Chapter II

CONTROL OPPORTUNITIES

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INTRODUCTION

This chapter lists demonstrated, effective control practices and suggests ways to choose mixtures of these and similar controls for the prevention and mitigation of resource impacts. Because economic and social analyses are not discussed in this handbook, the mixtures of controls presented in this chapter do not represent a "Best Management Practice" (BMP). These control mixtures form only the technical base for the BMP.

Control measures can be prescribed for various reasons, including: (1) protection of site productivity, (2) protection of capital investments, such as roads and buildings, and (3) protection of water quality. Many of the control practices can be used for all three reasons. For this reason, it may not be necessary to specifically formulate controls for water quality if controls imposed for site protection are adequate to meet water quality objectives.

DISCUSSION

CONTROLS TERMINOLOGY

Distinction is made between three classes of controls — procedural, preventive, and mitigative — according to the method of operation. These terms are further defined as:

Procedural controls. — Procedural controls are administrative actions or sanctions that result in reduced generation of transport of pollutants. Examples: enforcement of standards, bonding of operators.

Preventive controls. — Preventive controls apply to the pre-implementation phase of an operation. These controls are planning oriented and involve stopping or changing a planned activity before a pollution-causing disturbance is allowed to occur. Example: the location of roads and landings away from the stream.

Mitigative controls. — Mitigative controls include vegetative, chemical or physical measures which alter the response of the water-disturbing activity after it has occurred. Example: the revegetation of disturbed areas.

POTENTIAL RESOURCE IMPACTS

A resource may be damaged by impacts upon it if natural processes are altered. Potential resource impacts are defined and the related processes are discussed in the following paragraphs. These 11 impacts are considered to be those most important in terms of non-point source water pollution and silvicultural activities. They are listed alphabetically and not necessarily by order of importance.

Aerial drift and application of chemicals. — Any chemical pesticides, herbicides, or fertilizers allowed to fall or wash into a stream can affect dissolved oxygen, nutrient levels, and other characteristics of that stream.

Bare soil. — Bare soil is a result of reduction in vegetative ground cover, rock, and litter. Some bare soil is unavoidable as a result of silvicultural activities.

Bare soil can lead to reduced infiltration of water into the soil profile caused by surface crusting and the attendant soil compaction. This, in turn, can cause surface runoff and water concentration and finally lead to rill or gully erosion. In addition, some changes in the onsite chemical balance may occur as a result of increased nutrient leaching and a reduction in organic matter.

Channel gradient change. — A change in channel slope can alter energy relationships which, in turn, can cause channel scour deposition. Debris dams or improperly placed culverts in streams can cause changes in channel gradient.

Compaction. — "Soil compaction is the packing together of soil particles by instantaneous forces exerted at the soil surface resulting in an increase in soil density through a decrease in pore space. This loss of pore space reduces infiltration capacity, and water movement through the soil is slowed. Then surface runoff may occur more frequently and may increase in volume. Erosion begins; and, once begun, may be difficult to stop. In a logging operation, the extent of compaction depends on the type of equipment, the terrain over which the logs are skidded or hauled, the frequency of travel, and the type of soil and its moisture content." (Lull 1959).

Debris in channel. — Debris in the channel refers to those obstructions in a stream channel caused by silvicultural activities. Such obstructions include debris dams (logs, slash, rock, etc.), fill slope encroachment from roads, or any material deposited in the channel due to silvicultural activities.

Such obstructions can deflect flow which can erode streambanks. Debris can form dams and the attendant water impoundment can cause local flooding. In addition, during high flow, debris can float downstream, accumulate against bridges, and become a threat to bridge safety. Introduction of vegetative debris, in particular needles or leaves, can increase Biochemical Oxygen Demand (BOD) (Currier 1974, Ponce 1974). Encroachments and debris dams can alter velocity, thereby influencing exposure time to solar radiation with a resultant water temperature increase.

Excess water. — Excess water is the increase in channel flow resulting from evapotranspiration reduction due to canopy removal. Excess water can also be caused by reduced infiltration rates into bare or compacted soil. This water results in increased energy and consequent bank and channel erosion.

Onsite chemical balance changes. — Silvicultural activity can result in release of chemicals which, in turn, may leach or wash into streams, thereby affecting nutrient and Biochemical Oxygen Demand (BOD) levels in the water. For example, chemical balance changes may result from burning, excessive amounts of woody material, or crankcase oil spills.

Slope configuration changes. — Slope configuration changes refer to an alteration of the land slope. This may occur in roadbuilding when cuts and fills are constructed for the road base, contour terracing, etc. Slope configuration changes can weaken slopes, lead to mass failure, and intercept subsurface flow.

Stream shading changes. — Stream shading changes occur when trees and/or understory vegetation that contribute to the shading of water in streams are removed. Exposing streams to direct solar radiation increases water temperature.

Vegetative change. — Vegetative change includes the removal of vegetative ground cover, canopy cover, or a change in vegetative type.

Vegetative change has numerous potential effects, including changes in evapotranspiration, soil protection, soil mass movement, stream shading, and water velocity of over-the-ground flow on disturbed sites. These changes affect the hydrologic processes, surface erosion, soil mass movement, stream temperature, and ditch and stream velocity. Vegetative manipulation may also affect stream nutrients.

Water concentration. — Water concentration occurs when water is intercepted and allowed to converge instead of infiltrating into the soil or spreading naturally. Water concentration, as a resource impact, is closely related to bare soil, compaction, and excess water. Concentrated water moves with greater force than does the same amount of water in sheet flow. Concentrated flow may cause rill erosion, thus increasing the probability of gully erosion.

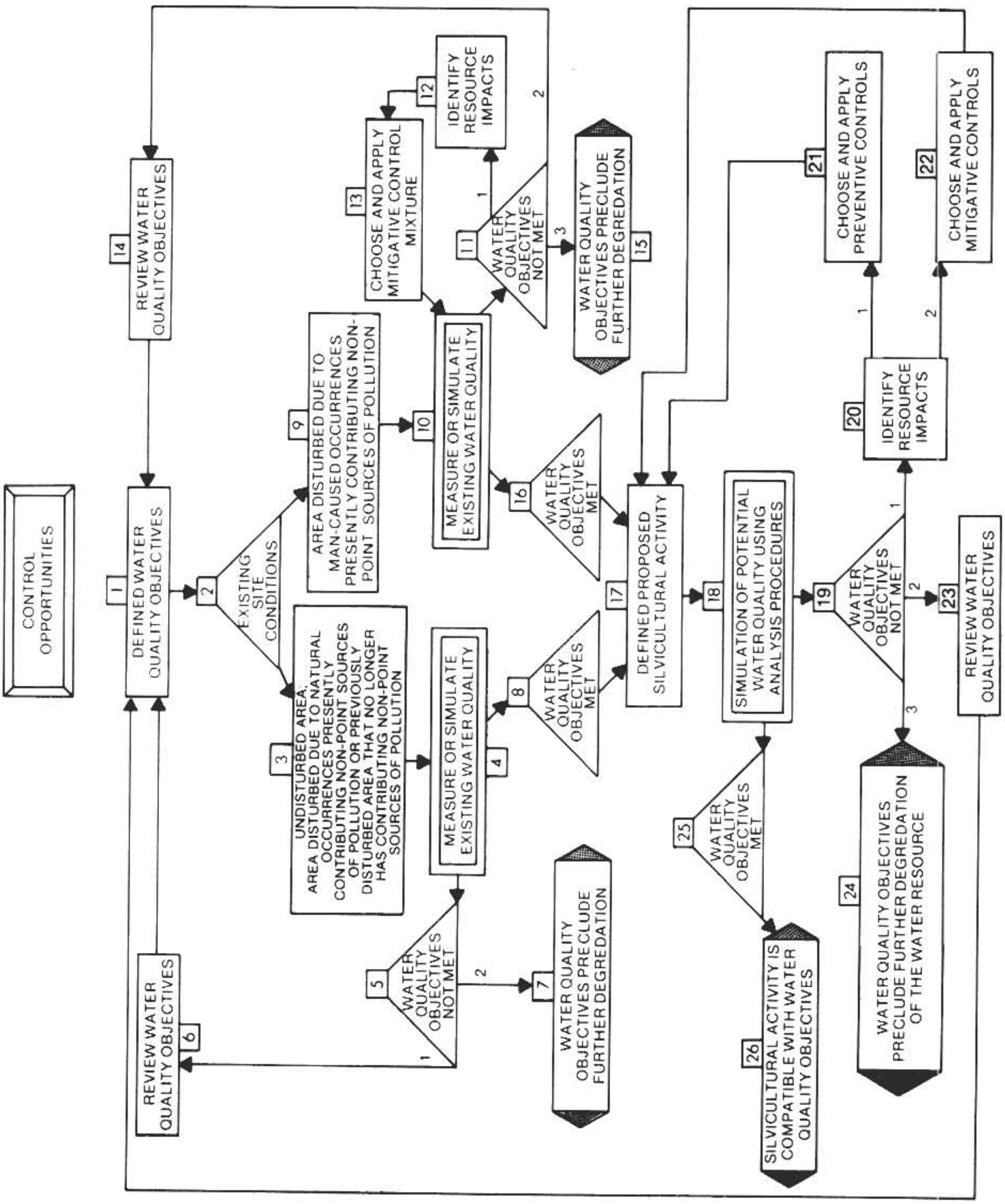

Figure II.1.—Procedural flow chart for utilizing control opportunities.

THE PROCEDURE

To meet established water quality objectives, existing water quality must be known. Then, the proposed silvicultural activity must be evaluated and the water quality that would result from it estimated. By comparing the water quality objectives with the existing and estimated water resource conditions, the degree and type of control necessary to meet the objectives can be determined.

The overall strategy for assessing and evaluating alternative control opportunities is described using a procedural flow diagram (fig. II.1), with a verbal description of the procedure. The controls procedure explains how to use the four major portions of the control information in the handbook's simulation procedure. Section A relates various silvicultural activities to the potential adverse resource impacts that may be associated with each activity. Section B suggests control opportunities for each potential resource impact. Section C indicates the relationship between resource impacts and simulation variables, and between control opportunities and the simulation variables. Section D describes all control opportunities in more detail. Appendix II.A presents three cases illustrating how to use the control information in relation to the overall use of this handbook.

PROCEDURAL DESCRIPTION

The following paragraphs describe the procedural flow chart in more detail. The indicated numbers do not represent sequential steps, but act as points of reference back to the flow chart, figure II.1.

DEFINED WATER
QUALITY OBJECTIVES
1

Prior to any evaluation of the potential change in the water resource due to a proposed silvicultural activity, water quality objectives must be specified. These objectives are generally established by legislative or regulatory authority. To ascertain if a potential change caused by a proposed silvicultural activity is acceptable, the change must be compared with water quality objectives.

EXISTING
SITE
CONDITIONS
2

At this point, a decision must be made as to whether any disturbance in a watershed is natural or man-caused.

The existing condition of the water resource before any proposed silvicultural activity takes place must be determined through the use of aerial photos, historical records, or on-the-ground observations.

UNDISTURBED AREA,
AREA DISTURBED BY
NATURAL OCCURRENCES
PRESENTLY CONTRIBUTING NON-POINT
SOURCES OF POLLUTION, OR
PREVIOUSLY DISTURBED AREA
THAT NO LONGER HAS CONTRIBUTING
NON-POINT SOURCES OF POLLUTION
3

The water resource condition in areas that have never been subjected to man-induced disturbances and in areas that have at one time been disturbed but have recovered sufficiently and no longer have contributing non-point sources of pollution is determined by the existing vegetation, soil, and geology. This represents the natural base condition of the water resource.

MEASURE OR SIMULATE
EXISTING WATER QUALITY
4

Existing water quality should be measured using a sampling scheme that enables the water quality parameters of interest to be evaluated. If measured data are not available and cannot be feasibly collected, the existing condition can be estimated using analysis procedures presented in subsequent chapters or locally derived methods.

WATER QUALITY OBJECTIVES NOT MET
5

The existing water quality is compared with the water quality objectives. If the existing condition exceeds the objectives, further evaluation is required.

REVIEW WATER QUALITY OBJECTIVES
6

First of two possible actions.

If the existing condition of the water resource does not meet the objectives, the objectives should be reviewed and possibly revised by the appropriate authority.

WATER QUALITY OBJECTIVES PRECLUDE FURTHER DEGRADATION
7

Second action.

Because the objectives are presently exceeded by the existing water resource condition, no silvicultural activity should be considered that would result in any further degradation. Alternative land use management of the watershed may be necessary.

WATER QUALITY OBJECTIVES MET
8

If the existing water resource condition meets water quality objectives, a proposed silvicultural activity plan can be formulated.

AREA DISTURBED BY MAN-CAUSED OCCURRENCES PRESENTLY CONTRIBUTING NON-POINT SOURCES OF POLLUTION
9

The water quality in areas that have been subjected to man-induced disturbances may be determined in great part by the non-point source pollution coming from the disturbed sites. It is, therefore, necessary to evaluate the impact of these contributing non-point sources to ascertain whether the existing water quality objective is being met.

MEASURE OR SIMULATE EXISTING WATER QUALITY
10

Existing water quality should be measured using a sampling scheme that enables the water quality parameters of interest to be evaluated. If measured data are not available and cannot be feasibly collected, the existing condition of the water resource can be estimated by using analysis procedures presented in subsequent chapters or locally derived methods.

WATER QUALITY OBJECTIVES NOT MET 11

The existing water quality is compared with the given water quality objectives. If the existing quality exceeds the objective, further evaluation is required.

IDENTIFY RESOURCE IMPACTS 12

First of three possible actions.

If a previous disturbance is impacting water quality so that objectives are not met, the simulation or measurement will show where the pollution is originating, how much pollution is present, and what kind of pollution is being produced. Using this information, determine which variables within the simulation procedure are causing the pollution. Then refer to section C, table II.2 of this chapter and relate the involved variables to the corresponding resource impacts. (To relate resource impacts to the involved processes, refer to the definitions of the resource impacts in the "Discussion" section of this chapter.)

For an example illustrating this use of the controls procedure, refer to example one in appendix II.A.

CHOOSE AND APPLY MITIGATIVE CONTROL MIXTURE 13

Using the list of affected variables involved, refer to section B or section C (tables II.3 to II.14) in order to choose controls potentially able to mitigate the impact. The controls procedure is used to prescribe mitigative controls for a previously disturbed site so the proposed silvicultural activity may be accomplished without exceeding the water quality objectives. This procedure should be run several times, thereby arriving at several choices for the manager. For an example illustrating this use of the controls procedure, refer to example one in appendix II.A.

REVIEW WATER QUALITY OBJECTIVES 14

Second of three possible actions.

If existing water quality does not meet the objectives after all feasible mitigative controls have been selected, these objectives should be reviewed and possibly changed by the appropriate authority.

WATER QUALITY OBJECTIVES PRECLUDE FURTHER DEGRADATION 15

Third of three possible actions.

