Listening to the Data

Non-Linear Concepts in Coastal Processes and Data Analytics

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Listening to the Data

- What's my motivation?
  - Share perspective on frequent themes in recent work
  - Illustrate ideas with examples
- Who is this talk for?
  - Practitioners - Coastal Managers – Science!
  - Refresher for some and knowledge builder for others
- What are we going to cover?
  - Linear and Non-linear concepts
  - Non-linear trends in data as they apply to coastal processes
  - Examples
  - Take home messages

How *DO* you measure coastal erosion?

- Cubic yards per year
  - volume over time
- Cubic yards per foot
  - volume over distance

- Focus on volume over time
  - What does it represent?
  - Dependent on system being analyzed

-If I were to ask you how you measure erosion – most of us would probably come up with an answer that includes cubic yards per year.
-some might say cubic yards per foot.
-in this talk we will focus on the time aspect, but already we can see that there are different ways to think about erosion.

What's in a name?

$$rate = \frac{measured\ volume\ change}{time\ between\ surveys}$$

- Cubic Yards per Year
  - Volume change over any period of time

-We use cubic yards per year as a common measure for comparison, but it actually represents any change in volume over any period of time.
-unfortunately I think it sometimes leads us into thinking of a fixed amount that we expect to change every year after year after year ..
- But we also know that this is not the case.

What's in a name?

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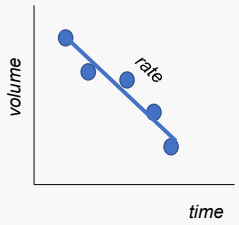
- Cubic Yards per Year
  - Volume change over any period of time
  - An average of change measured over several years



-erosion varies from year to year due to the random nature of the forces that act on the shoreline

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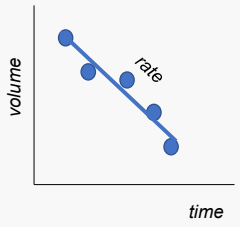
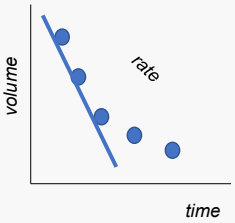
  - Volume change over any period of time
  - An average of change measured over several years
  - The instantaneous rate of change on a curve





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-and we also know that rates of erosion change over time in ways that are not linear, but are knowable.

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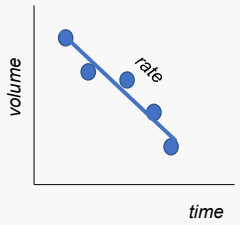

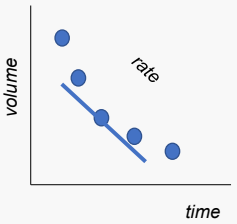

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-the rate changes as we move along a curve

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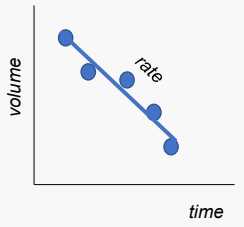

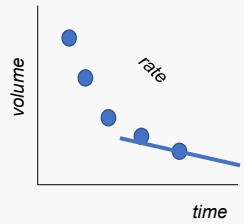

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-and the end rate is much different from initial rates
-it's essential to keep this in mind when designing and making recommendations.

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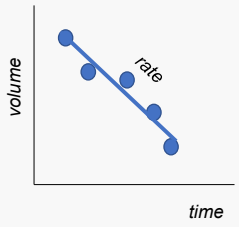
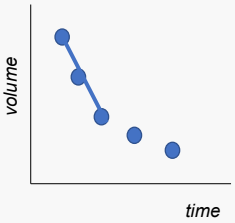
  - The instantaneous rate of change on a curve
    - Approximate by change over short intervals





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-it is also possible to approximate this curve with short segments.

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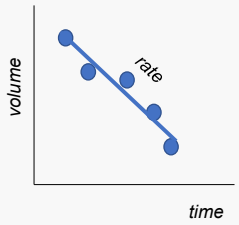

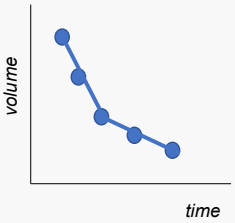

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-which provides a better model of what has occurred …

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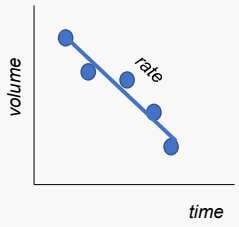

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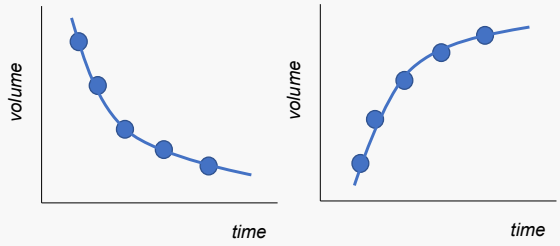
… than a straight line
-we can see, this is not a good model and does not point us in the right direction going forward.

Sources and Sinks

- All transient coastal processes behave in non-linear ways
- Driven by gradients, differences in energy dissipation
  - Inlet and shoal dynamics
  - Beach nourishment response
  - Moving toward more stable conditions
- One way to think about it:
  - sources and sinks



-we know that essentially all coastal processes behave in non-linear ways
-that's because they are driven by gradients, differences in the dissipation of energy over time and space.
-this is especially true for inlet and shoal systems, the best example being dredging of an inlet or when a new stable inlet is formed, the shoal will grow rapidly or the channel will fill rapidly at first after dredging, then the rate will slow over time.
-We also see it in beach nourishment, where erosion is highest in the initial response, followed by reduced rates of loss in later years.
-The way that I find helpful to think about this is as sources and sinks.
-in all cases, the system is moving back toward a new, and more stable condition

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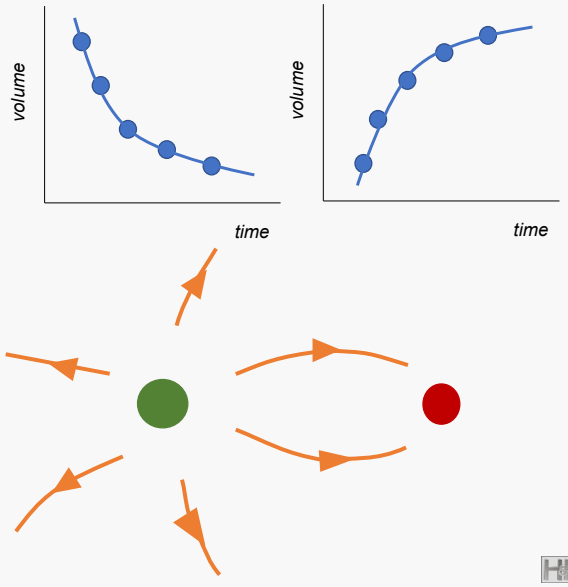

