Forest Service Handbook
National Headquarters - Washington Office
Washington, DC

Forest Service Handbook 2309.18 – Trails Management Handbook

Chapter 3 - Trail Preconstruction and Construction

Amendment: 2309.18-1991-2

Effective date: November 08, 1991

Duration: This amendment is effective until superseded or removed.

Approved by: F. Dale Robertson, Chief

Date approved:

Responsible Staff:

Last Change: 2309.18-1991-1

Superseded Document(s): 2309.18-91-1, March 21, 1991; 1, June 1987; New, June 1985

Digest: Following is an explanation of the changes throughout the directive by section.

This amendment is a reissuance of FSH 2309.18 to conform the format and structure of the Handbook to the requirements of electronic directive issuance.

This amendment makes no substantive changes to the text. The only changes made are those necessary to meet new format requirements or to correct spelling, punctuation, unit names or coding errors.

This Handbook is now available electronically in the National Information Center in the same format as the paper copy. Henceforth, amendments to this Handbook will be issued to Forest Service units electronically on a document basis.

Table of Contents

3.1 - Preconstruction 3
3.11 - Reconnaissance 3
3.12 - Location 6
3.12a - Alignment 6
3.12b - Grade 7
3.12c - Switchbacks and Climbing Turns 12
3.12d - Stream Crossings 14
3.13 - Survey 14
3.13a - Survey Precision 14
3.13b - Survey Procedures 15
3.14 - Design 20
3.15 - Drawings 20
3.16 - Specifications 24
3.16a - General 24
3.16b - Specifications - Detail 27
3.17 - Trail Construction Packet 32
3.2 - Construction 33
3.21 - General 33
3.22 - Construction Engineering 33
3.23 - Methods 33
3.23a - Force Account 34
3.23b - Contract 34
3.23c - Contributed 34
3.23d - Volunteer, Human Resource, and Cooperative Programs 34
3.24 - Construction Administration 34

3.1 - Preconstruction

Preconstruction work must begin early and be completed prior to construction. The level of detail of preconstruction work depends upon the type of facility being designed. A simple, low-standard hiker trail may require less preconstruction work than a high-standard barrier-free trail. Regardless of detail, the series of steps remains the same and begins with reconnaissance.

3.11 - Reconnaissance

The reconnaissance process includes the identification and evaluation of alternative routes and leads to final selection of the best possible routes and facility to meet the established objectives. Application of sound principles of trail location, alignment, and grade will minimize future operation and maintenance problems.

Examine good contour maps of the area when available to lay out preliminary trail routes before going to the field. Examine aerial photographs, when available, to identify terrain drainage patterns and vegetation. Sketch alternative routes on the photographs before any field work is done. Oblique-type aerial photographs are valuable for giving additional perspective to possible routes. Discussions with field personnel familiar with the area are very helpful. Aerial reconnaissance may be helpful to get a "feel" for the area and to aid in identifying control points. Use office study to reduce the number of routes to consider for field review.

Even with maps, photographs, and personal contacts, there is no substitute for on-the-ground examinations of potential routes. Carefully examine control points such as saddles, rock outcrops, and clearings, as well as important construction considerations, such as heavy vegetation areas, soft ground, stream crossings, unstable soils, and avalanche zones. Also review resource objective such as visual quality and wildlife. Walk each feasible route and mark the proposed alignment of each in relation to the maps and photographs. Identify the routes on the ground with different temporary markers that will be easily recognized and can be moved if necessary. A thorough and careful reconnaissance of routes will result in readily identifiable lines on the ground that can be evaluated and, after selection, staked as a trail location for construction.

Record all pertinent data of physical conditions and key features that are to be regarded as principal items for consideration in route selection. Much of this data can be recorded directly on maps and photos. Photograph key features and physical conditions along the various alternative routes. These photos provide valuable information for final route selection as well as preparation of the environmental assessment. Label all photos so the areas photographed can be related to the trail sections shown on the map and in aerial photos.

Numerous factors affect trail location. Carefully consider the conditions of various routes and avoid the following as much as possible:

1. Wet areas and flat areas with difficult drainage.

2. Stream bottoms subject to periodic floods, heavy seasonal runoff, or dramatic daily flow fluctuations from glacial melt.

