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Breaking up with Lane

*Rethinking stability and equilibrium
in stream restoration*



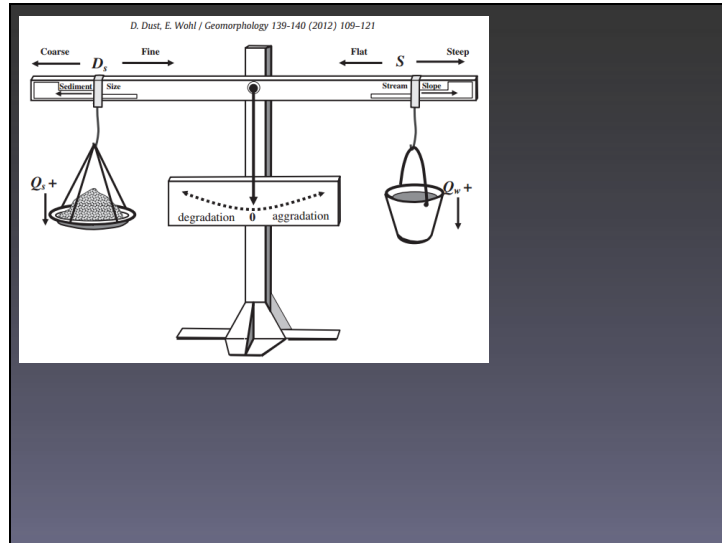
By: Mark Beardsley and Karin Boyd

Special thanks to: Jessica Doran
Scott Gillilan

This talk is a personal story about our relationship with Lane's Balance. We think it sheds some light on what we believe as a community, why there's been so much turmoil in our field, and maybe a little about what the future holds. I hope you like allegories.

We also want to have a little fun with you guys. Sometimes we get so busy and take ourselves so seriously we forget we're all just humans trying to do little something nice for the rivers we love.

This talk has more questions than answers, and we'll consider it a success if we can simply get you to stop for a few minutes to think about how the concepts of equilibrium and stability shape your view of stream restoration.



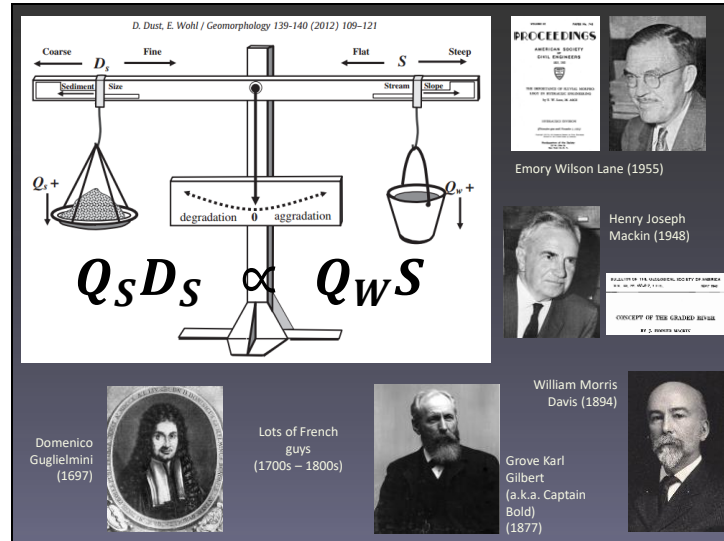
We all know Lane's balance. It's the most iconic symbol in our field.

If you have a stream that's in balance, and you change sediment or streamflow, or if you tweak sediment size or slope, the balance shifts to predict how it will either aggrade or degrade.

It's super intuitive, right?

Or is it?

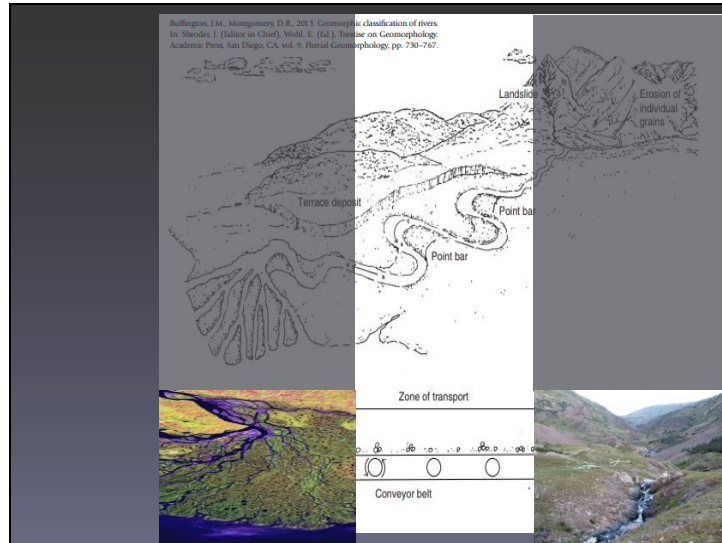
It's actually not at all that simple.



