COVER SHEET FOR GRANT PROPOSALS

State Board of Education

SBOE PROPOSAL NUMBER: (to be assigned by SBOE)	AMOUNT REQUESTED: $50,000

TITLE OF PROPOSED PROJECT:

Device for Subsurface Environmental Monitoring, Ready for Prototype

SPECIFIC PROJECT FOCUS: Create and demonstrate prototype while working with industry partner on specifications and business (licensing) relationship

PROJECT START DATE:	PROJECT END DATE:
NAME OF INSTITUTION: Boise State University	DEPARTMENT: Geosciences

ADDRESS: Department of Geosciences, Boise State University, 1910 University Dr., Boise, ID 83725

	E-MAIL ADDRESS: wbarrash@cgiss.boisestate.edu	PI PHONE NUMBER: 208-426-1229

	NAME:	TITLE:	SIGNATURE:
PROJECT DIRECTOR	Dr. Warren Barrash	Research Professor	[signature]
CO-PRINCIPAL INVESTIGATOR	Dr. Michael Cardiff	Assistant Research Professor	[signature]
CO-PRINCIPAL INVESTIGATOR			
CO-PRINCIPAL INVESTIGATOR			

	NAME:	SIGNATURE:
Authorized Organizational Representative	Mary Givens	[signature]
	Karen Henry	[signature]

DEVICE FOR SUBSURFACE MONITORING, READY FOR PROTOTYPE

US Patent-pending, Boise State University

Proposal section, 10 pages, p. 2-11:

1. Name of faculty member directing the project: Dr. Warren Barrash

2. Name of Idaho public institution: Boise State University

3. "Gap" Project Objective and Total Amount Requested: The objective of this project is to create a prototype of a device for subsurface monitoring to demonstrate the technology to potential licensees. Prototype development is the single most important next step for commercialization. A Boise State University (BSU) start-up company will be incorporated in parallel with prototype development as outlined in this proposal to take the prototype to commercialization. Activities in this project are planned so that (a) prototype development will meet industry specifications and (b) commercial production, distribution to vendor(s), and sales of the system under patent and contractual business arrangement(s) with established leading hydrology/engineering field equipment distributor(s) will follow shortly after completion of this project. Distribution and sales following development are realistically expected given the current gap in the market for temporary (reusable) modular packer-and-port systems and the potential for share in the market for permanent packer-and-port systems with the device (Modular Hydraulic Packer-and-Port system, or *MHPS*) which is easier to use and more adaptable to field conditions than currently available systems. The leading distributor of hydrologic-engineering field equipment (Solinst Canada) has expressed strong interest in providing in-kind assistance to us to expedite development of the *MHPS* to specifications that will fill the "gap" in the market (see Appendix C.3).

Total Amount Requested: A $50,000 budget is requested for this project (see Section 6 and Attachment 1).

Gap/Market Opportunity: The subject of this project is the *Modular Hydraulic Packer-and-Port System (MHPS), US patent-pending, Boise State University,* a new type of device for subsurface monitoring in wells (Figure 1) which: (a) provides location-specific water sampling and/or monitoring capabilities in multiple zones; (b) is light-weight, is an easily-managed size (individual packers are about 4 ft long), and is easily assembled (by two people using minimal supporting equipment) into a variety of configurations to suit a particular sampling and/or testing application; and (c) is easily disassembled to allow temporary use in new or existing wells; or (d) can be configured for permanent installation. Such targeted, location-specific sampling and/or monitoring is needed or is potentially useful at literally tens of thousands of sites with contamination or other engineering or mining management issues (such as concerns with water levels or water pressure, water chemistry and/or temperature, and their distributions in the subsurface) that require location-specific information in an aquifer, and that may require rearrangement or removal of the in-well packer-and-port system as testing progresses or the

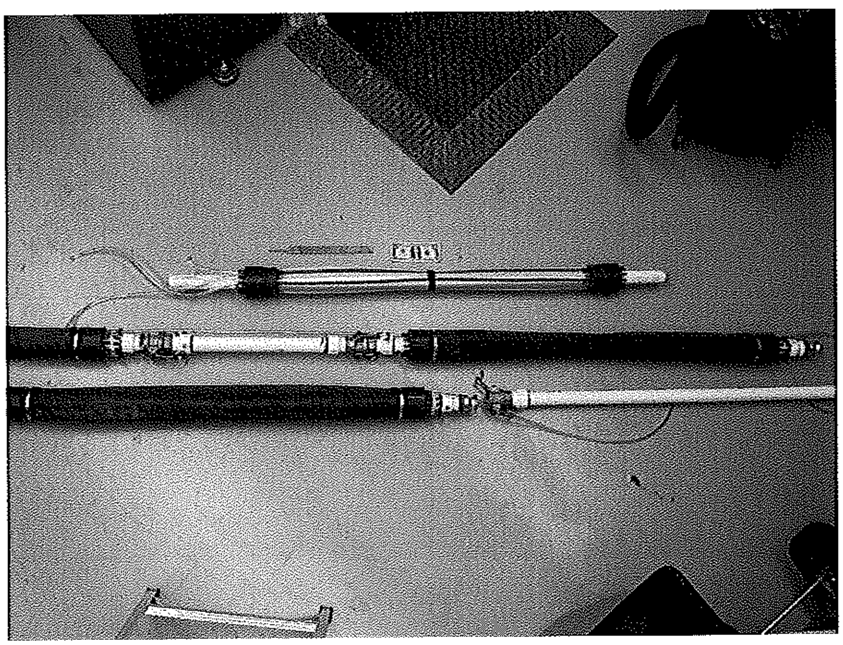

Figure 1. Example components of the Modular Hydraulic Packer and Port System (*MHPS*) in current-stage mock-up. Components are at scale (length between clamp rings is 1 meter) and made with low-cost, light-weight materials such as off-the-shelf PVC pipe, plastic tubing, and cam-locks similar to those that will be used for commercial-grade prototype.

project develops in successive phases. In addition, the *MHPS* provides the unique capability – i.e., not currently available in the market – for better targeting of isolated zone positions, more zones that can be isolated per well, and more dedicated sampling tubes that can be monitored or sampled per zone (i.e., for more parameters or chemical species as needed).

Intellectual property status: A provisional US patent application for the *MHPS* was filed on November 23, 2010 (assigned serial number 61/416,200) by patent attorneys at Zarian Midgley & Johnson, PLLC on behalf of Barrash and Cardiff and BSU following the BSU intellectual property policy. Non-Disclosure Agreements (NDAs) have been executed to facilitate discussions (a) with Solinst Canada on interest in assisting with *MHPS* development and developing a business relationship and (b) with TechHelp about engineering support on several *MHPS* components.

The technology: The technology was developed by Barrash and Cardiff in August 2010 with funding from Barrash's NSF grants: EAR-0710949 (Collaborative research: Hydrogeophysical quantification of hydraulic conductivity from electrical measurements of the effective properties of porous media) and DMS-0934680 (Collaborative research: Subsurface imaging and uncertainty quantification). The *MHPS* operates by inflation of flexible bladders (i.e., packers) with excess hydraulic head generated by adding water to a riser column that is open at the surface of a well and open to the bladders through holes in the riser. The excess head is the height of water in the riser that is greater than the height of water in the geological formation, or aquifer, that is pressing on the outside of the bladders or packers in the well. That is, the higher water pressure in the riser column and the inside of the packer (compared to the water pressure in the well and the aquifer outside of the riser and packers) forces the flexible packer to expand until it "seals" against the well wall or screen.

The science/technology is well established in theory and practice for inflation of flexible bladders with excess pressure or hydraulic head to achieve sealing against borehole walls to isolate specific intervals between packers. The hardware development and integration risk is low because no critical technology remains to be developed. Remaining development includes improving several important components and testing of materials (especially packer sections with collar connectors; packer material; bottom plug), and fabrication, assembly, and specification testing to optimize their ability to work together in the required manner.

Commercialization Partners: Initially we anticipate working with Solinst Canada who is interested in helping us develop the *MHPS* for commercialization (see Appendix C.3). Also we will be seeking guidance from Mary Givens, Director of the the BSU Technology Transfer Office (TTO) and working with MBA or business classes on strategies we can pursue with other possible national and international private sector distributors, and whether any of these arrangements would best develop with local management of fabrication (i.e., local commercial partners for financing and fabrication).

Partnerships with the public or private sector or contributes to new company creation: Product marketing and distributing will be in partnership with established company(ies) that provide technical equipment to the hydrologic and engineering communities such as Solinst Canada and RocTest Ltd – both of which have >10 year histories of working with Barrash on orders for and modifications of somewhat similar components worth thousands and tens of thousands of dollars. Discussions with Solinst Canada for possible marketing and distribution partnerships are underway and have included discussion of arrangements such as licensing with payment of royalties on sales.

Applications and markets for the technology including market demand projections: Applications include in-well subsurface: (a) 3-dimensional (3D) sampling for contamination distribution; (b) 3D monitoring of contamination presence or remediation progress; (c) 3D characterization of hydraulic properties that control water flow and contaminant transport and chemical behavior; and (d) 3D remediation engineering (controlled emplacement of chemical or biological agents; removal or injection of water or other fluids to mix, degrade, control movement, extract in targeted location-specific and time-specific manner as needed). Application environments include aquifers and the partially saturated zone between the land surface and the water table. Sites needing subsurface environmental characterization for water quality and engineering applications (including evaluation of contamination status, remediation, and monitoring) number in the tens of thousands (or more internationally). Better market demand projections will be part of the business planning component of this project. Range of applications and markets for the *MHPS* will be expanded from the initial design with follow-on variations for application to wells of different sizes and to different water chemistries.

The product, its potential market audience, the competition, barriers to market entry: Potential market audience includes hydrologic, engineering, mining, energy, and regulatory organizations interested in selling or buying in-well multi-level equipment to accomplish subsurface investigation, production, monitoring, or clean-up operations. There is no competition currently for temporary in-well multi-level packer-and-port systems. The *MHPS* can be adapted to permanent installation where competition exists from several types of established permanent in-well multi-level systems with overlapping sampling and monitoring capabilities. However the *MHPS* will be easier to install, will be competitive in price, and will allow greater numbers of sampling zones per well than existing permanent systems, and greater numbers of sampling lines (tubes) per zone for a given number of packers than existing systems.

Barriers to market entry in terms of target audience demand are lack of familiarity and experience with the *MHPS*. These barriers can be overcome in general by (a) marketing and distribution by Solinst, the most-established distributor of similar types of products, and (b) by generating high-credibility technical awareness through publications and by talks at professional meetings that can provide confirmation of the ease of use and robustness of packer performance for temporary or permanent use (already underway and generating interest). Barriers to entry in terms of product development include identification of packer material that is sufficiently flexible and durable, demonstration of packer clamping approach that assures no leaks or slippage, and demonstration of simple conversion from temporary to permanent installation with displacement of water fill (i.e., temporary configuration) in the riser and packers by commercially available non-contaminating pumpable sealing grout (e.g., Puregold ® by CETCO, www.cetco.com or equivalent).

The technology and the current state of the technology: The *MHPS* is a collection of easily assembled riser (PVC pipe) sections and riser-with-attached-inflatable-packer sections that can isolate specific intervals of a well for simultaneously sampling water and/or monitoring water for pressure, temperature, and/or other parameters in the separate, isolated intervals. The measurements or samples can be taken through commonly available plastic tubes (Figure 1) connecting the isolated zone(s) to the surface. The water level or pressure sensors (e.g., fiber optic transducers) need only go through the tubes to or slightly below the static water level while the water samples are pumped to the surface through other tubes (e.g., with a peristaltic pump).

The packers are inflated with hydraulic pressure that is greater than the static pressure in the undisturbed borehole; the excess hydraulic pressure is generated by simply pouring water into the riser (which is capped at the bottom) to a particular level above the static water level in the well (static water level is known by taking the simple measurement of water level in the well before placing the packer and port system in the well). The amount of excess head to add is known from tables we will provide. Similarly, the system can be easily removed by pumping water from the riser until the packers deflate, at which point the column can be raised with little effort because of buoyancy.

