2 PLANNING

A. INTRODUCTION TO ROAD PLANNING

Good planning can minimize the impact of a road on the environment and provide low-maintenance, low-cost access for landowners. It will pay many times over to sit down and seriously plan for the road and road network before making irreversible decisions that cost extra money, waste time later and damage the environment. Poor planning and road location is often associated with the most common causes of road failure and high maintenance costs. Road "planning" should not be the purview of heavy equipment operators blazing a path from one point to another. Rather, it is a systematic process that requires consideration of a number of variables and is a part of a larger management strategy that includes transportation and land use planning, logistics, economics and environmental protection.

Two basic tenets of road planning should be followed. **First, minimize the number of roads constructed in a watershed through basin-wide transportation planning.** If you don't own the entire watershed, consider meeting with other landowners to see how road network planning can benefit everyone by saving money and causing the least impact. Most landowners want to cause as little disturbance as is possible and to minimize construction and subsequent maintenance costs. There is great economic and environmental benefit to developing a coordinated road plan and reducing road construction in a watershed. Roads should be minimized because they remove land from production and often cause erosion and water quality degradation.

Second, existing roads should be used wherever possible, unless using such roads would cause more severe erosion and water quality or environmental problems than building a new alignment elsewhere. Alternatives to roads in sensitive environmental areas, such as streamside and riparian zones, should be identified wherever possible if their reopening or use would have unavoidable, adverse impacts. Existing roads might require some rebuilding or upgrading, but using them is usually much less expensive than new construction. Sometimes, because of property lines that divide ownerships, roads have been built close together on adjacent properties. Cooperative use of existing roads can prevent this kind of duplicate and unnecessary construction in the future.

Treat your neighbors well. Efforts should be made to develop easements or agreements that allow mutual use of roads on or near property boundaries, saving time and expense. Written and recorded rights-of-way mutually benefit all parties concerned. Such agreements should define the road location, ingress and egress routes, road width, levels of use, maintenance responsibilities, monetary considerations, and any other pertinent points. A survey, properly recorded, may be needed to clearly identify the boundary line. It is suggested that an experienced local attorney be consulted to ensure that all legal and liability requirements have been addressed.

B. NEED FOR A ROAD

Two of the most important steps in planning for a road are 1) determining whether or not the road is actually needed and 2) deciding what standard of road is called for. Ask yourself these questions:

- **What will the road be used for?** Will it be used for residential access, access for grazing or farming, timber hauling, fire control, and/or for recreation? What kind and size of vehicles, log yarding equipment or commercial vehicles will be used?

- **How often and when will the road be used?** Is it a one-time use (e.g., for timber removal or mining) or daily use (e.g. for residential access)? How fast do you expect vehicles to travel? Is it only to be used during the dry summer months or will you need to use it during wet weather conditions (i.e., does it need to be an all-weather road)?

- **Is there an existing road, either on your property or on an adjacent property that could be used or rebuilt?** If the road is being built for timber removal or other resource extraction, can an alternate harvesting, yarding or extraction method be selected that would either shorten the length of a new road or eliminate the need for a new road altogether?

A sound, thoughtful review of the present and future needs for this road will assure that it is needed and that it will accommodate the expected type and level of traffic. It is frustrating, and potentially costly, to build a road that cannot accommodate all the needed uses. At the same time forest, ranch and rural roads should be built to the minimum standard necessary to accommodate all reasonably anticipated uses and equipment.

C. ROAD SIZE AND STANDARDS

After deciding why a road is needed, you can determine the minimum size or standard that is appropriate to meet your requirements (Figure 9). Table 9 provides suggested minimum standards for single lane, packed gravel surface and native surfaced roads with traffic of less than 100 vehicles per day.

Horizontal curves occur where the road goes around a ridge, watercourse or other obstacle, and vertical curves are those where the road goes over the crest of a hill. Both kinds of curves require a minimum length of visibility at a given driving speed to assure safe stopping distances for trucks and other vehicles.

