Thank you. The title of my talk, 'The Fate of Eroded Soil' it is what becomes of or what happens to soil when it is eroded.

My first slide is to say that there are two main agencies that are responsible for soil erosion. One is water and the other is wind. I shall say nothing about wind erosion. My entire talk is about the fate of soil that is eroded by water.

Studies that have looked at soil erosion have usually looked at it from two points of views.

Either they look at places where soil is eroded from and the study is concerned to understand the amounts of soil that are lost from hill slopes such as this one or this one or this one or the processes that cause soil to be eroded from hill slopes like this.


The focus is on the amounts of erosion and the mechanisms of erosion.

The other group of studies in soil erosion is concerned with what are often called off-site impacts. That is the impact of soil when it arrives somewhere else where it is not wanted. The first group of studies is concerned about the fact that soil is being lost from places where it is wanted. The second group is concerned with studies trying to look at amounts of soil that arrive, in this case, in a residential street.

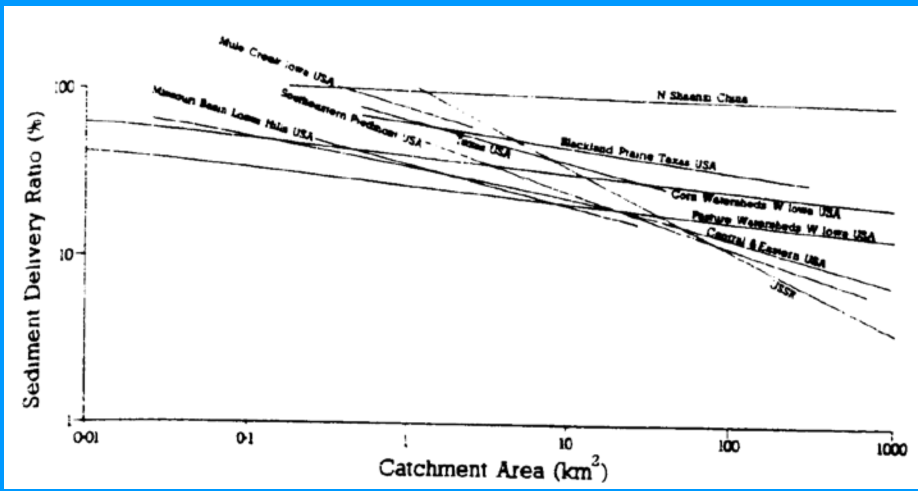
The road is covered in soil or here where the valley floor has been filled with coarse material off the hill slope and changing character of that valley floor.
or here where the valley floor has been filled with coarse material off the hill slope and changing character of that valley floor.

Probably, one of the most important types of studies of soil erosion where they are looking at the arrival of soil in places where it is not wanted is in studies that are looking at sedimentation rates in reservoirs. You can see this reservoir, you can see the wall in front is very, very high and you can already see that there is not much depth of water there.

In this slide, the reservoir is now completely useless because all of the water storage capacity has been filled with sediment. This construction for water storage no longer serves any useful purpose. We have these two types of studies. If you want to understand this in terms of this then generally that has been a problem.

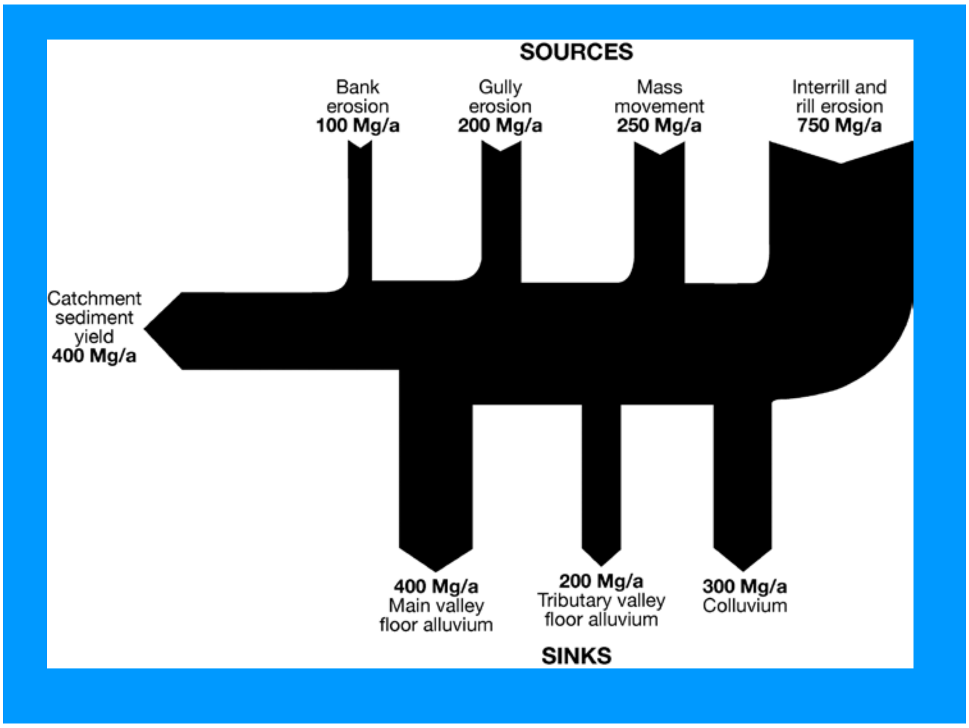
THE SCALE PROBLEM

The problem can be expressed as a problem of scale that whenever you try to make measurements of rates of erosion on hill slopes and relate them to rates of sedimentation in reservoirs, in this case, a small reservoir at the bottom of a small catchment and this hill slope is located in this small catchment. Then you find the two sets of information don't fit together. But in general, we find that if you take rates of erosion from measurements on hill slopes like that and you then multiply those rates of erosion by the size of catchment then the amount of sediment which arrives with the catchment outlet is generally much less.



(Walling, 1983)

Now, people have tried to reconcile these differences to try and explain why that if you have a catchment, the amount of sediment that leaves the catchment is much less than the amount of erosion within the catchment. That attempt has been expressed in what is called the sediment delivery ratio. The sediment delivery ratio simply compares how much sediment supposedly leaves the hill slopes and how much sediment arrives in the outlet of the catchment and clogs the values [ph] of the two. You can see that the sediment delivery ratios are on the whole quite small. This is a log scale. On this catchment here, only 10% of the sediment that is leaving the hill slopes is arriving in the catchment outlet. There's a big issue about where the rest of the sediment goes.



One way, people have tried to express that relationship is in these so-called catchment sediment budgets. What people have often done is to measure the different types of erosion and to measure the sediments at the catchment outlet. As I say, generally find that this number is much smaller than the sum of these numbers. What they have assumed very often is that all of the sediment that doesn't reach the outlets of the catchment is deposited in various low areas within the catchment so valley floor alluvium, tributary valley floor alluvium, and colluvium sediment at the bottom of the hill slopes.

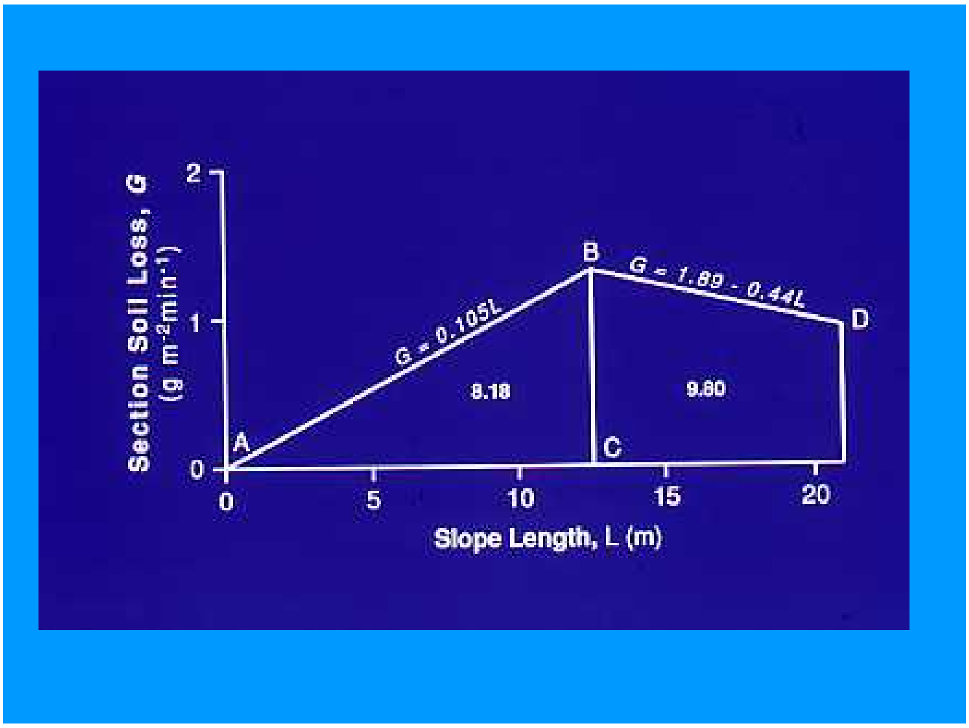
There are many things wrong with this diagram. The first thing is that it cannot possibly work. If you erode sediment off the hill slopes and it doesn't leave the catchment, eventually, the catchment will fill up with sediment. You can't do this forever. This diagram might work in the short term. It might be possible for a short period of time for rates of erosion on the hill slopes to be less than the rates of erosion or rates of sediment lost from the catchment. But in the long term, those numbers must be pulled up. Otherwise, if that were not true, we would have no valleys left in the world. They would all be filled up with sediment. This does not work in the long term.

But generally, whenever you see diagrams like this there is no attempt to provide any time scale over which they're meant to represent what is going on. If that diagram said 1950 to 1980, then it might be a reasonable diagram. But, if it is meant to be an abstract timeless statement then it cannot be true. The second main thing which is wrong with this diagram is that you will see how conveniently the numbers all add up. If you add those numbers and those numbers, they balance. The reason they balance is generally because they haven't all been measured. What happens is that some of these things are measured and where they don't measure, they just assume that the bounce must exist. There is no attempt in this diagram to show any assessment of uncertainty. These diagrams are really rather misleading in terms of what might be going on.

