THE LAND OWNER'S GUIDE
TO
PRIVATE ACCESS ROAD CONSTRUCTION

IN LARIMER COUNTY, COLORADO

PROPER PLANNING NOW….

LESS EXPENSE LATER !!!

USDA NATURAL RESOURCES CONSERVATION SERVICE

LARIMER COUNTY
COMMITTED TO EXCELLENCE

LARIMER COUNTY ENGINEERING DEPARTMENT

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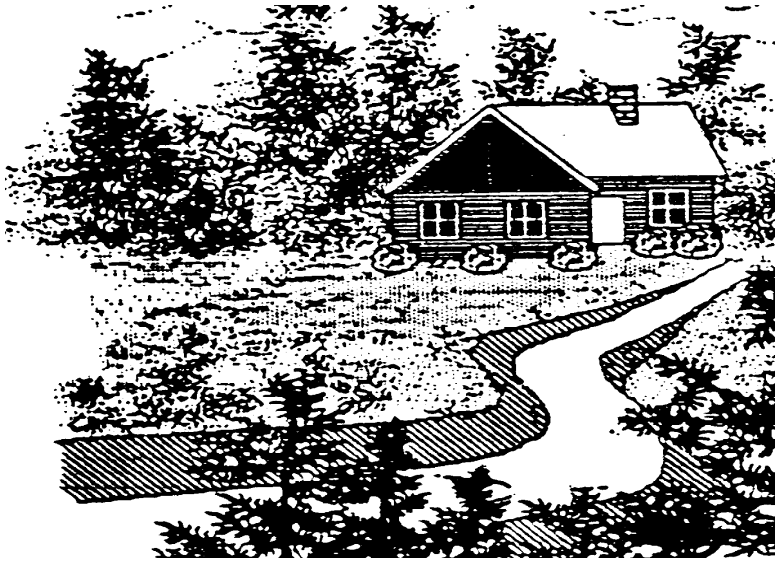
INTRODUCTION

It is ironic that two of the greatest attractions of rural Larimer County - beautiful scenery and clear water - can be compromised by roads designed to help people to enjoy these attractions. Poorly constructed access roads often cause severe erosion and stream sedimentation that benefit no one. Erosion and land disturbance can produce negative effects in rural environments, and can be disastrous in fragile mountain environments. A poorly designed road often causes frequent and costly repair for which the landowner must pay.

Ultimately, if you own the land, you are responsible for assuring that your road is properly constructed. Building an access road to even a single home in rural areas can be complicated and expensive - particularly in hilly or mountainous areas. Regardless of the advice received, it's important to remember that there are no inexpensive "short cuts" when building a functional, safe road that also minimizes land disturbance. Admittedly, it can be more expensive to build a good road -- **but it is always less expensive to build a good road the first time than to build a bad road over every year!**

How can you get the road you need? It can be achieved through careful planning, design, and supervision by you or by a reliable agent. You may be disappointed if you do not work closely with the contractor or bulldozer operator. Whether you do the planning yourself or hire a professional, some knowledge about planning, layout, and construction of access roads is valuable.



This booklet provides the basics. For many people and situations, the information provided may be sufficient to design and build a road. For others, professional on-site assistance may be necessary. This booklet does not address all the problems that may be encountered in road construction, however. You must determine the limits of your abilities, but professional assistance certainly should be sought for complex projects.

For additional information on access road design and construction, contact the Larimer County Engineering Department, your local Natural Resources Conservation Office or a private engineer. In addition, some useful references are listed on page 8.

Outline Guide Page

A. PRE-CONSTRUCTION PLANNING

Planning in advance is essential for constructing a good access road. Become familiar with the property and recognize its potentials and problems.

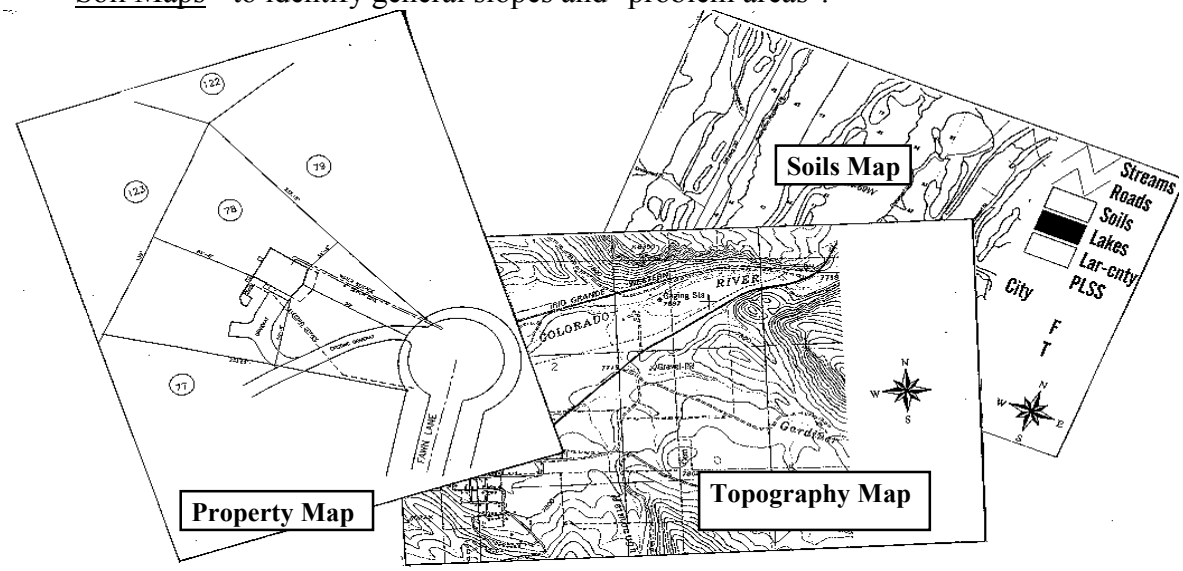
Overlooking this important phase can be an expensive mistake. The factors considered and decisions made in early planning represent the fundamental building blocks of a good road.

A.1 Getting To Know The Property

1.) **Secure the most detailed maps available for the property.**

The maps that may be needed include:

- Property Ownership Map (Survev Plat) - to locate property lines.
- USGS Topographic Maps - to determine elevations and important landscape features.
- Soil Maps - to identify general slopes and "problem areas".



2.) Carefully study the maps obtained and identify the property's important features and characteristics.

a) Using the property map, accurately draw ownership lines on the topography and soil maps.

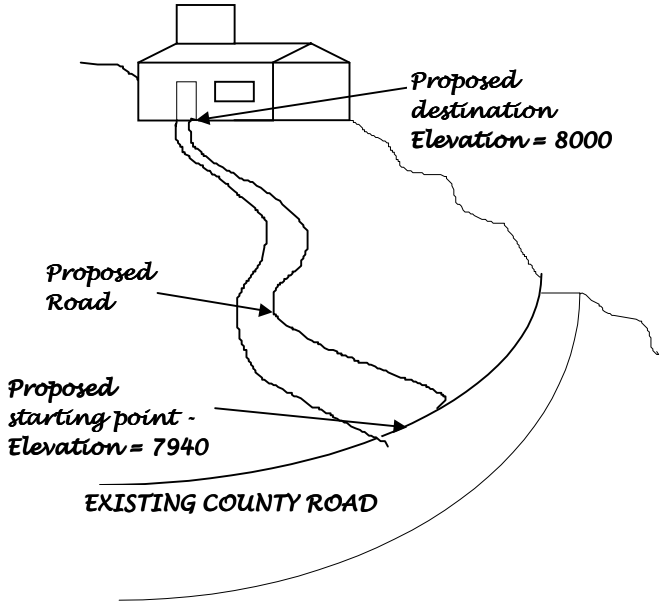
b) Using the soil and topographic maps, identify problem areas that should be avoided if possible. These include very steep, wet, or rocky areas, and soils that are shallow to rock or highly erosive. The Larimer County Soil Survey is an invaluable tool at this stage of planning. To obtain a copy of the soil survey and assistance in interpreting the soils information, contact your local Soil Conservation District office. Soils information is also very helpful in locating alternative homesites.

c) Using the topographic map, determine the **minimum length** for the road.
This may be done as follows:

On a topographic map, locate control points -- places through which the road must pass. Examples are the home site, the entrance, or high and low points in the road's path. Determine the total elevation difference between consecutive control points . Multiply each elevation difference by 12.5 to determine the minimum length of road required between the control points. This length assumes a road constructed on an average grade of 8 percent.

If you plan a road that will be shorter than this approximation, you may be headed for trouble. See Section B.1 for more on road grades.

EXAMPLE



COMPUTATIONS

Elevation of Destination = 8000
Elevation of Starting Pt. = 7940

8000 - 7940 = 60 feet
Road must climb

60 X 12.5 = 750 feet

Minimum length of an 8% road = 750 feet

A.2 Points To Ponder As You Plan

1.) Know the State and local laws, ordinances, and regulations.

Ordinances and regulations regarding access roads vary from state to state and county to county. Larimer County does not regulate private access roads which service a single parcel and residence. If the road accesses more than one residence, however, the road may be required to be constructed to certain minimum standards. These standards are designed to insure properly constructed roads in such cases to promote safe, accessible roads that minimize land disturbance during construction. Additionally, if the road is to access a public county or state road, a access permit is required. Contact the Larimer County Engineering Department for details.

2.) Plan ahead for possible certification to Larimer County Standards.

