>>Grace Weber: Hello and welcome to our Corrosion Webinar Series. My name is Grace Weber, and I will be hosting today's webinar. This event is put on by the Materials and Corrosion Laboratory within Reclamation's Technical Service Center, located in Denver, Colorado. We host corrosion-related webinars every year to share, with you, topics in cathodic protection, coatings, geosynthetics, and hazardous materials. Today's presentation will be the final webinar in our three-part series focusing on the rehabilitation of El Vado Dam. Our presenters will be sharing the coatings and cathodic protection efforts that are planned for El Vado. Before we get started, let's go over a couple of housekeeping items. We're hosting today's Corrosion Webinar on Microsoft Teams Live Events and we'll be recording the presentation. If you would not like to be part of the live recording, please leave at this time. The recording will be available after this webinar is over through the link you received in your email. During the presentation, please submit your questions and comments as they come up. To access the live Q&A chat feature, click on the Q&A icon, which looks like a chat bubble with a question mark inside. We will be monitoring the chat and hold a Q&A session at the end of this presentation. With that, I would like to welcome our two presenters for today. Our first presenter will be Dr. Chrissy Henderson. Chrissy has a Ph.D. in engineering from the University of Denver, a professional engineering license, and seven years of experience at Reclamation as a researcher and project manager on cathodic protection, materials, cavitation, and other related projects. A fun fact about Dr. Henderson is that she's also a flying trapeze artist in her free time, and she has performed in a number of trapeze circus shows in both Colorado and Arizona. Our second presenter will be Dr. Daryl Little. Daryl has been with Reclamation for over 15 years. He earned his Ph.D. in material science and engineering from the University of Virginia. As a member of the Materials and Corrosion Lab he has worked on many projects using his knowledge of material selection, corrosion, cathodic protection, and failure analysis. He has tested cathodic protection systems throughout Reclamation, as well as performed CP repair and system replacement. And now I will hand this presentation over to Chrissy.

>>Dr. Chrissy Henderson: Thank you very much, Grace, for the introduction. As Grace mentioned, this is the final in a three-part series. Umm. To start with, El Vado Dam is located on the Chama River in North Central New Mexico. It did complete construction in 1935 by the Middle Rio Grande District. And was then transferred to Bureau of Reclamation in the 50s. Cathodic protection was not added until the 80s. And there's some unique features regarding this dam. For one thing, it is one of the few steel lined dams in the US. The faceplate is steel lined and it also had a spillway that was steel lined. For this particular rehabilitation project, the faceplate will remain steel lined and will be updated with a new cathodic protection system. And it also will have a geomembrane added to it. The radial gate will become a newly installed radial gate, and will also have cathodic protection. Quick recap. Based on the first two webinars in the three part series. This dam is not the best location for a dam. There was a lot of geological instability that had created a significant amount of seepage and erosion issues. What you can see in this top picture is a dashed area which consists of a landslide zone that has really contributed to a significant amount of the issues seen. Because it's one of the few steel face rockfill dams, it does have some unique issues that have shown up with it. Because of the settlement that is happening along the dam, and the issues with the landslide and instability in the region, the steel plate has had quite a significant amount of bending and deformation and distress. You can see that in this image. It's also experienced cracking in a lot of its joints. This has allowed a significant amount of water jetting to occur, which actually just further enhances the problem. Because the water, as it seeps through, will erode out the soil by taking a lot of the fine... sands with it. This creates additional voids that were not supposed to be there. So, one of the ways that this rehabilitation project will deal with the erosion and seepage issues is through the use of a PVC membrane. Because the steel plating hasn't lost too much thickness over the years—this was determined with ultrasonic testing—it has been been determined that the steel plating will remain. However, as you can see in this image... the PVC geomembrane will actually be used on 88% of the dam faceplate. Primarily as a method to protect the dam and restrain a lot of the erosion and seepage issues. The little red portion that you see, at the bottom, is actually going to be primarily—all there. And will be the area that we will be protecting with our cathodic protection. This will be demonstrated throughout this webinar and we will elaborate further. In terms of the coatings—We are not going to be recoating the faceplate. A lot of that is being taken care of with the PVC membrane and the cathodic protection on the portion that's underwater. For cathodic protection design, we will need to treat the faceplate as bare. So, one of the things—there was a recoating effort that was done in the 1950s. However, there are not a lot of records, so it seems like this may be the only recoat that has been done. The idea for this rehabilitation project is that... The coating will be dealt with in terms of a hazardous material standpoint. Because we do have attachment points that will be occurring for both the geomembrane and the cathodic protection. And for that reason, we did have to do some hazardous materials mitigation, which was discussed in webinar number two. Our cathodic protection system was—that was currently on it, was not installed until the 80s. so El Vado Dam went a good 50 years without cathodic protection. However, for this rehabilitation project, the cathodic protection will be replaced. And with that, I'm gonna go ahead and hand this presentation over to Dr. Daryl Little.

