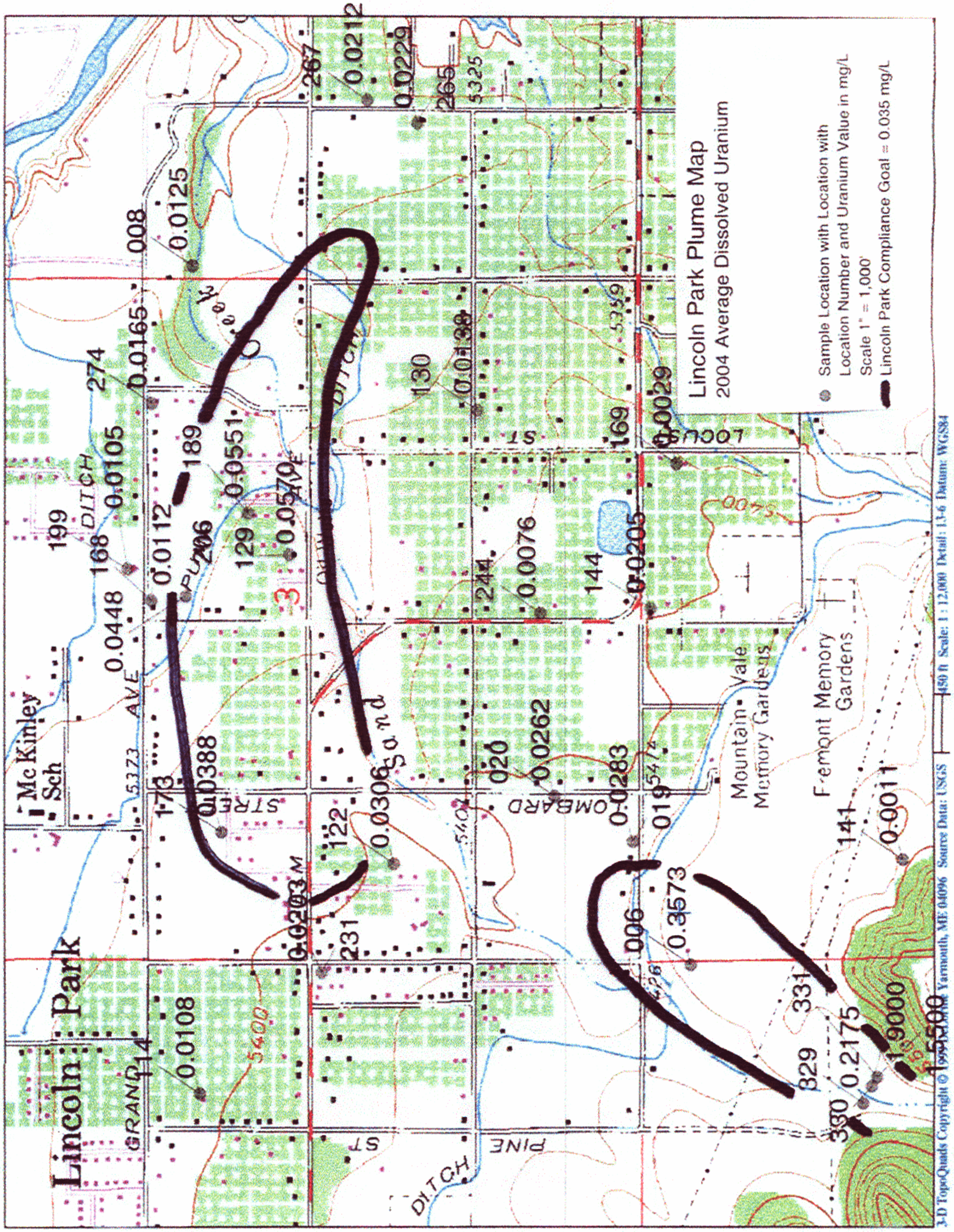


Figure 4. Distribution of maximum dissolved-uranium concentrations in water from wells less than 100 feet deep, 1987–89.

Chafin & Banta, 1999, p12

Patterson 2007
Figure 3a

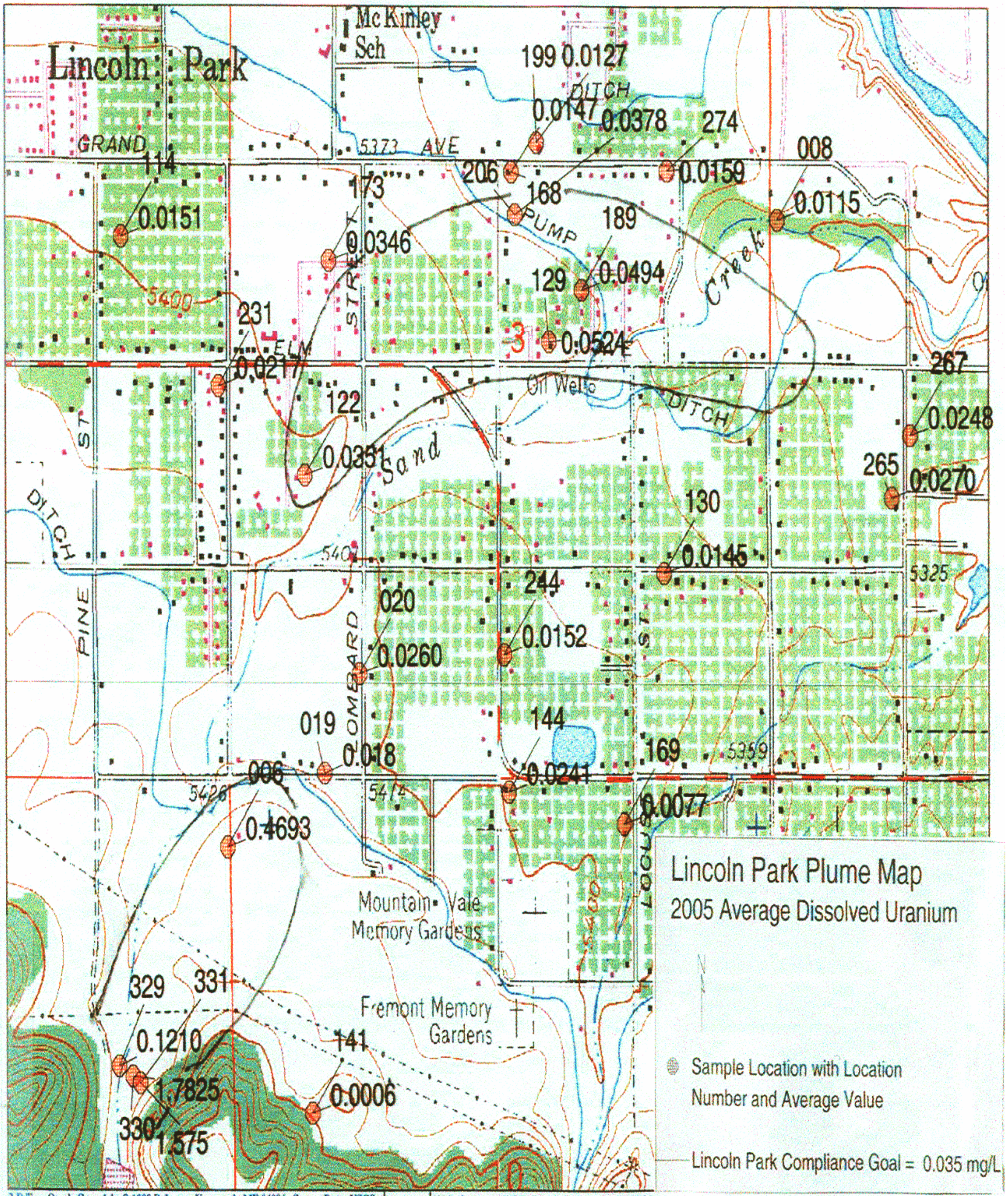
Figure 7-23 Plume Map for dissolved Uranium in groundwater below Lincoln Park.



Cotter (2005), p. 7-21

Patterson 2007
Figure 3ai

Figure 7-26 Plume Map for dissolved Uranium in groundwater below Lincoln Park



3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 Source Data: USGS 450 ft Scale: 1 : 12,000 Detail: 13-1 Datum: WGS84

Cotter (2006), p. 7-21

Patterson 2007
Figure 3aii

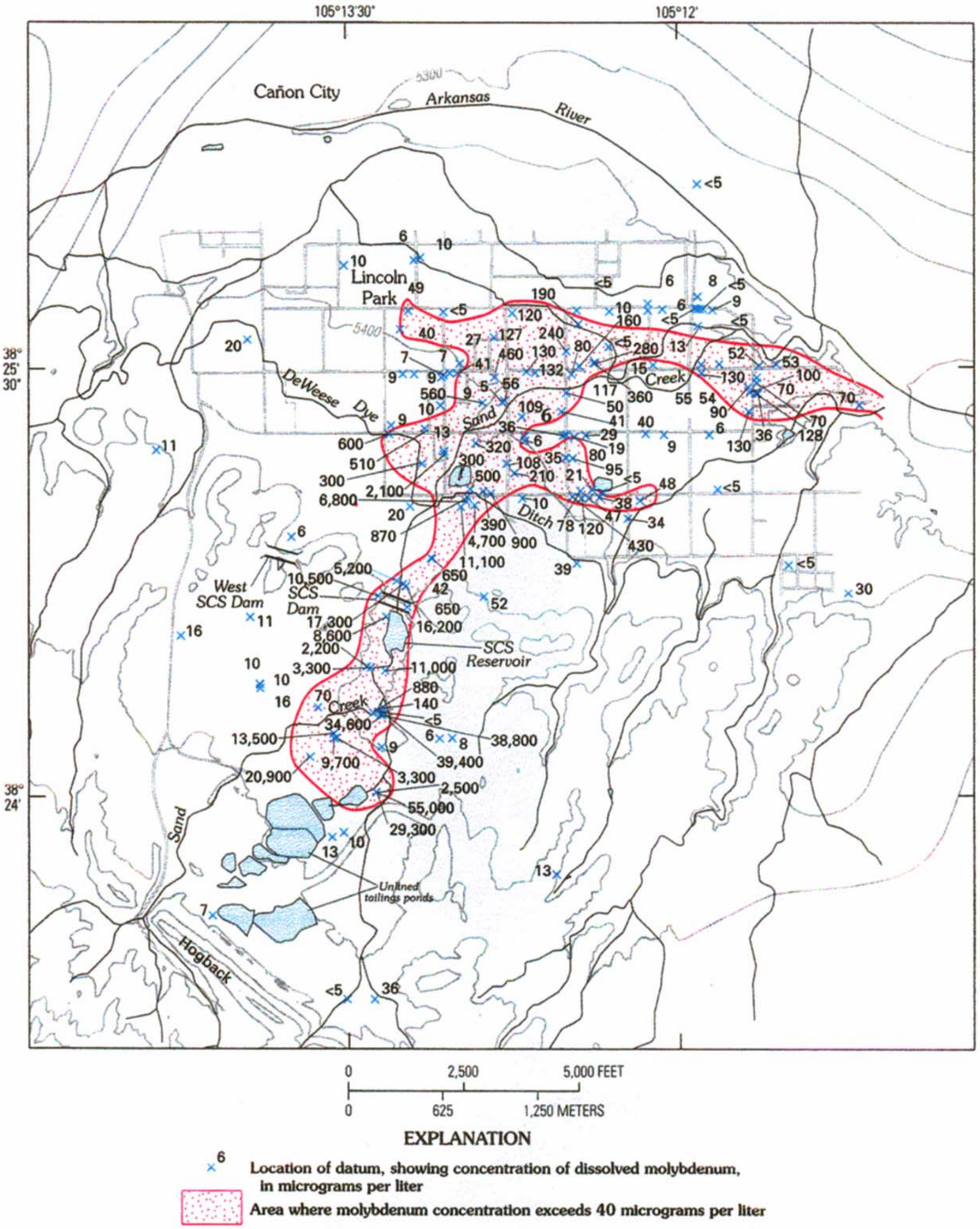
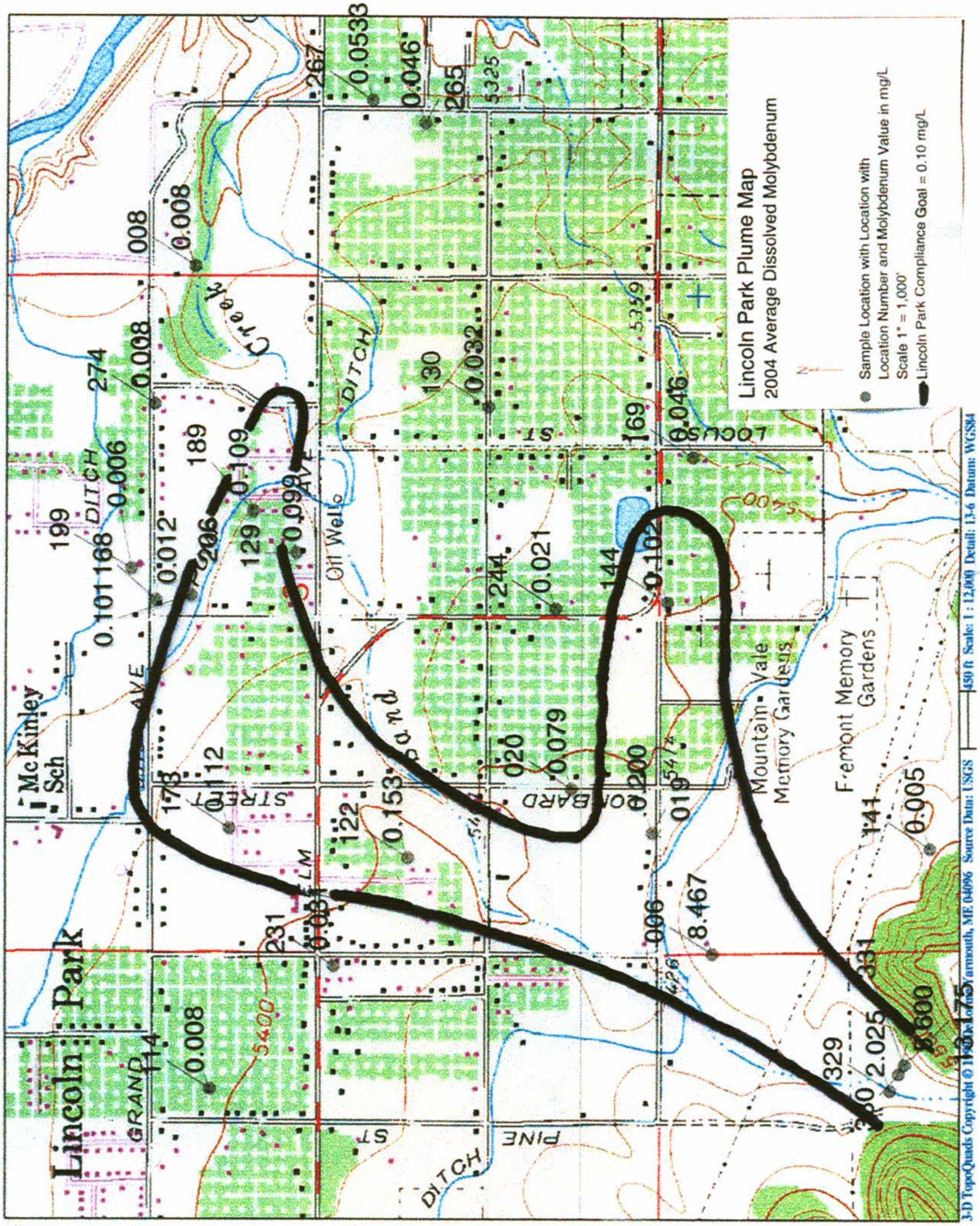


Figure 5. Distribution of maximum dissolved-molybdenum concentrations in water from wells less than 100 feet deep, 1987–89.

Chafin & Banta (1999), p. 13

Patterson 2007
Figure 3b

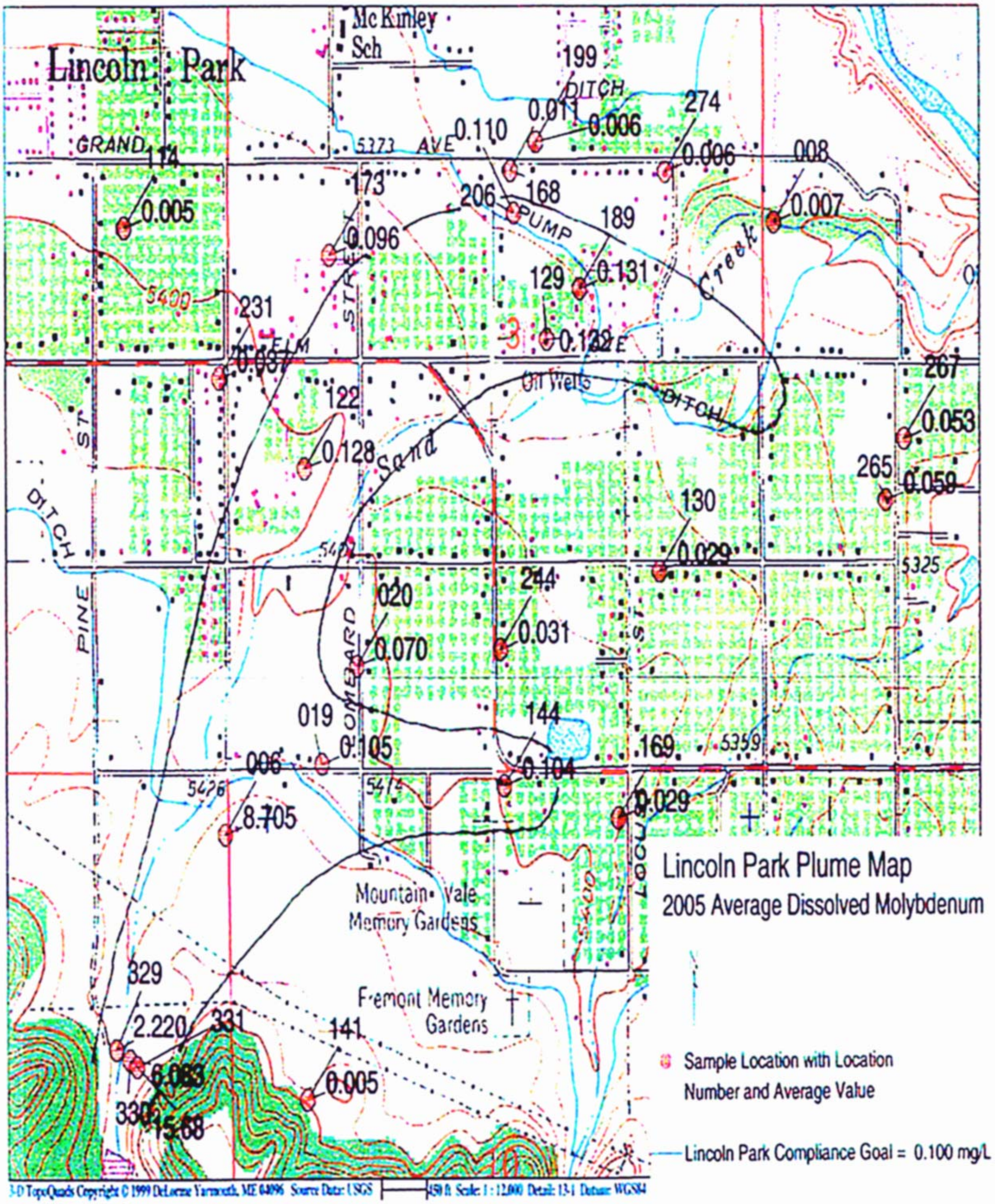
Figure 7-22 Plume Map for dissolved Molybdenum in groundwater below Lincoln Park.



Cotter (2005), p. 7-20

Patterson 2007
Figure 3bi

Figure 7-25 Plume Map for dissolved Molybdenum in groundwater below Lincoln Park



3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 Source Data: USGS 450 ft Scale: 1 : 12,000 Detail: 13-1 Datum: WGS84

Cotter (2006), p. 7-20

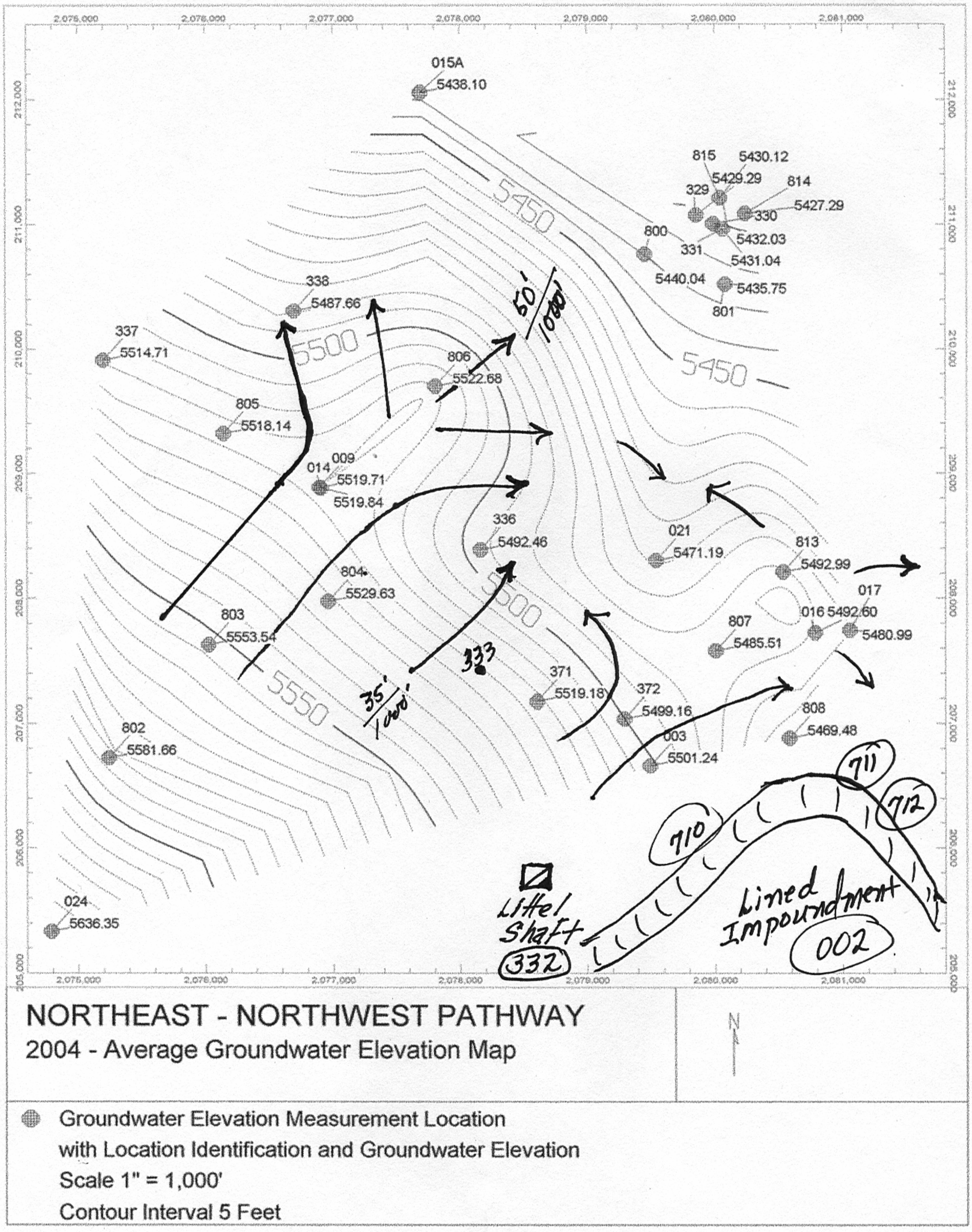
Patterson 2007
Figure 3bii

FIGURE 3c

Transparency of Figure 2b

(Only Available in Printed Copies)

Figure 7-28 Northeast/Northwest Groundwater Elevation Map



Cotter (2005), p. 7-26 [Flow lines, impoundment, Little Shaft, and underdrain locations drawn by Patterson.]

Patterson 2007

Figure 3d

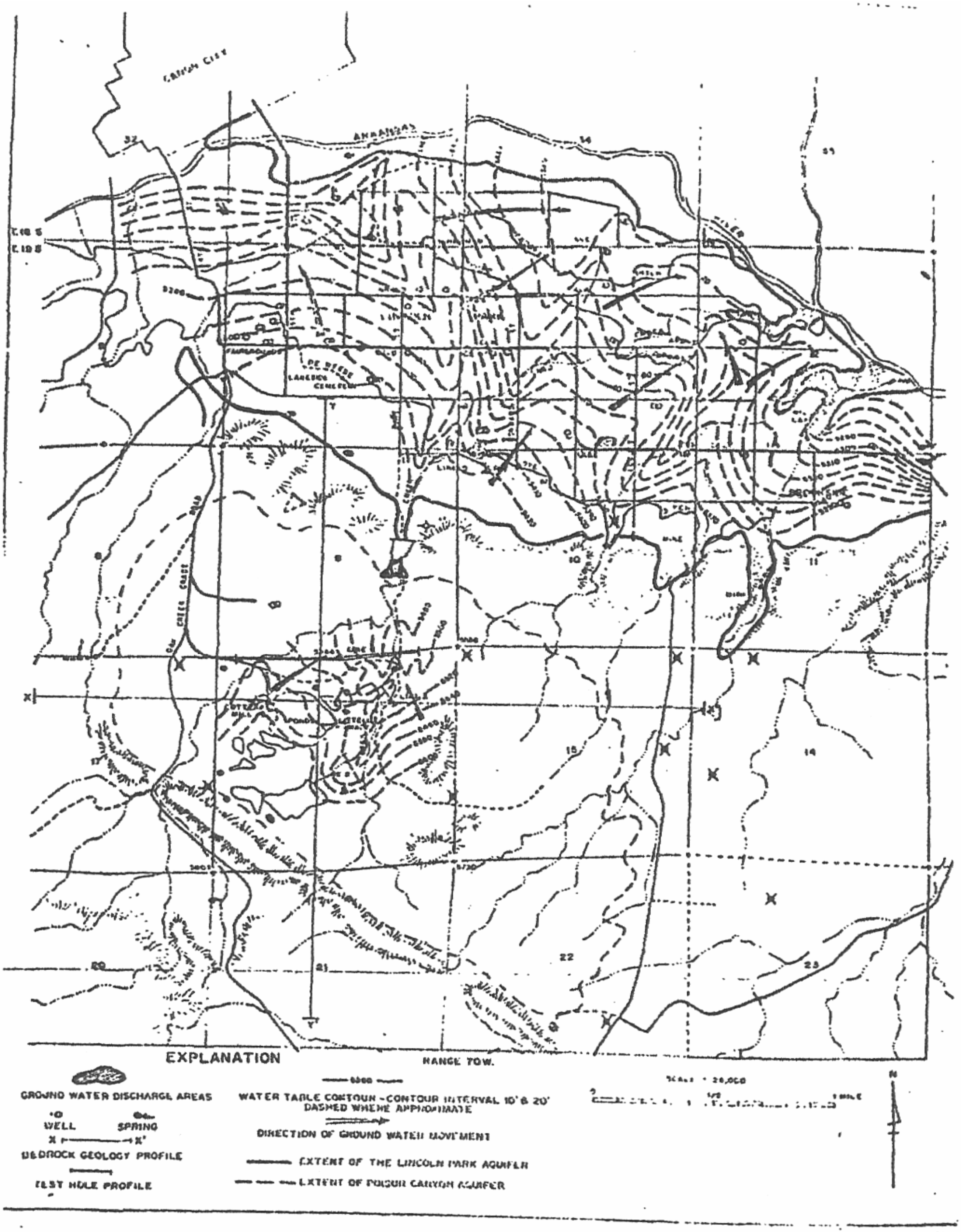


FIG. 10 - WATER TABLE MAP

HERSHEY - WOODLERSON ASSOCIATES, INC
CONSULTING GEOLOGISTS & HYDROLOGISTS
BOX 414
CANON CITY, COLORADO 81212
REVISED

Hershey (1977), p. 34

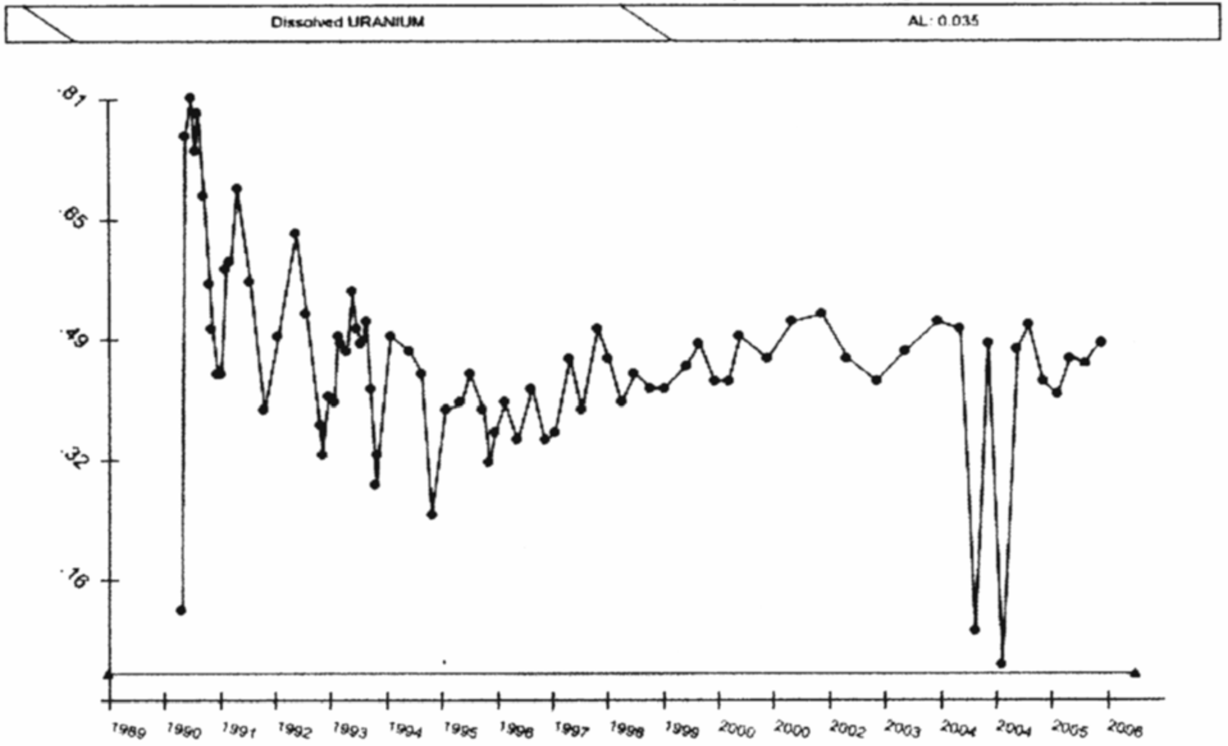
Patterson 2007

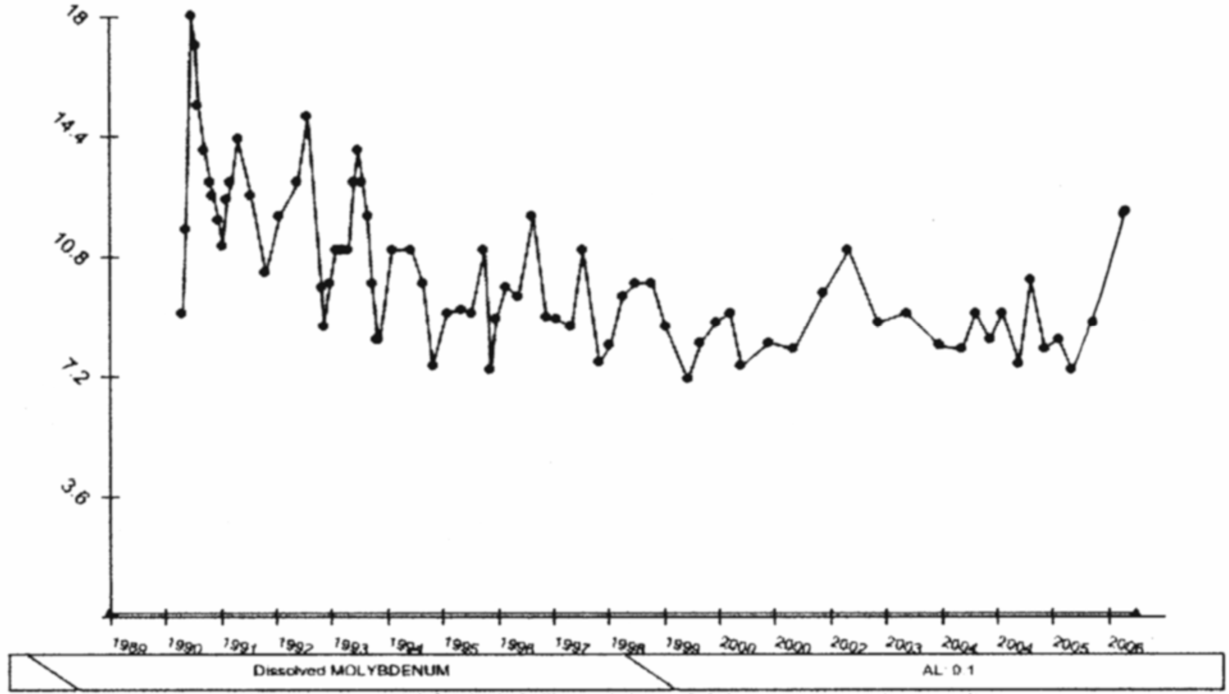
Figure 3di

CDPHE (2006), map provided for Community Advisory Group)

