

3E: TIMBER HARVESTING

Timber Harvesting Management Measure

The timber harvesting management measure consists of implementing the following:

- (1) Follow layouts for timber harvesting operations determined under the Preharvest Planning Management Measure, subject to adjustments made based on preharvest on-site inspections.
- (2) Install landing drainage structures to avoid sedimentation to the extent practicable. Disperse landing drainage over sideslopes.
- (3) Construct landings away from steep slopes and reduce the likelihood of fill slope failures. Protect landing surfaces used during wet periods. Locate landings outside streamside management areas.
- (4) Protect stream channels and significant ephemeral drainages from logging debris and slash material.
- (5) Use appropriate areas for petroleum storage, draining, and dispensing, and vehicle maintenance. Establish procedures to contain and treat spills that could occur during these activities. Recycle or properly dispose of all waste materials.

For cable yarding:

- (1) Limit yarding corridor gouge or soil plowing by properly locating cable yarding landings.
- (2) Locate corridors for streamside management areas according to the guidelines of the Management Measure for Streamside Management Areas.

For groundskidding:

- (1) To the extent practicable, do not operate groundskidding equipment within streamside management areas except at stream crossings. In streamside management areas, fell and endline trees in a manner that avoids sedimentation.
 - (2) Use improved stream crossings for skid trails that cross flowing drainages. Construct skid trails to disperse runoff and with adequate drainage structures.
 - (3) On steep slopes, use cable systems rather than groundskidding where groundskidding could cause excessive sedimentation.
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Management Measure Description

The goal of this management measure is to minimize the likelihood of water quality effects resulting from timber harvesting. This goal can be accomplished by taking precautions to control erosion and sedimentation during harvesting operations and by storing, handling, and disposing of petroleum products and vehicle maintenance products in an environmentally safe manner.

Reducing effects on soils and water quality from harvesting begins in the preharvest planning stage, when a system of roads, landings, and skid trails is planned. Preharvest planning, as described in the Preharvest Planning Management Measure, is performed to minimize the amount of disturbed area, which makes it easier to rehabilitate the site after

the operation is complete; locate roads on stable soils to minimize erosion and at a safe distance from streams; build stream crossings at the locations where they cause the least amount of instream disturbance and hydrological change; and limit disturbance to sensitive areas. Thoroughly review the Preharvest Planning Management Measure before incorporating the practices in this management measure into a harvesting plan. The practices in that management measure can serve as a guide for reducing soil disturbance and water quality effects during harvesting. Having a harvesting plan reviewed by a professional forester before starting any aspect of harvesting or road building is strongly recommended. The forester might be able to offer ideas specific to the planned harvest on how environmental damage and operational costs can be reduced.

Do an additional review of the harvesting plan in conjunction with a site visit to verify that the information used during planning is still valid. Aerial photos and topographic and soil maps can inaccurately represent actual conditions, especially if these media are more than a few years old. Before construction begins, verify that the soils and slopes where landings and skid trails are to be located are suitable to the use and that equipment maintenance or chemical handling areas are appropriately located. As the harvest progresses, make any alterations to the harvesting plan necessary to protect soils and water quality.

Conducting a harvest with attention paid to the potential for soil disturbance from the operation can result in significantly less water quality impairment than conducting a harvest with little or no attention paid to the potential for environmental damage. For instance, skid trails that are parallel to the slope of the land have far more potential to yield sediment-laden runoff than skid roads that run along the contour. Similarly, practices that minimize soil compaction on and prevent or disperse runoff from landings and loading decks can be implemented to reduce the potential for sediment-laden runoff and to minimize sediment delivery to surface waters. Incorporating these and other erosion reduction practices into a harvesting plan, conducting an on-site inspection during the planning stage before harvesting or road construction begins to ensure that the practices chosen are appropriate to the site, and properly implementing and maintaining the practices can significantly decrease water quality effects.

Spill prevention and containment procedures are necessary to prevent petroleum products from entering surface waters. Chemicals and petroleum products spilled in harvest areas can be transported great distances if they enter areas of concentrated runoff, and therefore can adversely affect water quality far from where they are spilled. Designating appropriate areas for the storage and handling of petroleum products and protecting these areas from precipitation can minimize the water quality effects that could result from spills or leakage.