Because the water resource goals or standards are presently being exceeded and the application of mitigative controls cannot correct the problem and objective revision is unacceptable, no silvicultural activity should be considered that would result in any further degradation of the water resource. Alternative land use management of the watershed may be necessary.

WATER QUALITY OBJECTIVES MET 16

If the existing water quality meets the objectives, a silvicultural activity plan can be formulated.

DEFINE PROPOSED SILVICULTURAL ACTIVITY 17

Define the silvicultural activity and, depending upon the size and complexity of the activity, such things as a cutting plan, logging plan, transportation plan, fuel management plan, and site preparation may be included in the operational plan.

The control procedure can be used as a reference in the formulation of the initial silvicultural plan. Refer to table II.1 for a list of silvicultural activities and related potential resource impacts. For an example illustrating this use of the controls procedure, refer to example two in appendix II.A.

Preventing pollution is vastly more effective than mitigating problems after they are created. Proper planning and a thorough analysis of the available options will allow the manager to choose the alternatives which best fit the management objectives, while minimizing non-point source pollution potentials and the need for mitigative control.

SIMULATION OF POTENTIAL WATER QUALITY USING ANALYSIS PROCEDURES
18

The potential condition of the water resource, assuming implementation of the proposed silvicultural operation, may be simulated using analysis procedures. Such analysis estimates the potential impacts of the silvicultural operation upon the water resource.

The control procedure can be used in the process of determining what variables are affected by what controls in the simulation process.

WATER QUALITY OBJECTIVES NOT MET
19

The potential water quality following the proposed silvicultural activity is compared with the given water quality objectives. If these objectives are exceeded, the proposed silvicultural activity should be reconsidered.

IDENTIFY RESOURCE IMPACTS
20

First of three possible actions.

If the proposed silvicultural plan is impacting water quality so that objectives are not met, the simulation will show where the pollution is originating, how much pollution is present, and what kind of pollution is being produced. Using this information, determine which variables within the simulation procedure are causing the pollution. Then refer to section C, table II.2 and relate the involved variables to the corresponding resource impacts. (To relate resource impacts to the involved processes, refer to the definitions of the resource impacts in the "Discussion" section of this chapter.)

For an example illustrating this use of the controls procedure, see example three, appendix II.A.

CHOOSE AND APPLY PREVENTIVE CONTROLS
21

The controls procedure can be used to add new control opportunities to the silvicultural plan if the plan has been shown through simulation to fall short of the objective. Refer to section C (tables II.3 to II.14) and relate the affected variables to potential preventive controls. Preventive controls are preferable over mitigative controls, thus the procedure indicates further simulation with preventive controls before trying mitigative controls.

For an example illustrating this use of the controls procedure, see example three in appendix II.A.

CHOOSE AND APPLY MITIGATIVE CONTROLS
22

If, after incorporating all feasible preventive controls, the water quality objectives are still exceeded, mitigative controls should be evaluated.

For an example illustrating this use of the controls procedure, refer to example three, appendix II.A.

REVIEW WATER QUALITY OBJECTIVES 23

Second of three possible actions.

If, after all feasible preventive and mitigative controls have been applied, the potential water quality resulting from the proposed silvicultural operation exceeds the water quality obejctives, these objectives should be reviewed and possibly changed by the appropriate authority.

WATER QUALITY OBJECTIVES PRECLUDE FURTHER DEGRADATION OF THE WATER RESOURCE 24

Third of three possible actions.

Because the potential water quality resulting from the implementation of the proposed silvicultural activity might exceed the water resource objectives even after all feasible preventive and mitigative controls have been applied, no silvicultural activity should be considered for the area at present. Alternative land use management of the watershed may be necessary.

WATER QUALITY OBJECTIVES MET 25

The existing water quality is compared with the given water quality objectives. If the existing quality exceeds these objectives, further evaluation is required.

SILVICULTURAL ACTIVITY IS COMPATIBLE WITH WATER QUALITY OBJECTIVES 26

The proposed silvicultural activity is compatible with the water quality objectives and may be implemented insofar as the water resource is concerned.

SECTION A: SILVICULTURAL ACTIVITIES AND POTENTIAL RESOURCE IMPACTS

This section provides a simple table with silvicultural activities listed in one column and the potentially adverse resource impacts resulting from each silvicultural activity listed in the second column (table II.1.). The list of potential impacts associated with particular silvicultural activities is suggested for initial consideration but may need to be revised according to local conditions.

Silvicultural activities listed are:

1. Methods of cutting
2. Felling
3. Yarding methods
4. Road and access system
5. Fuel management methods
6. Site preparation
7. Other activities

Adverse resource impacts include:

1. Aerial drift and application of chemicals
2. Bare soil
3. Channel gradient changes
4. Compaction
5. Debris in channel
6. Excess water
7. Onsite chemical balance changes
8. Slope configuration changes
9. Streamside shading changes
10. Vegetative change
11. Water concentration

Table II.1 can be used in two ways —

1. In the formulation of the silvicultural activity plan.
2. In the process of determining what variables are affected by what controls when running the handbook simulations.

Table II.1.—Silvicultural and related activities and associated potential adverse resource impacts

Activities	Potential adverse resource impacts
Methods of cutting:	
Clearcutting Seed tree cutting Selection cutting Shelterwood cutting	Excess water Streamside shading changes Vegetative change
Felling	Debris in channel Vegetative change
Yarding methods:	
Hand pulpwooding	Compaction
Animal skidding Tractor skidding	Bare soil Compaction Water concentration
Cable yarding—high lead	Bare soil Water concentration
Cable yarding—skyline	Bare soil Slope configuration changes
Cable yarding—balloon	Bare soil
Aerial skidding	Onsite chemical balance changes
Mechanized logging (feller, buncher, etc.)	Bare soil Compaction Water concentration

Table II.1—continued

Activities	Potential adverse resource impacts
Road and access system:	
Construction and maintenance	Aerial drift and application of chemicals (dust) Bare soil Channel gradient changes Compaction Debris in channel Slope configuration changes Vegetative change
Fuel management methods:	
Burying slash	Bare soil Compaction Slope configuration changes
Firelines and fuel breaks	Bare soil Compaction Slope configuration changes Water concentration
Broadcast burning Hand piling and burning Machine piling and burning Prescribed underburning Jackpot or spot burning	Aerial drift and application of chemicals (ash) Bare soil Compaction Debris in channel Excess water Onsite chemical balance changes Vegetative change Water concentration
Yarding unmerchantable material	Bare soil Compaction Debris in channel
Lop and scatter	Debris in channel
Rolling chopper	Compaction Onsite chemical balance changes Vegetative change
Chip and spread Masticate	Compaction Debris in channel Onsite chemical balance changes
Site preparation:	
Dozer stripping	Bare soil Compaction Excess water Slope configuration changes Vegetative change Water concentration
Terracing	Bare soil Compaction Excess water Slope configuration changes

Table II.1.—Continued

Activities	Potential adverse resource impacts
Machine scalping	Bare soil Compaction
Bedding	Bare soil Water concentration
Plowing Disking	Bare soil Debris in channel Slope configuration changes Vegetative change Water concentration
Drags	Bare soil Compaction Vegetative change Water concentration
Drainage	Bare soil Water concentration
Chemical treatment	Aerial drift and application of chemicals Debris in channel Vegetative change
Other Activities:	
Mechanized planting	Compaction Water concentration
Release from plant competition— Fire	See broadcast burning
Chemical	Aerial drift and application of chemicals
Mechanical	Compaction Water concentration
Thinning and cleaning—	
Hand	Debris in channel Vegetative change
Mechanized	Compaction Debris in channel Vegetative change
Fertilization Seeding with treated seeds	Aerial drift and application of chemicals Onsite chemical balance changes Vegetative change

SECTION B: POTENTIAL RESOURCE IMPACTS AND CONTROL OPPORTUNITIES

This section provides a list of potential adverse resource impacts in alphabetical order followed by a list of suggested controls that may alleviate each particular impact. Control opportunities applicable to all listed resource impacts are presented first. For a description of each control measure, refer to "Section D: Control Opportunity Descriptions" in this chapter.

This section can be used in three ways.

1. In the prescription of mitigative controls for a previously disturbed site. (See example one, appendix II.A).
2. In the formulation of the silvicultural activity plan. (See example two, appendix II.A.).
3. In the prescription of a mixture of preventive and mitigative controls for the alteration of the silvicultural activity plan so it will meet established goals. (See example three, appendix II.A).

Control Opportunities For All Listed Resource Impacts

Conformance to regulations (Procedural)

Enforcement of standards and bonding of operators (Procedural)

Limit disturbed area (Procedural)

Monitoring (Procedural)

Road drainage maintenance during storms (Procedural)

Select low impact equipment (Preventive)

Specify timing (Procedural)

Timely drainage maintenance (Preventive)

Control Opportunities For Aerial Drift And Application Of Chemicals

Chemical application (Preventive)

Control ash or dust buildup (Preventive/mitigative)

Keep pesticides and rodenticides well away from surface runoff (Preventive)

Revegetate treatment areas promptly as local conditions dictate (Mitigative)

Timing of chemical applications (Preventive)

Waterside area (Preventive)

Control Opportunities For Bare Soil

Administrative closure of roads (Procedural/preventive/mitigative)

Appropriate cross-section in roads (Preventive)

Armoring (Preventive/mitigative)

Avoid roading steep slopes (Preventive)

Brush barrier filter at the toe of fill (Preventive/mitigative)

Close roads after use (Procedural/mitigative)

Cut-and-fill slope configuration (Mitigative)

Directional felling (Preventive)

Drainage above cut slope (Preventive/mitigative)

Endline or fly material from waterside areas (Preventive/mitigative)

Fill slope design and locations (Procedural/preventive)

Hold water onsite (Preventive/mitigative)

Identify soil and geologic characteristics and map sensitive areas (Procedural/preventive)

Leave vegetation between strips (Preventive)

Limit equipment operation (Preventive)

Machine or hand plant (Preventive)

Prescribe and execute burns under conditions that will not result in total cleanup (Preventive)

Prescribe limits for the amount of area disturbed by equipment (Preventive)

Prescribe yarding and skidding layout (Preventive)

Prevent fire spread outside treatment areas (Preventive)

Protect road bare surface areas with nonliving material (Mitigative)

Reduce log length (Preventive)

Reduce logging road density (Preventive)

Revegetate treated areas promptly as local conditions dictate (Mitigative)

Slope length (Preventive)

Species selection (Preventive)

Stabilizing structures or cut slopes (Mitigative)

Type of site preparation treatment (Preventive)

Use maximum spacing and minimum strip width in site preparation (Preventive)

Waterside area (Preventive)

Windbreaks or uncut timber to prevent wind erosion (Preventive)

Control Opportunities For Channel Gradient Changes

Armoring (Preventive/mitigative)

Bridges (Preventive)

Ditch checks (Mitigative)

Ditch maintenance (Procedural/mitigative)

Maintain natural water courses (Preventive)

Oversize ditch drain (Preventive)

Reduction of impounded water (Mitigative)

Repair and stabilize damaged areas (Mitigative)

Space culverts to control velocity (Preventive)

Control Opportunities For Compaction

Administrative closure of roads (Procedural/preventive/mitigative)

Close roads after use (Procedural/mitigative)

Directional felling (Preventive)

Endline or fly material from waterside areas (Preventive/mitigative)

Identify soil and geologic characteristics and map sensitive areas (Procedural/preventive)

Leave vegetation between strips (Preventive)

Limit equipment operation (Preventive)

Machine or hand plant (Preventive)

Prescribe limits for the amount of area disturbed by equipment (Preventive)

Prescribe yarding and skidding layout (Preventive)

Reduce logging road density (Preventive)

Reduce vehicle travel (Preventive)

Revegetate treated areas promptly as local conditions dictate (Mitigative)

Rip or scarify compacted surfaces (Mitigative)

Road and landing location (Preventive)

Species selection (Preventive)

Timing of use of off-road, heavy equipment (Preventive)

Type of site preparation treatment (Preventive)

Control Opportunities For Debris In Channel

Bench cut and compact fill (Preventive/mitigative)

Bridges (Preventive)

Brush barrier filter at the toe of fill (Preventive/mitigative)

Directional felling (Preventive)

Eliminate source of debris (Mitigative)

Endline or fly material from waterside areas (Preventive/mitigative)

Fill slope design and location (Procedural/mitigative)

Full bench section (Preventive)

Haul woody material offsite (Mitigative)

Limit equipment operation (Preventive)

Locate activities producing small, woody fragment away from water (Preventive)

Locate corrals away from streams (Animal skidding) (Preventive)

Maintain ground cover (Preventive)

Protect road bare surface areas with nonliving material (Mitigative)

Remove debris from stream (Mitigative)

Repair and stabilize damaged areas (Mitigative)

Revegetate treated areas promptly as local conditions dictate (Mitigative)

Road and landing location (Preventive)

Waterside area (Preventive)

Woody debris disposal sites (Preventive)

Control Opportunities For Excess Water

Cutting block design (Preventive)

Identify soil and geologic characteristics and map sensitive areas (Procedural/preventive)

Machine or hand plant (Preventive)

Maintain ground cover (Preventive)

Outslope firebreak lines and terraces (Preventive)

Prescribe and execute burns under conditions that will not result in total cleanup (Preventive)

Revegetate treated areas promptly as local conditions dictate (Mitigative)

Species selection (Preventive)

Type of site preparation treatment (Preventive)

Use maximum spacing and minimum strip width in site preparation (Preventive)

Waterside area (Preventive)

Control Opportunities For Onsite Chemical Balance Changes

Chemical application (Preventive)

Control ash or dust buildup (Preventive/mitigative)

Haul woody material offsite (Mitigative)

Identify soil and geologic characteristics and map sensitive areas (Procedural/preventive)

Keep pesticides and rodenticides well away from surface runoff (Preventive)

Locate corrals away from streams (Animal skidding) (Preventive)

Machine or hand plant (Preventive)

Pile material in patterns (Preventive)

Protect fuel storage areas (Preventive)

Revegetate treated areas promptly as local conditions dictate (Mitigative)

Species selection (Preventive)

Type of site preparation treatment (Preventive)

Woody debris disposal sites (Preventive)

Control Opportunities For Slope Configuration Changes

Appropriate cross-section for roads (Preventive)

Avoid roading of steep slopes (Preventive)

Bench cut and compact fill (Preventive/mitigative)

Break gradient of firelines (Preventive/mitigative)

Divert water onto stable areas (Preventive)

Drainage above cut slope (Preventive/mitigative)

Full bench section (Preventive)

Identify soil and geologic characteristics and map sensitive areas (Procedural/preventive)

Limit equipment operation (Preventive)

Machine or hand plant (Preventive)

Maintain ground cover (Preventive)

Prescribe yarding and skidding layout (Preventive)

Reduce logging road density (Preventive)

Reduction of impounded water (Mitigative)

Revegetate treated areas promptly as local conditions dictate (Mitigative)

Road and landing location (Preventive)

Species selection (Preventive)

Stabilizing structures on cut slopes (Mitigative)

Type site preparation treatment (Preventive)