Patterson 2007
Figure 3e

Dissolved URANIUM at 006 reported in mg/L





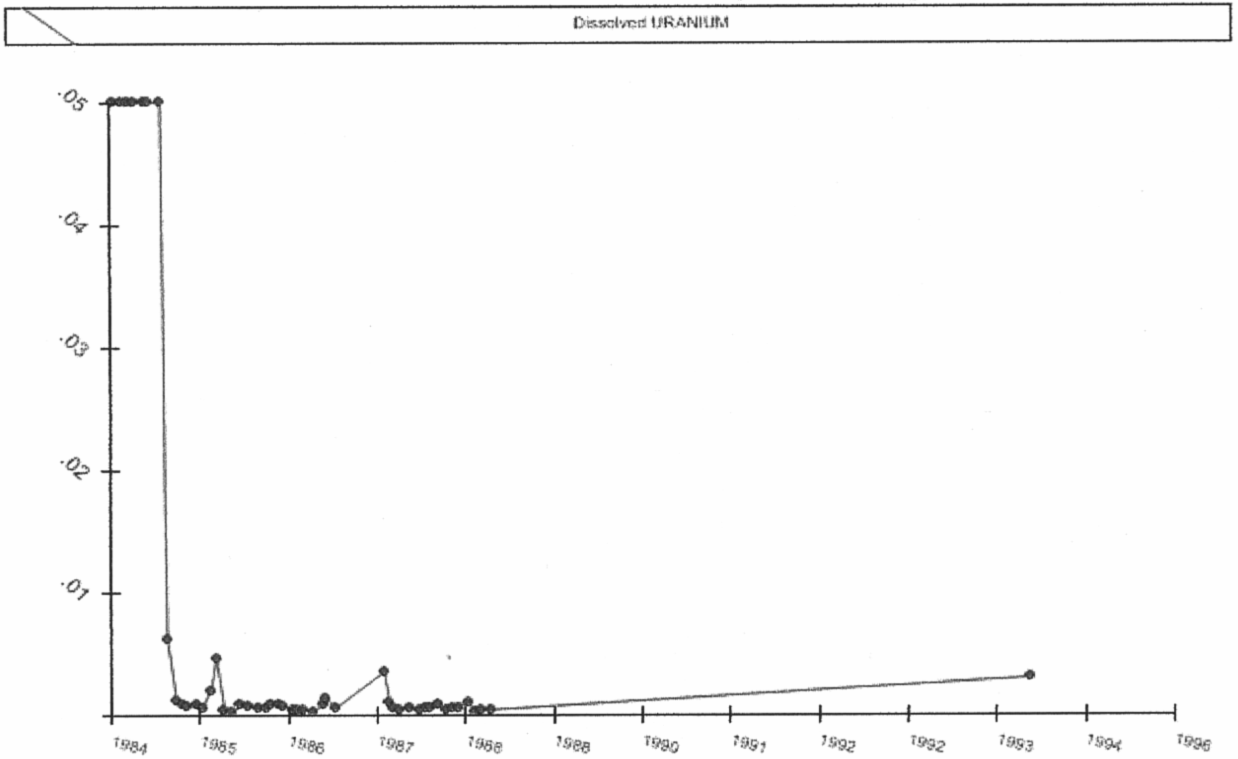
Dissolved MOLYBDENUM at 006 reported in mg/L

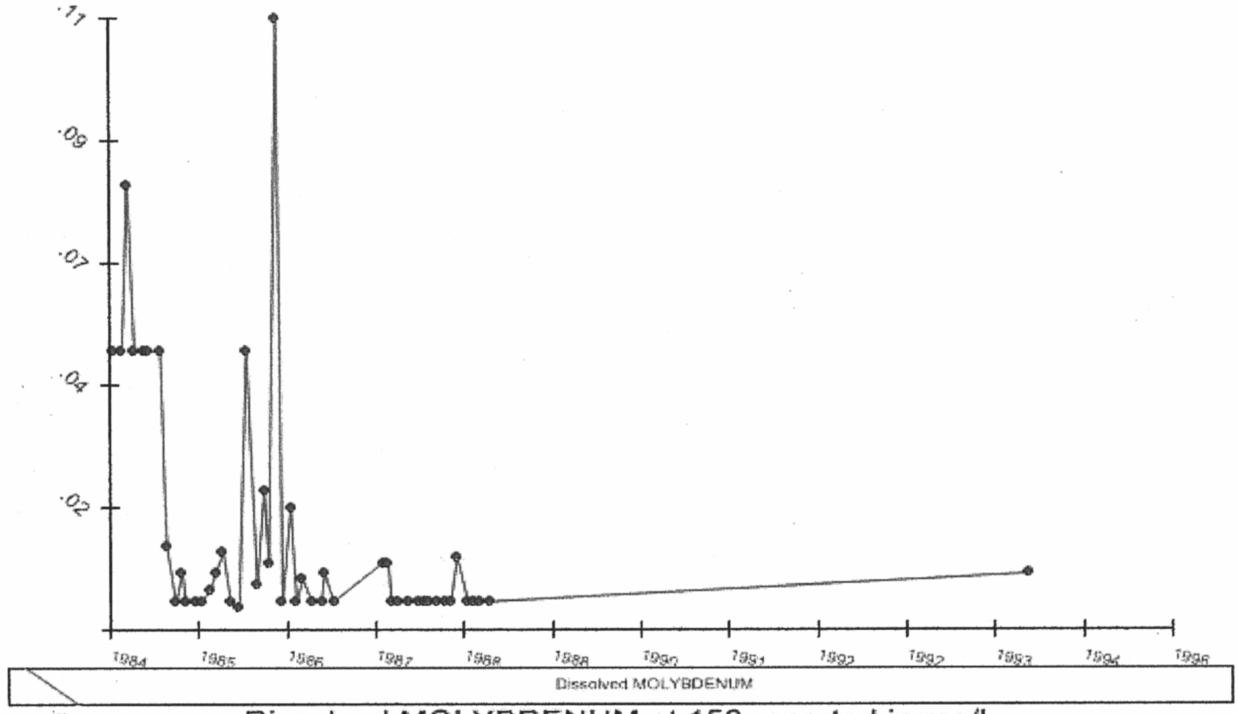
Location Descriptions: **1424 CEDAR (RAP WELL) (006)**

Available at: CDPHE Mapping Application website
[Last two 2006 results added – site not updated]

Patterson 2007
Figure 3f

Dissolved URANIUM at 153 reported in mg/L



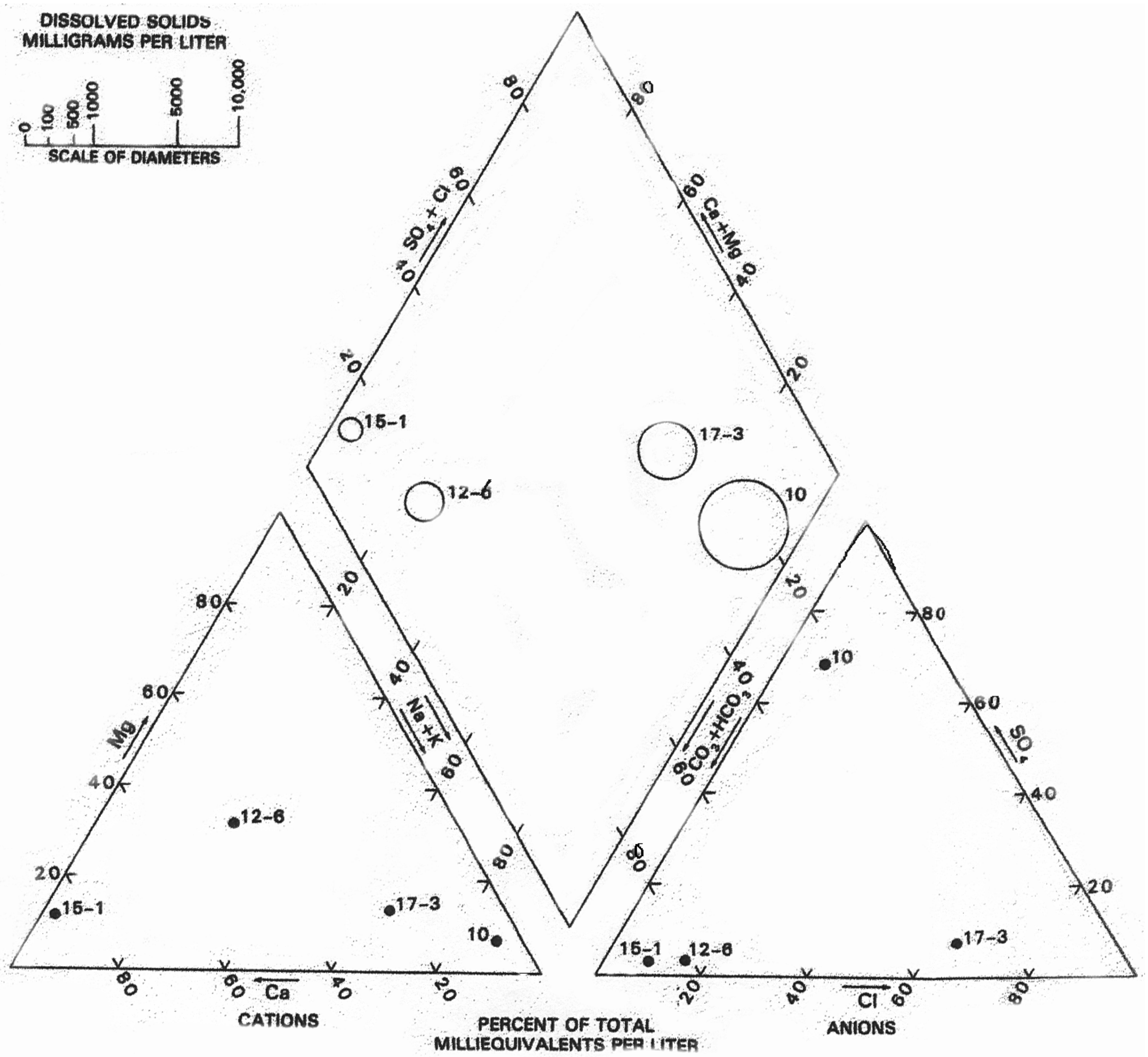


Dissolved MOLYBDENUM at 153 reported in mg/L

Location Descriptions: CHANDLER AIR SHAFT (153)

Available at: CDPHE Mapping Application website

Patterson 2007
Figure 3g



Trilinear diagram showing analyses represented by three-point plotting method.

Hem, J.D. (1992)

Patterson 2007

Figure 4a

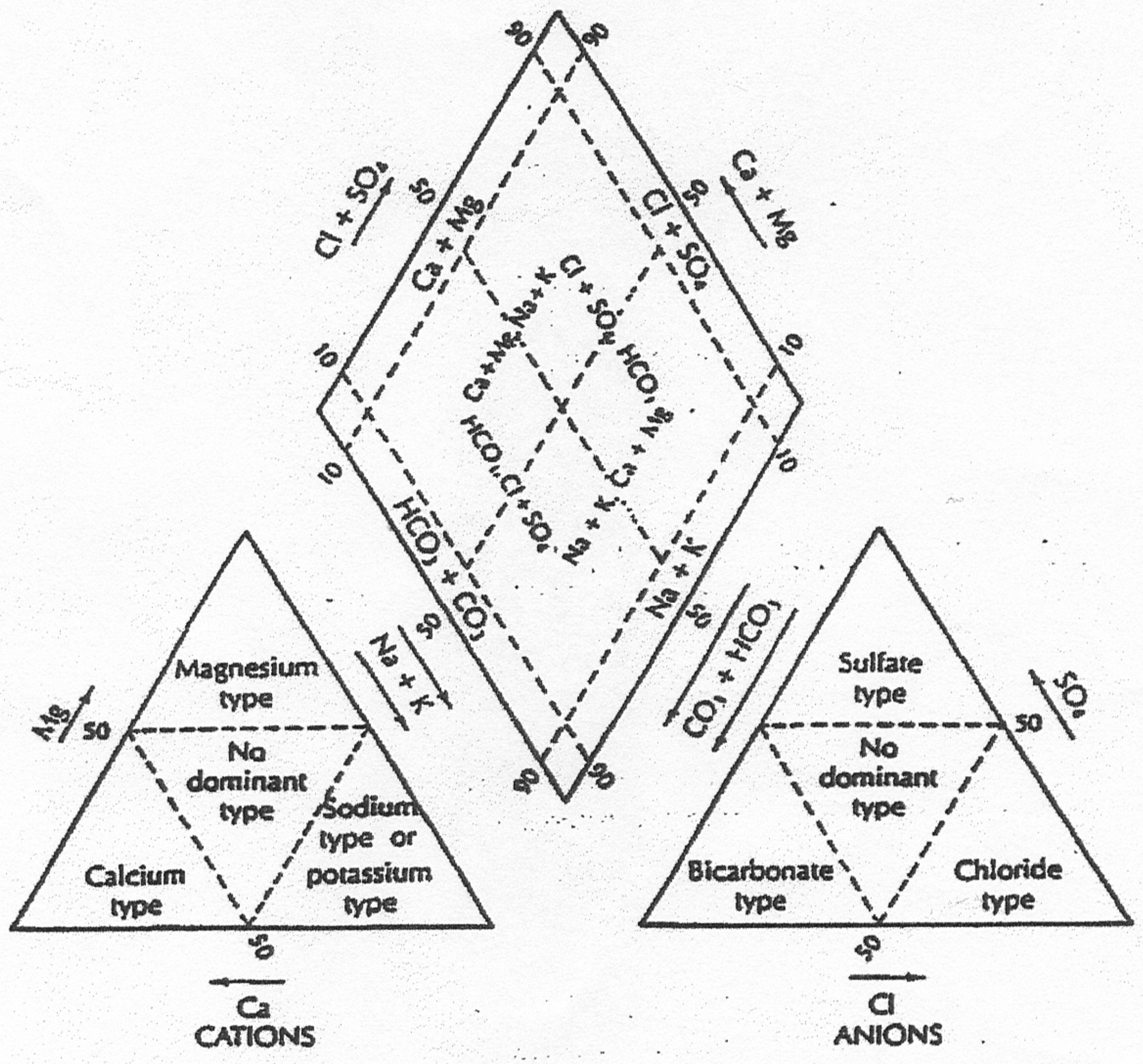


Figure 1. Hydrogeochemical classification system for natural waters using the Piper trilinear diagram.

Hem, J.D. (1992)

Patterson 2007

Figure 4ai

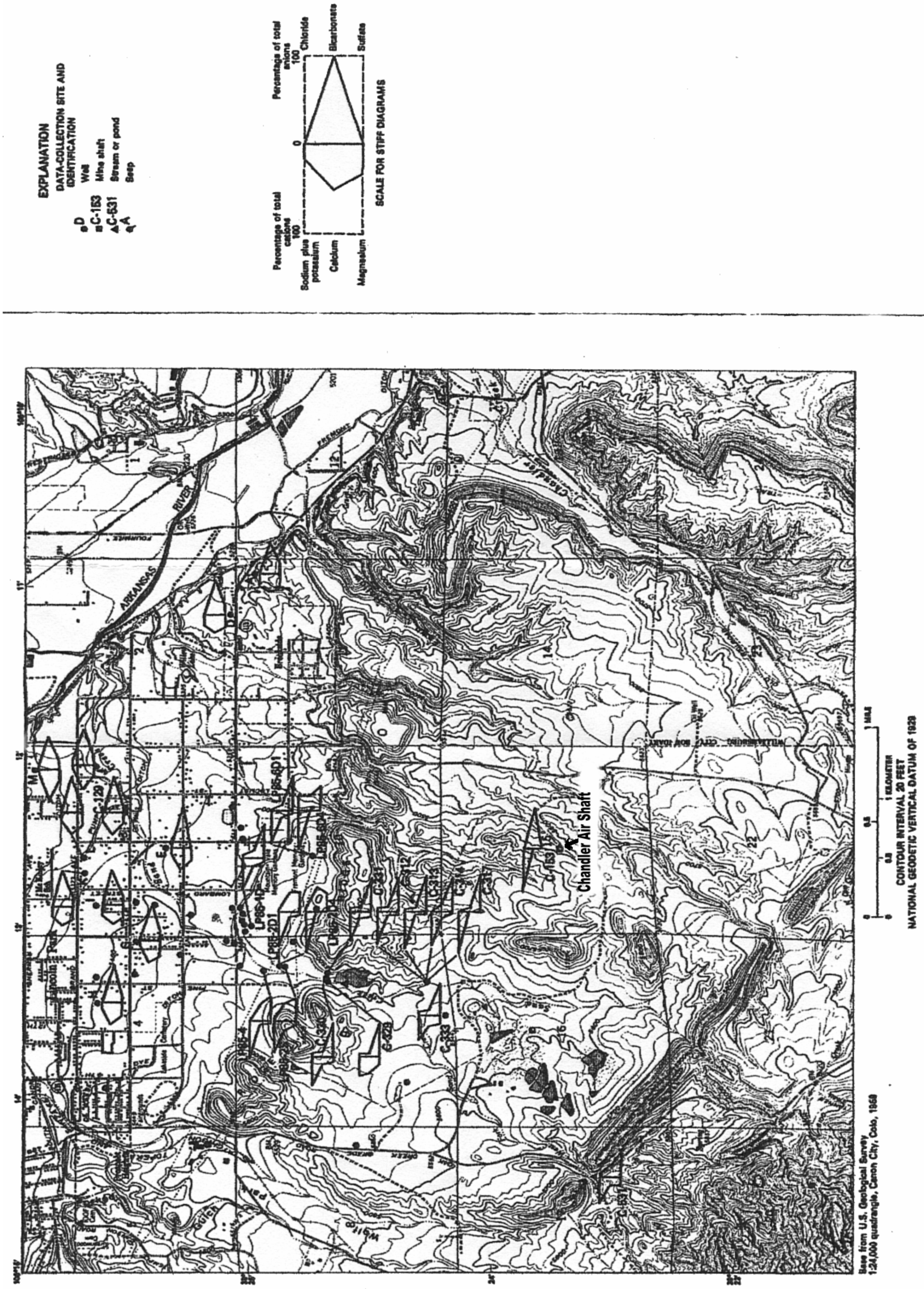


Figure 14.--Proportions of major ions in sampled water.

Hearn & Litke (1987)

Patterson 2007

Figure 4b

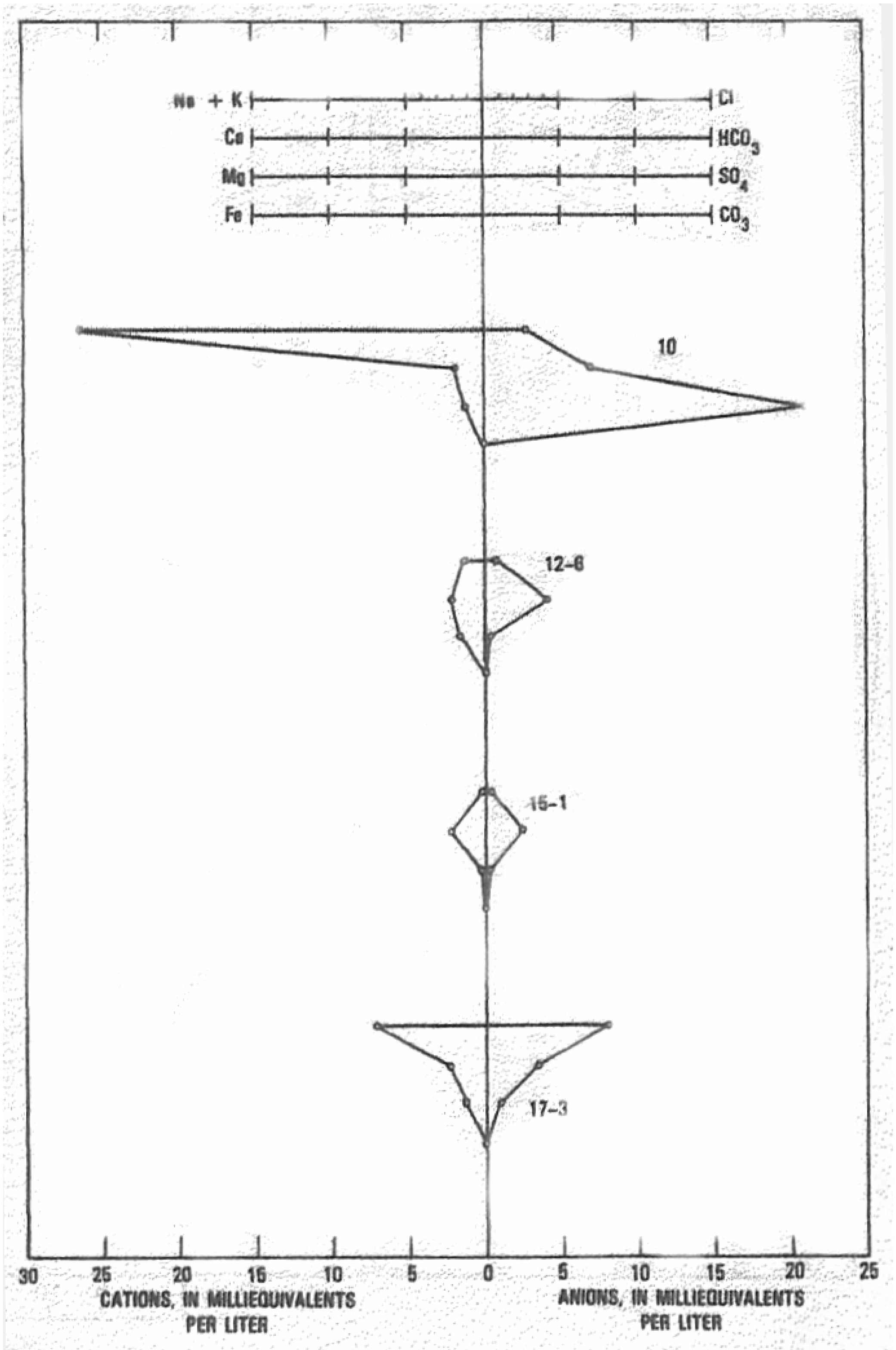


Figure 32. Analyses represented by patterns based on milli-equivalents per liter

Hem, J.D. (1992)

Patterson 2007
Figure 4bi

Characterization of Water from the Vermejo Formation

The major-ion composition of water from the Vermejo Formation is shown in figure 15. None of the water analyses plotted in this figure contained any significant concentrations of raffinate components other than sulfate. The analyses all have sodium as the major cation, but vary considerably in relative proportions of sulfate and bicarbonate.

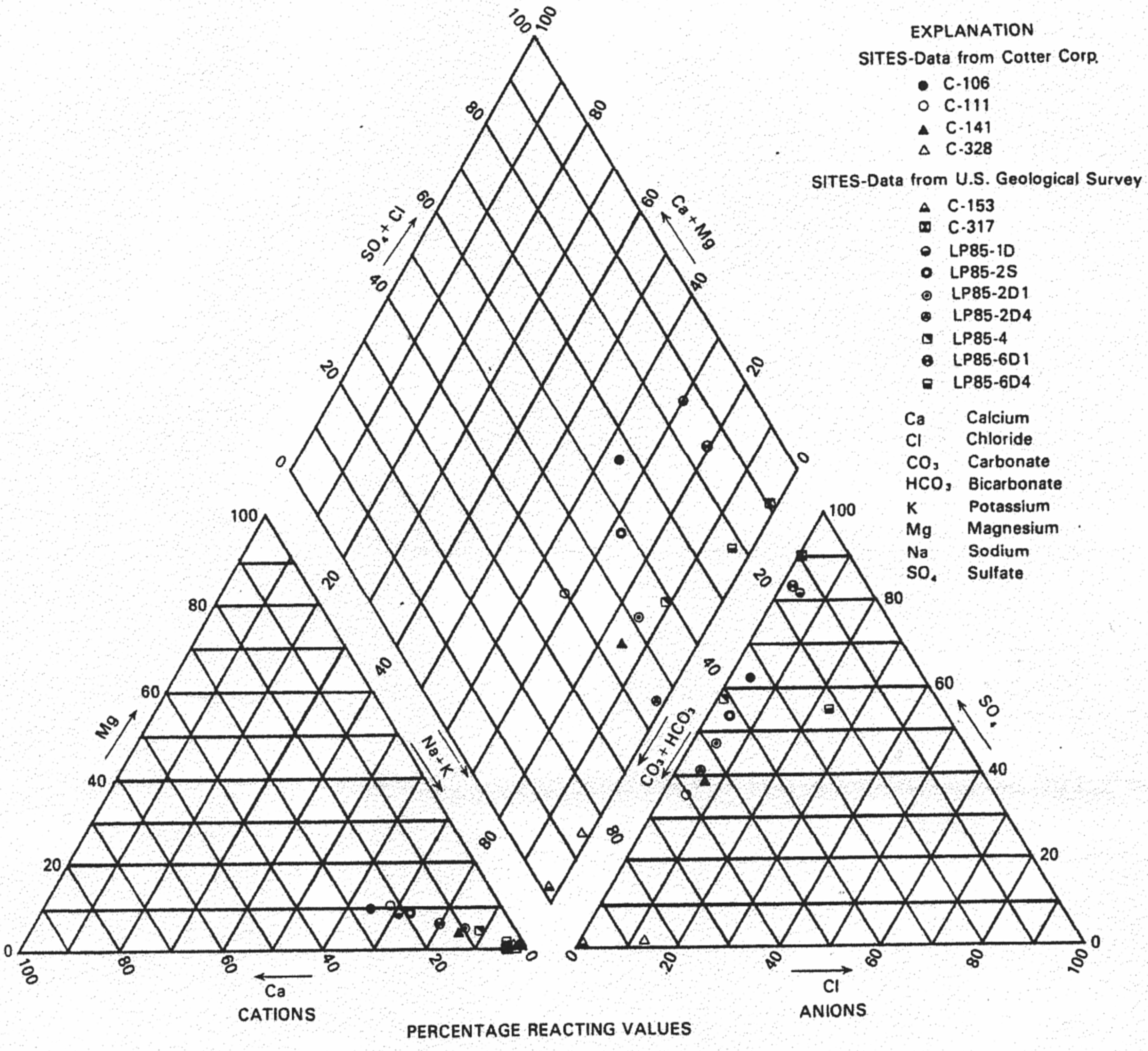


Figure 15.--Major-ion composition of water from the Vermejo Formation.

Hearn and Litke (1987), p. 48

Patterson 2007
Figure 4c

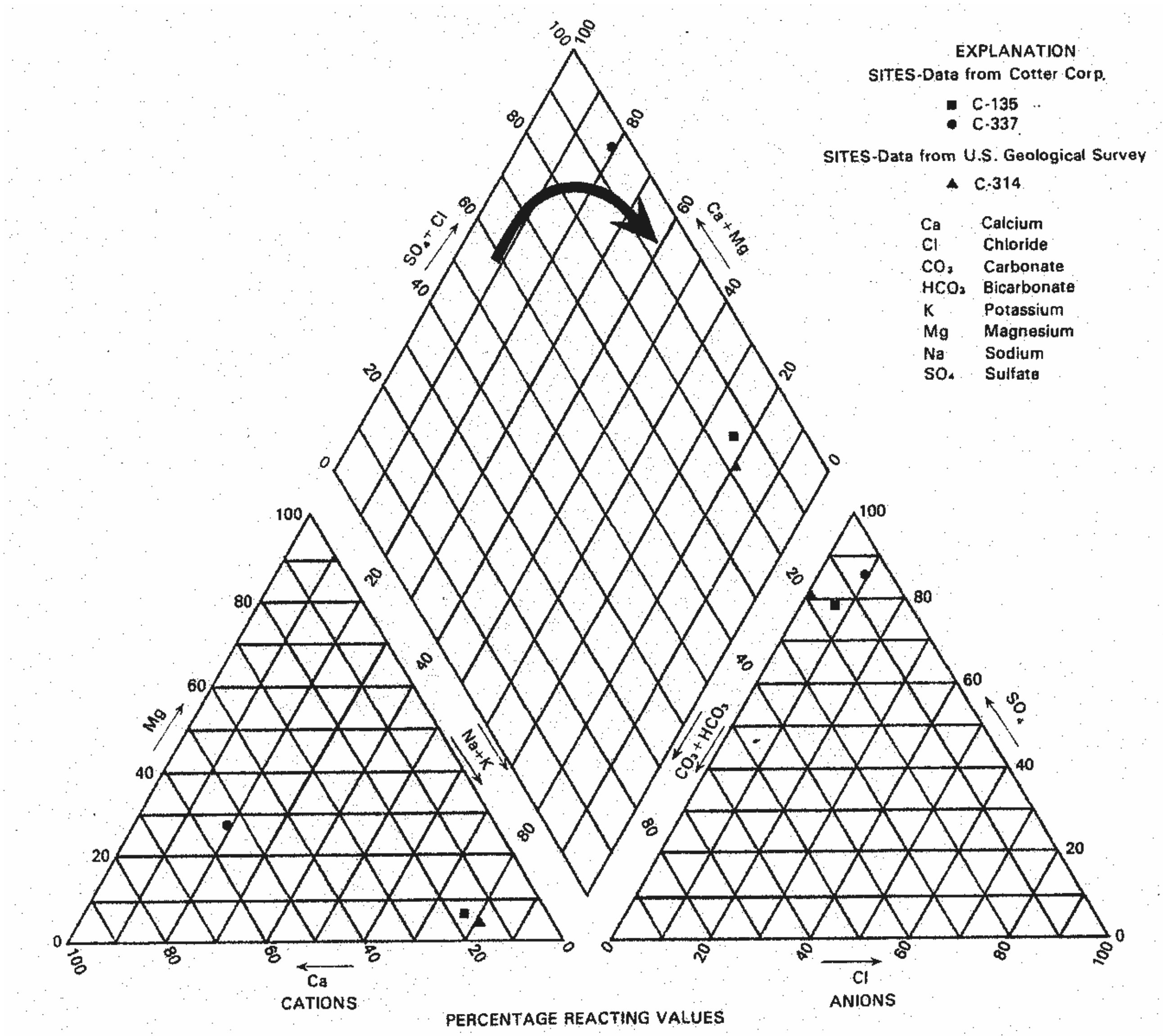


Figure 16.--Major-ion composition of water from the Poison Canyon Formation. (Arrow indicates chemical evolution of water in the Poison Canyon Formation reported by Howard, 1980.)

Characterization of Water from Alluvium

Fourteen analyses of water from alluvium in Lincoln Park were available (fig. 17). Statistics for these water analyses are presented in table 7. Cotter Corp. analyses for wells C-114 and C-137 and site C-520 are shown in figure 17; however, these older data are not included in the statistical analysis presented in this report. Specific conductance and alkalinity have the smallest coefficient of variation. Other variables have larger coefficients of variation, probably because of nonhomogeneity in the mineralogic composition of the alluvium.

Hearn and Litke (1987), p. 50

Patterson 2007
Figure 4ci

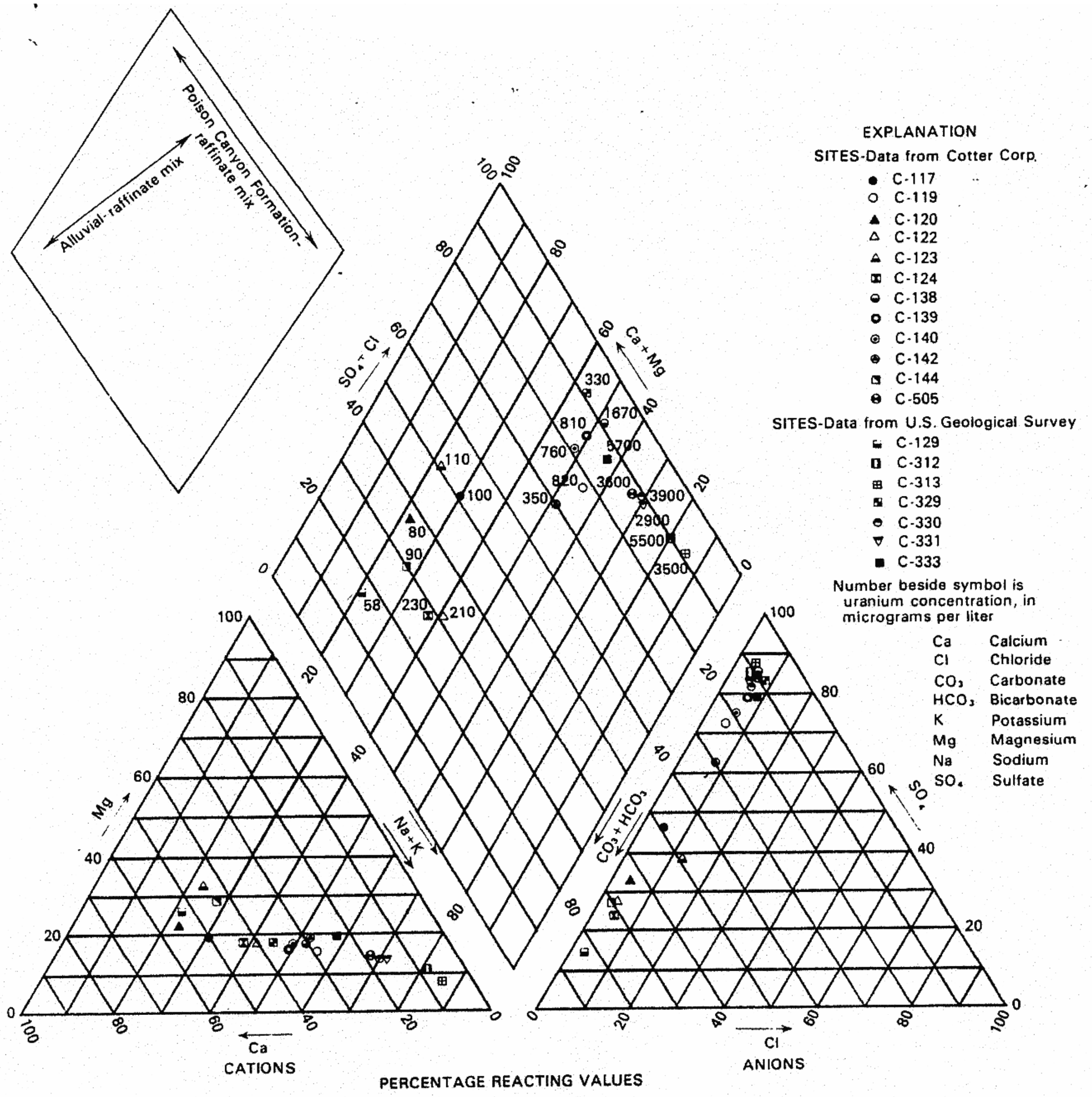


Figure 18.--Major-ion composition and uranium concentrations in raffinate-affected ground and surface water. (Small schematic diagram shows hypothesized mixing lines.)

