9th Annual Española Basin Workshop

Watersheds and Surface Water of the Española Basin

Ardyth Simmons, editor

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9th Annual Española Basin Workshop Watersheds and Surface Water of the Española Basin

March 4, 2010 Santa Fe, New Mexico

Santa Fe Community College

PROGRAM AND PRELIMINARY ABSTRACTS

Hosted by EBTAG (Española Basin Technical Advisory Group)

An ad hoc group of technical people who represent government and academic organizations conducting geologic, geophysical, and hydrogeologic studies related to understanding of the Española groundwater basin.

City of Santa Fe

Jemez y Sangre Water Planning Council

Los Alamos National Laboratory

New Mexico Bureau of Geology and Mineral Resources

New Mexico Office of State Engineer

New Mexico Environment Department

Santa Fe County

Española Basin Regional Planning Issues Forum (EBRPIF)

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Watersheds and Surface Water of the Española Basin

9th Annual Española Basin Workshop

Thursday, March 4, 2010

Jemez Room, Santa Fe Community College, Santa Fe, New Mexico

PROGRAM

7:45-8:30 am **Registration** - Pick up badges, programs and sign-in; poster setup and viewing

8:30-8:45 am **Welcome and Introductory Remarks**
Who is EBTAG and why the annual Española Basin workshops? Claudia Borchert, Chair of Española Basin Technical Advisory Group

8:45-9:05 am **Overview of Watersheds and Surface Water in the Española Basin**
Amy Lewis, Amy Lewis Consulting

9:05-9:45 am **Rio Grande Water Quality**
Water Quality of the Rio Grande – Dave Englert and Ralph Ford-Schmid, NMED DOE Oversight Bureau; Robert Gallegos and Amanda King, City of Santa Fe

9:45-10:00 am **Coffee Break**

10:00-11:00 am **Watershed and Surface Water Protection**
Collaborative Watershed Planning in the Upper Santa Fe River—A Look Back, a Look Ahead – Sandy Hurlocker, USFS
An Integrated Approach to Mitigating Sediment Transport in the Los Alamos/Pueblo Canyon Watershed – Steve Veenis, LANL
Developing a Living Santa Fe River – Claudia Borchert, City of Santa Fe

11:00-noon **Surface Water Studies**
Surface and Groundwater Interaction in Irrigated Lands, Alcalde, New Mexico – Carlos Ochoa, New Mexico State University
Surface-water to Groundwater Interactions In Streams Originating from the Sangre de Cristo Mountains – Steve Finch, John Shomaker and Associates
Update on the Buckman Direct Diversion Project—Only One Year Until Completion – Rick Carpenter, City of Santa Fe

Noon-1:15 pm **Lunch Break** (food available for purchase in the cafeteria next door)

1:15-2:00 pm **Restoration of Riparian Ecosystems**
Bioengineering and Community Engagement Strategies to Restore Ecological Conditions of Streams and Wetlands – Jan-Willem Jansens and Kina Murphy, Earth Works Institute
Measuring Effectiveness of Restoration Projects – Rich Schrader, River Source

2:00-4:30 pm **Poster Session**

Developing a Living Santa Fe River

BORCHERT, Claudia I., City of Santa Fe, 801 West San Mateo Road, Santa Fe, NM 87505, ciborchert@santafenm.gov

The City of Santa Fe Living River Program originates from an emerging recognition by the City's elected officials of the enhanced quality of life a living Santa Fe River brings to the community. Ever since the City of Santa Fe was established 400 years ago, it has been relying on Santa Fe River flows at a minimum for its domestic and agricultural needs. When the City's municipal needs outgrew the river's supply in the 1950s, the City began supplementing the river's supply with groundwater—first with wells within the City limits, and then with the Buckman wellfield on the banks of the Rio Grande northwest of the City.

As a result of the river's diversion for municipal use, in recent decades the Santa Fe River between the reservoirs and the City's wastewater treatment plant was often dry, except during storm events when short-lived, torrential flows are exacerbated by urban runoff. During the last two years, however, resulting from the City's commitment to a living Santa Fe River, the City has bypassed around its reservoirs to the Santa Fe River channel over 900 acre-feet, including 200 acre-feet in the fall of 2008, and 700 acre-feet during the summer of 2009. Depending upon hydrologic conditions in the upper watershed and pending approval from the City Council, the City plans on bypassing up to 800 acre-feet in 2010, an amount that can supply approximately 11,300 Santa Fe residents annually. Once a regional water supply project, the Buckman Direct Diversion, is fully operational, the City is planning on bypassing up to 1,000 acre-feet to the river annually.

The next steps in the living river program include: 1) developing a River Management Plan that defines how to share, based on a shared goal, the budgeted water among valid water right holders, the ecosystem, recreational uses and aesthetic desires; 2) finalizing a draft report that identifies what the living Santa Fe River's flow needs are in order to have a river that is physically, chemically, and biologically typical of the rivers in this region; 3) further hydrologic studies focused on understanding diversions, river infiltration rates, and the fate of infiltrated surface water, and 4) evaluating additional means to provide water to the Santa Fe River.

Update on the Buckman Direct Diversion Project—Only One Year Until Completion

CARPENTER, Rick, R., City of Santa Fe, 801 West San Mateo Road, Santa Fe, NM 87504-0909, rrcarpenter@santafenm.gov

The Buckman Direct Diversion (BDD) Project is a regional drinking water project that will supply up to 8,730 acre-feet of water per year (peak of up to 15 million gallons per day) to the City of Santa Fe and Santa Fe County. The project will divert surface water from the Rio Grande and pump the raw water 11 miles with over 1,100 feet of vertical lift to an advanced water treatment plant on the outskirts of Santa Fe. There the water will be treated with a somewhat conventional flocculation/sedimentation process but then treated using advanced unit processes of pressure membranes, ozone, and granulated activated carbon before it is introduced into the water system using 15 miles of new treated-water pipeline. The project also includes a diversion structure at the river, a sediment separation and sand return facility, an on-site solar power generation facility, water storage, and 5 new pump stations with ancillary facilities. The project will utilize a combination of San Juan-Chama water and water rights transferred from the middle Rio Grande area. The total project cost is $216 million. The project is on schedule and within budget. The project will become operational in Spring 2011.

The BDD is overseen by the Buckman Direct Diversion Board (Board). The Board is comprised of two City Councilors, two County Commissioners, and one member of the public. Votes are not weighted. The Board was created by a Joint Powers Agreement (JPA) in March, 2005, and a series of intergovernmental agreements that followed refined the roles and responsibilities of the Board. The City and County are 50%–s50% co-owners of the facilities (i.e., each fund equal shares), although the City of Santa Fe was identified as the Project Manager and Fiscal Agent (in charge of all planning, permitting, budgets and accounting, procurement, design, construction, and operations).