3. Avalanche-starting zones, tracks, and runout zones.

4. Locations subject to snow drifting and late-season snowmelt.

5. Rock slides.

6. Unstable, fragile, or color-contrasting soils.

7. Steep slopes and abrupt elevation changes.

8. Bluffs, ledges, and cliffs except where featured as a scenic resource for trail users.

9. Frequent stream crossings where fording is difficult or impractical.

10. Locations requiring bridges or culverts.

11. Heavy vegetation requiring clearing and annual maintenance.

12. Extensive need for swichbacks or long tangents.

13. Fragile vegetation areas.

14. Cultural sites except where featured as a trail objective.

15. Lightning-prone areas.

16. Road or railroad crossings with limited sight distances.

17. Known habitats of threatened or endangered species of plants or animals.

18. Private land requiring a right-of-way.

19. Timbered areas prone to blowdown.

20. Adverse effects on other resources such as wildlife.
21. Fences, cables, and guy wires.

Favor areas with the following features:

1. Natural stream crossings.

2. Ridges.

3. Benches.

4. Natural openings.

5. Open timber.

6. Light stands of brush.

7. Scenic vistas.

8. Observation opportunities with special features.

9. Access to water, horse feed, stable camp areas, and areas protected from the weather.

10. Natural drainages offered by sloped locations.

11. Well-drained soils.

12. Differing seasonal experiences and conditions.

13. Natural contours in topography.

14. Safe and quick crossing of roads and railroads.

15. Reasonable access to other transportation modes, such as roads, railroads, airplanes, and boats.

16. Good trailhead access.

After initial reconnaissance, prepare an environmental assessment for the project in accordance with FSM 1950. The environmental assessment should include alternative trail locations and the expected impacts on wet-area soils, slope soil

stability, stream crossings, visual resources, cultural sites, and planned recreational opportunities, as well as other natural resources such as wildlife. Measures to be taken during the location and design phase to mitigate the impacts are also in the assessment.

It is important to make a thorough economic analysis when evaluating possible routes. The cost of construction as well as the costs of long-term maintenance are important factors in the decisionmaking process.

A field review of the alternative routes shall be made to validate the reconnaissance and environmental assessment information. Agree on mitigating measures to be included in the design standards. Amend the environmental assessment if necessary, to reflect changes resulting from the final field review. The assessment should document the decisions regarding route selection, economics, and mitigating measurements.

After route selection, finalize the "flag line" on the ground. All alternative route markers need to be removed and obliterated so as not to confuse later location personnel and construction crews.

Also after final route selection, review the analysis of capital investment cost estimates. This will ensure that estimates made 1 to 3 years earlier remain realistic.

Commence formal right-of-way acquisition procedures.

3.12 - Location

The locations phase of the development process establishes on the ground the results of the planning, reconnaissance, and route selection steps. Location work should not begin until the environmental assessment is completed and the decision notice issued. How the trail is located will have considerable influence on the cost of construction and maintenance, degree of resource protection, and user experience.

3.12a - Alignment

Normally, trail alignment should follow the contours of the land and consist of a series of gently sweeping long curves. Long straight strectches (tangents) and sharp angular turns should be avoided as much as possible, although these too may add variety to the user's experience.

Alignment should take advantage of natural drainage to minimize the need for major drainage modifications. Locating the trail directly up or down a slope results in little opportunity to drain water off the tread. Proper drainage is a long-term investment that pays off in reduced future maintenance and reconstruction.

3.12b - Grade

Early reconnaissance and the environmental analysis should provide the range of preferred grades for a specific trail. The location of the gradeline on the ground is the most important element of trail development; the trail grade influences the length of trail, level of difficulty, and drainage and maintenance requirements. Therefore, grade usually is the controlling factor for trail location. Avoid undulate the grade to provide natural drainage and variation and to eliminate long, steady grades, which are tiring to the user.

A slight downhill grade is necessary for crossing drainages and to provide grade undulations for drainage purposes. These sections of grade must be considered and designed to avoid excessively steep sections of trail grade.

In areas where there is a potential for trail erosion, roll the grade to create natural-appearing drainage dips at appropriate intervals to divert water from the trail (ex. 01).

The spacing of drainage facilities to intercept water running down a trail is influenced by the soil type and grade which affects water velocity. Determine the appropriate spacing before locating the trail and establishing cross drainage provided by rolling the gradeline. Exhibit 02 shows spacing requirements for various soil types and percentage of grades.

Where soil types or tread-hardening techniques provide the necessary resource protection, steeper grades may be permitted on trails designated as more difficult or most difficult.

Some trails for hikers might be stepped in rock to 30 percent or more. A trail might have some short, steep pitches to take advantage of an area of hightly stable terrain that can be easily protected from erosion. Use runs of steps for certain types of trails when grades between control points would exceed either user comfort or soil stability.

Avoid flat grades where possible. Trails that must be located through meadows, savannahs, and other low areas should be considered for walkways, puncheon, or tread stabilization (ex. 03).