The principal benefits of this technology are: ease of assembly, ease of maintenance of a given configuration in the field, and ease of disassembly or modification compared to current technology – all of which save time (money) and aggravation, and allow the user to better configure the sampling and testing system to the needs and details of a given site at a given time (better results). Also supplementary pressurization through a manifold at the wellhead is no longer needed – which saves time, aggravation, and money because (a) less equipment needs to be purchased as part of the system, (b) less equipment needs to be available to make the system functional and keep the system functional in the field (e.g., for initial pressurization, maintenance of pressurization, and measurement of pressurization), and (c) down-time and aggravation are eliminated or greatly reduced by having an open riser system that doesn't require pressurization maintenance and is less prone to pressure leaks (which are difficult and time-consuming to locate and fix). Also tubes connecting the testing zones with the surface are outside the riser and do not need to be threaded through, and pressure-tight through, a manifold on top of the riser system at the wellhead. Importantly also, having the tubes on the outside of the riser allows for greater numbers of sampling tubes and/or zones to be used overall, and for easy modification of how many and which tubes are used to sample specific available zones.

The current state of the technology of the invention has been demonstrated in principle with adapted components during field research activities by PIs Barrash and Cardiff in 2010. That is, this project can focus on developing, testing, and refining a prototype rather than on demonstrating that a concept will work.

4. <u>How resource commitments reflect the priorities of Boise State University</u>: Resource commitments (Appendices A and C) include: (a) continued, normal use of research, office, and logistical space, equipment, tools, and utilities at BSU offices and laboratories including the BHRS; (b) continued normal support by the technicians at the COAS Scientific Shop; and (c) assistance by BSU TTO Director Mary Givens with guidance for intellectual property and business essentials. These commitments are consistent with BSU's priorities to support research and research contributions to education in existing degree programs – in a manner similar to what has been committed for similar research activity and equipment development support for Dr. Barrash's research program at BSU over the last 15 years (see Appendices B.1 and B.3).

5. <u>Evidence that the project will have a potential impact to the economy of Idaho</u>: At a minimum, BSU and the inventors will receive royalties in Idaho from sales of the *MHPS*. Unit sales (where a unit is an *MHPS* system for isolation of zones in an average 100 ft deep well with an average number of 5 packers) at fully established market share have been estimated to be in the thousands by both Solinst Canada and students in the MBA585 class at BSU. The best estimate from the class was 5000 units (systems) with pricing recommendation leading to a unit/system price by the MBA585 class of $6240 using cost-plus-30% pricing. At achievement of this level of sales ($31,200,000), the cost-plus portion of revenue from sales would be $9,360,000. Also the *MHPS* expands the market for Idaho measurement instrument manufacturer Quality Thermistor, and for resident environmental and engineering services providers such as URS, CH2MHill, and the INL among others. Actual licensing and perhaps fabrication and assembly of the *MHPS* may be managed by inventors Barrash and Cardiff in Idaho (i.e., providing jobs and revenue); currently Barrash and Cardiff are forming an LLC (i.e., to be incorporated and operated in Idaho) with a third research partner (Dr. Peter Kitanidis at Stanford University) to manage these operations and to develop and commercialize associated products and services related to hydrologic and hydrologic engineering capabilities using applications of the *MHPS*.

6. Specific Project Plan and Detailed Use of Funds: We have a project plan to address development of (a) the *MHPS* prototype and (b) the business side of commercialization.

Primary *MHPS* development tasks include: (a) collaboration with Solinst Canada on equipment and testing specifications and on finding sources for materials and supporting parts; (b) acquisition of stock materials and components; (c) working with TechHelp for engineering on several components; (d) working with the COAS Scientific Shop for fabrication of components for prototype(s); and (e) assembly and testing of prototype(s) in the lab and the field with (f) on-going feedback and iteration to refine the product. Tasks (a), (b), and (c) will proceed immediately upon project award and will be followed as soon as possible by (d) and (e), and then followed by (f) for the remainder of the project.

Primary business development tasks will proceed in parallel with the prototype development with the assistance of: Mary Givens, Director of OTT; MBA and undergraduate business students; and the Idaho Small Business Development Center on the BSU campus. Tasks will include: (a) completion of documents for US patent and filing by patent attorneys in association with BSU by October 2011; (b) formation of new Idaho company (Barrash Cardiff & Kitanidis LLC) by August 2011; (c) development of license agreement with BSU to market the *MHPS* by January 2012; (d) business plan development and continued market assessment throughout the project period; and (e) negotiation with and possible formalization of agreements with North American commercial partner(s) by July 2012. We (in association with BSU) will also (f) be exploring international patent and business arrangements throughout the project period including an expected PCT filing for European countries in late 2011 or early 2012.

Project reporting with HERC will occur quarterly. With respect to task milestones and performance metrics, we expect to have a set of first-round prototypes developed in 3-4 months with testing to follow for 1-2 months including shipment of an example subset to Solinst Canada for examination and feedback. Then we plan to repeat with refinements based on our experience and feedback from Solinst to have a tested, salable, "version 2" prototype by the end of month 10 to support serious negotiations with Solinst (and/or others) for a license agreement. Discussions with Solinst Canada for possible marketing and distribution partnerships have been initiated and have included discussion of arrangements such as licensing with payment of royalties on sales.

Detailed Use of Funds with Proposed Budget: The proposed budget of $50,000 (with no F&A charges) includes:

$32,200 for Salary (Barrash – 2 months, Cardiff – 1 month, student(s) – 3 months);

$8,700 for Fringe Benefits (according to official rates established by BSU); and

$9,100 Other Direct Costs including: parts and materials for fabrication and testing of prototypes; consulting cost estimate for TechHelp engineering design and specification assistance on selected *MHPS* components (e.g., collars, tube connectors, internal sleeve support); computing recharge center surcharge for CGISS research center (as per Geosciences Department policy); and vehicle costs for transportation to field site for prototype testing in wells. Materials and supplies include PVC stock bars for collars, custom rubber/synthetic packer sleeves, connectors for tubing, camlocks, tubes for fluid, risers, miscellaneous tools, and possibly components for a set of smaller-diameter prototypes.

7. Education and Outreach: Graduate student(s) in geosciences will be involved in assembly and in testing of the *MHPS* under different configurations in the lab and in the field. Engineering students will be involved with TechHelp in the design of components as a regular part of TechHelp operations. Also business students (MBA and/or undergraduates) have been and will continue to be involved in helping to prepare a business plan for the commercialization of the *MHPS*. We have had on-going success in attracting and involving high-quality students in research activities due to the strength and reputation of programs in hydrology and geophysics at BSU and due to the policy of providing either thesis work or broadening ("cross-training") experience for interested students in hydrology, geophysics, and geology.

8. Institutional and Other Sector Support: See Appendix A for a description of institutional facilities and equipment, and Appendices C.1 – C.3 for overall Institutional and other sector support including documentation of planned project technical assistance from TechHelp and from Solinst Canada (which has already begun providing this in-kind support and will continue to do so as per letter commitment from them).

Appendices:

Appendix A. Facilities and Equipment:

The Department of Geosciences at BSU is moving into the new Environmental Research Building (ERB) in May/June 2011 that includes dedicated lab space for Dr. Barrash that will support design, modification, and testing of components, alone and together, including barrel-scale submersion tests and individual component pressure tests. The College of Arts and

Sciences (COAS) supports two technicians with electronics and fabrication shop facilities to assist with equipment/instrument fabrication and modification; the technicians and facilities have supported projects such as this repeatedly in the past. Intermediate-scale assembly and testing will be conducted in a BSU staging and storage facility at 1029 Lusk St. (the edge of campus) that has full utilities. Additional equipment and instrumentation to support this project include vehicles, pumps, hoses, generators, flow-meters, fiber-optic transducers and data acquisition systems (including customized software for multi-well, multi-zone testing), and sampling instruments, hand tools, field support gear (tarps, tables, canopies, …). Field-scale testing will occur at the Boise Hydrogeophysical Research Site (BHRS) which is a research well-field 9 miles from the BSU campus. The BHRS has 18 fully screened wells, each of which is 60 ft deep, to support deployment of the *MHPS*. As many wells as are needed for a given testing plan will be used for full-scale testing of prototypes in the full variety of configurations and operational conditions necessary for development and prove-out of the *MHPS*, including simultaneous deployment of several system subsets in different configurations in several wells for active testing to demonstrate pressure-tight isolation of multiple zones within a series of hydraulically inflated *MHPS* packers.

Appendix B. Biographical Sketches and Individual Support for PI Barrash and Co-PI Cardiff:

Appendix B.1 Biographical sketch (2-pg NSF-style) for PI Warren Barrash Ph.D.

WARREN BARRASH, Ph.D.
Research Professor, Center for Geophysical Investigation of the Shallow Subsurface (CGISS) and Department of Geosciences, Boise State University, Boise, ID 83725

PROFESSIONAL PREPARATION

Dartmouth College	English	B.A., 1970
University of Idaho	Geology	M.S., 1978

University of Idaho | Geology | Ph.D., 1986

APPOINTMENTS

- 1993-present: Research Professor, Center for Geophysical Investigation of the Shallow Subsurface (CGISS) and Department of Geosciences; and Director (1997-present), Boise Hydrogeophysical Research Site, Boise State University, Boise, ID.
- 1989-1993: Hydrogeologist and Subsurface Program Manager, INEL Oversight Program, Idaho Department of Health and Welfare, Boise, ID.
- 1988-1989: Hydrogeologist and Consulting Manager, In-Situ, Inc., Laramie, WY.
- 1987-1988: Research Hydrogeologist, Western Research Institute, Laramie, WY.
- 1983-1987: Research Hydrogeologist, Nebraska Geological Survey, Scottsbluff, NE.
- 1978-1980: Geologist, Geoscience Research Consultants, Moscow, ID.
- 1970-1972; 1973-1974: Peace Corps Volunteer, Malaysia and Ethiopia.

PUBLICATIONS

Five publications closely related to the project:

Cardiff, M., Barrash, W., Malama, B. and Thoma, M., 2011, Information content of slug tests for estimating hydraulic properties in realistic, high-conductivity aquifer scenarios: Journal of Hydrology, v. 403, no. 1-2, p. 66-82.

Cardiff, M., Barrash, W., Kitanidis, P., Malama, B., Revil, A., Straface, S., and Rizzo, E., 2009, A potential-based inversion of unconfined steady-state hydrologic tomography: Ground Water, **47**(2), 259-270, doi: 10.1111/j.1745-6584.2008.00541.x.

Barrash, W., Clemo, T., Fox, J.J., and Johnson, T.C., 2006, Field, laboratory, and modeling investigation of the skin effect at wells with slotted casing, Boise Hydrogeophysical Research Site: Jour. of Hydrology, **326**(1-4), 181-198, doi:10.1016/j.jhydrol.2005.10.029.

Barrash, W. and Reboulet, E.C., 2004, Significance of porosity for stratigraphy and textural composition in subsurface coarse fluvial deposits, Boise Hydrogeophysical Research Site: Geol. Society of America Bulletin, **116**(9/10), 1059-1073, doi:10.1130/B25370.1.

Barrash, W. and Clemo, T., 2002, Hierarchical geostatistics and multifacies systems: Boise Hydrogeophysical Research Site, Boise, Idaho: Water Resources Research, **38**(10) 1196.

SYNERGISTIC ACTIVITIES

- Convened workshop June 8-9, 2006 at Boise State to help advance hydraulic tomography (HT). Participants came from nine universities and three European countries. Follow-up includes: data sharing and tech transfer, mini-symposium on HT at SIAM meeting March 2007, collaborative HT experiments at the BHRS in 2007, opinion paper on basin-scale HT in WRR, v. 44, 2008 (paper W03301).
- Co-originator and coordinator of combined hydraulic tomography – self potential – electrical resistivity tomography experiments at the BHRS in 2007 with participation

in experiments by researchers +/- PhD students from (in addition to BSU): Stanford, Arizona, Waterloo, Kansas Geol. Survey, INL, CEREGE (France), and CNR-IMAA and U Calabria (Italy); co-originator (with Straface of U. Calabria) and coordinator of course on hydrogeophysics offered by US and international research participants in association with the HT-SP-ERT experiments.