It is highly recommended that landowners use the proposed Larimer County Design Standards for Local Access Roads to design and construct roads accessing their residence. A certification process may be available for roads so constructed. Some of the benefits include; 1) a functional, safe road that will require minimal maintenance, 2) reduction of the negative effects of such

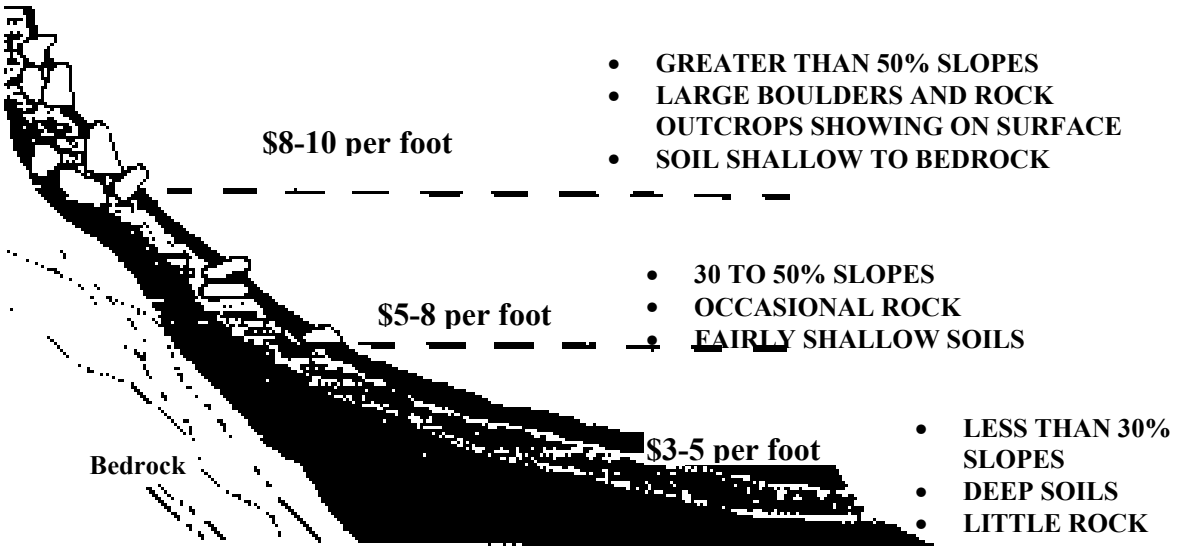
construction (e.g. erosion, land disturbance), 3) and possibly more reasonable property insurance rates. Contact the Larimer County Engineering Department for details.

3.) Be Prepared to pay the cost of constructing a good road.

The cost of constructing a road will vary greatly from site to site. The cost estimates below may increase due to the following:

- Steep land - costs increase due to more earth-moving on steep slopes.
- Winter construction - costs increase because it takes longer to build.
- Rocky land - the costs of moving or blasting rock are high.
- Drainage needed - surface and subsurface water must be managed.
- Low stability soils - extra precautions are required on such sites.
- Clearing required - wooded areas must be cleared.

APPROXIMATE COST PER LINEAR FOOT OF ROAD



<u>One important point!</u> **- if you cut corners during planning and construction, you will pay more for future maintenance.**

4.) Don't give your land away!

Erosion is the displacement of soil particles from the soil surface caused by wind, water, ice or gravity. Removal of surface vegetation and disturbance of the soil surface accelerates this process. As soil particles are displaced they are easily transported from the site and may affect water and air quality. The effects of erosion may have wide ranging consequences for your property as well as property of others and public lands and waters. If you lose the soil on an area, re-establishment of the vegetative cover will be difficult. Plants must have a good soil medium to grow and establish properly. The presence of good ground cover from plants and

reinforcement of the soil by the roots of these plants is the most effective way to protect your land, the land of others and our water resources from the effects of erosion.

Erosion control should be a normal part of all construction procedures, and therefore, erosion control practices are incorporated throughout this booklet. Take every precaution to keep your soil on your property. If road construction is done in a season that is not appropriate for seeding, there are alternatives to protect the soil resource. These include mulching, surface roughening and application of various erosion control blankets. Make sure you have planned on the appropriate measures to protect the soil and install any needed materials as soon as possible.

A.3 Deciding Where To Put The Road

1.) Get to know the property by walking over it - several times.

With the fundamentals in mind, walk over the property making notes of any features which are different or are not as indicated on the map. Working in a downhill direction may provide you with a better view of the terrain. Be sure to identify property boundaries and avoid locating the road too close to any boundary. Construction crews may venture across property lines without knowing it.

2.) Choose a starting point elevation on the existing road as close as possible to your destination's elevation to minimize your proposed access road's length and grade.

3.) Choose an entrance that provides good visibility from all directions.

A permit from the Colorado Department of Transportation or Larimer County Engineering Department will be required before establishing access from a public road administered by these agencies.

4.) Avoid streams, springs and other wetland areas.

If streams must be crossed, make crossings at right angles to the flow of the stream. Otherwise maintain a minimum undisturbed 20-foot strip of vegetated area along all live streams. Rather than routing stormwater directly into the stream, create a sinuous route through the vegetated area. Incorporate sediment basins or traps at discharge points to allow sediments to drop out of the water before it is released into the stream. Sediment traps can be constructed using logs or rocks found on the site. Strive to keep away from springs and wetlands. Route the road above wet areas where possible. Wetlands are an important part of the ecology of the landscape and are very effective in filtering runoff waters of sediments and other contaminants by providing buffers for large runoff events.

Any planned activity in wetland areas must be reported to the U.S. Army Corps of Engineers and may require a permit. This includes installation of structures to accommodate a crossing of live streams. Areas within the normal high-water line of streams are considered wetlands. Other wetland areas may be isolated from live streams but are equally important for protection of ground and surface water quality.

A.4 Assistance is Available

If by this point, road construction already seems like an overwhelming task for the novice, **don't give up!** Help is available, but don't expect someone else to plan and construct your road for you unless you are willing to pay for it. Helpful assistance is available to guide you through the decisions and actions which will lead to the desired properly constructed road. The table below is provided as a guide to locate sources of information or services helpful in planning, designing, and constructing your road.

Uniform Building Code Requirements:
Larimer County
Building Department
200 W. Oak, Basement
Fort Collins, CO 80522
Phone: 498-7700

Road Design, Erosion Control, Site Restoration:
Larimer County Engineering Department
218 W. Mountain Ave.
Fort Collins, CO 80522
Scott Cornell 498-5723

Soils Information, Erosion Conrol, Revegetation
Fort Collins Soil Conservation District
1415 N. College Ave, #3
Fort Collins, CO 80524
Todd Boldt 223-0960

Big Thompson Soil Conservation District
3825 Starlite Drive]
Fort Collins, CO 80524
Todd Boldt 223-0960

Wildfire Hazards:
Wildfire Safety Coordinator
Larimer County Building Department
200 W. Oak, Basement
Fort Collins, CO 80522
Tony Simons 498-7718

Livestock and Agricultural:
Larimer County Extension Office
200 W. Mountain
P.O. Box 543
Fort Collins, CO 80522
Phone: 498-7400

Septic System Requirements:
Larimer County Department of Health & Environment
1525 Blue Spruce Dr.
Fort Collins, CO 80522
Phone: 498-6775

Forest Management Issues
Colorado State Forest Service
Foothills Campus, Building 1052
Fort Collins, CO 80523
Michael Hughes 491-8453

Colorado State University
Access Permits (Roads & Utilities):
Larimer County
Engineering Department
218 W. Mountain Ave.
P.O. Box 1190
Fort Collins, CO 80522
Mike Bryant 498-5709

Zoning Information:
Larimer County
Planning Department
200 W. Oak, Basement
P.O. Box 1190
Fort Collins, CO 80522
Phone: 498-7683

Wildlife Behavior & Habitat:
Colorado Division of Wildlife
317 West Prospect
Fort Collins, CO 80526
Phone: 484-2836

U. S. Forest Information:
United States Forest Service
Arapahoe and Roosevelt National Forest
Visitor Information Center
1131 South College Avenue
Fort Collins, CO 80524
Phone: 498-2770

Weed Control:
Larimer County Weed District
Department of Natural Resources
200 W. Mountain, P.O. Box 1190
Fort Collins, CO 80522
Phone: 498-5768

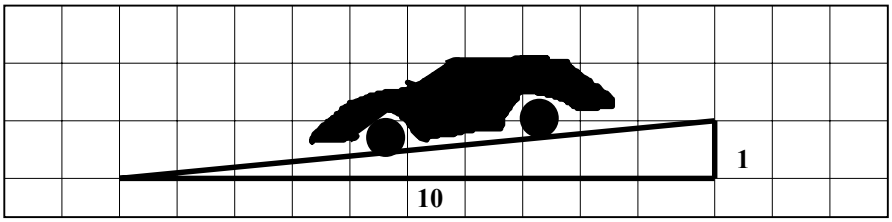
Wetland Mitigation Requirements:
Department of the Army Corps of Engineers
Omaha District
Tri-Lakes Project Office
9307 State Hwy 121
Littleton, Colorado
80123-6901
Terry McKee (303)979-4120

B. DESIGN GUIDELINES

It's important to understand the basics of designing roads before trying to locate or position a road on the land. The standards to which roads are constructed vary with their intended use. (A road built solely to accommodate logging operations would not be expected to meet the demanding standards of a subdivision road.)

B.1 Road Grade

1.) The grade of the roadbed should be less than 10% for best results (10 ft. vertical in 100 ft. horizontal).



Maximum sustained grades should never exceed

- 6 percent for natural soil and grass surface
- 10 percent for gravel or crushed stone surface
- 16 percent if paved.

These grades may be increased up to 12 percent on gravel roads (if crushed stone is used) and 20 percent on paved roads for short reaches (200 feet or less) where no other alternative exists.

Grades should be determined using techniques described in Section C.2.

2.) Steep grades should always be avoided at road curves or intersections.

B.2 Road Width

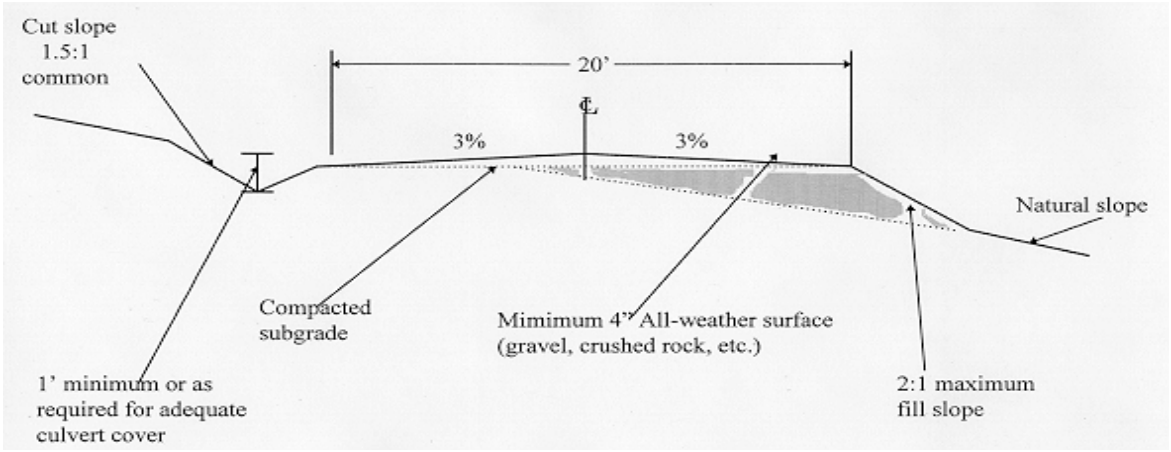
1.) The minimum width of the roadbed is 12 feet for one-way traffic and 20 feet for two-way traffic.

