IN THE MATTER OF SPARTON TECHNOLOGY, INC.
U.S. EPA DOCKET NO. RCRA-VI-001 (h)-96-H

REPORT OF W. PETER BALLEAU, CPG, P.Hg., ON SPARTON TECHNOLOGY, INC. SITE IMPACT ON GROUNDWATER-RESOURCE AVAILABILITY

February 3, 1997

The following is my assessment of the effect on the availability for public water supply of the groundwater resource near the Sparton Technology, Inc. (Sparton) Coors Road facility in Albuquerque caused by the presence of a plume of trichloroethene (TCE) in the shallow groundwater beneath the facility.

My comments are based on experience as a professional hydrogeologist and as President of Balleau Groundwater, Inc. where my work involves providing advisory services on the management of water-supply and water-quality issues. Attached is a copy of my CV. I draw in part on my work in Albuquerque for the past 20 years. A portion of my work is on sites regulated under Superfund, the Resource Conservation and Recovery Act and the New Mexico Water Quality Act authorities, including sites in the Rio Grande Valley in Albuquerque. I hold professional certification and registration as a hydrogeologist and geologist, and have testified as an expert witness on groundwater-development planning and corrective action in administrative hearings, and in Federal and State court.

I evaluated hydrogeologic conditions at the Sparton site, and have reviewed the reference material listed in Attachment 1. The information available is adequate to arrive at conclusions on questions involving:

BALLEAU GROUNDWATER, INC.
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1. The volume of water and radial distance from Sparton that the resource is unavailable for public water supply as a result of site conditions at Sparton.

2. The prospect that the affected resource will be needed for public water supply in the foreseeable future.

The hydraulic situation of the plume at the Sparton site is outlined in Reference 4 using 1993 and 1994 data and Reference 6 for 1996 data. I interpret the data to imply a plume with the general character summarized below.

	Approximate Plume Dimensions	Approximate Annual Rate of Change
Length	2,500 - 3,300 feet	50 - 200 feet/year
Width	500 - 1,700 feet	tens of feet/year
Depth	60 - 125 feet	3 feet/year
Area	30 - 90 acres	3 to 9 acres/year
Volume (@15 percent specific yield)	300 - 800 acre feet	30 - 80 acre feet per year
TCE Concentration	Peak 10,000 microgram/liter onsite	Declining
	5 - 3,200 microgram/liter offsite	Declining

The plume movement is northwest and downward in accordance with the prevailing hydraulic gradient and anisotropic hydraulic conductivity. Horizontal hydraulic gradients are from the Rio Grande and the Corrales Main Canal toward the New Mexico Utility (NMU) wellfields about three miles northwest. Vertical downward gradients are prevalent in the deeper well nests at the Sparton site and near the river valley throughout the Albuquerque Basin as a result of large-capacity public-supply wells depressurizing the deeper aquifer in the zone 500 to 2,000 feet below the water table. The product of horizontal and vertical hydraulic gradients with horizontal and vertical hydraulic conductivity accounts for a 30:1 horizontal versus vertical rate of plume movement as observed.

To illustrate the layout of the aquifer cross section and a poor water-quality zone in the Rio Grande alluvium below the floodplain relative to the larger aquifer system, I have

attached Figure 1, modified from a published section in Hawley and Haase (Reference 14). The line of section passes east-west about one mile south of the Sparton site. The water-quality zones are my delineation. The Sparton Site is in the expected zone of poor water quality. The nearest public-supply well, NMU RG-4462-S, is indicated 2.5 miles distant. The abundant water resource is available in the regional good-quality aquifer zones in the Upper Santa Fe Group marked on the figure.

TCE concentrations are reported by Sparton to be declining, although the plume front is expanding. I interpret the reported concentration pattern to be largely the result of dilution as the TCE annually mixes with about a ten percent larger volume of aquifer at the periphery of the contaminated water body. Processes other than dilution also may be acting to reduce concentration. The plume growth currently affects approximately an additional 50 acre feet per year (AFY) of water (6 acres per year x 60 feet thickness x 0.15 specific yield = 54 AFY).

Questions 1 and 2 are affected by whether or not the impacted water body is contained by hydraulic capture in an active control system, or is uncontained and allowed to passively expand and dilute with background waters. I assume that the future condition of the site will include active control and containment.

Hydraulic control and containment can be maintained at the site with practical capture-well layout and pumping rates. Question 1 reduces to determining a three-dimensional buffer zone around the contained water body. My reasoning is that a buffer zone somewhat larger than the impacted water body would be prudent to provide a factor of safety for locating public water-supply wells. The relative impact of a new water-supply well is related to its distance from Sparton capture wells, depth and pumping rate. In my opinion, the contiguous area where wells reasonably should not be completed for public water-supply purposes need not be greater than the half-width of the plume area, i.e., approximately one quarter mile (125 acres) around the plume center. Such wells reasonably should not be constructed with the top of perforations shallower than 500 feet below the water table. At greater distance and depth, large-capacity wells for any purpose would not be expected to cause the Sparton containment system to fail.

The standard of evaluation for the New Mexico State Engineer Office (SEO) permitting of any new well is that the new well not impair existing wells or be contrary to conservation of water or detrimental to public welfare. A new well application that caused failure of a TCE recovery and containment system might not be approved administratively because of effects on impairment, conservation and public welfare.

An adjustment in terms of Sparton capture-well placement and pumping rate might be required to prevent excursions of TCE induced by other wells at the one-quarter mile distance, but the Sparton system could be managed to securely maintain capture. For example, it can be shown that for any pumping rate introduced outside a capture zone, the groundwater divide enclosing the capture zone can be maintained by an adjustment in the capture wellfield pumping. Superposition of ambient gradients and drawdowns for the capture zone well and outside well give the relationship

$$Q_c = 2\pi\ TJd + Q_w\left(\frac{d}{D-d}\right)$$

where the capture well pumping rate (Q_c) can be determined from the transmissivity (T), ambient gradient (J), distance from capture well to capture zone divide (d), external well-pumping rate of (Q_w), and distance to the outside well from the capture zone well (D) for wells in the same depth interval.

