Flood Control in an Urban Area: Challenges for AMAFCA

John Kelly, Albuquerque Metro Area Flood Control Authority

Mr. Kelly is the executive engineer with the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA). After graduating from UNM in 1981 with a civil engineering degree and from NMSU in 1983 with an MBA, John's career has concentrated on flood control, starting with operations and maintenance work on the City flood control system, moving through a design and construction role while a staff engineer at AMAFCA, and now in a senior management role in the state's first and largest flood control district. AMAFCA is the leading flood control agency in the state with regard to implementation of storm water best management practices, aesthetic infrastructure designs, and providing multiple uses of its flood control facilities. AMAFCA is the highest bond-rated agency in the state, holding triple-A ratings from both Moody's and Standard & Poor's, the two leading bond rating agencies. One of John's first memories as a kid growing up in Albuquerque is the massive flood of 1963, which happened when he was 4½ years old and was the defining event for the organization for which he now works.

Thank you, Stephanie, for that introduction. We were created by the state legislature in 1963 as the Albuquerque Metropolitan Arroyo Flood Control Authority and to be the local sponsor for the Corps of Engineer's North and South Diversion Channels project. This project was sponsored by Senator Clint Anderson and initially, the sponsors didn't have a local agency to fund it. The city wasn't big enough to cover the limits of the project, the county didn't have the financial wherewithal, and so we were created by the state legislature. Like all New Mexico flood control authorities, our statute required that our first bond issue pass before the agency could come into being. The smart people at the time put that election off as long as they could. Lo and behold, two weeks before the election, we had one heck of a rain in Albuquerque. I do remember that night. My folks were having a dinner party and nobody could get there because Comanche Road was a raging river. We hopped in my dad's 1963 Galaxy 500 station wagon with all four brothers and drove over and looked at the Hahn Arroyo and saw that the culverts were washed out. We drove back to Comanche; it was still a raging river so we went back to the house and lit the Coleman lanterns because the power was out. You know what I remember most about this? Me and my four brothers ate pretty good that night because no one else could get there.

Needless to say, the bond issue passed. The Corps went to work on the North Diversion Channel and built a 9-mile continuously reinforced channel. That channel is designed for 44,000 cfs, which equates to about a 500-year-event; a 100-year-event is about 28,000 cfs. We saw 12,000 cfs back in 1980. The sister project was the South Diversion Channel, a riprap lined channel that heads up at the University of New Mexico pit and runs down to the river at the Tijeras Arroyo. A couple drop structures take care of the grade on this channel. Figure 1 shows a drop structure located just below I-25. I'm sure most of you passed it on your way here this morning. Since it was built, we have used our tax and authority to build about half of the surface drainage system in town.

Figure 1. South Diversion Channel Drop Structure

We share maintenance with the City of Albuquerque and Bernalillo County. We have 36 flood control dams, making us the largest non-federal dam owner in the state. We also have a system of supercritical trapezoidal concrete channels designed for hydraulic efficiency. This was a carry-over from the Corps of Engineers design on the North Diversion Channel; this design was followed through in the 1970s. I like to say that the most efficient thing in local government is our flood control system, just ask any kid who has been caught in there, if he survived. One of our real challenges, as we move into our storm water quality component under the EPA permit, is taking high velocity water and doing something with it to slow it down in order to remove trash, debris, and bacteria. We live in semi-arid grassland and the sediment loadings are incredible. That is one of the challenges we have when we slow water down, we are not just taking trash out, we are taking care of the sediment. That's good, because a lot of things adhere to the sediment.

The public challenged us to make those ugly concrete channels look prettier (Fig. 2), and then to allow us to use some of the 4,000 acres of right-of-way owned by AMAFCA. We were the first agency to use tinted concrete on a flood control channel in a nice earth tone color, and when this first came up the board almost didn't approve it. Back then concrete was about $70 a yard and tint was another $20 a yard. The board did not want to spend that much money to tint the concrete, grey was just fine in their opinion. But one of our engineers went back to the board with another argument, and said that tint was only 2 percent of the cost of the project, which convinced the board to go along with the tint. Thus most of our projects include tinted concrete. We use a lot of shotcrete applications, which gives a rough orange-peel finish and which does a couple things for us: the rough surface deters skateboarders and graffiti doesn't show up well on it. We also use a lot of riprap on channel sides where we have flatter slopes like along the bosques where slopes are lower and concrete lining isn't needed.

