The Slope of the Building Site

And why it matters so much

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To Begin, We Need Some Background Information That is Pertinent to this Discussion

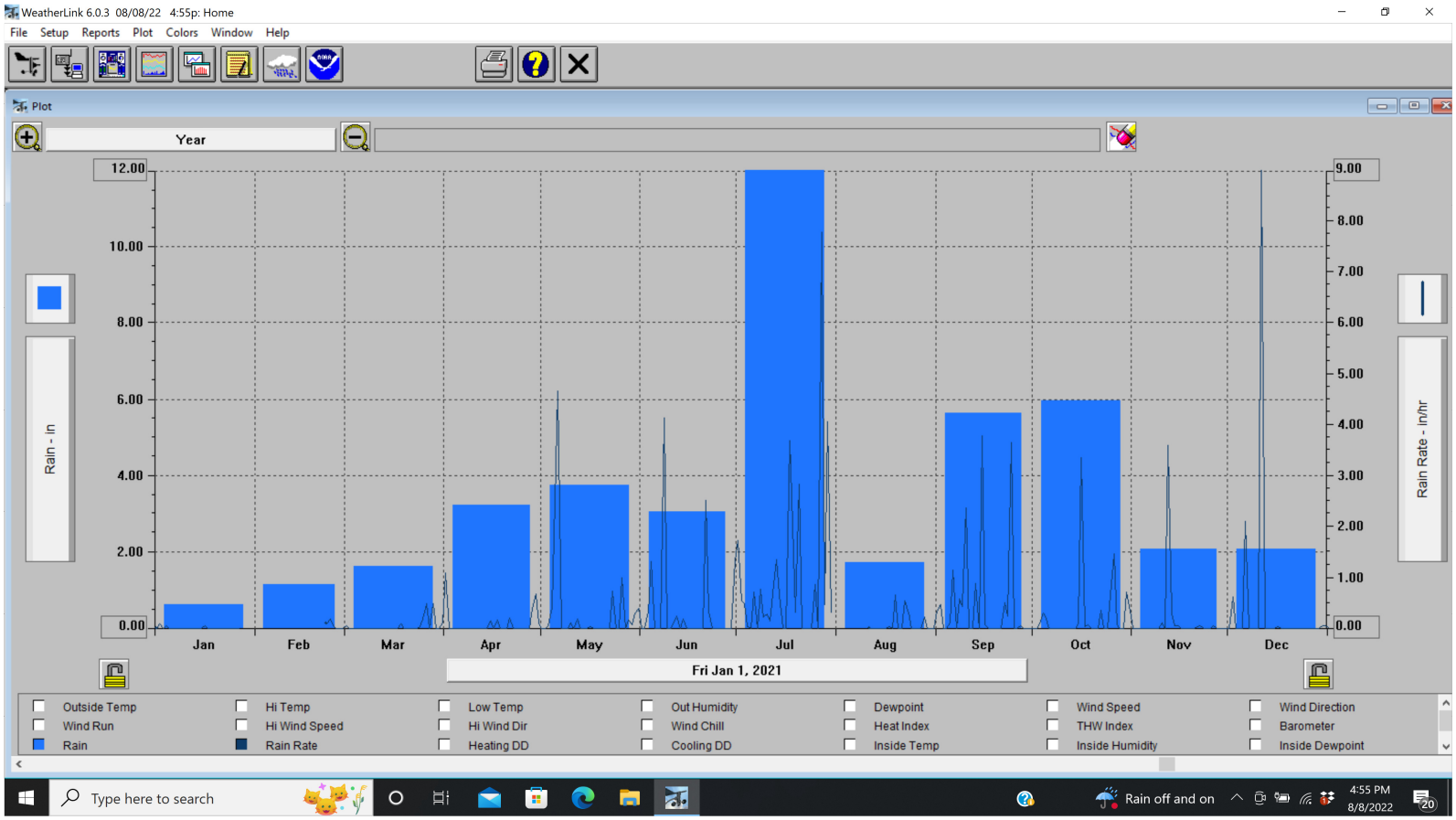
2021 Was a Relatively Rainy Year. Especially in July.

This is a graph from my weather station

By the end of July, the ground all around Windham was mostly saturated

On July 29th we received over 7 inches of rain over a 10-hour period

So, What Happened?



Culvert and Bridge over Wheeler Brook on 03Aug2021
Location: approx. 0.25 mile downhill from Distefano Property

The rainstorm on July 29th dislodged the 4’ diameter culvert and created a new branch of Wheeler Brook down the right side of the road. I believe it took approximately 2 months to repair

So, what caused the failure?