Now, I think what is going on, what is important is that we need to think about the fate of eroded soil. We need to think where does it go when it's eroded. How far does it move? What becomes of it?

What I want to do now is to talk about work that I've done over a number of years, 20 years now, looking at where sediment goes once it's eroded. I'll take a more or less chronological story in that this slide comes from work done 20 years ago.

What we were doing here was a typical study, if you like, of erosion on the hill slopes. It was not typical in the sense it's a very large scale study. This hill slope plot measures about 30 meters in length by 18 meters wide. Now the thing you need to note is that we measure what comes off the plot but we also have lines of people on the plot making measurements of what is happening within the plot. That is unusual in that those people who measure run-off plots, erosion plots like this, simply measure what comes off. What we were interested in was trying to understand what was going on within the plot. That gave us some interesting insights into the fate of eroded soil.
One of the things we did was to calculate how much sediment passed each of these cross sections.



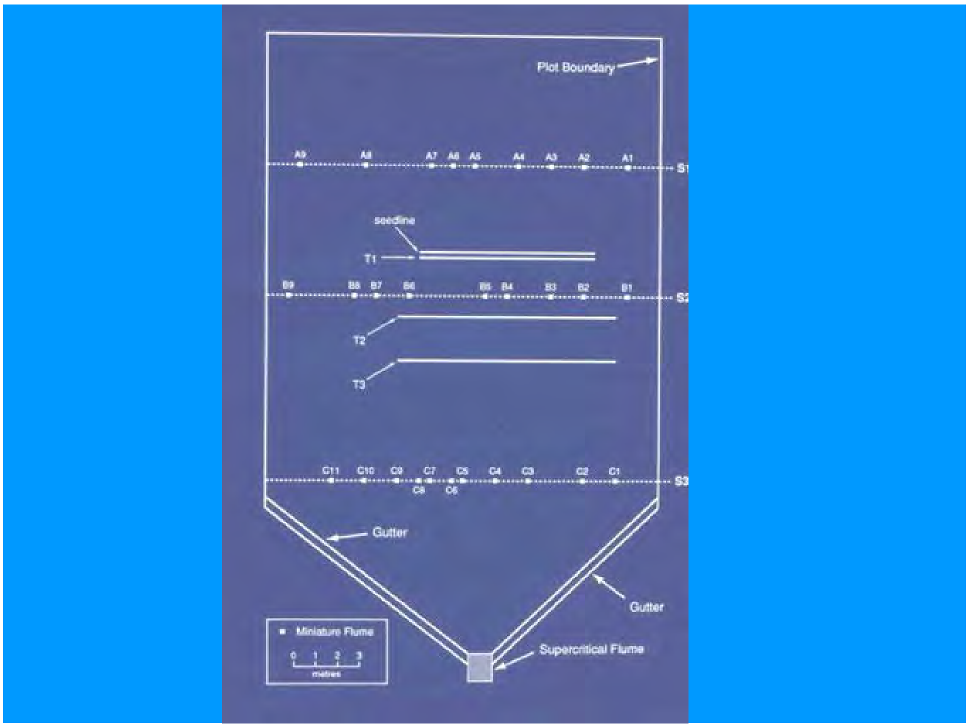
This is actually for a different plot but it's the same idea. If you stand at this point here and you measure the amount of sediment which is moving past that cross section, then if you assume that nothing leaves the top of the plot because effectively, there's almost no sediment transport at the top of the plot, the amount of sediment here is equal to this area here which must therefore be that triangle there. You can calculate the rate of change between there and there roughly if you assume it's a linear rate of change.

You see that the section sediment loss i.e. the amount of sediment going past here, past here, past here, past here increases, has a function of distance. If you measure the sediment at this point and you do the same analysis, you find that the amount of sediment being added as you go further and further down slope gets smaller and smaller. In fact, the sediment starts to be lost. What that suggests is that sediment being eroded here doesn't get to here but travels only some of the distance and then does not make it throughout the rest of the way.

Now one of the things we did on that large plot was to look at the movement of marked particles. The movement in marked particles is a theme that goes right through the 20 years. But, the theme is one of improving technology all the time. In 1992, there was no way of identifying soil particles really. What we wanted to know was how far an individual soil particle traveled during a storm event.

We wanted to be able to say, well, if a soil particle started here, where would it end up at the end of the event? The way we did this was to create artificial soil particles. What we used was magnetite. What you see here underneath this tape measure, these black lines are lines of magnetite.

The reason for using magnetite is that you can find it by using a detector. What you could do is put the magnetite down on the ground and then after the rain storm, go and measure the magnetic susceptibility of the hill slope sectioned down slope and see how much increase in magnetic susceptibility there has been as a result of the storm event.



What we did was to have a line of magnetite which is the one you saw in the first photograph with the tape measure. And then, we had three lines where we would measure the change in magnetic susceptibility after the storm event. In addition, you remember those cross-sections that we had on the plot? At those cross-sections, we have a number of small flumes that can catch water and sediment passing through. We were able to, at the end of the event, measure the magnetic susceptibility of these four, I suppose we looked at the seed [ph] line as well to see how much magnetite had been lost.

But also, we could use the water samples from these cross-sections to see whether any of the magnetite had passed through those points.

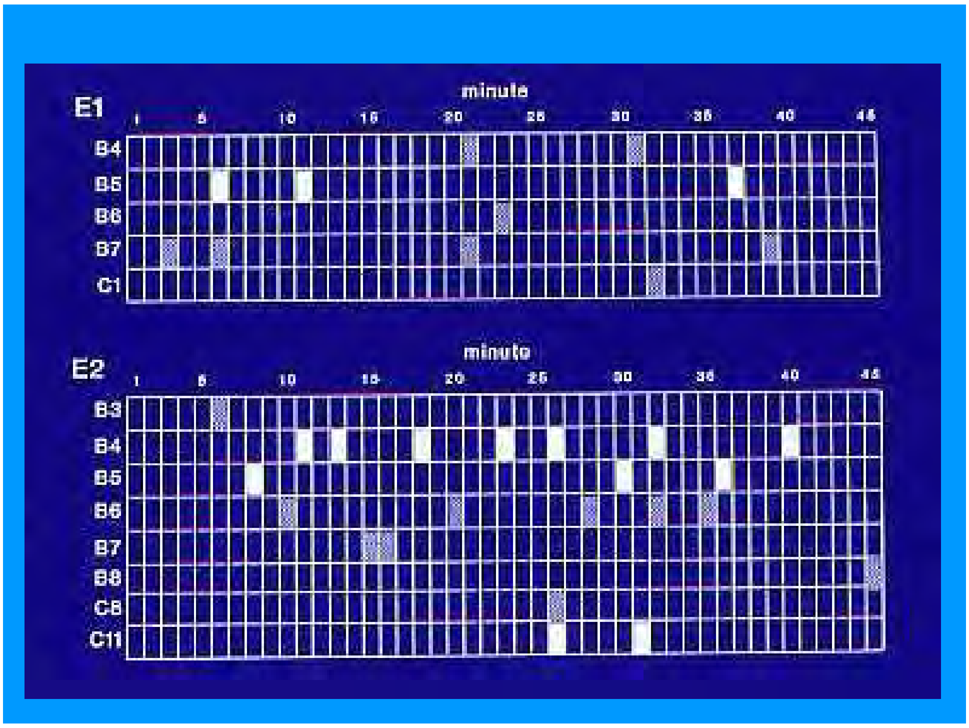
（次の図の説明の後に、この図にもどって再度説明された。）

If we go back to this line, what we are saying is that magnetite has been lost from there, magnetite is being deposited there but nothing really much has happened there or there. This marked sediment doesn't seem to have traveled very far at all. This distance is a few centimeters.

Table II Mean values of magnetic susceptibilities ($\bar{\kappa}$) and their standard deviations (σ) for the source-line, T1, T2 and T3 obtained prior to, and after rainfall simulation experiments, together with t-values comparing differences and their associated significance levels (p).

		prior to E1		E1		E2		E3
source-line	$\bar{\kappa}$	899		661		664		550
	σ	254		179		210		171
	t		4.84		-0.05		2.67	
	p		<0.005		0.96		0.01	
T1	$\bar{\kappa}$	52.8		123.5		145.4		139.8
	σ	19.1		69.1		78.1		66.8
	t		-6.24		-1.33		0.35	
	p		<0.005		0.19		0.73	
T2	$\bar{\kappa}$	63.9		69.3		69.6		69.0
	σ	11.1		15.2		16.4		16.5
	t		-2.05		-0.12		0.20	
	p		0.04		0.91		0.84	
T3	$\bar{\kappa}$	53.0		58.1		55.0		55.5
	σ	13.2		17.9		16.1		17.8
	t		-1.59		0.88		-0.12	
	p		0.12		0.38		0.90	

What we observe is that if we take the source line prior to the first experiment, we have a magnetic susceptibility which is around about 900 and it declines significantly after the first experiment, not so much after the second one remained quite a bit, after the second one or after the third one. If you look at the transacts we can see that a transact 1, there is a very significant increase in magnetic susceptibility after the first experiment and not very much after the others. Similarly, down here we find no significant increases in magnetic susceptibility.



