US Department of Justice

Randolph J. Seiler
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District of South Dakota

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May 29, 2015

United Order of South Dakota
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Rodney Freeman
Prehearing Chair
Water Management Board
P.O. Box 176
Huron, SD 57350

William R. Hansen, Chief
Water Rights Branch
National Park Service
1201 Oak Ridge Drive Ste 250
Ft. Collins, CO 80525

Re: National Park Service v. United Order of South Dakota
Sixth Judicial Circuit Court / Water Permit Application No. 2730-2

Ladies and Gentlemen:

Enclosed is the 1) NPS's Disclosure of Expert, 2) Curriculum Vitae of Jeffrey C. Hughes, 3) Curriculum of Andrew J. Long, PhD, 4) Curriculum of Rod Horrocks, 5) Expert Witness Powerpoint of Jeffrey C. Hughes, 6) Expert Witness Powerpoint of Andrew J. Long, PhD, and 7) Expert Witness Poweroint of Rod Horrocks.

Please consider this as service by mail upon you. Thank you.

Sincerely,

Randolph J. Seiler
Acting United States Attorney

Cheryl A Dupris

Cheryl Schrempp DuPris
Assistant U.S. Attorney

/rla
Enclosures

Cc: Peter Fahmy
Lois Witte

RECEIVED
JUN - 5 2015
WATER RIGHTS
PROGRAM

STATE OF SOUTH DAKOTA
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

WATER MANAGEMENT BOARD

IN THE MATTER OF WATER APPLICATION No. 2730-2, UNITED ORDER OF SOUTH DAKOTA	))))	**National Park Service's Disclosure of Experts**

Pursuant to the Procedural and Scheduling Order dated May 18, 2015, the National Park Service discloses the following names of persons that may testify as expert witnesses at the hearing on the above-captioned matter:

1. Jeffrey C. Hughes, 3221 Honeysuckle Court, Fort Collins, CO 80521

2. Dr. Andrew J. Long, 1608 Mountain View Rd, Rapid City, SD 57702

3. Rodney D. Horrocks, 2201 Wilson Ave. Hot Springs, SD 57747

A copy of each expert's *curricula vitae* and presentation, which will be offered into evidence in the event that the expert testifies at the hearing on the above-captioned matter, is attached.

DATED this 29th day of May, 2015.

RANDOLPH J. SEILER
ACTING US ATTORNEY

Cheryl A DuPris

Cheryl Schrempp DuPris
Assistant United States Attorney
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Cheryl.Dupris@usdoj.gov

CERTIFICATE OF SERVICE

I hereby certify that on this 29th day of May, 2015, a true and correct copy of the foregoing **NPS's Disclosure of Expert, Curriculum Vitaes of Jeffrey C. Hughes, Dr. Andrew Long, and Rodney D. Horrocks, and Expert Witness Powerpoints of Jeffrey C. Hughes, Dr. Andrew J. Long, and Rodney D. Horrocks**, were mailed postage pre-paid in the United States Mail to:

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And on the same date, the original was mailed to Jeanne Goodman, Chief Engineer, DENR Water Rights Program, Joe Foss Building, 523, E. Capitol Avenue, Pierre, SD, 57501.

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Curriculum Vitae

Jeffrey C. Hughes
3221 Honeysuckle Court
Fort Collins, CO 80521

Present position: Hydrologist, National Park Service
Water Resources Division
1201 Oakridge Drive, Suite 250
Fort Collins, CO 80525
(970) 225-3527

Education: B.S. – Watershed Management, Colorado State University (1981)
M.S. – Watershed Sciences, Colorado State University (1983)

Employment:

1988 – Present	Hydrologist, GS 9/11/12, National Park Service Water Resources Division
1986 – 1988	Research Associate, Colorado State University, working for the National Park Service, Water Resources Division
1986	Hydrologist, Resource Consultants, Inc.
1985 –1986	Hydrologist, U.S. Forest Service
1984 – 1985	Research Associate, Resource Consultants, Inc.
1984	Hydrologic Technician, Simons Li, and Associates
1983	Hydrologic Technician, U.S. Forest Service
1981 – 1983	Research Assistant, Colorado State University

Honors: National Park Service Fast Track Award, 1990; Unit Award for Excellence of Service (Water Rights Branch), 1992; Special Achievement Award, 1994; Star Award, 1996; Quality Step Increase, 1999; On-the-Spot Award, 2000; Time Off Award, and On-The-Spot Awards, 2001, Individual Cash Award, 2009; Individual Time-Off Award, 2010; Star Award, 2011; Individual Cash Award, 2014; Individual Time-Off Award 2014

Current Duties: Project Leader for the National Park Service, Water Resources Division, Water Rights Branch. Responsible for evaluating water right applications near NPS units and determining if the proposed

water development will adversely affect NPS water rights and water-dependent resources. File protests and objections when necessary. Also design and conduct studies to determine and protect NPS water rights and water-dependent resources. Oversee contracts and agreements with other private entities and other Federal agencies to perform work for the NPS. Provide water rights technical assistance to parks as needed.

Groundwater-related work:

Since 1994, evaluate water right permit applications to determine if proposed groundwater withdrawals will remove groundwater hydrologically connected to surface water within five NPS units within Montana (Glacier National Park, Yellowstone National Park, Big Hole National Battlefield, Little Bighorn Battlefield National Monument, and Bighorn Canyon National Recreation Area) as required by the Water Rights Compact between the State of Montana and the United States, National Park Service. This Compact also established the Yellowstone Controlled Groundwater Area, which is a designated basin surrounding the park within Montana for the protection of the Yellowstone geothermal system. Represent the NPS, Water Resources Division in meetings with the state of Montana concerning the management of the Controlled Groundwater Area. Also responsible for evaluating applications to appropriate groundwater for potential impacts to Florissant Fossil Beds National Monument, Colorado National Monument, Bent's Old Fort National Historic Site, Wind Cave National Park, and assist other NPS hydrologists on similar evaluations for Zion National Park, Great Basin National Park, and Lake Mead National Recreation Area. File objections when required.

Manage agreements and contracts with federal agencies and private consultants for groundwater-related work to increase our understanding of groundwater flow systems important to NPS units in Nevada, Arizona, Utah and South Dakota. Evaluate claims in the ongoing water rights adjudication in Montana for potential injury to Montana NPS water rights.

Publications:

Hughes, J.C., M.G. Cavendish, and M.D. Flora. 1986. A Summary of Water Quality for the Menard Creek Corridor Unit, Lancer Rosier Unit, and Little Pine Island Bayou Unit of the Big Thicket National Preserve, Texas (1975-1983). Technical Report 86-8. National Park Service, Water Resources Division, Fort Collins, CO. 69 pp.

Hughes, J.C., M.D. Flora and J.C. Woods. 1987. Big Thicket National Preserve: Water Quality Report 1984-1986. Water Resources Report 97-2. National Park Service, Water Resources Division, Fort Collins, CO. 80 pp.

Williams, O.R., J.S. Albright, P.K. Christensen, W.R. Hansen, J.C. Hughes, A.E. Johns, D.J. McGlothlin, C.W. Pettee, and S.L. Ponce. 1996. Water Rights and Devils Hole Pupfish at Death Valley National Monument. **In** Science and Ecosystem Management in the National Parks. W.L. Halvorson and G.E. Davis, editors. University of Arizona Press, Tucson, AZ. 364 pp.

Diaz, G.E., O. Elbadawy, J.C. Hughes and J.D. Salas. 1995. In search of Hydrologic Similarity: A Case Study on Molokai, Hawaii. **In** Proceedings of the Summer Symposium, American Water Resources Association. June 25-28, 1995. Edited by R. Herrmann, W. Black, R.C. Sidle and A.I. Johnson. Honolulu, HI. 496 pp.

Ayers, P.D. and J.C. Hughes. 2010. Underwater video habitat mapping at Obed Wild and Scenic River. Park Science, Vol. 27, No 2. p 24 – 25.

Hughes, J.C., J.R. Duncan, R.R. Knight, B.C. Harrold, and W.J. Wolfe, 2014. Challenges and Opportunities in Protecting the Obed Wild and Scenic River. Presses Universitaires de Bordeaux et LGPA-Editions, Bordeaux, *Dynamiques Environmentales*, 31, pp 67 – 79

Curriculum Vitae

Andrew J. Long, PhD
Research Hydrologist
U.S. Geological Survey
South Dakota Water Science Center (SDWSC)
1608 Mountain View Rd, Rapid City, South Dakota 57702

Office: 605-355-3237
Cell: 605-381-1251
Email: ajlong@usgs.gov
https://profile.usgs.gov/ajlong

Summary

My background includes over 20 years of experience modeling groundwater flow using MODFLOW, as well as developing new models for research. Currently, I am the lead modeler for a USGS groundwater availability study of the Williston and Powder River basins[1] and Project Chief for a regional model of the Madison and Minnelusa aquifers in the Northern Great Plains[2]. My role on many projects is that of team leader, coordinating the work of as many as six hydrologists and student employees. Informally, I mentor several younger hydrologists in my office, advising them in proposal and report writing, funding strategies, and career development.

My research has involved development and computer coding of new mathematical models to better understand and simulate dual-porosity flow and transport in karst aquifers (e.g., RRAWFLOW[3]). Inverse parameter estimation is an important component of all my models, and I have great interest in uncertainty analysis. I collaborate with hydrologists, biologists, and atmospheric scientists in the USGS and several universities, including Colorado State University; University of Texas; University of Rouen, France; and South Dakota School of Mines and Technology (SDSMT). One such interdisciplinary project involves climate-change effects on species that are dependent on karst aquifers[4]. Other research includes the development of groundwater age-dating models, multivariate analysis of hydrochemical data, and heat transport in karst conduits. My data-collection experience includes geophysical methods, hydrochemical sampling, age-dating tracers, dye tracing, aquifer pumping tests, and field electronics. I am an Adjunct Assistant Professor at SDSMT and have served on several graduate advisory committees.

Education

Ph.D., Geological Engineering (hydrology), 2000, South Dakota School of Mines and Technology
M.S., Geological Engineering (hydrology), 1995, South Dakota School of Mines and Technology
B.S, Geological Engineering, 1993, South Dakota School of Mines and Technology

[1] http://wy-mt.water.usgs.gov/projects/WaPR/
[2] http://sd.water.usgs.gov/projects/BHFlowModel/BHFlowModel.html
[3] http://sd.water.usgs.gov/projects/RRAWFLOW/RRAWFLOW.html
[4] https://nccwsc.usgs.gov/display-project/4f8c652fe4b0546c0c397b4a/52d5615ae4b0f19e63da8647

Positions Held

Hydrologist, Rapid City Water Department (1994-1995)
I worked in collaboration with the USGS to simulated groundwater flow in the karstic Madison aquifer using MODFLOW.

Research assistant, South Dakota School of Mines and Technology (SDSMT) (1995–1998)
I developed and wrote the FORTRAN computer code for a three-dimensional groundwater flow model for dual-porosity karst aquifers. Related to this, I collaborated with a team of researchers on the design of a numerical model to simulate surface-water and groundwater flow, dynamically linked to atmospheric processes. Also, I designed and applied a GIS-based analysis to assess karst aquifer vulnerability.

Consultant (1994–1998)
I conducted GIS analysis and groundwater modeling with MODFLOW related to a proposed low-level nuclear-waste site in Boyd County, Nebraska for the Boyd County Monitoring Committee, a consortium of local residents. I consulted for Terra Nitrogen in Sergeant Bluff, Iowa and simulated groundwater flow and transport with MODFLOW, MOC, and GIS analysis to assess the movement of ammonia contamination.

Hydrologist, USGS South Dakota Water Science Center (SDWSC) (Jan 1999 – Oct 2009)
This largely involved numerical modeling of groundwater flow and solute transport, dye tracing experiments in karst aquifers, conducting aquifer tests, geospatial aquifer analyses, and development of new research models.

Adjunct Assistant Professor, SDSMT (Oct 2005 – present)
I have served on the graduate advisory committees for five M.S. students and three Ph.D. students. Seven of these students were employed by the USGS and did their research primarily under my direction as part of their USGS work. I frequently give guest lectures at SDSMT.

Research Hydrologist, USGS SDWSC (Nov 2009 – present)
This includes development of innovative methods to better understand, quantify, and test hypotheses related to groundwater flow and transport in karst aquifers. Groundwater age dating, lumped-parameter models, aquifer classification, hydrochemical evaluation, heat transport, and groundwater recharge are some areas of my research.

Technical Skills

Scripting and Programming

- MATLAB scripting
- R scripting
- FORTAN programming
- Microsoft shell scripting

Data Analysis and Modeling

- MODFLOW groundwater modeling

- PEST inverse parameter estimation
- MATLAB & R
- Modeling groundwater age
- Principal component analysis
- Time-series analysis
- Heat-transport and geochemical modeling
- Groundwater Vistas
- ArcGIS

Field Skills

- Microgravity surveying – Scintrex CG-5 relative gravity meter
- Hydrochemical sampling of groundwater and surface water
- Aquifer pumping tests
- Dye tracing
- Field electronics
- Sampling in caves
- Streamflow measurement
- Some experience in ground-penetrating radar, seismic, and electromagnetic surveying

Sharing of Expertise

National Research Council (NRC) (Jan 2014 – present)

Currently, I serve on a national committee of university and government scientists to evaluate the implementation of the Edwards Aquifer Habitat Conservation Plan (http://www.eahcp.org/). This will result in one or more NRC reports to document the committee's evaluation and recommendations.

National Park Service (NPS) projects and advisory roles

- *Wind Cave National Park* (2007 – present) – I was Principle Investigator for two water-quality projects and a groundwater flow model. I conducted the groundwater and surface-water flow modeling for a fourth project and collaborated with biologists and climate scientists. I regularly advise NPS on hydrologic data collection for the park.
- *Niobrara National Scenic River* – I am advising NPS on the effectiveness of an existing groundwater flow model to evaluate interaction of groundwater and surface water.
- *Yellowstone National Park* – I am advising NPS on the potential to apply geophysical methods to better understand the hydrothermal system.

University Lectures and Seminars – I regularly give guest lectures at SDSMT classes and seminars, including:

- Integration of GIS with MODFLOW, Feb 2001, Mar 2003, Jan 2004
- Dual-porosity theory and modeling, Mar 2002
- Current research on age dating and tracer methods at the USGS, Apr 2004
- New methods for modeling karst aquifers, Feb 2005
- Artificial and natural tracers for the Madison aquifer, Jan 2006
- Environmental tracers as indicators of fast groundwater flow paths and potential anthropogenic influence in the karstic Madison aquifer, Mar 2006

- Environmental tracers as indicators of subaqueous karst-conduit flow paths and anthropogenic influence, Nov 2006
- Environmental tracers and dating karst groundwater: Madison aquifer, Feb 2007
- Understanding pore networks and chemical transport in karst aquifers, Nov 2007
- Karst groundwater studies at the USGS (ecology course), Nov 2009
- Dye tracing in the Madison aquifer (undergraduate groundwater course), Nov 2010
- Convolution and heat-transfer modeling of karst aquifers, Feb 2011
- Multivariate analyses and end-member mixing to characterize groundwater flow (ecology course), Nov 2011
- Groundwater modeling approaches and classification of karst aquifers (graduate groundwater modeling), Mar 2013
- Hydrochemical multivariate analyses to characterize groundwater flow (ecology course), Nov 2013
- Principal component analysis applied to chemical and hydraulic groundwater parameters (statistics for hydrology graduate course), Feb 2014
- Time-series modeling of groundwater and surface-water flow and transport: an underused toolset, SDSMT Earth Science Seminar Series, 7 Feb 2014
- Multivariate analysis to understand groundwater flow (ecology course), Nov 2014

Journal Referee

Journal referee for Journal of Hydrology, Water Resources Research, Journal of Geophysical Research—Earth Surface, Ground Water, Hydrogeology Journal, Contaminant Hydrology, Hydrological Processes, Hydrology and Earth System Sciences, Geoscientific Model Development.

Awards

- Four-time runner up—2011, 2012, 2013, and 2014—for best USGS groundwater report from a Water Science Center (http://water.usgs.gov/usgs/ogw/best-report/). I was first author on all four publications.
- Outstanding Recent Graduate Award, South Dakota School of Mines & Technology (SDSMT), for professional achievement within 10 years after graduation, 2004.
- Edward L. Tullus Academic Award for achieving high academic standards, SDSMT Dept. of Geological Engineering. Cash award with engraved Brunton compass, 1993.
- Outstanding Participation in the Field of Academic Achievement, SDSMT, 1992.
- Addison Wesley Mathematics Award, Normandale Community College, for excellence in mathematics, 1991.

News Media Highlights

- I was interviewed for a 2014 article in the Black Hill Pioneer about regional groundwater modeling of the Madison aquifer: http://www.bhpioneer.com/local_news/article_6355536e-077f-11e4-a517-0019bb2963f4.html.
- Lead author of a 2014 USGS report that was highlighted on a national USGS web site: http://www.usgs.gov/blogs/features/usgs_top_story/water-flows-and-energy-grows/
- I was interviewed for a May 2013 story on South Dakota Public Radio concerning water

demands and possible contamination from petroleum production in the Williston basin, North Dakota.

- I was Interviewed by the Rapid City Journal in 2005 for an article concerning declining water levels in the Madison aquifer.
- I was interviewed by South Dakota Public Broadcasting for a 2007 television story highlighting USGS dye-tracing activities and environmental-tracer studies in the Black Hills area, which raised awareness of the vulnerability of Wind Cave National Park to nearby development.
- I appeared on local television news in an interview about a water-quality of Wind Cave National Park, February 2012.

Technical Training Courses

- Advanced Modeling of Groundwater Flow, USGS National Training Center (NTC), 5 days, October 2000.
- Calibration and Uncertainty of Models, USGS NTC, 5 days, March 2002.
- Statistical Methods for Data Analysis, USGS NTC, 5 days, September 2003.
- Microgravity Workshop, USGS Arizona Water Science Center, 5 days, October 2004.
- Aquatic Chemistry, USGS NTC, 5 days, January 2005.
- Principles and Applications of Estimating the Age of Young Groundwater, USGS NRP, Reston, 3 days, April 2006.
- Multivariate Analysis for Hydrological, Biological, and Chemical Data, USGS NTC, 4 days, March 2009.
- Groundwater/Surface-Water Interactions USGS NTC, 5 days, February 2014.

Memberships in Professional Societies

- American Geophysical Union (AGU), 1997-present.
- European Geosciences Union (EGU), 2010-present.
- Union of Concerned Scientists, 2007-Present.

Community Leadership

Nov 2013 – present
Founder and Chair, Scientists Advocacy League, USGS SDWSC – This group was established to facilitate collaboration, mentor and share skills, coordinate common resources, provide a forum to discuss workplace concerns, and give scientists a collective voice to influence the functioning of their organization. Accomplishments include establishing a central GIS library and a standardized file-directory tree for all projects for the SDWSC.

2002, Mar 2014 – present
Twice served on Board of Directors – Breadroot Natural Foods Co-op, Rapid City, South Dakota.

2010 – present
Black Hills Runners Club – I regularly organize and lead group trails runs in the Black Hills of South Dakota.

References

Available upon request.

