>> **Dr. Henderson:** With this, I would like to go ahead and welcome our presenter for today. Bobbi Jo Merten has a PhD in coatings and polymeric materials from North Dakota State University. She is an SSPC Protective Coatings Specialist and has 11 years of experience at Reclamation as a TSC researcher and project manager on many coatings and relining projects. Dr. Merten's research includes coating lifecycle and econometric analysis. And she has developed an ASTM field technique for quantitative coating inspection. And now, I would like to go ahead and hand this presentation over to Dr. Merten. Just to double check—there you go

>> **Dr. Merten:** There we go. Took me a minute to get unmuted. Thank you, Chrissy, and thank you everyone, for joining. As you heard in the introduction that Chrissy provided, I have a nexus of experience and interest when it comes to corrosion, protective coatings, and the cost of those items together. So just to get us kicked off in this Corrosion Webinar, I want to give really a broad overview of the costs of corrosion. And I think that this has been best done by an association called NACE International, or National Association of Corrosion Engineers. And in 2016, they had done the NACE IMPACT study. And really, the goal of this analysis was to look at available studies and to use them to estimate the direct and indirect costs of corrosion to, essentially us, as a society. You know, whether it's our infrastructure providing water to our homes. Allowing us to drive over bridges to get to work. Or simply just looking at our home appliances that are subject to corrosion as well. So through those studies, they were able to estimate that the cost per year is about $2.5 trillion. And this works out to be about 3.4% of the global gross domestic product, or GDP. So with that, we essentially see a pretty staggering cost that can be associated, again either directly or indirectly to corrosion. But I think the outcome of this report was not fully gloom and doom. They did provide some opportunities here. And I think that's where we're focusing our research efforts at Reclamation. So specifically, the study indicated that about 15 to 35% of that cost could potentially be saved by using available corrosion control practices. So what we can do from there is to try to do what they consider a corrosion management system. So their recommendation is essentially to be adopting corrosion management systems. So, I think that's really a term that they use. But to really apply it for our own purposes, it just means to put a little bit more effort and investment and planning into corrosion itself and how you're going to manage it. If anyone's interested in learning more about the NACE IMPACT study, there's a link at the bottom here. It's pretty easy to find. I should also note that NACE has been merging with the Society for Protective Coatings. So, the new acronym that you'll be seeing is "AMPP." So, what does coating maintenance and cost really look like at organizations like the Bureau of Reclamation? So, this is pretty typical for many organizations. You essentially have the option to do spot repairs on your coated structure. This is where you're simply repairing the small areas that have defects or damage to them, and basically bringing the whole structure back to a fully protected condition. The next one, the next bullet here is a full recoat or relining. This is essentially the end of a given lifecycle. So, for the image on the right. Uh, this is a gate structure. If we were to completely blast, remove all of the coating from this structure and apply a brand new coating, that would be the beginning of a new lifecycle and that