The minimum tread width (driveable width) is 10 feet for one-way traffic and 16 feet for two-way traffic. The minimum recommended shoulder width is 2 feet on each side of tread width. Increase all widths by 4 feet if traffic from towed trailers of any kind is expected.

B.3 Side Slopes

1.) All roadcuts and roadfills should have side slopes that are stable for the particular soil and conditions.

- Cut slopes in rock may be vertical when less than 3 feet high. Cut slopes should not be steeper than 1.5 to 1 (1.5 feet horizontal for every 1 foot in rise) where the cut slope is greater than 3 feet high.
- Fill slopes should not be steeper than 2 to 1 (2 feet horizontal to every 1 foot of rise) unless an analysis of the soil shows steeper slopes to be stable. Where maintenance will be performed by mowing, cut and fill slopes should be no steeper than 3 to 1.



CROSS-SECTION OF ROADBED AND CUT & FILL SLOPES

B.4 Surface Drainage

No other aspect of road design is more important and less understood than surface drainage along the road. And unfortunately, this is the area where road-builders sometimes try to "save money"- an expensive mistake!

1.) The surface water from all sources must be conveyed from the roadway in order to control soil erosion, maintain a stable road surface, and reduce future maintenance and repairs.

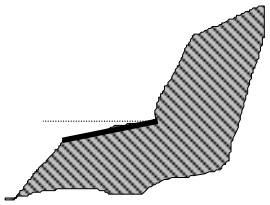
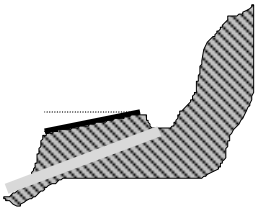
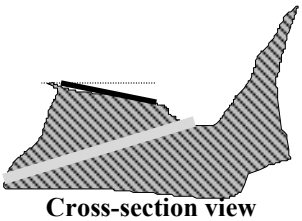
Surface drainage must be planned for water from the following sources:

1- Rainfall on the roadbed, as well as cut and fill slopes.
2- Overland storm flows from the watershed above the road.
3- Springs or live streams intercepted by the road.

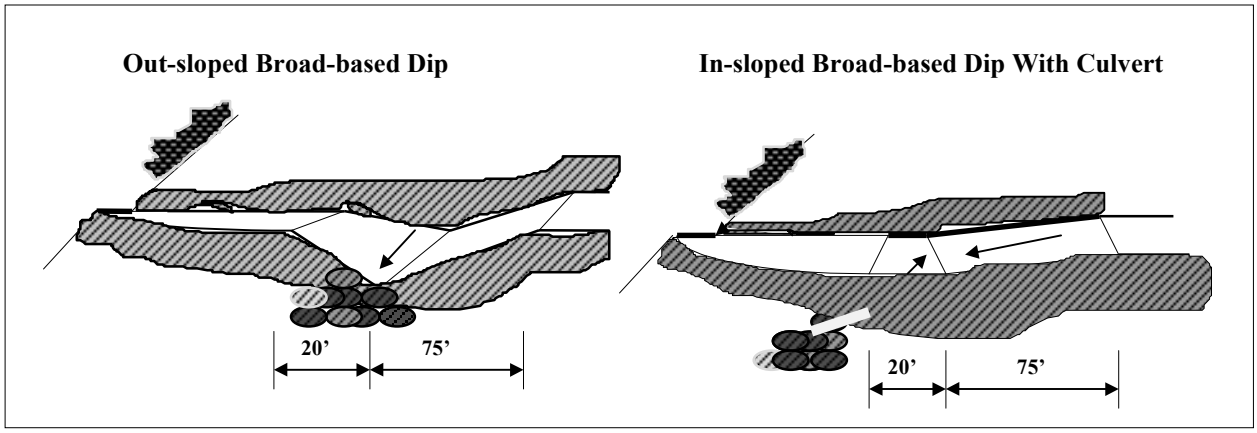
2.) If possible, shape the road to drain itself by means of cross-sloping and/or broad-based dips.

a) **Cross-sloping** involves sloping the road slightly to allow surface water to flow across and off the road rather than down the length of the road. Cross-sloping should be less than one-half inch in one foot (4%) or about six inches across the width of the road. See the chart on page 11.

CROSS-SLOPING CHART

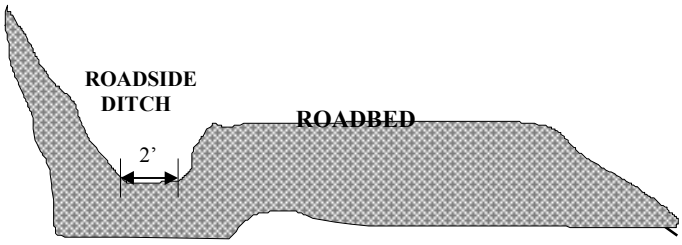
SOME SINGLE-FAMILY ACCESS ROADS OR OTHER SELDOM USED ROADS		**SOME SINGLE-FAMILY ACCESS ROADS AND ALL DEVELOPMENT ACCESS ROADS**	
 **Cross-section view of Road**	 **Cross-section view of Road**	 **Cross-section view of Road**	 **Cross-section view of Road**
Out-sloped road with out-sloped broad-based dips.	In-sloped road with in-sloped broad-based dips.	Out-sloped with roadside ditch and culverts.	In-sloped with roadside ditch and culverts.
Only requires culverts in the draws or low areas.	Requires culverts in draws and at location of dips.	Generally the most acceptable design.	Requires culverts every 130 to 200 feet.
Where overland flow from above road during storms is significant.	Where overland flow from above road during storms is small.	Requires periodic culverts to remove ditch water.	Requires periodic culverts to remove ditch and road water.
Road water flows freely off the roadbed.	Safer on roads that are often frozen, wet, icy, or slippery.	Road water flows freely off the roadbed.	Safer on roads that are often frozen, wet, icy, or slippery.

b) **Broad-based dips** may be used to carry surface water off the roadway. Properly constructed broad based dips allow a smooth crossing without bumping or bottoming out. On sections of a road where broad based dips are the primary means of surface drainage, construct the dips approximately 150 feet apart, outletting them on side ridges where possible. If the height of the fill slope at the outlet of the dip is 4 feet or greater, the broad-based dip should be in-sloped and a culvert installed.



3.) Construct roadside ditches on the inside of all roads that have overland flow from above the road during rain storms.

Flat bottom ditches, with flat areas two feet or more in width, provide for greater safety and reduced maintenance than do deeper "V" shaped ditches.



4.) Install culverts in natural draws on all roads. Culverts should be placed every 130 to 200 feet on all in-sloped roads.

a) What type of culvert pipe should be used?

Corrugated Steel Pipe

- Most common type in use
- Heavy duty and can take fairly "rough handling"
- More tolerant of improper installation practices

Corrugated Aluminum Pipe

-Lighter and easier to handle than steel.
-Will last longer than steel if properly installed
-More expensive than steel.
-Damages easily with rough handling.

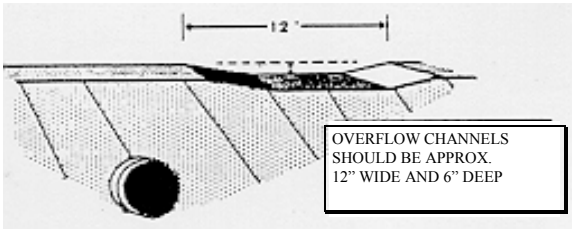
Double-wall Corrugated Plastic Pipe

-Lightest and most easily handled.
-Less expensive in smaller sizes.
-More easily crushed by inadequate cover or poor compaction of fill material around pipe.

b) Many factors affect the culvert size, including drainage area size, watershed land use, local rainfall, soil type, slope of pipe, fill over pipe, etc. All culverts should be designed using the 10-year, 24-hour storm as a minimum with no culvert less than 12 inches in diameter. Roads accessing more than one residence must design to the 50-year, 24-hour event where it is the only route for ingress and egress. Minimum diameter for culverts on these roads must be a minimum of 15 inches.

You may use the culvert design procedure in Appendix A (page 26) to determine the proper culvert size. If the procedures are difficult for you to understand or certain sections cause difficulty, contact the Larimer County Engineering Department or local Natural Resource Conservation Service Field Office (see p.8). These offices may be able to help you get through the procedures and calculations. However, you may be advised to seek assistance from a professional engineer. At any rate, it is important to correctly estimate culvert sizes. If you

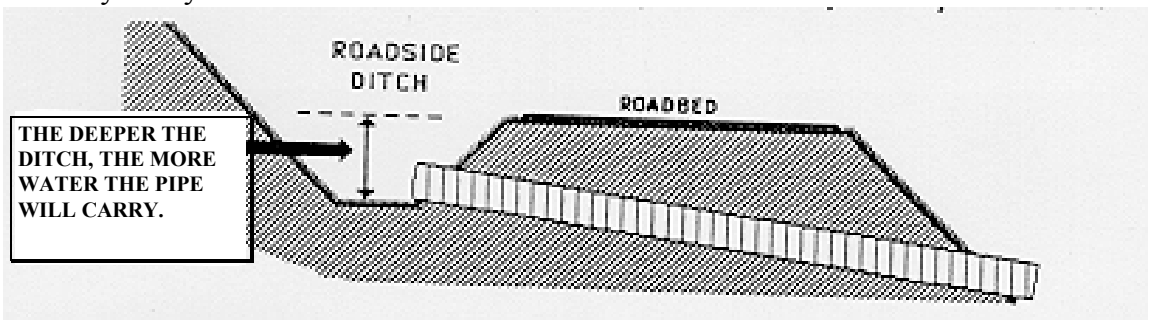
under estimate, you may encounter flooding and damage to the roadway. If you oversize culverts you may be spending considerably more money than is necessary.