Increase grades 10 to 15 percent at approaches to switchbacks to avoid cross cutting by trail users.

A level-off grade should be located at the end of steep sustained grades. A level-off grade is any grade less than the maximum preferred grade for the trail type. The length and grade of the level-off section relate to the difficulty level provided by the trail.

3.12b - Exhibit 01

SEE THE PAPER COPY OF THE MASTER SET FOR SECTION 3.12b - EXHIBIT 01.

3.12b - Exhibit 02

Frequency of Cross Drains

	Grade (percent)						
Material Type	2	4	6	8	10	12	15
Loam	350'	150'	100'	75'	50'	*	*
Clay-Sand	500'	350'	200'	150'	100'	50'	*
Clay or Clay-Gravel 75'		-	500'	300'	200'	150'	100'
Gravel (rounded rock)	-	-	750'	500'	350'	250'	150'
Shale or Angular Rock	-	-	800'	600'	400'	300'	250'
Sand	Varies with local amounts of fine clay and silt. Drainage diversions generally are not required in "pure" sand because of the fast rate of water absorption. For sand with appreciable amounts of fine binder material, use "clay-sand" distances as shown above.						

* Grades not recommended in this material.

- Generally no diversion required for soil stability.

3.12b - Exhibit 03

SEE THE PAPER COPY OF THE MASTER SET FOR SECTION 3.12b - EXHIBIT 03.

3.12c - Switchbacks and Climbing Turns

Switchbacks and climbing turns are used to gain required elevation within a limited working area, while maintaining acceptable trail grades.

Switchbacks are used in steep topography (ex. 01). Suitable terrain for a switchback construction and maintenance costs increase as the steepness of the side slope increases. Side slopes from 20 to 45 percent are preferred locations for switchbacks, although they can be constructed on side slopes of up to 55 percent, retaining, structures are necessary

3.12c - Exhibit 01

SEE THE PAPER COPY OF THE MASTER SET FOR SECTION 3.12c - EXHIBIT 01.

3.12d - Stream Crossings

Stream crossings normally are a location control point. Stream crossing structures are very costly to construct and maintain and, if located poorly, are susceptible to being damaged or destroyed by streamflows.

Locate stream crossings in an area having as many of the following features as possible:

1. A well-defined stream channel.

2. Minimal channel width.

3. A flat stream gradient.

4. Stable slopes on uphill trail grades on both side of the crossing.

3.13 - Survey

The purpose of a survey is to gather data to design the facility, provide quantity estimates, and develop plans. The plans and quantity estimates describe what is to be constructed and the work involved and provide the basis for cost estimating.

3.13a - Survey Precision

The necessary level of survey precision is that which will produce plans and quantity and cost estimates that will enable a contractor, volunteer group, or force account crew to construct the facility at the cost bid or estimated price.

Vary the precision of survey with the standard of the facility being surveyed, the severity of the terrain, and the physical features of the environment.

A cloth tape and Abney level survey are adequate for most trail surveys for new construction. Site surveys for structures such as bridges an retaining walls require more precision. Reasonably accurate elevations and contour mapping are required to design and lay out bridges and retaining walls. Cloth tape and hand level surveys are adequate for surveys involving flat topography and less complex structures. Transit, chain, and tripod level or plane table surveys are required for more complex sites. Aerial photography is an alternative to normal survey procedures for obtaining site plans. This procedures is very cost effective. The only limiting factor is that the site must have some canopy opening so that the ground is visible from the air.

Surveys for reconstruction of existing trails often are made by using a cyclometer. Sections of a reconstruction project involving tread excavation or other types of more complex construction may require a more precise survey than can be accomplished with a cyclometer.

3.13b - Survey Procedures

The following steps describe general survey procedures.

1. Perform a trail survey so that the final alignment will be designed to fit the ground over which it passes. Extra blasting and clearing of large trees to construct straight tangents from station to station are not permitted. Stake trails to gently curve by large boulders, trees, or other objects that are not necessary or desirable to remove and to provide built-in drainage. More difficult and most difficult hiker and pack and saddle trails may meander to avoid obstructions.

Stake the trail location at intervals of less than 100 feet. Stakes normally will represent trailbed elevation. Stakes are set at more frequent intervals when terrain and vegetation indicate the need. Location stakes or flagging tied above the stake should be intervisible. Trail users may remove or destroy survey stakes. When surveys are along trails of frequent use, metal tags or some other substitute for stationing may be required. Reference stakes are offset at intervals of 500 feet or less, as needed.