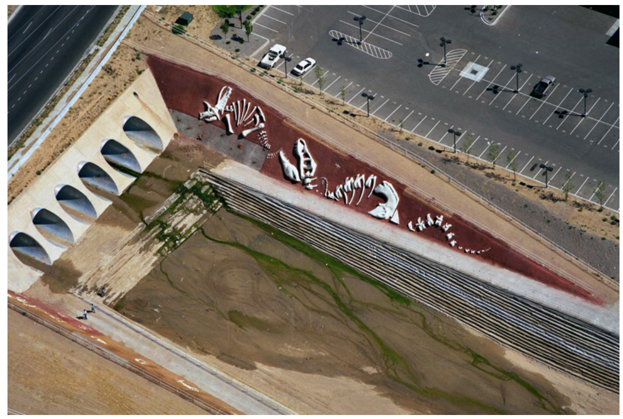

Figure 2. Calabacillas Arroyo at Coors Blvd.

We have also used soil cement extensively on our projects. Figure 3 shows Kinney Dam spillway designed by RTI. They did a great job on this project. The soil cement is alluvium right out of the bed of the arroyo, mixed with about 7 percent cement, enough water to hydrate it, and then it is placed with heavy earth-moving equipment. Those lifts on the spillway are 10 feet wide so we are making up in mass what we lack in rebar. The soil cement breaks at about 1,500 psi compared to 3,000 or 4,000 for concrete, and it looks like a nice set of sandstone layers.

Figure 3. Kinney Dam Spillway

We are the first agency in the state to landform a flood control dam. If you look at the crest of Las Ventanas Detention Dam, designed by Bohannon Houston, you see the crest varies horizontally and vertically. We don't have that long linear crest of the dam and it blends into the landscape better (Fig. 4). We have also varied the slopes by putting aesthetic fill beyond the structural fill so we can actually bring landscape in on a dam embankment (Fig. 2). We were able to build layers of geology into the Calabacillas Arroyo. On the West I-40 Diversion Channel project we have schools of salmon swimming upstream, if you can imagine that (Fig. 5). We are well known for the multi-use aspects of our facilities; we have bike trails up and down 60 percent of our flood control channels in town. It is a great independent transportation system off the highway grid. Our dams serve as anchors for parks, golf courses, and hang gliding areas all over town. At the Kinney Dam, we designed the dam with a two-stage pool, pre-sized for a future soccer field to be worked into the regional park complex. We also set the dam ramps at 20% slopes to meet future ADA requirements and to allow everyone access. With early coordination on the project, we enhanced its future multiple use.

Figure 4. Las Ventanas Detention Dam

Figure 5. West I-40 Diversion Channel

We are a co-permittee under the Albuquerque MS4 permit, which is the EPA storm water permit. We are partners with the City of Albuquerque, UNM, and the Department of Transportation. Our first mandates under the permit were to look at debris removal, characterize the trash going down the channel, and to look at bacteria in storm water. We were one of the last states to get permitted. The permit is in renewal right now. When we looked at debris in storm water in 1999, Don Dixon and crew got together and designed what we call the "shopping cart" and hung it off the Girard storm drain to see what we could catch. We caught a bunch of leaves.

Under the permit, we were required to conduct a gross pollutant study in which we characterized trash. We collected material from City pump station bar strains and we screened trash out of the arroyo system. We characterized the sample by volume. Figure 6 indicates what we found. Large natural materials and small natural materials (tumbleweeds, leaves, pine needles) made up 68 percent of the debris flow. Plastics made up 16 percent of the total, mostly those little water bottles we all like so much. Cigarette butts accounted for 6.4 percent and I think that was probably a function of the screen size that we used, but that surprised us all.