Control Opportunities For Streamside Shading Changes

Cutting block design (Preventive)

Directional felling (Preventive)

Revegetate treated areas promptly as local conditions dictate (Mitigative)

Waterside area (Preventive)

Control Opportunities For Vegetative Change

Cutting block design (Preventive)

Directional felling (Preventive)

Leave vegetation between strips (Preventive)

Machine or hand plant (Preventive)

Maintain ground cover (Preventive)

Prescribe limits for the amount of area disturbed by equipment (Preventive)

Revegetate treated areas promptly as local conditions dictate (Mitigative)

Species selection (Preventive)

Timing of chemical application (Preventive)

Type of site preparation treatment (Preventive)

Control Opportunities For Water Concentration

Administrative closure of roads (Procedural/preventive/mitigative)

Armoring (Preventive/mitigative)

Avoid roading of steep slopes (Preventive)

Break gradient of firelines (Preventive/mitigative)

Close roads after use (Procedural/mitigative)

Curbs and berms (Preventive/mitigative)

Cut-and-fill slope configuration (Mitigative)

Cutting block design (Preventive)

Ditch checks (Mitigative)

Ditch maintenance (Procedural/mitigative)

Divert water onto stable areas (Preventive)

Drainage above cut slopes (Preventive/mitigative)

Hold water onsite (Preventive/mitigative)

Identify soil and geologic characteristics and map sensitive areas (Procedural/preventive)

Leave vegetation between strips (Preventive)

Limit equipment operation (Preventive)

Machine or hand plant (Preventive)

Maintain natural water courses (Preventive)

Minimize convergence of firelines (Preventive)

Outslope firebreak lines and terraces (Preventive)

Oversize ditch drain (Preventive)

Pile material in patterns (Preventive)

Prescribe limits for the amount of area disturbed by equipment (Preventive)

Prescribe yarding and skidding layout (Preventive)

Reduce road grades (Preventive)

Reduce vehicle travel (Preventive)

Reduction of impounded water (Mitigative)

Remove debris from stream (Mitigative)

Repair and stabilize damaged areas (Mitigative)

Revegetate treated areas promptly as local conditions dictate (Mitigative)

Rip or scarify compacted surfaces (Mitigative)

Road and landing location (Preventive)

Road ditch (Preventive/mitigative)

Sediment trap (Mitigative)

Slope length (Preventive)

Space culverts to control road ditch erosion (Preventive)

Species selection (Preventive)

Timing of use of off-road, heavy equipment (Preventive)

Trash racks (Preventive)

Type of site preparation treatment (Preventive)

Use maximum spacing and minimum strip width in site preparation (Preventive)

Waterside area (Preventive)

SECTION C: CONTROL OPPORTUNITIES AND SIMULATION VARIABLES

The matrices (tables II.2 to II.14) in this section are the cross-reference system between the "control opportunities" and the handbook simulation procedure (chapters III through XI).

This section lists all variables used in the handbook simulation procedure along the horizontal axis of the matrices. Some of these variables change only with a change in location or area, for example, the R or rainfall factor in the Modified Soil Loss Equation. Other variables are measured values like bedload sediment in the total sediment procedure. The remaining variables (the ones of concern in this chapter) can be affected, either positively or negatively, by certain controls.

All controls, therefore, are listed along the vertical axis of the matrices (tables II.3 to II.14). The controls are listed under each resource impact they are associated with. The "X" symbols on the tables indicate which controls affect which variables. These "X's" are placed with reference to the way the variable is being used in the simulation procedures. For example, the variable "Type and location of the cut" has a specific definition. The use of this variable is to identify the hydrologic processes (i.e., evapotransporation and snowpack changes) as they affect streamflow and not the related effects on silvicultural activity such as site preparation.

The names of the controls and the "X's" on the tables are designed to represent most major relationships and, therefore, some specific controls and their relationships to variables may not be covered.

Table II.2 is a summary showing which simulation variables are affected by which resource impacts. The other 12 tables show which simulation variables are affected by which controls. Table II.3 shows control opportunities for all resource impacts. These controls should be considered in any silvicultural activity plan.

NOTE: In the process of selecting a mixture of controls to mitigate or prevent a specific resource impact, the effects of the selected controls on other areas of concern must be realized. For example, if, through simulation, a problem is noted with surface erosion related to road surfaces, the control lists under "Bare Soil," "Compaction," and "Water Concentration" would be referred to. A control frequently used to prevent water flow across road surfaces is "Drainage Above Cut Slope." But, in addition to preventing surface flow, it also affects slope configuration which indicates that drainage ditches above the cut slope could cause soil mass movement problems.

Table II.2—Potential resource impacts and the variables within the simulation procedure affected by those impacts

Resource impacts	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Aerial drift and application of chemicals												x	x																		
Bare soil				x								x	x		x							x					x				
Channel gradient change																					x										
Compaction											x	x			x																
Debris in channel																				x	x										
Excess water				x											x					x											
Onsite chemical balance changes																															
Slope configuration change										x						x			x		x			x	x	x					
Stream shading change																											x				
Vegetative change	x			x								x	x		x												x				
Water concentration				x											x					x											

[1]Measured value.
[2]Changes only with location.
[3]See "Surface Erosion," chapter IV
[4]See "Hydrology," chapter III
[5]See "Soil Mass Movement," chapter V
[6]Can be taken from chapter III or measured directly.
[7]Calculated value.

Table II.2—continued

Resource impacts	Chapter references to the simulation procedure and affected variables																					
	Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic-slope[1]	No specific variables, consider effects upon each total subject		
Aerial drift and application of chemicals																				x	x	x
Bare soil																						
Channel gradient change		x										x										
Compaction																						
Debris in channel	x	x										x								x	x	x
Excess water			x																			
Onsite chemical balance changes																				x	x	x
Slope configuration change																						
Stream shading change											x	x										
Vegetative change											x	x										
Water concentration			x																			

Table II.3—Control opportunities for all resource impacts and the variables within the simulation procedure affected by those controls

Control opportunities for all resource impacts	**Chapter references to the simulation procedure and affected variables**																														
	Hydrology variables (ch. III)								**Surface erosion variables (ch. IV)**											**Ditch erosion (ch. IV) (app. IV-C)**			**Soil mass movement variables (ch. V)**								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landsides[1]
Conformance to regulations	x	x	x	x						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Enforcement of standards and bonding of operators	x	x	x	x						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Limit disturbed area	x	x	x	x						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Monitoring	x	x	x	x						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Road drainage maintenance during storms											x	x	x	x	x		x			x	x	x		x	x		x				
Select low impact equipment		x	x	x						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Specify timing	x	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Timely drainage maintenance				x											x					x	x	x									

[1]Measured value.
[2]Changes only with location.
[3]See "Surface Erosion," chapter IV
[4]See "Hydrology," chapter III
[5]See "Soil Mass Movement," chapter V
[6]Can be taken from chapter III or measured directly.
[7]Calculated value.

Table II.3—continued

Control opportunities for all resource impacts	Chapter references to the simulation procedure and affected variables																					
	Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Conformance to regulations	x	x									x	x								x	x	x
Enforcement of standards and bonding of operators	x	x									x	x								x	x	x
Limit disturbed area	x	x									x	x								x	x	x
Monitoring	x	x									x	x								x	x	x
Road drainage maintenance during storms																				x	x	x
Select low impact equipment	x	x									x	x								x	x	x
Specify timing	x	x									x	x									x	x
Timely drainage mantenance	x	x									x	x								x	x	x

Table II.4—Control opportunities for aerial drift and application of chemicals and the variables within the simulation procedure affected by those controls

Control opportunities for aerial drift and application of chemicals	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage charactistics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Chemical application												x	x		x												x				
Control ash or dust buildup																															
Keep pesticides and rodenticides away from surface runoff																															
Revegetate treatment areas promptly												x	x									x					x				
Timing of chemical application												x	x		x												x				
Waterside area				x						x	x	x	x		x		x	x									x				

[1]Measured value.
[2]Changes only with location.
[3]See "Surface Erosion," chapter IV
[4]See "Hydrology," chapter III
[5]See "Soil Mass Movement," chapter V
[6]Can be taken from chapter III or measured directly.
[7]Calculated value.

Table II.4—continued

Control opportunities for aerial drift and application of chemicals	Chapter references to the simulation procedure and affected variables: Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Chemical application											x									x	x	x
Control ash or dust buildup																					x	x
Keep pesticides and rodenticides away from surface runoff																				x	x	x
Revegetate treatment areas promptly											x											
Timing of chemical application																				x	x	x
Waterside area											x	x								x	x	x

Table II.5—Control opportunities for bare soil and the variables within the simulation procedure affected by those controls

Chapter references to the simulation procedure and affected variables

Control opportunities for bare soil	Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Administrative closure of roads											x	x	x																		
Appropriate cross-section for roads			x							x						x		x	x	x				x	x	x					
Armoring												x	x									x									
Avoid roading steep slopes			x							x						x		x	x					x	x	x					
Brush barrier filter at the toe of fill																		x													
Close roads after use											x	x	x														x				
Cut and fill slope configuration			x							x						x		x	x	x					x	x					
Directional felling											x	x	x														x				
Drainage above cut slope			x	x						x					x			x		x	x	x			x	x					
Endline of fly material from waterside area to upslope landing											x	x	x														x				
Fill slope design and location										x	x	x				x		x	x	x				x	x	x					
Hold water onsite				x						x		x			x			x							x						
Identify soil and geologic characteristics and map sensitive areas											x			x									x							x	x
Leave vegetation between site preparation strips				x						x		x	x		x			x									x				
Limit equipment operation											x	x	x				x			x	x										
Machine or hand plant											x	x	x														x				

[1]Measured value.
[2]Changes only with location.
[3]See "Surface Erosion," chapter IV
[4]See "Hydrology," chapter III

Table II.5— continued

Control opportunities for bare soil	Chapter references to the simulation procedure and affected variables: Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Administrative closure of roads																						
Appropriate cross-section for roads																						
Armoring																						
Avoid roading steep slopes																						
Brush barrier filter at the toe of fill																				x	x	x
Close roads after use																						
Cut and fill slope configuration																						
Directional felling	x	x									x									x	x	x
Drainage above cut slope																						
Endline of fly material from waterside area to upslope landing											x									x	x	x
Fill slope design and location	x																			x	x	x
Hold water onsite																						
Identify soil and geologic characteristics and map sensitive areas																						
Leave vegetation between site preparation strips																						
Limit equipment operation	x	x																		x	x	x
Machine or hand plant																				x	x	x

[5]See "Soil Mass Movement," chapter V

[6]Can be taken from chapter III or measured directly.

[7]Calculated value.

Table II.5—continued

Control opportunities for bare soil	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Prescribe and execute burns under conditions that will not result in total cleanup												x	x														x				
Prescribe limits for the amount of area disturbed by equipment										x	x	x	x											x	x	x	x				
Prescribe yarding and skidding layout										x	x	x	x		x	x		x	x								x				
Prevent fire spread outside treatment areas												x	x														x				
Protect bare surface areas with non-living material												x	x									x									
Reduce log length										x	x	x						x													
Reduce logging road density			x							x	x	x	x			x		x	x					x	x	x					
Revegetate treated areas promptly as local conditions dictate				x								x	x									x					x				
Slope length										x								x						x							
Species selection										x	x	x	x		x												x				
Stabilizing structures or cut slopes												x	x														x				
Type of site preparation treatment										x	x	x	x		x	x	x	x	x						x	x	x				
Use maximum spacing and minimum strip width in site preparation				x						x		x				x	x	x	x						x		x				
Waterside area				x						x	x	x	x		x		x	x									x				
Wind breaks or uncut timber to prevent wind erosion																															

Table II.5— continued

Control opportunities for bare soil	Chapter references to the simulation procedure and affected variables: Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Prescribe and execute burns under conditions that will not result in total cleanup																						
Prescribe limits for the amount of area disturbed by equipment																						
Prescribe yarding and skidding layout																						
Prevent fire spread outside treatment areas																						
Protect bare surface areas with non-living material																						
Reduce log length																						
Reduce logging road density																						
Revegetate treated areas promptly as local conditions dictate											x									x	x	x
Slope length																						
Species selection											x											
Stabilizing structures or cut slopes																						
Type of site preparation treatment																				x	x	x
Use maximum spacing and minimum strip width in site preparation																						
Waterside area											x	x								x	x	x
Wind breaks or uncut timber to prevent wind erosion																				x	x	x

Table II.6—Control opportunities for channel gradient changes and the variables within the simulation procedure affected by those controls

Control opportunities for channel gradient changes	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Armoring												x	x									x									
Bridges																		x		x	x										
Ditch checks																					x	x									
Ditch maintenance																				x	x	x									
Maintain natural water courses																															
Oversize ditch drain																				x											
Reduction of impounded water				x											x					x					x						
Repair and stabilize damaged areas																				x	x	x									
Space culverts to control velocity																				x	x										

[1]Measured value.
[2]Changes only with location.
[3]See "Surface Erosion," chapter IV
[4]See "Hydrology," chapter III
[5]See "Soil Mass Movement," chapter V
[6]*Can be taken from chapter III or measured directly.*
[7]Calculated value.

Table II.6— continued

Control opportunities for channel gradient changes	Chapter references to the simulation procedure and affected variables: Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[6]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[8]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Armoring	x																					
Bridges	x	x																		x	x	x
Ditch checks		x																				
Ditch maintenance																						
Maintain natural water courses	x	x																				
Oversize ditch drain																						
Reduction or impounded water																						
Repair and stabilize damaged areas	x	x																				
Space culverts to control velocity	x	x																				

Table II.7—Control opportunities for compaction and the variables within the simulation procedure affected by those controls

Control opportunities for compaction	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Administrative closure of roads											x	x	x																		
Close roads after use											x	x	x																		
Directional felling											x	x	x														x				
Endline or fly material from water-side areas to upslope landings											x	x	x														x				
Identify soil and geology character-istics and map sensitive areas											x			x									x							x	x
Leave vegetation between site-preparation strips				x						x		x	x		x			x									x				
Limit equipment operation											x	x	x				x			x	x										
Machine or hand plant											x	x	x														x				
Prescribe limits for the amount of area disturbed by equipment										x	x	x	x				x							x	x	x	x				
Prescribe yarding and skidding layout										x	x	x	x		x	x		x	x								x				
Reduce logging road density				x						x	x	x	x			x		x	x					x	x	x					

[1]Measured value.
[2]Changes only with location.
[3]See "Surface Erosion," chapter IV
[4]See "Hydrology," chapter III
[5]See "Soil Mass Movement," chapter V
[6]Can be taken from chapter III or measured directly.
[7]Calculated value.

