LABORATORY 8: Outcrop Prediction

I. Outcrop Prediction

(A) Based on the assumption that contacts are perfectly planar, and are unaffected by faulting.

b) To use this method you must be given the attitude of the planar surface, and at least one place where it is exposed in the map area. You must also have an accurate topographic base map. A 3-point problem can be solved for the attitude.

c) The *outcrop prediction* method allows one to plot the location of the planar contact on the map if the above conditions are met.

d) The procedure works by orthographically calculating the intersection of the plane with the ground surface as described by the contour lines.

II. Special Cases

a) *Horizontal attitude*: In this case the geological contacts are parallel to topographic contours. A geologic map can be constructed from the singular occurrence of exposed contacts if the area is unaffected by faulting.

b) *Vertical attitude*: Topography has no effect; the contact line is drawn as a straight line parallel to the strike and passing through the position where it outcrops. In this attitude the outcrop width on the map is the same as the true thickness.

c) *Rule of V*: Inclined strata will form a "V"-shape outcrop pattern that points in the dip direction if the contacts are cut by a stream valley. Note that this is true only when the dip of the strata is greater than the slope of the valley.

III. General Solution for Outcrop Prediction

a) Given topographic map with location of exposure, and the attitude of the exposed contact. Assuming that the contact is planar we can proceed with the outcrop prediction.

b) Steps for solving problem:

1. Construct a fold line (FL) perpendicular to the strike of the contact and located to one side of the map. Below the fold line construct a grid to scale that conforms to the topographic *contour interval*. The grid lines are parallel to the original fold line. The grid lines have been constructed in Figure 8-1 below the map. Note that the grid lines are labeled 100-140 because these values represent the topographic relief of the map.

2. The elevation of the exposed contact should be taken from the contour map.

This point is projected parallel to the strike of the contact until it intersects the fold line. At the fold line, continue the projected line downward until it intersects the matching grid elevation. Plot this point. In the Figure 8-1 example, the position and attitude of the exposed outcrop is indicated by the strike and dip symbol.

3. Through the point identified in step (2) above, plot the trace of the contact dipping at the true dip angle in the grid profile. Make sure that the dip direction is correct. Note those locations where the contact intersects an elevation grid line. The projections of these intersections parallel to strike and to the map view represent structure contour lines of a specific elevation. Label these lines (which have a constant spacing) with the appropriate elevation number.

4. From each intersection of an equivalent structure contour and topographic contour from step (3), plot points that represent the outcrop geometry for that surface. Mark these locations with dots as has been done in Figure 8-1. Note that a certain amount of interpolation can be done to get better resolution of the contact position.

5. Using the pattern of dots trace the contact of the layer on the map surface. Remember the rule of "V" when constructing the contact. This has been done in Figure 8-1.

c) Note that if the thickness of the layer is given, the entire outcrop belt can be plotted for that particular unit since both the upper and lower contacts can be plotted. This, of course, works correctly only if the assumption that the unit is tabular is valid. Use the map scale to plot the other contact on the cross-section grid. This line will be parallel to the first contact plotted. Wherever the contact crosses elevation grid lines yields a position where the strike line of the contact is at the same elevation as one of the contour intervals. As in steps (4) and (5) these strike lines (structure contours) of known elevation can be projected to the map and therefore define points where the contact outcrops. Figure 8-2 displays the outcrop prediction for the above example if the stratigraphic thickness was approximately 13 meters. The structure contours for the lower stratigraphic contact are plotted as dashed lines to distinguish them from those of the upper contact.

D) As with most graphical solutions to structural problems, the outcrop prediction problem can also be managed mathematically. Consider the cross-sectional view of the problem in Figure 8-1. The spacing between adjacent structure contours is always the same, and is controlled by the equation:

Tan (Dip angle) = (Contour Interval) / (Structure Contour Spacing)

(Structure Contour Spacing) = (Contour Interval) / Tan(Dip Angle)

Using the example in Figure 8-1 would yield:

(Structure Contour Spacing) = (10 m) / (Tan 40°)

Structure Contour Spacing = 12 m

You would then draw parallel lines to the initial strike line spaced at 12 meter intervals. These structure contours would decrease in elevation in the dip direction, just as they do in Figure 8-1. Using this method you can avoid the time-consuming task of constructing the cross-sectional grid.