Many studies have evaluated and compared the effects of different timber harvest techniques on soil loss (erosion), soil compaction, and overall ground disturbance associated with various harvesting techniques. The data presented in Tables 3-24 through 3-28 were compiled from many studies conducted throughout the United States and Canada. Some of the data presented in the table should be considered as older data that were based on operations conducted prior to current understanding and concern for water quality protection. The studies examined different harvesting systems (e.g., clear-cuts, selective harvesting) using a variety of techniques (e.g., cable yarding, skidding). Local factors such as climate, soil type, and topography affected the results of each study. The major

Table 3-24. Soil Disturbance from Roads for Alternative Methods of Timber Harvesting (Megahan, 1980)

| Logging System (State) | Percent of Logged Area Bared | | | Reference |
|--|------------------------------|-------------------------|-------|----------------------------|
| | Roads | Skid Roads and Landings | Total | |
| Tractor: | | | | |
| Tractor — clear-cut (BC) | 30.0 | — | 30.0 | Smith, 1979 |
| Tractor — selection (CA) | 2.7 | 5.7 | 8.4 | Rice, 1961 |
| Tractor — selection (ID) | 2.2 | 6.8 | 9.0 | Haupt and Kidd, 1965 |
| Tractor — group selection (ID) | 1.0 | 6.7 | 7.7 | Haupt and Kidd, 1965 |
| Tractor and helicopter — fire salvage (WA) | 4.5 | 0.4 | 4.9 | Klock, 1975 |
| Tractor and cable — fire salvage (WA) | 16.9 | — | 16.9 | Klock, 1975 |
| Ground Cable: | | | | |
| Jammer — group selection (ID) | 25–30 | — | 25–30 | Megahan and Kidd, 1972 |
| Jammer — clear-cut (BC) | 8.0 | — | 8.0 | Smith, 1979 |
| High-lead — clear-cut (BC) | 14.0 | — | 14.0 | Smith, 1979 |
| High-lead — clear-cut (OR) | 6.2 | 3.6 | 9.8 | Silen and Gratkowski, 1953 |
| High-lead — clear-cut (OR) | 3.0 | 1.0 | 4.0 | Brown and Krygier, 1971 |
| High-lead — clear-cut (OR) | 6.0 | 1.0 | 7.0 | Brown and Krygier, 1971 |
| High-lead — clear-cut (OR) | 6.0 | — | 6.0 | Fredriksen, 1970 |
| Skyline: | | | | |
| Skyline — clear-cut (OR) | 2.0 | — | 2.0 | Binkley, 1965 |
| Skyline — clear-cut (BC) | 1.0 | — | 1.0 | Smith, 1979 |
| Aerial: | | | | |
| Helicopter — clear-cut | 1.2 | — | 1.2 | Binkley ^a |

^a Estimated by Virgil W. Binkley, Pacific Northwest Region, USDA Forest Service, Portland, OR, nd.

conclusions of these studies regarding the relative effects of different timber harvesting techniques on soil erosion, summarized below, are shared among the studies and enable cross-geographic comparison:

- Aerial and skyline cable techniques are far less damaging than other yarding techniques.
- Tractor, jammer, and high-lead cable methods result in significantly more soil disturbance and compaction than skyline and aerial techniques.
- Skyline yarding serves far more area per mile of road than skidding.

Although skidding can be damaging, areas disturbed by skidding operations can be rehabilitated without a net economic loss to the landowner. An analysis of the costs and benefits of rehabilitating skid trails in the southeastern United States by planting different species of trees indicated that the benefit/cost ratios of using shortleaf pine, hardwood pine, and hardwoods were 5.1:1, 2.8:1, and 1.3:1, respectively. Shortleaf pine yielded the highest benefit for costs incurred (Dissmeyer and Foster, 1986).

Table 3-25. Soil Disturbance from Logging by Alternative Harvesting Methods (Megahan, 1980)