Lane's balance is named after Emory Lane, but his famous 1955 paper is pretty is really just a plea to engineers telling them to pay attention to what these other guys had been saying.

* The idea of equilibrium in natural steams is most eloquently presented in Henry Mackin's 1948 paper "Concept of the Graded River" but it traces back through William Davis, Grove Gilbert (a.k.a. Captain Bold), and a bunch of French guys to an Italian from the 17th century named Domenico Guglielmini.

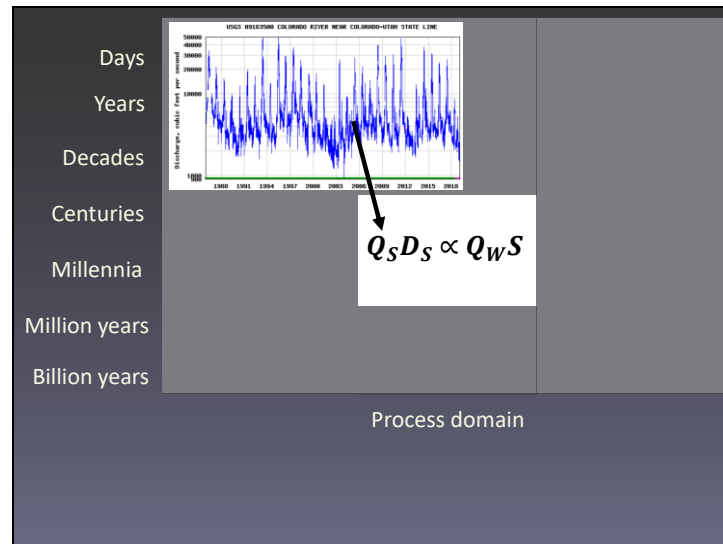
Did you know that the graphic representation of Lane's Balance doesn't appear in anything these guys wrote? It appeared mysteriously some time later.



One thing you get from reading the history of equilibrium is a feel for the theory's limitations in both time and space. Turns out that when they spoke of equilibrium, they were talking about a pretty small set of the world's rivers and a pretty narrow range of time scales.

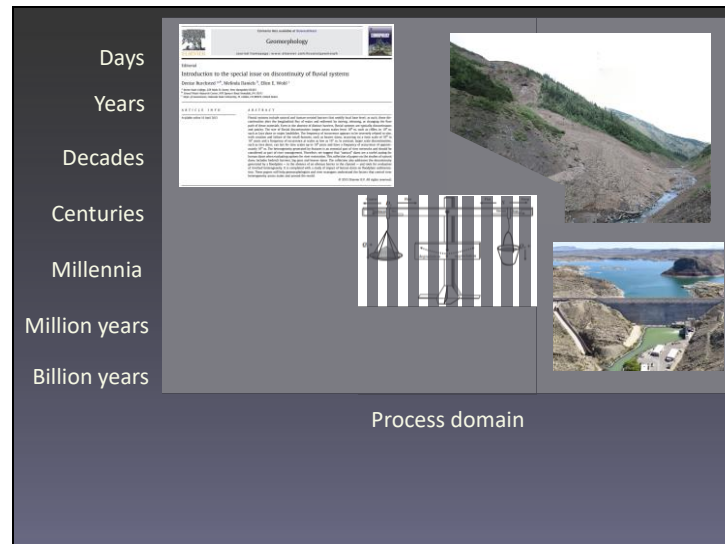
Lane's Balance applies only to graded streams. And by graded streams I mean

- those that are not obviously **DE**grading at the top of watersheds
- And those that are not obviously **Ag**grading at the bottom
- The zone in the middle (the zone of transport) is where you MIGHT find graded streams in equilibrium.



And the time scale is even more important.