Structure contours for the bottom of the bed in the example can be constructed mathematically also. The spacing between adjacent structure contours for the bottom of the bed is exactly the same as the top because both surfaces have the same dip (see Figure 8-2). The unknown value is the offset of structure contours of the same elevation for the top and bottom of the bed. In the Figure 8-2 example this value was calculated graphically be constructing the cross-section to scale. However, the problem can also be solved with trig:

(Offset) = (Thickness) / (Sin Dip Angle)

Therefore, for the Figure 8-2 example:

Offset = (12.8 m) / (Sin 40)

Offset = 19.3 m

The 110 meter structure contour for the bottom of the bed is offset 19.3 meters from the same 110 meter structure contour for the top of the bed. In this case the offset is to the west. You may need to sketch the problem in profile to verify the direction of the offset when solving mathematically. With the initial 110 meter structure contour plotted, the other structure contours on the bottom are spaced 12 meters apart with the elevation decreasing in the dip direction, just like the structure contours for the top of the bed. The spacing between structure contours is the same because both the top and bottom surfaces of the bed dip at the same angle.

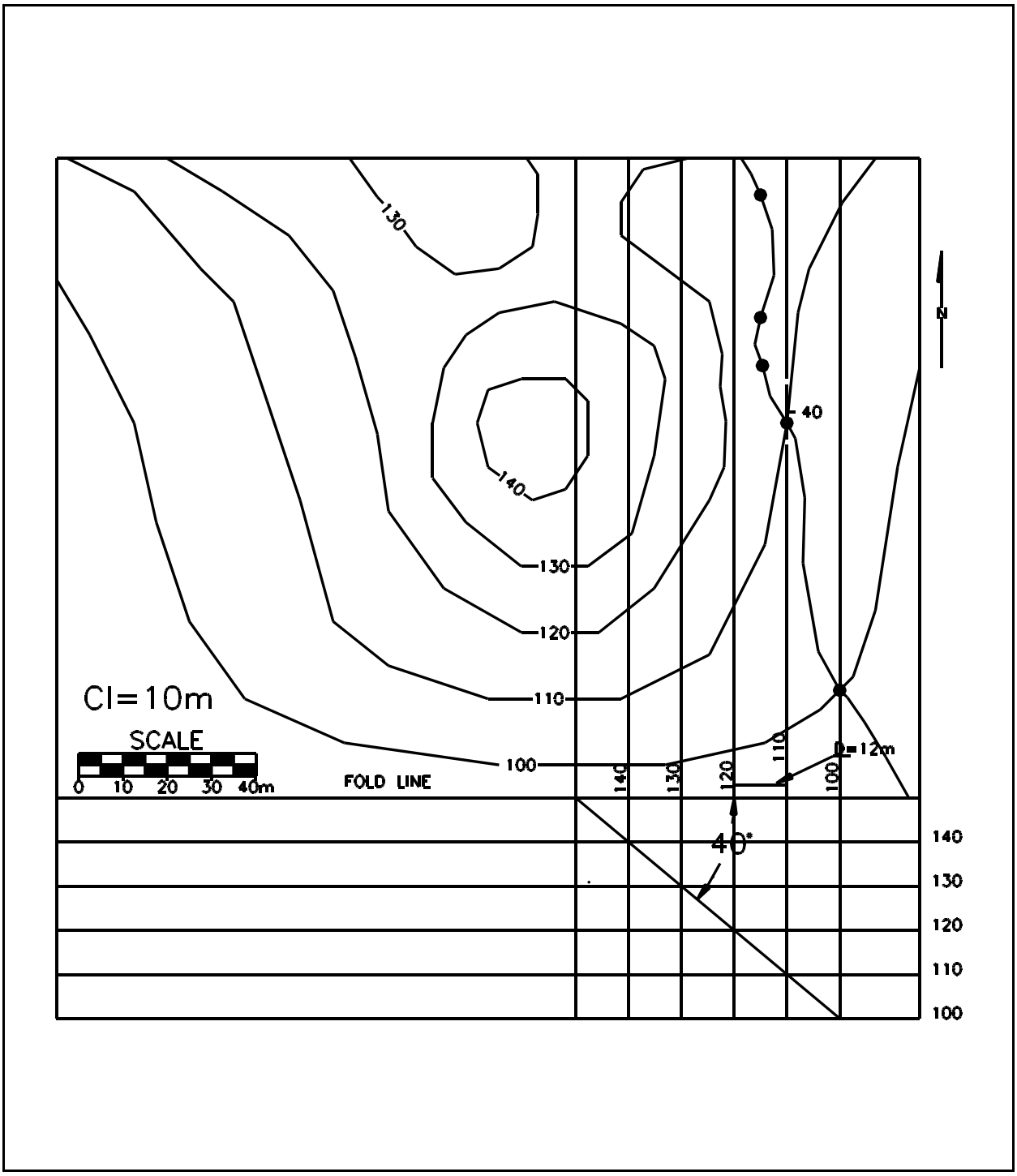

Figure 8-1: Initial setup of outcrop prediction example problem.

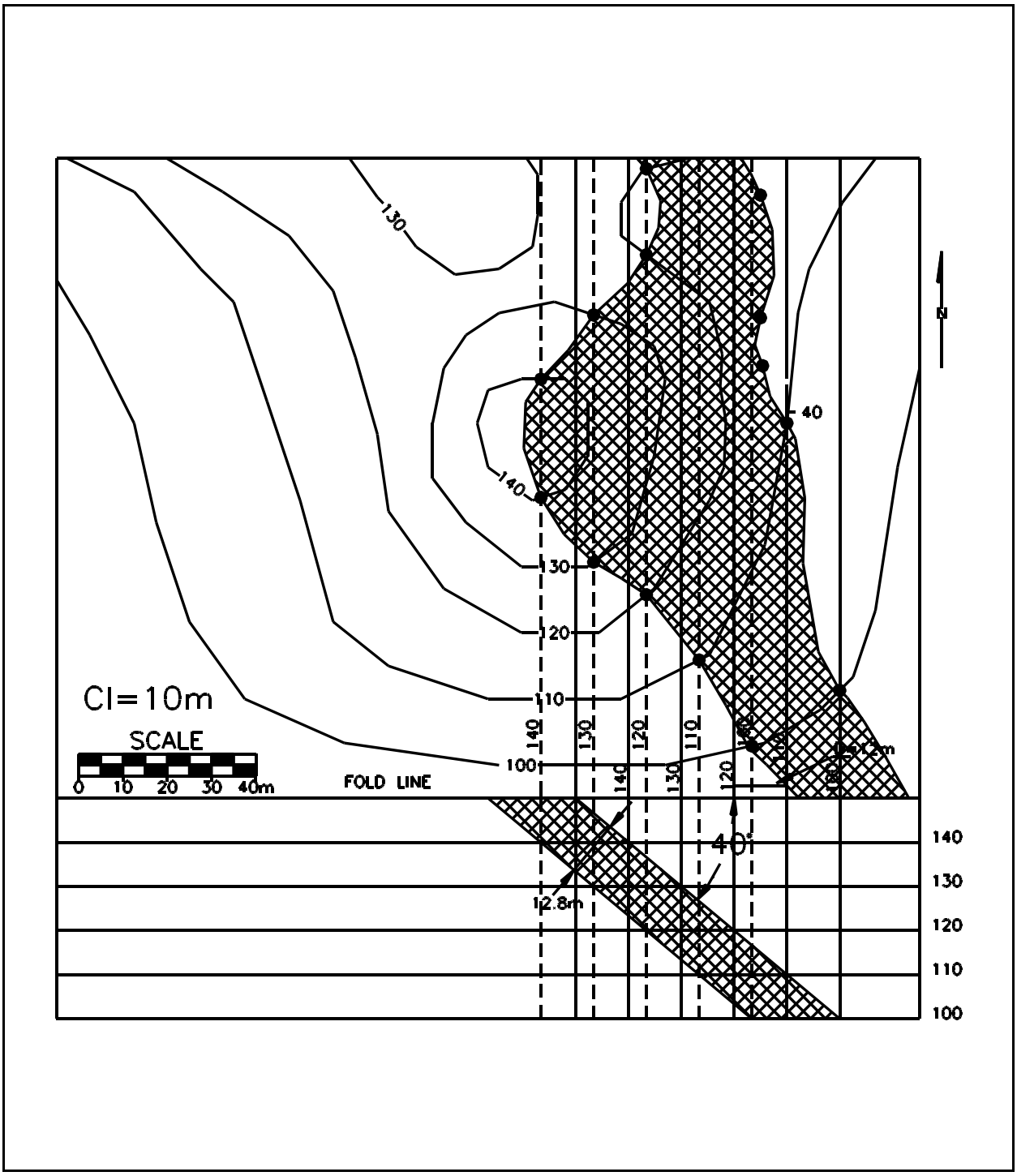

Figure 8-2: Final solution of example outcrop prediction problem.