The hydrologic principle is that the disturbance from any introduced pumping at any distance greater than the capture zone can be offset by adjusting the capture zone well-pumping rate to maintain the capture zone groundwater divide. The adjustment is smaller if new wells are placed at greater distance.

Wells screened in the deeper aquifer layers below 500 feet are protected by the resistance to vertical flow created by anisotropy in the aquifer. Particle tracking models show that vertical transport to the Albuquerque (the City) wellfields typically is less than 300 feet in 40 years.

Therefore, a reasonable public supply buffer zone around the impacted water body at Sparton is about 125 acres in area and 500 feet thick below the water table. Only a fraction of the water in the buffer zone, about 300 to 800 AFY, would be impacted by TCE. The majority of the water in the buffer zone would be of background water quality.

There would be some practical management risk of inducing an excursion of TCE out of the containment area if a large-capacity production well were placed in the unimpacted buffer zone. If containment were lost in such a case, the water produced by a well in the buffer zone would be of lower concentration in TCE than the concentration in the water induced to move from the containment zone. Water produced by a well in the buffer zone would be diluted by a ratio of fresh water depending on the specific geometry of the well screen in the buffer zone. The result may or may not be above Safe Drinking Water Act (SWDA) secondary Maximum Contaminant Levels (MCLs). Production wells outside the buffer zone would not be expected to induce any excursion of TCE, because hydraulic containment could be maintained.

The background water quality of the buffer zone water body is derived from the irrigated alluvial floodplain of the Rio Grande which is commonly high in total dissolved solids, hardness, iron, manganese and sulfides. SWDA secondary MCLs recommend such constituents be avoided where alternatives are available in public water supplies. Monitoring-well data at the Sparton site indicate that specific conductance values reach 1,100 micromhos per centimeter, and nitrite-nitrate nitrogen reaches 9.6 milligrams per liter (mg/l). Manganese reaches values up to 0.41 mg/l at background Well MW-51, which is above the SDWA secondary MCL of 0.05 mg/l. Monitoring-well data for October 1996 show that 21 wells tested for hardness exhibited values ranging from 180 to 285 mg/l as $CaCO^3$. The value of hardness in background Well MW-51 was 180 mg/l as $CaCO^3$. Water with hardness values above 180 mg/l as $CaCO^3$ is considered very hard (Hem, 1992) and is undesirable where alternatives are available. Hardness and manganese in background water and possible other constituents make the buffer zone water body described above not a desirable source for public water supply with or without TCE impacts.

Regarding the second question on the need for the affected resource to be available for public supply purposes in the foreseeable future, I have reviewed the resource base, history and planning for use of the groundwater in Albuquerque. My 1994 New Mexico Water Conference paper (Reference 3) on the subject is quoted below for perspective on the volume of the resource.

> *"I calculate the volume of stored groundwater to a depth of 600 feet below the water table in 2,100 square miles of the middle basin, using an assumed specific yield of 10 percent, to be 80 million a-f. That is equivalent to a 600-year supply at current pumping rates. Hawley and Haase (1992) identified the most productive part of the aquifer as the Upper Santa Fe unit of the Santa Fe Group. They mapped a 4 mile x 10 mile area near the City having a saturated thickness of 600 feet as the most productive aquifer zone. At an assumed 20 percent specific yield, the water volume in this most productive part of the aquifer is 3 million a-f. The City has produced an equivalent volume from the aquifer: 2.7 million a-f 1960-1992 (Thorn et al., 1993), or 3.14 million a-f since 1993 (City of Albuquerque, written communication, June 6, 1994). By contouring the cone of depression created by withdrawing 2.7 million a-f in 32 years, Thorn and others (1993) estimated that 0.99 million a-f (37 percent of withdrawals) to 0.50 million a-f (18 percent of withdrawals) had been derived from aquifer storage. Thus, most of the City's historic production (82 to 63 percent) has been derived from the surface-water sources."*

In my opinion, the stored groundwater remaining in the City wellfield totals about three million acre feet (AF) of high-quality resource. About one million AF has been depleted from that source in the past 40 years.

The 1982 City Wellfield Plan (Reference 13) called for 239 additional wells. In fact, the number of City wells (92) in operation in 1996 was fewer than in 1982 (96). The 1982 City Wellfield Plan is not an appropriate basis for projecting developments. A 1995-2004 Albuquerque City Council Decade Plan for Capital Improvements (Reference 1) includes funding in the decade for five new wells plus equal funding for replacement wells. The City-planned wells are four miles or more from Sparton's site and could not be affected by Sparton-site TCE impacts.

The Sparton site is near a proposed critical management area (CMA) where the SEO is considering a moratorium on new well permits (Reference 20). A map of proposed CMAs in the Albuquerque area with the Sparton site delineated is provided as Figure 2. There are administrative barriers that may make it difficult to permit new wells in or near CMAs in the future.

The City strategy for future development is to hold steady or reduce the groundwater withdrawals and to provide for growth of demand from renewable surface-water sources (References 7 and 9). Holding steady at the recent groundwater-depletion rate of 70,000 AFY means there is a 40-year supply from the local, high-quality City wellfield resource base. The NMU and the Rio Rancho Utilities rely on groundwater outside the City wellfield area where an equal or larger volume of stored groundwater is available. The entire 2,100 square mile Albuquerque Basin is estimated to have about 80 million AF of potable water. I consider that neither the impacted plume volume nor the buffer-zone clean water will be needed by the major public water supplies until after the site is remediated.