| Method of Harvest | Location | Disturbance (%) | Reference |
|--------------------------------|-----------|-----------------|-------------------------------|
| Tractor: | | | |
| Tractor — clear-cut | E. WA | 29.4 | Wooldridge, 1960 |
| Tractor — clear-cut | W. WA | 26.1 | Steinbrenner and Gessel, 1955 |
| Tractor — fire salvage | E. WA | 36.2 | Klock, ^a 1975 |
| Tractor on snow — fire salvage | E. WA | 9.9 | Klock, ^a 1975 |
| Tractor — clear-cut | BC | 7.0 | Smith, 1979 |
| Tractor — selection | E. WA, OR | 15.5 | Garrison and Rummel, 1951 |
| Ground Cable: | | | |
| Cable - selection | E. WA, OR | 20.9 | Garrison and Rummel, 1951 |
| High-lead — fire salvage | E. WA | 32.0 | Klock, ^a 1975 |
| High-lead — clear-cut | W. OR | 14.1 | Dyrness, 1965 |
| High-lead — clear-cut | W. OR | 12.1 | Ruth, 1967 |
| High-lead — clear-cut | BC | 6.0 | Smith, 1979 |
| Jammer — clear-cut | BC | 5.0 | Smith, 1979 |
| Grapple — clear-cut | BC | 1.0 | Smith, 1979 |
| Skyline: | | | |
| Skyline — clear-cut | W. OR | 12.1 | Dyrness, 1965 |
| Skyline — clear-cut | E. WA | 11.1 | Wooldridge, 1960 |
| Skyline — clear-cut | BC | 7.0 | Smith, 1979 |
| Skyline — clear-cut | W. OR | 6.4 | Ruth, 1967 |
| Skyline — fire salvage | E. WA | 2.8 | Klock, ^a 1975 |
| Balloon — clear-cut | W. OR | 6.0 | Dyrness ^b |
| Aerial: | | | |
| Helicopter — fire salvage | E. WA | 0.7 | Klock, ^a 1975 |
| Helicopter — clear-cut | ID | 5.0 | Clayton (in press) |

^a Disturbance shown is classified as severe.

^b C.T. Dyrness, unpublished data on file, Pacific Northwest Forest and Range Experiment Station, Corvallis, OR, nd.

Benefits of Timber Harvesting Practices

After a 1994 study of BMP implementation and effectiveness, the Virginia Department of Forestry concluded that harvesters often failed to seed bare soil with adequate ground cover. The department determined that ground cover of 70 percent or more is effective, while many sites studied had ground cover on only 0 to 35 percent of bare soil. The Vermont Agency of Natural Resources (1998) also studied the effectiveness of erosion control BMPs and concluded that the construction and proper placement of such BMPs before harvesting is essential for protecting water quality. The Agency also found that regularly maintaining BMPs increased the longevity of their effectiveness.

In general, poor BMP effectiveness can be due to many factors, including

- A lack of time or willingness to plan timber harvests carefully before cutting begins.
- A lack of skill in or knowledge of designing effective BMPs.

Table 3-26. Relative Effects of Four Yarding Methods on Soil Disturbance and Compaction in Pacific Northwest Clear-cuts (OR, WA, ID) (Sidle, 1980)

| Yarding Method | Bare Soil (%) | Compacted Soil (%) | Water Quality Effects |
|----------------|---------------|--------------------|-----------------------|
| Tractor | 35 | 26 | Greater |
| High-lead | 15 | 9 | |
| Skyline | 12 | 3 | |
| Balloon | 6 | 2 | Lesser |

Table 3-27. Percent of Land Area Affected by Logging Operations (Southwest MS) (after Miller and Sirois, 1986)

| Operational Area | Cable Skyline (% Land Affected) | Groundskidding (% Land Affected) | Water Quality Effects |
|--------------------------------|---------------------------------|----------------------------------|-----------------------|
| Cable corridors or skid trails | 9.2 | 21.4 | Greater |
| Landings | 4.1 | 6.4 | |
| Spur roads | 2.6 | 3.5 | Lesser |
| Water Quality Effects | Lesser | Greater | |

Table 3-28. Skidding/Yarding Method Comparison (after Patric, 1980)

| Harvesting System | Acres Served per Mile of Road | Water Quality Effects |
|-------------------|-------------------------------|-----------------------|
| Wheeled skidder | 20 | Greater |
| Jammer | 31 | |
| High-lead | 40 | |
| Skyline | 80 | Lesser |

- A lack of equipment needed to implement effective BMPs.
- The belief that BMPs are not an integral part of the timber harvesting process and can be engineered and fitted to a logging site after timber harvesting has been completed.
- A lack of timely BMP maintenance.