2. Slope stakes generally are not needed for construction control; however, slope stakes must be set for switchbacks, bridge approaches, or in other places where construction may require an abnormal amount of excavation.

3. The following situations are marked on the ground and recorded in a field notebook.

a. Shallow stream fords, gully crossings, and all watercourse crossings are staked for trailbed elevation at the channel bottom. The trailbed on each bank is staked 1 foot or more in elevation above the high watermark.

b. Switchbacks are staked at the radius point and at backslope and fillslope catch points.

c. The beginning and end of traffic control barriers are staked on the ground. Traffic barriers include those located at switchbacks, climbing turns, and precipice sections of the trail.

d. Stake the beginning, ending, and foundation elevation of retaining walls.

e. Stake the beginning and ending locations of puncheon, turnpike sections, and walkways.

f. Specify the type of trail passing sections and stake the beginning and end of each section.

g. Stake the location of cliff-like sections requiring extra bed width and safety barriers.

h. Mark danger trees prior to the contract pre-bid showing or commencement of work.

i. Clearly stake locations of the following drainage structures:
(1) Water bars.

(2) Metal culverts.

(3) Rock culverts.

(4) Rock underdrains.

(5) Rock spillways.

(6) Drainage dips.

j. Undulate the trail grade to provide drainage. It is more natural and less obvious to provide gentle grade undulations than to construct drainage dips after the trailbed has been excavated. Place sufficient centerline stakes to control the location of the grade undulations.

When drainage dips are constructed inan existing trailbed, the trail centerline usually is shifted. Shifting the trail centerline is necessary to avoid excessive trailbed width and sharp, unnecessary changes in the alignment. Increased backslope areas will occur.

As a rule, drainage dips are not constructed in an existing trailbed where the trail grade exceeds 10 percent. On grades that exceed 10 percent, water bars are installed to effectively shed the water from the trailway.

4. Document data collected during the location survey process. The survey data is extremely important for completing the plans and for developing the project cost estimate. The following measurements and findings must be recorded in the field notebook, tape recorder, or dictaphone.

a. Measure and record the percent of grade and percent of side slope at each centerline stake. Take cross slope measurements at each centerline stake. Take cross slope measurements at switchbacks, climbing turn locations, and other similar places.

b. Record detailed notes about topography between each 100-foot station for cost-estimating purposes.

(1) Classify the type of materials to be excavated. Terms often used to classify excavation include the following:

(a) Common Soil. Soil on rock that can be excavated without blasting.

(b) Fractural Rock. Rock material that can be excavated with moderate amounts of blasting.

(c) Fractural Rock. Rock material that can be excavated with moderate amounts of blasting.

(d) Talus Rock. Rock slides.

Example photographs should be taken of each material type classification.

(2) Classify the type of clearing between each 100-foot station for cost-estimating purposes. Indicate the species, size, and number of trees to be cleared.

c. Record the description and station location of all pay items and all work items that are incidental to a pay item.

The quantities of work items must be measured or estimated and recorded in the field notebook at the time location-staking is completed. Measurements may include estimated facial square feet of retaining walls, linear feet of turnpike, puncheon, passing sections, and drainage ditches, metal culvert lengths and sizes, and any other relevant information.

Availability of native building materials should be noted in the field notebook. For example, record the distance from the proposed rock retaining wall to the borrow

source for building rock. Also, record distances from suitable timber to where it is needed. When native building materials are more than 300 feet from where they are needed, the distance must be shown on the drawings. Describe the borrow source and restoration measures if needed. Sample field notes and format are shown in exhibit 01.

3.13b - Exhibit 01

SEE THE PAPER COPY OF THE MASTER SET FOR SECTION 3.13b - EXHIBIT 01.

3.14 - Design

Many design decisions are made during the planning, location, and survey phases of trail development. Items such as clearing and tread widths and types of material to be used may be prescribed through the planning process. The location and survey phases determine the length of trail, location and type of drainage facilities, number of switchbacks, designated trees to be felled, and location and length of puncheon bridges and walkways.

Items such as bridges, retaining walls, underdrains, or steps may require office design. The design process translates the field survey to drawings and specifications and produces an estimate of cost and a schedule of items.

Drawings, specifications, and cost estimates should be used for all projects regardless of who will construct the project. These documents are necessary to (1) allow the responsible official to ensure that management objectives have been accurately translated into a project proposal; (2) provide a means to communicate what is required the people who construct the facility; (3) permit the responsible official to determine that the finished facility is acceptable; and (4) provide a historical record of the facility for operation and maintenance needs.

