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# USGS WATER PROGRAMS AND INITIATIVES

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It is a pleasure to be here. I was here a few years ago. I have lots of new things to talk to you about what's going on at the USGS in general and particularly in relation to water. The USGS is about 130 years old. It is a federal agency. It is strictly a science agency. We do not manage or regulate. We try to provide information that people need to manage and protect our nation's resources, in this case, water.

This area, this part of New Mexico, is really significant from a historical perspective for us in the USGS because stream gaging actually started not very far from here at Embudo, New Mexico, on the Rio Grande. John Wesley Powell, our second director, said, "You know, if we are going to develop the western United States, we need to know how much water there is, and we need to measure the flow of the rivers." Nobody really knew how to do that back in 1888. We hired some young engineers, a fellow named Frederick Newell out of MIT, and said go out and take a bunch of guys, take the railroad, get off at Embudo, and spend

a few months seeing if you can figure out how to do gaging. And they did. They developed some outstanding techniques, parts of which we still use today, although there are a number of things that we are modernizing and improving upon. The basic principles were really ironed out here in northern New Mexico at Embudo and spread throughout the country starting 119 years ago.

We have a great tradition of that kind of appraisal of the nation's water resources, not just surface water but also ground water. We are always looking at what the issues of the future are and how we need to go about responding to the issues of the future. We have in the USGS recently completed a strategic science plan, which we are going to be sharing more broadly with the wider community. This covers all of the USGS. Just a comment to those not familiar with it—the USGS has four major scientific disciplines within it: water, which I represent; the geology discipline; the mapping folks who we all know for the wonderful topographic maps; and the newest part of the USGS, which is our biological resources discipline that looks at fish and wildlife and the research science behind those things. This positions our agency better than almost any agency we can think of in the world to deal with the natural resource issues because so many issues cut across these many disciplines.

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The science strategy we developed in the USGS has six major topics that we need to focus on for the future. I will quickly go through what those are and state a little bit about the water aspects of those topics. The first one is ecosystems and understanding how ecosystems function and how they will function in the future. An absolutely crucial question and one that you all probably regularly hear in this state is the relationship between water, particularly flow temperature, habitat quality for a variety of aquatic organisms, and I would add riparian organisms as well. Silvery minnows would be just one example. We see this issue cropping up everywhere in the country, wet places, dry places—it really doesn't matter. It is the big issue right now in the Southeast. How much water do those fish or shellfish or what have you need? I consider it to be the gridlock issue in water resources nationwide—that is, coming up with a good, strong definition of the hydrologic needs of the species that we can defend and then work toward protecting the amount of water needed. Our biological and hydrological capabilities in the USGS are crucial to that issue.

The second topic in the science strategy is the subject of climate variability and climate change. I think we all recognize that the importance of understanding climate and what the climate might be like in the future is crucial to understanding what water resources are going to be like. One of the aspects we have particularly stressed in recent years on this topic is understanding seasonal shifts in runoff patterns in various parts of the country. For large parts of the United States in the hundred or so years of historical record on streamflow, we do not see a strong climate change signal in most areas of the United States. What we do see is that in those areas where there is snow and ice, which is significant to the hydrologic system, there are strong changes. We are seeing it strongly in New England. We are seeing it strongly in the Sierra Nevada and less so in this part of the country. I think if we really get in and look closely at some of the higher mountain areas and the source area of the Rio Grande up in Colorado, I think we will see it, which means an increase in flows during the wintertime because we are seeing more rain and less snow in a lot of these environments. There are more melt events. Conversely, there are lower flows in what is usually the snowmelt season, say April through June in various areas. A lot of the places where we have done these analyses, we can see strong seasonal trends, but when we look at the entire year we basically see no trend at all. What we are seeing from climate change to date is this seasonal shift in areas where snow and ice are significant to the hydrologic system.