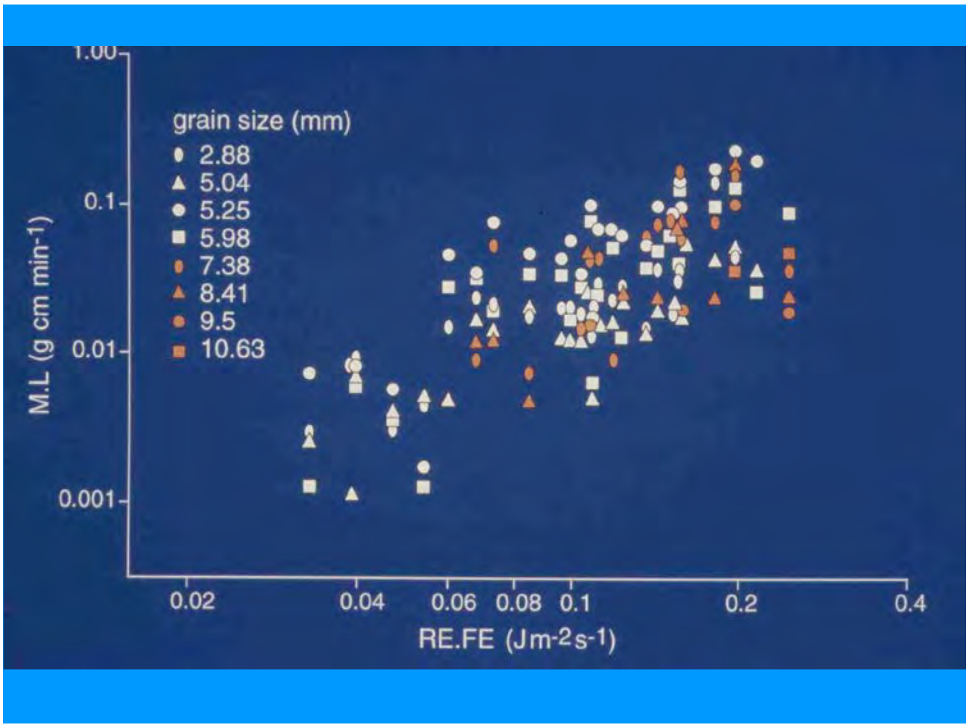
But, some magnetite does move and we have data from those cross-sections showing that there is evidence that amounts of magnetite do get through the second cross-section and even down to the third.

What that tells us is that most sediment that is eroded doesn't go very far. But some of it might go quite a long way. Not surprisingly, you can fit a statistical distributions list. What you get is a negative exponential distribution. Most things don't go very far and progressively as you give greater and greater distance, smaller and smaller amounts of sediment are moved up quite far.

The next step in this story was to try and understand that in a laboratory situation and rather than just fitting a statistical distribution to provide some sort of quantitative understanding of what controls how far sediment moves. This laboratory set up was a simple flume with a bed of sand. On that bed of sand, marked particles were placed. The sand couldn't move because it was glued into position. The only thing that could move were the individual marked particles.

We used two sources of water. Rainfall fell onto this and water also flowed from a trough at the top so we could have varying amounts of runoff and varying amounts of rainfall. The idea was to see how far particles traveled. Now, one of the constraints on this experiment is that in order for particles to be identified they have to be quite big. That is a problem now we still have in some degree.

We looked at particles that were between 2.88 millimeters in diameter up to about 10 millimeters. They're very big particles compared to the average soil particle.



What we discovered was that we could produce a relationship that seems to work over all particle sizes. In this graph, you can see no preferential position of the small particles compared to the large particles.

The graph shows the degree of scatter and it applies to all the particles. What this graph shows is if you take the mass of the particle and multiply it by the distance it's traveled you can relate that to the product of the rainfall energy and the flow energy. What these experiments gave us was an equation that would say if you know the size of the particle, you know the rainfall energy, you know the flow energy you could predict how far that particle will travel as a mean-median travel distance. As I say it works but it works for relatively large particles.

One of the things we did was then to take that regression equation and simply project it down to see what it would predict for the particles of magnetite that we'd used in the field experiment. The magnetite was 80 microns in diameter, three orders of magnetite smaller than to the particles we used here. The answer comes out to be not too bad. Certainly within the same order of magnitude has the observations. It suggests that this equation does give a reasonable prediction.

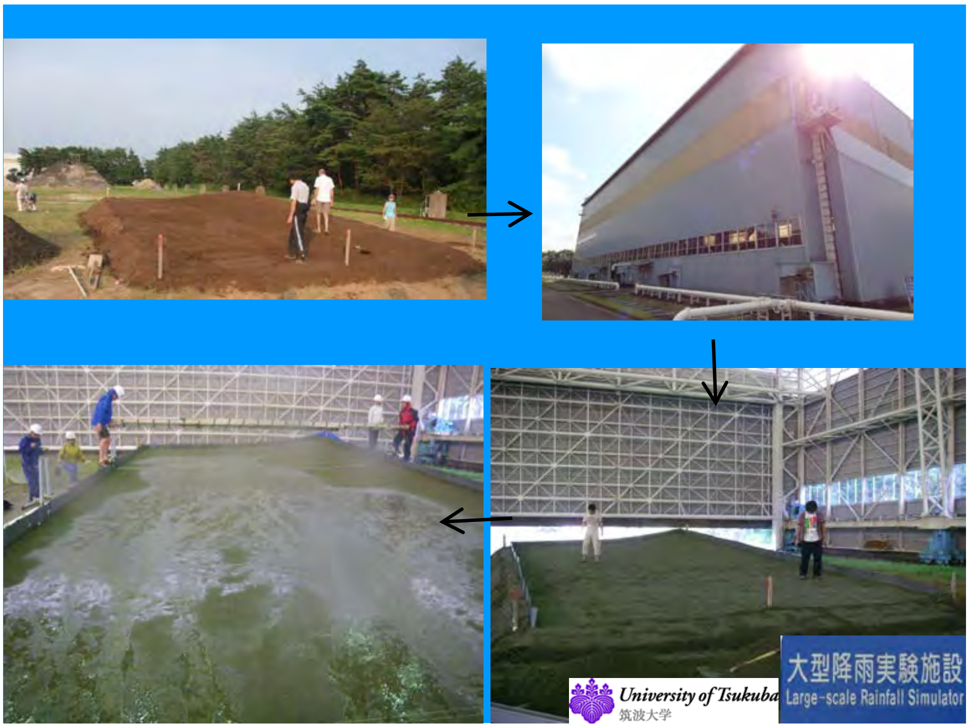
What those experiments did was to try and understand how far particles moved on hill slopes.

But, we can apply the same argument to sediment in river channels. If you have dry land rivers or in this case relatively small channels, they derive much of their sediment from the hill slopes. What is happening is sediment is being washed off the hill slope into the channels and then being moved through the channel. We can think about the travel distance of particles in the channel as well.

During a storm event, as the flow magnitude increases so the spatial scour and erosion will take place in that bed. As the storm ends and the discharge decreases you will get deposition. There is a cycle of scour and fill in the channel. What my colleague here is holding is two scour chains which can be used to measure how deep the scour and fill has been in the channel. You can think about this as a volume of sediment that has been picked up from here during the event and moved downstream. At the end of the event, it has been replaced by sediment that has come from upstream. In this particular channel, the scour and fill match as you would expect in a short term. The experiments were only for a few years. Essentially, you can think about it as a sort of conveyor belt. The sediment is here. A flow event happens and it's moved to there.

One of the things we tried to think about was how far does the sediment move. As you saw in an earlier slide, this is one of the channels in that small catchment. We have the volume of sediment going into the reservoir or the bottom of the catchment. By knowing how much goes into the reservoir, you can calculate knowing the depth of scour, how far sediment is moving.

On an annual basis because we could only survey the reservoir once a year while it was dry, sediment moves through this channel about half a kilometer. We have some estimates as to how far sediment moves through these channels in a year.

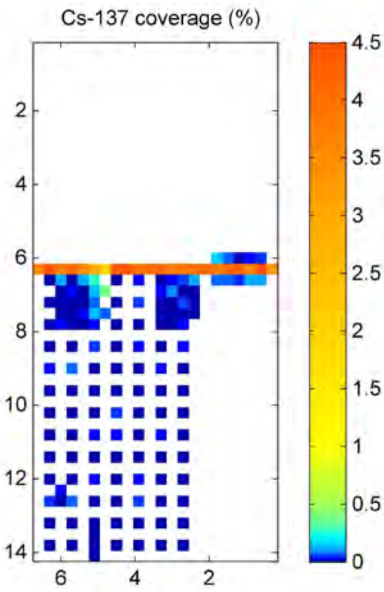


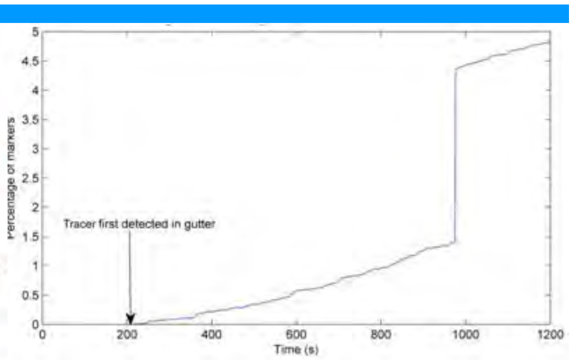
The next stage of the story comes to Tsukuba where I've been doing work with Professor Omda [ph] since 2009. In 2009, we did some experiments. The experiments were undertaken in the large rainfall simulator. Again, the question was can we try to understand and can we predict how far sediment will move? We constructed a hill slope and then moved the rainfall simulator over it and ran an experiment.

Now, the experimental design was that within this plot we have a line of sediment which you can see is a different color from the rest. The color isn't important because that is not going to help us identify it. But, what is important is that this sediment is very rich in Cesium-137 whereas this is not. The experiment was to see where this cesium enriched sediment moved during the experiment and then to see if we could develop a model to predict behavior.

This is a photograph of the experiment. You can see the plot was designed to be steeper on this side than on this side. The idea was that flow would then concentrate on this side and we would have areas with no flow on the outside. We wanted that because we wanted to be able to see what would happen to bits of the sediment where the only mechanism for moving the sediment was raindrop impact.

Here we just have raindrop impact. Here we have raindrop impact and a zone where the flow is not strong enough to pick up the sediment but will transport the sediment if it's been picked up by the rainfall. The rainfall will splash up sediment and the flow will then transport it. We got splash only, splash and flow transport and on this side, you can see these clearly defined challenges. We've got detachment by the flow. The experiment allowed us to look at three types of process causing sediment transport.