-if we think about a source (green) and a sink (red) that are in some sort of balance, we might have relatively small rates of change occurring

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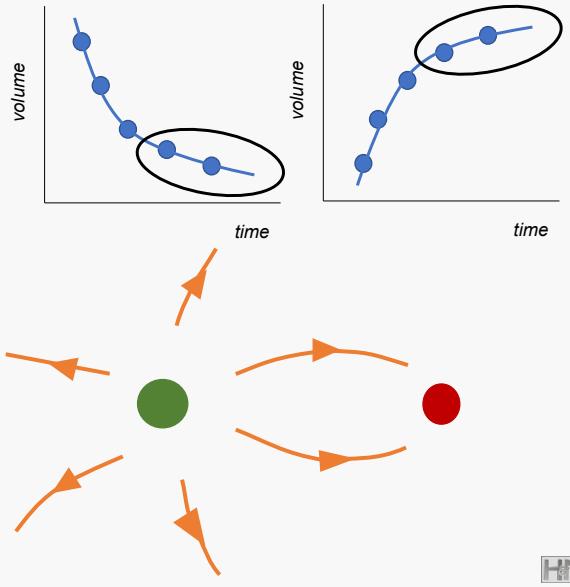

-like in this part of the curve.

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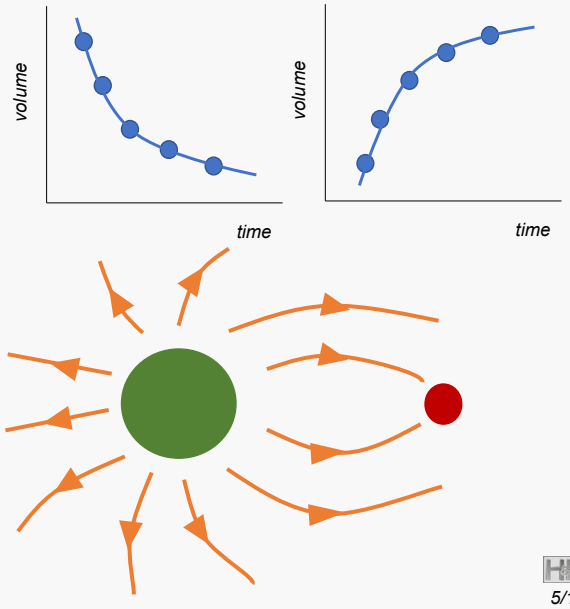

Now if we increase the source – we can think of that source as "pushing" more toward the sink

If you are near a large nourishment project, you can expect that sediment to come your way …

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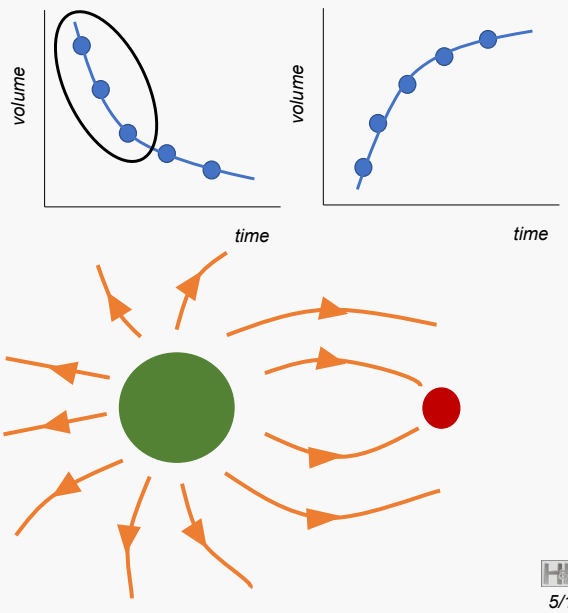

Quickly at first, then slowing over time

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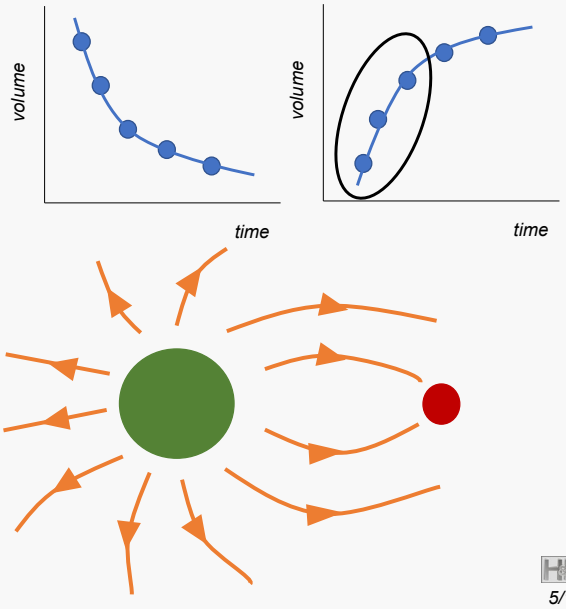

This is experienced as a rapid rise in volume at the sink

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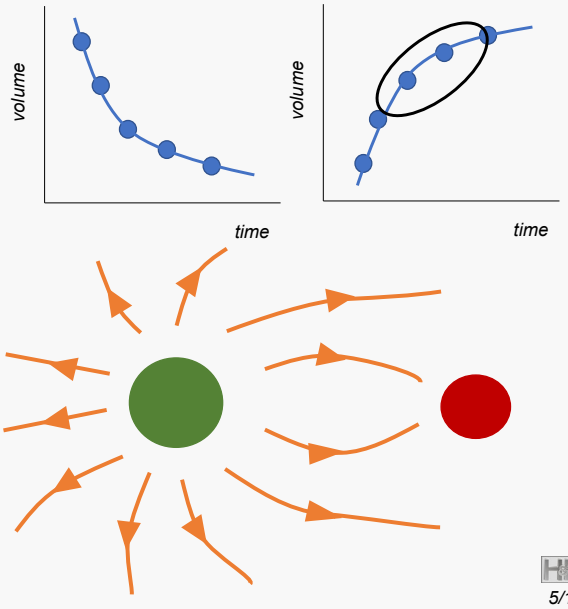

Also slowing over time.