>>Dr. Daryl Little: Well, good morning slash afternoon. My name's Daryl Little, and I'm gonna talk to you about the cathodic protection system on El Vado Dam. First, we're gonna start off with what is currently there, that we are actually in the process of removing. And it was a system installed using horizontal anode beds. There's two rectifiers on the left abutment side. Three rectifiers on the right abutment side. Um, three of them are 50 volt/50 amp rectifiers. The other two are 75 volt/75 amp rectifiers. For a total of eight—with a total of eight horizontal groundbeds. Uh, Chrissy—Yeah, thank you. Um, as you can see here—in the two circles shows the location of the rectifiers, and then also the horizontal groundbeds. The historical information we have actually originally called for even more groundbeds, including some deep wells. But unbeknownst to us as to what—when the decision was made or why the decision was made, only these eight horizontal groundbeds were installed. And this system was actually used to protect both the faceplate—the water side—and the soil side. Because the soil side of those faceplates was never coated. They went in bare. It was also there for protection of the soil side of the spillway and the radial gate. So, since they—since the new project, one of the things that's going to go away is that metal spillway. It's gonna be replaced with a concrete. So we no longer have a metal spillway. And therefore, that isolates that gate completely.

So—next slide, please—We have a new system going in! And instead of having one—instead of having one system that protects everything, we determined that it would be better to actually have two separate systems. Installing a galvanic system since—for the radial gate. Primarily because also we don't know how often or how much water will be on that gate at times. And it's—since it's now going to be in a concrete spillway, it's really isolated from the faceplate. And then we'll do an impressed current system for the faceplate. Now, the membrane is going to be on that top 88%. However, there's still that bottom, uh, 12% that is exposed to the water, that is also unknown on the condition of the coating. So, we're gonna assume bare. But there's also the downstream side of that faceplate. It's still in contact with soil. So, it still has to be protected. As you can see the... The rectifiers will actually be moved over to where the building is—that red arrow going to the top. So it'll be to the—on the left side of the spillway now. The galvanic system will be located—those anodes will be in the spillway, roughly... under the bridge or just to the downstream side of the roadway, or bridge. And then the groundbeds for the impressed current system were—will actually be deep well anodes. And they will be up on the hillside, far enough away so that we can get our remoteness. Next slide, please. So, here's a drawing showing where the new rectifiers are going to be. They're going to be on the outer wall of the control building. Nice thing is, this will now put them behind a fence, so we're going for safety this. time. They're not going to be—No one can just stroll up to them and check them out. Unfortunately that was... One aspect of the old design. So, we—one of the things that we're always looking at is improved safety and security of the... System. Or—and our—the components. The new groundbeds will be in a large field up on top of the hill. They'll actually be one of the last things installed as part of the new spillway project because that area will also more than likely be a staging area for the contractor. Next slide, please. So, the new system, like I said, two separate systems, the faceplate. The geomembrane is gonna cover most of that. But it's not covering everything. We have no idea what the coating is like down below. One of the things that—Reasons why they're not coating that covering, that geomembrane—is, we can't drop the reservoir level any further than that elevation. And, also, that would require some heavy equipment in there to remove the—All the dirt that's now piled up against the bottom of the dam. Umm. One thing about it though, no matter what, it's still a very large bare area to protect. So we know that that's quite a bit of current that's going to be required. So, these are some of the things that we're always thinking of, is—The "what if's." And sometimes we've—our systems look like they've been overdesigned. But there's always the "what if's." And the "what can't we predicts," So one of them is—How much coating is on it? Now, the gate—that's not going to be steel anymore, it's going to be concrete. So, therefore it's going to have its own own system. It's gonna be a brand new coated gate. So, therefore, that reduces how much current we actually need to protect it. And the anodes are going to be located at a distance from the gate, rather than via direct amount. A lot of our projects we've been mounting anodes directly on the gate. But in this case, we're going to put them a distance away and also lower them as—lower some of the bottom anodes as much as possible. And Chrissy will discuss that a little bit later. Because if we only have a little bit of water in that spillway, we want to make sure that we still have an anode in the water, and therefore protecting that gate. Next slide, please. So... Let's get into this. So, we have the deep well anode beds. We decided this—to go vertical rather than horizontal. One is, it allows us to get down into some of the some areas where we know we have good soil for an anode bed. So we know we need—since this is such a large structure—we know we have a lot of resistance in circuit. So we're trying to—We decided to go with a deep well, as we can go longer beds, and put them in ground that is of lower resistance than what is up—where the shallow beds currently are. It also allows us to go and put them all in one location versus spread