- Geomorphic equilibrium does not apply over the longest time scales like millions of years. In those time spans erosion and deposition are overwhelmed by massive planet-scale processes like climate change and uplifting.
- And it doesn't apply to human time scales like decades either, because these are too sensitive to the natural fluctuation of state variables. Also, most changes are threshold-type responses at this level.
 - The best way to think of this is that all the factors in Lane's Equation are actually highly variable functions. The relationship is only valid if you are analyzing it at a time scale long enough to get an average over the full range of natural variability.
 - Like for stream discharge, you need to be looking at a time scale long enough to include the full range of floods, droughts, and everything in between.
- The equilibrium concept explains general trends over hundreds or thousands of years.



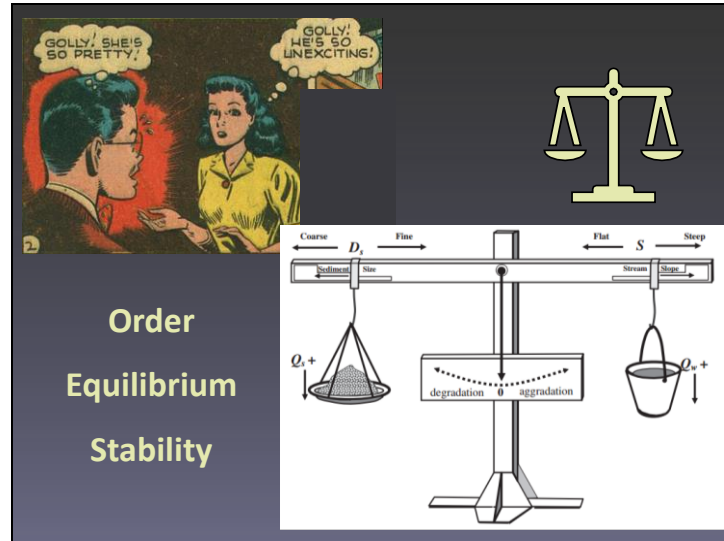
So, this is the zone where equilibrium **might** apply.

But even within this zone, it only applies to streams that flow through valleys of deformable material, and where sediment discharge is continuous.

- If geomorphologists have discovered anything in the 70 years since Mackin's paper, it is that there is a lot of discontinuity out there.
- These realities further limit the range where equilibrium concepts can even begin to apply.

The main point is this: We almost always use Lane's Balance to infer some sort of inherent dynamic equilibrium in stream systems. But Lane's Balance does not imply that at all! It refers to a general morphological pattern exhibited by a narrow range of stream types over a very limited time scale.

Stay in your lane, Lane!



Order
Equilibrium
Stability

I didn't really know all that when Lane and I first met.

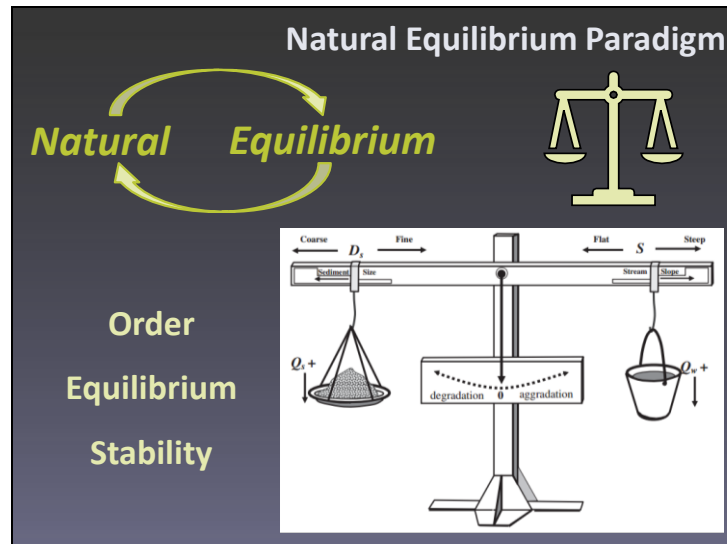
It was love at first site. I was infatuated.

She has that effect on everyone.

Lane's Balance is intellectually seductive.

