

Simple Method Using Underwater Epoxy to Install Temperature Sensors in Mountain Streams

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Hello, I'm Dan Isaak with the Forest Service Rocky Mountain Research Station in Boise, Idaho. I'm here today to talk about and run through some slides just demonstrating the application of a new method that we've developed that uses underwater epoxy to attach small temperature sensors to large rocks and boulders in streams. It makes it a little bit easier to monitor full year stream temperatures. My collaborators on this work are Dona Horan and Sherry Wollrab, both of whom are also fisheries biologists within the Aquatic Sciences Labs that we have here in Boise.

Before I get going then, one thing I should just mention, even though all the application and the validation work we've done today basically was done with a small digital temperature sensor, given that there is a lot of additional types of sensors out there now that are becoming smaller and smaller and battery lives are improving, all we're really demonstrating here is using glue to stick something onto a rock. So, potentially this sort of protocol could be used for other sources such as devices in streams as well.

Temperature is Important for Aquatic Organisms Like Fish

So, before I get into kind of running through some of the validation work that we did to develop underwater epoxy protocol, just a few slides here to kind of run through some of the original motivations for the work. We're fisheries biologists here in this lab so we're very interested in what aquatic organisms are doing. Temperature is one of the most important environmental variables for critters that live in streams because most of those critters are cold-blooded, i.e., their metabolism, their growth, their abundances are strongly controlled by temperature so it's critical that we have a better understanding of what's going on in different parts of the landscape and there's been a lot of work done that links fish to similar regimes in streams, but kind of the take home here is just highlighted in these two bottom panels. You can see strong trends and the abundance of different fish species, whether it's the rate at which they're growing or just their numbers within a particular region or stream across a broad temperature spectrum. So if we can get a better handle on what the spatial and temporal distribution of temperatures are across a big river network, then that's going to give us a lot better ability to predict and understand what's going on with regard to what types of different critters live in what part of stream networks.

Temperature is Important Within Regulatory Contexts

Another thing that other folks, especially within regulatory agencies, might be interested in when it comes to stream temperatures and thermal regimes is just from the regulatory point of view, agencies like state DEQ offices, Federal EPA administration, they're, they've got various thermal criteria that apply to inland waterways and there are certain criteria then that can or cannot be exceeded in different parts of the world. So, there's a strong interest in getting a better understanding of what, again, temperatures are like in different parts of river networks so you can understand when and where those potential criteria are needed.

Temperatures are Rising...
Global Trends in Air Temperatures

And then of course, we're all aware now temperatures are rising with global climate change occurring. Most of the records that we have available are based on air temperature trends as this graph shows.

Global Trends in River Temperatures

But in places where we've got good long term records of stream and river temperatures like these time series of European rivers, we can also see the quad systems warming up over the last century as well. So, there's a lot of impetus then in terms of trying to collect more temperature data, trying to establish long term temperature monitoring sites so that we can start to better describe and characterize some of these phenomenon.

We Collect Lots of Stream Temperature Data

So that being said, the last couple of decades has seen an explosion in terms of the amounts of temperature monitoring work that's going on. In the part of the United States that I live in, the northwestern U.S., we've literally got armies of people running around the forest and putting temperature sensors out in streams. There's dozens of different natural resource agencies that are involved in collecting this sort of information. Unfortunately at this point we haven't been very well coordinated in certain cases so we're collecting at times somewhat redundant data, but it's good overall that we're getting a lot more of this sort of information now and it's made much easier dealing with the advent of some of the small digital temperature sensors that have come along in the last decade or two.

Example Stream Temp Database Lower Snake Hydrologic Region

And this slide then just shows an example of stream temperature database that we've developed for a regional river temperature model that we've been working on. The domain we're looking at here is what we call the lower snake hydrologic region. It encompasses a big chunk of the state of Idaho, as well as the tip of Washington and Oregon. And last year when we were trying to pull this database together, we basically contacted a dozen or so different agencies just to find out what folks had or what information was collected from their particular part of the world. By the time we'd gotten copies of their data from them and organized that into a database for the lower snake, we had 6,700 summers of continuous temperature measurement at about 2,000 unique sites so there's a huge amount of this information out there.

