Coach Grades and Gradients

Coach files are a series of short lessons, each for a Road Scholar topic. Most started out as responses to questions from coaches. They are rough notes- maybe refined, maybe not. Questions and answers are from various events. You will be seeing Mapscans (screen grabs) from various USGS maps and some from AAA Road Maps. It's always better to have the whole map, so I will include the name and date of the USGS Topo map that the Mapscans come from. You can get the entire map free online from USGS.gov.

Grade and gradient are both numbers that show the slope, or steepness, of a hill or stream. They are both calculated the same way but are expressed in different units.

Grade shows the slope on land and is expressed as feet of rise (or fall) per 100 feet of distance.

Gradient shows the slope of a stream/river and is expressed as feet of fall per 1,000 feet of distance.

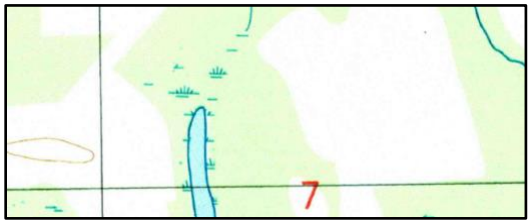
Grades on Road Maps

Roads are expensive to build, and the shortest road distance between two points is a straight line. In general, roads that curve and twist do so because of obstacles like streams or topographic features like hills. Roadways frequently follow rivers , which will show on a good road or topo map. If roads in a given area are twisty, it is an indication of hilly terrain and possible high grades on the roadway.

Slopes Without Math

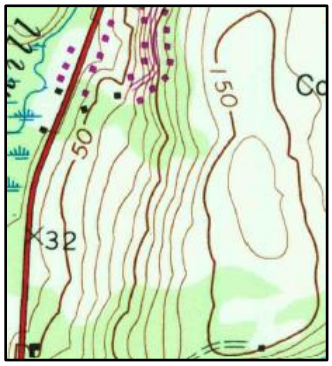
The whole point of a topographic map is to show the ups and downs of a landscape- the elevations and slopes. Contour lines close together show steep slopes.

Example 1 - Almost no contour lines- (10 ft interval). This shows land with very little slope.

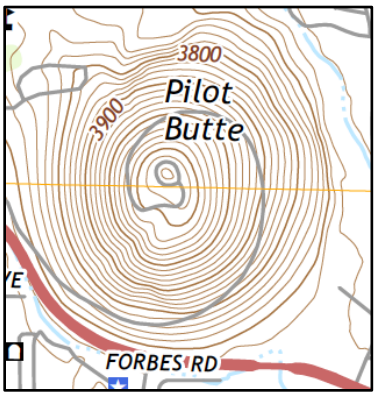


Example 2 - (10 ft interval) contour lines spaced close together shows a very steep slope.

Example 3-- (10 ft interval) contour lines further apart show a moderate slope



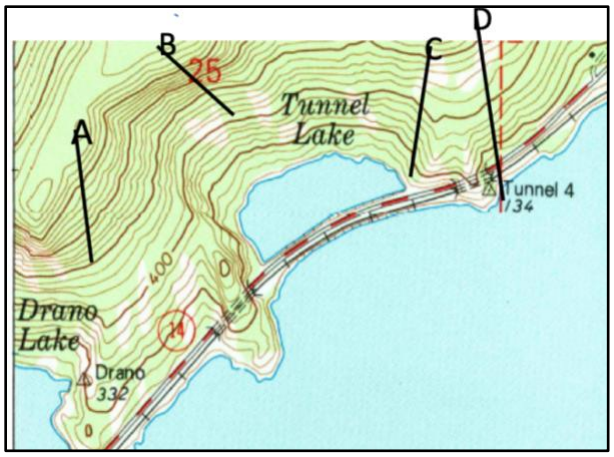
Example 4- Nice even closed contour lines (20 ft interval) with a consistent slope.
Pilot Butte is an inactive volcanic cinder cone in downtown Bend, OR. How cool is that?



