State of Nevada Briefing to the Nuclear Waste Technical Review Board (NWTRB)

Subject: Vadose (Unsaturated) Zone Hydrologic Concerns of the Proposed Nuclear Waste Repository, Yucca Mountain, Nevada

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Vadose (Unsaturated) Zone Hydrogeology at Yucca Mountain

General Concerns

- The DOE site-selection and investigative program to date has been based on unconservative assumptions with respect to the vadose zone.
- Vadose-zone hydrology remains essentially unknown. The database released by DOE is extremely sparse, and does not establish hydrologic processes at the site.
- The vadose zone is highly fractured from the uppermost welded tuffs to the water table. This promotes rapid vertical travel times for liquid and gas phase fluids.
- Vadose-zone hydrology at the site is probably extremely complex and can not be confidently characterized in the absence of site-specific data.
- To date, the DOE has not demonstrated data collection techniques suitable for confidently characterizing the hydrology of the vadose zone at the site.
- Moisture available for recharge occurs at the site, but it is not equally distributed in time or space. Confident recharge estimates can not be established at the Yucca Mountain site with the existing database and available methods.

SPECIFIC FIELD DATA COLLECTION CONCERNS

- Normal drilling and coring techniques introduce water-based drilling fluids which mask vadose-zone saturation and fracture flow.
- The DOE program has not demonstrated to date drilling methods capable of establishing reliable hydrologic process data throughout the entire vadose zone.
- There is no database or demonstrated methods that allows for confident estimation of the recharge rate on a Yucca Mountain site-specific basis.
- There has been essentially no release of water chemistry or isotopic data from either rock-matrix water or free water in the vadose zone that has been encountered in the drilling programs.
- There are some indications that former drilling and pump-testing programs have significantly disturbed the natural vadose system by adding large amounts of water or water-based drilling fluid to the vadose zone.

Database with Respect to Fracture Flow

- Core data indicates each stratigraphic unit is highly fractured in the vadose zone.
- There is evidence of active soil-gas circulation within the vadose zone at Yucca Mountain. Blowing wells on a seasonal basis indicate high degrees of fracture network continuity with large volumes of fracture porosity at depth and very rapid transport times of soil air.
- Hydraulic conductivity data from core indicate variable but very small hydraulic conductivities for the rock matrix of welded volcanic tuffs, and much larger hydraulic conductivities for the bedded tuffs.
- Moisture content of core samples suggests fracture flow.
- Saturation encountered in drilling suggests perched water and fracture flow.

Database with Respect to Recharge

- The climate is characterized by infrequent short term precipitation events, some of high intensities. These events concentrate moisture in time and space for recharge.
- Methods for establishing confident site specific recharge estimates at Yucca Mountain have not been developed.
- There is evidence that important recharge takes place along the ephemeral drainages and occurs by fracture flow.