Publications

Journal Articles

Long, A.J., 2015, RRAWFLOW: Rainfall-Response Aquifer and Watershed Flow Model (v1.15). Geoscientific Model Development., v. 8, p. 865-880, doi:10.5194/gmd-8-865-2015. [Link]

Long, A. J., 2014. RRAWFLOW: Rainfall-Response Aquifer and Watershed Flow Model (v1.11). Geoscientific Model Development Discuss., v. 7, 5919-5963, doi:10.5194/gmdd-7-5919-2014. [Link]

Long, A.J., and Mahler, B.J., 2013. Prediction, time variance, and classification of hydraulic response to recharge in two karst aquifers. Hydrology and Earth System Sciences, v. 17, p. 281-94, DOI: 10.5194/hess-17-281-2013. [Link]

Saller, S.P., M.J. Ronayne, and A.J. Long, 2013. Comparison of a karst groundwater model with and without discrete conduit flow, Hydrogeology Journal, v. 21 (7), p. 1555-1566, DOI: 10.1007/s10040-013-1036-6. [Link]

Valder, J.F., Long, A.J., Davis, A.D., Kenner, S.J., 2012. Multivariate statistical approach to estimate mixing proportions for unknown end members, Journal of Hydrology, 460-461, p. 65-76, DOI: 10.1016/j.jhydrol.2012.06.037. [Link]

Long, A.J. and Valder, J.F., 2011. Multivariate analyses with end-member mixing to characterize groundwater flow: Wind Cave and associated aquifers. Journal of Hydrology, v. 409, no. 1-2, p. 315-327, DOI:10.1016/j.jhydrol.2011.08.028. [Link]

Long, A.J., 2009. Hydrograph separation for karst watersheds using a two-domain rainfall–discharge model. Journal of Hydrology, v. 364, no. 3-4, p. 249–256. [Link]

Long, A.J., and Gilcrease, P.C., 2009, A one-dimensional heat-transport model for conduit flow in karst aquifers: Journal of Hydrology, v. 378, no. 3-4, p. 230-239. [Link]

Long, A.J., and Putnam, L.D., 2009, Age-distribution estimation for karst groundwater: Issues of parameterization and complexity in inverse modeling by convolution: Journal of Hydrology, v. 376, no. 3-4, p. 579-588. [Link]

Long, A.J., Sawyer, J.F., and Putnam, L.D., 2008. Environmental tracers as indicators of karst conduits in ground water, South Dakota, USA. Hydrogeology Journal, v. 16, no. 2, p 263-280. [Link]

Long, A.J. and Putnam. L.D., 2006. Translating CFC-based piston ages into probability density functions of ground-water age in karst. J. Hydrol. v. 330, no. 3-4, p. 735-747. [Link]

Long, A.J. and Putnam. L.D., 2004. Linear model describing three components of flow in karst aquifers using 18O data. Journal of Hydrology, v. 296, p. 254-270. [Link]

Davis, A.D., Long, A.J., Wireman, M., 2002, KARSTIC: a sensitivity method for carbonate aquifers in karst terrain: Environmental Geology v. 42, no. 1, p. 65-72. [Link]

Long, A.J. and Derickson, R.G., 1999. Linear systems analysis in a karst aquifer. Journal of Hydrology, v. 219, p. 206-217. [Link]

Other Publications

Mahler, B.J., Stamm, J.F., Symstad, A.J., Poteet, M.F., Musgrove, M., Long, A.J., and Norton, P.A., 2015, Effects of Projected Climate (2011–50) on Karst Hydrology and Species Vulnerability—Edwards Aquifer, South-Central Texas, and Madison Aquifer, Western South Dakota: U.S. Geological Survey Fact Sheet 2014–3046, 4 p. in review.

National Research Council, 2015, Review of the Edwards aquifer Habitat Conservation Plan: Report 1, The National Academies Press, Washington, D.C., 156 p.

Stamm, J.F., Poteet, M.F., Symstad, A.J., Musgrove, M., Long, A.J., Mahler, B.J., and Norton, P.A., 2015, Historical and Projected Climate (1901–2050) and Hydrologic Response of Karst Aquifers, and Species Vulnerability in South-Central Texas and Western South Dakota: Scientific Investigations Report 2014–5089, 62 p., in review.

Haines, S.S., Cook, T.A., Thamke, J.N., Davis, K.W., Long, A.J., Healy, R.W., Hawkins, S.J., and Engle, M.A., 2014, A framework for assessing water and proppant use and flowback water extraction associated with development of continuous petroleum resources: U.S. Geological Survey 2014–3010, 6 p.

Long, A.J., Aurand, K.R., Bednar, J.M., Davis, K.W., Mckaskey, J.D.R.G., and Thamke, J.N., 2014, Conceptual Model of the Uppermost Principal Aquifer Systems in the Williston and Powder River Structural Basins, United States and Canada: U.S. Geological Survey Scientific Investigations Report 2014-5055, 41 p.

Symstad, A. J., Long, A. J., Stamm, J. F., King, D. A. and Bachelet, D. M., 2014, Two Approaches for Planning Natural Resource Management in a Changing Climate at Wind Cave National Park: National Park Service Natural Resource Technical Report NPS/WICA/NRTR—2014/918, 87 p.

Thamke, J.N., LeCain, G.D., Ryter, D.W., Sando, R., and and Long, A.J., 2014, Hydrogeologic framework of the uppermost principal aquifer systems in the Williston and Powder River structural basins, United States and Canada: U.S. Geological Survey Scientific Investigations Report 2014–5047, 38 p.

Koth, K.R., and Long, A.J., 2012, Microgravity methods for characterization of groundwater-storage changes and aquifer properties in the karstic Madison aquifer in the Black Hills of South Dakota, 2009–12: U.S. Geological Survey Scientific Investigations Report 2012–5158, 22 p.

Long, A.J., Ohms, M.J., McKaskey, J.D.R.G, 2012, Groundwater flow, quality (2007–10), and mixing in the Wind Cave National Park area, South Dakota: U.S. Geological Survey Scientific Investigations Report 2011–5235, 50 p.

Long, A.J., and Putnam, L.D., 2010, Simulated groundwater flow in the Ogallala and Arikaree aquifers, Rosebud Indian Reservation area, South Dakota—Revisions with data through water year 2008 and simulations of potential future scenarios: U.S. Geological Survey Scientific Investigations Report 2010–5105, 64 p.

Putnam, L.D., and Long, A.J., 2009, Numerical groundwater-flow model of the Minnelusa and Madison hydrogeologic units in the Rapid City area, South Dakota: U.S Geological Survey Scientific Investigations Report 2009–5205, 81 p.

Banner, J.L., Musgrove, M., Rasmussen, J., Partin, J., Long, A., Katz, B., Mahler, B., Edwards, L., Cobb, K., James, E., Harmon, R.S., Herman, E., Wicks, C.M., 2008. Geochemistry and climate change *in* Martin, J.B. and White, W.B., eds., Frontiers of karst research. Karst Waters Institute Special Publication 13. Proceedings and recommendations of the workshop held May 3 through 5, 2007 in San Antonio, Texas, USA.

Putnam, L.D. and Long, A.J., 2007a. Analysis of ground-water flow in the Madison Aquifer using fluorescent dyes injected in Spring Creek and Rapid Creek near Rapid City, South Dakota, 2003-04: U.S. Geological Survey SIR 2007-5137, 27 p.

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Rod Horrocks Biography

Rod Horrocks worked as a cartographer and fossil preparator for six years while working on his Bachelor and then Master of Science degrees. The title of his thesis was, "A Comparison between Two Computer-Aided Cartographic Systems, With an Analysis of Their Work Flow ". He began his National Park Service career in 1992 and has worked for the National Park Service as a Physical Scientist for 22 years. He began his career at Timpanogos Cave National Monument, followed by a stint at Great Basin National Park in 1996. He was the first Cave Management Specialist at each of these parks. His co-lateral duties have included cartographer, museum technician, fossil preparator, geologic technician, hydrological technician, and air quality technician. In 1999, he moved to Wind Cave National Park, where he has been for sixteen years. Rod specializes in digital cave cartography, cave lighting design, paleontological field work, fossil preparation and curation, cave tour-route development, and cave restoration. He has been a member of the National Speleological Society for 32 years and is a Fellow of that Society. He was awarded the Certificate of Merit by them, and was the Chairman of the Cave Conservation and Management Section for 11 years, Chairman of the Survey and Cartography Section for two years, and Chairman of the Timpanogos Grotto for ten years. He was also the editor of the *Underground News* newsletter for 9 years, the *Utah Caver* for 6 years, and the *Inside Earth* newsletter for 6 years. He has had seven peer-reviewed articles published in journals and books and 36 other cave and karst-related articles published in newsletters, magazines, books, and conference proceedings.

Work History:

* Wind Cave National Park (Physical Scientist)	1999-Present
* Great Basin National Park (Cave Management Specialist)	1996-1998
* Timpanogos Cave National Monument (Cave Mgmt. Specialist)	1992-1996

Peer-reviewed Articles Authored:

1) 2015. *"Wind Cave, Guidebook to the Geology of the Black Hills".* John Lufkin, Jack Redden, Alvis Lisenbee, Editors. Golden Publishers.
2) 2009. *"Developing a Cave Potential Map for Wind Cave, Caves and Karst of the USA",* Arthur N. Palmer and Margaret V. Palmer, Editors. National Speleological Society, Huntsville, Alabama, p. 218-220.
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National Park Service
U.S. Department of the Interior

Application 2730-2 by the United Order of South Dakota

Jeff Hughes, Hydrologist
National Park Service – Water Resources Division

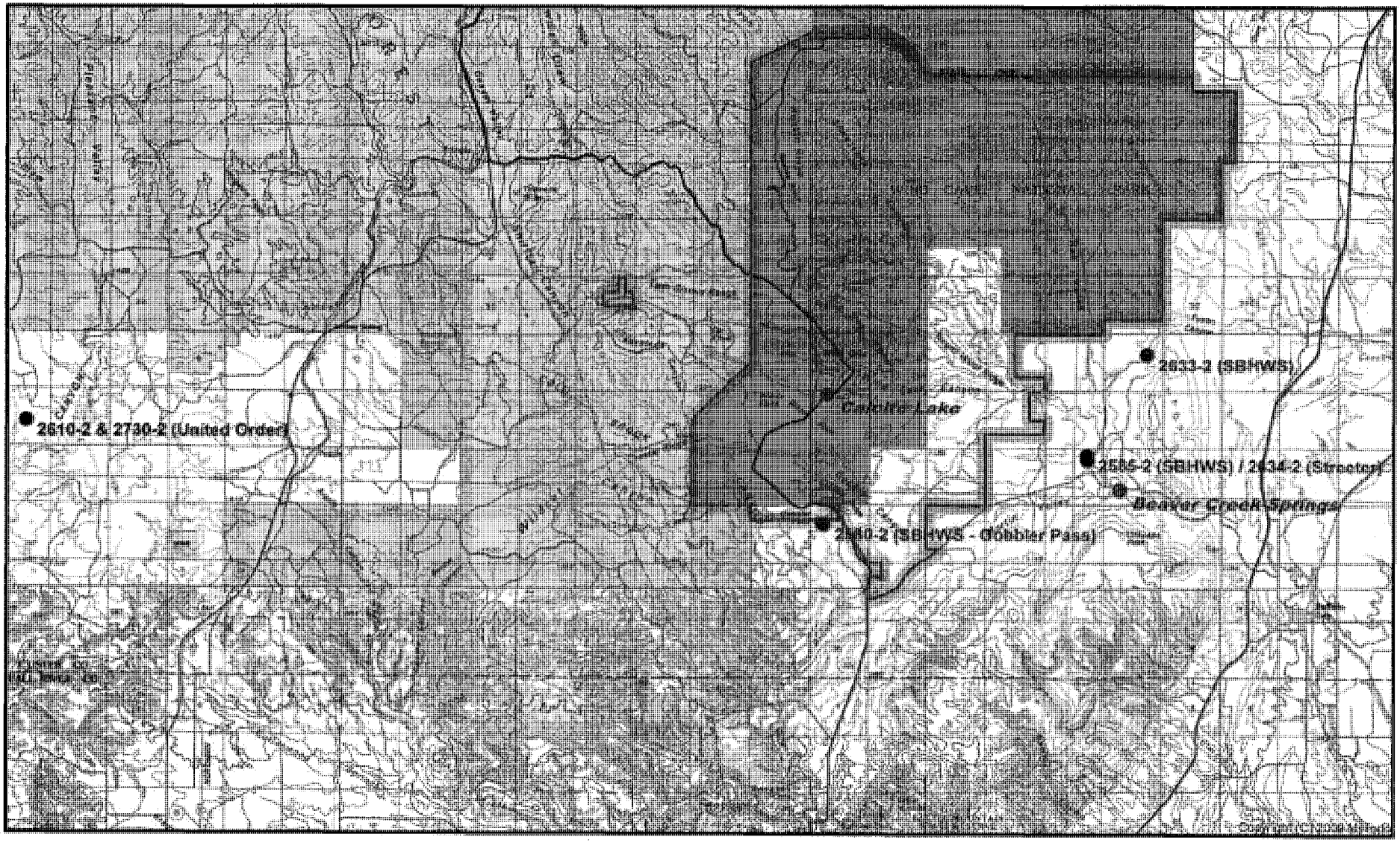
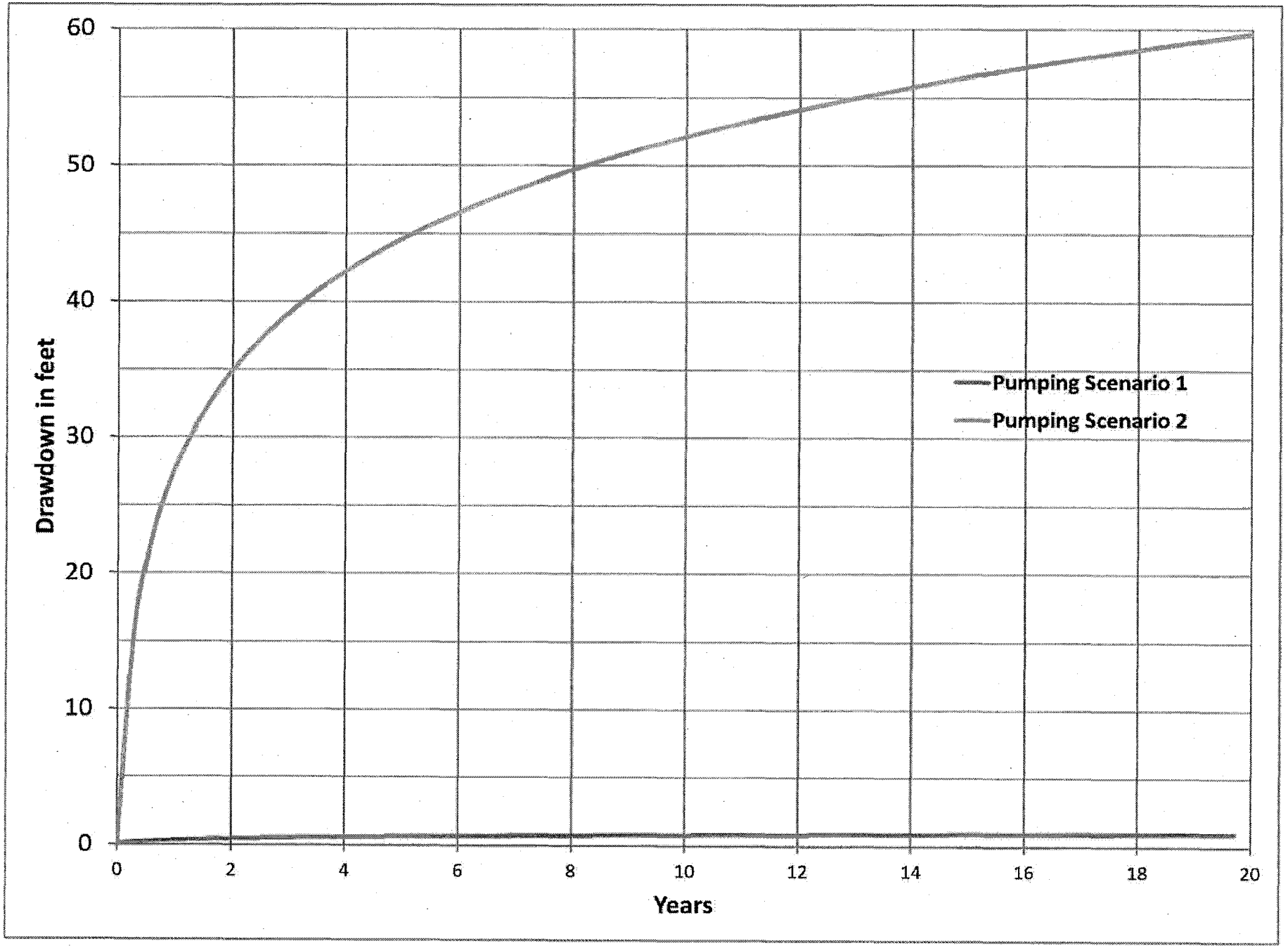


Figure 1: THWELLS Location Map

- Theis analysis
  - Scenario 1 – Existing withdrawals
    - 2610-2 (United Order of SD) 25.8 afy
    - 2634-2 (Mr. Streeter & SBHWS, Inc.) 12.5 afy
  - Scenario 2 – Potential withdrawals
    - 2730-2 (United Order of SD) 153 afy
    - 2634-2 (Mr. Streeter only) 4.08 afy
    - 2585-2 (SBHWS, Inc.) 720 afy
    - 2580-2 (SBHWS, Inc. – Gobbler Pass well) 228 afy


60
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30
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Drawdown in feet
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6
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12
14
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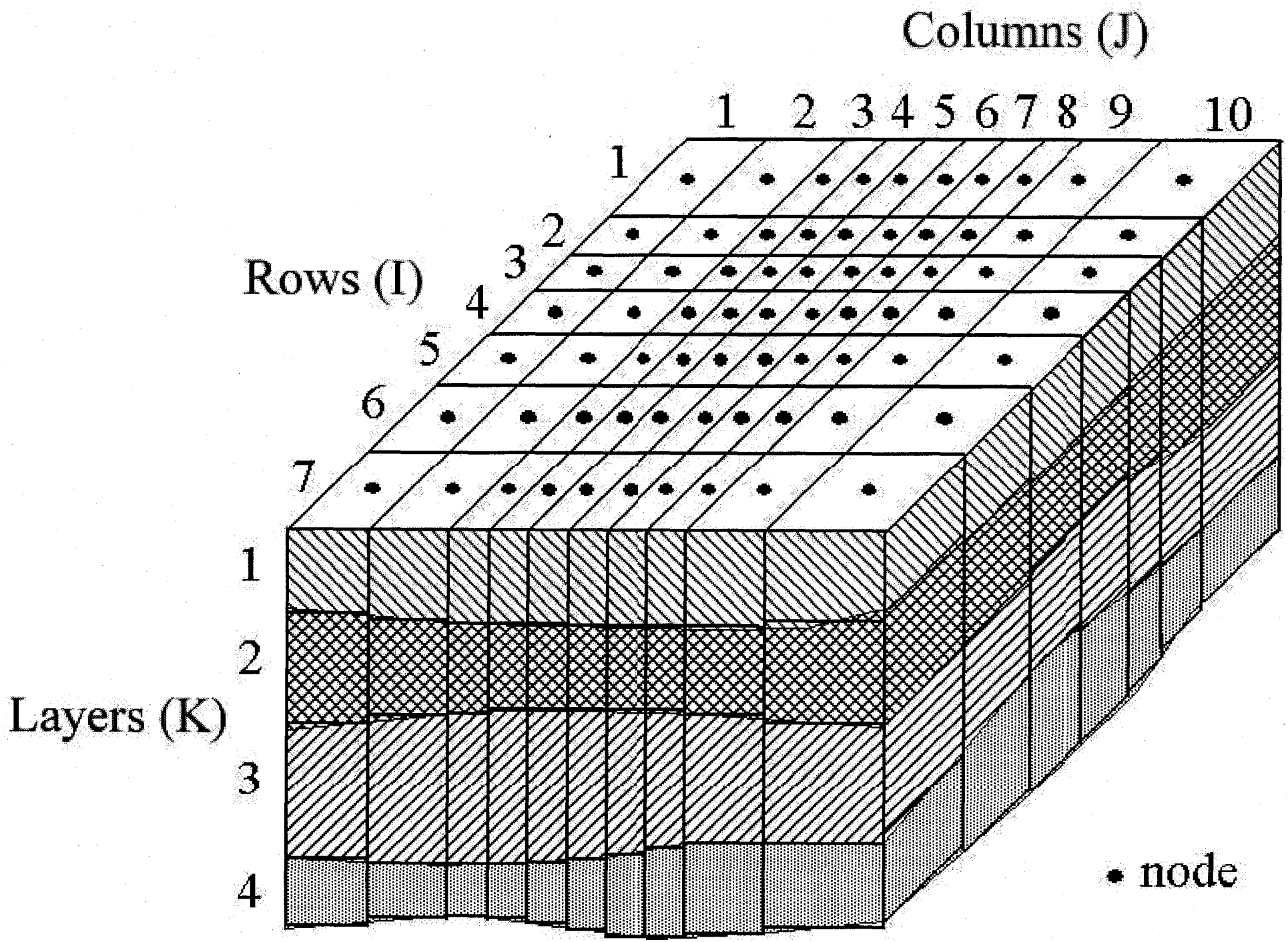
Years
Pumping Scenario 1
Pumping Scenario 2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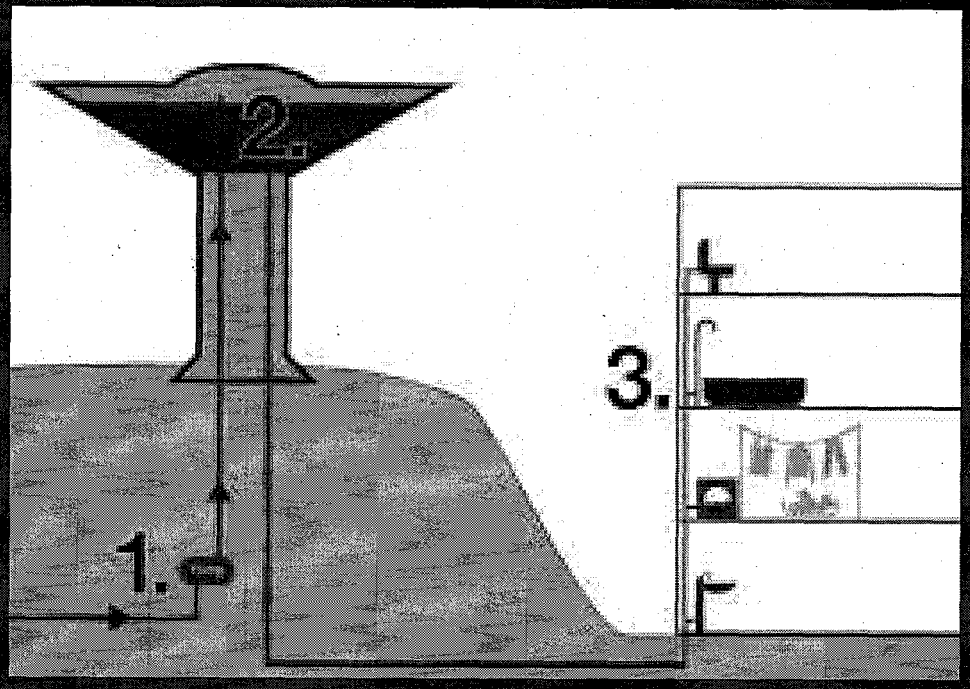
USGS
science for a changing world