- Wheeler Brook drains a large area of land.
- The ground was saturated and could not hold any more water.
- The flood plain of the brook filled up with what appears to be 3 or 4 feet of rushing water.
- The volume of water sent downstream overwhelmed the capability of the culvert.
- Water backed up in front of the culvert. This was aggravated by natural debris that had been carried downstream that was too large to travel through the culvert.
- Water built up so much that it formed a new branch of the brook on the right side of Wheeler Road
- Ultimately the water pressure and momentum blew out the culvert.
- This failure likely occurred within a second. If a car had been on the bridge at that moment, the occupants would would likely have been injured or killed. The car, no-doubt would have been destroyed.

Wheeler Brook Today with an approx. 6’ Diameter Culvert Waiting for the Next Big Rain Event

Will this New Culvert Survive the Next Big Rainstorm?

That Depends-

- How saturated is the land?
- How fast does the rain come down?
- How long will the rain event will last?
- How much debris gets washed down the brook?

Picture is of approx. 16” diameter cut logs rolled down into the Wheeler Brook flood zone below the building site. Another longer log is sitting above

Next time the flood zone fills up with 3’ of rapidly flowing water (and there will be a next time), these logs may very well attempt to flow through the culvert

We can’t do anything about natural debris, but when mankind enters the picture, we inevitably alter the environment

This won’t help

So, what's my point? And where am I going with this?

It's all about the slope of the terrain, the nature of flowing water, and the potential of severe erosion on steep inclines

- Erosion is caused by the momentum of flowing water
- Momentum in simplest terms is equal to Mass X Velocity. And it's important. A bug smacking into you at 30 mph will sting your skin. A bus will kill you.
- When the momentum of flowing water is high enough it will cause erosion if the ground isn't held in place by a network of root systems that cling to the soil.
- We can't control the mass part of the equation. That's determined by the amount of rainfall over a given period of time that can no longer be absorbed by the ground.
- The only thing we can control, on developed property, is the velocity of the runoff, and that's where slope becomes so important because as water flows downhill, its velocity is always increasing under the acceleration of gravity. Higher slope angles produce faster flow rates than shallow angles for a given distance of travel
- Ultimately, flooding and erosion is all about how fast and much water is shed off a piece of developed property in a given period of time.
- Constructing structures on sloped property only aggravates the flooding potential because structures are incapable of absorbing rainwater the way that natural soil and vegetation does.
- So, all we can do, is hopefully keep the water velocity under control to prevent erosion and slow the transfer of water into our brooks.
- For once erosion begins, the debris it picks up (soil, trees, or whatever) only adds to the mass of the flow field, which further increases the momentum. Think of it as a snowball rolling down a hill, getting larger and larger. And if you think of a log flowing down a flooded brook at 15 mph, it also has a lot of momentum. You wouldn't want to hit get by it.

The 20% Grade Requirement

- This is a common municipal zoning requirement, based on observations over many decades throughout the country
  - Development on land with slopes greater than 20% experience more issues with respect to erosion
  - The erosion potential is increased when impervious structures on that slope occupy a greater percentage of the property in relation to its natural state
- The way Windham's 20% grade requirement is stated, development of any type is prohibited on land that has a 20% or larger grade. That means you're not supposed to mess with it, and if you do, it's forever altered
- It's supposed to be used as a "Go/No-Decision" in the question of developing a piece of property. Once a piece of property has been developed, it's too late to go back and measure the slope "in it's natural state"
- Hence, once a piece of property has been altered by earth moving equipment, the only way to determine the percent grade in the undeveloped state is to use topographical maps
- Question: **If my property is sitting on a slope with greater than a 20% grade does that mean I can't develop it?**
  - From a legal standpoint, the way the law is currently written: Yes, you can't legally develop it.
  - From an engineering standpoint, with respect to executing a calculated design to minimize the risk of erosion and instability: No……but it <u>will</u> cost more
  - Civil Engineers can plan property development, even on relatively steep slopes to minimize risk by using
    - Retention ponds
    - Terraced slopes
    - Protective Walls

Well, How Does One Measure Slope on Hilly Terrain?

