University of Minnesota Nutrient Management Podcast Episode "Field to stream to gulf - Part One"

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	(Music)
Paul McDivitt:	Welcome back to University of Minnesota Extension's Nutrient Management Podcast. I'm your host, Paul McDivitt, Communications Specialist here at U of M Extension. Today, we have another special episode of the podcast with Extension educator Greg Klinger and Kevin Kuehner from the Minnesota Department of Agriculture. We're continuing the discussion from our two-part episode from July on soil and nutrient loss in southeast Minnesota. So, be sure to give that a listen.
Paul McDivitt:	This two-part episode focuses on what happens to soil and nutrients after they leave the field. Can you each give us a quick introduction?
Greg Klinger:	Sure, as Paul said, this is the Extension Educator Greg Klinger from Rochester. Speaking with Kevin Kuehner from the Minnesota Department of Agriculture and Root River Field to Stream Partnership. Again, this is a follow-up conversation on the one we had about soil and nutrient losses from farms in southeast Minnesota, but this time we're discussing more, again, what happens to that soil and those nutrients when they leave the field. Before Kevin introduces himself, I just wanted to start this podcast with an idea, which really has to do with, to my mind, the just unpredictability and unexpected behavior of nature. So I used to think that once soil was washed off the field, it went right to the nearest stream, it zipped down that stream into a larger river, and it ended up in the ocean.
Greg Klinger:	And what I've realized, over time, is actually a very different sense of that. The soil washing off your field, you know, most of it might get trapped in that little wooded ravine or that wood lot below your field for a decade or more. Make its way onto the floodplain of your local stream in the next decade or two. Settle out on a sandbar of the, you know, like Minnesota or the Cannon or the Zumbro River in a few more decades, and not even make it down to the Mississippi River for a thousand years. In fact, if you listen to experts talk about the mouth of the Mississippi and the Gulf of Mexico, they're actually getting much less soil coming down than they used to. Mostly because of the lock and dams on the upper Mississippi, here. Also, dams on the Missouri River that actually trap a lot of that sediment.

Greg Klinger: So, soil movement can really be a lot slower, a lot more unpredictable, and over shorter distances than you might think. And we'll get into some of that nuance today. Kevin, you want to introduce yourself and just give the elevator talk version of what the Root River Field to Stream Partnership does?

Kevin Kuehner: Yeah, I'm Kevin Kuehner and with the Minnesota Department of Agriculture and I'm based in Preston, and starting about 10 years ago we started a project, a collaborative effort between many different groups and organizations to have a better understanding of how agricultural practices affect water quality. It's a research and demonstration project taking place in the river watershed. The Root is one of 80 major watersheds across the state and one of the more complex watersheds just because of the geology and the modern precipitation that we receive here in the southeast corner of the state.

Kevin Kuehner: With that, what we did is we selected three small watersheds that represent the unique diversity of southeast Minnesota, ranging from the glacial till flat area to the west, to the thin soils over fractured bedrock. What we call the karst area in the center portion of the watershed, to the steep ravines and bluffs to the east, in what we call the bluff land karst. What we did is we installed monitoring equipment at the outlets of those three watersheds... and by the way these watersheds are very small, they're less than 5000 acres in size, and the reason we did that was to help us better understand these complex questions that we have. We also installed edge-of-field monitoring sites that are, what we call, nested within these small watersheds to help us understand what's coming off of the fields as well.

Greg Klinger: Great, thanks Kevin. So, in the last podcast we left off discussing how much nutrients and soil were leaving the field edges from these fields that you're monitoring within those watersheds. We know that most soil that erodes within a field actually never leaves the field, it just moves down slope. It's not really a water quality issue, although it does, you know, impact crop yields over time. And as a recap, how much soil, how much phosphorus, how much nitrogen was coming off of those fields you monitored?

Kevin Kuehner: From 2010 through 2017, that's what we consider our baseline period. That eight year period we've been measuring both sediment and nutrients phosphorus and nitrogen in surface runoff. We've also been measuring the components of nitrogen that are coming through subsurface loss, through tile drainage, and in ground water, but I'm going to just focus on the sediment and what we call sediment bound nutrients. So, that portion of nitrogen that's attached to the sediment both phosphorus and nitrogen. These fields that we select, it was really important for us to select fields that we felt were really representative of the farming systems that we had within each of those selected watersheds. We've got a diversity of, you know, corn, soybean rotation fields that are just managed for that, to some fields that are managed for continuous corn silage with manure, and another field that's managed for corn, soybeans, and alfalfa. So, we've got a good diversity and mix of practices, again, that we feel are representative of those particular landscapes.

