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ROADMAP FOR NATIONAL AND INTERNATIONAL DESALINATION RESEARCH

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The idea of this conference is to consider the problems and challenges facing the desert southwest concerning its water resources and how we are going to plan for the future. We have heard about the Tularosa Basin National Desalination Facility and some of the research efforts the Bureau of Reclamation has been working on the past couple of years. I think these efforts are incredibly important, but I want to underscore how critical the problem really is.

In 1990, there were 20 percent more New Mexicans than there were in 1980. In 2000, that number was 20 percent again. I think we can expect this increase to occur for another couple of decades. So by the year 2020, there will be 45 percent more New Mexicans than there are right now.

When you think about that population growth, you start to wonder if the technologies that we are putting on the table adequately address our future growth needs. My concern is that we may not have stretched far enough to really meet our future needs. When we wrote our planning document to develop a roadmap, we did it with the knowledge that two paths need to be followed.

The first path is the one that looks at our current technology, reverse osmosis, and looks for ways to improve it, that is, to incorporate what we already know into reverse osmosis to make it more efficient and better in all ways. But I think we would be remiss if we did not consider alternate paths; things we might do that are beyond what reverse osmosis may be able to do for us. In particular, we are looking at how we can develop novel ways of looking at things. How can we plan a process that engineers creativity into the process itself? That is what a roadmap is all about; it is a planning document to engineer creativity into what we do.

Right now the City of Albuquerque is using about 170 gallons of water per person per day. They are hoping to knock that number down by 15 percent. Meanwhile we are going to experience a 45 percent growth in the number of people in Albuquerque. Quite clearly, conservation is not going to get us all the way to where we need to be. We will have to obtain additional water supplies.

Let's kick in one more factor. The 150 gallons per person per day is the water that is used for municipal and some light industrial applications. Last night we all sat down and had a really wonderful meal. How much water was involved in the making of that meal? I can give you an idea: the total water usage for each human in the United States is about 1,500 gallons per person per day - ten times larger than the numbers for which we are planning. The increase in population that we are looking at is something that definitely requires planning. And it definitely requires that we stretch beyond the current technology and start to look for next generation improvements that can address the concerns that are in front of us.

I want to point out a couple of things: our roadmap effort has produced a real document (http://www.usbr.gov/pmts/water/media/pdfs/rroadmapreport.pdf). We have worked together with the Bureau of Reclamation to produce a document that is real; the ideas embodied in it are planning scenarios. The question we all have is whether this document 20 years from now will be looked at as a work of fiction or a work of facts. If it is a work of facts, you will all forget my name and we will be trying to figure out how to solve our water problems. If it is a work of fiction—all efforts in the library that are works of fiction are filed by the author's name. So I hope I am not associated with this document 20 years from now.

When you prepare a road map, you must being with a vision and that vision must lead to quantifiable goals and workable components. This vision has four workable components: 1) we must be able to produce water that meets our need for safety; 2) we must produce water that meets our need to have sustainable supplies; 3) we must produce water that it is affordable (and that is the one component everybody pays the most attention to); and 4) what we produce must be adequate to assure local and regional availability during periods of drought or shortages.

When we started this process to develop new ideas, we started with a vision. The vision lead to the idea of having water that is safe, sustainable, affordable, and adequate. Figure 1 shows the architecture of the roadmap process. We had to define high level needs and the way we did that was through the observation or examination of many case studies. We looked at case studies from particular regions of the country and considered the problems that existed in those regions. We then would excerpt and generalize those needs to come up with some high level defined needs. The next step was to define critical objectives or measurable milestones that allow us to determine how we are progressing. And lastly, we identified the technology areas and specific research areas that need attention. Those technology areas will have a set of milestones associated with them and will have a set of measurable quantities that will tell us how good we are doing. That way we can eliminate the ones that are not working and put more effort into those that are.