Good Question

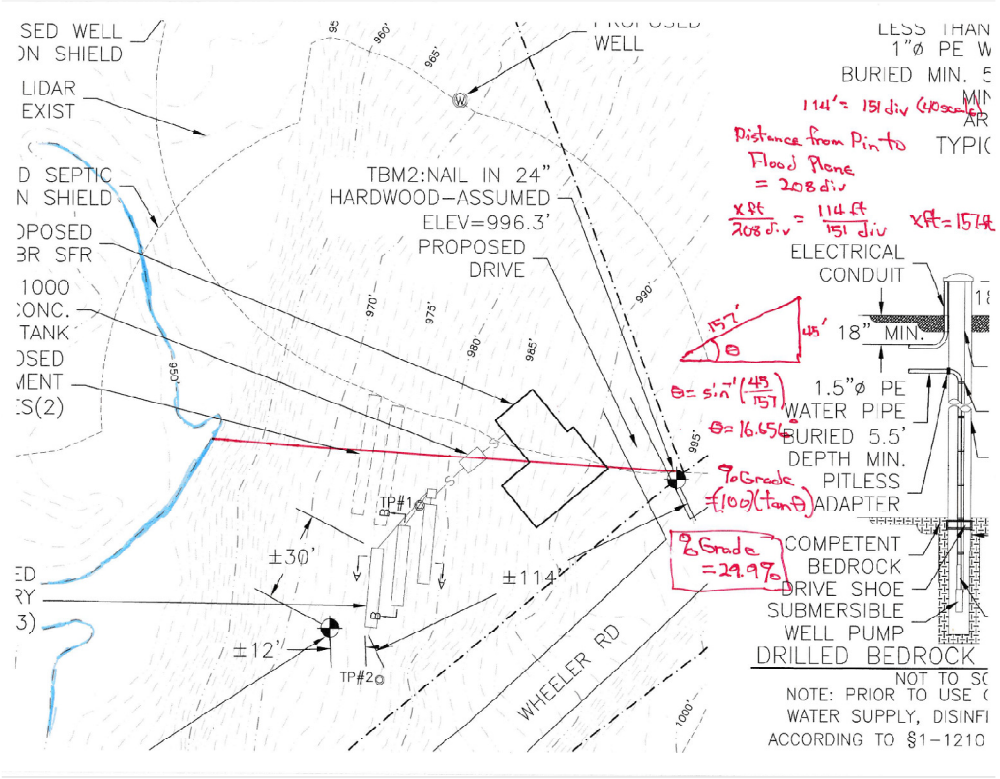
- Most municipalities do not specify a means to quantify slope on a piece of property. Though some do.
- It's not a one-sized fits all type of problem because every property is different, and the topography of many, if not most, pieces of property can be complex
- However, the topography of property in question is relatively simple, as we shall see. It sits on the side of a hill that leads down to a brook, and the slope of the hill is relatively constant.
- From a mathematical standpoint, if the slope the slope of a hill is constant, that means we're measuring the slope of a line. That's an easy case to measure because the slope on a line is the same no mater where you measure it.
- But slopes generally aren't constant, and that's where measurements get more complicated.
- Engineers live with the adage, "If in doubt, average"
  - In the past, if a slope looked questionable, a crew would go to the site and take multiple angular measurements across the site, as well as downstream (remember the water has to go somewhere)
  - The average slope would be computed and the standard deviation of the measurements would be calculated
  - If the Std Dev, is too high to have confidence in the measurements, the crew would go out make more measurements, until the Std Dev was low enough to have confidence in the average.
  - That "average" becomes the percent grade for the site
- It's not elegant but it's better than nothing

This is the slide from the first hearing that caused so much confusion and controversy

It was simply a first-order estimate of the slope going down the side of the hill to Wheeler Brook

It was based on all of the considerations I've brought up-

- The slope of the **entire** site (hillside) leading to the brook is what's important
- The relative straightness of the contours tells me the hillside is mostly planar
- Hence, additional measurements along each side of the foundation will yield a similar answer

