Structural Map Exercise 1

Heron Glen Golf Course, Hunterdon County, New Jersey

Well Logging

Well logging, also known as borehole logging is the practice of making a detailed record (a well log) of the geologic formations penetrated by a borehole. The log may be based either on visual inspection of samples brought to the surface (geological logs) or on physical measurements made by instruments lowered into the hole (geophysical logs).

Well logging can be done during any phase of a well's history; drilling, completing, producing and abandoning. Well logging is done in boreholes drilled for the oil and gas, groundwater, minerals, geothermal, and for environmental and geotechnical studies.

Gamma Rays and Gamma Logs

Gamma radiation (or gamma rays) is the highest form of electromagnetic radiation with high frequency (very short wavelength) that are naturally produced in the universe by very high energy events (such as supernovas), and they naturally on Earth by decay of high energy states in atomic nuclei (gamma decay).

Gamma ray logging is a method of measuring naturally occurring gamma radiation to characterize the rock or sediment in a borehole. It is commonly used in mineral exploration, water-well drilling, and formation evaluation in oil and gas well drilling.

Three elements and their decay chains are responsible for the radiation emitted by rock: potassium, thorium and uranium. Shales often contain potassium as part of their clay content, and tend to absorb uranium and thorium as well. A common gamma-ray log records the total radiation and cannot distinguish between the radioactive elements.

Because different types of rock emit different amounts and different spectra of natural gamma radiation, gamma logs are used to differentiate and correlate strata in the subsurface. This difference in radioactivity between shales and sandstones/carbonate rocks allows the gamma tool to distinguish between shales and non-shales.
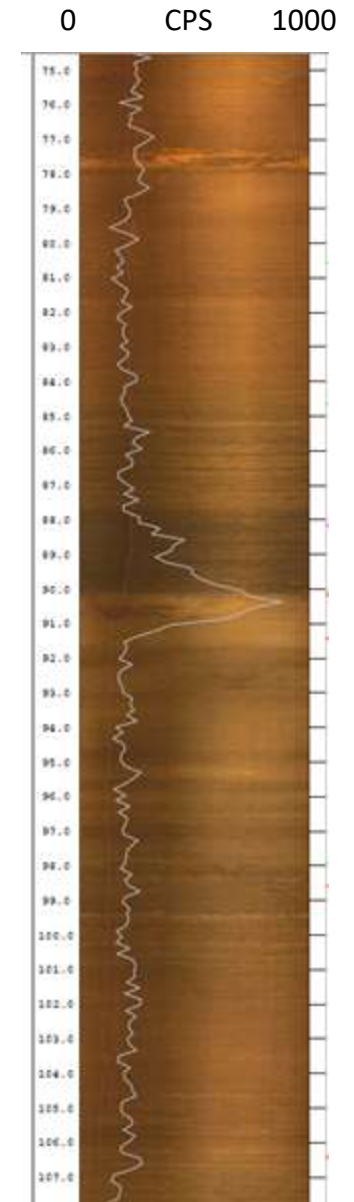
Background

A hydrogeological framework study of the the Brunswick bedrock aquifer was conducted in the vicinity of the Heron Glen Golf Course in Raritan Twp., Hunterdon County in 2003 by the NJ Geological Survey to assist the county in evaluating the groundwater potential for it's irrigation and supply wells. Outcrops in the vicinity were mapped and geophysical logs were run in 3 out of 6 wells located on site.

Borehole data were collected in two monitoring wells and a domestic-supply well for the golf course. Optical televiewer, VHS borehole video, and fluid-temperature and electrical-conductivity/resistivity probes were run in the water wells that are developed in red and gray mudstone and black shale of the Passaic Formation.

Borehole flow analyses were conducted on two golf-course wells using a heat-pulse flow meter run under ambient and/or pumping conditions.
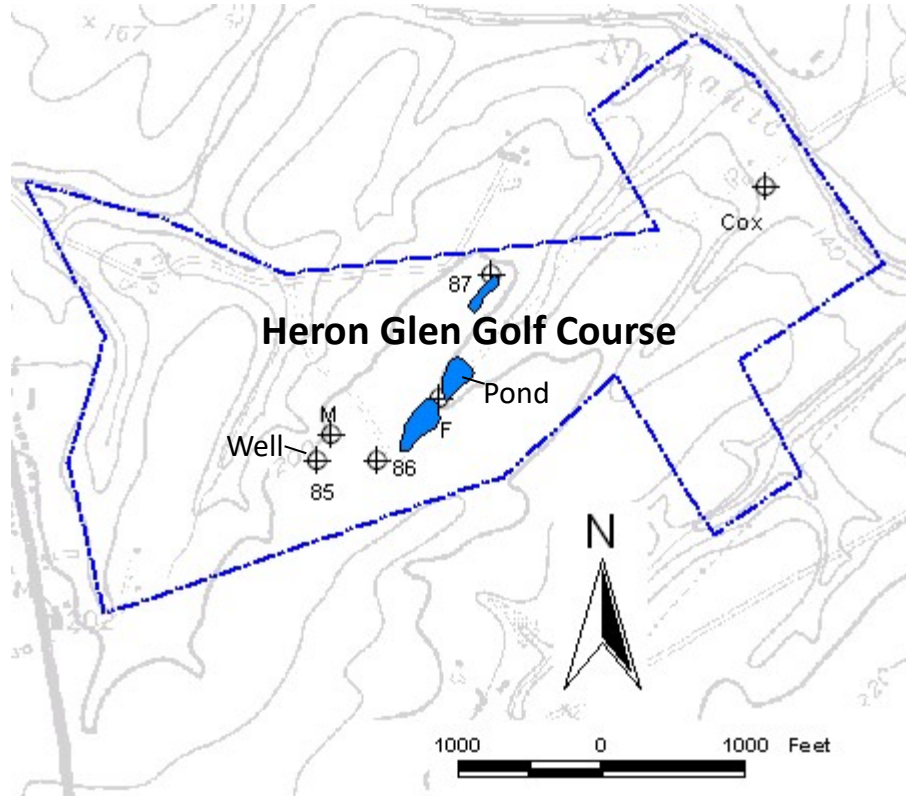
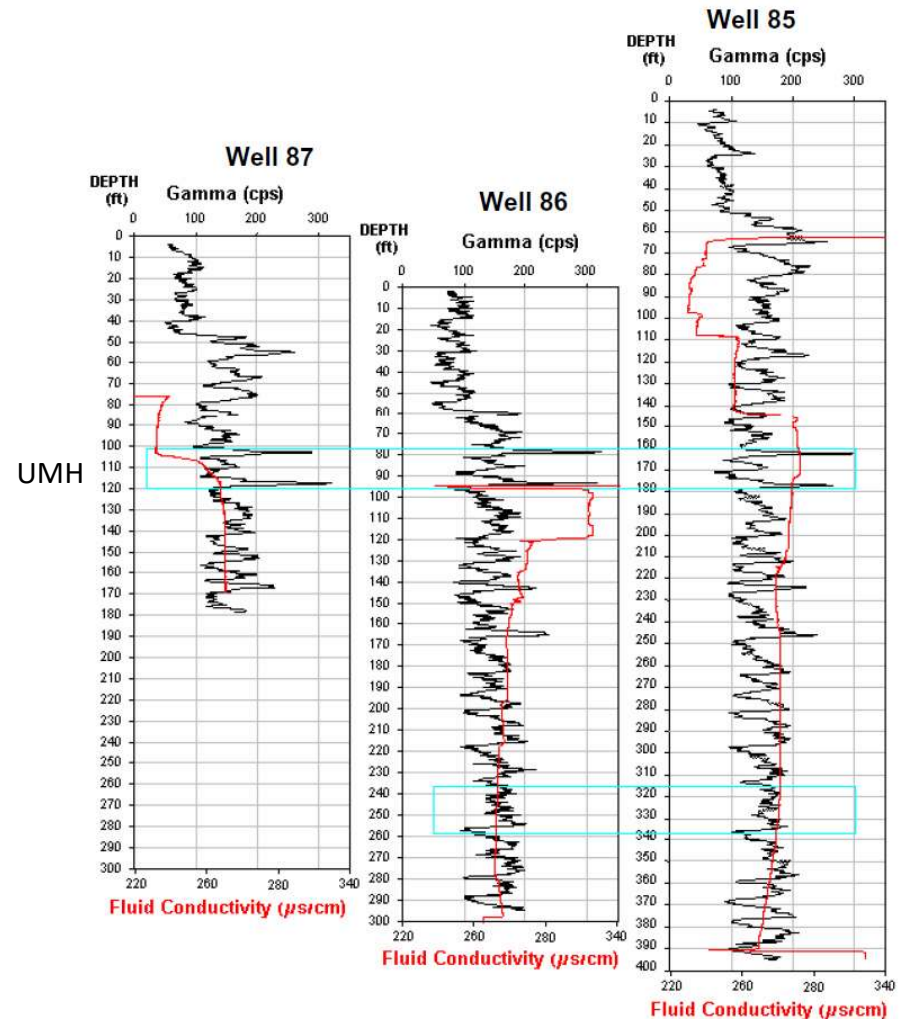Figure 1. The Heron Glen Course course property boundary (blue line), well locations and IDs, and Ponds.