It is also important to provide passing lanes and turnouts on narrow, single lane roads, and turnarounds are needed at the end of all dead-end roads. Turnouts should generally be located so you can see from one to

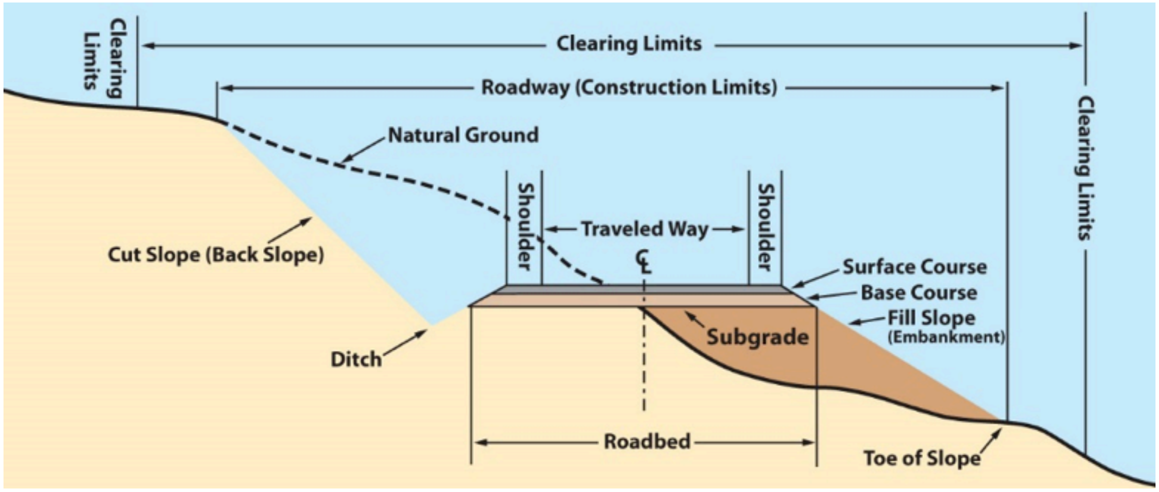

FIGURE 9. *Road element terminology (Steinfeld et al., 2007).*

the next, and so oncoming traffic can safely pass without vehicles ever having to back up.

In some situations, long, straight roads may encourage excessive speeds. To discourage unsafe driving speeds, straight sections of road can be limited to 400 feet, or less. The road should be contoured to the landscape to minimize cuts and fills. Rolling grades or rolling dips, used for surface road drainage, also help keep travel speeds at a safe level.

Other considerations may also dictate road size. For example, in erodible, unstable or steep terrain, small narrow roads are often preferred because of their smaller footprint, reduced excavation requirements, and lessened environmental impact. Spur roads and other low volume roads are often narrower and of lower standard than trunk roads that service large areas or serve as major connecting links in the road network.

All other conditions being favorable, financial considerations and planned uses may play large roles in determining road standard and size. Costs are directly proportional to the standard of the road, and high standard roads are usually built where economic returns from land management (such as logging, mining or residential development) can pay for the

TABLE 9. Typical minimum standards for low-volume roads[1]

Design standard	Collector or mainline road	Rural access or secondary road
Design speed (mph)	40–55	20–30
Road subgrade (ft)	16–20 ft wide (optional 2–3 ft ditch)	12–16 ft wide (optional 2 ft ditch)
Running surface width (ft)	12–16 ft	12 ft
Road grade (%)	12% max.	15% max.
Curve radius (ft)	80 ft min.	50 ft min.
Road shape	Outsloped, insloped, crowned (5%)	Outsloped, insloped, crowned (5%)
Road drainage types	Ditch, ditch relief culverts, rolling dips	Ditch, ditch relief culverts, rolling dips, water bars
Road surface material	Gravel, chip-seal, pavement	Native or gravel

[1]based on Keller and Sherar (2003) and Oregon Department of Forestry (2000)

FIGURE 10. *This well-built permanent road is designed for year-round use. It is contoured to the natural topography, is slightly outsloped, has no outside berm, is occasionally rolled to provide continuous surface drainage and is rock surfaced for wet-weather traffic. This self- maintaining design will provide years of uninterrupted use.*

added improvements, or where planned uses require high standard roads (e.g., for wet weather access to residential properties).