- Originator and coordinator of the BHRS, a field-scale subsurface control volume/test cell for multidisciplinary research, teaching, and asset for the research community at large – including using recent professional meetings for active recruitment of collaborative participation by the research community (e.g., SEG Workshop in Aug. 2006, AGU in Dec. 2006 – led to: current NSF project with Slater (Rutgers), Revil (Colorado School of Mines), and Binley (Lancaster U., UK); broadened participation in HT-SP-ERT collaborative experiments in 2007; current NSF project on subsurface imaging with Kitanidis (Stanford), Borcea (Rice), and others.
- Developed exchanges with University of Tubingen (Germany) including visits by researchers and extended stays and research collaboration at Boise State by a PhD student and post-doc leading to publications and continued professional interaction.

COLLABORATORS (last 5 yr)

A. Binley (Lancaster U., UK), G. Bohling (Kansas Geol. Surv. [KGS]), L. Borcea (Rice U.), J. Bradford (Boise State University [BSU]), J. Butler, (KGS), M. Cardiff (Stanford U.), O. Cirpka (U. Tubingen, Germany), W. Clement (BSU-ret.), T. Clemo (Intera, Inc.), B. Dafflon (U. Lausanne, Switzerland), J. Fox (Idaho Dept. of Environmental Quality), K. Holliger (U. Lausanne, Switzerland), B.X. Hu (Florida State U.), D. Hyndman (Michigan State U.), J. Irving (U. Lausanne, Switzerland), A. Jardani (Colorado School of Mines [CSM]), T. Johnson (INL), P. Kitanidis (Stanford U.), M. Knoll (BSU-ret.), K.Kuhlman (Sandia), C. Leven (U. Tubingen, Germany), B. Malama (Sandia), M. Meerschaert (Michigan State U.), G. Moret (Pennsylvania State U.), J. Mwenifumbo (Canadian Geol. Surv.), E. Reboulet (KGS), A. Revil (CSM), E. Rizzo (CNR-IMAA, Italy), P. Routh (ConocoPhillips), L. Slater (Rutgers), V. Sridhar (BSU), S. Straface (U. Calabria, Italy), D. Walsh (Vista-Clara, Inc.), J. Yeh (U. Arizona).

CURRENT & PENDING SUPPORT (Note: Dr. Barrash is in a 100% soft money position)

Measuring and modeling hydrologic fluxes and states from aquifer to atmosphere; currently funded by DoD EPSCoR (4.5 mo/yr, present to October 2012).

Advancing hydrogeophysical quantification of hydraulic conductivity from electrical measurements of the effective properties controlling fluid flow in porous media; currently funded by NSF (1.5 mo/yr, present to mid-2011).

Collaborative Research: Subsurface Imaging and Uncertainty Quantification, currently funded by NSF (4.5 mo/yr, present to September 2012).

Stream-aquifer interactions in a semi-arid riparian system; currently funded by Inland Northwest Research Alliance (1.5 mo/yr, present to December 2010).
Imaging of phreatophyte root distributions in shallow riparian aquifers, in prep. for submission to NSF December 2010 (requesting 1 mo/yr for mid-2011 to mid-2014).

Appendix B.2 Biographical sketch (2-pg NSF-style) for Co-PI Michael Cardiff Ph.D.

Michael Cardiff, Ph.D.
Assistant Research Professor, Center for Geophysical Investigation of the Shallow Subsurface (CGISS)
Department of Geosciences, Boise State University, Boise ID 83725
Phone: 208-426-4678; Fax: 208-426-3888; E-mail: michaelcardiff@boisestate.edu

Professional Preparation

Oberlin College	Mathematics & Geology	B.A., 2001
Stanford University	Civil & Env. Engineering	M.S., 2005
Stanford University	Civil & Env. Engineering	Ph.D., 2010
Boise State University	Geosciences	Postdoctoral, 1/2010 - present

Appointments

- 2010-present: Postdoctoral Researcher / Assistant Research Professor, Center for Geophysical Investigation of the Shallow Subsurface (CGISS) and Department of Geosciences, Boise State University, Boise ID.
- 2004-2010: Research Assistant / Teaching Assistant, Department of Civil & Environmental Engineering, Stanford University, Stanford CA.
- 2001-2004: Senior Associate & Database Administrator, Project Performance Corporation (environmental consulting firm), McLean, VA.
- 2000-2001: Field/Research Assistant, Dept. of Geology, Oberlin College, Oberlin OH.

Publications

(i)Publications most closely related to the proposed project

Cardiff, M., Barrash, W., Malama, B. and Thoma, M. (2011). Information content of slug tests for estimating hydraulic properties in realistic, high-conductivity aquifer scenarios. Journal of Hydrology, v. 403, no. 1-2, p. 66-82.
Cai, Z., Wilson, R., Cardiff, M. and Kitanidis, P. K. (2010). Increasing confidence in mass discharge estimates using geostatistical methods. Ground Water, doi: 10.1111/j.1745-6584.2010.00709.x.

Cardiff, M., Liu, X., Kitanidis, P. K., Parker, J. C. and Kim, U. (2010). Cost optimization of DNAPL source and plume remediation under uncertainty using a semi-analytic model. Journal of Contaminant Hydrology 113(1-4): 25-43, doi:10.1016/j.jconhyd.2009.11.004.

Cardiff, M., Barrash, W., Kitanidis, P. K., Malama, B., Revil, A., Straface, S. and Rizzo, E. (2009). A potential-based inversion of unconfined steady-state hydraulic tomography. Ground Water 47(2): 259-270, DOI: 10.1111/j.1745-6584.2008.00541.x.

Cardiff, M. A. and Kitanidis, P. K. (2008). Efficient solution of nonlinear, underdetermined inverse problems with a generalized PDE model. Computers & Geosciences 34: 1480-1491, doi:10.1016/j.cageo.2008.01.013.

(ii) Other significant publications

Liu, X., Cardiff, M. and Kitanidis, P. K. (2010-in press). Parameter estimation in nonlinear environmental problems. Stochastic Environmental Research and Risk Assessment, DOI: 10.1007/s00477-010-0395-y.

Straface, S., Chidichimo, F., Rizzo, E., Riva, M., Barrash, W., Revil, A., Cardiff, M. and Guadagnini, A. (2010-in review). Joint inversion of hydreogeophysical data at the Boise Hydrogeophysical Research Site. Journal of Geophysical Research.

Cardiff, M. and Kitanidis, P. K. (2010). Fitting data under omnidirectional noise: A probabilistic method for inferring petrophysical and hydrologic relations. Mathematical Geosciences, DOI: 10.1007/s11004-010-9301-x.

Cardiff, M. and Kitanidis, P. K. (2009). Bayesian inversion for facies detection: An extensible level set framework. Water Resources Research **45**(W10416), doi:10.1029/2008WR007675.

Parker, J. C., Kim, U., Kitanidis, P. K., Cardiff, M. and Liu, X. (2010). Stochastic cost optimization of multi-strategy DNAPL site remediation. Ground Water Monitoring & Remediation **30**: 65-78, doi: 10.1111/j.1745-6592.2010.01287.x.

Synergistic Activities

- Published open-source code with majority of research completed during Ph.D. studies including MATLAB code for performing level set based inversion, MATLAB code for fitting petrophysical relations under omnidirectional noise, and MATLAB code for interfacing inverse modeling routines with COMSOL Multiphysics. Noted availability of code in published journal articles.
- Participated in processing and sharing (online database) of results from 2001 Hydraulic Tomography / Self-Potential / Electrical Resistivity Tomography field experiment for availability to broad community.
- Developed lesson plans and materials integrating COMSOL Multiphysics software into undergraduate / Masters-level class on ground water flow, and taught students about use of COMSOL user interface for studying flow and transport problems. Developed open

final project for students that allowed them to study various groundwater systems using COMSOL. Received Stanford Centennial TA award for this effort.

- Shared results of COMSOL-based inversion routines with COMSOL software developers, resulting in inclusion of freely-available sample problem in the COMSOL documentation that can be tested by users interested in imaging and inverse problems.

Collaborators (past 48 months)
W. Barrash (Boise State U.), L. Borcea (Rice U.), Z. Cai (U. of Sheffield, UK), F. Chidichimo (U. Calabria, Italy), O. Cirpka (U. Tubingen, Germany), T. Clemo (Intera, Inc.), B. Dafflon (U. Lausanne, Switzerland), A. Crespy (U. Paul Cézanne, France), A. Guadagnini (U. Calabria, Italy), A. Jardani (Colorado School of Mines [CSM]), T. Johnson (INL), U. Kim (U. Tennessee Knoxville), P. Kitanidis (Stanford U.), X. Liu (Stanford U.) B. Malama (Sandia),), J. Parker (U. Tennessee Knoxville), A. Revil (Colo. School of Mines),), M. Riva (U. Calabria, Italy), E. Rizzo (CNR-IMAA, Italy), S. Straface (U. Calabria, Italy), M. Thoma (Boise State U.), R. Wilson (U. of Sheffield, UK)

Graduate Advisors and Postdoctoral Sponsors
M.S. Advisor: Peter K. Kitanidis (Stanford)
Ph.D. Advisor: Peter K. Kitanidis (Stanford), *Ph.D. Committee:* David L. Freyberg (Stanford), Rosemary Knight (Stanford), Steven Gorelick (Stanford)
Postdoctoral sponsor: Warren Barrash (Boise State Univ.)

CURRENT & PENDING SUPPORT (Note: Dr. Cardiff is in a 100% soft money position)
Collaborative Research: Subsurface Imaging and Uncertainty Quantification, currently funded by NSF (9 mo/yr, present to May 2012).
Teaching 2 graduate hydrogeology courses per year; currently funded by Geosciences Department (3 mo/yr, present to May 2012).
Imaging of phreatophyte root distributions in shallow riparian aquifers, in prep. for submission to NSF (requesting 2.5 mo/yr for 2011-2014).

Appendix B.3. Full CV for Project Director Warren Barrash Ph.D.:

WARREN BARRASH

Research Professor
Center for Geophysical Investigation of the Shallow Subsurface (CGISS) and Department of Geosciences
Boise State University, Boise, ID 83725
Phone: 208-426-1229

Fax: 208-426-3888
Email: wbarrash@cgiss.boisestate.edu

EDUCATION

Ph.D. 1986, Geology, University of Idaho (Whittenberger Fellow, 1981-82)
Dissertation: Hydrostratigraphy and hydraulic behavior of fractured Brule Formation, Cheyenne County, Nebraska
M.S. 1978, Geology, University of Idaho
B.A. 1970, English, Dartmouth College (Honors Major)

PROFESSIONAL EXPERIENCE

Research Professor, Center for Geophysical Investigation of the Shallow Subsurface (CGISS) and Department of Geosciences, and Director, Boise Hydrogeophysical Research Site, Boise State University, Boise, ID, 1993-present
Hydrogeologist and Subsurface Program Manager, INEL Oversight Program, Idaho Department of Health and Welfare, Boise, ID, 1989-1993
Hydrogeologist and Consulting Manager, In-Situ, Inc., Laramie, WY, 1988-1989
Research Hydrogeologist, Western Research Institute, Laramie, WY, 1987-1988
Research Hydrogeologist, Nebraska Geological Survey, Scottsbluff, NE, 1983-1987

PROFESSIONAL AFFILIATIONS AND REGISTRATION

Member, American Geophysical Union
Member, Geological Society of America
Member, Association of Groundwater Scientists and Engineers (NGWA)
Member, International Association of Hydrological Sciences
Registered Professional Geologist, #805, Idaho Board of Registration

TEACHING EXPERIENCE

Boise State University:
Advanced Hydrogeology (3 cr); Fall, graduate-level, cross listed with Civil Engineering
Applied Hydrogeology (3 cr); Spring, graduate-level, cross listed with Civil Engineering
Hydrogeophysics Seminar (1 cr); Fall and Spring 2000-2006, grad/undergrad-level
Tectonics of the Pacific Northwest (3 cr); Spring 1994, grad/undergrad-level
University of Idaho:
Sedimentology (3 cr); Fall 1982, undergrad-level

INTERNATIONAL WORK EXPERIENCE

Tuberculosis Control Officer, Peace Corps/Malaysia, 1970-72
Smallpox Eradication Officer, Peace Corps/Ethiopia, 1973-74
Trek Leader, Nepal, 1986, 1988, 1990

RESEARCH INTERESTS

1. Measuring and modeling heterogeneity in natural aquifers using hydrologic, geophysical, and geostatistical methods, including the use of classical methods and development of new methods for measuring permeability, investigation of scale effects, investigation of petrophysical relationships, and developing methods for supplementing hydrologic data with geologic and geophysical data.
2. Investigation and modeling of flow and transport in groundwater systems.
3. Late-Cenozoic tectonics in the Pacific Northwest.