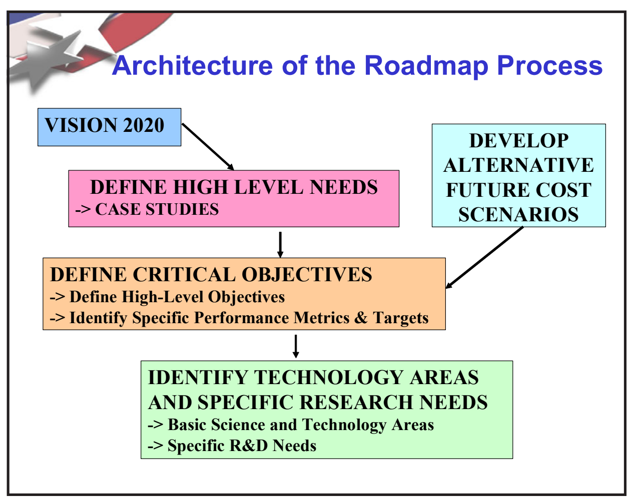

Figure 1.

Developing a roadmap is a people process. Many people are involved. Figure 2 summarizes the people involved in our effort. We broke into four main areas: membrane technologies; alternative/thermal technologies; reclamation/reuse technologies; and concentrate disposal technologies. The themes for those four areas will be continued in the future. We did not have enough experts in thermal technologies to do an adequate job so we combined them with alternative technologies, which I think will be very important in the future.

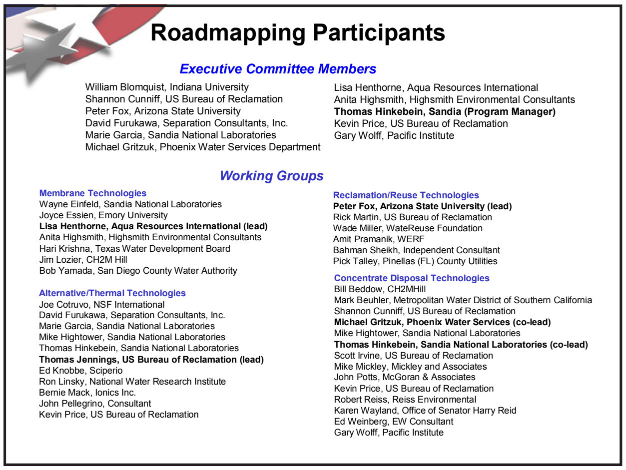

Figure 2.

One of the main area categories was reclamation and reuse. We seldom consider reclamation and reuse as being a desalination activity, but, in general, the technologies are so similar that the benefits derived from studies in reclamation and reuse are usually directly applicable to desalination, at least partly applicable.

Lastly we considered concentrate disposal. In the Southwest and other inland environments, concentrate disposal is one of the more costly aspects of the problem. As a matter of fact, concentrate disposal usually runs between one-third and one-half of the total cost of the process when applied to an inland environment.

As an example of one of the case studies, consider the study we did looking at inland urban and rural areas where a number of challenges were identified (Fig. 3). These areas are all grappling with sustainability and adequacy concerns resulting from the persistent drought. An additional major concern is concentrate disposal. We summarized the needs that derive from these challenges in terms of broad-based statements about the kinds of improvements that needed to be made—reducing cost and enabling the disposal of concentrate.

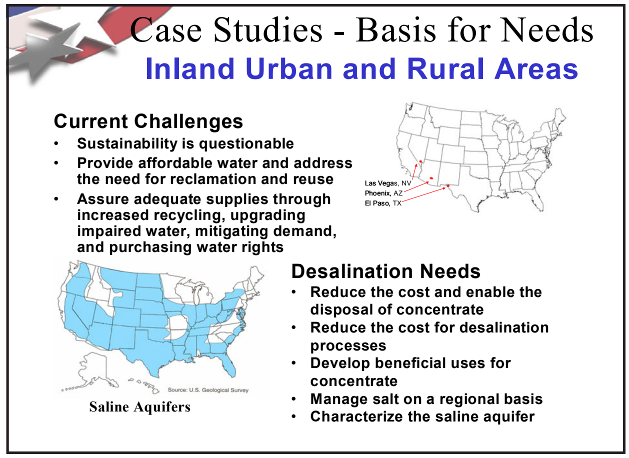

Figure 3.

Reducing the cost of the desalination processes is also important (Fig. 4). In 1965, Gordon Moore made the observation that exponential growth was occurring in the semiconductor industry. For semiconductors, the growth rate is 37 percent and double every two years. Another industry that began in the 1960s was membrane separation. In this case, the improvement is 4 percent per year. If we want larger improvements, we must adopt a better growth process. The exponential growth noted in the graphs in Figure 4 is based on the premise that future gains are based on past successes. (We can all be tall when we stand on the shoulders of giants.)