3.15 - Drawings

Trail drawings commonly consist of straight-line diagrams or construction logs, which communication to the constructor the location of all items of work described in the specifications. Exhibit 01 is an example of a straight-line diagram; exhibit 02 is an example of a construction log.

3.15 - Exhibit 01

SEE THE PAPER COPY OF THE MASTER SET FOR SECTION 3.15 - EXHIBIT 01.

3.15 - Exhibit 02

Reconstruction Log

Barclay Lake Tr. 1055

Station	Work Item	Remarks
0+00	Begin project	
0+40 - 0+80	Remove outslope	
0+90	Provide clearance right (rock)	
3+70 - 4+10	Relocate right	
4+50	Provide clearance right (rock)	
4+10 - 5+23	2" surfacing	
9+66	Gravel borrow site	
9+92 - 10+15	Remove slide debris	
10+56 - 12+65	2" surfacing	
13+07 - 13+27	2" surfacing	
13+12	Construct lead off ditch 5' left	
13+27	Remove step root	
13+40	Construct lead-off ditch 6' left	
14+90	Construct lead-off ditch 5' left	
15+67	Remove step root	
16+58	Construct lead-off ditch 7' left	
17+37	Construct lead-off ditch 5' left	
18+00 - 18+24	Install log rounds	
18+40 - 18+75	Install log rounds	
19+90 - 28+65	Relocate log right	
20+27	Construct Dip	

3.15 - Exhibit 02--continued

Station	Work Item	Remarks
(Continue in similar manner	station 21+30 to station 103+07)	
103+07 - 103+43	Relocate right	
103+60	Construct lead-off ditch 10' right	
104+18 - 104+40	Install log rounds	
107+40	Construct lead-off ditch 6' right	
108+53	Construct lead-off ditch 6' right	
110+35 - 110+43	Construct rock crib 1.5' x 8'	
111+11	Construct lead-off ditch 8' right	
111+58	Construct lead-off ditch 4' right	
111+71 - 111+79	Install log rounds	
111+93 - 112+11	Install log rounds	
112+42 - 112+55	Install log rounds	
116+38 - 116+66	Relocate right. Keep existing trend open for drain	
117+37	Construct lead-off ditch 9'right	
119+15	End project	

3.16 - Specifications

Trail construction specifications describe the work required. Forest Service Standard Specifications for Construction of Trails (EM 7720-102) should be used where the complexity of the project warrants them. Consult chapter 5 of this handbook for commonly used design exhibits for the preconstruction and construction of trails.

3.16a - General

The standard trail construction specifications include written descriptions (EM 7720-102) and standard drawings showing dimensions, sizes, and configuration of components for the various items of work described in the written specifications. This data is entered by the designer for each project. The completed standard drawings reflect the trail standard prescribed in the planning and earlier development phases.

1. Estimate of Quantities. Standard trail construction specifications contain the items of work described. The estimate of quantities is the number of units required for each item.

2. Estimate of Costs. Unit prices are calculated for each item included in the project. Various cost-estimating procedures are available for determining unit prices. FSH 7709.56, chapter 7, contains information on cost estimating that can be applied to estimating trail construction costs. Exhibit 01, Form FS-7700-18, Cost Estimate for Transportation System Facilities, is an example of a completed cost estimate.

3.16a - Exhibit 01

SEE THE PAPER COPY OF THE MASTER SET FOR SECTION 3.16a - EXHIBIT 01.

3.16a - Exhibit 01--Continued

SEE THE PAPER COPY OF THE MASTER SET FOR SECTION 3.16a - EXHIBIT 01.

3.16b - Specifications - Detail

1. Clearing and Grubbing. The width and height of clearing is determined by the intended use of the trail and the level of difficulty. The clearing widths and heights should have been identified during the standard determination phase of the development phase. The clearing heights and clearing widths left and right of the trail centerline should be entered on Form FS-7700-61, Clearing Limits, (ch. 5, ex. 01) or Form FS-7700-62, Clearing Limits, (ch. 5, ex. 02).

It may be necessary to change clearing widths. For example, if the vegetation changes from timber to low brush, reduce the clearing limit. Fast-growing brush require a greater clearing width. On steeper side slopes, extend the clearing to clear higher cut slopes. Additional clearing may be needed for trail passing sections, safety barriers, or turnpike sections.

Brush and slash disposal areas should be designated. In areas near streams, lakes, and switchbacks identify other locations than downhill.

In addition, exhibit 01, chapter 5, contains a provision for leaving trees that are a specified distance from the centerline but within the clearing limits. The trail standard prescription should indicate if certain trees may be left, and, if so, the size and distance from the centerline should be entered. Exhibit 01, chapter 5 also permits specifying different stump heights for stumps left in place.