The BDD is a very large, complex, costly, and challenging project. Through the years the project has been faced with many challenges, such as political conflicts, legal disputes, regional partnering relationships, protracted permitting efforts, electric power, funding and bonding, water-quality sampling and monitoring, water rights, and planning for future water-quality and water-quantity issues. Staff is currently struggling with human resources issues, including recruiting, training, and certifying for 31 new positions, union negotiations, and project acceptance transitioning to City operations.

The BDD Project dates back, at least indirectly, to 1976 when the City and County executed a contract with the federal government to receive San Juan-Chama Project water deliveries. The first BDD engineering feasibility report was released in 1998. The JPA that created the BDD Board was executed in March 2005. Requisite federal environmental permitting was completed in October 2007. Engineering and design began in March of 2008 and the contractors broke ground for construction in September of 2008. City hiring will begin this Spring and training and certification for project operators and maintenance staff will begin in September 2010. The transition from substantial completion to project acceptance testing will begin in January 2011 and the project will become fully operational by City staff by May of 2011. The City of Santa Fe will operate the project at least until December of 2015, at which time the roles and responsibilities of the operational entity will be up for renegotiation between the City of Santa Fe and Santa Fe County.

A Surface Water–Groundwater Interaction Model for the Northern Española Basin, New Mexico

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Modeling of surface water/groundwater interaction is of great importance in groundwater management, especially in arid and semiarid regions. The traditional approach to water resources management has been treating the surface water and groundwater as separate entities. However, new trends and developments in land and water resources management have indicated that the development of either of these resources affects the quality and quantity of the other. Understanding the hydrologic interactions is the key element for the conservation and effective management of limited water resources in semiarid climates such as New Mexico.

To improve the understanding of hydrologic interactions and explain the long-term characteristics of a New Mexican hydrologic system, a 3-D long-term groundwater model with a monthly stress period was developed for the irrigated cropland corridor and its vicinity along the Rio Grande in the Northern Española Basin. More specifically, the modeled area extended along the Black Mesa Reach of the Rio Grande from about south of Embudo gauging station on the north to the confluence with the Rio Chama on the south. The western boundary of the model coincided with the physical boundary of the Velarde Sub-basin, which is one of the 10 sub-basins in the Española Basin according to the recent water plan reports. The model was supported by a 3-D geological model constructed based on available borehole logs and geological maps of the area. The irrigation canals were defined as the surface water features in the model and the interaction of the canals with the river and the shallow groundwater in the region was investigated by implementing a Streamflow Routing Package (SFR) in the model.

The long-term transient model simulated the heads with an absolute residual mean of 0.51 m in the target wells with SSR of 83.5. The same model indicated that all the irrigation canals recharged the shallow groundwater except the small portion near the north. The river flow predicted by the calibrated long-term transient model was compared to available records of the San Juan Pueblo Gauging Station from 1973 to 1987. The model predicted the river flow between +8% and -12% on the average for 14-year span defined as 158 monthly stress periods.

Isotopic Composition of Natural Nitrate in Groundwater in Los Alamos, New Mexico,

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Los Alamos National Laboratory (the Laboratory) has established background concentrations for various dissolved constituents in local groundwater from perched-intermediate and regional aquifers in the vicinity of Los Alamos, New Mexico. Typical background concentrations of nitrate (NO^{3-}) are approximately 0.31 mg/L as N (0.02 mM). We are using stable isotopes of oxygen and nitrogen in NO^{3-} to distinguish natural from anthropogenic sources, define groundwater flow paths and evaluate groundwater mixing. Following the approach of McMahon and Bohlke (2006), we have explored the $\delta^{18}O$ [NO^{3-}] and $\delta^{15}N$ [NO^{3-}] of water samples taken from background wells and springs in the Los Alamos area. NO^{3-} from a spring and a well located in the Valles Caldera, upgradient and upwind (relative to prevailing winds) of Los Alamos, has $\delta^{18}O$ and $\delta^{15}N$ values of approximately -2.6‰ and 4.8‰ respectively. Tritium and unadjusted radiocarbon analyses indicate that these caldera waters predate Laboratory operations that began in 1943. NO^{3-} from groundwater locations in Los Alamos that exhibit background conditions has isotopic values similar to those of caldera groundwater. Because local groundwater is relatively oxidizing, denitrification is not expected to be a factor in altering isotopic compositions of NO^{3-}. Results indicate that there is little direct atmospheric contribution to dissolved NO^{3-}, and that most NO^{3-} is derived from bacterial nitrification in which one oxygen atom comes from atmospheric oxygen and two oxygen atoms come from soil porewater. Oxygen isotope values plot at or slightly below the expected isotopic trend for a 1:2 mix of these two sources, indicating either slight fractionation of oxygen isotopes during nitrification in the vadose zone or potential mixing with geologic sources of NO^{3-}. Development of a robust isotopic data set for natural background NO^{3-} improves our ability to distinguish between natural and anthropogenic sources of NO^{3-}, allowing for better characterization of groundwater contamination and improved remediation decisions.

In addition, we have developed a probabilistic approach to interpreting isotopic results in a mixed source environment. Defining a probability distribution function rather than a single point for each end member allows us to determine the likelihood of different scenarios of mixing occurring among various sources resulting in $\delta^{18}O$ and $\delta^{15}N$ signature for any individual sample. This more rigorous approach to interpreting isotopic results will allow us to quantify the probablility of contaminant sources occurring in samples and can be applied in any isotopic mixing scenario where the sources have been characterized sufficiently to allow description by a probability distribution function.

Application of the Sitewide Geologic Framework Model to MDA-T and MDA-G at Los Alamos National Laboratory

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The 2009 Geologic Framework Model (GFM) for the Pajarito Plateau was completed last year and reflects information derived from revised surface geologic contact data from recently remapped geologic quadrangles, subsurface contact data from newly developed cross sections and from recently drilled wells of the Environmental Programs at the Laboratory, and new sedimentation models for the Española Basin.

The 2009 GFM was defined by an ensemble of 34 Arc/INFO surfaces representing the various geologic surfaces. In order to improve the visualization capabilities and facilitate the conversion from the GFM to geometric volumes that can be meshed for flow and transport modeling, the GFM was converted to EarthVision "faces" files.

EarthVision allows for true 3-d visualization and model analysis. Here we present the details of the EarthVision model for MDA-T and MDA-G on the Pajarito Plateau. This example illustrates refinement of the 2009 GFM and the utility of EarthVision for model visualization.