Road classification also indirectly affects road standard.[1] Forest, ranch and rural roads are often divided into classes called permanent, seasonal and temporary, in generally decreasing order of road standard and size. **Permanent roads** form the core of the all-season road network, and are surfaced to allow winter uses, such as log hauling and year-round residential access (Figure 10). Permanent roads have watercourse crossings designed to accommodate at least a 100-year flood flow, including debris and sediment loads, at all streams. **Seasonal roads** are a part of the permanent road network with drainage structures (or fords) designed to pass the 100-year flow, but they may not be of sufficient standard for heavy, wet-weather use or hauling (Figure 11). Both permanent and seasonal roads require regular, seasonal and storm period inspection and maintenance.

Temporary roads are lower standard roads with a surface adequate for use during the dry periods and drainage structures adequate for flows during the anticipated period of use, but are removed before the beginning of the wet weather period (Figure 12).[2]

Upon abandonment or closure, all drainage structures and stream crossing fills are removed, and the road surface is permanently drained using a combination of outsloping, rolling dips, waterbars and ditches.

For combined public use and commercial routes (e.g., forestry or mining), road standards and size may also be dictated by mining, harvesting and yarding equipment needs, as well as the season of use. For example, U.S. federal forest roads are classified for the combined use of forestry and recreation. Roads are classified by use type and traffic levels into 5 maintenance classes. Other types of land use have their own special or unique requirements for standards. Features such as paving or rock surfacing, dual lanes, and oversized drainage

[1]See Appendix C for the California Forest Practice Rule specifying these requirements.

[2]See Appendix C for the California Forest Practice Rule specifying these requirements. Temporary roads on timber harvest plans may remain in-place for the life of the approved plan (several years) before they are removed *only if their drainage structures are designed to accommodate the 100-year design flood event and road surfacing and surface drainage is designed for the expected use during that period. That is, it must meet standards for at least a seasonal road.*

FIGURE 11. *Seasonal roads are built to the same specifications as permanent roads, but are not surfaced for all-weather traffic. They typically provide summer or dry period access to watershed areas. The potentially erodible road surface may be waterbarred before each winter (not shown), or outsloped with rolling dips to provide for rapid drainage of surface runoff.*

FIGURE 12. *Temporary roads are often spur routes constructed off permanent or seasonal roads that provide short-term access to watershed areas. They are usually outsloped, unsurfaced and used only during dry soil conditions. All stream crossings need to be physically excavated and removed upon the completion of operations or prior to the onset of the wet weather (winter) season (October 15 for non-federal CA forestry roads). In forested areas, if the roadbed is ripped or tilled, it can be planted with trees to return the site to productivity.*

structures can all add substantially to construction costs. If these features are not needed, given the planned use of the road and requirements for environmental protection, they should not be built into the project.

D. ROAD SYSTEM LAYOUT

In forest and ranch road planning, the concepts "less is best" and "avoid the worst" generally describe the most economical and environmentally sound approach to planning for road building and road system layout. Some of these important concepts are listed below:

1. Minimize total road miles in your watershed;

2. Minimize new road construction by using existing roads that are stable and in good repair;

3. Minimize construction of permanent and seasonal roads by using these standards only when absolutely necessary; use temporary roads to minimize long-term maintenance and reconstruction costs and reduce environmental damage;

4. Strictly minimize the number of watercourse crossings by building roads near ridges;

5. Minimize cuts, fills and vegetation clearing by contouring roads across the landscape; particularly by avoiding steep terrain;

6. Minimize road construction work near streams and riparian zones, and on unstable areas, inner gorges and steep slopes;

7. Minimize road width;

8. Minimize road gradient;

9. Minimize the concentration of runoff on and from the new road; and

10. Avoid problem areas and serious obstacles, when possible.

Road system layout is influenced by many factors, including topography, property lines, obstacles (rock outcrops, unstable areas, wetlands, etc.), and proposed land use activities. Controls on the location of a road include both natural features and man-made elements (e.g., Table 10).