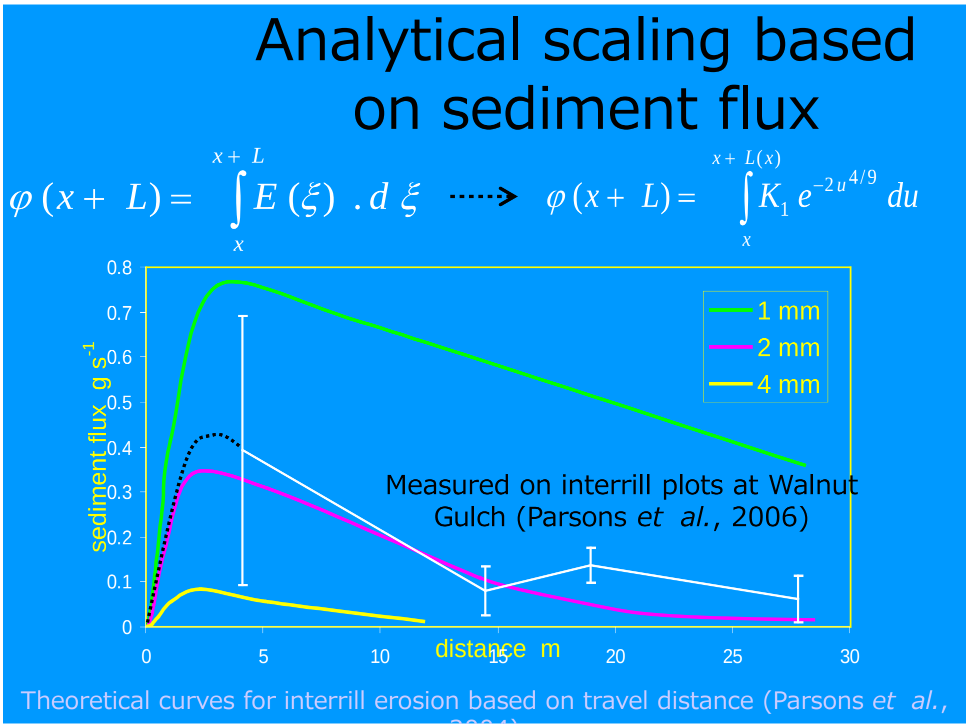




左の図

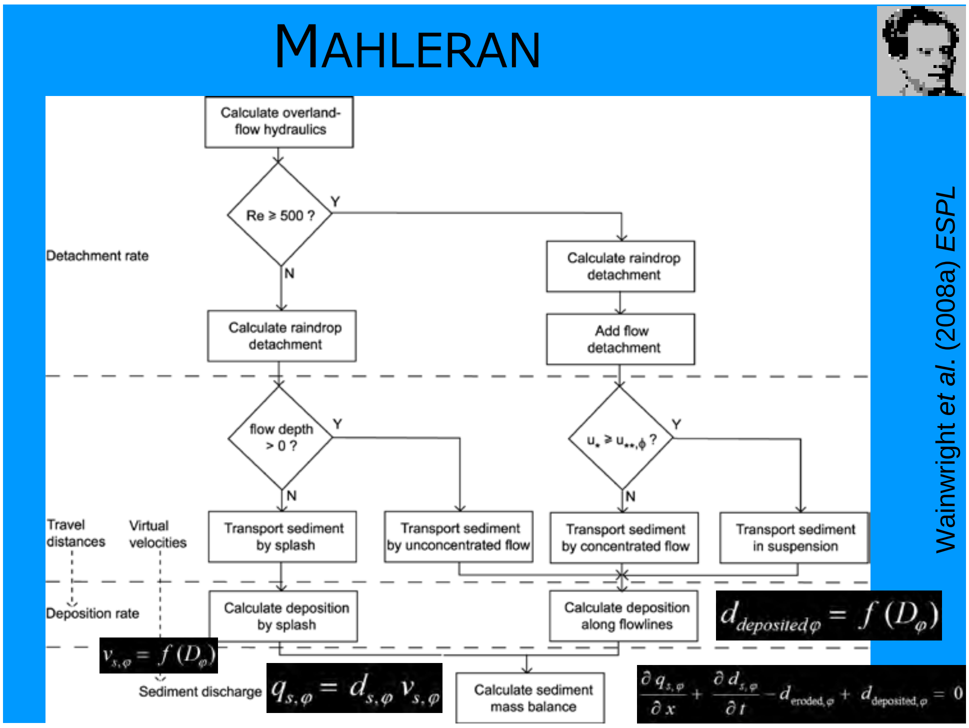
This is the cesium measurements after the experiment.

Prior to the experiment, every cell along this line had the same amount of cesium enriched sediment in it. There's a uniform amount and there was none in this area here. We have a map of each of these cells. Each of the covered cells has the surface straight off and then the cesium content of that cell was measured. We have to thank the Master students of Professor Omda who diligently worked by collecting all of the data for those cells and processing.

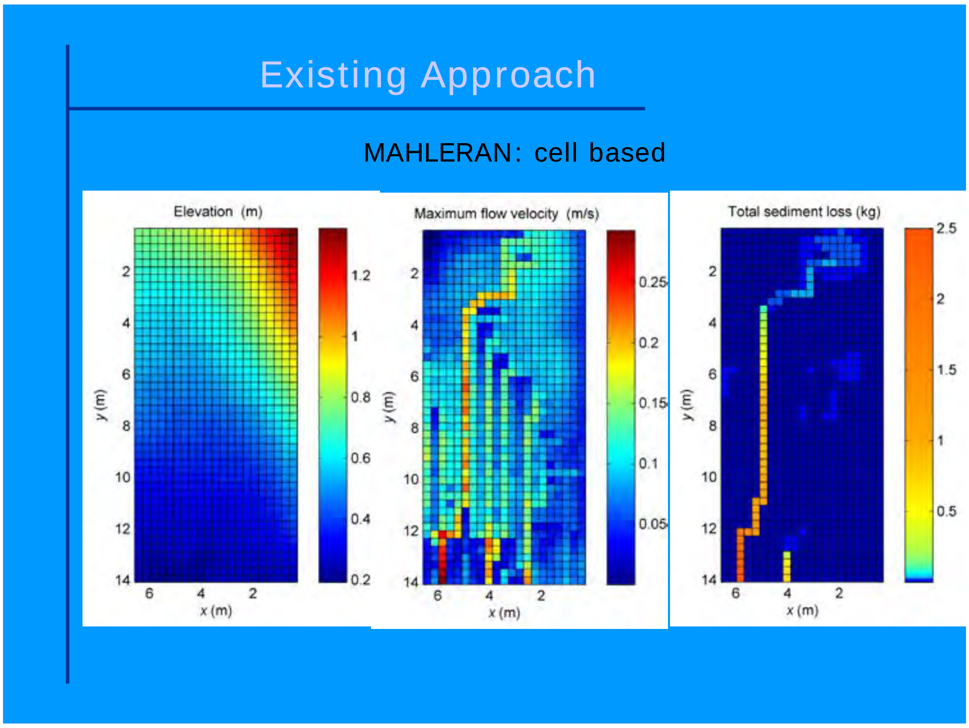


Now, coming out of our previous work on transport distance, we have been able to produce a model of certain transport which is based on the particle size and how far it moves. What we end up with is a relationship like this that says the sediment flux first of all increases and then slowly decreases with distance down slope. For the case where sediment is moved by raindrops and flow operating together, no flow detachment, all of the detachment is achieved by the raindrops but the flow transport is there.

We have a model that is based upon transport distance. That graph illustrates a part of the model. The model as a whole covers the three types of processes that we talked about; splash only splash transport, flow transport, and flow detachment. That theoretical model was developed and then tested on plots in Arizona. The lines here show you the results from the experiments to test them all. As you can see the model seems to give us a reasonable prediction of the behavior of the plots.



That's just a summary of how the model works so you could calculate raindrop detachment. And then, if there is no flow then the transport is only by rain splash. You can calculate the deposition by splash. If there is flow then there is transport by a concentrated flow. Then, the question again is there concentrated flow and so on? The model is a comprehensive model of different types of sediment transport.



左の図

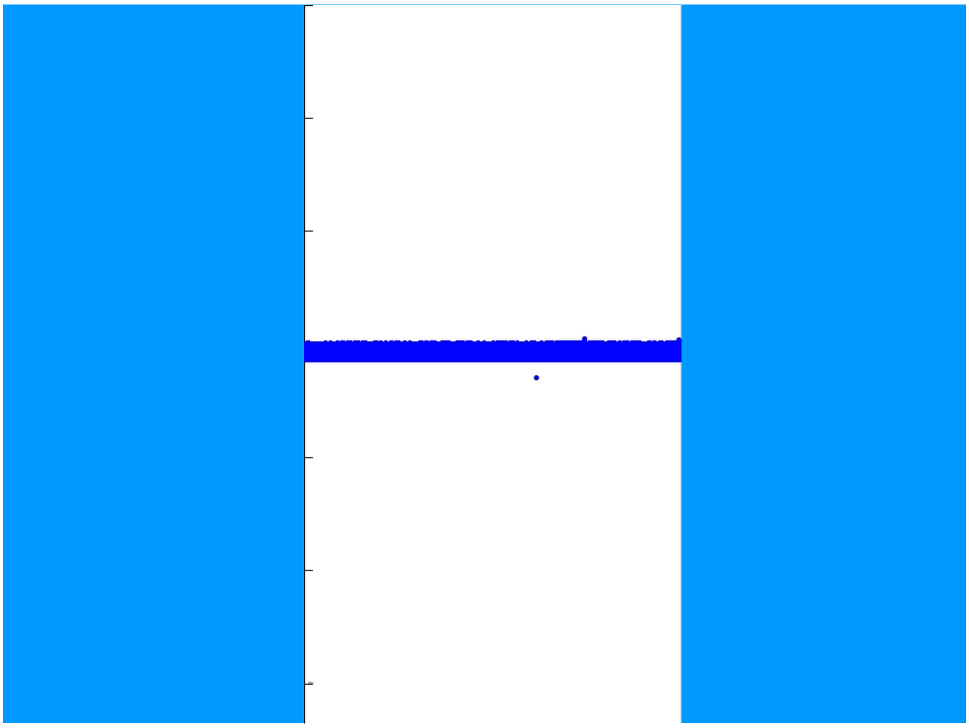
What it will allow us to do is for this laboratory plot to calculate the amount of sediment transport.　This is a DEM [ph] of that plot which illustrates the side slope.