Problem #1: If contour lines are very close together in an area, what does that tell us?
The area is very steep (similar)

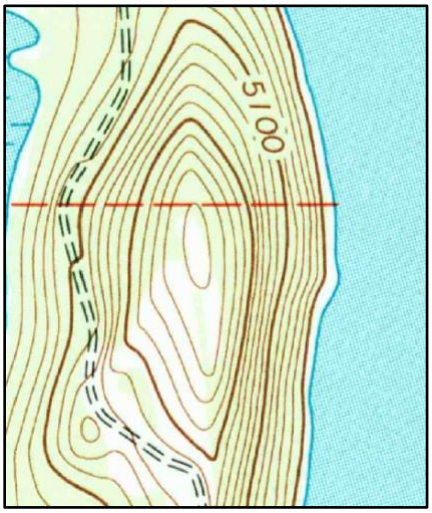
Problem #2: On the Mapscan below, which line shows the most gradual slope?
A) A B)B C)C D)D D

Problem # 3: On the Mapscan below, which line shows the steepest slope?
A) A B)B C)C D)D B



Problem # 4: Imagine yourself standing on the top of the hill shown in the Mapscan below.

In what compass direction is the steepest downhill slope?
A) North B) East C) South D) West B) East Contour lines are closest together on the East side

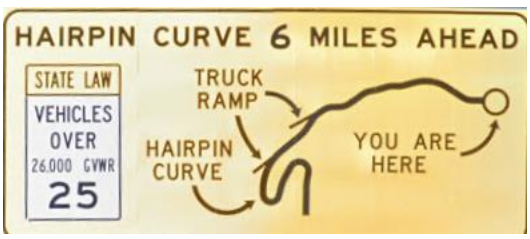


Slope/Grade On Highway Signs

Highway signs warn motorists of steep slopes ahead. Usually, such signs warn of an approaching downhill slope rather than an approaching uphill slope. Highway signs express slope as a percentage grade.

On a long or steep up-hill slope, vehicles tend to slow down because of the extra demand on engines. It may be an inconvenience, but not something dangerous. On long downhill slopes it's easy for cars, and especially trucks, to pick up too much speed. Slowing down can cause brakes to overheat and fail, resulting in a dangerous loss of control.

When a downward slope is just too much for your truck: a warning sign on the top of Wolf Creek Pass over the Continental Divide in Colorado.
https://www.youtube.com/watch?v=X6LzWZYWpOU



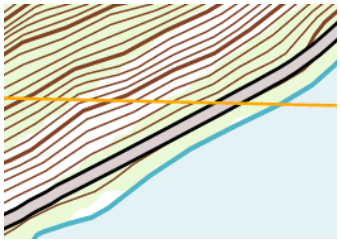
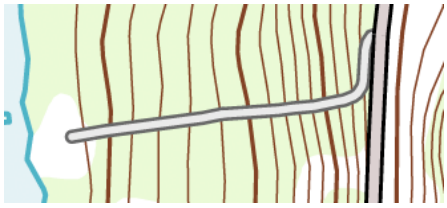
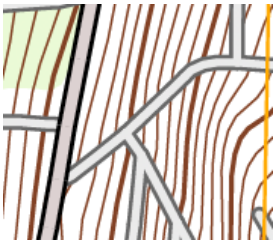
Mountain highways may have runaway truck ramps, an emergency feature on long downgrades.

Calculating Road Grades

The grade of a roadway (or the land it is on) is calculated by "rise over run" or:

Grade= [elevation change in feet / horizontal distance in feet] x 100

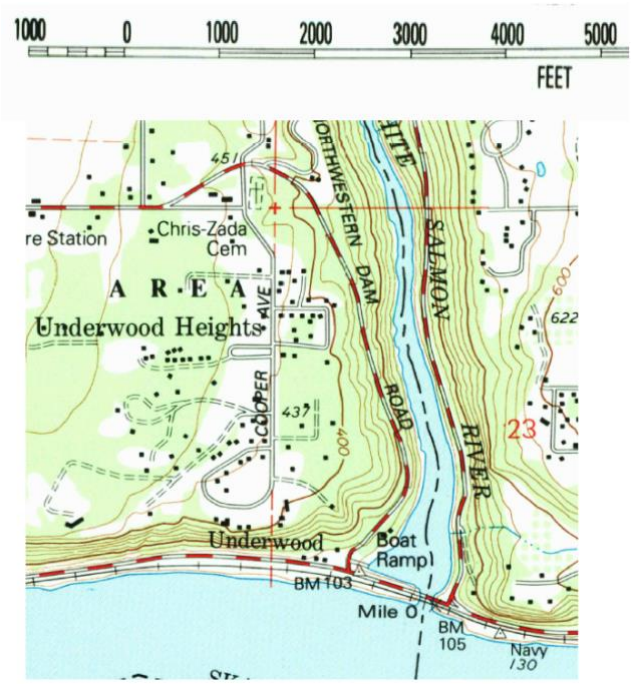
Local roads with slope calculations- 10 ft contour interval scale about 1:6000
(measurements may not match what shows on your screen)