Properties of Hydrogeologic Units Within the Unsaturated Zone*

Yucca Mountain, Nevada

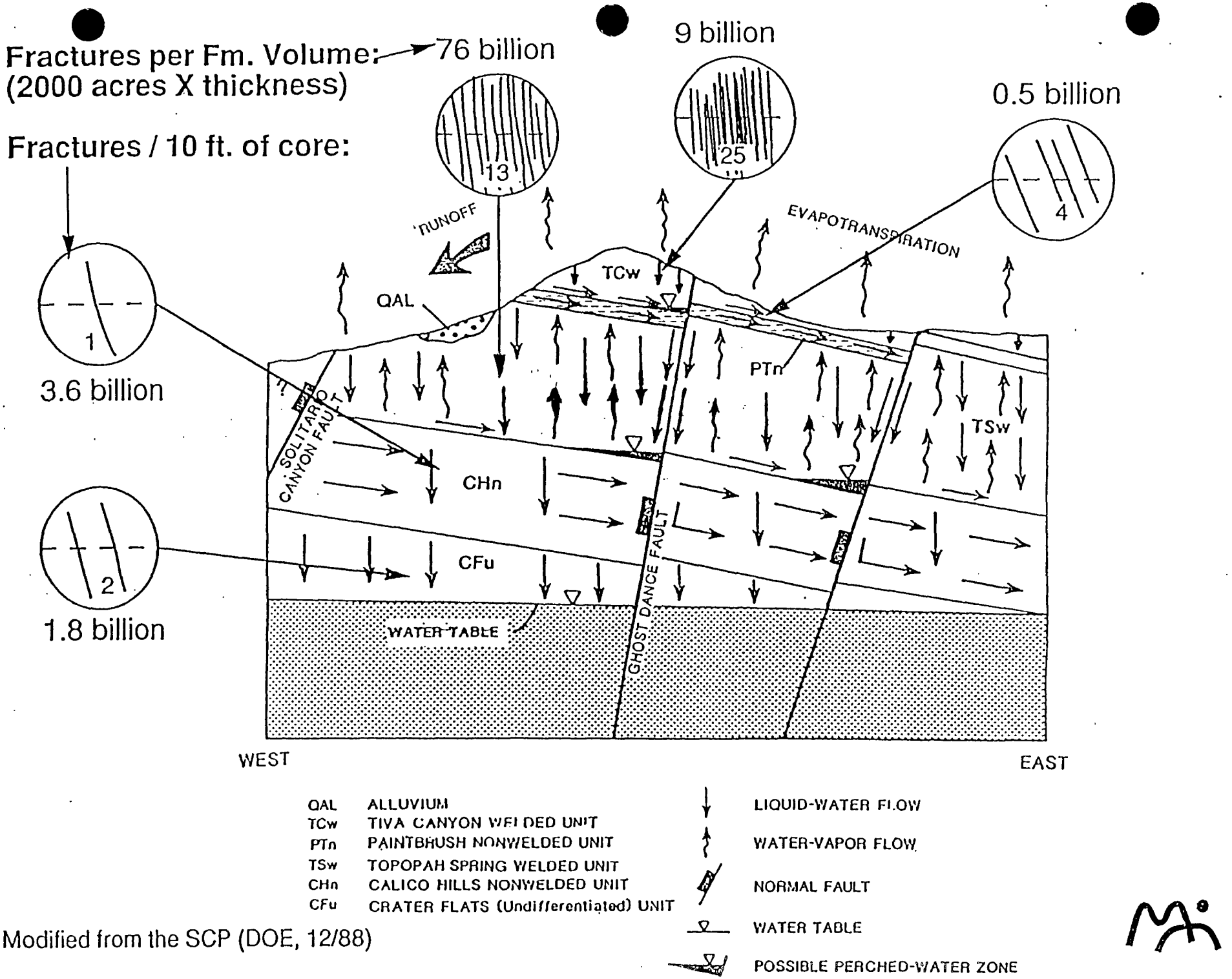
Hydrogeologic Unit	Thickness Range, m	Porosity	Saturated Hydraulic Conductivity mm/yr	Saturation (percent)
Tiva Canyon welded	0 - 150	0.12	0.73	67
Paintbrush nonwelded	20 - 100	0.46	3285	61
Topopah Spring welded	290 - 360	0.14	1.10	65
Calico Hills nonwelded (vitric)	100 - 400	0.37	1460	90
Calico Hills nonwelded (zeolitic)		0.31	2.92	91
Crater Flat unit (undifferentiated)	0 - 200	0.23	18.25	88

*Table 1 of P. Montazer & W.E. Wilson, 1984, USGS, WRIR84-4345.

APPARENT FLOW REGIMENS WITH ASSUMED STEADY RECHARGE RATES

Hydrogeologic Unit	Saturated Hydraulic Conductivity mm/yr.	Assumed Steady Recharge Rate mm/yr. matrix flow (M) fracture flow (F)			
		0.5	1.0	5.0	10.0
Tiva Canyon, welded	0.31 [c] 0.73 [b] 1.0 [a]	M/F	M/F	F	F
Paintbrush, nonwelded	109 [b] 3,300 [a] 12,300 [c]	M	M	M	M
Topopah Spring, welded	0.05 [c] 0.06 [b] 0.70 [a]	M/F	F	F	F
Calico Hills, nonwelded (vitric)	55 [b] 85 [c] 107 [a]	M	M	M	M
Calico Hills, nonwelded (zeolitic)	0.01 [b] 0.50 [a] 0.63 [c]	M/F	F	F	F
Crater Flat unit (Undifferentiated)	18.25 [b] 22.0 [a] 88.0 [a]	M	M	M	M

DATA SOURCES:
[a] Environmental Assessment, 1986, DOE/RW-0073.
[b] USGS, WRIR84-4345, 1984.
[c] SAND 84-1471, 1984.