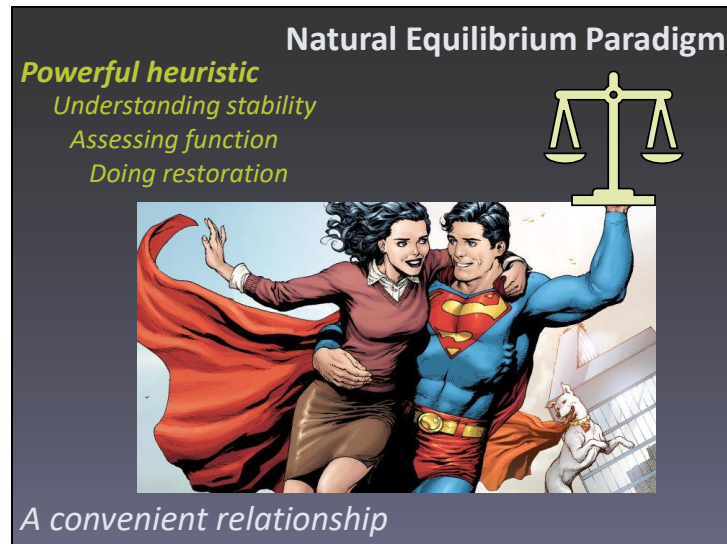
It suggests order. It suggests equilibrium. To many it implies stability, and to some, justice.

In other words, the symbol implies so much more than the limited theory it represents.



Lane's Balance exemplifies the Natural Equilibrium Paradigm — the idea that natural streams are in equilibrium, and that equilibrium is what imparts natural form and function.

- It implies that equilibrium and stability are inherent qualities of natural functioning stream systems.
- It implies that stream impairment is a disruption of balance and loss of stability.
- And that when streams are knocked out of balance, they **strive** to re-establish it.
- And it implies that when we impair a stream, we can fix it by helping it re-establish balance.



The idea of Natural Equilibrium is a comfortable and convenient way of thinking about rivers and streams.

Let's face it. Stream ecosystems are wickedly complex. It's nice to have someone by your side to help you make sense of it all.

The Natural Balance is a powerful heuristic. It is a convenient conceptual model.

But is it a good model or a bad model?

True models help us focus on what's important. False models lead us astray.

Bad models, like bad relationships, can make us do things we later regret.

Let's think about how the paradigm guides us through:

- Understanding stability
- Assessing function, and
- Doing restoration

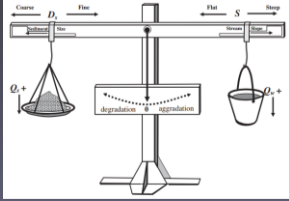
Natural Equilibrium Paradigm

Stability



1. Thou shalt transport the streamflows and sediment of thy watershed.
2. Thou shalt maintain thy dimension, pattern, and profile.
3. Thou shalt not aggrade nor degrade.

(per Rosgen 1996)

Stability. For us, it is not so much about how much, but what kind.

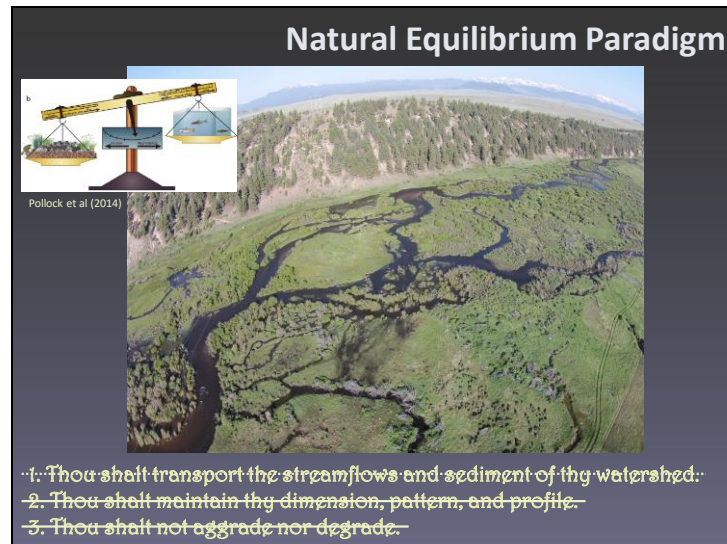
The definition I learned, and the one most frequently cited, states that in order for a stream to be stable it must in the present climate—now, for the sake of argument, let's ignore the fact that the present climate is changing...

...In order to be stable, it (1) must transport the streamflows and sediment of its watershed while (2) maintaining its dimension, pattern, and profile without (3) either aggrading or degrading.

This definition is founded explicitly on the premise that natural streams strive for equilibrium, but we know that isn't always true. In fact, at the time scales that matter, it is usually false.

When streams experience a change in conditions, like a flood or burst of sediment, they simply respond. They don't know that there is some statistically optimal form to strive towards.