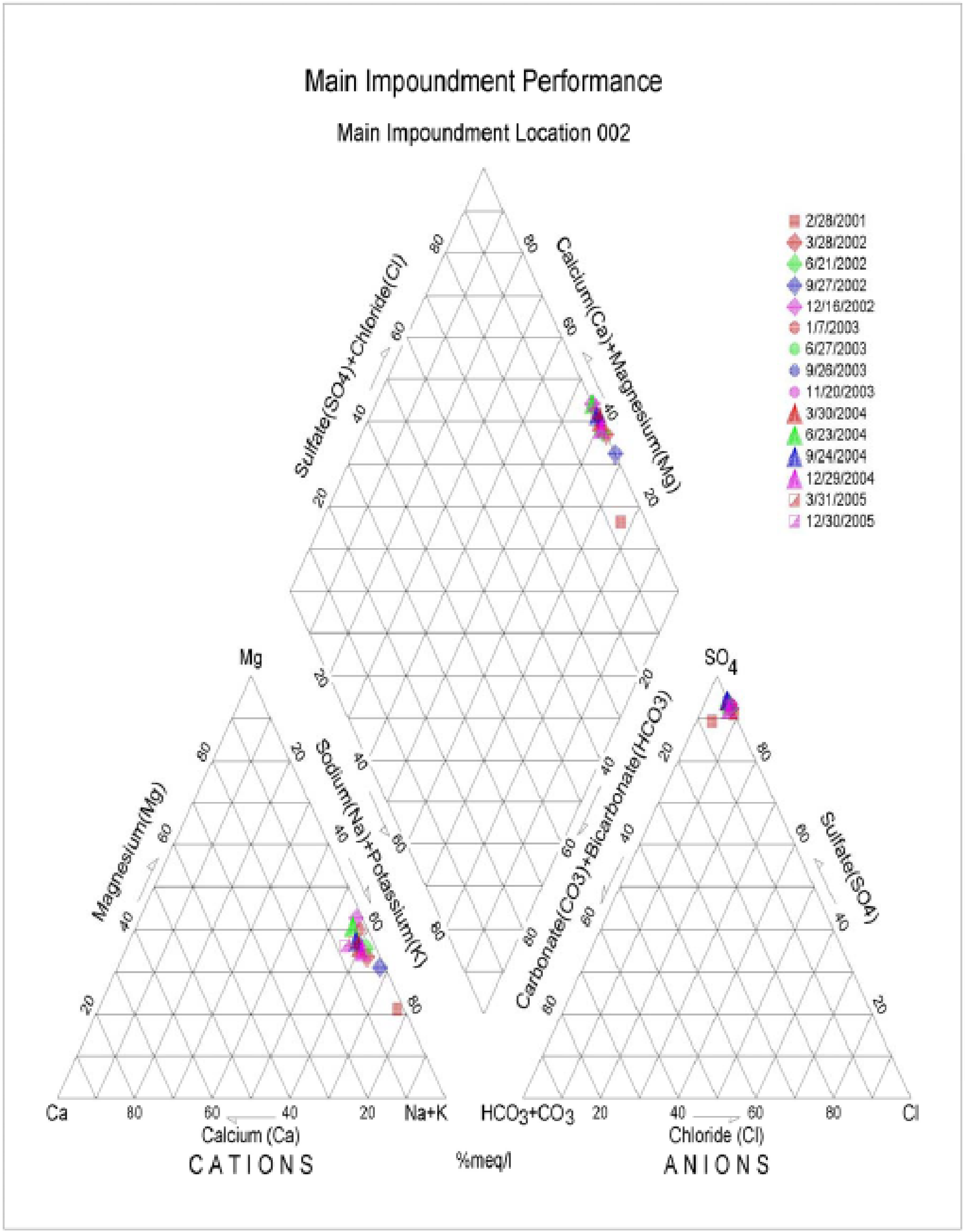
The predominant lithology of material yielding water to these wells is identified in the drillers' logs as "sand and boulders." Some wells penetrate weathered or fractured bedrock (notably wells H, I, K, and L, where gray clay and shaly weathered detritus of the Pierre Shale are penetrated); however, the bedrock does not seem to yield substantial quantities of water, because there is no variation in water composition relative to differences in subcrop formation, and because the water-quality variables have no tendency toward bimodal distributions. Therefore, the water quality probably is primarily dependent on surface recharge to the alluvium, and on chemical reactions between this recharge and the alluvium. Such recharge is primarily water from the De Weese Dye Ditch. Recharge by precipitation is small because annual mean precipitation is 13 in., whereas potential evapotranspiration is 33 in

[Note from Patterson: Last remark not necessarily true, as storms in each season are intense**]**

Hearn and Litke (1987), p. 52

Patterson 2007
Figure 4cii

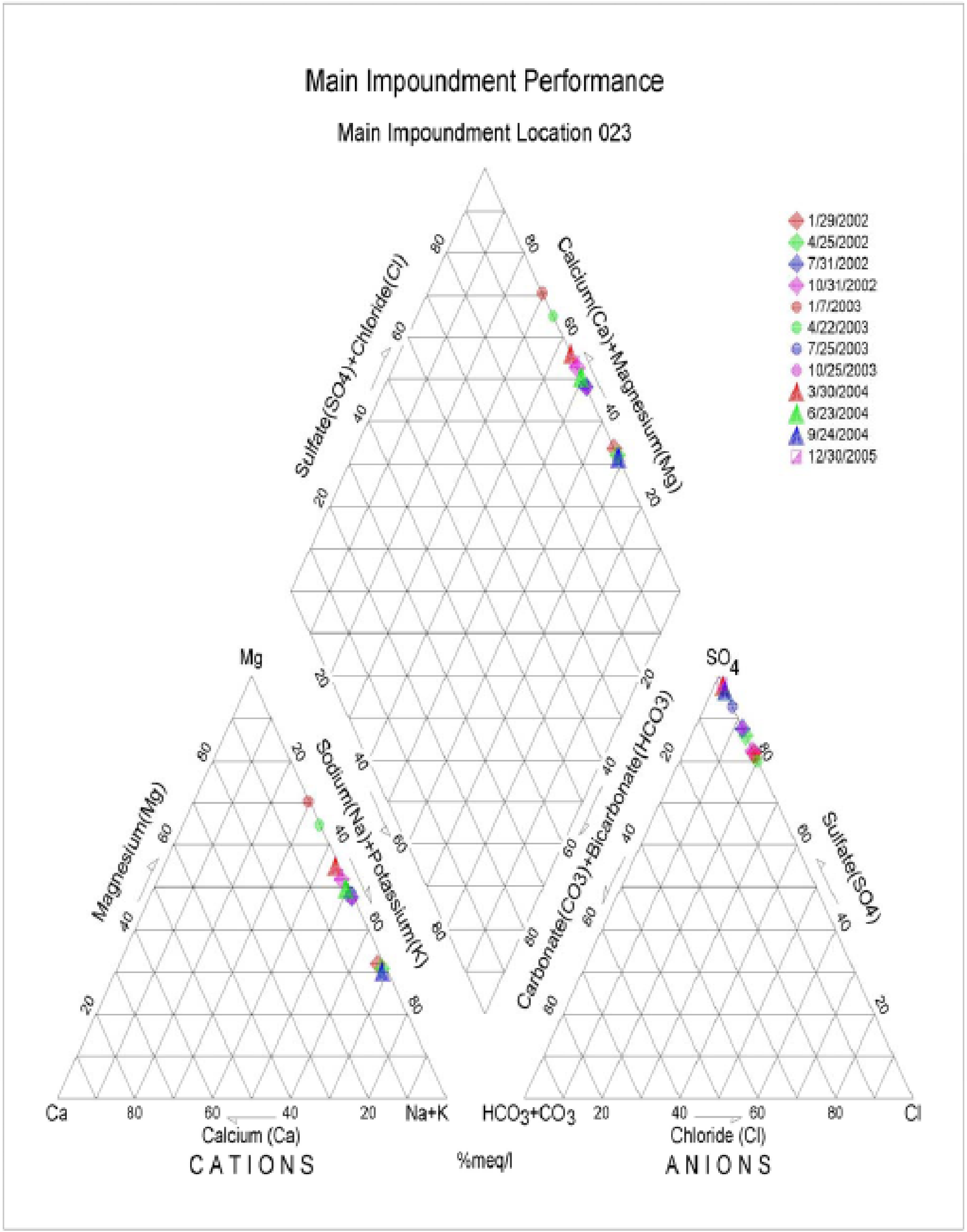
Figure 7-52 Primary Impoundment Monitor Location 002



Cotter 2005, p. 7-45

Patterson 2007
Figure 4d

Figure 7-53 Secondary Impoundment Monitor Location 023



Cotter 2005, p. 7-46

Patterson 2007
Figure 4di

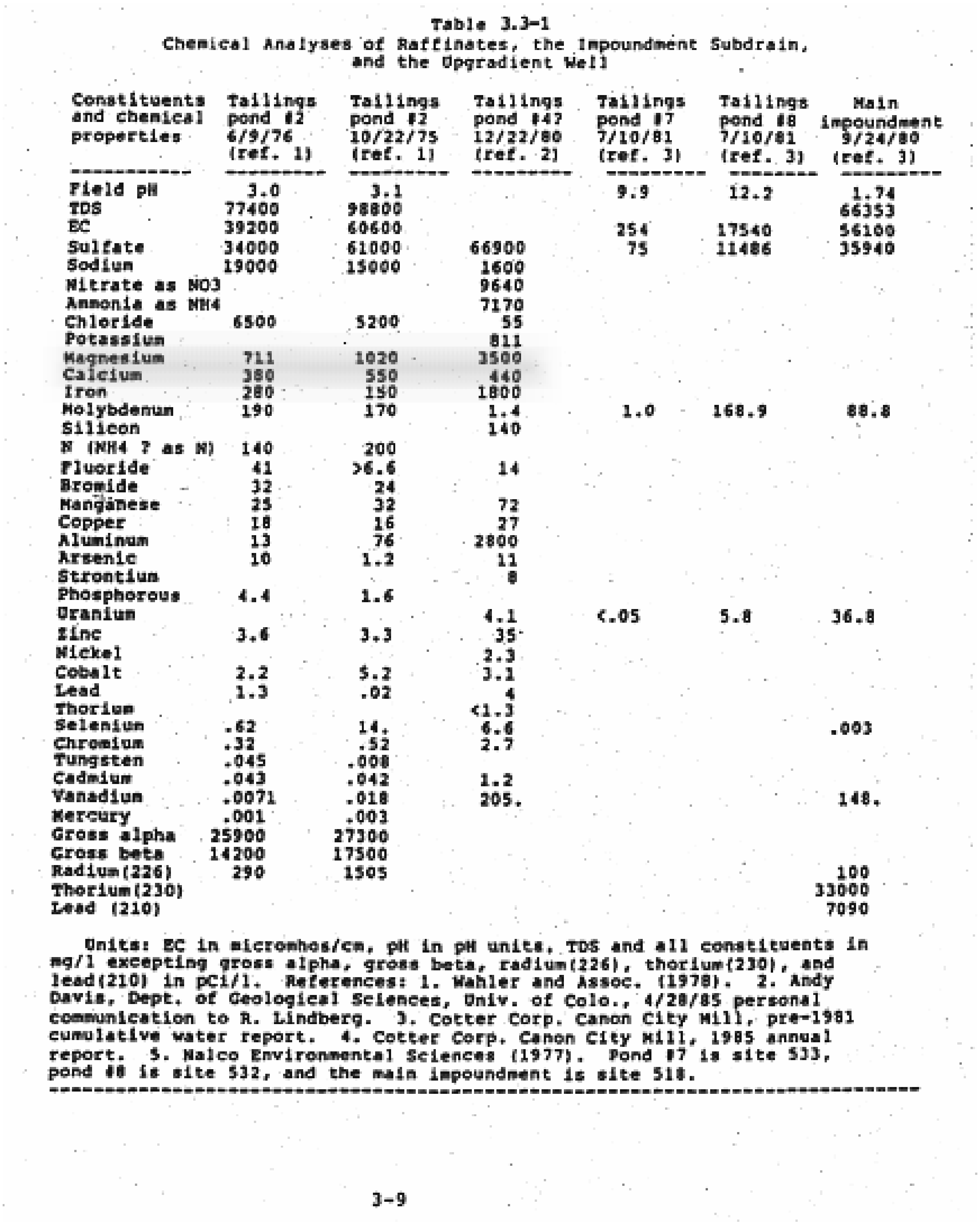


Table 3.3-1
Chemical Analyses of Raffinates, the Impoundment Subdrain, and the Upgradient Well

Constituents and chemical properties	Tailings pond #2 6/9/76 (ref. 1)	Tailings pond #2 10/22/75 (ref. 1)	Tailings pond #47 12/22/80 (ref. 2)	Tailings pond #7 7/10/81 (ref. 3)	Tailings pond #8 7/10/81 (ref. 3)	Main impoundment 9/24/80 (ref. 3)
Field pH	3.0	3.1		9.9	12.2	1.74
TDS	77400	98800				66353
EC	39200	60600		254	17540	56100
Sulfate	34000	61000	66900	75	11486	35940
Sodium	19000	15000	1600			
Nitrate as NO3			9640			
Ammonia as NH4			7170			
Chloride	6500	5200	55			
Potassium			811			
Magnesium	711	1020	3500			
Calcium	380	550	440			
Iron	280	150	1800			
Molybdenum	190	170	1.4	1.0	168.9	88.8
Silicon			140			
N (NH4 7 as N)	140	200				
Fluoride	41	>6.6	14			
Bromide	32	24				
Manganese	25	32	72			
Copper	18	16	27			
Aluminum	13	76	2800			
Arsenic	10	1.2	11			
Strontium			8			
Phosphorous	4.4	1.6				
Uranium			4.1	<.05	5.8	36.8
Zinc	3.6	3.3	35			
Nickel			2.3			
Cobalt	2.2	5.2	3.1			
Lead	1.3	.02	4			
Thorium			<1.3			
Selenium	.62	14.	6.6			.003
Chromium	.32	.52	2.7			
Tungsten	.045	.008				
Cadmium	.043	.042	1.2			
Vanadium	.0071	.018	205.			148.
Mercury	.001	.003				
Gross alpha	25900	27300				
Gross beta	14200	17500				
Radium(226)	290	1505				100
Thorium(230)						33000
Lead (210)						7090

Units: EC in micromhos/cm, pH in pH units, TDS and all constituents in mg/l excepting gross alpha, gross beta, radium(226), thorium(230), and lead(210) in pCi/l. References: 1. Wahler and Assoc. (1978). 2. Andy Davis, Dept. of Geological Sciences, Univ. of Colo., 4/28/85 personal communication to R. Lindberg. 3. Cotter Corp. Canon City Mill, pre-1981 cumulative water report. 4. Cotter Corp. Canon City Mill, 1985 annual report. 5. Nalco Environmental Sciences (1977). Pond #7 is site 533, pond #8 is site 532, and the main impoundment is site 518.

3-9

Geotrans, Inc. (1986) – Remedial Investigation – p. 3-9

Patterson 2007
Figure 4e

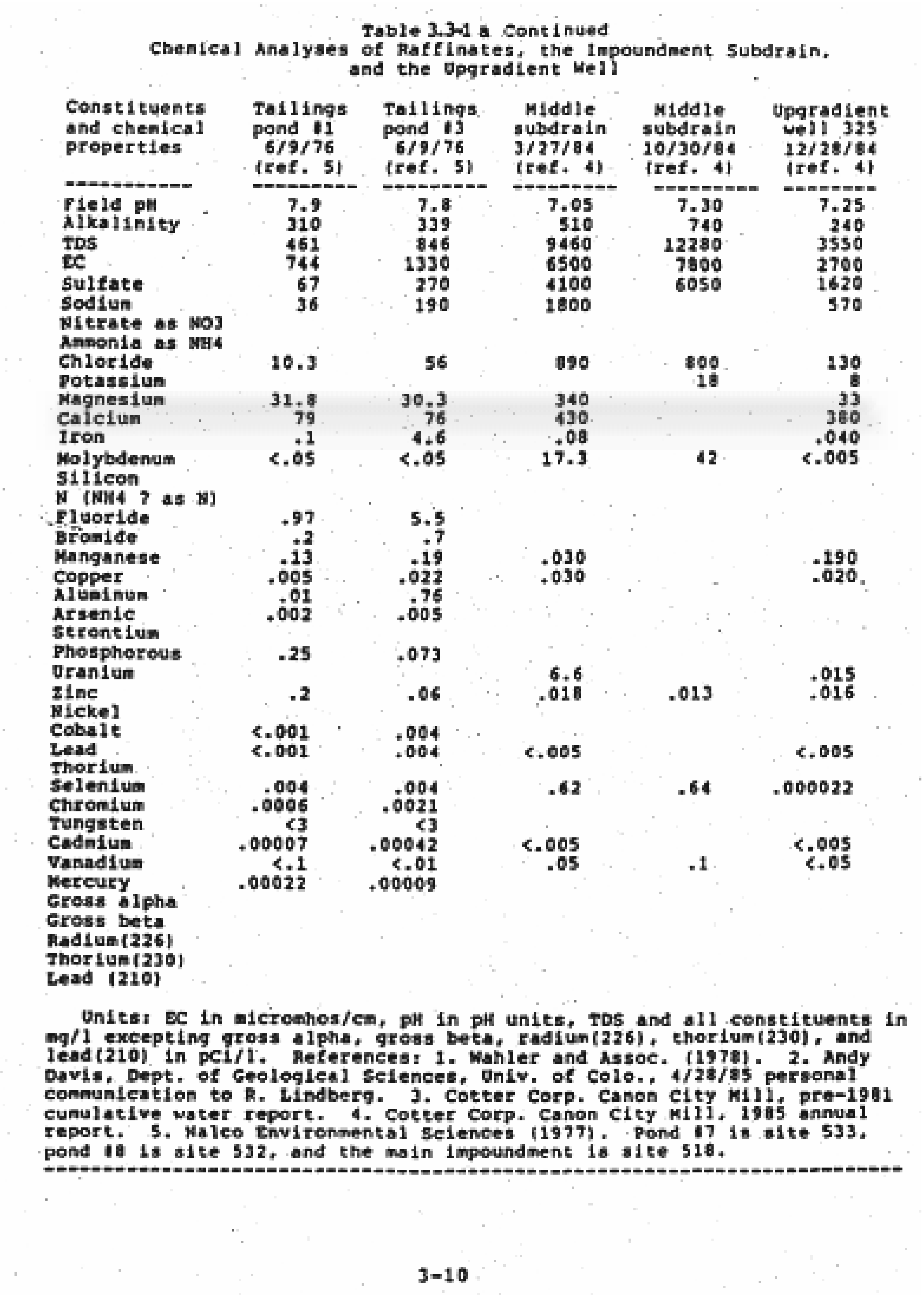


Table 3.3-1 a Continued
Chemical Analyses of Raffinates, the Impoundment Subdrain, and the Upgradient Well

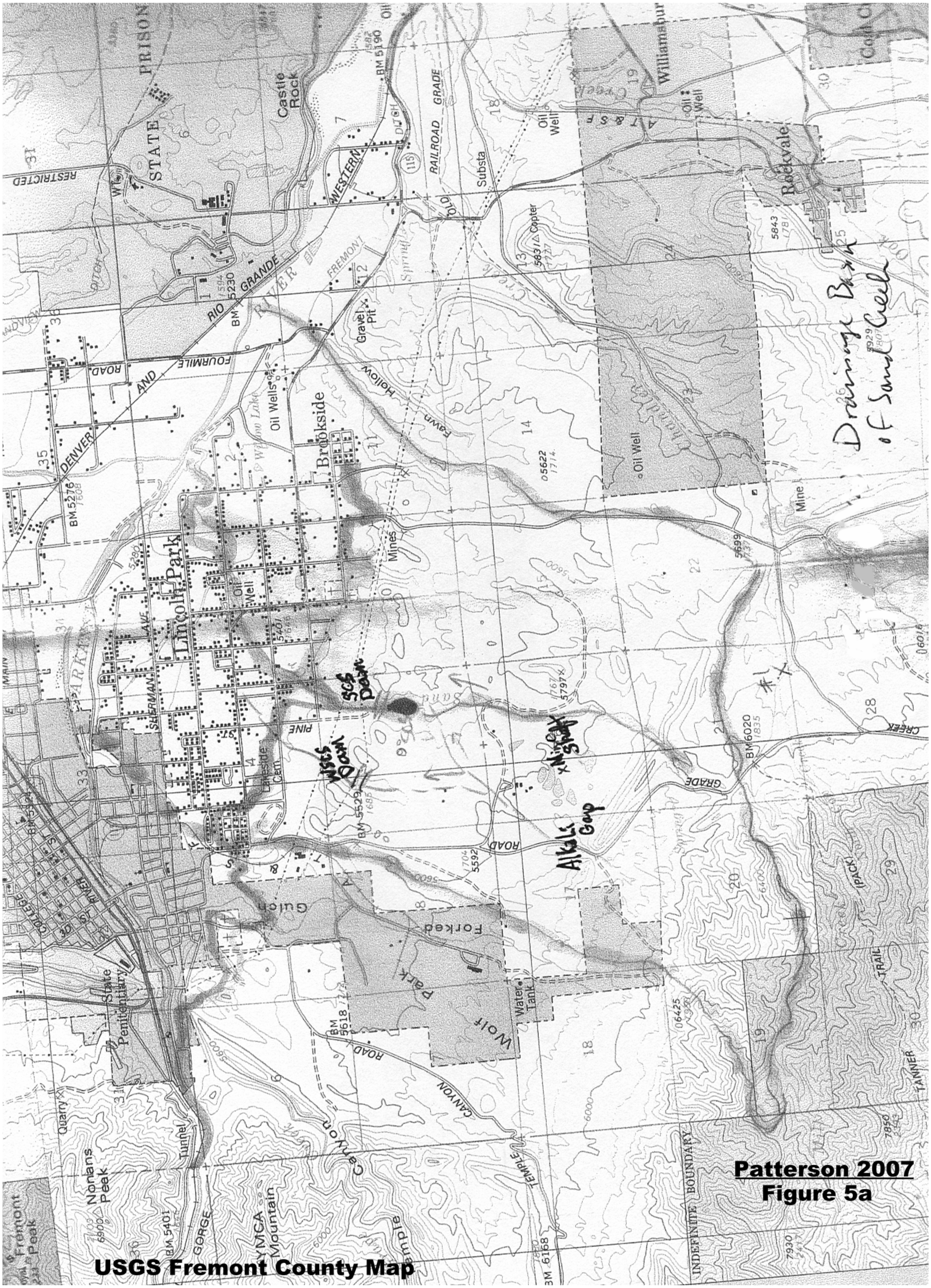
Constituents and chemical properties	Tailings pond #1 6/9/76 (ref. 5)	Tailings pond #3 6/9/76 (ref. 5)	Middle subdrain 3/27/84 (ref. 4)	Middle subdrain 10/30/84 (ref. 4)	Upgradient well 325 12/28/84 (ref. 4)
Field pH	7.9	7.8	7.05	7.30	7.25
Alkalinity	310	339	510	740	240
TDS	461	846	9460	12280	3550
EC	744	1330	6500	7800	2700
Sulfate	67	270	4100	6050	1620
Sodium	36	190	1800		570
Nitrate as NO3					
Ammonia as NH4					
Chloride	10.3	56	890	800	130
Potassium				18	8
Magnesium	31.8	30.3	340		33
Calcium	79	76	430		380
Iron	.1	4.6	.08		.040
Molybdenum	<.05	<.05	17.3	42	<.005
Silicon					
N (NH4 ? as N)					
Fluoride	.97	5.5			
Bromide	.2	.7			
Manganese	.13	.19	.030		.190
Copper	.005	.022	.030		.020
Aluminum	.01	.76			
Arsenic	.002	.005			
Strontium					
Phosphoreus	.25	.073			
Uranium			6.6		.015
Zinc	.2	.06	.018	.013	.016
Nickel					
Cobalt	<.001	.004			
Lead	<.001	.004	<.005		<.005
Thorium					
Selenium	.004	.004	.62	.64	.000022
Chromium	.0006	.0021			
Tungsten	<3	<3			
Cadmium	.00007	.00042	<.005		<.005
Vanadium	<.1	<.01	.05	.1	<.05
Mercury	.00022	.00009			
Gross alpha					
Gross beta					
Radium(226)					
Thorium(230)					
Lead (210)					

Units: EC in micromhos/cm, pH in pH units, TDS and all constituents in mg/l excepting gross alpha, gross beta, radium(226), thorium(230), and lead(210) in pCi/l. References: 1. Wahler and Assoc. (1978). 2. Andy Davis, Dept. of Geological Sciences, Univ. of Colo., 4/28/85 personal communication to R. Lindberg. 3. Cotter Corp. Canon City Mill, pre-1981 cumulative water report. 4. Cotter Corp. Canon City Mill, 1985 annual report. 5. Halco Environmental Sciences (1977). Pond #7 is site 533, pond #8 is site 532, and the main impoundment is site 518.

3-10

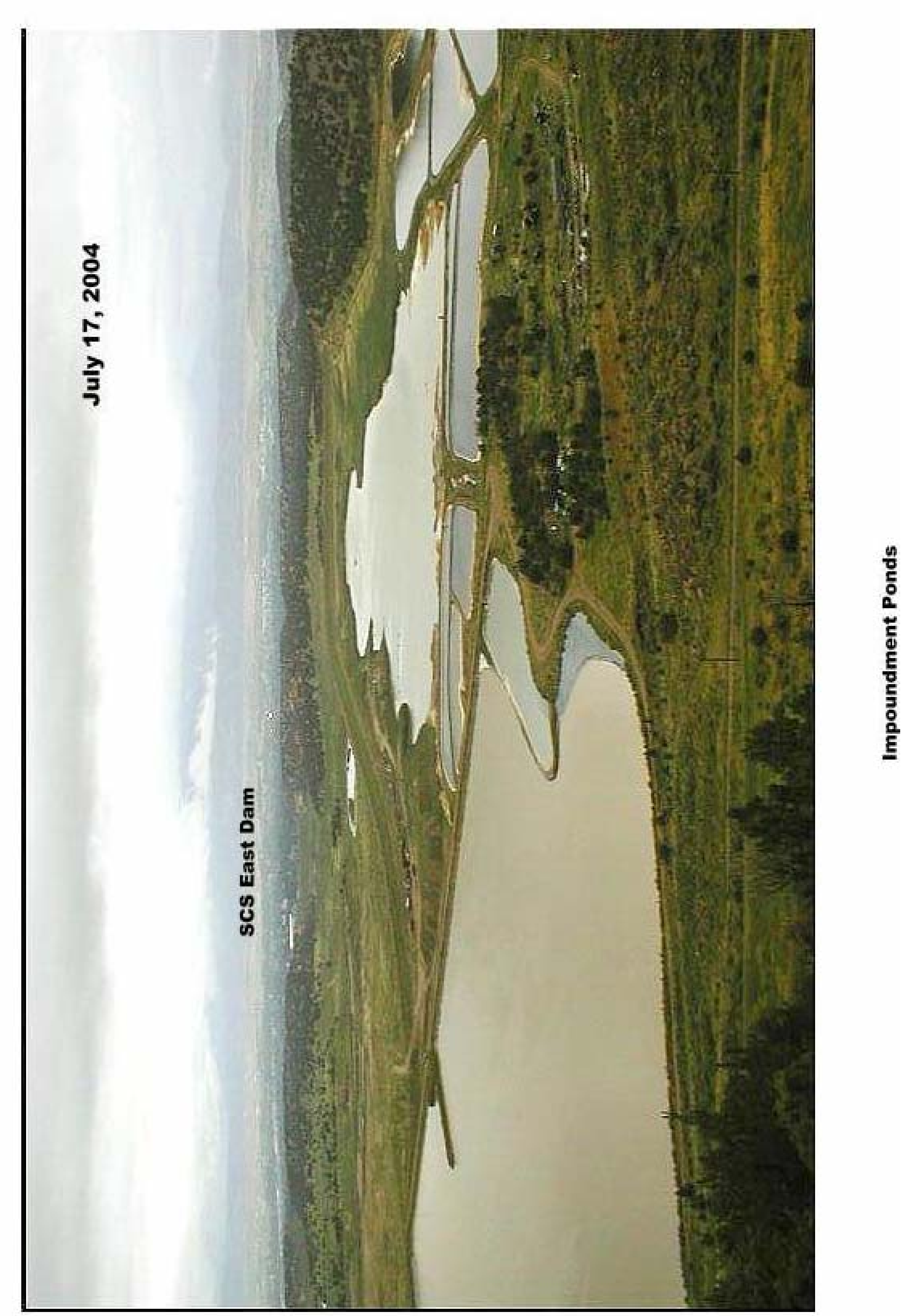
Geotrans, Inc. (1986) – Remedial Investigation – p. 3-10

Patterson 2007
Figure 4ei



Patterson 2007
Figure 5a

USGS Fremont County Map



2004 Photo (Courtesy of Jeri Fry)

Patterson 2007
Figure 5b

APPENDIX A

REVIEW OF DOCUMENTS

APPENDIX A

REVIEW OF DOCUMENTS

INTRODUCTION

The following is a selection of some of the documents I reviewed for the TAG project. In general, I will present the documents in historical order. The older documents contain much original data, and track the history of monitoring and remediation efforts at the site. The reports commissioned by Cotter often appear written in a non-critical style, but may contain some unguarded statements on future areas of criticism that had not yet emerged. Various outside comments from EPA, independent consultants, and some internal Colorado Department of Health (CDH or CDPHE) reviewers in the documents are also insightful.

The most critical recent documents are from the USGS reports on water quality and hydrology from 1987 to 1999. These *seem* to put to rest many of the older concerns about the deep, east, and west contaminant migration paths while, frankly, still leaving many questions unanswered. Background levels of contaminants and appropriate tracers to identify raffinate are also examined

Despite some documents being USGS products, I still sense a pro-Cotter bias in these reports. I say this somewhat guardedly, because I do see the reasoning, but hard data is still lacking to disprove the deep, east, and west paths. Similarly, I feel background levels of contaminants in the area could have been set lower using a broader regional picture of natural water chemistry. Certainly, better tracers than simply using regulatory MCL's of U and Mo could be found to identify raffinate-affected water. In summary, the USGS papers still contain the most authoritative data set and interpretation of ground water conditions at the site and give some predictions of the success of future remediation activities.

[Please refer to the final report for Figures, a List of Acronyms and Abbreviations, and the References for cited documents]

TABLE OF CONTENTS

1.0 NALCO Environmental Sciences. 1975-76. *Environmental Report for the Cotter Uranium Mill, Canon City Colorado.*

This report was prepared for Cotter in the late 1970's to make the case for construction of the new mill and impoundment ponds. It has some elements, while lacking others, of an Environmental Assessment (EA) and an Environmental Impact Statement (EIS) combined, as well as presenting a pro-Cotter case for new construction. The conclusions are glowingly positive, with no reported negative effects from the mill, and it includes numerous positive benefits.

The report does present a large compendium of baseline data on site: Demographics and land use; Climate and weather data; Geography; Geology (including seismology); Surface and ground water hydrology; Water quality; Ecology; including Flora (vegetation stands and types) and Fauna (includes mammals, reptiles, birds, and pest insects). Endangered species (whooping crane, greater sand hill crane, black-footed ferret, peregrine falcon) are considered possible as occurring or visiting in Fremont County.

It includes background radiology, including many appendices showing calculations of radon (Rn), uranium (U), and other nuclides emitted from mill operations, including capped tailings. Also calculated are radiation levels in air for gaseous radon, particulates, and water. These calculations are difficult to fully relate to as they give concentration values as radiation levels in micro Curies per second (uCi/sec).***** These of course, will be different mass concentrations for each nuclide. Airborne dust values are given, showing high values at the plant site, but decreasing rapidly with distance from the plant.

Social and economic benefits are listed and described, including tax base and spin off jobs such as housing construction.

Health risks are described and tabulated, then discounted as minor and trivial, partly because of distance from the plant to Canon City (no mention of Florence or Lincoln Park.).

Water contamination from chemical emissions is discussed and a useful tabulation of water quality data from surface and ground water sites is presented. Unfortunately, NALCO does not specify whether samples were filtered before analyses. It cannot be known if values represent "dissolved" or "total." In ground water, there is little particulate matter, but surface water can have a significant level of transport by sorption on colloids. In any case, it makes comparison with future results impossible.

Current monitoring program methods are listed: Water quality; Air quality; and, Ecological methods. Gross alpha counts not attributable to radium were found in several offsite locations.

Economic benefits are described. Letters of recommendation are presented. A letter from Al Hazle, then Director of the Occupational & Radiological Health Division for Colorado, states that for approval to be granted, Cotter must (among other things):

1. Prepare a full EIS;
2. Investigate tears in liner of Pond #2;
3. Comply with NRC Reg Guide 3.8;
4. Seepage from unlined ponds must be determined;

5. Hire a qualified hydrologist;
6. Monitor surface and ground waters both up gradient and down gradient from the mill;
7. Determine ground water flow pattern and present in map form;
8. Submit monitoring plan within 30 days (Dec 8, 1975, that's across Christmas-he must be serious);
9. If any ground water pollutants are associated with the mill, corrective action must be taken before license is issued.

Cotter then requested more time. Follow-up letters discuss a site inspection in which no outright violations were found, but many questions arose. To date, no comprehensive and complete EIS per the National Environmental Protection Act has even been done at this site.

* The conversion factors for converting U(pCi) to U(ug) is: 1 ug U = 0.677 pCi (multiply pCi units by 677 to get U in ug, by 0.677 to get mg U).

For older values with the unit uCi/ml x 10^{-5}, multiply (uCi/ml x 10^{-5}) by 10,000 to get pCi/liter, then divide pCi/l by 677 to get mg/l.

2.0 USEPA (ORP-LVF) *Review on Environment Report for the Cotter Uranium Mill (NALCO ENVIRONMENTAL SCIENCES).* USEPA Document I.D. #296765 – no date.

This document points out the rather large number of inconsistencies and omissions in the NALCO Environmental Report. It is not dated, but apparently written after the Wahler design report, and probably around July of 1978 when a transmittal letter was sent with a longer version of these same EPA comments (USEPA, 1978). The following is a summary of the comments:

1. **General comments:**
   - No mention of QA/QC plans
   - Illegible figures
   - Large number of typos, and illegible illustrations raise questions of credibility
2. **Specific comments (related to water quality, geology, hydrology):**
   - Questions much of analytical methodology, data reporting, and assumptions of airborne radioactivity.
   - Questions NALCO statement that there are no liquid discharges to surface or ground water from mill site.
   - Data for contamination is poorly reported, contains errors, and does not adequately address extent and nature of contamination.
   - No projections of any future contamination.
   - By comparison to other millsites, windblown dust travels much farther than claimed. Need to show comparisons and data.
   - Ecological exposure pathways are too simplistic.
   - No mention of scaled up estimates of contamination based on increased production rates or population increase.
   - Insufficient monitoring wells on plant site.
   - Contrary statements such as "All mill effluent is confined to ponds" in clear disagreement with data
   - State and Federal experts should review monitoring plans, lest they become "pointless technical exercises".
   - Section on on-site reclamation is too brief. Stated objective is to reduce radon emissions to two times background, but no background value is given.
   - Concerned that lasting maintenance of site is necessary after shut-down in current location.
   - Criticizes the geology report by Hershey as going nowhere and answering none of the stated objectives.
   - Criticizes Hershey for not presenting chemical analyses of water seeping from ponds into holes Z-1 and Z-2, etc.
   - More chemical indicators of pollution should be used (Ra, U, as well as As, Se, Mo).
   - How was sampling done? Filtered or not?
   - Analyses of particulates on filters should be analyzed.

