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## Dedication

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Jerry Sedlak was a 1978 OSU Forest Engineering Masters Alum; served on the FE Department Advisory Committee; and assisted regularly with guest lectures, field trips, research efforts, and job opportunities for FE students. He was President of Emerald Valley Thinning, a member of the Associated Oregon Loggers, the Society of American Foresters, and actively involved in the Springfield, Oregon community. Jerry is remembered as an innovative and tenacious logger who coupled his professional engineering background with a deep respect for forestry.

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# Practical Methodology for Operational Layout of Commercial 

## Skyline Thinning Systems

by
Jennie L Cornell
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#### Abstract

Cornell, JL, and L Kellogg. 2004. Practical Methodology for Operational Layout of Commercial Skyline Thinning Systems. Research Contribution 45, Forest Research Laboratory, Oregon State University, Corvallis.

On-the-ground harvest unit layout, especially in skyline-thinning operations, is critical to meeting multiple resource objectives of the land manager and maintaining the economic viability of the timber harvesting operator. This phase of an operation can optimize the layout and harvesting of a sale or unit. Detailed layout by a knowledgeable professional can help to identify areas in the sale or unit that may be operationally or economically unfeasible to thin.

This publication is an overview of practical methodology aspects for the layout of skyline thinning operations. The information presented is drawn largely from the personal experiences of the authors, the individuals cited, and publications from research at Oregon State University. The publication provides a general outline of the components of the overall planning process that results in the implementation of skyline thinning operations on the ground.


Keywords: Commercial thinning, forest harvesting, forest engineering, harvest planning, logging, silviculture

## Abbreviations, Conversions, and Symbols

1 acre (ac) $=0.404 \mathrm{ha}$
1 foot $(\mathrm{ft})=0.305 \mathrm{~m}$
1 inch (in. or ") $=2.54$ centimeters (cm)
1 mile $(\mathrm{mi})=1.61$ kilometers $(\mathrm{km})$
${ }^{\circ}=$ degrees

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## Introduction

With the current trends in reduced harvests from older forests on public lands in the Pacific Northwest, the focus is shifting towards commercial harvesting of younger timber on both public and private lands to satisfy the demand for wood and fiber products. An


Figure 1. The planning process. increasing proportion of that harvest is from commercial thinning of young stands (McNeel and Dodd 1996), although commercial thinning has declined on private industrial lands in recent years.

This publication outlines the operational aspects of planning, laying out, and successfully implementing commercial skyline thinning in mountainous terrain. The main focus is on practical layout procedures. Most of the information is derived from years of practical experience by successful operators, technical reports, and papers from research and continuing education events conducted at the Department of Forest Engineering at Oregon State University. Kellogg et al. (2002) provide a broad overview of timber harvesting systems.

## Planning Process

The planning process (Figure 1) begins at the overall strategic level (Step 1). At this level, the land manager makes decisions for landscape-level planning on the basis of stand inventory structure, projected prices and market demands for different products, and environmental constraints. On private land, long-range timber harvesting schedules are planned for extended periods, usually through an entire rotation age. The manager considers a variety of factors to determine harvest schedules and production levels, such as combining one or more commercial thinnings with a final harvest. The combination and timing of harvesting techniques and silvicultural treatments are based on the desired outcomes and objectives of the land manager-for example, enhancement of wildlife habitat or a long-run
sustained yield for a given harvest volume. This concept in overall long-range planning applies to all types of land managers; however, the specific approach varies from the family forest owner with as few as 10 ac up to large industrial landowners with millions of acres, public lands managed by local, state and federal agencies, and tribal holdings.

Step 2 is outlining a tactical plan. This plan focuses on a shorter time frame, such as 5 or 10 yr . The plan focuses on generating specific target harvest volumes from the landscape, as defined in the strategic plan; developing an overall transportation plan to address current and future needs; prescribing harvesting and silvicultural systems; and meeting environmental constraints and wildlife habitat needs.