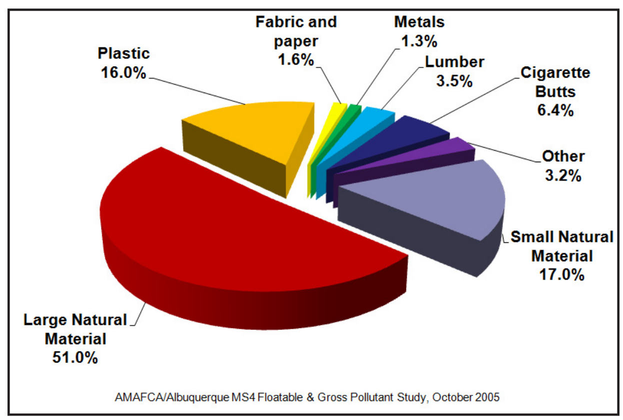

Figure 6. Gross Pollutant Study Debris Characterization by Volume

What we have done on debris removal? We had some good learning experiences with our existing system. Amole Dam, built in the mid-70s on the west side, fills with water, and drains down into the conservancy district's canal (Fig. 7). After the dam drains, you can typically see the accumulated trash, and we wondered why the trash was just sitting down there (Fig. 8). We took a better look at it and realized the ports were on an incline just like the baffle on a septic tank. So that was an easy solution for dams – just put inclined ports in the principle spillway outlet (Fig. 9). Our dams had a simple bar screen across the principle spillway pipe so we went in and modified quite a few of them with the inclined riser. Figure 10 shows a completed project at the South Baca Dam.

Figure 7. Amole Dam

Figure 8. Trash Collecet at Amole Dam

Figure 9. Inclined Port Spillway Tower at South Baca Dam

Figure 10. Completed Inclined Port Spillway Tower at South Baca Dam

I spoke earlier about our high-velocity system of channels. Peeling water off the side of a super-critical channel is a challenge. We have worked extensively with UNM's hydraulic laboratory and civil engineering department on this to the tune of $50,000 a year. I'm sorry we can't also do that with NMSU. We have looked at ways to peel water off the channel without adversely affecting the 100-year-design flow. The setup in Figure 11 has worked pretty well. Freeboard walls have been added on either side, we have sunk the channel, and diverted water off the side. On our first one of these, we had an inlet dead center in the channel but we saw some safety concerns with that and hopefully someone could swim by a storm water quality diversion like this. That pipe runs over into a debris removal structure, this was designed by Bohannon Houston. The pipe comes in and was designed for mechanical maintenance. Figure 12 shows a hanging baffle and a weir so water comes in on the left bank, goes under the baffle, and over the weir so we get a really good capture of the sediments and floatables behind the baffle. That way relatively clean water will go down to the secondary environmental pump. We have modified this design in different ways in different locations.

Figure 11. North Pino Channel Debris Intake Structure

Figure 12. North Pino Arroyo Debris Removal Structure

Figure 13 shows the La Orilla outlet debris baffle; this is where it runs into the Rio Grande. This is a joint use facility with the MRG where we bleed storm water into it from Alameda Road all the way down almost to Montano. We designed this with the hanging baffle and the weir (the weir was already in the structure) and you can see how effective it is at removing trash before it gets into the river. A really easy way to do this is within a manhole (Fig. 14). In a typical storm drain manhole, one pipe going in and one pipe going out. We decided to put a sump in the manhole and a tee on the outlet pipes so the water has to come in, go under the tee, resulting in capturing the floatables. Then if someone forgets to maintain it (this thing is out of sight and out of mind), the water will go over the top of the tee and you have not compromised the flood control function. For this to work very well, however, you must use a vacuum truck for maintenance.

Figure 13. La Orilla Outlet Debris Baffle

Figure 14. By-Pass Manhole Debris Containment after One Year of Operation and Before Maintenance

In our Bear Canyon Arroyo (Fig 15), we looked at a system that the City Refuse Dept. could maintain. We placed screens across the arroyo as we had excess capacity in the channel because of upstream dams. The screens are set up so the City can come in with their normal refuse truck and empty the screens. These work fairly well but you end up taking to the dump 68 percent large and small natural vegetation.