3.0 **Hershey, L.A. 1977.** *Geohydrology of the Cotter Mill Environment.* For NALCO Environmental Sciences.

Geohydrology of the Cotter site was investigated by L.A. Hershey, consulting geologist, hydrologists and engineers of Canon City. Hershey presents useful geologic data, maps, many well logs, and many cross-sections of the plant site showing wells.

He discusses the coal mine situation and proposes the "deep path." Hershey describes water sources and use at the plant. Ground water contours and flow maps are presented, showing mounding under the ponds, rapid flow and ground water divides in subsurface channels filled with alluvium. His ground water table contour map seems to show the "west path" and the "east path" fairly clearly (Fig. 3di).

4.0 Wahler, W.A. and Associates. 1978. *Investigations related to migration of raffinates, from the existing Cotter tailings impoundments*. Prepared for Cotter Corporation.

[My remarks in brackets]

The Wahler Report (1978) is the first of several follow up studies Cotter commissioned after receiving critical commentary about the NALCO Report *[note-a formal Environmental Impact Statement (EIS) has never been done]*. The Wahler report represents a distinct improvement over the NALCO report. It contains better illustrations and has more focus. It fairly identifies: 1). That seepage of raffinates into Lincoln Park has occurred; 2). That the principal water quality concern in Lincoln Park is not with the radioactivity in the water, but with the toxic heavy metal aspect of U and other elements; and 3). That raffinates seep from the unlined pond and travel through a complex permeable zone consisting of alluvium and jointed bedrock.

The report correctly specifies that the best way to eliminate pollution is at the source, and removal of the mill tailings from the unlined ponds is necessary. ***[Unfortunately, the recommendation is to place the waste in the new lined impoundment, which was later shown to be flawed from the start with reported tears in the new liner.]***

Wahler also recommends: 1). Sealing the Littell Shaft; 2). Pumping degraded surface water from the SCS Dam back into the new lined impoundments; 3). Constructing three interception trenches to collect and pump back degraded seepage found in shallow alluvium back into the lined impoundments; 4). Constructing two deep wells in rock formations where significant seepage was encountered, and pumping it back; and, 5). Removing the wastes on an accelerated schedule if the monitoring wells show that the seepage interception systems are not working. This plan advocates direct placement of the wastes in the new lined impoundment without reprocessing. These programs are not designed or expected to eliminate contamination, only to reduce it.

The study sets out to determine: 1). The extent to which raffinates have migrated into Lincoln Park; 2). The mechanism through which this migration has occurred (Deep path, NW, Sand Creek, or S shallow paths); 3) The severity of the problem; and, 4). Appropriate remedial methods to minimize or eliminate or reduce the migration of raffinates from the Cotter property.

NALCO (1975-76) and Hershey & Associates (1977) drilled 57 test wells on site. Wahler drilled 17 core holes, 9 single observation wells and 25 observation wells ***[no distinction was made, so I do not know the difference between these]***. These wells revealed that seepage was present mainly in fractures in the Poison Canyon and much less in the overlying alluvium.

The geophysical survey was considered a failure, and a review of water-bearing formations is presented. The well drilling program indicated the ground water flow paths are complex and interconnected in unexpected ways, probably by fractures in the top 100 feet of the underlying formations.

The ground water flow is mainly to the northeast in the western part of section 16 and to the northwest in the eastern part (drainage divides of Hershey). This shows that the alluvium under Sand Creek Channel is the main conduit.

Evaluation of water quality in the area calls for "complete" water analyses. ***[I agree with this. No real interpretation can be made unless all components are analyzed. A "complete" analysis would include Ca, Mg, Na, K, HCO_3 + CO_3 (important for the future PRTW study), SO_4, Cl, Total Fe, natural U, Mo, Se, F, As, Pb, and conductivity (EC).]***

No water analyses were done before Cotter began operation. ***[In other words, the search for "background" levels of dissolved components is rendered almost impossible. Identification of raffinate-affected water cannot really be done with certainty, and constitutes an opinion.]***

Chemical types of water for the area are presented. Raffinate waters are sodium sulfate waters high in Se, Mo, and radiation emitters. Acid leach raffinates have less bicarbonate than alkaline leach waters. The map of EC in the ground water clearly shows a plume in the northwest near Prospect Heights, in addition to Lincoln Park. No EC plume is seen near Brookside at the time of measurement (1978), ***[but it may be there by now]***. The Mo, Se, U, and gross alpha plumes are only under Lincoln Park. ***[This is not a problem-EC is present in MUCH higher and therefore more easily measured amounts.]***

All of the local ground waters have elevated gross alpha. There is an unknown alpha emitter in the waters. Radium is highly adsorbed onto clays and does not travel much off the plant site. Gross alpha is naturally high throughout the area (mainly radon + radium). ***[Station 38 is mislabeled on Wahler's water quality maps. It is labeled "28", which appears elsewhere. Values reported for U and Mo in "native" ground waters and the Arkansas River seem incredibly high.]***

Migration paths: The presumption is that seemingly unnaturally high values of Mo and U in ground waters may be attributable to contamination from a path other than the "middle" or sand Creek path. Initially, Wahler is very taken with the idea of the "deep path", but then abandons the idea. It is proposed that raffinates use the Littell shaft to enter the deep subsurface where as many as 20 permeable beds in the Vermejo Formation could transmit the raffinates up dip to Lincoln Park. Wahler's refutation of that argument is that the high concentrations of raffinate-derived chemicals are confined to a narrow tongue along Sand Creek.

Remedial Actions suggested by Wahler: 1.) Seepage interception trenches and pump-back wells; 2.) Recycling of unlined pond material through mill and placement in lined impoundment (7 years); 3.) Wolf Park mine back filled and plugged in 1978.

It's also recommended that valuation of effectiveness of seepage interception system must be done, along with the following:

- Complete pumping of water from SCS reservoir
- Install an open sump through the alluvial soils in the bottom
- Remove contaminated soil within & around SCS Res.
- Install pump back system above SCS Res.
- Collect & return any contaminated seepage waters encountered in the construction of the new impoundment.
- Find & seal any old exploration borings.
- Resample all wells at same time to get clear picture of raffinate plume.
- Locate new sampling stations.
- Monitoring-Monthly for one year, then re-evaluated.

The 1978 monitoring program included observation wells OW-1C, 4C, 5C, 6B, wells at stations 11, 24, 40, 45, the observation well adjacent to Wolf Park shaft (later abandoned because poorly constructed), and the springs, upon which the lined impoundment was then constructed. Concern is raised for contaminated ground water N of the SCS dam. The statement is made that the dam "chokes" and slows ground water migration ***[I cannot determine why that would be, unless mounding under the dam reverses the local flow gradient]***.

How to recognize dilution and diminishment of contaminated ground water in LP if source is cut off? Wahler dismisses sulfate and EC as these are also characteristic of the Vermejo. They feel gross alpha is misleading, uranium is confusing, and recommend Mo and Se.

Wahler appendices contain some "complete" analyses, many with divergent values for splits, attributed to sample handling, not lab error.

Notes:

The conversion factors for converting U(pCi) to U(ug) is: 1 ug U = 0.677 pCi (multiply pCi units by 677 to get U in ug, by 0.677 to get mg U. For older values with the unit uCi/ml x 10^{-5}, multiply (uCi/ml x 10^{-5}) by 10,000 to get pCi/liter, then divide pCi/l by 677 to get mg/l.

[For example: U values for seeps east of the SCS dam were as high as 11,500 pCi/l. This is equivalent to 11,500 / 677 = 16.99 mgU/l (since 1 mg = 1000 ug, this equals 16,987 ugU/l). For comparison, the current MCL for uranium is 35 ugU/l.]

5.0 **Shelton, D., CGS. 1978.** Letter reviewing Wahler (1978), *Investigations related to the migration of raffinates from the existing Cotter tailings impoundments*.

[My comments in brackets]

From: Dave Shelton, Colorado Geological Survey ***[grad school classmate of mine]***
To: Al Hazle, CDH

Shelton states that Wahler makes 2 conclusions: 1). That raffinate contamination has gotten offsite in ground water (no disagreement by Shelton); and 2). That the postulated deep(er) paths don't exist (disputed by Shelton for lack of supporting evidence).

Shelton's reasons for disputing the second conclusion are that key wells OW-2 and OW-3 are shown to exist, but no discussion of them is in the text. These wells are critical because of their location and they at least theoretically sample multiple formations at depth. The other OW wells are not sufficiently described to know what formations they sample or at what depth. The entire series of wells drilled by Hershey & Assoc are not discussed. [I thought these wells looked promising to detect deeper contamination]. It is generally true that most contamination will follow the line of least resistance, which is the shallow aquifer consisting of alluvium and fractured Poison Canyon Fm., but that does not preclude significant and unexpected contamination from other pathways.

Wells OW-2 and C12-18 are critical for long-term sampling but not included are past values for these wells nor are they planned to be used for future monitoring. <u>These are serious omissions</u>.

6.0 **USEPA (1978).** Comments on Wahler & Associates (1978). *Uranium-Vanadium tailing impoundment environmental report supplement.* From: USEPA, Administrative Record Document ID #296750

Summary of Comments:

Needs more detail on actual U content of tailings to weigh between reprocessing vs removal to prevent further contamination.

What effects of the sanitary seepage field can be expected?

Critical to assess which ponds are leaking and to what degree.

Show ALL pump tests rather than selected ones. Detailed discussion of protocol & methods needed.

Need another method of handling tailings (tailings de-watering) to lessen risk of ground water contamination.

Need backup clay retention system in lined pond design as hypalon liner reliability is unknown.

Need tile drains under ponds in high bedrock permeability areas.

No details given on program to assess if hypalon liner is leaking, and no indication of what measures would be taken to mitigate if it were found to be leaking.

CDH should request NRC assistance to evaluate adequacy of dam.

Operational details are lacking.

Monitoring should be monthly, not quarterly.

Should consult regulations of New Mexico or Texas for guidelines.

Need acoustic surveys to monitor dam safety.

Piezometers should have capability to be sampled for water quality.

No mention of long term monitoring.

Hydraulic handling of reprocessed tailings will cause further gw pollution.

7.0 Hart, F.C. & Associates. 1981. *Field Investigations of Uncontrolled Hazardous Waste Sites*. Prepared for USEPA, and subcontractor to Ecology and Environment, Inc.

[My comments in brackets]

This document was funded by the USEPA, and it has a very different tone when compared to NALCO or Wahler (reports funded by Cotter). The initial assessment is that it was ***impossible** to get definitive answers to questions concerning*:

*water quality,
*the nature, levels of contamination,
*the migration of contaminants,
*the enforcement of a water quality program.

[It must be noted that these concerns have not been fully addressed to this day.] The reasons for this are given as the complexity of the site and varying interpretations of data, and poor data presentation. Hart describes wading through huge volumes of data, and still remaining unsure they had been shown everything, stating, "...no guarantee that all documents had been made available..." ***[This is a serious and ongoing problem-there is little effort made to present data in a complete and understandable way.]***

The purpose of the study was to advise EPA on whether to continue to let Colorado manage the site, or to put it back under EPA management. They were unable to reach conclusions, but did make recommendations. ***[To me, that, in itself, is a conclusion.]***

Source of Contamination: Unlined ponds allowed liquid fraction of wastes to enter ground water. CDH requested Cotter line ponds by Dec 1971, but they had not complied except for pond #2 by the date of this document. Unlined ponds still existed despite unanimous agreement that all tailings should be removed to a lined impoundment.

Wahler studied the issue in 1978, but before the report was issued, the CDH had issued approval for construction of a lined impoundment. This was felt to be a mistake by many reviewers as CDH was inheriting a problem, with no chance of implementing modifications or dealing with reservations about construction, eventually with 70+ tears in the liner, and poorly graded material in the underliner *[this was a problem]*. CDH was forced to approve retroactively.

Implementation of the new pond had many problems including inadequate cover over the hypalon liner, visible tears in the hypalon, over-drain problems, improper disposal of barrels in the impoundment, and damage due to truck traffic, as reported by CDH personnel on-site inspections.

The Sand Creek basin is considered a "recharge area" for ground water. The main area of infiltration of surface water into ground water is considered to be the SCS dam. The SCS dam was constructed in 1971 to control flood potential from the Cotter site. It almost always has water impounded behind it. The dam is underlain by 35 ft of colluvial/alluvial silty sand. The bedrock is the silty clay shale of the Vermejo Formation. The water table below the dam site varies from 6.5 ft to 12 ft seasonally. It is believed to be the main location where contaminated surface water infiltrates the ground water.

It is apparent that since raffinates are confirmed in Lincoln Park, the SCS dam is being bypassed, probably by ground water, as the dam is the location where ground and surface waters mingle.

Hart proposes three avenues of ground water contamination: 1). Direct recharge from unlined tailings ponds into the ground water; 2). Indirect recharge from surface water running off contaminated soils and infiltrating to the ground water; and, 3). The Wolf Park (Littell) shaft, which may have acted as a conduit for contamination to bypass normal percolation through thick sedimentary sequences.

The Chandler airshaft, 1 mile east of the mill, flows 10 gals/minute to ground water, and this water may be contaminated, possibly with subsurface connection to the Wolf Park Shaft. ***[It is my understanding that Cotter now owns that property. Testing that water would be the definitive proof of the deep path.]***

The shallow path is probably mainly along Sand Creek drainage. The ground water flowing in the shallow alluvium both above and below the SCS Dam have never been quantified. The contaminated ground water bypasses the dam in fractured bedrock alongside the dam and in alluvium beneath the dam where backfilling did not reach. The flow of contaminated water would be much greater after runoff events.

Deeper paths would include the underlying bedrock and direct passage through abandoned mine workings. There is no question that the mine workings are contaminated. Many samplings have confirmed that. The chemistry in the deeper mine waters is unknown. The discharge of these contaminated waters could occur downstream from the SCS dam, in the shallow subsurface of the Sand Creek alluvium, at which point, there is no barrier to flow downgradient to the Arkansas River.

Water Monitoring: In 1968, CDH initiates water quality monitoring of ponds, streams, and wells on or adjacent to the Cotter site, when the CDH took over regulation of Cotter's radioactive materials license from the Nuclear Regulatory Commission. By January, 1971, CDH had requested Cotter to make changes in their liquid waste handling. In 1977, the NALCO (1975-76) report compiled much water quality data and generated some new data, along with subcontractor Hershey's (1977) logs of 57 wells drilled. In 1978 inadequacies and unanswered questions in the NALCO report prompted the contracting of Wahler & Associates to study the seepage problem.

Wahler's report recommended sampling every month for a year, using U, Mo, Se, As, Pb, Cl, Ra, SO_4^{-2}, and electrical conductivity to "fingerprint" raffinates. This was revised five months later by hydrologist John Logan to include only U, Mo, and EC. The problems associated with fingerprinting are:

1. No pre-Cotter water quality records.
2. Complex geology (some formations, esp. the Vermejo, have waters similar in many ways to dilute raffinates) & complex pathways.
3. Lack of agreement among investigators over "fingerprinting" parameters.
4. Possibility of additional sources. ***[I take this to mean the old metal smelters.]***

Wahler established "background" levels in 1978, but these were immediately challenged by Bob Shukle of the Water Quality Division of the CDH. Shukle felt that some wells included in the study were already contaminated by Cotter. A map is shown with Shukle's "affected area" versus John Logan's. Shukle's boundaries extend far into Lincoln Park (15 wells), while Logan's identified four wells narrowly concentrated around the SCS Dam. The wells in Lincoln Park had not been correlated with the geohydrologic units from which they withdraw water. By 1981, Wahler had changed the monitoring program three times, and a comprehensive database did not yet exist.

Lincoln Park Water Quality: Cattle began experiencing unusual symptoms (Larry Wagner to Art Graber, 1968-uncertain if it was selenosis or molybdenosis-as they are similar.). The Bosco well was sampled in 1968 and found to have high concentrations of Mo, Se, and TDS. In 1975, the University of Colorado water quality study ***[I was a graduate student in that lab at the time, working on other projects]*** took place and found high levels of Mo, and excessive values of gross alpha and beta, and selenium.

In 1979, the Los Alamos Scientific Laboratory (LASL), now Los Alamos National Laboratory (LANL), collected and analyzed water, soil, and vegetation in Lincoln Park. They concluded that potential health and ecological problems were possible from high levels of U and Mo.

Dr. Roy Williams of the NRC recommended moving the tailings to a lined facility, as soon as possible. ***[It is uncertain to me why Al Hazle of CDH was so ready to approve the new impoundment, even though Cotter had violated rules by beginning construction without approval.]***

Summary of File Information:

- "It was apparent that certain inconsistencies and issues have been repeatedly raised over the years."
- "An item-by-item review of these documents would have resulted in a cumbersome report."
- John Logan, a consultant hydrologist hired by Cotter, who consistently favored reducing standards and lowering expectations states, "I can certainly be wrong. After all, the available data on the deep path are rather scanty." A coal seam was encountered in the "most impacted" Lincoln Park well and "the identification of that coal is of great interest, because if it were to be the Wolf Park seam, the deep migration path would be strongly supported."
- (See wells 138 and 006, described later)
- License Application and Safety Review-Cotter Corp. 1979, purports to contain a list of "all previous documents" or summaries. These were not included.

CDH Correspondence Reviewed by Hart:

Aug. 13, 1979, L.T. Reynolds of CDH labs commented on FELRS draft saying, "U at 80 ug/l and Mo at 300 ug/l were too high to be a screening limit for investigation." He criticized long time frames for completion of analysis.

Hart points out that Bob Shukle (Water Quality Division of CDH) has been the most vocal critic of Cotter, including: 1). Objecting to pre-licensing construction of new impoundment because of inadequacy of interception trench to contain seepage; 2). Challenging selection of background values for U and Mo as being too high; 3). Stating the deep path is "possible," not improbable; 4). Needing CDH splits for quality control and verification of Cotter's analyses; and 5). Disagreeing with selection of background levels of U and Mo, and "personally questions the intent for which the assumptions were made."

In July of 1979, the Assistant Attorney General of Colorado stated that the water quality agencies "do have jurisdiction to take action on the Cotter problem." However, no action by either division was taken.

September 1979, CDH from Bob Shukle to Al Hazle: He states that Cotter should be given 10 days to come up with tracers to identify raffinate in ground water in case the new impoundment should leak. No action.

February 1980: CDH from Shukle to Al Hazle, points out that: 1). Wells 15, 16, 17 were completed without prior CDH approval as required in section 19B of License Amendment 11; 2). Condition of pond #2 is questioned; 3). Section 31B of license was probably not being complied with; 4). The replacement for well OW-2A was not operational. ***[Due to well re-numbering, it is difficult to see which well this is, but I think it's the one that was supposed to monitor the Wolf Park mine];*** 5). Data is very poorly presented; and 6). Item 21A compliance uncertain-needs close review-significantly lower levels of effluent from old tailings pond.

March 1980: Shukle again criticized that section 19B was out of compliance (contamination control north of SCS dam). There is no evidence significantly diminishing levels on contamination from old tailings pond.

Replacement well for OW-2A: Cotter proposed casing from 5-50 ft. Shukle recommended casing on a basis determined during drilling. He states, "Re-drilling of well OW-2A gives Cotter the chance to start developing this data, yet Cotter chooses the means which will provide the least benefit. …Cotter Corp. has not in the past nor is it at present, complying with all license conditions and several of the above items (in the memo) substantiate this position."

He surmises that Cotter's proposals for additional work on the shallow path "is simply buying time and avoiding the issues." He writes, “The Water Quality Department is of the position that the department should not accept the program but instead require an immediate demonstration of the effectiveness of the containment system and immediate improvement in deficient areas." ***[This is after the Asst. Attorney General stated that the Water Quality Division had jurisdiction]***.

September 26, 1980, Memo from Bob Schukle to Al Hazle (CDH): Items included, #2). Pond 2 being used for collection of raffinates after commitment was made not to do that; #3). Wastes commingled after commitment to not commingle wastes; #4). Well OW-2 was not replaced as committed; and #15). A meeting to develop contamination control north of the SCS reservoir was to be scheduled by Cotter and it was never done.

October 1, 1980, Shukle to Hazle (CDH): On the pump-back system he states, "If the trench depth assumption (Shukle's) is correct......the system is not being operated correctly by Cotter and is only collecting a fraction of the wastes." He continues, “If Cotter states that they can move the existing tailings in 3-6 months, they should be held to it." Cotter replied by asking for 3 years.

Cotter also stated that the original agreement had been signed only by Cotter's attorney, and therefore did not have to be honored. Shukle points out that since almost all the important documents from Cotter are submitted and signed by their attorney, this raises serious questions about keeping commitments.

Hart points out that Cotter's license Amendments are very difficult to read. Cotter is seemingly in non-compliance with determining ground water pathways, including deep path. CDH says that even though pathways are important enough to be a license condition, that if the issue is not resolved, all Cotter has to do is submit a proposal and a timeline for implementation. This method of deferring important issues is characteristic of the way CDH deals with Cotter.

Screening criteria of 300ug/l for Mo and 80ug/l for U are much too high, says the Water Quality Department of CDH. The matter was not resolved. Cotter was then required to present data in such a way as to identify trends by 3/1/80. This had not been done by 4/23/81. Deep monitoring wells were to be installed N and S of SCS dam, and this was not followed up. Wolf Park shaft was to be monitored before license was issued, but the license was issued, and Wolf Park was not sampled yet. Ken Weaver of CDH was transferred off the project during this critical phase, and Mr. Gamewell was assigned, but he was not up to speed enough to answer questions as of 4/23/81. Gamewell was unclear if the license was approved, even though Cotter was in operation.

NRC Evaluation (2/19/79): "This mill would probably not be authorized if it were a new application because of proximity to Canon City." NRC says that if appropriate mitigating measures and requirements are implemented by CDH, it would probably be OK. FIT and Hart says it does not believe CDH is up to the job. In 1979, the National Wildlife Federation requested an EIS for the site. NRC agreed, but it was never done. ***[Stoller Report of 1998 is 1st for wildlife – to date NO EIS per the National Environmental Protection Act (NEPA) has been performed at this site.]***

CBI Investigation (9/5/1980, File #79-07-0064): At the request of the Governor, the Colorado Bureau of Investigation (CBI) was requested to investigate certain allegations concerning criminal violations by Cotter. The CBI investigated certain practices at Cotter concerning radiation exposure hazard to workers and issues of reporting. They found that Cotter "...occasionally fabricated or altered data." It was reported that, "CDH enforcement was not always as effective as it could have been." Contributing factors: 1). Announced inspections; 2). Failure to conduct prompt follow-up inspections; 3). Failure to cite violations; 4). Failure to enforce; and 5). Compliance inspections were not regular and too far apart. The results were forwarded to Fremont County Sheriff's Department for action. No follow-up action was taken. CBI forwarded this report to the Fremont County District Attorney-No action.

EPA Evaluation of NALCO Report – July 24, 1978: The suggested modifications of Cotter programs covered 20 pages. These remarks were included: 1). Reports (NALCO, various Wahler) were not coordinated; 2). Present location not acceptable as mill and waste disposal site; 3). Urged CDH to increase vigilance (not reflected in documents- per FIT); 4). Urged study of alternative mill site (not done-per FIT); 5). CDH authorized pre-licensing construction of lined impoundment in early 1979; 6). Paul Osborne, EPA hydrologist, echoed Bob Shukle's concerns about completeness and accuracy of studies done on design of Cotter's new pond and monitoring programs; 7). Osborne felt these reservations should be pre-licensing conditions; and 8). Osborne felt that pre-licensing construction would put tremendous pressure on CDH to approve license even though there were strong reservations about continuing to use the site.

EPA Position Paper by Paul Smith – Feb. 26, 1980: Mr. Smith pointed out, "Since the new mill was 75% complete before CDH gained authority for pre-construction licensing, EPA had little success in having alternate and more remote sites considered." He continued, "The success of the review process was undermined by the pre-licensing construction." CDH came under a great deal of criticism for this.

8.0 Colorado Department of Health. Aug. 17, 1979. *Final Executive Licensing Review Summary (FELRS): Review Summary for Evaluation of the Application and Environmental Report for a Radioactive Materials License Submitted by the Cotter Corporation for a Uranium Mill at Canon City*.

[My comments in brackets]

It is stated that "discrepancies abound". CDH says Lincoln Park waters are "generally acceptable," but advises against using for drinking and livestock watering. "Generally acceptable" is not defined.

*CDH says future contamination will be negligible when all control measures are implemented.

*Does not take into account travel time for contaminants in deeper ground water.

*Existing contamination not well defined.

*John Logan, hired by Cotter, states that "The waters in the Wolf Park mine shaft have been tested many times and contain raffinates without doubt."

*Mr. Logan reports that the most affected well in Lincoln Park (#006) intersects a coal seam. If that seam were shown to be the Wolf Park, a deep migration path would be strongly supported ***[I agree]***. If the Wolf Park mine waters were shown to be polluted, it would be an enormous clean-up cost to Cotter. Cotter back-filled the shaft with unusual alacrity to "prevent surface contamination from entering the shaft," and degraded the monitoring well that was supposed to have sampled it.

*CDH didn't agree with EPA that contamination sources and pathways needed to be better defined before licensing, but did express many uncertainties.

*CDH expressed that no health hazard existed.

*CDH has never completely audited Cotter's water quality data.

*CDH oes not support a policy of "close vigilance" as required by the NRC.

*Internal disagreements between agency experts are still unresolved.

*Piecemeal licensing approach will require increasing amounts of CDH time.

CONCLUSIONS AND RECOMMENDATIONS (presented as Q and A)

1. Q. Is the water in the mill site vicinity contaminated?

A. Can't tell using existing data-data poorly defined and reported. Problems include unknown well depths, undefined back ground levels, unidentified sampling parameters, conflicting interpretations. Trends not available from existing format.

2. Q. Is there a "plume"

A. Yes, but the size depends on the determination of natural background data.

Recommendation from CDH: It is IMPERATIVE a quality assurance program be implemented. Cotter collects all samples and data, and apparently is not to be trusted.

3. Q. What actions has CDH taken?

A. Definitively-not many

Problem areas include:

*Transfer of old tailings
*Tracer program-develop a reliable tracer for identification of raffinates in ground water
*Determine routes and rates of present and potential offsite ground water contamination
*Investigate deep pathway
*Develop better format for data analysis
*Hazard assessment of Wolf Park mine waters. A license condition-not done by 1/1/80
* Adequacy of existing data-audit never done
* Determine affected area-needs establishment of back ground levels
* NRC recommended against siting new mill in old location. Stringent monitoring was requested to make sure safety to residents was maintained. No such efforts have been made.
*Sample Chandler air shaft water. Not done to date of this report.

[I observed water at Brookside that seemed to be coming from Chandler, and it seemed very contaminated and was precipitating large amounts of iron oxide, generally indicative of mine waters that contain much soluble iron when underground, because of low oxygen, then precipitate iron oxides when they are exposed to the atmosphere. CGP.]

FIT feels that CDH is unlikely to be able to monitor Cotter effectively and provide guidance that a regulatory agency ought to be able to do. FIT feels the public has a right to prompt and efficient resolution of any issue concerning public health.

FIT feels the water quality program has not been adequately enforced.

9.0 Cotter Corporation, 2005. *CY2004 Annual Environmental and Occupational Performance Report, ALARA Review*.

I. SECTION 7: "LIQUIDS MANAGEMENT"

["Water Quality" would be a more appropriate title]

pg 7-1: OVERVIEW

The report states, "The concentration of U and Mo in the ground water continues to decrease."

This statement is not fully defensible. Wells such as #006 (Bosco field well) continue to be high and don't appear to be decreasing in Mo and U, but actually is increasing as of 2007. The nature of the word "decrease" must be clarified. The implication by Cotter is that the decrease is linear. This would be a straight-line decrease to some low end point at a definable moment. This is incorrect. In a case where there actually is a decrease, the curve must be described as exponential and asymptotic. Which means slowly (in fact more slowly as time goes on) decreasing to a steady-state level. Ideally, this level would be background, but "background" for U and Mo is a very muddy topic in this area.

The steady-state end point may also represent a steady state release from previously contaminated soils and sediments or even slow arrival of U and Mo from deep paths through permeable coal layers in the Vermejo Formation. In either case, levels would take a tremendously long time to achieve background, or never reach it, if long-delayed contamination is surfacing.

Well 006 (Fig. 3f) appears to be increasing in U to levels around 0.5 mg/l (500 ug/l), and appeared in 2004 to be leveling off to a steady-state of around 9.0 mg/l Mo (9000 ug/l). However, sampling in 2006 had a high of between 13 and 14 mg/l Mo (13,000-14,000 ug/l), showing an increase.

Well 138, the Bosco field well, was sampled until 2000. U values are somewhat similar to 006, while Mo values are high in 138 and even higher in 006. According to Hearne and Litke (1987, p 16), the significance of well 138 is that it probably receives water from an artesian coal seam encountered at 88' in well LP85-1D, evidence of the “deep path” of contaminant migration (Fig. 2ei). I have mapped this coal seam (Fig. 2b). The location of well #006 was chosen somewhat upgradient of well #138, although the similarity of U and Mo values would at least imply that the wells encounter similar subsurface conditions. It would seem to me, as a matter of speculation, that the failure of U levels in well #006 might in part be due to a steady flow of contaminated water from the "deep path".

I question the use of wells #019 and #020 as "compliance" wells. The implication is that when levels in these wells are lower than the MCL, the goal has been achieved. This is hardly the case when adjacent wells are still higher in the mg/l range for U and Mo. It merely points to the complexity in the subsurface aquifer and results from any well will be misleading unless placed in context.

pg 7-2 The calculations of U and Mo recovered match the concentration levels in the water pumped back to the impoundment from well #'s 005, 333, 710, 711, and 712. What do they mean by "recovered"? If these amounts are cycled back to the main impoundment, they will simply add to the concentration levels already present.

If no "fluids" are entering the ground water from the main impoundment, how are the high values in Bosco well #006 explained?

The Arkansas River is claimed to have suffered no impact, yet total dissolved solids (TDS) increase by over 20% on most sampling dates. Even though U and Mo may be below MCL, there seems to be an increase in the major constituents. It could be argued this is caused by passing through Canon City-hard to prove without better tracers.

This also again points out the issue of the focus of this cleanup. Is it just driven by the MCL's for U and Mo, or is seepage to the ground water system the focus? Once U and Mo are diluted to the point of being non-detectable, the effect of the high TDS waters seeping from the ponds can still be measured.

Fluoride (F) characterizes some different water sources, especially the Vermejo Formation. Unfortunately, F is not currently reported. I have asked the CDPHE for all the fluoride numbers they have, but received no response to date. I have some numbers from the older literature, but even these have been omitted from the CDPHE graphing application website.

Fluoride is characteristic and obvious. This makes me question the geochemical reasoning being applied to the management of this site. Despite the CDPHE's rebuttal, I must agree with the EPA that CDPHE is seriously under-staffed in the Water Quality Division.

pg 7-2 to 7-4 SURFACE WATER MONITORING

The sampling locations for Sand Creek at Ash and at the Arkansas River and DeWeese-Dye Ditch (DWD) at Cedar Avenue are not shown on fig. 7-1. Table 7-1 should be arranged (to my taste, anyway) with the upstream site (#907) above the downstream site (#904). The numbers should be reversed, also, for a more intuitive presentation.

These are not critical issues, yet they point out that Cotter does very little to make its data presentation accessible to the reader. Important related items are left out of figures and related information is not included. I will continue to point out similar (and more serious) incidences. The art and science of data presentation is sorely lacking in communications from this site. The meaningful information is often very hard to retrieve from the extensive and complicated data sets and maps provided, much of which seems extraneous.

The CDPHE graphing application website utility is very useful, but many components, such as F, and many critical wells and sites have been omitted, e.g. the original Wolf Park (Littel) Mine Shaft sampling location and data is not available on the website.

pg 7-9 GROUND WATER MONITORING

Well 024 at Alkali Gap is the background well for the plant site. Water from this well is a Na-Ca sulfate-bicarbonate type, probably typical of blended waters of the area. TDS (1,300) are above drinking water standards, but not unusual for a ground water from this area.

Previously, surface water was sampled at Alkali Gap (# 531) but was discontinued in 1988. I discovered this data and was amazed at several things about it:

1. This water is a sodium-sulfate water with high fluoride and high uranium (100 ug/l), characteristic of the Vermejo Formation, not the granites and metamorphic rocks of the drainage basin of Sand Creek.

2. This water is quite variable in TDS. This is consistent with a surface water site affected by runoff.

3. This water type should not be sodium-sulfate or that high in F and U. In that sense it resembles raffinate-affected water. The source for this water should be granite and metamorphic rocks of the Wet Mountains, which yield a Ca-bicarbonate water, possibly with F and U.

4. Hearn and Litke postulated "industrial activities" or a deep aquifer. I have mapped the formations around the Chandler Syncline and the water coming through Alkali Gap flows over the Trinidad Sandstone and the Vermejo FM before it enters the plant site (Fig 2f). Vermejo-derived water is high in TDS, sulfate, and fluoride.

High F waters were also found in Lincoln Park in wells LP85-6D and LP85-4. I locate these along the subcrop of the Vermejo Formation. This strongly indicates water from deeper aquifers is affecting Lincoln Park wells. CDPHE and Cotter no longer report F, so I had to rely on historic data from USGS and others for this information. This might be a good fingerprint for the "deep path".

Well 114 is the background well for Lincoln Park. U values are 12.5 times higher than Well #024, the background well south of Cotter: (U=0.0125 in well 114 and 0.001 in well 24, both in mid July, 2004). Mo values are less different in the wells, but well 114 has nearly the same to nearly double the Mo values in July and April, 2004 (0.009 mg/l for well 114 vs 0.005 mg/l for 024, and July, 2004, 0.007 mg/l for 114 vs 0.05 mg/l for 024, April, 2004). The graphs on 7-10 and 7-14 suggest otherwise for Mo in the long-term, but verify the increase in U for 114. **This indicates well 114 is effected by raffinates, and therefore not a good choice as a background well in Lincoln Park.**

pg 7-11: The data for U and Mo in well 006 is extremely high for a Lincoln Park location – why isn't this the compliance well? Also, the data should have been presented on two separate plots, one for U and one for Mo. Presenting it this way makes U look misleadingly low (Fig. 3f).

pg 7-12: In Well 122, I do not see a conspicuous decline in U or Mo, despite what the text says. I absolutely disagree with the use of "moving averages" to analyze U and Mo data from the "compliance wells". This has a tendency to smooth out the high spikes and the low points which occasionally appear in these data. My sense is these mean either there's a lot of variability in this site (seems to be, but it's non-sense variability), or the sampling and analytical methods are inferior. The State should keep better track of that, except they seem understaffed in the Water Quality Division (WQD).