Summer is Not the Whole Story Full year temperature data needed

A lot of times though it's scattered across different agencies and different databases so we don't know exactly how much until we try to pull it together for efforts like that. One of the limitations though to that previous database that we just looked at, and many other databases in mountainous parts of the world, is that there is concern given that a lot of streams and mountain environments are driven by snow melt runoff and you get a really big flood each year, there's concern about losing your instrument and so typically what people do or have done in the past is they'll go out and collect summer data only. So they'll go out some time in late June, early July when the spring snow melt has kind of passed and things are still laid down a bit, they'll put a temperature sensor out and then they'll run back to that place in September, maybe early October to retrieve that temperature sensor before you start getting a lot of snow in these areas and then you can't logistically make it back to a lot of these places. So maybe 95% of data that we have in those big temperature databases then is just this summer data only so that gives us a pretty myopic view a lot of times of what's going on with thermal regimes in streams and that's unfortunate because fish and other aquatic organisms that are strongly temperature dependant, they are doing things year round that are controlled by temperature. So ideally we would want to have a full measure of that annual thermal cycling stream if we can get it. So that's a lot of impetus then behind why we try to start thinking about developing an easy protocol that could facilitate doing more of this full-year temperature monitoring.

Lands administered by USFS

Another factor that motivated us to want to develop a protocol is that we've got a lot of land to cover. The agency that I work with, the U.S. Forest Service, the land that we administer covers about 10% of the lower 48 states and on that 10% of the land service area we estimate there is approximately half a million stream kilometers that are potentially large enough to have fish in them. So there's a huge amount of area to cover and a lot of time these are really remote landscapes as well so the thought of having to go back to each of these individual sites, as pretty as these landscapes are, that's not necessarily a bad thing but it does double the amount of travel that you have to do and ultimately when you're doing that to collect two or three months of data when it would be much more efficient if you could just simply lock a temperature sensor in place and then let it run, collect data for a year or two years or more and come back to that site once a year or once every few years as opposed to having to make two trips there every year.

Stream Temperature Sensors

And so one of the last things that has removed a potential obstacle then has been the increase of in recent years in the capacity of the batteries or extended deployment and also increases in memory capacity so that these small digital temperature sensors can store now more temperature data. So there's a lot of different instruments out there, the top two in this graph, the Onset TidBit, that's one that we use a lot, we kind of like it because it has a good five year battery life, it's already water proof when you take it out of the box so you don't have to do a lot of fiddling around with it, relatively small size and it has a good memory capacity too so and you can change the logging interval on those to make that memory last over shorter or longer periods of time just depending on how frequently you want to collect information.

Maxim makes another popular one, the iButton and those are nice if you want to collect or put out lots of instruments. They're a little less precise, but they're less expensive, but they also have smaller battery and memory capacity. One of the drawbacks to these instruments that we've found at least is that they're not waterproof initially. You've got to do some additional work to set them up before you go out into the field. Those are just a couple of sensors that are out there, Madgetech and other vendors make these same sorts of things and so if you're interested in doing this, you can essentially shop around and find something that fits your needs.

And then down lower in this graph are just some different sensor packages that are more or less powered on different platforms. You can fly over streams to collect temperature data, you can put out mock hydro-lab, etc., lots of different things going on now to collect more temperature information. The things we're going to focus on here today with the underwater epoxy protocol though are these small compact digital temperature sensors that are easily attached to a rock.

Overcoming Logistical Issues

So, given that, we've got a lot of need for collecting more full-year data. We've got instruments now we think that can do it. Kind of the last big obstacle then, as I alluded to before, is that when you're working in mountain stream environments, these are highly dynamic systems. You've got, in most regions of the world, snow packs that accumulate in these systems in the winter and then as it warms up in the spring and the summer, that melts and runs off and so you get these big snow melts peaks every year and that typically will mobilize the stream bed, it will do a lot of things that potentially can destroy instruments that you put in these systems.

One of the positive things about that high amount of energy in these systems though is it also recruits large substrate to the system so there's also a lot of big rocks in streams, some of which are large enough that they're typically not mobilized by a big flood. So we kind of put two and two together with this and we thought, well if we can find some glues and we've got these small digital temperature sensors, a lot of times they're no bigger than the size of a quarter, wouldn't it be possible to simply glue these things onto the downstream side of a rock that's big enough that it's not going to go anywhere in a flood, and then you're basically using that large rock as kind of a shield against that temperature sensor. If you pick a good rock that is big enough that it's not going to go anywhere you should have a safe little habitat for that sensor to live for a year or five years depending on how long you're going to keep it out there.