CONCLUSIONS

In my opinion, the following conclusions are warranted:

1. Up to 800 AF of the groundwater resource in 30 to 90 acres of surface area in the Albuquerque Basin is unsuitable for public water supply due to TCE impacts at the Sparton site. That volume of water is planned to be contained from further migration.

2. Due to practical uncertainties in controlling induced excursions of impacted water, public-supply wells reasonably should not be placed within a buffer zone of one quarter mile radius of the impacted water body and should not be constructed with a screened interval shallower than 500 feet below the plume.

3. The background water quality in the shallow buffer zone is undesirable for public water supply with or without the TCE contamination.

4. The future amount and cost of water produced from the groundwater resource for public water supply for the foreseeable future in the Albuquerque Basin will be the same with or without the TCE plume at the Sparton site.

I state under penalty of perjury that the foregoing is true and correct.

Executed on February 3, 1997.

BALLEAU GROUNDWATER, INC.

W. Peter Balleau, CPG, P.Hg
President

AMERICAN INSTITUTE OF HYDROLOGY
Certificate Number 238
W. PETER BALLEAU
Professional Hydrogeologist

Attachments: Reference List
Balleau Resume
2 Figures

ATTACHMENT 1

REFERENCES

1. Albuquerque City Council, "Capital Improvement Plan."

2. Anderholm, S.K., 1988, "Ground-Water Geochemistry of the Albuquerque-Belen Basin, Central New Mexico," U.S. Geological Survey, Water-Resources Investigations Report 86-4094.

3. Balleau, W.P., 1994, "The Water Future of Albuquerque and Middle Rio Grande Basin," in Proceedings of the 39th Annual New Mexico Water Conference, New Mexico Water Resources Research Institute, Report No. 290.

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18. Metric Corporation, October 31, 1996, "Containment Well & Discharge Location Map, Sparton Technology, Inc.," Figure 1, revised December 3, 1996.

19. National High Altitude Photography Program, July 12, 1986, photograph number 379-12.

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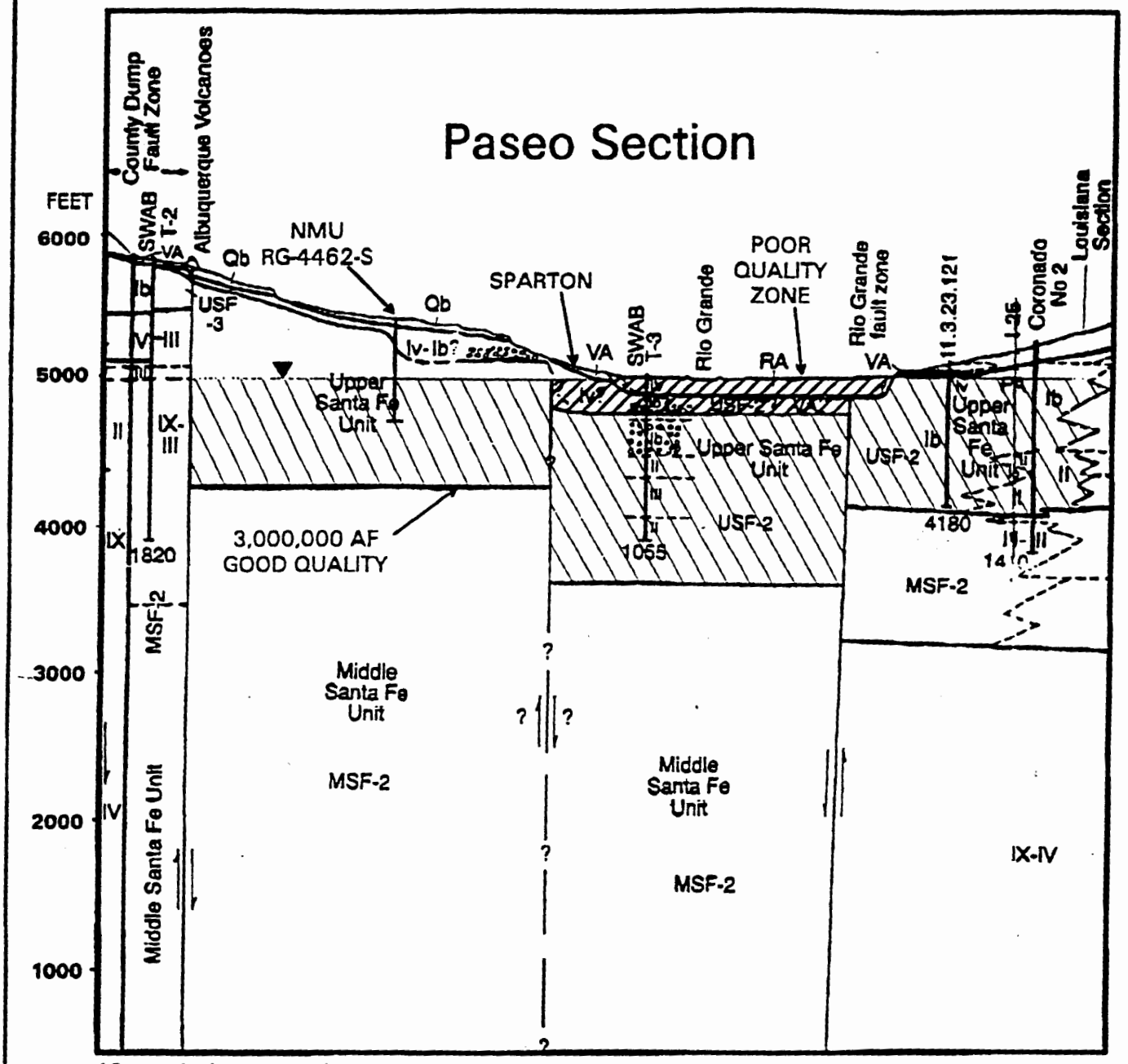