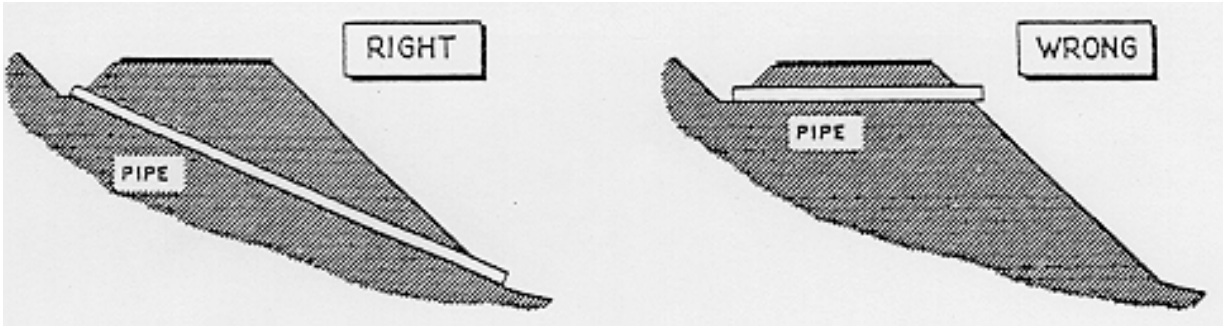
Where it is impractical to install the proper size of culvert, an adequate overflow area should be provided to allow storm flows to overtop the road and discharge on natural ground, not fill material. The overflow should be protected with rip rap or other means as needed to prevent road washouts or erosion.

c) How should culverts be installed?

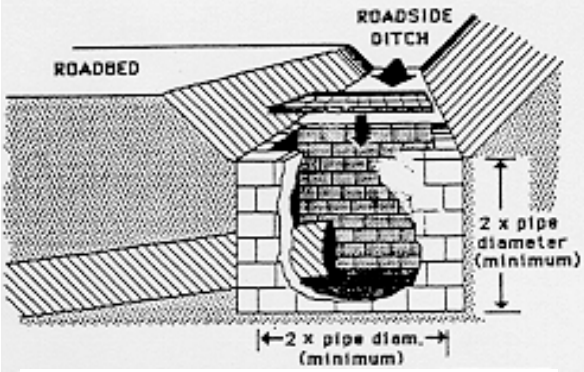
1.) Install culverts at or below natural ground. The steeper the pipe is installed (or the more fill over the pipe), the more water it will carry. In addition, pipes with shallow cover are easily crushed by heavy vehicles.



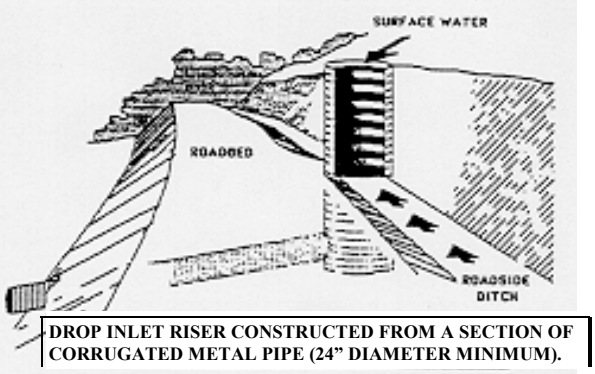
2.) Outlet the culverts at or beyond the toe of the slope. Erosion protection, such as rock rip-rap or geotextile fabrics, is often necessary at the outlet of culverts. Never outlet a culvert on fill material without such protective measures. It is usually less expensive to extend the culvert to stable natural ground than to protect the fill material against erosion from the culvert outlet.



3.) Insure each culvert has an adequate inlet. Most culverts never carry as much water as they should due to poorly constructed inlets. The culvert may be large enough to carry the required flow, but the inlet may not let the water into the culvert. Be sure the roadside ditch is wide and deep enough to allow flowing water easy entry into the pipe.
Although not always necessary for an adequate inlet, the structural culvert inlets shown below provide some examples that can be low in maintenance, as well as very effective.

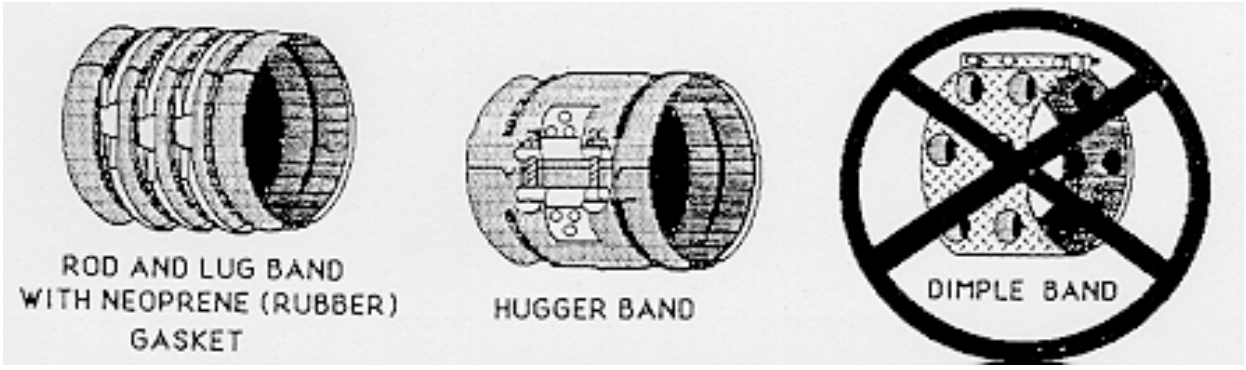


"DROP BOX" INLET CONSTRUCTED OF BRICKS,CEMENT BLOCKS. OR POURED CONCRETE.

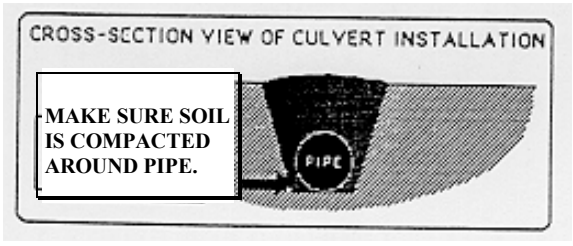


DROP INLET RISER CONSTRUCTED FROM A SECTION OF CORRUGATED METAL PIPE (24" DIAMETER MINIMUM).

4.) Use watertight connecting bands when connecting two joints of culvert pipe. Since pipe generally comes in 20 foot sections, properly installed culverts on sloping roads often require connecting bands. Connecting bands should result in strong **watertight** joints. Rod and Lug type or "hugger" type bands provide secure, trouble free joints if properly installed. "Dimple Bands" are not acceptable and should not be used.



5.) Properly compact soil material placed around culvert pipes. The soil used to backfill around the pipe should be placed in layers of 4-6 inches and compacted. Insure that soil is placed all around and under the pipe. This is especially important when using plastic pipe.



Culverts should be specified and installed to withstand at least 10 tons of bearing capacity.

B.5 Subsurface Drainage

Subsurface drainage refers to water which is below the normal ground surface. It may be a natural condition or it may be created by failure to properly remove surface water.

Poorly drained roads fall apart in bad weather with even minimal traffic. Wet foundation soils swallow up stone as fast as it is hauled in. Erosion control and stability of fill and cut slopes are impossible to maintain without proper drainage.

1) Locate poorly drained soils on soil survey and watch for signs of subsurface drainage problems before and during construction-

The following may be signs of wet soils with subsurface drainage problems:

- Soils that are grayish in color.
- Areas with numerous springs or seeps.
- Low areas or ground with a soft mushy surface.
- Areas predominated by water-tolerant plants such as alders, willows, poplar, cattails, reeds, etc.

If these conditions are present you are dealing with a **wetland**. Any planned disturbance of wetland areas requires notification of the Army Corps of Engineers, before construction, and may require a permit if it is allowed at all. ***It is best to avoid wetlands!***

2) If possible, maintain the water table at least 24 inches below the road surface.

One or more of the following may be needed to reduce problems on wet soils:

- Improved surface drainage.
- Removal of nearby shade trees to let sunlight dry the road.
- Use of large (3 inch) stone for the road surface.
- Installation of fabric filter cloth under the surface gravel to prevent stone from sinking and disappearing into the soft soil.
- Installation of subsurface drainage tile (must consider effects to wetlands though).
- Relocating the road to a drier area - (***The best idea!)***.

B.6 Curves and Switchbacks

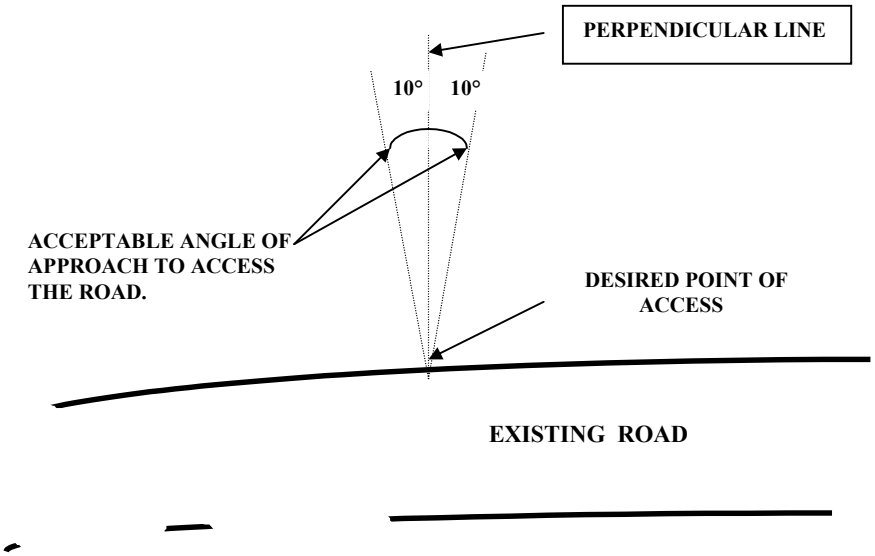
1) The minimum radius of curvature of the centerline of the road should be as follows:

- 100 feet for flat to rolling terrain
- As terrain allows in mountainous or steep terrain (avoid undue site disturbance)

2) Plan switchbacks and curves on grades as flat as possible.