A lot of work needs to be done, and I think it is going to combine the talents not just of hydrologists, but also of water resource engineers, economists, and others, thinking about a new paradigm for water management, a paradigm that recognizes a nonstationary world. The future is not going to look like the past, and we need to know how to develop, whether we are looking at the 100-year flood, looking at the safe yield of a reservoir, or things of that kind in this nonstationary world that we all now realize that we are living in.

The third topic is energy and minerals. Now that sounds mostly like a geologic topic, but they are important considerations for our water discipline at the USGS. Things like the Questa Mine here in New Mexico are a prime example where there are questions of understanding geochemistry, mineralized areas, and the whole issue of what you need to do to clean up and how clean you need it to be considering that the environment in its natural state was not completely pure with respect to heavy metals. This is an example where hydrology is crucial.

Another issue is the connection between climate and energy and water. The biofuel developments that are going on in the nation and the growing demand for corn have implications for water availability for processing and for irrigation. This is one of the things that I am very interested in watching. If anyone here has insights on it, I would love to hear from you later today. We do know anecdotally that there are areas of the country, particularly on the High Plains, where irrigated agriculture became uneconomical a decade or two ago, largely because of energy costs and increased pumping lifts. Now with the price of corn having increased so much, we are seeing some of those areas potentially coming back and being economical again. People are beginning to pump water to irrigate some of those lands that they may have stopped irrigating years ago. I do not know if that is a tiny phenomenon or a big one at this point, but I think it is an issue to be watched. Our energy future is clearly very much tied to and influenced by our water future.

Natural hazards are another really important area for the USGS and for people to think about with respect to earthquakes and volcanoes, hurricanes and their effects on coastal areas, but most certainly flooding and the importance of our stream gaging network. Our ability to provide up to the minute information directly to users as well as to the National Weather Service to facilitate their forecasts is really an important area. One of the research questions that we are very interested in is the question of the relationship between climate warming associated with the greenhouse effect and flooding. My own opinion is that there is a lot of hype going on about greenhouse warming and associated increases in flooding. Thus far, the empirical record is not at all clear that this is the case. What we see in the United States is increasing economic damages associated with floods over the last several decades, but as a physical phenomenon, the evidence is not at all clear that there is any kind of increase in flooding occurring. I think it is a very important research question and one important to hazard mitigation in the future.

The fifth topic in our science strategy has to do with human health, which is not a topic people often think about with respect to the USGS. Other parts of the USGS, particularly the biological division, are very interested in things like avian influenza and are doing a lot of important monitoring on issues like that. From a water perspective, we are very interested in the issue of mercury, for example, and understanding the geochemical and hydrologic conditions that bring about the methylation and movement of mercury into the food chain and the implications that has for animal health as well as human health. Also, advances in the understanding of pathogens and source tracking are important. If you find an area that has certain kinds of pathogens or bacteria in it, what was the source? Is it a wild animal source? Is it a domesticated animal source? Is it a human source? Is it a bird source? All these possibilities are out there. Before the taxpayer is asked to make huge investments or private industry is asked to make large investments to clean that up, we really need to know the source of the contamination. Using DNA-based techniques to try to answer these questions is a real frontier area for a wide range of scientific folks in the future.

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The sixth and final topic in our science strategy is something we are calling water census. I will say a little bit more about that because it is obviously central to our mission in the water resources programs of the USGS. We have been thinking about this idea of water census for a long time. The nation has a census of population, a census of agriculture, a census of manufacturing; we have economic statistics and all kinds of information about our nation and its resources. What do we have that pulls together the fundamental information about our water resources? The answer is that we really do not have anything. The fact is there

has been no organized national effort to look at our nation's water availability and water use nationwide consistently since 1978, which was the second national assessment conducted by the Water Resources Council. We think a broad overview of understanding our resources and how they are changing is part of what is needed for proper stewardship of our nation's water resources.