Figure 2 (right).
Natural gamma-ray and fluid temperature logs for wells 85 to 87. The gamma ray logs show two sharp peaks around 300 cps at two depths in each of the wells. These are probably black shale beds, because they commonly exceed 200 cps throughout the basin stratigraphic section.

The depths (ft) to the top of the upper marker horizon (light blue outline UMH) are:

Well 87	-100
Well 86	-80
Well 85	-160

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Heron Glen Golf Course 3-Point problem to solve the strike and dip of bedding based on the depth (red) value to a stratigraphic marker horizon in three wells
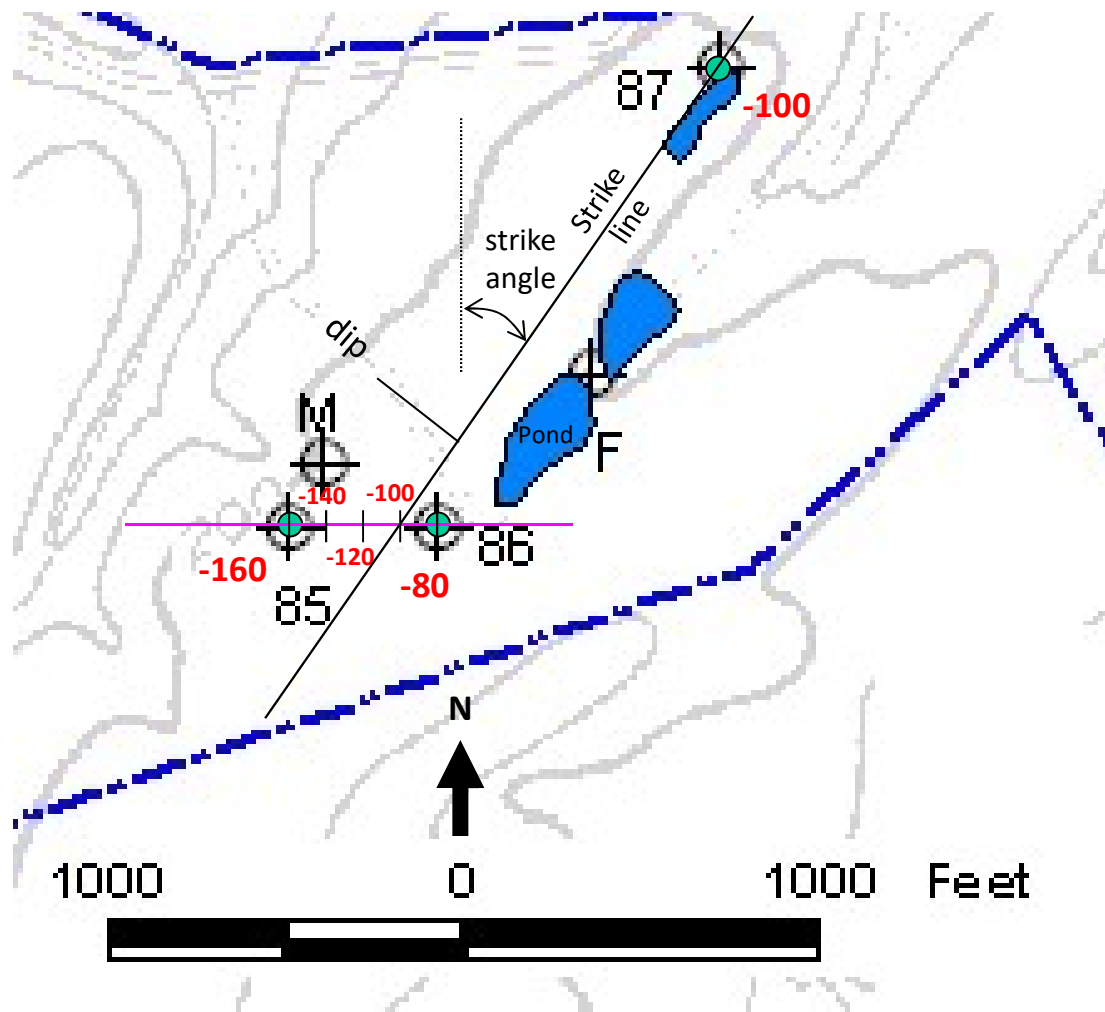

Figure 3. Details of figure 1.

Assuming that all three wells are at about the same surface elevation, the depth value in well 87 (−100) lies between between the values for wells 85 (-160) and 86 (-80).

1) Draw a line (purple) through the wells with the highest and lowest values, and determine where −100 values lies along its length.

There are -80 units difference. So -100 lies ¼ of the distance between the wells, from well 86:

$$(-80/4 = -20),$$
$$-80 + -20 = -100.$$

2) Draw a strike line from the -100 graticule to well 87, thereby connecting the two points where the bed is −100 ft below the surface.