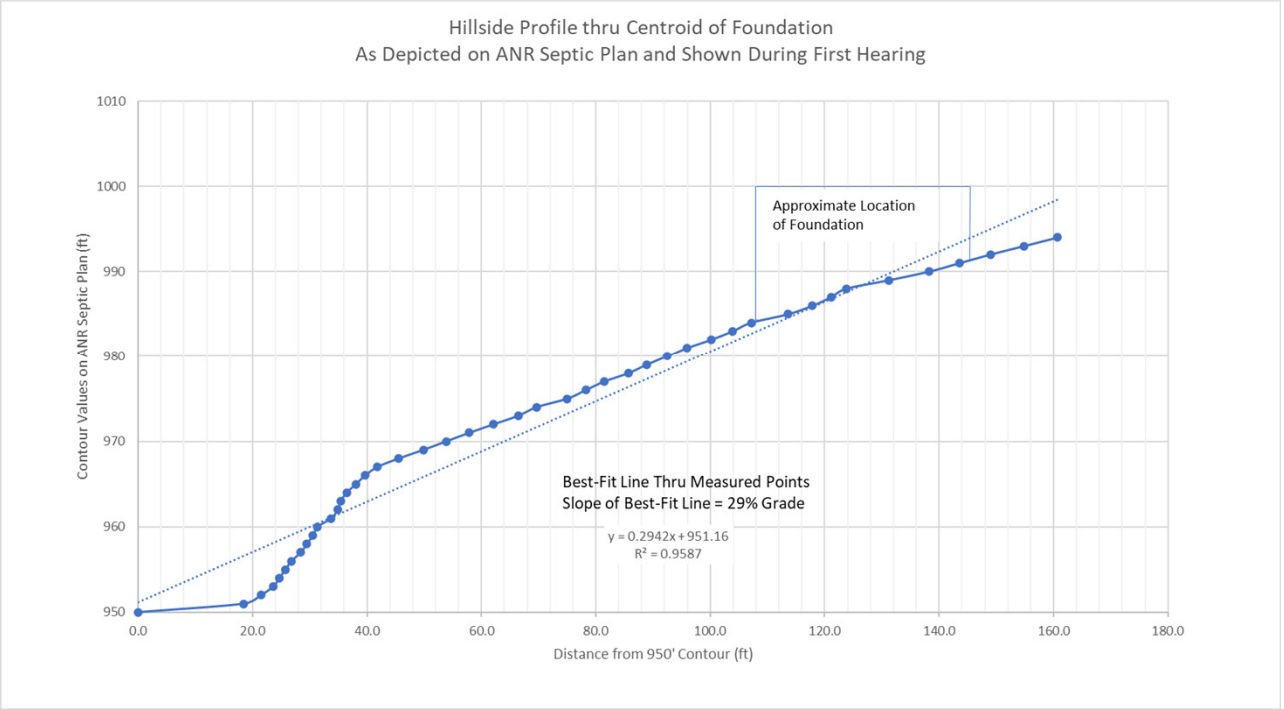


Here's another look at the data from another perspective (a cross-section of the site)

This is a more elegant approach

- A best-fit line is calculated from the data
- That's another way of coming up with an average slope
- The correlation coefficient (R squared) is at .95 indicating it is a reasonably good approximation of the slope

And guess what?
The answer is the same that I came up with my crude measurement of the topo map



But still, it's not perfect. No measurement in engineering is perfect. There are no absolutes, but the laws of physics. But as engineers, we always strive to do better, as the next slide will show