In order to meet this definition, you would have to hold the needle on Lane's Balance straight down and fix both the sliders (since you aren't allowed to aggrade, degrade, or change form). So where does that leave us? There are zero degrees of freedom in this model. No room for adaptation or resilience.



Here's a natural stream near my house.

- I suppose it has to transport the water and sediment of its watershed, but it also retains a healthy portion of each, so I don't know about #1.
- It regularly changes shape, so #2 is out.
- And while I haven't gone out and measured it, there is plenty of science that shows systems like this are slowly aggrading. So much for #3.

And yet there is also good scientific evidence showing that streams like this persist for thousands of years.

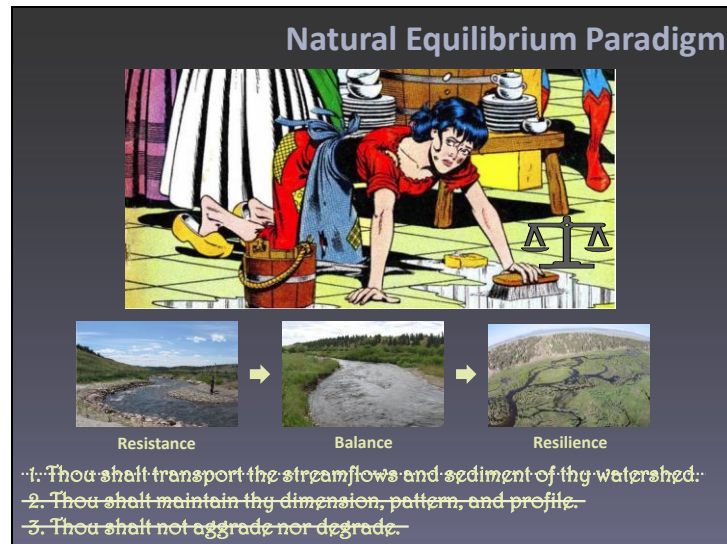
Would you call this system unstable simply because it retains water and sediment?

Or because it changes shape?

Or because it slowly aggrades?

Do you think this stream needs any help from us performing its natural functions?

These are the kinds of questions you start asking when you look outside the lens of the Natural Equilibrium Paradigm and apply some good old-fashioned common sense.



Sigh. It's been rough between me and Lane lately.

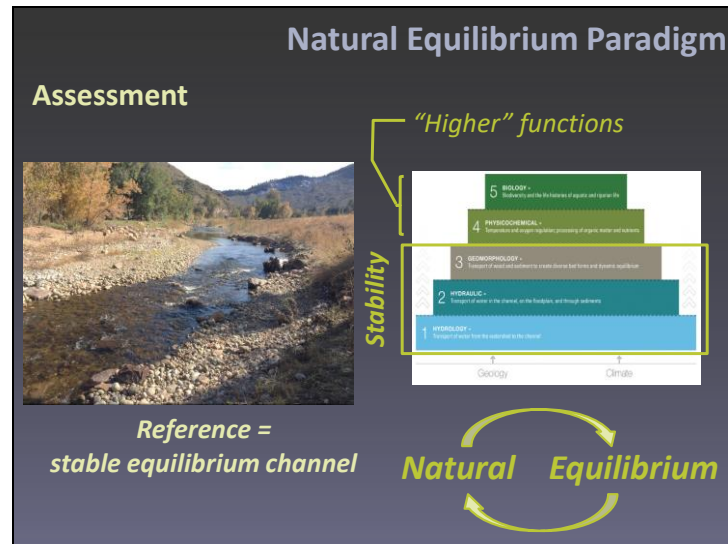
We've been wrestling over this stability definition a long time.

The concept of stability is important, but I really don't think this definition captures it.

I think we may just be growing apart, me and Lane.

- In the old days, we thought about stability mostly as a factor of resistance to erosion. (Are the stream bed and banks strong enough to resist erosion?)
- The first big paradigm shift got us thinking a lot more about equilibrium. (Is the stream in balance with its incoming flow and sediment?)
- And now we are realizing the importance of adaptability and resilience. (How does it deal with disturbance and stress?)

Notice that the trend is increasing appreciation of stochasticity, dynamics, and disturbance—all things we know are common and important in the natural world.

