DR. ANDY FISHER: Enhancing groundwater recharge with stormwater

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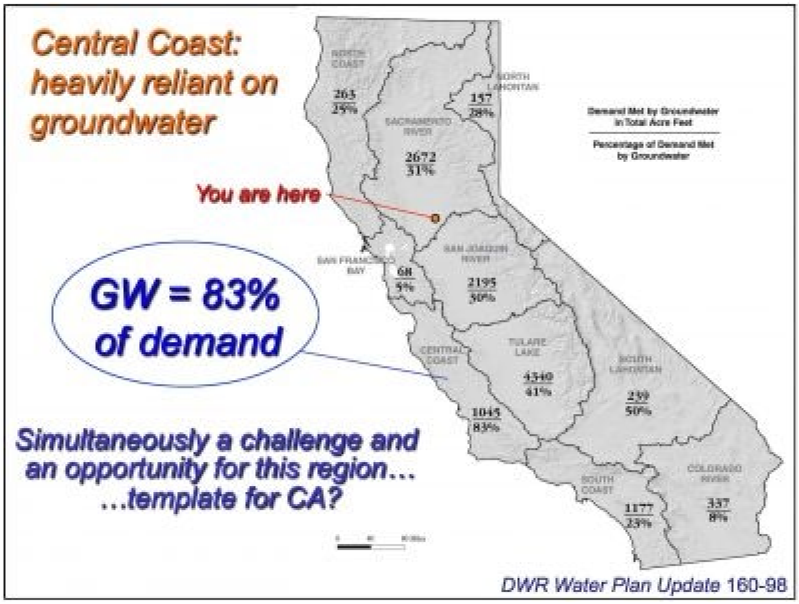
Dr. Andy Fisher discusses how distributed stormwater recharge projects in the Pajaro Valley can help to address groundwater overdraft

Dr. Andy Fisher is a professor at UC Santa Cruz and Director of UC Water, as well as the founder of the Recharge Initiative, a focused effort to protect, enhance, and improve the availability and reliability of groundwater resources. Dr. Fisher focuses on stormwater capture and recharge, including development of a metered recharge pilot project in the Pajaro Valley Water Management Agency where he looks at stormwater quality and at using GIS to map ideal locations for groundwater infiltration.

In this seminar presented by the State Water Board's STORMS program, Dr. Fisher discussed the stormwater projects he's been working on in the Pajaro Valley, stepping through the process of mapping, modeling, measuring, and then ultimately monetizing or incentivizing groundwater recharge.

Within California, there are really three distinct and compounding threats to groundwater: increasing demand, shifting land use, and the increasing the intensity of rainfall, he began. "*This is something that is seen in the hydrologic record; it's not a modeling prediction, it's actually occurring right now. Both shifting land use and the increased intensity of rainfall lead to a reduction in groundwater recharge, simply because there is less opportunity for water that hits the landscape to infiltrate before it runs off.*"

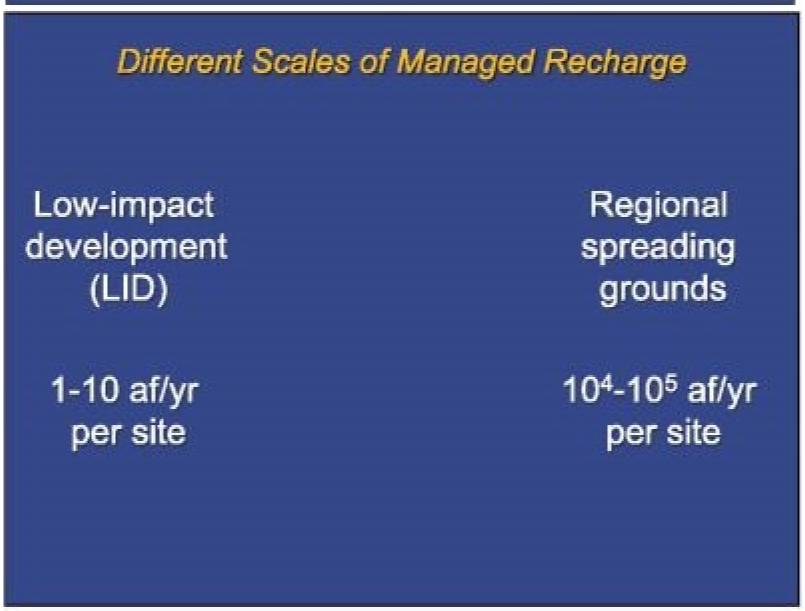
The Recharge Initiative has four components: mapping the locations where enhanced recharge might best be accomplished; modeling the availability of stormwater from hill slopes; design and create field projects and measure or validate the benefits to water supply and the improvements to water quality; and then monetize activities and policies that incentivize stakeholders and strengthen partnerships.



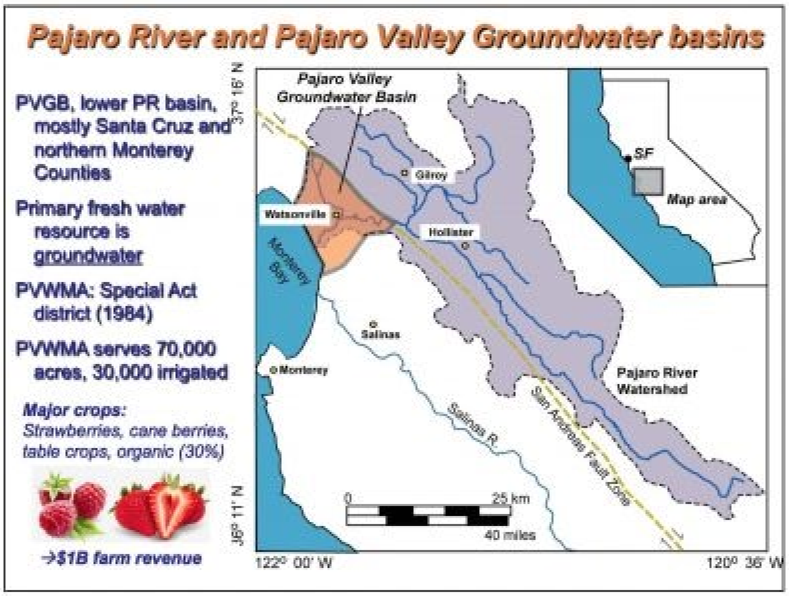
The area in which Dr. Fisher works at the northern end of Monterey Bay is located in California's Central Coast hydrologic region, which is the region of the state that uses more groundwater to satisfy freshwater demand than any other part of the state. He presented a diagram from the California Water Plan, noting that the graphic shows water use; the number on the top is water use in thousands of acre-feet and the bottom is the percent that is satisfied by groundwater. "*Other parts of the state use more groundwater than the Central Coast, but they are at sort of a third or a quarter or half of the total supply. Central Coast region, it's about 85%*," he said.

The other challenge for the Central Coast region is that they are 'off the grid' in terms of water transfers; there is no imported water being delivered to the Central Coast area. "*As a result, we really have to figure out a way to generate enough water to provide for needs in that region without thinking about bringing in water from elsewhere*," he said.

Dr. Fisher presented two forms of managed recharge: on the left, a picture of a feature of Low Impact Development in the form of a vegetated swale; these are often small scale systems that are set up very close to the source of runoff. The picture on the right shows the large scale spreading grounds for Orange County.



"*Typically Low Impact Development sites are built to put on the order of an acre-foot or ten acre-feet a year into the ground, and these big regional spreading grounds are 10,000 to 100,000 acre-feet per year*," said Dr. Fisher. "*But the area we're really focused on is the space in between, what we call distributed stormwater collection leading to managed aquifer recharge. And the ultimate goal is to get something on the order of 100 to 1000 acre-feet per year, per project site into the ground*."



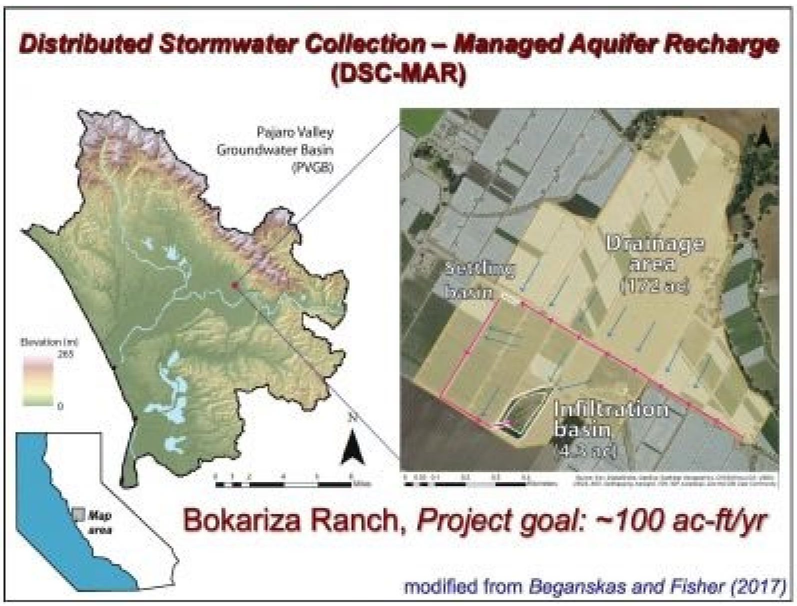
The Pajaro Valley Basin is shown in orange on the map; it's located on California's Central Coast on the northern side of Monterey Bay. The Pajaro Valley basin is an agriculturally-developed basin that produces high value crops such as strawberries and cane berries. If the Pajaro Valley were a county, it'd be the smallest in California by far, but it would be number five in farm income, he noted.

The Pajaro Valley Basin has no imported water, so virtually all of their water supply is groundwater. The Pajaro Valley Water Management Agency manages the groundwater; the agency is a special act district set up in the 1980s to address groundwater overdraft, which at that time was well understood to be on the order of tens of thousands of acre-feet per year.