would be a maintenance activity that we would call a full recoat or a full removal and recoating of that structure. The other thing that we can do is we can add cathodic protection. The cathodic protection galvanic anodes are shown also in this image. There are essentially 6 anodes being welded to the face of this gate structure. We see that as a secondary protection mechanism, with the coating itself being the primary mechanism. So, what the cathodic protection will do for you is help to protect that coating system in any areas where the the coating is essentially either weak or missing. And those are the areas where we tend to see rusting. And if you look kind of closely, you can see a few areas where rust is apparent. So we are putting coatings and cathodic protection together here with the goal of protecting those areas that are not protected by the coating. As we look at the different maintenance options, we, um—Those people that have experience going through contracting for these different maintenance activities—you've seen the difference in the amount of cost and the amount of effort for each of them. Essentially, spot repairs and cathodic protection can be relatively low-cost activities. You know, for a typical structure, you're probably looking at the tens of thousands of dollars to maybe hundreds of thousands for really large or complex structures. The full relining or the full recoating is really where we tend to see that it's a really high-cost activity. It would typically be an order of magnitude higher than the other options here. So, as an industry, cost is important to us as well. Uh, we're seeing cost increases really across the board in the coating industry. There's a few reasons or drivers for this that we tend to point to. One of them is that our structures tend to be pretty inaccessible. So it can cost a lot of money to ship lots of equipment, materials, people to remote areas and then to have to manage the waste in those remote remote areas as well, coming out of the projects. The next one is the need for our structures to stay in service. A full recoating job can take much longer to complete than a typical service outage. So, this requires careful planning. It requires an extended outage. And that can come with the lost benefit of revenue. So, if you're not able to generate hydropower, we're not generating that revenue. So that's a cost associated as well. The final one here is uh, regulations. So, there are increasing regulations across the industry. These are related to safety of employees, as well as the environment. And while all of them are important, they do tend to come with increased cost. It's important that we also talk about the cost of not maintaining coatings. So while it can cost much—can cost a lot of money to to proceed with these contracts to do maintenance activities—This is the cost of not performing that that maintenance. So, really the primary issue here is the corrosion and metal loss that we see if we're not providing coating maintenance at at an appropriate timing. This can lead to weld repairs, or in some cases, even having to do full section replacements of steel structures. If this hasn't been anticipated, or even even if you're planning for it, it can result in significant design work to make sure it's performed properly. It can also be really time intensive in the field. Again, time is valuable, so extending contract time or schedule is not always something that is really even feasible. We can also see that this can quickly exceed hundreds of thousands of dollars for these activities. Especially if you're combining the cost to the contracts themselves, the cost to the government workers that are inspecting, cost to the designers that are assisting with the design work. For example, we have an image on the lower right here—This is a steel plate that had corrosion pitting that went all the way through the wall of the plates. This was unanticipated, somewhat hidden underneath an existing coating system, and did result in a contract modification for an existing contract that had exceeded more than a half million dollars just to deal with the corrosion pitting that wasn't anticipated on the project. So that cost figure would be not just for the holes, the pitting holes shown here, but other pitting—extensive pitting on that project. So, I think the bottom line here in this conversation is really related to just how critical these structures, especially at the Bureau of Reclamation, are for the Western United States. And we really kind of approach this issue from the perspective that replacing these structures is generally cost prohibitive. So we really do want to be as proactive as we can to deal with corrosion. So, the rest of the webinar today is focusing on the research efforts themselves that have been undertaken primarily in the Materials and Corrosion Laboratory, but with really generous and necessary support from other partners, as well as from some of the TSC economists, providing support where needed here too. So really the goal, um, the overarching goal for these research projects can be broken down into two things. Really, these are the two opportunities that we see. The first one is to maximize the coating lifecycle. Again, the coating lifecycle is going to be that total service life of your coating from the day you apply a brand new coating to the day that you have to completely remove it. We focus on this again because that coating removal cost tends to be the highest cost item—about an order of magnitude or more than the spot repair that you can do on these structures. So the more we can do to extend that date, the more your annualized cost of that coating is reduced. On the other side of this coin, however, we want to be able to time that so that we do replace the coating system before you have significant metal loss. So, the two studies discussed in the webinar today are a cathodic protection payback period. Essentially, in this study, we are going to be looking at the break-even point for cathodic protection, in which that small investment—typically small investment—tens of thousands of dollars to design and install a cathodic protection system—can actually pay for itself in extended coating life. The second one is an econometric analysis to better understand corrosion cost trends and predict future costs. So this is combined—this project combines a rather large dataset of contracts that have already been put in place or executed to maintain coatings. It's focused on large diameter coatings and specifically the removal and replacement of the interior coating, which is generally known as relining. So the econometric analysis is performed on that dataset to help us understand some of the cost drivers. So, first the cathodic protection break-even analysis. In this study, we were interested in what other researchers had potentially done to understand the relationship between coating lifecycle and adding cathodic protection to a coating—to a coated structure to extend