on both sides. Because we don't have—There's been some questions as to who really owns some of that land on the left of abutment side, but we know we have a good field to go into. We also know that by doing these deep wells, we can get pretty far out from the structure, and therefore we get what's called remote. And remote is something that we are always striving for so that we get good current distribution on the structure. So we get a nice even protection. Versus protecting one part of the structure more than another. We also have that nice hill, so we can spread these deep wells out, so that we also won't cause interference between the beds themselves. So, these are all things that we wanna look at. Designing these anode beds, one of the things to really look at is that discharge capacity. We know that we have to have a lot of current. But, we also know if we don't design the beds correctly, you're not gonna—you actually, when you turn up the rectifer to get the current to protect the structure—you actually could be exceeding the discharge capacity of the groundbed. And you'll dry it out. And then you shorten the life of your bed. So, we want to make sure that we are designing—sort of, we designed down the road. We don't design for the immediate. And by doing that, we know that we're not going to dry out that bed. But if we see that we're turning it up and we're not getting a lot of current out of it, then... They have these—If you see this little goose-necked vent—that actually allows you to add water to your anode bed. So that you can almost, in a way, reenergize it. You're gonna basically put water back into that bed. So, by doing that, then the resistance decreases. And therefore you can put more current out. Next, please. So, deep well versus horizontal. One, about the deep well, less ground taken up. So, you're digging down versus out. Often it's easier to get an anode bed remote from a structure. A lot of the pipelines that we're working on, we have a right of way that's maybe 100 feet. The pipeline might be in the middle, might be over on one side. So, you're looking at—We might have, if we used a horizontal bed, the farthest we can get away from the structure is maybe 35 feet, 40 feet. Well sometimes that's not enough to get that remote. But if we go vertical, we can get 100, 150 feet away from the structure. And therefore get that remoteness without getting outside of our right of way. And right of way is critical on all these jobs because if we can only—If you go out of your right of way now, you're either buying someone's land or violating a treaty or... Something like that. Can't have that happen. So, we look at down. Any way to get that distance. Umm. Now, these deep wells, or even the horizontals, they are treated like one large anode. So, the picture that you see up there with the galvanic—You see those white bags—each one of those is an anode. So if we did—when we did our calculations, That anode bed is calculated, and all you're doing is you're calculating the resistance of that bag. When we're doing the impressed current, that trench is also filled with—it's not a bagged anode—but it's filled with coke breeze. Well, now that coke breeze, even though it has maybe six anodes in it—that entire volume of coke breeze is a single anode. And that's what we use for the calculations. So, the nice thing is, it makes it look like you have a much—and even though you have multiple anodes in it—it looks like you have one large, long anode. And when you're running the resistance calculations, long and skinny has a smaller resistance than the short and fat. And therefore, that long and skinny, you get that lower resistance, you get more surface area per your current discharge. And you get a lower circuit resistance. Next, please. In this case, we are actually—we gave options. One, we can use a high silicon cast iron anode in our deep wells, this is something that we've been doing for years. But they also make these mixed metal oxide anodes. They have been used successfully. The one thing to look at between the two is—one, your current discharge capacities. The high silicon cast iron seemed to be a little bit more forgiving when it comes to that. But, also, the high silicon cast iron are a lot heavier. So, when you're looking at putting an anode down 150, 250 feet into the ground on a cable, those are a lot heavier. And when you're looking at putting 12 in a deep well, that's a significant undertaking compared to the mixed metal oxide, where each one of them weighs maybe a couple pounds. Compared to 60 pounds. So, these are all things that—it's not just the design. We're looking at the designs, but we're also thinking down the road of how—What's that cost on installation? Not necessarily the materials, but the labor. So you're looking for something that is... Feasible. And this is all the feedback that we hope to get from our partners in the field—is on constructability issues. So, if you ever see something that you're like, "yeah, no, that's not really the easiest way to do it," please let us know. We—we're all ears. Chrissy, next slide please. So, one of the things we have to do is, we're gonna have to make some cable attachments to the dam faceplate. And we're gonna make them at the top with a... metal—Basically, we're going to do a thermoweld, or a metallurgical bond. And... it's a—basically, some people call it a shot. So, you have this mold. Cable goes in it. You get a metallic powder that is a combination of black powder and metal filings. You light it and it melts it and forms a really strong bond to the faceplate. So, that's how we're gonna bond our cables. Next, please. Now, in order to... help out—if we could just bond our cables at one part of this faceplate and say, okay, we're bonded—However, the downside is, we really wanna go back to looking at that circuit resistance. So, what we need to do is do multiple attachments. And so