Here's Is Another Way To Calculate Slope On a Terrain

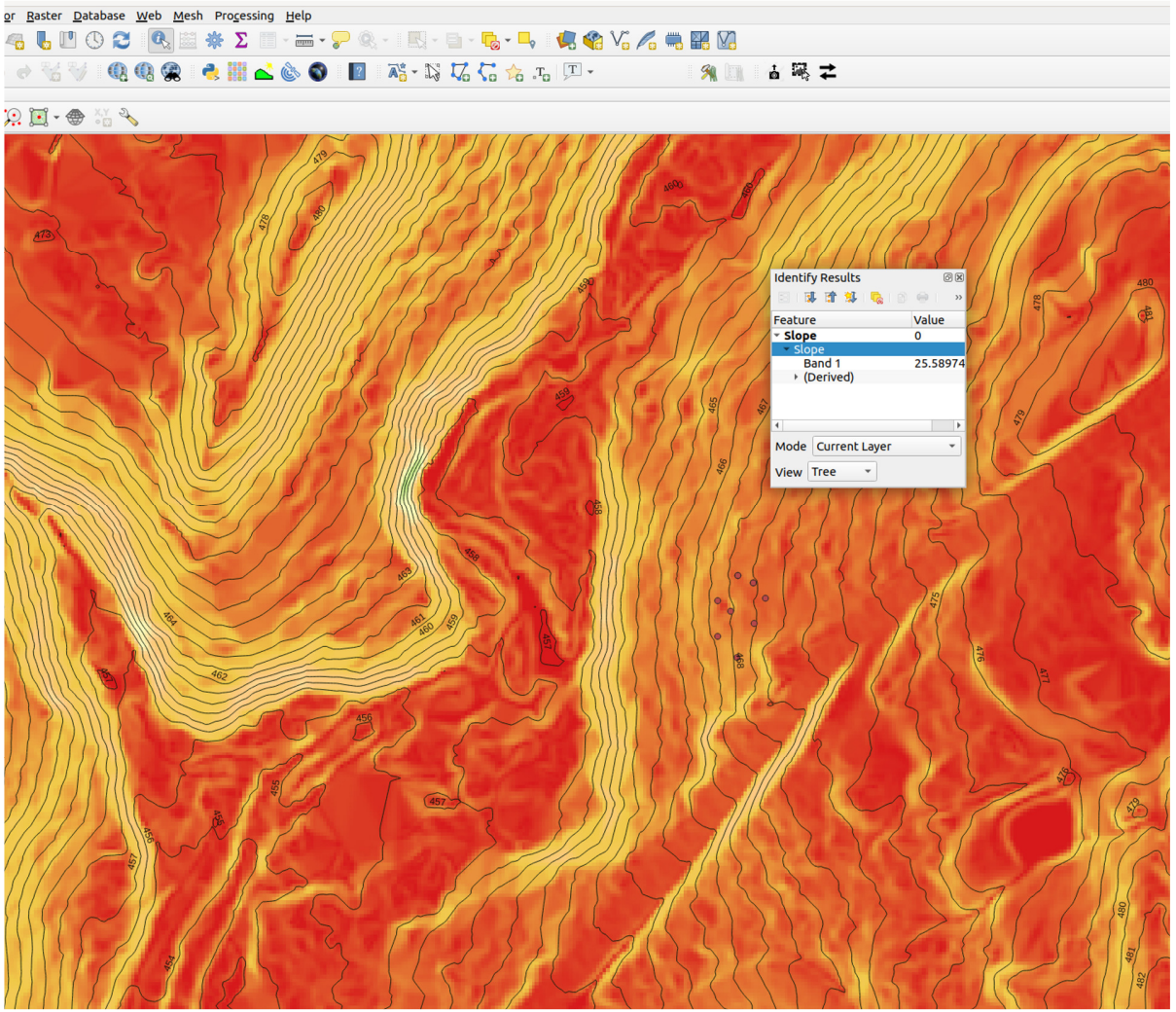
Enter The Digital Domain: QGIS. Geospatial Information Software. Think of it as Google Earth On Steroids

This is a topographical map of the building site near Wheeler Brook

- The elevations are expressed in meters
- The contour lines are spaced at 1-meter intervals
- The little dots are the GPS coordinates of the foundation corners

But what are the colors? Well, they represent the slope of the terrain wherever they lie

- Red is relatively flat
- Yellow is steep
- And that green is occasionally a waterfall in heavy rain events



Can you tell where the Wheeler Brook Flood Plain Is?