There is a story I like to tell about this whole idea of water census. It comes from your neighboring state of Texas and the drought they had in the late 90s. It was a very, very severe drought, and all kinds of key water managers in the state went into the office of then Governor George Bush to talk about the water crisis. Governor Bush said to them, "Well, how much water is there in Texas?" They were all kind of dumbstruck by the question. On the one hand, they said that was really kind of a simplistic question. As they thought about it and as I think about it, it is a really great question. We will answer it in perhaps somewhat complex ways. How much water is in the streams? How much water is in surface water reservoirs? How much water is in the aquifers in different parts of the state? How much water is in the soil? We break it apart into these various components, but that basic question remains of knowing what's out there and how that has changed on time scales of days, weeks, months, years, decades, or even centuries.

I think it is really an important perspective. It is not unlike thinking about your own personal finances or your business or your agency. What is our income? What is our outflow? How much do we have in the bank? Just basic questions like that set the stage for understanding where we are and enable us to plan for the future. To us, water census means taking a consistent and broad look at questions concerning basic statistics of streamflow, low flows, high flows, how they change over time if they are in fact changing, ground-water levels and their changes, and the amount of water we have in storage in our major aquifers. I would point out that we at the USGS in the Albuquerque office have a project funded by the New Mexico Office of the State Engineer to look at changes in storage in a portion of the High Plains aquifer in New Mexico to understand how those changes have taken place since development began and the rate of those changes currently. Conducting similar studies across many of our aquifers on an ongoing basis is important. Describing the depletion of our aquifers, describing the impact of that depletion on streams and wetlands, and describing our nation's water use and what the real trends are in water use is part of this study. One of the interesting trends I see in irrigation is actually a slight decline in the western United States and an increase in the eastern United States. These are interesting trends that we must stay on top of and understand if we are going to be able to look forward to their implications for our water resources.

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Finally, the water census really means organizing the information into models that look at the sources, storages, and the outflows of water including the human aspect. The work we did years ago in collaboration with Albuquerque and the State in the Middle Rio Grande is an excellent example. We worked on understanding how the system evolved over 100 years of development and were able to ask "what if" questions about future strategies.

In 2002, Congress asked us about water availability and use and the need for an assessment. We provided them with a document that described what we think would be an appropriate program to analyze water availability and use by looking at water resources region by region across the nation. We published that blueprint as USGS Circular 1223. Congress funded us to conduct a pilot study of water availability and use and to put recommendations into practice to see what it looked like. Congress chose the Great Lakes basin as the test bed. I think what they had in mind is that they wanted to make sure Governor Richardson knew how much water there was up there to tap. That was the wisdom behind their plan. The products from that study are now coming out, and we have a new website with those products. We think that is an important effort. It forms an important part of our USGS science strategy.

I want to say a bit about some specific programmatic areas in the USGS and things that are going on currently. There always is a concern about the viability and the strength of our stream gaging program. I started off by mentioning that stream gaging by the USGS started right here in New Mexico at Embudo. We are very proud of what we have accomplished with a national network of about 7,400 stream gages nationwide, most of them real-time

gages. We have been concerned over the last 15 years with the stability of the network and the need to modernize it. I think we have made some headway on those issues.

We were seeing, particularly in the 1990s, the loss of gages that had very long records. With conditions like climate change and ground-water depletion, this becomes an important issue to be able to have records that are often as long as 80, 90, and 100 years. Those are great assets to the understanding of our nation's water resources. We do not want to lose them. Back in the mid-1990s in any given year, we were finding that something on the order of 100 to 150 long-record stream gages were being shut down every year and that was because of a lack of funding, both in our budgets and in our partners' budgets.

If you are not aware of it, stream gaging is very, very much a partnership activity in the USGS. In fact, the majority of the money that pays for our stream gaging comes from state and local agencies. In various parts of the country, those agencies were having budget problems and shifting priorities. We would find really important stream gages that would have to be shut down because there was no source of funding for them. We were losing as many as 150 per year of these long-record stations, where long is defined as 30 years or more.