we're actually going to do two attachments at the top left, top right, and top middle of the faceplate. And then that's going to be covered with the geomembrane. And the reason for doing two cables at each location one, is—we're only really going to use one to attach to the rectifier—but, it's always best, since it's going to be difficult to get back and fix the cable, to do the two attachments. Go ahead and do it. We run the cables. That gives us a spare. Or we connect both up. It doesn't matter. That's gonna—if we connect both, now we have two parallel cables going to the rectifier. So, that just reduces the circuit resistance a little bit. The other thing that this allows us to do is prevent some of the attenuation that would be possible. Because if you connect on one end, all that current's going through and at the other end—say if you connect to the right—at the left abutment, if you don't have a connection, you could get attenuation. So, a decrease in the protection or current that's collected onto the structure—might be less on that side than on the right side. So, by doing multiple attachments, we're actually helping out with that attenuation issue. Next, please. So, like I said, redundancy. Redundancy is always a good thing. Going back—since this is gonna be underneath the membrane—we don't want to mess with that membrane again. It's just like not wanting to dig up a pipe. After you've buried it. So, redundancy is always something we look at. Minimize that attenuation and decrease the cable resistance in the circuit by doing multiple cables. So, as you can see here, We're gonna make that metallurgical bond, then we're going to coat it with a mastic. And then on top of that will be the geomembrane. Next. So, a couple of things that we looked at were challenges. One is, how large of a bare surface area this structure is. Needs a lot of current. You have structure resistance versus surface area. So, it may seem like, hey, we've covered a good portion, 88%, of that front face of the dam. So, it's no longer in contact with the water. We're getting rid of all that spillway. We're getting rid of the gate. So, our system should be smaller. But that's not actually true. So, I threw up this equation. This is a resistance equation. Rho is our electrolyte resistivity. So... Say that's just—we'll just make it a constant for this demonstration. Then we have D. Well, D is diameter of the plate. So, since it's in the denominator, as it goes up, the resistance goes down, but since we've now made this D smaller by getting rid of a lot of the surface, we actually increased our resistance. But we did get rid of a lot of surface area as well. So, there's a little bit of a balance. But in the end, our system actually got bigger than the original one. But, we now know that... That system—We know all that current is going to the faceplate. It's not going to the faceplate, to the gate, to the spillway. So trying to—when you have multiple structures like that, sometimes it's hard to direct current to that structure. So you may get, where the faceplate is, protected. But the spillway wasn't quite as protected as we wanted. Now we know that everything's going to the faceplate. Now, the other one that we—that was a, a mind boggle in a way, was this electrolyte... resistivity. So, we have voids behind that faceplate. Those voids have—some of them are fairly large, 14-foot diameter or more. Because they had cracks in the faceplate, the water washed away the fines and created a void. So, because of that, we're now going to grout. Well, the grout is just like grout. When you grout cracks in concrete, that grout sometimes goes where you don't want it to go. So, we're—there's gonna be a lot of ports on this. There's gonna be a lot of grout going in. So, we're hopefully going to get as many of the voids grouted as possible, which puts an electrolyte, now, right up against the surface. But there still could be voids back there. So, in the end, after grouting, how much of that faceplate is in contact with soil or water on the downstream side of it is still an unknown. So, we're going to have to make assumptions. The other one is the resistance. So, the higher the resistance of the electrolyte, the harder it is to push the CP current. And... the lower, the easier it is. So, if you have different resistivities of soils behind the faceplate—in this case it's changing because of elevation due to changes in the saturation level of soil. I mean at the bottom, you still have some cracks in that plate, so you basically have water on both sides, fully saturated. So, the bottom of that faceplate is going to be a much lower resistivity. But as you go higher, now that we put this membrane on, you don't have the water getting up to that area. So, you have higher resistivity soil. So, it's harder to push the current to where it's drier. A lot easier to push it to where it's wet. But the benefit is, where it is drier, where you do have the higher resistance, you also have lower corrosion rates. So, you're still pushing current there, but you also don't have as much corrosion drive. But with the seasonal changes, with the water elevation, you're going to get changes in your resistivity behind that faceplate as well. So, there's more uncertainty in our... in our situation. And therefore, we have to put a little bit more thought into—okay, let's make sure that we have enough current. To take that into account, so that we know, you know—nice thing is since we don't have a coating, we don't have to worry about damaging a coating with overpolarizing the structure. But we still don't want overpolarize the structure and just—that's a lot of current. That's a lot of money for electricity. So, there's a nice—there's a balance that we're always trying to look into. Next. Okay, so with that, I'm gonna turn it over to Chrissy, and she'll talk about the cathodic protection system for the radial gate.

