

# **Instructors Manual**

for

## **Construction Surveying and Layout**

**Third Edition**

**Part Three - Applications**

*Chapters 19-22*

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## Chapter 19 - Layout Techniques

### QUESTIONS AND PROBLEMS

**1. Discuss why planning is the most important part of layout.**

The first step in any layout is planning. That is why it is the most important part of layout. Without planning, a systematic approach to the layout will not be developed and layout will proceed haphazardly. Points will be laid out too late, or months too early. Always plan!

**2. Describe why it is important to have common offsets on a project.**

If variable offset distances are used, undoubtedly there will be a mistake made by using the incorrect offset distance to locate a point. Consistency is a requirement of establishing offset distances.

**3. What is the purpose behind the concept of performing layout from critical to non-critical points?**

Identifying the critical lines enables the layout persons to begin the layout at points that absolutely must be correct. If these points are correct, then the rest of the project will fall into place easier.

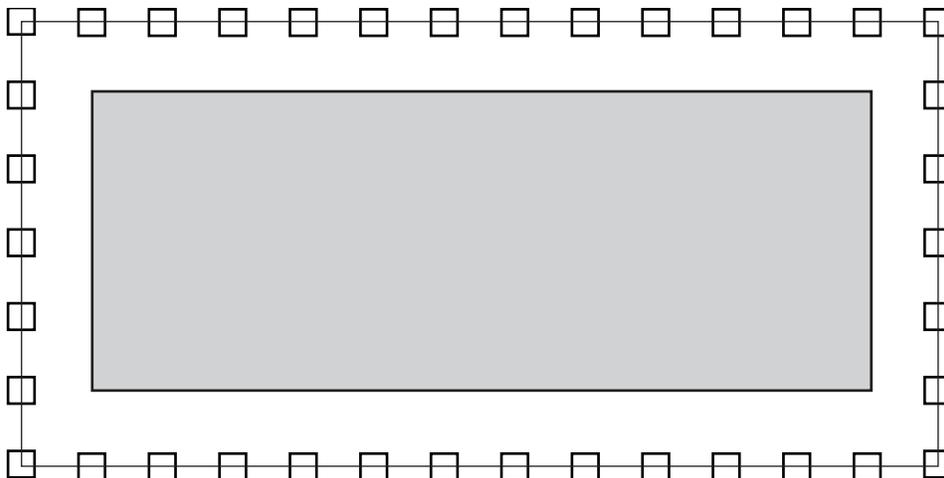
**4. What would be the benefit of beginning at the middle of a project with the most critical control line and working to the outside?**

If the layout is started at the middle of a project, any error that occurs will be able to be distributed to the outside of the structure. Everything will fit better if that is the case.

**5. Describe a situation in construction (not surveying layout) where measuring techniques to avoid cumulative errors is used.**

This is important to the carpenter when constructing a wall with windows and doors in it. If short measurements are taken between each door and window, small errors could accumulate and cause the length of the wall to be greater. By holding the end of the tape at one end of the wall and adding the dimensions needed to locate each door and wall, cumulative taping errors will be eliminated.

**6. Illustrate how the layout rule “surround the site with control” would work on a rectangular building.**



There will always be a long BS and short FS when the building is surrounded with control.



7. Refer to *Chapter 3, Fieldwork Practices*, and list the tolerance for the following layout activities: footings, foundations, batter boards, anchor bolts, walls, columns, locating rebar, setting the office trailer, offset points, slope stakes.