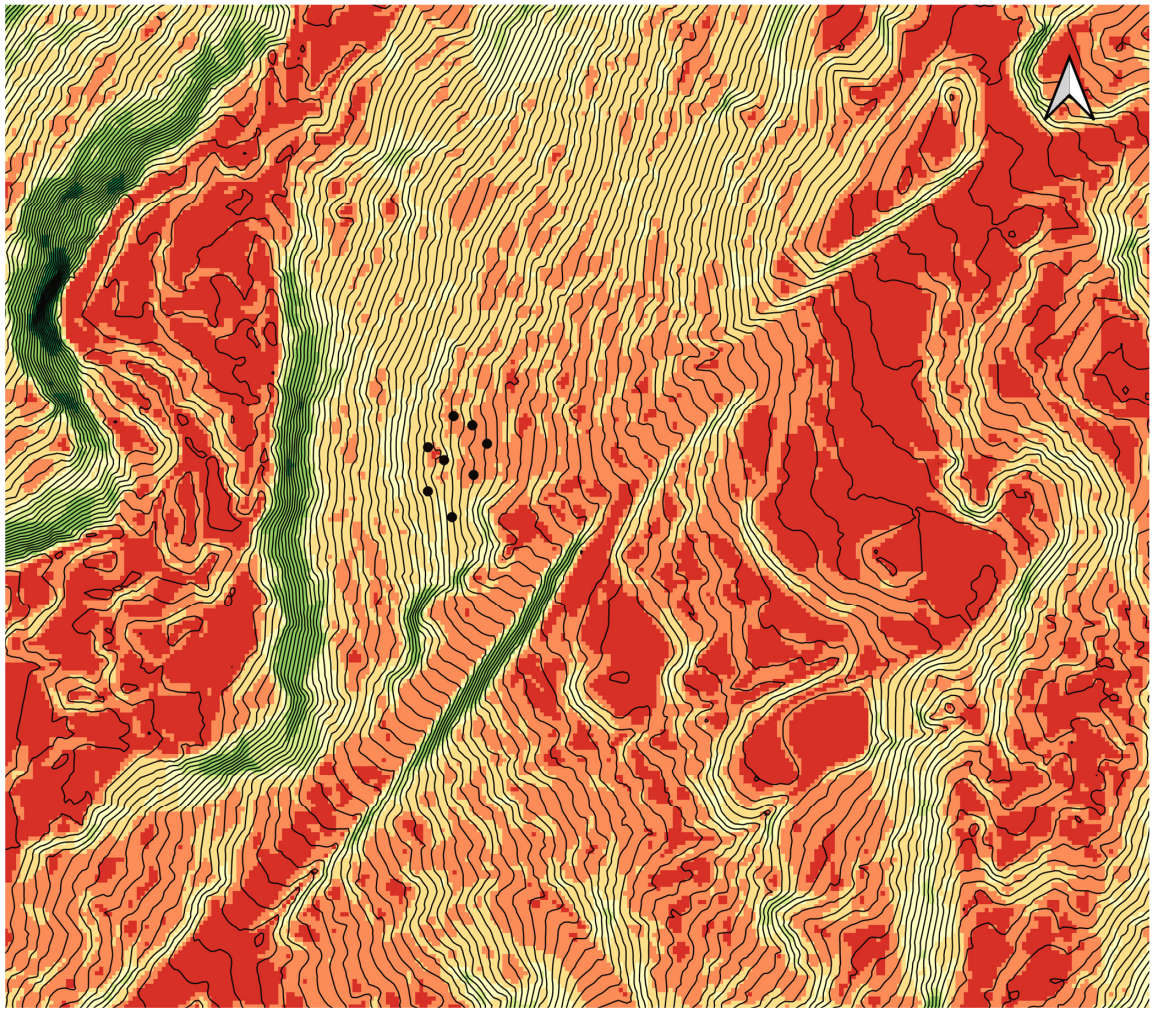
This is another plot of the homesite except this time

- The contours are set a 1-ft increments.
- The slope of the homesite is now quantified in percent grade

This is truly a civil engineer's dream tool (although it has steep learning curve)

So what is the area that we're concerned with?
If you've been following along you should realize it's the entire area around the foundation down to the brook. It's the developed part of the hillside.

And yes, the grade going downhill on the hillside is above 20%



Concluding Remarks (finally!)

A letter to F. Seawright sent on Aug 7, 2022

I guess it depends on how much time we are allotted. I do want to refer to the Kentucky floods, but I won't be surprised if I get shut down. If you get a chance to speak, I would love for you to add your two-cents worth with respect to what has happened in Kentucky, and how their situation is similar to ours. It should be a stark warning for us. People have got to realize that all the water that flows out of Windham, including our crap, silt, and whatever else that makes it to the brooks, flows past somebody else downstream, all the way to the ocean. We have a responsibility to more people than just ourselves when it comes to protecting the environment. Our brooks and streams are the headwaters, and water never gets purer as it flows downstream. If we build structures on hilly terrain without doing due diligence, the results can be disastrous in the valleys below us.

I know there is a great desire for people to move to Windham so that we can be a "real" community again, but if we let people blindly whittle away at our hillsides, we are not only inviting disaster, we will be morally at fault for enabling it. Back in February, in one of my early emails to town officials as well as ANR, I told them that a civil engineer needs to look at the site and design a plan to prevent that hillside from sloughing off into Wheeler Brook. I told them that there are multiple methods that a CE can use to minimize the risk, such as a retention pond that could be excavated and backed up with large boulders from the quarry. But that would cost money. What most people don't seem to understand is that if you build on property with excessive slope, you will need to spend more money to ensure you don't screw up the environment for both you, your neighbors, and those downstream from you. Whether that puts too high of a price tag on our "affordable housing" dream promoted by the town leaders remains to be seen, but no matter what, in the long run, you can't have your cake and eat it too. It comes down to a choice to either preserve our environment in a deliberate, equitable, and engineered manner, or piss it all away. P