the coating service life itself. There's just—there's rather limited information that we were able to find in this area. But for example, we have some references here that said that it in fact does extend the coating service life. And the way it does it is by allowing a facility to delay the recoating until essentially the coating is deteriorated far beyond a normal point that we would allow a coating to be deteriorated. So here they had said about 20% deterioration of that coating system. I think 20% deterioration is going to be somewhat um—somewhat subjective from an inspector's standpoint. But it's probably fair to say that at the Bureau of Reclamation, we are intending to remove and replace coatings that do not have cathodic protection with much less of a deterioration than 20%. Probably about half of that deterioration. And in some cases our tolerance is much less than that. So this could be seen as a pretty significant increase in deterioration being allowed. So in the research project, the research objective itself was to perform a break-even analysis to estimate that payback period. So here the payback period is going to be the extended service life of the coating system, which would allow for, essentially, the costs incurred for cathodic protection to be paid for. So the inputs for the analysis are the installation costs. That's going to be the design of the cathodic protection system, purchasing materials, and installing and initializing that system. And then we also have some maintenance costs as well. So there should be a regular checking on the cathodic protection system. We typically say annually. You also need to make sure that these anodes are being replaced on time as well. So an anode that's installed may, for example, have a 20 year service life. The output here is the "when" of this equation. So when does that extended coating service life pay for the cathodic protection system itself? So in this specific analysis, we looked at an actual installation of cathodic protection system. So some actual cost for it on some gate structures. And in this we found—we were basically able to use a couple of different scenarios because there were four identical gates that received the cathodic protection system. So using the different scenarios for each of them, we did see a cost savings. Or essentially that the cathodic protection system could pay for itself. And the extended service life for each of those scenarios ranged between 15 to 30% of extended service life. So this would essentially be for, you know, a 20-year coating system—If you could push that 20-year coating system to the 23rd year or the 26th year before recoating it, the cathodic protection system that was installed had effectively paid for itself in that increased service life. A few other interesting outcomes came out of this analysis. Because we were studying impressed current cathodic protection systems and galvanic anode cathodic protection systems, we were able to sort of compare the effects of of each of those. And what we were able to note is that the impressed current system has economies of scale. This essentially means that the payback period was decreasing as the surface area increases. So the simplest example of this is to say—If you have a single gate being protected with impressed current, um, you will see economies of scale if you can additionally protect two, three, or four gates in addition to that. And generally the reason breaks down to being that, for an impressed current system, you must buy—you much must purchase and install—a transformer and rectifier system. And they can be one of the more costly items for that cathodic protection system. So, if you can spread that cost across two gates, three gates, four gates—that's where you're seeing your economies of scale. So on the other hand, the galvanic anode cathodic protection is really economical for those smaller surface areas. So, this is essentially just reinforcing—for some of the design work and for anyone who might be trying to make a decision between the two cathodic protection system types—the galvanic anode system may be a better use and can be quite economical if you have smaller structures. So, moving on to the next research project here, and this is where we're going to spend the rest of our time discussing. And this has really been a somewhat significant undertaking. So there's a lot of information to share here out of this research project. But essentially, like I said previously, the econometric analysis is compiling a dataset of coating contracts that had already been executed or were at least awarded. So Reclamation has 188 steel penstocks And that was really kind of the focal point for the project. We did have some partners that also had some projects that they could contribute. But really the main point here is that the focus or the the scope of the analysis is on structures like penstocks. Really, the study defines the scope as being large diameter relining projects. So the steel penstocks at Reclamation are meeting that definition of large diameter. In this study it was about 3.5 feet, or 42 inches, was the minimum diameter allowed for entry of the data into the study. So, kind of just to provide some justification here for the research on this intro slide for the project. With nearly 200 penstocks at Reclamation, we were able to calculate the total square footage of the interior surfaces. It comes out to be about 6.6 million square feet of interior surface area. If you were to use a somewhat typical relining cost of $50 per square foot, you will see that the total replacement cost for relining the interior of all of Reclamation's penstocks is approaching half of a billion dollars. So really, that large ticket—that large price tag there—is one of the motivators for ensuring that we're putting a little bit of focus on understanding these costs. The figure at the bottom of the slide here provides the breakdown of those penstocks by region. The left bar, or the the left axis here, shows the count of penstocks. And the right axis, or the the yellow bar, shows the total surface area for each of those regions as well. And as of about 2021, about 120 of those penstocks had yet to be relined, meaning that they had not yet had a contract put in place for their relining. The average age of those penstocks is about 63 years old. So the assumption here is that a lot of these penstocks are needing to go through a coating removal and replacement in the somewhat near future, let's say. So through this process with Reclamation and its partners, we were able to pull together a dataset of 73 relining jobs. So a relining job is going to be a single pipe, or a single large diameter pipe, that was relined. All of these contracts are based on award data, so it does not include modifications to contracts. We know from experience that modifications do tend to result in higher costs. It also does not include the non-contract costs. So, these would be the costs associated with the government