A: No Road Sign	***B: Road Sign 20% Grade***	***Road Sign C: 22% Grade***
		
height difference= 10 ft map length=55mm= 330 m=1083 ft Grade=- 0.92 ft/100 ft "road sign grade"= 1% (A grade this slight would not have a sign; nothing to warn about)	height difference= 150 ft Map distance= 39mm= 234m = 768 ft Grade= 19.5 ft/100 ft "road sign grade" = 20%	height difference= 110 ft in Map distance= 25mm=150m= 492 ft Grade = 110/492 x 100= 22.35 ft/100 ft "road sign grade" = 22%

From *Zombie Bedtime Rhymes*, using USGS Questa, NM 1995. Entire Event is posted on SOinc.org.
Story: As we turn on to the Mine Road, I see a warning sign. "Caution! 8% grade- trucks use low gear" says the sign. I can see that this is a twisty, turny road with switchbacks.

Problem # 5: According to the grade sign, how many feet of roadway would be needed for the road to climb a vertical distance of 600 feet? Express in feet. 7,500 feet
Since you read the story, you know the road has an 8% grade. That means it climbs 8 feet for each 100 feet of length. To find how many feet of road is need for 600 vertical feet, set up a proportion:
8 ft vertical / 100 ft horizontal = 600 ft vertical / ?? ft horizontal **Answer = 7,500 ft**

The following problem is from "The Three Pigs", a pandemic event run on-line on the Scilympiad platform. Since the Mapscan will display in various sizes on computer screens, distance measurements were provided to teams. The Mapscan is from USGS Hood River, WA-OR. The large river shown is the Columbia River. Mapscan is not actual size.



Story: We drive over to Pig Brother #2's house to do the inspection. We drive Westward on WA 14, on the bank of the Columbia River. Right after crossing the White Salmon River, we stop to look at BM 103 ft. We turn right onto Northwestern Dam Road and drive up to the 400 ft contour line. We can see Pig 2 ahead of us, walking up the Road. He's carrying a bundle of sticks to build his house!

Pig 2 says "Home Depot isn't delivering during the pandemic. I really feel the road grade every day when I carry my sticks uphill. And the road is exactly 3621 feet long, measured from WA 14 just West of the BM103 ft up to the 400 ft elevation mark." We do the inspection. Suddenly, there is a familiar sound- it's the wind huffing and puffing again! Half the house blows down. The house fails. Poor Pig 2! Who woulda figured? We have a quick snack, then leave to see Pig # 3.

Problem # 6: What is the grade of Northwestern Dam Road, figured from its intersection with WA 14 to the 400 ft contour line? Express your answer in feet of rise per 100 ft of horizontal distance. Express your answer to the nearest hundredth of a foot.

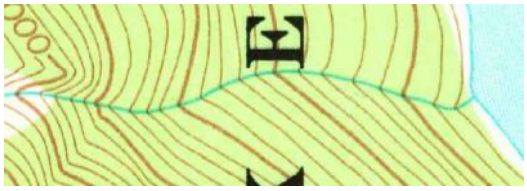
Road grade= 8.20ft/100 ft
road distance = 3621 ft (given
elevation difference= 400 at contour line -103 at BM= 297 ft
297 ft elevation difference /3621 ft road distance = .082 x 100 = **8.20ft/100 ft grade**

Both road grade problems and stream gradient problems can be fairly easy or very difficult. A short straight road or stream makes for simple measurements; a long, twisty road or stream is much more difficult to measure accurately. Some problems may give you measurements, but you should be able to make them if needed.

Stream Gradients

Just as with grades, the steepness of a stream can be judged from the contour lines around it.

Comparison of Three Streams

5 ft contour interval	*20 ft contour interval*	*40 ft contour interval*
A	***B***	***C***
		

Problem # 6: Based on these three topo Mapscans, rank the streams from steepest to most gradual.

A) A,B,C B) C,B,A C) B,A,C D) A,C,B

B) C,B,A Closeness of the contour lines in C, plus the large 40 ft interval, shows a steep slope

Problem # 7: Assuming adequate water, which of the above streams is likely to flow fastest?

Stream C because of the steep slope.