<i>To be laid out</i>	<i>Tolerance</i>
Footings	Not listed in chapter 3, however, footings have to be in the correct location so the walls can be located properly on them. Since footings are much wider than the walls, having them within a tenth will generally be sufficient.
Foundations	Not listed in chapter 3, however, foundations are an integral part of the structure of a building. The overall dimensions of the building are used in locating the foundation walls. Typically this would be to the nearest hundredth.
Batterboards	Not listed in chapter 3, however, batterboards are essentially secondary control lines that are used to locate walls, anchor bolts, etc., therefore they should be located to the nearest hundredth
Anchor bolts	Hundredth
Walls	Interior walls – half an inch, Plumbing a wall – hundredth in 10 feet
Columns	Hundredth
Rebar	0.05 is typical, although when there is lots of rebar in a structure, locating them to the hundredth is not unusual
Office trailer	Nearest foot is typical
Offsets	The same tolerance that was used for the point that the offset stake is set for.
Slope stakes	Tenth

8. Describe why consistency is so important in layout.

Consistency is important so there will be no communication mistakes in the layout. For example, if all the offsets of column lines are 2 feet to the West, and all of a sudden 2 feet to the East is used, there is a great chance that a mistake will be made. Consistent methods should be used in all aspects of layout so mistakes can be avoided.

9. If radial layout with a total station was used to lay out a “T” shaped building, what “change technology” method could be used to check the layout?

Using a chain to check the building dimensions and also the diagonals between the rectangular shapes within the building.



**10. List five items that should be considered when planning a bridge layout.**

1. Width of the river
2. Terrain surrounding the river.
3. Type of surveying instruments available.
4. Measurement skill of the construction surveyor.
5. How the work will be checked
6. etc.

**11. Research local building codes and determine the frost depth for your area. How deep should monuments be set in that area?**

This varies tremendously. For example, in Florida or Texas or other southern states where there freezing temperatures do not occur, there is no frostline. However, in the Midwest, Indian for example, the frostline for Lafayette Indiana is 30 inches. If you go further North to North Dakota, the frostline will exceed 60 inches.

**12. Contact a professional surveying company and conduct an interview on the types of control they provide on construction sites. Determine if a “report of survey” is provided for the work performed. Determine the type of monuments set, and the instruments and methods of measurement used.**

There is no single answer for this question. It is dependent on the responses from the professional surveyor.

**13. Describe how primary control could best be protected on a building site.**

There are many ways to protect primary control. The best method is to set the control off of the building site so it will not be disturbed by the construction activities. If it is not possible to set it off of the site, look for a location on the site that is out of the way of the construction activities. Plan to put the control in concrete and protect it with concrete traffic barriers.

**14. Describe how primary control could best be protected on a highway project.**

On a highway project, control that is located within the Right of Way of the project is likely to be destroyed by the equipment. The best place to place control is outside of the ROW on private land where the points should not ever be disturbed. Always plan to get permission from the landowner.

**15. Develop a Table that lists the differences and similarities between primary, secondary, and working control.**

<i>Type of Control</i>	<i>Similarities</i>	<i>Differences</i>
Primary	All of these points are established for the same reason—the layout of the structure.	Primary should be permanent and is set in concrete. Secondary is semi-permanent and may be in concrete or wooden stakes. It is established close to the work. Working control are those lines that are placed for the crafts to build from.
Secondary		
Working		



- 16. Visit a local school and sketch a rough site plan showing the streets, roads, and outline of the building. If you were to lay out that building and the site, describe and illustrate where you would locate the control.**

This answer is case dependent. All schools are different and conditions are unique. Review the chapter and follow the principles discussed.

- 17. Explain the concept behind the rule of thumb “get ½ of what follows you.”**

It is necessary to layout to required tolerances. However, if the tolerance for a wall is  $\pm 1/2$ ", the layout person should not perform the layout to  $\pm 1/2$ ", instead, it is a good rule of thumb to get half of the tolerance. In this case, the layout person should measure to  $\pm 1/4$ " or, one half of the tolerance that is expected. If the layout person were to take the  $1/2$  and the craftsman were to take  $1/2$ " it is possible that the wall could be off 1".