RESEARCH GRANTS RECEIVED

National Science Foundation, $335,000 (2009-2012), Boise State University: CMG Collaborative research: Subsurface imaging and uncertainty quantification.

Army Research Office, $665,000 (2009-2012), Boise State University: Measurement and modeling hydrologic fluxes and states from aquifer to atmosphere at multiple scales.

National Science Foundation, $127,000 (2007-2010), Boise State University: Collaborative research: Hydrogeophysical quantification of hydraulic conductivity from electrical measurements of the effective properties of porous media.

U.S. Environmental Protection Agency, $218,000 (2007-2010), Boise State University: Hydrogeophysical methods for environmental sensing research initiatives in hydrogeophysics and hydrogeochemistry.

U.S. Environmental Protection Agency, $1,600,000 (2006-2009), Boise State University: Hydrogeophysical methods for quantitative site characterization and imaging of fluid flow and mass transport in the shallow subsurface.

U.S. Environmental Protection Agency, $720,000 (2004-2006), Boise State University: Time-lapse imaging of fluid flow and contaminant transport in the shallow subsurface.

U.S. Dept. of Energy, $100,000 (2003-2005), Boise State University: Subcontract to prime contractor Montana State University within: Assessment of geologic carbon sequestration potential for the Northern Rockies and Great Plains region.

Inland Northwest Research Alliance (Idaho National Engr. and Envir. Laboratory), $150,000 (2000-2003), Boise State University: High-resolution 3D sedimentary architecture and transport parameter distributions in heterogeneous alluvial deposits with georadar.

Army Research Office, $150,000 (2000-2001), Boise State University: Instrumentation in support of hydrologic testing at the Boise Hydrogeophysical Research Site.

Army Research Office, $300,000 (2000-2003), Boise State University: Research on inverse methods applied to geophysical and hydrologic field techniques in support of development of the Boise Hydrogeophysical Research Site.

U.S. Dept. of Energy, $250,000 (1996-1999), Boise State University: Reconnaissance investigation of Birch Creek Valley hydrostratigraphy and hydrology with geophysical methods.

Army Research Office, $2,000,000 (1996-2001), Boise State University: Three-dimensional characterization and modeling of permeability in a field-scale control volume.

U.S. Dept. of Energy/EG&G Idaho, $100,000 (1994), Boise State University: Data management for the Large Scale Infiltration Test at the INEL; from instrumentation output to on-site quasi-real-time data review.

Idaho Water Resources Research Institute, $7,600 (1994-1997), Boise State University: Hydrologic modeling of groundwater flow and boundary effects due to complex stratigraphy and faulting in the deep Boise aquifer system with support from high-resolution seismic reflection profiling.

Army Research Office, $300,000 (1994-1997), Boise State University: Joint inversion of hydrologic and geophysical data for permeability distribution of an alluvial aquifer.

U.S. Dept. of Energy, $150,000 (1990-1993), Idaho Department of Health and Welfare, INEL Oversight Program: Evaluation of vadose zone hydrology at the Idaho National Engineering Laboratory (in collaboration with University of Idaho).

U.S. Dept. of Energy, $450,000 (1990-1993), Idaho Department of Health and Welfare, INEL Oversight Program: Investigation of three-dimensional distribution of ground water contamination and hydrologic properties in the Eastern Snake River Plain aquifer at the Idaho National Engineering Laboratory (in collaboration with Boise State University, Idaho State University, and University of Idaho).

U.S. Bureau of Mines, $200,000 (1987-1990), Western Research Institute: Development of database management system of hydrologic and mining data for permitting and groundwater management, Wyoming (in cooperation with Wyoming Department of Environmental Quality).

South Platte Natural Resources District, $45,000 (1984-1986), Nebraska Geological Survey: Investigations to determine stratigraphic controls on and hydrologic behavior of fractured Brule aquifer, Cheyenne County, Nebraska.

RESEARCH GRANTS: Major Participation in Writing and/or Co-PI

Center for Environmental Sensing, Boise State University/EPA Seed Grant Program, $50,000 (2007-2008): Field portable electrochemical sensors for water soluble arsenic species.

U.S. Dept. of Energy, $55,000 (2005-2006) and supplements of $119,000 (2006-2007) and $131,000 (2008-2010), Boise State University: share of initial $480,000 grant and supplemental grants of $1,005,000 and $1,435,000 to eight universities for the Inland Northwest Research Alliance Water Research Consortium.

University of Minnesota, Institute of Rock Magnetism, Grant for no-fee use of instrumentation, (2006), Boise State University, Effect of complex magnetic susceptibility on electromagnetic induction responses for environmental and hydrological applications

U.S. Dept. of Energy, $280,000 (2005-2009), Boise State University: Subcontract to prime contractor Montana State University within: Identification, Assessment and Evaluation of GHG sources and Carbon Sequestration Sinks in the Northern Rockies, Phase II.

Office of Research Administration, Boise State University, $150,000 (2005-2006), College of Arts and Sciences and College of Engineering: Environmental Hydrology Research Center.

U.S. Environmental Protection Agency, $1,000,000 (2001-2004), Boise State University: Time-lapse imaging of fluid flow and contaminant transport in the shallow subsurface.

Council of State Governments/U.S.-Asia Environmental Partnership, $150,000 (2001-2002), Boise State University: The Malaysia/Idaho Partnership for the Environment.

Inland Northwest Research Alliance (Idaho National Engr. and Envir. Laboratory), $150,000 (2001-2003), Boise State University: Tomography and Biogeochemical Reconnaissance for Characterizing Microbial and Solute Transport in a Heterogeneous Alluvial Aquifer.

Army Research Office, $300,000 (1998-2001), Boise State University: Hydrogeologic property estimation using borehole radar.

PEER-REVIEWED PUBLICATIONS

Bradford, J.H., Clement, W.P., and Barrash, W., 2009, Estimating porosity with ground-penetrating radar reflection tomography: A controlled 3D experiment at the Boise Hydrogeophysical Research Site: Water Resources Research, v. 45, W00D26, doi:10.1029/2008WR006960.

Cardiff, M., Barrash, W., Kitanidis, P., Malama, B., Revil, A., Straface, S., and Rizzo, E., 2009, A potential-based inversion of unconfined steady-state hydrologic tomography: Ground Water, vol. 47, no. 2, p. 259-270, doi: 10.1111/j.1745-6584.2008.00541.x.

Clemo, T., Barrash, W., Reboulet, E.C., Johnson, T.C., and Leven, C., 2009, The influence of wellbore inflow on electromagnetic borehole flowmeter measurements: Ground Water, vol. 47, no. 4, p. 515-525, doi: 10.1111/j.1745-6584.2008.00559.x.

Hu, B.X., Meerschaert, M.M., Barrash, W., Hyndman, D.W., He, C., Li, X., and Guo, L., 2009, Examining the influence of heterogeneous porosity fields on conservative solute transport: Journal of Contaminant Hydrology, v. 108, p. 77-88.

Jardani, A., Revil, A., Barrash, W., Crespy, A., Rizzo, E., Straface, S., Johnson, T., Malama, B., Miller, C., and Cardiff, M., 2009, Reconstruction of the water table from self potential data:

A Bayesian approach: Ground Water, vol. 47, no. 2, p. 213-227.
Malama, B. and Barrash, W., 2009, Flow in the neighborhood of a confined aquifer observation well: Journal of Hydrology, v. 364, p. 107-114, doi:10.1016/j.jhydrol.2008.10.014.
Mwenifumbo, C.J., Barrash, W., and Knoll, M.D., 2009, Capacitive conductivity logging and electrical stratigraphy in a high-resistivity aquifer, Boise Hydrogeophysical Research Site: Geophysics, v. 74, no. 3, p. E125-E133, doi:10.1190/1.3106760.
Malama, B., Kuhlman, K.L., and Barrash, W., 2008, Semi-analytical solution for flow in a leaky unconfined aquifer toward a partially penetrating pumping well: Journal of Hydrology, v. 356, p. 234-244, doi:10.1016/j.jhydrol.2008.03.029.
Yeh, T.-C. J., Lee, C.-H., Hsu, K.-C., Illman, W.A., Barrash, W., Cai, X., Daniels, J., Sudicky, E., Wan, L., Li, G., and Winter, C.L., 2008, A view towards the future of subsurface characterization: CAT scanning groundwater basins: Water Resources Research, v. 44, doi:10.1029/2007WR006375.
Jardani, A., Revil, A., Boleve, A., Crespy, A., Dupont, J.-P., Barrash, W., and Malama, B., 2007, Tomography of the Darcy velocity from self-potential measurements: Geophysical Research Letters, v. 34, L24403, doi:10.1029/2007GL031907.
Johnson, T.C., Routh, P.S., Barrash, W., and Knoll, M., 2007, A field comparison of Fresnel zone and ray-based GPR attenuation-difference tomography for time-lapse imaging of electrically anomalous tracer or contaminant plumes: Geophysics, v. 72, no. 2, G21-G29.
Johnson, T.C., Routh, P.S., Clemo, T., Barrash, W., and Clement, W., 2007, Incorporating geostatistical constraints in nonlinear inverse problems: Water Resources Research, v. 43, no. 10, W10422, doi:10.1029/2006WR005185.
Malama, B., Kuhlman, K.L., and Barrash, W., 2007, Semi-analytical solution for flow in leaky unconfined aquifer-aquitard systems: Journal of Hydrology, v. 346, no. 1-2, p. 59-68.
Barrash, W., Clemo, T., Fox, J.J., and Johnson, T.C., 2006, Field, laboratory, and modeling investigation of the skin effect at wells with slotted casing: Journal of Hydrology, v. 326, no. 1-4, p. 181-198, doi:10.1016/j.jhydrol.2005.10.029.
Clement, W.P. and Barrash, W., 2006, Crosshole radar tomography in a fluvial aquifer near Boise, Idaho: Journal of Engineering & Environmental Geophysics, v. 11, p. 171-184.
Clement, W.P., Barrash, W., and Knoll, M.D., 2006, Reflectivity modeling of ground penetrating radar: Geophysics, v. 71, no. 3, p. K59-K66, 10.1190/1.2194528.
Moret, G.J.M., Knoll, M.D., Barrash, W., and Clement, W.P., 2006, Investigating the stratigraphy of an alluvial aquifer using crosswell seismic traveltime tomography: Geophysics, v. 71, no. 3, p. B63-B73, 10.1190/1.2195487.
Barrash, W. and Reboulet, E.C., 2004, Significance of porosity for stratigraphy and textural composition in subsurface coarse fluvial deposits, Boise Hydrogeophysical Research Site: Geological Society of America Bulletin, v. 116, no. 9/10, p. 1059-1073.
Moret, G.J.M., Clement, W.P., Knoll, M.D., and Barrash, W., 2004, VSP traveltime inversion: Near-surface issues: Geophysics, v. 69, no. 2, p. 345-351.