Understanding Water Quality in the Rio Grande at the Buckman Direct Diversion Site and Otowi Bridge

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This presentation was prepared jointly by the City of Santa Fe and the New Mexico Environment Department (NMED) – Department of Energy (DOE) Oversight Bureau as part of a study to assess water quality in the Rio Grande at the Buckman Diversion Site and above Otowi Bridge. At the request of the Buckman Direct Diversion Board, Los Alamos National Laboratory (LANL) initiated bimonthly monitoring of the Rio Grande in July of 2008. The ongoing monitoring effort is to provide a characterization of contaminants, including LANL-derived contaminants, in the Rio Grande across all seasons and flow regimes. Along with the bimonthly data, this study also incorporates storm event samples collected by the NMED. Additional data sources include flow data from the United States Geological Survey. The study develops upon findings from an independent assessment by Kerry Howe of the ability of the City/County Water Treatment Plant (C/CWTP) to remove specific contaminants from Rio Grande water. Dr. Howe found the Rio Grande to be an acceptable source on an annual average basis, although he recommended minimizing the impact of storm events on water-treatment operations.

For the study, levels of gross alpha and beta were analyzed, along with alpha, beta and gamma emitters including americium, cesium, plutonium, radium, strontium and uranium. In addition, polychlorinated biphenyls (PCBs), suspended sediment concentration, and turbidity were graphed against flows of Rio Grande at the Otowi Gauge. Evidence from this analysis confirms that the contaminant levels in the Rio Grande are nearly always below levels established by the U.S. Environmental Protection Agency. In the case of PCBs, detects above regulatory standards were explained by detects of congeners in field blanks, an issue that was later rectified by altering the source of blank water.

In comparison with LANL's bimonthly data, samples collected by the NMED during storm events indicate elevated gross alpha and beta levels. Plutonium detected in stormwater from 2009 is indistinguishable from plutonium fallout from atmospheric testing of nuclear weapons. In the case of PCBs, data collected in an earlier study (2002–2003) show detections above the Human Health water quality criteria only during storm events, although detections during 2009 storm events were all below applicable criteria. To understand the implications for water quality over time, definitions of storm events and their frequency are considered, and the radionuclide constituents examined in more detail. Gross alpha and gross beta are shown to have a good correlation with suspended sediment concentration. These data suggest that while storm event flows account for a small percentage of annual flow conditions, additional storm event sampling is needed to determine the origins and identity of radionuclides in the Rio Grande during these particular events. These water quality dynamics may have important implications for the operation of water-treatment facilities.

Surface-water to Groundwater Interactions along Streams Originating from the Sangre de Cristo Mountains, New Mexico

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The interaction between surface water and groundwater drastically changes downstream as water flows from the Sangre de Cristo mountain block to the mountain front, basin, and basin center (Rio Grande). Case studies include the Santa Cruz River, Rio Pojoaque, Santa Fe River, and Galisteo Creek watersheds. Each one of these systems has its own unique characteristics and hydrologic interaction between surface water and groundwater that was distinguished by a detailed review of streamflow, well data, geologic setting, and existing studies.

The Santa Cruz and Santa Fe Rivers have similarities that include large mountain-block watersheds, a mountain-front reservoir, and downstream diversions. The primary difference is the permeability of basin-fill sediments underlying the stream bed. The Santa Cruz River is underlain by low-permeability sediments with limited groundwater development from Chimayo to Española, and the stream is gaining from groundwater inflow. The Santa Fe River is underlain by permeable basin-fill sediments with significant groundwater development and the stream is losing to groundwater. The Rio Pojoaque gains from a perched mountain-block groundwater reservoir (glacial till), losses to the regional groundwater system near the mountain front, and gains from the groundwater system near the basin center. Galisteo Creek has a relatively small mountain-block watershed, and streamflow is dominated by stormwater runoff. Stream flow is losing to the alluvial channel, but the alluvial channel receives groundwater inflow from adjacent bedrock units. A variety of groundwater flow models have been developed to simulate these differences in surface water and groundwater interactions and to calculate streamflow depletion effects. Slight differences between model representation of the surface water and groundwater interactions and actual conditions can result in erroneous water management decisions.

Climate Effects on Oxygen Isotope Recharge Elevation Calculations from the Sierra de Los Valles and the Pajarito Plateau

HEIKOOP, Jeffrey M.[1], LONGMIRE, Patrick [1], DALE, Michael[2], and CHRYSTAL, Abbey E.[1]; [1]Earth and Environmental Sciences Division, MS-D462, Los Alamos National Laboratory, Los Alamos, NM 87545, jheikoop@lanl.gov; [2]New Mexico Environment Department, Department of Energy Oversight Bureau, 1183 Diamond Dr. Suite B., Los Alamos, NM 87544.

Recharge elevation estimates for regional aquifer groundwater beneath the Pajarito Plateau differ depending on lines of evidence considered. Hydrologic, chloride mass balance, infiltration, and precipitation considerations suggest that significant recharge derives from precipitation falling in the Sierra de Los Valles upgradient of the Pajarito Plateau. Elevations calculated from a calibration of oxygen isotopes in modern spring discharge versus recharge elevation, however, suggest significant recharge from precipitation falling on the Pajarito Plateau proper. It should be noted that the oxygen isotope technique calculates the elevation at which precipitation falls, not necessarily the elevation of actual recharge following downgradient surface flow. This fact cannot explain the observed discrepancy noted above, as it leads to overestimation of recharge elevations, whereas the oxygen isotope measurements appear to underestimate the elevation at which recharging precipitation originally fell. For simplicity sake, we refer to the elevations calculated in this manner as recharge elevations.

The slope of the modern oxygen isotope recharge relationship for the Sierra de los Valles/Pajarito Plateau is -0.3 ‰/100 m. This slope is consistent with similar relationships determined around the world, so this factor is unlikely to contribute significantly to the recharge discrepancy observed. Much of the regional aquifer beneath the Pajarito Plateau, however, is mid-Holocene in age. Could the *intercept* of the oxygen isotope–recharge relationship have been different in the past? Past higher overall $\delta^{18}O$ of regional precipitation, relative to modern regional precipitation, would lead to underestimated recharge elevations when using the modern calibration.