Underwater Epoxies Evaluated

Clear winner: Fox Industries FX-764

So, that was kind of the genesis of ideas, the next thing was to try and implement it and so we looked around, we tried to find a variety of different underwater epoxies from different vendors so that we could run kind of a comprehensive test. We evaluated eight different products for this particular protocol. Initially, we tested these in the laboratory just to get a sense of how easy was it to work with these things because ultimately we're going to be trying to do this out in the field under field conditions so we needed something that wasn't too difficult to work with. It also needed to obviously perform well under really controlled relatively benign conditions. So if these candidate epoxies weren't strongly adhering sensors to rock within a laboratory environment, then there's no way they were ever going to do it in a dynamic field environment.

So we tested a bunch of these things, but the clear winner based on our tests, at least in the laboratory conditions, is a product that's made by Fox Industries. It's what they call FX-764. It's two part epoxy and so it can basically use--just grab a little bit of each type of epoxy, you blend it together wearing gloves so it doesn't get on your skin and after a few minutes you end up with a gray sort of putty that's flexible and then the basic idea is that you just apply a little bit of that epoxy to the back of your temperature sensor and then you just stick that on a rock.

Easy Application, Cement-Like Adhesion

In the case of the Fox product that we're using, it takes about 24 hours before it solidifies but it does have a fairly gooey consistency so even initially once you've mixed it up and once you've stuck that temperature sensor to a rock, it does a pretty good job of staying where you put it. Just as insurance we'll typically lean a rock against our sensors in the field just to kind of hold them there for that first hour or two as it's starting to set up, but once that's been done then these things seem to do a pretty good job of staying where you put them. And literally then, once that glue sets up, it's almost like it's been cemented onto the rock so it's good for what we want, but in some cases if you had to retrieve that sensor, that can be a little of a challenge if you want to remove it from the rock. Typically you're looking at having to use something like a chisel or small screw driver to kind of chip it off the rock.

**Field Trial Assessments:
Heat Conduction Effect? NO**

So we felt like we had something fairly promising with the Fox epoxy in combination with the small digital temperature sensors, but we still needed to do some field validation work just to confirm that the method we're trying to develop wasn't going to give us a biased result. So the first thing we wanted to assess in our field trials was whether or not attaching these things to large rocks was going to potentially bias our temperature readings simply by the large rocks which are a lot of times are large enough that they're sticking above the low-flow level of the stream and gathering of heat energy from the sun there's the possibility that that heat energy could be transferred into the temperature sensor. And so the first thing we do to evaluate that in our field trials was to, one, find big black rocks, something's that going to push the limit of where we might see something happening, where we're gaining a lot of heat energy during the summer, attach temperature sensors to those—this arrow points to the sensor location—and then we also at these same sites put out temperature sensors that we need held on the bottom of the streams by putting rocks on top of them, but they weren't directly in contact with a large rock the way they were with the epoxy protocol. So we had a treatment and a control of a temperature sensor at eight or nine different locations and we simply compared the temperature readings then that we were getting at both of those sensor locations at the individual sites across those sites. It was a little bit hard potentially to read the numbers here at the bottom of this table, but the take-home was that we couldn't see any measurable difference in the temperature readings in the sensors that were attached to rocks and the control sensors that weren't attached to rocks. So this is part of what was published then in the North American Journal of Fisheries Management a few years ago as part of this validation work.

**Field Trial Assessments:
Direct Solar Effect? Yes**

One of the other things that we wanted to test in this protocol then was whether or not direct exposure to the sun was potentially going to bias our results so it was easy to stick a temperature sensor on a rock and just leave it to do its thing, but depending on what the sun angle is coming over that rock, once you have direct solar radiation hitting those things, you know, the potential is there that it could potentially bias the results. So what we did in that case was to attach temperature sensors to a rock, some of which had solar shields on them, some of which did not and this graph then just shows the temperature traces for four different temperature sensors that were deployed in the field and these were all attached to the same rock and then this is the temperature trace over the span of seven or eight days, each of those cycles representing one day. Approximately halfway through that trial then, here at about time 180 or 200, we removed the solar shield from two of those temperature sensors. So we've got the control data here where everything is being treated the same way, everything has a solar shield on it here, we remove the solar shield and you can immediately see spikes occurring in those temperature records. So, this told us basically that it's probably going to be mandatory that these things are also shielded from direct exposure to the sun. As a field trial site then we've got some estimates of the magnitude of that potential bias. If you don't have a solar shield I think it's somewhere on the order of .2-.5 degrees Celsius per day depending on if you're looking at a mean daily temperature or a maximum daily temperature.