中央の図

This is the predictive flow path and you can see these strong flow paths down in the middle on the right hand side and the smaller flow paths were also visibly photographed.

右の図

This also predicts total sediment loss from the plot.



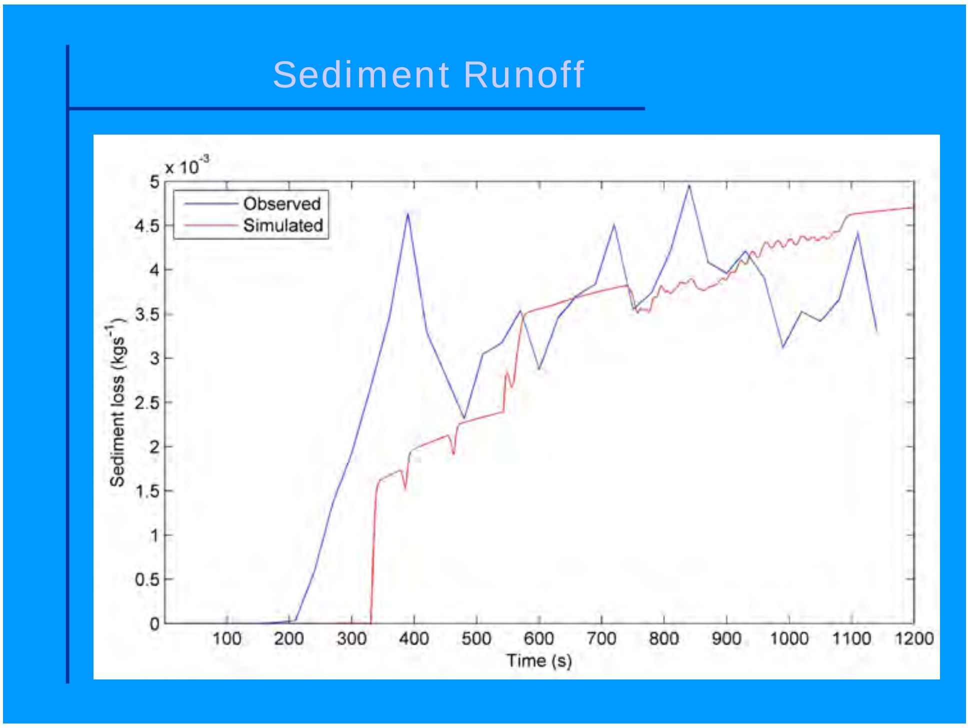
（上図は動画の一部）

But the problem with total sediment loss is – what that does is tells you the amount of sediment. It doesn't tell you where your marked cesium enriched sediment was. The difficult task is to know what happens to this. In the first time step you can make this a simple task because any sediment that is removed from this band will be cesium enriched sediment. But in the second time step that sediment will have moved to here where it is now mixed with sediment which is not cesium enriched. It is a proportion of the total sediment in that cell. The question is, what is the chance that the cesium enriched sediment will be picked up compared to the background sediment? How do you calculate that in terms of knowing what is the depth of soil to which you mean to apply the model? Our task then was to develop and construct this model essentially to move these marked particles.

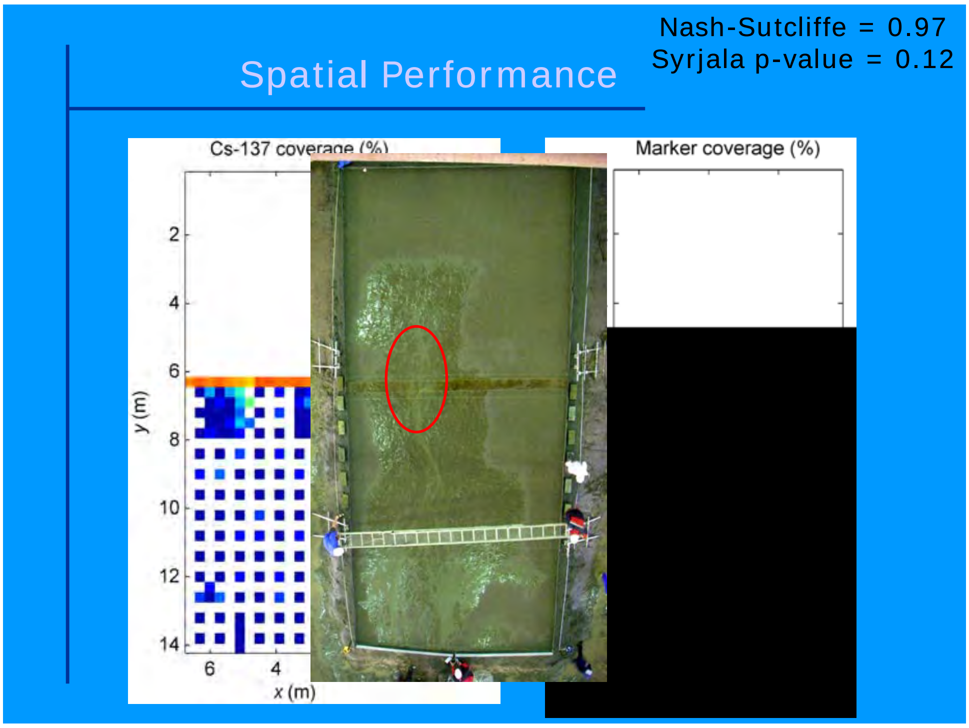
（以下の説明の途中で、上図に重ねた、粒子の移動を示す動画有り。）

What this model then does is to show what becomes of these particles during an event.

What you see first of all is there are very distinct lines where the sediment moves relatively quickly. There is an area over here where not very much happens. This is the area of splash. You can see part of it is moving around. Slowly, therefore, you can build up a pattern of where the cesium ought to be in relation to the experimental observation.



We then developed a model which is based on Mahleran Model. This produces sediment loss that was observed. In the experiment, we measured the sediment coming off. This is the simulated sediment loss which is a reasonable approximation.

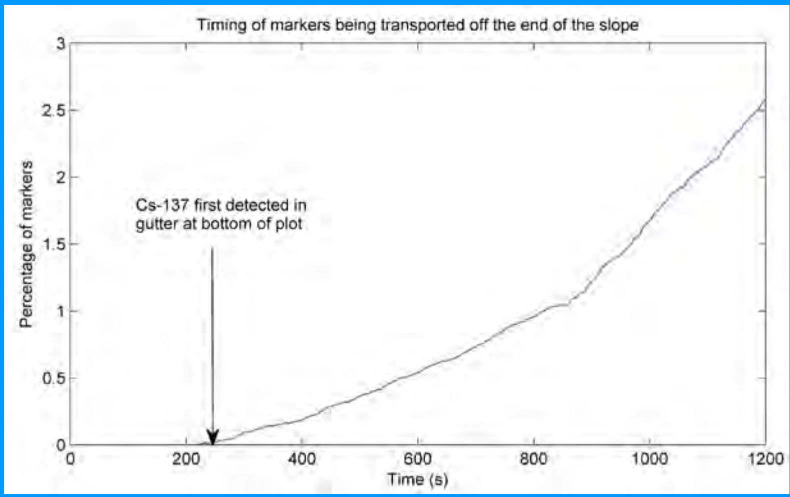


This is the spatial performance of cesium coverage. This tells us where the cesium was detected. This tells us where the model predicts that it should be detected. You can see a reasonable match in terms of the splash either side here and the very distinct flow line comes from here and so on.

Obviously, this is more detailed because it's easy in the model to tell you what happens in every cell or else this only tells you what happens in a portion of the cell. We can see that breakthrough of a very low cesium content there is picked up by the model.