- 18. List ten objects that could be used as benchmarks along a typical city street.**

1. Top of curb
2. Sidewalk
3. Base of light pole
4. Rim of manhole
5. Concrete step
6. Fire hydrant
7. Roadway pavement
8. Driveway
9. Top of metal fence post
10. Electrical transformer base

- 19. Explain why vertical control should be placed on the first concrete poured on the jobsite.**

- 20. Describe how you think a 1,000,000-square-foot factory might be laid out.**

That is really an open question. It all depends on the type of building, the location, the methods of construction, type of instruments available, skill of the persons doing the layout, etc. There isn't one answer because there are too many unknowns.

- 21. Describe how you think a 1000-square-foot residential structure might be laid out.**

A 1000 square foot structure could be a 20' by 50' building or some combination of dimensions and shapes. It is not a large structure so several layout methods could be used. Of course, radial layout can be used if there are coordinates for the corners of the structure. However, if there aren't coordinates and there are just building dimensions, then it is likely that baseline offset will be used. The builder will establish a baseline, probably one face of the structure, and will measure building dimensions along the baseline and set up an instrument at those points on the baseline and turn 90° angles to establish the corners. When all points are set, diagonals will be measured where possible to confirm that the structure is square.



**22. Describe how a 50-foot-long bridge over a small stream might be laid out.**

With a bridge this small, it is likely that centerline will be easily established on both sides of the stream. It will be possible to stretch a chain across the stream to locate center of the face of each abutment. An instrument will then be set on that point on each abutment and the designed angle of the abutment to the centerline turned. The ends of the abutments and offset points can then be set. These points will be used by the crafts to dig the footings and set the forms for the abutment.

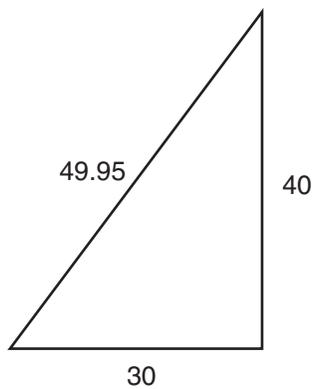
**23. Describe how a bridge over the Mississippi River might be laid out.**

This type of bridge will have huge abutments and will probably have half a dozen or more piers in the middle of the river. It is likely that in addition to the centerline of the roadway, offset points will be established up and down the river from the centerline. The points will be similar to surrounding the bridge with a control traverse. The coordinates of each point around the bridge will be known. The establishment of centerline will be easily done by projecting the centerline from one side to the other with a Total Station. Distances between the abutments will be shot with the total station and the face of each abutment established on the ground. The TS will then be used to turn the appropriate angle for the face of the abutment. The location of the piers will be done from the centerline stakes or the offset control points or with the use of GPS. A barge will be used to go out and mark the position by driving sheet piles to surround the location of the pier. The water will then be pumped out of the area where the pier will be constructed. Caissons will be drilled or driven to create the foundation for the pier. They will be laid out from an instrument set on the side of the sheet piling with a backsight onto centerline or another control point. This will be repeated for each of the piers on the river.

**24. List 5 uses of the 3/4/5 triangle method of layout in a building.**

1. Establish a baseline and use the 3/4/5 to establish the initial corners of the building.
2. Establish the corners of the building by measuring a combination of 3/4/5 along the sides and checking the hypotenuse to square the corner.

**25. Instead of a 90-degree angle, how far off will the angle be from 90 if the triangle measurements are 30/40/49.95?**



Using the following formula.

$$\sin = \frac{\text{Opposite}}{\text{Hypotenuse}}$$

Calculate Angle A and B and add them together. Subtract that from 180° to get angle C.

$$\sin A = \frac{30}{49.95} = 36^\circ 54' \qquad \sin A = \frac{40}{49.95} = 53^\circ 21'$$

Added together, these angles total 90° 07' 10"

Subtracted from 180°, Angle C is 89° 52' 50"



**26. List 10 ways to check radial layout.**

1. Calculate all layout values at least two times to ensure that the numbers are correct before going to the field.
2. Shoot the distance to the backsight and compare
3. Turn an angle from the backsight to another control point and compare.
4. Layout the building from one control point and move the instrument to another control point and check the layout from there.
5. Layout the building and then check the layout distances with a chain.
6. Layout the points and check their location with GPS.
7. Set up your instrument on the layout points and turn angles between control points and compare.
8. Set up the instrument and perform a resection to obtain the coordinates of a random control point and then calculate and turn angles to the points laid out.
9. Eyeball the alignment of points to see if it looks right.
10. After the points are laid out, do an as-built and shoot the points and compare them to the planned location.