staff executing the contract, whether it's in the contracting office, the design work that's performed, or the on-the-ground inspection, or anything else at the facility. For the cost data used in this analysis, all of those costs are indexed to 2020 dollars. This provides a uniform date so that we can compare all costs to one another. Sort of an apples-to-apples type of scenario. The data table shown here itself, these are essentially what we call the statistics for that dataset. The left column provides the variable that was studied, or the variable that is being tracked and accounted for in this study. The next column is the average in this study, followed by the minimum value and the maximum value for the study. So, just to provide a few—kind of run through this table and make sure we're kind of defining a lot of these variables used in the study. The first one that you see is the total cost. So that would be the total contract cost for all of the aspects of that contract associated with a coating removal and replacement itself. So, if we're looking at a contract that had not just coating work on it, but mechanical or electrical or other kind of distant items, distantly related in scope to the large diameter pipe relining. We were able to essentially exclude those other costs so we could really focus on the direct costs of the coating reining, as well as some of the indirect costs like the proportion of the mobilization and demobilization to the site. But you can see here, the average total cost is about $1.2 million per large diameter pipe relining. With a minimum cost there of $44,000 and a maximum cost of $8.8 million. So we had quite a spread in terms of the size of the work, so to speak. and that's the next, um, you'll see down in in just a minute here, the average cost per square foot is the next row. So you can see that ranged from $19 to $382 per square foot, with an average of $85. And then the very next variable we show is the actual quantity. So the quantity is the square foot of coating repair, the removal and replacement performed for that project. So again, you can see an average is around 26,000 square feet, but a really broad spread in terms of the minimum and the maximum square footage. The next set of rows here in the table is for the existing lining type. Leading into this project, it's really unknown if the existing lining has an effect on the overall cost. But we essentially were attempting to account for all variables that could result in that sort of outcome. So, you can see the way to interpret this is to say that—for coal tar enamel, 88% of the existing projects were lined with coal tar enamel, 4% cement mortar lining, 3% polyurethane, 4% vinyl, and 4% epoxy. And this number does not add up to 100% because we had some projects with multiple existing lining types. Similarly, you can see the new lining type, again not knowing whether or not this is a variable that contributes to cost, but allowing us to test for it. 8% polyurethane, 3% vinyl, 90% epoxy. And then, likewise, we get into some of the physical features of the pipe itself. So, looking at an average diameter, average slope, average pipe length. We also tracked whether or not robotic coating application was being used on the project. And we're also reporting here the average year for the data. So, this shows that the data ranged from 1999 to 2020. So about a 20-year spread for the dataset itself. And then we also tracked which region the project occurred in. So, we were able to use some geographical regions here and apply those to partners as well. And then the very last column here shows that 88% of the data is Reclamation projects. So 12% of that coming from partners on this project. So that was a pretty extensive overview of the dataset itself. It really is important to understand the approach and the carefulness essentially being taken into an analysis like this. Really, you know, with a lot of data-based research efforts, it's garbage in, garbage out. So I think one of the points here is to just try to really be careful and demonstrate that care that was taken in the treatment of the data and the compilation of the data itself. So, once the data was collected, this is really where the project was turned over to our economists. We're fortunate to have economists in the Bureau of Reclamation that have extensive experience performing econometric analyses such as was performed here with the data provided. So, essentially what our economists were able to do was to develop a model using the data provided. And this slide really provides the outcome of really what was a tremendous undertaking by the economists that worked on the analysis. But really we're fast forwarding for you to just show you what the final model looks like. So the top right corner, we can see that we're showing cost per square foot and the area relined as the two axes values. So we've got a single line drawn to represent kind of the final model space. And then we have a gray area to show, um, sort of that error that's expected as well. So, this is a cost per square foot table. We also, in our final report, show the data for the total relining cost itself versus the area relined. I think the cost per square foot as a coating specialist is just a little bit more interesting to me. And I think from an application perspective, it can help to see, you know, what the cost is on a cost per square foot basis. For a facility that knows the surface area that it needs to have recoated. So really the main outcome here, which is essentially what we expected going into the analysis, is that we can see that the cost per square foot is decreasing as the area relined increases. So this is essentially an economies of scale. And again, this was totally an expected outcome of this analysis. So, the model itself and the coefficients from that model are shown here in the lower table. You can see most of the variables shown here are variables that I showed on the previous slide. One of the more interesting things is that in the analysis the economists did, they were looking for some interaction variables. So we have two of them here. And essentially the way that the economist is finding this is by testing different scenarios and looking to see the goodness of fit for that final model with the data itself. So, we've got an independent variable here of the area relined. Again this is a negative coefficient value because cost is decreasing as the area relined increases. We had an interesting outcome in which there's a cost increase associated with Reclamation owning the pipe being relined. We spend a little bit of time describing potential reasons for this in our final report. But I won't discuss that further here. The area weighted diameter is what's being shown as this next variable, and the area weighted slope. So, we have a cost increasing as the diameter decreases. This would be expected because we know that working at really high slopes can require some additional safety—engineered safety inputs—on