EXERCISE 8A: Outcrop Prediction

When constructing your problem, you should copy the base map contours, map boundary, etc., onto a sheet of your drafting paper with a rapidograph. Be aware that reproduction of this laboratory manual often distorts the scale of maps used for problems. You should check for this eventuality, and if the distortion is significant use the scale bar of the map for the problem construction. Those of you who have had training with AutoCAD are encouraged to use that program to plot your final map. Color with your colored pencils only after allowing sufficient time for the rapidograph ink to dry. In the below problems it is important to remember the following definitions:

- Stratigraphic Contact: refers to the original stratigraphic sequence and, therefore, gives relative age information. For example, if the contact of a sedimentary or volcanic unit is referred to as the upper stratigraphic contact, then you can be sure that the contact is the original top of the unit and that rocks adjacent to that contact are younger that those adjacent to the other contact of the unit.

- Structural Contact: refers to the present position of the contact. For example, the upper structural contact is simply the present contact that is vertically uppermost in the current structural position. Note that in an overturned sequence of strata that the upper structural contact of a unit is the stratigraphically lower (oldest) contact. Also note that if a sequence of sedimentary strata is vertical (dip = 90), there is no structural upper and lower contact, however, there is still a stratigraphic upper and lower contact.

Problem 1: The stratigraphic upper (younger) contact of a geological formation outcrops at points X, Y, and Z on the map in Figure 8-3. The thickness of the bed is 50 feet. Assume that the formation is not overturned and is planar. Draw both the upper and lower stratigraphic contacts on the map. Color the formation red, the stratigraphically older formation green, and the stratigraphically younger formation blue.

Contour Interval = 50 feet

Problem 2: The upper stratigraphic contact of a sandstone bed crops out at points A, B, and C, on the map in Figure 8-4. The lower stratigraphic contact of the sandstone outcrops at point D. Determine the strike and dip and draw in both stratigraphic contacts on the map. Color the sandstone red, the stratigraphically older unit green, and the younger unit blue. What is the thickness of the sandstone bed?

Contour Interval = 10 feet

Problem 3: The outcrop pattern of the stratigraphic top contact of a Cretaceous formation is displayed on the map in Figure 8-5. Find the strike and dip of the contact. Copy the map boundary and contour information onto your paper so that it is included with your solution. On this base map plot the structure contours using the contour interval of the top contact. Assume that the Cretaceous is 200 feet thick and that the lower contact of the cretaceous is parallel to the upper contact. Calculate the position of the lower Cretaceous contact based on the thickness. Plot the structure contour lines for the lower stratigraphic contact and label with appropriate elevation values.

Contour Interval = 200 feet

Problem 4A: Copy the base map and contacts from Problem 3 onto a separate sheet of paper. Fossils collected several feet structurally above the upper Cretaceous contact are Tertiary. Fossil data collected from all sedimentary rocks structurally below the Cretaceous strata are Triassic. Points 1,2, and 3 on the map in Figure 8-5 are outcrops of the upper structural contact of a basalt flow, and point 4 is the outcrop of the lower structural contact of the same flow. At point 4 the basalt flow was vesicular. At points 1,2, and 3, the strata structurally above the basalt flow appears to have been affected by contact metamorphism. What is the attitude of the basalt flow? What is the thickness of the basalt flow? Color the outcrop area of all Triassic volcanic rocks black. Color all Tertiary sedimentary rocks blue, Cretaceous sedimentary rocks red, and Triassic sedimentary rocks green.

Problem 4B: On a separate sheet of paper describe in order of oldest to youngest all of the geological events represented on your map. Label each event sequentially with a number, starting with (1) for the oldest. Be sure to use all time constraints available in the above problem description. If you must explain any contacts on your map with a fault or unconformity, use a thick line for fault contact (suggest your #2 pen), and a hachured line of normal thickness (#0 pen) for an unconformable depositional contact. Hachures on an unconformable contact always lie on the side of the contact occupied by relatively younger strata.