>>Dr. Chrissy Henderson: Yeah, thank you, Daryl. So, as Daryl mentioned, we do have two systems. And the radial gate will be on its own system. So, what's going to be happening is that the spillway is planned to be moving into the hillside, but it's also going to be widening. So they are going to be doing some spillway modifications. The steel plating on one side of the spillway will still be there, but it's gonna be encased in concrete and it will actually be a separate wall. They're basically gonna use that—just, more as a retaining wall than as part of the spillway. So, we won't actually need cathodic protection anymore for the spillway itself, like we did before. Now, the radial gate, however—during the hazardous materials mitigation—the second webinar that we gave—it was determined that they are getting rid of the radial gate and they will be replacing it with a new gate. So, in this case we're going to have a new gate and it's going to be newly coated. So, we are going to apply a cathodic protection system that will essentially be protecting that new gate. Some of the coating options—it looks like they're spec'ing out, possibly, for an abrasion resistant type of epoxy, and a polysiloxane top coat. Now, if you look at this image here, what you see is this particular wall that is currently in place. That is part of the old spillway wall, and that's actually still going to remain. The CP system however, is located—it's going to be on the other side of that bridge. So, if we go back to an image we saw earlier when Daryl was talking... Essentially, if we blew this up, we would be looking—you can see in this image that the existing spillway wall is drawn in. And then you have your new spillway. So, you do see the existing wall is being used as a retaining type wall. You're going to have the encased concrete involved. Your new spillway is in place. You're gonna have your new gate. And then your CPP system is probably—in this image, it's going to be located more on that right side of that bridge. And... Our goal with this galvanic anode system. We, instead of doing a direct mount, we decided that we would do more of a remote location. So, we're putting the anodes as far away as we can. It is close to remote, not quite fully remote. But it is far enough that we feel that we can get a good, even current distribution to spread across the gate. Instead of having a localized point source for current distribution in certain spots on the gate, the remote allows us to have more of an even distribution. We are—because we have these anodes mounted onto a concrete wall, we will be doing a coating between the anode and concrete wall. The idea is to use either a high solid epoxy or 100% solid epoxy. A few options there. But we wanted to make sure that we weren't sending current through the concrete into any rebar or other metalwork that could be present. And we wanted to make sure that the current from the anodes was specifically headed to the gate and not elsewhere. So, that is why we are adding a coating behind them. So, for our galvanic anodes, we're gonna be using these type of anodes. It's a high potential, so we chose that for our design. Sometimes you can get a standard potential, which has a lower... driving voltage to start. So, in this case we have like a minus 1750 millivolts. But your standards, you might see like a minus 1500. We—basically, our design takes into account the shape of these anodes and the dimensions. And we are able to choose the number of them and correlate that with the size and dimensions needed for the design-specific criteria. There are other types of galvanic anodes. we tend to use a lot of magnesium. When we're dealing with freshwater situations, there are zinc anodes. However, you can have issues with passivation, which essentially means they form a protective coating and then they're no longer active anodes. So, we try to avoid that. There are a lot of situations where zinc anodes could be problematic, so general rule of thumb, we like to stick with the magnesium type anodes. And in this case its... Its shape is in such a way where we could mount it on the wall and still treat it like a good, long slender type anode. If you recall from what Daryl was discussing, long and slender can be better than short and fat. Currently, we are in the mobilization phase. And grouting is our next step. We will basically—this project is possibly going to be running until 2026. So, essentially we're going to—there are quite a number of phases to the project. But our cathodic protection will be installed in several different portions of the phase. Now, I'm gonna go ahead and hand this back to Grace.