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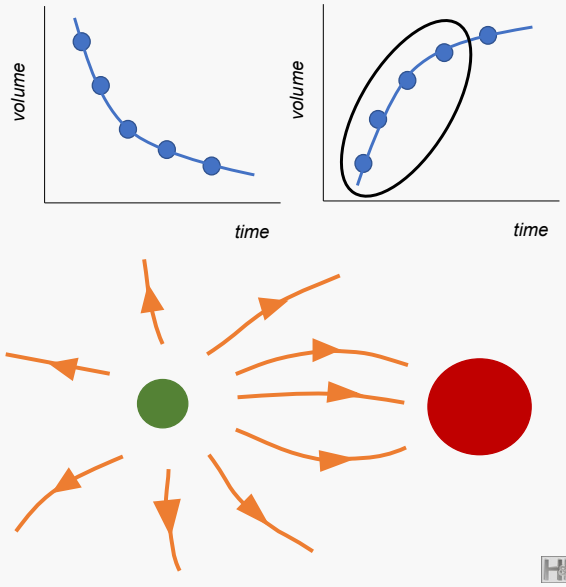

The same is true if we increase the sink by, say, dredging, at first we see rapid changes as the dredged area retains sediment that would otherwise recirculate or bypass
-we can think of this as a “pull” even though that is not technically what is happening
-and all that sediment has to come from somewhere …

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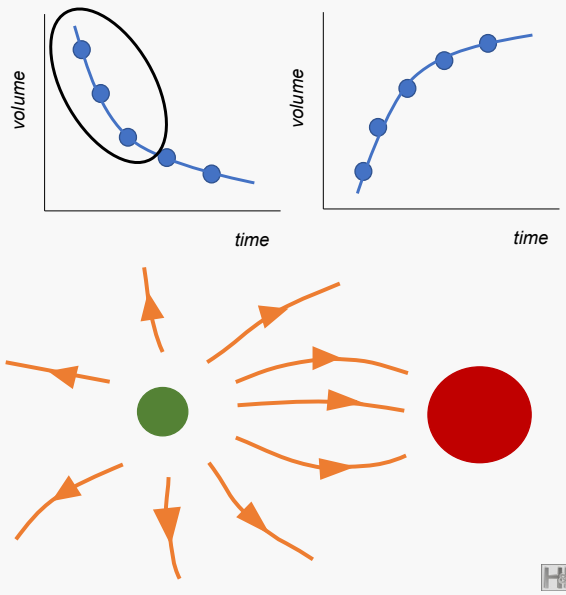

… which is likely to be the adjacent beaches and other shoal features.

Sources and Sinks

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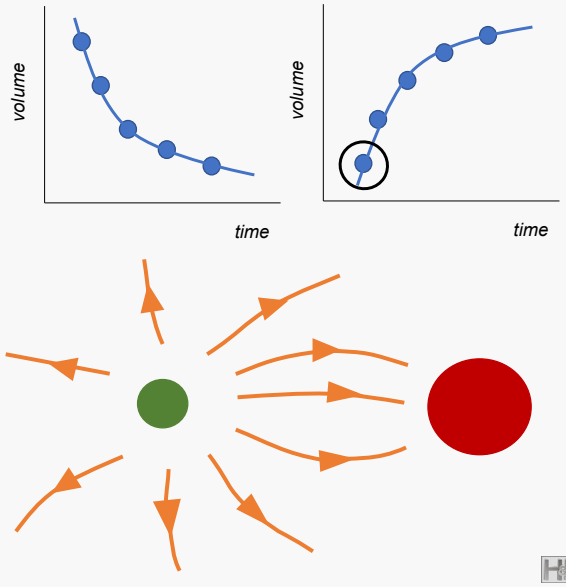
  - Beach nourishment response
  - Moving toward more stable conditions
- One way to think about it:
  - sources and sinks
- How do we know where we are on the curve?



So as we think about our designs and recommendations, it's important to understand where we are on the curve

Sources and Sinks

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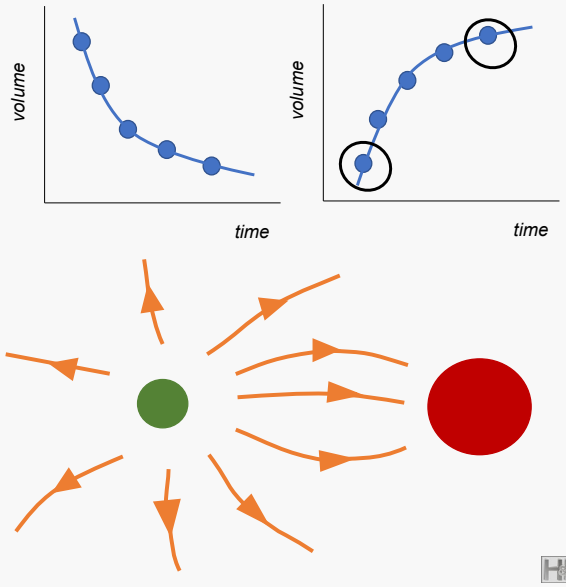

- And where our proposed activity may put us on the curve.

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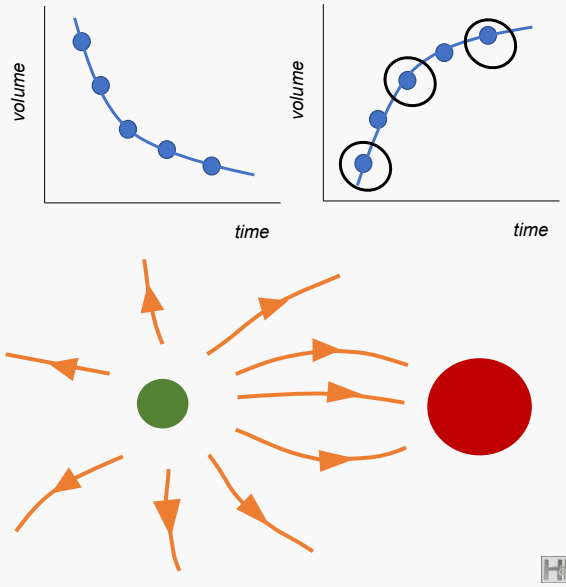

How far will we be moving from the current conditions, and which way will we be going - There are two factors to consider