The graphs for these two sites show the huge variability in concentration that comes from the seasonal irrigation. It is truly hard to draw a meaningful trend line through this data. Cotter should always present the confidence level in the "fit" of their trend lines. This enables the reader to evaluate the quality of the trend.

I suggested to CDPHE that Cotter present the data for U and Mo as mass, rather than concentration. This seems the only way to eliminate the confusing effect of the dilution by the DeWeese Dye Ditch. I was told that they used to, but had stopped, and wasn't given a reason. It does serve to lower the "moving average" for concentration levels to below MCL's in some cases, which is to Cotter's advantage and the citizen's disadvantage.

pg 7-18, table 7-3: Same comment: Presenting U and Mo as average *concentration* for the year is a red herring. This practice should be vigorously protested. After all, if the DeWeese-Dye Ditch was lined, contaminant concentrations would swing way up in the seepage water. What would also become obvious is how much water Lincoln Park is losing because of the SCS dam and barrier. The water rights issue seems to need renewed investigation or review.

pg 7-20, 7-21, figures 7-22, 23: There are not really enough data points outside the plume area to actually define the plume, as the number of wells sampled in LP has been greatly reduced over the years.

pg 7-22 Mill Complex Groundwater Quality

Interpreting the ground water on the mill site is extremely complex. Theoretically, each ground water source should exhibit different major-ion chemistry. However, extreme variability in water quality values for sites on or near the plant is the rule.

Locations 003 and 371 seem to have an exponential decrease in Mo. The eventual steady-state value for Mo remains to be seen, but as the slope of the curve decreases, the time required will be very long (10-20 years). The U values for these wells do not suggest a trend to me. In addition, the U values are too much lower than Mo to be adequately portrayed on the graph. Again, U should be plotted on a graph separate from Mo. Well 372 seems to be having an upswing in Mo values. What these relate to remains to be seen, but if the increase is related to the chemical fixation pilot test as Cotter suggests, it gives a good idea of the travel time of contaminants. Well 808 seems to be anomalous until it is placed on the groundwater table map. Well 808 is just SE of a groundwater mound (of unknown origin) and receives flow from the NW. Analysis of the water types in wells 372 and 808 reveals them to be very different from adjacent wells, or indeed, any other waters on the Cotter mill site.

Comparing ratios of major components (in milli-equivalents per liter) and other factors

Well	TDS	U	Mo	Na/Ca	SO4/HCO3
003	11,400	14	70	5.8	9.3
371	9400	5.5	28	5.8	12.8
372	1130	0.0021	0.220	17.2	2.8
808	660	0.001	0.007	6.3	1.1
024	1300	0.0015	0.02	4.7	2.9
DWD	375	0.004	nd	3.3	0.31
Ark R	150	0.0034	0.01	0.37	0.38

- Well 372 water could be characterized as Na sulfate/bicarbonate. It most resembles well #024, background. How could ground water traverse the entire mill site and not be changed?
- Well 808 water is Na sulfate/bicarbonate
- DWD water resembles Arkansas River water, except it has picked up some Na and sulfate.
- Vermejo Fm waters are quite variable, as would be expected from the lithologic variability of the formation, but are mostly Na sulfate or bicarbonate in type with TDS from 420-2200 range, often with several mg/l of fluoride.
- Water from the Poison Canyon Fm is also quite variable, but on average tends to be mainly Na sulfate but some are Ca sulfate or bicarbonate types.

Recharge water for these formations and the Cotter site in general should be a Ca bicarbonate type resembling DWD water, and this is reflected in the values for unaffected alluvium as well.

Well 808 has considerably more bicarbonate than others, which suggests a source from outside the basin. I speculate city water is pumped in at this location, which makes the conspicuous ground water mound shown just NW of the pond area.

Well 372 is harder to explain. The water clearly resembles well 808 in that it has more bicarbonate than Well 003 or 371, but has much more Na than any of the other wells. This site does present mysteries. In any case, the water from Wells 371 and 003 is clearly different from Wells 372 and 808. The differences are not the same in all comparisons. The only way they really are different is in lower TDS, U, and Mo. 808 water really stands out by being a bicarbonate water-looks like it's from somewhere outside the basin because recharge water entering the basin doesn't have that composition.

pg. 7-26, Figure 7-28: The ground water table map.

Much pertinent data is left out of this map, making it very difficult to orient data with known important sites on the facility. The main impoundment is not shown, the impoundment underdrain wells are not shown, well 333 is not shown, the Littel Shaft is not shown, and etc.

Many of these features I have plotted on a blow-up of the table map (Fig. 3d). They clearly show that well 003 is cross-gradient to the main impoundment, and well 808 is not receiving seepage from the main impoundment, rather from the ground water mound to the NW.

pg 7-28

The concentration of U and Mo in the underdrains - Wells 710, 711, and 712 - look quite variable, but basically are holding steady from the early 1980’s at a high level of U and Mo. I would not be so bold as to draw a trend line, myself, nor consider them decreasing in contamination.

pg 7-29 Permeable Reactive Treatment Wall (PRTW)

I have commented on the PRTW in my Public Comments on the RAP, April 2005, (Appendix B, Sec. 4.3). With the amount of bicarbonate in the water, the PRTW and process was not likely to succeed because of the reduction and sequestration of U and Mo coincided with the high pH values generated by the reaction of the iron filings with acid in the water. It was no surprise that the precipitation of calcium carbonate blocked the pores.

As an experimental technology, the PRTW generated some data that could have been predicted by a rudimentary computer model. As a proposed remedy for the seepage plume, it seemed ill-considered.

pg 7-38 to 7-48 Piper diagrams

In viewing the original literature on Piper diagrams, it is apparent that they are being used incorrectly in this instance. Piper diagrams are useful to show water types, but much less so to show mixing of very different waters. In the original conception by Piper and others, the TDS of the waters was to be shown by the radius of the data point plotted from the radius of major ions in the water. In Cotter's presentation, no reference to TDS is made. The usefulness of the Piper diagrams is reduced greatly if used in this way.

As an example, if you were to mix a high TDS water with low TDS water, a huge shift would occur with only a small amount of mixing. There is no inherent way on a Piper diagram to show this accurately.

In addition, during this mixing, different ions could precipitate and change ratios, notably calcium, magnesium, and sulfate. The TDS values for the comparison wells range from 2200-2500 for up-gradient wells to 11,800 or so for down-gradient wells.

Again, I see no way water could traverse the plant site from 024 to 372 and 808 and not change more than the data presented show.

Using Wells 372 and 808 to determine mixing is not applicable, as these wells are clearly different water types than Wells 003, 333, and 371. It is not known how these waters started or even where they came from, so it is impossible to tell if they've been mixed or not.

I cannot find CY2004 data for well 710 anywhere in this report or on the CDPHE site. In fact, the sampling for well 710 in 2004 was reported as “no flow.” Therefore, the Piper diagram is based on sampling from 2000-2003, and does not reflect anything for a report in 2004.

pg 7-49 location 023

The following are checks on accuracy of analyses, including: TDS, milligrams/liter, charge balance: milli-equivalents/liter, Piper/Stiff, water type: milli-moles to place point, add TDS to show conc.

I calculated totals of the mass of constituents in each well to see if the analyses were reliable (see Appendix D, Spreadsheets). Generally they were off by a fairly large amount, as has been noticed before in years past. There are two ways of verifying the correctness of an analysis.

1. Mass balance: Do the masses of the major ions in solution equal the mass listed as total dissolved solids (TDS)? In general the data presented by Cotter differ by a significant amount, as much as 20%

2. Charge balance: Does the combined positive charge of the cations (+) equal the combined negative charge of the anions (-)? Again, the balance is poor at best for analyses reported by Cotter, differing by 20% or more. This indicates that the quality of analyses is poor, and interpretations made from this data are less reliable.

Another more serious error occurs in the mass balance of well 023. Previous year's analyses give the TDS for this well in the 300,000 mg/l range. The value for 2004 is reported as 15,800 mg/l. A cursory look at, and accuracy check of, the data, shows that the sum of major constituents for this site is 163,598 mg/l (this is the sum of Ca + Na + Mg + K + HCO3 + SO4 + Cl, all in mg/l). This confirms there is an error in the reported 15,800 mg/l.

This is serious in that no one checked the data and the person who calculated the data did not see it. It's pretty obvious. It seems the CDPHE is seriously understaffed in the WQD, as they evidently have nobody with the time or expertise to check this. If this obvious error passed through to the final report, in addition to: 1). The analytical errors indicated by the imbalances in the mass and charge of the analyses; and 2. The improper use of Piper diagrams, then doubt is cast on the more significant conclusions in the remainder of the report.

II. NUMERICAL CHECKS ON ACCURACY OF SELECTED CY2004 WATER QUALITY DATA (for folks with Chemistry background)

I did some standard tests to check the accuracy of the water chemistry of the annual report water data. These tests are routinely used to determine the quality of analyses. I am attaching my spreadsheets so you can see for yourselves.(see Appendix D). The large number of analyses precluded the complete analysis of the data set, but I tried to do at least two for each well or site, and to have them be on approximately the same dates. February and May were chosen as representative months. The Arkansas River values were scrutinized more closely as some inconsistencies were noted.

1. Compare calculated total dissolved solids TDS (total dissolved solids) with lab TDS:

Method: Add up all the milligrams of dissolved components (Na, K, Ca, Mg, Cl, HCO3, SO4, and NO3). This is TDS calc. Lab TDS are generally determined by evaporation. A measured amount of water in a beaker of known weight is evaporated to dryness and the residue left in the beaker weighed.

If the analytical work was good, these two numbers should be very similar (ideally 100%, but you never get it, therefore +/- 10% is traditionally acceptable). E.Ethington of CDPHE told me he would accept 80% off, and that is not an acceptable practice.

All the major components in the water except silica and fluoride were reported. Neither of these would change things too much. I've seen some few silica numbers as high as maybe 40 mg/l back in the old literature but normally silica is in the teens. Silica doesn't count in charge balance calculations, which I show next, and these are somewhat more definitive.

Fluoride is rarely more that 2 mg/l, so no big change from not having silica and fluoride in the calculation.

I didn't add in U and Mo. They were only high enough to matter in some wells, but these already had very high TDS so the % change would be small if they were added in.

Usually +/- 10% is acceptable for the comparison of calcTDS to labTDS. As you can see, the analyses are quite variable, with fairly wide variation. Again, ideally, each result should be 100%. I think the important thing here is that the numbers are just all over the map. It speaks ill of the care taken in analyses, and for the State in not checking it. An obvious decimal point error occurs for well 23 where 15,800 mg/l was entered instead of 158,000 mg/l.

Many other obvious oversights were noted. In well 144, a 170% error is noted. This is very simple checking of the data for typos and inaccuracies, which was apparently not done.

2. Charge balance, or cation/anion ratio: This factor is another check on quality of analyses. In a water of any type, the positive charges on the dissolved ions (cations) must charge match the negative charges (anions), as the water must be electrically neutral (+ = -).

The method is to add all the positive charge (milliequivalents cations) and the negative charge (milliequivalents anions) and compare. Again, they should be equal. I made a percent of them, also, so you can see how widely variable the data is. As an outside observer of lab performance, my impression is that this is very sloppy work. As above, how can Cotter be trusted with critical numbers, like U and Mo, when the basic water chemistry is fumbled so badly?

3. Additional comments: I was really struck by how many even whole numbers were being reported. Either some aggressive rounding off of values or really inaccurate and imprecise lab methods were used for so many numbers to be so neat and even. Nature isn't that way. I was really amazed to see numbers like 2500 mg/l and 500 mg/l continually reported, which is not realistic at all, and makes it truly difficult to accurately calculate ratios of dissolved ions, like Ca/Mg, as is suggested for leak detection from the lined impoundments.

4. Arkansas River data: I compared upstream and downstream at high water and low water. A few inconsistencies appeared. I was struck that the low water TDS, except for one month, June, which you'd expect, the TDS numbers are very similar. The sodium values, which should have been reduced by dilution in June, were the same as other months. This is very unusual. In addition, the downstream site, after the Arkansas. River had passed through Canon City, had less TDS than the upstream site. This is highly unlikely. In October, a huge increase in SO_4^{2+} (sulfate) affected the river as it passed through town, although other components were unaffected, including sodium. Not impossible, just really unusual.

Subsequently, the cation/anion balance and the TDS comparison showed too much variation. I question whether the data was carefully collected, analyzed, and transcribed, by the Cotter Corp. analysts and field technicians, or subsequently checked and verified by the CDPHE.

5. U and Mo Plume Contour Maps. Pp 7-20, 7-21: In examining the boundary contours of U (0.035mg/l) and Mo (0.100 mg/l), I found that the zone closest to the Sand Creek gap perhaps needed to be re-interpreted.

I noticed that the plume contours on both U and Mo plume maps appeared to be hand drawn more or less equidistant between wells with extremely high concentrations of U and Mo and wells with fairly low concentrations. While this may look reasonable to the observer, it does not follow accepted procedure for drawing contours.

Normally, the concentration between adjacent points is expressed as a gradient. It can be calculated how far away from the lower concentration well the MCL contour will be by adding increments of concentration gradient until the value is reached. Note that mg/l is the same as ppm:

a. As an example: Well 331 had 13.175 ppm Mo (an extremely high value) and the next adjacent Well 141, had Mo at 0.005 ppm. The horizontal distance between the wells is 37mm. The concentration gradient between wells is then :

$$(13.175 - 0.005)/37 = 0.3559 \text{ ppm/mm}$$

b. The distance from the low well to the MCL contour (0.1 ppm Mo) is then:

$$\text{Dist} = (0.1 - 0.005)/0.3559 = 0.27 \text{ mm}$$

Instead of **0.27mm**, the contour was placed **25mm** away from Well 141, which is off by a factor of 10.

In interpreting this, you must take into account that the Sand Creek gap is essentially a point source for the seepage contaminants. There is conjectured to be a bedrock channel under the alluvium that contains the plume. I have a certain amount of trouble with this because it should be extremely difficult to maintain a concentration gradient that steep between the pollution plume and the relatively pure water outside of it. My feeling is that rapid diffusion of U and Mo would take place as soon as the contaminant plume left the confines of Sand Creek gap. This is a reasonable conjecture. However, the number of sample locations, especially on the NW side of the plume, is insufficient to define it. I believe it is possible that the plume diffuses and widens immediately after leaving the gap and becomes quite broad. Whether this is true or not could only be substantiated by more sampling.

The plume boundaries farther out in Lincoln Park are fairly accurate, although I see no reason to have an isolated high of U centered around Well 129. This local, isolated high in U could actually be explainable if there was a subsurface (deep path) source for U below Wells 129, 173, 189, etc. The northern E-W extension of the U and Mo plumes seen clearly in Chafin and Banta's (1999) USGS maps (Fig. 3a and 3b) does coincide with the Trinidad Formation, which is actually omitted from their Geology Map (Fig. 2a). Compare their plume contours to my modification of their Geology map (Fig. 2b), and you will see that the E-W extension of the plume coincides with the "red" line indicating the Trinidad Formation emerging in Lincoln Park. Likewise, the southern E-W extension in Chafin and Banta's plume map corresponds to the base of the Vermejo Fm, where the Wolf Park coal seam is located (Fig. 2b) and contacting Wells such as 138 and 006.

III. FINAL COMMENTS ON THE DATA PRESENTATION:

1. In addition to the poor quality of the data, there is a significant omission in the text that has actually been carried through for the last few annual environmental reports. On p. 7-12, the graph for dissolved Mo in Well 006 is not present and has been replaced by a duplicate of the U graph below. This seems more serious as this is the most contaminated well off the plant site and was adjacent to Well 138, which was the well that poisoned the livestock originally.
2. I am concerned that Well 138 was dropped from the sampling list, if only for symbolic reasons, as it was the well that first drew attention to contamination by raffinates from the unlined ponds. I feel it should have been retained. I recognize that it was a hand dug well and not specifically designed for sampling. Well 122, while providing a useful data point, is not nearly so contaminated and does not catch the eye in the same way with milligram levels of U and Mo, although it provides a useful data point near the edge of the plume.

In addition, because of the extremely high levels of U and Mo in Well 006, I recommend it be converted to a pump-back well.

3. The presentation of data in the annual environmental report and other reports from Cotter is extremely confusing and hard to follow. When data is presented, it is extremely limited. A case in point is the ground water contour map on p. 7-26. Many useful pieces of information are omitted from this figure including the pond boundaries, the golf course boundaries, section lines (many wells are located via section lines), and pumping or water injection locations.

4. The omission of data and poor data quality makes actual interpretation of water quality and flow in the subsurface on the plant site in Lincoln Park almost impossible. At this point I give a strong vote of "no-confidence" in Cotter's data sets. More seriously, if the major ions aren't correct, how can the data in sensitive contaminant chemistry be trusted? Important decisions are being made on the basis of sub-standard data.

IV. SUPPLEMENTAL QUESTIONS WHICH HOPEFULLY CAN BE ANSWERED BY CDPHE: Via E-mail or at a Community Advisory Group

1. Has Cotter adjusted the pH of the ponds in any way besides adding the tailings from the alkaline process in 1999-2001? If so, how did they do that and assure that the mixing was uniform throughout the water column? In other words, is there a pH stratification in the ponds? I agree that the CDPHE diffusion calculations are correct for the addition of a tracer at the surface of the ponds. Would that not be similarly applicable for alkaline process tailings laid in on top of the previous acid process tailings?
2. Is there any way of determining the pH and chemistry at the tailings/cover layer, membrane boundary? I know that lysimeters were installed at one time. Are they currently in use for sampling?
3. I note that dissolved iron levels are very high in sample locations 002 (Primary Impoundment Pond) and 023 (Secondary Impoundment Pond). The pH levels in 023 are below 4, which would allow for fairly high solubility of divalent iron, as is seen. However, those samples from 002 are around pH 4.1-6.28. The solubility of Fe^{2+} can range from fairly high at pH 4.1, to very low, at pH 6.28. If the surface water is oxygenated, the solubility of iron would, of course, become very low.

   If DO (dissolved oxygen) were measured, Eh, (oxidizing potential) could be calculated. That would at least give an idea of the redox conditions in the surface waters of the ponds, which would be a check on the iron concentrations, to see if they are reasonable. I presume that in the deeper levels of the pond, the waters are reducing and acid, which would allow for high values of dissolved iron, and also calcium and magnesium, because of the pH. Mixing with ground waters or spring waters of the site (pH >7) should cause rapid precipitation of iron oxides, calcite, and high magnesian calcite, as my modeling has shown. While, on the one hand, this would be a good thing, plugging leaks as was so nicely shown in plugging of the PRTW, it would tend to mask any seepage from the lined impoundments.
4. Surely the pH = 11 value for PW-2 is a typo? Or is it contamination by drilling fluids?

APPENDIX B

SPECIAL STUDIES AND
ANSWERS TO
COMMUNITY QUESTION

APPENDIX B

SPECIAL STUDIES AND ANSWERS TO QUESTIONS

TABLE OF CONTENTS

1.0 UPTAKE OF URANIUM AND OTHER HEAVY METALS BY PLANTS: A short report in response to a citizen inquiry about the safety of garden vegetables and non-treated irrigation water. C.G. Patterson, Ph.D.

The general line of search I used was twofold: Geobotanical Prospecting, a field pioneered in the US by a USGS scientist, Helen Cannon, back in the 1950's and 60's, and Phytoremediation, the use of plants to extract heavy metals in soils on contaminated sites.

GEOBOTANICAL PROSPECTING.

The primary references on this were in USGS Prof. Paper 300, "Peaceful Uses on Atomic Energy, a conference held in Geneva Switzerland, 1955", and Brookins, "Geobotany and Biogeochemistry in Mineral Exploration". There was also some information in Rose, Hawkes, and Webb, "Geochemistry in Mineral exploration". Much of the work reported was on Colorado Plateau ores which applies directly to Lincoln Park.

I looked up the use of <u>indicator plants</u> in prospecting for uranium deposits. There are a number of behaviors plants can do with respect to heavy metals in the soil:

1. They are poisoned
2. They ignore the metal and will not take it up
3. They take up the metal in the same proportion as it occurs in the soil
4. They accumulate the certain metal they have an affinity for.
5. They accumulate elements that occur with, and indicate the presence of another element (i.e. Se and U)

Back in my USGS days, I spent quite a few years prospecting for uranium in western Colorado and SE Utah. One of the things we noticed was that certain plants always grew on uranium deposits. The main one was <u>Astragalus Pattersonii</u> (no relation to me), a scruffy looking little vetch or pea plant that smelled strongly of garlic. The others were plants of the Stanleya genus, called <u>"Prince's Plume</u>". This is a handsome tall yellow flowering plant. Both these plants, it turned out, were selenium accumulators, which made them in the category of uranium "indicators".

Selenium very commonly occurs with uranium in sedimentary type deposits like on the western slope. Some bacteria in the root of the plant draw it in. Selenium itself can be toxic, and is apparently much more readily taken in than uranium. The presence of uranium in soil has been shown to dramatically increase the uptake of selenium, calcium, phosphorous, and sulfur. Other plants used as "indicators" are those that take up sulfur, sodium, or calcium, also common in U deposits or raffinate, like <u>onion, lily, buckwheat, or mustard.</u>

The uptake of uranium is somewhat seasonal: Most plants will take up uranium in the same amount as in the soil. I found only a few references to plants taking up U itself in amounts greater than the soil, although some do. True uranium accumulators are rare, but they include: <u>Conifers (pines and junipers) and Rose family plants</u>.

The presence of gypsum, selenium, or calcite (all present in Lincoln Park soils), increases the solubility and amount of uranium to be absorbed by plants.

Plants much more readily take up elements like selenium, molybdenum (the original cause of the poisoning of Bosco's cows), cadmium and zinc. These elements will be concentrated in the stems and leaves of the plants. Metals such as uranium, lead, and arsenic, are absorbed less by the plants. A major source on exposure to these metals in a garden would be soil clinging to root crops, such as carrots, onions, or potatoes, although some is absorbed as well, and clinging to leaves from irrigation by sprinklers.

Secondly, I looked up references to "Phytoremediation", the application of certain "accumulator plants" to selectively up take contaminants such as heavy metals from the soil. These may be natural or genetically modified. Certain bacteria of the Thiobacilli genus can also do this under the right conditions.

PHYTOREMEDIATION

The two main plants that can be used to selectively uptake U in cleanup sites are sunflowers (used at Chernobyl) and a small flower called Alpine Pennycress. These are currently under research by a number of scientific and government agencies to determine their abilities in cleaning up soils contaminated with heavy metals. (Do a GOOGLE search on "Phytoremediation" to see the studies.)

TOXICITY

The reference sources I used for toxicity of uranium in plant material were Gough, Shaklette, and Case, "Element Concentrations Toxic to Plants, Animals, and Man," USGS Bulletin 1466, and the USEPA's website links to Savannah River, Argonne Nat'l laboratory, etc.

Soluble uranium has been referred to as "the most toxic heavy metal", considered not for its radioactivity, but for its poisonous aspect. It strongly damages the kidneys, the endocrine system, and the reproductive system, both in acute (high dose, short time) or chronic (low steady dose) over a long time-the Lincoln Park situation. There is very little chance of any *acute* exposures to U or any other heavy metals in vegetables in Lincoln Park, but chronic exposure is highly indicated.

The findings include:

1. No observed toxicity to the plants, even at fairly high U content in soil.
2. No toxicity from U to grazing animals under natural conditions has ever been reported.
3. Under experimental conditions, no toxicity to grazing animals, even at very high concentrations, from yellowcake (U_30_8), pitchblende ($U0_2$), or UF_4. High toxicity from certain U compounds such as U-nitrate, U-trioxide, U-4 oxide, certain U-fluorides and chlorides.
4. Toxicity to man is not well known, but is certain to be toxic at some levels within the range of mammals.

Studies on the Navaho reservation have shown damage to the endocrine and reproductive systems of young girls, as well as uranium being readily uptaken by lettuce and radishes irrigated with contaminated ground water.

SUMMARY and RECOMMENDATIONS

It is without question that plants in the Lincoln Park area, whether garden or wild, absorb uranium. The toxicity of U from ingested garden vegetables is not well known, but I personally would be wary of a steady diet of the same type of locally grown garden vegetables for an extended period of time (many years to a lifetime, and especially for pregnant women, babies and growing children). For intermittent consumption, I would consider the vegetables to be safe, not because they don't have U in their tissues, but because the toxicity of U is low. However, there are many more elements to worry about besides U.

There are other elements in the soil of Lincoln Park that are much more toxic and readily accumulate in garden vegetables. These are Molybdenum, Selenium, Lead, and possibly Arsenic.

You need to have a soil sample of your yard, garden, and of your garden vegetables to be 100% sure. There may well be a soil analysis of yards and gardens, but in my experience, the CDPHE prefers not to sample garden vegetables.

That said, I would take special care to thoroughly wash all vegetables from the garden because of U (and the other elements of concern) clinging to the leaves as a residue from evaporated irrigation water, soil clinging to roots, or from blown dust. Likewise, take special precautions to thoroughly wash the hands of all children after outdoor play, and also of gardeners and outdoor workers, such as landscapers. Consider restricting children to indoor play on dry, windy days. Vacuum, with a HEPA filter vacuum in your house very frequently, particularly in summer or on dusty days.

2.0 LINER LEAKAGE AND CONTAMINANT TRANSPORT FROM LINED IMPOUNDMENTS: A response to CDPHE's analysis by E. Ethington, 2006. C. G. Patterson, Ph.D.

Questions concerning the integrity of the Hypalon liner and composition of clay liner and protective cover were raised at the time of construction. Observations of multiple (70) rips and tears caused by factors such as heavy equipment, rubble in protective cover, and the possibility of a high percentage of sand in the clay liner have led to concerns about leakage from the lined impoundments. The construction was undertaken in a rapid fashion (Hart, 1981), prior to receiving approval from the CDH (now CDPHE). Observers at the time felt that undue haste caused certain design standards not to be applied, both in method of construction and quality of materials.

CDPHE has presented an analysis of the situation involving use and discussion of transport equations through lined impoundments. This analysis implies that under ideal circumstances, which are lacking in my opinion, leakage from the impoundments is so small as to be trivial or not happening at all. In addition, a consultant firm hired by Cotter performed a geophysical survey to detect leakage and/or contamination from the lined impoundments. I will offer comments and recommendations on both studies.

I feel that there are sufficient factors that cause the situation to deviate from ideal circumstances, and that further investigation is necessary to insure the integrity of the pond liners. A properly chosen tracer and thoughtful tracer study should be designed and carried out. The data from the geophysical study is presented in a misleading way and should be recast to enable better interpretation.

All factors being in good order, CDPHE's calculations are valid. A properly designed Hypalon liner makes a pond very impermeable. Any deviation from ideal renders the calculation inadequate to describe the real situation.

It has been reported that the clay barrier under the liner has a high percentage of sand in the clay. This could raise the hydraulic conductivity to values as high as 10^{-3} cm/sec or greater, at least 2 orders of magnitude than those suggested by CDPHE.

It was reported that during construction, about 70 separate tears, rips, or other holes in the liner were observed. While some of these holes may be self-limiting, if not altogether self-healing, others, such as those caused by larger rocks within the protective cover layer over the Hypalon, may have a configuration that does not seal itself, and remains a conduit for fluids. The number of such holes and size is speculative, but many were reported as large holes.

I believe that the historical record is sufficiently contradictory as to warrant a serious consideration of a tracer study that is designed in such a way as to give as rapid and unequivocal an answer as possible to this issue.

3.0 EVALUATION OF POTENTIAL TRACERS TO DETECT LEAKAGE FROM THE LINED IMPOUNDMENTS, COTTER URANIUM MILL SITE, CANON CITY, CO: A response to CDPHE's analysis by E. Etherington. 2006. C. G. Patterson, Ph.D.

Evaluation of potential tracers to detect leakage from the lined impoundments, Cotter Corporation Uranium Mill site, Canon City, CO

Charles G. Patterson, Ph.D.
PO Box 3007
Eldorado Springs, CO 80025
303-494-364 cpatter@rmi.net
EPA TAG Advisor to CCAT (Colorado Citizens Against ToxicWaste, Inc.)

My client, CCAT, requested me to evaluate and comment on several matters relating to the investigation of leakage from the lined impoundments on the Cotter Site.

These matters include:

1. Use of Mg^{2+} as a tracer to identify leakage from the lined impoundments.
2. Recommendations for a suitable replacement for Mg^{2+} as tracer.
3. Possibility for, and evidence of, leakage from the lined impoundments

In preparing these comments I have consulted many documents and letters concerning these issues.

My qualifications for this study are a Ph.D. and M.S. in Geology/Geochemistry from University of Colorado. Both theses were under the direction of Dr. Don Runnells. In addition to academic qualifications, I have carried on a consulting practice in Geology/Geochemistry for over 20 years. I have worked independently, with Dr Runnells' consultancy, Shepherd-Miller, Inc., of Ft Collins, and several other consulting groups.

This included working as a technical advisor/expert witness for WCC (Western Colorado Congress) on a lawsuit involving the Uravan Superfund Site.

I worked for the USGS for 8 years as a uranium chemistry specialist in the Uranium-Thorium Branch (now Sedimentary Resources) and in the Central Mineral Branch.

As a TAG Advisor, or Citizen Advisory Board member, I have worked on several Superfund sites, including Globe/ASARCO, VB/I-70, and Leadville/California Gulch.

I have taught Geology, Environmental Science and other courses such as Hydrology, at Red Rocks Community College for 35 years, and have taught Geochemistry of Hazardous Materials at the graduate level at UC-Denver for 2 years.

I have approximately 50 scientific publications and maps, including encyclopedia articles on Oxidation-Reduction in Groundwater (Encyclopedia of Geochemistry-Fairbridge) and geochemistry of Natural Waters (Compton's Encyclopedia of Science).

1. Comments on the use of Mg^{2+} as tracer or indicator of leakage from the lined impoundments.

Introduction:

In the Cotter Annual Environmental and Occupational Performance Report and ALARA Review, (ALARA) CY 2005 (p. 7-34) it is stated that the basis for the Main Impoundment Performance Monitoring is the use of the Piper Diagram to describe different water types. A useful summary of methods of presenting water-quality data can be found in Hem, USGSWSP 2254, p. 173-180, including a discussion of Piper diagrams and some helpful suggestions on construction, interpretation, and ways to plot data to convey maximum information. Some of these plotting methods would be useful in the Piper Diagrams presented by The Cotter Corporation ALARA, (p.7-35 - p.7-47), and would aid considerably in interpretation of the data. A useful addition to the data shown on the Piper diagrams in the ALARA is to indicate TDS (total dissolved solids) by plotting each data point on the combined diagram as a circle, the radius of which is proportional to TDS. TDS is a primary factor in identifying water from different sources. (see overhead #1) The Stiff diagrams of Hearne and Litke (USGSWI-4014, 1987),are another useful way to show water types and TDS on the same figure.

Specifically, it is said that solutions from the main impoundment are set apart from ground water by having high concentrations of magnesium. The criteria for leakage would be a shift in the magnesium content as shown on the Ca-Mg-Na triangle of the Piper Diagram towards the 40% magnesium level.

In reviewing the documents related to the site, I have not been able to find any definitive and complete analyses of the interstitial waters in the ponds. The "Clay Liner Evaluation Report"(Terra Vac, Vols. I & II, 1994). The analyses for site 023, listed as "secondary impoundment" on the "water sampling locations" sample site description list, is the only site to show high magnesium, but the site is apparently a surface water grab sample, not characteristic interstitial fluids, and seems to exhibit substantial variation month-to-month, presumably because of evaporation and fresh water injection. This site is described as "main impoundment" on the Piper diagram on page 7-46, 2006 ALARA report. If a full analysis of both primary and secondary impoundment interstitial fluids exists which shows high magnesium levels, I would appreciate being able to see it.

Even if so, I feel that magnesium is a poor choice as a tracer for a number of reasons.
The need for a suitable tracer or indicator for leakage at the lined ponds has been known for two decades, although no mutually agreeable component or components has been found. The problem is to not only identify raffinate-derived fluids in the subsurface, but to differentiate old unlined pond leakage from leakage from the newer, lined impoundment.

The residual contamination from the old ponds is thought to mask any leakage from the new lined impoundments. Leakage from the lined impoundments is bound to be of less volume than from the old, unlined ponds and could easily be obscured by the greater volume of contaminated ground water from the older ponds as they slowly leave the area.

The solutions from the old unlined ponds and the new lined ponds should be similar. It is commonly agreed from various authors and from my research of the literature that raffinates should be high in TDS (thousands to hundred of thousands of mg/l), sodium, sulfate, U, and Mo (mg/l levels), and of low pH (1-3) if from the acid process. I have not seen in any raffinate analysis anywhere with an unusually high amount of magnesium.

A tracer should be able to differentiate the old ponds from the new ponds by pinpointing the source of contamination. In this case, where multiple sources of contamination exist, and the contaminant fluids are similar, determining a suitable tracer is quite difficult.

The qualities of a useful and accurate tracer, or indicator of contamination, are listed below.

1. The component should be characteristic of the raffinate from the lined ponds and different from the previous raffinate contamination from the old, unlined ponds.
2. The component should be "conservative", and not be involved in any chemical reaction such as sorption, dissolution, or precipitation which would either change it's original concentration, or, more importantly, its ratio with another component of interest. Magnesium is involved in any of several precipitation reactions, including high-magnesian calcite, dolomite, and sepiolite (Mg-silicate).
3. The component should travel with the groundwater by advection/diffusion, without significant retardation by solids in the aquifer, such as clays or iron oxides, both of which are very abundant in the raffinate or in the aquifer. Magnesium is significantly retarded, as is calcium, by clays in the lining and in the aquifer.
4. If the contaminant solutions are so similar that they cannot be differentiated, then a good case for a stable tracer that is introduced into the lined impoundments can be made.

Several indicators of contamination have been suggested over the years by various authors. Most authors (Hearne and Litke, Wahler, Geotrans, Stephens, Runnells) have suggested some combination of Na, Cl, SO_4^{-2}, TDS, or it's analogue, EC. All of these components are characteristic of raffinate. They are all stable and conservative, advective and non-reactive. However, none of these differentiate between the old ponds and the new ponds, although they are distinct from the springs underlying the main impoundment.