Groundwater principals and the Black Hills

Andy Long, USGS

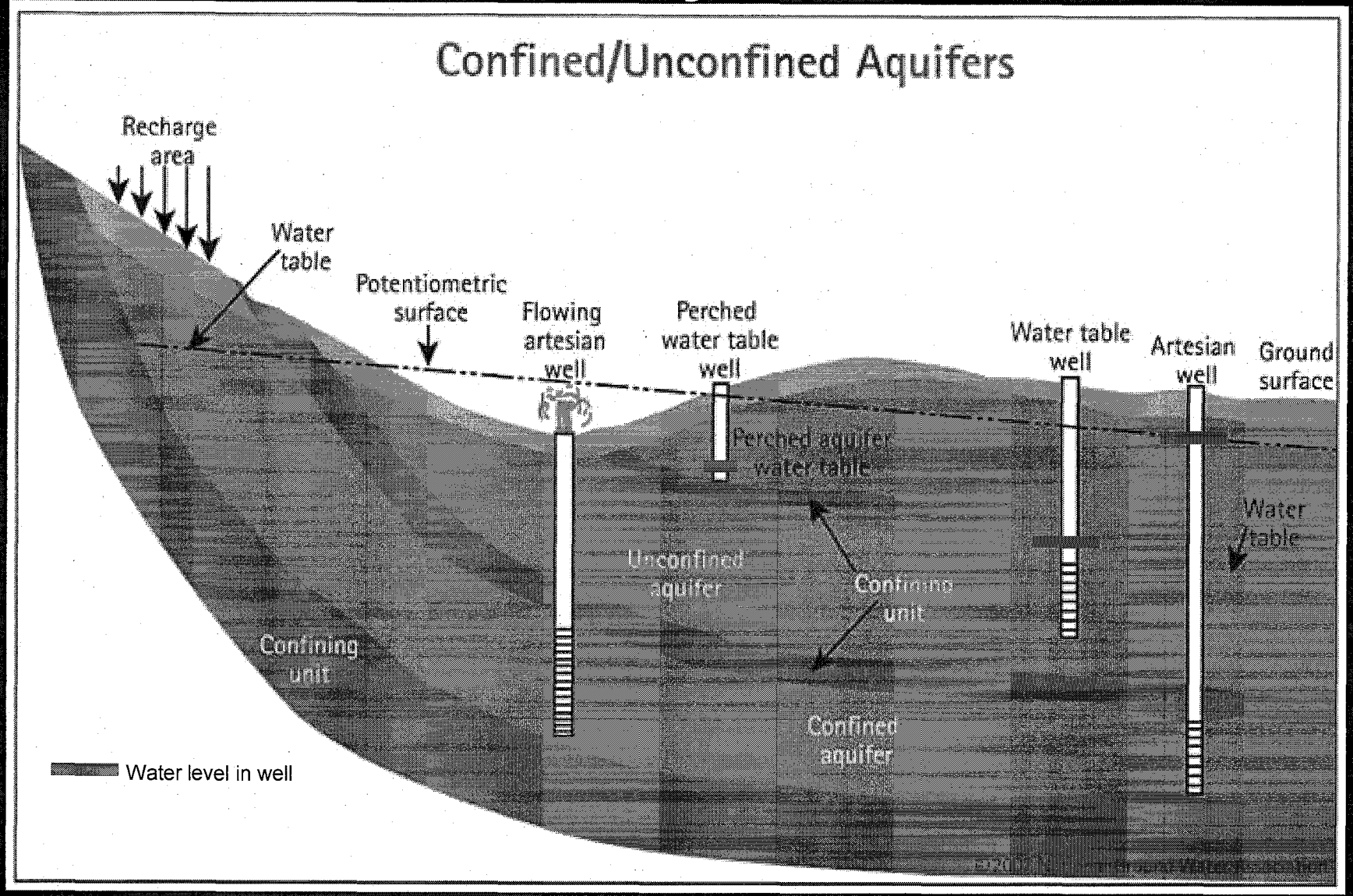
U.S. Department of the Interior
U.S. Geological Survey

Basic hydraulics



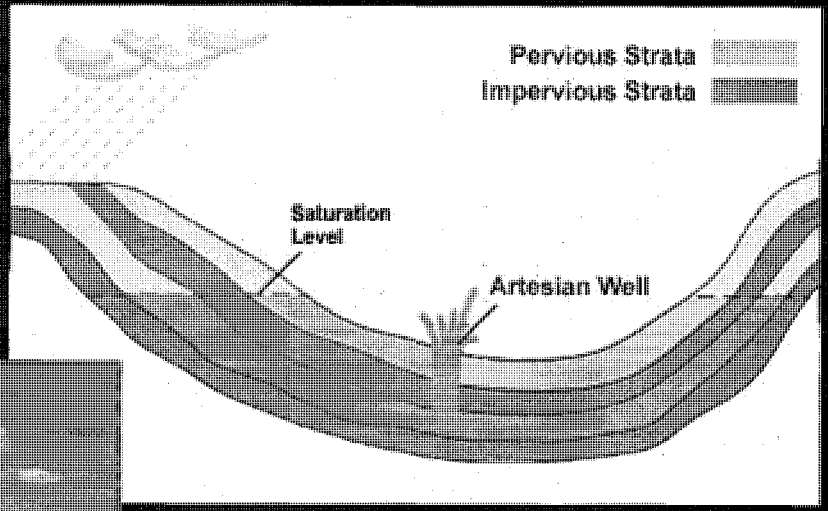
USGS

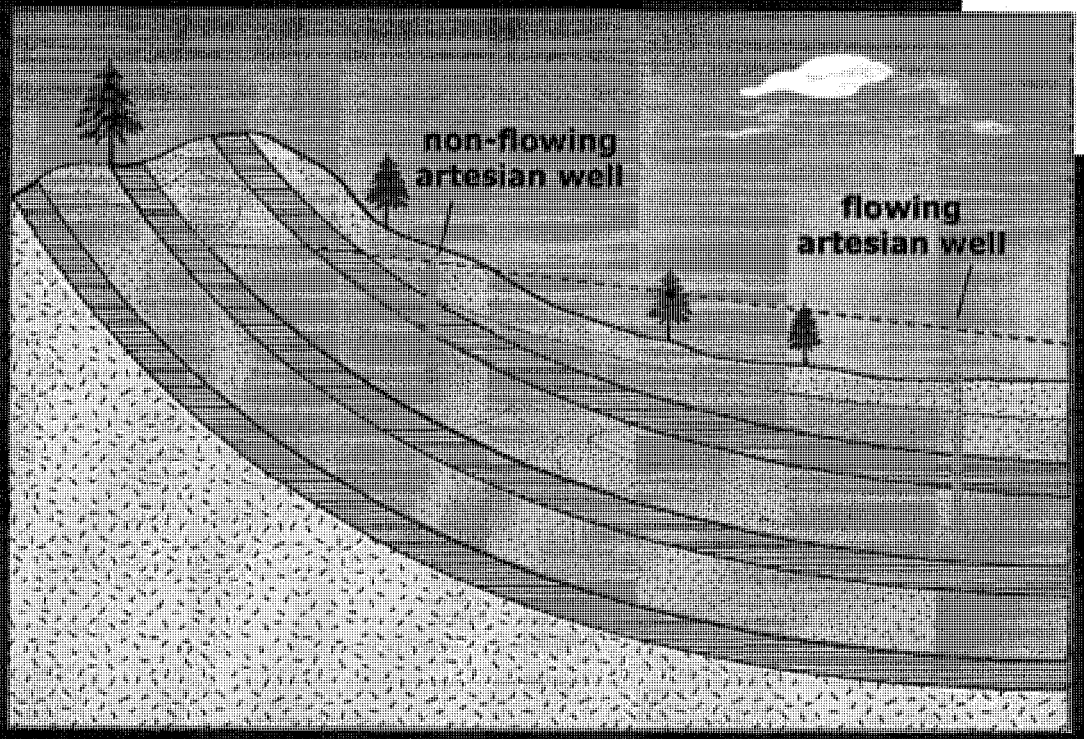
Groundwater hydraulics



USGS

Artesian pressure





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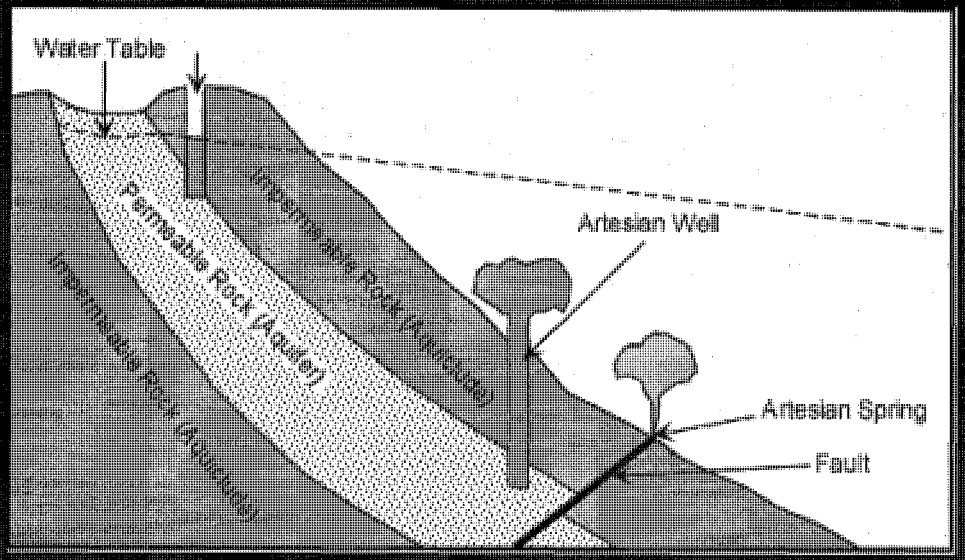
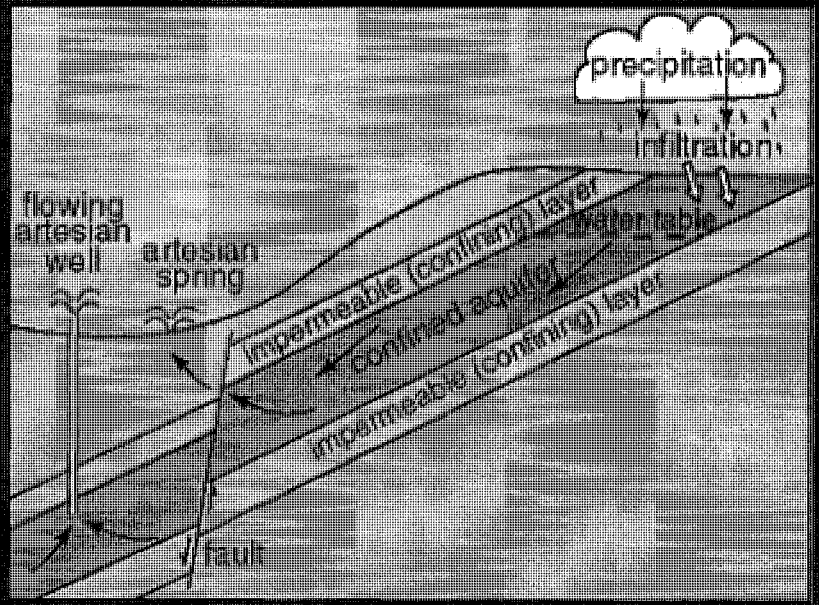
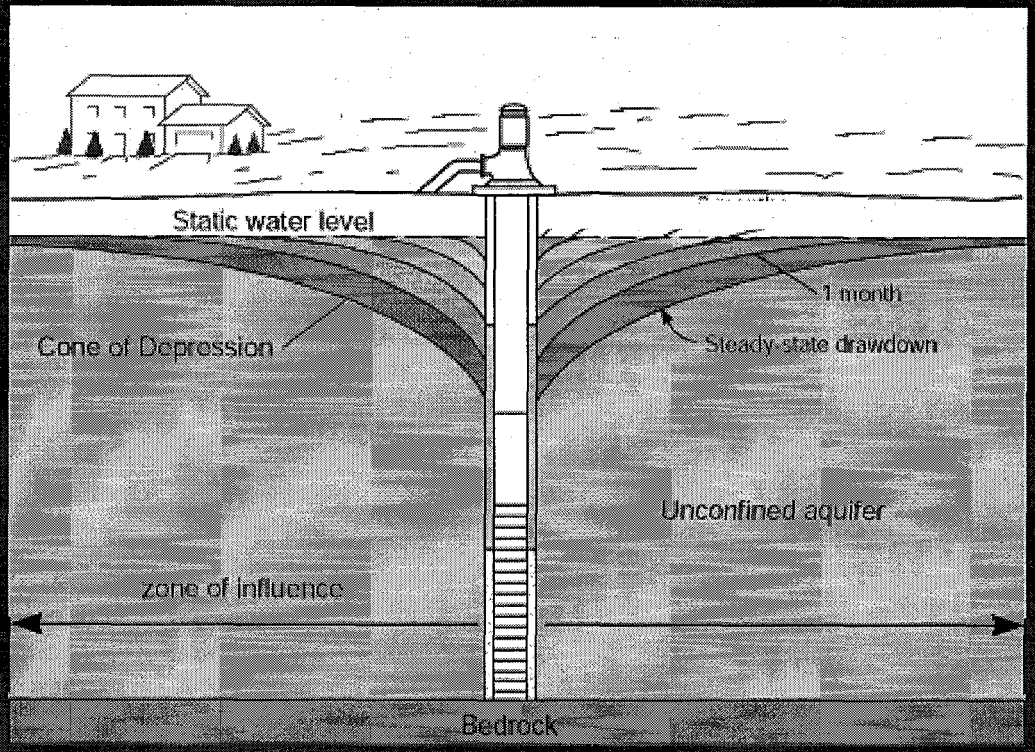
Artesian springs





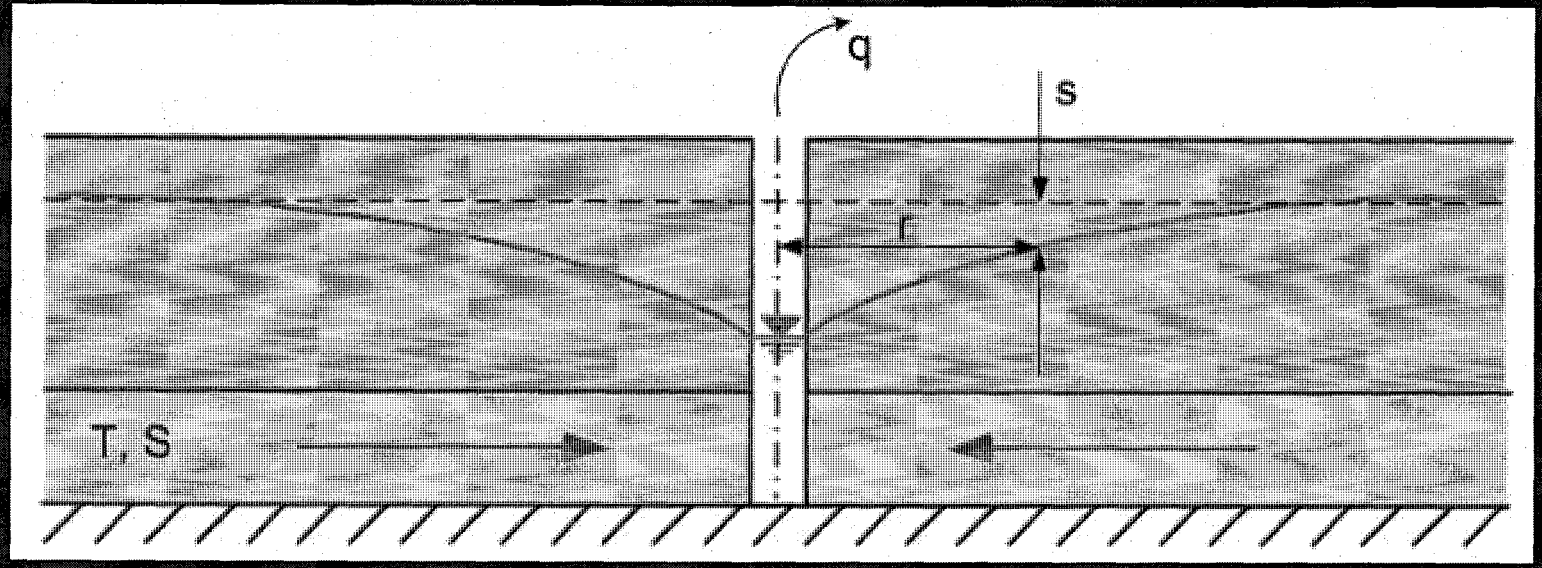
USGS

Water-table drawdown (unconfined aquifer)



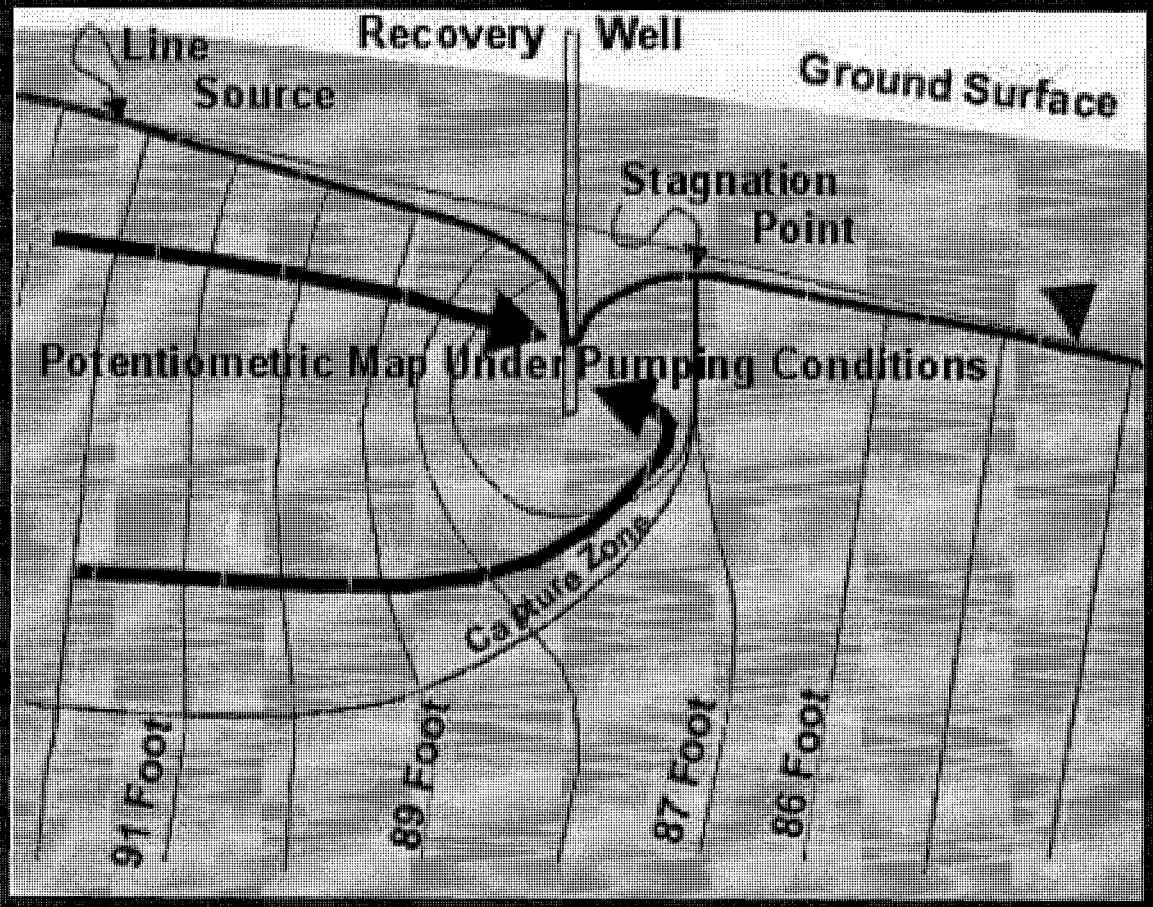
USGS

Pressure-head drawdown (confined aquifer)