Sources and Sinks

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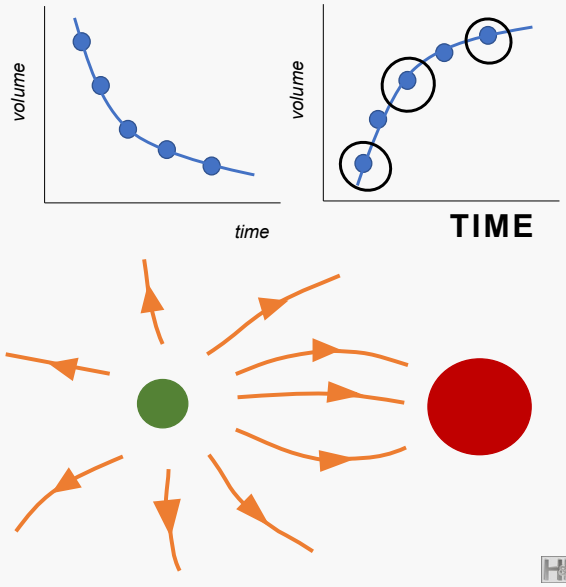
- One way to think about it:
  - sources and sinks
- How do we know where we are on the curve?
  - **TIME**



One is time – how long has it been since the disturbance

Sources and Sinks

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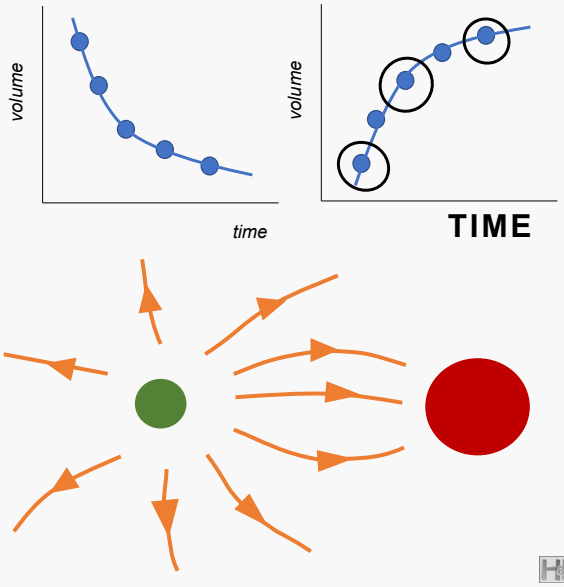
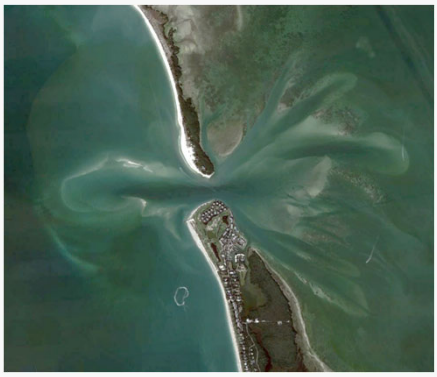
- One way to think about it:
  - sources and sinks
- How do we know where we are on the curve?
  - **TIME**
  - Where are you in the process?
  - How significant is the imbalance?



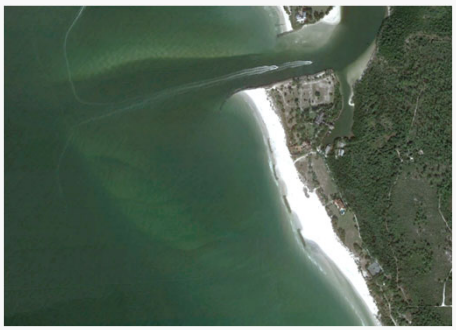
And the other is severity.
How significant was the change
More significant changes can be expected to have longer lasting effects.

Inlets and Adjacent Beaches

Ebb Shoal Growth
and Adjustment



Fill Placement
Downdrift of Inlets



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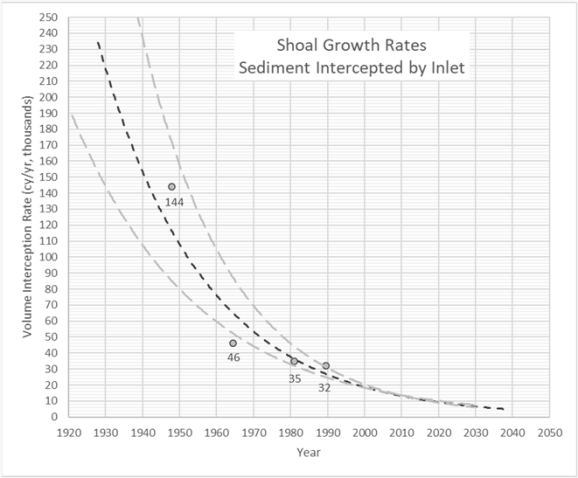
So for a quick re-cap:
Coastal processes are non-linear
– we can think about this as sources and sinks, or pushes and pulls
-it is important to know where we are on the curve, so we can know where we are headed
-next up are two examples where non-linear effects and push and pull come into play.
-first is an example of a sink as a result of formation of an inlet and dredging at an ebb shoal
-then an example where both the source and the sink were involved, with fill placement downdrift of an inlet.

Ebb Shoal Dynamics

- Opened in 1920s
- Natural Evolution to 1980s

1880s

1970s



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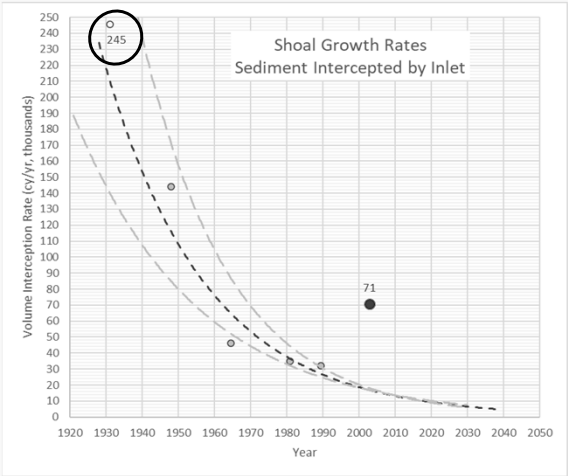
In this case the ebb shoal is at Redfish pass, which opened in the 1920's.
Building on the work of others, it is possible to put together the volume change rates for the ebb shoal over certain short periods of time and fit a trendline (the black line in the center)
This is a simple exponential function, but it actually works quite well.
I wanted to try something, and sure enough, if we go back and look at how much volume would have moved into the ebb shoal during that very initial period between when the inlet opened and the beginning of this record, which started in the 1940's …

Ebb Shoal Dynamics

- Opened in 1920s
- Natural Evolution to 1980s
- Verify trend with initial growth period



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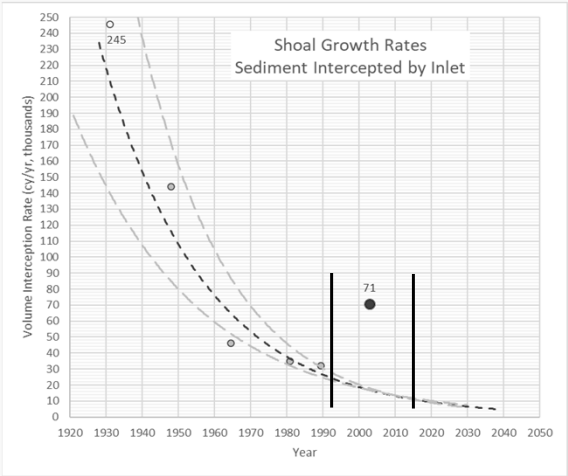
… we find that the data fits quite well. This gives me a lot more confidence in the model.
But there's also this other new datapoint that is way off the trend.