Some authors have suggested U and Mo (Chafin, 1999, USGS, USGSWRI 98-4228), but these are both subject to reaction, complexation, retardation, and give anomalous results in some downgradient wells (Banta, 1999, Chafin and Banta, 1999). Since these are the contaminants that are driving the cleanup, they are of obvious interest, but probably should not be used as absolute indicators of contamination.

Use of Mg as Tracer:

Currently, the use of Mg, or more accurately Ca-Mg, on the Piper Diagram is being advocated by Cotter and the CDPHE to identify leakage from the main impoundment. It is stated that since the pond solutions are "high" in Mg, that mixing of leakage water with ground water should cause a "shift towards the 40% Mg line". <u>I have searched for an analysis of the pore waters in the pond</u>

that would represent the potentially leaking fluids, but have failed thus far to find one. Some early analyses of raffinates do not even include Mg. It is very difficult for me to evaluate Mg as a tracer or indicator without knowing the composition of the pond waters.

I have examined the chemical data for water sampling locations #002 (primary impoundment) and #023 (secondary impoundment) under the supposition that they represent the leaking fluids, I have found both these sample locations to have a wide range of chemical composition, which varies by the season and the year. Examples include location #023, where sulfate on 3/31/05 was 39000 mg/l, and only 9300 mg/l on 6/29/06. The TDS (total dissolved solids) varies by as much as 100% between different sampling times (this information is not shown by the Piper diagrams). Location #002 show a TDS of 35,300 mg/l on 3/31/05, while 12/30/05 shows 187000 mg/l. The Ca/Mg ratio changes as well in these locations.

These represent surface water "grab" samples and may or may not represent the chemical composition of the interstitial fluids in the impoundments. It makes it difficult to interpret the chemistry of the underdrains if the surface water chemistry in the ponds is so variable.

To me it seems the underdrains (710, 711,712) would be a more appropriate location to look for fluids typical of the pore waters in the impoundments. If, as has been suggested by the CDPHE, that contamination from the old unlined impoundments is masking whatever leakage might be coming from the lined ponds, perhaps the question can be raised of why a leakage detection system was not installed in the lined impoundments when they were constructed?

I have examined the Piper Diagrams and seen none that are very close to the 40% Mg except #002 and #023. I am presuming these are surface water "grab" samples. Sample #002 shows Mg values ranging from 10% Mg to 45% or so, but changes over time, sometimes more magnesium, sometimes less. This is likely to be the water that is contaminating the other wells, but the magnesium values from this sample location are not constant.

Sample #023 also has high % Mg water, but values seem to be trending to lower % Mg with time. Both waters are very high in Na, SO_4^{-2}, Cl, and TDS. These values are closer to consistent than the Ca/Mg ratio.

How can magnesium or any other component from these waters be a good tracer if the chemistry varies so much over time?

I have calculated and plotted values of % meq cations on the Piper diagram for location #023, 12,30/05.

	mg/l	meq/liter	%meq cations	total meq cations
Calcium	468	23.35	2.44	973.1
Magnesium	698	57.44	5.9	
Sodium	19300	874.1	89.8	
Potassium	698	18.0	1.84	

I plotted these values on the Piper diagram for #023, p 7-46 and found <u>they plotted at a considerably different point than that shown on the diagram.</u> This is of potentially great significance as the Piper diagram, as stated, is the basis for determining leakage from the lined impoundments. I wish you would check these for me, but I determine these values according to Hem, WSP 2254, which is arguably the most authoritative manual on water chemistry available today.

This apparent plotting error is of great concern and seems to affect all the plots. I wish you would have someone check these results. I would be happy if someone could show an error in my calculations and plots (who knows, maybe I'm having brain fog), but they are fairly routine and I have done this possibly thousands of times in the past.

I have modeled these waters using two different computer codes: WATEQ4F and PHREEQC, both from USGS. I am very familiar with these models, and have been using these specific codes since their inception in the early 1970's. Several important issues with the data became apparent as I tried to perform this work. In general, the data in the ALARA and other Cotter tabulations are of extremely poor quality: Here are some examples:

a. Obvious typographical errors abound, such as having the TDS value be less than a component, like SO_4^{-2}. Examples include location #023, 9/27/05, where sulfate is given as 48,000 mg/l, but TDS (sum of all components) is given as 21,460 mg/l. A simple lack of a zero, perhaps, but someone should have checked it.

b. A routine check of cation/anion charge balance showed that imbalances of over 30% one way or the other were quite common. Imbalances of this magnitude will not be accepted by the code for modeling as some component is missing or the analysis is not correct.
Examples include #002, 34% greater positive charge, #005, 68% greater positive charge, #023, 30% greater negative charge.

c. The Ca/Mg ratio would change from well to well, even if adjacent, sometimes in the same well over different months or years. Location #002 varied from Mg/Ca = 12.3 to 5.2 over 5 months in 2004. Location #023 varied from Mg/Ca = 20 to Mg/Ca = 5 over the same time interval in 2004. The Mg ranged from 42% to 11% over that period. How can a component so variable be used as a tracer?

Chemically, despite the fact that there is no consistency in the Mg concentration, the Ca concentration, or Ca + Mg, or Ca/Mg in the impoundment waters, both components were found to be at or near saturation with calcite, high-magnesium calcite (which I use as a surrogate for dolomite) in the waters that were sufficiently within balance to model. Depending on which sampling month I choose to model, the solids are either over- or under-saturated in samples from the ponds or in ground water contamination derived from the ponds (either old ponds, or lined impoundments). The USGS (Chafin & Banta, (USGSWIR 98-4228, p.39), and had the same difficulty with imbalance of charge in the water analysis.

PHREEQC (a water chemistry modeling program), Parkhurst (1995), USGSWRI 95-4227), allows for mixing of solutions in various ratios. Under 1:1 mixing with adjacent groundwater, both calcite and dolomite (high magnesian calcite) would precipitate or dissolve, as would gypsum. The concentration of SO_4^{-2} is sufficiently large as not to be affected by this precipitation.

In conclusion, I find the use of Mg, Ca, Ca/Mg, or Ca+ Mg to be unsuitable as an indicator of contamination or as a tracer to indicate leakage from the lined impoundments.

2. Recommendations for a suitable replacement for Mg^{2+}:

If a suitable tracer cannot be found or employed, I would recommend observing the wells most likely to be encountering leakage and evaluate them. Underdrains 710, 711, and 712 seem ideal for this purpose. Underdrain 710 has the least rise in TDS over background ground water, but 711 and 712 have double the TDS of 710 and all show a migration to the Na + K and SO_4^{-2} vertex, indicating contamination by raffinate. If a tracer is used that is found in raffinate in both the new impoundment and old ponds area, then at least use a tracer whose values are closer to consistent over time than the Ca/Mg ratio.

Well 808 is very low in TDS and is a Na-bicarbonate-sulfate type of water. That would indicate to me it is being recharged by water from the ground water "hump" immediately to the northwest, as flow lines would indicate. The origin of this "hump" and the one adjacent to it to the NW is unknown, but it would seem an explanation of its presence is necessary for a fuller understanding of the ground water regime near the pond area (see overhead #2, Flow lines of groundwater contours as shown on fig.7-28).

Recommendation for a Chemical Tracer:

My recommendation for a chemical tracer would be to inject a conservative and inert component such as KBr, perfluorocarbons (PFC), or even Freon, at several locations near the base of the pond, but without further damaging the liner. Although these all occur in the pond fluids, the current levels of these compounds has been established by the USGS (Chafin and Banta, 1998), and can be used as baseline values. These compounds can be detected at the ppb (parts per billion), ug/l, to ppm (parts per million), mg/l, levels easily. If the tracer appeared in #711, 712, or other adjacent well it would indicate leakage from the lined impoundment. If a tracer were simply dumped on the surface of the pond, as Mr. Ethington has calculated, diffusion would delay the appearance of the tracer for a large number of years. It has been shown in the investigations of Terra Vac, that getting close to the liner without damaging it is possible.

It seems to me that it would be worth a try in order to lay this question to rest.

Some final comments on the data presentation in the ALARA report:

1. In addition to the poor quality of the data, there is a significant omission in the text that has actually been carried through for the last few ALARA reports. On p. 7-12, the graph for dissolved Mo in well #006 is not present and has been replaced by a duplicate of the U graph below. This seems more serious as this is the most contaminated well off the plant site and was adjacent to well #138, which was the well that poisoned the livestock originally.

2. I am concerned that well #138 was dropped from the sampling list, if only for symbolic reasons, as it was the well that first drew attention to contamination by raffinates from the unlined ponds. I feel it should have been retained. I recognize that it was a hand dug well and not specifically designed for sampling. Well #122, while providing a useful data point, is not nearly so contaminated and does not catch the eye in the same way that milligram levels of U and Mo, although it provides a useful data point near the edge of the plume.

In addition, because of the extremely high levels of U and Mo in well #006, I recommend it be converted to a pump-back well.

3. The presentation of data in the Environmental, ALARA, and other reports from Cotter is extremely confusing and hard to follow. When data is presented, it is extremely limited. A case in point is the ground water contour map on p. 7-26. Many useful pieces of information are omitted from this figure including the pond boundaries, the golf course boundaries, section lines (many wells are located via section lines), and pumping or water injection locations.

4. The omission of data and poor data quality makes actual interpretation of water quality and flow in the subsurface on the plant site in Lincoln Park almost impossible. At this point I give a strong vote of "no-confidence" in Cotter's data sets. More seriously, if the major ions aren't correct, how can the data in sensitive contaminant chemistry be trusted? Important decisions are being made on the basis of sub-standard data.

Supplemental questions which hopefully can be answered at the CAG or via email:

1. Has Cotter adjusted the pH of the ponds in any way besides adding the tailings from the alkaline process in 1999-2001? If so, how did they do that and assure that the mixing was uniform throughout the water column? In other words, is there a pH stratification in the ponds? I agree that your diffusion calculations are correct for the addition of a tracer at the surface of the ponds. Would that not be similarly applicable for alkaline process tailings laid in on top of the previous acid process tailings?

2. Is there any way of determining the pH at the tailings/cover layer, membrane boundary? I know that lysimeters were installed at one time. Are they currently in use for sampling?

3. I note that dissolved iron levels are very high in sample locations #002 and #023. The pH levels in #023 are below 4, which would allow for fairly high solubility of divalent iron, as is seen. However, those samples from #002 are around pH 4.1-6.28. The solubility of Fe^{2+} can range from fairly high at pH 4.1, to very low, at pH 6.28. If the surface water is oxygenated, the solubility of iron would, of course, become very low.

   I don't imagine that anyone there knows how to take a correct Eh, but possibly ORP or DO was taken? With DO I could calculate an Eh. That would at least give an idea of the redox conditions in the surface waters of the ponds. I presume that in the deeper levels of the pond, the waters are reducing and acid, which would allow for high values of dissolved iron, and also calcium and magnesium, because of the pH. Mixing with ground waters or spring waters of the site (pH >7) should cause rapid precipitation of iron oxides, calcite, and high magnesium calcite, as my modeling has shown. While, on the one hand, this would be a good thing, plugging leaks as was so nicely shown in plugging of the PRTW, it would tend to mask any seepage from the lined impoundments.

4. Surely the pH value for PW-2 of 11 is a typo? Or is it contamination by drilling fluids?

4.0 PUBLIC COMMENTS SUBMITTED FOR CCAT, On Proposed RAP Revisions by CDPHE. April 2005. C.G. Patterson, Ph.D.

4.1 RAP Section 10.0 – NE/NW SHALLOW GROUNDWATER PATHWAY, April 2005. Comment Submitted by: Charles G. Patterson, Ph.D., CCAT EPA TAG Advisor

The **Northeast Pathway** is postulated to be in shallow alluvium exiting the plant site through the unnamed gap in the Raton Ridge and thence through the Willow Lakes area and into the Arkansas River. Monitoring wells for this pathway are **#016 and #017**. Neither of these wells has shown elevated levels of U or Mo, and my feeling is that this path is not a source of contamination to offsite areas at present. However, Wells **#016 and #017** in the Northeast Pathway should not be abandoned as they may: **a)** show contamination in the future from the shallow or possibly the "deep" path; and **b)** at present, they provide an additional set of values to estimate local background for contaminants.

The **Northwest Pathway** also lies in shallow alluvium and travels under the *Shadow Hills Golf Course* and thence through another gap in the Raton Ridge. The West SCS Dam is in this gap. Wells **#009**, and **#014** are in the flow path above the dam, and well **#15A** and **#15B** are below the dam. In addition, wells **#803-806** are on the corners of the Shadow Hills Golf Club. Well **#15B** collapsed to a level above the ground water surface and is now dry, although it has not been measured in recent years. The other wells produce water from deeper levels and all show elevated levels of the contaminants of concern, U and Mo, far in excess of background. It seems clear that regardless of any subsurface conditions (the ground water "divide") that there is contamination migrating in the NW direction and under the dam. Both the USGS investigators and the CDPHE use the word "most" when referring to contamination along Sand Creek pathway, not "no” contamination. It is unacceptable that measurable contamination levels in excess of local background be omitted from scrutiny and analysis. Further, contamination levels from this path could be causing the anomalous E-W lobes in the "plume" maps as irrigation water smears and spreads the contaminants. In addition, these wells may provide data if or when contamination from the deep pathway reaches the surface.

Recommendations:

1. Do not Delete RAP Section 10, as further investigation is justified.
2. Wells #016 and #017 in the Northeast Pathway should not be abandoned.
3. Analyses and statistics for wells #803-806, #15A, and #15B should be included in RAP reports
4. The Northwest Pathway should receive increased scrutiny, not less.

4.2 RAP Section 11.0 – WOLF PARK MINE SHAFT. Comment Submitted by: Charles G. Patterson, Ph.D., CCAT EPA TAG Advisor

The Wolf Park (Littell) Mine shaft has long been suspected of being contaminated by raffinates and tailings from early in the operation of the Cotter Mill. The shaft is adjacent to the impoundment ponds and may have had raffinate and other waste intentionally dumped down the shaft as some eyewitness reports suggest. The "Deep Path" for contamination involves waste migrating from the depths of the mine up dip in permeable beds of the Vermejo Fm (or even in void space of abandoned mines) to emerge in the Sand Creek alluvial aquifer of Lincoln Park. The feasibility of the deep path has been suggested by many workers. A resistivity profile done in 1979 by *Amuedo* and *Ivey* disclosed a zone of low resistivity under the alluvial deposits in Lincoln Park which could indicate either a zone of high free ion concentration (which would be indicative of raffinates), or possibly a more conductive bedrock layer such as a coal seam or a shale.

In truth, this route using the mineshaft as a conduit to deeper layers is almost the only way contamination could travel by a deep path. The Poison Canyon Fm is of low permeability, which would prevent surface contamination from reaching lower levels. The Vermejo Fm is an isotropic, with high conductivity beds sandwiched between low conductivity beds. This situation would tend to resist flow across the bedding planes, but it could allow flow along permeable beds encountered deeper in the mine, as well as mapped and unmapped mine workings which are locally felt to be interconnected and may provide flow to seeps along the Arkansas River near Chandler Gulch.

As a preliminary calculation to demonstrate at least the possibility of interconnection of the mines underlying the Cotter area, I took water table data from 3 mines or deep wells close to the mines: the Wolf Park (central), the Chandler (SW), and the Rockvale (NW, well 111). Banta and Chapin felt that because water levels were different in all the wells, that they are not hydraulically connected. Actually, the hydraulic gradient between them is 0.0044 – less than the Sand Creek (middle) shallow pathway. If the shafts are somewhat collapsed, that would provide enough resistance to flow to cause the observed hydraulic head as the groundwater flowed, especially if there were downgradient discharge.

That the mine works have been backfilled and grouted may have served to prevent further surface contamination, but it also prevented direct sampling of the mine water to verify if tailings and raffinate had ever been dumped.

I also noted an observation in one of the early papers, possibly Wahler, noting that aerial photos reveal a fracture pattern in the Raton Formation. Some fractures trend along the long axis of Chandler syncline, another set perpendicular to that. These same orientations were noted in 1910 by Washburne in the Chandler coal seam in the Littell Mine. Fractures are an ideal pathway for ground water movement.

In summary, I still feel that the deep path is a real likelihood, despite the USGS comments, and should still be taken seriously and subjected to study. The flow could be there, the hydraulic continuity, a possible zone of highly concentrated water below the Sand Creek gravels, and there are lots of historic accounts of illegal dumping and interconnected mine workings.

Recommendations:

1. RAP Section 11.0 should not be deleted, rather study of this issue should be increased in scope.

2. Install a line of piezometers to detect ground water pressure, hydraulic conductivity, and therefore likelihood and direction of flow between the mine shaft and Lincoln Park, along the most permeable layer of the Vermejo that the mine intersects.

3. A fluorescent dye tracer test should be performed to determine hydraulic connectivity and to track leakage into springs and seeps. There are some technical issues with the transport of U and Mo, but the reaction rate is unknown. However, other components of raffinate are more mobile and could cause degradation of surface springs and ground water in Lincoln Park if they were to emerge from the deep path. Without being able to directly measure the Eh (redox potential) or dissolved oxygen of the mine waters it would be impossible to confirm the exact chemical behavior of U or Mo in the deeper parts of the mine. A tracer test would confirm conductivity, but possibly after a long time interval, depending on the permeability of the layers. (A tracer test from the lined impoundment pond would also be appropriate.)

4. I strongly recommend tests of this sort be performed by an independent 3rd-party consultant chosen by the EPA (or the CDPHE, second best). Cotter Corp. has an intimate knowledge of the site, more than any other entity, and also has a considerable vested interest in the outcome of such tests, and should not be considered reliable in the placement and screening of wells or the performance of tracer dye studies.

4.3 RAP Section 12.0 – DAM TO THE DEWEESE DYE DITCH. April 2005. Comment Submitted by: C.G. Patterson, Ph.D., CCAT EPA TAG Advisor

An overview comment for this entire section is that the remediation guidelines for facilities such as Cotter require that the remediation plan be maintenance free:

> "In the selection of disposal sites, primary emphasis must be given to isolation of tailings or wastes, a matter having long-term impacts, as opposed to consideration only of short-term convenience or benefits, such as minimization of transportation or land aquisition costs. While isolation of tailings will be a function of both site and engineering design, overriding consideration must be given to siting features given the long-term nature of the tailings hazards."
>
> "Tailings should be disposed of in a manner that no active maintenance is required to preserve conditions at the site," (Colorado Radiation Regulations, Part 18, Appendix A, Criterion 1.C & D)

I. The **Pump Back System**, although useful to lower contaminant levels in Lincoln Park ground water, initially had the negative effect of increasing concentrations of U and Mo as the initial flushing pushed a slug of contamination into the alluvial aquifer. Once flushed through, U and Mo levels did begin to decrease, although not below MCL's in Lincoln Park. The long-term decrease seems to be leveling off at a low contaminant level, but not below MCL values along the Sand Creek aquifer. Plots of contaminant levels shown in USGS WRI Report 98-4228 show a steadily decreasing trend, but the decrease is asymptotic at best, either leveling off to some value or rising gently again (wells #9, 802, 804, 339). In any case, should the pump back and/ or flushing operations cease, the levels of contaminants would surely rise again

The guidelines clearly state that this system shall not be expected to operate into perpetuity, as do some acid-mine drainage systems (Leadville/Cal Gulch, Idaho Springs/Argo). The leveling off to some value or steady increase may indicate contamination coming from a different source such as the "deep path", or unreported increase in leakage rates from the lined impoundment. More work needs to be done to clarify the issue of long-term ground water contaminant levels. At this point in time, it is unclear what is actually going on with the U and Mo levels, but "wait and see" is probably not the best choice.

II. The **PRTW** represents a treatment technology that is considered to be still in the developmental stage around the country. All available guidelines listed by the DOE, USEPA, Dept of Navy indicate:

a) The technology is more effective for U (97% removal) than Mo (55% removal) at Monticello, UT.

b) The major problems with the barriers include:

- plugging by precipitated salts,
- plugging by oxidation and hydrolysis of the zero valent iron filings,
- loss of capacity as sorption sites are filled by contaminants and any other chemical in ground water that has similar characteristics to the contaminants,
- overall limit of capacity determined by flow rate and volume of ground water,
- concentration of contaminants in ground water,
- and concentration and type of dissolved minerals in water.

c) The zero valent iron, when at maximum capacity of contaminants, must be replaced, there is no way to regenerate the PRTW in the ground, and the removed materials constitute a "mixed waste" (low activity LLW and hazardous waste), which must be removed to a suitable site, such as Envirocare in Utah (apparently the only site in the country currently licensed to accept such waste).

For what purpose was an experimental technology that is only partially successful at removing the contaminants, requires replacement and maintenance at unforeseen intervals, and generates a hard to dispose of hazardous waste even considered for this site?

I will be interested to see the technical report on the PRTW, if and when it comes out. Presumably, Cotter will not attempt this again. I was dismayed, at the 2/10/05 Superfund Meeting in Canon City, to hear an apparently serious discussion of using the PRTW technology again. I have communicated with the project leader at the Monticello site, which resembles Cotter in many ways, but have yet to hear back from him.

Recommendation: The CDPHE website has a page on PRTWs, but it only has general information about PRTWs in other states. I recommend that documented data, analysis, and all information pertaining to Cotter's PRTW be placed on this website. This is an excellent avenue to fulfill the requirement in the Consent Decree of 1988 to provide RAP documents to citizen stakeholders within the Lincoln Park/Cotter Superfund Site.

4.4 RAP Section 14.0 and 15.0 – GROUND WATER COMPLIANCE and MONITORING. April 2005. Comment Submitted by: C.G. Patterson, Ph.D., CCAT EPA TAG Advisor

Specific issues addressed in this review section are:

I. Adequacy of monitoring well network

II. Back ground values for U and Mo as relates to plume boundaries

III. Use of other components as indicators of raffinate

IV. Reporting of data:

- a) Dissolved vs Total concentration
- b) Concentration vs mass
- c) Reportage of dry well values as zeros or non-detects

I. Adequacy of monitoring well network.

The integrity of the well sampling program depends on having an adequate number of wells to show the exact extent of contamination (see below), and to intercept pollution from sources that may have not reached Lincoln Park due to long transit time. The elimination of a well from the sampling network may be acceptable if it can be clearly shown that the well is redundant to the sampling scheme. Affected homeowners are stakeholders in the elimination of wells and every effort should be made to explain and justify elimination of a well in order to alleviate concerns. The CDPHE needs to maintain a diligent effort to help preserve the peace and mental health of the residents. To the extent that residents are living in fear and dread, the CDPHE has failed its mission to the people of Colorado.

Elimination of a well cancels the ability to do comparison of long-term trends. Loss of data may be considerable.

Recommendation: A map and list of the previous sampling network compared to the current sampling network must be presented and distributed by the State, with the decision process for the elimination of any well being clearly stated. It is the CDPHE/EPA duty and obligation to the citizens that counts here, not an obligation to Cotter Corp.

II. Background values for U and Mo as relates to plume boundaries

Many outlying wells and seeps I wanted to investigate are not on the Cotter website via the *Cotter Mill Monitoring Application*. I was looking for a regional background that is more reasonable than the current cut-off values of 31ug/l for U and 40 ug/l for Mo, which seem unreasonably high when looking at regional background levels. These regional levels seem to fall more in the range of 0-5 ug/l for each component. The justification that "Canon City is uranium country-it's all over" is not adequate. Banta and Chapin admit that raffinate affected waters may have U and Mo in that low range.

Recommendation: The plume map should be contoured down to 5 ug/l for each component for a more accurate picture.

III. Use of other components as indicators of raffinate

This is a tough issue. Sulfate and Electrical Conductivity (EC) and Total Dissolved Solids (TDS) are associated with raffinate, which is a sodium sulfate water with high TDS. Unfortunately, water from the Vermejo Fm is of this type, and water from the Poison Canyon Fm is Ca-Na sulfate. Simple dilution makes them less distiguishable from raffinate. Oxygen isotope ratios could possibly be used as they indicate evaporation, which is characteristic of the ponds. Tracer dye studies would also be a solution, although transit times would delay results for a few months to several years.

The question remains whether the CDPHE feels it is necessary to identify raffinate in Lincoln Park water or just base their activities on clean up levels of U and Mo. It seems to me the bigger question is "Is there leakage from the site?", not just whether the groundwater drinking water standards or MCLs are violated. I know the legal standard ends up being related to regulatory levels to determine success or failure of remediation, but another regulatory standard is that the site should not leak.

Recommendations:

1. Initiate discussions between agencies and stakeholders regarding constituents used to determine impoundment leakage and on-site sources of groundwater contamination.

2. Base remediation goals on the regulatory standard requiring no leakage from an impoundment pond or contamination source, and base remediation success on whether leakage of contaminates into the groundwater has stopped.

IV. Reporting of data

a) Dissolved vs Total concentration: Unless the regulatory standard specifies "dissolved" rather than "total", the total number should be calculated and presented. It has been repeatedly shown, notably at Rocky Flats and at Savannah River, that radionuclides will attach to colloids (clays, sesquioxides) in the aquifer and move with the ground water. This was considered impossible until it was demonstrated at those and other sites. (Many references on pg 150, in Fetter, "Contaminant Hydrology", 1993, Macmillan). Further, “total” concentration was tested at this site in the beginning, and then dropped around 1991.

Recommendation: Resume testing for “total” as well as “dissolved”.

b) Concentration vs mass of U and Mo: I was dismayed to hear Jeff Deckler say he had instructed Cotter to stop reporting mass movement of U and Mo, and just use concentration. The concentration is so variable, because of dilution by the DeWeese Dye Ditch, that concentration numbers are nearly meaningless, unless "one is using the letter of the law to avoid the spirit of the law." Mass transport is the ONLY measure of whether, and how much, the site is leaking.

Recommendation: Resume reporting mass movement of U and Mo.

c) Reportage of dry well values as zeros or non-detects: There is anecdotal evidence that dry wells have been reported as "zero" or non-detect during monitoring. If true, the practice would

be reprehensible and totally misleading and needs to stop immediately and past data corrected to reflect only wells that had water at sampling time.

Recommendation: Do not report dry wells during sampling as “zero” or non-detects. Correct any data where this practice may have occurred.

5.0 Comments on "Geophysical Results for Cotter Corporation, Canon City, Colorado" by HydroGeophysics, Inc., Oct. 2005. C.G.Patterson, Ph.D.

This geophysical survey was performed to detect leakage from lined impoundments using a "Super Sting" R-8 resistivity instrument manufactured by Advanced Geosciences, Inc.

The report summary indicates that leakage from the lined impoundments, although suggested by the survey, can also be explained by other factors on the site including residual contamination from the old ponds, or fine-grained sediments, or surface water infiltration. Historically, subsurface contamination near the lined impoundments has been explained by the presence of residual contamination from the unlined ponds that remained in the area would mask any evidence of leakage from the new from the new, lined impoundments. Unless a suitable method to unequivocably detect leakage from the lined impoundments can be found, I would have to be in general agreement with this observation.

However, I've looked over the report and a number of things do stand out, which still leave the distinct possibility that the survey either detected leakage, or, more likely, was incapable of differentiating leakage fluids from the lined impoundments from ordinary subsurface variations in grain size of the shallow alluvium, and so to draw a strong conclusion about the results of the survey seems unwarranted.

I went to the web site of Advanced Geosciences, Inc., to see the specifications of the instrument they used. It appears to be a reputable unit, which they rented for between $150 and $400 per day.

Advanced Geosciences listed other ground water investigations to demonstrate the effectiveness of their instrument and survey methodology. I was able to compare sites with similar geologic conditions and subsurface contamination from leaking ponds to the results from the Cotter site.
The comparison sites had subsurface conditions consisting of both alluvium saturated with fresh water or polluted water, dry alluvium, and bedrock similar to geologic materials encountered on the plant site. Comparisons, in studies like this, may be of limited usefulness individual site characteristics will ultimately determine the results.

I did note some potentially misleading discrepancies and inconsistencies in the data presentation.

pg 5 This figure provides a cross-section of a resistivity survey done with a different method in order to show the superior resolution of their "geometric inversion" method, which also incorporates topography. However, there is no depth scale on the traditional section (top cross-section), making it look less detailed by comparison to their technique (bottom cross-section). In the absence of a depth scale, there is no way to tell, but the depth represented on the top cross-section (traditional method) is likely 2-3 times greater than the depth scale on the bottom cross-section (geometric inversion method), thus making the top cross-section look less accurate as the scale is greatly reduced. If so, it seems to me this presentation is designed to be misleading and gives a false sense of the capability of the instrument and the method used in the study.

pg 6 The cross-sections shown are chosen to indicate the superiority of the geometric inversion method to other conventional methods. Their method more accurately shows the size of the pollution plume at Hanford, WA, which is a site that resembles the Cotter site in many important

respects. Both consist of highly concentrated inorganic contaminants in shallow ground water. The geometric inversion technique indeed does make the plume appear much larger than previous methods, giving an appearance of increased accuracy to their method.

Note the apparent resistivity values on the vertical scale on the left, which color codes the degrees of resistivity. Low values of resistivity indicate contaminated water.The most highly polluted water in the aquifer has values from 122 to 206 ohm-meters (ohm-m), while less polluted water is indicated by much higher values, up to 738 ohm-m.

Refer to their color vertical scale on the Cotter profiles on figures 1-10. Fifty-five (55)
ohm-m is the HIGH END cutoff on most of the sections, and the blue-yellow color break is at 15 ohm-m, as opposed to 206 ohm-m for the Hanford section.

The maximum value recorded at the Cotter site was 385 ohm-m, which was not plotted
on the figures.

To recap, high values of resistivity are "good", indicating either clean water or dry alluvium or bedrock, while low values of resistivity may be "bad", indicating either moist clay and silt or highly contaminated water in the aquifer.

In the introduction, the report states that it is difficult to differentiate between saturated aquifer material or dry fine-grained material (clay and silt), both of which will read much the same, and dry coarse-grained material.

The choice of colors on the resistivity scales is arbitrary. There is a huge visual impact
between the blue/yellow transition, despite the fact they are gradational, giving the impression that yellow/red transition is "safe".

However, the yellow/blue cutoff was 15 ohm-m for this study, but it was 206 ohm-m for Hanford, a site with essentially the same subsurface conditions as the Cotter site.

No attempt is made to standardize the survey with values taken from known polluted sites and known unpolluted sites. This would increase the credibility of the interpretation of the results. Otherwise, "normal" values at the Cotter site would indicate extremely contaminated water at Hanford, WA.

pg 7 last sentence before sec 3.1.1 "Electrical resistivity methods are not able to discriminate between unsaturated conditions in porous media and saturated conditions in low-porosity media".

sec 3.1.1 The probable top of the Poison Canyon Fm. is detected at 50-60 ft.

pg 8 It is stated that the coarse-grained nature of the alluvium around MW-003 (polluted) masks the ability to detect the pollution. "It appears that lithology (rock & alluvium type) may cause the largest influence on apparent resistivities due to the presence of sandstone." (sic) (Do they mean sandstone, or sandy, unconsolidated alluvium?)

Next p9: Same comment. Do they mean claystone and siltstone or clayey and silty alluvium?
Without being more definite, the interpretation "suggests" the presence or absence of moisture or rock type, yet without any kind of control.

In the summary, the conclusion is made that high conductivity (low resistivity) zones are related to moist fine-grained material. This is a judgement on their part that is partly contradicted by the disclaimer in the intro.

Figures 2-7 correlate low resistivity (high conductivity) mainly with lithology.

Figures 8,9, and 10 show extensive low resistivity zones at shallow depths on the west side of the ponds. These are useful plots. Higher conductivities along the SW end of line #6 which is away from the pond, and conductivities on line #2, adjacent to the pond, are interpreted as meaning that pollution from the old ponds either might actually be diluted by water coming from the new impoundment, or flowing toward the new impoundment.

In summaries of the report, it would be more accurate and less misleading to say "relative" resistivity differences. When the yellow/red zones at the N end of the pond are described as "highly resistive, and therefore dry", the author neglects to mention the range of values encountered would be considered indicative of wet, polluted ground at any other site I investigated.

Their color choice obscures that interpretation. If the same graph colors had been used for this job as were used at Hanford, the whole plot would be blue/purple. It would seem that the values have not been verified and standardized with samples before making definitive interpretations.

Line #2 is the only survey line that was established down gradient from the lined ponds in the direction ground water actually flows on the site. Refer to the ground water table map in the Cotter (2005) Environmental report (fig 7-20, pg 7-19) and my more detailed version in this report.

In summary, I feel the results of the geophysical survey could be interpreted in several different ways, one way being the presence of high ionic strength water being found in the proximity of the lined impoundments. To conclude the data shows no leakage from the lined impoundment is not warranted by the results. That conclusion is contradicted by the text. I see no reason to choose one interpretation over another, based on the results of the study.

6.0 Community Questions and Answers, Issues on Water Contamination and Remediation. Answers from C.G. Patterson, Ph.D (2004)

QUESTIONS:

1. Why were Uranium & Molybdenum the only constituents monitored for in the majority of private wells in Lincoln Park for so many years? Do you agree with this decision? What impact did this have on the community's ability analyze the movement of Cotter's raffinates, and to compare years of data to determine the extent of progress in remediation?

> A. I cannot second guess the decision to report Mo and U (I think other components are analyzed for but not reported) except that these represent the contaminants of concern from the plant. As the CDPHE puts it, the cleanup is "driven" by these elements. Economy could be the justification, although I feel that only reporting Mo and U and drawing plume boundaries based on the MCL (maximum concentration level) is misleading for several reasons. First, the plume boundary is an artificial one, and does not reflect the total extent of the plume. Banta and Chapin state clearly that levels below those reported still might indicate raffinate. Other, more elevated levels of some components like sulfate or chloride would indicate the raffinate more accurately. What I'm trying to say here is that the State's position seems to be that they are only concerned with whether you're getting poisoned, and not whether raffinate is getting off the plant site-the letter of the law but not the spirit. Any change in data gathering or reporting diminishes the ability to compare with the past.

2. Why were so many private wells eliminated from the sampling program years ago? Do you agree with the choice of wells to monitor, up to around 2000 when EPA made Cotter add approximately 10 private wells to the plan? Why did EPA come in recently (around 2000) and tell CDPHE & Cotter to add private wells to the monitoring?

> A. Again, reasons of economy could be cited. If the ground water could be fairly characterized with the least number of wells, then the State would approve the lower number. Apparently, the EPA doesn't agree, and I don't either. For a well to be withdrawn, the State should show a) that it is below contaminant levels, and b) that it is clearly redundant w/r to a nearby well. Furthermore, if it is your own well, and it showed contamination, you'd still like to know.