We are now in our fourth generation of storm water retrofits. You will recall from Figure 12, the North Pino Arroyo Structure, that the system worked very well for floatables and sinkers but we had a lot of material that was suspended in the storm flow coming over the weir and running into the secondary pond. Jerry Lovato from our office had been to a storm water conference in Denver four years earlier and he came back with one heck of an idea. We used the coanda screen technology, which uses a wedge wire screen with a half-millimeter spacing between wedge wires. This screen allows little slivers of clean water to be shaved off as the water flows down it (Fig 16). It works in a vertical or incline setting. You have moving water flowing down, sort of like a cheese grater in reverse because as it slices off slivers of clean water, the trash and debris continue rolling down the screen. Figure 17 shows the screen functioning as you can see the water coming over the weir and dropping into the first six inches of the screen. The half-millimeter spacing will take 1 cfs per square foot, which is a heck of a flow rate, and you can see the trash rolling down the screen here.

Figure 15. Bear Canyon Arroyo Debris Screen

Figure 16. Coanda Screen Installation over New Clean Water Gallery

Figure 17. North Pino Coanda Screen Operation

We have set up a similar but bigger project on the Vineyard Arroyo where the screen crosses the entire arroyo before flows make their way into the North Diversion Channel. The screen is sized for the 10-year-event coming down the arroyo (Fig. 18). Figure 19 shows what happens after a storm. The system has been on the ground for one full season, and you can see that water from a small storm came over just enough to come down and drop through the screen. You can see the debris washing down the stream and onto the screen. We have been critiqued by EPA about doing these end-of-pipe treatments, and they want to know why the program isn't up in the watershed, or why it isn't keeping the streets cleaner, or cleaning drop inlets more. The reason is that those are roles for the City, UNM, and the New Mexico Department of Transportation (DOT) in the storm water program; we are confined to the property and facilities we have.

Figure 18. Vineyard Arroyo SWQF Complete

Figure 19. Vineyard Arroyo SWQF After Storm

We must track fecal coliform. This is the only standard we do not meet for storm water. During a storm event, we have huge fecal loads, 80,000-100,000 colonies, but we meet the annual loading under TMDL regulations because of the clean trickle flow that runs down the diversion channel 24/7. EPA required us to look at the sources of fecal matter and we worked with the New Mexico Environment Department (NMED) and Bernalillo County on this. Two studies have been done: the first was done by the City using an antibiotic resistivity analysis and the other study was done by AMAFCA, NMED, and the County using DNA to source track. The pie chart on Figure 20 is a composite of the sampling they found showing the sources of fecal coliform in storm water. You will see that we have a huge canine source, a huge avian source as well as cows, horses – we even have coyotes for .5 percent. These numbers varied depending on where the test was taken. If you tested further up toward the mountains, there was more of a canine and wild source.

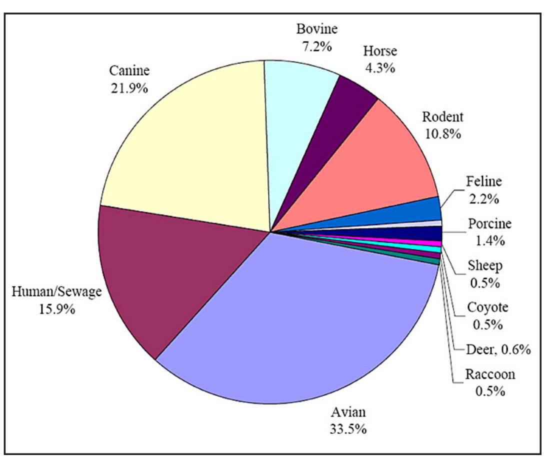

Figure 20. Middle Rio Grande Microbial Source Tracking NMED, AMAFCA, & Bernalillo County

We were surprised at the amount of human sewage that was showing up. Some of it was attributed to leaking septic tanks and some of it is attributed to how the testers typed the human sewage. For example, they went down to the sewage treatment plant, pulled samples off the grid chamber, typed those, and then matched them up to storm water. But what else flows into your sewage treatment plant? Restaurant floor washings go into the sewage system, but they can also be taken outside in a bucket and dumped into the parking lot, which eventually washes into the gutter and into storm drain system. So it may have been somewhat overstated in the study just by the way it was typed.