10x vertical exaggeration

Paseo del Norte Hydrogeologic Section

MODIFIED FROM HAWLEY AND HAASE, 1992

SHEEHAN, SHEEHAN & STELZNER, P.A. / SPARTON

SPARTON REGIONAL GEOLOGIC UNITS AND WATER QUALITY ZONES

Date 2/1/97	**FIGURE 1**
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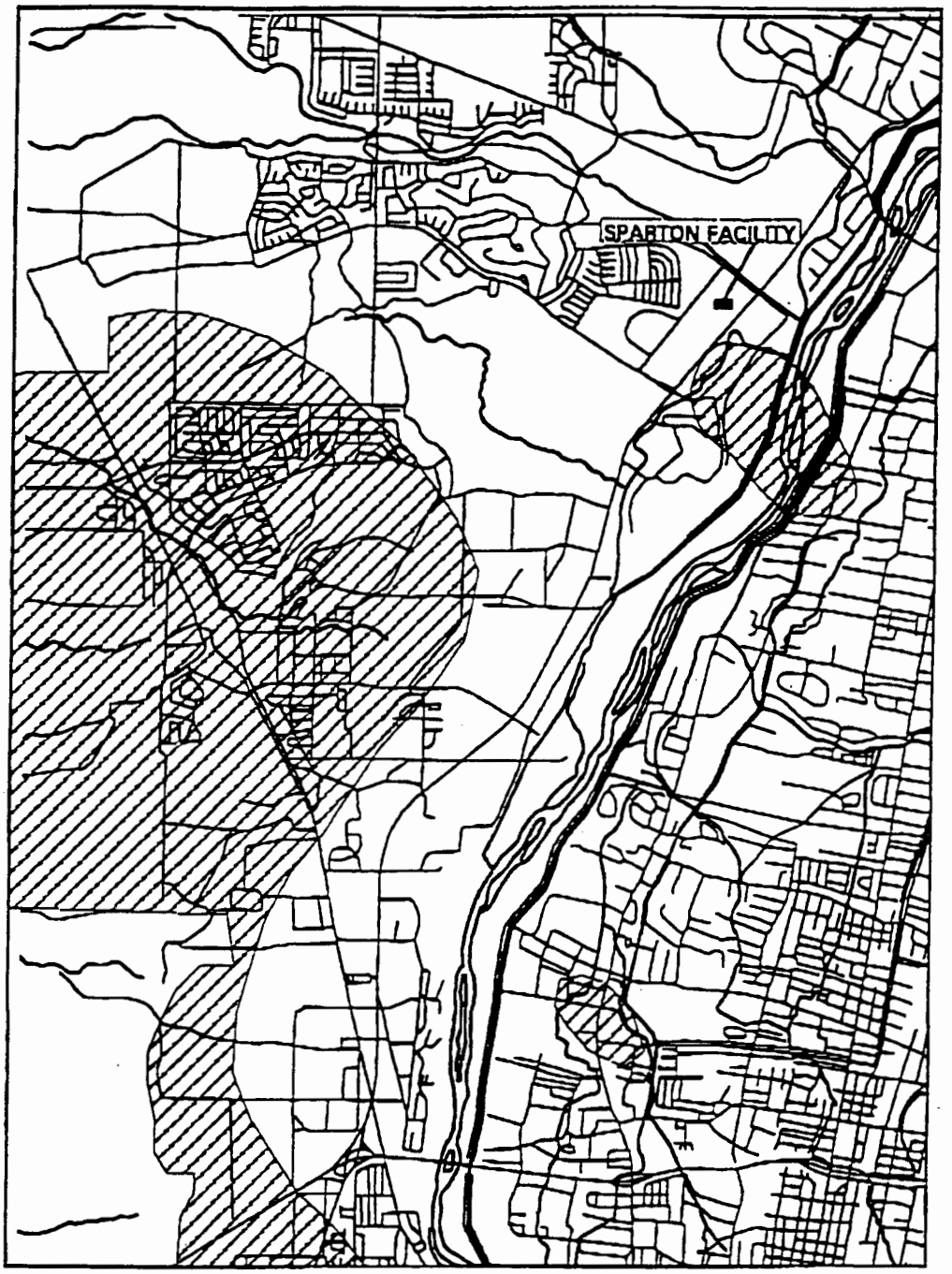

APPROXIMATE LOCATION OF CRITICAL MANAGEMENT AREAS

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SHEEHAN, SHEEHAN & STELZNER, P.A./SPARTON

SEO PROPOSED CRITICAL MANAGEMENT AREAS NEAR SPARTON SITE

FIGURE 2

BALLEAU GROUNDWATER, INC.

901 RIO GRANDE BLVD. NW, SUITE F-242
ALBUQUERQUE, NEW MEXICO 87104

W. PETER BALLEAU, CPG, P. Hg.

Hydrogeologist

EDUCATION: Bachelor of Arts in Geology, 1968, University of New Mexico

REGISTRATION: Certified Professional Geologist (#2716) by the American Institute of Professional Geologists (1975)
Registered Geologist (#18432) in the State of Arizona (1985)
Certified Professional Hydrogeologist (#238) by the American Institute of Hydrology (1984)

PROFESSIONAL SOCIETIES:
American Association for the Advancement of Science
American Geophysical Union
American Institute of Hydrology
American Institute of Physics
American Institute of Professional Geologists
American Water Resources Association
Association of Ground-Water Scientists and Engineers (National Ground Water Association)
Geological Society of America
Geological Society of Australia
New Mexico Geological Society
Albuquerque Geological Society

CAREER EXPERIENCE:

1992 to date:	President and Hydrogeologist, Balleau Groundwater, Inc.
1991 to 1992:	Vice-President and Director of Leggette, Brashears & Graham, Inc.
1985 to 1991:	Associate and Senior Associate with Leggette, Brashears & Graham, Inc. and Manager of Albuquerque Regional Office
1977 to 1985:	Supervisory Hydrologist, Bureau of Indian Affairs, Albuquerque, New Mexico
1975 to 1977:	Senior Hydrogeologist with Leggette, Brashears & Graham, Inc.
1973 to 1975:	Hydrogeologist with the firm of Leggette, Brashears & Graham, Inc.
1971 to 1973:	Groundwater Geologist with the Geological Survey of Western Australia
1968 to 1970:	Geologist with Water Development Division, Government of Kenya

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SUMMARY OF PROFESSIONAL EXPERIENCE:

Career experience in major aspects of hydrogeology, with particular emphasis on arid-zone hydrology, mine dewatering, water-rights litigation support, and computer modeling of regional aquifer systems. Water-supply planning and wellfield layout for municipal, industrial and governmental projects also have been major activities. Contamination and water-quality projects include assessment of NPDES effects and groundwater discharge effects on surface-water standards, landfill leachate ion-balance work, evaluation of groundwater discharge permits, UIC and UST projects, geothermal project effects, salt-water intrusion, and detailed characterization and three-dimensional aquifer modeling of uranium mine and Superfund sites.

Government employment in East Africa, Western Australia and in New Mexico included water-supply development in remote areas, regional aquifer studies, management of water-resources programs, and acquisition and protection of groundwater rights. Consulting experience is in the northeast and western United States, the Gulf Coast, and in northern Alberta, the Yemen Arab Republic, Ireland, Peru, Chile, Mexico and Honduras. Major consulting projects have included wellfield development for the World Bank and USAID in the middle east; litigation support for the United States in several basin-wide adjudications; dewatering design and environmental assessment for major mines in Nevada, Alberta and Ireland; dam and reservoir seepage modeling studies on the Rio Grande; regional water planning in seven New Mexico counties and for the State of Mississippi; and permitting for municipal and agricultural water in southwest Florida.

Formal testimony has been presented as an expert witness in hydrology and hydrogeology in Federal and State Courts, and in administrative hearings on more than 25 cases.

PUBLICATIONS:

"Surface Water and Groundwater for Growth in the Albuquerque Basin," in The Water Future of Albuquerque and Middle Rio Grande Basin, Proceedings of the 39th Annual New Mexico Water Conference, 1994.

"Demonstrating Impairment of a Water Right," New Mexico Natural Resources Law Reporter, 1993.

"The Use of Consultants in Water Rights Matters," Cambridge Institute Seminar Proceedings, Understanding and Protecting Your Water Rights in New Mexico, 1992.

"The Transition from Ground-Water Mining to Induced Recharge in Generalized Hydrogeologic Systems," Proceedings Focus Conference on Southwestern Ground Water Issues, 1988 (with A.B. Mayer).

"Water Appropriation and Transfer in a General Hydrogeological System," Natural Resources Journal, Vol. 28, No. 2, Spring 1988, pp. 269-291.

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"Hydrological Investigation of the Magnesian Limestone of Southeast Durham, England - A Discussion," Journal of Hydrology, 1973.

"Outline of Ground Water at the Fortescue River Basin," Western Australia Geological Survey Record, 1973.

"North Gnangara Sand Beds Aquifer - Tentative Water Balance and Yield Analysis," Western Australia Geological Survey Record, 1972/14.

"Saturated Sands at Yenart Soak," Western Australia Geological Survey Annual Report, 1971.

"Summary of Aquifer and Bore Characteristics of North Gnangara Borefield," Western Australia Geological Survey Annual Report, 1971.

PROJECT EXPERIENCE IN WATER MANAGEMENT:

- Carlin, Nevada: Assessment of dewatering requirement and layout of structures for water control in slope of mine highwall. Interpretation of aquifer tests.

- Sandia Mountains, New Mexico: Hydrologic evaluation of subdivision development effects on San Pedro and La Madera Creeks.

- Chihuahua, Mexico: Field investigations and evaluation of effects of Etapa II wellfield expansion on El Sauz agricultural developments.

- Sangre de Cristo Mountains, Santa Fe County, New Mexico: Evaluate hydrologic effect and water supply availability for subdivision development.

- Las Vegas Valley, Nevada: Hydrologic representation for negotiation of water rights between Nevada, U.S. agencies and Tribe. Apply models of basin to appraise hydrologic impacts of new water right at levels of 7,500 to 15,000 AFY including drawdown, basin water balance, water quality and subsidence effects.

- Tesuque Creek, New Mexico: Hydrologic evaluation of groundwater effects of hotel development and return flow quantities for lease of water.

- Bosque del Apache, New Mexico: Documentation of water-right administrative history and quantification of consumptive use on 6,000-acre wildlife refuge.

- Rio Elqui, Chile: Inspection and interpretation of underground mine water situation with projection of dewatering performance and flow in mine workings at elevation 3800 meters in Andes.

- Tonque Arroyo, New Mexico: Hydrologic opinion on administrative record of water rights for use in development of destination resort on Indian Pueblo lands.

- Rio Chama and Rio Santa Cruz, New Mexico: Hydrologic support for Indian Pueblo water claims based on availability of surface water and groundwater, historic uses and future demands.

- Pojoaque River Basin, New Mexico: Hydrological support for negotiation of groundwater and surface-water rights among Federal, State and private water claims.

- Jemez River Basin, New Mexico: Water resource and hydrologic support. Water claim in negotiation. Preparation of hydrologic factbook and advisory services and representation.

- Rio San Jose, New Mexico: Comprehensive basin assessment of historic natural water supply, water uses, future demands and groundwater sources.

- Carlin, Nevada: Plan for injection of mine dewatering water in foothills of Tuscarora Mountains as hydrologic barrier controlling influence of mine activities.