Modified from the SCP (DOE, 12/88)

SUMMARY

- Fracture flow or perched water (local saturation) is likely to occur at any zone where the vertical water flux is greater than the saturated hydraulic conductivity of the rock matrix.
- Fracture flow indicates very rapid travel times within the vadose zone measured in months, years, or tens of years.
- The physics of vadose flow processes, involving both vapor and liquid flow in nonisothermal environments, are too complex to model in a fractured and porous rock environment. Only abundant site-specific data can establish site-specific processes.

Conclusions

- The arid climate does not ensure waste isolation.
- Vadose-zone hydrology at Yucca Mountain is highly complex, but little documented or understood.
- Fracture flow occurs and could be a common process.
- Soil-air travel time in the vadose zone is rapid to the accessible environment (land surface).
- Travel time to the underlying saturated zone could also be rapid with fracture flow.
- An abundant site specific database of appropriate parameters is necessary within the repository block.

REFERENCES

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YANG, I. C., et al., 1988, Triaxial-compression extraction of pore water from unsaturated tuff, Yucca Mountain, Nevada; U. S. Geological Survey, Water-Resources Investigations Report 88-4189.

VITAE

MARTIN D. MIFFLIN

EDUCATION:

Ph.D., 1968, University of Nevada, in Hydrogeology.
M.S., 1963, Montana State University, in Applied Science.
B.S., 1960, University of Washington, in Geology.
Washington State University, Eastern Washington.

PROFESSIONAL EXPERIENCE:

President and Senior Hydrogeologist of Mifflin & Associates, Inc., a consulting firm which conducts hydrogeologic and geologic investigations, July, 1986 to Present.

Research Professor, Water Resources Center, Desert Research Institute, University of Nevada System. Research in ground-water problems in arid-zone hydrology. Specific areas of activity: carbonate-rock hydrology, ground-water exploration and development, exploratory-drilling techniques, vadose-zone moisture conditions, and recharge in arid terrane. During this period of time, major ground-water exploration and development programs were established for the State of Nevada (Jean Prison water supply, Valley of Fire State Park), the U.S. Air Force (Tonopah Test Range, Tolicha Peak), and Nevada Power Company (Meadow Valley Well Field development, monitoring, and modeling; carbonate-rock ground-water exploration program near Moapa). Program Director of the Yucca Mountain Candidate High-Level Nuclear Waste Repository technical support program for the State of Nevada (1983-1986), Sept., 1977 to July, 1986.

Senior Hydrogeologist, UNDP, Chile. Leave of absence from the Desert Research Institute for service in Region 4, Chile United Nations Development Program (UNDP) project. Water-resource assessment project in semi-arid region of Chile, chief resident administrative responsibility for the UNDP of the project, March, 1978 to March, 1979.

Water Resources Center Associate Director and Research Professor, Desert Research Institute, Las Vegas, Nevada. Head administrator for the Water Resources Center of the Desert Research Institute in the Las Vegas branch office. General responsibilities included research funding, direction, and execution of program of the Water Resource Center in Southern Nevada. Areas of research interest during this period included land subsidence caused by fluid withdrawals and associated earth fissures and faults in Las Vegas Valley and Mexico, deep carbonate-rock aquifers in Nevada as a potential water-supply alternative for Eastern and Southern Nevada, and waste-water treatment by natural marsh systems in Las Vegas Valley. Expert testimony on the Cross Florida Barge Canal ground-water hydrology was given to the State of Florida Bureau of Planning and Florida Cabinet in July, 1976; as well as serving on the board of review for the Water Element of the State Plan of Florida from 1976 to 1977. Periodic consulting 1975, 1976, 1977 for the Comision del Plan Nacional Hidraulico, in the area of ground-water policy and executed programs of resource evaluation and advanced training of personnel, July, 1975 to Sept., 1977.