Best Management Practices

Harvesting Practices

- ◆ *Based on information obtained from site visits, make any alterations to the harvesting plan that are necessary or prudent to protect soils from erosion and surface waters from sedimentation or other forms of pollution.*
- ◆ *Fell trees away from watercourses whenever possible, keeping logging debris from the channel, except where debris placement is specifically prescribed for fish or wildlife habitat.*
- ◆ *Immediately remove any tree accidentally felled in a waterway.*

- ◆ *Remove unwanted slash from water bodies and place it above the normal high water line or flood level to prevent downstream transport.*

As discussed in Chapter 2 and in Chapter 3, section B, *Streamside Management Areas*, streams have natural amounts of organic debris (e.g., fallen leaves, twigs, limbs, and trees), and the amount varies with season, tree falls, storms, and so forth. Aquatic organisms are adapted to the presence of and variability in the quantity of organic debris in streams. Large woody debris, or LWD, affects channel morphology, provides structure and complexity to aquatic and terrestrial organism habitats, and is a source of nutrients for aquatic organisms. When the quantity of LWD and organic debris in general that reaches a stream is changed, either to too much or too little, it can be detrimental to the aquatic system's ecology and ability to support life. Removing excessive slash from a stream helps maintain water flow and avoids the addition of excessive nutrients. In instances where the addition of organic debris—especially LWD—to a stream is desirable, an appropriate amount may be left in stream channels or on stream banks. Slash left in streams adds nutrients, regulates stream temperature, and traps fine sediments where these effects are desirable (Jackson, 2000). Consult with a fisheries biologist or the state forestry or ecology department for specific guidance for your area.

Leave pieces of large woody debris in place during stream cleaning to preserve channel integrity and maintain stream productivity. Indiscriminate removal of large woody debris can adversely affect channel stability. Figure 3-34 presents one way to determine debris stability. State forestry or ecology departments can help with such determinations for particular regions and stream types.

Where desirable, leave slash on the harvest site and distribute it to provide good ground cover and minimize erosion after the timber harvest.

Leaving slash on disturbed soils can help reduce erosion until new vegetative growth is established. The quantity of slash to leave depends on the erodibility of the soil, though leaving an amount that provides 40 to 60 percent ground cover for soils that have low to high erodibility, respectively, is recommended. Leaving slash on the ground significantly reduces erosion potential. It also keeps the nutrients contained in the slash material on the site for incorporation into the soil and new vegetative growth.

Practices for Landings

- ◆ *Make landings no larger than necessary to safely and efficiently store logs and load trucks.*
- ◆ *Install drainage and erosion control structures as necessary.*

A slight slope on landings facilitates drainage. Also, adequate drainage on approach roads prevents road drainage water from entering the landing area.

- ◆ *Do not exceed a 5 percent slope on landing surfaces and shape them to promote efficient drainage.*
- ◆ *Do not exceed 40 percent slope on landing fills and do not incorporate woody or organic debris into fills.*
- ◆ *If landings are to be used during wet periods, protect the surfaces with a suitable material such as a wooden mat or gravel.*

- ◆ *Install drainage structures—such as water bars, culverts, and ditches—on landings to avoid sedimentation. Disperse landing drainage over side slopes. Provide filtration or settling if water is concentrated in a ditch.*

- ◆ *Upon completion of a harvest, clean up, re-grade, and revegetate landings.*

- Upon abandonment, minimize erosion on landings by adequately ditching or mulching with forest litter.
- Establish a herbaceous cover on areas that will be used again in repeated cutting cycles, and restock landings that will not be reused.

- If necessary, install water bars for drainage control.

- Landings should be ripped to break up compacted soil layers and allow water infiltration. This will also aid in the establishment of new vegetation.

- Runoff on and from landings should be dispersed with waterbars or dips.

- ◆ *Locate landings for cable yarding where slope profiles provide favorable deflection conditions so that yarding equipment does not cause yarding corridor gouge or soil plowing, which can concentrate drainage or cause slope instability.*

- ◆ *Locate cable yarding corridors for streamside management areas according to the Streamside Management Areas management measure. Avoid disturbing major channel banks in SMAs with yarded logs.*

Ground Skidding Practices

- ◆ *Skid uphill to log landings whenever possible. Skid with ends of logs raised to reduce rutting and gouging.*

This practice disperses water on skid trails away from the landing. Skidding uphill lets water from trails flow onto progressively less-disturbed areas as it moves downslope, reducing erosion hazard. Skidding downhill concentrates surface runoff on lower slopes