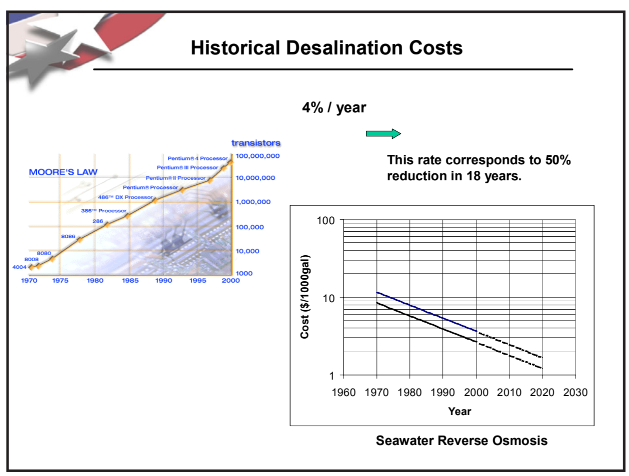

Figure 4.

Think about concentrate disposal as being able to turn a sow's ear into a silk purse, which is one of our goals. Can we develop beneficial uses of concentrate that will improve the way that we look at this process and actually enable us to pay for the processes? In the Phoenix area, they have so much salt in the valley that being able to deal with that salt represents a long-term problem for them.

Lastly, and probably one of the most important areas, is being able to characterize the saline aquifers so that we know what our source terms are.

How do you tell what good will happen with any improvements that you might make? Consider the ideas embodied in Moore's Law in Figure 4. How does the number of transistors on a chip relate to anything? If you plot the number of improvements that can be made (in any technology as a function of time) on a semi-log plot, and as long as you don't start to run into barriers, those improvements end up plotting on a straight line (Figure 5). The idea behind these plots is that, as embodied here, we can make improvements that are so much greater than anyone can imagine because we are standing on the shoulders of all of those improvements that came before and we can see a lot further as a consequence. If we apply the same kind of curves to the cost of sea water desalination between 1970 and 2000, we find a band of improvement that results from plotting the data that actually is linear. And if we do not run up against constraints, we could continue to have improvements well into the year 2020. However, I think there will be constraints. It was the overall opinion of everybody participating in developing the desalination road map that the 4 percent per year improvement is going to eventually start to run into trouble as we get closer and closer to thermodynamic minimums. Currently we are functioning at about three times the thermodynamic minimum and there is still room for improvement. But at what point do we cease being able to make these improvements? We will be looking for improvements that some people refer to as "and now a miracle occurs."

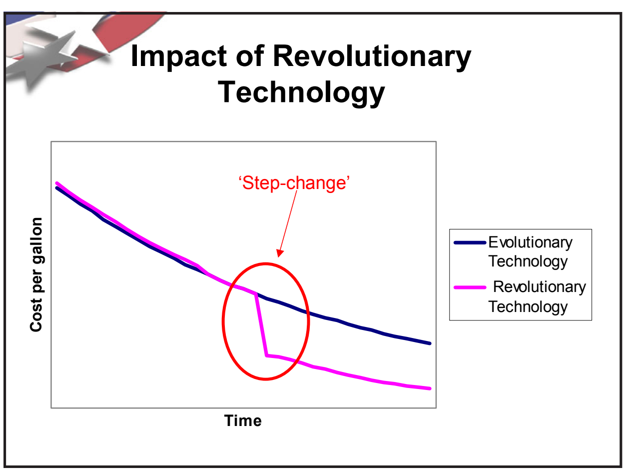

Figure 5.

Concerning our critical objectives as they apply to concentrate removal or the concentrate disposal process — our near-term (between now and six years from now) critical objectives are to reduce capital costs by 20 percent; increase energy efficiency by 20 percent; reduce operating costs by 20 percent; and reduce the cost of zero liquid discharge processes by 20 percent. You can see the constant theme of 20% improvements over the next 6 years or so. That is consistent with the 4 percent improvements that have been observed historically. Thus the kinds of improvements we hope to achieve are consistent with the steady-as-you-go incremental improvements to the existing processes.