Kevin Kuehner: In what we've found for sediment loss coming off of those fields, and this is an average, and again, with these data... especially sediment of phosphorous, it can get a lot of variability from year to year, but on average what we've been seeing over those last eight years, we've been seeing about 1300 pounds per acre of soil loss that has been delivered off of those fields. We also find a little over about a pound, about 1.4 pounds of total phosphorus that is also being delivered off of the field. For total nitrogen, we see a relatively low amount of nitrogen coming off of the surface of these fields, but where we do pick up most of that is through leaching processes underneath these fields and we detect more of that in ground water. But with regard to what's attached to soil, we typically see, you know, upwards of maybe about 10 pounds per acre of nitrogen that's attached to the soil.

Kevin Kuehner: Those are averages, but we can see in a really wet year upwards of 10,000 pounds per acre of soil loss, and upwards of 10 pounds per acre of nitrogen.

Greg Klinger: Okay, thanks for clarifying that. So the main things that are determining, let's say, variation those losses are really location to location and year to year, is that the kind of the big things that determine how much is being lost?

Kevin Kuehner: Yeah, there's a variety of different factors, it's primarily of course the amount of rainfall that we receive and even the timing of that rainfall is primarily one of the bigger drivers. For instance, if we get most of that rainfall in the early part of the season, especially April and May, verses if we get most of that rainfall later in the season like now, August and September, we tend to see much greater losses of sediment and nutrient loss in surface runoff in the early part of the season when we have those bigger rains. When simply the crops aren't at full canopy and we don't have a lot of opportunity to intercept those raindrops.

Greg Klinger: So focusing a little bit here on, let's say phosphorus, what I get out of the data is that, let's say, the amount of P loss and you said it's basically, roughly one pound of phosphorous for 1000 pounds of soil, but the amount of overall phosphorus loss is going to be most closely related to that amount of soil we lose. But also some of the other important things you saw were things like soil test value, effective debt and also, I guess, I mean, you didn't deal with this directly in this project, but you always see things like tillage make a big difference in the sense that, for instance a no-tilled field, you typically see very very little soil loss, but because that phosphorus is kind of stratified in the top of the soil, you might get more than that one pound P for 1000 pounds of soil in that situation.

Kevin Kuehner: Yeah, so certainly management does play a key role in those losses and what we have found, and other studies that found this too, is that there's really kind of two main things... well, with regard to phosphorus really, the biggest thing you can do to control your phosphorus loss from a management perspective is good soil conservation practices, because like we mentioned about it, we're seeing about a pound and a half of phosphorus for every 1000 pounds per acre of soil loss. It ends up being about 80% of the total phosphorus that we measure is associated with that sediment loss. Kind of the simple way of looking at it is if you can control your soil loss, you can control upwards of 80% of your phosphorus loss. That other 20% is primarily what we call in the dissolved form, and that's basically the water soluble form of phosphorus. That really isn't associated with this sediment and that typically happens, let's say, in the early spring when the ground is still frozen, or late winter, and as that water travels over the soil's surface it can pick up that dissolved fraction of the phosphorous.

Kevin Kuehner: How we manage our soil test levels, you know, keeping our soil test levels in check, and also how we incorporate our fertilizers and also our manure management practices can have an impact on those phosphorus losses. But by and large the take home here is you can control a vast majority of your phosphorous by having good soil conservation practices in place.

Greg Klinger: And I think that's this distinction between, you know, soil associated, or sediment associated phosphorus and dissolved phosphorus, it's a really important one, because when you think about how soil moves in water it settles out. But water just kind of keeps moving, so for instance you have that dissolved phosphorus, it probably only takes a couple of months from when it gets into that local stream, you know, in a runoff even or whatever, to when it gets all the way down to the Gulf of Mexico. You know, the Root to the Mississippi to the Gulf, in the sense that once it's in the water, it's mostly, generally speaking, going to stay put, whereas P attached to soil, it's going to probably take a much longer time to get down to the Gulf of Mexico because soil doesn't stay in water indefinitely, you know, it settles out when the current slows down.