3) Measure the strike angle from North, using a protractor (~30°).

4) The dip line is perpendicular to strike in the direction that beds are inclined.
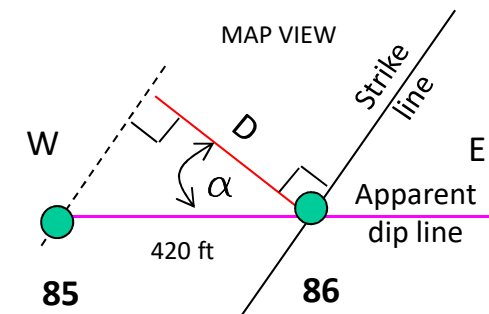
Heron Glen Golf Course 3-Point problem to solve the strike and dip of bedding based on the depth (red) value to a stratigraphic marker horizon in three wells

Figure 3. Details of figure 1.
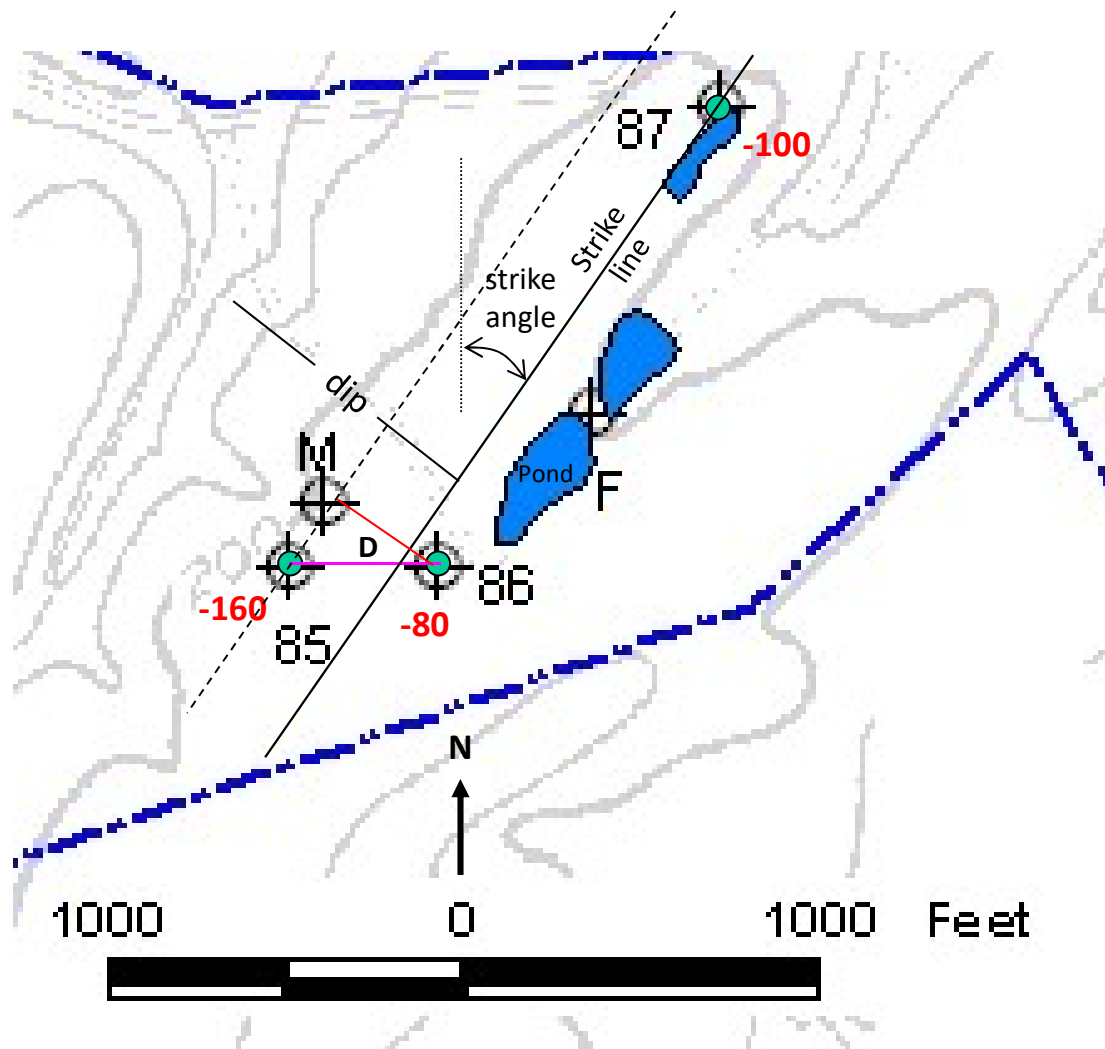
Knowing the distance between the two wells (D), and correlated stratigraphic depth points, we can use analytical geometry to calculate stratigraphic dip:

A survey shows that there is 420 ft distance between wells 85 and 86.

1) Calculate the length of the dip line (D) from well 86 to a strike line running through 85 (below). This is the true distance that the marker horizon varies in the vertical dimension by 80 ft.
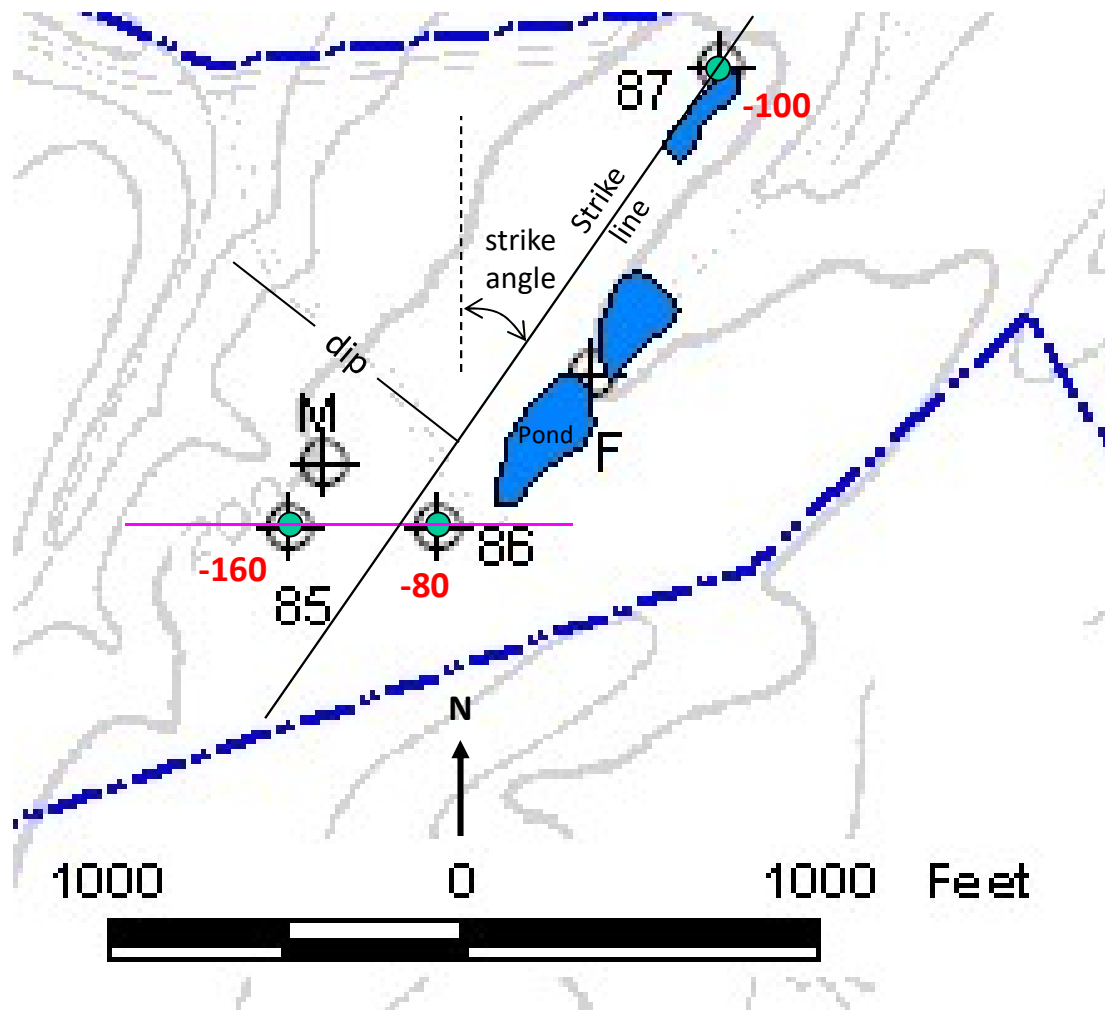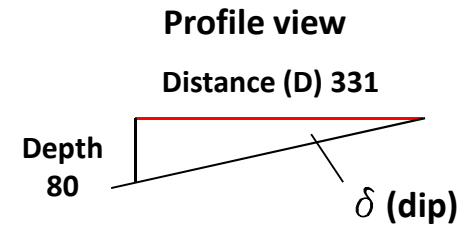