B.7 Intersection With Public Road

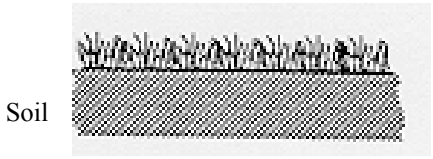
1) For safety, the angle of intersection of a proposed access road and a public or private roadway should be no less than 10 degrees from perpendicular for at least 50 feet, and the clear sight distance to each side should be no less than 200 feet. Sight distance requirements vary depending on the speed limit for the road being accessed. Check with the Larimer County Engineering Department or Colorado Department of Transportation to be sure of requirements for accessing these public road systems.



B.8 Road Surfacing

1) Choose the type of surfacing material by considering traffic needs, frequency of usage, grade of road, soil type on natural roadbed, available materials, cost, and aesthetics.

Grass

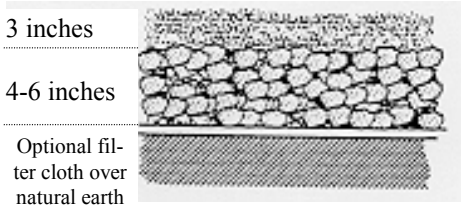


- Not for daily or wet weather use.
- For use on dry soils only.
- On grades less than 8%.
- Least expensive.
- May require soil amendments, mowing, etc.

Road Base (crushed rock) Only

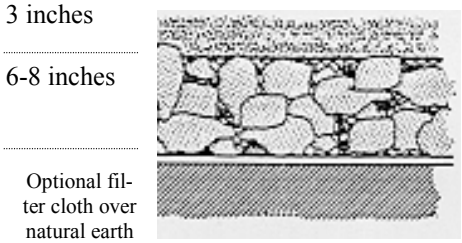
- Medium to high traffic.
- For use on naturally sandy or gravelly roadbed soils.
- On grades of 15% and less.
- Specify "ABC" or "base course".
- Requires periodic grading.

Road Base (crushed rock) Over Washed Gravel



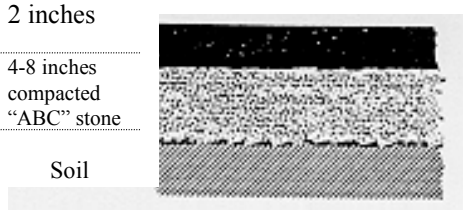
- Medium to high traffic on soft soils.
- On grades of 15% and less.
- Specify "ABC over washed gravel".
- Requires periodic grading.
- Use fabric filter cloth in poorly drained areas.

Road Base (crushed rock) Over Large Rock



- For wet sections of roads with soft mushy soil.
- For all traffic conditions.
- On grades less than 16%.
- Specify "3 inch washed stone" or "ballast tone".
- Requires periodic grading.
- Use fabric filter cloth in poorly drained areas.

Pavement



For heavy traffic on all soils.
On grades up to 20%.
Requires extensive base preparation.
Most expensive.
Subject to frost damage on wet soils.

2) Road base (crushed rock) surfacing should be applied as soon as possible after construction (while soil surface is still freshly disturbed) to reduce soil erosion, and insure a good bond between the soil and surfacing materials.

C. ROAD LAYOUT: LOCATING THE ROAD ON THE LAND

After becoming familiar with the property and the design concepts of road construction, It's time to actually lay out the road. Laying out a road consists of staking or flagging the centerline of the road, identifying locations for broad-based dips and culverts, and possibly staking cut and fill slopes.

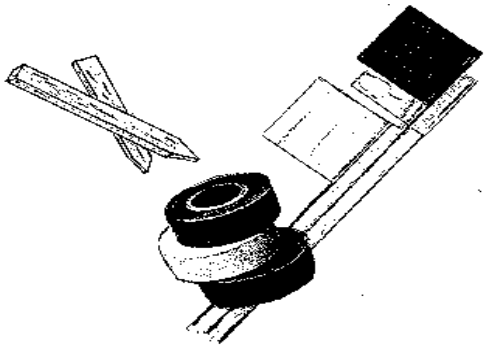
C.1 Obtain the Following Equipment for Laying Out the Road:

- **Clinometer or Abney level -** Inexpensive hand-held tools to measure road grade. May be obtained where forestry or surveying supplies are sold.

Abney Level

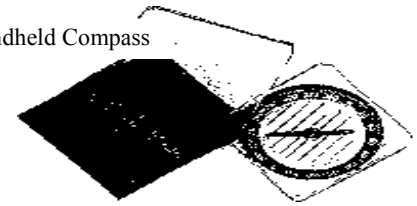
Clinometer

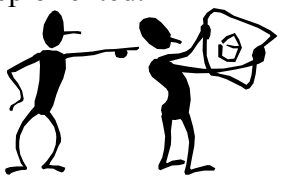
- **50 or 100 Foot measuring tape -** To measure road width, length, distance between dips, cut/fill slopes, etc.



- **Survey flags, colored plastic tape, or Stakes -** To mark the proposed route and location of culverts, dips. edges of cut/fill slopes, etc.
- **An ax and/or bush hook -** To drive stakes and to cut dense vegetation.
- **Compass -** To determine **aspect** and to keep oriented.

Handheld Compass





- **Notepad and a map or aerial photo -** To make useful notes about the location of the road and potential problems.

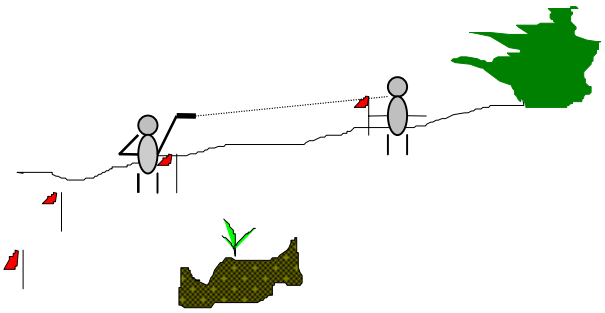
C.2 Locating The Road On A Desired Grade

1) One-person Method

a. Tie colored plastic tape eye-level to a tree, brush, limb, etc. at the starting point of the road.
b. Walk a short distance along the proposed route of the road and, using a clinometer or Abney level, shoot back to the colored tape to determine the grade of the proposed road.
c. Move up or down the hill until the desired grade is found, and then flag this position (again at eye-level).
d. Walk further along the proposed route and repeat the procedure above, always shooting back on the previous tape.

2) Two-person Method

This method is similar to the above procedure except that instead of shooting **back** to the **previous tape,** the person with the level (the "instrument-man") shoots **forward** out the proposed road to **another person** (the "flag-man"). He directs the flag-man to move up or down the hill and flag a position marking the desired road grade. The flag-man may mark his position (to be the centerline of the road) with plastic survey flags, wooden stakes, paint on trees, or colored tape. (Before using this two-person method, the instrument man should locate his eye-level on the flag-man, and always shoot this same spot on the flag-man during the survey).



If the desired endpoint is missed after following a predetermined fixed grade, the road locators should work backwards from the endpoint and connect the two surveys at the most convenient point. It may be necessary to repeat earlier surveys several times working in both directions to find the best route. Nobody said it would be easy!

C.3 Marking the Proposed Road

1) Using plastic survey flags, wooden stakes, colored tape, or paint, mark the following <u>clearly:</u>

- Centerline of the road
- Location of culverts and broad-based dips
- Curves and switchbacks
- Edges of cut and fill slopes on very steep areas
- Any planned turnouts, parking, or passing areas

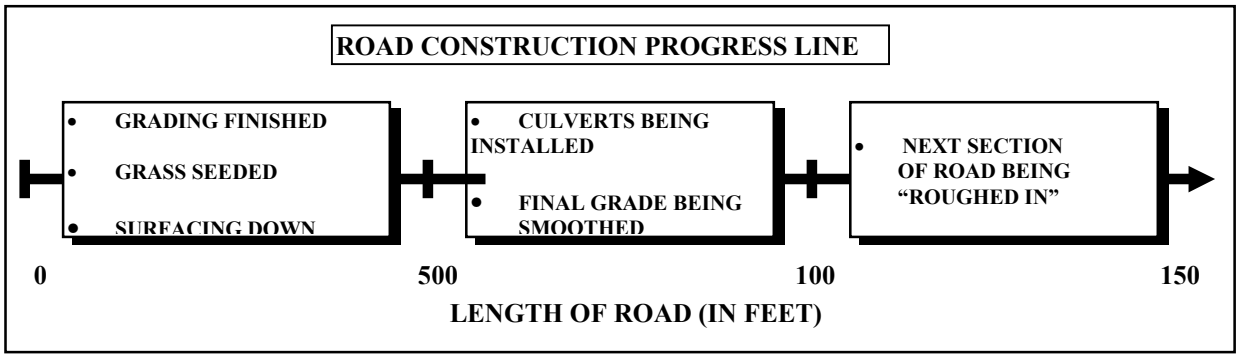
D. GETTING READY FOR CONSTRUCTION

- when do I start?
- what materials do I use?
- who do I get to do the work?

D.1 Setting a Schedule

1) Plan the timing of the actual road construction to occur during the milder, drier seasons of the year.

2) Establish a construction schedule which will require that the road be completely finished in segments of 500 feet or less.
Maximum effectiveness is insured when stone surfacing and seeding are performed while cuts and fills are still fresh. However, if the season is not right for seeding, alternative methods to control erosion may be necessary.



D.2 Obtain The Materials

1) Develop a Bill of Materials for each segment of the road.

Check early with suppliers about availability, shipping times, price, terms, and other specifics. Be sure to specify the details on the type of materials desired. Culverts, drop inlet boxes, silt fences, erosion control netting, fabric filter cloth, crushed stone, riprap, seed, fertilizer, lime, and mulching materials may be needed.

2) Plan to have materials BEFORE they will actually be used.

Have you ever started a job, only to find you didn't have everything needed to finish? Failure to have materials on hand when they are needed results in unnecessary delays. Such delays are expensive. **Planning is the key!**

3) Materials to be used should be inspected upon arrival and sub-standard materials rejected. For example, if "dimple bands" are delivered when "hugger" bands were specified, send them back!

D.3 Hiring The Right Contractor

1) Hire a contractor who has the right equipment for the job.