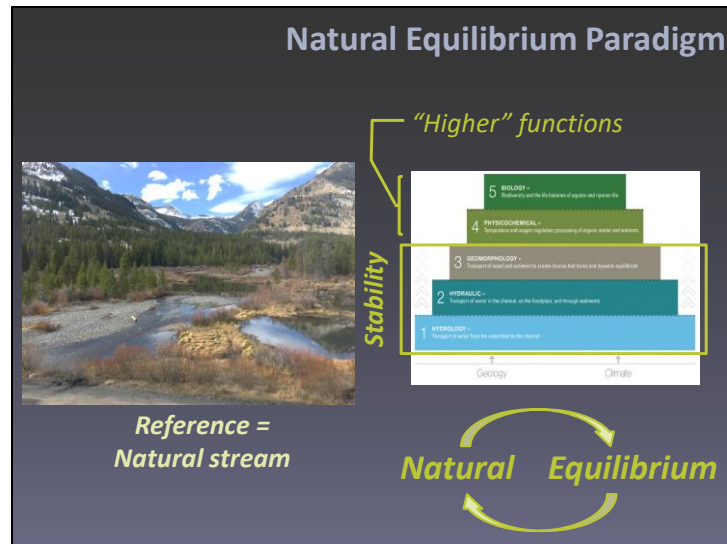


Now let's look at stream assessment.

If we assume that natural functioning streams ought to be in stable equilibrium,
then evaluating function is largely a matter of assessing channel stability.

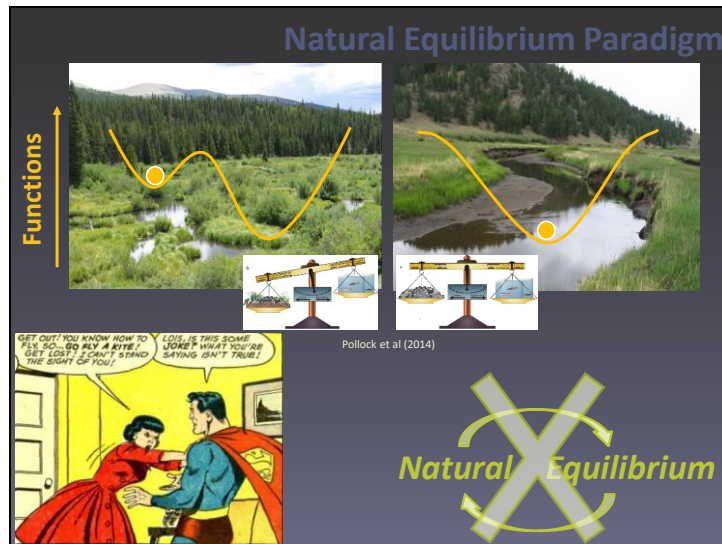
This is the rationale underlying hierarchical frameworks like the stream functions pyramid.

- The foundation of the pyramid is an assessment of channel stability using hydrological and geomorphological parameters.
- Models like this assume that “higher” functions (like biogeochemical processes and all the plant and animal communities in stream ecosystems) are a product of stability and can mostly be inferred.



But the real issue is one of reference.

I have to think that if we are evaluating natural function, the proper reference is a natural unimpaired stream, not a hypothetically stable one.



Tension has been building between Lane and me.

Here are two mountain meadow reaches that I study. I am sure that the one on the left is more natural and less impaired. I think it is a better reference even though it is surely less in balance than the E-channel on the right.

* But that's because I'm looking at it outside the lens of the Natural Equilibrium Paradigm implied by Lane's Balance.

In fact, the better function in the natural stream on the left is a direct result of its disequilibrium and dynamic form!

Disequilibrium is what drives the formation and maintenance of physical and biological diversity

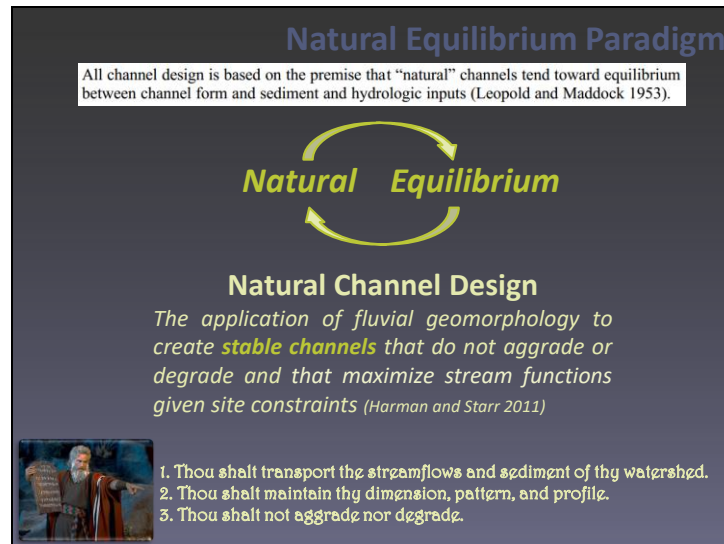
- The riparian and stream biota have evolved with, and are dependent upon, the complexity and disturbance inherent to a naturally dynamic system.
- The stream on the left is also more stable by virtue of its resilience and dynamic (not static) form.