>>Grace Weber: Thanks, Chrissy. So, really quickly, we're just gonna go over some of the capabilities of the Materials and Corrosion Lab group in terms of cathodic protection and coatings. So, most of what was discussed in this presentation had to do with some of the design aspects. So, we can provide a variety of expertise and services in this area, including basis of design, material selection, specs, quantities, drawings, construction support, and also design reviews. So, some of that, you kind of saw throughout this presentation. And in addition to that, we can provide services and expertise in two other areas—laboratory and research work, and also field work. So, we can provide things like standardized and specialized lab testing, coatings evaluation, lab-scale coating application, and coatings and cathodic protection research. And over on the—back to the right side of the table. Our field work includes things like inspections—so, corrosion inspections, cathodic protection or coatings inspections—condition assessment, cathodic protection system testing, rectifier inspection. CP system or coatings repair, maintenance, and installation. As well as QA/QC. So, if you have any questions on any of those capabilities or you're interested in reaching out to us, please feel free to do so through the contact info that was at the beginning of this presentation. But, with that, thanks Chrissy and Daryl for your presentation, and we will now begin the Q&A session. So, please continue to submit your questions and comments, and we will address as many as we can. So, to start out... If the membrane ends up getting holes Down the road, or later on, will the CP system protect at those areas?