EXERCISE 8B: Outcrop Prediction

When constructing your problem, you should copy the base map contours, map boundary, etc., onto a sheet of your vellum paper with a rapidograph. Alternatively, you can print the base map on vellum with a laser printer, and draft the answer onto that copy. Be aware that reproduction of this laboratory manual often distorts the scale of maps used for problems. You should check for this eventuality, and if the distortion is significant use the scale bar of the map for the problem construction. Those of you who have had training with AutoCAD are encouraged to use that program to plot your final map. Color with your colored pencils only after allowing sufficient time for the rapidograph ink to dry. In the below problems it is important to remember the following definitions:

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Problem 1: The map in Figure 8-6 is a topographic map of the USA campus. In the northwest corner of the campus the stratigraphic lower contact of clay unit outcrops at the strike and dip symbol. Using this information construct the outcrop pattern of this contact. The clay unit has been determined to have a true thickness of 70 feet. Assuming that the upper stratigraphic contact is parallel to the lower contact, construct the outcrop pattern of the top of the clay unit. Color the clay unit red, the underlying sand yellow, and the overlying sand & gravel unit green. Because of the small map scale and the small contour interval, you should calculate the spacing on the structure contours mathematically rather than graphically. For the same reason, use trig to calculate the offset of the bed bottom and top structure contours.