Ebb Shoal Dynamics

- Opened in 1920s
- Natural Evolution to 1980s
- Verify trend with initial growth period
- Change of pattern after dredging in 1980s



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This is the result of dredging that occurred in the 1980's and represents the period between the two black bars.

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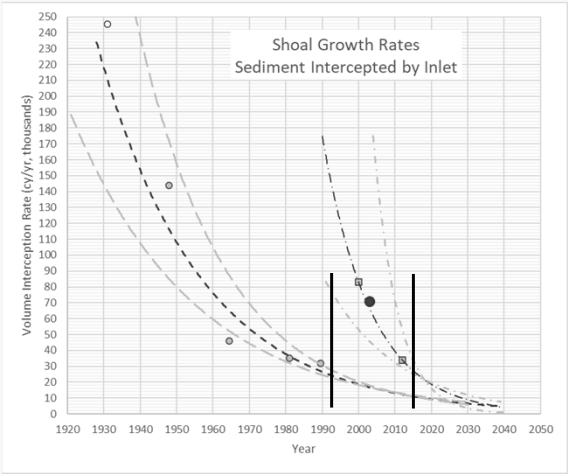
- Change of pattern after dredging in 1980s



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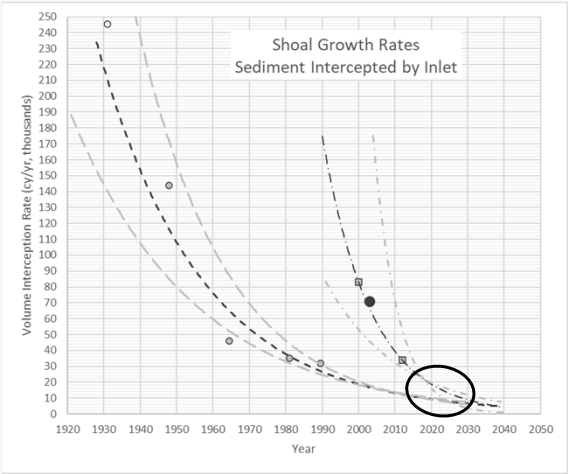
But if we do a little math, it's possible to split this period up and fit our non-linear trendline, which also drives toward the predicted line from the historic model.

Ebb Shoal Dynamics

- Opened in 1920s
- Natural Evolution to 1980s
- Verify model with initial growth period
- Change of pattern after dredging in 1980s
- In present times the gap between post-dredging curve and historic curve has narrowed and will continue to narrow if undisturbed



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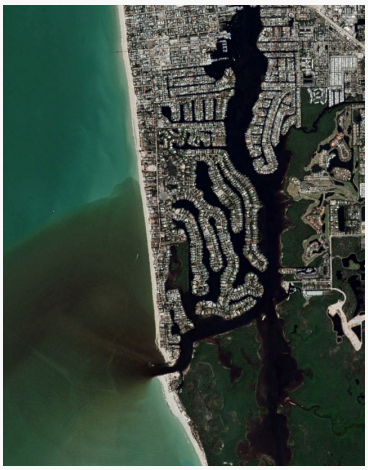
And we can see that there still remains a gap, this means that 30 to 40 years after the dredging, this shoal is still catching up. It is still trapping and retaining sediment that would otherwise have moved on.
So why does this matter?
It shows the long lasting effects of our projects and the need to be mindful of where we are on the curve, and where a project may be taking us.

Fill Placement Downdrift of an Inlet

- Gordon Pass – Inlet to Naples Bay
- 1960 - Major navigation project
  - Recurring maintenance dredging
  - Fill placement predominantly to south side
  - Consistent with net drift in the area



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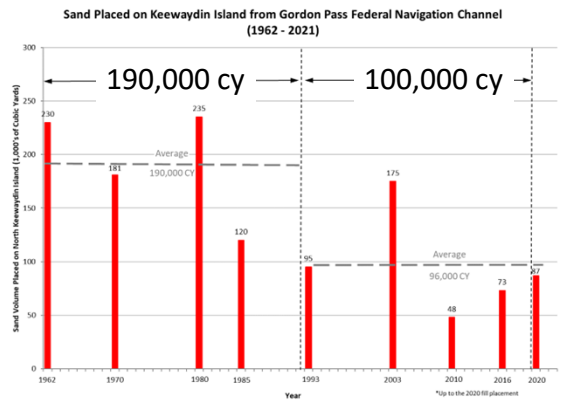
Next we have an example where both the source and the sink have changed.

Fill Placement Downdrift of an Inlet

- Gordon Pass – Inlet to Naples Bay
- 1960 - Major navigation project
  - Recurring maintenance dredging
  - Fill placement predominantly to south side
  - Consistent with net drift in the area
- Early years – large projects
- Recent years – smaller projects
- Reduced source – same sink
- Near Stable -> Erosional



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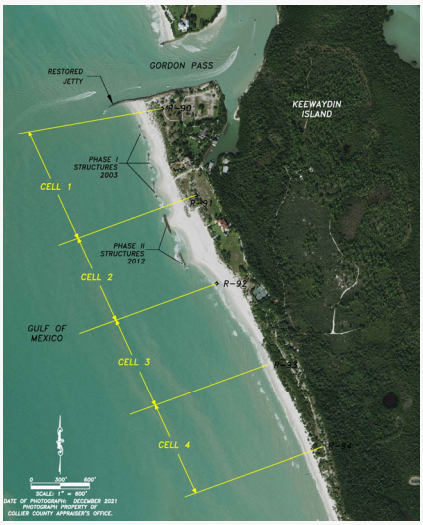
- With all of this, a more or less stable shoreline became erosional

Fill Placement Downdrift of an Inlet

- Construction of Erosion Control Structures
  - Phase I - 2003 – Cell 1
  - Phase II - 2012/13 – Cell 2