We do several things to take care of bacteria as well as heavy metals. Many storm water pollutants are bound to sediments and our sediment removal program removes a lot of that right out of the system. Many of our projects have constructed wetland areas that slow the water down. Figure 21 show sediment removal at the North Diversion Channel. Figure 22 shows the long vegetated swale we created going through the entire inlet to the North Diversion Channel. If we slow water down and get some UV on it, you will knock the fecals out. We have done the same at our North Pino Pond where we have built a secondary environmental pond that serves as an extended detention pond. It allows us to slow the water down, drop out more sediments, and allows the sun to work on the bacteria. It works pretty well. We planted the pond with wetland vegetation to take up some of the nutrients and it does a good job. However, mallards live there and they contribute fecal matter to a storm water quality pond. It's one of those things where you try something and you get unintended consequences.

Figure 21. Sediment Removal at North Diversion Channel

Figure 22. Bear Canyon Inlet Bio-Swales

Our storm water quality education program is now a 7-way partnership with the City, County, CNM, SSCAFCA, AMAFCA, DOT, and UNM. We are contributing $80,000 a year for storm water quality education programs and really pushing people to pick up after their dogs. Mutt mitts are now a common feature at almost any city park and along most arroyos. Even with our efforts, we still have direct fecal inputs into the system from our homeless population. Nobody wants to deal with that, but we have had to in at least one spot.

Referring back to Figure 20, we see that human sewage is 16 percent and avian sources are 34 of the total. We developed a project in one location where we were able to knock both those out. We had been looking at a demonstration project to deal with the pigeon problems on our diversion channels, primary at the bridges. We went to the police department and said, "We've got a real problem at Indian School Bridge over the diversion channel, it has turned into a homeless campsite." This area is close to UNM but far enough away where nobody was bothering folks sleeping under the bridge. And if they are sleeping under the bridge, you can guess what they do first thing in the morning. We went in with an Avian Control Project. You have seen the bird spikes and spiders on buildings; we put those on the bridge piers and portions of the abutments. But what was really successful was what we call bird slides. An abutment seat is about 6 feet long and 2 feet deep, perfect for your cardboard and sleeping bag. Figure 23 shows what we did: we put in a stainless steel bird slide so pigeons couldn't roost. It was fun watching them fly in and hit that stainless steel. They were like deer walking on ice. They cannot land and they just slide off. About 5 homeless guys were quite unhappy with our project. Of course, all we did was move them, but they are not doing things in the channel anymore.

Figure 23. North Diversion Channel, Indian School Bridge Avian Control Project - Bird Spikes and Spiders

We are grappling with a couple current issues: one deals with two documented fish kills in the North Diversion Outfall, another deals with water quality data, part of the work of a UNM student who identified a few things in the river no one has ever studied.

One fish kill occurred in 1989 and the only documentation we had on the event was a letter in the file indicating we called the Department of Game and Fish. Two Staff members, Paul Cassidy and Jack Kelly, went out and determined it was a DO (dissolved oxygen) issue. There was a bunch of carp and a few other types of fish dead. It was due to mixing stratified water. A crew went out, buried all the dead fish, and nobody thought anything more about it. Then in 2004, we had another fish kill at the North Outfall. This occurred while the USGS and the U.S. Fish and Wildlife Service were out looking at the outfall as a potential nursery habitat for the silvery minnow. They were monitoring the outfall for dissolved oxygen and after a small storm, we had a fish kill. They monitored oxygen and after an evening storm, the DO drops down to nothing, crept back; another small storm hits and it dropped back down (Fig. 24). They did not find any silvery minnows but the experience made us take a whole other look at the North Outfall. The North Diversion Channel Outfall goes out to the balloon fiesta area and then turns and drains into the river north of Albuquerque. It also travels through the southern boundary of the Pueblo of Sandia. The concrete channel goes under the railroad bridge, through the outfall area, and past the levee into the river. The fish kill was in the embayment area. We looked at this and decided the problem was the bathtub drain area where the channel drops five feet to go under the railroad bridge. The water in that area is known the get stagnant. The theory was that this water had been pushed down the channel displacing water in the embayment area. That's why the DO dropped and caused the fish kill. What did we do? We opened the existing drain in the bathtub area and instead of keeping it closed as we would normally, we opened it to keep water flowing through the sink of stagnant water. It also made sense to put another drain in. Figure 25 shows the new drain and we thought we had the problem solved.