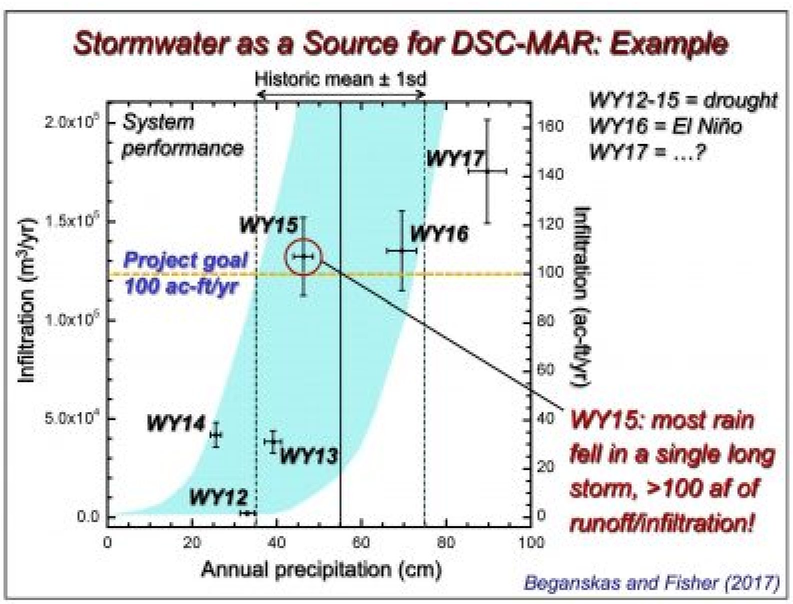
"*Because the amount of water that's pumped from the ground in addition to losses to the ocean exceeds what flows into the aquifer, this aquifer is in overdraft*," Dr. Fisher said. "*The exact amount of overdraft is not clear but it's on the order of 10-15,000 acre-feet per year which is about 20 to 30% of what's pumped* *in the basin. And as a result, seawater is moving in along the coast; the affected area outlined in red is from a few years ago, but it indicates and area where there's significant seawater intrusion to the point where that water in the ground cannot be used to grow those crops that are of interest, and it can't be used for human consumption, either*."

AN EXAMPLE DISTRIBUTED STORMWATER CAPTURE MANAGED AQUIFER RECHAGE PROJECT

He then presented a picture of a project site, located adjacent to the Pajaro River in the back of the basin, about 170 acres on a working ranch. The drainage area is marked in tan. "*Water flows across the landscape and through ditches, flows into a sediment settling basin and then continues on its way and eventually into a 4 acre infiltration basin where it's allowed to percolate into the ground*," he said. "*The goal of this project was to get about 100 acre-feet per year into the ground*."



He then presented a slide with pictures showing the project when it was empty, and another showing the project when it is full. The project site was instrumented with a number of different tools, including a real-time monitoring system that allows data to be collected and viewed remotely; it also allows the landowner, the grower, or other stakeholders in the region to see what's going on at the field site.

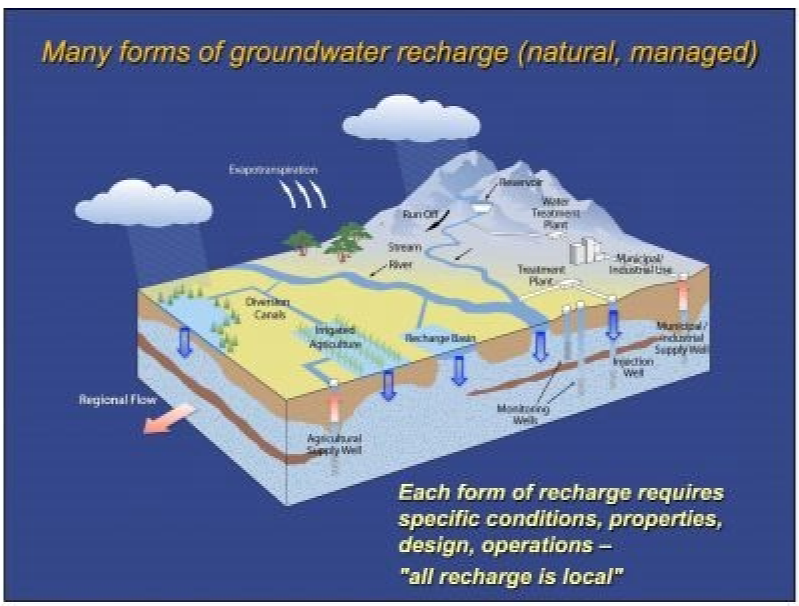


Dr. Fisher then presented data for three different water years. The graph shows the amount of infiltration, determined by calculating a mass balance on the basin. The infiltration in acre-feet is shown on the right hand side. The project goal was 100 acre-feet per year. The first three years of the project also happened to be the first three years of the drought, although things eventually did improve.

The water year 2015 was still below mean precipitation, but during that season, most of the rain fell during one week in December. "*As a result of the intensity of that storm, even during the drought, we happened to hit our project target, so this was really an epiphany that said, this is what we need in a world where rainfall is becoming increasing intense when more of it is falling during a short period of time. Water year 2016 was even better; about the same amount of infiltration occurred but much higher rainfall. The difference here is important and it has to do with the distribution of rain during the year. How intense the storms were and how widely separated they are*."

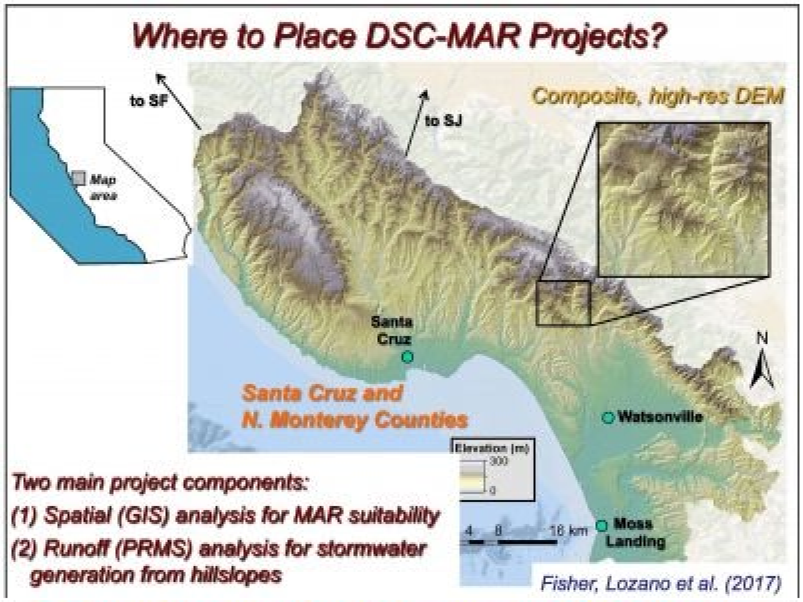
The third year was an El Nino year and was something different entirely, he said. "*We definitely got a lot more rain, but again the rain was kind of spread out throughout the year and so we didn't get a proportionally equivalent amount of recharge*," he said. "*But out of the six years of monitoring, we have three that met our project goal, and three where the rainfall and runoff was quite low.*"

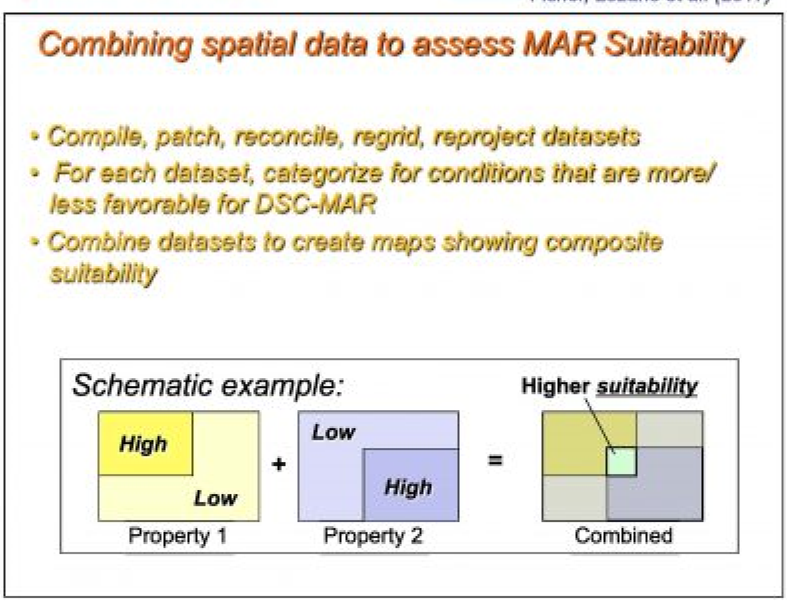
MAPPING TO DETERMINE SUITABLE LOCATIONS



The next challenge was to figure out how to site similar projects across the landscape, given that the groundwater recharge conditions are highly variable from place to place, not only within the Pajaro Basin but around the state.

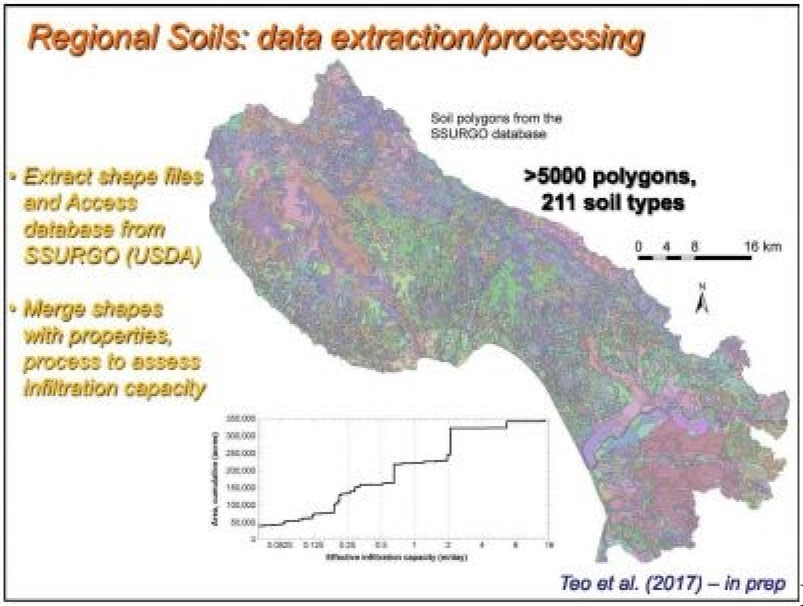
They undertook a project in collaboration with the Resource Conservation District of Santa Cruz County to identify sites for distributed stormwater collection could lead to managed aquifer recharge. The study region was all of Santa Cruz County, the northern part of Monterey County, and a little bit of San Benito. The general concept of the mapping work was to bring different data sets into a geographic information system or GIS, and then co-register them and overlay them to see where the different conditions correspond.





The concept is that if there are two maps of different soil properties, each with higher value areas and lower value areas, when the maps are laid on top of each other, the places where the high values overlap are the areas that are ideal.

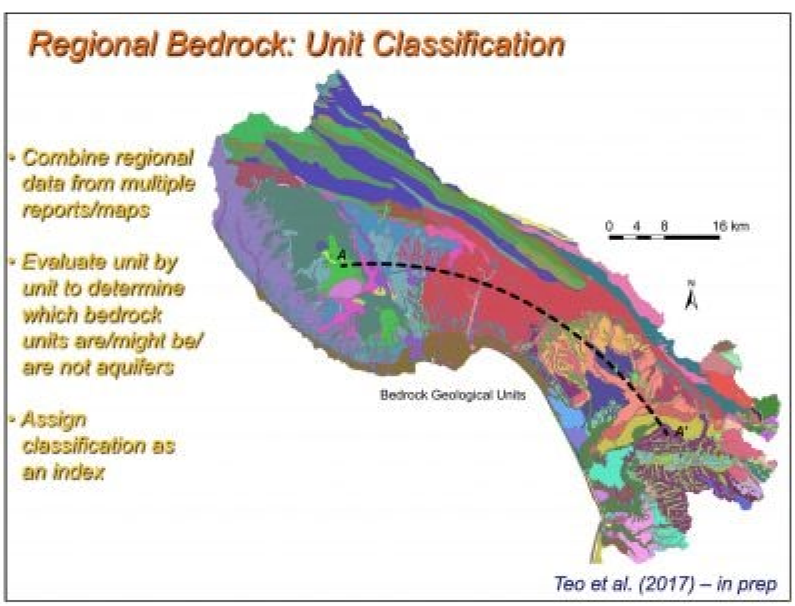
He then stepped through the process.