MAP VIEW

Because COS (α) = D / 420,

D = COS(α) * 420 = (0.788 * 420) = ~331'

Heron Glen Golf Course 3-Point problem to solve the strike and dip of bedding based on the depth (red) value to a stratigraphic marker horizon in three wells

Figure 3. Details of figure 1.

2) Use the rise (80 ft) and the run (331 ft) to calculate the dip:

Profile view

Distance (D) 331

Depth 80

δ (dip)

TAN (δ)= opposite/adjacent

δ = TAN^{-1} (80/331) = 13.6°

Another means would be to calculate the apparent dip (λ) along the line of section between the two wells using the rise (80 ft) and run (distance between two wells = 420 ft).

TAN (λ)= opposite/adjacent

λ = TAN^{-1} (80/420) $\simeq$ 11°

Heron Glen Golf Course 3-Point problem to solve the strike and dip of bedding based on the depth (red) value to a stratigraphic marker horizon in three wells

Figure 3. Details of figure 1.
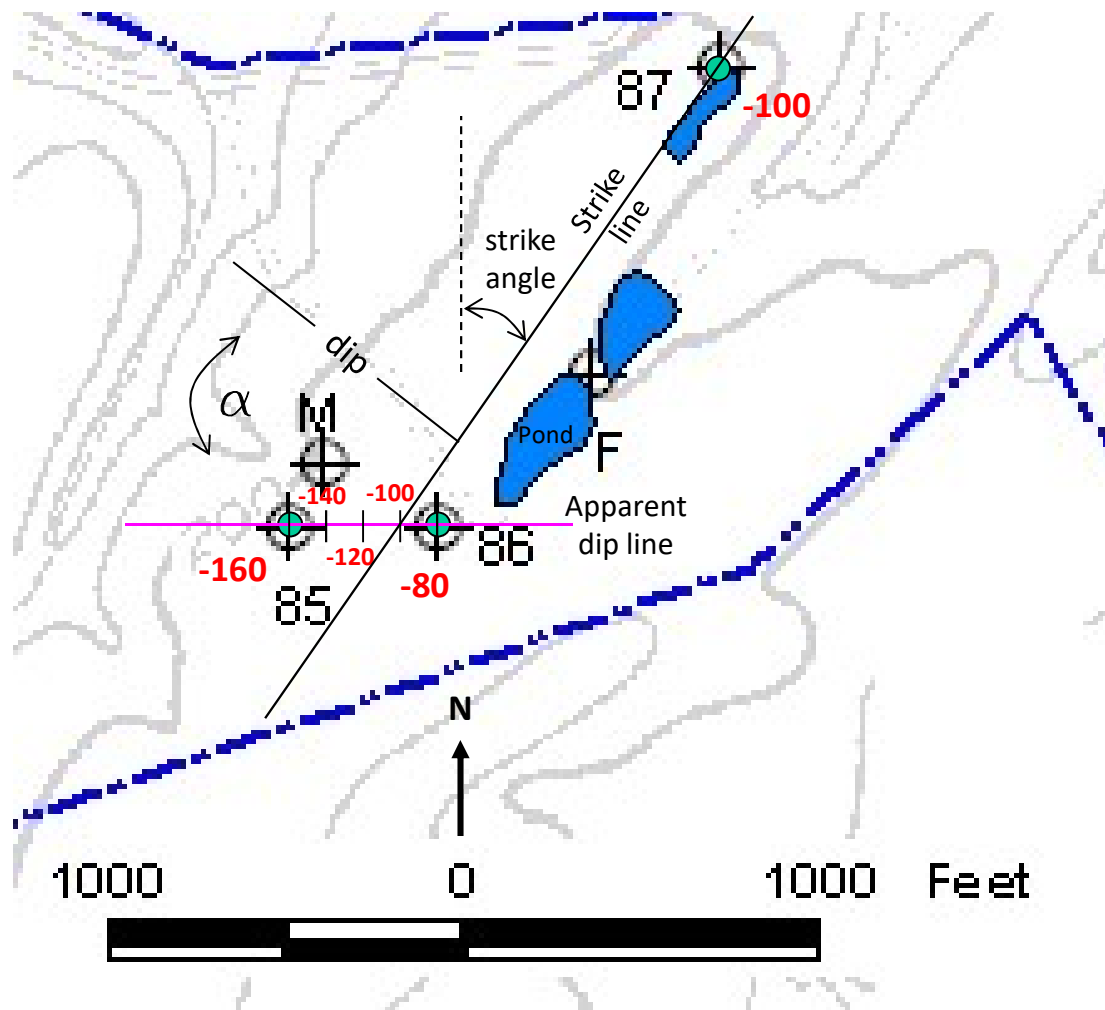
Then use the deviation angle between the dip line and the line connecting the two wells ($\alpha = 39°$), to calculate stratigraphic dip using the following equation that relates apparent dip to true dip:

$$\text{TAN}(\lambda) = \text{TAN}(\delta) * \text{COS}(\alpha)$$

where λ is apparent dip, δ is true dip, and α is the deviation angle between the dip line and the apparent dip line

or rearranged,

$$\text{TAN}(\delta) = \text{TAN}(\lambda) / \text{COS}(\alpha).$$

In this case, solving for λ:

$\lambda = \text{TAN}^{-1}(\text{TAN}(14) * \text{COS}(39)) = \text{TAN}^{-1}(0.249 * 0.777) = \sim 11°$

Note: These are a very important equations to remember because of their usefulness in many situations.