Resident Consultor, International Bank for Reconstruction and Development (World Bank). Leave of Absence from the University of Florida in order to accept an 18-month position as World Bank Resident Consultor in ground water to the Plan Nacional Hidraulico (PNH), a newly-created planning organization within the Mexican government. Held additional position of Jefe de Aguas Subterraneas (chief in charge of ground-water planning and associated investigations within PNH). Responsibilities involved training and development of professional staff, development of procedures and policy, and direction of ground-water studies designed for both short and long-term planning of ground-water exploitation and management. PNH was a joint effort by the United Nations Development Programs (UNDP) and the Mexican Government. The effort of the UNDP was executed by the World Bank (International Bank for Reconstruction and

Development) and the procedure was to supply five resident consultors who were expert in various disciplines in water-resource planning and development. I was also appointed to a Mexican government management role, and maintained the Bank title. Subsequently, the experimental program was judged successful by the UNDP, World Bank, and the Mexican Government formalized the organization into the continuing national planning agency for water-resource development in Mexico (Comision del Plan Nacional Hidraulico, ASRH), Sept., 1973 to July, 1975.

Associate Professor Geology, University of Florida. Teaching responsibilities in the following courses: Physical Geology, Introductory Geosciences, Geomorphology, Structural Geology, Ground-Water Geology and Hydrogeology. Research was more or less limited to local problems of ground-water pollution and continued work (summers of 1970, 1972) on isostatic rebound in the Lahontan Basin of the Great Basin. Member of the University of Florida Graduate Faculty, served on graduate committees (M.S. and Ph.D.) for Geology, Environmental Engineering, Coastal Engineering, and Civil Engineering graduate students. Considerable involvement in ground-water pollution aspects of the Cross Florida Barge Canal controversy, with testimony given to Florida Legislative committees, the State of Florida Cabinet, and the U. S. Presidential Council on Environmental Quality. Principal expert witness in ground water for EDF and the Department of Interior in court proceedings (U.S. Government vs. Florida Canal Authority) in August, 1973, Sept., 1969 to July, 1975.

Research Associate, Desert Research Institute and Nevada Center for Water Resources Research. Activities primarily research in ground water and hydrogeology. Principal Investigator or co-investigator in research dealing with the following: hydrologic safety, AEC underground nuclear detonation; investigation of land subsidence in Las Vegas Valley and the development of the theory of mechanics; investigation of the hydrogeology of Las Vegas Valley for feasibility of artificial recharge; delineation of ground-water flow systems using studies of fluid potential, water chemistry, isotopes, and other methods: paleohydrologic investigations in Nevada (surface and ground water); stratigraphic studies of alluvial basins; documentation of mudlump formation and hydrologic relationships causing formation, and developing a theory for mechanics of formation; investigations of carbonate-terrain hydrology in Nevada using tritium and hydrogeochemical techniques; exploration and development of ground water in a number of arid areas for federal, state, and private agencies; investigation of techniques for delineation of ground-water flow systems. Other activities included guest and substitute lecturing in ground water, hydrogeology, and physical geology, and direction of graduate student research in the Great Basin on hydrologic problems, July, 1963 to Sept., 1969.

Graduate Research Assistant, Montana State University (the Montana State University experience consisted of 1/2-time teaching of geology laboratories and two winters of snow avalanche research), Sept., 1962 to June, 1963.

Geologist, GS-7, U.S. Geological Survey, field mapping in the Lemhi Range and Beaverhead Range, Idaho and Montana, May, 1962 to Sept., 1962.

Graduate Teaching Assistant, Montana State University, Sept., 1960 to June, 1962.

Apprentice Geologist, Pan Petroleum Corp., Field-reconnaissance mapping in Western Alaska, April, 1959 to Aug., 1959.