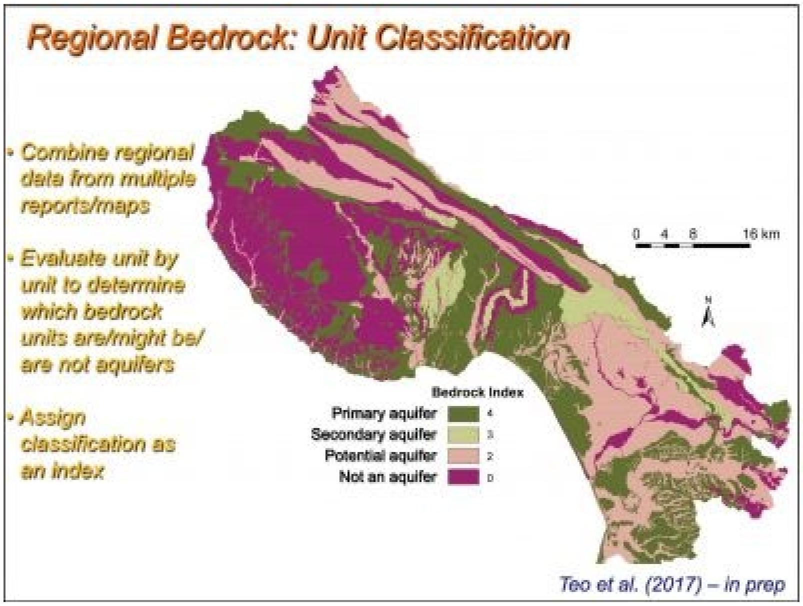


He presented a map from a soils database for the study region, noting that it includes more than 5000 little soil shaped polygons which have been mapped out by researchers, growers, the agricultural extension office, and the soil conservation service, and then put into a database that is publicly available.

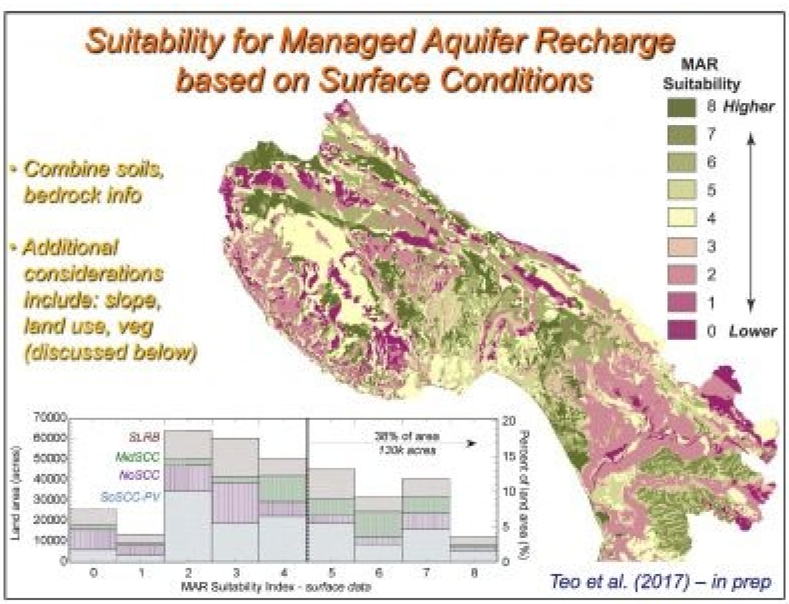
The infiltration capacity or the ease with which with which water will flow vertically through the soil is then calculated for each polygon. The calculated values ranged from essentially 0 up to 16 meters per day, so there is quite a range of soil properties.

The data from multiple layers is combined and assigned an infiltration capacity to produce the map, with the areas in blue having a relatively high infiltration capacity and the areas shown in pink or range have a low infiltration capacity. "*This is the approach we take*," Dr. Fisher said. "*We gather data, classify it, and then start to combine it*."

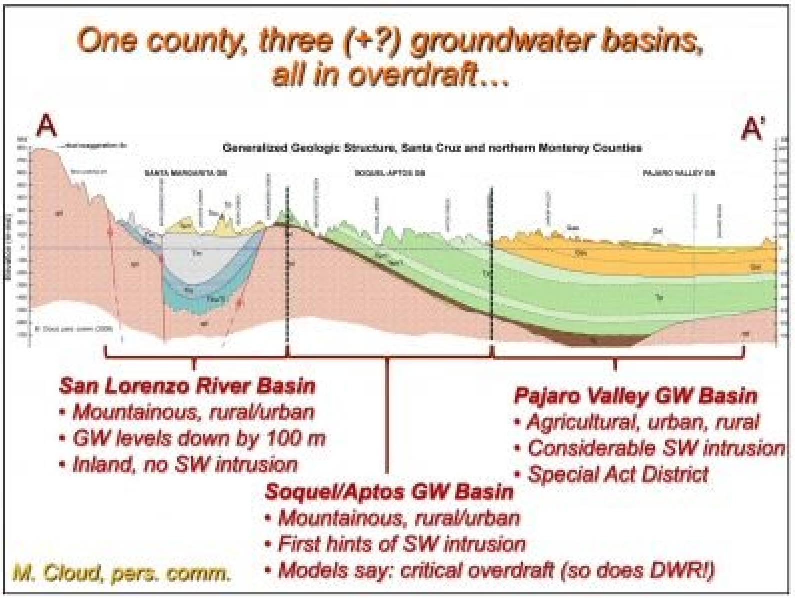




In the Pajaro Valley, the large areas in red tend to be floodplains or wetlands, areas with hydrophobic soils that water does not filtrate very easily, he said. That is then combined with the geological map, and areas that are aquifers are shown in green; pink signifies not an aquifer. There are also areas in between where it may be in aquifer in some places but not in others. The light green represents secondary aquifers that aren't heavily used in that particular part of the region.



Those datasets are combined to make the initial surface map of managed aquifer recharge suitability. Areas that are in the greener colors are highly suitable, tans are moderately suitable, and then the pinks and reds have low suitability. Based on this initial map, about 40% of the area is moderately to highly suitable, based on these surface conditions. It does vary by basin; there's actually four different groundwater basins in this study region, Dr. Fisher said.

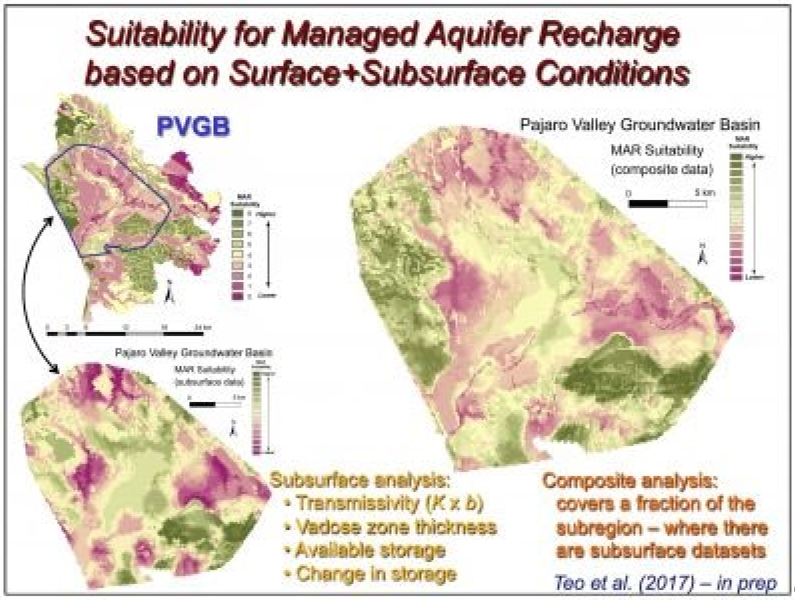


However, surface data is not quite enough; you need to look into subsurface as well, he said. He presented a cross-section of the study area from Santa Cruz County down into Monterey County.

"*This is a geological cross-section showing the Santa Margarita groundwater basin, the Soquel-Aptos groundwater basin, and the Pajaro Valley groundwater basin,*" he said. "*I put this slide in to really make the point that especially in California, the variability is just extreme from one place to another. These are just a few miles apart, but they are a completely different geology. Water that falls in the Santa Margarita Basin is not going to go into Soquel-Aptos or Pajaro Valley; it's pretty much stuck in that basin where it's going to flow out to streams or to the ocean. Each basin has different requirements, different geology, and different land use, and all that needs to be taken into account in siting groundwater projects*."

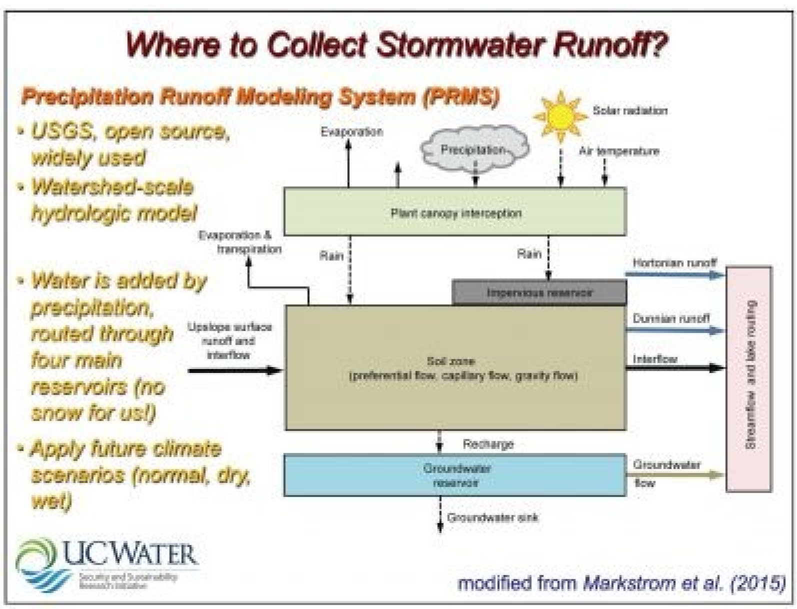
The subsurface data from groundwater models is then compiled, and other characteristics of the aquifers are assessed, such as the measure of the ease in which water can flow through the aquifers, the thickness, the ability of the aquifers to store water, and whether or not water levels have gone up or down with time.