a job and that can result in higher cost. Sorry—the slope is increasing. The slope increase results in a cost increase. And the diameter has the opposite effect. This brings us to the interaction variables that I mentioned, where both of these two items—the area weighted diameter and the area weighted slope—seemed to show an interaction with whether or not robotic application was being used. And here's a good area to point out the statistical significance being reported here. So for most of these final model variables, we were able to see an error of 1% or less, essentially. But we do have just a few of them where we're at a 5% or a 10% error level. So, overall this was a a really high, a really good fit of R-squared of 0.92, essentially, for the full model. And the last couple variables shown here at the bottom is just to demonstrate that there's an impact based on the region in Reclamation as well. So the model itself is based on the Lower Colorado region, and then you can see the coefficient for the other four regions in Reclamation, each of them being a little bit lower cost than Lower Colorado. So we wanted to just give a little bit of an opportunity to explore that interaction variable that was observed in this experiment too, with the robotic application. So the graphs here show the robotic cost effect for diameter and for slope. The top graph is showing the pipe diameter versus the cost. And essentially, again, this is a model. So, this is a prediction of that cost, based on the data that was used in this analysis. It's important to also discuss robotics as a newer technology. That's one of the reasons that we wanted to account for it in this analysis as a separate variable. The thought here is that with continued work in this area—continuing to grow this database and potentially running additional analyses in the future—we would be able to see, potentially, the cost of implementation of that new technology into the industry as it becomes a mature technology, potentially resulting in cost reduction. But for now, you know, going back—using the existing dataset that does represent the introduction of robotic coating application into the industry—we're seeing a little bit higher cost on average. Here, again, the robotic cost is generally from this model's results, higher than the manual application cost. The other thing that the model can benefit from in the future is expanding the datasets across more pipe diameters. In this particular dataset, we did not have data for robotic application above about 20- or 24-foot diameter. So it's really an—You can see a significant error, essentially, in that area. And more data will help to better predict those costs in the future. Final bullet to pull out here—to point out here on this slide is that the non-contract savings are not accounted for in any of this analysis that's being performed here. So, we're really just looking at the contract costs themselves. And when it comes to robotic application, you can also see efficiencies on the job site where you're completing the project faster. So that might be reducing your outage time period and resulting in more revenue generation. And we can also see improved safety if applied correctly too. So the next piece that we're talking about here is getting into cost prediction for future spending at Reclamation specifically. So this is sort of a—this is a secondary prediction type modeling exercise that was taken in this research project. We knew that about 121 penstocks had not had contracts for a full removal and replacement that we were aware of, or that we could locate. So if you break them down by region and assume that each region has the resources to remove and recoat approximately one pipe per year per region, we can kind of plan out the execution of that pipe relining across Reclamation. So, in this figure, in the top here, you can see that the Missouri Basin region has the largest number of penstocks to recoat. There are 38 of them. So you can see that each of those 38 bars, or one per year, is drawing out the longest time horizon here, or time period, to complete all of the removal and replacement activities. So in this prediction model, essentially what we're able to do is to take the variables that were studied in the econometric analysis and plug in the actual information to have a cost prediction for that project itself. So the lower table is essentially the outcomes of looking at each of those penstocks that need to be relined, looking at the physical features of them so that we can input those variables into the model itself. And then we're predicting the present value cost in millions of dollars, as well as an annualized cost in millions of dollars. So, overall you can see a present value cost around $167 million for those remaining penstocks. Or an annualized cost of about $7 million. So one of the other interesting efforts and outcomes of that research project is the cost forecasting tool. So this is a Microsoft app tool that can be used if you have some basic information about a project to get a really low level—what we're calling here a preliminary level predicted cost for relining large diameter pipes. So it's really important that the disclaimer here is also taken seriously. This is in no way a replacement for professional cost estimating. But what this potentially will be able to do for you is to provide a ballpark figure for understanding potential future costs. So that could be important from a budgeting perspective. And just give you a starting points before you begin those conversations with cost estimators themselves. It's really more of a planning tool than anything here. But as you can see, it's rather simple information being required. Simply enter in the total amount or the total area of relining that's required for a large diameter pipe interior. What is your average diameter? Average slope? Couple of our other important variables in the model—Is it a Reclamation contract, yes or no? Is robotics being used by the contractor, yes or no? And what's the geographic region? And then we've got some pop-ups here where you can look at more information. And you can also click the "Show/Hide Results" to populate the values over here at the right. We do have these resources available both internally to the Bureau of Reclamation—that's through the link shown at the bottom here, that's a Power App. And there's also a version of this tool that has been prepared in Microsoft Excel, and this can be shared to any users outside of the Department of Interior. And there is a link to that—This is on the Reclamation Information Sharing Environment, or RISE, which is also where you can find the final report that is publicly available for this project. And you simply go to this site, and there's an area where you can download the Excel tool. So, with that, that's the end of the presentation. As appropriate, I can pull up the App tool and provide a demonstration for that. But I will send it back over to Chrissy for questions.