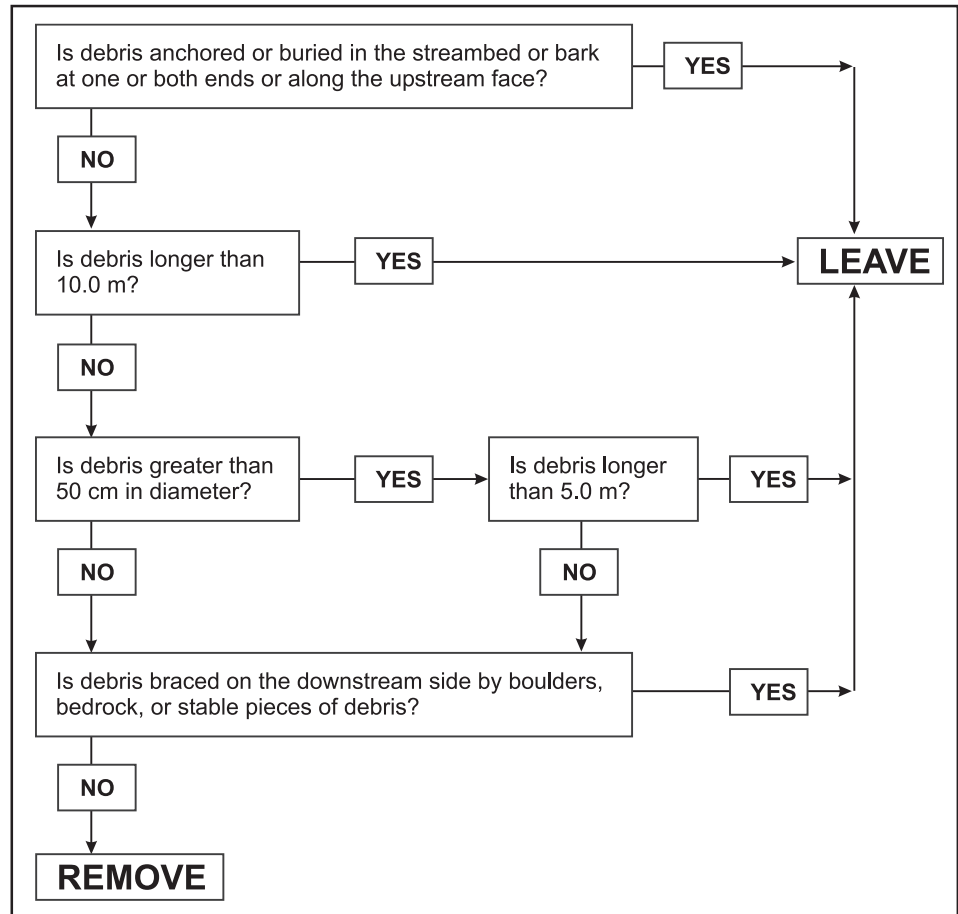


Figure 3-34. General large woody debris stability guide based on Salmon Creek, Washington (after Bilby, 1984).

along skid trails, resulting in significant erosion and sedimentation hazard. If skidding downhill, provide adequate drainage on approach trails so that drainage does not enter the landing.

- ◆ *Skid along the contour (perpendicular to the slope), and avoid skidding on slopes greater than 40 percent.*

Following the contour reduces soil erosion and encourages revegetation. If skidding has to be done parallel to the slope, skid uphill, taking care to break the grade periodically.

Avoid skid trail layouts that concentrate runoff into draws, ephemeral drainages, or watercourses and avoid skidding up or down ephemeral drainages. Use endlining to winch logs out of SMAs or directionally fell trees so tops extend out of SMAs and trees can be skidded without operating equipment in SMAs. In SMAs, endline trees carefully to avoid soil plowing or gouge.

Suspend ground skidding during wet periods, when excessive rutting and churning of the soil begins, or when runoff from skid trails is turbid and no longer infiltrates within a short distance from the skid trail. Further limitation of ground skidding of logs, or use of cable yarding, might be needed on slopes where there are sensitive soils and/or during wet periods.

Retire skid trails by installing water bars or other erosion control and drainage devices, removing culverts, and revegetating.

- After logging, obliterate and stabilize all skid trails by mulching and reseeding.
- Build cross drains on abandoned skid trails to protect stream channels or side slopes in addition to mulching and seeding.
- Restore stream channels by removing temporary skid trail crossings.
- Distribute logging slash throughout skid trails to supplement water bars and seeding to reduce erosion on skid trails.

Cable Yarding Practices

- ◆ *Use cabling systems or other systems when ground skidding would expose excess mineral soil and induce erosion and sedimentation.*

- Use high-lead cable or skyline cable systems on slopes greater than 40 percent.
- To avoid soil disturbance from sidewash, use high-lead cable yarding on average-profile slopes of less than 15 percent.

- ◆ *Avoid cable yarding in or across watercourses.*

When cable yarding across streams cannot be avoided, use full suspension to minimize damage to channel banks and vegetation in the SMA. Cut or clear cableways across SMAs where SMAs must be crossed. This will reduce the damage to trees remaining and prevent trees next to the stream channel from being uprooted.