"*The areas in the basins where groundwater levels have gone down indicates they have space, they can potentially receive infiltrating water,*" Dr. Fisher said. "*The thickness of the soil zone is important because if it's too thin, you don't get enough treatment benefit as the water flows through, but if they are too thick, you lose confidence that the water you infiltrate will actually reach an aquifer, so we try to find the sweet spot*."

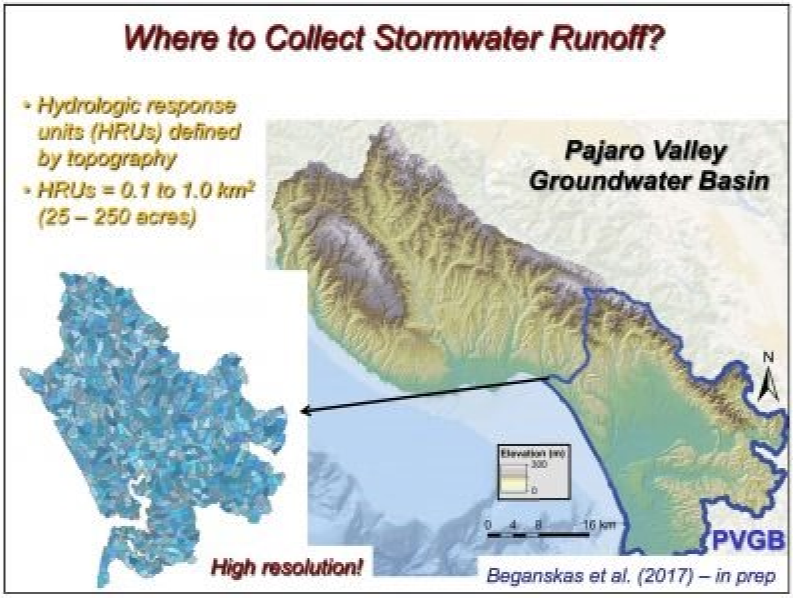


The four datasets are combined and a subsurface map is generated, showing higher suitability areas in green, lower suitable areas in orange. The result is a composite MAR suitability map, including six different data sets, the surface data plus the subsurface data.

MODELING AVAILABLE STORMWATER RUNOFF



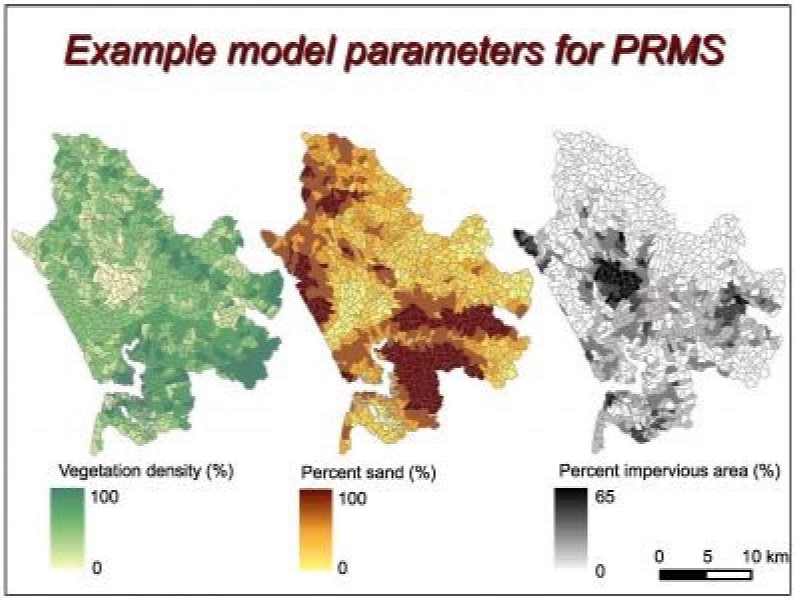
While the map shows the sites which are likely to be good places to put water in the ground, they don't determine whether there is water available to put in the ground. "*To look at that problem, we run a rainfall runoff model, the Precipitation Runoff Modeling System or PRMS. This is an open source program that was designed and built and is maintained by the USGS. It's a watershed scale model that lets us route water across the landscape. The diagram on the right shows you the different reservoirs and flows that are represented by the mathematical model*."

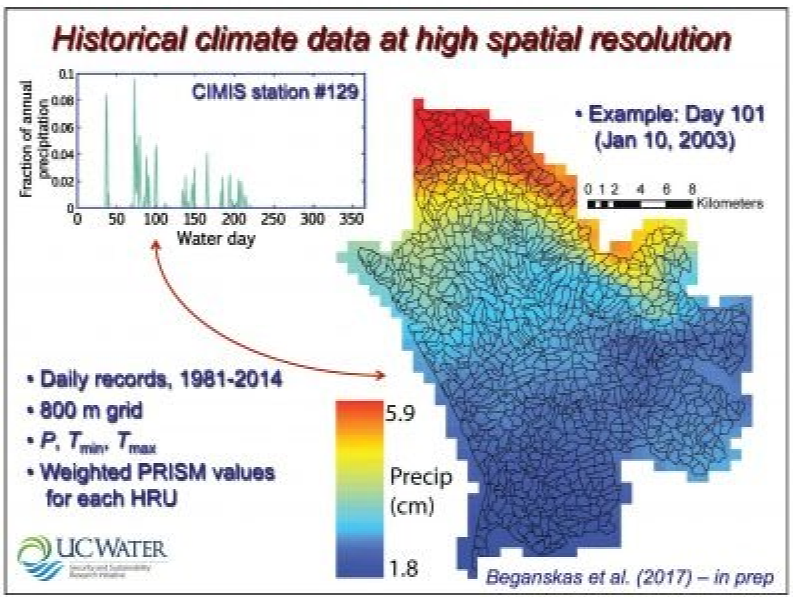


In order to determine the runoff, datasets to represent the properties of the plants, the soil zone, and the groundwater are input into the model, and then the model simulates the rain on the landscape. This is done by dividing up the area into HRUs, of hydrologic response units. "*You can think of them as little places on the landscape with similar properties*," he said. "*They are defined based on the topography, but then also based on things like land use and vegetation*."

He noted that in this application of PRMS, the gridding of the modeling into such fine cells is a little bit unusual as it's usually used for modeling large areas, such as the entire Mississippi drainage basin, for example, or to model entire continents. "*We're looking at areas that have properties on the basis of around 25 to 250 acres – little postage stamps. These are about the size of individual stormwater collection systems, so it fits well within our goal for the project*."

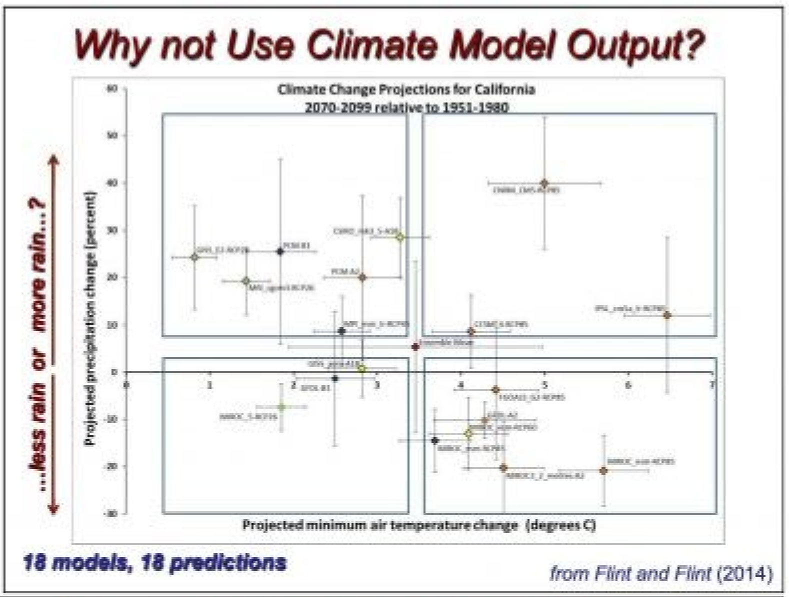
With the HRUs identified, they next need to be populated with more than 80 datasets for all the different properties, such as vegetation density, the percent of the shallow soil that's made of sand, the percent impervious area, the presence of concrete or roads or other structures.

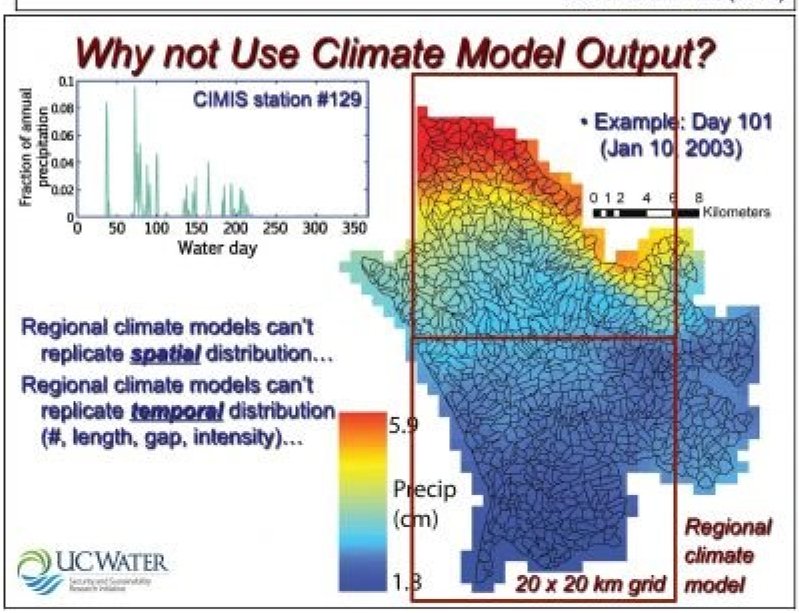




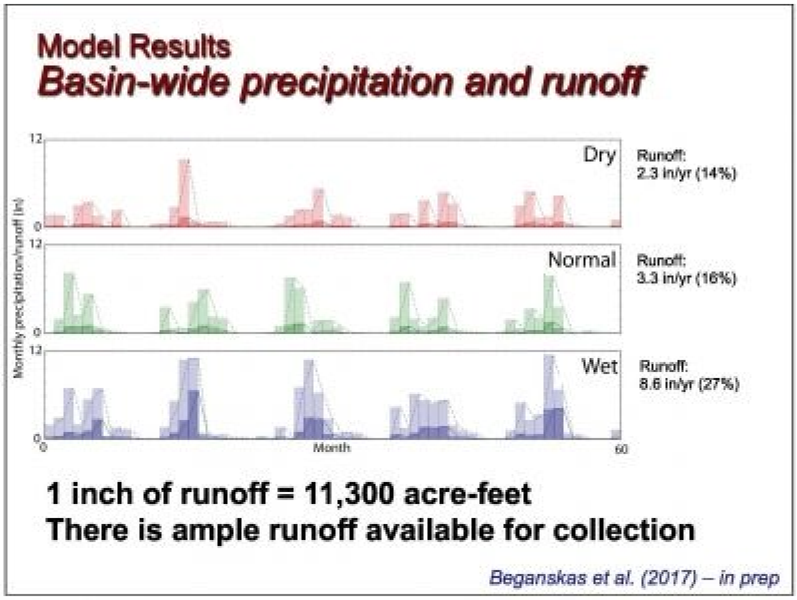
Next step is to rain on the landscape in order to generate runoff with the model. Dr. Fisher said the approach they took was a novel approach. "*The typical approach folks would take is to take output from a climate model, and apply wetter periods, dry periods, and make a projection*," he said. "*We decided to do instead was to use the historic record from 1981 to 2014, which is available in this PRSM data set at an 800 meter grid spacing, so a very fine grid spacing. This is an example for this one day, January 10th, 2003, when almost six centimeters of rain here in the northern end of the Pajaro Valley groundwater basin and about 2 cm on the southern end. This kind of granularity of variability in rainfall day by day, and temperature is important for representing, for example, the pathway that storms take as they move through the region*."