3. Why were the vast majority of private wells sampled only in the summer, for years up to around 2003, when that is the time of year that the irrigation ditch waters enter the wells, diluting the level of raffinate constituents in the well water? What impact does this now have on the community's ability to

compare monitoring over the years to determine exactly how much the constituents have reduced in the wells?

> A. Sampling only in the summer gives a highly misleading picture of contaminant levels. The DeWeese-Dye ditch dilutes by at least 10x. The ditch cannot be counted on to flow into perpetuity, and thus does not provide an accurate estimate of future contaminant levels. It is sort of deceitful to use those numbers to determine if clean-up is successful. On the other hand, many wells would have little or no water in them without the contribution from the ditch. The ditch water serves to smear and spread the pollution, in addition to diluting it. Again, any change in sampling procedure or locations diminishes the community's ability to make comparisons. Each change should be justified as eliminating a redundancy or giving a real improvement in data quality.

4. The frequency of sampling private wells was also annual in the vast majority of cases. The EPA recently requested the wells in the new program plan be sampled quarterly. What impact does this have on our ability to compare progress over the years?

> A. Only the identical months can be compared-and that comparison depends on the contribution of the ditch for that year and month, as well as precipitation for that year and month. I think every the report for every sampling event should be accompanied by a map of the ground water table contours for that exact period. Quarterly sampling is better.

5. The plume maps and quality of reports generated by Phil Stoffey, from Cotter's monitoring data, appear to be very deficient to the lay person. What is your opinion of this, and how should it have been handled? What do you suggest for future reports?

> A. As above, other components in addition to Mo and U should be presented (sulfate and chloride are the ones I'd pick) as well as a map of the ground water table for that exact time. This has to be because of the huge fluctuation in the ground water levels throughout the year. All pertinant details should be presented on the maps such as location of the lined ponds, and the nature of all wells on the plot, whether observation, sampling, or injection.

6. Annual RAP Reports from 1988 (date of Consent Decree) to the present, either weren't submitted by Cotter yearly, or when submitted starting around 1995, were incorporated into the Annual ALARA Report. The Consent Decree required a yearly RAP Report with a Summary and details of the status of each requirement of the RAP. Jeff Deckler told us at the last Superfund Meeting on May 11, 2004, that the department is in the process of rewriting the RAP, because much of its requirements have been met.

How can the community track the progress regarding water issues, if it is difficult to put together all the RAP annual reports? A CCAT representative asked for these reports for months, and finally we were sent approximately a 20 page list of titles of documents where RAP information could be found. What do you suggest about this issue? Would you ask the department to put all the RAP reports (no matter what they are incorporated in) onto a table for you and a representative from CCAT to review?

> A. I personally feel that the information should be easily retrievable in an understandable format and at a location where it can be viewed and compared to previous years. The current practice is not transparent and seems to make citizen review of the data and documents difficult. I am happy that the water quality data is being made available on the CDPHE website for citizens to review, although I have noted that not all wells are included, nor are all chemical components listed, even though they were analyzed for a particular well. In particular, fluoride seems to have been removed from earlier data sets
> and is not longer analyzed for, even though it is a good pathfinder element for Vermejo Formation water.

7. The RAP and Feasibility Studies suggested several alternatives to remediating the water. Flushing and pumping back have been used, as well as the PRTW. Flushing and the PRTW have failed. The only thing successful has been trying to stop all water from the watershed (?) from getting past the SCS Dam. The choice of digging up all contaminated soils in the Old Ponds Area has never been done, and that is an area many documents suggest is a major source of groundwater contamination. There is also a possibility that the new impoundments leak. These solutions were debated and actions chosen during the TQEM process which ended in 1995. What do you think about the decisions that were made? What do you think about how it is determined whether the new impoundments are leaking or not?

> A. The new impoundments may be leaking. The Wahler report documents tears in the liner, and is confirmed by the Bruskin report. I have personally worked with leaking liners at Summitville and at a power plant and know that they cannot be repaired. The only way to prevent further contamination from the lined and the unlined ponds is either to make the basin completely impermeable or to remove the impoundments altogether (Banta and Chapin Alternative 3: Remove all materials after giving the ground water a good flushing).

APPENDIX C

CCAT Newsletter Article (Previously Unpublished)

A Modest Proposal, or

"Where to not put a nuclear facility"

Charles G. Patterson, Ph.D.
USEPA TAG Advisor to CCAT

A Modest Proposal, or

"Where to not put a nuclear facility"

Charles G. Patterson, Ph.D.
USEPA TAG Advisor to CCAT

As the Technical Assistance Grant (TAG) advisor for Colorado Citizens Against *ToxicWaste*, Inc. (CCAT), one of my duties is to research the technical documents relating to the Lincoln Park/Cotter Superfund site thoroughly so I can offer technical advice and interpretation for the CCAT board, as well as the general public. My expertise is in geology, hydrology, and geochemistry, in which I hold a Ph.D. from the University of Colorado. I have been in private consulting since 1974 in and around Colorado. I have been doing Superfund work since the mid 1980's, including the Leadville/Cal Gulch site, and more recently with the ASARCO/Globe and VB/I70 sites in North Denver. These sites have mainly involved heavy metal contamination in soils, surface and ground water related to mining, milling, and smelting operations.

As a private consultant, I also have been involved in the selection for low-level nuclear waste disposal sites, and as a technical expert in a lawsuit at the Uravan Superfund site. There, I was hired by a citizen's group similar to CCAT that opposed importation of off-site radioactive waste to the Uravan Superfund site.

In reviewing the geology and hydrology of the Cotter site, I was struck by how unsuitable the area is for a uranium milling facility. A manual for site selection called "Hydrogeologic Factors in the Selection of Shallow Land Disposal Sites for the Disposal of Low-Level Radioactive Waste," in U.S. Geological Circular 973 (Fisher, 1986), discusses the major criteria for site selection. Although published in 1986, the guidelines are still valid and constitute standard practice. Though technically Cotter is not authorized to receive "low-level radioactive waste," they are authorized to handle and store waste that is both low and high in radioactivity. I also noted that the material from Cotter is considered "hazardous waste" under RCRA, and has some separate guidelines concerning heavy metals and pH. Some of these guidelines are similar, such as protection of ground and surface water, and control of fugitive dust emissions, but others are specific to radioactive waste.

The requirements for mill tailings containing uranium and its decay products, thorium and radium, include protection from radon gas emissions (generated by radioactive decay of radium) for a minimum of 200 years, and 1000 years if possible. The NRC also requires perpetual government custody of the piles, as the radionuclides involved have long half lives (U from 1/2 billion to 4.5 billion years; Th 77,000 years; and Ra 1,600 years.). In other words, the piles stay "hot" for a long time. Since Colorado is an "Agreement" state, that duty falls to the CDPHE, under EPA and NRC supervision and guidelines.

So, what do we look for and why? If I were picking a site for a new mill, where would I put it? What would the site conditions be? Why NOT where it is now? The list of hydrogeologic factors to consider in the U.S. Geological Survey Circular 973 is comprehensive (Fisher, 1986). The considerations are:

*Precipitation-amount and type;
*Surface drainage-susceptibility to erosion and flooding;
*Topography;
*Site stability;
*Geology;
*Thickness of the host soil-rock horizon;
*Soil and sediment permeability;
*Soil and water chemistry; and
*Depth to the water table.

In addition, you should also think about:

*Meteorology - prevailing winds and storms; and
*Proximity to built-up areas such as towns, schools, or agricultural areas such as fields, dairy farms, and etc.

How does the present Cotter site stand up to these criteria?

Precipitation.: Rainfall here is low at 12-14"/yr, but it often occurs as violent thunderstorms which may cause flash flooding and erosion, or threaten to overtop tailings impoundments or erode earthen dams, as feared in 2004.

Surface drainage: The two SCS dams (east and west) offer some protection against offsite flooding, although a breach of the tailings dam would send contaminated tailings over unprotected ground and cause further ground water degradation.

Topography: The site is in a topographic basin, which appears to offer isolation from the surroundings, but is misleading (see Geology, below).

Site stability: There are no active earthquake faults in the area. There is no landslide hazard.

Geology: Here is where things begin to fall apart. The basin Cotter sits in is a geologic structure called the Chandler syncline. It is essentially a big taco-like fold with the long axis of the taco pointing E-W. In order, from the surface down, are found first the Poison Canyon Formation. It is claystone to conglomerate-may be fractured-which allows rapid ground water flow. ("Poison Canyon" is the “type” locality-no implication of "poison"). Next down is the Raton Sandstone, which forms the ridge of the basin surrounding the Cotter Mill and tailings impoundments. Below that is the thick Vermejo Formation, mined for coal, which is pierced by mineshafts deeply below the Cotter plant, and emerges at the surface under Lincoln Park. The thin Trinidad Sandstone is below the Vermejo Formation, and below all these rock units sits the Pierre Shale, a 4000 foot thick clay shale-more about that later.

Extensive mining of coal from the Vermejo Formation has left a vast network of mapped and unmapped mine workings below the Cotter property. Access to surface contamination through the deep mine shafts, "the deep path," has been suspected by many workers, and I am convinced it could exist.

Cotter backfilled the Wolf Park shaft, which prevented contaminated surface water influx, but that also prevented further sampling of mine waters.

The rocks below the plant site are variably permeable with fracture porosity, moderate hydraulic conductivity (granular porosity), and mine openings. My opinion is that this is not a good site geologically because of unpredictable ground water flow, which is hard to predict and to control.

Thickness and permeability of the host soil-rock horizon: The plant site is directly underlain by up to 60 feet of hydraulically permeable stream gravels, which allow water to soak in and travel down to bedrock, at which point the water can migrate laterally downgradient towards Lincoln Park and the Arkansas River.

Soil and Water Chemistry: Water entering the plant site is of fairly good agricultural quality, but rather high in carbonate, as is seepage water from any leaks in the liner of the lined storage impoundment. As we heard at a Cotter/Lincoln Park Superfund Site Community Advisory Meeting (CAG) in Spring of 2005, concerning the failure of the PRTW (permeable reactive treatment wall), the main reason for the failure of the "wall" (basically iron filings dumped into a trench) was the precipitation of calcium carbonate, which clogged the pores of the iron filings as the electrochemical reaction with the incoming ground water raised the pH. This clogging began less than one year after installation, rather than the proposed 50-year life of the installation. It is my opinion that this could have been predicted, pre-construction, with a cursory glance at the water chemistry of the site.

The water chemistry here is unsuitable for "in-situ" electrochemical methods of removing U and Mo from the water because of high carbonate and calcium values. It needs to be treated differently, such as with a “water treatment system” that would return clean ground water that has been blocked from Lincoln Park for many years. Unfortunately, this is a nuclear site, and the demand for a “water treatment system” for perpetuity is complicated because federal and state radiation regulations do not allow for any remediation systems that require maintenance after closure of the facility. <u>The system needs to keep itself contained on its own.</u> The current pump-back system, preventing water from leaving the Cotter site and entering Lincoln Park, will present a difficult problem when Cotter can no longer pump contaminated water from the SCS Dam area back to the tailings impoundment.

Depth to water table: This is variable, but we do know from reports at the time of construction of the lined impoundment, that several springs were encountered in the excavation, which means that the ***ground water table intersects the base of the impoundment pond waste pile.*** The base of the impoundment liner must be ten's of feet, at least, above the highest possible water table. Ground water contamination is the reason this Superfund Site exists, and should not be allowed to continue. Cotter is currently proposing "selective excavation" of more highly contaminated areas of the old tailings pond area, but this doesn't correct the fact that the liner in the new impoundment was deficient in construction, and may be leaking. In my opinion, this pond should be abandoned altogether.

Proximity to urban and agricultural areas: In the last decade, when Cotter was dormant, the Canon City limits encroached on the plant site. The city limits now border Cotter property on the West, with hundreds of upscale new homes. The golf course and nearby neighborhoods and farms increase the likelihood of dust and water contamination to residents and livestock.

In summary, the Cotter site fails the U.S. Geological Circular 973 major criteria for site selection in many ways, i.e. ecologically, chemically, and hydrologically. The facility was located during the cold war uranium boom, when people didn't think about these things much, but even early reports express doubts about the suitability of the site, especially when the new impoundments were built (USEPA, no date, and Wagoner, USEPA, 1978).

Where would I put the plant site?

It would be hard to imagine a worse place for a nuclear facility. Despite comments by a former Mill manager, Mr. Marcott, that the site was chosen for it's favorable topography to contain spills. That quality is entirely superficial (and surficial) as I have demonstrated. The ground water pathways are very vulnerable to contamination. The alluvial gravels which lay directly below the site are highly permeable and subject to contamination by surface spills and impoundment pond leakage. The shallow underlying bedrock is fractured, which allows direct flow. The deeper bedrock levels are pierced by numerous mine workings that may provide egress of contamination outside the topographic basin via a deep path, by allowing communication between the contaminated ground of the Cotter site and the Lincoln Park area outside the topographic barrier of Raton Ridge.

Most of the contamination migration issues could be put to rest by locating a new plant on Pierre Shale. Shale is mostly clay, which is impenetrable to ground water, and the clay chemically binds the contaminants to itself. This meets the primary requirement of a radioactive waste site. The site must not contaminate the air and water around it and it must do that without human assistance for a very long time. A site on Pierre Shale, topographically removed from the Arkansas River, geographically removed from population and agriculture centers, could be found in Fremont County.

The USGS recommended the best long-term ground water clean up would involve removing the waste piles. As long as Cotter is going to do some excavation removing contaminated soil from the Old Tailings Pond Area , why not look for a better site for the plant somewhere in Fremont County. If the geology and hydrology are good at a new site, the Environmental Impact Statement should be an easy task. I recommend this be seriously considered. The current site is not self-maintaining, which makes future environmental problems a certainty. This would be a good way to head into the future, especially with the looming energy crisis making nuclear energy a much more likely (if not attractive) option. There are sites in Fremont County far more suitable than the current location. In order to stay competitive, Cotter should consider re-locating. That is my **"modest proposal."**

I was talking with a citizen in Florence one day, who commented: "What's the big deal? This is already ***uranium*** country, what's the problem with a little more?" Well, that ***is*** the problem. Guidelines for exposure to radioactivity specify certain limits to exposure. If you already have a high background level, a "little more" could put you into a dangerous level.

References:

Fisher, J.N. 1986. *Hydrogeologic Factors in the Selection of Shallow Land Disposal Sites for the Disposal of Low-Level Radioactive Waste.* U.S. Geological Circular 973.

NALCO Environmental Sciences. 1975-76. *ENVIRONMENTAL REPORT FOR THE COTTER URANIUM MILL.* Prepared for the Cotter Corporation.

USEPA. Etal. 1978. *USEPA (ORP-LVF) review comments on environment report for the Cotter Uranium Mill (NALCO ENVIRONMENTAL SCIENCES)*, Document ID #296765.

Wagoner, D.A., USEPA, etal. 1978. Transmittal letter with Comments on *NALCO ENVIRONMENTAL SCIENCES ENVIRONMENTAL REPORT FOR THE COTTER URANIUM MILL.* Document ID #296751.

APPENDIX D

ACCURACY CHECK OF WATER QUALITY DATA

Water quality data checked
is from Cotter’s CY2004 and CY2005
Annual Environmental Report and ALARA Review

2004	**DATA**												
site	**Na**	**K**	**Ca**	**Mg**	**Cl**	**HCO3**	**SO4**	**NO3**	**calcTDS**	**labTDS**	**calc/lab**	**meqcation**	**meqanion**
001	100.00	5.70	340.00	55.00	65.00	65.00	890.00	120.00	1640.70	1820.00	0.90	26.17	23.36
001												0.00	0.00
002	5700.00	140.00	500.00	2600.00	1400.00		21000.00	44.00	31384.00	29600.00	1.06	500.70	477.42
002	9500.00	110.00	420.00	3000.00	1600.00		41000.00	75.00	55705.00	60700.00	0.92	700.99	899.97
003	2800.00	3.20	390.00	260.00	400.00	1000.00	7300.00	58.00	12211.20	12100.00	1.01	167.78	180.60
003	3000.00	3.60	500.00	260.00	600.00	1000.00	7500.00	19.00	12882.60	11400.00	1.13	182.34	189.77
005	1400.00	9.70	300.00	240.00	400.00	520.00	4100.00	15.00	6984.70	6980.00	1.00	98.39	105.41
005	1200.00	15.00	400.00	210.00	340.00	420.00	3600.00	6.60	6191.60	6070.00	1.02	91.98	91.53
006	400.00	3.30	140.00	52.00	100.00	240.00	1200.00	4.10	2139.40	2050.00	1.04	29.47	31.80
023	32300.00	190.00	568.00	7540.00	3000.00	0.00	120000.00	59.00	163657.00	15800.00	10.36	2116.86	2583.98
008	18.00	2.20	85.00	19.00	10.00	280.00	77.00	0.60	491.80	359.00	1.37	6.68	6.48
008	26.00	2.40	95.00	22.00	14.00	250.00	100.00	1.80	511.20	424.00	1.21	7.79	6.60
019	43.00	2.80	85.00	24.00	16.00	250.00	110.00	1.70	532.50	445.00	1.20	8.24	6.87
019	52.00	2.80	75.00	28.00	16.00	260.00	130.00	3.30	567.10	472.00	1.20	8.47	7.47
020	28.00	2.50	50.00	24.00	12.00	260.00	52.00	4.80	433.30	390.00	1.11	5.80	5.76
020	29.00	2.20	75.00	28.00	13.00	270.00	56.00	2.10	475.30	359.00	1.32	7.42	5.99
021	1100.00	8.00	220.00	50.00	160.00	250.00	2800.00	0.70	4588.70	4330.00	1.06	65.13	66.92
021	1100.00	8.60	200.00	59.00	170.00	250.00	3200.00	12.00	4999.60	4500.00	1.11	64.89	75.71
023	15000.00	14.00	400.00	750.00	2200.00	0.00	52000.00	91.00	70455.00	74400.00	0.95	761.54	1146.17
023	22000.00	180.00	420.00	6000.00	2400.00	0.00	94000.00	99.00	125099.00	133000.00	0.94	1515.90	2026.38
024	170.00	2.10	64.00	3.30	66.00	280.00	620.00	0.10	1205.50	1270.00	0.95	11.22	19.36
024	360.00	2.40	65.00	3.20	55.00	280.00	620.00	0.20	1385.80	1290.00	1.07	19.88	19.05
114	25.00	11.00	75.00	28.00	10.00	270.00	59.00	1.30	479.30	426.00	1.13	7.46	5.96
114	23.00	4.30	93.00	31.00	13.00	310.00	69.00	3.20	546.50	449.00	1.22	8.34	6.94
122	25.00	2.80	70.00	19.00	8.00	250.00	38.00	0.10	412.90	340.00	1.21	6.26	5.12
122	29.00	5.90	70.00	20.00	10.00	250.00	47.00	2.70	434.60	373.00	1.17	6.60	5.40
129	30.00	5.30	75.00	24.00	12.00	260.00	49.00	2.90	458.20	388.00	1.18	7.21	5.67
129	27.40	2.70	82.00	24.00	12.00	260.00	84.00	1.00	493.10	415.00	1.19	7.38	6.36
130	24.00	2.60	64.00	29.00	9.00	300.00	41.00	0.90	470.50	404.00	1.16	6.73	6.04
130	26.80	2.60	78.50	30.10	9.00	270.00	50.00	1.00	468.00	400.00	1.17	7.67	5.74
141	400.00	4.90	34.00	8.70	42.00	500.00	460.00	0.00	1449.60	1300.00	1.12	20.66	18.96
141	422.00	5.50	38.60	9.70	38.00	610.00	480.00	0.00	1603.80	1190.00	1.35	21.98	21.06
144	33.00	2.70	88.00	28.00	10.00	320.00	68.00	0.90	550.60	464.00	1.19	8.26	6.96
144	37.00	3.00	91.80	29.20	7.00	420.00	70.00	0.50	658.50	390.00	1.69	8.74	8.55
325	100.00	6.40	280.00	26.00	80.00	280.00	1500.00	1.90	2274.30	2530.00	0.90	20.81	38.11
329	230.00	6.10	290.00	92.00	160.00	270.00	2000.00	0.00	3048.10	3210.00	0.95	32.62	50.58
330	760.00	5.60	210.00	90.00	150.00	490.00	1900.00	0.40	3606.00	3360.00	1.07	52.46	51.83
331	1080.00	6.10	300.00	130.00	180.00	390.00	2800.00	0.00	4886.10	4690.00	1.04	74.75	69.77

2004	DATA											
site	cat/an	%cat/an	%tdscalc/tdslab	TDS/MG	TDS/NA	TDS/SO4	NA/SO4	NA/CL	MG/CA			
001	1.12	112.00	90.15	29.83	16.41	1.84	0.11	1.54	0.16			
001		0.00										
002	1.05	104.87	106.03	12.07	5.51	1.49	0.27	4.07	5.20			
002	0.78	77.89	91.77	18.57	5.86	1.36	0.23	5.94	7.14			
003	0.93	92.90	100.92	46.97	4.36	1.67	0.38	7.00	0.67			
003	0.96	96.08	113.01	49.55	4.29	1.72	0.40	5.00	0.52			
005	0.93	93.34	100.07	29.10	4.99	1.70	0.34	3.50	0.80			
005	1.00	100.49	102.00	29.48	5.16	1.72	0.33	3.53	0.53			
006	0.93	92.66	104.36	41.14	5.35	1.78	0.33	4.00	0.37			
023	0.82	81.92	1035.80	21.71	5.07	1.36	0.27	10.77	13.27			
008	1.03	102.97	136.99	25.88	27.32	6.39	0.23	1.80	0.22			
008	1.18	117.97	120.57	23.24	19.66	5.11	0.26	1.86	0.23			
019	1.20	119.94	119.66	22.19	12.38	4.84	0.39	2.69	0.28			
019	1.13	113.40	120.15	20.25	10.91	4.36	0.40	3.25	0.37			
020	1.01	100.73	111.10	18.05	15.48	8.33	0.54	2.33	0.48			
020	1.24	123.78	132.40	16.98	16.39	8.49	0.52	2.23	0.37			
021	0.97	97.32	105.97	91.77	4.17	1.64	0.39	6.88	0.23			
021	0.86	85.70	111.10	84.74	4.55	1.56	0.34	6.47	0.30			
023	0.66	66.44	94.70	93.94	4.70	1.35	0.29	6.82	1.88			
023	0.75	74.81	94.06	20.85	5.69	1.33	0.23	9.17	14.29			
024	0.58	57.95	94.92	365.30	7.09	1.94	0.27	2.58	0.05			
024	1.04	104.32	107.43	433.06	3.85	2.24	0.58	6.55	0.05			
114	1.25	125.24	112.51	17.12	19.17	8.12	0.42	2.50	0.37			
114	1.20	120.30	121.71	17.63	23.76	7.92	0.33	1.77	0.33			
122	1.22	122.37	121.44	21.73	16.52	10.87	0.66	3.13	0.27			
122	1.22	122.25	116.51	21.73	14.99	9.25	0.62	2.90	0.29			
129	1.27	127.27	118.09	19.09	15.27	9.35	0.61	2.50	0.32			
129	1.16	115.90	118.82	20.55	18.00	5.87	0.33	2.28	0.29			
130	1.12	111.50	116.46	16.22	19.60	11.48	0.59	2.67	0.45			
130	1.34	133.79	117.00	15.55	17.46	9.36	0.54	2.98	0.38			
141	1.09	108.97	111.51	166.62	3.62	3.15	0.87	9.52	0.26			
141	1.04	104.36	134.77	165.34	3.80	3.34	0.88	11.11	0.25			
144	1.19	118.72	118.66	19.66	16.68	8.10	0.49	3.30	0.32			
144	1.02	102.22	168.85	22.55	17.80	9.41	0.53	5.29	0.32			
325	0.55	54.60	89.89	87.47	22.74	1.52	0.07	1.25	0.09			
329	0.64	64.49	94.96	33.13	13.25	1.52	0.12	1.44	0.32			
330	1.01	101.21	107.32	40.07	4.74	1.90	0.40	5.07	0.43			
331	1.07	107.14	104.18	37.59	4.52	1.75	0.39	6.00	0.43			

2004	**DATA**												
site	**Na**	**K**	**Ca**	**Mg**	**Cl**	**HCO3**	**SO4**	**NO3**	**calcTDS**	**labTDS**	**calc/lab**	**meqcation**	**meqanion**
331	840.00	6.20	330.00	140.00	200.00	380.00	3000.00	0.00	4896.20	4990.00	0.98	66.20	74.33
333	700.00	4.90	230.00	120.00	180.00	360.00	1900.00	25.00	3519.90	3560.00	0.99	53.19	50.94
333	650.00	5.00	260.00	130.00	180.00	350.00	1900.00	44.00	3519.00	3520.00	1.00	53.24	51.08
336	380.00	4.70	140.00	55.00	100.00	240.00	1200.00	1.60	2121.30	2060.00	1.03	28.85	31.76
336									0.00			0.00	0.00
346	400.00	5.20	195.00	105.00	92.00	400.00	1200.00	31.00	2428.20	2320.00	1.05	36.62	34.64
371	2300.00	8.70	380.00	210.00	340.00	290.00	5200.00	73.00	8801.70	8990.00	0.98	140.66	123.79
371	2100.00	8.50	320.00	240.00	400.00	640.00	5600.00	170.00	9478.50	10100.00	0.94	131.07	141.11
372	320.00	2.60	17.00	2.10	65.00	250.00	540.00	0.00	1196.70	1120.00	1.07	15.58	17.17
372	385.00	2.60	18.20	2.30	44.00	300.00	600.00	0.70	1352.80	1150.00	1.18	18.60	18.66
526	22.00	18.00	56.00	17.00	10.00	200.00	55.00	0.70	378.70	306.00	1.24	5.65	4.72
711	2000.00	11.00	520.00	280.00	600.00	640.00	5300.00	130.00	9481.00	9410.00	1.01	139.87	139.86
712	2100.00	14.60	544.00	324.00	620.00	1100.00	4500.00	210.00	9412.60	10000.00	0.94	149.31	132.60
801	714.00	12.50	359.00	89.40	150.00	340.00	2400.00	0.60	4065.50	3930.00	1.03	57.93	59.78
802	383.00	4.40	168.00	65.70	80.00	300.00	1100.00	22.00	2123.10	2120.00	1.00	31.25	30.43
808	190.00	3.20	26.00	4.40	12.00	290.00	220.00	0.60	746.20	663.00	1.13	10.35	9.68
808	190.00	3.00	26.00	4.20	11.00	290.00	230.00	1.50	755.70	660.00	1.15	10.33	9.88
814	600.00	4.40	160.00	70.00	100.00	330.00	1700.00	1.10	2965.50	2940.00	1.01	41.04	43.64
814	520.00	4.30	100.00	80.00	100.00	340.00	1680.00	1.00	2825.30	2850.00	0.99	35.24	43.39
815	220.00	2.50	34.00	11.00	22.00	240.00	290.00	2.80	822.30	733.00	1.12	12.63	10.64
815	130.00	1.90	16.00	7.00	8.00	280.00	78.00	2.60	523.50	416.00	1.26	7.31	6.48
904	10.00	1.60	32.00	9.00	7.00	97.00	47.00	0.00	203.60	184.00	1.11	2.83	2.77
904	14.00	1.70	40.00	8.50	9.00	91.00	47.00	0.00	211.20	193.00	1.09	3.37	2.72
904	11.00	3.70	34.00	9.50	8.00	85.00	56.00	0.00	207.20	198.00	1.05	3.07	2.78
904	11.00	1.10	24.00	6.00	4.00	72.00	32.00	0.00	150.10	62.00	2.42	2.22	1.96
904	19.00	1.70	54.10	14.20	10.00	120.00	160.00	0.00	379.00	280.00	1.35	4.77	5.58
907	7.00	1.40	29.00	7.00	6.00	94.00	54.00	0.00	198.40	239.00	0.83	2.38	2.83
907	11.00	1.60	32.00	6.50	10.00	90.00	29.00	0.00	180.10	150.00	1.20	2.67	2.36
907	8.00	3.20	30.00	7.00	8.00	82.00	35.00	0.00	173.20	146.00	1.19	2.52	2.30
907	7.00	1.00	22.00	4.50	3.00	62.00	18.00	0.00	117.50	51.50	2.28	1.81	1.48
907	19.00	1.70	42.00	10.00	8.00	120.00	96.00	0.00	296.70	224.00	1.32	3.82	4.19
1451	500.00	4.00	99.00	60.00	94.00	270.00	1500.00	0.00	2527.00	2410.00	1.05	32.63	38.31
1453	420.00	3.50	1.50	1.60	94.00	180.00	450.00	0.00	1150.60	1290.00	0.89	19.32	14.97
1455	370.00	4.50	250.00	87.00	96.00	500.00	1400.00	0.00	2707.50	2500.00	1.08	36.51	40.05

2004	**DATA**											
site	**cat/an**	**%cat/an**	**%tdscalc/tdslab**	**TDS/MG**	**TDS/NA**	**TDS/SO4**	**NA/SO4**	**NA/CL**	**MG/CA**			
331	0.89	89.06	98.12	34.97	5.83	1.63	0.28	4.20	0.42			
333	1.04	104.41	98.87	29.33	5.03	1.85	0.37	3.89	0.52			
333	1.04	104.23	99.97	27.07	5.41	1.85	0.34	3.61	0.50			
336	0.91	90.81	102.98	38.57	5.58	1.77	0.32	3.80	0.39			
336		0.00		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
346	1.06	105.74	104.66	23.13	6.07	2.02	0.33	4.35	0.54			
371	1.14	113.63	97.91	41.91	3.83	1.69	0.44	6.76	0.55			
371	0.93	92.88	93.85	39.49	4.51	1.69	0.38	5.25	0.75			
372	0.91	90.74	106.85	569.86	3.74	2.22	0.59	4.92	0.12			
372	1.00	99.69	117.63	588.17	3.51	2.25	0.64	8.75	0.13			
526	1.20	119.80	123.76	22.28	17.21	6.89	0.40	2.20	0.30			
711	1.00	100.01	100.75	33.86	4.74	1.79	0.38	3.33	0.54			
712	1.13	112.61	94.13	29.05	4.48	2.09	0.47	3.39	0.60			
801	0.97	96.91	103.45	45.48	5.69	1.69	0.30	4.76	0.25			
802	1.03	102.70	100.15	32.32	5.54	1.93	0.35	4.79	0.39			
808	1.07	106.89	112.55	169.59	3.93	3.39	0.86	15.83	0.17			
808	1.05	104.56	114.50	179.93	3.98	3.29	0.83	17.27	0.16			
814	0.94	94.03	100.87	42.36	4.94	1.74	0.35	6.00	0.44			
814	0.81	81.22	99.13	35.32	5.43	1.68	0.31	5.20	0.80			
815	1.19	118.75	112.18	74.75	3.74	2.84	0.76	10.00	0.32			
815	1.13	112.83	125.84	74.79	4.03	6.71	1.67	16.25	0.44			
904	1.02	102.37	110.65	22.62	20.36	4.33	0.21	1.43	0.28			
904	1.24	123.83	109.43	24.85	15.09	4.49	0.30	1.56	0.21			
904	1.10	110.29	104.65	21.81	18.84	3.70	0.20	1.38	0.28			
904	1.13	113.20	242.10	25.02	13.65	4.69	0.34	2.75	0.25			
904	0.86	85.52	135.36	26.69	19.95	2.37	0.12	1.90	0.26			
907	0.84	83.83	83.01	28.34	28.34	3.67	0.13	1.17	0.24			
907	1.13	113.13	120.07	27.71	16.37	6.21	0.38	1.10	0.20			
907	1.10	109.53	118.63	24.74	21.65	4.95	0.23	1.00	0.23			
907	1.23	122.72	228.16	26.11	16.79	6.53	0.39	2.33	0.20			
907	0.91	91.21	132.46	29.67	15.62	3.09	0.20	2.38	0.24			
1451	0.85	85.18	104.85	42.12	5.05	1.68	0.33	5.32	0.61			
1453	1.29	129.06	89.19	719.13	2.74	2.56	0.93	4.47	1.07			
1455	0.91	91.16	108.30	31.12	7.32	1.93	0.26	3.85	0.35			