Since the cost of equipment time will be a major portion of the total expense of the initial road construction, the "right" equipment will save money. (Would you hire a carpenter by the hour who uses a rubber hammer for driving nails?) Some type of survey equipment will be needed to properly slope the roadbed and the cut and fill slopes. A qualified contractor will have either a tripod or a handheld level to assure that the road is built to your specifications.

2) Hire a contractor experienced in rural road-building.

Just because a contractor has heavy equipment does not mean he can build roads. Check around a bit:
1) Get out and look at some roads built by contractors.

2) Talk to landowners who have hired the contractor in the past.

3) Hire a contractor with an attitude toward high quality.

A competent contractor should be willing to provide references. His major concern should be to provide you with a well-built road, not finding reasons to cut corners. He should show concern and knowledge for every aspect of properly designing and constructing the road.

D.4 Getting Started On The Right Foot

1) Discuss your plans and specifications with the contractor.

Establish the rules. Walk over the site with the contractor. Give him a copy of the specifications you have developed for your road and discuss each point. Resolve any questions. Consider his suggestions, but do not allow him to change the specifications to save money (his money) at the expense of quality (your money).

2) Agree on the dollars and "sense".

Many earth-moving contractors insist on **payment by the hour.** This relieves the contractor of any risk. **Lump sum payment** on a job-basis is usually advantageous to the landowner who knows the kind of finished product he wants and maintains close supervision of the contractor's work to insure that quality work is performed. Either payment method may be used if you are comfortable with the arrangement. It is not always wise to pick the contractor based on price alone. A higher price may reflect higher quality in workmanship. Compare price and quality.

3) It is advisable to have someone knowledgeable of your road specifications to supervise or periodically check the progress of construction.

This is one of the most neglected aspects of any type of construction. Supervision is imperative to assure that you will end up with a quality road. You should become familiar with the design requirements and schedule of the construction and make time to check work.

E. CONSTRUCTING THE ROAD

E.1 Clearing the Way for Construction

1) Clear the vegetation from a right-of-way at least wide enough for the roadbed and cut and fill slopes.

Access roads in wooded areas require that trees and brush be removed prior to cutting in the road. Where deep cuts or fills are required, it will be necessary to clear a wider area. At curves, the area cleared should provide good visibility of traffic from both directions. Where snow and ice on the roadbed may present problems, it is a good practice to remove enough vegetation to allow maximum penetration of sunlight to the roadbed.

2) Make plans in advance to use or sell timber, pulpwood, or firewood. If many large mature trees will be removed, consult a forester for an estimate of their value.

3) To aid in removing stumps, some bulldozer operators prefer to have the trees cut 3 or 4 feet above the ground, rather than at ground level.

4) Do not place trees or brush in areas to be covered by soil fill material!

It's impossible to compact soil adequately around brush and this leads to future unstable road fills. Brush should be either burned, removed from the site, or piled below the toe slope of the fill to trap sediment. Remove all trees from the area to be filled with soil.

E.2 During Construction

1) Make sure after clearing that all your flags and stakes remain and are understood by the contractor's crew.

2) Be alert for problem areas, such as wet or unstable soils, and correct immediately as previously discussed.

3) Do not allow the equipment to 'rough in' more than 1000 feet of road until the first 500 feet are completed.

Drainage structures, such as culverts, should be installed, fill material properly compacted, and surfacing material put down as construction progresses. Seeding should begin on segments as soon as the grading on that segment is completed.

4) Have an agreement with the contractor that he will check with you before placing any surfacing material (gravel or pavement).

Before surfacing the road, be sure that drainage structures are installed properly, that adequate erosion and sediment control measures are maintained, and that the roadbed's in-sloping, out-sloping or crowning is satisfactory.

5) Maintain close supervision and make sure your plans are followed; ask questions if something does not look right.

F. GETTING VEGETATION ESTABLISHED

Re-establishing vegetation on disturbed soils is considered the most effective solution to controlling erosion and loss of soil at construction sites. The cover provided by grasses and other vegetation minimizes the impact of precipitation and slows runoff. The roots of established vegetation forms a matrix to reinforce the soil and also promotes infiltration into the soil. These effects decrease the water flowing along the surface and slows its velocity, thereby protecting the soil particles from displacement and transport. The soil tends to stay in place and is not carried away in runoff. This keeps the soil on your property to promote good vegetative cover and protects streams and other waters from contamination with silt and other materials that might damage the quality of the waters receiving the runoff.

Seeding to re-establish vegetation can be accomplished by several methods. Drill seeding is probably most effective but may not be possible in many areas involved with road construction (cuts and fills). Hand seeding can be effective if properly done and hydroseeding may be the only way to efficiently seed steep areas. Most seeding rates are based on drill seeding techniques. It is wise to double these rates when hand seeding and increase rates by 50% when hydroseeding.

F.1 Hand Seeding

1) If the ground surface has become hard or crusty, scarify or roughen up the surface.
This seedbed preparation may be done with a farm tractor and disk, a garden tiller, or even a hand rake. (The latter may be the only way possible for steep road banks or cut/fill slopes.) Do not disturb the ground too deeply—just enough to break the surface crust.

2) Apply fertilizer per soil test:

To determine the fertilizer needs of the soil to be seeded, an analysis of nutrient content, organic matter content, and texture should be done. Contact your local Natural Resources Conservation Field Office, the Larimer County Extension Office, or the Larimer County Engineering Department for recommendations and advice.

If native grasses are seeded they will require less fertilizer and will establish and persist on the site much better than many commercial or introduced species. Slow-release, organic fertilizers are recommended.

3) Use the Seeding Tables in Section F.4 to determine the proper type of vegetation for your area. Seeding mixes and rates of application, in lbs. per acre, can be complicated to figure out if you are not experienced. Assistance can be obtained through the Larimer County Engineering Department, Larimer County Extension Office, NRCS District Office, or local seed distributors.

4) Rake over the area after applying the seed to maximize seed contact with the soil. For best results the seed should be covered with ¼" to ¾" of soil.

5) Mulch the seeded areas with 60-80 bales of straw or hay per acre. This equals about 1-2 bales per 1000 sq. ft. This mulching technique is most effective when the material is crimped into the soil to hold it in place. A shovel may be used on small areas.

About 25% of the ground surface should be visible after mulching. Hay is usually less expensive than straw, however, it is more difficult and time-consuming to spread. Hay may also contain undesirable weed seeds. It is best to use certified, weed-free, native hay.

6) Areas to be vegetated where water has a concentrated flow should have the mulch anchored with some type of erosion control netting.

This netting, usually made of plastic or plastic-like material, sometimes filled with straw or coconut fiber, is held to the ground by large wire staples. Properly anchored and keyed straw bales can be effective as well. Contact your Natural Resources Conservation Service Field Office or the Larimer County Engineering Department for more information on sources and installation of netting and other erosion control materials.

F.2 Drill seeding

Drill seeding involves mechanically placing seed at a specified depth in the soil using specialized machinery. This insures that the seeds are placed in full contact with the soil for proper germination. Though very effective this method is limited to larger areas where slopes will allow safe use of the machinery. The area should be mulched as described in the previous section.

F.3 Hydroseeding

Specify that the following materials be applied:

- Fertilizer as required from soil test.

- Suitable seed according to the rates and season on the Seeding Tables
- 2000 lbs. of wood cellulose mulch or comparable material per acre. (On slopes, a tackifier should be added)
- Most effective when seeding done as separate operation from hydro-mulching.

F.4 Picking the proper plants

While sycamores and redwoods are beautiful trees, and rhododendrons are beautiful shrubs, they won't grow here. Many problems have arisen over the years with the deliberate and accidental introduction of non-native plant species to Colorado. One hundred thirty or 10 percent of the native plant species in Colorado have been displaced by noxious weeds. Leafy spurge and purple loosestrife (sold as an ornamental) are spreading rapidly along waterways and in wetlands in the county. Another problem with introduced species is that they almost always require a great deal of water. In Colorado, as in much of the West, water is a valuable commodity. It has always been important to conserve water in Larimer County, but with the population increasing, it has never been more important.

One easy way to conserve water and avoid noxious weeds is to plant native species. Native species evolve over the years and become adapted to the local conditions such as soils, precipitation, etc.. These species have a niche (role in the ecological community) which other parts of the ecology depend on and evolve with. Native species require far less water and maintenance than introduced species.

For the sake of simplicity we will divide Larimer County into three areas: plains, foothills and mountains. There are a variety of sources of native seed and planting stock but not every native species is commercially available. The tables in Appendix B (page 33) list a variety of native plants that are usually readily available. These lists are by no means comprehensive. The species selected will depend on the site characteristics. Further guidance in seeding can be obtained from your local NRCS Field Office, the Larimer County Extension Office or the Larimer County Engineering Department.

The Colorado State Forest Service has two excellent guides for selecting and planting trees: "Trees for Conservation: A Buyer's Guide" and "Trees for Conservation: Planning, Planting and Care." Both are available from the Colorado State Forest Service or the NRCS.

G. MAINTENANCE

Even the best planned and constructed roads will require some maintenance.

G.1 Maintaining Your Investment

1) Schedule periodic inspections of the entire road in early March and August, as well as after large storms.

A suggested method is to walk the entire length of the road examining culverts, cut slopes, and the road bed itself. Make sure the drainage dips and cross-sloping are still functioning and the roadbed is free of ruts and ridges. Then walk back along the toe of the fill slope examining the drainage outlets and the general condition of the fill slope.

2) Any blockage or damage to culverts or drainage. Structures should be repaired immediately.

3) Bare or eroding areas should be reseeded according to Section F or stabilized by some other means.

Where repairs are made in mid-winter, it may be best to only mulch the disturbed areas and perform the seeding later in the proper season. Rills 10 inches or less in size can be reshaped with hand tools. Larger rills or gullies will require that additional fill be hauled in and some may require machine shaping. Be sure to compact new fill very well to prevent it from being washed out by subsequent rains. At culvert outlets, rock riprap, underlain by fabric filter cloth, may be needed.

4) Maintain all vegetation along roads (including road shoulders, cut and fill slopes, and other areas as follows:

Apply fertili1izer annually per soil test if vegetation is not responding well. It is advisable to obtain an opinion and recommendations from a professional in these cases. Over fertilizing can harm vegetation, encourage weeds, and cause contamination of runoff water.

5) Trim back or remove vegetation that crowds the roadway, Prevents surface water from flowing freely to drainage structures, or shades problem areas.