So why not use the climate model output? He presented a result [lower left] from a recent USGS analysis of climate models for California, noting that half of the models say it's going to be wetter, half the models say it's going to be drier, so which one do you use. "*One approach climate models take is to average everything together and then you get almost no change, and the same with temperature*," he said. "*They all say warmer world but some say 5 degrees, some say 2 degrees, so which one do you want to use. So we decided to avoid this ambiguity entirely and create a catalog from the historic record, run simulations with current day conditions, drier conditions, wetter conditions, and see what the result looks like.*"



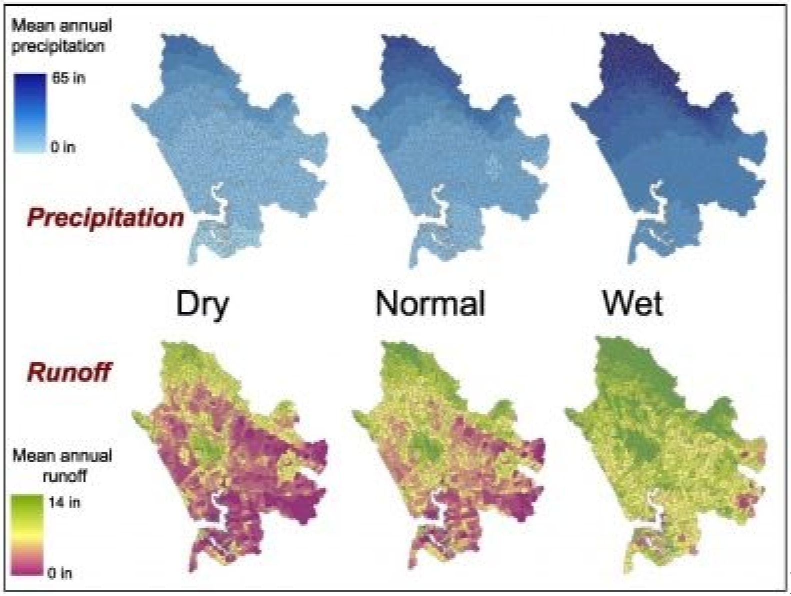


The other challenge is that the state of the art for regional climate models is a 20 kilometer grid, so they can't replicate spatial or temporal distribution. "*If we use the output from climate* *models, we'd be assigning one set of rainfall to this entire area, and then one set to this entire area, again missing out on all the detail that actually occurs in the observation record*."



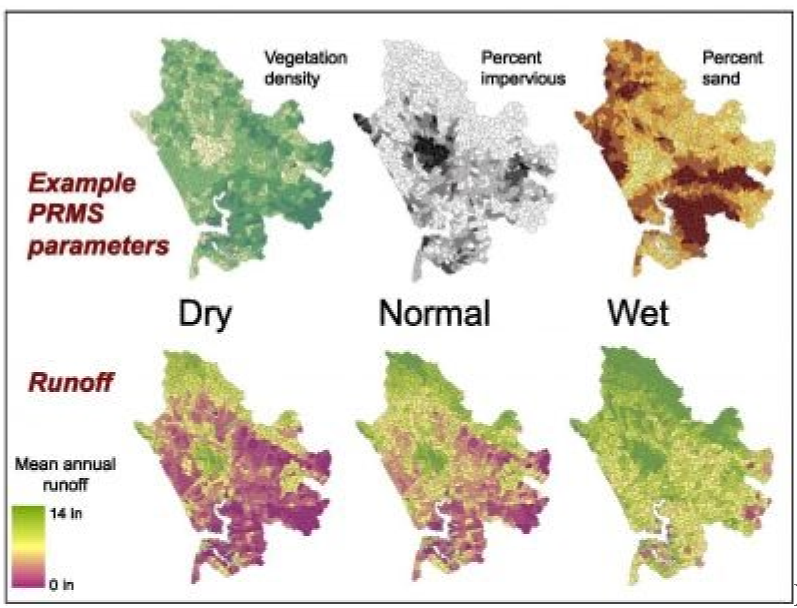
So they took the observational data and assembled a catalog. They first plotted total annual precipitation, then selected five dry years, seven normal years, and five wet years. "*What we do is we string these together in a future scenario which has wet periods and dry periods, because at the end of the day, we don't' know what the climate is going to be 50 years from now. What we know is some years will be wetter and some will be drier, and we need to be ready for all of the above*."

He presented some slides from the climate modeling (above) showing a dry simulation, a normal simulation, and a wet simulation. "*All the years, even the dry years, have the occasional months with significant rainfall, just like we saw at our field site*," he said.



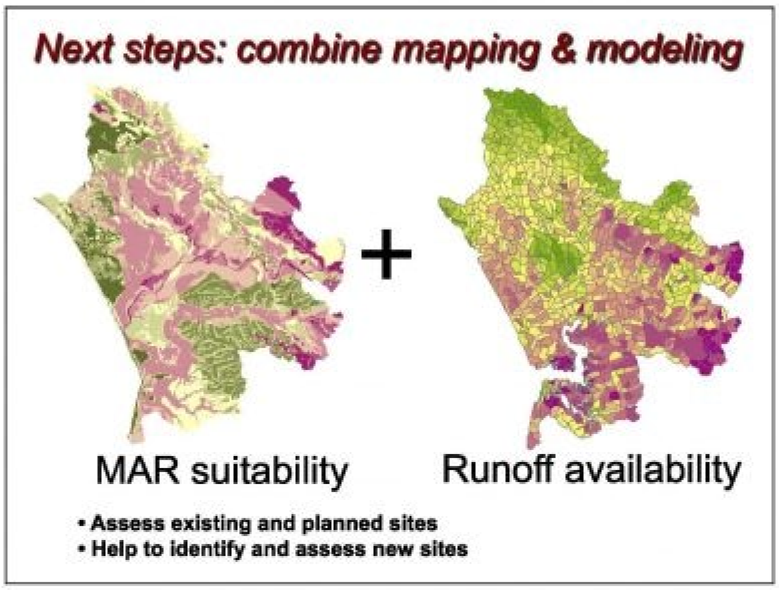
He then presented the runoff predictions, noting that while there's a lot less runoff during the dry years, each year typically has one or two months where there is some runoff. "*The thing to realize is that it only takes an inch of runoff from the basin to generate a significant resource*," he said. "*So we're probably not going to be able to infiltrate a lot of extra stormwater runoff during dry years, but there will be some*."

He also noted that during the normal and the wet years, there's a lot more persistence in the runoff. "*That is, you're much more likely to get a wet month after a wet month after a wet month, and that really compounds the effects of stormwater generation and opportunities to infiltrate groundwater*," he said.



He then presented the same data spatially for dry, normal, and wet conditions. *"It's interesting that they have the same pattern, higher to the north, lower to the south, but during the wet years, you get up to 60" of rain in the* *southern Santa Cruz mountains*," he said. "*Along the coast because of the dunes, there are also areas even during dry years that generate a lot of runoff. The area in the dunes to the south only gets runoff during wet years. During the dry years, it's not much, although there are individual polygons which might be good places to collect a little runoff, so the variability is really important. There's not going to be one project that's going to work all over the basin, we've got to pick our sites carefully*."

There is variability because there are numerous properties to each location, such as the amount of vegetation, the amount of impervious area, and the amount of sand, he said. *"What's nice about the modeling is that it tells you something that might be somewhat intuitive, but allows us to hang numbers on that. It allows us to make predictions and say here's how much more runoff we think we're going to generate during a wet year for example, or during a dry year.*"

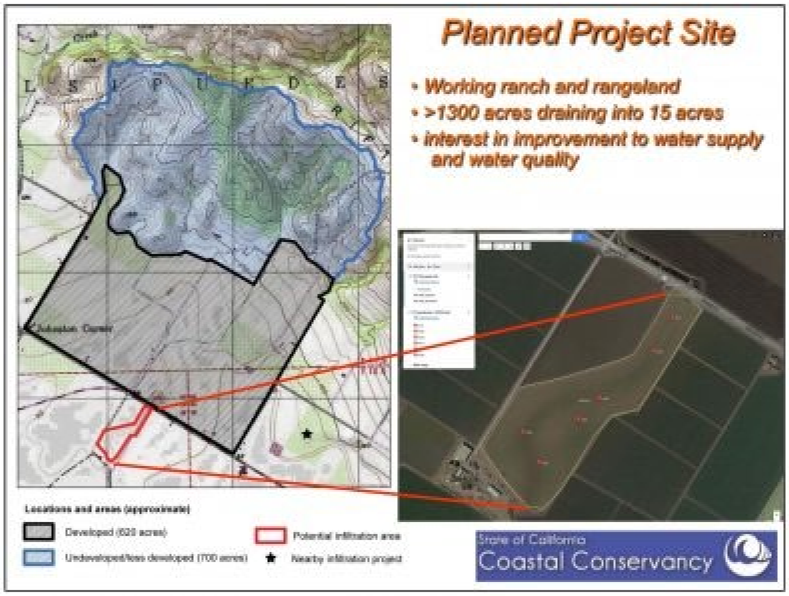


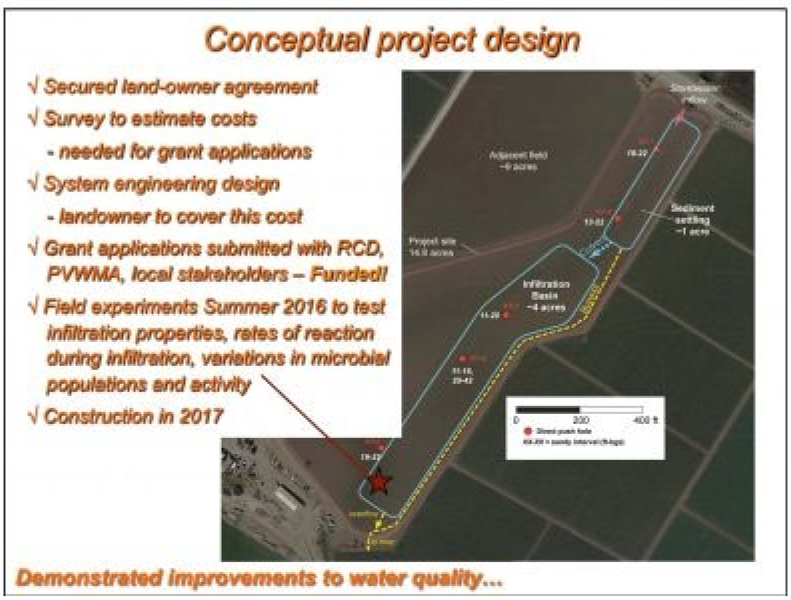
The next step is to combine the managed aquifer suitability map with the runoff map. "*That's what we're in the process of doing, along with regional partners, the counties, municipalities, and local water agencies*," he said.