Step 3 is annual (i.e., project-level) planning. A harvest goal is set, based on the tactical plan, and the annual planning process allocates resources to accomplish the desired outcomes. This includes budgeting to ensure adequate resources are available to meet the overall plan objectives. On Federal land, project-level planning differs and is referred to as a "Logging Feasibility Report" (personal communication, Rick Toupin, Forest Engineering Specialist, USDA Forest Service Region 6, Portland, Oregon).

The last two steps are on-the-ground application of the general objectives across the landscape with specific unit plans and layout. The operational planning (Step 4) is specific and defines harvest unit boundaries and volumes; silvicultural prescriptions; transportation systems; general harvest systems, such as ground-based or cable-based operations; and the constraints and timing of the harvest operation. This is where the "how-to" is decided for implementing a harvest system design to accomplish forest management objectives. This step is largely completed by the land manager, the operations forester, or both.

This publication focuses on Step 5, the final step: on-the-ground layout. This step is often carried out by the logging contractor in consultation with the land manager.

The field layout of a skyline thinning unit is completed 1 wk to 3 mo before harvesting begins. Public agencies and a few private land managers typically complete the layout before the award of a contract. The specifications for appropriate equipment are used in designing the unit based on what appears to be the best logging system match for specific terrain and stand conditions. Logistical and operational feasibility problems may occur during logging, however, because each logging contractor can have different equipment and crew capabilities. Contract loggers often find it difficult and time-consuming to examine a commercial thinning sale when preparing a bid. Consequently, some problems may arise because of equipment limitations. Also, on-the-ground layout can lead to some areas of the operational harvest unit plan or timber sale being deleted because physical or economic limitations would make thinning infeasible. In this publication, for the most efficient process, we assume that the contractor is responsible for completing the final field layout in accordance with land manager objectives and constraints.

## Field Layout

## Importance

In planning on-the-ground implementation of operational plans, there are several factors to consider and a distinct process to follow to optimize the effectiveness of the layout activities and the harvesting system. The cost of harvest unit planning and layout is nominal compared with the gain in benefits from having a detailed, well-thought-out and well-executed plan. The increased efficiency and productivity of felling and of overall harvesting operations, including yarding and log hauling, far outweigh the time and money invested in a good operational plan and ground layout (Kellogg et al. 1998).

Many factors affect the investment in the harvest unit layout and plan. Those factors include experience of the layout person, availability of accurate topographic maps, steepness of the terrain, variability of the topography, drainage density, size and stocking distribution of the timber, density and species of the understory vegetation, maximum and average yarding distances, accessibility for equipment and people, weather conditions, and environmental and contract constraints. These factors should be considered when scheduling the layout work in order to allocate sufficient time for the layout person to complete a comprehensive and high-quality plan.

## Knowledge and Experience Base

Some operators hire layout persons on a contract basis. Others use personnel within their own organization or do the work themselves. Whether the layout person is a contractor, a company employee, or an owner and operator, the requirements for a successful layout plan are the same.

The layout person needs to be familiar, in particular, with the harvest system that is to be used and how it will meet the overall management and harvesting objectives for the unit. The yarder and skyline carriage capabilities and characteristics determine landing location and size, landing frequency, maximum yarding distances, lateral yarding limits, maximum payloads, and acceptable skyline rigging configurations. The equipment and layout required to cable-thin a young-growth plantation can be quite different from the equipment that was used to harvest the unit the first time, especially if it was a long-span setting yarding large timber in a clearcut.

The layout person must have expertise in applying different harvesting system configurations on the ground and know the minimum anchor, support, and lift tree requirements for a harvest system. Skills in map reading, drawing layout plans, trigonometry, and basic surveying are also required. Communications skills are invaluable when relating the completed layout plan to the landowner, the operator, and the timber-falling and yarding crews.