Past regional precipitation could have had higher $\delta^{18}O$ if temperatures were warmer (global relationship is +0.58 ‰/°C) or if a greater proportion of monsoonal precipitation was recharged (monsoonal precipitation from the Gulf of Mexico is ~ -6 ‰ whereas winter precipitation from the Pacific is ~ -13 ‰). Several lines of paleoclimate evidence will be presented that suggest regional precipitation during the mid-Holocene may indeed have had higher $\delta^{18}O$. These include carbon isotopic measurements of soil organic matter in the Great Plains, isotope-age relationships from groundwater in the Albuquerque Basin, foraminifera abundance in the Gulf of Mexico, oxygen isotope measurements in speleothems from the Guadalupe Mountains, and tree-ring records from bristlecone pines in the White Mountains of California. If $\delta^{18}O$ of regional precipitation was approximately 1 ‰ higher during the mid-Holocene, recharge elevations would be underestimated by ~ 300 m using the modern relationship. 1 ‰ heavier precipitation would correspond to a ~ 1.7 °C higher temperature or an increase in monsoonal precipitation of 15 % during the mid-Holocene. A 1‰ increase in past precipitation would be sufficient to reconcile the recharge elevation determinations, with precipitation contributing to recharge primarily being sourced in the Sierra de los Valles. These results suggest that the modern oxygen isotope–recharge relationship needs to be used with caution, taking the age of recharged waters into account.

Water Quality Standards and Proposed Triennial Review Changes for the Rio Grande

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New Mexico's surface water-quality standards establish the following designated uses for the reach of the Rio Grande extending from the Rio Pueblo de Taos to the Cochiti Pueblo border (excluding tribal waters): irrigation, livestock watering, wildlife habitat, marginal coldwater aquatic life, warmwater aquatic life, and primary contact. Numeric water-quality criteria are in place to protect these uses. The standards are identified under segment 114 in the water quality standards (20.6.4.114 NMAC).

The federal Clean Water Act requires the state to conduct a formal review of its water quality standards every three years. New Mexico is in the midst of the current "triennial review". The public hearing took place in December 2009, and the Water Quality Control Commission will likely deliberate and adopt amendments sometime in 2010. Among the amendments under consideration is a proposal by the New Mexico Environment Department to add public water supply as a designated use on the Rio Grande in segment 114 because of plans to divert San Juan-Chama water at the Buckman Direct Diversion. Los Alamos County and Española also have long-term plans to use water from this reach. The Department has also proposed radionuclide criteria in response to public concerns that discharges from Los Alamos National Laboratory could threaten public water supplies downstream.

The Department's radionuclide proposal reads as follows: The following criteria based on a 12-month rolling average are applicable to the public water-supply use for monitoring and public disclosure purposes only:

Radionuclide	**pCi/L**
Americium-241	1.9
Cesium-137	6.4
Plutonium-238	1.5
Plutonium-239/240	1.5
Strontium-90	3.5
Tritium	4,000

The criteria values were derived based on current U.S. Environmental Protection Agency guidance for estimating the risk of cancer from low-level exposure to radionuclides. If adopted, the proposal will establish the state's policy regarding the safe level for radionuclides and ensure that the public is informed regarding the presence of these materials in the Rio Grande.

Collaborative Watershed Planning in the Upper Santa Fe River—A Look Back, a Look Ahead

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After more than 10 years of project planning and implementation, the upper Santa Fe River watershed is well on the way to becoming a sustainable landscape that is more resilient and resistant to disturbances, especially large-scale crown fires in the ponderosa pine vegetation that comprises most of the lower slopes of the watershed.

The collaborative effort that led to this improved condition is notable in the way it gathered community support and reversed more than 70 years of "hands off" management assumed to be the best way to meet the protection intent of a Department of Agriculture closure.

This presentation recounts how the community of interests coalesced to support the 7,500-acre thinning project that seamlessly benefited both City of Santa Fe and Santa Fe National Forest lands. The presentation will also describe the effort needed to maintain this community of interests during implementation, as well as review how an extension of the model in the form of a set of watershed management recommendations is intended to maintain the gains made so far.

Finally, the presentation highlights the strengths of the collaborative work, as well as potential difficulties, and ponders how such an approach might be applied to other resource areas, such as water management across multiple jurisdictions and land ownership patterns.

Bioengineering and Community Engagement Strategies to Restore Ecological Conditions of Streams and Wetlands

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In 2000, Earth Works Institute (EWI), a New Mexico nonprofit corporation based in Santa Fe, launched the Galisteo Watershed Restoration Project. The goal of this multijurisdictional, landscape-wide watershed restoration initiative has been to create a system of long-term care for the land and its waterways, springs, and wetlands by involving residents and landowners in multiple-party stewardship teams for specific areas of concern at a community level. Besides residents, partners typically include County, State, and Federal agencies, college programs, local schools, and conservation organizations. The working goal of the initiative has been to create and maintain a working landscape in the Galisteo watershed that reflects people's care and stewardship for the land. In 2008, EWI expanded the initiative to include central Santa Fe County, the City of Santa Fe, and other areas in northern New Mexico.

Restoration sites are used as a means for testing bio-technical restoration strategies, public education, community mobilization, and green workforce development. From an ecological point of view, restoration sites address urgent problems of surface-water pollution and the improvement of wildlife habitat. Techniques include headcut and gully stabilization, removal of non-native vegetation, replanting of native trees and shrubs, Induced Meandering, managed grazing, and road and trail reconstruction. Until about 2005, most of these techniques were still in a testing phase. After 2005, the techniques have been used in a deliberate and well-tested manner. All techniques are based on natural processes and natural and locally available materials. Over time, stream and soil stabilization techniques included more rock material to increase project success. Several sites have required maintenance and follow-up work. However, project costs were less than 50% of standard engineered solutions.

The role of community members has gradually increased over time. In the last few years, EWI has organized communities in Community Stewardship Teams with specific committees for monitoring, tree planting, etc. Community members have assisted with site selection, local outreach, the formulation of community preferences for the treatment strategy, and field monitoring of project results.

Monitoring findings have indicated that project success cannot be based only on vegetation regeneration or geomorphological terrain data and cannot be measured in only 2 or 3 years after project completion. Some projects performed well for about 3 or more years, after which one or two floods wreaked havoc again at the restoration site. Other projects showed poor initial results by seeming to have achieved greater ecological functionality after a decade. In many cases, water infiltration improved, as shown by greater regeneration of native plants, and soil loss was reduced, while the sites maintained a natural appearance. Community mobilization and replication of restoration techniques has in several cases led to independent initiatives by community members, which expanded the acreage covered by the project.

More work must be done to identify the root causes of land, stream, and water-supply degradation. Preliminary observations trace many of the root causes of degradation back to poor land and water use practices and regulations and the lack of enforcement of beneficial regulations. Besides historical deleterious land use impacts, the greatest problems of land health in the area stem from diversion of water in wells throughout Santa Fe County, poor road-drainage management, unchecked runoff from urban development, and land and water disputes that lead to the neglect of land and water resources.