STORMWATER RECHARGE PROJECTS AND WATER QUALITY

At the present time, they are working on two groundwater recharge projects that are currently active; there are three more in development that are to be constructed this year.

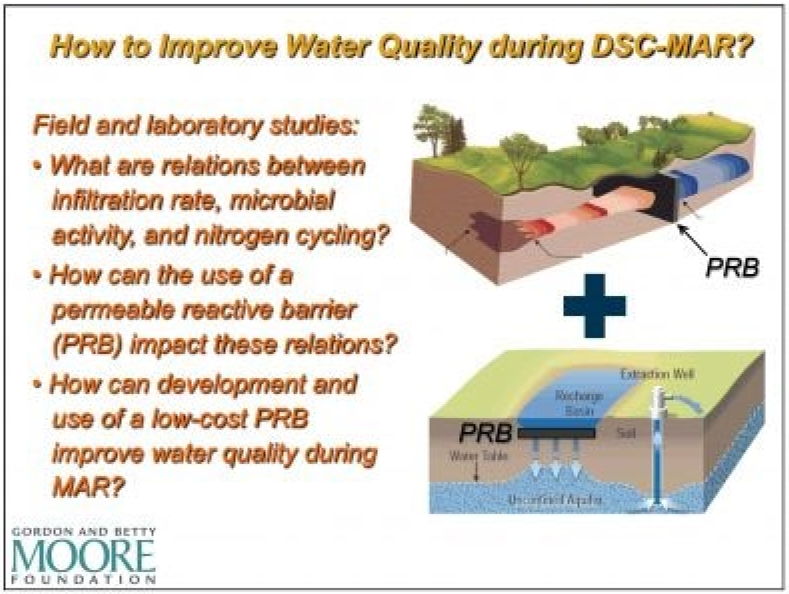
Dr. Fisher presented a slide of one of the new projects being constructed on a working ranch. The area being drained is over 1300 acres; the landowner has allocated about 15 acres in this parcel, seven of which will be used for a sediment collection system and then an infiltration system as well. This project was proposed by Dr. Fisher's group, the Resource Conservation District, and the Pajaro Valley Water Agency and it was just approved a couple of weeks ago by the Coastal Conservancy.





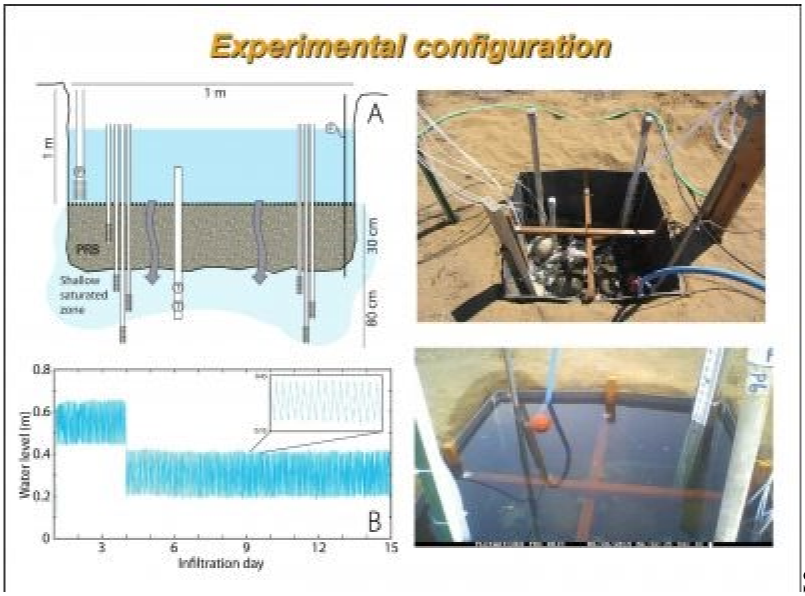
He acknowledged it's quite a process to identify sites, do field studies with drilling to determine if conditions are right, and securing the cooperation of the landowner.

There are often questions and concerns about the water quality of the stormwater that is infiltrating into the aquifer. Dr. Fisher said that at another site they had studied about 10 years ago, they found a significant load reduction simply with water percolating through shallow soil if the conditions are right.



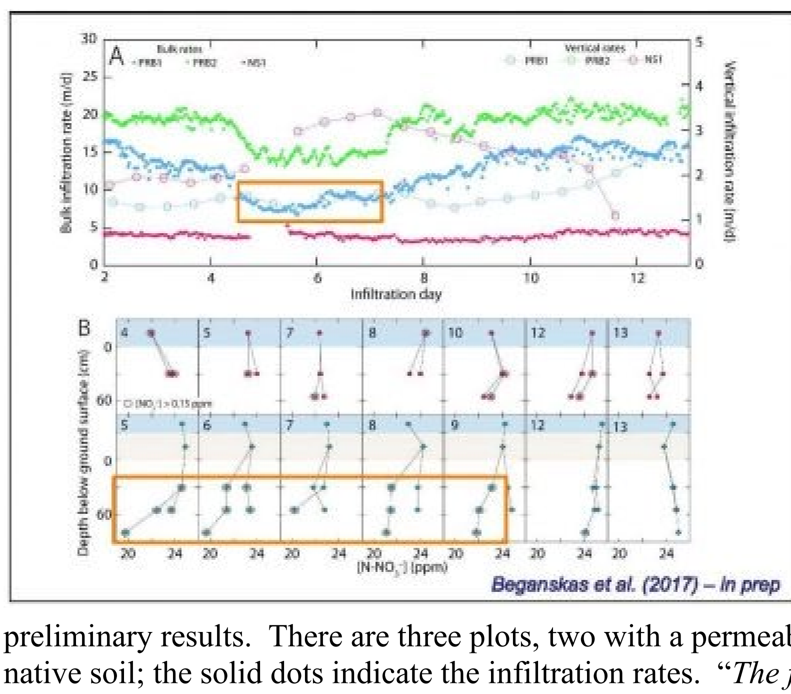
"*But what we were interested in was can we enhance the ability to remove nutrients, such as nitrate for example through modification of the soil substrate*," he said. "*The approach we're taking is to investigate the addition of what's called a permeable reactive barrier, or PRB. These have been used as vertical walls where water with some solutes and contaminants in it flows through and then it gets cleaned up by the time it comes out the other end. It's just driven by natural flow in the aquifer. Typically these walls might be on the order of a foot thick or two feet thick and filled with materials like a carbon source or chunks of iron or other material that's needed to treat the water*."

"*Our idea was to turn this on its side and to put a PRB as part of a recharge basin and see whether we could get some kind of water quality improvement, as well as what the operational effort be, and especially once we scale up, how hard is it going to be put one of these in and maintain it, if indeed it's worthwhile*," he said.



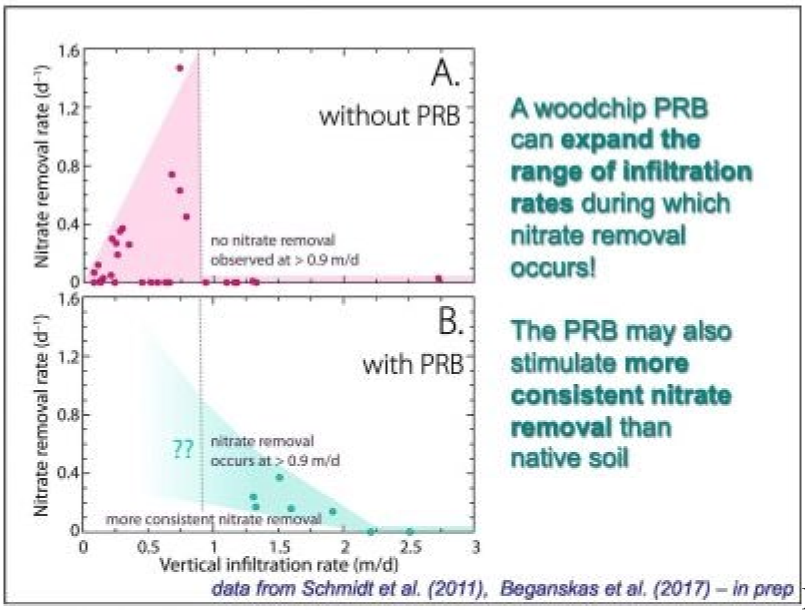
So they set up an experimental plot and instrumented 'the heck' out of it, Dr. Fisher said. "*We put in temperature probes to measure the flow rate, and pressure gauges, and fluid samplers at multiple depths; we drive water into the ground as we pour the water into the system. … We're using ambient groundwater and percolating it on to the ground; the water is rich in nitrate, it has about 20 to 30 mg per liter of nitrate/nitrogen, so 2 to 3x the drinking water standard*."

They ran infiltration tests for 2 weeks to mimic the conditions that would occur during the rainy season when one of these systems would get wet and stay wet for a while.



He then showed some of the preliminary results. There are three plots, two with a permeable reactive barrier and one with native soil; the solid dots indicate the infiltration rates. "*The first thing you'll notice is a big difference in rates although they are all pretty high; these are in meters per day*," he said. "*The difference between the plots, that's just natural variability. It has nothing to do with our testing. When you go out to a field, and you pick three spots in the ground, they are not going to* *be the same. They are all going to be a little bit different. The ones in blue and green have a permeable reactive barrier, this time made of redwood chips. We also tested with biochar but I'm just going to tell you about the redwood chips here. These tests lasted two weeks*."