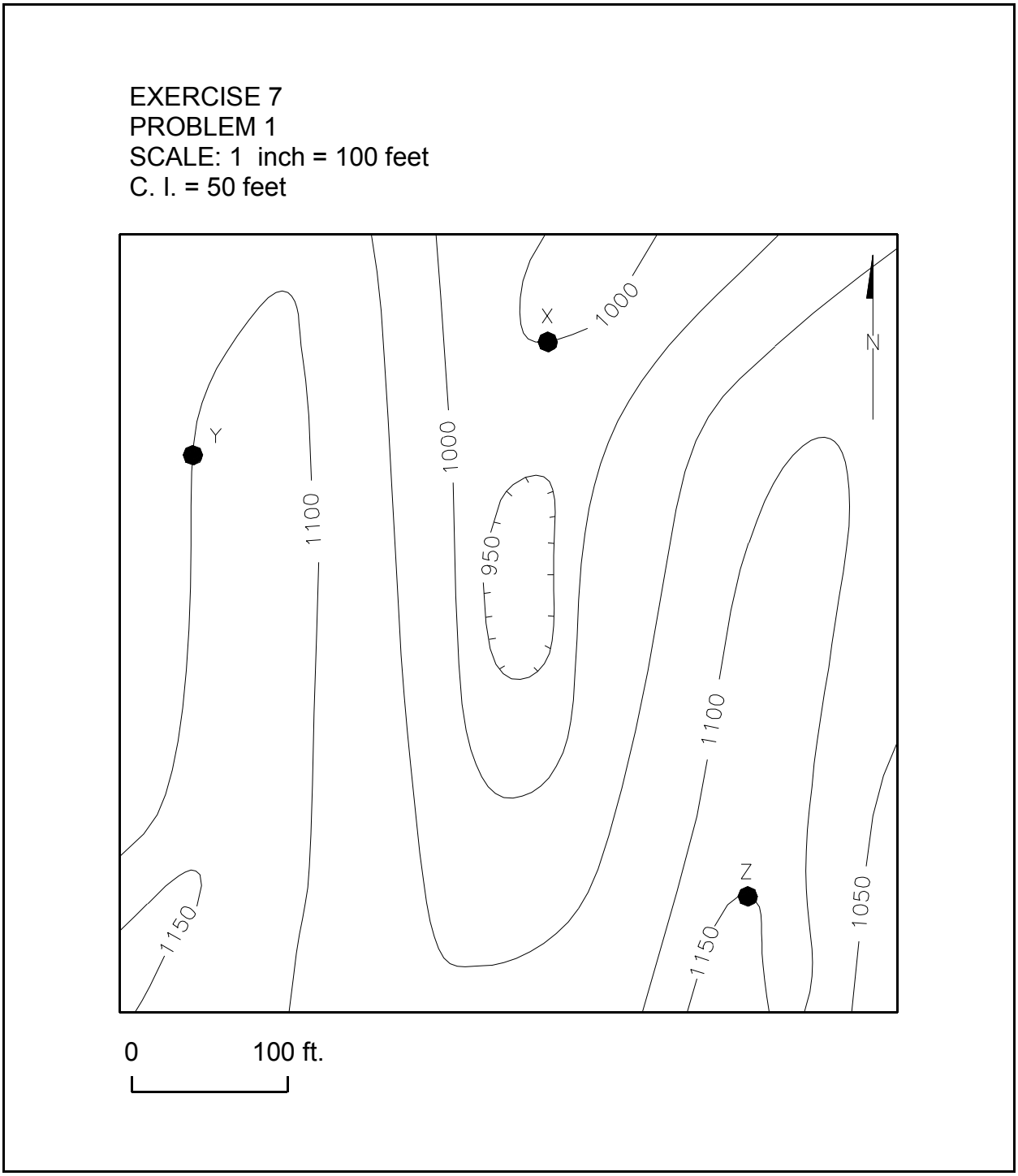

Figure 8-3: Topographic map for problem 1.