Heron Glen Golf Course 3-Point problem to solve the strike and dip of bedding based on the depth (red) value to a stratigraphic marker horizon in three wells

87

-100

Strike line

strike angle

dip

α

M

Pond

F

-160

-80

85

86

N

1000   0   1000   Feet
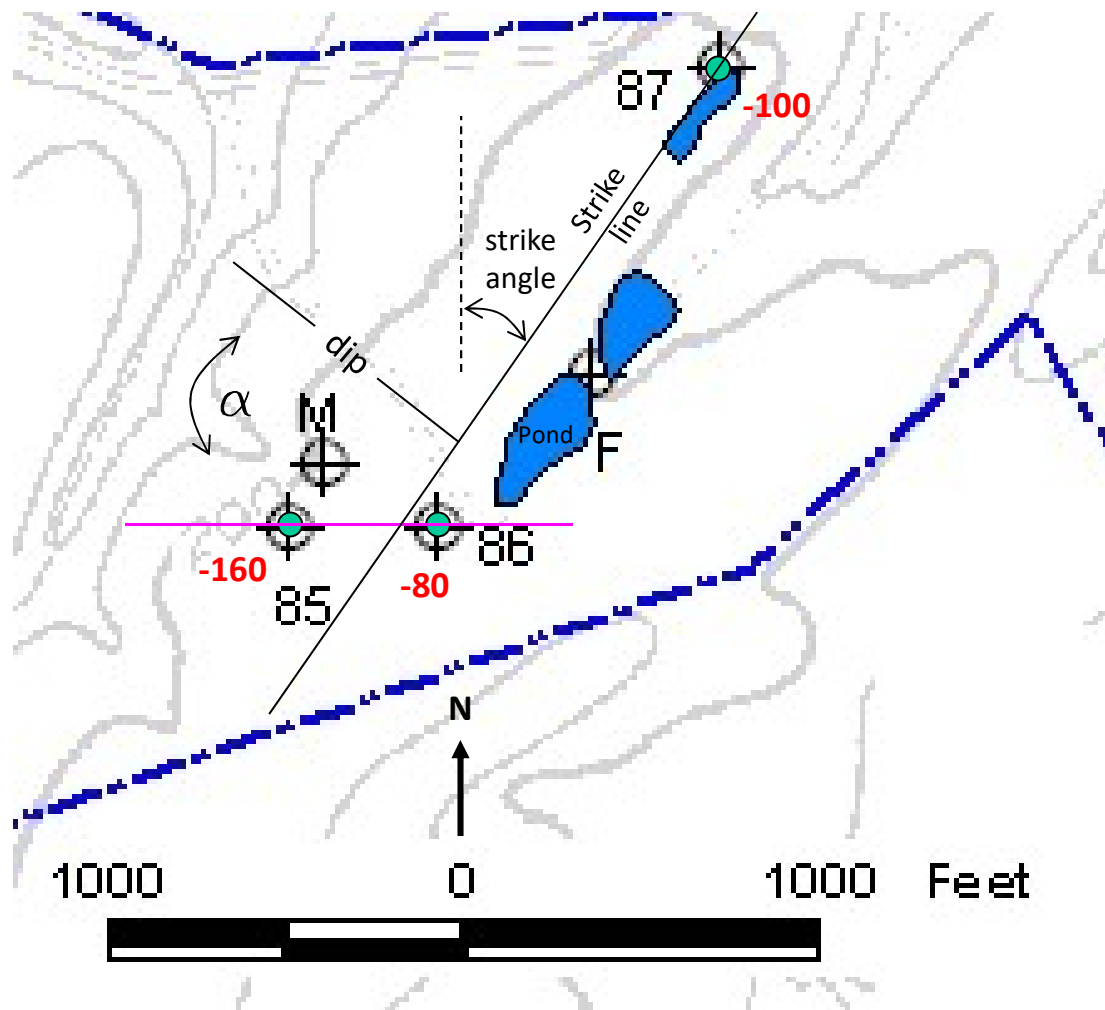
In a similar manner, let's say that we know the dip in the area from nearby outcrop readings (14º), and we want to determine the apparent stratigraphic dip for a cross section drawn through Wells 85 and 86.

 Using the apparent/true dip equation,

$$\text{TAN}(\lambda) = \text{TAN}(\delta) * \text{COS}(\alpha),$$

or

$$\lambda = \text{TAN}^{-1}(\text{TAN}(\delta) * \text{COS}(\alpha)).$$

Therefore, solving for λ:

$$\lambda = \text{TAN}^{-1}(\text{TAN}(14) * \text{COS}(39)) =$$
$$\text{TAN}^{-1}(0.249 * 0.777) = \sim 11º$$

Figure 3. Details of figure 1.