**27. For baseline layout, describe the significance of having four points monumented on the baseline.**

If a baseline is established with only two monumented points, and one of the points is destroyed, the baseline is gone.

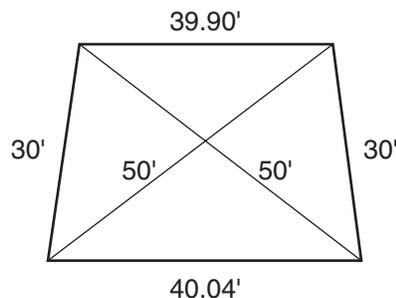
If the baseline is established with three monumented points, and one of the points is destroyed, the baseline is still there, but there is no check to make sure one of the remaining points has not moved.

If a baseline is established with four monumented points and one point is destroyed, three points will remain and you will be able to check the baseline by setting an instrument on one of the points and sighting the remaining two points.

**28. For an “L” shaped building, in which the longest side is parallel to a baseline, how many instrument setups will be needed to set the corners of the building?**

Three instrument setups on the baseline.

**29. Illustrate with a sketch how a building will not be square even if the diagonal distances between opposite corners are the same length.**



As you can see here, the two diagonals are the same length, but the corners are obviously not square with each other. This is why a surveyor cannot depend on such a method to make 90 degree corners. Using the 3/4/5 triangle method would be much more accurate.



**30. Describe the advantages and disadvantages of the method of intersection layout.**

The greatest advantage is that once the monuments are in place, no angles or distances will need to be measured to establish the points on the project.

The major disadvantage is that it will be time consuming to put in the large number of monuments needed to perform intersection layout.

**31. How many monuments would need to be set for an intersection layout around an 800-foot by 1200-foot building if the column lines in the building are 50 feet on center?**

Divide each dimension by 50 to get the number of monuments on a side.

$$800 \text{ ft} / 50 \text{ ft on center} = 16 \text{ monuments}$$

$$1200 \text{ ft} / 50 \text{ ft on center} = 24 \text{ monuments}$$

Each of these will be doubled since there is an opposite side to each.

$$16 \text{ times } 2 = 32$$

$$24 \text{ times } 2 = 48$$

Adding together, the total number of monuments needed around the site to perform layout by intersections is 80 monuments.

**32. For the building you visited in Question 16, develop a layout plan for laying it out by each of the layout methods described.**

- a) 3/4/5
- b) Intersections
- c) Baseline Offset
- d) Radial

Because this answer is project specific, there can be many solutions. Therefore, it is not possible to provide an exact solution. The student should simply follow the principles that have been put forth in the text and develop a plan that meets these principles.

**33. After laying out a 200-foot by 600-foot building, it is found later that the target was set up 0.02 feet off of the backsight that was 500 feet away. Proportionally, a foresight point 300 feet away will be off by how much? Would this be acceptable for anchor bolt layout?**

Set up a proportion of the known error to the distance and set it equal to the unknown error to the distance. Like this:

$$\text{Proportion: } 0.02/500 = x/300$$

$$\text{Solving: } x = .012 \text{ error}$$

The acceptable tolerance for setting an anchor bolt is 0.01. This value is slightly larger by 0.002. Even though this is larger than the tolerance, 0.002 is not measurable, so I would accept this layout situation.

**34. Looking outside where you are right now, identify five objects that could be used as natural backsights. Describe why they would be good.**

Examples would be: a church steeple, cell tower, water tower tall building, power pole, highway sign, etc.