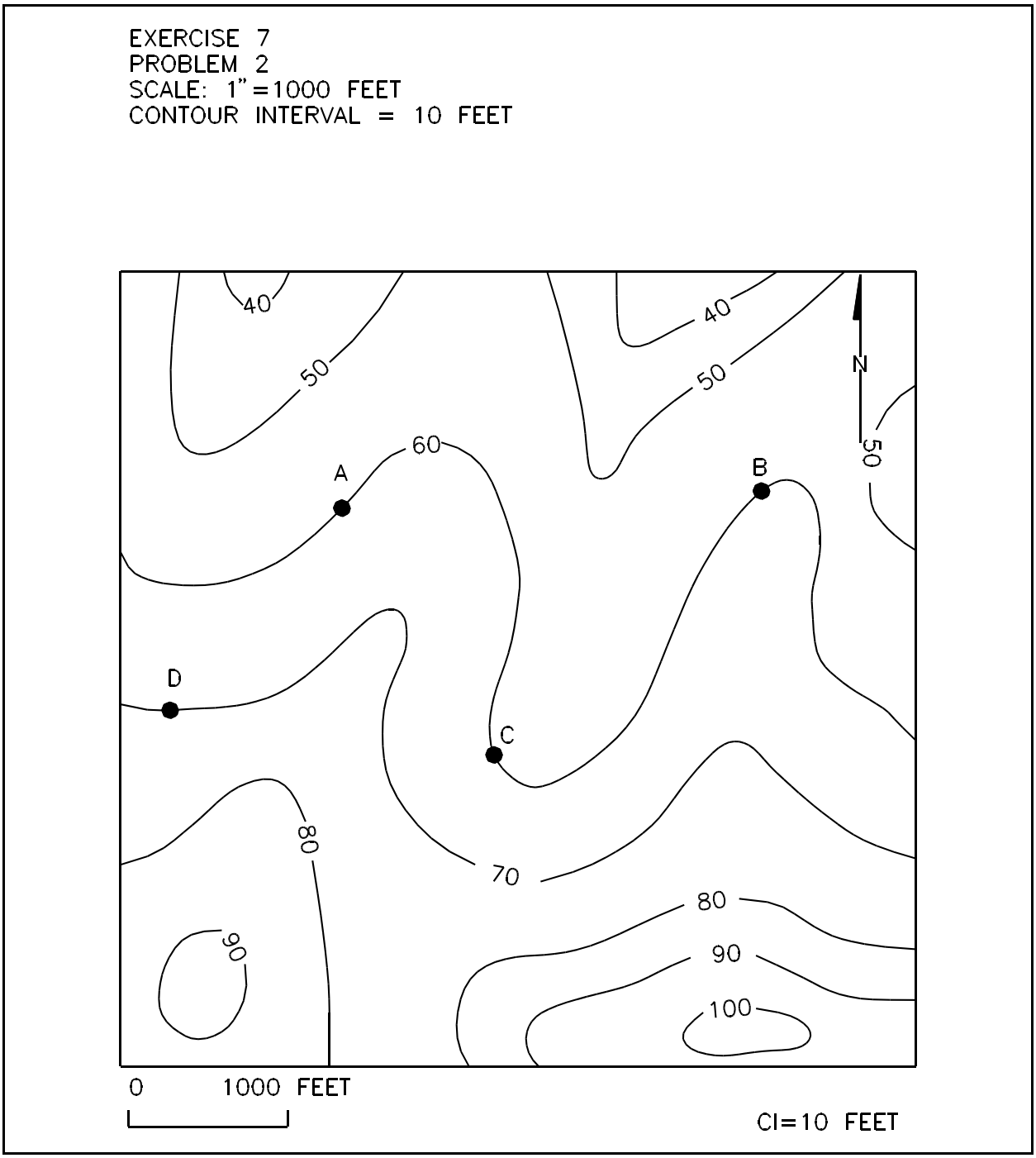

Figure 8-4: Topographic map for problem 2.

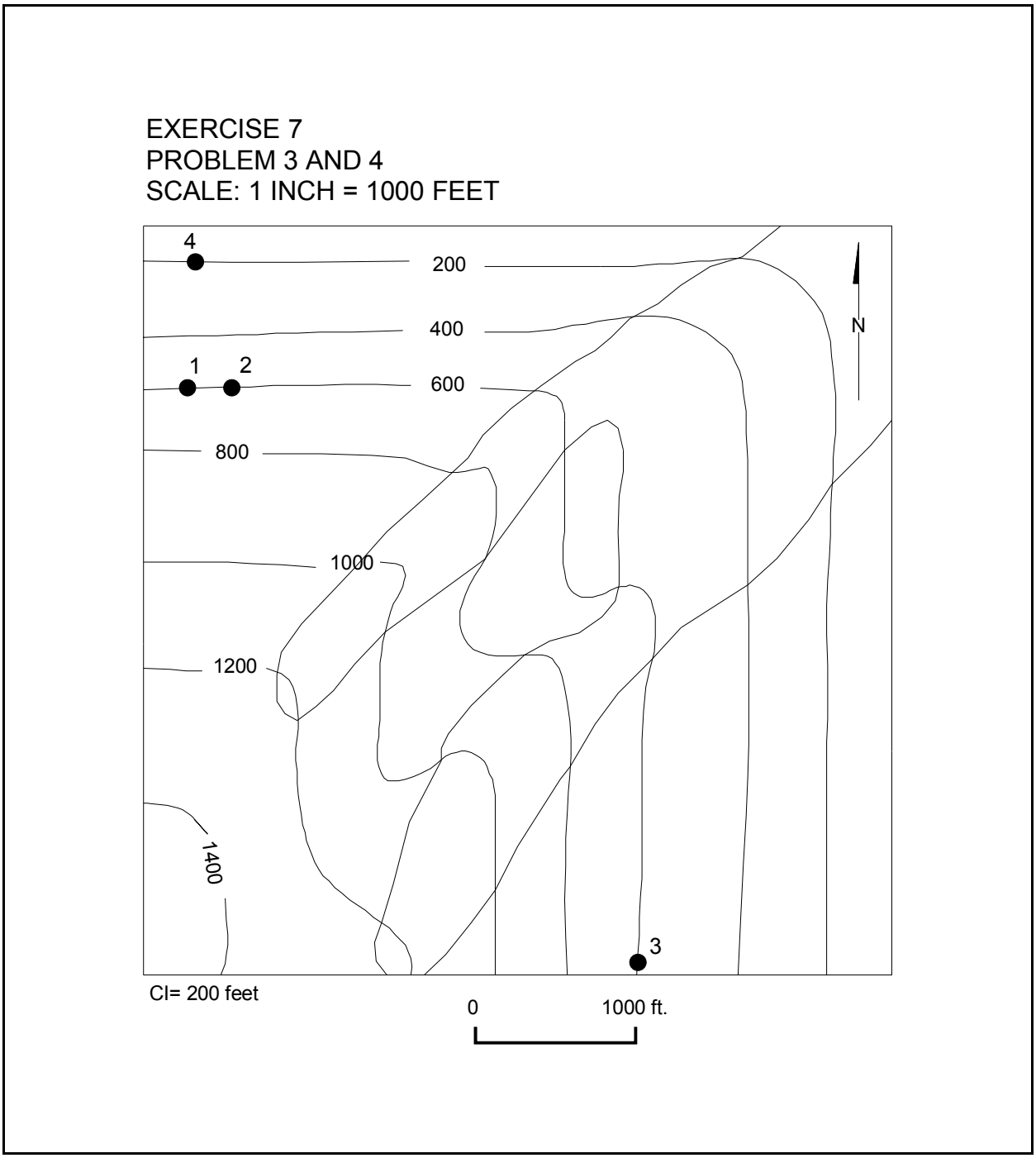

Figure 8-5: Topographic map for problems 3 and 4.