>>Dr. Daryl Little: So you're—I'm guessing you're thinking, if you get holes underneath the geomembrane. so it'll—The membrane will shield current coming—So. Because of the type of membrane it is, it will shield a majority of the current coming through the water. But remember, we still have current actually coming from the backside of that faceplate. So... While—even if you get a hole in the faceplate, you'll still have some cathodic protection right around that area. So, we should be good.

>>Grace Weber: Okay, thanks Daryl. Next question. Why can't the faceplate and the radial gate be on the same CP system like how it was before?

>>Dr. Daryl Little: Well, we actually looked at that. There was three of us that went through discussion. And—like how I was saying how—where—the radial gate—The water on the radial gate is going to fluctuate. There are times when the old gate has been out of the water. And so you'd have no cathodic protection on it at all at those times. Which is fine because it's out of the water. However, as the water does fluctuate and you get water on that gate, it changes the resistance of it in the circuit. So, you have a pretty high change in, or fluctuation in resistance. On the old system, every time—since the faceplate used to be all underwater and that water elevation changed, you had a change in resistance there. So, the system was constantly getting bombarded with changes. Well, by taking the gate out of that and putting the membrane down, those fluctuations and changes in resistivity of the electrolyte, as well as the amount of structure exposed to that electrolyte, has decreased. So, we're making a system that's a lot easier to control at all times. The galvanic system—the nice thing with that is that it's self-regulating. Umm. And since we don't—we know that our—with the anodes on the gate, it also gives us something that's a little bit easier to replace if there is a question of, hey, you know wait, we need more. We can easily go and add more. Umm. We add another anode or something. That's one reason why we took it out is because it's something that—What can we control? And instead of having one system that continues to change, how about we take out the big faceplate, make that more of a constant, and then just focus on the gate. And we know that, now the system that we're putting on the gate is focused on the gate. Versus it just being a small piece of what it was before. Hopefully that answers.

>>Grace Weber: Yeah, thanks Daryl. Next question. Could you address test stations and where the test leads will be connected?

>>Dr. Chrissy Henderson: In this case, we're actually going to be doing test stations separately because we have two separate systems. And the nice thing about having a galvanic anode system that is remote is that you can bring the leads up to a test station. You don't have the issue where there's a direct mount and you can't take the anode off to get your potential readings that you need. Your "instant OFF," is what we call it. And that is a very important reading to have. So, in this case, because it's a remote system, we actually are bringing the test leads, or the anode cable up. And also we'll have the structure cables coming from the gate. And they'll meet in a test station that is up near the bridge deck, in that general area. And then basically, personnel can do their regular maintenance checks to make sure the system is performing. With the faceplate, we have a lot of the structure cables, the anode cables, and a lot of that is going into rectifiers. We've got a splice box, basically to bring it all towards—Umm, into the general area where we're keeping those. We do have test stations. I believe they are going to be along the roadway. Daryl can correct me if I'm incorrect there. But umm, it'll basically allow us to check the potentials of the faceplate, in that case.

>>Dr. Daryl Little: Yeah, there should be three test stations. And even if they somehow get damaged or lost, we have the spare structure cables going to the rectifiers. We can connect a cable there in order to do the testing. Now, I already looked and saw that, um, one of the other questions is, how do we plan on measuring the protection levels on the back and the front of the faceplate?

So. On the front of the faceplate, what we do is we have what's called a submersible. And it's basically a PVC pipe with holes in it that the reference electrode is in. And we slide it down the face of the dam. And... Then it's just like, basically we're putting—the same thing you could say is—if we could do it from a boat, we would drop—we would lower the reference electrode down into the water and get it close to the faceplate. And then we would make our measurement. And make the connection either at the junction boxes for the rectifiers or... in the test stations. Now, for the downstream side, yes, that's a little bit more tricky. There are these wells drilled—there's three wells drilled in the roadway. That were used for monitoring water level. And so, in the past—we would end up doing the same thing that we did in the past, where we actually lowered our reference electrode down the wells. And we'll take a measurement that way. If this was—If we could rely on that there was a lot more fines in this, then we could actually put a reference electrode on the backside of the dam and get at least a general measurement. We're not gonna get anything that's right up close to an area. We don't have the ability to put a reference electrode right up against the downstream side. And if you put in a permanent, those are only good for so long. Umm, often they have a 5 to 10 year life. And we'd never be able to really replace it. So... We're gonna have to rely on more of a global or widespread measurement on the backside of the dam using those wells.

>>Grace Weber: Thanks Daryl. The next question is—How does a remote anode provide an even current distribution on the radial gate?