Oldenborger, G.A., Knoll, M.D., and Barrash, W., 2004, Effects of signal processing and antenna frequency on the geostatistical structure of ground-penetrating radar data: Journal of Environmental and Engineering Geophysics, v. 9, no. 4, p. 201-212.

Tronicke, J., Holliger, K., Barrash, W., and Knoll, M.D., 2004, Multivariate analysis of crosshole georadar velocity and attenuation tomograms for aquifer zonation: Water Resources Research v. 40, no. 1, W01519, doi:10.1029/2003WR002031.

Barrash, W. and Clemo, T., 2002, Hierarchical geostatistics and multifacies systems: Boise Hydrogeophysical Research Site, Boise, Idaho: Water Resources Research, v. 38, no. 10, 1196, doi:10.1029/2002WR001436.

Barrash, W. and Dougherty, M., 1997, Modeling axisymmetric and non-symmetric flow to a well with MODFLOW, and application to Goddard2 well test, Boise, Idaho: Ground Water, v. 35, no. 4, p. 602-611.

Barrash, W. and Morin, R., 1997, Recognition of units in coarse, unconsolidated braided-stream deposits from geophysical log data with principal components analysis: Geology, v. 25, no. 8, p. 687-690.

Morin, R.H., Barrash, W., Paillet, F., and Taylor, T., 1993, Geophysical logging studies in the Snake River Plain aquifer at the Idaho National Engineering Laboratory, INEL wells 44, 45, 46: U.S. Geological Survey Water-Resources Investigations Report 92-4184, 44 p.

Barrash, W. and Ralston, D.R., 1991, Analytical modeling of a fracture zone in the Brule Formation as an aquifer receiving leakage from water-table and elastic aquitards: Journal of Hydrology, v.125, p.1-24.

Barrash, W. and Morin, R.H., 1987, Hydrostratigraphy and distribution of secondary permeability in the Brule Formation, Cheyenne County, Nebraska: Geological Society of America Bulletin, v. 99, p. 445-462.

Palmer, P., Barrash, W., Derkey, P.D., Wotruba, N.J., Fakourbayat, M., and Miller, S.T.,1985, Phosphate resources of the Johnson Creek 7.5-minute quadrangle, Caribou County, Idaho: U.S. Geological Survey Mineral Resource Map MR-80.

Barrash, W., Bond, J.G., and Venkatakrishnan, R., 1983, Structural evolution of the Columbia Plateau in Washington and Oregon: American Journal of Science, v. 283, p. 897-935.

Barrash, W. and Venkatakrishnan, R., 1982, Timing of late Cenozoic volcanic and tectonic events along the western margin of the North American plate: Geological Society of America Bulletin, v. 93, p. 977-989.

Barrash, W., Bond, J.G., Kauffman, J.D., and Venkatakrishnan, R., 1980, Geology of the LaGrande area, Oregon: Oregon Dept. of Geol. and Min. Ind. Special Paper no. 6, 47 p.

PROCEEDINGS

Clement, W. P. and W. Barrash, 2006, Crosshole radar tomography in an alluvial aquifer near Boise, Idaho: SAGEEP2006, The Symposium on the Application of Geophysics to Engineering and Environmental Problems, Seattle, WA.

Johnson, T.C., Routh, P.S., Knoll, M.K., and Barrash, W., 2005, Attenuation difference tomography of cross-well radar data using Fresnel theory: SEG Expanded Abstracts, p. 1069-1072.

Smith, R.W., McLing, T.L., Barrash, W., Clement, W.P., and Erickson, N.P., 2004, Geologic Sequestration of CO_2: A uniform strategy for assessing mineralization trapping potential across rock types: Carbon Sequestration Conference, Washington DC, May, 2004.

Barrash, W., Knoll, M.D., Hyndman, D.W., Clemo, T., Reboulet, E.C., and Hausrath, E.M., 2003, Tracer/Time-Lapse Radar Imaging Test at the Boise Hydrogeophysical Research Site: Proc. of SAGEEP03, Symp. on the Appl. of Geophysics to Engr. and Envir. Problems, April 6-10, 2003, San Antonio, TX, p. 163-174.

Clemo, T. and Barrash, W., 2003, Inversion of borehole flowmeter measurements considering well screen clogging and skin: Proceedings of MODFLOW and more 2003: Understanding through modeling, September 16-19, 2003, Golden, CO, p. 99-103.

Goldstein, S.E., Johnson, T.C., Knoll, M.D., Barrash, W., and Clement, W.P., 2003, Borehole radar attenuation tomography during the Tracer/Time-Lapse Test at the Boise Hydrogeophysical Research Site: Proc. of SAGEEP03, Symp. on Appl. of Geophysics to Engr. and Envir. Problems, April 6-10, 2003, San Antonio, TX, p. 147-162.

Liberty, L., Wood, S. and Barrash, W., 2001, Seismic reflection imaging of hydrostratigraphic facies in Boise: 71st Ann. Mtg, Society of Exploration Geophysicists, p. 1393-1396.

Barrash, W. and Clemo, T., 2000, Hierarchical geostatistics of porosity derived from neutron logs at the Boise Hydrogeophysical Research Site, Boise, Idaho: Proceedings of TraM'2000, Liege, Belgium, May 23-26, 2000, IAHS Publ. no. 262, p. 333-338.

Barrash, W., Clemo, T., and Knoll, M.D., 1999, Boise Hydrogeophysical Research Site (BHRS): Objectives, design, initial geostatistical results: Proceedings of SAGEEP99, The Symposium on the Application of Geophysics to Engineering and Environmental Problems, March 14-18, 1999, Oakland, CA, p. 389-398.

Clement, W.P., Knoll, M.D., Liberty, L.M., Donaldson, P.R., Michaels, P., Barrash, W., and Pelton, J.R., 1999, Geophysical surveys across the Boise Hydrogeophysical Research Site to determine geophysical parameters of a shallow, alluvial aquifer: Proceedings of SAGEEP'99, March 14-18, 1999, Oakland, CA, p. 399-408.

Peretti, W.R., Knoll, M.D., Clement, W.P., and Barrash, W., 1999, 3-D GPR imaging of complex fluvial stratigraphy at the Boise Hydrogeophysical Research Site: Proceedings of SAGEEP99, March 14-18, 1999, Oakland, CA, p. 555-564.

Barrash, W. and Knoll, M.D., 1998, Design of research wellfield for calibrating geophysical methods against hydrologic parameters: Proceedings of the 1998 Conference on Hazardous Waste Research, May 18-21, 1998, Snowbird, UT, Great Plains/Rocky Mountain Hazardous

Substance Research Center, Kansas State University, p. 296-318.
Barrash, W., Morin, R., and Gallegos, D.M., 1997, Lithologic, hydrologic and petrophysical characterization of a coarse-grained, unconsolidated aquifer, Capital Station site, Boise, Idaho: 32nd Symposium on Engineering Geology and Geotechnical Engineering, March 26-28, 1997, Boise, ID, p. 307-323.
Michaels, P. and Barrash, W., 1997, The effect of sparging on P and SH vertical seismic profiles: Proceedings of SAGEEP97, The Symposium on the Application of Geophysics to Engineering and Environmental Problems, March 23-26, 1997, Reno, NV, p. 781-789.
Barrash, W., Donaldson, P., Huang, K., Knoll, M., Michaels, P., and Pelton, J., 1997, Toward joint inversion of hydrologic and geophysical data for permeability distribution in an alluvial aquifer: Selected Research in Environmental Quality FY1996, Proc. of Joint USAF/Army Contractor/Grantee Mtg, January 14-17, 1997, Panama City, FL, p. 9-17.
Michaels, P. and Barrash, W., 1996, The anomalous behavior of SH-waves across the water table: Proc. of SAGEEP96, Symposium on the Application of Geophysics to Engineering and Environmental Problems, Apr. 28-May 1, 1996, Keystone, CO, p. 137-145.
Barrash, W., Donaldson, P., Michaels, P., Pelton, J., and Urban, S., 1995, Joint inversion of hydrologic and geophysical data for permeability distribution in an alluvial aquifer: Proc., Envir. Site Characterization and Monitoring Research Program, Contractor/Grantee Mtg, Air Force Office of Scientific Research, May 11-12, 1995, Hanscom AFB, p.1-9.
Barrash, W., Morin, R.H., Wood, S.H., and Bennecke, W., 1994, Hydrostratigraphic interpretation of the upper portion of the Snake River Plain aquifer near the Idaho Chemical Processing Plant at the INEL: Proc. of the 30th Symposium on Engineering Geology and Geotechnical Engineering, March 23-25, 1994, Boise, ID, p.181-193.
McCurry, M., Estes, M., Fromme, J., Welhan, J., and Barrash, W., 1994, Three-dimensional chemical structure of the INEL aquifer system near the Idaho Chemical Processing Plant: Proceedings of the 30th Symposium on Engineering Geology and Geotechnical Engineering, March 23-25, 1994, Boise, ID, p. 207-219.
Nordin, J., Barrash, W., Barteaux, W., and Nolan, T., 1987, Groundwater treatment at the Hoe Creek underground coal gasification site: Proc. of the Thirteenth Annual Underground Coal Gasification Symposium, August 24-26, 1987, Laramie, WY, p. 243-249.
Morin, R.H. and Barrash, W., 1986, Defining groundwater and heat flow in fractured Brule Formation, western Nebraska, using borehole geophysical methods: Proc. of National Water Well Association Conference on Surface and Borehole Geophysical Methods and Groundwater Instrumentation, October 15-17, 1986, Denver, CO, p. 545-569.

TECHNICAL REPORTS

Miller, C., Barrash, W., Clement, W., and Routh, P., 2008, Controlled-source electromagnetic survey at New Hyde Park, New York: Technical report for U.S. EPA Grant X-96004601-0,

CGISS, Boise State University, Boise, ID, 43 p.
Reboulet, E.C. and Barrash, W., 2003, Core, grain-size, and porosity data from the Boise Hydrogeophysical Research Site: Center for Geophysical Investigation of the Shallow Subsurface Technical Report BSU CGISS 03-02, Boise State University, Boise, ID, 87 p.
Barrash, W., Clemo, T., Hyndman, D.W., Reboulet, E., and Hausrath, E., 2002, Tracer/Time-Lapse Radar Imaging Test; Design, operation, and preliminary results: Report to EPA for Grant X-970085-01-0 and to the U.S. Army Research Office for Grant DAAH04-96-1-0318, Center for Geophysical Investigation of the Shallow Subsurface Technical Report BSU CGISS 02-02, Boise State University, Boise, ID, 120 p.
Hausrath, E.M., Barrash, W. and Reboulet, E.C., 2002, Water sampling and analysis for the Tracer/Time-Lapse Radar Imaging Test at the Boise Hydrogeophysical Research Site: Report to EPA for Grant X-970085-01-0 and to the U.S. Army Research Office for Grant DAAH04-96-1-0318, Center for Geophysical Investigation of the Shallow Subsurface Technical Report BSU CGISS 02-03, Boise State University, Boise, ID, 86 p.
Huang, K., Clemo, T. and Barrash, W., 1998, Program developments for modeling groundwater flow in 3D heterogeneous aquifers with MODFLOW and MODFLOWP: Report to U.S. Army Research Office for Grant DAAH04-94-G-0271, BSU CGISS Technical Report 97-02, Boise State University, Boise, ID, 31 p.
Liberty, L.M., Barrash, W., and Bolger, R.D., 1998, Southern Grande Ronde Valley seismic project - Phase I: Walkaway tests: Report to Oregon Department of Geology and Mineral Industries, Center for Geophysical Investigation of the Shallow Subsurface Technical Report BSU CGISS 98-04, Boise State University, Boise, ID.
Liberty, L.M., Barrash, W., Knoll, M., Hudson, W.K., and Bolger, R.D., 1997, Geophysical Investigations of Birch Creek Valley near the Northern Boundary of the INEEL: Report to Idaho Water Resources Research Institute, Center for Geophysical Investigation of the Shallow Subsurface Technical Report BSU CGISS 96-06, Boise State University.
Barrash, W. and Dougherty, M.E., 1995, High-resolution seismic reflection profiling and modeling of hydrogeologic system, Goddard2 well, northwest Boise, Idaho: Report to Idaho Water Resources Research Institute for Grant 684-K102, Technical Report BSU CGISS 95-17, Boise State University, Boise, ID.
Dougherty, M.E., Vincent, R.J., and Barrash, W., 1995, Seismic reflection tests at the western Idaho Fairgrounds, Ada County, Idaho: Center for Geophysical Investigation of the Shallow Subsurface Technical Report BSU CGISS 95-19, 70 p.
Barrash, W., Bishop, C., Norrell, G., Rohe, M., Starr, R., and Whitaker, C., 1994, Data Management/Integration Test Plan for the Large-Scale Integrated Test, Idaho National Engineering Laboratory: EG&G Idaho Report EGG-ER-11368 to U.S. Department of Energy under contract DE-AC07-76ID01570.
Barrash, W., 1991, Duplicate sampling of groundwater collected with submersible and piston pumps south of the Radioactive Waste Management Complex, INEL, Aug. 1990: Idaho