PROFESSIONAL AFFILIATIONS

Geological Society of America
National Water Well Association
Sigma Xi

PROFESSIONAL HONORS AND OTHER PROFESSIONAL ACTIVITIES:

DRASTIC Advisory Board Member, National Water Well Assoc., 1986-1987

Invited Speaker, 15th Annual Rocky Mountain Groundwater Conference on Today's Groundwater Issues, Phoenix, Arizona, Sept. 1986, "Total Basin Concept - Groundwater Flow Systems"

Invited Speaker, International Workshop on Regional Aquifers, Sponsored by the Institute of

Geophysics, UNAM, Mexico City, Feb., 1985, "Hydrogeology of regional systems in the Great Basin"

Co-Leader, Field trip, White River Hydrological (Karst) System, S.E. Nevada, 6th Conference on Karst Hydrogeology and Speleology (Friends of the Karst), Sept. 1979

Moderator, Water Supply Planning Session, AWRA Conference "Water Resource Management in a Changing Society," Sept., 1979, Las Vegas

Geological Society of America Meinzer Award Committee, term 1977-1980

Elected to DRI Faculty Senate, 1975-1978

Moderator, Special Session on Ground-Water Quality, Las Vegas Valley, NWWA Tech. Meeting, Las Vegas, 1976

Selected as resident international consultant in the field of ground water to the Mexican Government by the World Bank and UNDP, 1973-1975

Trustee: Florida Defenders of the Environment (1970-1977) FDE Scientific Committee Co-Chairman (1971-1974)

Appointed Chairman, Environmental Impact Committee City of Gainesville-Alachua Co. joint committee (Jan. 1973; resigned Aug., 1973)

Elected Foundation Advisory Member, Environmental Information Center, Florida Conservation Foundation, Inc., 1972

Elected member University of Florida Presidential Faculty Concerns Committee, 1971

Appointed member of University of Florida Ad Hoc Com. on Environmental Programs, 1971

Designated Program Moderator (1970 Nat. GSA Evening Discussion of Hydrology Section)

Member of the U.S. delegation to the Inter. Assoc. of Sci. Hydrol., Symposium Hydrology of Deltas, Bucharest, Rumania, 1969

Granted first sabbatical leave offered to DRI faculty, 1969

Elected to DRI Faculty Organization, 1968 to 1969

Program Chairman, Sigma Xi Luncheon Lecture Series at University of Nevada, 1965 to 1966

Co-Author of scientific paper nominated for the G.S.A. Meinzer Award, 1965

NSF Basin and Range Field Conference Co-leader, 1965

INQUA Great Basin Field Conference Co-leader, 1965

Sigma Xi (Nominated at Montana State University for M.S. thesis).

CONSULTING EXPERIENCE:

Consultant to the U.S. Nuclear Regulatory Commission on Yucca Mountain, Nevada, 1982 to 1984.

Consultant to Government of Ecuador, ground-water development for irrigation, Rio Guayas Basin, 1982 to 1983.

Consultant to USAID, University of Wisconsin, and OTDC, Government of Tunisia, on design and feasibility of potable water development for dispersed populations in Central Tunisia, Feb.-Mar., 1980.

Consultant for the organization, and participant in "Seminar on Development and Rational Management of Groundwater of the Yucatan Peninsula" sponsored by the Banco de Mexico, S.A., Dec. 3-7, 1979, Merida, Yucatan, Mexico, 1979.

Consultant to Mexico, reviewer of all ground-water studies by CPNH 1973-77, Comision del Plan Nacional Hidraulico, ASRH, July 1977. State of Florida, Div. of State Planning, Water Element of State Comprehensive Plan, Panel of Experts, review of water element, 1977.

State of Florida, Dept. of Planning: testimony to the Florida Cabinet on hydrologic impacts of Cross Florida Barge Canal, June, 1976.

Ground-water consultant to Arthur D. Little, Inc. on bi-national water-resource development project for Colombia and Venezuela. Consultant to Mexico, organization of PNH-sponsored symposium entitled "La Soreexplotacion de Agua Subterranea en Algunas Partes del Mundo," Mexico City, Dec., 1975.

Nevada and California (1969-1973): runoff/erosion studies with respect to timbering activities in the Sierra Nevada (1972, major lumber company). Florida: lake dewatering hydrogeological studies for Lake Apopka (1970, Citrus Growers). Numerous

hydrogeological studies for land developers as senior hydrologic consultant for the firms Eco Impact, Inc. and Environmental Science Engineering, Inc. (1972-73). Solid-waste disposal and site suitability for Alachua County (1972). Three landfill sites located, evaluated, and subsequently adopted by the County. Landfill monitoring, Alachua County (1972-73). OffShore Nuclear Power Plant site evaluation - aspects of tectonic history and seismic hazards (major engineering firm, 1973).