6) With vehicle travel, road surfacing materials such as gravel will be worked off the roadway. From time to time it will be necessary to grade the road to bring the material back to the roadway. Some reshaping may be necessary to maintain proper cross slopes or crowns.

APPENDIX A

ESTIMATING STORM WATER FLOW

AND

SIZING CULVERTS

Estimating Stormwater Flow and Sizing Culverts

One of the most important exercises in planning a new road is estimating the expected flows from drainages you will cross with your road. You must have this information to properly size culverts to be placed in the drainage. Larimer County requires culverts in rural driveways to be sized to accommodate at least a 10-year storm event. The following guidelines will assist you in calculating the flow of water you could expect in a particular drainage in such events. If you have trouble working through this exercise, contact the Larimer County Engineering Department for help or consult a professional engineer. Underestimating the culvert may compromise an costly road project and overestimating will add unnecessary cost to the construction.

1) Estimate the drainage area (A). This is the number of acres of the drainage basin above the road that will drain to the point at which the culvert is to be placed. The simplest way to do this is to outline the basin on the topography map on which you have plotted the road alignment. Then estimate the square feet in the basin and divide by 43,560. This is the area, in acres, which will drain through the proposed culvert. The number will be used in a formula later to calculate the expected flow of water from the storm event.

2) Calculate the slope of the drainage using the following formula:

$$S = E/L \times 100,$$

where S = drainage slope, in percent
E = elevation difference
L = length of the basin above your road

The numbers to be used in the formula are found by following three steps:

a) Measure the length (L) of the basin from the top to the point at which the culvert is to be placed.

b) Subtract the elevation at the culvert from the elevation at the highest point in the basin. This is the difference in elevation (E).

c) Divide the difference in elevation (E) by the basin length (L). Multiply this number by 100. This is the percent slope (S) of the basin drainage.

3) Estimate the type of terrain in the basin from the following table. From Table 1 pick the appropriate numbers (C')coinciding with the best description of the land within the basin area. You should end up with three numbers - one for topography, one for soil type, and one for cover. Add these together and subtract the sum from 1.0. This is the runoff coefficient (C).

$$1.0 - (C'_{topo} + C'_{soil} + C'_{cover}) = C$$

4) Calculate the "time of concentration" (T_C) for the basin feeding your culvert. The following formula can be used:

$$T_C = \frac{1.87(1.1-C)D^2}{S^{\alpha}}$$

where T_C = time of concentration, in minutes
C = Runoff coefficient
S = Slope of the basin drainage, in percent
D = Length of basin, in feet

5) Calculate the rainfall intensity (I) for the time of concentration ,which you calculated above, using the following formula:

$$I = PC_T$$

where, P = 1- hour precipitation amount for the site location, in inches
C_T = Factor for times of concentration
less than one hour (see table 3)

P can be determined by finding your location on the map of Larimer County (Fig.1) and picking the number coinciding with the line nearest your location. For instance, Red Feather Lakes indicates a 1-hour rainfall of 1.4 inches for a 10-year storm event.

6) Calculate the maximum rate of runoff (Q) for the drainage feeding the culvert with the following formula:

$$Q = CIA$$

where, Q = maximum rate of runoff, in cubic feet per second
C = runoff coefficient
I = rainfall intensity during the time of concentration, in inches per hour
A = Area of the drainage basin

7) Pick the proper size culvert for this location using the nomograph on page 16 (Fig.2). Here's how you do it. On the right side is a vertical line titled "Headwater Depth in Diameters". Pick the mark on that line marked 1.5. Next, find the rate of discharge (Q) you just calculated on the middle line. With a straight edge draw a line through these two points to the line on the left titled "Diameter of Culvert". The mark on this line nearest the line you drew will tell you the proper size culvert to install. If the line crosses between two numbers, you should pick the larger number.

Example:

The location of your land is just west of Drake, where the star can be seen on ***Figure 1***. On a topo map the drainage above your proposed culvert location measures an average width of 600 ft. and it is 1500 feet from the top of the drainage basin to the spot at which your road will cross. The elevation at the top of the drainage is 8120 ft. and where the road crosses the drainage the elevation is 7930 ft.

1) Calculate the area of the drainage basin (A):

A = 600 ft. x 1500 ft. = 900,000 ft.^{2}) 43,560 ft.^{2} /acre = **20.7 acres**

2) Calculate the slope (S) of the drainageway:

S = (8120 ft. - 7930 ft.)) 1500 ft x 100 = **12.6%**

3) The drainage basin is in forest and the soil appears sandy. The slopes in the drainage are moderately steep (25%). From ***Table 1*** the runoff coefficient factors (C') are .025 (topography), .40 (soil), and .20 (cover). Adding these numbers and subtracting the result from 1.0 yields a runoff coefficient (C) of 0.375.

C = 1.0 - (.20 + .40 + .025) = 1.0 - .625 = **.375**

4) Calculate the Time of Concentration (T_c) for the basin above your culvert location using the slope (S) and runoff coefficient numbers you have calculated above:

$$\mathbf{T_c} = \frac{1.87(1.1 - C)(\text{length of basin})^2}{S^{\alpha}} = \frac{1.87(1.1 - .375)(1500\text{ ft.})^2}{12.6^{\alpha}} = \frac{52.51}{2.33} = \mathbf{22.5\ minutes}$$

5) Calculate the rainfall intensity (I):

From ***Figure 1***, the one hour precipitation amount for a ten year storm event in your area is about 1.6 inches. You calculated a time of concentration of 22.5 minutes. To adjust the precipitation amount to this time interval, you should multiply by .68 since the time is halfway between the 15 minute and 30 minute intervals. (See Table 3)

I = 1.6 inches x .68 = **1.09 inches**

6) Now you can calculate the maximum rate of runoff (Q) for the drainage as follows:

Q = C x I x A = .375 x 1.09 x 20.7 = **8.46 cubic feet per second**

Note: if you wish to design the culvert to accommodate a storm event of greater magnitude use the factors (Cf) from ***Table 2*** to adjust Q in the equation.

The equation now becomes: $Q = C \times C_f \times I \times A$

For a 100 year event, C_f is 1.25, so : Q = .375 x 1.25 x 1.09 x 20.7 = 10.58 cfs

7) Size the culvert:

Using ***Figure 2***, line up the 1.0 headwater depth mark and your calculated 8.5 cfs discharge (Q) with a straight edge. Draw a line through these two points and find the culvert size on the left-hand vertical line. In this case the line crosses very close to the **21 inch diameter** mark. This is the size of culvert you should place in the drainage.

Table 1.

Factors for figuring C values

Description of Area	C'value
Topography	
Flat land, 0-3% slopes	.25
Hilly land, 4-10% slopes	.10
Steep land, 11%+ slopes	.025
Soils	
Tight, impervious clay	.10
Medium, combination of clay & loam	.20
Open, sandy loam	.40
Cover	
Cultivated lands	.10
Woodlands	.20
Grassland	.25

Table 2.

Factors for adjusting Q to storm events greater than 10 year event

Event	C_f
25 year storm	1.1
50 year storm	1.2
100 year storm	1.25

Table 3.