Dept. of Health and Welfare, INEL Oversight Program Tech. Report 91-01, 43 p.
Barrash, W. and Marts, K., 1991, Duplicate sampling of groundwater collected in the area between the Idaho Chemical Processing Plant and the Central Facilities Area, INEL: Idaho Dept of Health and Welfare, INEL Oversight Prog Tech Rept 91-02, 51 p.
Marts, K. and Barrash, W, 1991, Duplicate sampling of perched groundwater beneath the percolation ponds at the Idaho Chemical Processing Plant, INEL, April 1991: Idaho Dept. of Health and Welfare, INEL Oversight Program Technical Report 91-03, 34 p.
Barrash, W., Martin, J.W., and Sharum, U., 1988, Status report of groundwater quality at the Hoe Creek underground coal gasification site, Powder River Basin, Wyoming: Western Research Institute, Laramie, WY, Report to U.S. Department of Energy, cooperative agreement DE-FC-21-86MC11076, 67 p.
Barrash, W., Martin, J.W., and Sharum, U., 1988, Status report of groundwater quality at the Hanna underground coal gasification site, Hanna Basin, Wyoming: Western Research Institute, Laramie, WY, Report to U.S. Department of Energy, cooperative agreement DE-FC-21-86MC11076, 60 p.
Barrash, W., Moody, C.G., and Poulson, R.E., 1988, Report on environmental sampling at the in-situ oil shale experimental area near Rock Springs, Wyoming: Western Research Institute, Laramie, WY, Report to U.S. Department of Energy, Laramie, WY, 31 p.
Nordin, J.S., Barrash, W., and Nolan, B.T., 1988, Groundwater restoration field test at the Hoe Creek Underground Coal Gasification site: Western Research Institute, Laramie, WY, Report to U.S. Dept. of Energy, cooperative agreement DOE/MC/11076-2454, 30 p.
Barrash, W., Schowengerdt, R.S., and Smith, P., 1987, Hydrogeology of the Hoe Creek underground coal gasification site, Powder River Basin, Wyoming: Western Research Institute, Laramie, WY, Report to U.S. Department of Energy, cooperative agreement DE-FC-21-86MC11076, 71 p.
Barrash, W., Ralston, D.R., and Howard, H.R., 1982, Geologic assessment of White Arrow Ranch for geothermal development, Idaho: Howard-Donley Associates, Moscow, ID, Report to Morrison-Knudsen Co., 58 p.
Bond, J.G., Kauffman, J.D., Miller, D.A., and Barrash, W., 1978, Geology of the southwestern Pasco Basin: Report to Rockwell Hanford Operations, RHO-BWI-C-25, 217 p.
Barrash, W. and Kaplan, L., 1975, An account of smallpox eradication operations in Gishe woreda, Ethiopia: World Health Organization, WHO/SE/75.72, 8 p.

ABSTRACTS

Barrash, W., Bradford, J., and Malama, B., 2008, Boise Hydrogeophysical Research Site: Control volume/test cell and community research asset (abs.): Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract H51K-05.

Barrash, W., Carrasco, P., Kaplan, L., Gebu, T., and de Quadros, C., 2008, Gishe expedition for smallpox eradication in central Ethiopia, May-June 1974 (abs.): East Africa-South Asia Smallpox Eradication, Centers for Disease Control and Prevention, July 12, 2008, Atlanta, GA.

Thoma, M.J., Malama, B., Bradford, J., Barrash, W., Johnson, B., Hinz, E., and Murray, S., 2008, Using ground penetrating radar to monitor transient unconfined aquifer response to pumping (abs.): Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract H51M-06.

Barrash, W., Revil, A., Cardiff, M., Johnson, T., Malama, B., Rizzo, E., Miller, C., and Straface, S., 2007, Combined hydraulic tomography – self potential – electrical resistivity tomography for parameter estimation in the unconfined aquifer at the Boise Hydrogeophysical Research Site (abs.): EOS Trans. AGU, v. 88, no. 52, Abstr. no. H33M-04, FAll Meeting, Dec 10-14, 2007, San Francisco, CA.

Barrash, W., Clemo, T., Johnson, T., Leven, C., Malama, B., and Nelson, G., 2007, Hydraulic tomography at the Boise Hydrogeophysical Research Site (abs.): SIAM Conf. on Mathematical and Comp. Issues in the Geosciences, March 19-22, 2007, Santa Fe, NM.

Barrash, W., Malama, B., Routh, P.S., Johnson, T.C., and Clemo, T., 2007, Joint inversion at the Boise Hydrogeophysical Research Site (abs.): AGU Spring Meeting, May 22-25, 2007, Acapulco, Mexico.

Malama, B., Kuhlman, K., and Barrash, W., 2007, Leakage theory for unconfined aquifers (abs.): AGU Spring Meeting, May 22-25, 2007, Acapulco, Mexico.

Barrash, W. and Routh, P.S., 2006, Boise Hydrogeophysical Research Site: Field-scale test facility for addressing fundamental questions of environmental science (abs.): AGU Fall Meeting, Dec. 11-15, 2006, San Francisco, CA, EOS, v. 87, no. 52, Abstract H51D-0519.

Barrash, W., Clemo, T., Johnson, T., Leven, C., and Nelson, G., 2006, Hydraulic tomography at the Boise Hydrogeophysical Research Site (abs.): Hydraulic Tomography Workshop, June 8-9, 2006, Boise State University, Boise, ID.

Barrash, W., Clemo, T., and Reboulet, E.C., 2006, Modeling and verifying multiscale, multifacies heterogeneity in a shallow fluvial aquifer (abs.): SEG Hydrogeophysics Workshop, July 31-August 2, 2006, Vancouver, BC.

Clemo, T. and Barrash, W., 2006, Sensitivity of flowmeter calibration to incoming flow through a well screen (abs.): Geological Society of America Ann. Mtg., Philadelphia, PA, Oct 22-25, 2006, GSA Abstracts with Programs v. 38, no. 7, p. 431.

Clemo, T. and Barrash, W., 2006, In-well fluid hydraulics simulation for modeling of borehole flowmeter response in a layered aquifer: MODFLOW and more 2006: Managing Ground-Water Systems: Poeter, Hill & Zheng (eds), International Ground Water Modeling Center, Golden CO, p. 721.

Johnson, T.C., Routh, P.S., Clemo, T., and Barrash, W., 2006, Plausible solution space sampling to quantify resolution and uncertainty (abs): AGU Fall Meeting, December 11-15, 2006, San Francisco, CA, EOS, v. 87, no. 52, Abstract NS23A-08.

Leven, C., Barrash, W., and Dietrich, P., 2006, Application of the concept of sensitivity coefficients to pumping test data from the Boise Hydrogeophysical Research Site (abs.): AGU Fall Meeting, December 11-15, 2006, San Francisco, CA, EOS, v. 87, no. 52, Abstract H43B-0506.

Malama, B., Barrash, W., Hyndman, D., and Nelson, G.K., 2006, Solute transport in a medium with spatially variable porosity (abs.): AGU Fall Meeting, December 11-15, 2006, San Francisco, CA, EOS, v. 87, no. 52, Abstract H41G-05.

Barrash, W., Clemo, T., Fox, J.J., and Johnson, T.C., 2005, Accounting for aquifer heterogeneity in analysis of the skin effect (abs.): AGU Fall Meeting, December 5-9, 2005, San Francisco, CA, EOS, v. 86, no. 52, Abstract H51A-0336.

Clemo, T., Barrash, W., and Johnson, T.C., 2005, Fluid mechanics of borehole flowmeters (abs.): AGU Fall Meeting, December 5-9, 2005, San Francisco, CA, EOS, v. 86, no. 52, Abstract H21C-1353.

Johnson, T.C., Routh, P.S., Clemo, T., Barrash, W., and Clement, W.P., 2005, Geostatistically constrained inversion and uncertainty estimation (abs.): AGU Fall Meeting, December 5-9, 2005, San Francisco, CA, EOS, v. 86, no. 52, Abstract H13C-1345.

Barrash, W., Kaleris, V., Clemo, T., Johnson, T., Leven, C., and Reboulet, E., 2004, In-well flow effects on borehole flowmeter profiles in long-screened wells (abs.): Spring AGU Meeting, May 17-21, 2004, Montreal, Canada, EOS, v. 85, no. 17, NS41A-13.

Barrash, W., Knoll, M., Clement, W., Clemo, T., Michaels, P., 2004, Determining distributions of hydrologic and geophysical parameters in a heterogeneous fluvial aquifer, Boise Hydrogeophysical Research Site (abs.): Geological Society of America, Rocky Mountain and Cordilleran Sections, Boise, ID, May 3-5, 2004, Abs. with Prog., v. 36, no. 4, p. 76.

Clement, W.P., Barrash, W., Knoll, M., 2004, Crosshole radar tomography in an alluvial aquifer near Boise, Idaho (abs.): Geol. Soc. Am. 56th Ann. Mtg. Rocky Mtn Sec. and 100th Ann. Mtg. Cord. Sec., Boise, ID, May 3-5, 2004. Abs. with Prog., v. 36, no. 4, p. 31.

Goldstein, S.E., Johnson, T.C., Knoll, M.D., Routh, P., and Barrash, W., 2004, Time-lapse imaging of a bromide tracer test in a coarse alluvial aquifer using crosswell radar attenuation-difference tomography (abs.): Spring AGU Meeting, May 17-21, 2004, Montreal, Canada, EOS, v. 85, no. 17.

Johnson, T.C., Barrash, W., Knoll, M., 2004, Fresnel volume attenuation difference inversion of borehole georadar data using analytically computed sensitivities (abs.): Geological Society of America 56th Ann. Mtg. of Rocky Mountain Section and 100th Ann. Mtg. Cordilleran Section, Boise, ID, May 3-5, 2004, Abs. with Programs, v. 36, no. 4, p. 76.

Moret, G.J.M., Knoll, M.D., Barrash, W., and Clement, W.P., 2004, Investigating the hydrostratigraphy of an unconsolidated aquifer using crosswell seismic traveltime tomography (abs.): Spring AGU Mtg, May 17-21, 2004, Montreal, EOS, v. 85, no. 17.

Johnson, T.C., Barrash, W., and Knoll, M., 2003, Imaging tracer movement in a heterogeneous sedimentary aquifer with Fresnel zone attenuation difference tomography (abs.): Geological

Society of America Annual Meeting, November 2-5, 2003, Seattle, WA, Abs. with Prog., v. 35, no. 6, p. 252.

Tronicke, J., Holliger, K., Barrash, W., Knoll, M.D., 2003, Aquifer zonation using multivariate analysis of crosshole georadar tomograms (abs.): EGS-AGU-EUG Joint Assembly, Nice, France, 06 - 11 April 2003, Geophysical Research Abstracts, v. 5, 07006.