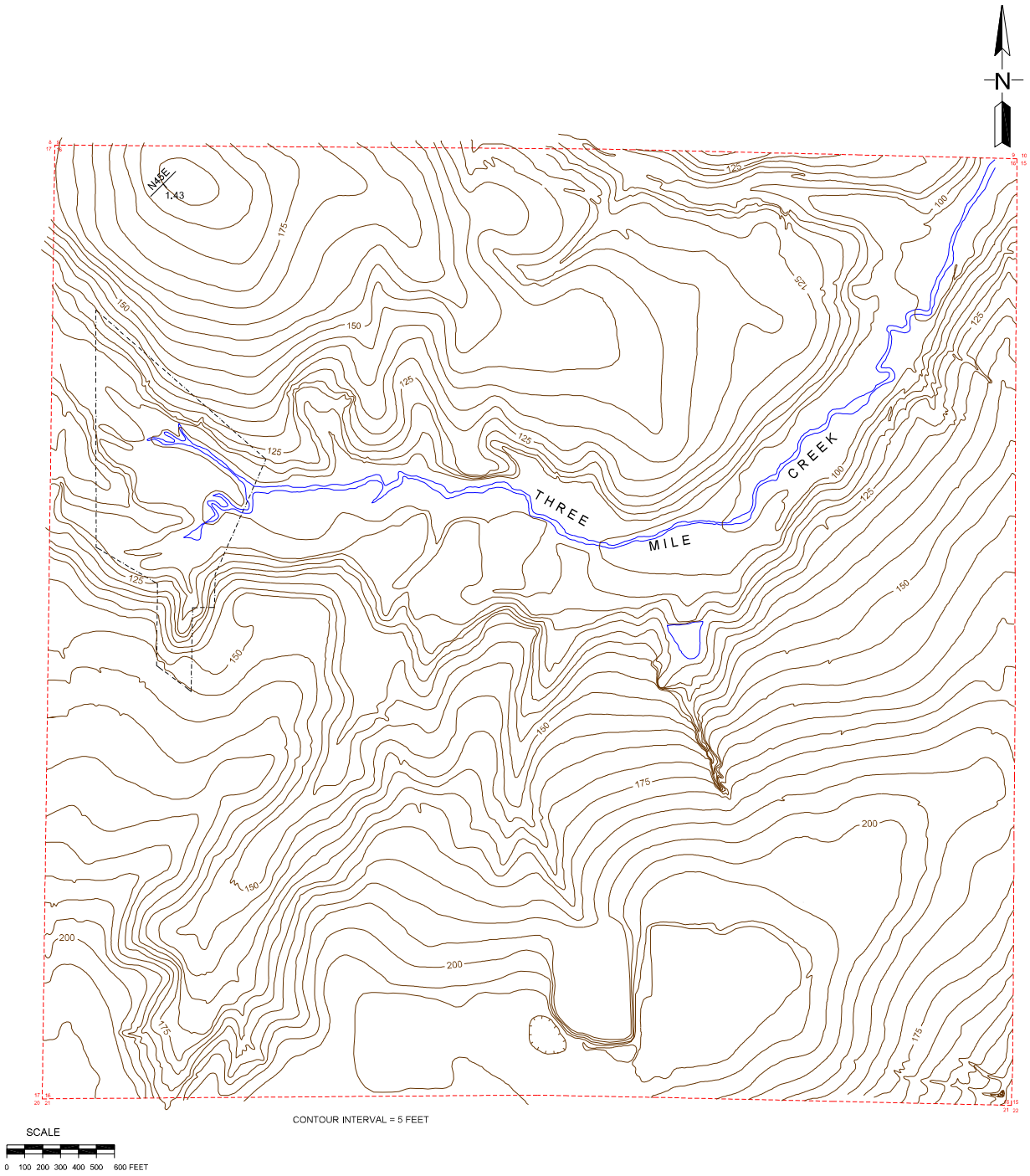

Figure 8-6: USA campus topographic map.