Now, we could force that stream on the left into equilibrium and get it to behave more like the one on the right, so that it conveys its flow and sediment in a properly efficient manner.

And the Natural Equilibrium Paradigm pretty much tells us we **should**!

But if we build that, they would leave! They being all the functions and the complexity and the biota, that is.

And aren't those the things we said we care about most?



Restoration

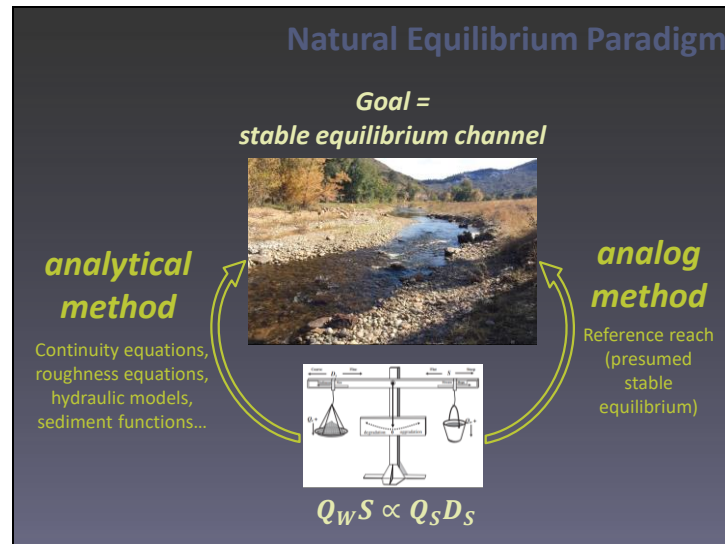
Natural Channel Design is *the application of fluvial geomorphology to create **stable channels** that do not aggrade or degrade.*

Again, the assumption is that streams are naturally stable by virtue of equilibrium. And that functionality is a product of that stability. Therefore, to restore functions, we must attain balance and stability.

- In 1953, Leopold and Maddock said that all channel design is based on the premise that natural channels tend toward equilibrium.

Well, there you have it.

66 years and still going strong.



The goal of natural channel design is a stable equilibrium channel, but there are two ways to get there:

- In the analytical method, people derive design parameters using equations and models to solve for equilibrium.
- In the analog method, you get those parameters from a reference reach that you presume to be stable.

Nobody ever does exclusively one method or the other, but there are definitely two different camps.

And they really don't get along with each other.

I wonder if all the turmoil and fighting isn't more a sign of deeper insecurity about the whole approach, rather than simple disagreement over methods.



Reality check.

Are we ever really confident we can nail sediment balance to build a stable static channel in perfect equilibrium?

It sure doesn't seem like it.

In almost all cases where I've seen Natural Channel Design applied, you also get a healthy dose of bank hardening, grade control, and artificial structure.

I don't blame people for doing this. If I was being graded by the three stability commandments, I'd probably add some safety factors too!

Natural Equilibrium Paradigm

How it usually goes...



Standards for ecologically successful river restoration
(Palmer et al 2005)

1. Guiding image of dynamic state
2. Ecosystems are improved
3. Resilience is increased
4. No lasting harm
5. Ecological assessment