Inexpensive Solar Shield Neoprene flap + Cable ties

So our solution to this was just to develop a fairly inexpensive and flexible solar shield. We tried a bunch of different things here—I'll talk about another solar shield what we've also developed later in the presentation—but our initial efforts had developed a solar shield just consisted of using a small patch of neoprene with a couple cable ties. The onset temperature sensors that we're using have a small little tab at the top of the sensor, it's got a hole already it, which is convenient then for just running those cable ties through and attaching this neoprene flap. And so for a buck or two bucks, whatever the cost is for a small patch of neoprene we've got a fairly durable solar shield now and in some of the field deployments we've done we've seen these things easily last up to a couple of years. We haven't had sensors longer than that, but we're getting good retention of these solar shields. The other nice thing about the neoprene approach is that over time as these things sit in the stream then you parasites actually colonizing the surface of this neoprene and so it begins to pretty quickly blend in with its surroundings which almost makes these temperature sensors invisible. So if you're working in a place that has a lot of high human traffic, it's not uncommon for people to—when they see things in streams—want to pick them up and take them home with them and this is an option that helps you kind of camouflage your sensors. So our experience is that we can put these out even near campgrounds and places where people are walking by them all the time but it's virtually invisible so you get better retention of with regard to people not stealing and taking them home.

One modification that we've also done to these neoprene solar shields is we've started attaching a small lead weight to the outer edge of the solar shield and that just helps make sure the flaps kind of hangs down over the front of the sensor so that as you get currents and other things bumping that flap you're not potentially flipping it up and allowing sunshine to directly hit the solar shield or excuse me the temperature sensor.

**Field Trial Assessments:
Durability of Installations?**

So the last big question then we want to address with this underwater epoxy protocol is obviously just the question of how durable are these installations going to be. The big motivation ultimately for getting into this is would these things stay where we put them. And so in the winter and the spring of 2010, we went out and we instrumented eleven different sites on eleven different rocks in streams in central Idaho and then we went through a big snowmelt run off—we actually in these particular instances we discharged data from one of our study streams so we had some big spikes actually in run-offs that were a lot higher than the flows that we typically get so we ran these things through some pretty extreme conditions during that first set of field trials. The two photos sort of down here just show the same rock that we looked at previously. This is that same location now at flood stage where you can see the water levels up by two or three feet and that sensor is down here somewhere still doing its job. This first field trial then with eleven sensors, came back in the summer of 2010 to check whether they were still there and in nine of the eleven cases, so about 82%, the sensors were still there and were functioning as we'd hoped they would be.

Large Scale Field Assessment

That encouraged us officially that we wanted to try and do a larger scale field test. So later in 2010 then, we put out 300 temperature sensors using the epoxy protocol across the states of Idaho, Montana, Oregon, Washington and then a few of temperature sensors even in Nevada. We've tried to bracket and get a wide range of stream conditions so one of the things we thought might be most important in terms of affecting retention success was just the steepness of the stream because that gives us some indication of the amount of power and energy that it has at higher flows. And so we put these sensors out in a range of positions from fairly low gradient systems that are more typical of larger rivers that kind of meander back and forth gently to really high grade, high energy, steep mountain streams that gradient is up to 15%. So those went out the summer of 2010.

This last summer in 2011 we revisited about 86 of those sites. At those 86 sites, three-fourths of the sensors were still there doing their job collecting temperature data. I'll point out that the runoff year that we had in the spring of 2011 was an above average year. So again we tested these things under some pretty rigorous field conditions. The 74%, that's an average across all sites, including the really high gradient sites. If you constrain the source of streams that you're looking at to something that's a little bit more benign and you're looking at slopes that are 3% or less which typically constitutes the great bulk of most river networks, the retention success is somewhat higher an average of about 85%. And this graph then just summarizes in a continuous manner what that effect of stream slope is relative to the proportion of sensors that we had retained. This blue line is just the predicted mean relationship from a logistic progression and the red Xs just show—give you a “yes” or a “no” depending on whether or not the sensor was retained at the site. So you can see in these lower slopes systems, lower gradients, we're approaching upwards of 90% retention and then as you get into a higher and higher stream slope that just decreases a little bit or a lot actually, but again, places that constitute most streams—the largest bulk of the network typically in this range. So we've got I think a system now that works pretty well under most common stream environments and sorts of places that we'd like to monitor.