- ◆ *Yard logs uphill rather than downhill.*

When yarding uphill, log decks are placed on ridges or hilltops rather than in low-lying areas. This approach results in less soil disturbance for two reasons: (1) lifting the logs

reduces their weight on the ground and thus the amount of friction and ground scouring, and (2) yard trails radiate outward from the elevated position of the log deck, dispersing runoff in numerous directions from the deck.

Downhill yarding does the opposite. The full weight of the logs is transferred to the ground, and runoff from all of the yard trails is directed downslope to the log deck, concentrating the erosive effect of rain. If yarding uphill is not possible, soil disturbance can be minimized during downhill yarding by suspending logs from a pulley system so that the logs are lifted partially or completely off the ground.

The amount of soil disturbance caused by yarding depends on the slope of the area, the volume yarded, the size of the logs, and the logging system. Megahan (1980) ranked yarding techniques (from greatest effect to lowest effect) based on percent area disturbed as follows: tractor (21 percent average), ground cable (21 percent, one study), high-lead (16 percent average), skyline (8 percent average), jammer in clear-cut (5 percent, one study), and aerial techniques (4 percent average). Aerial and skyline cable techniques are far less damaging than other yarding techniques.

The amount of road needed for different yarding techniques varies considerably (Sidle, 1980). Skyline techniques use the least amount of road area, with only 2 to 3.5 percent of the land area in roads. Tractor and single-drum jammer techniques use the greatest amount of road area (10 to 15 percent and 18 to 24 percent of total area, respectively). High-lead cable techniques fall in the middle, with 6 to 10 percent of the land used for roads. Compared to the skyline and aerial techniques, tractor, jammer, and high-lead cable methods result in significantly higher amounts of disturbed soil (Megahan, 1980). Figure 3-35 shows a typical cable yarding operation (OSHA, 1999).

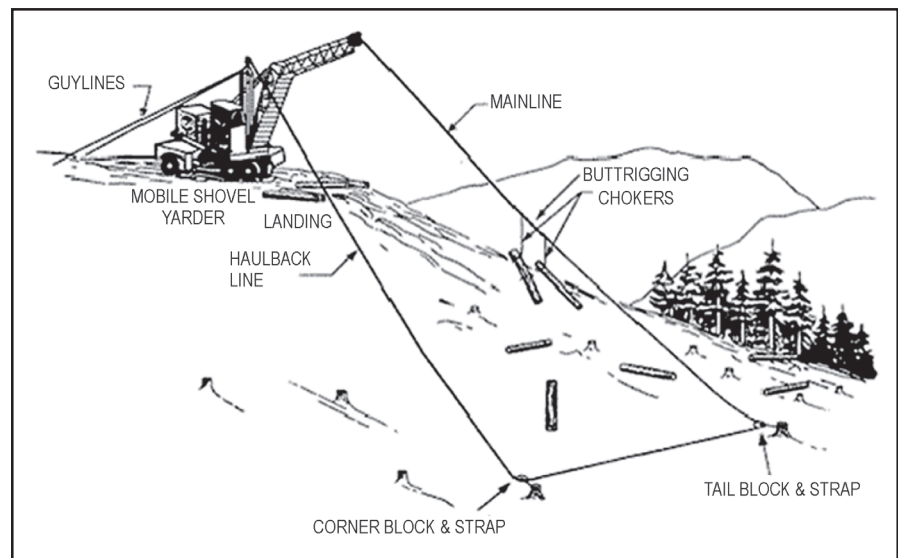


Figure 3-35. Typical cable yarding operation (OSHA, 1999).

Other Yarding Methods

◆ Horse logging

Horse logging can be a viable alternative to mechanized logging for small harvests or for sensitive environmental areas of a larger harvest. Horses give a lot of control for logging in partial cuts because logs are cut to log length, not left at tree length, and this improves maneuverability around trees that are left in place. This maneuverability combined with the narrower path needed by horses compared to a skidder means that fewer trees have to be removed solely for access. Soil is compacted and disturbed less with horse logging than with a skidder because a horse weighs about 1,600 pounds compared to a rubber-tired skidder that weighs about 10,000 pounds.