Table II.7— continued

Control opportunities for compaction	Chapter references to the simulation procedure and affected variables: Total sediment variables (ch. VI): Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[1]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[6]	Median size material-mass movement[6]	Stream temperature variables (ch. VII): Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	Dissolved oxygen & organic matter (ch. IX): No specific variables consider effects upon each total subject	Nutrients (ch. X)	Introduced chemicals (ch. XI)
Administrative closure of roads																						
Close roads after use																						
Directional felling	x	x									x									x	x	x
Endline or fly material from waterside areas to upslope landings											x									x	x	x
Identify soil and geology characteristics and map sensitive areas																						
Leave vegetation between site-preparation strips																						
Limit equipment operation	x	x																		x	x	x
Machine or hand plant											x									x	x	x
Prescribe limits for the amount of area disturbed by equipment																						
Prescribe yarding and skidding layout																						
Reduce logging road density																						

Table II.7—continued

Control opportunities for compaction	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Reduce vehicle travel											x	x	x														x				
Revegetate treated areas promptly as local conditions dictate				x								x	x									x					x				
Rip or scarify compacted areas											x	x	x		x		x								x						
Road and landing location				x						x	x				x	x		x	x	x	x	x		x	x	x	x				
Species selection										x	x	x	x		x												x				
Timing of use of off-road heavy equipment											x					x	x														
Type of site preparation treatment										x	x	x	x		x	x	x	x	x						x	x	x				

Table II.7— continued

Control opportunities for compaction	Chapter references to the simulation procedure and affected variables																				
	Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[6]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Reduce vehicle travel																						
Revegetate treated areas promptly as local conditions dictate											x									x	x	x
Rip or scarify compacted areas																						
Road and landing location	x	x																		x	x	x
Species selection											x											
Timing of use of off-road heavy equipment																						
Type of site preparation treatment																				x	x	x

Table II.8—Control opportunities for debris in channel and the variables within the simulation procedure affected by those controls

Control opportunities for debris in channel	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Bench cut and compact fill			x							x	x					x		x	x	x	x	x		x	x	x	x				
Bridges																		x		x	x										
Brush barrier filter at toe of slope										x																					
Directional felling											x	x	x														x				
Eliminate source of debris											x																				
Endline or fly material from waterside areas to upslope landings											x	x	x														x				
Fill slope design and location										x	x	x				x		x	x	x				x	x	x					
Full bench section			x							x	x	x				x		x	x					x	x	x	x				
Haul woody material offsite											x	x	x							x	x										
Limit equipment operation											x	x	x				x			x	x										
Locate activities producing small woody fragments away from water											x		x							x	x										
Maintain ground cover				x							x	x	x				x										x				
Protect road bare surface area with nonliving material												x	x																		
Remove debris from stream																															

[1]Measured value.
[2]Changes only with location.
[3]See "Surface Erosion," chapter IV
[4]See "Hydrology," chapter III
[5]See "Soil Mass Movement," chapter V
[6]Can be taken from chapter III or measured directly.
[7]Calculated value.

Table II.8—continued

Control opportunities for debris in channel	Chapter references to the simulation procedure and affected variables																					
	Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[6]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables, consider effects upon each total subject		
Bench cut and compact fill																				x	x	x
Bridges	x	x																		x	x	x
Brush barrier filter at toe of slope																				x	x	x
Directional felling	x	x									x									x	x	x
Eliminate source of debris	x	x																		x	x	x
Endline or fly material from waterside areas to upslope landings											x									x	x	x
Fill slope design and location	x																			x	x	x
Full bench section	x	x																		x	x	x
Haul woody material offsite	x	x																		x	x	x
Limit equipment operation	x	x																		x	x	x
Locate activities producing small woody fragments away from water	x	x																		x	x	x
Maintain ground cover																				x	x	x
Protect road bare surface area with nonliving material																				x	x	x
Remove debris from stream	x	x																		x	x	x

Table II.8— continued

Control opportunities for debris in channel	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual Precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Repair or stabilize damaged areas																				x	x	x									
Revegetate treated areas promptly as local conditions dictate				x								x	x									x					x				
Road and landing location			x							x	x					x		x	x	x	x	x		x	x	x	x				
Waterside area				x						x	x	x	x		x		x	x									x				
Woody debris disposal sites																															

Table II.8— continued

Control opportunities for debris in channel	Chapter references to the simulation procedure and affected variables																					
	Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables, consider effects upon each total subject		
Repair or stabilize damaged areas	x	x																		x	x	x
Revegetate treated areas promptly as local conditions dictate											x									x	x	x
Road and landing location	x	x																		x	x	x
Waterside area											x	x								x	x	x
Woody debris disposal sites	x	x																		x	x	x

Table II.9—Control opportunities for excess water and the variables within the simulation procedure affected by those controls

Control opportunities for excess water	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Cutting block design	x	x		x					x	x			x		x			x									x				
Identify soil and geology characteristics and map sensitive areas											x			x									x							x	x
Machine or hand plant											x	x	x														x				
Maintain ground cover				x							x	x	x				x										x				
Out slope fire break lines or terraces															x	x		x							x	x	x				
Prescribe and execute burn under conditions that will not result in total clearing												x	x														x				
Revegetate treated areas promptly as local conditions dictate				x								x	x									x					x				
Species selection										x	x	x	x		x												x				
Type of site preparation treatment										x	x	x	x		x	x	x	x	x						x	x	x				
Use maximum spacing and minimum strip width in site preparation									x	x		x	x		x			x							x		x				
Waterside area				x						x	x	x	x		x		x	x									x				

[1]Measured value.
[2]Changes only with location.
[3]See "Surface Erosion," chapter IV
[4]See "Hydrology," chapter III
[5]See "Soil Mass Movement," chapter V
[6]Can be taken from chapter III or measured directly.
[7]Calculated value.

Table II.9—continued

Control opportunities for excess water	Chapter references to the simulation procedure and affected variables: Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)										Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[6]	Coarse material-mass movement[5]	Median size material-mass movement[6]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Cutting block design											x	x										
Identify soil and geology characteristics and map sensitive areas																						
Machine or hand plant																						
Maintain ground cover																				x	x	x
Out slope fire break lines or terraces																						
Prescribe and execute burn under conditions that will not result in total clearing																						
Revegetate treated areas promptly as local conditions dictate											x									x	x	x
Species selection											x											
Type of site preparation treatment																				x	x	x
Use maximum spacing and minimum strip width in site preparation																						
Waterside area											x	x								x	x	x

Table II.10—Control opportunities for onsite chemical balance changes and the variables within the simulation procedure affected by those controls

Control opportunities for onsite chemical balance changes	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Chemical application												x	x		x												x				
Control ash or dust build-up																															
Haul woody material offsite											x	x	x																		
Identify soil and geology characteristics and map sensitive areas											x			x									x							x	x
Keep pesticides and rodenticides well away from surface runoff																															
Locate corrals away from streams (animal skidding)												x	x				x	x													
Machine or hand plant											x	x	x														x				
Pile material in patterns											x	x	x																		
Protect fuel storage areas																															
Revegetate treated areas promptly as local conditions dictate				x								x	x									x					x				
Species selection										x	x	x	x		x												x				
Type of site preparation treatment										x	x	x	x		x	x	x	x	x						x	x	x				
Woody debris disposal sites											x	x	x																		

[1]Measured value.
[2]Changes only with location.
[3]See "Surface Erosion," chapter IV
[4]See "Hydrology," chapter III
[5]See "Soil Mass Movement," chapter V
[6]Can be taken from chapter III or measured directly.
[7]Calculated value.

Table II.10—continued

Control opportunities for onsite chemical balance changes	Chapter references to the simulation procedure and affected variables: Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Chemical application											x									x	x	x
Control ash or dust build-up																				x	x	x
Haul woody material offsite																				x	x	x
Identify soil and geology characteristics and map sensitive areas																						
Keep pesticides and rodenticides well away from surface runoff																				x	x	x
Locate corrals away from streams (animal skidding)																				x	x	x
Machine or hand plant																				x	x	x
Pile material in patterns																				x	x	x
Protect fuel storage areas																				x	x	x
Revegetate treated areas promptly as local conditions dictate											x									x	x	x
Species selection											x									x	x	x
Type of site preparation treatment																				x	x	x
Woody debris disposal sites																				x	x	x

Table II.11—Control opportunities for slope configuration changes and the variables within the simulation procedure affected by those controls

Control opportunities for slope configuration changes	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Appropriate cross section for roads			x							x						x		x	x	x	x			x	x	x					
Avoid roading of steep slopes										x						x		x	x					x	x	x					
Bench cut and compact fill			x							x	x					x		x	x	x	x	x		x	x	x	x				
Break gradient of fire lines										x						x		x						x	x	x					
Divert water onto stable areas															x										x						
Drainage above cut slope			x	x					x	x					x			x		x	x	x		x	x						
Full bench section			x							x	x	x				x				x	x	x		x	x	x	x				
Identify soil and geology characteristics and map sensitive areas											x			x									x							x	x
Limit equipment operation											x	x	x				x			x	x										
Machine or hand plant											x	x	x														x				
Maintain ground cover				x							x	x	x				x										x				
Prescribe yarding and skidding layout										x	x	x	x		x	x		x	x								x				
Reduce logging road density										x	x	x	x			x		x	x					x	x	x					
Reduction of impounded water				x											x					x					x						
Revegetate treated areas promptly as local conditions dictate				x								x	x									x					x				
Road and landing location			x							x	x					x		x	x	x	x	x		x	x	x	x				

Table II.11—continued

Control opportunities for slope configuration changes	Chapter references to the simulation procedure and affected variables																					
	Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Appropriate cross section for roads																						
Avoid roading of steep slopes																						
Bench cut and compact fill	x	x																		x	x	x
Break gradient of fire lines																						
Divert water onto stable areas																						
Drainage above cut slope																						
Full bench section	x	x																		x	x	x
Identify soil and geology characteristics and map sensitive areas																						
Limit equipment operation	x	x																		x	x	x
Machine or hand plant											x									x	x	x
Maintain ground cover																				x	x	x
Prescribe yarding and skidding layout																						
Reduce logging road density																						
Reduction of impounded water																						
Revegetate treated areas promptly as local conditions dictate											x	x										
Road and landing location	x	x																		x	x	x

Table II.11—continued

Control opportunities for slope configuration changes	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual Precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Slope rounding or reduction in slope cut			x							x						x			x					x	x	x	x				
Species selection										x	x	x	x		x												x				
Stabilize structures or cut slopes											x	x	x														x				
Type of site preparation treatment										x	x	x	x		x	x	x	x	x						x	x	x				

[1]Measured value.
[2]Changes only with location.
[3]See "Surface Erosion," chapter IV
[4]See "Hydrology," chapter III
[5]See "Soil Mass Movement," chapter V
[6]Can be taken from chapter III or measured directly.
[7]Calculated value.

Table II.11— continued

	Chapter references to the simulation procedure and affected variables																					
	Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
Control opportunities for slope configuration changes	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Slope rounding or reduction in slope cut																						
Species selection											x											
Stabilize structures or cut slopes																						
Type of site preparation treatment																				x	x	x

Table II.12—Control opportunities for stream shading and the variables within the simulation procedure affected by those controls

Control opportunities for streamside shading	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Cutting block design	x	x		x						x		x	x		x			x									x				
Directional felling											x	x	x														x				
Revegetate treated areas promptly as local conditions dictate				x								x	x														x				
Waterside area				x						x	x	x	x		x		x	x									x				

[1]Measured value.
[2]Changes only with location.
[3]See "Surface Erosion," chapter IV
[4]See "Hydrology," chapter III
[5]See "Soil Mass Movement," chapter V
[6]Can be taken from chapter III or measured directly.
[7]Calculated value.

Table II.12 — continued

Control opportunities for streamside shading	Chapter references to the simulation procedure and affected variables																					
	Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Cutting block design											x	x										
Directional felling	x	x									x									x	x	x
Revegetate treated areas promptly as local conditions dictate											x									x	x	x
Waterside area											x	x								x	x	x

Table II.13—Control opportunities for vegetation changes and the variables within the simulation procedure affected by those controls

Control opportunities for vegetation changes	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual Precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Cutting block design	x	x		x						x			x		x			x									x				
Directional felling											x	x	x														x				
Leave vegetation between site preparation strips				x					x	x		x	x		x			x									x				
Machine or hand plant											x	x	x														x				
Maintain ground cover				x							x	x	x				x										x				
Prescribe limits for the amount of area disturbed by equipment										x	x	x	x				x							x	x	x	x				
Species selection										x	x	x	x		x												x				
Timing of chemical applications												x	x		x												x				
Type of site preparation treatment										x	x	x	x		x	x	x	x	x						x	x	x				
Revegetate treated areas promptly as local conditions dictate				x								x	x														x				

[1]Measured value.
[2]Changes only with location.
[3]See "Surface Erosion," chapter IV
[4]See "Hydrology," chapter III
[5]See "Soil Mass Movement," chapter V
[6]Can be taken from chapter III or measured directly.
[7]Calculated value.

Table II.13 — continued

Control opportunities for vegetation changes	Chapter references to the simulation procedure and affected variables																					
	Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[6]	Median size material-mass movement[6]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Cutting block design											x	x										
Directional felling	x	x									x									x	x	x
Leave vegetation between site preparation strips																						
Machine or hand plant											x									x	x	x
Maintain ground cover																				x	x	x
Prescribe limits for the amount of area disturbed by equipment																						
Species selection											x											
Timing of chemical applications																				x	x	x
Type of site preparation treatment																				x	x	x
Revegetate treated areas promptly as *local conditions* dictate																				x	x	x

Table II.14—Control opportunities for water concentration and the variables within the simulation procedure affected by those controls

Control opportunities for water concentration	Chapter references to the simulation procedure and affected variables																													
	Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual Precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Administrative closure of roads											x	x	x																		
Armoring												x	x									x									
Avoid roading of steep slopes			x							x						x		x	x					x	x	x					
Break gradient of fire-lines										x						x		x						x	x	x					
Close roads after use											x	x	x														x				
Curbs and berms										x								x						x	x	x					
Cut and fill slope configuration			x							x						x		x	x	x					x	x					
Cutting block design	x	x		x						x			x		x			x									x				
Ditch checks																					x	x									
Ditch maintenance																				x	x	x									
Divert water onto stable areas															x										x						
Drainage above cut slope			x	x						x					x			x		x	x	x		x	x						
Hold water onsite				x						x		x			x			x							x						
Identify soil and geology characteristics and map sensitive areas											x			x									x							x	x
Leave vegetation between strips				x					x	x		x	x		x			x									x				
Limit equipment operation											x	x	x				x			x	x										
Machine or hand plant											x	x	x														x				
Maintain natural water courses				x																											

Table II.14—continued

Chapter references to the simulation procedure and affected variables

Control opportunities for water concentration	Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Administrative closure of roads																						
Armoring																						
Avoid roading of steep slopes																						
Break gradient of fire-lines																						
Close roads after use																						
Curbs and berms																						
Cut and fill slope configuration																						
Cutting block design		x									x	x										
Ditch checks																						
Ditch maintenance																						
Divert water onto stable areas																						
Drainage above cut slope																						
Hold water onsite																						
Identify soil and geology characteristics and map sensitive areas																						
Leave vegetation between strips																						
Limit equipment operation	x	x																		x	x	x
Machine or hand plant											x									x	x	x
Maintain natural water courses	x	x																				

Table II.14—Control opportunities for water concentration and the variables within the simulation procedure affected by those controls