An Integrated Approach to Mitigating Sediment Transport in the Los Alamos/Pueblo Canyon Watershed

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A sediment and contaminant transport mitigation project is underway within the Los Alamos/Pueblo Canyon (LAP) watershed within and adjacent to Los Alamos National Laboratory (the Laboratory). This effort is being coordinated with the New Mexico Environment Department and is also in concert with ongoing support from the Laboratory on the City and County of Santa Fe's Buckman Direct Diversion project. The effort is being implemented throughout a large geomorphically and hydrologically complex watershed using an integrated watershed-scale approach with the goal of improving water quality in stormwater runoff.

The LAP watershed, including main-stem Los Alamos and Pueblo Canyons and their tributaries, includes several current and former technical areas at the Laboratory. Investigations of the nature, extent, transport, and potential risk from contaminants in the watershed were conducted from 1997 to 2004. The results of these investigations indicate that no human-health or ecological risk above regulatory standards is present from residual contaminants that remain in sediments. However, contamination including polychlorinated biphenyls (PCBs) is present in stormwater runoff that occurs predominantly in response to monsoon-season precipitation events. Contaminants measured in stormwater runoff are generally adsorbed to suspended solids, particularly finer grain sizes. Extensive burning of a mixed conifer stand and thick forest groundcover (duff) during the May 2000 Cerro Grande fire caused a temporary perturbation in the runoff response to typical summer precipitation. Although runoff from the Cerro Grande burn area was initially the predominant source of runoff for several years after the fire, at present the most important source for stormwater in these canyons is urban runoff from the Los Alamos townsite.

The goal of the mitigation project is to reduce transport of contaminated sediments in stormwater in three ways: (1) reduce the magnitude and/or frequency of runoff events that propagate through the watershed; (2) reduce the erosion of contaminated sediment deposits during runoff events; or (3) enhance sediment deposition during runoff events. The fundamental approach is to reduce flood energy within the main channel, enable better channel-floodplain interaction, create floodplain roughness to trap sediments, stabilize and enhance an existing wetland to sustain its sediment-trapping efficiency, and use grade-control features to promote burial of older contaminated sediment deposits with new, less-contaminated sediment. Here we present an overview of the actions completed and underway within the watershed and initial results that provide insight into their efficacy.

Two key structures constitute the anchor points of the mitigation actions in Los Alamos and Pueblo Canyons. In lower Pueblo Canyon, a grade-control structure will stabilize the terminus of an existing wetland supported by effluent from the Los Alamos County wastewater treatment plant. Deposition of contaminated sediment will occur in dense wetland vegetation (particularly reed canary grass, *Phalaris arundinacea*) which adds roughness and decelerates flow. In lower Los Alamos Canyon, the area upstream of a large weir was modified to promote short-term retention of stormwater runoff and deposition of bedload and suspended solids. Additional actions taken farther up Los Alamos and Pueblo Canyons compliment these key structures.

The effectiveness of the mitigation actions will be evaluated using stream discharge data and sampling and analysis of stormwater collected throughout the watershed including locations that bound key mitigation features.

Updated Compilation Map and Cross Sections of the Southern Española Basin

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We present an updated and expanded version of the geologic map and cross sections associated with New Mexico Bureau of Geology and Mineral Resources (NMBGMR) Open-file Report 481. When complete, this map will be released as a new NMBGMR Open-file Report. The area covered by this map extends from the Rio Grande eastward to the upper western slopes of the Sangre de Cristo Mountains. The area was expanded to include structures associated with the Caja del Rio horst, a newly interpreted feature from U.S. Geological Survey Professional Paper 1761, and all of the Ancha Formation north of the Rio Galisteo. The northern and southern boundaries remain unchanged, corresponding with the southern limits of the town of Pojoaque on the north and much of the Rio Galisteo on the south. The western extent of the map has expanded to incorporate the Tetilla Peak and Montosa Peak quadrangles (from U.S.G.S. Professional Paper 1761), the White Rock quadrangle, (NMBGMR Open-file Geologic Map 149), and the northern half of the Madrid quadrangle (NMBGMR OFGM-40). The eastern extent of the map has been expanded to include the western parts of the Aspen Peak (this study) as well as the McClure Reservoir and Glorieta quadrangles (NMBGMR OFGM 7 & 11, respectively). The northwest corner of the Bull Canyon quadrangle (this study and U.S.G.S. MF 823) was also added.

In addition to extending cross sections westward across the Caja del Rio horst and its southern continuation, the Cerrillos uplift, newly interpreted faults from aeromagnetic and gravity data are added to the map (using U.S.G.S. Professional Paper 1761). A northern cross section extends between Gallina Arroyo and the Buckman well field. This cross section illustrates the north-down, monoclinal flexure (Rancho Viejo hinge zone of Professional Paper 1761) that defines the southern limit of the deeper part of the Española Basin. Significant fault additions and revisions occur in the poorly exposed uplands between Buckman and Santa Fe. Here, the San Isidro Crossing fault is interpreted as a zone about 1 km wide, generally with two main fault strands that are down-to-the-east. In the eastern uplands north of Las Campañas, faults are generally east-down and included in the Jacona fault zone and the newly recognized Calabasa Arroyo fault. To the west, near the Buckman well field, large faults are generally west-down. Major fault changes also occur in the vicinity of Eldorado. The San Isidro Crossing fault is shown as a continuous, albeit segmented, fault extending under the Ancha Formation between the Santa Fe River and the Rio Galisteo.

The GIS data for the geologic map utilizes a new geodatabase schema (see: http://geoinfo.nmt.edu/statemap/datamodel) that allows attribution of much more information for geologic features (e.g., faults, folds, and contacts). For instance, attributes in the geodatabase now specify the interpretative basis, scientific confidence, exposure, and source data for geologic features. Aside from greatly expanded feature attribution, the new geodatabase structure will allow GIS users to display the data in novel ways and to perform more complex spatial queries and analysis.

Overview of Watersheds and Surface Water in the Española Basin

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The Jemez y Sangre Regional Water Plan, completed in 2003, assesses the water resources of the Española Basin. An important component of the water plan was devoted to answering the question "How much water do we have?" To answer this question, water budgets were developed for 10 watersheds in the Jemez y Sangre Water Planning Region, including groundwater and surface water components. An overview of the sources of inflows and losses are presented for each watershed.

The developed water budgets present only the big picture of the amount of water coming in and going out of each watershed; however, they may not ultimately answer the question of "How much water do we have?" Many factors complicate the answer to this question. First of all, the water budgets show only annual flows and are not reflective of seasonal variability. Second, the amount of water available within a watershed is spatially highly variable; that is, there may or may not be water available at a given point of diversion. Third, the "wet-water" budgets do not reflect the extant delivery obligations to senior water-right owners downstream of the watershed; that is, all water within a watershed is likely not available for use within that watershed. And last, the water budgets are constantly in flux, changing from year to year due to climatic conditions. The bottom line in answering the question "How much water do we have?" is anything but easy.