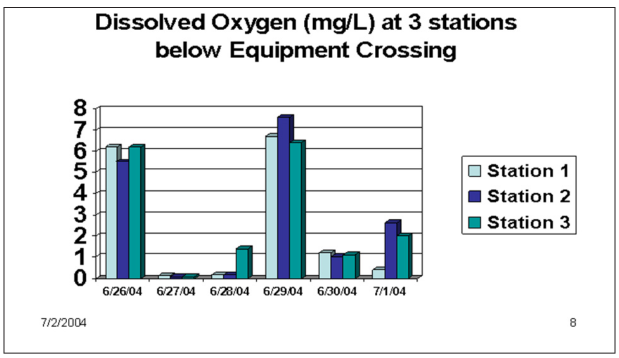

Figure 24. NDC Dissolved Oxygen over Time

Figure 25. North Diversion Channel "Bathtub" Drains

The event took place in 2004 and nothing happened in 2005 through 2006. In 2008, David Van Horn, a UNM graduate student in biology, presented his study on Middle Rio Grande water quality, a study designed to look at nutrient loadings in the Rio Grande. He had 4-way probes set up at Alameda and Rio Bravo and one of the results of the study was that we have a sag in DO. Figure 26 shows the discharge into the Rio Grande and the North Diversion Channel discharge. The drop in DO relates to the flows in the North Diversion Channel; flows in the North Diversion Channel are followed by a subsequent spike in the Rio Grande, and then DO drops. What did we do? The USGS installed DO monitors in the pilot channel to start watching the pilot channel better. We installed a new DO monitor just upstream of the diversion channel because we wanted to see what was coming down the river; there are no gauges upstream. Then we did what all good engineers do, we did a study. A project to look at storm water quality facilities in the North Diversion Channel was actually in the works at the time. We broadened the project and included a big component to look at the Van Horn data and what was going on with DO.

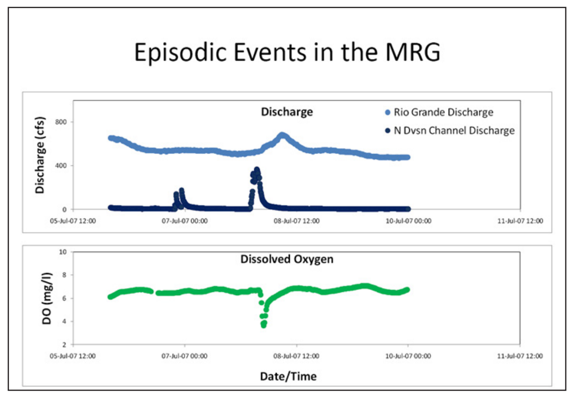

Figure 26. Van Horn Study

First we looked at the diversion channel and confirmed our storm water was full of oxygen, as it should be, as it rushes down the arroyo through drop inlets. Sure enough, the data shows DO at about 5 parts per million (Fig. 27). We looked at the embayment area again. The graph in Figure 28 provides the USGS results. You will note that we are all over the place with DO above 5, below 5. We then looked at the profile of the embayment area. Figure 29 provides the measured dissolved oxygen concentration; the top line reflects the top 18 inches of the pilot channel as we move through the channel from the river upstream and the lower line is the lower 18 inches. The lower 18 inches is deficient in DO. That's when we realized we did have a problem in the embayment.