Control opportunities for water concentration	Chapter references to the simulation procedure and affected variables: Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Minimize convergence of firelines															x										x						
Outslope firebreak lines and terraces															x	x		x						x	x	x					
Oversize ditch drain																				x											
Pile material in patterns											x	x	x																		
Prescribed limits for the amount of area disturbed by equipment										x	x	x	x				x							x	x	x	x				
Prescribe yarding and skidding layout										x	x	x	x		x	x		x	x								x				
Reduce road grades										x						x		x	x		x										
Reduce vehicle travel											x	x	x														x				
Reduction of impounded water				x											x										x						
Remove debris from stream																															
Repair and stabilize damaged areas											x									x	x	x									
Revegetate treated areas promptly as local conditions dictate				x								x	x														x				
Rip or scarify compacted surface											x	x	x		x		x								x						
Road and landing location			x							x	x					x		x	x	x	x	x		x	x	x	x				
Road ditch			x	x														x		x	x	x									

Table II.14—Control opportunities for water concentration and the variables within the simulation procedure affected by those controls — continued

Control opportunities for water concentration	Chapter references to the simulation procedure and affected variables																					
	Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Minimize convergence of firelines																						
Outslope firebreak lines and terraces																						
Oversize ditch drain																						
Pile material in patterns																				x	x	x
Prescribed limits for the amount of area disturbed by equipment																						
Prescribe yarding and skidding layout																						
Reduce road grades																						
Reduce vehicle travel																						
Reduction of impounded water																						
Remove debris from stream	x	x																		x	x	x
Repair and stabilize damaged areas	x	x																		x	x	x
Revegetate treated areas promptly as local conditions dictate																				x	x	x
Rip or scarify compacted surfaces																						
Road and landing location	x	x																		x	x	x
Road ditch																						

Table II.14 — continued

Control opportunities for water concentration	Hydrology variables (ch. III)								Surface erosion variables (ch. IV)											Ditch erosion (ch. IV) (app. IV-C)			Soil mass movement variables (ch. V)								
	Basal area	Type and location of cut	Rooting depth	Delivery (user judgment)	Latitude[1]	Seasonal precipitation[1]	Width of opening[1]	Normalized hydrograph[1]	R (Rainfall)[2]	LS (Length-slope)	K (Soil erodibility)	VM (Vegetation-management)	Ground cover density	Soil texture	Surface water flux	Slope gradient	Surface roughness	Distance	Slope shape	R (Hydraulic radius)	S (Slope of channel)	N (Friction factor)	Soil depth	Slope gradient	Drainage characteristics	Slope configuration	Vegetative cover	Annual Precipitation[1]	Storm intensity & duration[1]	Parent material[1]	Natural landslides[1]
Sediment traps										x					x			x													
Slope length										x						x		x						x							
Space culverts to control velocity																				x	x										
Species selection										x	x	x	x		x												x				
Timing of use of off-road heavy equipment											x						x														
Trash racks																				x	x										
Type of site preparation treatment										x	x	x	x		x	x	x	x	x						x	x	x				
Use maximum spacing and minimum strip width in site preparation										x		x	x		x			x							x		x				
Waterside area				x						x	x	x	x		x		x	x									x				

[1]Measured value.
[2]Changes only with location.
[3]See "Surface Erosion," chapter IV
[4]See "Hydrology," chapter III
[5]See "Soil Mass Movement," chapter V
[6]Can be taken from chapter III or measured directly.
[7]Calculated value.

Table II.14 — continued

Control opportunities for water concentration	Chapter references to the simulation procedure and affected variables: Total sediment variables (ch. VI)										Stream temperature variables (ch. VII)									Dissolved oxygen & organic matter (ch. IX)	Nutrients (ch. X)	Introduced chemicals (ch. XI)
	Bankful width-depth	Water surface slope	Change in discharge or duration[4]	Bankful discharge[7]	Suspended sediment[1]	Bedload sediment[1]	Surface erosion sediment[3]	Fines-mass movement[5]	Coarse material-mass movement[5]	Median size material-mass movement[5]	Vegetative shading	Length-exposed reach	Location-latitude[1]	Year-day-month[1]	Stream width[1]	Discharge[6]	Bedrock[1]	Azimuth[1]	Topographic slope[1]	No specific variables consider effects upon each total subject		
Sediment traps																						
Slope length																						
Space culverts to control velocity	x	x																				
Species selection											x											
Timing of use of off-road heavy equipment																						
Trash racks	x	x																				
Type of site preparation treatment																				x	x	x
Use maximum spacing and minimum strip width in site preparation																						
Waterside area											x	x								x	x	x

SECTION D: CONTROL OPPORTUNITY DESCRIPTIONS

All controls are listed in alphabetical order with a brief description of each control. Some reference sources are listed, but, in general, the following can be contacted for further information regarding the controls.

Engineering Controls
- Engineering, Forest Service
- Soil Conservation Service
- Soil Conservation Districts
- State and county highway departments

Silvicultural Controls
- State and Private Forestry Offices, Forest Service
- Timber Management, Forest Service
- Watershed Management, Forest Service
- Soil Conservation Service
- Soil Conservation Districts

This section can be used in any phase in the process of choosing mixtures of controls.

Administrative Closure of Roads
Procedural/Preventive/Mitigative — Bare Soil, Compaction, Water Concentration

Closing roads to all traffic during wet periods of the year prevents rutting and related concentrated flow in ruts. It also reduces compaction and sediment production on road surfaces.

Appropriate Cross-Section for Roads
Preventive — Bare Soil, Slope Configuration Changes

Consider the erosion potentials from various cross-sections of the road. Choose cross-sections that offer the least impact on the resource.

Design combinations can be chosen from existing typical cross-sections. See State or local highway departments for information. The least erodible section will vary with condition of soils, cross slopes, precipitation, and road locations. Some examples are:

1. Crown with ditch and culverts
2. Crown with ditch and water bars
3. Dips
4. Inslope with culverts
5. Inslope with water bars
6. Outslope
7. Turnpike

Armoring
Preventive/Mitigative — Bare Soil, Channel Gradient Changes, Water Concentration

Armoring protects ditches, channels, and low water crossings or outfalls. In addition, it stabilizes the channel, prevents damage from eddies, reduces erodible material, and reduces maintenance.

Some examples of armoring are: armor ditches, armor cut banks for concentrated flow, armor fill slopes below vertical curve sags, armor culvert inlets, armor tops of cut ditches, armor at cross drainage pipes and ground or channel culvert discharges.

Avoid Roading of Steep Slopes
Preventive — Bare Soil, Slope Configuration Changes, Water Concentration

If alternatives are available, locate roads on flatter slopes. Vary both the grade and alignment to minimize mileage on steeper slopes. Roads should be built to grade on slopes. Such road planning reduces bare soil per mile of road, reduces slope of cut-and-fill slopes, and reduces length of cut-and-fill slopes.

However, it should be noted that increasing road mileage can also increase total sediment production.

Bench Cut and Compact Fill
Preventive/Mitigative — Debris in Channel, Slope Configuration Changes

Cut benches into natural slope and compact fills to reduce mass failure. This method is usually used on cross slopes greater than 30 percent in unstable material. Compaction increases shear strength within fills, reduces length and amount of fill slope material, and reduces the probability of slumps within the fill. Benches reduce chances for mass failure.

Break Gradient of Firelines
Preventive/Mitigative — Slope Configuration Changes

Change gradient of fireline at intervals by angling slightly up or downslope. This will reduce the length of the distributed slope and reduce both water velocity and concentration Outsloping should also be continued with gradient breaking to prevent water concentration, especially in sensitive areas.

Bridges
Preventive — Channel Gradient Changes, Debris in Channel

Use bridges or large oval or arch over live streams. Streamflow will be restricted less than the flow through culverts. In addition, channel scour will be reduced because outlet velocities from culverts are eliminated.

Standard bridge design methods are available through State highway offices.

Brush Barrier Filter at the Toe of Fill
Preventive/Mitigative — Bare Soil, Debris in Channel

Build a debris barrier of slash at the toe of the fill to trap sediment from roads or landings. Barriers may be covered with filter cloth. Brush barriers are often considered a temporary measure effective only until vegetative cover is established.

Chemical Application
Preventive — Aerial Drift of Chemicals

Select chemicals on the basis of particle size and volatility. Heavier and larger particles drift less. Choose the most accurate application method for the job within economic reason (e.g., helicopter, fixed wing aircraft, or low elevation spraying). Accurate placement of the chemical cuts down on aerial drift of chemicals. Choose the proper size nozzle, correct formulations, and carriers for site specific conditions. Use properly trained and licensed application personnel to reduce the likelihood of accidental spills and increase the probability that chemicals will be mixed and applied properly. Use only EPA-approved chemicals and follow the label instructions.

See also "Conformance to Regulations" and "Timing of Chemical Application."

Close Roads After Uses
Procedural/Mitigative — Bare Soil, Compaction, Water Concentration

Close temporary timber access roads to all traffic when not used for timber needs. This allows the road's surface to stabilize and vegetative cover to become established. Rutting is substantially reduced.

Drainage facilities need to be oversize or removed to prevent destruction during periods of nonuse and reduced maintenance. Drainage maintenance must be kept current. The road surface may be scarified and seeded upon closure.

Conformance to Regulations
Procedural — All Resource Impacts

Follow EPA regulations regarding chemical handling and application. Regulations are designed to reduce application error.

Refer to various EPA handbooks for the most up-to-date regulations.

Control Ash or Dust Buildup
Preventive/Mitigative — Aerial Drift of Chemicals, Onsite Chemical Balance Changes

Avoid ash or dust concentration in areas where wind or chemical seep could deposit materials into waterways.

Slash burning can be done on a dispersed rather than on a concentrated basis. In addition, cuts and fills from roadbuilding or landing construction can be located away from streams and/or stabilized quickly.

Curbs and Berms
Preventive/Mitigative — Water Concentration

Construct asphalt or concrete curbs or earthen berms on roadway above tops of fill slopes to prevent water on road surface from running over fill slope.

See local Forest Service or State or county highway departments for standard drawings. Some examples are: asphalt or concrete curbs on paved roadway and earth dikes on roadway.

Cut-and-Fill Slope Configuration
Mitigative — Bare Soil, Water Concentration

Leave bank surfaces rough or bench them. Such treatment may reduce flow velocity and aid in revegetation.

Information can be obtained from the Forest Service, Soil Conservation Service, or State highway departments. Some examples are: rough cut banks and bench fill or cut banks.

Cutting Block Design
Preventive — Excess Water, Streamside Shading Change, Vegetation Change, Water Concentration

Limit the size of cutting blocks and disperse them to prevent excess water in subsoil and to maintain root strength. This will allow soils under fully vegetated units to be dried through evapotranspiration during growing seasons and the distances from top to bottom of cutting blocks to be reduced.

This application is most effective on areas with fine-textured subsoils (clays) and erodible surface soils (like those derived from decomposed granite); on steep slopes; on clearcut and seed tree cut areas; and on areas with heavy precipitation falling as rain. Specific treatment methods include:

1. Orient cutting blocks with adequate buffer strips.
2. Orient cutting blocks at right angles to slopes.
3. Disperse cutting blocks.
4. Design more but smaller cutting blocks.

Directional Felling
Preventive — Bare Soil, Compaction, Debris in Channel, Streamside Shading Changes, Vegetation Changes, Water Concentration

Use directional felling as a way of concentrating felled trees to increase logging efficiency and to lessen site disturbance. Use direct felling to prevent trees from falling into the water, especially in waterside areas. Also, fell trees that are close to roads or streambanks and that would naturally uproot before the next silvicultural activity; this will reduce potential bank erosion.

Ditch Checks
Mitigative — Channel Gradient Changes, Water Concentration

Construct a series of armored check dams in the road side ditch. This reduces velocity in ditch by reducing effective grade, mitigates cut bank undercutting, and controls grade.

Ditch Maintenance
Procedural/Mitigative — Channel Gradient Changes, Water Concentration

Clean ditch to original cross-sections and leave grass lining and vegetative cover. This prevents undercutting and degradation of ditch edges and reduces sediment leaving ditch.

Divert Water Onto Stable Areas
Preventive — Slope Configuration Changes, Water Concentration

Avoid diversion of water onto erosive or mass failure-sensitive areas. Water on such areas can increase erosion. Damage can be avoided by locating sensitive areas before an activity is started. Consult soil, hydrologic, and geologic maps to locate sensitive areas.

Drainage Above Cut Slope
Preventive/Mitigative — Bare Soil, Slope Configuration Changes, Water Concentration

Place drainage above cut slope parallel to roadway to intercept overland and some shallow, subsurface flow before it can run over and down the cut slope.

Use engineering design obtainable from Forest Service or State or local highway departments. Design examples are: use of a perforated pipe at top of cut bank and ditch above cut.

Eliminate Source of Debris
Mitigative — Debris in Channel

Seek out and eliminate sources of organic debris pollutant to prevent their continued entry into water. Specific treatments are: burning woody debris, burying woody debris, constructing barriers to keep debris out of channels, hauling debris off-site, rearranging debris, and revegetating.

Endline or Fly Material from Waterside Areas to Upslope Landings
Preventive/Mitigative — Bare Soil, Compaction, Debris in Channel

Remove organic material, resulting from silvicultural activity, from waterside areas. Facilitate harvest of merchantable material and removal of unused material and slash, within environmental constraints of the area. Equipment used must be capable of pulling or lifting logs from beds to landings. Lifting the leading end of the log or the entire log is desirable. Material that might enter water must be removed.

This method applies in areas where tractor or other ground-lead methods would cause compaction or channelization of riparian soils, or cause pollution of water. Soil conditions may influence the need for this control, which is more critical as slopes steepen.

Enforcement of Standards and Bonding of Operators
Procedural — All Resource Impacts

Consider contracts with specifications for bonding all contractors and permittees using performance criteria. Insure that planned erosion control measures and all other planned controls are actually carried out on the ground.

Enforcement controls, combined with monitoring, can insure protection of water quality according to project plans. Sample contracts are available from State foresters or Forest Service State and Private Forestry offices.

Fill Slope Design and Location
Procedural/Preventive, Mitigative — Bare Soil, Debris in Channel

When constructing roads, do not allow debris to reach stream. Prevent fill slope material from reaching stream by following design, controlling blasting, and controlling length of fill slope during construction. Reduce fill slope length to prevent stream encroachment by toes of fill slopes.

Designs can be obtained from highway departments. Specific treatments include: gabion placement at the fill slope edge and retaining structures at the toe of fill slope.

Full Bench Section
Preventive — Debris in Channel
Slope Configuration Changes

Build roadbed entirely on natural ground in steep areas. Side casts and fill slopes are eliminated.

Dispose of excess material in stable areas. See Forest Service or local highway department for design specifications.

Haul Woody Material Offsite
Mitigative — Debris in Channel,
Onsite Chemical Balance Changes

Haul chips and other small woody material that result from silvicultural activity and that could add chemicals or result in debris in the stream, to offsite disposal areas.