Barrash, W., Knoll, M.D., Clement, W.P., Clemo, T., and Michaels, P., 2002, Determining the three-dimensional distribution of permeability in a heterogeneous fluvial aquifer with hydrologic and geophysical methods, Boise Hydrogeophysical Research Site (abs.): Fall AGU Meeting, Dec. 6-10, 2002, San Francisco, CA, EOS, v. 83, no. 47, p. F461.

Johnson, T.C., Barrash, W., and Clemo, T., 2002, Modeling well-bore skin effects at pumping and observations wells under variable pumping rate (abs.): Fall AGU Meeting, December 6-10, 2002, San Francisco, CA, EOS, v. 83, no. 47, p. 453-454.

Leven, C., Barrash, W., Hyndman, D.W., and Johnson, T.C., 2002, Modeling a combined tracer and time-lapse radar imaging test in the heterogeneous fluvial aquifer at the Boise Hydrogeophysical Research Site (abs.): Fall AGU Meeting, December 6-10, 2002, San Francisco, CA, EOS, v. 83, no. 47, p. F487.

Moret, G., Buursink, M., Knoll, M.D., and Barrash, W., 2002, Comparing seismic and radar cross-hole tomography to quantify subsurface porosity (abs.): Subsurface Science Symposium, INRA/Idaho National Engr. and Env. Lab., Boise, ID, Oct. 13-16, 2002.

Clement, W.P., Liberty, L.M., and Barrash, W., 2001, Using cross-hole GPR reflections to improve tomographic imaging and hydrogeologic interpretation (abs.): Geol. Soc. of America Ann. Mtg, Nov. 1-10, 2001, Boston, MA, Abst with Progr, v. 33, no. 6, p. A-45.

Peretti, W.R., Knoll, M.D., Barrash, W., Clement, W.P., and Reboulet, E.C., 2000, Radar stratigraphy, lithostratigraphy, and hydrostratigraphy of coarse fluvial deposits at the Boise Hydrogeophysical Research Site (abs.): Geological Society of America Annual Meeting, Nov. 13-16, 2000, Reno, NV, Abs. with Prog., v. 32, no. 7, p. A410.

Purvance, D.T. and Barrash, W., 2000, The electrical-hydraulic conductivity correlation observed at the Boise Hydrogeophysical Research Site (abs.): Spring AGU Meeting, May 30-June 3, 2000, Washington, DC, EOS, v. 81, no. 19, May 9, 2000 Supplement, p. S212.

Reboulet, E.C. and Barrash, W., 2000, Statistical analysis of grain-size distribution and porosity data from coarse braided-stream deposits at the Boise Hydrogeophysical Research Site (abs.): Geological Society of America Annual Meeting, November 13-16, 2000, Reno, NV, Abs. with Prog., v. 32, no. 7, p. A410.

Barrash, W. and Clemo, T., 1999, Hierarchical geostatistics of porosity derived from neutron logs at the Boise Hydrogeophysical Research Site, Boise, Idaho (abs.): Geol. Soc. America Ann. Mtg, Oct 25-29, 1999, Denver, CO, Abs. with Progr, v. 31, no. 7, p. A149.

Barrash, W. and Knoll, M.D., 1999, Boise Hydrogeophysical Research Site (abs.): Geological Society of America, Rocky Mountain Section, Abs. with Prog., v. 31, no. 4, p. A2.

Clement, W.P., Liberty, L.M., Knoll, M.D., and Barrash, W., 1999, Imaging a shallow, unconfined, alluvial aquifer with radar and seismic methods at the Boise Hydrogeophysical Research Site (abs.): Geological Society of America Annual Meeting, October 25-29, 1999, Denver, CO, Abs. with Prog., v. 31, no. 7, p. A144.

Reboulet, E.C. and Barrash, W., 1999, Identification of hydrostratigraphic facies in coarse, unconsolidated, braided-stream deposits at the Boise Hydrogeophysical Research Site (abs.): Geological Society of America Annual Meeting, October 25-29, 1999, Denver, CO, Abs. with Prog., v. 31, no. 7, p. A350.

Barrash, W. and Knoll, M.D., 1997, Research wellfield for calibrating geophysical measurements against hydrologic parameters (abs.): Fall AGU Meeting, December 8-12, 1997, San Francisco, CA, EOS, v. 78, no. 46, p. F319.

Liberty, L.M., Barrash, W., Knoll, M.D., Bolger, R.D., and Hudson, W.K., 1997, Geophysical modeling of southern Birch Creek Valley adjacent to the eastern Snake River Plain, Idaho: Implications for groundwater flow (abs.): Geological Society of America Annual Meeting, Oct. 20-23, 1997, Salt Lake City, UT, Abstr. with Progr., v. 29, no. 7, p. A326.

Barrash, W. and Morin, R., 1996, Resolution of units in cobble-and-sand (braided stream) deposits from geophysical log data using crossplots and principal component analysis (abs.): Geological Society of America Annual Meeting, October 28-31, 1996, Denver, CO, Abs. with Prog., v. 28, no. 7, p. A462.

Huang, K., Barrash, W., and van Genuchten, M.T., 1996, Solution of non-equilibrium solute transport using modified Picard iteration (abs.): 1996 Agronomy Abstracts, Annual Meeting of the American Society of Agronomy, Crop Science Society of America and Soil Science of America, November 3-8, 1996, Indianapolis, IN, p. 187.

Barrash, W. and Dougherty, M.E., 1995, Accurate simulation of axisymmetric and non-symmetric flow to a well with MODFLOW (abs.): Geological Society of America Annual Mtg., Nov. 6-9, 1995, New Orleans, LA, Abstr. with Progr., v. 27, no. 6, p. A187.

Barrash, W., Morin, R.H., Wood, S.H., Anderson, S.A., Jensen, R.G., and Bennecke, W.M., 1993, Geophysical logging evidence for stratigraphic controls on hydrology in the Snake River Plain aquifer at the Idaho National Engineering Laboratory (abs.): Fall AGU Mtg, Dec. 6-10, 1993, San Francisco, CA, EOS, v. 74, no. 43, p. 283-284.

Bennecke, W.M., Wood, S.H., Olsen, J., and Barrash, W., 1993, Cross-flows in observation boreholes induced by distant pumping of basalt aquifers: eastern Snake River Plain, Idaho (abs.): Geological Society of America Cordilleran and Rocky Mountain Sections Meeting, May 19-21, 1993, Reno, NV, Abs. with Prog., v. 25, no. 5, p. 8.

Morin, R.H., Paillet, F., Taylor, T., and Barrash, W., 1992, Vertical profiling of hydrogeology of the Snake River Plain aquifer with geophysical well logs, INEL (abs.): Spring AGU Mtg, May 12-16, 1992, Montreal, EOS, v. 73, no. 14, p. 124-125.

Barrash, W., 1991, Monitoring for impact of INEL on the Snake River Plain Aquifer (abs.): Northwest Science, v. 65, no. 2, p. 73.

Barrash, W. and Ralston, D.R., 1988, Analytical modeling of a fracture zone in the Brule Formation as an aquifer receiving leakage from water-table and elastic aquitards (abs.): Spring AGU Hydrology Days, Ft. Collins, CO, EOS, v. 69, no. 18, p. 566.
Barrash, W. and Morin, R.H., 1985, Hydrostratigraphic characterization of fractured Brule Formation in western Nebraska using geological, geophysical and hydrological techniques (abs.): Fall AGU Meeting, San Francisco, CA, EOS, v. 66, no. 46, p. 891.
Fitzgerald, J.F., Barrash, W., and Jones, R.W., 1979, Challis Volcanics in Morgan Creek area, Idaho (abs.): Geological Society of America Abs. with Prog., v. 11, no. 6, p. 272.

Appendix C. Institutional and Other Sector Support:

Appendix C.1 Institutional and Other Sector Support Form

INSTITUTIONAL AND OTHER SECTOR SUPPORT (add additional pages as necessary)	
A. INSTITUTIONAL / OTHER SECTOR DOLLARS	
Source / Description	Amount
Solinst Canada, Ltd. has committed to providing technical expertise in consultation with PIs Barrash and Cardiff to facilitate the development and testing of the *Modular Hydraulic Packer-and-Port System* (US patent-pending Boise State University) of this proposal.	In-kind
TechHelp, a business development assistance resource of Boise State University, University of Idaho, and Idaho State University with office and New Product Development Lab space on the Bpise State University campus.	(see Appendix C.2.)
B. FACULTY / STAFF POSITIONS	
Description	
Drs. Warren Barrash (Research Professor) and Michael Cardiff (Assistant Research Professor) are %100 soft money research faculty	
Mary Givens, Director of the Technology Transfer Office	
Technical support staff: John McDonald and Randy Nuxoll (College of Arts and Sciences Scientific shop)	

C. CAPITAL EQUIPMENT Description
Field vehicles (pick-up with crane, van)
D. FACILITIES & INSTRUMENTATION Description
Office -- modern faculty office facilities are located in the new ERB Building that opened for occupancy in mid- May, 2011
Laboratory – modern laboratory facilities, including 600 sq ft laboratory for Barrash and Cardiff, available in new ERB Building that opened for occupancy in mid-May 2011; field laboratory for full-scale testing at the Boise Hydrogeophysical Research Site (http://cgiss.boisestate.edu/hydrogeophysical_research_site.htm)
Staging and intermediate-scale in-door testing facility at Lusk St.
Field equipment and support equipment for testing includes equipment and instrumentation to support this project include vehicles, pumps, hoses, generators, flow-meters, fiber-optic transducers and data acquisition systems (including customized software for multi-well, multi-zone testing), water sampling pumps, hoses, and sampling instruments, hand tools, field support gear (tarps, tables, canopies, ...).

Appendix C.2 Draft Contract for Engineering Design Services with TechHELP:

Proposal – Boise State University / Department of Geosciences – Preliminary Design – Subsurface Investigation Apparatus – Collar

Contact Information

TechHelp Manufacturing Specialist

Name: Blake Young

Address: 1910 University Drive / TechHelp

Boise, Idaho 83725
Telephone: 208-426-5635, 447-7511 (Cell)
email: blakeyoung@boisestate.edu

Client

Contact Name: Warren Barrash, PhD, PG
Address: 1910 University Dr. / Dept. of Geosciences
Boise, ID 83725
Telephone: 208-426-1229
email: wbarrash@boisestate.edu

Current Situation

On November 19, 2010, Warren Barrash from Boise State University's Center for Geophysical Investigation of the Shallow Subsurface (CGISS) visited Steve Hatten and Blake Young at TechHelp in Boise regarding design assistance in support of a HERC grant application. On May 3, 2011 Warren met again with Blake Young to discuss additional requirements for the project. At these meetings, Barrash presented an overview of an innovative assembly for subsurface investigation. The current apparatus is functional but requires mechanical design improvements to increase its market viability.

Desired Situation

The goal of this project is to produce a preliminary design and associated drawings with which Barrash may fabricate prototypes for testing. The end goal is to develop the product to enable investigation of potential market opportunities and production. The focus of the design effort will be on the collar portion of the apparatus, where the packers and tubing are attached

TechHelp and its New Product Development Lab (NPD Lab) team are well suited to develop mechanical designs and engineering drawings for this project. The NPD Team, which includes TechHelp mechanical engineers, mechanical engineering student designers, and prototyping resources, has produced mechanical designs for manufacturers in Idaho for over 10 years.

Collar Requirements (Preliminary) -

The collars will have an outside diameter that will allow it to fit inside a 4in diameter well/hole and have a 1.25 schedule 40 PVC tube to pass through the center. This allows for the connection of tubing (1/2in OD LDPE) with a 3/8in inside diameter. It is important that this inside diameter stay constant as instruments of this size will need to pass through the apparatus. The current prototype uses barbed fittings that press-fit into the LDPE tubing. Although this works will, an alternative would like to be found. The number of tubes is currently 12, but there should be as many as is practical to allow for connecting and disconnecting tube ends at the Collar flange. The fittings that hold the tubes in place must not hang over the edge of the collar and must be able to be easily connected and disconnected. Tubes, including all connections, must remain water tight. Radial hole in collar allows air or water to inflate packer around collar.