◆ *Helicopter yarding*

Helicopter yarding is a practical and environmentally friendly alternative yarding approach for use on public and private timberlands where other yarding systems would be physically, economically, or environmentally infeasible. According to the Helicopter Logging Association (1998), the benefits of helicopter timber harvesting include:

- Minimum damage is caused to the following:
 - The soil layer. Very little vehicular traffic is associated with the method.
 - Water resources. There is a negligible increase in stream turbidity compared to conventional yarding methods.
 - Riparian areas.
 - Wildlife habitat.
- Damage to retained trees is reduced. Fewer trees are felled per acre and ground-based skidders are absent.
- Road density is lower. A combined helicopter and tractor logging approach can reduce road density by approximately half compared to conventional tractor methods. Environmental damage is thus reduced, and forest access points are fewer.

◆ *Shovel harvesting.*

Shovel harvesting is more widely used in the coastal areas of the Pacific Northwest and the wetland areas of the Southeast than in other parts of the United States (Aust, Virginia Tech, personal communication, 2000). The process of shovel harvesting involves a shovel logger moving in lines parallel to a road, picking up logs that have been felled by a logger and lifting debris out of gullies as it moves forward. The shoveler starts at the nearest access point and moves logs until they are within reach of a road, where they can be retrieved (Figure 3-36) (Humboldt State University, 1999).

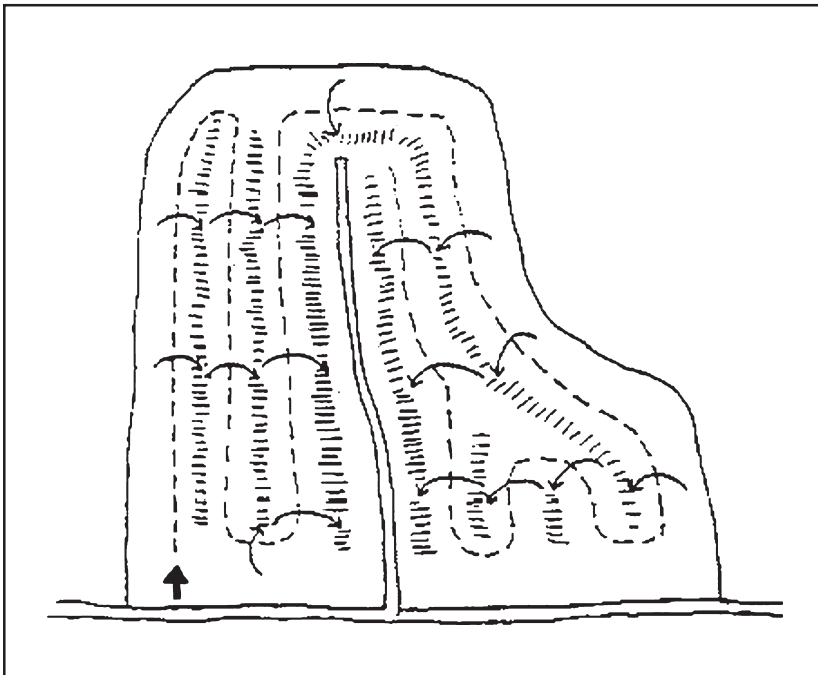


Figure 3-36. Common pattern of shovel logging operations (Humboldt State University, 1999)

Shovel logging is considered an environmentally friendly means to harvest timber. Operations require fewer people and fewer access roads, produce no skid trails, reduce ground disturbance in environmentally sensitive areas such as wetlands, and disturb SMAs less than any conventional logging method. Table 3-29 compares the costs of various yarding methods.