In 2001, Congress responded to that concern and gave us a significant increase in federal funding for stream gages that enabled us to start on the process of building what we consider a federal backbone of stream gages with a very thoughtful design of where those gages ought to be. It is a little bit like the National Weather Service that designed their Doppler radar system. Congress didn't say that they would fund it only if they could find partners. Congress said, "This is important to the nation's safety and wellbeing, and we are going to put these out in a designed pattern and pay for them with federal funds." Our view on where the stream gaging ought to be is that we must have a base paid for with federal funds. The partnership would come into play when more gages are required based on locality and particular needs.

We did get a funding increase in 2001 that enabled us at least temporarily to stabilize the network. However, the funding did not increase for several years, and the effects of inflation had caused us to get back into the situation where we were losing somewhere on the order of 100 long-record stream gages per year. Fortunately the administration has considered this to be an important issue, and in fiscal year 2007, we received an increase in funding for stream gages in our budget. In 2008, there is a proposed increase. If Congress will pass the 2008 appropriation, I think we will see some positive results.

Just to give you a flavor of that, the federal line item for stream gaging, which is called the National Streamflow Information Program, in 2007 was funded at $16.6 million. The House appropriations bill calls for increasing that to $21.6 million. That is a 30 percent increase. That is really good news for the stream gaging network if it is enacted. The Senate also proposed an increase, but not as large. The Senate called for an increase from $16.6 up to $18.9 million, or a 14 percent increase. If Congress can enact either one or a compromise between the two, it will be good news for the stream gaging program. We feel that it will improve the network's stability and also the modernization of the network. Part of that modernization is moving from gages that report to the satellite and back down and into the internet on a four-hour time scale down to gages that report on a one-hour time scale with the modernization of our radios. We are very excited about the prospect of a more modern and a more stable stream gaging network.

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As I said, I think these partnerships for stream gages are extremely important. I want to say just a bit about stream gaging in New Mexico. Back about 20 years ago, we had 196 continuous record stream gages operating in the state. Today that number has grown from 196 up to 221. All indications are that there will continue to be some growth, particularly in some of the urban or fringe urbanizing areas of the state. We are getting more and more of the high data rate radios, so we are reporting more frequently. We have about 13 state and local agencies contributing to stream gaging. They provide, along with our cooperative funding, 66 percent of the total funds. We have six

federal agencies providing 25 percent, and then the National Streamflow Information Program monies, the monies that we control on our own are providing only about nine percent of the total funds and covering 19 of the stream gages. That federal funding has enabled us to add recently the Pecos River at Red Bluff gage and the Rio San Jose gage in 2007. We are seeing some progress.

I want to talk about new mechanisms for data delivery because we are really excited about the things the internet is doing in terms of enabling us to get the data to many kinds of users in an effective manner. We have a new system called IDA, the instantaneous data archive, a place where people can go to get data. We collect data on a 15-minute interval in most cases. For various kinds of studies, engineering studies of floods or water quality and so forth, understanding the true shape of the hydrograph is crucial. Downloading the data on a daily basis going back in history does not really give you the definition that you need in order to do some of those scientific studies. The IDA database, which we are gradually filling with all the data across our offices and across the country, goes back and fills in a lot of that 15-minute data that is so useful to scientists and engineers. We already have 1.5 billion individual data values in that database. We are only about halfway there, but that is now publicly available.

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We have a system called StreamStats and that application is being developed for the state of New Mexico. It has to do with the ability to get streamflow statistics at any given location. I think many of you are familiar with our regional regression equations that say things like the 7-day, 10-year low flow is a function of drainage area, elevation, percent forested, or various other characteristics of the watershed that are based on the data from our stream gaging. This system enables you to go onto a computer in a GIS environment and point and click on any point on any stream and have it return back to you the available stream characteristics at that arbitrary point and then return the corresponding regression estimates. It is a tremendous time saver to anyone who needs to develop that kind of information, whether it is the 100-year flow, the 7-day, 10-year low flow, the mean annual flow, or any of these kinds of statistics. It is a great system, and it should be operational fairly soon for New Mexico and is operational in a number of other states.