Example Field Deployments

Direct sensor attachment method

So this slide then just shows some photos of what a typical field site looks like after you instrument it and in here we're looking at the direct sensor attachment method where we just put the epoxy right on the sensor and the sensor goes right on the rock. In each case, the red arrow in the photo then points to the sensor and you can see in all cases you've got that neoprene flap, that solar shield on top of the sensor. You can also see, a little bit harder to see, but notice in this photo at least and in this photo there's a rock also then leaning against the temperature sensor and again is just to hold it in place that first hour or two while the epoxy is setting up. And then at that point these things are pretty well cemented in place and they're not going to go anywhere. Because we're not necessarily coming back to these sites that frequently then we'll typically also add a metal tag, a numbered tag that's also glued onto the rock using the Fox epoxy and we'll also in some cases put a little bit of white spray paint on the rock just so that when we or someone else comes back to these sites one, two, five years in the future, it's going to be a little bit easier to find that exact same site.

Example Field Deployments

PVC container method

And so, one of the things that we noticed in the summer—well in this last summer 2011, we went back to those 86 sites that we used to assess our retention success and we checked the sensors. That first year we were basically gluing these things directly on the rock and we weren't providing the sensor any sort of protection and one of the things we noticed was that on the onset sensors at least there's two small glass bulbs on the faceplates of those things that are used for doing the optical download and in a lot of cases it was pretty common for one or both of those glass bulbs to be clipped off and presumably what's happening is that during high flows you've got small pea gravel and other things that just kind of distended in the flows and those are at some point coming by the sensor and clipping those off. In terms of the sensors still collecting data, it doesn't seem to affect that and so these things are still blinking away, still collecting information, but it does make it impossible at that point to download the sensor without having to send it back into the vendor. And so one of the things that we wanted to come up with this last year and that we started prototyping now is going to what we call the PVC container method and this then is the same basic idea, but now instead of directly attaching the temperature sensor onto a rock, we're putting that sensor in a protective housing and we're then using the epoxy to glue that housing onto the rock and we think this has several advantages. In addition to providing better protection for the sensor so they're not going to be damaged or destroyed, it's also going to make those sensors really easy to replace. So at the end of the service life of that particular instrument, whether that's one year or five years from now, you come back to the site, you can just unscrew it, unscrew the top of these, pull out the existing sensor, put in a new sensor and you're good to go. So that's going to make long-term monitoring at sites much easier than it would be if say we had to reestablish the site and play around with setting up epoxy gluing something else on the rock. It also makes it a lot easier to do periodic data downloads. One of the things that originally interested us is doing this is that Onset makes an underwater data shuttle, which we thought was really great, we can glue these things on rocks and then we can just come there with a data shuttle, retrieve the data underwater, we don't really ever have to uninstall our sensors, but again that problem with slight damage to the glass beads that are used for the downloads gets in the way of performing those underwater downloads so this makes it possible to simply unscrew the temperature sensor from its housing, put it above the water surface and download it onto any sort of field computer. Obviously that protects it better than just having these things out there naked, just sitting on the rocks. It also provides a really good solar shield for these things, you can't—it's difficult to imagine too much sunlight getting into these things given that they're almost entirely encased within these PVC housings. The one kind of unknown at this point is that we haven't yet gone back to revisit as many of these PVC casing sites because we just put those out this last summer so it's not clear at this point yet whether or not we're going to get as high of a retention success with this type of housing as we are with the direct attachment method, but that's something that again we have several hundred sensors out there now that are sitting in the PVC housing that we'll go back to in subsequent years to continue quantifying that retention success.