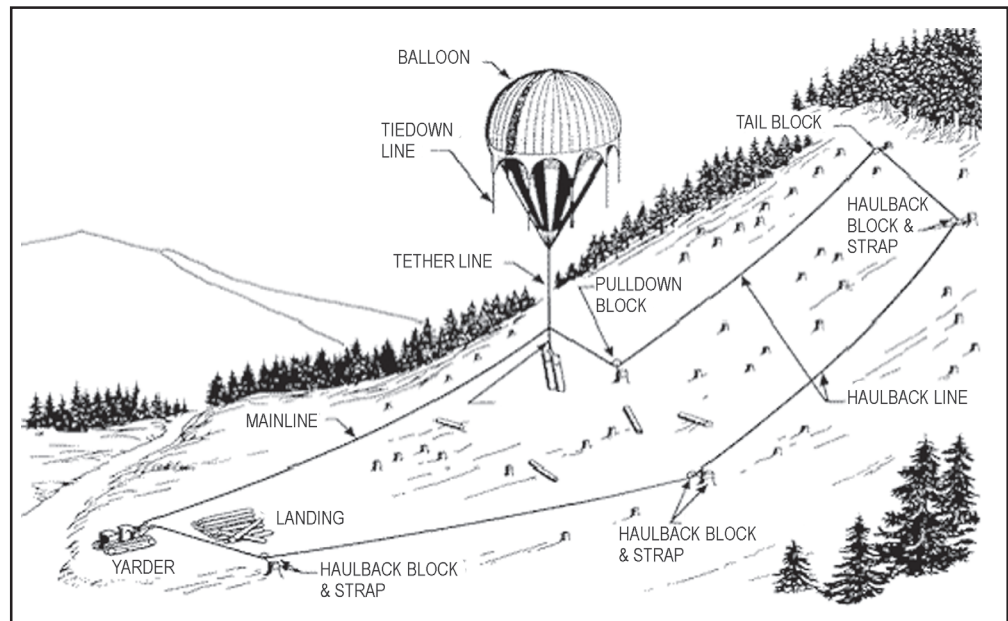
◆ *Balloon harvesting.*

Balloon harvesting involves using hot air or helium balloons to remove logs from a harvest site for loading on trucks (Figure 3-37). Because the logs are lifted off the ground and taken to a log landing, they are not dragged up or down a slope and disturbance to the

Table 3-29. Costs Associated with Various Methods of Yarding

| Yarding Method | Cost Range |
|--------------------|--|
| Cable Yarding | \$90 to \$135/ac, depending on yarding distance, crew size, and size of landing. <ul style="list-style-type: none"> • Clear-cutting costs \$50 to \$60/mbf • Thinning costs \$200/mbf |
| Helicopter Yarding | \$3,000 to \$3,500/hr; or \$180 to \$300/mbf \$175 to \$285/mbf |
| Shovel Harvesting | \$25.00 to \$83.84/hr |

ground is reduced. In areas where road construction is expensive, balloon harvesting can save money and protect the environment because of the smaller number of roads and skid trails needed. The environmental benefits realized from balloon harvesting are similar to those associated with helicopter yarding. Additionally, balloon harvesting permits access to wet sites such as wetlands and steep slopes where ground skidding would not be feasible because of the potential for environmental damage or the cost of road construction (Aust, Virginia Tech, personal communication, 2000).

**Figure 3-37. Balloon harvesting practices on a steep slope (OSHA, 1999).**

Winter Harvesting

Winter harvesting is a component of several state timber removal programs. In winter frozen ground provides conditions that do not exist during other times of the year for timber harvest activities and an opportunity for low-impact logging (Logan and Clinch, 1991). Areas where winter road construction and harvesting are particularly advantageous include wetlands (see Chapter 3, section J, Management Measure for Wetlands Forest Management of this document for a discussion of BMPs specifically for wetland harvesting), sensitive riparian areas, and sites where erosion and soil compaction would be expected to be a serious problem during nonfrozen conditions.

BMP guidelines for warmer months apply during winter harvesting as well. Additional practices that can be implemented to ensure the protection of water quality include the following (Logan and Clinch, 1991; North Dakota Forestry Service, 1999):

- ◆ *Consult with operators experienced in winter logging techniques.*
- ◆ *Compact skid trail snow before skidding logs.*

Compacting the snow prevents damage to soils that are still wet or not completely frozen.

- ◆ *Avoid steeper areas where frozen skid trails may be subject to erosion the following spring.*
- ◆ *Before felling in wet, unfrozen soil areas, use tractors or skidders to compact the snow on skid trails. Avoid steep areas where frozen skid trails might be subject to erosion the following spring.*

Petroleum Management Practices

- ◆ *Service equipment where spilled fuel or oil will not reach watercourses, and drain all petroleum products and radiator water into containers.*
- ◆ *Dispose of wastes and containers in accordance with proper waste disposal procedures.*

Do not leave waste oil, filters, grease cartridges, and other petroleum-contaminated materials as refuse in the forest.

- ◆ *Take precautions to prevent leakage and spills.*

Ensure that fuel trucks and pickup-mounted fuel tanks do not have leaks. Use and maintain seepage pits or other confinement measures to prevent diesel oil, fuel oil, or other liquids from running into streams or important aquifers, and use drip collectors on oil-transporting vehicles.

- ◆ *Develop a spill contingency plan that provides for immediate spill containment and cleanup, and notification of proper authorities.*

Have materials for absorbing spills easily accessible, and collect wastes for proper disposal.