1. HARVESTING AND YARDING TECHNIQUES

For timberland owners, road systems are often planned around the preferred method of timber harvesting and yarding for the terrain, and hauling routes for logs. Downhill tractor skidding, a common yarding technique in the past, required roads to be built in lower hillslope positions where slopes may be steeper, soils less stable and streams are larger and more incised into the landscape, or near floodplains and riparian zones where aquatic values are higher. These conditions can lead to greater erosion and soil loss from road construction, higher long-term maintenance costs, and higher environmental impacts. In forestry, cable yarding allows most roads to be built near ridges and in upper hillslope areas where environmental impacts are usually significantly reduced. Integrated planning for modern yarding techniques and road location and design will achieve the most economically and environmentally sound road system for that land use.

2. ROAD CONSTRUCTION VERSUS ROAD RECONSTRUCTION (UPGRADING)

In the last 70 years, tens of thousands of miles of low standard road have been constructed on private forest and ranch lands in California and throughout the western USA. Most of these roads were built to accommodate

TABLE 10. Some man-made controls which affect road location[1]

Control	Comment
Legal	Boundary lines limit the location of the road. Talk to adjacent landowners and work out written right-of-way agreements to share roads and reduce road construction.
Specific location	The beginning and ending points of a road are often fixed. They may be certain geographic features (e.g., a ridge top) or desired road intersection. These represent major controls.
Safety	Each class of road and level of use have specific safety requirements. Common sense should be applied in setting speed, grades, curve radius, sight distance, and turnouts. Regulations may specifically dictate certain safety-related road parameters.
Pollution control	Roads should avoid problem areas. Allow ample room to trap sediment in a buffer before it reaches a stream. Do not allow any direct discharge points where road runoff flows directly into a stream. Avoid floodplains, landslides, unstable or erodible soils, wetlands, and waterbodies, as well as slopes over 40% wherever possible.
Design elements	Physical limits for curve radius, road grade, pitch grade, stopping distance, fill slope length and separation from streams are set by you! Design to reduce maintenance costs and pollution potential. Road width may be dictated by emergency vehicle or equipment access requirements.
Migrating fish	Observe and maintain substantial buffers. Know what species use your streams, their habitat requirements, the susceptible periods of their life cycle, and their environmental tolerance limits. Permits may be needed from regulatory agencies (e.g., Department of Fish and Wildlife, NOAA Fisheries, etc.).
Approach road permits	Issued by the state's Department of Transportation or the jurisdictional county for roads connecting to public highways. Locations of intersections may be restricted.

[1] modified from USDA-SCS/USFS (1981)

timber harvesting, ranching and rural development. Some of these roads are now abandoned and grown over with vegetation. Some were built in locations which would not be acceptable for new road construction today. As these areas are re-entered for additional logging and/or rural land development, decisions must be made as to whether or not it is better to use the existing poorly maintained or abandoned road system, or to build a new road network in a better location using state-of-the-art techniques and standards (Figure 13).

The answer lies in considering both economics and environmental impacts. In many instances, reconstruction can be viewed as an opportunity to cost-effectively improve watershed conditions and reduce the threat of long-term erosion, while providing the opportunity to economically access a previously harvested or managed area.

Roads can be reconstructed for use, for stabilization, or for permanent closure. For example, in a final forest re-entry in an area it is often possible to temporarily open an old road for forestry activities, and then to systematically and permanently close it upon completion of operations, thereby removing all erosion threats. Proactively planning for this option, where it can be used, is often both economically and environmentally advantageous. Similarly, an old, abandoned road system may be located in an environmentally suitable location, but it is now overgrown with vegetation. In this case, reconstruction may cost significantly less than new construction in a different location and result in little erosion. Except in the worst cases, where reopening a road would cause excessive erosion risk, old roads that are not needed and pose environmental threats may be temporarily reopened without regard to road standard (i.e., pioneered open) so they can be permanently decommissioned.