Temporal Performance

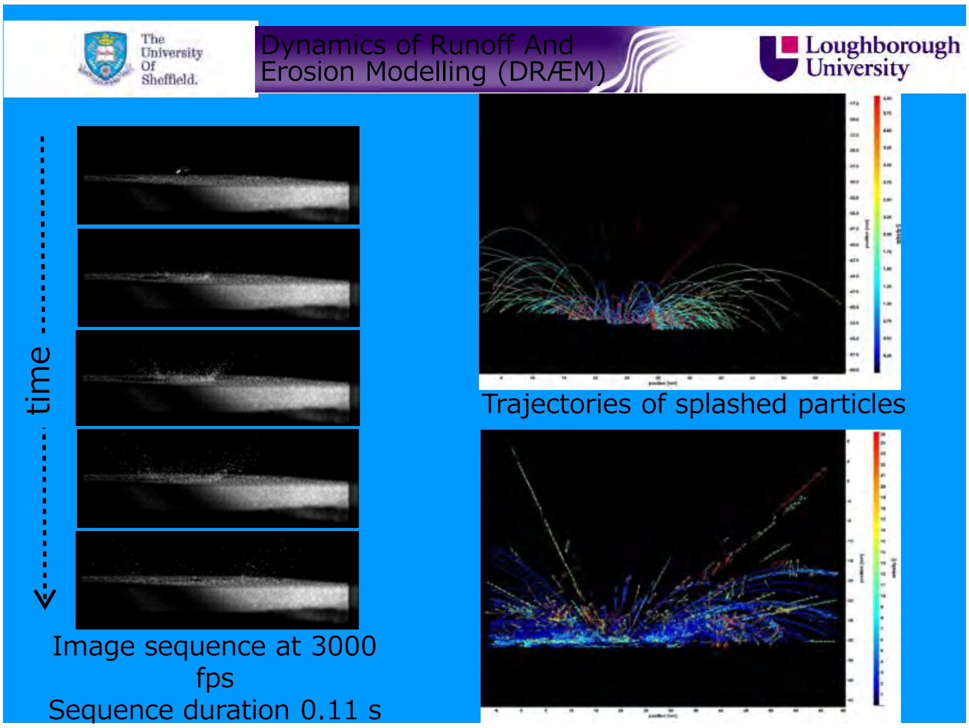
Sediment runoff at bottom of plot



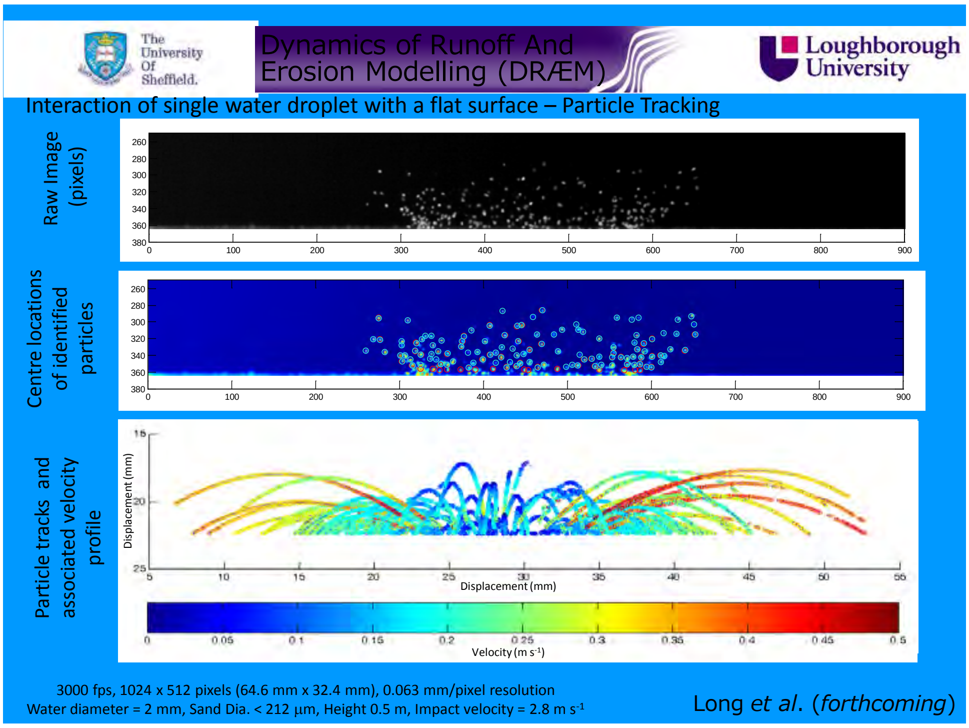
If we compare when cesium is first detected in the outflow it's there and our prediction is only very slightly...

AT THE RAINDROP SCALE

What we've been able to do with that is to develop a model that allows us to see where sediment is going to and which seems to predict reasonably well. We're also interested in trying to understand these processes at other scales. What I'll talk about now is some work that's been going on over the last year or two. All of the issues is what happens to sediment when it's detached by raindrops.

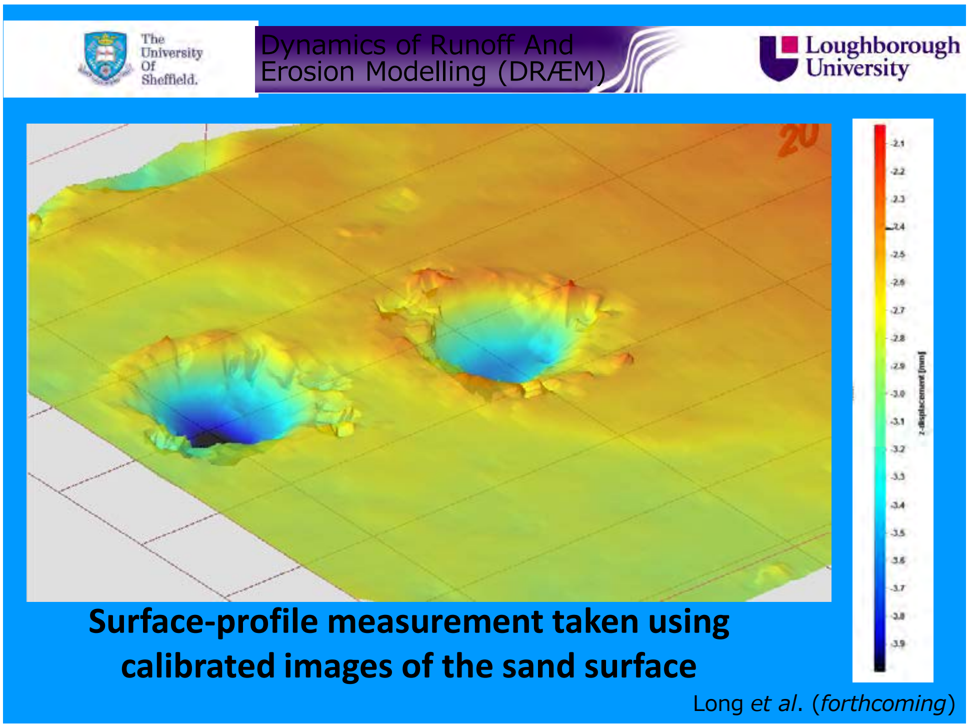


For this, we've been using particle imaging velocimetry which enables us to track individual particles as you can see the images are sequenced at 3000 frames per second. From that, you can track where each droplet goes. Because the water droplets and the segment rich droplets behave differently, you can then separate out the sediment particles from the water particles.

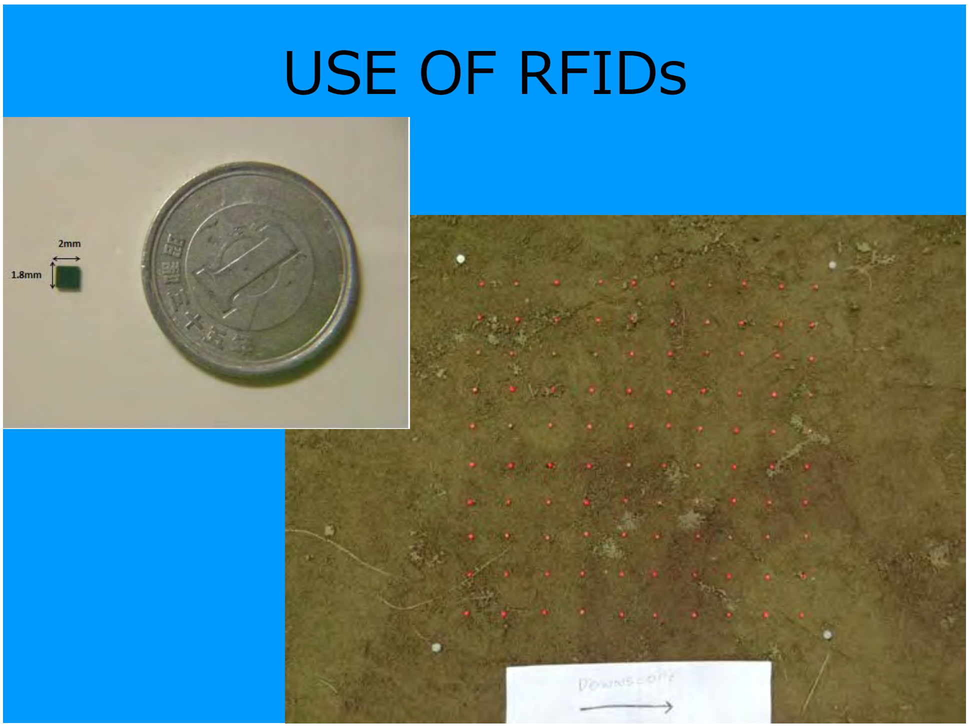


We have this distribution of where the sediment particles go. This shows what becomes of them. That's the raw image that we work with. That's what comes out of the photography. The centers of individual particles are identified. Because of the frequency of the photography, it's relatively easy to say that there aren't that many options where this particle will be in the next photograph.

You can assume it has a parabolic trajectory. Therefore, you can look for it in certain places. This particle is not suddenly going to go over there. It's going to go slightly in that direction. But because you can predict what sort of behavior it is, you can then map all of those centers through time to get this distribution of where the particles have traveled. What the layout [ph] then allows us to do is to see both how far particles move and how quickly they move and what angles they are rejected from the surface?

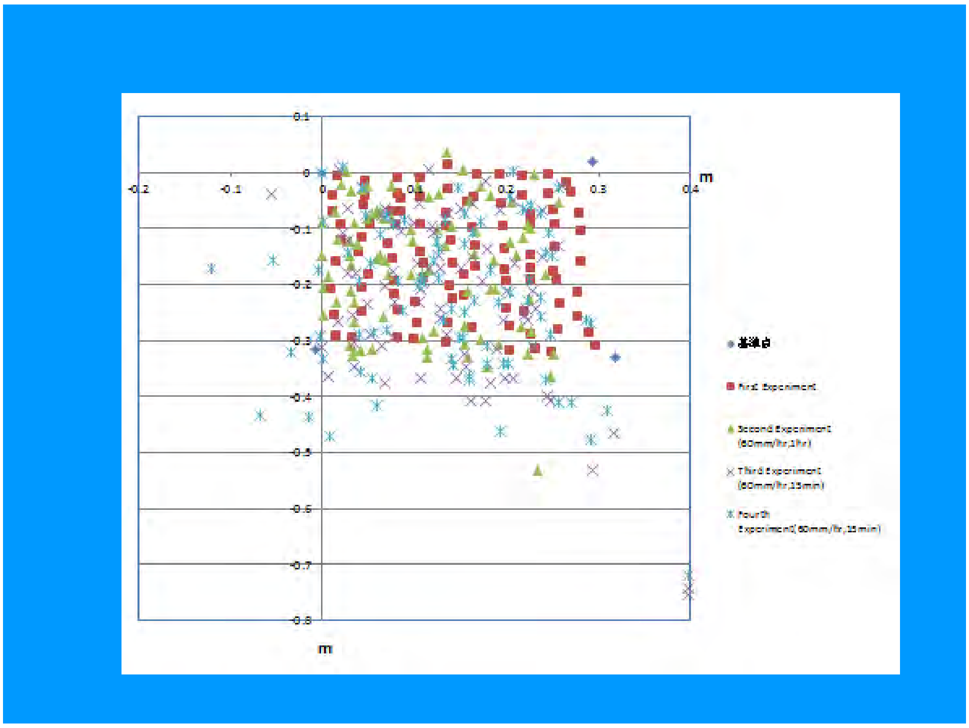


We could also use the photography to see the fall of the ground surface that the raindrop creates. You can see that after the raindrop impact there was a crater. That crater is then surrounded by an area of sediment and further out there are individual particles which do not obviously create a topographic expression. We're now able to see what happens during the impact of a single raindrop.