>>Dr. Chrissy Henderson: If you look at an anode, essentially what you're gonna do is you can think of the potential on the anode as being a series of gradient lines. And they radiate away from the anode itself. At the, umm—As you move closer, you've got stronger, higher potential gradient lines that are essentially a lot closer together. They're more of a localized type of gradient line. But as you follow these gradient lines outwards, you actually get to a distance, a remote distance, where you could actually kind of think of the gradient line as being a super widespread area that really delivers kind of the same potential for a larger area that it's covering. And the reason why we can do that is because oftentimes in our designs, the potential that we're trying to reach—we wanna get to like a minus 850 millivolts. And that's a good protected potential to be at. And that—even one of our criteria that we do use via the NACE standards. But, I mean, you'll have an anode that has a starting potential of—in this case, the high potential ones—minus 1750. So it's a very—you actually can have your gradient lines spread out quite a bit, and you're still within that protected range. So... That also—the description I just gave you regarding the potential field and how the gradient lines work is another reason why sometimes we choose not to do direct mounts, especially when you have a highly sensitive coating—to overpolarization—because you can sometimes get that high potential too close to the coating. And so you actually want more of a remote distribution. So, I kind of think of it as looking at the way the gradient lines are kind of radiating out from these things.

>>Dr. Daryl Little: You know, I just thought of an interesting analogy for remoteness and distribution. So, take a headlamp or take a flashlight. And you shine it on a spot on the gate. And that's more of a hotspot. But as you walk away, more of the gate gets illuminated until you're far enough away where the entire gate is illuminated fairly evenly. And at that point in time, you're now remote.

>>Dr. Chrissy Henderson: That is a great analogy. I really like that one.

>>Dr. Daryl Little: Let me know if that's a good analogy for anyone else.

>>Grace Weber: Okay. How does the current go through the concrete and into the rebar if there was no coating behind the gate anodes?

>>Dr. Daryl Little: Well, if your anode and that concrete are both in the water—Concrete always has a moisture level. So, it is essentially just a different electrolyte. So, if you don't have a—something blocking the current right next to the anode, your current is actually—it's going to go directly into the concrete. Just a different resist—it's just an electrolyte of a different resistivity. And then it's gonna find that rebar that may only be three or four inches away. So, all we're doing is, essentially—You look at—Almost as if, uh... Kind of like when we took an—if we took an anode and put it directly on a gate. If we didn't have that coating there to protect it, it would go directly to the gate right there. It's just that, in this case, it would—it's kind of looking at it the same way—but now that gate is coated in concrete.

>>Grace Weber: Thanks, Daryl. I think we just have time for one more question. So, last question. Are the existing CP system groundbeds completely depleted?

>>Dr. Daryl Little: The answer to that is no. I went down... six... months ago, maybe. And I actually removed the—went into the junction boxes and found a bunch of broken wires. So I rehooked it up and we were getting—It increased... We were only seeing maybe an output of less than an amp. And—like a lot less than an amp. And then, fixed some broken cables, and we were—it jumped up to where we were actually getting 1, maybe 2-3 amps out of the existing system. So, whereas five years ago or more when I went down, our rectifiers were putting out 40 amps. Each. Now they're only putting out about 3 amps, maybe 4 amps each. So, while it's still—We're still getting some current out of the anode beds in question. We're getting a lot less. And these are typical—we designed for about 20 years. And these were the existing ones. So they went in in the 80s. So, we've gotten a lot more than 20 years out of it. But we are also seeing where we're not getting much left. So it made sense—We actually... Had redesigned the system. And we were pursuing replacing the old system. Quite a—about five years ago or more when this Dam Safety project came up and said, wait a second, we have other issues as well, so let's handle that. And we just added the cathodic protection to the new project as a whole. If we had put on a new system, and then they came in and got rid of a lot of that—got rid of the spillway at that time, then we'd have to rethink about the system that's already been installed. So, it actually turned out to be good timing. But a lot of our systems, the ideal way to go about it is keeping an eye on them, testing them. When you start seeing where you're not getting a lot of current out, even though you're turning up the rectifiers, you check to see if maybe the beds are dried out. Umm. But you also look at how long—how old is the system? And you kind of play the game of alright, I know I can't afford to replace it right now. So you start looking at Projecting replacement. How much money it's gonna cost. And at the same time, you continue to turn up your system, and just kind of milk out as much as you can so that your structure is never not protected. And that's kind of what we're doing now.

>>Grace Weber: Got it. Thanks, Daryl. All right, that is all the time we have for today. Thank you both Chrissy and Daryl for your presentation. If anyone in the audience has any remaining questions, please reach out to either Chrissy or Daryl. And keep an eye out for our next webinar, which will be on coatings research. Thank you everyone for joining.