Packer is held in place by one clamp on each end. Clamps must not protrude substantially beyond the flange OD. The collar should also have numbers on the two outside faces. These numbers correspond to the small tubes and will be used in the experiments that are performed. An additional feature is a directional arrow that shows what side is up facing.

The existing sleeve is made from a piece of rubber tubing. The tubing is rolled up in shipment which creates creases on the edges. When installed on the packers, the creases flatten the sleeve in the middle of the assembly and bind when placed into well/holes. A solution for this problem needs to be explored.

Project Recommendations: Preliminary Design – Collar

Process Step

1. Kick-off meeting – Early July, 2011
   The purpose of this meeting is to clarify the project steps and to solidify the project requirements and deliverables for the design team and Barrash. At this meeting Barrash will present any updated product requirements, and the group will discuss deliverables and timeline. Estimated time – 2 Student hours, No charge for TechHelp.

2. New Design Concept Generation –
   Using brainstorming techniques and gathering information from existing products and literature, the New Product Development (NPD) team will produce several concepts that meet the requirements delineated by Barrash above. Concepts may be expressed and recorded graphically via hand sketches and/or basic solid modeling. Estimated time – 6 Student hours, 2 TechHelp hours.

3. Meeting: Concept Alternatives Review and Selection –
   The NPD team will meet to present the generated concepts to Barrash. Benefits and drawbacks of each alternative concept will be discussed, and one to two concepts will be chosen to progress into the next design phases. Estimated time – 2 Student hours, No

charge for TechHelp.

4. Preliminary Design and Modeling –
   NPD team will develop preliminary design CAD models addressing and displaying product features and functionality, complete preliminary analysis of mating features, and make preliminary materials selection. Estimated time – 40 student hours, 6 TechHelp hours.

   Prototypes: Prototypes will be fabricated by a Lab in the College of Arts and Sciences. If NPD Lab prototyping services are required, an additional proposal/quote is required.

   Deliverables: Three-dimensional design electronic files, simple engineering drawings, color printouts clarifying product features and functionality.

5. Meeting: Preliminary Design Review – ECD 8/31/2011
   Barrash and the NPD design team will meet to assess the state of the Collar (i.e., connector, features and functions) design development. Barrash will redirect team as necessary to meet requirements and objectives. Estimated time – 2 student hours, No charge for TechHelp.

Investment

Project Step	*BSU Engineering Student COST*	*TechHelp COST*
1. Kick-off meeting -	$80	*no charge*
2. New Design Concept Generation –	$240	$180
3. Meeting: Concept Alternatives Review and Selection –	$80	*no charge*
4. Preliminary Design and Modeling –	$1600	$540
5. Meeting: Preliminary Design Review –	$80	*no charge*
Sub-Totals:	$2080	$720
Total:		**$2800**

Other Expenses (i.e. Purchased parts, vicinity travel, etc.) not to exceed **$500.**

Barrash (Department of Geosciences) shall pay TechHelp for services rendered under this Agreement for each step of the project per the above pricing, of which the design portion is firm and fixed unless another contract is approved. Invoicing will occur at the monthly.

If fewer hours are required, the invoice will be adjusted accordingly. If not satisfied with the material or methods presented, the Barrash may cancel at any time and will be liable to pay only for the completed activities listed above.

IN WITNESS WHEREOF, the parties hereto have entered into this Agreement. The pricing terms of this Agreement shall be from 11/19/10 to 08/30/11. The anticipated project duration is from 07/01/11 to 08/30/11.

TechHelp	Client
By: ______________________	By: ______________________
Printed Name: Steve Hatten Title: Director	Printed Name: Warren Barrash, PhD, PG Title: Research Professor and Director, Boise Hydrogeophysical Research Site
Date: ______________________	Date: ______________________

TechHelp

Additional Provisions

Services and Scope of Work: In consideration of the mutual covenants set forth herein, TechHelp shall perform the services described in the proposal. Once signed by both parties proposal stands as a legally binding contract. All services to be provided hereunder by TechHelp may be performed by employees or independent contractors of TechHelp.

Confidentiality: The term "Confidential Information" shall include, without limitation, any and all trade secrets, business methods, business records and files, computer programs, customer and supplier lists, product specifications, drawings and prototypes, price lists, reports, or other confidential or proprietary information of any type or description, whether such information is written form, maintained in computer form, or otherwise with respect to a party hereto.

Intellectual Property Rights: Client shall retain all right, title and interest throughout the world in each invention, discovery, or copyrightable material that is derived through or in connection with this Agreement and that is or may be patentable or otherwise protected under Title 35 of the United States Code.

Insurance: During the term of this Agreement, Client shall obtain and maintain in full force and effect, comprehensive general public liability insurance coverage at its normal and customary level.

Indemnification: TechHelp indemnifies and agrees to defend and hold harmless Client and its employees, officers, directors, and agents from any and all liabilities, claims, demands, causes of action, or expenses, including attorney's fee, arising from the gross negligence or intentional misconduct of TechHelp in the performance its duties herein. Although TechHelp may provide engineering and technical advice in the performance of this Agreement, Client acknowledges that it will rely on its own judgment in making final decisions with respect to all engineering and technical matters affecting the design, construction, material, and other aspects of any product produced pursuant to or as a result of services described in this Agreement. Recognizing the limited nature of the participation of TechHelp in such matters, Client agrees to indemnify, protect, and hold harmless TechHelp and its employees, officers, directors, and agents from and against any and all liabilities, claims, demands, causes of action, or expenses, including attorneys' fees, that arise out of or are in any way related to this Agreement, except for any liability, claim, demand, cause of action, or expense resulting from the gross negligence or intentional misconduct of TechHelp.

Anti-Discrimination: Any Business using Federal funds shall (a) comply with all relevant federal, state and local laws designed to prevent discrimination, so that Client does not discriminate against any person who performs work hereunder because of race, religion, color, sex, physical handicap unrelated to such person's ability to engage in this work, national origin or ancestry, or age; (b) include in all solicitations or advertisements for employees the phrase "equal opportunity employer"; (c) include those provisions in every subcontract or purchase order so that they are binding upon such subcontractor or vendor; and (d) be declared in default of this Agreement if it fails to comply with the reporting requirements of (c) above, or if Business is found guilty of any violation of any foregoing laws.

Remedies: In the event of any default, and under this Agreement, the non-defaulting party may terminate this Agreement and pursue any and all other remedies available at law or in equity against the defaulting party, except as herein limited. If Client has any claims against TechHelp with respect to any goods or services furnished hereunder, such claims may be brought only in action for breach of contract and Client shall not make any claim based on any theory of tort, including, without limitation, strict liability or negligence theories. The total liability of TechHelp for all claims arising under this Agreement shall not exceed the total compensation paid to TechHelp hereunder.

Other Agreements: This Agreement sets forth the entire understanding between the parties with respect to the subject matter hereof, merges all discussions between them, and supersedes and replaces any agreement, whether oral or written, which may have existed among TechHelp and Client to the extent that any such agreement relates or related to the subject matter hereof.

Binding Effect: Except as specifically limited herein, this Agreement shall be binding upon and inure to the benefit of the parties, their successors and assigns; provided that the Client may not assign this Agreement without the prior written consent of TechHelp.

Impact Reports: Client acknowledges that TechHelp is a publicly supported program and that some data regarding the impact of this project must be collected by TechHelp to report to government sponsors. Client agrees to provide response to reasonable requests for follow-up information regarding this project. TechHelp agrees to report all information provided in compliance with second paragraph above.

Appendix C.3 Letter of Interest in Assisting with Development by Solinst Canada:

Solinst® *High Quality Groundwater & Surface Water Monitoring Instrumentation*

Solinst Canada Ltd.
35 Todd Road
Georgetown, ON, L7G 4R8
TEL: (905) 873-2255 or (800) 661-2023
FAX: (905) 873-1992 or (800) 516-9081
E-mail: instruments@solinst.com
Web Site: www.solinst.com

November 26, 2010

Boise State University
Attn: Warren Barrash

Dear Warren,

We are writing to you at this time to express our interest and commitment in supporting your proposal for funding under the HERC Research Proposal Development Grant towards developing your Modular Packer & Port System. Solinst Canada Ltd. is committed to participating in research and development opportunities that will assist in developing instrumentation and monitoring systems that can be commercially marketed for applications in groundwater management issues. We are very involved in providing technologies for monitoring groundwater contamination issues as well as both surface and subsurface hydrology and very interested in being actively involved as a partner institution in this initiative.

Solinst Canada Ltd. is prepared to provide in-kind support towards this project. The in-kind support would include technical feedback regarding design, materials, installation and ease of production. We are committed to providing industry with the most current and applicable equipment for field monitoring of groundwater problems and we see the opportunity to interact with your research group at Boise State University to be extremely valuable.

We look forward to our involvement and potential for interaction leading to the development and commercialization of technologies.

Best regards,
SOLINST CANADA LTD.,

Sarah Belshaw,
President.

/sb

Attachment 1. Summary Proposal Budget:

SUMMARY PROPOSAL BUDGET

Name of Institution: Boise State University

Name of Project Director: Dr. Warren Barrash

A. FACULTY AND STAFF

Name/ Title	Rate of Pay	No. of Months CAL	ACA	SUM	Dollar Amount Requested
Dr. Warren Barrash, Research Professor	57.69 pr hr	2			$20,000
Dr. Michael Cardiff, Assistant Research Professor	38.46 per hr	1			$6,700
% OF TOTAL BUDGET:	53.4%			SUBTOTAL:	$26,700

B. VISITING PROFESSORS

Name/ Title	Rate of Pay	No. of Months CAL	ACA	SUM	Dollar Amount Requested
% OF TOTAL BUDGET:				SUBTOTAL:	

C. POST DOCTORAL ASSOCIATES / OTHER PROFESSIONALS

Name/ Title	Rate of Pay	No. of Months CAL	ACA	SUM	Dollar Amount Requested
% OF TOTAL BUDGET:				SUBTOTAL:	

D. GRADUATE / UNDERGRADUATE STUDENTS

Name/ Title	Rate of Pay	No. of Months CAL	ACA	SUM	Dollar Amount Requested
MS graduate student(s)	14.00 per hr	2.5			$5,500
% OF TOTAL BUDGET:	11%			SUBTOTAL:	$5,500

E. FRINGE BENEFITS

Rate of Pay (%)	Salary Base	Dollar Amount Requested
28%	$20,000	$5,700
30%	$6,700	$2,400
10%	$5,500	$600
	SUBTOTAL:	$8,700

F. EQUIPMENT: (List each item with a cost in excess of $1000.00.)

Item/Description	Dollar Amount Requested
SUBTOTAL:	

G. TRAVEL:

Dates of Travel (from/to)	No. of Persons	Total Days	Transportation	Lodging	Per Diem	Dollar Amount Requested
					SUBTOTAL:	

H. Participant Support Costs:	Dollar Amount Requested
1. Stipends	
2. Travel (other than listed in section G)	
3. Subsistence	
4. Other	
SUBTOTAL:	

I. Other Direct Costs:	Dollar Amount Requested
1. Materials and Supplies -- Materials and supplies (prototype components, testing consumables, etc)	$4,000
2. Publication Costs/Page Charges	
3. Consultant Services (Include Travel Expenses) -- Tech Help consulting (see Appendix 6)	$2,800
4. Computer Services -- CGISS computing recharge center	$2,000
5. Subcontracts	
6. Other (specify nature & breakdown if over $1000) vehicle mileage costs for travel in Boise and to field site for testing	$300
SUBTOTAL:	$9,100
J. Total Costs: (Add subtotals, sections A through I) **TOTAL:**	$50,000
K. Amount Requested: **TOTAL:**	$50,000

Project Director's Signature: [signature]	Date: 5/26/11