- Harris Creek, Catron County, New Mexico: Evaluation of sources and yield of streams and springs and develop settlement of water-right claims.

- Boulder Basin, Nevada: Hydrologic support for litigation of mine-water disposal effects.

- San Juan River, New Mexico: Evaluation of effects of generating station water use on Navajo Reservoir contract water demands and on prior rights and shortages.

- City of Santa Fe, New Mexico: Subdivision lot-size assessment based on availability of water.

- San Miguel County, New Mexico: Inventory of wells, water use, future sources of groundwater, aquifer tests to quantify yields, and evaluation of hydrologic effects of commingling wells on extensive ranch lands.

- Middle Rio Grande, New Mexico: Evaluate effects of Albuquerque municipal wellfield expansion on irrigation canal and diversion supplies based on application of Albuquerque Basin hydrogeologic model.

- Northern Sangre de Cristo Mountains, New Mexico: Evaluation of water resource and administrative status of water rights on extensive ranch lands.

- Doña Ana County, New Mexico: Specification and hydrologic supervision of drilling 1,000-gpm capacity public supply well for regional water system. Hydrologic support for water-rights transfer to wells.

- Animas River, New Mexico: Hydrologic evidence on effects of an application to appropriate 30,000 AFY of surface water for municipal use.

- Farmington, New Mexico: Aerial photographic interpretation and quantification of historical use of water for irrigation on County fairgrounds properties. Presentation of testimony.

- Rio Rancho, New Mexico: Hydrologic effects on surface water and groundwater of microchip manufacturing plant wellfield in Rio Grande basin-fill aquifer. Presentation of testimony.

- Santa Fe County, New Mexico: Ranch well and water-right review of resource and administrative status of lands west of City of Santa Fe.

- Seboyeta, New Mexico: Inspection and plan for watershed management in extensive ranch lands in Rio Puerco basin for control of erosion and restoration of perennial baseflow.

- Las Cruces, New Mexico: Numerical model calculation of University wellfield capacity for 40 and 100-year term, and identification of sources of water, capture zone delineation, and water-quality projections.

- Manzano Mountains, New Mexico: Subdivision water availability and effect on prior water wells.

- Tularosa Basin, New Mexico: Ranch water inventory with geologic, well history, aerial photograph interpretation, irrigated acreage delineation, and conclusions on administrative standing of water rights.

- Gila River Basin, Arizona: Hydrologic evaluation of Federal Court findings on interrelationship of groundwater and surface water under Arizona and Federal law.

- Changkeng, China: Hydrologic assessment of a planned open-pit gold mine in karst geology on tributary of river Xi. Analyze available data on groundwater and surface water resources, including borehole, pump test, spring flow, precipitation and gaging data. Assess feasibility of dewatering operations and prepared preliminary cost estimates.

- Cañada Ancha, Santa Fe County, New Mexico: Field testing and model evaluation of the hydraulic connection between the Rio Grande and a shallow alluvial aquifer.

- Santa Fe, New Mexico: Development of a water-supply plan for western Santa Fe County for use in County-wide development.

- Galisteo Creek, New Mexico: Evaluation of water availability and hydrologic effects of a proposed residential subdivision. Ensure regulatory compliance with County land development code regarding development water supplies.

- Carlin Trend, Nevada: Development of a numerical model (MODFLOW) for evaluation of an open-pit mine dewatering project. Analysis of extensive pump test, monitoring well and streamflow data for hydrogeologic site characterization and model calibration.

- Albuquerque, New Mexico: Investigation and declaration with the State Engineer Office of the historic water rights associated with a 45-acre school parcel in urban area.

- Albuquerque, New Mexico: Hydrologic investigation and characterization of the origin and extent of saturated soils at a residential subdivision.

- Lake DeSmet, Wyoming: Advisory services in preparation for litigation on the hydrologic effect of a change in reservoir stage on coal reserves, the efficacy of a slurry trench for protection of coal reserves, the delineation of wetlands, and the water quality of a reclaimed coal mine site.

- Crownpoint, New Mexico: Analysis of hydrologic and water-quality effects of a proposed in-situ uranium solution mining project in response to a Draft Environmental Impact Statement. Evaluate restorability of aquifer, excursion control, exemption from Underground Injection Control standards and brine disposal alternatives.

- Morenci, Arizona: Yield analysis for wellfield in tributary of Gila basin for use in mine and mill water supply.

- Cajamarca, Peru: Mine hydrology study for feasibility reports involving dewatering, water supply and hydrologic effects.

- Kelley Creek Basin, Nevada: Review and commentary on three-dimensional groundwater flow model focusing on water-balance for the pre-mining basin for water-rights purposes.

- Battle Mountain, Nevada: Assessment of hydrologic effects of mine development in the Shoshone Range, including geothermal response at Beowawe area.

- Albuquerque, New Mexico: Field tests and water-balance study to determine the source of water in soils in a residential subdivision involving an inverted water table.

- Maggie Creek Basin, Nevada: Evaluate hydrologic effects of mine dewatering on fisheries resources of Tuscarora Mountains.

- Kilkenny, Ireland: Evaluate dewatering requirements and hydrologic effects, including those on fisheries, of dewatering an underground mine.

- Albuquerque, New Mexico, South Valley: Hydrology effect of 100,000 acre-foot superfund remediation system. Assess depletion of Rio Grande and conservation of stored aquifer resource.

- Animas River, New Mexico and Colorado: Yield analysis of surface-water system and downstream-depletion impacts on existing water users due to operation of Animas-La Plata Project.

- State of Mississippi: Water-planning advisor to State legislative task force on groundwater plan for Mississippi.

- Taos Plateau, New Mexico: Preparation of basin-wide groundwater development plan and three-dimensional groundwater flow model of regional aquifer system.

- Colfax County, New Mexico: Regional water plan, groundwater inventory and impacts of 40-year demands.