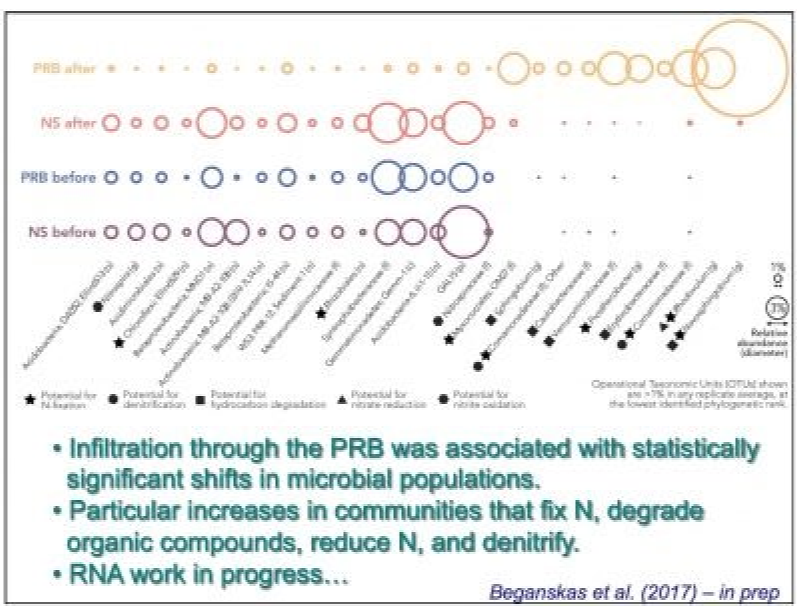
"*Temperature probes measure the vertical infiltration rate*," he said. "*It's on the order of a tenth of the total rate, so much of the water going into the perc systems is turning and flowing sideways once it gets into the soil. Only about 10% actually flows vertically. So measuring the vertical rate is very important if you want to understand how a system that is four or five acres in size is going to infiltrate. It's mainly going to be vertical*."



He presented another diagram, this one showing nitrate concentrations as a function of depth, noting that the top plot shows native soil and the bottom plot shows one of the plots that had the permeable reactive barrier made of about a foot of wood chips at the top of the soil. "*I want you to particularly notice this time period when the infiltration rates were relatively low, and we get a significant and repeatable decrease in nitrate concentration with depth in the system*," Dr. Fisher said. "*I'm not going to show you the data, but we have isotope analyses that show that this is denitrification, it's microbes in the subsurface consuming that nitrate as an oxidant and putting it back into the air as the nitrogen that we breathe. It's removing it from the hydrologic system*."

Dr. Fisher said they tested up to very high infiltration rates again showing vertical rates that are on the order of up to 2 meters per day. "*Earlier studies in this area show that there was a limit, and when we got above about .9 meters per day, we had no more nitrate removal*," he said. "*But the addition of the PRB, we've increased the infiltration rates at which we get significant nitrogen cycling. In other words, we can have water flowing in faster and still remove nitrate by adding the permeable reactive barrier. So it's expanding the envelope of conditions across which we can actually improve the water quality during infiltration*."

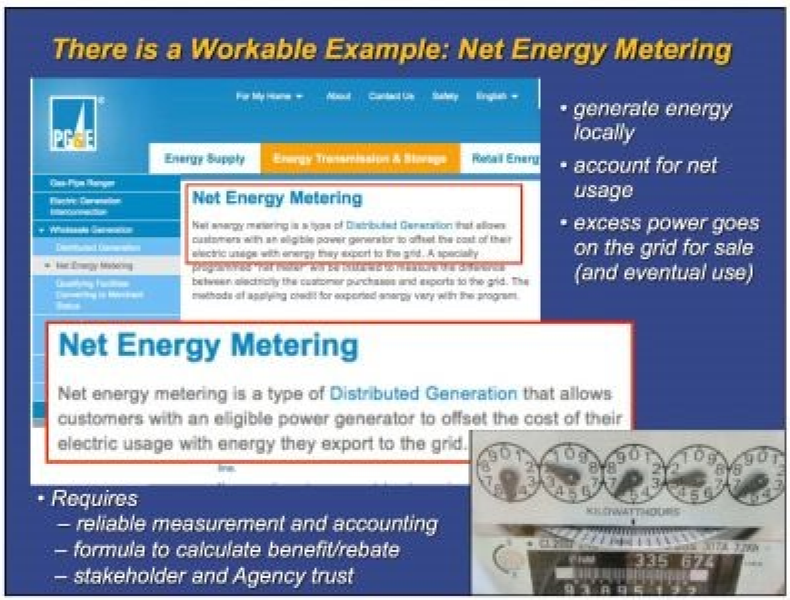
He presented a graphic of a full-sized managed recharge percolation basin with a PRB. *"In an earlier study, we showed 600 kg of nitrate removed from annual operation of a system that's about 4 acres in size*," he said. "*Based on the calculations I just showed you, we'd get more than twice as much nitrogen removed if that had been lined with wood chips. In part it's because it's at the higher rates of infiltration that this makes the system more effective at denitrifying. So it compounds the effects, you're getting faster infiltration and faster nitrate removal at the same time*."



They have also begun microbial studies to find out which bugs that live in the soil are actually responsible and whether they're being changed in their populations because of the use of the PRB, he said. He presented a slide of some of the preliminary data, noting that the different groups of bacteria are listed along the bottom of the graphic; those with stars indicate nitrate fixers and the circles are denitrifiers. 'NS' stands for Native Soil; the size of the circle indicates the fraction of the microbes in the soil who are present. He noted that before infiltration, they all look very much the same; the top line shows the PRB after infiltration.

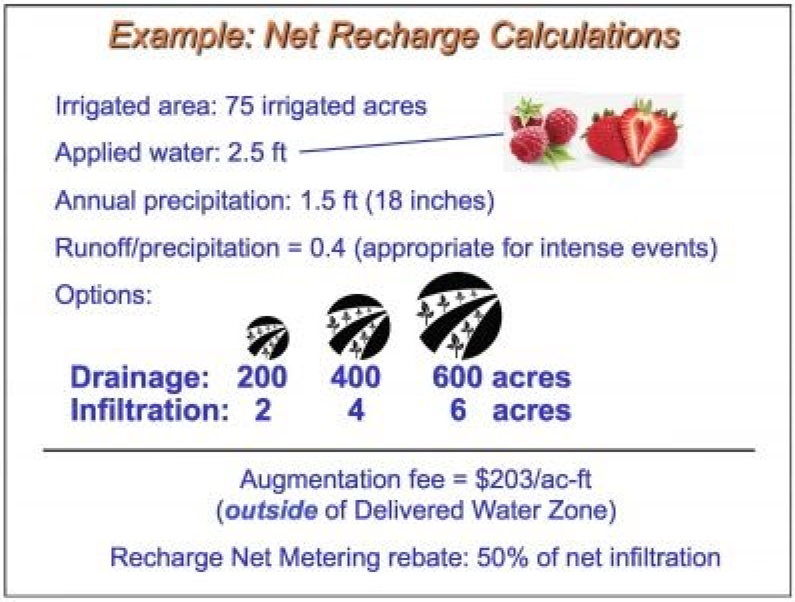
"*And so our hypothesis was that we would see a significant shift in the microbial population, and now using tools and modern genetics, we can actually test that*," he said. "*The work with DNA tells what's present, but it doesn't prove they're active. We have work underway right now with RNA and RNA is ephemeral; it goes away is it's not being generated. We captured environmental samples in the field and got them right into liquid nitrogen; they are being analyzed now so we can figure out which genes were active, which microbes were using those to accomplish denitrification as a result of this process. I think this is an important part of figuring out where it might work and where it might not work. That work is underway.*"

INCENTIVIZING GROUNDWATER RECHARGE

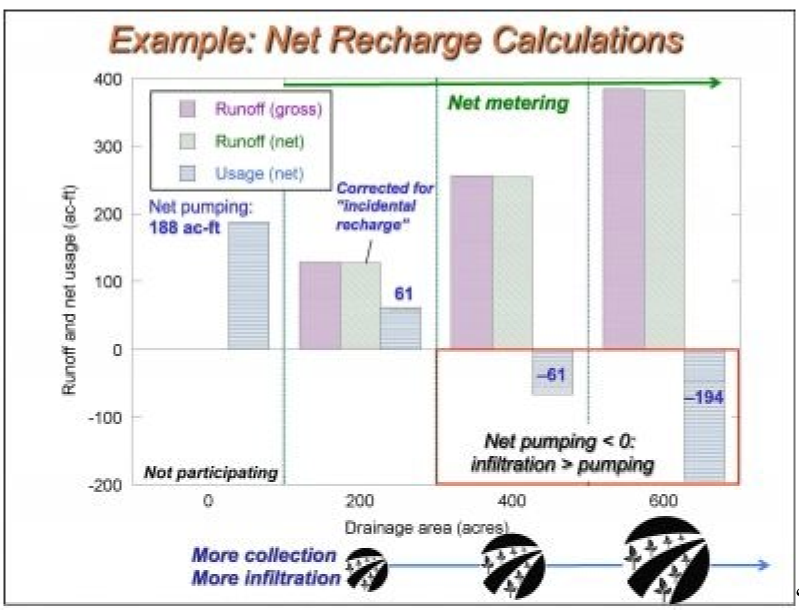


Lastly, Dr. Fisher turned to incentives. Putting these systems in actually requires a commitment from a lot of different groups, including landowners and tenants, he acknowledged. Such systems remove land from production and there are maintenance costs, such as the need to periodically scrape sediment out of the recharge basins.

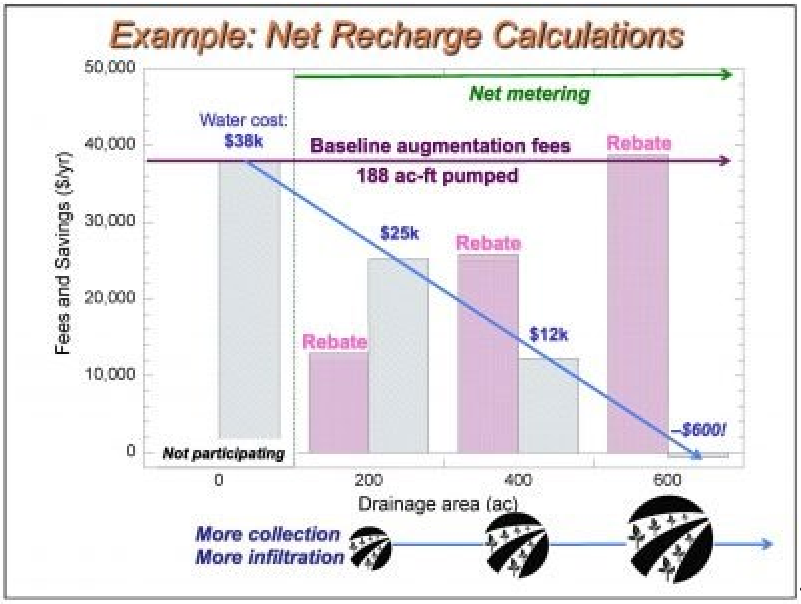
So how can people be encouraged to put systems like this in if they are going to be taking on a cost? Dr. Fisher says there is a model called Net Energy Metering, which was developed and implemented by PG&E. Dr. Fisher explained that the concept is that if you have solar panels on your house and you generate electricity that is more than you need, you can put that power back onto the grid and your power meter would run backwards. It requires being able to measure and account for what you're getting credit for, there needs to be a formula, and everybody has to trust each other, he said.