Our long-term objectives are regulated by the fact that the population is growing at a very high rate and we need to make substantial improvements in our ability to deliver water to major population areas as well as small population areas. We must deliver water in such a way as to match population growth in order to keep costs at a reasonable level based on today's standards.

I excerpted a study from efforts that were done in Phoenix Arizona by Mike Mickley on disposal options (Figure 6). The Phoenix group was talking about a large pipe-lining project to deliver all of the concentrate to the Gulf of Mexico. That pipeline project was very expensive and had geopolitical problems associated with crossing six state boundaries plus an international boundary, which were going to be monumental. We proceed anyway and figured the cost of the project. The Pipeline bar in the Figure 6 graph has a white area (above the capital cost and operating cost) that includes the cost of the lost resource. All the water that is delivered to the Gulf of California is water that is no longer in the system and thus a lost resource and it does represent a cost. You can do the same kind of analysis for evaporation ponds and for thermal evaporation over the top of evaporation ponds. What you come up with when you evaluate the comparison of disposal alternatives is that the cost of concentrate disposal, if all of the costs are factored in, are, in fact, pretty high. When a true accounting of all costs are considered, concentrate disposal results in increasing the cost of the desalination process by a lot. Further, it gives us added pause when we start to consider the cost of lost water and looking at ways to recover that lost water.

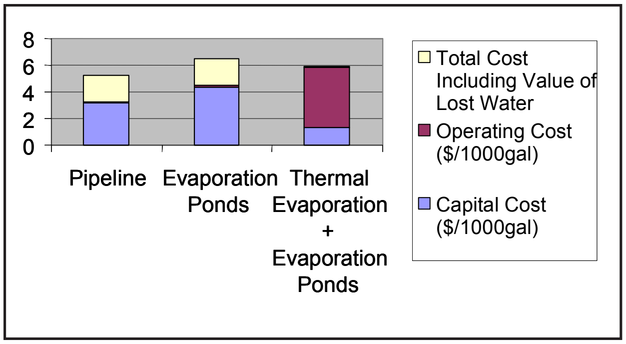

Figure 6.

Let's look at the current costs associated with a couple of options as shown on Figure 6. These are not all of the options; only a couple of options. You will note that currently, evaporation ponds in the Phoenix area are out of sight because the land costs are so great. And even efforts like enhancing evaporation or spraying water into the air really does not change the economics substantially. But you can begin to look at each of these processes and say, "If we did the best that we could, how might we decrease the cost of each alternative by 2008 and by 2020?" We can then start to compare these alternatives with other processes that we might dream up. We have seen some of those processes presented in the last couple of days. We want to take those ideas and evaluate them using the same yardstick indicating how well the economics and other factors compare with the current technologies.