- Baton Rouge, Louisiana: Yield analysis and wellfield design for aquifers at industrial site requiring 40 million gallons per day.

- Boulder Valley, Nevada: Reservoir seepage investigation for 500-acre surface storage reservoir.

- Grant, Luna, Hidalgo and Catron Counties, New Mexico: Regional water plan for four counties in southwestern New Mexico.

- Carlin Trend, Nevada: EIS hydrology report for mine-dewatering impacts at Carlin.

- Sarasota, Florida: Simulation of agricultural wellfield effect on municipal wells with salt-water transport impacts.

- Cochiti Dam, New Mexico: Development of dewatering plan and three-dimensional surface- and groundwater flow model to correct waterlogged lands below Cochiti Dam.

- Elko, Carlin Trend, Nevada: Preparation of mine-dewatering model for use in mine planning in north-central Nevada.

- Jemez River, New Mexico: Preparation of a three-dimensional model to display the effects of development of wellfields in the Jemez River alluvium in terms of aquifer drawdown and surface-water depletion.

- Santa Fe, New Mexico: Simulation of effects of new withdrawals of groundwater in Santa Fe Group aquifers at the municipal wells.

- Grants, New Mexico: Aquifer and stream simulation three-dimensional model of the Rio San Jose, New Mexico.

- Jemez Mountains, Baca Location, New Mexico: Study of geothermal hydrology, ion-balance and potential flow depletion at the Jemez Mountains, New Mexico.

- Grants, New Mexico: Quantitative studies of hydrological impacts of development of the Rio San Jose, New Mexico.

- Roswell Basin, Otero County, New Mexico: Preparation of three-dimensional digital model of flow systems in Permian rocks of the Pecos River Basin.

- Santa Fe County, New Mexico: Review and parameter specification for U.S. Geological Survey three-dimensional model of groundwater flow in Rio Pojoaque Basin, a tributary of the Rio Grande.

- Sanaa and Taiz, Yemen Arab Republic: Field review of Sanaa, Yemen wellfield for World Bank. Site selection and feasibility tests for aquifers for municipal supply near Taiz, Yemen for U.S. Agency for International Development.

- Ft. McMurray, Alberta, Canada: Design and supervision of depressurization for Athabaska tar sand open-pit mine. Parameter estimation and geotechnical review of three-dimensional digital model of gas-driven aquifer.

- Perth, Western Australia: Quantitative flow system studies of coastal aquifers of the Perth Basin, including feasibility studies for a 20-MGD (91,000 meters^3/day) municipal wellfield.

- Pilbara District, Western Australia: A regional inventory of groundwater in the West Australian Hammersley-Pilbara Iron Ore Province.

- Northeastern Province, Republic of Kenya: Resource surveys for the Water Development Division of the Government of Kenya.

PROJECT EXPERIENCE IN WATER QUALITY:

- Santa Fe County, New Mexico: Hydrologic evaluation of an application for landfill permit.

- Choloma, Honduras: Assessment of hydrologic and water-quality impact of regional wellfield water-supply development.

- Seboyeta, New Mexico: Uranium mine tailings hydrologic characterization and management plan. Field work, data interpretation, and modeling of groundwater conditions and migration.

- Santa Fe County, New Mexico: Subdivision report on projected 100-year effects of septic tank effluent on groundwater and wells.

- Rio Grande, Rio Arriba County, New Mexico: Development and hydrologic support for water-quality standards on water of Indian Tribe treated as a State under Clean Water Act.

- Las Cruces, New Mexico: Numerical model calculation of University wellfield yield-capacity for 40 to 100-year term, and identification of sources of water, capture zone delineation, and water-quality projections.

- Albuquerque Airport: Assessment of sources of volatile organic contamination of commercial property west of airport.

- Albuquerque South Valley: Field sampling for toxic soils at site of demolition of chemical storage facilities.

- Seboyeta, New Mexico: Review of dewatering and water quality control studies of a closed uranium mill tailings pile. Assess tailings hydraulics and water balance and drainage and pumping systems. Evaluated groundwater quality to determine impact from tailings water. Review interpretation of data from field testing characterization program (test borings, laboratory analysis, pump testing, and cone penetrometer testing). Examine alternatives to enhance drainage. Assist with regulatory representation with the New Mexico Environment Department, the New Mexico State Engineer Office and the U.S. Nuclear Regulatory Agency.

- Crownpoint, New Mexico: Analysis of potential hydrologic and water-quality effects of a proposed in-situ uranium solution mining project for use in response to a Draft Environmental Impact Statement. Evaluate restorability of aquifer, excursion control, exemption from Underground Injection Control standards and brine disposal alternatives.

- Albuquerque, New Mexico: Investigate the groundwater hydrology of a light industrial site. Performed site inspection, review of historical references and analyzed historic gradients. Review State regulatory agency files to determine the potential for nearby contaminated groundwater to impact the subject site.

- Albuquerque, New Mexico: Site inspection and regulatory review of a site investigated by the New Mexico Environment Department for potential inclusion to the National Priorities List of Superfund.

- Albuquerque, New Mexico: Investigate the potential contamination impacts of a closed municipal solid waste landfill on a nearby planned water-supply well.

- Rio Grande, New Mexico: Develop water-quality standards for a reach of the Rio Grande and adjacent surface-water bodies in north-central New Mexico. Evaluate upstream water quality and hydraulic data and effects on Clean Water Act jurisdictional waters. Perform analyses of the scientific basis of specific criteria and resulting effects on upstream permitted discharges.

- Albuquerque South Valley, New Mexico: Identify flow-pattern in groundwater at industrial site to indicate offsite sources of potential contamination.

- Albuquerque South Valley, New Mexico: Compile historical land- and water-use information and evaluate use of environmental tracers for active Superfund site.