Factors to adjust precipitation amount to time interval less than one hour

Duration (minutes) :	5	10	15	30
Ratio to 1 hour :	0.29	0.45	0.57	0.79

LARIMER COUNTY PRECIPITATION DEPTH – DURATION – FREQUENCY MAP

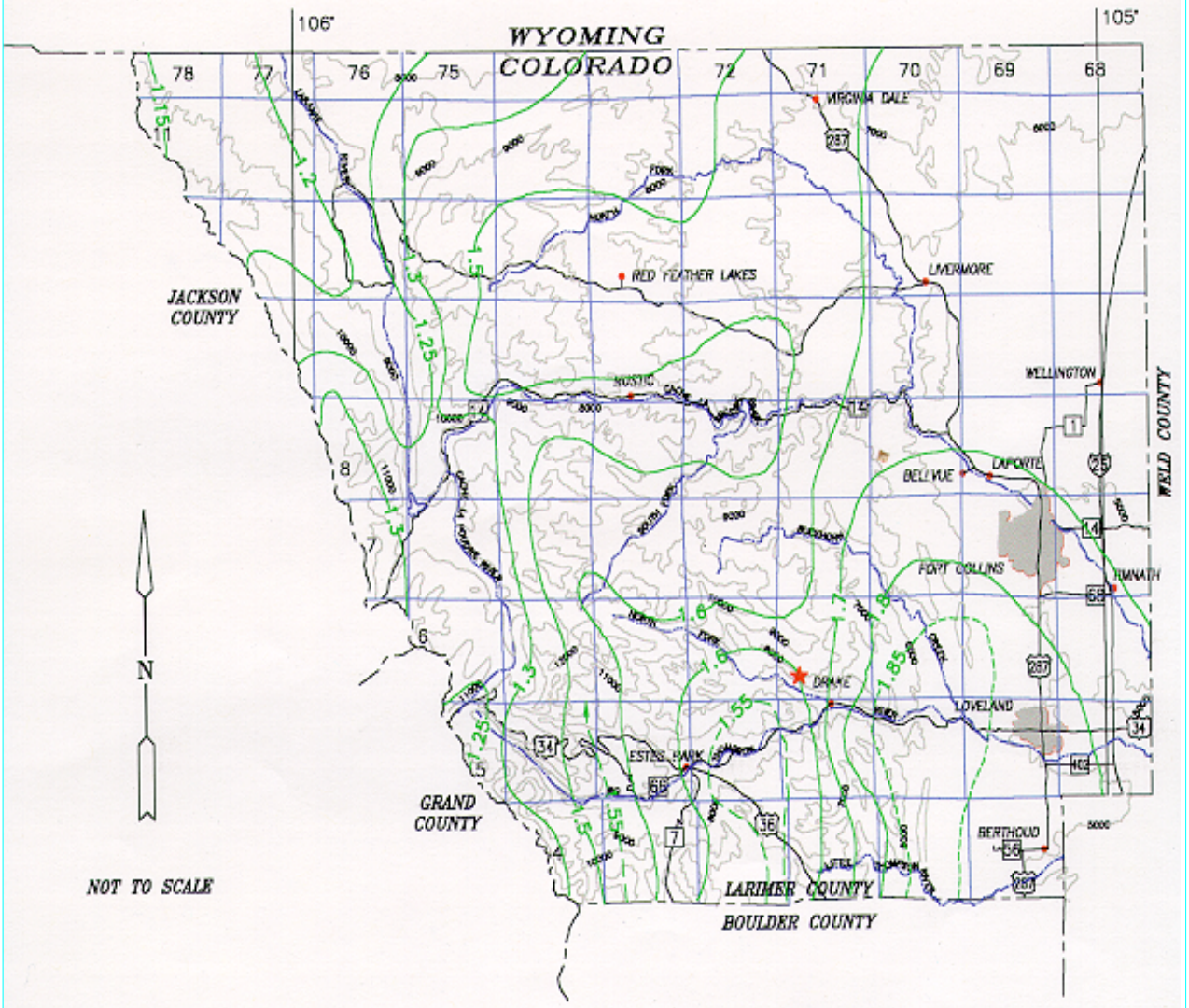


FIGURE 1

ISOPLUVIALS OF 10 YR. – 1 HR.
PRECIPITATION IN INCHES

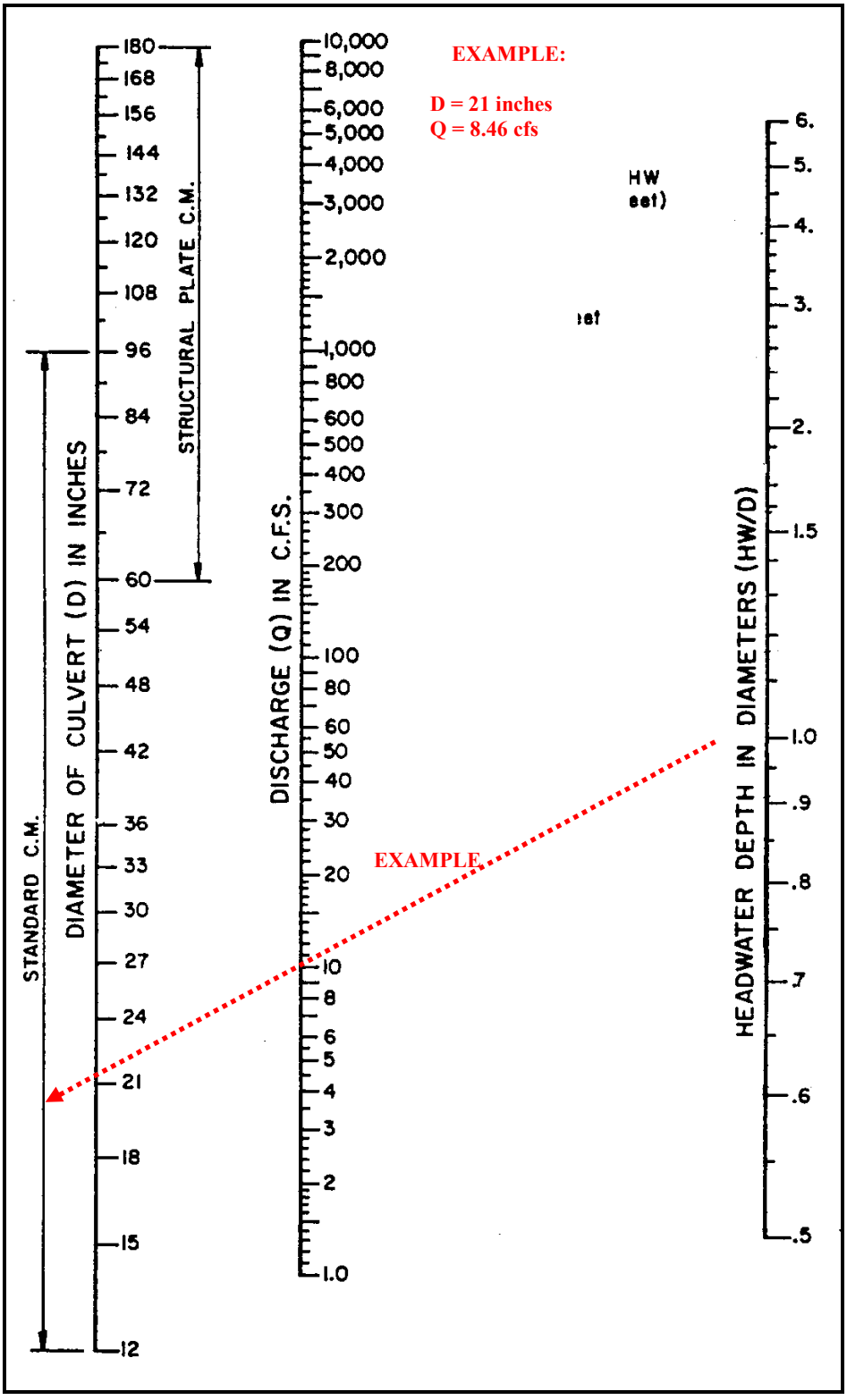


Figure 2. CULVERT DIAMETER FOR CORRUGATED METAL PIPE CULVERTS WITH INLET CONTROL (Adopted from: U.S. Dept. of Commerce, Bureau of Public Roads, Dec. 1965)

APPENDIX B

PLANT MATERIALS

FOR

REVEGETATING DISTURBED SITES

PLAINS SPECIES

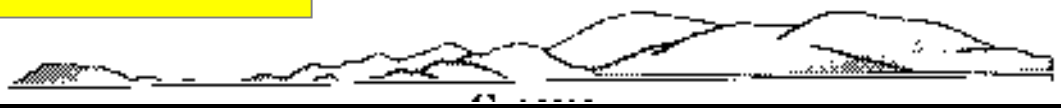
Grasses		
Species	**Pounds of *PLS per acre**	****Percent of mix**
blue grama	3	10-20
sideoats grama	9	20-40+
western wheatgrass	16	30-50+
green needlegrass	10	5-20
switchgrass	5	0-20
big bluestem	11	0-10
yellow indiangrass	10	0-10
little bluestem	7	0-10
buffalograss	6	0-10
alkali sacaton (for saline & salty areas)	2	10-25

*PLS = Pure Live Seed - the portion of the seed that is a live seed of the desired kind
**Percent of mix - ranges are suggested percentages and by no means absolute

Shrubs		
cotoneaster	honeysuckle	chokecherry
lilac	native plum	sand cherry
Woods rose	four-wing saltbush	buffaloberry
winterfat	rubber rabbitbrush	

Trees		
green ash	cottonwood	golden willow
hackberry	honeylocust	Colorado blue spruce
eastern red cedar	ponderosa pine	Rocky Mountain juniper
narrowleaf cottonwood		

FOOTHILLS SPECIES



Grasses		
Species	**Pounds of *PLS per acre**	****Percent of mix**
blue grama	3	5-20
sideoats grama	9	20-50
western wheatgrass	16	20-40
green needlegrass	10	5-20
switchgrass	45	0-20
big bluestem	11	0-15
yellow indiangrass	10	0-10
little bluestem	7	5-15

Consider the following species for severely disturbed sites where quick establishment is critical.

streambank wheatgrass	11
prairie sandreed	6
[1]hard fescue	4
[1]Canada bluegrass	3
[1]annual ryegrass	10

*PLS = Pure Live Seed - the portion of the seed that is a live seed of the desired kind
**Percent of mix - ranges are suggested percentages and by no means absolute
[1] Introduced species

Shrubs		
honeysuckle	chokecherry	lilac
skunkbush sumac	Woods rose	buffaloberry
golden currant	serviceberry	mountain mahogany
red-osier dogwood	rubber rabbitbrush	

Trees		
eastern red cedar	Rocky Mountain juniper	ponderosa pine
pinon pine	narrowleaf cottonwood	

MOUNTAIN SPECIES

Grasses		
Species	**Pounds of *PLS per acre**	****Percent of mix**
mountain brome	19	0-20
needleand thread	15	0-15
slender wheatgrass	11	5-10
western wheatgrass	16	5-15
Sandberg bluegrass	3	0-10
bluebunch wheatgrass	14	5-15
Indian ricegrass	13	0-5
big bluegrass	3	0-10
streambank wheatgrass	11	0-25

Consider these species for severely disturbed areas where quick establishment is critical.

thickspike wheatgrass	11
[1]intermediate wheatgrass	15
[1]hard fescue	4
[1]Canada bluegrass	3
[1]timothy	2

*PLS = Pure Live Seed - the portion of the seed that is a live seed of the desired kind
**Percent of mix - ranges are suggested percentages and by no means absolute
[1]Introduced species

Shrubs		
shrubby ciuquefoil	Woods rose	common juniper
thimbleberry	wax currant	skunkbush sumac
golden currant	chokecherry	buffaloberry
mountain mahogany	serviceberry	snowberry
bitterbrush	holly grape	kinnickinnick

Trees		
ponderosa pine	Colorado blue spruce	Douglas fir
Engelmann spruce	lodgepole pine	white fir
bristlecone pine	aspen	alder

WILDFLOWERS

Another way of adding color to an area while keeping maintenance to a minimum is to seed wildflowers. Like native grasses, native wildflowers will thrive in areas where other commercial species will not. Many species have the additional benefit of being perennials. To determine which wildflowers are indigenous to your area, refer to "Wildflowers of America," by H. W. Rickett (an 11-volume series available at your local library). Below are some suggested wildflowers.

PLAINS

yarrow	lance leaved coreopsis	plains coreopsis
perennial gaillardia	annual gaillardia	baby's breath
blue flax	prairie coneflower	smooth aster
New England aster	golden aster	prairie aster
blazing star/gayfeather	scarlet globemallow	plains wallflower

FOOTHILLS

pasque flower	silky lupine (poisonous to sheep)	Indian paintbrush
sulphur flower	perennial lupine (poisonous to sheep)	blue flax
yarrow	blazing star/gayfeather	harebell
low fleabane	plains wallflower	penstemon

MOUNTAINS

pasque flower	Colorado blue columbine	sulphur flower
rose pussytoes	Indian paintbrush	baby's breath
bellflower	wallflower	fleabane daisy
perennial gaillardia	silky lupine (poisonous to sheep)	dame's rocket
blue flax	perennial lupine (poisonous to sheep)	penstemmon
catchfly	yarrow	Rocky Mountain iris
arrowleaf balsam		

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Acknowledgment

The authors have drawn freely from the publications listed. The reader is encouraged to consult these publications if detailed information beyond the scope of this booklet is desired.