Easy Method for Full Year Data Equipment List

So, in terms of the equipment that you need to actually install sensors, it's pretty low tech. Again, one of the appeals for us, working with Forest Service, we have to hike into a lot of these streams, you're carrying stuff for miles a lot of times on you're back so you don't want to be having to deal with a lot of heavy equipment as maybe has been the case in the past when people tried to instrument sites for temperature monitoring. But now this is basically all you need to set up a site. You've got your epoxy, you've got your data shuttle—you know that's kind of an optional thing, but that's what I alluded to with regards to being able to do an underwater download—metal tags—you can get those easily from forestry supply companies—we'll use that then to monument the rock that the temperature sensors get attached to. You've got your temperature sensors, wire brush—we'll use those typically to scrape off the surface of the rock, make sure we have a good clean surface before we attach our temperature sensors, rubber gloves to keep the epoxy from getting on your hands. And then we've also found a plastic view box to be a useful thing and that's basically just allows you to lay that view box on top of the water surface and you get a really clear view of that attachment site where you're putting a temperature sensor or to inspect the temperature sensor after it's in place—just feel confident that you've got a good adhesion to that rock surface.

**Easy Method for Full Year Data
Underwater Epoxy Protocol**

This slide just kind of sums it all up then. Basically now we've got a pretty good system using the underwater epoxy with the modern digital temperature sensors that can collect a lot of data at a site for a long time where for \$100, maybe a little bit more than that, you've got a system now where you can collect and monitor stream temperature data continuously at a site for upwards of five years.

Regional Temperature Sensor Network

And so, now that it's easy to do, it's such an important variable, lots of people are starting to do it. This map just shows kind of the emerging regional temperature sensor network that's out in the northwestern U.S. where people are now actively monitoring full-year stream temperatures. Not all the points on this map are instrumented using this underwater epoxy protocol, but the vast majority of the green sites, which are Forest Service sites, have been instrumented using the underwater epoxy and as of two years ago, none of those sites were on the map. So this is rapidly growing, a lot of people are applying it, and I'll point out too that we have not yet updated this map with the thousand or so new sites that we and other agencies have instruments this last year, many of which were done using underwater epoxy. It's easy to do, it's valuable, and so it's just exploding, the amounts of full-year temperature monitoring that's going on now.

Uses for Full Year Data

And, there's going to be a tremendous amount of utility that we can get from that full-year data. This is just kind of a quick bullet list of some of the things we'll be using this information for. Probably the most important thing on this list is simply the fact that now that it's easy to do, there's going to be a lot more people doing it and that's also going to make it a lot easier to do long-term trend monitoring, which is really important for understanding environmental changes that might be associated with land management for climate change. Some of the other things, just quickly, we think we'll be able to get a much better definition of thermal criteria and the thermal niches that aquatic organisms need now. That we can go to specific places within stream networks, put temperature sensors there where we know certain thermal [] are exceeded, directly measure those things over the course of the year or multiple years and know exactly what it is that radiates distribution of organisms and streams. We're going to be able to characterize full-year thermal regime, as opposed to just looking at summer maximum temperatures, which we've focused the vast majority of our efforts on in the past. All the data that are collected using—or full-year data that are going to be collected by this means and others can feed directly into predictive models that we are developing and others are developing to map out stream temperature patterns across river networks and regional advantages that we can better understand the effects of climate change. We're going to be able to use these sorts of data for short-term sensitivity analyses wherein we look at the relative changes across hundreds of different temperature sensors during say two different contrasting climate years to get a sense of which site and which types of streams may be more or less sensitive to climate forcing. And then as I alluded to at the beginning of this slide, this is going to make doing long-term monitoring much easier and in some cases then if we can get enough full-year data at a site, two, three years, etc., we think we'll be able to make some link function to the near, near the long-term air temperature and discharge monitoring stations so that we can reconstruct stream temperatures going back 50 or 60 years at a site. So, getting this sort of full-year data is just going to open up a whole fleet of possibilities that we're really excited about.

Relevant Publications
Field test and validation work

If you want to know more about this then, or get into some of the details, there are a couple different publications out there that are particularly relevant, first of which is the paper we published in the North American Journal of Fisheries Management in 2011, and this has just been the field test and validation work with a lot more details on exactly what the numbers are that were the result of that. And then we've also developed a detailed how-to guide, which is basically has a lot of pictures, lots of detailed instructions on how to establish sites and both of these then are available for download off the U.S. Forest Service Stream Temperature website that we maintain.

Available for Download at...

To find that website then just do a Google search on stream temperature forest service and it should pop up somewhere near the top of the list. Both of those documents as well as other things that we're doing that pertain to climate change and thermal regime in streams are all available at that site.

And then to conclude this presentation then I think now we're going to flip over to a video presentation of the epoxy protocol that Dona Horan and Sherry Wollrab are going to lead so thank you very much.