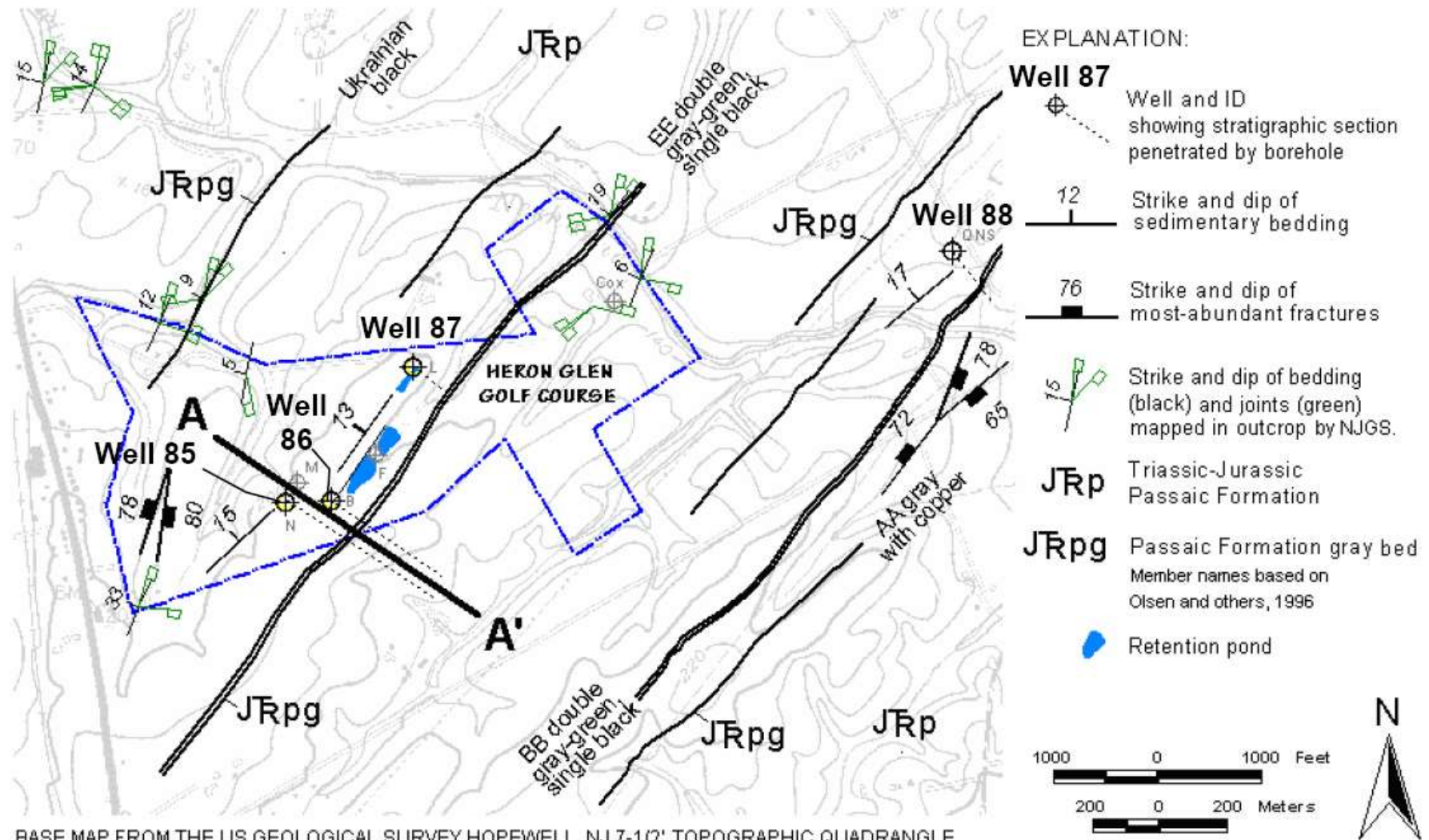## Wells 85 to 88 - Brunswick middle gray and lower red zones

Figure 4. Map summarizing the results of the NJGS work at the Heron Glen Golf Course. Strike and dip of bedding near the wells stems from a statistical analysis of the optical borehole imaging results for the three wells.
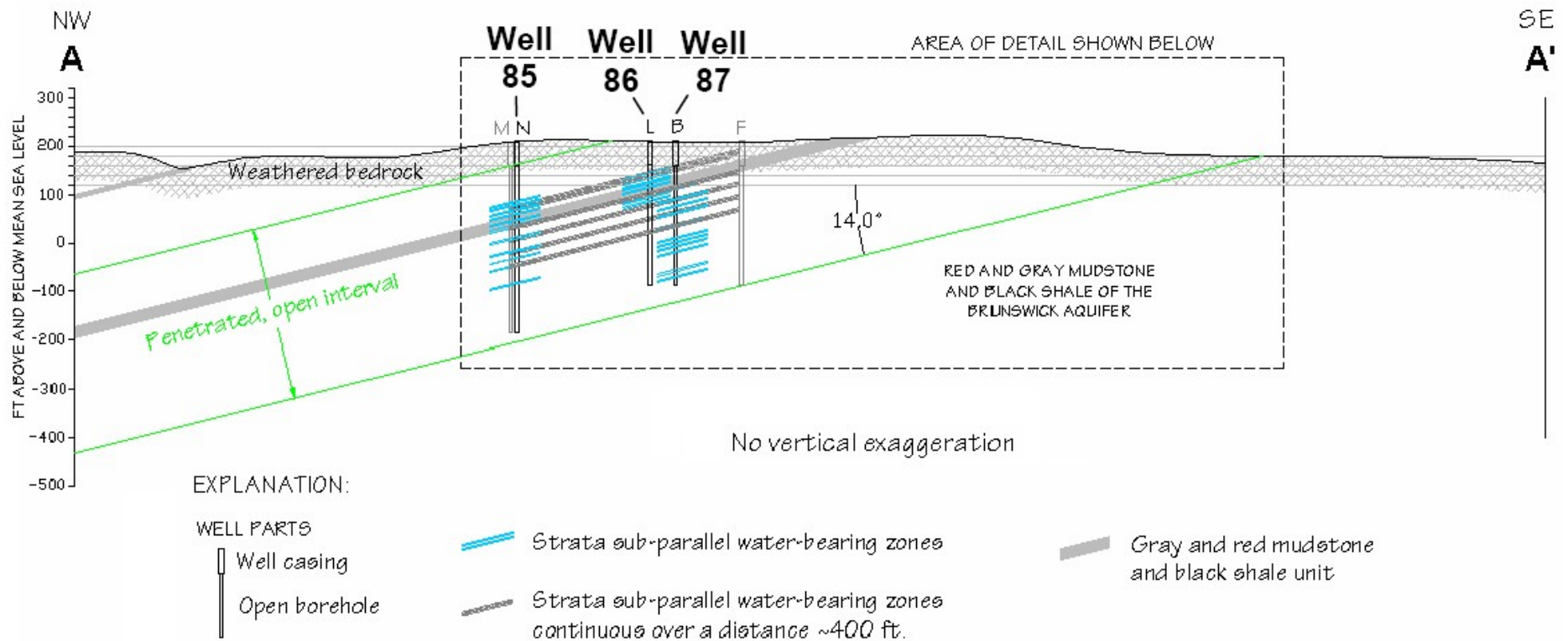
Figure 5. Profile showing the results of the NJGS work at the Heron Glen Golf Course. Strike and dip of bedding near the wells stems from a statistical analysis of the optical borehole imaging results for the three

Structural Map Exercise 2

Three-point problems in areas of topographic relief.
The Stony Brook-Millstone Research Well Field, Mercer County, NJ

In the Heron Glen Golf Course 3-point problem, we assumed that depths to a stratigraphic marker horizon were referenced to the same elevation. In actuality, there is only small differences in the elevation of the three well heads, so that the assumption did not effect the outcome. However, in areas of noticeable topographic relief, depth reference to stratigraphic elevations must be made to a common datum, such as sea level, in order to make calculations that take spatial variations in surface elevation (or topographic variations) into account.

Stony Brook-Millstone Research Well Field 3-point problem

The NJGS conducted a hydrogeological framework study of the the Brunswick aquifer at the hydrogeological research site (well field) located in the nature preserve at the Stony Brook - Millstone Watershed Association, Hopewell Twp., Mercer County, NJ. A circular array of wells were drilled in 1966 as test wells for a field project designed to demonstrate the uneven (anisotropic) groundwater flow directions in fractured shale. As part of the NJGS study, borehole images were collected for some of the wells during 2001-2008. The aquifer is red and gray mudstone and dark gray shale of the Passaic Formation.

Complete the problem(s) on the following pages and hand them in at the start of next lab.

Grading of the results will depend on the accuracy of your results, and the manner in which you present them.