Hold Water Onsite
Preventive/Mitigative — Bare Soil,
Water Concentration

Retaining water in place through restriction of water movement is one key to minimizing pollution. Use control measures that will disperse water and not allow water to concentrate to prevent sediment movement and establishment of bare soil. Keep unnecessary site disturbance at a minimum for all silvicultural activities and use site stabilization techniques before, during, and after completing these activities. Check local sources for acceptable measures to prevent or remedy the unnecessary movement of water.

Identify Soil and Geologic Characteristics and Map Sensitive Areas
Procedural/Preventive — Bare Soil, Compaction, Excess Water, Onsite Chemical Changes, Slope Configuration Changes, Water Concentration

Using soil analysis techniques, determine the soil/moisture relationship of sites where degradation is likely to occur with normal use. Define the limiting percentage of compaction that will be tolerated on a given percentage of the site area. Also, define what percent of the area may be compacted. Before beginning the operation, study surveys of the area to locate sensitive areas. Avoid these sensitive areas during the operation. Such determinations aid in identifying the types of systems that could be used to carry out the silvicultural prescription, aid in selecting proper equipment, and also may reduce the number and cost of mitigative measures.

Useful information may be obtained from compartment examinations, soil surveys, hydrologic surveys, and geologic surveys. This technique is especially effective in areas prone to mass movement.

Keep Pesticides and Rodenticides Well Away From Surface Runoff
Preventive — Aerial Drift of Chemicals,
Onsite Chemical Balance Changes

Exposing chemicals to surface runoff areas can seriously influence both plant and animal communities. Identify potential surface runoff areas and restrict chemical use near these areas. Pesticides are commonly applied in aerial operations and chemical drifting is a major problem. Regulations concerning chemical use, application procedures, and critical on-the-ground problem areas must be understood by licensed personnel before chemical application.

Refer to controls on "Chemical Application," "Conformance to Regulations," and "Timing of Chemical Application."

Leave Vegetation Between Strips
Preventive — Bare Soil, Compaction,
Vegetation Changes, Water Concentration

When using stripping techniques for site preparation, leave some unstripped ground at intervals; this forms small filter strips around and within the stripped areas.

Refer to Forest Service Region 4 handbooks for more information on stripping techniques.

Limit Disturbed Area
Procedural — All Resource Impacts

Limit areas where work activity takes place at any given time. Require that one operational area be stabilized before beginning work on another area. An operational area can be defined in terms of the maximum number of active cut blocks, maximum number of acres without seeding, or maximum miles of road without installation of permanent erosion controls. Active areas should be only large enough to allow most equipment to work concurrently.

This control is especially useful on large projects.

Limit Equipment Operation
Preventive—Bare Soil, Compaction, Debris in Channel, Slope Configuration Changes, Water Concentration

Limit or eliminate operation of heavy equipment on unstable or highly erodible soils. In addition, equipment operation in streams should be minimized. Limit equipment operation by cable methods of logging and by winching (endlining) logs in unstable areas.

This application is most effective on steep grounds where soil masses are unstable and/or where soils are erodible.

Locate Activities Producing Small, Woody Fragments Away From Water
Preventive — Debris in Channel

Keep chipping and mastication operations well away from streams and water courses.

Locate Corrals Away From Streams (Animal Skidding)
Preventive — Debris in Channel, Onsite Chemical Balance Changes

When using animals in logging operations, place corrals well away from stream courses. Animal waste should be kept out of the water. Water may have to be hauled for the animals.

Machine or Hand Plant
Preventive—Bare Soil, Compaction, Excess Water, Onsite Chemical Balance Changes, Slope Configuration Changes, Vegetation Changes, Water Concentration

The method of tree planting, either by machine or hand, often governs the intensity of site preparation treatments. Machine planting usually requires that the site be cleared of logs, limbs, and other larger debris. Debris is not a problem for hand planting as long as crews can walk through it and trees can be planted at the prescribed spacing. If debris is too heavy for hand planting, the situation is often rectified by a light burn which consumes the small material and often does not expose excessive amounts of soil. In some areas, fire will expose unacceptable amounts of bare soil and mechanical removal of debris is the only alternative. Also, mechanical debris removal is needed to reduce fire hazard and for other resource purposes. In many situations machine planting and associated site preparation can be fully acceptable.

Maintain Ground Cover
Preventive — Debris in Channel, Excess Water, Slope Configuration Changes, Vegetation Changes

Maintain as much vegetation, which may include trees, understory, and litter, as is consistent with management objectives; or establish tree regeneration and desirable species of understory vegetation. Evapotranspiration reduces amounts of water in the soil. Mechanical protection strengthens slopes against mass failure.

Vegetation, through physiological use of soil moisture, will dry soil masses and prevent saturation of subsoils. Ground covered by vegetation will be protected from the impact of raindrops during heavy precipitation, thus preventing detachment and downhill transport of soil particles. Vegetation will produce a protective layer of duff. Infiltration will be enhanced and ground surface water flow will be reduced or eliminated. Tree roots and roots of other species reinforce the soil mass.

Maintain Natural Water Courses
Preventive — Channel Gradient Changes, Water Concentration

Keep stream channels free of debris which might deflect or constrict water flow and which could accelerate bank or channel erosion. Keeping streambanks and channels stable in this manner will reduce sediment loads. Road crossings, bridges, culverts, fords, and other stream encroachments should be aligned and constructed to reduce impacts on flow characteristics.

Remove all introduced organic material from the stream course as soon as it is introduced to prevent damming and streambank alteration. Refer to controls on "Directional Felling" and "Waterside Areas." Both are important in maintaining natural water courses.

Minimize Convergence of Firelines
Preventive — Water Concentration

When locating and constructing firelines, avoid downhill convergence. If firelines do not converge, water will be prevented from concentrating severely.

Monitoring
Procedural — All Resource Impacts

Monitor silvicultural and related activities with periodic inspections. Schedule inspections to allow for maintenance prior to periods of heavy runoff. Pay particular attention to drainage facilities. Monitoring by itself is not a control; however, it is a way to make sure other controls are carried out properly. See "Enforcement of Standards and Bonding of Operators."

Outslope Firebreak Lines and Terraces
Preventive — Excess Water, Water Concentration

When constructing firebreak lines or terraces, make certain they are outsloped so water is not concentrated by insloping. Gully erosion can be controlled by outsloping.

Information regarding laying of grade and other design criteria can be obtained from local highway departments or Forest Service Engineering personnel.

Oversize Ditch Drain
Preventive — Channel Gradient Changes, Water Concentration

Install culverts that are larger than necessary for anticipated runoff, thus allowing some debris plugging before water will flow over road.

See Forest Service or State and county highway departments for culvert size requirements. This is particularly effective when roads are closed to users and when maintenance inspections are infrequent.

Pile Material in Patterns
Preventive — Onsite Chemical Balance Changes, Water Concentration

Pile debris from cutting, site preparation, or fuel management in patterns which prevent concentration of water. Gullying can be prevented by avoiding water concentration around piles of material. Avoid diverting water onto sensitive areas.

Prescribe and Execute Burns Under Conditions That Will Not Result in Total Cleanup
Preventive — Bare Soil, Excess Water

Fuel treatment burns should be cool enough to leave unburned and partially burned material on the site. This offers some ground cover protection for the soil. Alter firing patterns to reduce overall burn intensity so less soil is bared. Some fuel treatment goals may have to be revised as a result of this control. Consider special burning techniques such as the jackpot or spot burn.

The Forest Service and its State and Private Forestry offices will have fuel treatment guidelines that describe fire manipulation in detail.

Prescribe Limits for Amount of Area Disturbed by Equipment
Preventive — Bare Soil, Compaction, Vegetation Changes, Water Concentration

Minimize bare soil area necessary to satisfy silvicultural objective. Increase the amount of acres served by roads or landings by planning truck roads, skid roads, and landings at the same time and by maintaining wider spacing between truck roads and skid roads.

Prescribe Yarding and Skidding Layout
Preventive — Slope Configuration Changes, Water Concentration

Design yarding and skidding patterns to radiate downhill. Skid roads oriented this way will spread, rather than collect, water. Thus, water will not be concentrated and its energy for eroding material into bodies of water will be reduced. The water will also have an increased opportunity to infiltrate.

Water concentration caused by skid roads and trails becomes more severe with increased slope and precipitation and decreased soil particle size. Water concentration must also be considered on shallow slopes particularly in the Southern United States.

Prevent Fire Spread Outside Treatment Areas
Preventive — Bare Soil

Take steps before the fuel treatment operation to prevent fire spread outside treatment areas by using firebreaks and having equipment available. If fires are contained, less bare soil is exposed and aerial drift of ash and dust can be reduced.

Protect Fuel Storage Areas
Preventive — Onsite Chemical Balance Changes

Place fuel storage areas in locations well away from streams or water courses and take precautions to impound or divert a possible fuel spill.

Dimensional ditches and impoundments with straw bales to soak up excess fuel can be effective.

Protect Road Bare-Surface Areas With Nonliving Material

Mitigative — Bare Soil, Debris in Channel

Armor bare soil related to roads, especially in specific locations that are not able to be revegetated.

Use appropriate structural thickness designs and pavement design methods. See local Forest Service or county highway department for appropriate design criteria. Examples are:

1. Gravel road surface: high cost although lower than asphalt paving.
2. Asphalt road surface: high cost relative to other treatments.
3. Spot gravel on critical areas of road surface: used on "soft" areas of road.
4. Dust oil applied to road surface: prevents aggregate breakdown, must be used frequently to be effective.
5. Shot crete surface of cut-and-fill slopes: used only when all else fails; cost is high.
6. Jute mats or excelsior pads on cut-and-fill slopes: rarely used singly, usually used in combination with revegetation.

Prescribe limits for the amount of area disturbed by equipment by constructing narrow truck roads and avoiding unnecessary movement of vehicles off established road and landing areas.

Do not make unnecessary roads. Roads should be designed using such techniques as "rolling dips."

Reduce Road Grades

Preventive — Water Concentration

Reducing road grades tends to reduce ditch erosion and road surface erosion by reducing water velocity. However, there is the possibility of increasing road mileage, in order to use flatter grades, to the point where total sediment yield is increased. Refer to road design standards of local highway departments.

Reduce Log Length

Preventive — Bare Soil

Reduce log length prior to yarding, skidding, or hauling to require less turning space in the woods and to allow use of lower standard roads. (The use of smaller vehicles can mean less turning space which, in turn, reduces the amount of disturbed area.)

However, logging efficiency must be considered. The additional cost of bucking tree-length logs into one or more logs in the woods must be compared with the potential disturbance and exposure of bare soil if the logs are not bucked

Reduce Logging Road Density

Preventive — Bare Soil, Compaction, Slope Configuration Changes

Hold logging road density in areas sensitive to mass failure to a minimum. If critical areas must be crossed, use bridge, complete fill techniques, or center balance slope methods.

Note that reduction of roads could require a more expensive logging systsem.

Reduce Vehicular Travel

Preventive — Compaction, Water Concentration

Since ruts and compacted tracks can cause water concentration, a simple reduction of vehicular travel to only that which is absolutely necessary would help alleviate water concentration impacts.

Reduction of Impounded Water

Mitigative — Channel Gradient Changes, Slope Configuration Changes, Water Concentration

Divert water from impoundment to prevent excess water from accumulating and increasing the surface erosion and mass failure risk. Drain impounded water away and spread water over more absorbent surfaces. Increase the absorption rate of the impoundment, if possible, by ripping, scarifying, roughening the surface, or establishing vegetative cover. In addition, during or after the operation, prevent debris dam or barrier formation that could lead to water concentration. Locate and remove small dams before problems become large and costs go up.

Specific examples include:

1. Install a ditch drain culvert that discharges onto undisturbed natural ground above and as near to streams as possible.
2. Drain project prior to seasonal shutdown. Ditch, crown, water bar, and remove temporary fills and culverts.
3. Keep project drained during construction; construct ditches, temporary culverts, etc.

Remove Debris From Stream

Mitigative — Debris in Channel, Water Concentration

Remove organic and inorganic debris which has entered the stream from silvicultural and related activities. This reduces pollution from debris and prevents undercutting of slopes.

Debris removal should utilize least damaging methods. Specific treatments include:

1. Hazard debris removal
2. Lining out debris
3. Lifting out with loader
4. Lifting out with helicopter
5. Scattered, free floating debris (chips, slack, fragments) can be gathered by towed or stationary booms or partially submerged screens.

Repair and Stabilize Damaged Areas
Mitigative — Channel Gradient Changes, Debris in Channel, Water Concentration

Shape and stabilize areas damaged during the operation with organic or inorganic material using outsloping techniques to prevent water concentration. Restore streambanks and stream bottoms to as near original configuration as possible. Prevent continued deterioration of the aquatic environment. Use combinations of soil replacement, placement of gabions, and riprap.

A field decision will have to be made regarding whether or not the repair effort would cause more damage than that existing before repairs were undertaken. Forest Service, Soil Conservation Service, or county agents can offer design advice.

Revegetate Treated Areas Promptly As Local Conditions Dictate
Mitigative — Aerial Drift of Chemicals, Bare Soil, Compaction, Debris in Channel, Excess Water, Onsite Chemical Balance Changes, Slope Configuration Changes, Streamside Shading Changes, Water Concentration

Revegetate using artificial techniques to establish a plant cover on bare soil surfaces — usually skid trails, ditches, and other disturbed *areas. Stabilize the soil surface. Revegetation* can also increase shading on water. Apply grass, shrub, tree seed, or sod and/or seedlings to exposed areas; add fertilizer, lime, mulch, or jute mats as local conditions dictate. This will reduce soil eroding energy from water related sources.

See Soil Conservation Service, Forest Service, or extension agent for local grass species and requirements for fertilizer, lime, mulch, etc. Grass cover can be very difficult to establish on arid or sterile soils or on fill slopes over 1:1. Jute mats or excelsior pads are often required to hold seed to establish grass in critical areas.

Rip or Scarify Compacted Surfaces
Mitigative — Compaction, Water Concentration

Ripping or scarifying may restore the site's natural water-holding capacity, restore water infiltration capability, increase root permeability, and increase the site's potential to reestablish a vegetative cover. On trails compacted by off-road, heavy equipment, the compacted layer can be remedied by single ripping when layer width is less than two times the depth of compaction. On landings and concentrated use areas where compaction has occurred, the site should be ripped to the depth of compacting. On skid trails, roads, and landings with surface compaction of 8 inches or less, scarification can mitigate some damage.

Need for treatment is determined by examination and testing proctor curves.

Road and Landing Location
Preventive — Compaction, Debris in Channel, Slope Configuration Changes, Water Concentration

Avoid unstable areas and critical slope configuration. Prevent water from accumulating, channeling, eroding, and degrading water and site quality. Keep logging roads and skid trails out of stream bottomlands. Avoid sustained grades; attempt to vary the grade. Whenever possible, locate water concentrating activities on high ground.