>> **Dr. Henderson:** Alright. Thank you, Dr. Merten. Uh, we're going to go ahead and begin the Q&A session now, so feel free to start sending in your questions. I do want to reiterate to folks on the webinar that we do put the PDF of the slides up on our training website, usually within 30 days after a webinar. So you can access those links via the PDF. So don't worry if you weren't able to grab them while the webinar was happening. They will be on the PDF and you will have access to that at the training website. And I think, Grace, you can go ahead and type in the web address for that, so people can access it on the chat feature. The live Q&A event. So you can get to that training website and access the PDF there. You can also access previous webinar content there as well. We do have a question that has come in. It is: has similar cost analysis been done for Reclamation bridges? If so, where could we find data statistics for this? Or is your project specific to just the hydraulic steel structures and pipelines?

>> **Dr. Merten:** That's a really great question. The quick answer is no. We have not researched the cost for recoating bridges at Reclamation. The entire research effort here could be considered a first approach to studying the corrosion costs in this way. It really does provide a framework though for performing additional or future studies on other targeted structures. I think what we found important in this analysis is that we needed to simplify the structure to something that really was common. So, a large diameter pipe allows us to look at a feature that has that cylindrical shape. We know that they have different diameters, slopes, they can bend, they can bifurcate, lots of little interesting features like that. But very, very different than a bridge structure per se. Or even gate structures. But certainly this analysis could be applied to other specific structures at Reclamation. The penstocks and the penstock interiors are often considered one of the more critical structures from the perspective of its challenges associated with replacing them. So, we are essentially needing to provide great corrosion protection to the existing penstocks because the replacement is seen as not possible. I think the same argument could be made for some bridge structures as well, but they're generally a little bit more accessible