Greg Klinger: I think that's really important to the discussion today to understand that. As Kevin mentioned, most of the nitrogen that comes out of crop fields really comes out... moves through the soil rather than over the surface, that is worthy of a discussion of its own, and we'll have that discussion on another day, but I think for purposes of today and this podcast really going to focus on nutrients moving over the soil surface and particularly probably soil and phosphorous. So, you have all that edge of field monitoring telling you what's leaving fields, but you also have monitoring equipment that it's telling you what's leaving fields in terms of soil, nitrogen, and phosphorous, but you also have this monitoring equipment in the streams themselves that those fields are actually feeding into. How does what you see in the stream compare to what's leaving the field?

Kevin Kuehner: It's interesting, when we look at the numbers and we look at the average soil loss from these representative farms nested within these watersheds, and we compare that to what we're measuring coming out of the mouth of these small watersheds, we see a very large reduction in that sediment in phosphorus load. So if we're measuring about 1400 pounds, or 1300 pounds coming off of the field, we're seeing around 60 to 70 percent less sediment coming out of the watersheds. We're measuring about 400 pounds on average coming out of these small watersheds. And for phosphorous, coming off of the fields, we see again, about a pound and a half and coming out of the watershed we see about half that, so about point seven pound per acre per year.

Kevin Kuehner: A lot of that is interesting, I think, to us when we look at that information, and it is certainly to our farmers that are participating in that, and the number one question is, well, where is that sediment and where is that phosphorous going, and what happens to it once it leaves the field? I think it really kind of boils down to just these natural, well, this combination of factors, but sort of these natural, physical processes that occur in watersheds. And that any opportunity where that sediment has an opportunity, or that water has an opportunity to slow down once it leaves the field, there's an opportunity for settling of the sediment within the run-off water itself.

Kevin Kuehner: There's a lot of various factors that can play into that. In a watershed, some of them just, physical factors that are just inherent would be just the topography of the watershed, how connected the watershed is, how connected the watershed is, how many streams are within that watershed and how connected it is to the fields. Of course, precipitation events and a variety of different factors, but there's also one really, of course, really big one that a lot of times we sometimes don't have a really good handle on and that is just the existing practices that a lot of farmers have been using over the years. So as that sediment comes off of the field, you know, it may move into the next neighboring field, into a grass waterway where it could slow up and settle out. And then the next event, maybe a month later, it might move a little bit further with the next event only to come to a maybe a fence line, you know, on the neighboring farmer's field.

Kevin Kuehner: And then after that, maybe a year later, another big event comes through and then that sediment moves a little bit further, but then it gets into a terrace that another farmer has. So it just has this kind of long, very slow process of moving through the watershed, but obviously fields that are very close to the stream are going to have a much faster delivery, what we call, a delivery rate than let's say a field that's much further away from the stream. Generally, what we find, too, is size of the watershed really makes a difference. So smaller scale watersheds tend to have a higher delivery of sediment, verses watersheds that are much larger. They have a much lower delivery of sediment.

Greg Klinger: Can you define that term? What does delivery mean?

Kevin Kuehner: Yeah, what we call it is... delivery is actually soil loss off of the field, delivered off of the field. When we get to a watershed, we often call the sediment delivery ratio, which is basically all the sediment from all the different sources that are coming out of the watershed verses what's actually measured. On a field scale, the way we can measure that is we can measure the sediment delivery ratio, we can measure that by actually trying to model or estimate the amount of erosion that's occurring within the field because we know that all that sediment that may erode from the top of the hill down to the bottom of the hill doesn't necessarily mean that's getting delivered off of the field, but that's still erosion that's occurring within the field.

Kevin Kuehner: And there's various models that have been developed that can help estimate the amount of gross erosion that's taking place within the field, so we typically have probably gross soil erosion rates of between two to five tons per acre per year. But, again, what we're measuring is what's actually delivered off of the field. What we tend to find is that sediment delivery ratio at the field's scale, what we've been seeing on our edge-of-field site is between about 15% to upwards of about 40% of that gross erosion that's occurring of both sheet and rill erosion and also gully erosion that's occurring within these fields is actually getting delivered off of the field. It's a fraction of that gross erosion that's actually making its way out. That same process occurs at the watershed scale as well, except there's more opportunities for that sediment to actually slow up and settle up before it actually gets to the stream itself.