Require that hydrologic and soils information be put into an area logging plan. Develop a transportation plan that serves all of the resources with the least total impact by reducing duplication of roads. Specific considerations are:

1. Avoid known slump/slide areas.
2. Avoid areas with high risk of mass failure.
3. Avoid concave slopes in close proximity to streams.
4. Place roads on convex slopes above streams.

Road Ditch
Preventive/Mitigative — Water Concentration

Drain inside road ditch with pipe or water bar.

This is a positive method of controlling surface routing across a road. A plugged ditch may cause mass failure and accelerated road surface erosion. Therefore, maintenance is necessary.

Road Drainage
Preventive — Compaction, Excess Water, Slope Configuration Changes, Water Concentration

Divert road runoff at frequent intervals to reduce volume and velocity, thereby reducing erosion potential and providing the opportunity for water to infiltrate soil before reaching stream. Road drainage and spreading techniques include dipping of sustained grades, outsloping and/or insloping and cross draining of water onto areas most capable of spreading and infiltrating the runoff. This control could pertain to tractor trails, roads, and landings. Additional treatments are lead off ditches and water bars. For design specifications, consult Forest Service regional road manuals and related publications.

Road Drainage Maintenance During Storms
Preventive — All Resource Impacts

Patrol roads when heavy precipitation is forecast and during precipitation. Keep drainage system functioning during runoff (unplug culverts, remove slides from ditches, etc.). Storm patrol organization and procedures must be established before the storm occurs. Labor and equipment must be available for emergency work. Storm forecasting is required.

Storm patrol is particularly useful in areas of frequent, very heavy rainfall with steep slopes and unstable material.

Sediment Trap
Mitigative — Water Concentration

Excavate or dam a sediment pond below culverts. This sediment trap provides a pond of water below the culvert, thus allowing sediment to settle out.

See Forest Service or State or local highway department for design characteristics. Application is very site specific. This is a short-term control which is usually effective only until vegetative cover has become established. Pond will eventually silt full.

Select Low Impact Equipment
Preventive — All Resource Impacts

Determine what type of equipment can minimize compaction and accomplish the required work. Make determinations of the equipment's pulling capacity, pounds/square inch of float, speed, and stability.

May require equipment other than what is presently used in the area or a change to a different system that meets the resource objective (i.e., tractor to cable).

Slope Length
Preventive — Bare Soil, Water Concentration

Avoid silvicultural treatments using long downslope distances to prevent high overland water velocities and decrease erosion.

The Forest Service has standard placement tables for critical distances.

Space Culverts to Control Road Ditch Erosion
Preventive — Channel Gradient Changes, Water Concentration

Space ditch drain culverts to control quantity and velocity of water flowing in roadside ditches. Proper drainage regulates water quantity and velocity, soil detachment, and transport.

See Forest Service or state highway departments for standards. Additional ditch drain culverts may help to control active ditch erosion.

Species Selection
Preventive — Bare Soil, Compaction, Excess Water,
Onsite Chemical Balance Changes,
Slope Configuration Changes, Vegetation Changes,
Water Concentration

The tree species to be planted often govern the type and the intensity of site preparation treatments. Tree seedlings have varying tolerance to plant competition. As a general rule, tolerant species require less intensive treatments, while intolerant species require more intensive treatments.

Specify Timing
Procedural — All Resource Impacts

Specify timing of control application and/or work phases that are critical to quality control. Timing should be specified in terms of both calendar and spatial relationships. Such timing specification should be used for vegetative establishment, culvert and bridge installation, earth work, establishment of size, number, and placement of active areas, and the scheduling of activity on these areas.

Stabilizing Structures on Cut Slopes
Mitigative — Bare Soil,
Slope Configuration Changes

A variety of engineering structures may be installed where the toes of unstable slopes have been truncated by bank cutting in streams, road cuts, skid roads, or firelines. Cut banks and/or fill slopes at the toes of slopes can be counterbalanced with rock to stop mass soil wasting at toes of unstable slopes and potential upslope mass failure. Specific treatments include: Steel cribbing structures, gabions, corrugated pipe, and rock.

Timely Drainage Maintenance
Preventive — All Resource Impacts

Keep maintenance current, particularly off drainage facilities. Insure that drainage facilities are functioning properly at all times, especially prior to periods of heavy runoff.

Much of the drainage maintenance work can be done by personnel other than maintenance crews. Quite often the only "equipment" needed is a shovel.

Timing of Chemical Application
Preventive — Aerial Drift of Chemicals, Vegetation Changes

Apply chemicals during calm, dry weather (mornings and evenings). Little drift is encountered if chemicals are applied during calm weather. Rainstorms can wash freshly applied chemicals into water. Avoid high runoff periods when applying chemicals. Refer to "Chemical Applications" control for further considerations.

Timing of Use of Off-Road, Heavy Equipment
Preventive — Compaction, Water Concentration

Analyze soil to determine its characteristics and define the soil moisture limits for using heavy equipment. Limit use of heavy equipment when soil moisture is high and thus reduce chances of soil compaction. Include timing constraints in contracts if applicable.

Trash Racks
Preventive — Water Concentration

Locate trash racks at, or upstream from, culvert entrances to catch debris before it plugs culverts. This can reduce bank cutting around culvert entrances caused by plugging and reduces the chance for water to overflow roads during high water. Note, however, that with great amounts of debris, trash racks are not effective; they may actually make the problem worse. Numerous standard drawings exist. See Forest Service or State highway department.

Type of Site Preparation Treatment
Preventive — Bare Soil, Compaction, Excess Water, Onsite Chemical Balance Changes, Vegetative Changes, Slope Configuration Changes, Water Concentration

Site preparation is used to create a favorable environment for tree establishment and to secure acceptable tree survival and stocking. There is a broad range of site preparation treatments with a wide range of potential impacts. The treatment chosen for a given site is governed by the site's physical and residual stand characteristics, the tree species to be planted, whether the trees can be machine or hand planted, and whether regeneration will be by seedlings or seed. Site preparation uses hand and mechanical methods, herbicides, and fire, or combinations of these treatments.

The principle here is that many characteristics will govern what site preparation treatments are used. Several possible treatments can be applied to a given site; the one chosen depends upon the management goals for that site.

Refer to Dissmeyer and Singer (1977) and Balmer and others (1976) for more complete information.

Use Wind Breaks or Uncut Timber to Prevent Wind Erosion
Preventive — Bare Soil

Leave wind breaks or uncut timber around silvicultural and related activities in wind erosion areas. These can slow or disrupt wind currents which could cause erosion. Disrupted wind currents will drop suspended soil particles.

Use Maximum Spacing and Minimum Strip Width in Site Preparation
Preventive — Bare Soil, Excess Water, Water Concentration

Leave undisturbed vegetation or ground cover between site preparation strips. Leave the maximum width possible to meet silvicultural prescriptions. Continuous blocks of bare soil will be broken up, thus preventing water concentration and surface soil loss.

Waterside Area
Preventive — Aerial Drift of Chemicals, Bare Soil, Debris in Channel, Excess Water, Streamside Shading Changes, Water Concentration

Waterside areas are strips of vegetated land where treatment is carefully controlled. Such zones are often located between cut, site-prepared, burned, fertilized, herbicided, and pesticided areas, roads, and streams. Vegetation in the waterside area reduces amounts of debris, surface runoff, erosion, and chemicals reaching the stream while reducing the impact of some management activities on water temperatures. Use mapping and on-the-ground reconnaissance to identify aquatic areas which, because of direction of flow, shoreline arrangement, exposure, wind patterns, and related phenomena, are susceptible to temperature changes. Modify silvicultural prescriptions accordingly.

Provide shade on treated areas and in strategic locations near riparian zones and water surfaces to disrupt radiation patterns and slow air movement into sensitive areas. Maintain temperature regimes of the aquatic environment. Leave as much native vegetation on treated areas as possible. Avoid "total cleanup" of debris. Protect vegetation in riparian areas and leave substantial windfirm trees in areas where they will obstruct radiation onto riparian zones and onto water, particularly in the shallows.

Refer to the "Directional Felling" control for harvesting timber in waterside areas. The Forest Service's State and Private Forestry group has information on proper layout and design of waterside areas.

Woody Debris Disposal Sites
Preventive — Debris in Channel,
Onsite Chemical Balance Changes

Do not pile woody material or ash where it could wash into streams. Chemical seep from wood should not be allowed to reach water bodies.

Downstream culverts and trash racks will need less maintenance and organic matter will be prevented from changing the chemical balance in streams. Very little is known about water pollution caused by chemical leaching from wood.

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APPENDIX II.A: EXAMPLES ILLUSTRATING VARIOUS USES OF THE CONTROL OPPORTUNITIES

EXAMPLE ONE — MITIGATIVE CONTROLS FOR A PREVIOUSLY DISTURBED SITE

Example one procedure. — This example illustrates the use of the controls procedure to prescribe mitigative controls for a previously disturbed site (disturbed by man) so that silvicultural activity can be accomplished without exceeding water quality objectives. (Fig. II.A.1 illustrates this application of the procedure.)

This procedure should be run several times, thereby arriving at several choices for the manager.

1. Simulate, using handbook procedures, or measure watershed condition before silvicultural planning begins.
2. If a previous disturbance (a road, a landing, etc.) is impacting water quality so that objectives are not met, the simulation will show where the pollution is originating, how much pollution there is, and what kind of pollution is being produced. Using this information, determine which variables within the simulation procedure are causing the pollution. Then refer to table II.2 and relate the involved variables to the corresponding resource impacts (bare soil, compaction, etc.). (To relate the resource impacts to the involved processes — increased runoff, reduced infiltration, etc. — refer to the definitions of the resource impacts in the "Discussion" section of this chapter.)
3. Once the resource impacts are identified, refer to section B or section C, tables II.3 to II.14 of this chapter for a list of controls that could mitigate the resource impacts. At this point, a mix of such controls is selected.
4. Then use section D for a description of the selected controls. Reference sources are listed in section D for those controls needing an expanded, technical definition.
5. Use section C to cross-reference the control opportunities with the variables and procedures used in the handbook simulation.
6. Simulate (using handbook procedures) the potential outcome of using the new mixture of mitigative controls to meet the water quality objectives.
7. If the water quality objectives are not met, new mixes of mitigative controls will have to be chosen and simulated again using the handbook procedures.

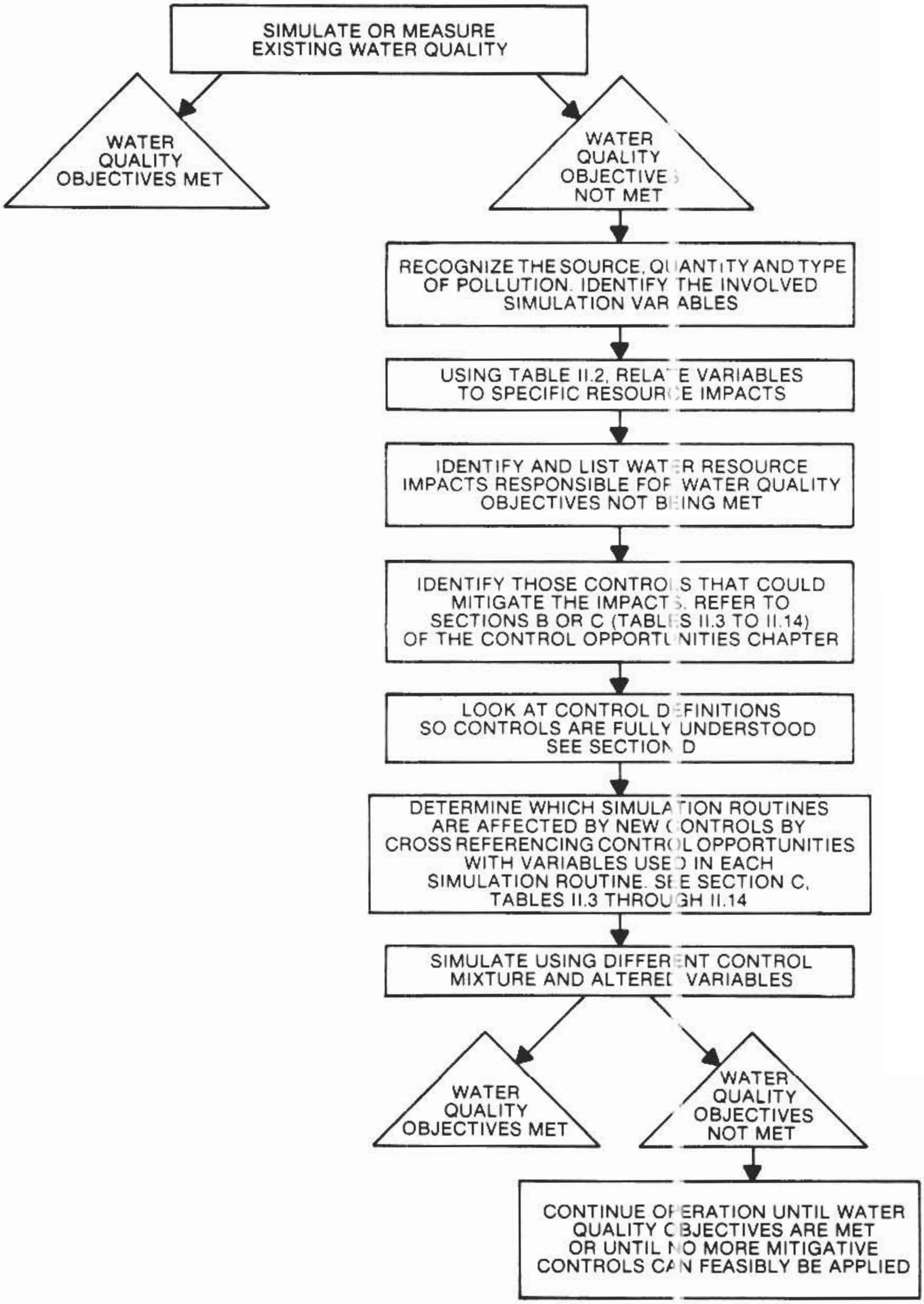

Figure II.A.1—Example one procedure.

EXAMPLE TWO — CONTROLS IN THE FORMULATION OF SILVICULTURAL PLANS

Example two procedure. — This example illustrates the use of the control as a reference to help in the formulation of the initial silvicultural plan. (Fig. II.A.2 illustrates this application of the procedure.)

This procedure should be run several times, thereby arriving at several choices for the manager.

1. List the resource impacts associated with silvicultural activity by referring to section A, table II.1, of this chapter. For example, bare soil and compaction might be associated with tractor skidding operations.
2. Once the resource impact has been determined, a list of controls which could prevent or mitigate each impact can be made by referring to section B.
3. Then go to section D for an expanded definition of each control.
4. Refer to section C for cross-correlation between the control and the variable or variables it affects for simulation of possible effects on the stream.
5. Narrow the control list to those controls most effective in preventing or mitigating resource impacts.
6. Include the most effective controls in the proposed silvicultural plan.