The most commonly used units of measurement for clearing are linear feet or miles. The number of trees outside the clearing limits designated for felling should be measured on an individual basis. The locations of designated trees must be shown on the straight-line diagram or construction log.

2. Trailbed Excavation. Trailbed construction deals with modifying the natural terrain as needed to provide user safety, comfort, and convenience and to protect adjacent resources and the trail facility. (Form FS-7700-63, Typical Trailway Cross Sections (ch. 5, ex. 03), Form FS-7700-64, Trailbed and Slope Finish (ch,. 5, ex. 04), and Form FS-7700-65, Talus and Rubble Rock Section (ch. 5, ex. 05).)

Trailbed construction may be as simple as delineating the trail through relatively flat and dry areas by mowing or as complex as benching or retaining steep sidehill routes or providing suitable trailbed through savannahs, wet areas, and meadows.

The trail tread width may be the same as the trailbed width unless some type of protective surface is constructed such as aggregate or bituminous pavement. The trail width is selected according to the type of use and level of difficulty desired and

should be provided as part of the trail standard prescription. The trail width and corresponding trailbed width is entered on the appropriate specification.

The trailbed width may be widened when passing sections or barriers are required. See Form FS-7700-67, Trail Passing Sections (ch. 5, ex. 06).

Specifications permit varying the degree of trailbed finish to provide for the desired level of difficulty. Complete Form FS-7700-64 (ch. 5, ex. 04) to indicate how much rock and root removal will be required.

See Form FS-7700-68, Shallow Stream Ford and Gully Crossing-Rock Structure, Form FS-7700-69, Shallow Stream Ford and Gully Crossing-Log Structure, Form FS-7700-66, Drainage Dips, and Form FS-7700-65, Talus and Rubble Rock Sections (ch. 5, exs. 07, 08, 09, and 05).

Linear feet or miles are the most common units of measurement for trailbed excavation. The lump-sum method of measurement would be appropriate for projects requiring little or no excavation to construct the tread.

3. Turnpikes. Turnpike construction is a technique to provide a stable trailbed in areas of high water tables and fairly good soils. Form FS-7700-70, Turnpike, (ch. 5, ex. 10) covers turnpike construction. Ditches are excavated on each side fo the trailbed to reduce the water table, and the material excavated is placed on the trailbed to raise the trail grade above the surrounding water table. Often it is necessary to bring in borrow material to complete turn-pike construction.

If the ground is wet, turnpike sections should sit through a winter and spring season to permit full consolidation before use. Geotextiles greatly improve the effectiveness of the turnpike section. Consult a materials engineer to determine if a fabric should be used.

4. Switchbacks. Form FS-7700-71, Switchback Details, (ch. 5, ex. 11) provides the details for switchback construction. Use the type of traffic barrier shown. Follow chapter 5, exhibit 11 to plan and place the location and radius of each switchback.

5. Reconstruction. Specifications may be followed for reconstructing existing trails. Combine whatever aspects of the specifications are required to reconstruct the given area. The most common reconstruction projects include adding drainage dips, check dams, and rock spillways and removing slough and berms (see Form FS-7700-75, Check Dams (ch. 5, ex. 12).

6. Drainage. Proper drainage is the most important factor in producing a lasting, low-maintenance facility. Keep water within manageable limits to prevent damage from erosion and to keep the facility usable during the travel season.

Remove water from unpaved trail surfaces as quickly as possible. Outsloping hillside trail treads, where trail grades are slight, may be the only feature necessary to ensure quick water removal and surface protection. Sloping the trailhead downward toward the downward edge 1/2 to 1 inch per foot of trailbed width is normally sufficient, but this calculation is based on the specific soil type.

When trail grades are greater than trail tread outsloping, surface water travels along the trail before it escapes. The greater the difference, the greater the risk of damage. Other, more intense methods are employed to ensure proper drainage on greater trail grades.

Basically, trail surface erosion results from three factors: soil type; velocity of water along the trail; and length of time running water is allowed on the trail. By modifying any of these three items, erosion potential is changed. The most common modification is to reduce the length of time running water is allowed to operate on the surface material by increasing the number of structures designed to remove this water.

Exhibit 02 in section 3.12b of this handbook recommends frequency (in feet) of diversion structures for various soil types and trail grades. These structures may be water bars, grade dips, culverts, or other such devices designed to remove the water.