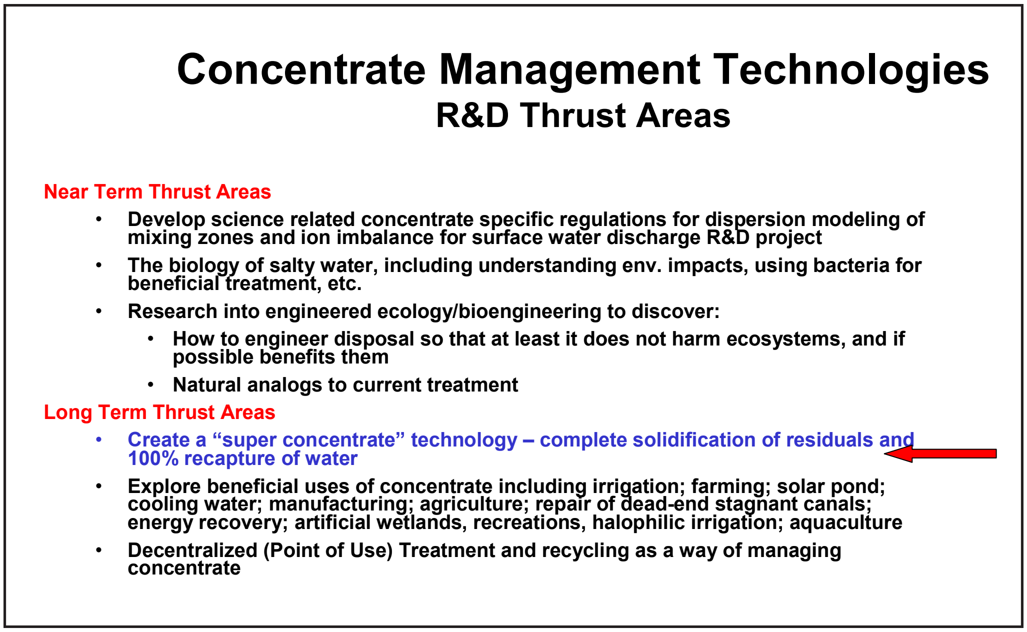

Figure 7.

Zero liquid discharge is likely to be one of the most important driving factors when we consider concentrate disposal, especially in the arid West where we need all of the water we can get. Environmental concerns are one driver for concentrator facilities (zero liquid discharge). Another driver is lost water. Uses and markets for individual salts are emerging and processing companies are beginning to develop.

When we created the roadmap, we developed near-term and long-term thrust areas (Fig. 7). These were determined by a "people-process" where you ask people, "What do you think is the best way to move forward?" One idea put forward for a long-term thrust area was the idea of developing solidified residuals and a recapture of 100 percent of the water, again recognizing the value of a lost resource.

A couple of ideas have been advanced to deal with those issues; you heard earlier a bit about the dewvaporation process that James Beckman of Arizona State University is developing. In this process, air evaporates water from saline feeds and forms pure condensate at atmospheric pressure with humidification-dehumidification. The process naturally transfers heat released by dew condensation to assist evaporation on opposite sides of a heat transfer wall. The process is highly energy efficient and shows minimal fouling. The external heat source can come from waste heat, solar collectors, or fuel combustion. Figure 8 depicts the equipment involved in the process.

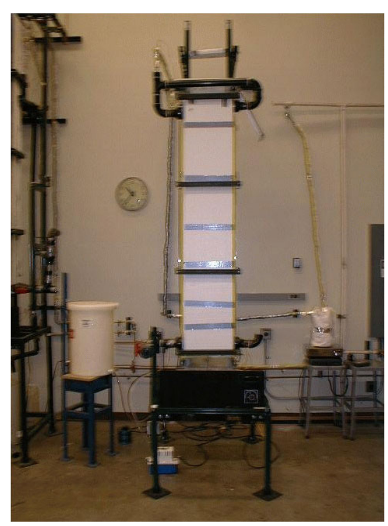

Figure 8.

Another process that deserves an honorable mention in terms of how one might deal with water loss is a wind-aided intensified evaporator (Figure 9). E. Leshman, J. Gilron, Y. Folkman and O. Kedem from Lesico Ltd. and Ben Gurion University are investigating this method. The process allows water to drip down plastic sheets that wave back and forth in the wind allowing the boundary layer to break up and eventually a solid material is formed out of the discharge from the test facility. The process shows minimal fouling. The costs associated with the wind-aided evaporator vary between \$3.2 to \$3.8/1000 gallons, which is substantially less than the costs associated with straight evaporation ponds. This may potentially be a technology that will prove efficient and cost-effective and I am sure there are others to consider.

Figure 9.

Sandia's National Desalination Program consists of three main activities. The first is the work on the National Desalination Research Implementation Plan that is part of the roadmap. That effort is a joint activity with the Bureau of Reclamation, Water Reuse Foundation, American Waterworks Association, and the National Water Research Institute. We will be doing follow-on activities to develop ideas for conducting research in all the main research areas that we talked about plus at least one other that relates to some of the non-technical factors associated with the development of desalination technologies.

The second main activity is the idea of developing demonstration-scale desalination processes, along the same lines as those pursued by the Bureau of Reclamation. It is our goal to make sure that we coordinate with the Bureau in selecting the "right" processes to be tested so we know we are putting our resources into the right places. Our third main activity concerns the development of advanced concept desalination processes. In the future, we will be spending more effort in attempting to go way outside the traditional technologies that are being pursued. Again, we want to examine technologies that can really break through a lot of the cost barriers that are associated with reverse osmosis.

Thank you for your attention today.