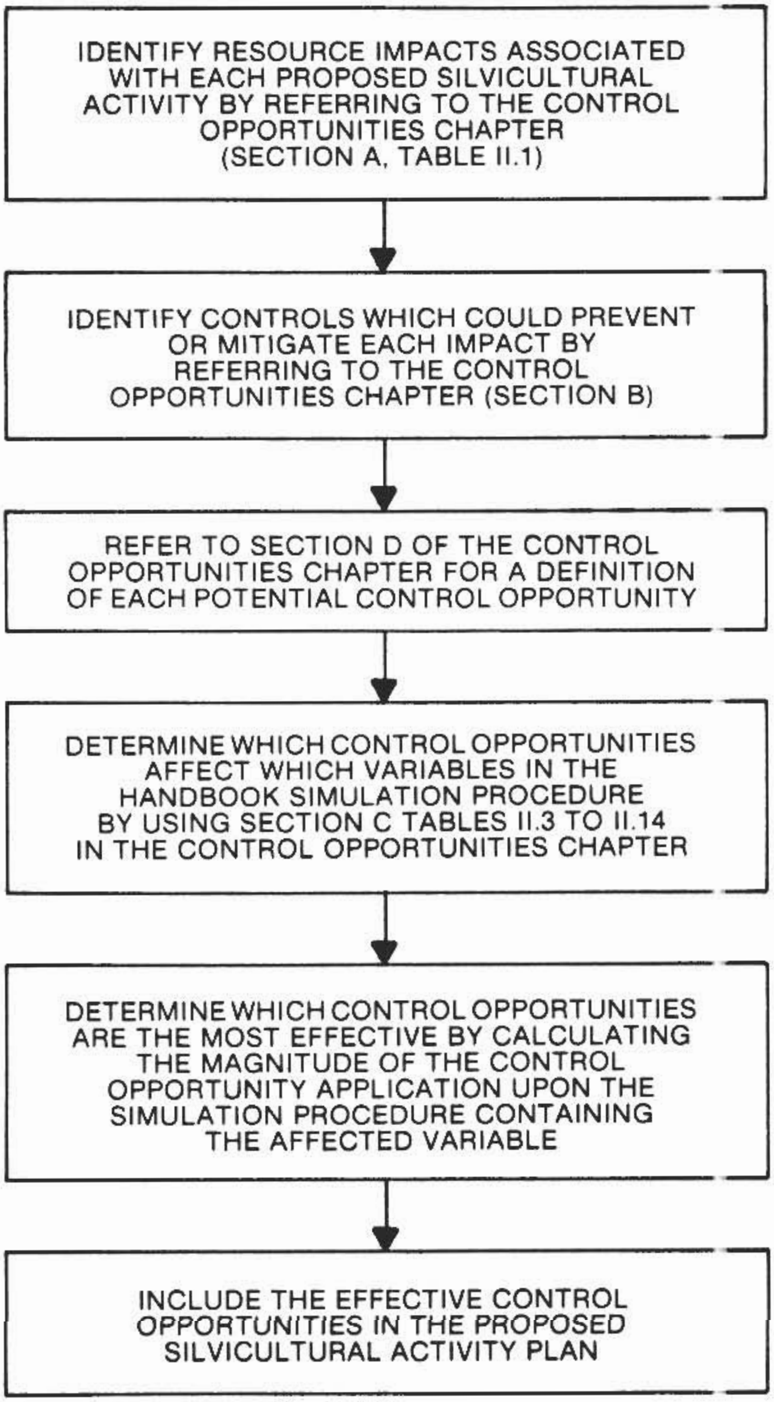

Figure II.A.2.—Example two procedure.

EXAMPLE THREE — ADDING CONTROLS WHEN PLANS DO NOT MEET WATER QUALITY OBJECTIVES

Example three procedure. — This example illustrates use of the controls procedure as a way to add new control opportunities to the silvicultural plan if the plan has been shown, through simulation, to fall short of the water quality objectives. (Fig. II.A.3 illustrates this application of the procedure.)

This procedure should be run several times, arriving at several control mixes that all meet the water quality objectives, to give the manager a choice.

1. Simulate (using the handbook simulation procedure) the water quality based upon the proposed silvicultural plan.
2. If the simulation procedure shows the silvicultural plan to meet the established water quality objectives, then no further reference needs to be made to the controls chapter. If the silvicultural plan is shown, through simulation, not to meet the established water quality objectives, then a new mix of controls should be selected using the controls procedure.
3. If objectives are not met, the simulation will show where the pollution is originating, how much pollution there is, and what kind of pollution is being produced. Using this information, first determine which variables within the simulation procedure are causing the pollution. Then, refer to table II.2 and relate the involved variables to the corresponding resource impacts (bare soil, compaction, etc.) (To relate the resource impacts to the involved processes — increased runoff, reduced infiltration, etc. — refer to the definitions of the resource impacts in the "Discussion" section of this chapter.)
4. When the water resource impacts have been identified, refer to section B or section C, tables II.3 to II.14, for a list of controls that could prevent the water resource impacts. At this point, a mix of such controls is selected and is added to, or used to replace, parts of the silvicultural plan. Determine which variables should be altered by referring to the tables in section C. The values of the variables should be altered to reflect the new control mixture before the next simulation. For example, if a simulation shows too much heat resulting from too much sunlight striking the water surface of a stream, the next step would be to check the cutting block design in the cutting and logging portions of the proposed silvicultural plan to find out which parts of the plan are directed toward the problem. If the plan calls for cutting blocks to be located too close to the stream, then a new control relating to cutting block design and location should be added to the plan to prevent water temperature increase.
5. Then use section D for description of the selected controls. Reference sources are listed in section D for those controls needing an expanded, technical definition.
6. Use section C to cross-reference the control opportunities with the variables and procedures used in the handbook simulation.
7. Simulate (using handbook procedures) the potential outcome of using the new mixture of preventive controls to meet the water quality objectives.
8. If the water quality objectives are met, no further simulations using different mixtures of controls are needed (unless economics dictate several simulations). If the water quality objectives are not met, new mixes of controls will have to be chosen and simulated again using the handbook procedures.
9. If after the addition of preventive controls the objectives are not met, the simulation will show where the pollution is originating, how much pollution there is, and what kind of pollution is being produced. Using this information, determine which variables within the simulation procedure are causing the pollution. Then refer to table II.2 and relate the involved variables to the corresponding resource impacts (bare soil, compaction, etc.). (To relate the resource impacts to the involved processes — increased runoff, reduced infiltration, etc. — refer to the definitions of the resource impacts in the "Discussion."
10. When the water resource impacts have been identified, refer to section B or section C, tables II.3 to II.14, for a list of controls that could mitigate the resource impacts. At this point, a mix of such controls is selected and

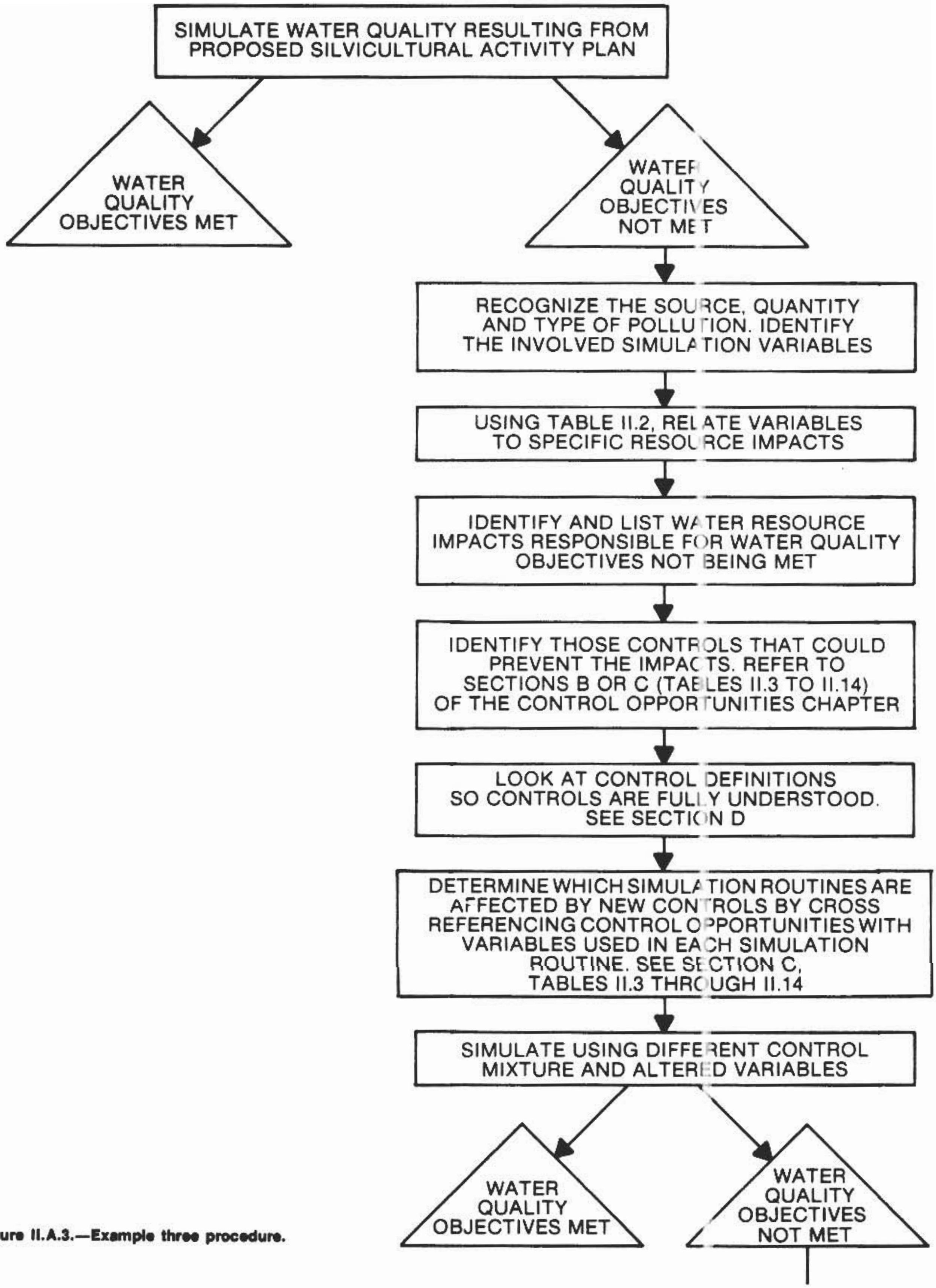

Figure II.A.3.—Example three procedure.

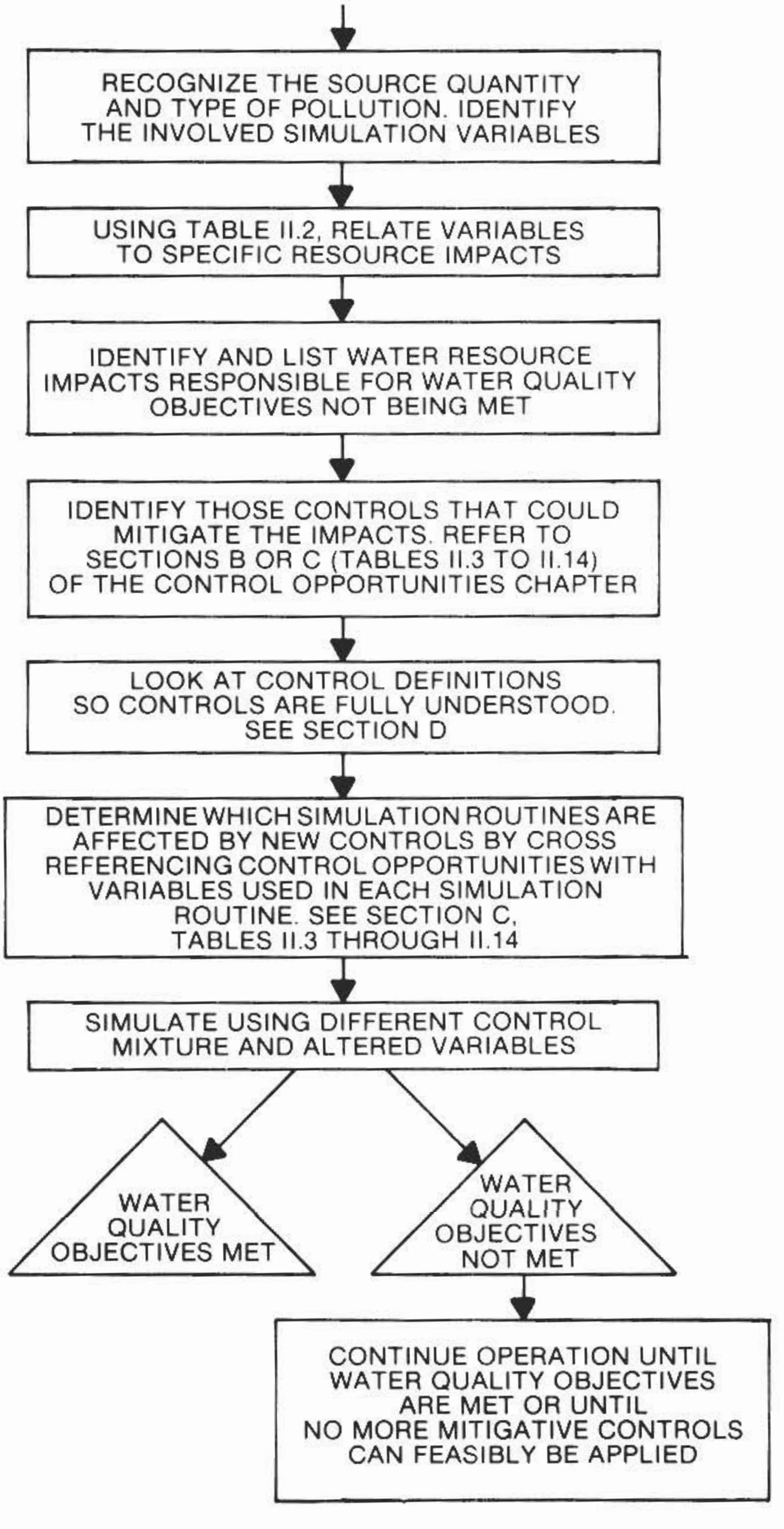

Figure II.A.3.—Example three procedure — continued.

is added to the silvicultural plan. For example, if a simulation shows too much sediment resulting from road related surface erosion, the next step would be to check the transportation portion of the silvicultural plan to find out what controls directed toward the problem are part of the plan. If plans call for the road surface to be "dirt," then a new control (Protect Road Surface Area) can be added to the plan to mitigate the surface erosion.

11. Then use section D for a description of the selected controls. Reference sources are listed in section D for those controls needing an expanded, technical definition.
12. Use section C to cross-reference the control opportunities with the variables and procedures used in the handbook simulation.
13. Simulate (using handbook procedures) the potential outcome of using the new mixture of mitigative controls to meet the water quality objectives.
14. If the water quality objectives are met, no further simulations using different mixtures of controls are needed (unless economics dictate several simulations). If the water quality objectives are not met, new mixes of controls will have to be chosen and simulated again using the handbook procedures.