They've been working on developing a pilot program in the Pajaro Valley based on this idea. Dr. Fisher gave a scenario to illustrate how it would work. "*Imagine 75 acres and you're growing tasty berries so you need 2 ½ feet of water which is around 190 acre-feet per year. In this area, precipitation averages 18 inches, and so let's assume during the big events, we get a runoff of 40% of that. Imagine that we have different drainage areas flowing into different infiltration areas, and I've just assumed for the sake of argument, the infiltration area is 1% of the drainage area. In this region, landowners and growers, they pay for water. And they pay about $200 an acre-foot, so that's a fee that they are already paying for the privilege of pumping groundwater.*"



"*Let's assume that the recharge net metering program provides a rebate at a level of 50% of the net infiltration – infiltration that wouldn't have occurred without the project being there,*" he continued. "*So here's an example. Here is a grower who doesn't participate and pumps about 180-190 acre-feet of water. This grower has drainage from 200 acres that they put into the ground, and in this case,* *their net infiltration is the green bar, and therefore the net pumping is the blue bar, they've driven that pumping down to about 1/3 of what it was. If you're draining 400 to 600 acres, in fact you're net pumping is negative, you can't see it here, but that means more water is going into the ground then is being extracted, so they are growing berries and they are making water at the same time*."

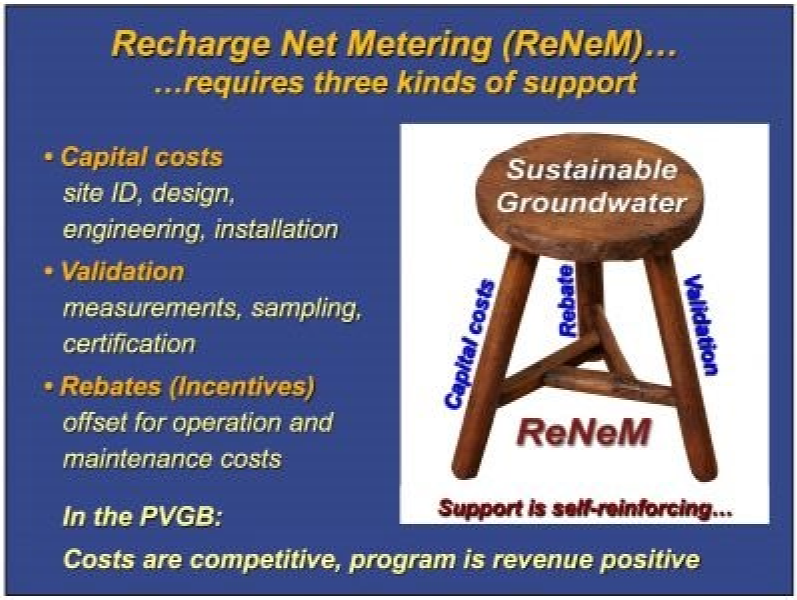


"*What is means in terms of funding looks something like this*," he said. "*The water cost for this grower is about $38,000 per year. And if they are not participating, they are going to be paying all of that. They are going to be writing checks for $38,000 to pump that groundwater. But if they are draining 200, 400, or 600 acres and collecting that stormwater runoff, then they generate a rebate, and the rebate gets bigger the more water they collect, and by the time you get to 600 acres, in fact they aren't paying a penny at all for water and they are getting a little bit of money back at the end of the year*."

It isn't just a crazy idea, they are actually trying it in the Pajaro Valley as a pilot program with the goal of getting 1000 acre-feet per year into the ground through 8 to 10 field projects. Dr. Fisher's group is the third party certifier; the Resource Conservation District of Santa Cruz County helped to identify the sites. They write grant proposals to raise the money to put these in the ground; they sit with the engineers and develop the plans so that they can measure how they work. "*That's really important because if we try to come in later after something's already been built and measure the flows, often it's impossible because the water is coming from everywhere*," he said.

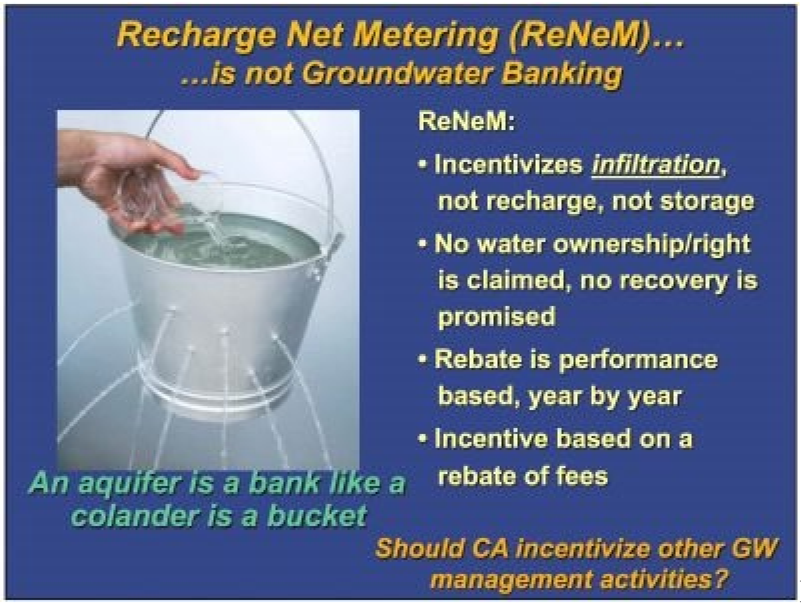
They work with the landowner and tenants to validate the project; they are willing, because it is their validation that gives them the rebate. "*They and the agency have to agree up front to accept our numbers; to not quibble with us about how much water went into the ground*," he said. "*We'll make the measurement and then we certify it for the landowner and tenant, and for the agency*."

As of right now, one site has been operational in the past year; three more are supposed to go online before the start of the rain in fall of 2017. They have a cue of additional sites as people want to be a part of the program. "*Right now, we're just limited by our own capacity to actually evaluate sites, get them funded, raise the capital, and then actually get them put in*," he said.



Recharge net metering (or ReNeM) is a three legged stool. There are three kinds of costs: the capital costs to build the systems, the validation or monitoring costs, and the rebate. "*The rebate is the smallest of the three legs in terms of magnitude, but it really has a big impact*," Dr. Fisher said. "*The water agency has agreed that they are going to cut checks this year. They are not just going to put a credit on the bill, they are actually going to send people a check in the mail, and I think this is really going to get people excited about putting water into the ground and connecting with their aquifers.*"

"*When you do the math on the cost to the agency, this is the cheapest water they are ever going to produce*," he added. "*All of that water that goes into the ground can then be pumped by other customers who then pay full freight with augmentation fees, so it's net revenue positive for the agency*."

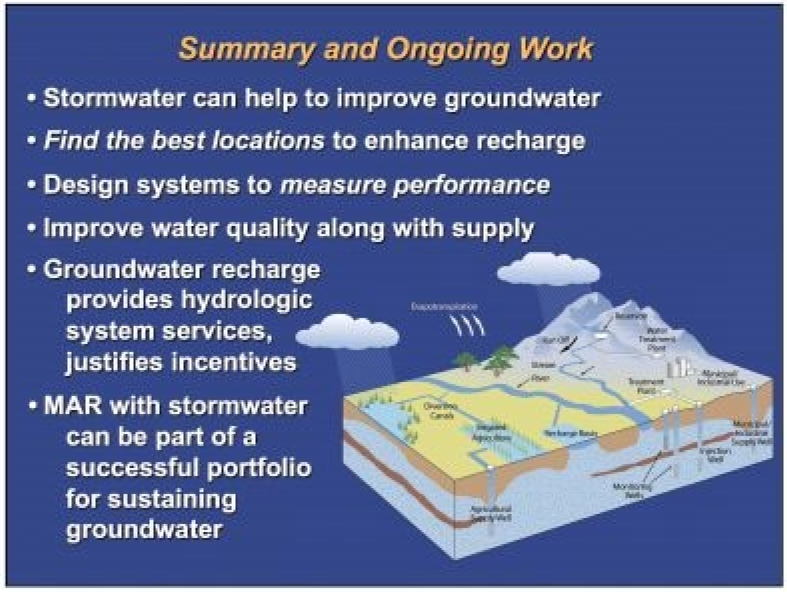


But recharge net metering is not a bank. "*We're really trying to incentivize the process of infiltration, not the storage of water*," he said. "*An ancillary benefit is that it will put more water into storage without a doubt, but the focus is simply on getting that water into the ground in the first place. No water right is claimed so nobody owns it. Because people get the benefit based on putting it into the ground, they are actually not that worried about who is going to pump it out. What they are worried about is whether they can keep their system maintained so they can get the rebate next year by putting more water into the ground. The rebate is performance based so that builds in interest among participants in keeping their projects going and we've said in the program documents, if the project doesn't work, we're going to sunset it and start a new project. We're not going to keep running projects that don't generate a benefit*."

Since the incentive is a rebate of fees, the agency isn't coming up with money to buy water; what they are doing is allocating part of the funding for their rebate program to support the recharge net metering program.

"I wonder if there might be other ways that groundwater sustainability practices could be incentivized around California," he said. "*I know the Pajaro Valley is a special case in many ways, but I think there are aspects to this that might apply to other parts of the state*."

SO IN CONCLUSION …



Stormwater is a resource; it has historically been treated as a nuisance and as a liability, so shifting to thinking about it as a resource is really important, Dr. Fisher said. "*It's an ongoing work that we all have to do to get people on board with the idea of thinking about the benefits of retaining some of that stormwater a little bit longer on the landscape,*" he said.

In order to be effective with stormwater infiltration, we need to find the best places to do it, and not all of the landscape is equally viable for stormwater projects, he said. "*We also need to design and build our systems so that we can actually measure their performance, which is important; it's a requirement within SGMA that water budgets be developed for basins, and you can't do the budget if you can't measure how much water you are putting in the ground. So it's not just for the rebate program, but for the water balance overall, we need to be able to measure how these systems work*."

"*We also need to improve water quality with supply and the technology exists to do that*," he said. "*PRBs are one approach, and there are other approaches that can be used as well. Especially with real-time data systems, we can manage these systems so that we do not put water in the ground unless we're ready, unless that water is good enough quality, and I think we're capable of doing that.*"

"T*he concept of the recharge net metering is that groundwater recharge is a hydrologic system service*," he said. "*It provides benefit intrinsically through the process of infiltration and recharge, and that's the win. By claiming that as the benefit, it simplifies some of the issues associated with incentivizing recharge and particularly with groundwater banking which is a real challenge, so overall I'd say that managed recharge with stormwater can be part of a portfolio; it's not going to be the silver bullet for the state, it's not going to be silver bullet for this area either, but I think it can have an impact at the tens of percent level, in terms of bringing the basin back into balance*."

"*And with that …* "