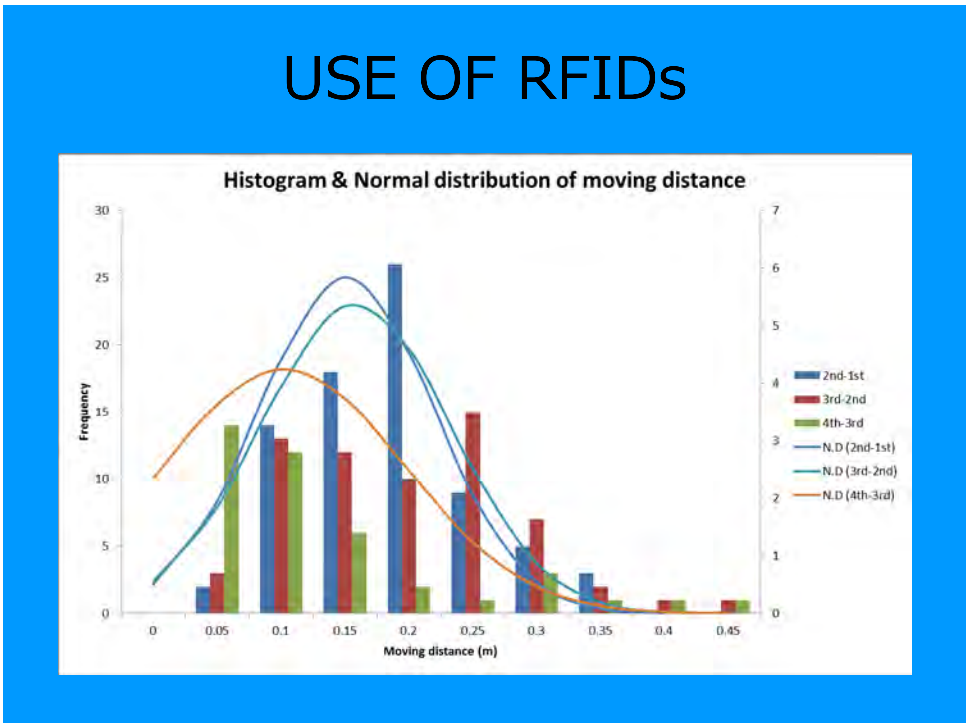


Related to that is more work that we've been doing in Tsukuba. These are RFID tagged particles. These are an updated version of the particles that I was using in the laboratory a decade ago.

The difference is that a decade ago, all I could do is produce colored particles and see where the colored particles were. The RFID technology allows us to identify each particle separately and see therefore, where an individual particle is gone. This work is again done with students of Professor Omda.



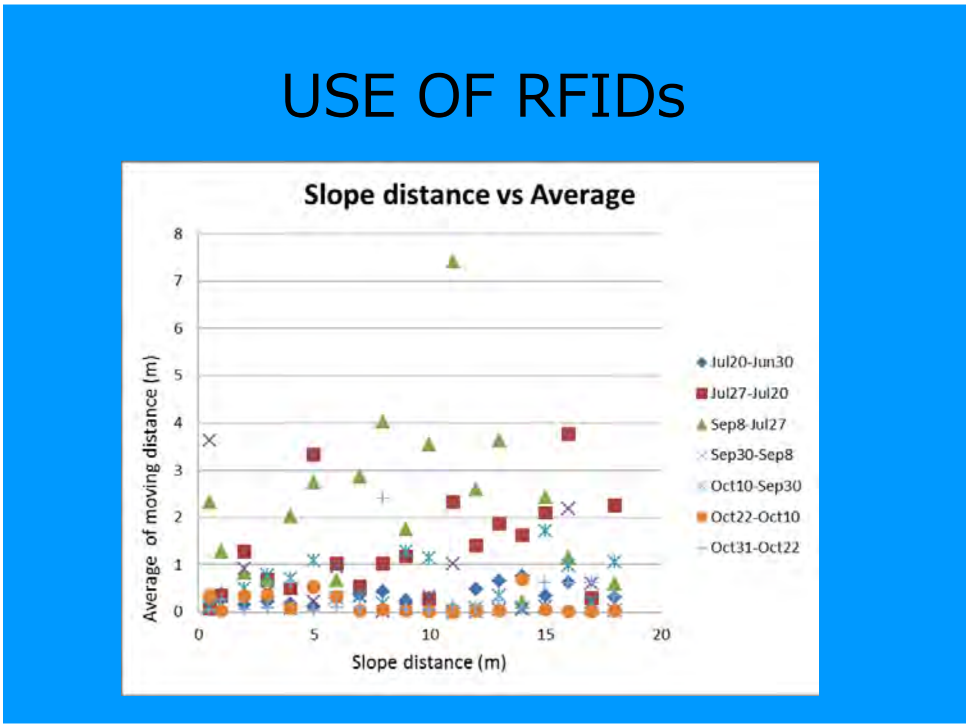
We’ve been able to map where the displacement of those individual particles during a series of events



and then to produce a distribution curve for how far particles traveled. Again, we're able to start thinking how far do individual particles move under a particular process.

USE OF RFIDs

With Mr. Noguchi, we’ve been looking at particles in the field of Fukushima. Here our RFIDs on this plot located in various positions particularly so lines across and down slope.



The preliminary analysis of those results shows that with different distances down slope and different storm intensities we get different spatial patterns as you might expect that as the storm intensity increases there's more runoff. There's a stronger relationship with particle travel distance and distance down slope simply because there is more run-off and therefore more power to transport these particles. We are beginning by using this technology to understand yet more about how sediment moves.

AT THE CONTINENTAL SCALE

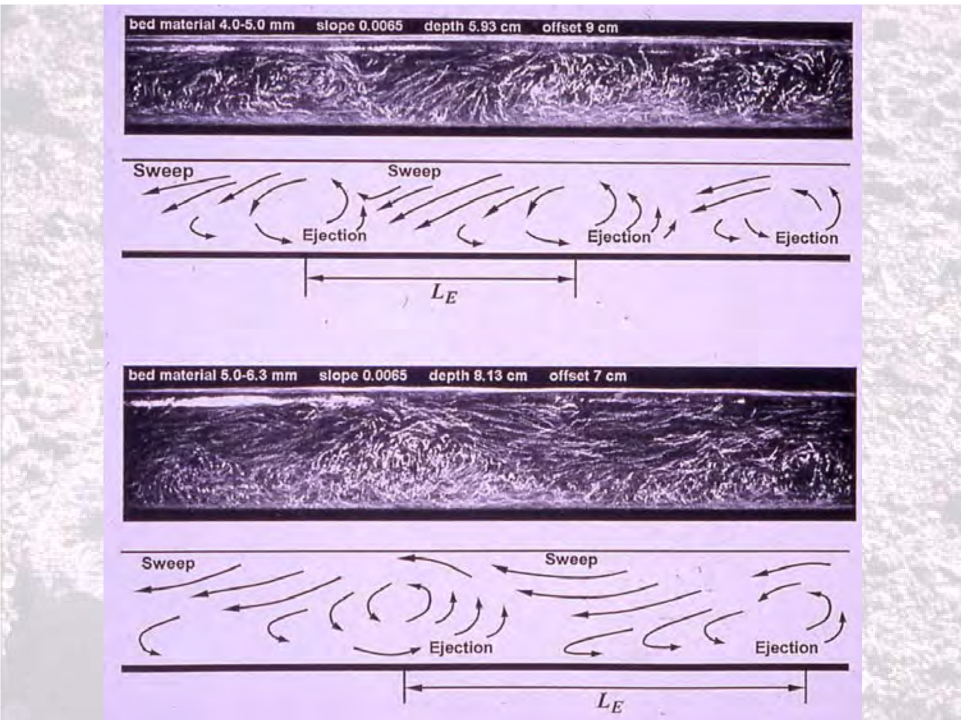
Finally, if we think about sediment transport at a continental scale, then again there is an accepted view. The accepted view is this that if you want to know how fast continents erode then all you really need to worry about is suspended sediment because for the time you get to the downstream end of large rivers, almost all of the sediment which is being transported is being transported in suspension. By measuring suspended sediment load we can estimate rates of continental erosion.

For continental erosion, the assumption that suspended sediment travels at the same speed as the water, determines our estimates of the rates of continental erosion.

$$Q_s = SSC * Q$$

Now, the way this is done is to attain a rating curve between discharge and sediment. You go along in four different stage levels of the river. You take samples of water and that gives you a way of rating the amount of sediment for a given discharge. Then, if you have a continuous recorded discharge then what people have done is to simply apply this equation. You know the suspended sediment concentration from the rating curve, you measure the water discharge and by multiplying those two together you get the amount of sediment. That equation assumes that sediment travels at the same speed as the water. If you were to imagine doing this analysis and you had fish in the ocean that swam upstream and you took a rating curve of the numbers of fish in the water and then you multiplied that by the discharge, you would get an apparent loss of fish from the land to the ocean.

By taking those two things and assuming the sediments traveling at the same speed or indeed in the same direction can lead you to the wrong conclusion.



There's a good reason why suspended sediment should not travel with the same speed as the water because the reason the sediment is in suspension is because of turbulence. Turbulent structures typically look like this. You're going to have suspended sediment brought down to the bed and then swept off of it. It's more likely that suspended sediment will spend its time traveling vertically and reaching the bed and then being picked up off the bed. There's a good chance that once you get down here you will have to wait to be re-entrained.

We can think about suspended sediment moving with the water, being deposited on the bed, picked up and moved again. It has what you can describe as a virtual velocity which is not the same as the velocity of the water. That was our idea. We thought it's very difficult to test this idea.