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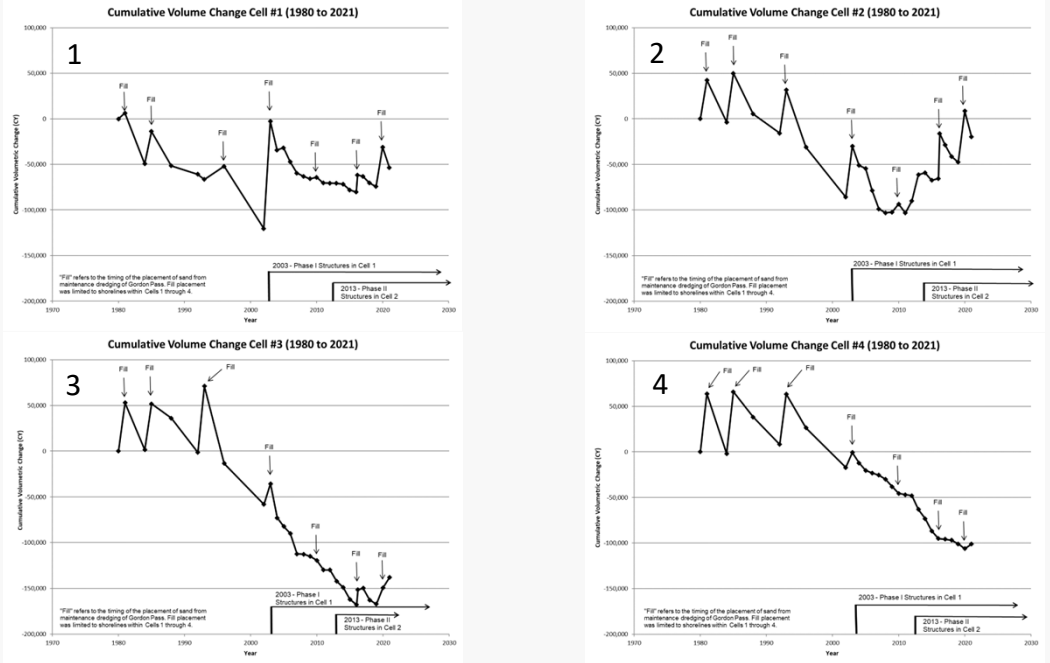
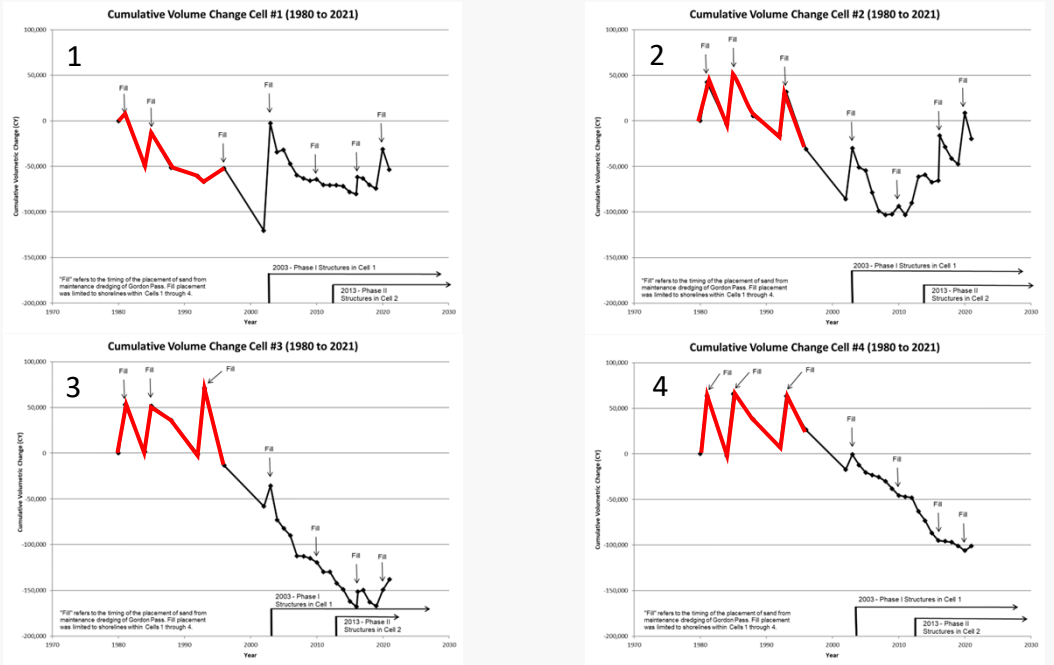
In response, permeable erosion control structures were installed, first in 2003, then in 2013



13/15

- The way that I like to look at this, is as volume in place in each cell over time relative to an arbitrary datum. In this case, pre-fill 1980.

EXAMPLE: FILL PLACEMENT



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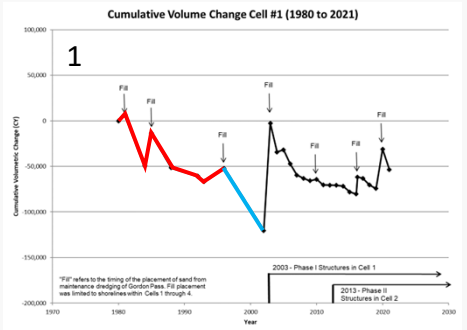
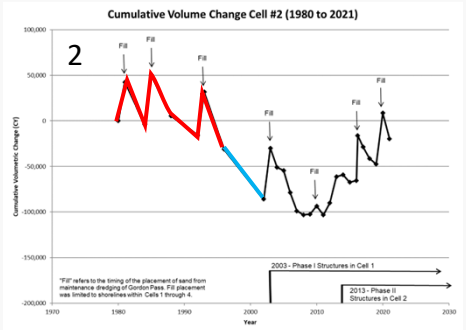
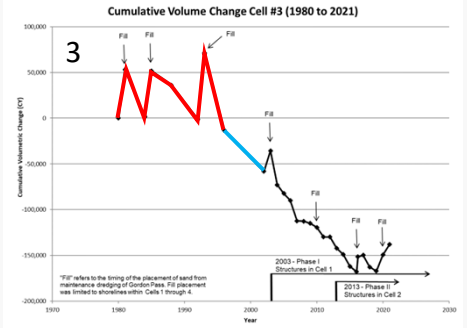
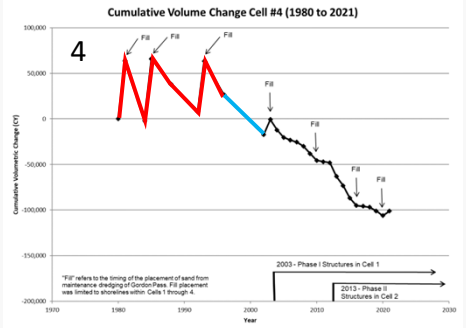
- We can see that in the initial years, fill placement roughly matches erosion. Good. This results in a near stable shore condition.