## Information Gathering Equipment Selection and Operational Considerations

- Availability of qualified operators with suitable equipment
- Compatibility with harvest unit, timber size, and stand management objectives
- Cost effectiveness
- Maximum yarding distance
- Volume and value removed
- Seasonal operating restrictions
- Other environmental constraints
- Review contract requirements and constraints with land manager
- Collect stand information data, preliminary logging plan maps, unit boundary maps, topographic maps, and transportation maps with hauls routes identified



## Unit Layout: Landing \& Corridor Location

- General reconnaissance of the entire unit
- Locate suitable and safe landings
- Decide on layout pattern (parallel versus fan-shaped)
- Identify problem areas and concerns
- Flag skyline corridors
- Clearly mark support, lift, and anchor trees and tailholds


## Mapping the Layout Plan

- Prepare unit layout map showing the location of landings, skyline corridors, and bearings/azimuths, and any special concerns or considerations
- Communicate and give copies of unit map to land manager, operator, falling crew, and yarding crew;
- Understand the harvest sequence


## Follow-Up

- Check back with crews after falling and yarding starts to make sure the layout is matched with the harvest system and sequence of operations
- Adjust as necessary

Figure 2. The ground layout process.

## Unit Layout

The general ground layout process is outlined in Figure 2. The important factors and steps in the process are discussed below.

## Information Gathering: Equipment Selection and Operational Considerations

The first step is to determine the appropriate equipment for the given operational unit. Factors to consider include availability of equipment in the region, timing of availability, operating cost, and, more importantly, cost per unit of production (e.g., \$/ton). The availability of qualified contractors with suitable equipment is a major component of this consideration. Other useful information to gather includes topographic maps, timber cruise data, road maps with haul roads and routes, preliminary logging plan maps from the landowner, and contract requirements.

Cable systems for skyline harvesting include three main categories: standing skyline, live skyline, and running skyline. Manual or mechanical slackpulling and non-slackpulling carriages can be used with these systems. Yarders are usually of two types: swing boom or nonswing boom. In cable thinning, a standing skyline configuration (single span or multispan) (Figure 3) with a slackpulling carriage typically is used. Both types of yarders have been used successfully with this skyline and carriage combination. Live-skyline and running-skyline systems increase potential for residual stand damage along skyline corridors and are generally not preferred for thinning applications. Also, these systems are not commonly used with intermediate supports, and intermediate supports are often used in skyline thinning.

The type of equipment used for yarding affects the number of lift trees and the minimum tree sizes and rigging configurations needed for anchors, support trees, lift trees, and tailholds for the harvesting system. Some basic guidelines can be used in the layout process to ensure operational feasibility. Examples of yarder guyline configurations and anchoring zones for selected yarders are illustrated in Figure 4. Guidelines for maximum vertical line angles are illustrated in Figure 5 (Pyles 1991). Guidelines for anchor size and minimum rigged tree size are given in Tables 1 and 2. Consultation with equipment manufacturers and the local Safety Code is recommended to verify these guidelines with the actual operational situation on the ground. Examples from the Oregon safety code are referenced in this publication; additional sources for safety codes in California, Idaho, Washington, and British Columbia are cited (see p. 11).


Table 1. Holding power of stumps. Within similar soil conditions and species, the holding power of a stump increases with the square of the diameter. ${ }^{1}$

| DBH (in.) | $(\text { DBH })^{2}$ (in. $\left.{ }^{2}\right)$ | Holding factor |
| :---: | :---: | :---: |
| 10 | 100 | 2.56 |
| 24 | 576 | 5.76 |
| 36 | 1296 | 12.96 |
| 48 | 2304 | 23.04 |

${ }^{1}$ From Forest Engineering Institute Notebook (1994).

Operational considerations for corridor layout include the average yarding distance, the maximum external yarding distance, and the lateral yarding distance between skyline corridors (Figure 6). Additional considerations include maximum payloads, volume and value removal per acre, timber size and species, location of suitable anchors and lift trees, access for landings and haul routes, topography, stream types and other drainages, type of suspension to be used (i.e., full versus partial $\log$ suspension), seasonal operating restrictions, residual stand damage restrictions, maximum piece size, property lines, survey monuments, and other environmental and regulatory constraints.