Suspended sediment

A first approximation for the travel distance of particles suspended in water flows as:

$$L_{s,\varphi} = 7.28 \times 10^{2} \; e^{\left(7.33 \times 10^{-3}\,\omega\right)} \; e^{\left(-6.127\, D_{\varphi}\right)}$$

where Ls, φ is the median travel distance in suspension for a particle of size φ [m]

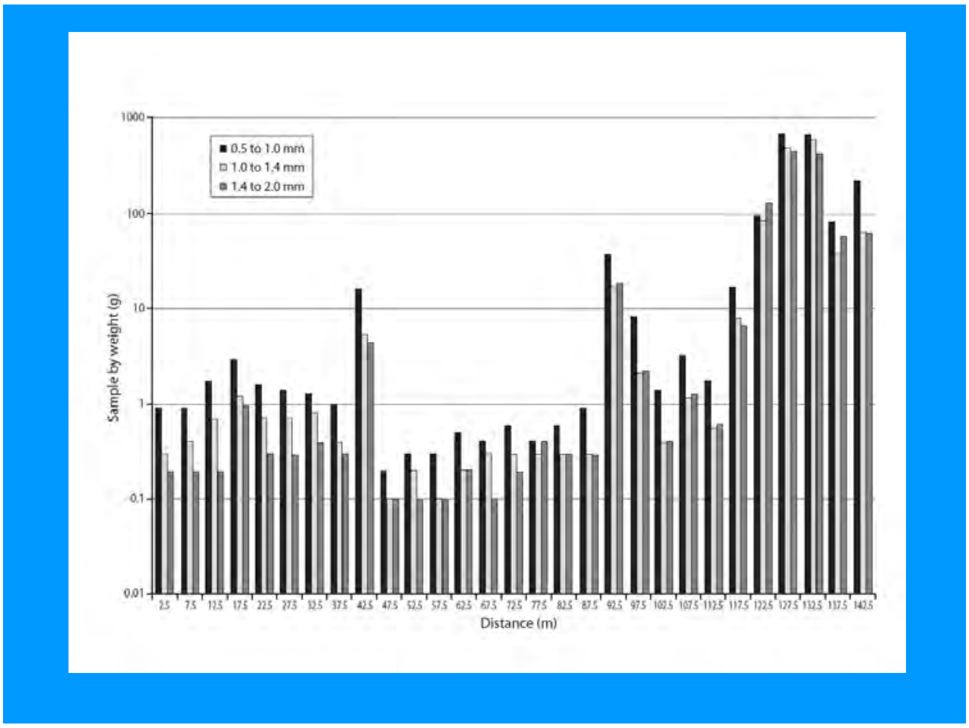
ω is stream power [J m^{-2} s^{-1}], calculated as $\omega = g\,h\,u\,S$

D is the dimensionless particle size

But, if you look at the wind erosion literature, they think suspended sediment has a finite travel distance but the fluvial literature does not. The fluvial literature thinks it stays in suspension forever but the aeolian literature thinks differently. There's a reason for thinking that perhaps things aren't as the fluvial geomorphologists think.

Here again Tsukuba comes to the rescue. You have still just the finest flume in the world. We thought this flume is long enough possibly to test the idea that suspended sediment does not just travel with the water. That if we started water flowing down this flume [Unclear] sediment that would go into suspension, some of it would be left behind when we turned off the water.

We did an experiment. We set the flume going with a discharge and we added some fine sediment well above the threshold for suspension. We previously sprayed this sediment with fluorescent paint so that we could see if it's still in the flume and it was.



These are the results of how much sediment is left in the first 145 meters of flume. The last few meters were affected by the – we are at the bottom so you get a backwater effect. Also, this is a log scale because these numbers as you can see are very, very small unless in the graph whereas these numbers are several hundred grams. To get a graph to show something, we have used a log scale. Important point is that if you sum all of this, 18% of the sediment we put into the flume was still there at the end of the experiment.

What this graph gives us is the tail end of a distribution curve. We know that the tail of a distribution curve that starts here and goes up and then at some point reaches a maximum value and then will come down here. We also know the total area under that distribution curve because we know the weight of the sediment we put in. And so, we can fit the curve that will have the right total area and is a reasonable fit to these data.

If we do that we find that the mean travel distance of the sediment is around about 170-180 meters. In the same time, the water would have traveled 350 meters. What we calculate is that the velocity of the sediment is about half the velocity of the water on average. The surprising thing is that if you look at these three bars for the three sediment sizes, they are as what you might expect the one we are [Unclear]. The reason we studied the sediment in these three sizes is we expected to find that the travel distances of the coarsest sediment would be the shortest. As we got to the finer and finer sediment, it traveled further and further but our results are the opposite of that; 40% of the sediment between half and 1 millimeter is deposited in flume but only 12% of the sediment between 1.4 or 2 millimeters.

There's an interesting result is the fact that the finer sediment doesn't travel as far as the coarser sediment in this experiment. I think that has to do with the difference in rest times. Once fine sediment is deposited, it's actually very difficult to get it re-entrained. It probably travels further in an individual state but has to wait longer before being re-entrained.

CONCLUSIONS

- All eroded soil travels a finite distance before being deposited
- Understanding of these travel distances is fundamental to spatial scaling rates of erosion
- Travel distances are important for understanding the fate of contaminants in the environment

To conclude, all eroded soil travels a finite distance. Understanding these travel distances is fundamental to the idea of scaling erosion maps. How we match what we leaves catchments with what we measure on hill slopes can only really be understood if we think about how far sediment travels. That’s important for understanding the fate of contaminants in the environment. How long contaminants stay in the environment will depend on their travel distance time, their travel distances, and how far they move in a particular time. Understanding travel distance is crucial to the fate of eroded soil.

以下質疑

Male Participant

Dr. Parsons I will start. You have the sediment delivery ratio as first in your talk and then you measured that each particle has a finite travel distance. I would like to know the relation between the sediment delivery ratio and the actual travel distance. Do you have any idea to combine?

Tony Parsons

The sediment delivery ratio is based on the idea that you measure sediment loss and you multiply it by the area of catchment. But, if the sediment leaving the catchment has only traveled a short distance then you have multiplied by the wrong number. Most sediment that leaves the catchment if you measure that coming out has come from a relatively small area close to the channel. If you think about the sediment at the top of the hill slope that isn't going to come out of the catchment for many, many years. You cannot assume that the area of the catchment matters.

Some years ago, I was at a conference and I was talking about measuring soil loss. I said, what we need to measure is not sediment loss from an area but sediment flux across a line. Then, a few years later I went back to the conference and said, in fact that's what we've been measuring all the time but we have called it sediment loss for an area, but when we measure sediment coming out of a plot, we're measuring something crossing a line. It doesn't tell us what happened up there. Maybe the amount of sediment crossing the line at the bottom is not related to the area at all. I think that's why if we measure travel distance we can understand how much lives the catchment as a function of travel distance of sediment. That's a long answer.

Male Participant

But still maybe lots of things to do?

Tony Parsons

Yes, still lots of things to do but I think understanding travel distance is crucial to do.

Male Participant

Thank you very much for your very nice presentation. I think you focused more about some larger particles, I'm working on some model with the nuclear transport in a catchment. In that model we consider the sediment transport also because basically [Unclear] for us maybe basically transport is the sediment. In our model, I think always when we go to calculate we found always that the simulated sediments are higher than [Unclear] always but after your presentation I found data because we assumed that all the sediments flows same as the water. I think as you mentioned that maybe our assumptions are wrong. We should revise...?

Tony Parsons

I think so. Yes, a lot of the work is done with large particles for the reasons I explained but initially they were doing ones we could see now that we use RFIDs even though the RFID itself is quite small [Unclear] to make it look like a soil particle it's still quite big. But, the magnetite was soil sized. It was 80 microns and the dominant size of raindrop detached soil is 100 microns. The problem with magnetite is it's a lot heavier than soil. The reason we ground it down to 80 microns was to make it have the same mass as the soil particle of 100 microns. We have the same mass but it also has a small area. It had this small target to the raindrops. There is an issue. With the cesium rich soil, we are looking at real soil particles. I think that is very promising. We can now model reasonably successfully I think where real soil particles are going.

Male Participant

Do you have any paper on this...?

Tony Parsons

About?

Male Participant

...journal papers or?

Tony Parsons

On all of this?

Male Participant
Yeah.

Tony Parsons
Everything up to the cesium experiments are in the [Unclear]. That paper came out last year. The only things that aren't published are the RFID work which we haven't quite started and we will finish soon. The flume work which is the same, the paper is half written and I hope will be distributed in a month or so. But everything else has been published.

Male Participant
Maybe I can make one question [Unclear] from your conclusion, the particle size and the weight of this eroded soil particle materials are being broken down for understanding the contaminants. I can understand that your study might be important to understand the sediment as a physical contaminant but I'm not clear about how much helpful is your study in understanding the sediment as a chemical contaminant. Is there any?

Tony Parsons
Yeah. The only way in which it's relevant to the chemistry is if the contaminants are adsorbed on to soil particles. As an example, if cesium adsorbs on the clay particles and therefore to a large extent will travel where the clay particles go to. It's not entirely true because some of the cesium will be desorbed from the soil particles by plant roots and taken up into the plants. We can't simply say where the soil goes, the cesium goes. But we can if we understand the mechanisms of adsorption and desorption of contaminants onto soil particles, then we can use that to understand, if we understand where soil particles go. We can understand something of where chemically attached contaminants go. The story is more complicated but that is part of a bigger story.

Male Participant
Yeah because I didn't see any chemical composition in [Unclear] soil particle.

Tony Parsons
Yes.

Male Participant
What is inside that so that maybe helpful to understand.

Tony Parsons
Yeah. Now, I'm interested in where soil particles go. The reason we did the cesium experiment was because that was a way of identifying particular soil particles. We could say these soil particles can be detected because we can measure the cesium activity in a soil sample. It's the same approach as using the magnetite saying this is something we can find and is like a soil particle or is a soil particle in the case of cesium. What we're trying to do is understand where soil goes. How things are adsorbed onto soil particles is a separate issue. Maybe we'll get to investigate that as well in the next few years. Thank you.

Male Participant
Thank you very much.

Tony Parsons
Thank you.

END