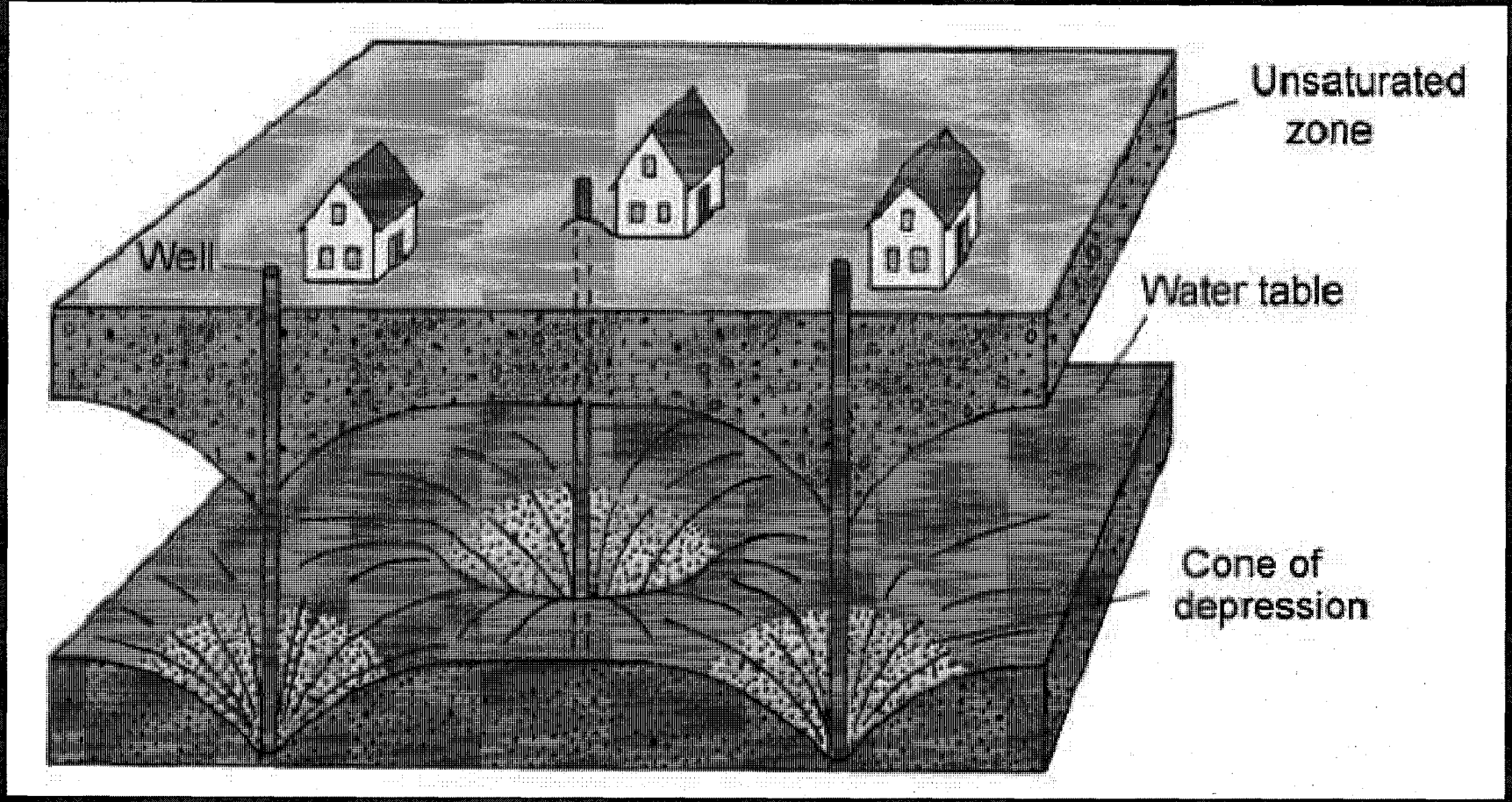
USGS

Sloping water table



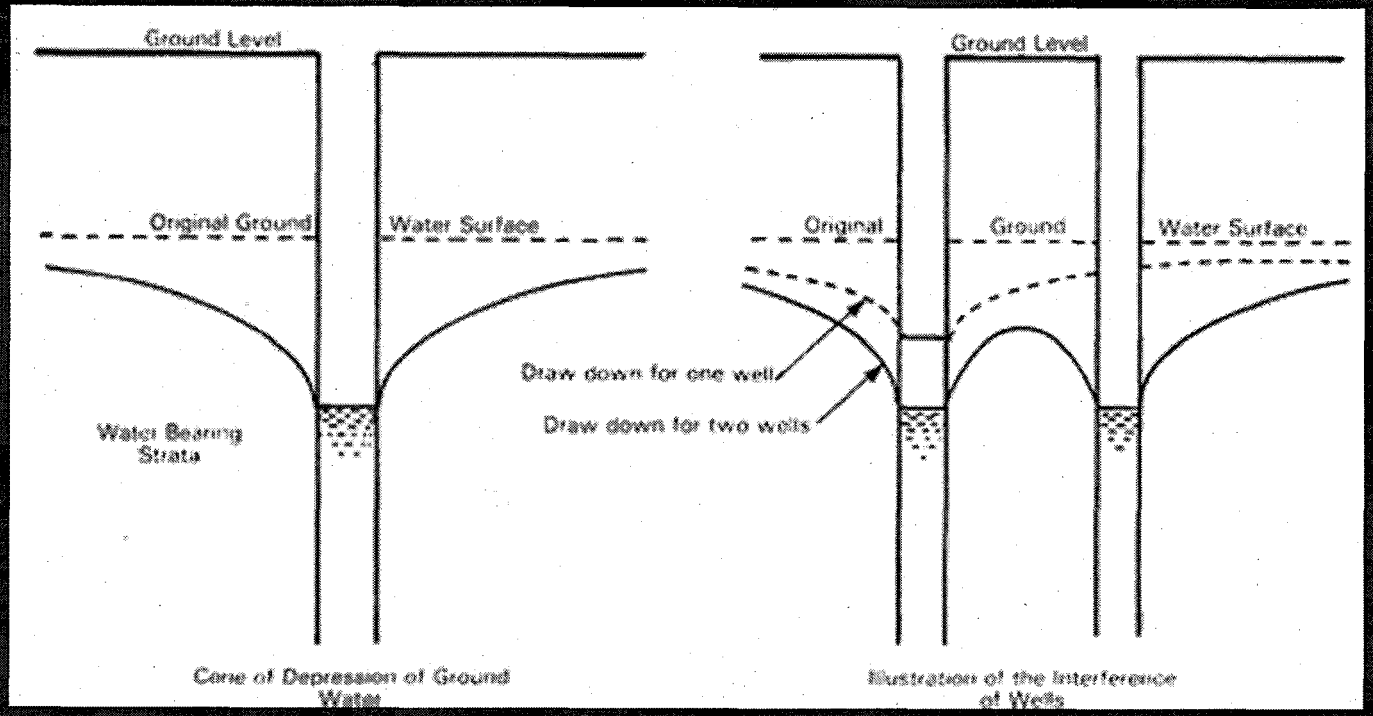
USGS

Well interference



USGS

Well interference

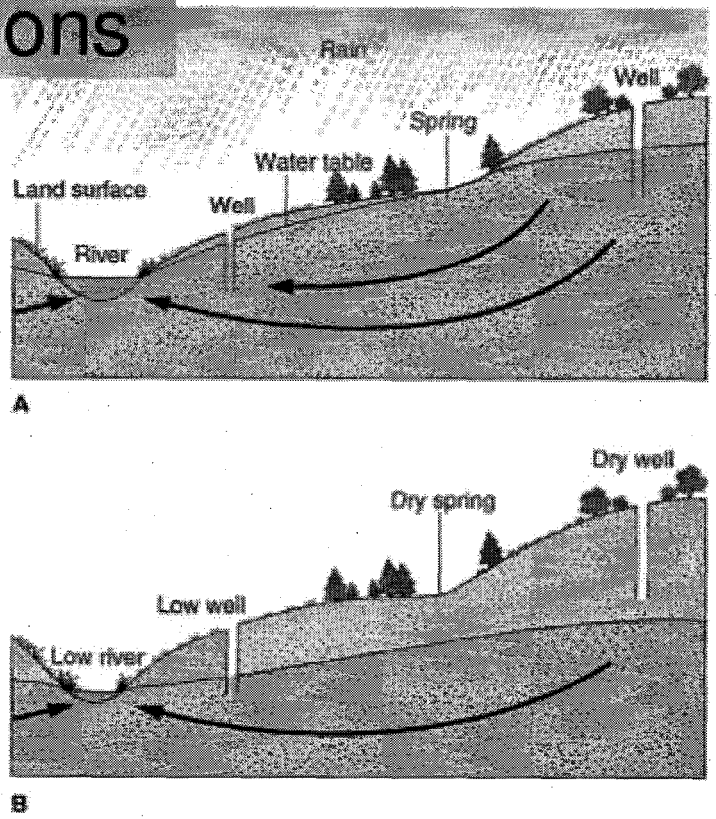


USGS

Natural water-table fluctuation

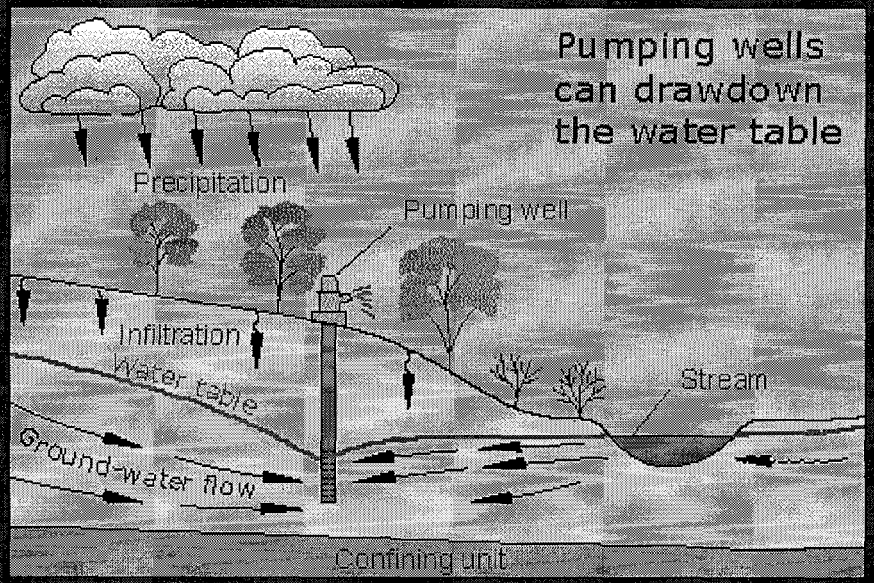
Natural Water Table Fluctuations

- Reduction of infiltration causes water table to drop
  - Wells go dry
  - Springs go dry
  - Discharge of rivers drops
- Artificial causes
  - Pavement
  - Drainage