Stony Brook-Millstone Research Well Field
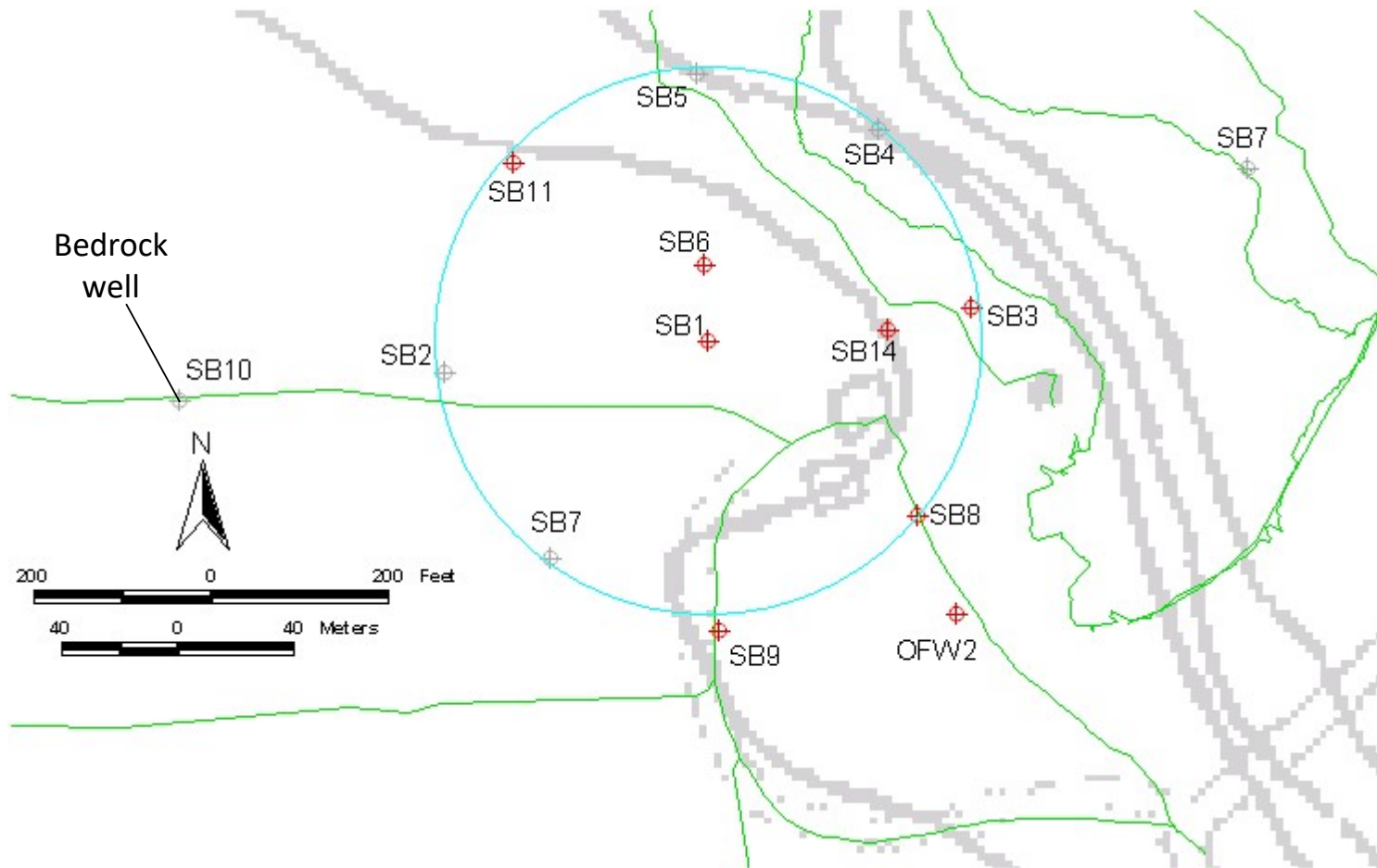
Bedrock monitoring wells were drilled in a circular arrangement about 300' around a central pumping well (SB-1). The level of water within the monitoring wells varies during a pump test as a result of groundwater flowing unevenly through the rock to the pumping well. Over time, the water levels in wells aligned along bed strike drop faster than those aligned up- or down-dip. *The NJGS collected borehole images in the wells with red symbols.* The green lines are GPS tracks on foot trails.
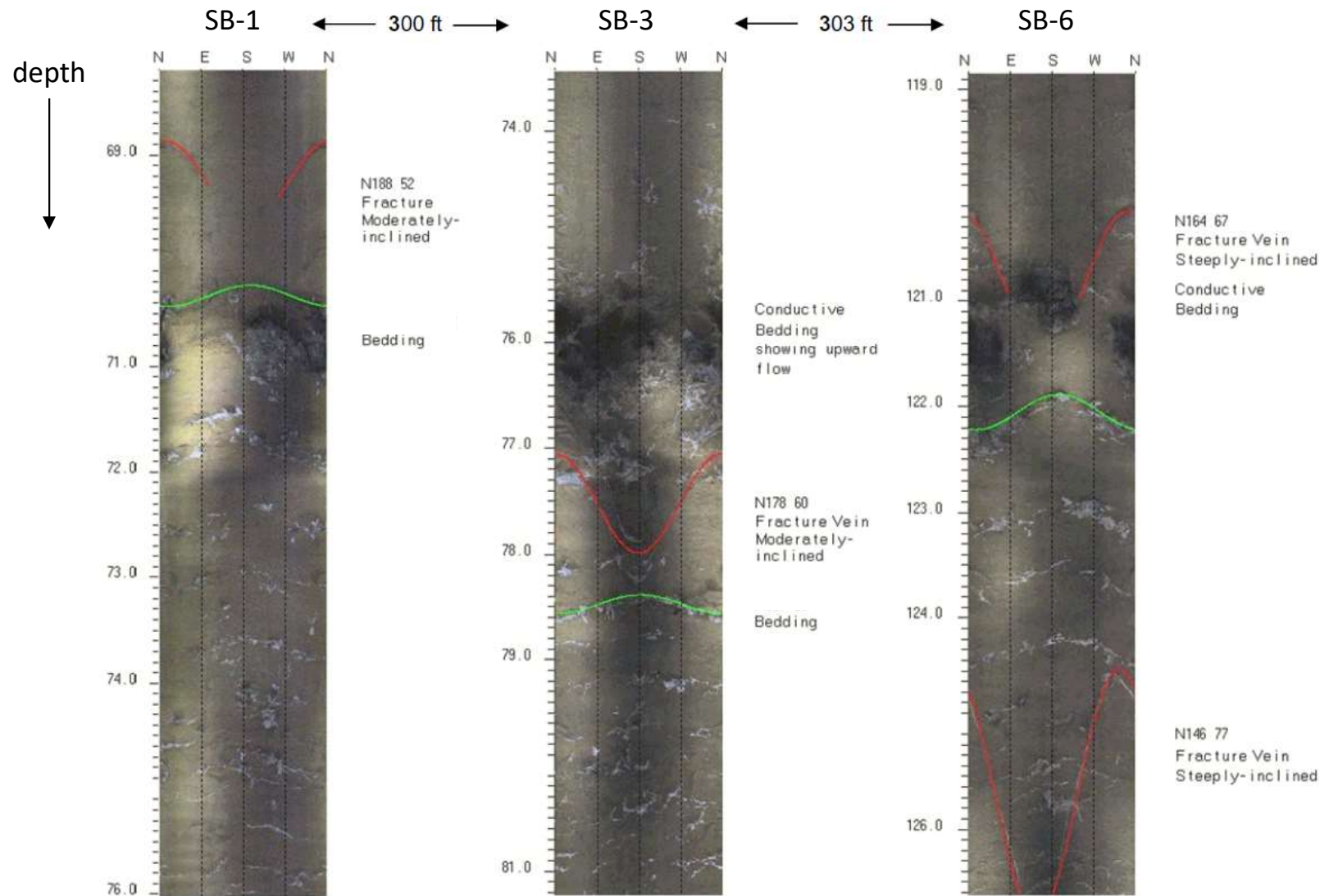
SB-1 ← 300 ft → SB-3 ← 303 ft → SB-6