**35. In the process of bucking in on line, the instrument is exactly in the middle between Points 1 and 2. If the instrument line of sight is 2 feet to the right of the 2nd point after plunging the scope, about how much should the instrument be moved?**

One foot

**36. Describe how double-centering is important in highway or railroad construction.**

In highway or railroad construction, you are dealing with a linear route. The project is narrow but can extend for miles and miles. It is typical to have to prolong the line of the route beyond the existing points. This is done by setting up on the last established point and backsighting to other points on centerline. The instrument is then plunged and a new point on line is established. To eliminate instrumental error, the instrument should then be turned 180° back to the backsight and plunged again to the new point. If two lines are marked on the new point, simply split the difference and mark the midpoint or, double-center.

**37. Describe how double-centering could be used in building layout.**

Anytime critical points need to be laid out, double centering should be used. If you are doing a baseline offset method of layout, you will be turning lots of 90° angles. To set an anchor bolt template in the middle of the structure, it would be best to double center the location so any instrumental or sighting errors can be eliminated.

**38. Setting grade is simply another term for what process in layout?**

Leveling

**39. Draw and label grade stakes for the following information:**

a) Fill 2.3'



b) Cut 15.9



c) On grade



**40. List 5 applications of “setting grade” in the construction of a building.**

- 1) Setting grade for the excavation of the site.
- 2) Setting grade for the caissons
- 3) Setting grade for the foundation forms
- 4) Setting grade for the anchor bolts.
- 5) Setting grade for finish floor.
- 6) Setting grade for the sitework.
- 7) Etc.

**41. What is the most important aspect of setting grade on a roadway?**

Confirming that the grade stakes are based on a benchmark network that has been checked and rechecked to be sure the elevations are correct from start to finish of the project.

**42. Describe the objective of slope staking.**

The objective is to determine that point where the design slope meets the original ground and set a stake at that point. An operator can then begin the cut or fill at that point.

**43. In the process of setting slope stakes, what critical field-determined value besides the distance measured is needed? How is it obtained?**

The height (elevation difference) between the finish grade and the original ground is very critical to the slope staking process. It can be obtained by the use of a hand level, automatic level, or laser level using differential leveling field procedures.

**44. If a fill area on level ground has a top (base) of 45 feet, side slope at 1-1/2 to 1 left, and side slope of 2 to 1 right, with a height is 15 feet, what is the distance from the centerline to the slope stakes?**

Left Side	Right Side
$d = \text{base}/2 + s(h)$	$d = \text{base}/2 + s(h)$
$d = 45/2 + 1.5(15)$	$d = 45/2 + 2(15)$
$d = 22.5 + 22.5$	$d = 22.5 + 30$
$d = 45 \text{ feet left of centerline}$	$d = 52.5 \text{ feet right of centerline}$

**45. If a cut area has a level base of 24 feet with side slopes of 2 to 1, what is the distance between the slope stakes right and left if the height is 10 feet?**

Left side + base + right side = total distance between stakes  
 $s(h) + \text{base} + s(h) = \text{distance}$   
 $2(10) + 24 + 2(10) = 64 \text{ feet}$

**46. In the illustration to the right, the right-of-way (ROW) that was purchased from the landowner is 175' wide and the centerline of the road project is in the center of the right-of-way. What is the actual distance between the slope stakes right and left? Is there a problem?**