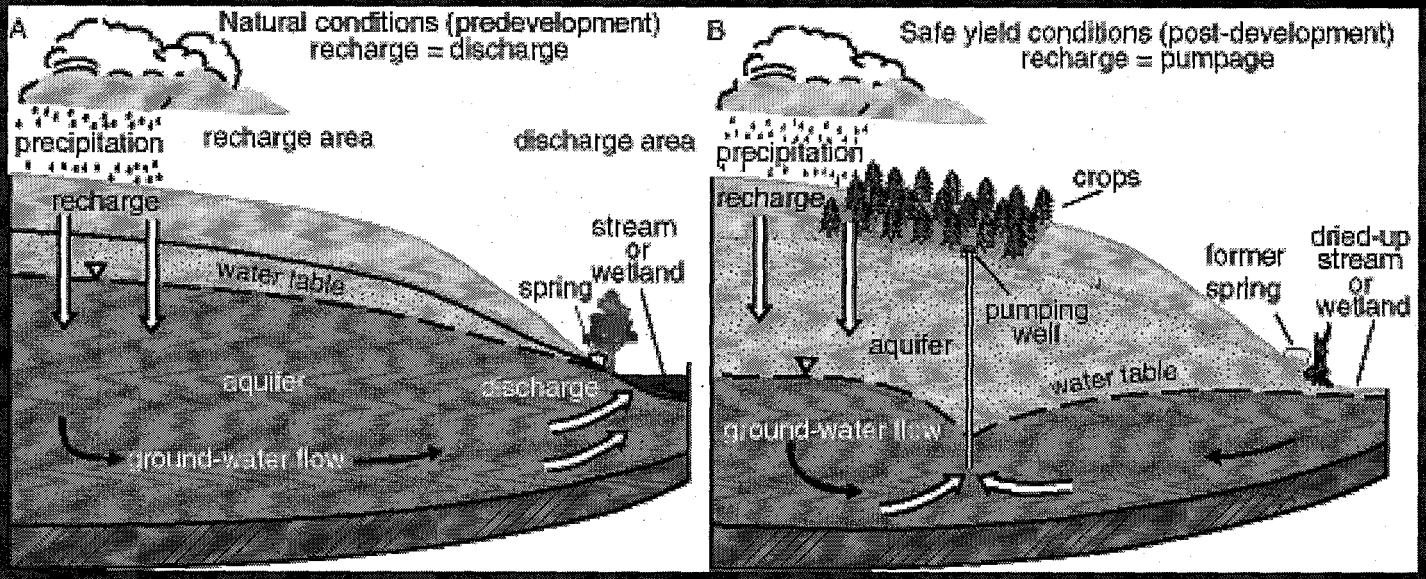
USGS

Influence of pumping



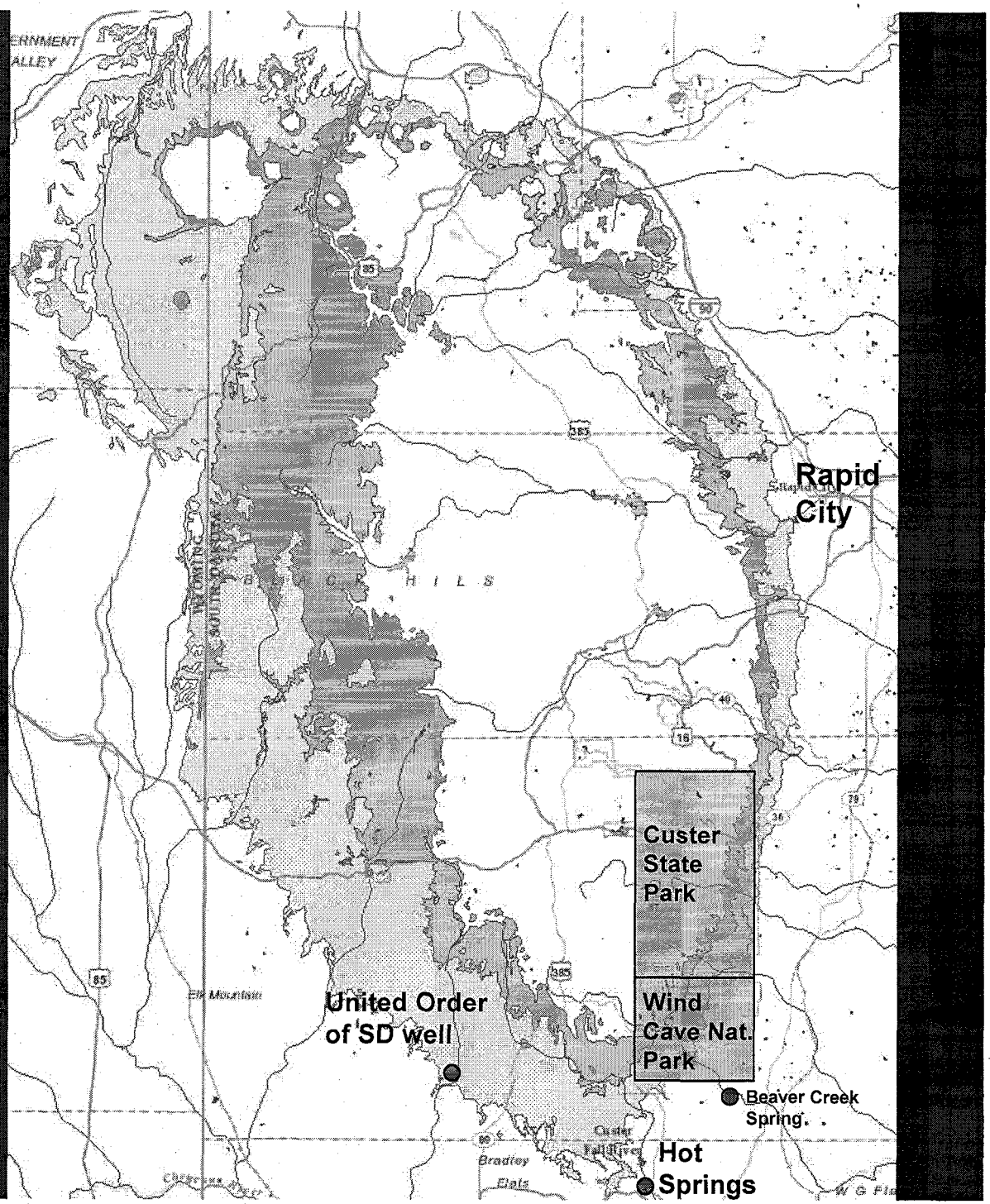
USGS

Influence of pumping



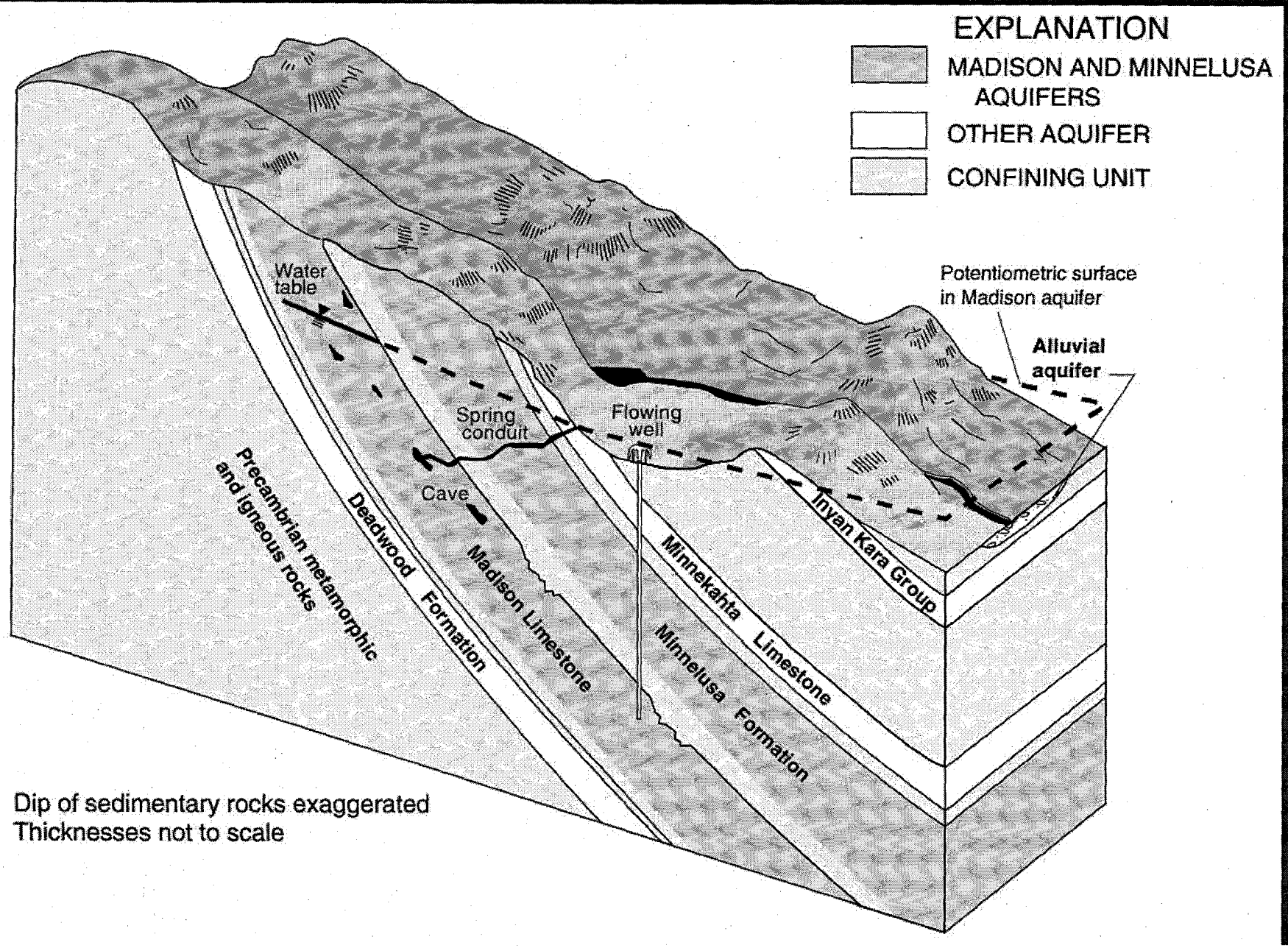
USGS

Map of Black Hills showing outcrops of the Madison and Minnelusa aquifers

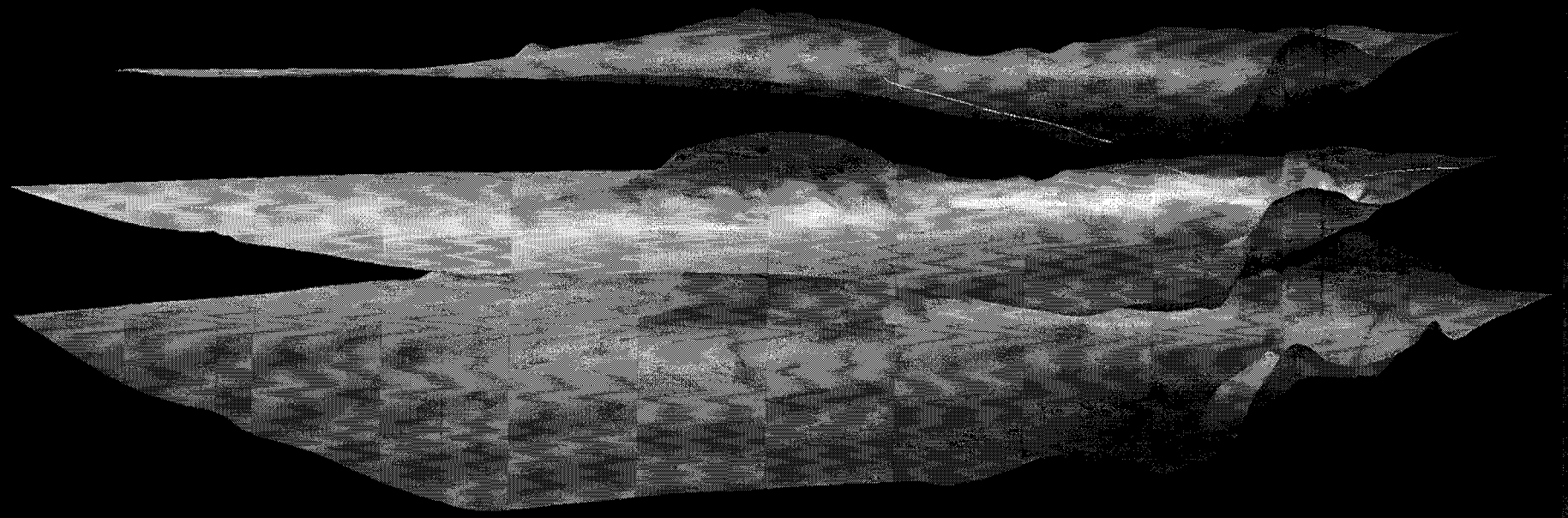


USGS

Block diagram of major aquifers

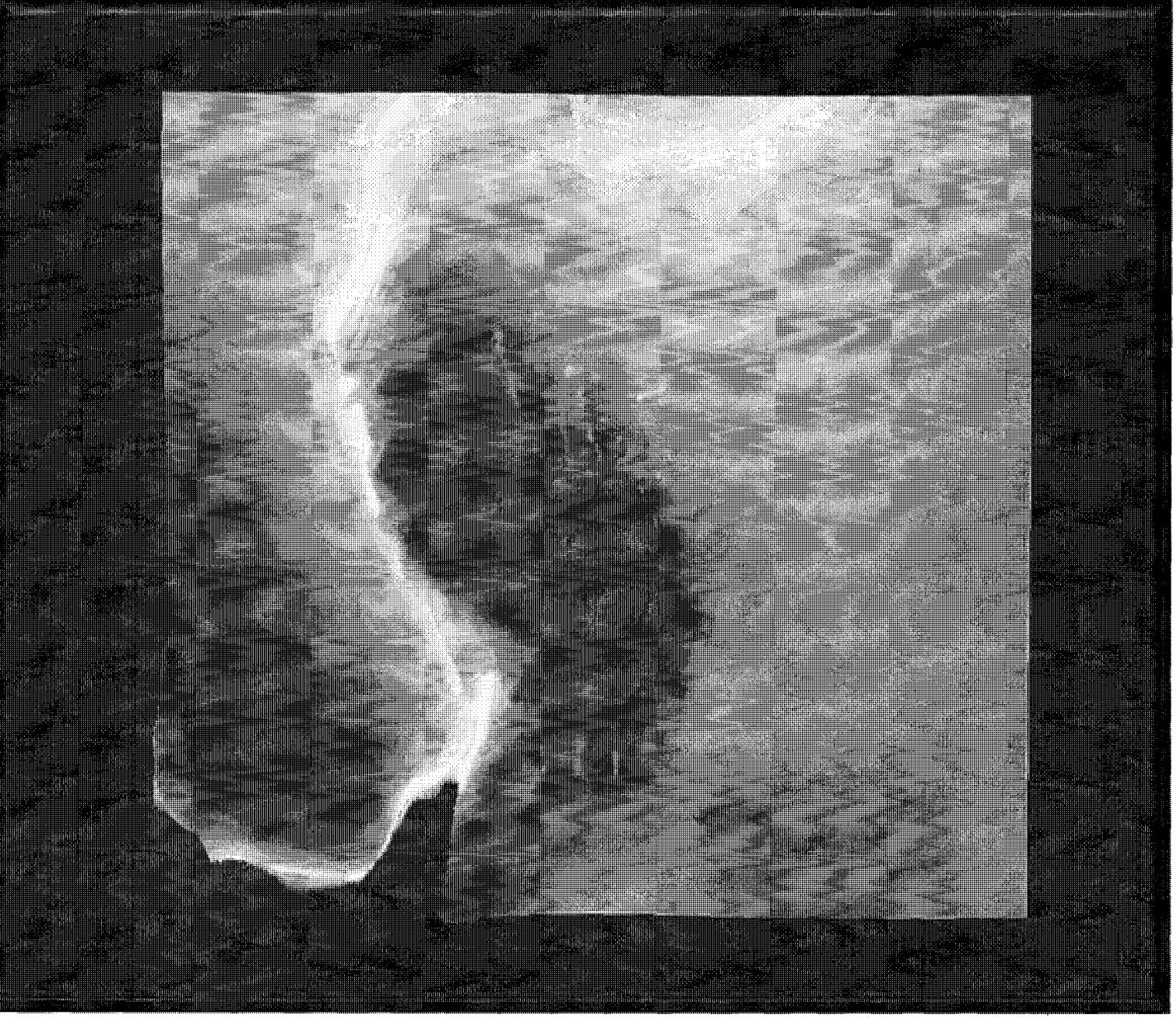


3-D Hydrogeologic Framework



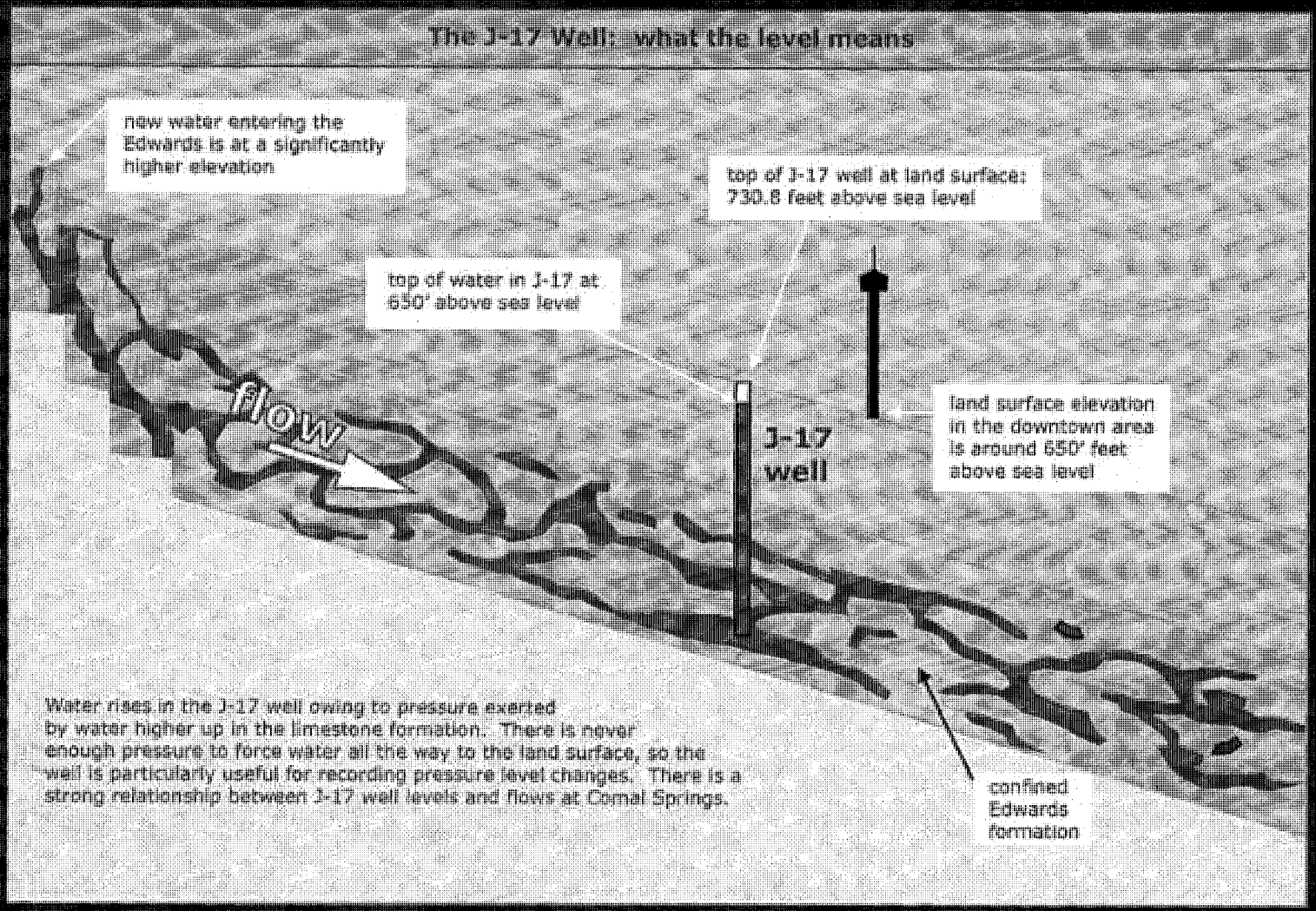
USGS

3-D Hydrogeologic Framework:



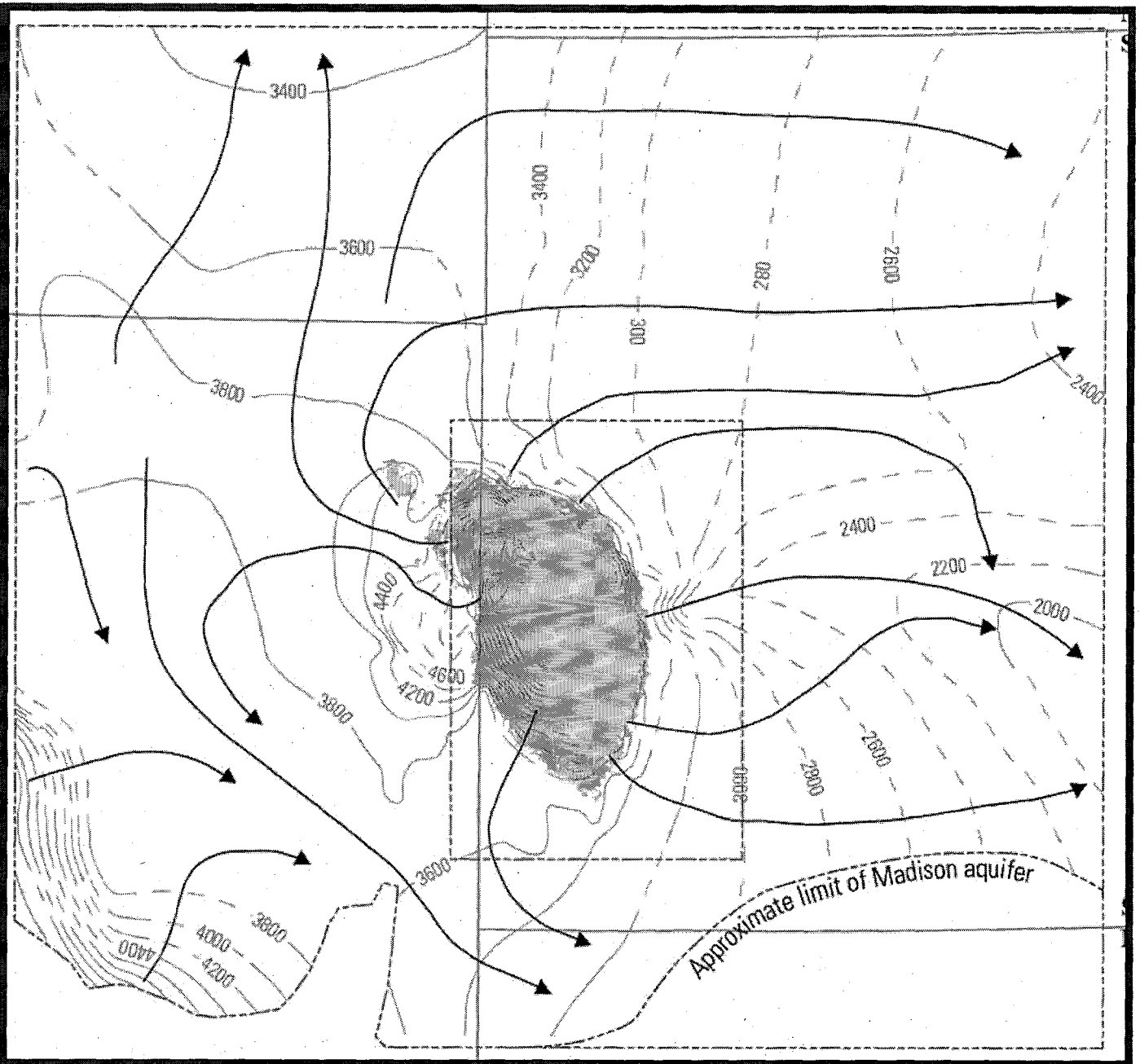
USGS

Caves, conduits, and fractures in the Madison aquifer



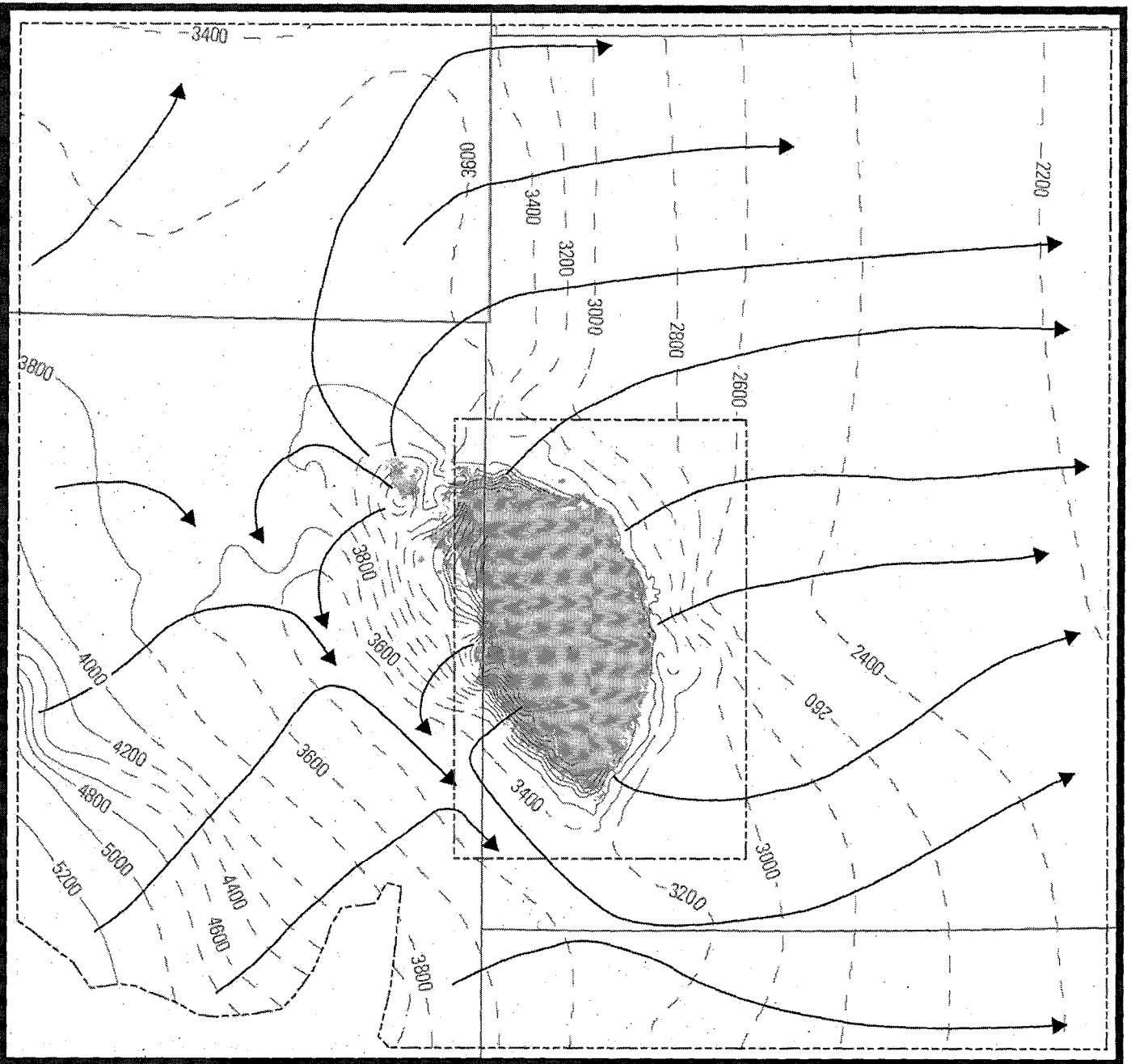
USGS

Groundwater flow in Madison aquifer



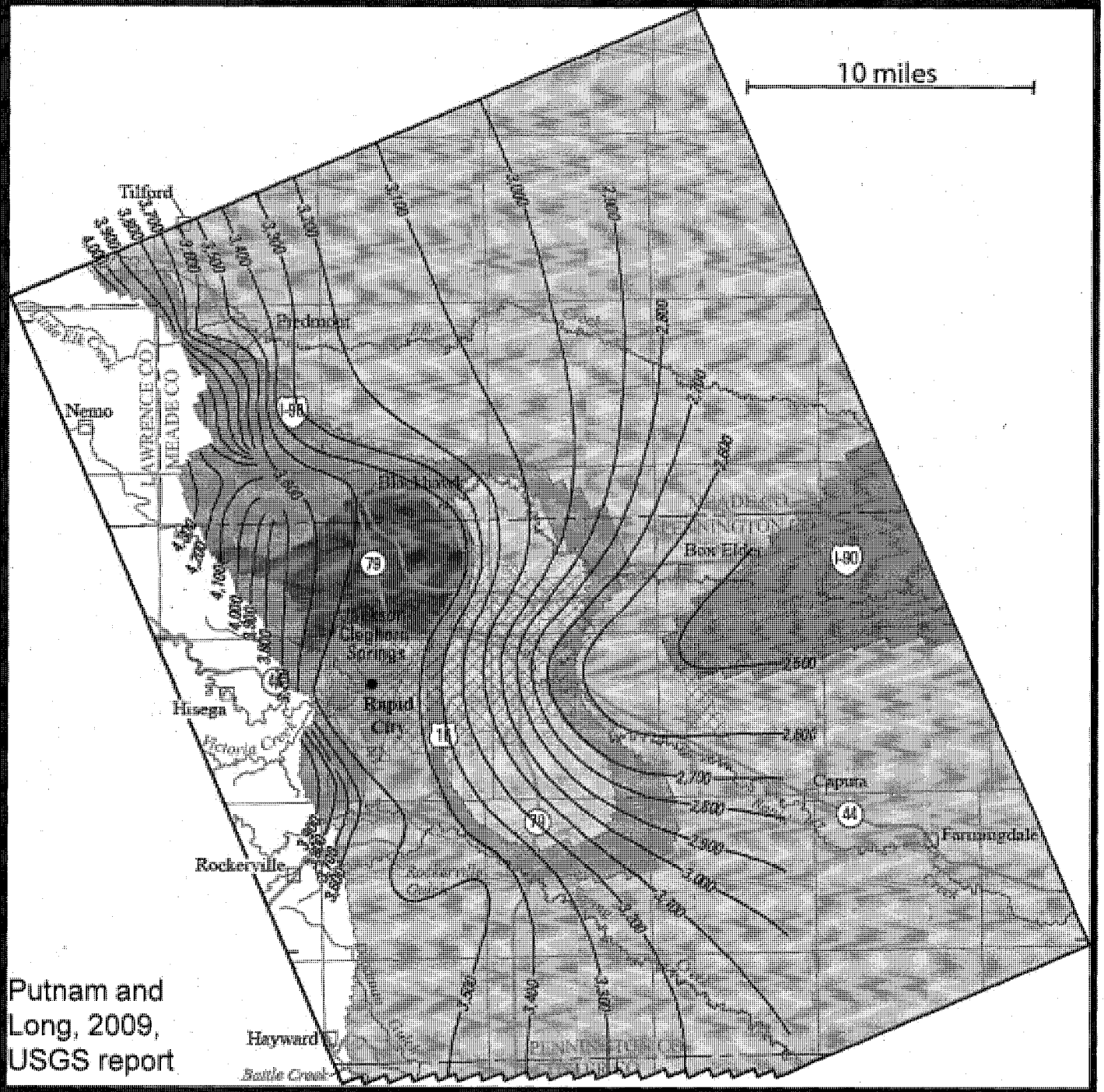
USGS

Groundwater flow in Minnelusa aquifer



USGS

Permeability is spatially variable in the Madison aquifer



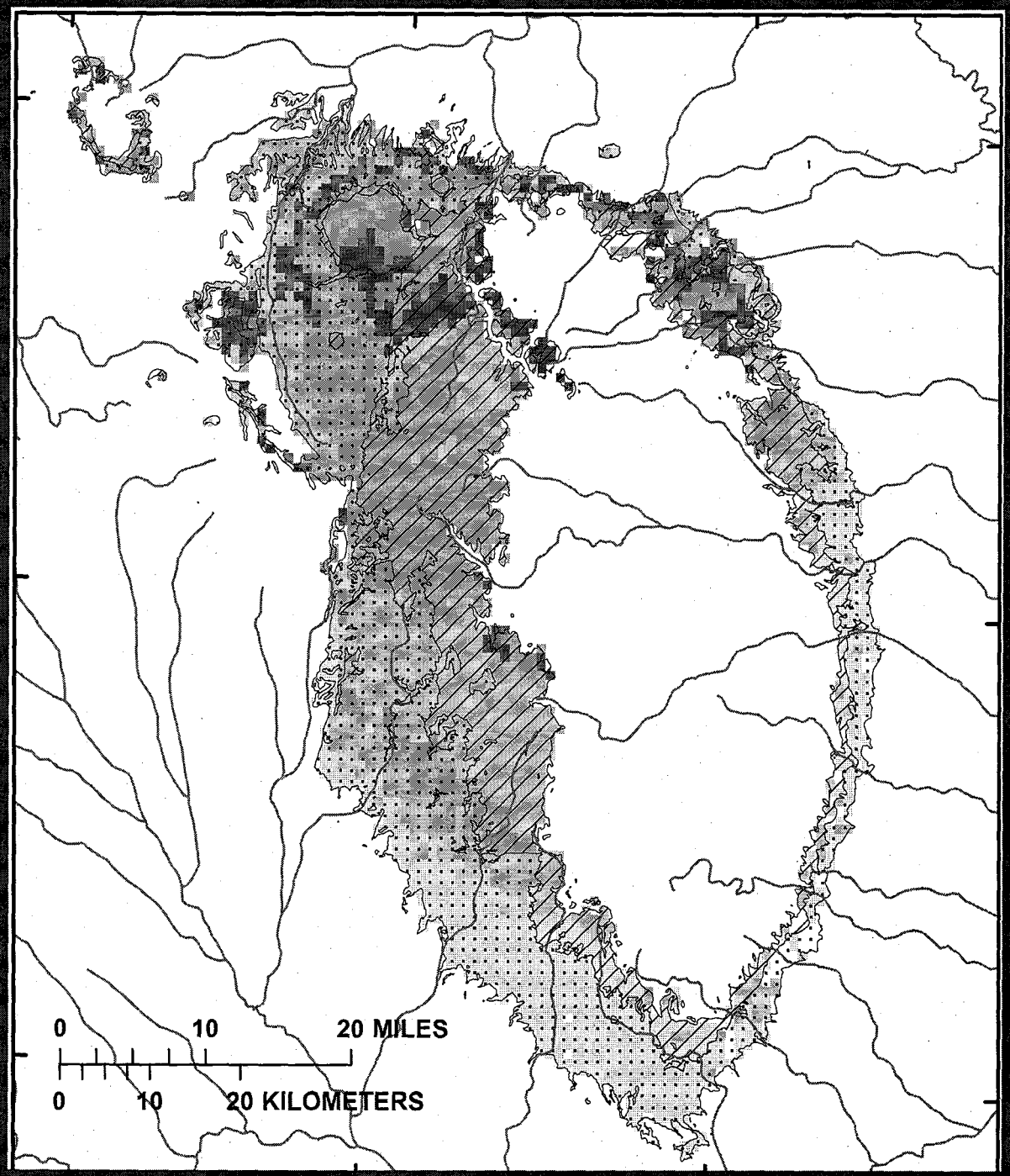
Putnam and Long, 2009, USGS report

USGS

Precipitation recharge

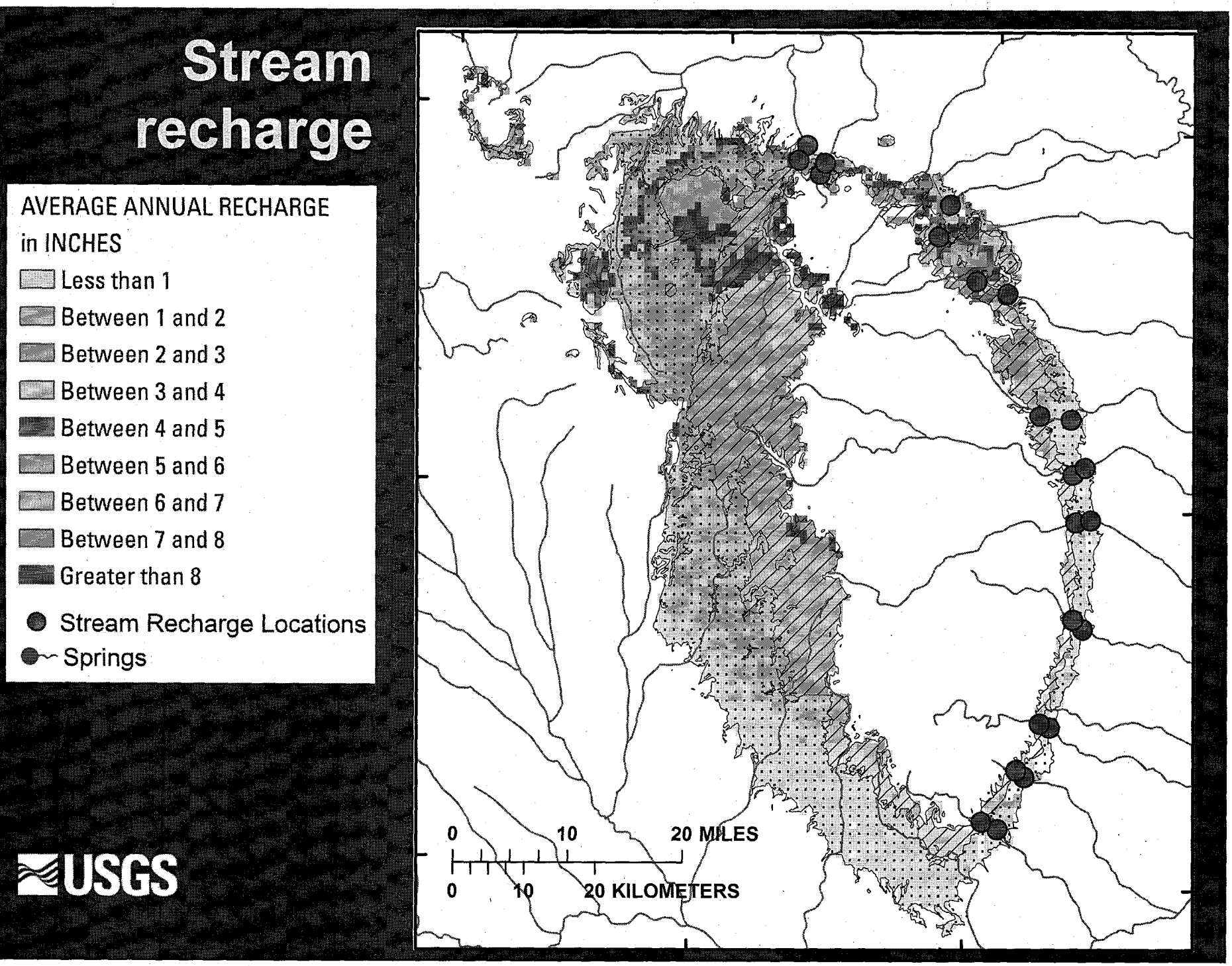
AVERAGE ANNUAL RECHARGE
in INCHES

- Less than 1
- Between 1 and 2
- Between 2 and 3
- Between 3 and 4
- Between 4 and 5
- Between 5 and 6
- Between 6 and 7
- Between 7 and 8
- Greater than 8



USGS

Stream recharge

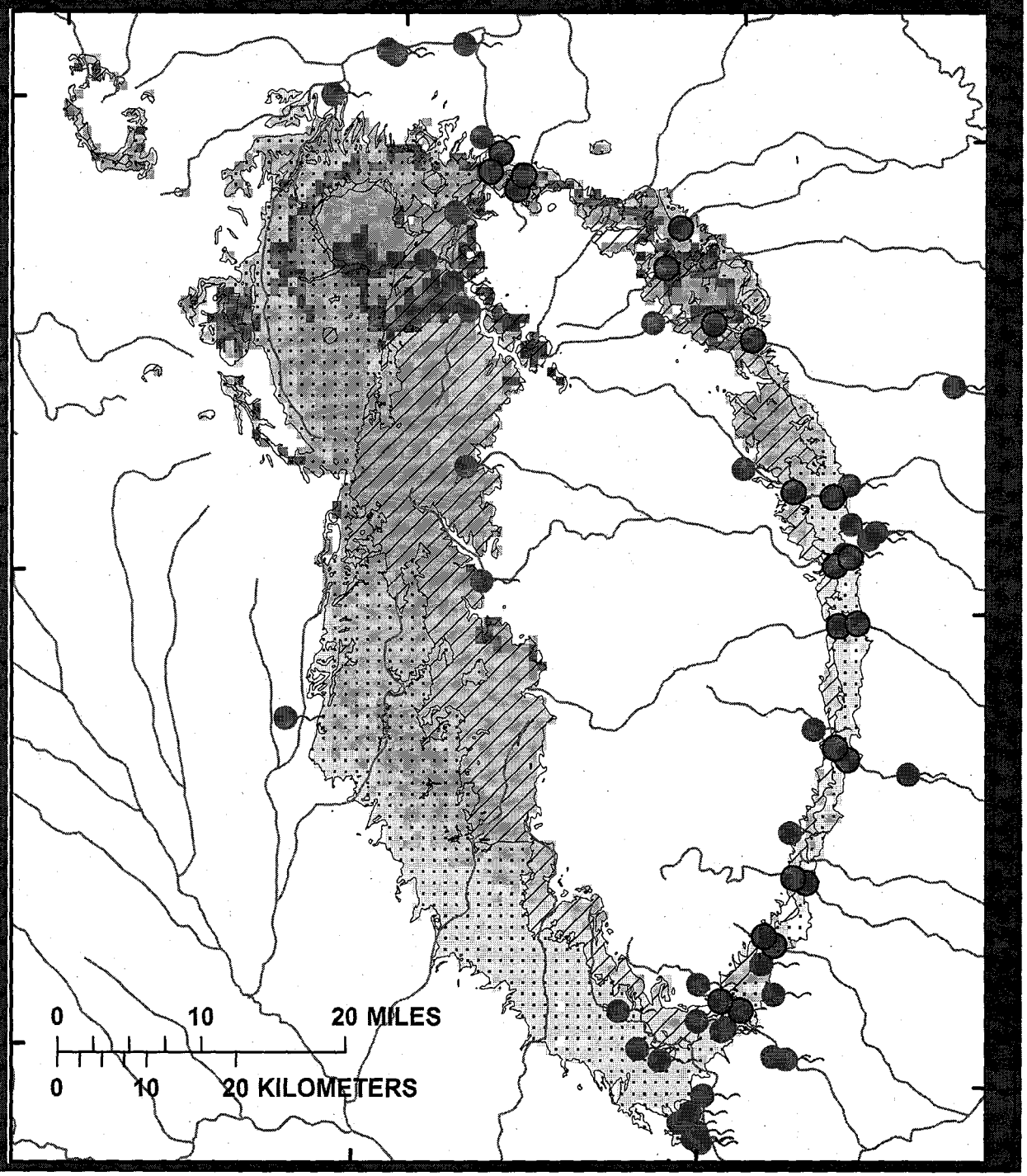


Spring discharge

AVERAGE ANNUAL RECHARGE
in INCHES

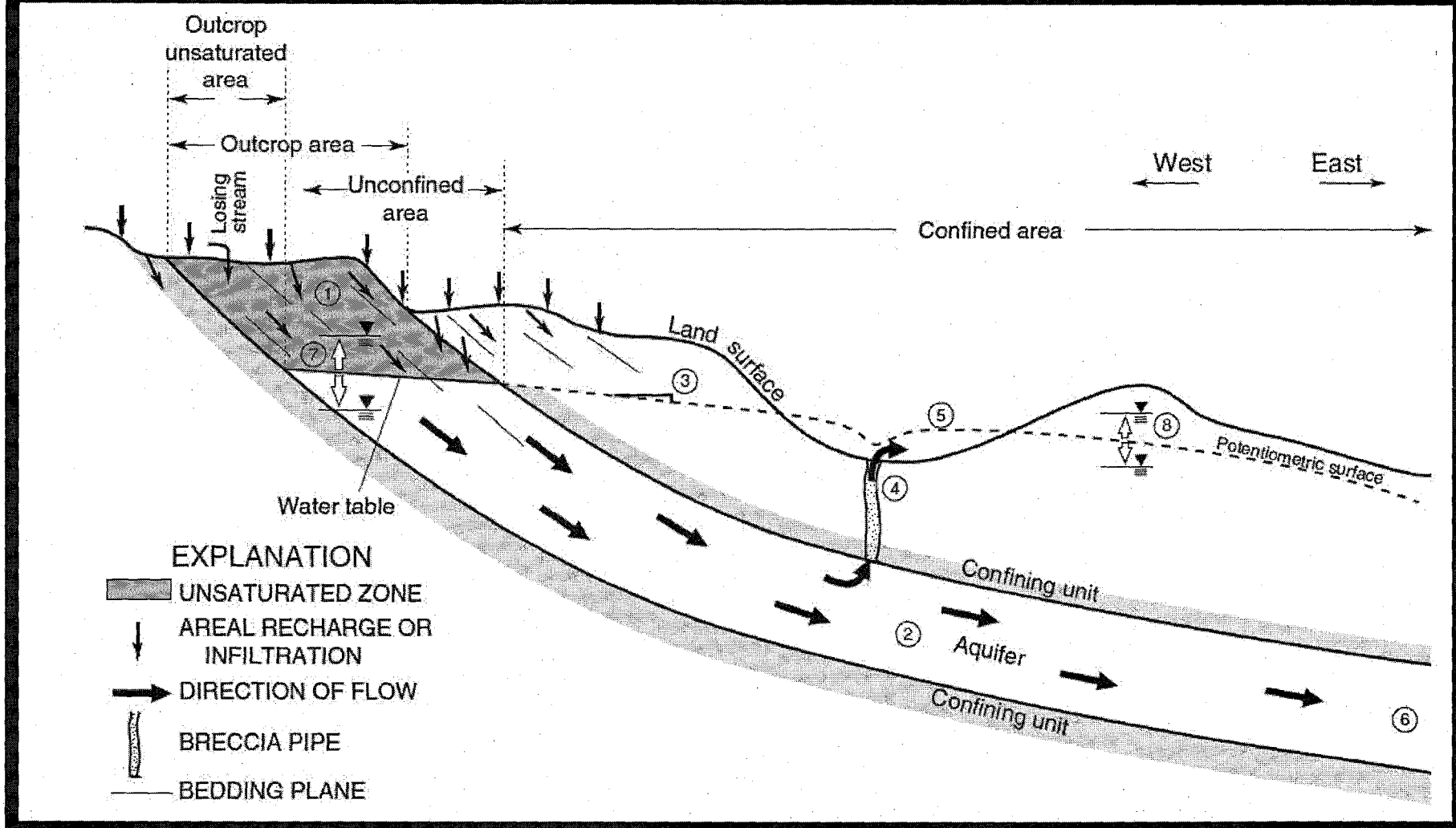
- Less than 1
- Between 1 and 2
- Between 2 and 3
- Between 3 and 4
- Between 4 and 5
- Between 5 and 6
- Between 6 and 7
- Between 7 and 8
- Greater than 8