When roads are planned for reconstruction, and to be a part of the permanent and seasonal road network, it is best to

FIGURE 13. *Because of our increased awareness of the potential impacts to streams in a watershed, some roads which were built in the past would not be built in the same locations today. In this example, a side-cast constructed road was built alongside a large, fish-bearing stream and ditch relief culverts still discharge muddy road runoff into the channel during storms (below person in photo).*

anticipate upgrading all drainage structures to current design standards (100-year peak flow, including debris and sediment loads) and redesigning road surface drainage to more modern standards (e.g., outsloping with rolling dips). Regulations may dictate some of the reconstruction standards that occur. For example, in California the Forest Practice Act and Rules require replacement and upgrading of all stream crossings to accommodate the 100-year peak flow, including debris and sediment loads, on watercourse crossings that need reconstruction.[3]

3. SELECTING FAVORABLE GROUND FOR NEW ROADS

In laying out a new road system in a watershed, the most favorable ground should be identified and utilized wherever possible. Favorable ground consists of ridges, saddles, natural benches and flatter natural slopes. Less excavation is needed if the road is built in comparatively low gradient areas and utilizes natural benches. Generally, a slight slope can improve road drainage, but steep slopes pose a number of problems. Well-drained soils are preferred for roads in order to maintain a dry travel surface. Terrain to avoid includes hard rock areas, inner gorge slopes, steep slopes, watercourse and lake protection zones, highly erodible soils, floodplains, flood prone areas, riparian areas, wet areas and swamps, areas of unstable soils or naturally occurring asbestos, and sensitive wildlife habitat (Figure 14).

If any stream crossings are required, you should identify the best locations for the crossings first and then plan to bring the road to those locations. Stream crossings are ideally placed where the channel is straight and narrow, the banks are low and the soil is firm and rocky. The approaches to the crossing should be as low or flat as possible and outside the 100-year floodplain, and the banks should allow for crossing directly perpendicular to the channel.

4. ROAD ROUTING THROUGH DIFFICULT TERRAIN

Avoidance is almost always the best solution to road-building in difficult terrain. Indeed,

[3]See Appendix C for the California Forest Practice Rule specifying this requirement.

Unacceptable option: Roads should not be built or reconstructed next to stream channels where multiple crossings are required. Many older roads may have been built in these locations and they are expensive to maintain and can greatly impact the stream. Whenever possible, these roads should be decommissioned and moved to more favorable locations.

Least preferred option: Roads built on steep or inner gorge slopes near streams should be avoided if possible. If not, they may require special construction techniques, such as full bench endhauling. Roads will require high maintenance and slopes in these areas may be unstable and prone to road failures that impact streams.

Preferred option: Roads should be aligned to take advantage of benches, low gradient slopes, upper hillslope areas and ridges. Generally, roads in these locations will be farthest from streams, have the fewest stream crossings, cost less to construct, be easier to drain, and require less maintenance.

FIGURE 14. *Road location (Modified from: Adams and Storm, 2011).*

the recognition and avoidance of unstable slopes is without doubt the most effective and cost-efficient method of managing landslide-prone terrain. Similar avoidance measures should be taken for highly erodible soils, steep slopes, water bodies, wetlands and other obstacles which are likely to threaten the integrity of the road or degrade environmental conditions. When possible, all serious obstacles to road construction should be avoided through complete realignment or by locally changing grade and circumventing problem spots as they are encountered. **It is far better to plan for a route containing fluctuating grades than to build a straight road which ignores the landscape through which it traverses.** Construction and maintenance costs will be minimized by sticking to the most favorable terrain.

In order of priority, the road planner and designer should consider:

1. **Avoiding** unstable slopes or soils.

2. **Preventing** destabilization using special road building techniques, when potentially unstable slopes cannot be avoided (consult a qualified geologist).

3. **Stabilizing** slopes which show signs of instability using special techniques developed by a licensed engineer or engineering geologist.

4. **Protecting** downslope resources when an unstable area cannot be physically or economically avoided, prevented, or stabilized.

Federal and state requirements for road planning, location, construction and maintenance of forest roads in the U.S. often include protection of resources through the application of best management practices (BMPs). The most common requirements include the following:

- Avoid filling wetlands and lowlands if practicable alternatives exist—especially in breeding and nesting areas for migratory birds and spawning areas for fish.
- Limit the number, length, and width of forest roads and skid trails to minimum necessary to accomplish the forest and ranch management goals, consistent with topographic and climatic conditions.
- Locate roads outside of riparian management zones (RMZs), except at stream crossings.
- Place bridges or culverts in road fill to prevent constriction of expected flood flows – other design methods may also be appropriate.
- Stabilize fill to prevent erosion and sedimentation—before, during, and after road construction.
- Minimize the use of equipment in wetlands outside of fill areas.
- Minimize disturbance of wetland and aquatic vegetation during the design, construction, and maintenance of roads.
- Design, construct, and maintain wetland crossings to avoid disrupting movement of fish and other aquatic species.
- Use good quality fill from upland sources whenever feasible.
- Place fill so as to not affect any threatened or endangered species and to prevent any adverse modification or destruction of critical habitat for these species.
- Do not place fill near public or private water intakes or where it could be eroded and delivered to a stream.
- Do not place fill in areas of concentrated shellfish production.
- Do not place fill in National Wild and Scenic River Systems, riparian zones, or stream channels.
- Use fill that is clean, stable and not highly erodible.
- Remove all temporary fill and restore disturbed areas to their original elevation and slope.

If it is impossible to move the alignment to avoid serious obstacles, construction costs and maintenance requirements are likely to climb sharply as special construction techniques (such as endhauling of fill material) are employed to build a stable road bench and to minimize post-construction erosion.

E. PRELIMINARY ROAD LOCATION

The road should be plotted and located by a person with some knowledge of the area to be served by the road and of the terrain where the road is to be built. A tentative road location should first be roughly plotted on aerial photographs and topographic maps. At this stage, several alternate routes should be developed and plotted for investigation during later field reconnaissance. These alternative locations should be visually fitted to the topography (roughly paralleling the contour lines) as much as possible to minimize cutting and filling. Aerial photos and satellite imagery (e.g., Google Earth) are useful for identifying natural features on the landscape that don't show up on the topographic map.

One procedure for plotting an alignment on topographic maps is shown in Figure 15. Using the known contour interval printed on the map, together with a set of measuring dividers, you can easily plot a tentative course for the road while keeping within the allowable grade limits. By combining this method with observations from aerial photographs, some of the recognizable obstacles and control points can be located, and a route with a suitable average grade can be identified and plotted on the topographic map.

Table 11 shows the computations for the example in Figure 15, including three possible alignments for a road to be built from point "1" to point "4." A simple, 6-step methodology can be followed to arrive at these "paper alignments."

1. Mark the beginning (1) and ending points (4) of the road.

2. Mark other known control points along the route (control points are natural features that dictate or limit your choice of road location, such as a stream crossing, lake, landslide, rock outcrop or saddle in a ridge).

3. Compute the elevation difference between each control point.

4. Compute the estimated average grade of each road segment between control points (dividing the difference in elevation between two points by the length of road between them gives the sustained or overall grade of the road segment).

5. On a divider, set the scale distance equal to the contour interval (C.I.) divided by the decimal percent grade (distance = C.I./grade). Then, simply mark the primary and alternate road alignments using the dividers as set, and move from one contour line to the next.