depth

SB-1

N188 52
Fracture
Moderately-
inclined

Bedding

SB-3

Conductive
Bedding
showing upward
flow

N178 60
Fracture Vein
Moderately-
inclined

Bedding

SB-6

N164 67
Fracture Vein
Steeply-inclined

Conductive
Bedding

N146 77
Fracture Vein
Steeply-inclined

FIGURE 3M7. Stratigraphic correlation of wells at the Stony Brook-Millstone Watershed Association well field based on OPTV records showing a major water-bearing zone in a gypsum-soil horizon and other geologic structures. Depth values are in feet below land surface.

Well and Marker Bed Elevations (MSL-ft)

| Well ID	Ground Elevation	Marker bed depth	Marker bed elevation
SB-1	167	71	167 - 71 = 96
SB-3	155	76	155 - 76 = 79
SB-6	168	121	168 - 121 = 53

Print out the map on the next page and use it to complete this exercise. Using the Heron Glen example and method, determine the strike and dip of the bedrock strata from the elevation values for the maker bed.

Use the 3-point problem to solve for bedding strike and dip.
Put a strike and dip symbol on the map in the correct orientation with a dip label. Show all of your work and calculations in the margins. Attach (staple) an extra page if you prefer. There is bonus work on the last page.
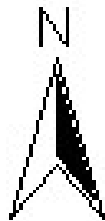
HINT: Use your engineer rule and the map scale to determine distance increments and distances between two wells and follow the procedure for the Heron Glen example.

Name:

Date:
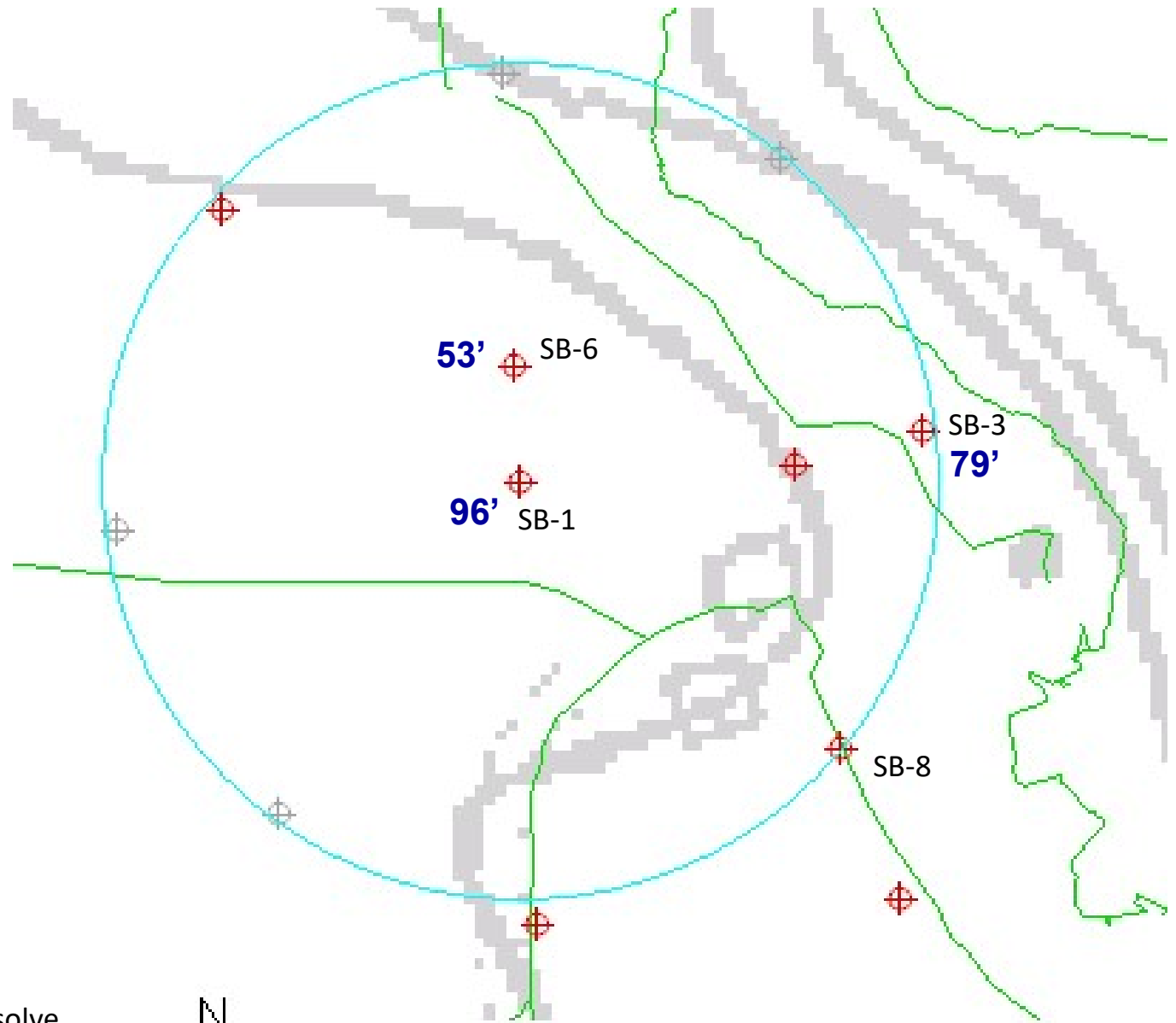
53' ⊕ SB-6

⊕ SB-3

79'

⊕

96' SB-1

⊕ SB-8

Use the 3-point problem to solve for bedding strike and dip.

Put a strike and dip symbol on the map in the correct orientation with a dip value.

N

| 200 | 0 | 200 | Feet |

| 40 | 0 | 40 | Meters |

Bonus Questions

You must answer the first correctly and attempt the second in order get get credit.

1) What is the apparent dip of bedding along a line connecting well SB-1 and SB-8?

2) Knowing what you know about the strike and dip of bedding, and taking into consideration that groundwater levels in wells aligned along bed strike with the pumping well drop the fastest, speculate on why wells SB-6 and SB-10 were drilled?