Aqueous Geochemistry and Environmental Fate of Uranium in the Española Basin, New Mexico

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The regional aquifer within the Española Basin contains highly variable background concentrations of total dissolved uranium ranging from 0.002 to 7.6 micromolar. Numerous volcanic glass deposits in various stages of alteration contain roll-front uranium(VI) ore bodies east of the Rio Grande between the cities of Santa Fe and Española. The regional aquifer typically is oxidizing with respect to uranium, sulfur, and nitrogen, and contains measurable concentrations of dissolved oxygen greater than 0.03 millimolar. Oxygen ($\delta^{18}O$) and hydrogen ($\delta^{2}H$) isotopes plot on an approximate meteoric water line with slope of -7.7 and show nearly 5 per mil $\delta^{18}O$ and 40 per mil $\delta^{2}H$ variation. Oxygen isotope ratios from hydrothermal springs east of Nambe, NM are heavier than the local meteoric water line suggesting enhanced water-rock interaction at these sites.

The regional aquifer consists of calcium-sodium-bicarbonate, sodium-calcium-bicarbonate, and mixed major ion compositions with bicarbonate concentrations commonly exceeding 3.3 millimolar. Uranyl carbonato complexes are predicted to dominate in regional aquifer groundwater. Concentrations of natural reductants including hydrogen sulfide and dissolved organic carbon are not sufficient to enhance stability of uranium(IV) aqueous complexes and solid phases in the regional aquifer. Background distributions of total dissolved uranium are hypothesized to be controlled by precipitation of uranium(VI) minerals, specific adsorption of uranium(VI) complexes onto hydrous ferric oxide, and cation exchange of the uranyl cation with calcium in smectite. The regional aquifer shows variable saturation with respect to soddyite and approaches saturation with respect to haiweeite depending on pH and the activities of calcium and silica.

Anthropogenic uranium has been released from Los Alamos National Laboratory outfalls to surface water since 1943. West of the Rio Grande, surface water and alluvial and perched intermediate-depth groundwater provides recharge to the regional aquifer beneath the Pajarito Plateau. Elevated above-background concentrations of dissolved uranium (maximum of 0.025 micromolar) occur in the regional aquifer downgradient from Laboratory outfalls. Laboratory uranium contamination in groundwater is limited to the area west of the Rio Grande.

Private Domestic Well Testing in the Santa Fe Region

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The New Mexico Environment Department, Los Alamos National Laboratory (the Laboratory), the City of Santa Fe, Santa Fe County, and the Good Water Company sampled 475 private domestic wells throughout the Santa Fe region during 2009 for analyses by the Laboratory of major anions/cations, heavy metals, trace elements, fluoride, and nitrite/nitrate. Test results were compared with U.S. Environmental Protection Agency (EPA) Maximum Contaminant Levels (MCLs) for public drinking-water systems, and with New Mexico Water Quality Control Commission (WQCC) groundwater standards. Well owners were provided test results along with interpretive letters including, when necessary, information on potential health risks and options for water treatment.

Eighty-two percent of all private wells tested did not contain any constituents at concentrations exceeding human health standards set by EPA or WQCC. Potentially hazardous concentrations of arsenic, uranium, fluoride, nitrate, selenium, and barium, however, were detected in 48, 29, 11, 9, 3, and 1 individual wells, respectively. Beryllium, cadmium, chromium, lead, mercury, radium, and thallium were not detected at concentrations exceeding human health standards in any well. Six percent of the wells tested contained sulfate, chloride, and/or total dissolved solids at concentrations exceeding WQCC aesthetic standards, but did not contain any constituents at concentrations posing health hazards.

Arsenic exceeding the EPA MCL of 0.01 mg/L was detected in 10% of the wells tested (20% in western Santa Fe, and 15% in Eldorado). Arsenic was positively correlated with pH, sodium, fluoride, lithium, and boron. Upwelling of deep mineralized groundwater along fractures and faults in western Santa Fe transports soluble arsenic into shallower aquifers. Arsenic also may be released during desorption reactions with clay minerals and hydrous ferric oxide occurring along flow paths in shallow aquifers.

Uranium was detected in excess of the EPA and WQCC health standards, both set at 0.03 mg/L, in 22% of the wells tested in the mountain front area. Proterozoic rocks are the likely source of uranium. The positive correlation of uranium and sulfate in mountain front groundwater suggests that oxidation of sulfide minerals in the Proterozoic rocks may be a potential release mechanism for uranium.

Fluoride exceeding the WQCC groundwater health standard of 1.6 mg/L was detected in water with low concentrations of calcium in isolated areas throughout the study area. Calcium can control fluoride concentrations by precipitation of fluorite. Low concentrations of calcium, potentially resulting from cation exchange, can enhance the increase of fluoride concentrations.

Nitrate detections exceeding the EPA MCL of 10 mg/L as N appear to be associated with localized contamination from onsite septic systems, particularly in the fractured bedrock terrain of the mountain front area. Fractured bedrock generally has a higher degree of vulnerability to contamination from septic systems and other waste discharges relative to basin-fill sediments.

Proposed Metering and Monitoring to Serve in the Administration of Water Rights in the Rio Pojoaque River Basin.

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A metering and monitoring program was implemented in the Pojoaque River Basin for management and administration of basin water resources in accordance with conditions set in the Aamodt Settlement Agreement. This program will help improve our understanding of the hydrologic system and the temporal and spatial availability of surface and groundwater in the basin for future uses. It will also provide valuable field information that may be used to develop and calibrate hydrologic models that may be used for future basin administration. The program consists of a surface-water metering network and a groundwater monitoring network. The surface-water network involves flow measurement in the river(s) and at diversion points to canals and acequias. The groundwater network involves monthly water-level measurements in some wells and continuous recordings in others. Currently, the total number of wells measured is approximately 44 and the total number of surface measurement points is approximately 24. It is anticipated that more surface and groundwater measuring locations will be added in the future.

Surface and Groundwater Interaction in Irrigated Lands, Alcalde, New Mexico

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In arid and semiarid environments, an important source of groundwater supply may come from shallow aquifers. In agricultural valleys of northern New Mexico, the use of traditional surface-irrigation systems has the potential to contribute to shallow aquifer recharge. A study aimed to quantify water budget components and to characterize surface water and groundwater interactions is being conducted in an agricultural valley located in the northern portion of the Española Basin. At the Alcalde Valley, research trials and modeling efforts for characterizing hydrological interactions in the surface-vadose zone-aquifer continuum have been performed for representative crops (alfalfa, grass, and apple) and soils (Fruitland sandy loam, Werlog clay loam, and Abiquiu-Peralta complex) commonly found in this irrigated valley. Also, extensive field measurement campaigns and automated monitoring of climate variables, river and canal water flows, and shallow aquifer fluctuations are being conducted. A water budget approach is being used for characterizing surface water components at the field and valley scales.