- Stream Recharge Locations
- Springs



USGS

Profile view of an artesian spring in the Black Hills

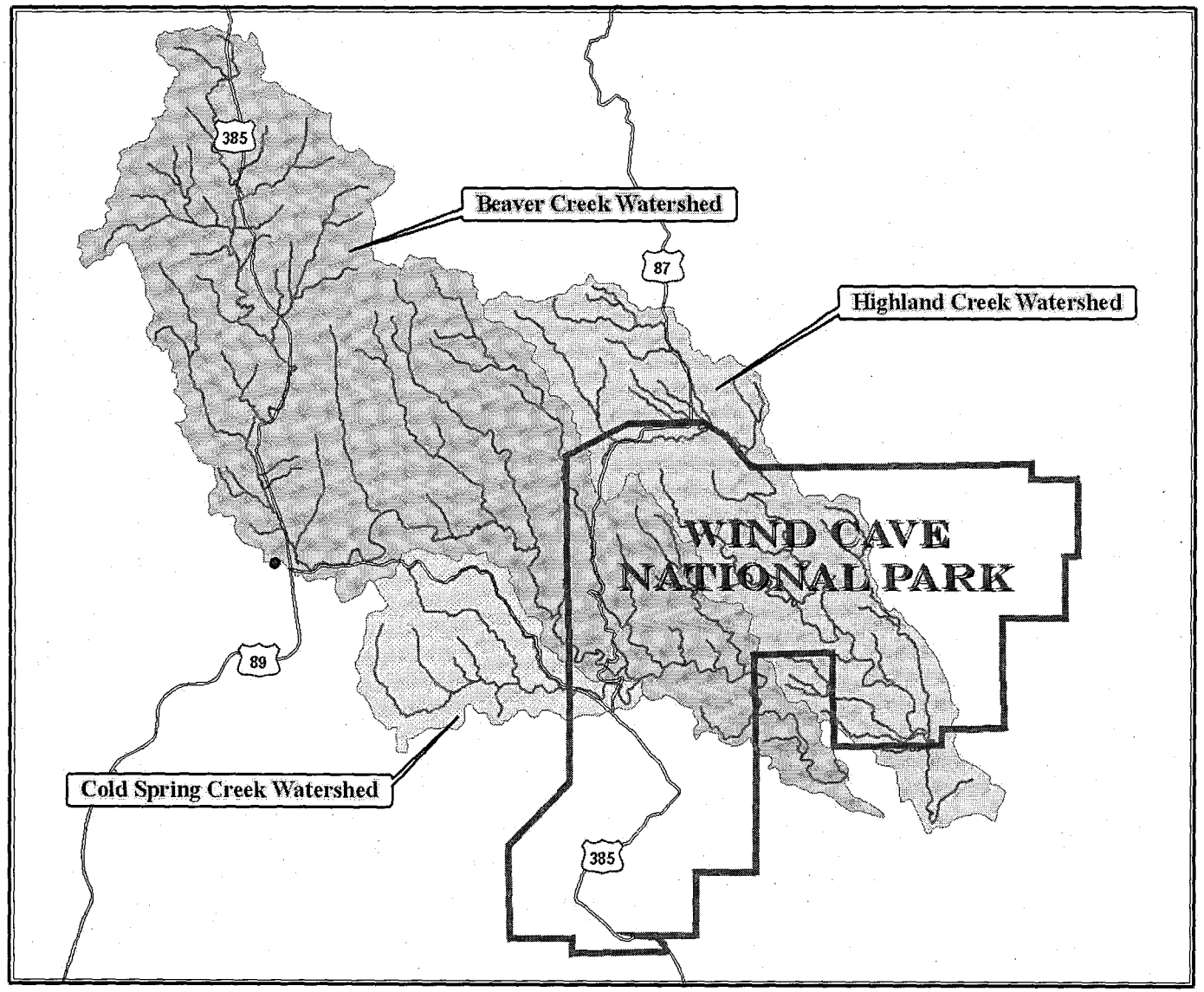


USGS

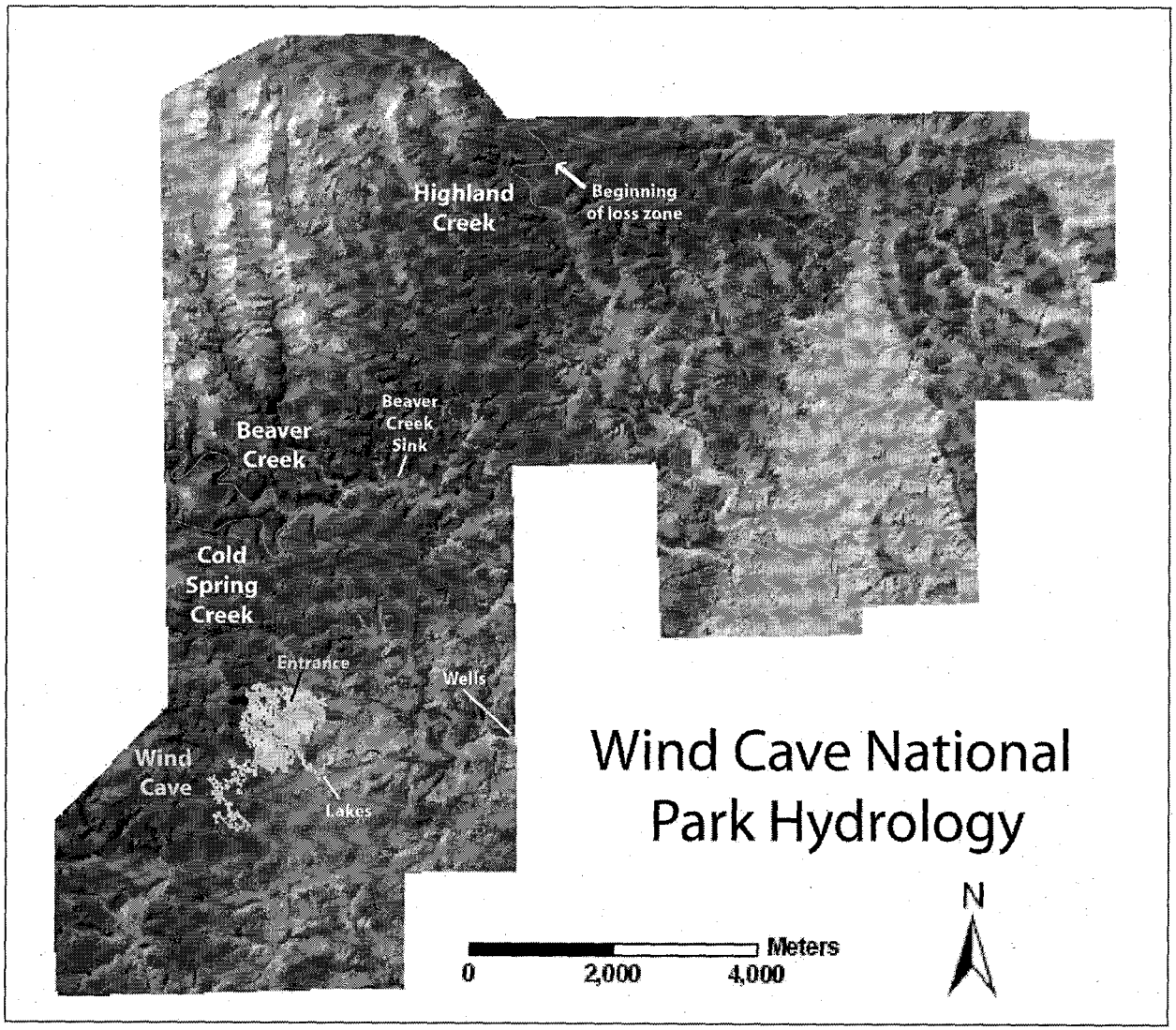
The Significance of the Wind Cave Lakes

Rodney D. Horrocks, Physical Science Specialist, Wind Cave National Park

Wind Cave National Park

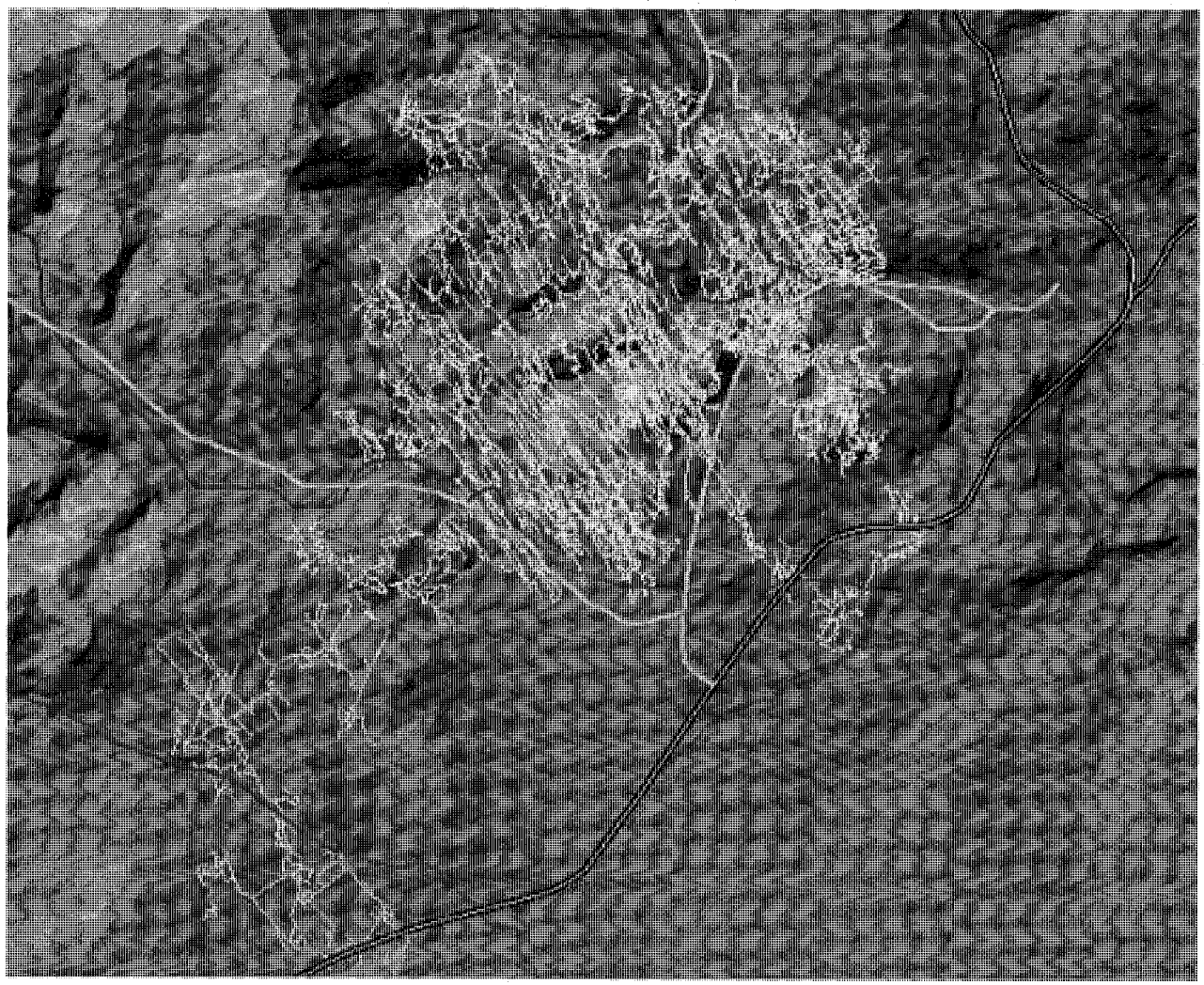


Wind Cave National Park



Wind Cave National Park

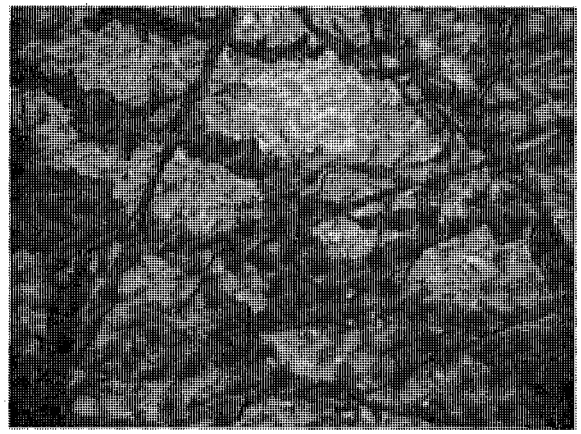
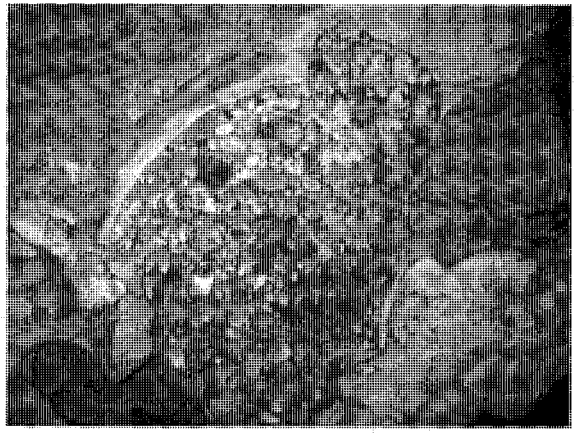
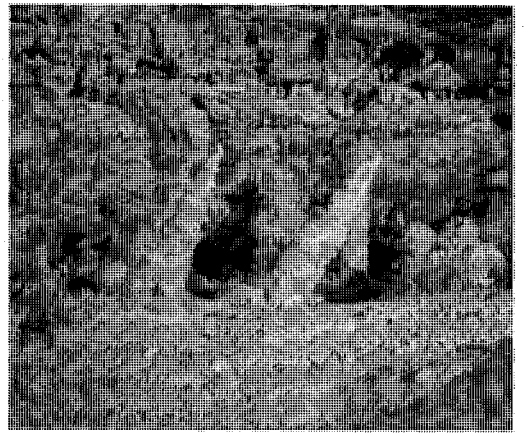
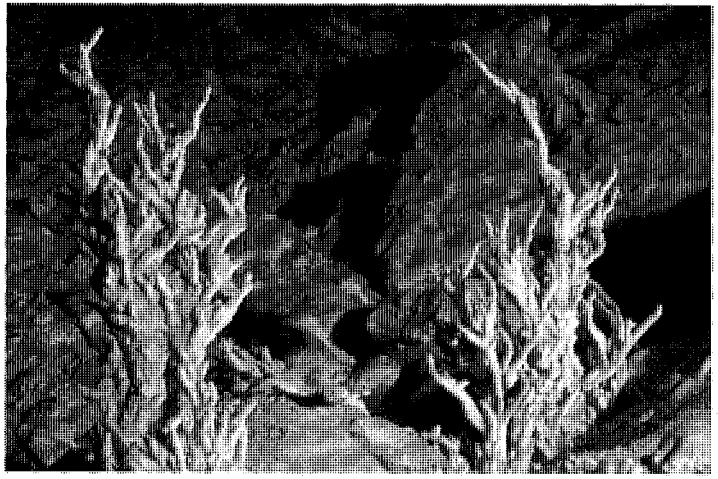
The most complex cave in the world was created by water

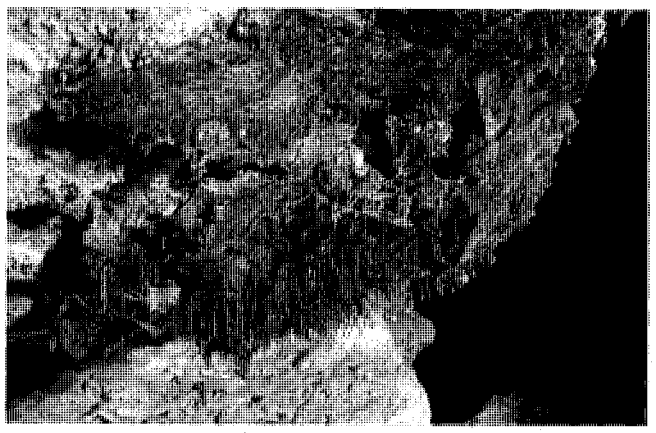


122.12 Miles of Surveyed Passage

Wind Cave National Park

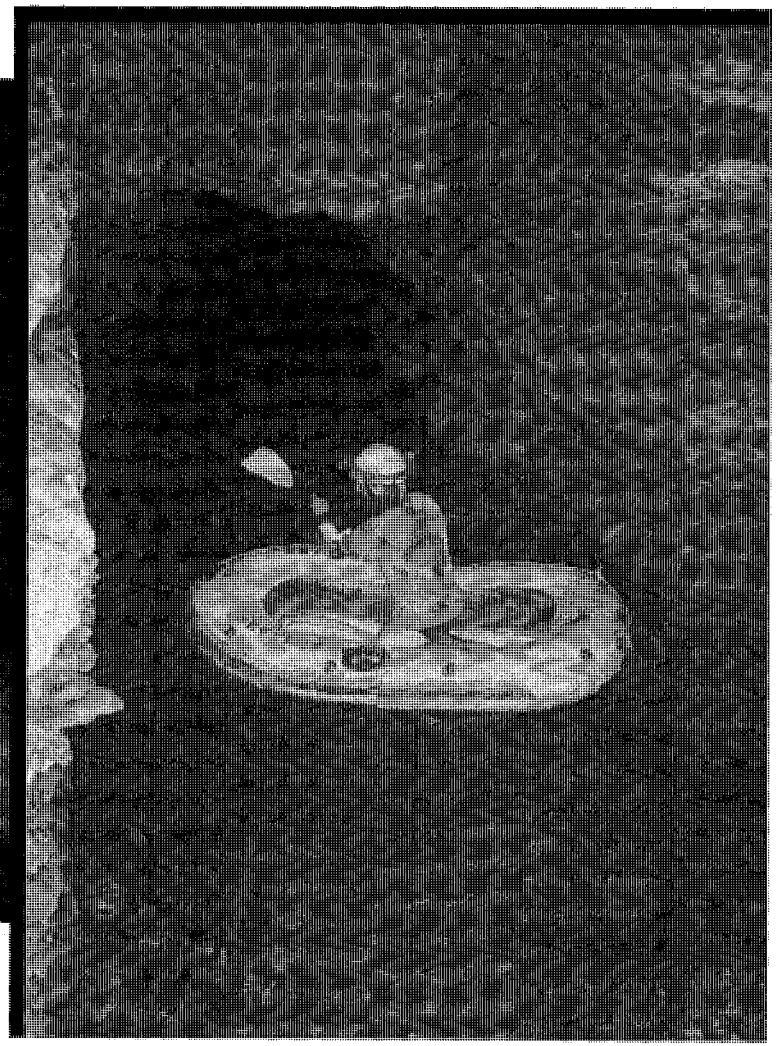
Significant Water Related Features Found in Wind Cave



Wind Cave National Park

Wind Cave Currently Intersects the Water Table



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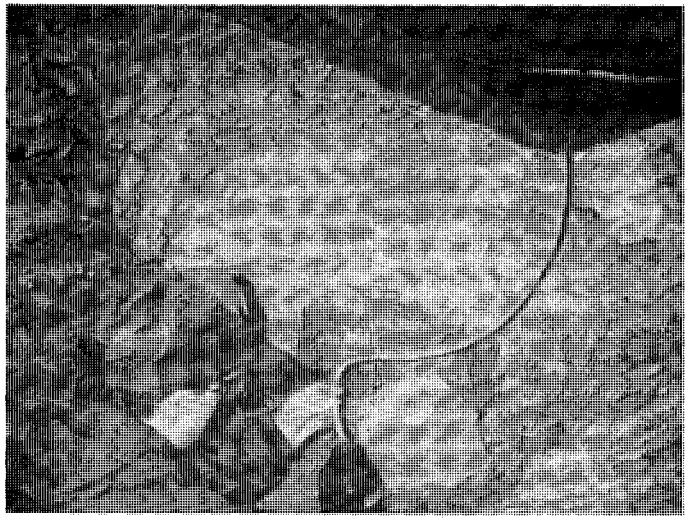
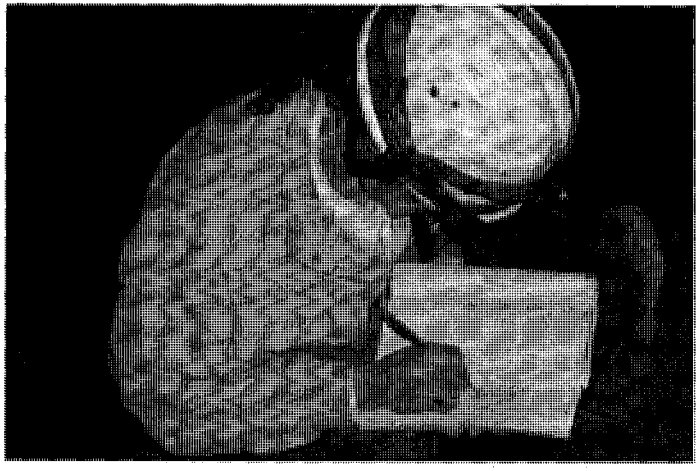
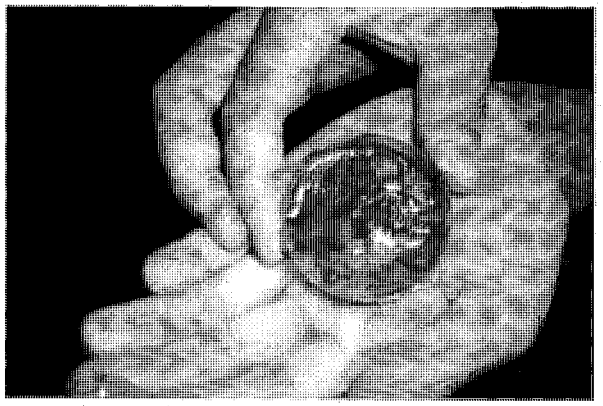
Hydrological Research in Wind Cave







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Published Hydrological Research to Date:

Alexander, E. Calvin, Jr. and Davis, Marsha. 1988. Water Budget for Wind and Jewel Caves. University of Wyoming NPS Research Center: 175-179.

Gries, John Paul. 1959. Preliminary Report on the Potential Ground Water Within the Boundaries of Wind Cave National Park, Custer County, South Dakota 17 p.

Heakin, Alan J. 2004. Streamflow and Water-Quality Characteristics for Wind Cave National Park, South Dakota, 2002-2003. USGS Scientific Investigations Report 2004-5071, 68 p. with CD.

Millen, T.E. & D.N. Dickey. 1987. A Stable Isotopic Investigation of Waters and Speleothems and in Wind Cave, South Dakota: An Application Of Isotope Paleothermometry. National Speleological Society Bulletin 49: 10-14.

Miller, T.E. 1989. Evidence of Quaternary Tectonic Activity, and for Regional Aquifer Flow at Wind Cave, South Dakota. National Speleological Society Bulletin 51: 111-119.

Ford, D.C., A.N. Palmer, & others. 1993. Uranium-Series Dating of the Draining of an Aquifer: The Example of Wind Cave, Black Hills, South Dakota. *Geological Society of America Bulletin 105*: 241-250.

Schroeder, W. 1989. Report on Location and Quantitative Water Measurements of Surface Water Resources within Wind Cave National Park Fall 1987 to Winter 1988. 15 p.

Whalen, P.J. 1994. Source Aquifers for Cascade Springs, Hot Springs, and Beaver Creek Springs in the Southern Black Hills of South Dakota. MS Thesis, South Dakota School of Mines and Technology, 299 p.