Greg Klinger: Hey, man, I love having these conversations because I just learn something new every time. We had this discussion and one of the things that really struck me, Kevin, when we were talking about this last week, before we had that conversation, I'd never thought about road ditches as being sediment control structures, but in a lot of ways they are because they're actually setting, you know, one of many things that are settling out soil, and that's really a pretty fascinating thing to think about. All the infrastructure that we have that we don't even think of as sediment control, but it really is.

Kevin Kuehner: Yeah, and I think to, I guess, add to that point is during the study, one of the things that we've been doing with working with these farmers, there's about 50 farmers within these three study watersheds, we've been really trying to do our best to quantify and document a lot of the existing practices that the farmers have. I think that was something that a lot of us maybe, when we're working a watershed project, some may feel like we're starting from scratch. That, we have to have more practices because there's not a lot out there, but when in fact there's a lot of existing practices that are currently out there and in these really tiny watersheds that we've been evaluating, we quantified over, well, 67 total of what we call these push-up ponds, and these were a common practice installed in the 1950's and 60's by farmers. And actually, their main intended purpose was for livestock, an access for livestock watering, but of course these little push-up ponds actually also are really effective at helping slow the water up and trapping some sediment and phosphorus and sediment bound nitrogen as well.

Kevin Kuehner: An incredible amount of density of those types of practices, which is pretty typical especially in Fillmore County, Houston County, and Winona and Wabasha Counties to have these push-up ponds. The other thing we documented, we documented over 45 linear miles of grass waterways that farmers had either put in themselves, or through various cross-shared programs that put in over the years. 12 miles of terraces and a variety of other types of practices that we're able to document. Obviously all of those practices are having a positive impact and can certainly help take some credit for why we're seeing some of the sediment reductions that we're seeing at the small watershed scale.

Kevin Kuehner: Now, with that said, we identified a variety of other locations that we feel that are really critical in terms of being a source of sediment within these watersheds and that was kind of the whole point of what we call phase two of this project which is to target some additional practices to see if we can move the needle even more at the watershed scale.

Greg Klinger: Yeah, absolutely. That's a great point. Just to reiterate, how big are these three watersheds? You're talking about, 55-some miles of terraces and grass waterways, I think it'd be good to get context of what area that encompasses.

Kevin Kuehner: Yeah. So if you combine the total acres between these three different watersheds, it's about 10,000 acres.

Greg Klinger: Okay.

Kevin Kuehner: Each watershed's roughly in that three to four thousand acre range. About 50 farmers, and there's about 500 crop fields within those areas. These are very, very small watersheds compared to a lot of the other watersheds that are being monitored throughout the state. Typically, the watersheds that are being monitored are at that 100,000 acre scale to upwards of 500 to even a million acres sized scale.

Greg Klinger: Sure. So we'll revisit some of those points you brought up, but when you talk about the existing practices, I think that's a really good lead in to something that I wanted to bring up, which is really that the reason that a lot of those sediment control structures are here in the first place, with the exception of those ponds you're talking about. If you look at the history of this region, it had some really dark days of slow erosion in the past, particularly in this time period of about 1900, 1910, to about 1940, and you start seeing those practices getting put into place as a response to that.

Greg Klinger: I think for those who are interested in history, it's really hard to over-emphasize how bad things were in terms of... I mean, you read the stories about this and I'm sure you know people, or some of the old timers around here actually, you know, they may have been young but they lived through some of this stuff. But, roads and bridges were constantly getting washed out during that time. You always hear about spring just completely drying up. The descriptions of the streams of that time, that are in the 1930, 1940 time period, really they describe them as looking like gravel roads. I think that's such an interesting description. Almost without water, most of the time, but then basically filling to the brim after every rain, and some people described them as looking kind of like the desert washes they get out in Arizona and Nevada, where, again, it's these huge braids of streams going across the valley floors with almost no water most of the time.