Nevada and California (1963-1969): ground-water exploration and water supply development in arid terrain for U.S. Fish and Wildlife Service, Nevada State Parks, and several development and mining firms; ground-water supply and contamination studies, U.S. Gypsum.

PUBLICATIONS AND REPORTS:

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Mifflin, M. D., A. Elzeftawy, S. W. Wheatcraft, and J. W. Hess, 1982, Henderson, Nevada rapid infiltration basin siting and monitoring study: WRC-DRI Project Report, 100 p.

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Elzeftawy, A. and M. D. Mifflin, 1982, Soil sample analyses from borings of the RIB site for the City of Henderson: WRC-DRI Letter Report to URS/City of Henderson, 8 p.

Mifflin, M. D., 1982, Exploration and development of a ground-water supply for the southern Nevada Correctional Center, Jean, Nevada: WRC-DRI, 43 p. and Appendices.

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Mifflin, M. D., 1967, Formation of mudlumps in Pyramid Lake, Nevada: Geol. Soc. Am., Program 1967 Annual Meeting, p. 149-150 (Abst.).

Mifflin, M. D., 1967, Strange things are rising in Pyramid Lake, Nevada: State Journal, Science in Nevada, July 2, 1967 Issue.

Maxey, G. B., M. D. Mifflin, P. A. Domenico, and A. McLane, 1966, Geology and water resources of Red Rock Ranch: Mim. Rept. to the Red Rock Ranch Stockholders, 48 p., 2 maps.

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Morrison, R. B., M. D. Mifflin, and M. Wheat, 1965, Rye Patch Dam Pleistocene stratigraphy: INQUA VII Congress, Northern Great Basin and California Guidebook, p. 28-33.

Morrison, R. B., M. D. Mifflin, and M. Wheat, 1965, Pleistocene stratigraphy at the Badland Amphitheater on the Truckee River north of Wadsworth: INQUA VII Congress, Northern Great Basin and California Guidebook, p. 38-43.

Domenico, P. A. and M. D. Mifflin, 1965, Water from low-permeability sediments and land subsidence: Am. Geophy. Union, Water Resources Research, vol. 1, no. 4, p 563-576.

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Mifflin, M. D., G. B. Maxey, P. A. Domenico, D. A. Stephenson, and J. R. Hardaway, 1964, Hydrological investigations of the Sand Springs Range, Fairview Valley and Fourmile Flat, Churchill County, Nevada: VELA UNIFORM, Project SHOAL, AEC Report VUF-1001, p. 239-364.

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Mifflin, M. D., 1963, Preliminary report on the ground-water possibilities in the Valley of Fire State Park, Nevada: Desert Research Institute Letter Report of Sept. 19, 1963, to Dean L. Kastens, Director of the Nevada State Park Service, 6 p.

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Mifflin, M. D. and G. B. Maxey, 1963, Preliminary report of the geology and hydrology of the Settlemeyer Site, Carson Valley, Nevada: Desert Research Institute Mim. Rept. to Bureau of Sport Fisheries and Wildlife, U.S. Fish and Wildlife Service, 13 p.

Mifflin, M. D., 1963, Geology of a part of the southern margin of the Gallatin Valley, Southwest Montana: M.S. Thesis, Montana State University, Bozeman, Montana, 111 p.; Program of the 16th Annual Meeting, Geol. Soc. Am., Rocky Mtn. Sect. (Abst).

STUDIES DIRECTED AND/OR COAUTHORED IN MEXICO (In Spanish by Plan Nacional Hidraulico, Secretary of Water Resources, Mexico):

Ground-Water Reconnaissance and Availability, Region Closed Basins, No. Central Mexico, 1976.

Ground-Water Reconnaissance of Region Rio Lerma Basin, Central Mexico,1976.

Ground-Water Reconnaissance and Availability, Region Rio Bravo , 1975.

Ground-Water Reconnaissance and Availability, Region NW Pacific coast, NW Mexico, 1975.

Ground-Water Availability, Exploitation and Policy, National Water Plan of Mexico, in Plan Nacional Hidraulics de Mexico (1974) (1975), 1975.

Ground-Water Reconnaissance and Availability, Region Papaloapan, SE Mexico, 1974.