↑ NCD Goal = *stable equilibrium channel*

Ecological Goal = *dynamic natural system* →



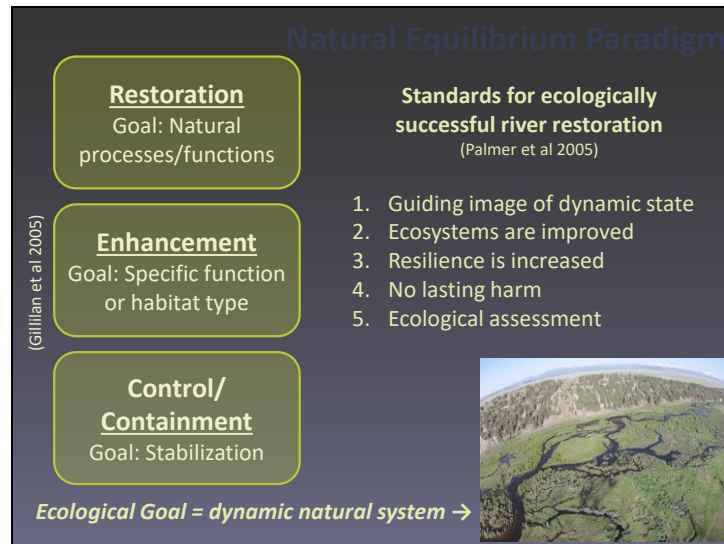
I hate to be too hard on natural channel design and sediment balance, because I truly believe these were the process-based restoration concepts of their day. But that day has come and gone. Science has come a long way since the 1950s, and we need to get with the times.

For us, it is not about who's name is on the approach or what you call it, it comes down to whether the approach helps us succeed in ecological river restoration.

- Does the goal of creating a static equilibrium channel go with the guiding image of a dynamic state?
- Does it improve ecosystems?
- Does it increase resilience?

I'm afraid that stabilizing channels often does quite the opposite.

But, of course, I am peeking over the top of my Natural Equilibrium Paradigm glasses again.



When Palmer et al published their ecological standards, practitioners responded by defining these three categories: Restoration, Enhancement, and Control

The Natural Equilibrium Paradigm would have us view them as something of a sequence.

- First order of business is to establish balance by stabilizing the system.
- Then we can start enhancing it with habitat or other attractive features, incrementally gaining more and more restoration as we go.

I guess it's no wonder people became so comfortable using the term "restoration" for pretty much any activity that manipulates a river.

But we see it differently. We see these as three different and often competing goals.

The road to ecological restoration does not necessarily pass through control and stabilization. Oftentimes it goes in entirely the opposite direction.

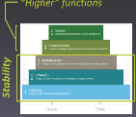
We might gain benefits from controlling and enhancing rivers, but we shouldn't expect a whole lot of **ecological success** until we're ready to embrace the guiding image of a dynamic natural state.

That time is now.

Natural Equilibrium Paradigm



Static channel form and equilibrium are not universal criteria for stability



Stream functions are not just the product of stable equilibrium



Restoration is not just creating stable equilibrium channels



It's time to let go of the Natural Equilibrium Paradigm.

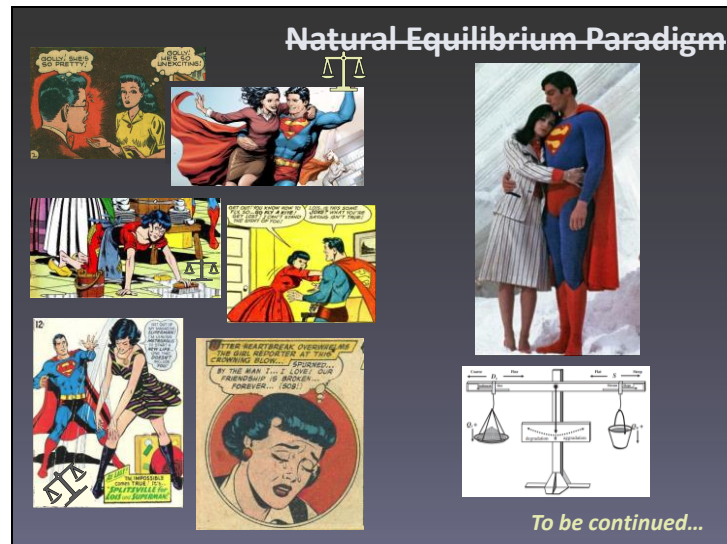
It was nice and convenient thinking of streams as simple ordered systems that are either in or out of balance. But when I really think about it, I know it isn't true.

- Static channel form and sediment balance are not universal criteria for stability
- Stream functions are not simply a product of stable equilibrium
- And restoration is not just creating stable channels.

It's going to be lonely without Lane, but it's time to move on.

We're breaking up.

Splitsville!



Breaking up is never easy. But the sadness won't last forever. We'll be better off in the long run. But more importantly, so will our streams.

And just in case you are wondering, Lane and I are still friends. We have nothing against Lane's Balance. We just have to stop pretending it means more than it does.

Disequilibrium is not unnatural.

It's OK to be out of balance.

Embrace your dynamic self.

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