Greg Klinger: It's really interesting because that's basically what the streams in this area were becoming in that time, was desert washes. I actually, back in my office, I have a photograph and it's taken back in, I think, in the 30's and 40's and it's a photograph with some cars on the Highway 61, kind of by Weaver, and they're buried in about seven feet deep of soil that just washed over them. And if you look at the context of that photo, upstream in the Whitewater Valley that feeds into that area, they had just had a three inch rain and that three inch rain was enough for soil to move, again, tons of soil to move across that road so fast that it trapped cars in it. So you think of how often today we get three inch rains and it makes me feel pretty grateful that things are a lot better than they were then.

Greg Klinger: Actually, I think it's also interesting, too, if you have kids, or if you live in any of these valleys around here you have kids with a lot of energy or just kids who like digging, you know, want to dig a hole up to China... actually, by the way Kevin you got young kids, are they still interested in doing that digging holes to China, or is that kind of past its prime?

Kevin Kuehner: No, they still enjoy it.

Greg Klinger: Okay, good. I wasn't sure, you know. It's the internet age, so maybe they're just too well-educated these days to realize that they can't go through the center of the earth, but anyways. If you start digging in these valleys around here and any of the main valleys, especially the smaller ones, say the south branch of the rut, or south fourth of the rut or Rush Creek or the Whitewater River, as you dig the soil gets lighter color as you go down, but you get to a point in all of these valleys where the soil starts to get dark again. And it's usually between, when you read the descriptions, like eight and 12 feet, and what you realize when you do that is that dark part was the top soil before that really bad period of soil erosion. And everything that's above it, the lighter colored stuff that's eight, 10 feet deep, that all washed in since 1930, 1940, and that's pretty incredible to think about.

Greg Klinger: There's a lot we have to be thankful for in terms of those conservation practices. Getting back to the data, one observation I've made is actually pretty counterintuitive of what you're monitoring in the streams because the most soil erosion and the most phosphorous loss is actually coming from the flattest landscape of those three watersheds. So I'm really curious, what's the reason for that?

Kevin Kuehner: You're referring to the till area?

Greg Klinger: Yeah, the till area.

Kevin Kuehner: Yeah, we've been measuring about, roughly around that 400 to 500 pounds per acre out of the till area, the karst-

Greg Klinger: And that's soil you're talking-

Kevin Kuehner: Soil, yeah. Soil. The karst watershed, we're seeing about half that, about 250 pounds, and then the bluff land we're seeing about, similar to the till, which is about that 400 to 500 pounds per acre. So it was surprising to us. When we first started this project, we just kind of assumed that that bluff land watershed, because of the very steep topography, and that's just what you tend to think about when you look at that watershed that you think that watershed would have much more greater sediment loss, versus the till. The till watershed is flat watershed, roughly, zero to two percent sloped, tile drained and you just want to think that that till watershed would have an equal amount of sediment loss compared to the bluff land.

Kevin Kuehner: That was kind of a surprise to us, but then when we start looking at the information and looking at kind of what's happening there, there's kind of, probably multiple reasons why that till watershed probably is maybe yielding a little more sediment loss or the bluff land I yielding a little bit less. I guess, however you want to look at it, but the till watershed primarily we do have more flow in that till watershed, so if we have more flow we're going to have a higher delivery of sediment or load of sediment. Also, the other thing is in that till watershed is it's pretty, what we call, homogenous which is just, it's very not-complex. It's corn, soybean rotation with a drainage ditch in that watershed and so what goes in typically goes out. Not a lot of opportunity for trapping or some of these more complicated things that could be happening in these other watersheds.

Kevin Kuehner: As we get in the bluff land watershed, our much steeper fields, what we tend to have over there is, well, most of the really steep area, number one is not crop land, it's about 40% of that is in forest cover. And then the other factor is just there's a lot of practices in place to help kind of slow that water up and allow for more trapping of that sediment. Now with that said, those are the total loads of sediment coming out of these watersheds, in terms of comparison. But when you look at what we call the flow-weighted mean concentration, which is-

Greg Klinger: Can you... okay, sorry.

Kevin Kuehner: Oh.

Greg Klinger: I was going to ask you to define that.