One emerging trend in our program is real-time streamflow, which is an important step forward for everyone. We are seeing more and more of the use of real-time delivery of ground-water level information. I used to scoff at the idea of real-time ground-water information because it seemed to me that things don't change that fast with ground-water, so why would I need it in real-time? What I have seen in various parts of the country is that it becomes a very useful tool. For one thing, it tells you if your equipment is not working properly because you can see either the lack of data or something that looks suspicious. It can tell you when you need to service the equipment, and if everything looks fine you can probably go longer periods of time without making a field visit. Particularly for those sites where the aquifer is very tightly connected to streams and to month-to-month climate variations, it gives you the ability to understand whether you are seeing recharge or declines. It helps in the management of a drought situation. Finally, and I think very importantly, real-time ground-water information increases public awareness of ground water. When people can actually see on a day-by-day basis what is happening to the aquifers in their part of the state, it helps to educate and make people understand what is truly happening to their aquifers.

We are doing more and more with real-time water quality information in a variety of locations around the country to help people with operational decisions or public health considerations like bacterial counts. We all know that currently there is no technology that measures bacteria in real-time. You still have to collect a sample and send it to the laboratory and wait for an incubation period and do a counting on the result. What we have found though is that at any given location on any given stream some things that we can measure readily in real-time, like turbidity for example, can be good statistical indicators of bacterial counts. There may be a lot of noise and a lot of error in that relationship, but there still is a relationship. It enables us to make an estimate of the expected concentration of say, fecal coliform, E. coli, or what have you, and the uncertainty bands to make statements like, "We

think there is a ten percent chance that this water is above the health criteria," or "We think there is a 95 percent chance that this water is above the health criteria." We are finding that public health agencies are actually using this information to make decisions about warning the public. We think that is a really exciting development.

Sediment is a very important topic in this state. I think it will become more and more important as the City of Albuquerque moves to withdrawing surface water from the Rio Grande. Sediment data collection is a very expensive process, very labor intensive, and we are finding that there are some new and emerging technologies for measuring sediment loads on a continuing real-time basis, using technology like multi-channel acoustic Doppler current profilers as well as some optical techniques that are still in the research phase. We think it is an important development.

Finally I will just mention a great new research tool. Fiber optic cable is a wonderful system for making temperature measurements. We have a new method where you can literally string a long fiber optic cable in a stream and identify the temperature anomalies. Those temperature anomalies tell you where the zones of ground-water movement into the surface water system are taking place and help to quantify the ground-water/surface-water interaction.

While I am on the subject of ground water and surface water, I also want to mention that we have a new model that is almost ready for public release within the next few months. The final documentation is in its final review phase. It is a model called GS Flow. It is a model that attempts to look at ground water and surface water as a very, very integrated system. It couples our watershed model called PRMS, our ground-water model MODFLOW, and a new unsaturated zone model that connects the two. Much work was done to make sure that we conserve mass and energy throughout the entire system and are able to look at large, large watershed aquifer systems. We did not want to look just at questions of ground-water/surface-water interaction of pumping right next to the stream and things like that, but to look closely at basin-wide effects on time scales of decades and even centuries and spatial scales of many miles. I think GS Flow will be a really great additional tool for the water resources community.

I want to quickly mention that the National Water Quality Assessment program is very active here in New Mexico with some water quality monitoring being done on both surface water and ground water. A very intensive study on the movement of contaminants to large public supply wells is going on in Albuquerque as part of a national effort to get a better understanding of the special characteristics of contaminant transport into large public supply wells.