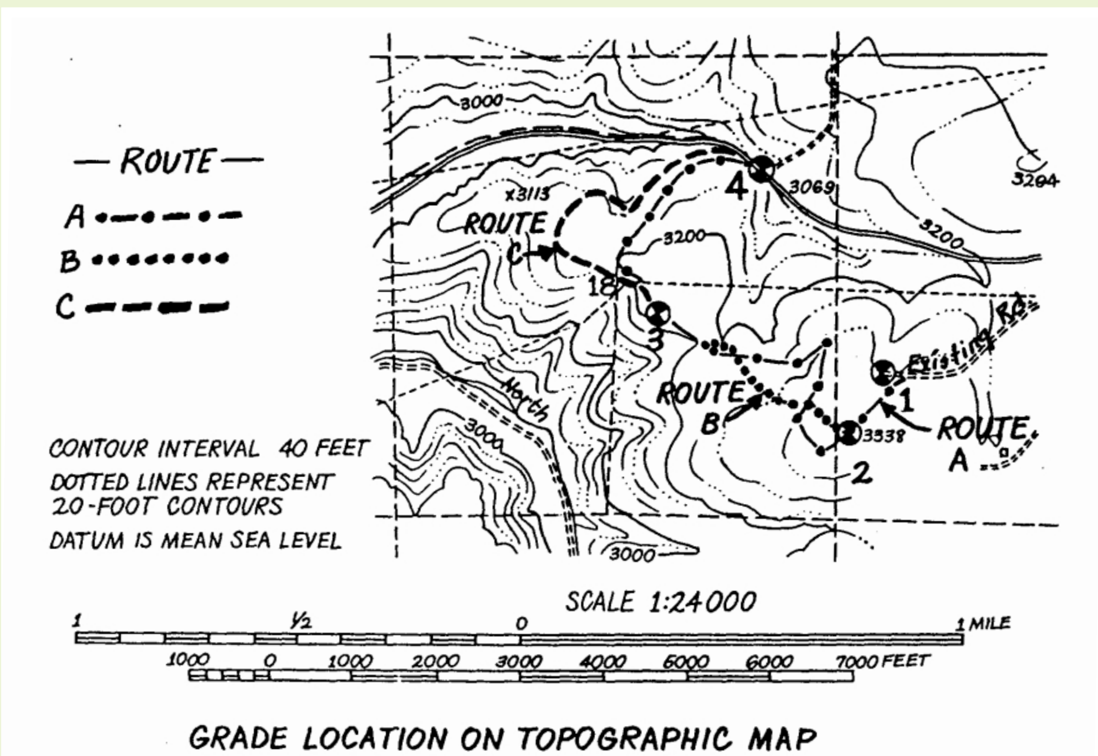

FIGURE 15.
On this topographic map, three preliminary road routes across a hillside have been identified. Identifying possible alternate routes on maps and photos can save time and money when the next step of field reconnaissance is performed. Several alternate routes should always be identified in the planning process since field conditions may require minor or major adjustment of the route (USDA-SCS/USFS 1981).

TABLE 11. Control section and grade computations for three possible road routes (see Figure 15)[1]

Route	Road reach	Elevation difference between control points (ft)	Estimated road distance between control points (ft)	Estimated average road grade (%)	Caliper distance setting	Measured road distance (ft)	New estimated road grade (%)	Comment
A	1 to 2	+58	800	+7	290	800	7	Route is too long; try again
	2 to 3	–128	3,200	–4	500	3,200	4	
	3 to 4	–150	2,400	–6	330	2,200	7	
B	1 to 2	+58	800	+7	290	800	7	Route is OK; field check
	2 to 3	–128	2,000	–6	330	2,100	6	
	3 to 4	–150	2,400	–6	330	2,200	7	
C	1 to 2	+58	800	+7	290	800	7	Route is OK; field check
	2 to 3	–128	2,000	–6	330	2,100	6	
	3 to 4	–150	3,000	–6	400	2,600	6	

[1]USDA-SCS/USFS (1981)

For example:

- Contour interval = 40 feet
- Max. desired grade = 8% (or 0.08)
- Computation: 40/0.08 = 500 feet

In this example, you must go 500 feet before climbing 40 feet to keep the grade to 8%. The dividers should be set at a spacing equal to 500 feet on the map. Then the dividers can be used to mark where the proposed road will cross each contour line on the map (at 500 foot intervals).

6. If any road segment fails to reach the identified control points or endpoints, or if the required grade between these points would be too steep, then either individual segments or the whole road needs to be re-routed until each alternative segment and grade is satisfactory.

With several alternative alignments available, at least on paper, other tests can be made before going out in the field to scout the routes. You can overlay the routes with soil maps to identify potentially unstable or erodible sites. Aerial photos and satellite imagery can be viewed to identify possible landslides or rock outcrops that lie in the path of one or more of the routes. Ownership boundaries can be identified and, if necessary, permission can be secured to scout possible alignments that lie on adjacent property.

For most roads, half a day spent in the office can save much wasted time in the field trying to identify possible alignments for the road. Remember, topographic maps are not always accurate in the small details of the landscape, so no alignment is satisfactory until field reconnaissance is performed. Most small benches, streams and unstable areas will not show up on the standard 1:24,000 scale topographic sheet. While general routing of the alignment, from starting point to ending point, can be performed ahead of time and then be used to guide subsequent field work, field reconnaissance and assessment is the critical next step to confirm the map route and identify all the marked and unmarked features along the possible alignment.