2005	DATA												
site	Na	K	Ca	Mg	Cl	HCO3	SO4	NO3	tdscalc	tdslab	tdscal/lab	meqcation	meqanion
002	6700.00	180.00	510.00	2300.00	1200.00	24.00	17000.00	37.00	27951.00	35300.00	0.79	522.83	388.78
002	6810.00	322.00	842.00	2390.00	1400.00	12.00	26000.00	19.00	37795.00	187000.00	0.20	555.42	581.32
003	2800.00	5.00	420.00	240.00	360.00	870.00	6500.00	11.00	11206.00	11400.00	0.98	167.68	159.92
003	3170.00	3.29	495.00	212.00	320.00	980.00	6800.00	84.00	12064.29	11760.00	1.03	185.83	168.02
005	1200.00	13.00	400.00	210.00	280.00	510.00	3800.00	6.50	6419.50	5920.00	1.08	91.93	95.48
005	1000.00	12.00	340.00	8.90	260.00	450.00	1100.00	3.90	3174.80	5280.00	0.60	63.31	37.68
005	861.00	6.84	270.00	104.00	130.00	440.00	2000.00	5.90	3817.74	3510.00	1.09	61.21	52.61
006	430.00	3.30	120.00	46.00	55.00	230.00	1100.00	6.40	1990.70	2170.00	0.92	29.34	28.33
006	461.00	3.70	152.00	53.50	86.00	230.00	1300.00	6.40	2292.60	2190.00	1.05	32.97	33.36
006	485.00	3.73	172.00	51.50	58.00	280.00	1100.00	5.60	2155.83	2000.00	1.08	34.89	29.22
008	18.00	2.10	83.00	19.00	9.00	230.00	65.00	2.70	428.80	424.00	1.01	6.57	5.42
008	18.00	2.30	88.00	21.00	12.00	240.00	70.00	2.00	453.30	377.00	1.20	6.99	5.76
008	15.20	2.22	71.80	15.60	7.00	260.00	63.00	1.10	435.92	320.00	1.36	5.61	5.79
019	33.00	2.40	66.00	26.00	9.00	250.00	70.00	1.60	458.00	447.00	1.02	6.99	5.83
019	35.40	2.10	57.90	20.80	7.00	220.00	61.00	1.80	406.00	322.00	1.26	6.26	5.10
019	13.00	1.80	69.80	12.40	3.00	210.00	11.00	0.80	321.80	278.00	1.16	5.14	3.77
019	23.00	2.57	68.60	25.00	7.00	320.00	27.00	0.10	473.27	342.00	1.38	6.59	6.01
020	28.00	2.30	83.00	29.00	7.00	300.00	53.00	4.90	507.20	479.00	1.06	7.86	6.30
020	29.20	2.00	78.60	27.80	9.00	300.00	70.00	4.10	520.70	436.00	1.19	7.58	6.69
020	26.60	3.00	86.10	27.30	8.00	300.00	55.00	1.70	507.70	417.00	1.22	7.82	6.32
020	29.00	1.87	77.20	27.00	7.00	340.00	43.00	4.50	529.57	405.00	1.31	7.44	6.74
021	1100.00	8.80	190.00	53.00	160.00	240.00	2800.00	6.90	4558.70	4630.00	0.98	63.90	66.85
021	1100.00	9.00	180.00	52.00	180.00	250.00	2600.00	1.90	4372.90	4480.00	0.98	63.32	63.34
021	1190.00	9.00	200.00	54.80	180.00	270.00	3000.00	18.00	4921.80	4730.00	1.04	68.63	72.25
021	1280.00	8.29	239.00	53.00	220.00	320.00	2800.00	8.00	4928.29	4560.00	1.08	74.48	69.88
023	20200.00	110.00	490.00	5100.00		4.00	39000.00	37.00	64941.00	94100.00	0.69	1362.00	812.64
023	19500.00	328.00	497.00	5430.00			9300.00	47.00	35102.00	102000.00	0.34	1363.38	194.38
023	22900.00	413.00	596.00	6140.00			48100.00	29.00	78178.00	21460.00	3.64	1582.94	1001.91
023	19300.00	698.00	468.00	698.00	4000.00		30000.00	62.00	55226.00	143000.00	0.39	972.94	738.44
024	350.00	2.20	63.00	3.60	30.00	260.00	640.00	0.60	1349.40	1250.00	1.08	19.35	18.44
024	360.00	2.20	63.00	3.60	74.00	260.00	610.00	0.80	1373.60	1240.00	1.11	19.80	19.06
035	440.00	4.60	240.00	68.00	200.00	280.00	1300.00	70.00	2602.60	2560.00	1.02	37.62	38.43
035									0.00		#DIV/0!	0.00	0.00
035									0.00		#DIV/0!	0.00	0.00
035									0.00		#DIV/0!	0.00	0.00
035									0.00		#DIV/0!	0.00	0.00
035									0.00		#DIV/0!	0.00	0.00

2005	DATA											
site	cat/an	%cat/an	%tdscalc/tdslab	TDS/MG	TDS/NA	TDS/SO4	NA/SO4	NA/CL	MG/CA	Fe	Mn	CO3
002	1.34	134.48	79.18	12.15	4.17	1.64	0.39	5.58	4.51	150.00	100.00	4.00
002	0.96	95.54	20.21	15.81	5.55	1.45	0.26	4.86	2.84	164.00	81.00	
003	1.05	104.85	98.30	46.69	4.00	1.72	0.43	7.78	0.57		0.43	
003	1.11	110.60	102.59	56.91	3.81	1.77	0.47	9.91	0.43	0.20	0.05	
005	0.96	96.29	108.44	30.57	5.35	1.69	0.32	4.29	0.53		4.50	
005	1.68	168.03	60.13	356.72	3.17	2.89	0.91	3.85	0.03	0.19	1.80	24.00
005	1.16	116.34	108.77	36.71	4.43	1.91	0.43	6.62	0.39	0.75	0.09	
006	1.04	103.57	91.74	43.28	4.63	1.81	0.39	7.82	0.38			
006	0.99	98.80	104.68	42.85	4.97	1.76	0.35	5.36	0.35			
006	1.19	119.40	107.79	41.86	4.45	1.96	0.44	8.36	0.30			
008	1.21	121.29	101.13	22.57	23.82	6.60	0.28	2.00	0.23			
008	1.21	121.38	120.24	21.59	25.18	6.48	0.26	1.50	0.24			
008	0.97	96.95	136.23	27.94	28.68	6.92	0.24	2.17	0.22			
019	1.20	119.79	102.46	17.62	13.88	6.54	0.47	3.67	0.39			
019	1.23	122.65	126.09	19.52	11.47	6.66	0.58	5.06	0.36			
019	1.36	136.35	115.76	25.95	24.75	29.25	1.18	4.33	0.18			
019	1.10	109.69	138.38	18.93	20.58	17.53	0.85	3.29	0.36			
020	1.25	124.75	105.89	17.49	18.11	9.57	0.53	4.00	0.35			
020	1.13	113.28	119.43	18.73	17.83	7.44	0.42	3.24	0.35			
020	1.24	123.90	121.75	18.60	19.09	9.23	0.48	3.33	0.32			
020	1.10	110.36	130.76	19.61	18.26	12.32	0.67	4.14	0.35			
021	0.96	95.58	98.46	86.01	4.14	1.63	0.39	6.88	0.28			
021	1.00	99.97	97.61	84.09	3.98	1.68	0.42	6.11	0.29			
021	0.95	94.98	104.05	89.81	4.14	1.64	0.40	6.61	0.27			
021	1.07	106.59	108.08	92.99	3.85	1.76	0.46	5.82	0.22			
023	1.68	167.60	69.01	12.73	3.21	1.67	0.52	#DIV/0!	10.41	400.00	240.00	4.00
023	7.01	701.38	34.41	6.46	1.80	3.77	2.10	#DIV/0!	10.93	279.00	254.00	
023	1.58	157.99	364.30	12.73	3.41	1.63	0.48	#DIV/0!	10.30			
023	1.32	131.76	38.62	79.12	2.86	1.84	0.64	4.83	1.49			
024	1.05	104.93	107.95	374.83	3.86	2.11	0.55	11.67	0.06			
024	1.04	103.89	110.77	381.56	3.82	2.25	0.59	4.86	0.06			
035	0.98	97.91	101.66	38.27	5.92	2.00	0.34	2.20	0.28		0.01	
035	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
035	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
035	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
035	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
035	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			

2005	**DATA**			
site	**U**	**Mo**	**COND(lab)**	**tds/COND**
002	27.00	5.10	32900.00	1.07
002	19.70	2.16	39400.00	4.75
003	10.00	36.00		#DIV/0!
003	10.80	80.90	13000.00	0.90
005	11.00	14.00	6960.00	0.85
005	4.80	8.90	6240.00	0.85
005	1.66	5.37	4310.00	0.81
006			2520.00	0.86
006			2900.00	0.76
006			2800.00	0.71
008			2660.00	0.16
008			621.00	0.61
008			530.00	0.60
019			629.00	0.71
019			540.00	0.60
019			438.00	0.63
019			560.00	0.61
020			7150.00	0.07
020			652.00	0.67
020			652.00	0.64
020			635.00	0.64
021			5930.00	0.78
021			5730.00	0.78
021			5850.00	0.81
021			5730.00	0.80
023	37.00	3.30	67100.00	1.40
023	29.60	1.91	72200.00	1.41
023			163000.00	0.13
023			83100.00	1.72
024				#DIV/0!
024				#DIV/0!
035	0.20	0.07	3390.00	0.76
035				#DIV/0!
035				#DIV/0!
035				#DIV/0!
035				#DIV/0!
035				#DIV/0!

2005	DATA												
site	Na	K	Ca	Mg	Cl	HCO3	SO4	NO3	tdscalc	tdslab	tdscal/lab	meqcation	meqanion
035									0.00		#DIV/0!	0.00	0.00
036	260.00	1.50	11.00	0.60	26.00	100.00	600.00	9.90	1009.00	872.00	1.16	12.41	15.02
036									0.00		#DIV/0!	0.00	0.00
036									0.00		#DIV/0!	0.00	0.00
036									0.00		#DIV/0!	0.00	0.00
036									0.00		#DIV/0!	0.00	0.00
036									0.00		#DIV/0!	0.00	0.00
122									0.00		#DIV/0!	0.00	0.00
122									0.00		#DIV/0!	0.00	0.00
122	27.00	3.20	82.90	21.70	10.00	270.00	46.00	3.20	464.00	383.00	1.21	7.23	5.72
122									0.00		#DIV/0!	0.00	0.00
129	27.00	2.60	88.70	22.40	12.00	270.00	52.00	3.40	478.10	404.00	1.18	7.56	5.90
129									0.00		#DIV/0!	0.00	0.00
129									0.00		#DIV/0!	0.00	0.00
130									0.00		#DIV/0!	0.00	0.00
130									0.00		#DIV/0!	0.00	0.00
130	25.00	2.20	79.10	29.40	10.00	280.00	57.00	2.60	485.30	412.00	1.18	7.56	6.10
130									0.00		#DIV/0!	0.00	0.00
141									0.00		#DIV/0!	0.00	0.00
141									0.00		#DIV/0!	0.00	0.00
141	397.00	5.20	38.50	9.60	40.00	510.00	480.00		1480.30	1280.00	1.16	20.83	19.48
141									0.00		#DIV/0!	0.00	0.00
144									0.00		#DIV/0!	0.00	0.00
144									0.00		#DIV/0!	0.00	0.00
144	33.00	3.00	102.00	28.20	5.00	350.00	51.00	0.60	572.80	475.00	1.21	8.98	6.95
168									0.00		#DIV/0!	0.00	0.00
168	14.90	1.50	83.10	16.90	11.00	230.00	39.00	1.40	397.80	359.00	1.11	6.25	4.91
168									0.00		#DIV/0!	0.00	0.00
325	524.00	6.40	234.00	22.70	64.00	380.00	1500.00	7.70	2738.80	2540.00	1.08	37.45	39.39
329									0.00		#DIV/0!	0.00	0.00
329									0.00		#DIV/0!	0.00	0.00
329	507.00	5.80	342.00	96.40	130.00	300.00	1800.00	2.10	3183.30	3050.00	1.04	48.11	46.09
329									0.00		#DIV/0!	0.00	0.00
330									0.00		#DIV/0!	0.00	0.00
330									0.00		#DIV/0!	0.00	0.00
330	771.00	5.30	245.00	86.70	140.00	350.00	1900.00	1.90	3499.90	3390.00	1.03	54.42	49.27
330									0.00		#DIV/0!	0.00	0.00

2005	DATA											
site	**cat/an**	**%cat/an**	**%tdscalc/tdslab**	**TDS/MG**	**TDS/NA**	**TDS/SO4**	**NA/SO4**	**NA/CL**	**MG/CA**	**Fe**	**Mn**	**CO3**
035	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
036	0.83	82.63	115.71	1681.67	3.88	1.68	0.43	10.00	0.05			10.00
036	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
036	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
036	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
036	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
036	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
122	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
122	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
122	1.26	126.42	121.15	21.38	17.19	10.09	0.59	2.70	0.26	0.10		
122	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
129	1.28	128.09	118.34	21.34	17.71	9.19	0.52	2.25	0.25			
129	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
129	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.10		
130	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
130	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
130	1.24	123.86	117.79	16.51	19.41	8.51	0.44	2.50	0.37			
130	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
141	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
141	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
141	1.07	106.92	115.65	154.20	3.73	3.08	0.83	9.93	0.25	10.20	0.04	
141	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
144	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
144	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.10		
144	1.29	129.26	120.59	20.31	17.36	11.23	0.65	6.60	0.28			
168	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
168	1.27	127.19	110.81	23.54	26.70	10.20	0.38	1.35	0.20			
168	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
325	0.95	95.07	107.83	120.65	5.23	1.83	0.35	8.19	0.10			
329	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
329	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
329	1.04	104.38	104.37	33.02	6.28	1.77	0.28	3.90	0.28	0.62	0.47	
329	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
330	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
330	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
330	1.10	110.45	103.24	40.37	4.54	1.84	0.41	5.51	0.35	1.25		
330	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			

2005	**DATA**			
site	**U**	**Mo**	**COND(lab)**	**tds/COND**
035				#DIV/0!
036			1260.00	0.69
036				#DIV/0!
036				#DIV/0!
036				#DIV/0!
036				#DIV/0!
036				#DIV/0!
122				#DIV/0!
122				#DIV/0!
122	0.06	0.13	607.00	0.63
122				#DIV/0!
129				#DIV/0!
129				#DIV/0!
129	0.02	0.03	632.00	0.00
130				#DIV/0!
130				#DIV/0!
130			639.00	0.64
130				#DIV/0!
141				#DIV/0!
141				#DIV/0!
141	0.00	0.01	1920.00	0.67
141				#DIV/0!
144				#DIV/0!
144	0.02	0.08	713.00	0.00
144				#DIV/0!
168				#DIV/0!
168	0.02	0.01	572.00	0.63
168				#DIV/0!
325	0.00		3190.00	0.80
329				#DIV/0!
329				#DIV/0!
329	0.14	2.06	3600.00	0.85
329				#DIV/0!
330				#DIV/0!
330				#DIV/0!
330	1.71	6.10	4290.00	0.79
330				#DIV/0!

2005	DATA												
site	Na	K	Ca	Mg	Cl	HCO3	SO4	NO3	tdscalc	tdslab	tdscal/lab	meqcation	meqanion
331									0.00		#DIV/0!	0.00	0.00
331									0.00		#DIV/0!	0.00	0.00
331	963.00	6.20	384.00	135.00	180.00	400.00	2900.00		4968.20	4580.00	1.08	74.05	72.01
331									0.00		#DIV/0!	0.00	0.00
333									0.00		#DIV/0!	0.00	0.00
333									0.00		#DIV/0!	0.00	0.00
333	861.00	6.30	341.00	168.00	250.00	370.00	2700.00	46.00	4742.30	4610.00	1.03	70.01	70.07
333									0.00		#DIV/0!	0.00	0.00
333									0.00		#DIV/0!	0.00	0.00
336									0.00		#DIV/0!	0.00	0.00
346									0.00		#DIV/0!	0.00	0.00
346	380.00	5.50	194.00	102.00	96.00	440.00	1300.00	43.00	2560.50	2370.00	1.08	35.43	37.68
346									0.00		#DIV/0!	0.00	0.00
371									0.00		#DIV/0!	0.00	0.00
371									0.00		#DIV/0!	0.00	0.00
371	2290.00	8.84	398.00	216.00	390.00	4400.00	32.00		7734.84	9660.00	0.80	141.60	83.78
371									0.00		#DIV/0!	0.00	0.00
372									0.00		#DIV/0!	0.00	0.00
372	376.00	2.50	17.30	2.20	55.00	250.00	550.00	1.10	1254.10	1140.00	1.10	18.14	17.12
506	18.50	2.41	79.30	18.70	12.00	270.00	52.00	1.00	453.91	376.00	1.21	6.40	5.86
526	16.50	1.90	51.40	14.50	5.00	180.00	35.00		304.30	271.00	1.12	4.55	3.82
526									0.00		#DIV/0!	0.00	0.00
710	970.00	6.20	470.00	180.00	470.00	390.00	2500.00	34.00	5020.20	5350.00	0.94	82.36	72.25
711									0.00		#DIV/0!	0.00	0.00
711									0.00		#DIV/0!	0.00	0.00
711	2160.00	6.57	508.00	270.00	640.00	700.00	5400.00		9684.57	10400.00	0.93	145.58	141.96
711									0.00		#DIV/0!	0.00	0.00
712									0.00		#DIV/0!	0.00	0.00
712									0.00		#DIV/0!	0.00	0.00
712	2050.00	12.90	597.00	320.00	610.00	670.00	5200.00		9459.90	10900.00	0.87	149.32	136.45
712									0.00		#DIV/0!	0.00	0.00
802	393.00	5.00	185.00	71.20	91.00	406.00	968.00	23.10	2142.30	2030.00	1.06	33.02	29.75
802									0.00		#DIV/0!	0.00	0.00
808									0.00		#DIV/0!	0.00	0.00
808									0.00		#DIV/0!	0.00	0.00
808	212.00	2.78	23.50	3.93	12.00	290.00	230.00	1.90	776.11	690.00	1.12	11.17	9.91
814									0.00		#DIV/0!	0.00	0.00
814									0.00		#DIV/0!	0.00	0.00
814	693.00	4.00	222.00	86.80	90.00	370.00	910.00	4.30	2380.10	3250.00	0.73	49.72	27.62

2005	**DATA**											
site	**cat/an**	**%cat/an**	**%tdscalc/tdslab**	**TDS/MG**	**TDS/NA**	**TDS/SO4**	**NA/SO4**	**NA/CL**	**MG/CA**	**Fe**	**Mn**	**CO3**
331	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
331	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
331	1.03	102.83	108.48	36.80	5.16	1.71	0.33	5.35	0.35			
331	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
333	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
333	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
333	1.00	99.90	102.87	28.23	5.51	1.76	0.32	3.44	0.49			
333	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
333	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
336	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
346	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
346	0.94	94.03	108.04	25.10	6.74	1.97	0.29	3.96	0.53			
346	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
371	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
371	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
371	1.69	169.00	80.07	35.81	3.38	241.71	71.56	5.87	0.54			
371	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
372	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
372	1.06	105.98	110.01	570.05	3.34	2.28	0.68	6.84	0.13			
506	1.09	109.09	120.72	24.27	24.54	8.73	0.36	1.54	0.24			
526	1.19	119.22	112.29	20.99	18.44	8.69	0.47	3.30	0.28			11.00
526	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
710	1.14	114.00	93.84	27.89	5.18	2.01	0.39	2.06	0.38			
711	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
711	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
711	1.03	102.56	93.12	35.87	4.48	1.79	0.40	3.38	0.53			
711	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
712	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
712	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
712	1.09	109.43	86.79	29.56	4.61	1.82	0.39	3.36	0.54			
712	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
802	1.11	111.00	105.53	30.09	5.45	2.21	0.41	4.32	0.38			
802	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
808	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
808	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
808	1.13	112.71	112.48	197.48	3.66	3.37	0.92	17.67	0.17			
814	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
814	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
814	1.80	180.01	73.23	27.42	3.43	2.62	0.76	7.70	0.39			

2005	DATA			
site	U	Mo	COND(lab)	tds/COND
331				#DIV/0!
331				#DIV/0!
331			5580.00	0.82
331				#DIV/0!
333				#DIV/0!
333				#DIV/0!
333	3.30	6.20	4580.00	1.01
333				#DIV/0!
333				#DIV/0!
336				#DIV/0!
346				#DIV/0!
346			2970.00	0.80
346				#DIV/0!
371				#DIV/0!
371				#DIV/0!
371			10700.00	0.90
371				#DIV/0!
372				#DIV/0!
372			1670.00	0.68
506				#DIV/0!
526			37.40	7.25
526				#DIV/0!
710			6510.00	0.82
711				#DIV/0!
711				#DIV/0!
711			12700.00	0.82
711				#DIV/0!
712				#DIV/0!
712				#DIV/0!
712			10900.00	1.00
712				#DIV/0!
802			2720.00	0.75
802				#DIV/0!
808				#DIV/0!
808				#DIV/0!
808			1050.00	0.66
814				#DIV/0!
814				#DIV/0!
814			4040.00	0.80

2005	**DATA**												
site	**Na**	**K**	**Ca**	**Mg**	**Cl**	**HCO3**	**SO4**	**NO3**	**tdscalc**	**tdslab**	**tdscal/lab**	**meqcation**	**meqanion**
814									0.00		#DIV/0!	0.00	0.00
815									0.00		#DIV/0!	0.00	0.00
815	167.00	1.94	23.00	8.60	12.00	250.00	180.00	5.00	647.54	605.00	1.07	9.47	8.26
815									0.00		#DIV/0!	0.00	0.00
808									0.00		#DIV/0!	0.00	0.00
904									0.00		#DIV/0!	0.00	0.00
904	20.30	1.90	52.30	13.60	12.00	120.00	110.00		330.10	277.00	1.19	4.70	4.60
904									0.00		#DIV/0!	0.00	0.00
904									0.00		#DIV/0!	0.00	0.00
907									0.00		#DIV/0!	0.00	0.00
907									0.00		#DIV/0!	0.00	0.00
907	7.36	1.40	28.20	6.10	6.00	78.00	21.00		148.06	124.00	1.19	2.28	1.88
907A													

2005	**DATA**											
site	**cat/an**	**%cat/an**	**%tdscalc/tdslab**	**TDS/MG**	**TDS/NA**	**TDS/SO4**	**NA/SO4**	**NA/CL**	**MG/CA**	**Fe**	**Mn**	**CO3**
814	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
815	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
815	1.15	114.59	107.03	75.30	3.88	3.60	0.93	13.92	0.37			
815	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
808	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
904	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
904	1.02	102.21	119.17	24.27	16.26	3.00	0.18	1.69	0.26			
904	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
904	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
907	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
907	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
907	1.21	120.87	119.40	24.27	20.12	7.05	0.35	1.23	0.22			
907A												

2005	DATA			
site	U	Mo	COND(lab)	tds/COND
814				#DIV/0!
815				#DIV/0!
815			930.00	0.65
815				#DIV/0!
808				#DIV/0!
904				#DIV/0!
904			455.00	0.61
904				#DIV/0!
904				#DIV/0!
907				#DIV/0!
907				#DIV/0!
907				#DIV/0!
907A			211.00	0.00

APPENDIX E

Curriculum Vitae

Charles G. Patterson, Ph.D.

CHARLES G. PATTERSON, Ph.D.

P.O. Box 3007 El Dorado Springs, CO 80025 (303) 494-3645

EDUCATION

Ph.D. 1996	DEPARTMENT OF GEOLOGICAL SCIENCES, UNIVERSITY OF COLORADO. Dissertation title: Electrochemistry of Groundwater: 1. Redox Gases 2. Electromigration.
M.S. 1980	DEPARTMENT OF GEOLOGICAL SCIENCES, UNIVERSITY OF COLORADO. Thesis title: Geochemistry of Boulder Creek.
B.A. 1972	DEPARTMENT OF GEOLOGICAL SCIENCES, UNIVERSITY OF COLORADO. Geology major. Emphasis in Mathematics, Chemistry, Physics, Biology and German

WORK EXPERIENCE

9/88 to present — ADJUNCT PROFESSOR, Red Rocks Community College, Golden, Colorado. Prepare and teach transfer level courses and labs in Physical Geology, Environmental Science, and a variety of weekend seminar courses such as Gems, Crystals and Minerals and the Great Ice Age

1994 to present — TECHNICAL ASSISTANCE GRANT ADVISOR. Provide technical advice and representation for small minority communities undergoing USEPA Superfund cleanup. Funded by grant from USEPA, principally involved in Globeville community, Northeast Denver, contaminated with smelter emissions from ASARCO plant.

1993 to present — ADJUNCT PROFESSOR, The Naropa Institute, Boulder, Colorado Prepare and present classes on Ecology, Evolution, Watershed Science, Water Analysis (River Watch Program), Sustainable Communities, Natural Science, and Natural History of the Boulder Region.

1978 to present — CONSULTING GEOCHEMIST

A wide variety of consulting work in water quality, soils, mineral exploration and environmental areas including:

* Geologic and geochemical analysis of nuclear disposal sites in western Colorado
* Soils and wetlands surveys for commercial and municipal facilities including the siting of a low-level nuclear waste repository in Nebraska and wetland pond construction at the Denver International Airport
* Water quality studies and permitting for mining industry
* Pit lake hydrologic modeling for gold mining industry
* Mining claim evaluation in Colorado and Arizona
* Water well and septic systems siting in Jefferson and Boulder counties
* Environmental Geology of Clear Creek County for the County Planning Commission

1972 to 1985 — PROFESSOR OF GEOLOGY, Red Rocks Community College

* Developed and taught courses in the Physical Sciences, including Physical, Historical and Environmental Geology; Hydrology, Mineralogy; Petrology; Economic Geology; Field Geology; Geology of Colorado. Courses included the associated laboratory and field trip activities.
* Taught math courses covering topics through College Algebra part-time in the Mathematics Department.
* Produced curriculum guides and learning objective lists for the Geology courses and associated labs

* Produced many educational video-tapes for classroom use (after completing a certification course in video-tape production at the University of Oregon in 1976)
* Faculty Advisor to KRMA Channel 6 on the project to introduce BBC Geology series "The Earth Explored" to American audiences nationwide. Also authored faculty manual for the telecourse, which was aired 1984-85 academic year
* Member of Faculty Senate
* Chairman and member of Petroleum Technology Advisory Committee, 1974-1985
* Presented geology lectures, films, and field trips to community groups and schools, including: Colorado Mineralogical Society, Colorado Mountain Club, Colorado Scientific Society, Graland School and Longmont Junior High
* Conducted numerous weekend field trips while acting as faculty advisor to the Geology Club

6/88 to 12/95

GEOCHEMIST, RESEARCH ASSISTANT for Dr. Donald D. Runnells, University of Colorado, Boulder.
* Configured custom GC system for analysis of dissolved gases in samples of ground water and developed methods of analysis
* Selected wellsites, supervised drilling, and sampled ground water
* Sampled and analyzed stream sediments from Leadville for heavy metals (original Ph.D. dissertation topic, funded by USGS)

1/90 to 5/91

GRADUATE FACULTY , Environmental Science, University of Colorado at Denver
* Designed and taught graduate course entitled "Soil Chemistry of Hazardous Materials"

5/80 to 1/88

GEOLOGIST, U.S. Geological Survey, Central Mineral Resources, Lakewood, Colorado.
* Conducted mineral and energy resource evaluation of Wilderness Study Areas in Colorado, Utah, Wyoming and Montana.
* Organized and designed geologic mapping and geochemical sampling programs
* Interpreted geologic and geochemical data
* Produced final reports and maps
* Supervised activities of several field assistants

9/85 to 9/87

INSTRUCTOR, Colorado Mountain College, Leadville, Colorado.
* Developed and taught courses in Environmental Technology and Chemistry, including: Seminar on Acid-mine Drainage, Environmental Geology, The Geology of Leadville, Earth Sciences and Soil Chemistry, College Chemistry
* Produced 11 curriculum guides and course descriptions for a new program in hazardous waste management and water quality
* Involved in the Environmental Planning Task Force for EPA cleanup of the California Gulch Superfund site.

1978 to 1986

EDUCATIONAL CONSULTANT for the Colorado Outward Bound School.
* Conducted seminars and classes on the Geology of Canyonlands National Park in Utah, Marble, Leadville and other locations for Outward Bound courses for staff and students

Summer, 1971

FIELD ASSISTANT for the Institute for Arctic and Alpine Research, University of Colorado.
* Surveyed glacial surfaces and mapped glacial deposits on Baffin Island, N.W.T.
* Conducted computer analysis of data

9/69 to 5/71

WORK STUDY ASSISTANT in Geology Department, University of Colorado, Boulder.
* Conducted geophysics experiments and laboratory work
* Responsible for seismograph installation * Prepared thin and polished specimens

GRANTS & AWARDS

1979, 1994 Warren O. Thompson Fund, Department of Geological Sciences, University of Colorado
1988 U.S. Geological Survey Grant-in-aid ($10,000)
1990 Electric Power Research Institute ($250,000)

PROFESSIONAL ACTIVITIES

1990 - 1994 President, Geology Club, University of Colorado, Boulder

1998 – 2002 VB/I70 superfund site working group

PRESENTATIONS

1992 American Geophysical Union Regional Meeting, Boulder, Colorado, “Microbially produced gases as indicators of redox conditions in shallow ground water”

1993 Water-Rock Interaction International Conference, Park City, Utah, “Measurement and interpretation of redox gases in aqueous environments”

1993 American Ground Water Association, Albuquerque, New Mexico, “Electromigration as a method of remediating sulfate from shallow ground water”

1995 Boulder Creek Watershed Forum/ Dept. of Geological Sciences Colloquium, “Geochemistry of Boulder Creek”

1999 Boulder Creek Watershed Forum, “Geology and Geochemistry of Boulder Creek”

2000 National Conference of TAG Advisors, “Remedial Actions in Globeville, Colorado”

REFERENCES

Dr Anne Z. Parker, Chair
Environmental Studies Department
The Naropa University
2130 Arapaho Ave,
Boulder, CO 80302
303-546-3525

Professor John D. Stanesco
Chair, Science Department
Red Rocks Community College
13300 W. 6th Ave,
Lakewood, CO 80228
(303)-914-6290

Dr. Steven Schmidt
EPO Biology
University of Colorado
Boulder, CO 80209
(303)-492-6248

Ms Rosemarie Riley
Director, Globeville Community Resource Center
4400 Lincoln St.
Denver, CO 80216
303-298-8822

PUBLICATIONS

Patterson, C.G., and Runnells, D.D. (2001). Low Temperature Geochemistry. In: Meyers, R., (ed.) *The Encyclopedia of Physical Science & Technology*, Academic Press.

Patterson, C.G. (1999). Oxidation-Reduction. In: Marshall and Fairbridge (eds), *Encyclopedia of Geochemistry*, Kluwer Academic Pub., Lancaster, U.K.

Patterson, C.G. and Runnells, D.D. (1996) A field test of electromigration as a method for remediating sulfate from shallow ground water. *Ground Water Monitoring and Remediation*, Vol. XVI, No. 4, Fall.

Patterson, C.G. and Runnells, D.D. (1992). Dissolved gases in ground water as indicators of redox conditions. In: *Proceedings of the 7th International Symposium on Water-Rock Interaction*, Park City, Utah, 13-19 July 1992, v. 1, p. 517-520.

Patterson, C.G., (1992). Reply to McFarland and Sims, (1991)"Thermodynamic framework for evaluating PAH degradation in the subsurface" In *Ground Water*, Vol.29, No.6, p. 885-885. Reply pub. in Vol. 30, No.2.

Soulliere, S.J., Leibold, A.M., Patterson, C.G. and Martin, C.M. (1987). Mineral resource potential of the Sewemup Mesa Wilderness Study Area, Mesa and Montrose Counties, Colorado. *U.S. Geological Survey Bulletin* 1736-B, 24 p.

Patterson, C.G., Green, G.N., Case, J.C., Schreiner, R.A. and Thompson, J.R. (1987). Mineral resource potential of the Indian Creek Canyon, Bridger Jack Mesa and Butler Wash Wilderness Study Areas, San Juan County, Utah. *U.S. Geological Survey Bulletin* 1754-A, 25 p.

Patterson, C.G., Green, G.N., Case, J.C., Schreiner, R.A. and Thompson, J.R. (1987). Mineral resource potential of the Behind The Rocks Wilderness Study Area, Grand and San Juan Counties, Utah. *U.S. Geological Survey Bulletin* 1754-B,18 p.

Patterson, C.G., Scott, D.S., Kulik, D.M., Loen, J.S. and Koesterer, M.E. (1986). Mineral resource potential of the Honeycomb Buttes Wilderness Study Area, Fremont and Sweetwater Counties, Wyoming. *U.S. Geological Survey Bulletin 1757-B*, 19 p.

Patterson, C.G., Toth, M.I., Kulik, D.M., Esparza, L.E., Smauch, S.W. and Benham, J.R. (1987). Mineral resource potential of the Pryor Mountain, Burnt Timber Canyon, and Big Horn Tack-On Wilderness Study Areas, Cody County, Wyoming and Big Horn County, Montana. *U.S. Geological Survey Bulletin* 1723, 34 p.

Patterson, C.G. (1984). Curriculum guides for Physical Geology and Geology of Colorado. *Red Rocks Community College in-house publications.*

Patterson, C.G. (1984). Faculty manual to accompany "The Earth Explored", a video-tape series on Geology (broadcast nationally on PBS stations), KRMA, Denver, ch. 6, 70 p.

Toth, M.I., Stoneman, R.J., Patterson, C.G. and Jackson, L.L. (1983). Geology and mineral resource potential of the Black Ridge Canyon Wilderness Area, Mesa County, Colorado. *U.S. Geological Survey Open-File Report 83-794*, 30 p.

Toth, M.I., Patterson, C.G., Kulik, D.M., and Schreiner, R.A., 1987, Mineral Resources of the Dominguez Canyon Wilderness Study Area, Delta, Mesa, and Montrose Counties, Colorado. *U.S. Geological Survey Bulletin 1736-A*, 10 p.

Toth, M.I., Davis, L.L., Patterson, C.G. and Seeley, J.L. (1983). Geology and mineral resource potential of the Dominguez Canyon Wilderness Study Area, Delta, Mesa and Montrose Counties, Colorado. *U.S. Geological Survey Open-File Report 83-797*, 29 p.

Soulliere, S.J., Leibold, A.M. and Patterson, C.G. (1983). Geology and mineral resource potential of the Sewemup Wilderness Study Area, Mesa and Montrose Counties, Colorado. *U.S. Geological Survey Open-File Report 83-796*, 26 p.

Patterson, C.G., Dubiel, R.F., Larson, M.J., Milde, P.G., Bromfield, C.S. and Peterson, F. (1983). Geology of the Bull Mountain, Mount Ellen-Blue Hills Wilderness Study Areas, Garfield and Wayne Counties, Utah. *U.S. Geological Survey Miscellaneous Field Studies Map MF-1756*.

Larson, M.J., Bromfield, C.S., Dubiel, R.F., Patterson, C.G. and Peterson, F. (1983). Geology of the Little Rockies, Mount Hillers and Mount Pennell Wilderness Study Areas, Garfield and Wayne Counties, Utah. *U.S. Geological Survey Miscellaneous Field Studies Map MF-1757*.

Larson, M.J., Bromfield, C. S., Dubiel, R.F., Orkild, P.O., Patterson, C.G. and Peterson, F. (1983). Geology of the Fiddler Butte and Fremont Gorge Wilderness Study Areas, Garfield and Wayne Counties, Utah. *U.S. Geological Survey Miscellaneous Field Studies Map MF-1755*.

Hovorka, D.S., Patterson, C.G. and Toth, M.I. (1983). Geology and mineral resource potential of the Palisade Wilderness Study Area, Mesa County, Colorado. *U.S. Geological Survey Open-File Report 83-795*, 24 p.

Dubiel, R.F., Bromfield, C.S., Larson, M.J., Orkild, P.P., Patterson, C.G. and Peterson, F. (1983). Geology of the Dirty Devil I, Dirty Devil II and Horseshoe Canyon Wilderness Study Areas, Garfield and Wayne Counties, Utah. *U.S. Geological Survey Miscellaneous Field Studies Map MF-1754*.

Stanesco, J.D. Patterson, C.G. and Matthews, V.M. (1979). Sackung features on Keystone Mountain, Colorado. *Geological Society of America Abstracts, Fort Collins meeting, v.11, n.6, p.303*.

Patterson, C.G. (1974). Geologic factors affecting land-use planning in Clear Creek County, Colorado. Report prepared for the firm of Chapman, Phillips, Brandt and Reddick, which was then included in a larger long-range planning report for Clear Creek County, Colorado.