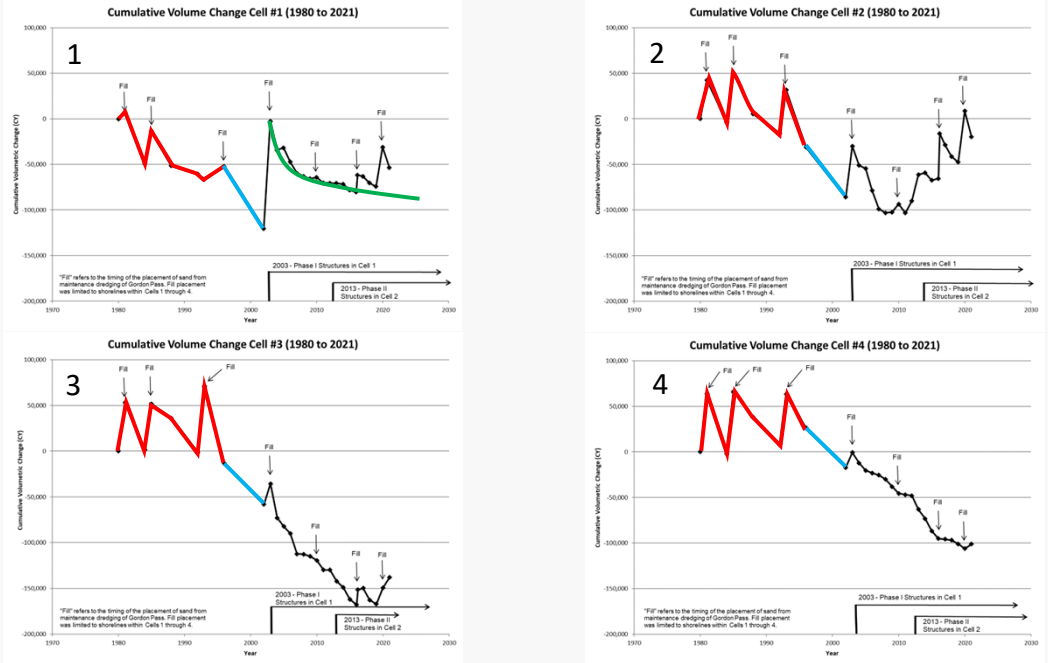






However, as soon as the project size decreases, we enter a slide, with volume losses across all 4 cells.

EXAMPLE: FILL PLACEMENT



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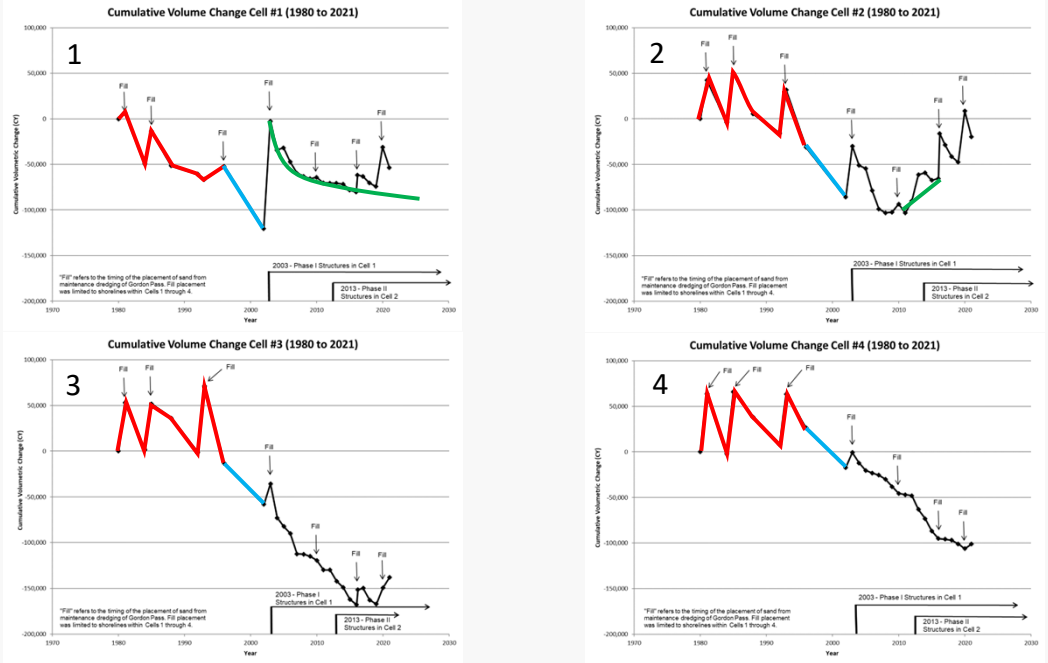
But beginning in 2003, with the permeable structures that were constructed in Cell 1, the erosion stresses are reduced in cell one, which reduces the sink (the losses to downdrift beaches) bringing it more into line with the available source.

-we can see the non-linear response as the shoreline moves toward its new balanced condition

- We can also see that subsequent fill projects tend back toward that new equilibrium



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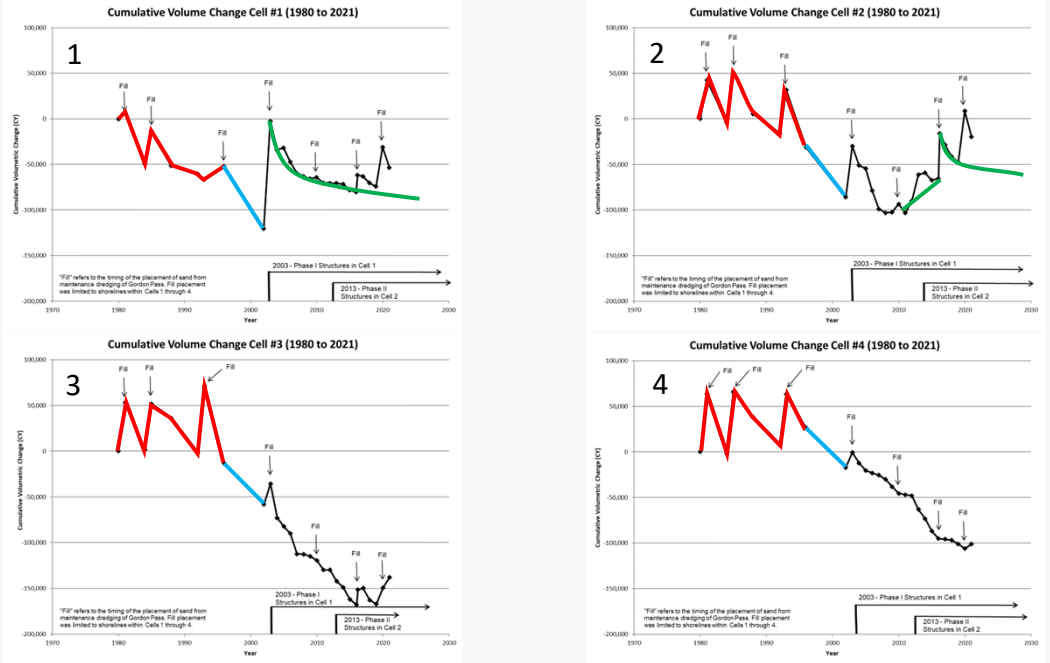
- When we look at cell 2 – those erosion control structures were built between fill events, and we see the shore respond to the reduced sink (the reduction in erosion stresses) by increasing in volume.