than many of our penstocks. But that's a really great question. Thank you. And just to be clear, the answer is we do not currently have a database compiled of costs for recoating bridge structures at Reclamation or with any other partners.

>> **Dr. Henderson:** Alright, uh, here's another question. What is the shelf life of the cost model and tool in terms of being able to reliably predict coating cost?

>> **Dr. Merten:** That's a really great question. So the—in effect, the question is asking, you know, how long are these variables going to be useful and how long can we continue—or sorry, how long are these coefficients for this final model going to be accurate such that we could continue using them? I don't think that there's a really well agreed upon response for that. My gut reaction would be to say that it's probably within the five year range or so. And at that point you would really benefit from updating this model with new cost data. And you can do that by building upon the existing cost data that we're showing here for 73 realigning jobs. And run the model again. So you know the best case scenario might be that within the next three to five years, we have some additional funding that we could execute a follow-on project. You know, that would again be keeping the focus specifically on the large diameter pipe relining projects as well.

>> **Dr. Henderson:** Any idea if the pandemic or the supply chain issues that we're currently facing changed this model significantly, or would that have to be reevaluated?

>> **Dr. Merten:** That's also a great question. It would have to be reevaluated. And I think we we could even set up the study such that we would try to test for that as well. Because the more data that we get, the more we could play around with this time variable here and see if there are any cost trends that are actually associated with the time period itself in which the work was performed. So we could see some cost increases potentially in the years of contracts that are awarded around 2020, 2021, 2022. And if we were looking at contracts that extend out to more like a 2023, 2025 timeframe. And let's just assume that some of the cost increases in materials and labor do come down, we might be able to observe that. But again, we would need a sufficiently large dataset to do that with good statistical significance.

>> **Dr. Henderson:** Okay. Can you give us a rundown of when impressed current cathodic protection would become more cost effective than a galvanic anode cathodic protection system?

>> **Dr. Merten:** Yeah. So generally speaking, you know, the way that it was described in the outcome of that study is to say that it has economies of scale. And we don't have a good example to provide for you in terms of actual surface area where impressed current becomes cost effective. But if I could kind of just generally pick examples for you—this gate structure that you see here has galvanic anode cathodic protection. Here, this is a better photo of it. So that one had

galvanic anode cathodic protection. But there are some gate structures that are kind of similar size and nearby that I believe are in an impressed current system. And I think it's four of them that are together on that impressed current system. So if that helps to provide a little bit of scale for you, this might be kind of in the realm of where you see both options being considered because both could be possible. Certainly if you had only one gate like this, you would probably certainly be looking at galvanic anode. And if you're looking at a large pipeline system where the pipeline itself is steel and you need to protect all of it, we tend to see more impressed current cathodic protection systems for long pipelines. I hope that answers that question.

>> **Dr. Henderson:** Excellent. Yeah, definitely. If anybody has any additional questions, feel free to pop them in the chat. Otherwise, we will probably go ahead and close up this webinar. I'm not seeing any more come in, so we will go ahead and finish up. If you have any remaining questions that do come up for you, please feel free to reach out to Dr. Merten. You can also reach out to me and I can get your questions to her. Also, keep an eye out—We've got two more webinars planned for 2023—the fiscal year 2023. And I just really want to thank you guys for joining! Thank you very much.

>> **Dr. Merten:** Thank you everyone.