- Albuquerque Downtown site, New Mexico: Advise on Hazardous Ranking System status of site proposed for listing.

- Rio Grande, New Mexico: Assess impacts on water-quality standards from City of Albuquerque water treatment plant discharges including arsenic effects on fish consumption.

- Rio Grande Valley, New Mexico: Evaluate the timing and extent of contamination in soil and water from an underground storage tank site. Testimony presented in U.S. District Court.

- Rio Grande, New Mexico: Development of Water Quality Standards for reaches of the Rio Grande on three Pueblos treated as States under the Clean Water Act.

- State of Mississippi: Water-planning advisor to State legislative task force on groundwater plan for Mississippi.

- Colfax County, New Mexico: Regional water plan, groundwater inventory and impacts of 40-year demands.

- Grant, Luna, Hidalgo and Catron Counties, New Mexico: Regional water plan for four counties in southwestern New Mexico.

- Carlin Trend, Nevada: EIS hydrology report for mine-dewatering impacts at Carlin.

- Sarasota, Florida: Simulation of agricultural wellfield effect on municipal wells with salt-water transport impacts.

- Jemez Mountains, Baca Location, New Mexico: Study of geothermal hydrology, ion-balance and potential flow depletion at the Jemez Mountains, New Mexico.

- El Paso, Texas: Hydrologic assessment of soil and groundwater contamination conditions at a casting-foundry site in the Rio Grande Valley.

- Albuquerque, New Mexico: Hydrologic investigation and remediation design and operation for UST site.

- Corrales, New Mexico: Hydrologic investigation and remediation design and operation for UST site.

- Tatum, New Mexico: Hydrologic investigation and UST site characterization on behalf of the State of New Mexico.

- Barelas, New Mexico: Hydrologic investigation and UST site characterization on behalf of the State of New Mexico.

- Albuquerque, New Mexico: Investigation of 1,500-gallon tanker spill on I-25 and associated contamination.

- Taos, New Mexico: Nitrate contamination source and mitigation study for municipal effluent and sludge in the Rio Pueblo de Taos, a tributary of the Rio Grande.

- Acoma, New Mexico: Water-quality impacts of municipal sewage effluent transported via groundwater to springs in Rio San Jose, New Mexico.

- Laguna, New Mexico: Environmental assessment of groundwater levels and water quality associated with reclamation of the Jackpile open-pit uranium mine.

- Woodbridge, Connecticut: Landfill leachate ion-balance studies for Connecticut Department of Environmental Protection.

EXPERT TESTIMONY:

NM State Engineer Office (August 4, 1995) - on the aerial photograph interpretation of historical use of water on San Juan County Fairgrounds property.

NM State Engineer Office (April, 19, 1994) - on the hydrologic effects of an application to appropriate groundwater for Intel microchip manufacturing at Rio Rancho, New Mexico.

U.S. District Court for New Mexico (February 16, 1993) - on the hydrologic characteristics of the Tesuque Formation, basin yield, water balance, and water quality (NM v. Aamodt).

U.S. District Court for New Mexico (June 1-4, 1992) - on the timing and characteristics of a gasoline release at a site in the middle Rio Grande valley (Ever Ready v. Ranger, et al.).

NM State Engineer Office (December 13, 1991) - on an application to transfer water rights to Mountain Ranch Subdivision in the Sandia Underground Water Basin.

NM District Court for Taos County (February 6, 1990) - on the water-quality impacts of municipal sewage effluent and sludge disposal in a case for condemnation of property.

FL Division of Administrative Hearings (August 25, 1989) - on an application to the Southwest Florida Water Management District for an agricultural consumptive use permit and the effects on a City of Sarasota wellfield.

NM State Engineer Office (August 4, 1987) - on an application to change points of diversion and to enlarge the place of use of water from wells at La Madera, New Mexico.

NM State Engineer Office (June 23-24, 1987) - on an application to combine and commingle wells in Bluewater Basin.

NM State Engineer Office (April 14, 1987) - on an application to appropriate groundwater for public supply in Magic Valley, Bernalillo County, New Mexico.

NM State Engineer Office (December 10, 1986) - on an application to commingle and combine wells in Bluewater Basin.

NM State Engineer Office (August 20, 1986) - on an application for transfer of water rights to wells in Canon Alegré, Sandoval County, New Mexico.

NM State Engineer Office (June 18, 1986) - on an application for enlarged place of use of wells under RG-26816 for La Madera Water Users Association.

NM District Court for Cibola County (January 13-14, 1986) - appeal of State Engineer decisions, presented assessment of effects using applicant's three-dimensional computer model of Bluewater Basin.

NM Environmental Improvement Division (August 20, 1985) - on the effects of City of Grants sewage sludge Discharge Plan DP-60.

NM State Engineer Office (March 21, 1984; October 30, 1984; December 4, 1984; February 5, 1985; May 1, 1985; and November 21, 1985) - a series of hearings on permits to transfer groundwater to Plains Electric Escalanté Generating Station.

NM State Engineer Office (January 26, 1983) - on the permit and plan of replacement for Plains Electric Escalanté Generating Station.

U.S. District Court for New Mexico (January 28, 1981) - aquifer tests and hydrologic simulation of a groundwater development plan for four Pojoaque River Pueblos in NM v. Aamodt.

NM Public Service Commission (October 2, 1980) - hydrologic constraints on development and longevity of Public Service Company of New Mexico's Baca Unit 1 Geothermal project.

NM State Engineer Office (April 11, 1980) - on the groundwater permit for Union Geothermal Company's Baca Project.

NM Water Quality Control Commission (February 7, 1980 and December 3, 1981) - on the reclassification of designated uses and stream standards for the Rio San Jose.

NM Environmental Improvement Division (January 14-15, 1980) - regarding Bokum Mar Mine Ground Water Discharge Application.