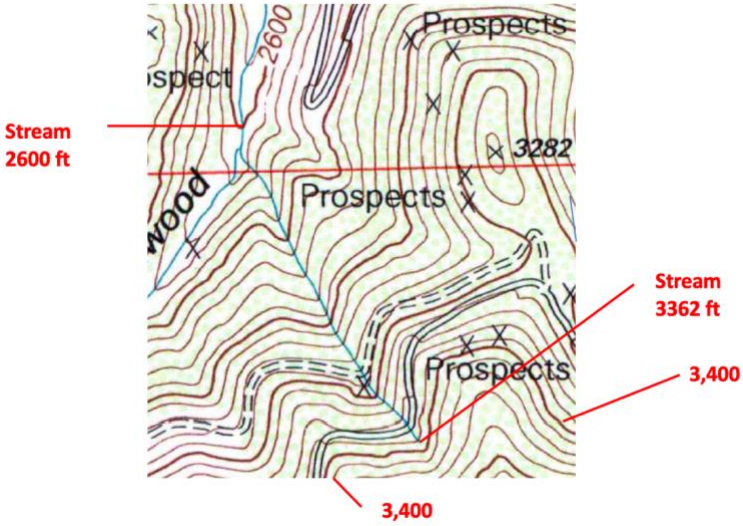
Problem # 8: Based on the Mapscan for stream B, in what direction is the steam flowing?

Stream B flowing to the Southeast. The "V" shape of the contour lines shows evidence of the stream eroding into the slope as it flows.

The basic idea for stream gradient is the same as for roads, but stream gradient is always expressed as feet of drop per 1,000 feet of stream distance rather than the change per 100 feet in road gradient.

Stream Gradient= [elevation change in feet / horizontal distance in feet] x 1000

This problem is from *We All Talk About Bruno,* a pandemic event run on the Scilympiad platform. In this system there is no way to control what size each team will see graphics, so line measurements cannot be made. (Angles can be measured.) Measurements were provided. This is an enlarged Mapscan.



Problem # 9: Deadwood Creek originates at an elevation of 3362 ft. Mirabel measures its length on the topo map as 29mm from its origin North to the 2600 ft elevation contour. What is the stream gradient of Deadwood Creek along this length? Express your answer as feet of drop per 1000 feet of stream length to the nearest tenth of a foot.

333.7 ft per 1,000 ft

highest stream elevation= given =3362 ft
lowest stream elevation= given =2600 ft
elevation change= 3362- 2600= 762 ft
Stream length = 29mm= .029m x scale 24000= 696m
converting to feet: 696m x 3.281 ft/m= 2283.576 ft

formula: Stream gradient= feet of drop per feet of distance x 1,000=
762 ft drop/ 2283.576 ft stream distance= .3336871 x 1000= 333.687 ft/1000 ft gradient
Rounding to nearest tenth of a foot= 333.7 ft per 1,000 ft

To Get USGS Topo Maps Online: Example using Questa, NM 1:24000 map dated 1995

1. Try Google. Enter "USGS Questa NM 1995 topo map". Make sure you get to the USGS site rather than a commercial site that will sell you the map, or download in a form that requires special software to view.

2. ***www.usgs.gov*** Is the website for The United States Geologic Survey. USGS no longer prints routine paper topo maps. You can order custom printed maps, but you can download most USGS topo maps for free.

If you have a large monitor, you can display downloaded maps actual size on your screen. This allows you to make measurements and calculations. You can thus do practice events without the hard topo map. How cool is that?

The USGS site changes constantly but this worked as of October 2024:
Example using Questa, NM 1:24000 map dated 1995 needed for *Zombie Bedtime Rhymes* (a Road Scholar resource event on soinc.org)

Steps: usgs.gov → products → topographic maps → get topo maps → historical topo map collection → (see menu) search by map name → Enter "Questa" in search box → click "24K" below search box → Slide date bar to about 1980 → Results should show: Questa, NM 1995" → pick "↓GEOPDF 17 MB" from menu. Downloading may take a while.

On your own computer: by adjusting "view" to 100% you will have the same map used in competitions. Save any maps as, for example, "USGS Questa NM 1995" and all your downloaded maps will be together. You can make measurements right on your screen but note that "actual size" on your screen is probably different than the same setting on another screen. Try adjusting your screen so that the black UTM grid measures as 42 mm squares. You cannot print a whole map on a standard printer, but you can screen grab one map sector at a time and print it actual size on an 8.5" x 11" sheet of paper.