Follow separate specifications provided for: culverts, Form FS-7700-76 (ch. 5, ex. 13) and Form FS-7700-77 (ch. 5, ex. 14); water bars, Form 7700-78 (ex. 15); rock spillways, Form FS-7700-79 (ch. 5, ex. 16); rock underdrains, Form FS-7700-80 (ch. 5, ex. 17); and installation of open top drain (ch. 5, ex. 18).

The location, length, and type of drainage facility required is shown on the drawings.

The type of drainage facility selected depends on the Recreation Opportunity Spectrum (ROS) setting, the type of use, the amount of water involved, and the physical setting of the trail.

On flatter grades, outsloping the trail adequately protects the trail tread. In the intermediate range of grades, drainage dips are the most effective means to control drainage. On steeper grades, rock and log water bars are necessary to control drainage.

7. Trail Structures. Specifications are provided for the following structures: log stringer bridge, Forms FS-7700-84, FS-7700-85, and FS-7700-86 (ch. 5, ex. 19, 20, and 21; footlog bridge, Form FS-7700-87 (ch. 5, ex. 19, 20, and 21; footlog bridge, Form FS-7700-87 (ch. 5, ex. 22); trail puncheon bridge, Form FS-7700-88 (ch. 5, ex. 23); log retaining wall, Form FS-7700-89 (ch. 5, ex. 24); rock retaining wall, Form FS-7700-90 (ch. 5, ex. 25); and puncheon walkway, Form FS-7700-93 (ch. 5, ex. 26).

a. Bridges. Bridges are designed to support the maximum snow load, snow grooming equipment, or pack and saddle stock. They must be appropriate for the prescribed ROS class and in accordance with the established visual quality objectives for the area through which the trail passes.

Except for foot bridges made of logs, the travelway width of structures is generally wider than the width of the trailbed.

The lengths and sizes of structural members are determined and entered on the drawings. Where Regions have standard design tables for sizing structural members, bridge design shall be approved by the Forest Engineer. If standard desing tables are not available or if a type other than a log stringer is required, the bridge design must be approved by the Regional Engineer.

b. Stairways. Steps provide an opportunity to gain needed elevation rapidly over short distances. The proper use of steps can allow other portions of the trail to be constructed on lesser grades, which reduces soil erosion, especially where side drainage is difficult. Steps are used on trails designed for foot traffic. The minimum width of steps should not be less than the tread width of the trail of which they are a part (Forms FS-7700-91 and FS-7700-92, Trail Stairways (ch. 5, ex. 27 and ex. 28).

Steps may be constructed of rock, native logs, or treated wood. Materials that require little or no future maintenance are preferred. Treated railroad ties may be used in a variety of step situations.

The appropriate design for steps should reflect user requirements, difficulty level provided by the trail, and overall recreation prescription for the area. The type of steps to be constructed depends on the site and materials available. The rock and log riser, overlapping rock plank stairways and crib ladder stairways can be used when the overall slope of the stairway is relatively flat (25 percent or less). The other stairways are used for steeper installations.

A fairly accurate profile is needed to adequately design the layout of steps.

The need for handrails along stairways depends on possible safety hazards relative to the difficulty level offered, amount of use, season of greatest use, and physical capabilities of the user.

Sections acquiring surfacing must be shown on the plans.

c. Barriers. Barriers are typically needed at switchbacks, along sections in rock cliffs, or to control use (Forms FS-7700-98 and FS-7700-99, Log Barriers (ch. 5, ex. 29 and 30); Forms FS-7700-101 and FS-7700-102, Rock Barriers (ch. 5, ex. 31 and 32); and Forms FS-7700-103 and FS-7700-104, Treated Timber Barriers (ch. 5, ex. 33 and ex. 34). The type of barrier required usually depends on the materials available.

Use of barriers will require additional trailbed width. This must be reflected on the appropriate specification.

The location of barriers is shown on the drawings.

d. Fence Crossings. The use of fence openings, gates, or stiles are required when trails cross fenced boundaries. Obtain written approval from the fence owner prior to construction.

Fence openings, designed to restrict unwanted passage, are preferred to other methods. A simple V-shaped post dodgeway is effective and requires little or on maintenance (ch. 5, ex. 35, Fence Stiles and Ladders).

If fence opening are impractical or are not allowed by the owner, stiles and fence ladders provide a safe crossing for hikers while protecting the fence itself and effectively restricting undesirable use. There are many acceptable designs for these structures.

Special project specifications are developed when fence crossings are required.

Avoid installing gates on trails, since they can be left open and lead to undesirable use. When used, design gates to blend in with the surroundings and to be self-closing and latching.