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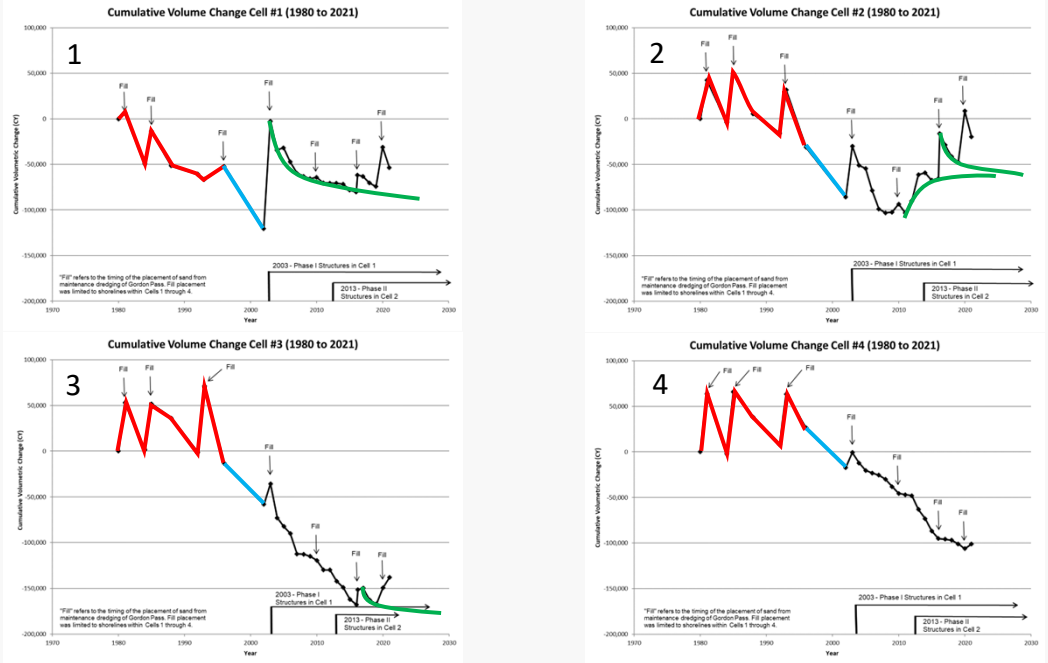
We also see that after fill, the non-linear response appears to tend toward a similar volume, that new balanced condition.



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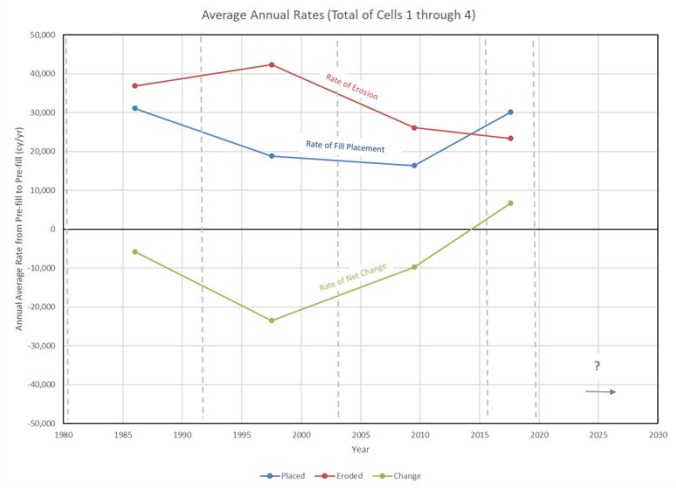
And although it's a little early, it looks like Cell 3 is also going to maybe tend toward a balanced condition, setting up that non-linear response.

Interaction Between Fill and Erosion

- Summarizing the data
- Fill Placement
  - Not in our hands – USACE
- Erosion
  - Natural processes
  - Modified to:
    - Establish equilibrium
    - Reduce total erosion
    - Enable future dredge sediment to be placed in adjacent areas of lower erosion stress



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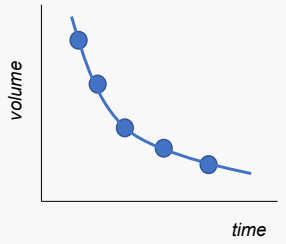
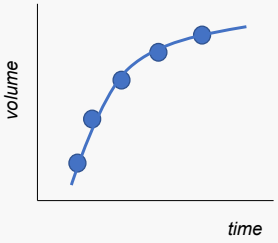
This is an example of the interaction between fill and erosion - source and sink.
This graph shows rates of erosion (red line), and rates of fill placement (blue line), taken from adding up all of the annual changes across all four cells.
It shows an initial period where erosion and fill placement are similar, and there is minimal net change, shown by the green line at bottom.
The second set of dots from the left show the reduced rate of fill placement, but continued and somewhat elevated erosion.
Then after 2003, at the third set of dots, we see the reduction in erosion due to construction of the permeable erosion control structures, and the corresponding reduction in net change.
In recent times the fill placement has increased, while the rate of erosion remains low.
This has allowed a slight reversal into slight gains at the now stable beach.

Summary

- Volume change as an annual rate (cy/yr) is often an approximation of a non-linear response
  - sources and sinks
- Non-linearity is dependent on timescale and progress
  - Where are you on the curve?
  - How long is it going to take to get where you want to go?
  - Can we modify the curve?
  - What happens if we modify the curve?





EXAMPLE: FILL PLACEMENT