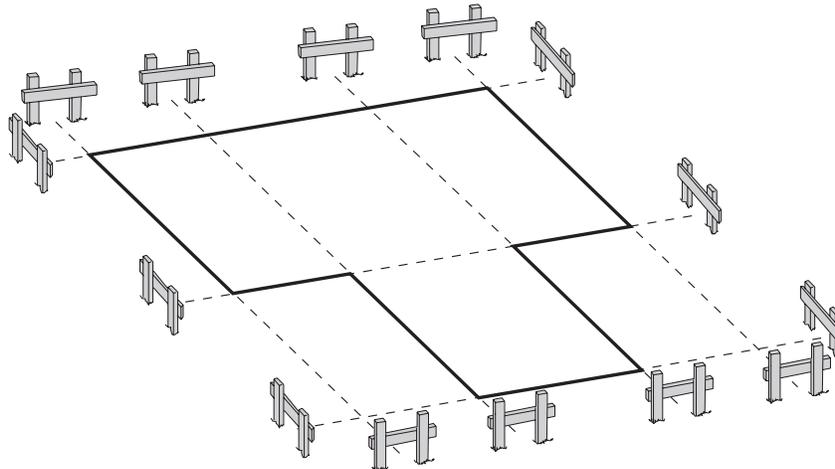
The calculated distance between the slope stakes is 176.1 feet. The purchased right of way is 175 feet. Therefore, there is a problem in that the road as designed is too wide for the purchased right of way. The design will probably have to be changed by making one of the slopes steeper.



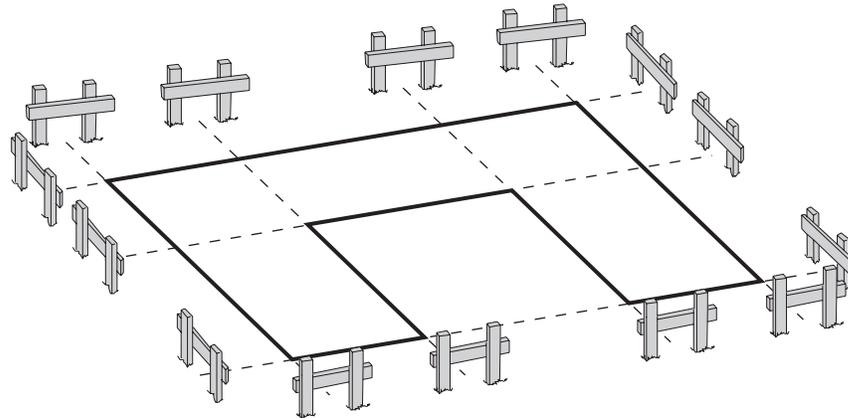
47. Describe and compare the various methods and equipment that can be used for vertical alignment. List uses, ranges (if applicable), and versatility.

<b>Method</b>	<b>Uses, range and versatility</b>
Plumb bob	Can be used in almost any application. Is limited by the length of string. Very versatile and easy to use.
Carpenter's level	Any vertical application. Good for short heights between floors or for a single column. Cumulative error can result. Easy to use, but limited range.
Pocket Laser	Very convenient tool. Can be used in most vertical applications. Limited to about 100 feet vertical. Easy to use, but can be difficult in a high rise when the floor is vibrating, for the beam will then move.
Utility Laser	Any vertical application. Very versatile. Can be used to project a single vertical line or a vertical plane. Has great range of over 1000 feet. Very simple to use.
Zenith Plummet	This is a highly specialized piece of equipment used for the precise plumbing of structures. It is essentially an automatic level that shoots a line vertically. Can easily be checked to be sure it is projecting a plumb line. Can be used in the tallest of buildings. Simple to set up and operate.
Total Station/Theodolite	An optional diagonal eyepiece can be attached to the eyepiece of many surveying instruments. This makes the instrument very versatile and useful for multiple applications. Easy to use but can be limited in very steep applications.

48. Draw a “t” shaped foundation and place batter boards as needed at the corners.



49. For the following foundation, place batter boards as needed to string every line.



50. Develop a poster that provides a new employee with rules for setting string lines.

## **IF YOU ARE GOING TO USE STRINGS, FOLLOW THE RULES**

1. Keep it tight
2. It should be thin.
3. Use braided string
4. Switch to Piano wire for ultimate strength and thinnest
5. Fasten it securely
6. Tie it/wrap it/bind it
7. Check it, check it, check it.