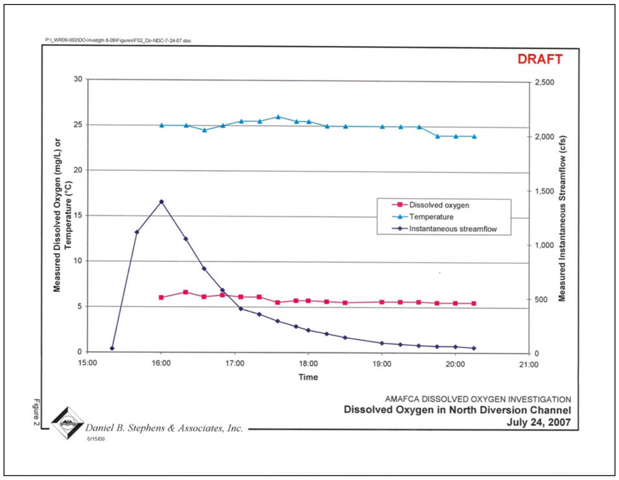

Figure 27. Dissolved Oxygen in North Diversion Channel July 24, 2007

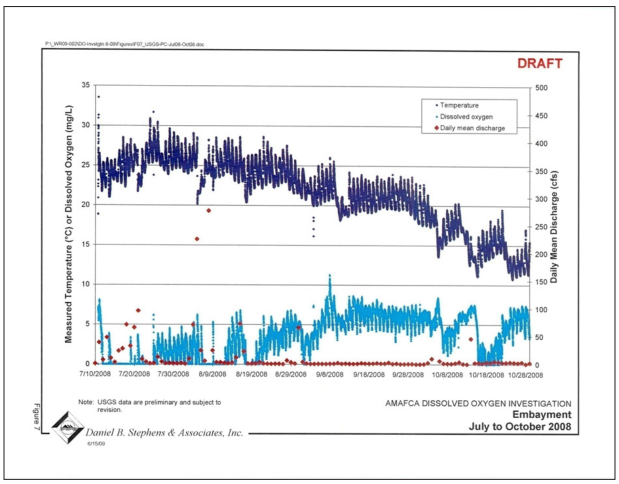

Figure 28. Embayment July to October 2008

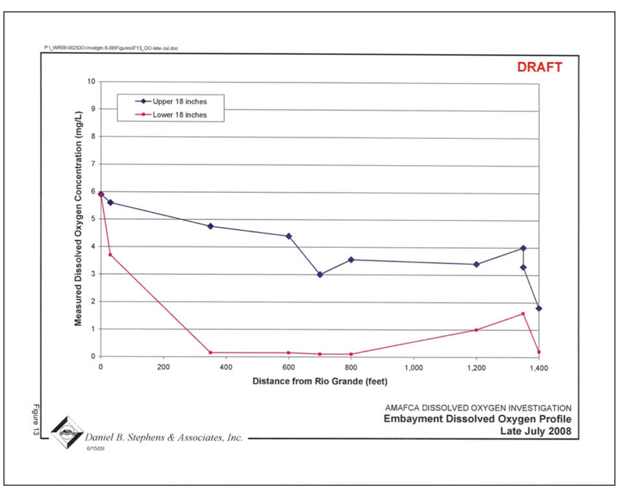

Figure 29. Embayment Dissolved Oxygen Profile Late July 2008

We looked again at the provisional water quality data from Van Horn (Fig. 30). The stream flow in the Rio Grande is the dark line and stream flow in the diversion channel is the lighter line. It's easy to see the response here. Following a storm, the diversion channel spikes followed by a spike at the Rio Grande at Alameda shortly after. You can see the data from a couple other storms that occurred over a five-day period. These results are what Van Horn found. But let's look at the next storm as shown in Figure 31. After the first storm, the DO dropped. We look at the second storm and the DO drops but there is no flow in the North Channel so something else is causing the sag and it is not necessarily the North Diversion Channel. Since Van Horn used 4-way probes, we looked at specific conductance as an indicator of salt in storm water. It should show up high from a natural arroyo system like the Jemez watershed, and it would be low for storm water in an embayment; rainfall has very low specific conductance. Look at Figure 32; you have a flow in the North Diversion Channel, with all that nice clean rainwater running down, and the specific conductance does drop (7/27/06). If we look over at the next storm, the specific conductance spiked (7/28/10), and that is the indicator that we had something coming down from upstream. We don't know if it was wash from the Jemez because we haven't checked or had gauges on those. Could it be from the Montoya's? Could it be from Rio Rancho?