Another program that is important in New Mexico in the future is our ground-water resources program. We are going back and restudying major aquifer systems that we looked at seriously in the 1970s and 1980s through our regional aquifer system analysis program. In fiscal year 2009, we are planning to go back to remodeling our High Plains aquifer system across all of the states of the High Plains area.

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Something that may be in the future before the USGS is the transboundary aquifer study—legislation that was passed by Congress and signed by the president last year to look at transboundary U.S.-Mexico aquifers in the states of Texas, New Mexico, and Arizona. This has been proposed for funding in the Senate appropriations bill, but not in the House bill, so we do not know how that is going to come out. A million dollars has been proposed. Half of that money would go to the water institutes; half of it would go to the USGS for our internal use, and it would be split three ways into a Texas piece, a New Mexico piece, and an Arizona piece. Basically, it is one-sixth of a million dollars to the New Mexico Water Resources Research Institute and one-sixth to the USGS-New Mexico office for that work. We will wait and see what Congress does with that appropriation as to whether it moves forward. It would certainly be significant here in New Mexico.

Finally, I want to mention an exciting development from my perspective in the Congress. The Secure Water Act was recently introduced in the Senate, and Mike Connor had a lot to do with that. Senator Bingaman and Senator Domenici are cosponsors along with Senator Cantwell of Washington and Senator Johnson of South Dakota. It is a bill that focuses on the matter of water science and information for the

future of the nation. It focuses on the issue of climate change and its implications for water management. The idea is to engage all of the water agencies—the Army Corps of Engineers, the Bureau of Reclamation, the Department of Agriculture, NRCS, NOAA, and USGS—in this question of the implications of climate change for water resources management. It also calls for specific areas of enhancement of USGS water science and information, such as the National Streamflow Information Program, improvements in ground-water data availability, improvements in information about water use, and improvements in the methodologies. I think this is really important to the universities. Making the methods of water measurement more efficient and more accurate I think is crucial. It is specifically called out in this legislation. It calls for the assessment of water availability and use, really very much along the lines that I described at the beginning of my talk about the water census. We are very pleased to see this congressional focus on works of water science and information for the future of water management.

For the USGS water programs, partnerships are really the key to our success. We value those partnerships enormously. We have been at that partnership process for 115 years through our cooperative program. The Office of the State Engineer and the cities, the counties, the tribes, and other federal agencies are very, very important partners to us. They help us set our direction and provide a very large fraction of our funding. Our partnerships with the universities are also very important, including that other university (UNM) that you mentioned a few minutes ago as well because it happens to be fairly close to our major office in the state. We are always looking for an infusion of young, energetic talent from the students coming into our work place.

**Question:** When you were talking about your strategic science plan including climate change and shifts in seasonal runoff in snow and ice, some organizations and groups have been using tree ring data, ice cores, ocean phenomena, and they are looking at long-term changes in runoff. Is the USGS looking at long-term changes?

**Hirsch:** We are very much looking at those kinds of things. Julio Betancourt is a name fairly prominent in the area of tree ring study and other paleoclimate type research that we do. We are learning, for example, that over the last several hundred years there have been a number of very, very prolonged and severe droughts in the southwestern United States. In some respects, the 20th century was a pretty benign and plentiful time period. We are very much engaged in that kind of paleo perspective in water. At the same time, we think it is very important to look at greenhouse warming and the addition of carbon dioxide to the atmosphere and its affect as well as the changes that have occurred in the last few years as that phenomenon has increased in importance.

**Question:** Just one comment on a historical note. Mike Kernodle and I have a paper coming up in *Ground Water* on New Mexico's contributions to hydrogeology and hydrology starting with Powell, Newell, and Bryan and up to Theis, and the paper covers that work.

**Hirsch:** The paper demonstrates the important role the state of New Mexico and USGS people along with university people have played in the history of the development of ground-water science. I'd love to get a copy of that myself.