Wind Cave National Park

Hydrologic Profile of Wind Cave

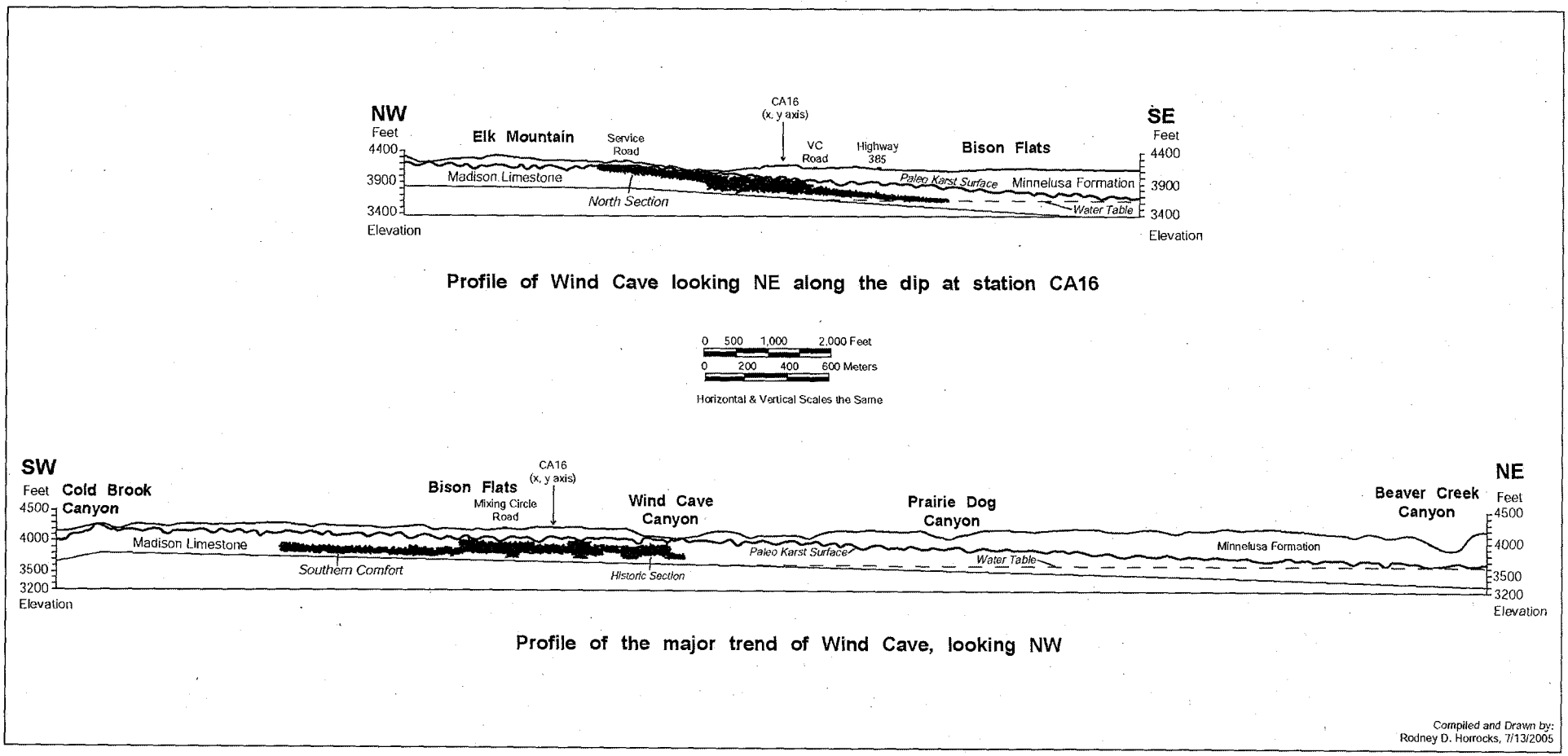
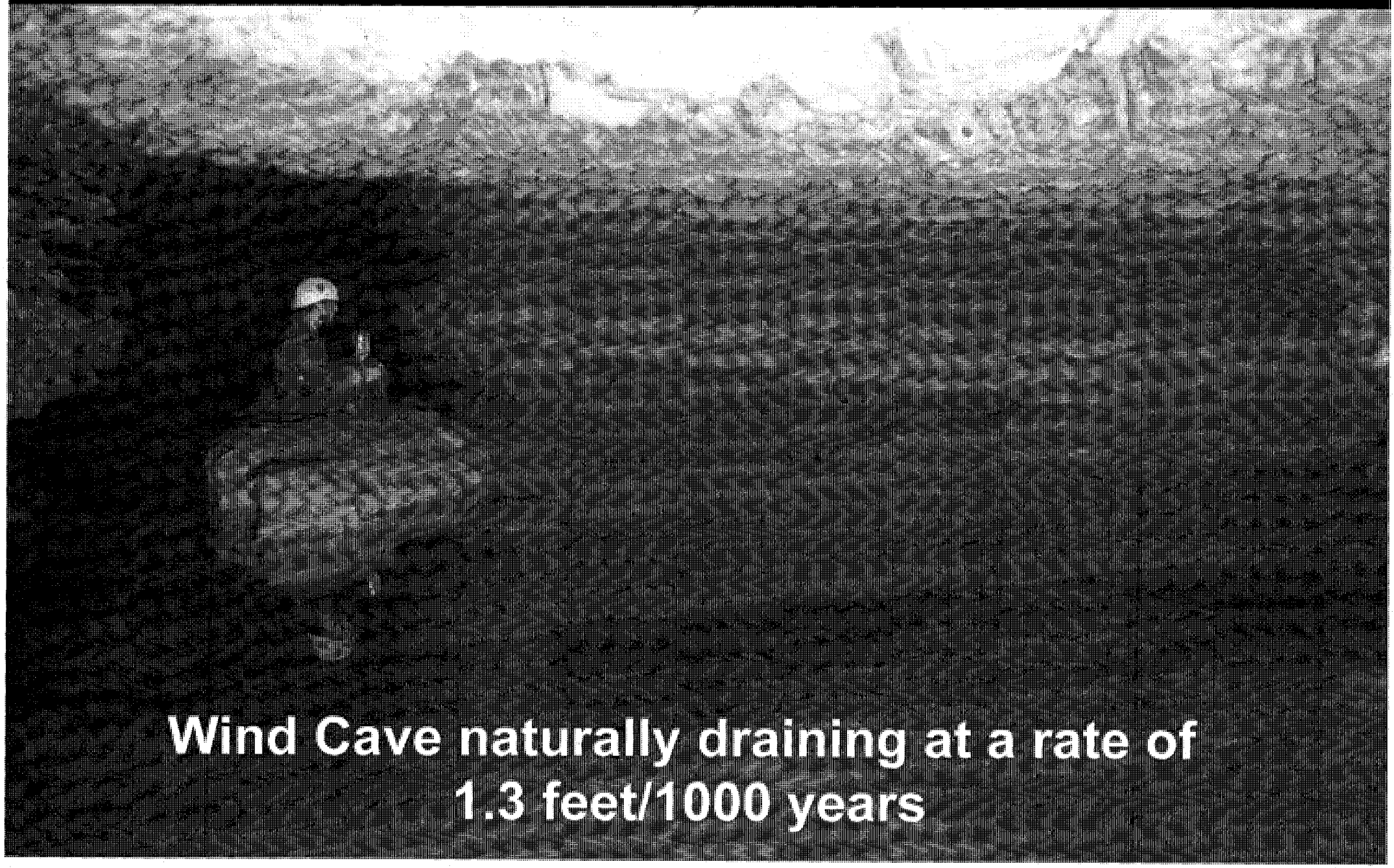


Fig. 4, Profiles showing the relationship of surveyed passages in Wind Cave with structural geological and hydrological factors.

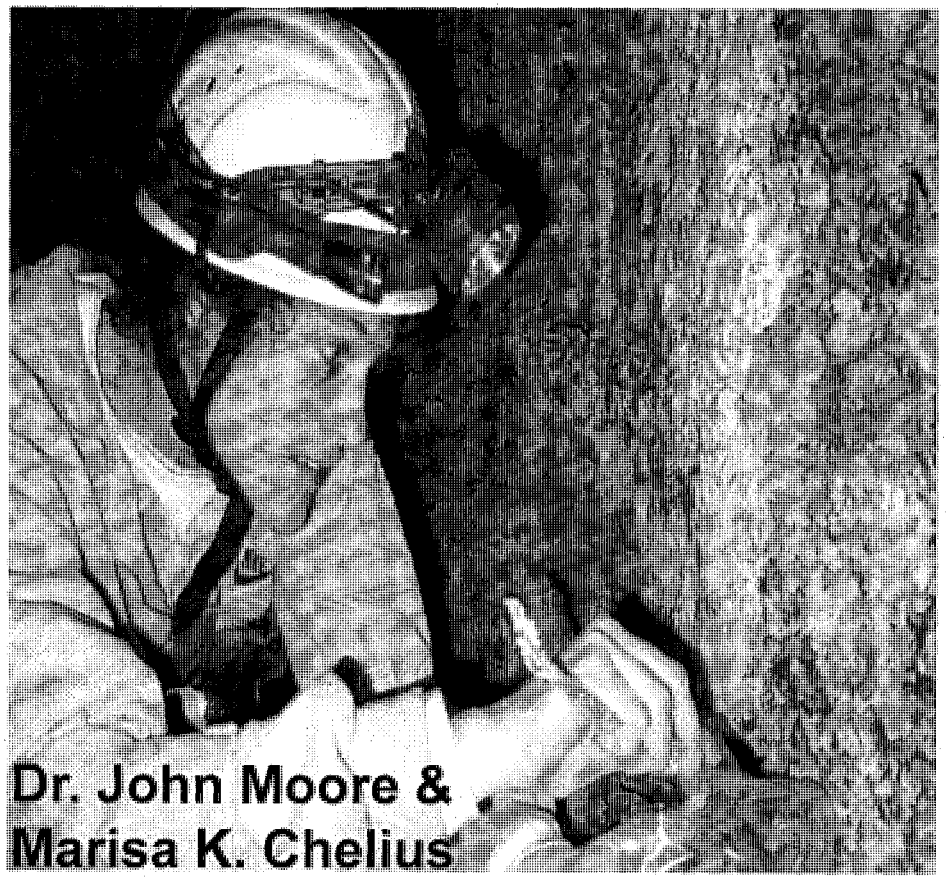
Wind Cave National Park

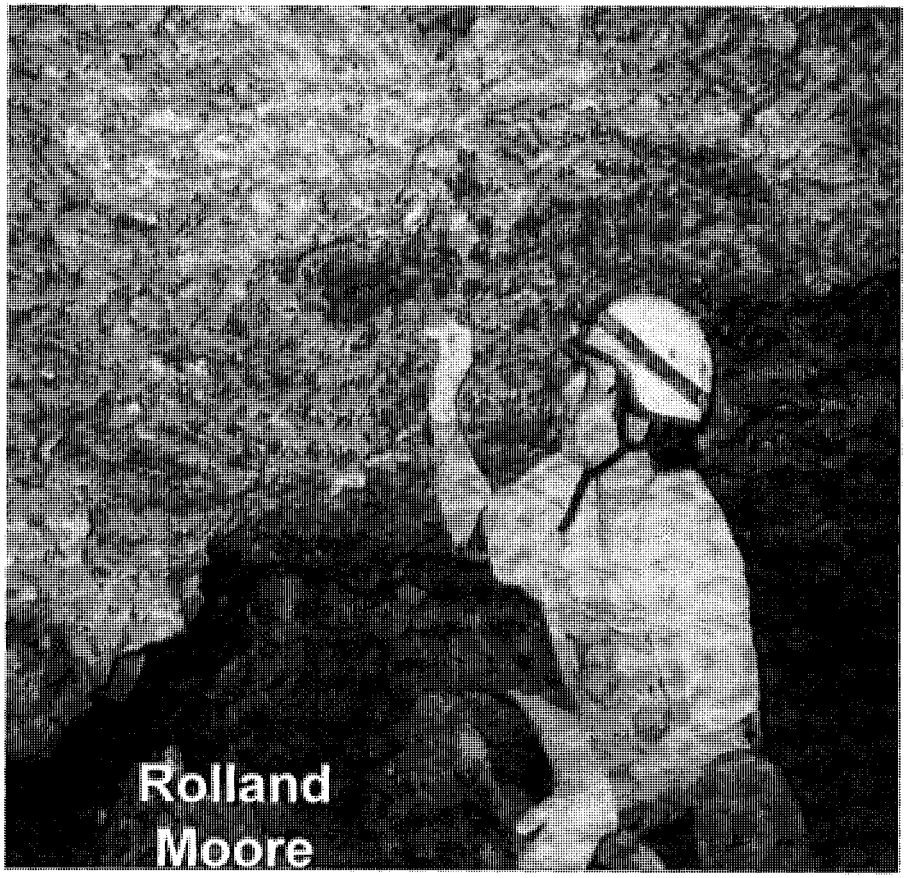


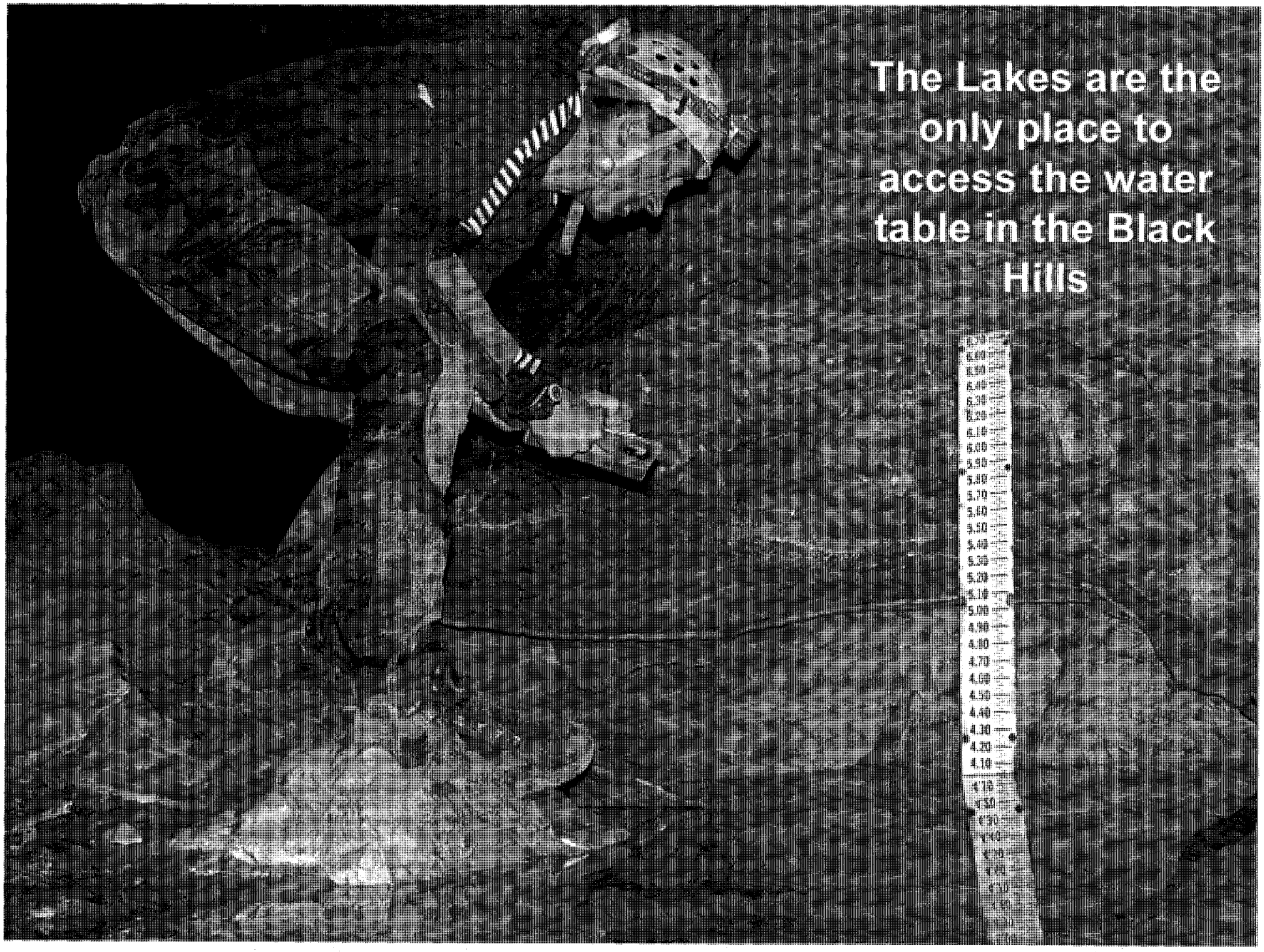
Wind Cave naturally draining at a rate of
1.3 feet/1000 years

Wind Cave National Park

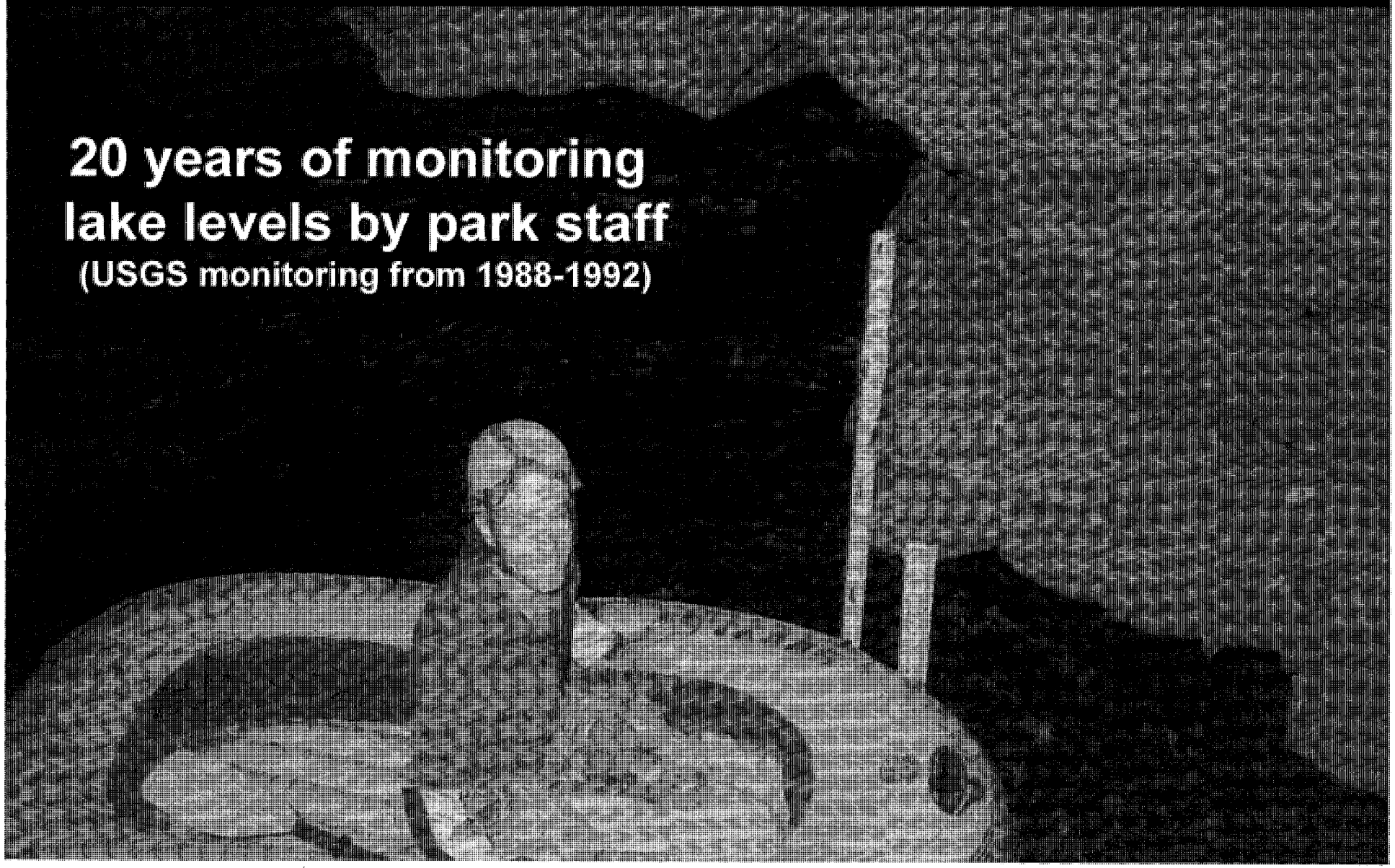
Microbial research started in Wind Cave, but not in the Lakes


Dr. John Moore &
Marisa K. Chelius


Rolland
Moore


The Lakes are the only place to access the water table in the Black Hills

Wind Cave National Park



20 years of monitoring lake levels by park staff

(USGS monitoring from 1988-1992)