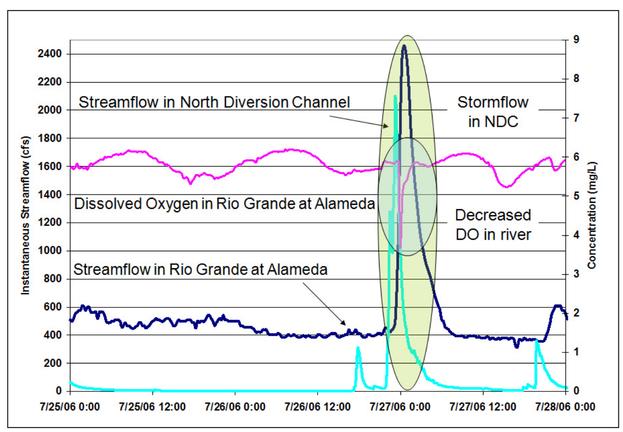

Figure 30.

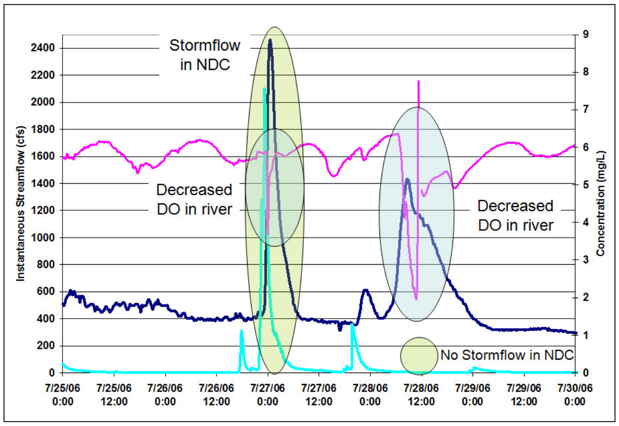

Figure 31.

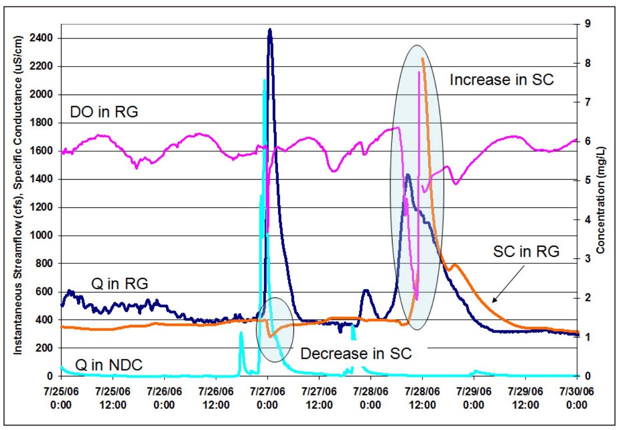

Figure 32.

So what have we done without more information? For one, we have engaged Van Horn to QAQC data so that we have a better validity in front of us and NMED. We have also worked with the Southern Sandoval County Arroyo Flood Control Authority and we have installed four continuous reading probes up at US 550, North Diversion Channel, at Alameda and at Rio Bravo. These probes are being monitored by the USGS and being paid for by AMAFCA and SSCAFCA. We hope that with better baseline data of QAQC/USGS data, we can get a better handle on what's causing DO sags in the river.

So what are we doing with the embayment given our issue of a sink of standing water that is causing sags? D.B. Stephens is looking at a few options; one is to bring a circulation channel through the Bosque and down through the pilot channel to keep circulation going there. The trouble is that the channel would have to be dug out deep enough to provide circulation at Rio Grande flows of 400-500 cfs. We have looked at mechanical aeration and also looked at filling it in. The real constraint is having the equipment crossing – that is what sets up the hydraulic control for the whole outfall. So we are looking at potentially filling in the upper two-thirds of that channel and leaving enough of the embayment area open so that it is naturally circulated from the river flow. We are looking at those possibilities right now and we have some permitting issues to work through. Hopefully we'll bring a project online in a year or so.

Let me finish here with another thought. AMAFCA's former mission was to "build flood control dams to where people won't get flooded." I like to tell people that we now are dealing with a diversion channel system that was designed in the 1950s, built in the 1960s, and designed with that hydraulic efficiency parameter foremost. The channel runs through the sovereign nation of Sandia Pueblo, through the critical habitat of two endangered species, and into the Rio Grande above the City's Drinking Water Project Diversion Dam. We are not in the flood control business anymore. One last thought: The ABCWUA Drinking Water Project Diversion Dam is 2¼ miles downstream from the North Diversion Channel Outfall.

Thank you.