Field-scale water balance results show that surface irrigation water percolates below the root zone and helps replenish the shallow aquifer. Deep percolation rates ranged between 15% and 60% and water level fluctuations in response to deep percolation varied from 0.01 to 0.38 m, depending on irrigation amount, soil properties, and depth to the water table. Valley-scale results show that a significant amount of the total water diverted in this floodplain valley returns back to the river. On average, 59% returns as surface return flow, 12% as canal seepage, and 21% as deep percolation from irrigation. Also, valley-scale results show a seasonal trend in water-level fluctuations in response to irrigation inputs, where the water table rises up to 0.6 m within 3 to 5 weeks after the onset of the irrigation season that starts in April and then decreases gradually to baseline level by the end of the irrigation season, in late November.

Results from this study show that in agricultural valleys with permeable alluvial soils, surface irrigation can contribute to shallow aquifer recharge and that significant amounts of the total water diverted into the Alcalde Valley returned back to the river after completing important production and hydrological functions in this irrigated valley of the Española Basin.

Differentiation among Multiple Sources of Anthropogenic Nitrate in Mortandad Canyon, Pajarito Plateau, Using Dual Stable Isotope Systematics

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The groundwater system beneath Mortandad Canyon on the Pajarito Plateau has been affected by multiple sources of anthropogenic nitrate contamination. Average NO_3-N concentrations of up to 18.2±1.7 mg/L have been found in wells in one of the perched intermediate aquifers. Sources of nitrate potentially reaching the alluvial and intermediate aquifers include: (1) sewage effluent, (2) neutralized natural abundance nitric acid from a chemical waste-treatment facility, (3) ^{15}N-depleted neutralized nitric acid, and (4) natural background nitrate. Each of these sources is unique in its $\delta^{18}O$ and $\delta^{15}N$ values. Using nitrate stable isotope ratios, a mixing model for the three anthropogenic sources of nitrate was established, after applying a linear subtraction of the background component.

The spatial and temporal variability in nitrate contaminant sources through Mortandad Canyon is clearly shown in the resulting ternary plots. Whereas microbial denitrification has been shown to change nitrate stable isotope ratios in other settings, the redox potential, relatively high dissolved oxygen content, increasing nitrate concentrations over time, and lack of observed NO_2^- in these wells suggest minimal changes to the stable isotope ratios has occurred. Changes in the nitrate stable isotope ratios over time reflect changes in the volume of effluent released, and/or changes to the $\delta^{15}N$ and $\delta^{18}O$ values of nitric acid used during liquid waste processing. Temporal trends indicate that the earliest form of anthropogenic nitrate in this watershed was neutralized natural-abundance nitric acid. Alluvial wells preserve a trend of decreasing nitrate concentrations and mixing models show decreasing contributions of ^{15}N-depleted nitric acid, consistent with smaller volumes of effluent released from the chemical waste-treatment facility.

Nearby intermediate wells show increasing nitrate concentrations and mixing models indicate a larger component derived from ^{15}N-depleted nitric acid. These data indicate that the pulse of neutralized ^{15}N-depleted nitric acid that was released into Mortandad Canyon between 1986 and 1989 has infiltrated through the alluvium and is currently affecting two intermediate wells. This hypothesis is consistent with previous research suggesting that the perched intermediate aquifers in the Mortandad Canyon watershed are recharged locally from the alluvial aquifers.

Watershed-Scale Investigation of Sediment Contamination—Chromium and PCBs in Sandia Canyon, Pajarito Plateau, New Mexico

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Contamination in sediment deposits in canyons at Los Alamos National Laboratory (the Laboratory), on the Pajarito Plateau of northern New Mexico, is being systematically investigated at a watershed scale from the sources to the Rio Grande. This work includes detailed geomorphic mapping (1:200 scale) in a series of investigation reaches, descriptions of post-1942 sediment deposits in each reach, and sediment sampling and analysis for an extensive suite of potential contaminants. Here we discuss investigations conducted in Sandia Canyon as one example, focusing on chromium and polychlorinated biphenyls (PCBs), the primary contaminants of concern in this watershed.

Sandia Canyon extends approximately 16 km from its headwaters in the Laboratory's Technical Area 3 (TA-3) to the Rio Grande. The main contaminant sources are located in TA-3, including a power plant where chromium in the form of potassium dichromate (used as a corrosion inhibiter) was released from 1956 to 1972, and a former transformer storage facility where PCBs were spilled. Within 1 km of the sources is a large sediment deposition area, about 600 m long, averaging about 35 m wide, and having a maximum thickness of 4.6 m, that includes an extensive cattail wetland fed by effluent discharges. Dissolved chromium, in the form of hexavalent chromium, interacted with organic-rich sediments in the wetland and was partially converted to the less mobile trivalent chromium. Approximately 84% of the total of ~18,000 kg of anthropogenic chromium associated with sediment in Sandia Canyon occurs in this reach. PCBs also have a strong affinity for sediment and organic matter, and this reach similarly contains ~84% of the estimated ~76 kg of PCBs in Sandia Canyon sediment deposits.

Downstream, the stream channel passes through a steeper bedrock-controlled inner canyon with thin and narrow alluvial deposits for about 3 km before reaching a broad, lower-gradient area with thick alluvium. Effluent and stormwater runoff largely infiltrates into the alluvium in this area, resulting in attenuation of floods and deposition of sediment and associated contaminants. In addition, enhanced runoff resulting from extensive development in the headwaters has caused progressive incision and bank erosion in the western part of this downstream alluvial area, and up to 3.6 m of incision has occurred here since 1942. This incision has supplied a large volume of noncontaminated pre-Laboratory sediment that has contributed to reductions in contaminant concentrations in sediment carried by floods.

Although flash floods produced by runoff from developed areas at TA-3 occur frequently during summer thunderstorms, they rarely extend beyond the eastern Laboratory boundary (about 9.5 km downstream from TA-3 and 6.5 km above the Rio Grande). Chromium, PCBs, and other contaminants are found at low concentrations near the LANL boundary, but have not been identified in the next investigation reach about 3 km farther downstream. The processes of contaminant-sediment interaction, sediment mixing, flood attenuation, and sediment deposition have been effective at retaining much of the contaminants released in this watershed close to the source areas and limiting downstream transport, such that there has been no recognized transport of chromium, PCBs, or other contaminants from Sandia Canyon to the Rio Grande.