8. Surfacing. Some type of surfacing is often required for very high use trails or when soil, moisture, and volume of traffic make it impossible to hold the trail tread. In these situations, use of some type of surfacing may be more cost effective than maintaining and unsurfaced trail and will prevent undersirable environmental damage to the trail corridor. Sections requiring surfacing must be shown on the drawings.

Specifications are available for pit-run aggregate, screened aggregate, crushed aggregate, and bituminous surfacing. Consult a materials engineer when surfacing material may be required.

Crushed aggregate must be densely graded and have a high percentage of fractured pieces with fracture faces to allow interlocking. The gradation for screened and crushed aggregate is shown on Form FS-7700-94, Aggregate Surfacing (ch. 5, ex. 36). The gradation and quality requirements should reflect locally available materials.

Geotextiles greatly increase the effectiveness of surfacing, permit the use of less expensive surfacing material, reduce the amount of material needed, and may eliminate entirely the need for surfacing. A special project specification must be written providing an installation requirement if fabric is to become part of the surfacing construction phase. Consult a materials engineer regarding the use of a geotextile when poor soils are encountered.

Complete chapter 5, exhibit 36 to show the required widths and depths of aggregate surfacing. Consult FS-7700-102 for specifications when bituminous plant mix pavement is necessary.

9. <u>Signs and Posts</u>. Specifications provide for installing posts and signs and constructing cairns. The specification assumes signs will be furnished by the Government. A special project specification is necessary to describe where Government-furnished signs can be obtained.

Use Form FS-7700-96, Sign and Post Installation Diagram (ch. 5, ex. 37) to locate posts and signs. Use Form FS-7700-97, Rock Cairn Construction (ch. 5, ex. 38) to construct cairns.

3.17 - Trail Construction Packet

The following steps should be followed in developing in developing a trail construction packet:

1. Conduct a plan-in-hand ground review. Make any needed changes to the trail route or plans. This now becomes the final location and plan for the project.

2. Finalize the straight-line diagram or construction log to show what is required and where it is to be located.

3. Select the standard trail construction specifications required for the project from EM-7720-102.

4. Prepare and obtain approval of special project specifications.

5. Complete the necessary standard drawings.

6. Prepare an engineer's estimate.

7. If the trail is to be constructed by a contractor, prepare a schedule of items and Form FS-6300-4, Request for Contract Action. Submit these to Administrative Services along with plans, drawings, and specifications.

3.2 - Construction

3.21 - General

Construction is the final step of the development process. The goal of construction is to construct a facility to meet the established management, economic, maintenance, and environmental objectives.

3.22 - Construction Engineering

Construction engineering consists of all staking, controlling, inspecting, and measuring of trail construction or reconstruction, including the following elements:

1. Redesigning, adjusting, and changing the drawings, specifications, and materials to meet field conditions.

2. Inspecting and monitoring operations to secure compliance with drawings and specifications.

3. Inspecting, testing, and accepting materials and equipment to be installed.

4. Inspecting, measuring, and recommending acceptance of completed work.

5. Preparing partial and final payment estimates for contracted or performed construction.

3.23 - Methods

The four primary means of accomplishing the trail construction job are by force account, contract, labor contributed from other programs, and from volunteers.

3.23a - Force Account

The use of regular Forest Service crews has been the most common means of accomplishing construction work in the past. However, with recent personnel and travel restrictions, it is becoming a less common method.

3.23b - Contract

With increasing emphasis on expansion of trail opportunities, constrained personnel ceilings, and reduction of energy consumption, contracting trail construction and maintenance activities offers a practical alternative method of accomplishing the task.

3.23c - Contributed

Sometimes it is possible for construction to be accomplished by other Forest Service work crews. For example, fire crews sometimes are available to work during periods of low fire danger. Just as with force accounts, the crews must be supervised if a quality job is to be the result.

3.23d - Volunteer, Human Resource, and Cooperative Programs

Use volunteer, human resource, and cooperative programs to extend trail construction budgets. Integrate these resources into the total trail management job. Train and supervise to ensure that the work meets established construction standards. Crews must be under the supervision of a qualified trail supervisor. Develop supervisors in volunteer organizations, human resource, and cooperative programs.

3.24 - Construction Administration

Only persons certified in trail construction contracting may administer trail construction contracts (FSH 7109.17).

Inspections and maintenance of inspection records are required for all four means of construction accomplishment.

The key to a high-quality construction job that results in low operation and maintenance costs and long-term public service are conscientious planning, preconstruction, and supervision of the contractor or crew during construction. Good supervision will ensure application of proper trail construction methods,

adherence to the appropriate trail design guides, and the cost-effective completion of the project.