Kevin Kuehner: Okay, so flow-weighted mean concentration is the total load of what we're measuring divided by the volume of water, so it's-

Greg Klinger: And-

Kevin Kuehner: ... It's a way for us to sort of normalize the data based on volume of water. It kind of apples, apples comparison between watersheds, sort of normalizing it for the volume of water that those watersheds have. So, even though the till watershed may get more water, we can normalize it using this flow-weighted mean concentration. And in particular, what we like to use, or I like to use is a flow to mean concentration during storm events, because that really highlights what may be happening within these watersheds. And what we tend to find is in the bluff land watershed, we do see very high concentrations of both sediment and phosphorus within that watershed. And that likely is an indicator of just that steeper topography and that quick movement of water and potentially more risk for some really high concentrations, but fortunately these concentrations aren't long-lived.

Kevin Kuehner: They typically are very high for maybe a period of a day or two days, but then they quickly go back down again and that's the result of this dilution effect and the effect of the groundwater that's coming into these systems and feed these systems, especially in the bluff land and in our karst watersheds.

Greg Klinger: Yeah. Great thanks that's really helpful to understand that. I wonder if you could walk us through a couple, you know, speaking of what happens during storm events. Actually, you know what, scratch that. I think we covered that pretty well.

Greg Klinger: I'm curious, how often do you see soil and nutrient losses in these streams? Is it really a, it's all the time kind of fairly similar? Is it just like when you have a really big stinking rain, or is it something in between?

Kevin Kuehner: Yeah, that's a good question and now that we have, you know, this will be our 10th year of monitoring, but I'll kind of share what we've learned and summarize with our first eight years. What we're finding at the small watershed scale, in terms of our loading and our losses, is actually pretty similar to what we're seeing coming off of the fields, and that it's really just probably one or two or three events in a given year that really count for the majority of the loss. When we look at the cumulative, let's say, sediment and phosphorus loss coming out of these watersheds over this last eight, nine years is actually when we look at that data, what's really interesting to us is that it's not the constant supply of sediment or phosphorous coming into these systems. It's very episodic, and particularly, I'm going to highlight year 2013 because what we found with that one particular year is that almost 50% of that eight year period of that loss during that time period came through in that one year alone.

Kevin Kuehner: And it kind of highlights to the fact that it's these really big events, especially in May and June, and that was the year in 2013 that was the case where we had exceptional amount of rainfall in May and June and that pretty much led to 40 to 50% or more of our eight to nine year study period loss. I think what that really highlights is that no, we're not seeing these sediment losses and phosphorus losses like a continuous supply constantly throughout the year, it's just these certain events that really cause them. And at the same time, I think, that really highlights, we need to figure out ways of how can we be more resilient to handle some of those events, especially in May and June because going back to our edge-of-field data is that's where we find about 80% of our sediment loss occur in just those two months alone. And over 60% of our phosphorus loss occur in those two months alone.

Kevin Kuehner: Trying to figure out ways to make our farms and watersheds more resilient, especially during the months of May and June because, again, that's where the lion's share of the bulk of our loss occurs.

Greg Klinger: Yeah, that's... man, that's a pretty sobering thought to think that you could have conservation practices that work reasonably well most of the time then you have something like that, a year like 2013 and all of a sudden they just don't hold up. You kind of understand where I'm going with that?

Kevin Kuehner: Yeah, I think it probably just highlights, again, especially some of these really bigger events in May and June, how significant they really can be. And certainly, if we didn't have the level of practices that we have now, certainly could be much worse, but I think it just highlights that, to evaluate what practices are really effective in that May, June period. So, minimum tillage, no-till type of operations, cover-crops, terraces, grass waterways, all those practices are certainly good, but again, in May and June to make sure that you're prepared for that big rainfall event, because that can be a very big proportion of the total load.

Paul McDivitt: You're listening to part one of our two-part special episode on what happens to soil and nutrients after they leave the field, with Extension educator Greg Klinger and Kevin Kuehner from the Minnesota Department of Agriculture. Be sure to listen to part two and check out the links and information about the Root River Watershed and Field to Stream Partnership, as well as other subjects discussed today, that we included in this episode's Minnesota Crop News blog post.

Paul McDivitt: We'd like to thank the Minnesota Agricultural Fertilizer Research and Education Council, AFREC, for supporting this podcast. Thanks for listening.

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