Use of Congener Homologs to Evaluate PCBs in the Rio Grande Near Los Alamos National Laboratory, New Mexico

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Polychlorinated biphenyls (PCBs) are a class of organic chemicals that had widespread use in electrical transformers and other industrial applications. Although production in the U.S. was stopped in 1977 because of environmental concerns, PCBs are persistent in the environment and present risks to human health and ecosystems in many areas. The New Mexico Department of Game and Fish has issued fish advisories in the Rio Grande both upriver and downriver of Los Alamos National Laboratory (the Laboratory), as well as in Abiquiu and Cochiti Reservoirs, because of elevated PCB concentrations in fish. The New Mexico Environment Department has also required the Laboratory to implement mitigation actions in the Los Alamos Canyon watershed because of elevated PCB concentrations measured in stormwater runoff in this watershed.

PCBs have a strong affinity for sediment and organic matter, adsorbing onto particles and being transported in the suspended load of streams. PCBs include 209 *congeners* that are distinguished based on the number and arrangement of chlorine atoms on the biphenyl rings. These congeners can in turn be grouped into 10 *homologs* based on the number of chlorine atoms. Variations in the percentage of these 10 homologs in samples of environmental media can be used to compare samples and evaluate similarities or differences in possible sources for PCBs.

In 2008 and 2009, we sampled recent sediment deposits along the Rio Grande upriver and downriver from Los Alamos Canyon and other canyons draining the Laboratory to help evaluate sources and concentrations of PCBs in the river. These samples were collected during November–December low-water conditions, and included a range of particle size and geomorphic settings in each sample area (e.g., high-water deposits from snowmelt runoff and slackwater deposits representing late-season flows). Sediment samples were also collected from four areas within the Los Alamos Canyon watershed, which includes the primary potential Laboratory sources of PCBs reaching the Rio Grande, to allow comparison with homolog signatures along the river.

The sediment samples from the Rio Grande show that the homolog signatures in each area vary between sampled layers, indicating variability in the sources of sediment and associated PCBs in each depositional event. The 2008 samples, on average, also differ from the 2009 samples, indicating variability in sources between the two years. However, the average homolog signatures from each sample area in each year are generally similar above and below Los Alamos Canyon, but differ from the signatures in sediment samples collected in the Los Alamos Canyon watershed. This indicates that, based on homolog patterns, there are no recognizable Laboratory contributions to PCBs in the Rio Grande from the Los Alamos Canyon watershed.

Data on PCB concentrations in sediment can be compared with estimates of sediment flux to estimate average annual PCB flux in the Rio Grande and in lower Los Alamos Canyon. Use of the average PCB concentration along the Rio Grande at Otowi Bridge (0.000076 mg/kg) and the average annual suspended sediment flux (2,100,000 Mg/yr) yields an estimated PCB flux of 0.16 kg/yr. In lower Los Alamos Canyon, the average PCB concentration of 0.0026 mg/kg and the estimated average suspended sediment flux of 2000 Mg/yr yield a PCB flux of 0.005 kg/yr, or 3% of the total in the Rio Grande. These flux estimates, although preliminary, support the interpretation based on homolog signatures that Los Alamos Canyon is a minor contributor to PCBs in the Rio Grande.

Measuring Restoration Effectiveness —How Do You Know Whether Restoration Projects Work?
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Restoration projects are great opportunities to learn and find ways to adapt techniques and methods for improving the ecological conditions of watersheds. Schrader will present approaches for getting measurable monitoring results that inform decision-makers and citizens about riparian vegetation, water temperature, shallow groundwater, and other ways to evaluate restoration project effectiveness. Examples from watersheds in northern New Mexico will be presented that include involving citizen volunteers.

Measured Stream Inflow and Outflow for Selected Reaches of the Santa Fe River, New Mexico

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Thirteen seepage investigations have been conducted on the Santa Fe River from May 1973 to April 2007. In the first six of these studies, streamflow was measured from the Santa Fe River below Nichols Reservoir to the Santa Fe River above Cochiti Lake, the current gauging station at the mouth of the La Bajada Canyon, which is located 7.9 miles above the confluence with the Rio Grande. The next seven seepage investigations were conducted on specific reaches of the Santa Fe River below Nichols Reservoir. In 1997, two of these measurement studies were conducted 1-1/2 miles upstream of the gauging station, Santa Fe River above Cochiti Lake. The five most recent investigations were conducted either from the St. Francis Bridge or the gauging station, Santa Fe River above St. Francis, downstream for two or three miles on the reach of the river that flows over the Santa Fe municipal well field.

The Santa Fe River upstream of St. Francis Bridge has several diversions and urban runoff inflows so no consistent gain or loss is apparent. Downstream of St. Francis Bridge, the next 7 miles has shown a rather consistent flow loss until the Siler Road or Airport Road Santa Fe wastewater-treatment plants are reached. During most of the year for several miles below this inflow, effluent makes up most of the flow of the river. Several miles downstream from the wastewater inflows, the streamflow again increases in magnitude partly due to inflow from springs and La Cienega and Alamo Creeks. Streamflow at the most downstream gauging station, Santa Fe River above Cochiti Lake, is captured by Cochiti Reservoir that also impounds the flow of the Rio Grande.

For most reaches upstream of the wastewater-treatment plants, measured flows consistently decrease in a downstream direction. For the Santa Fe River, measured outflow for most reaches are closely related to magnitude of the upstream measured inflow.

Buckman Wellfield and Its Relation to Groundwater beneath Los Alamos National Laboratory

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The regional aquifer beneath Los Alamos National Laboratory (LANL) is a complex hydrogeological system. It is a part of the large-scale regional aquifer within the Española Basin. Based on existing water-level data, the general direction of groundwater flow beneath LANL is predominantly from west to east. The large-scale flow direction is controlled by areas of aquifer recharge to the west (the flanks of the Sierra de los Valles and the Pajarito fault zone) and discharge to the east (the Rio Grande and the White Rock Canyon springs).

The Buckman wellfield is located just east of the Rio Grande. Understanding of the hydrogeological characteristics of the aquifer pumped by the Buckman wellfield is provided by existing information related to (1) basin geology and hydrostratigraphy, (2) hydrogeologic data (pre- and postdevelopment water levels, pumping drawdowns, spring-discharge rates, etc.), (3) ground-surface subsidence, (4) groundwater geochemistry, and (5) naturally occurring stable isotopes. Analyses of these data suggest that the deep section of the regional aquifer pumped at the Buckman wellfield is in a relatively poor hydraulic connection with the Rio Grande and the aquifer beneath LANL. These conclusions can be explained by the pronounced westward-dipping stratification of the Santa Fe Group sediments near the Buckman wellfield, which causes the regional aquifer to be highly anisotropic and under confined (artesian during predevelopment) conditions. The aquifer properties may provide natural protection of the groundwater resources pumped by the Buckman wellfield.