## Landings and Corridors

Once equipment feasibility and operational considerations have been evaluated and the harvest equipment and systems selected, the layout of the harvest unit on the ground begins. In skyline thinning, this primarily involves locating suitable landings and flagging the location of skyline corridors. This layout procedure involves a preliminary reconnaissance of the unit in order to develop an overall plan on how to log the unit safely and efficiently with the given equipment.

A preliminary reconnaissance map of a harvest unit is illustrated in Figure 7. Reconnaissance includes consideration of limiting factors such as road access and surfacing; truck turnaround locations for loading; landing locations and size; adequate guyline anchors for the yarder; adequate size and location of suitable trees for intermediate support, lift trees and tailholds; potential problem areas for log lift and


Figure 4. Examples of guyline configurations for various yarders (OROSHA, Chapter 437, Division 7). Consult the manufacturer, the appropriate Safety Code, or both for exact specifications.

## Safety Codes

## California

Department of Industrial Relations. (Cal/OSHA). Division 1. Chapter 4. Subchapter 13. (2001, November).
Safety Code: http://www.dir.ca.gov/title8/sub13.html
Division Management Officials:

| Acting Chief | Deputy Chief |
| :--- | :--- |
| Division of Occupational and Health Services | Cal/OSHA Enforcement |
| 455 Golden Gate Avenue, $10^{\text {th }}$ Floor | 2100 East Katella Avenue, Suite 215 |
| San Francisco, CA 94102 | Anaheim, CA 92806 |
| (415) 703-5100 | (714) 939-8093 |
| Fax (415) 703-5135 |  |

## Idaho

Idaho Minimum Safety Standards and Practices for Logging. Idaho Industrial Commission; IDAPA 17 Title 08 (1997, July).
Rules: http:www2.state.id.us/adm/adminrules/rules/idapa17/17index.htm
Administrative Rules
650 West State Street
Room 100
P.O. Box 83720

Boise, Idaho 83720-0306
(208) 332-1820

Dennis Stevenson, Administrative Rules Coordinator

## Oregon

Oregon Safety and Health Code. (OR-OSHA). Oregon Administrative Rules. Division 7. Chapter 437.
Subdivisions 0600-0690. (2003, December).
Rules: http://www.cbs.state.or.us/external.osha/standards/div_7.htm
Field Offices: http://www.cbs.state.or.us/external.osha/maps.htm

## Washington

Safety Standards for Logging Operations. Washington Administrative Codes. (WAC). Chapter 296-54. (2003, May).
Washington Administrative Codes: http://www.leg.wa.gov/wac/index.cfm?fuseaction=chapterdigest\&chapter =296-54
Washington Department of Labor and Industries Area Offices: http://www.lni.wa.gov/Main/ContactInfo/OfficeLocations/default.asp

## British Columbia

Worker's Compensation Board of British Columbia. Occupational Health and Safety Regulation. Part 26 Forestry Operations. (2003, December).
Regulations: http://regulation.healthandsafetycentre.org/s/Part26.asp
Labor and Industries Home Page: http://www.worksafebc.com/


- Guyline anchors

Cati/Ground based yarding
$\ldots \rightarrow$ Small Type N Stream (20ff brush $\begin{gathered}\text { buffer) }\end{gathered}$
$x \times x$ Sharp topog break
$\wedge$ Ridgeline
... Old surfaced read (Impassable)

* Surfaced landing


Planned-sales


Figure 7. Reconnaissance map and field notes.


Figure 8. Designed landing for a Koller 501 yarder.
skyline deflection; and the overall sequence of harvesting. Sometimes a surveyed traverse of the unit boundaries is completed to provide better control for the overall unit layout.

## Locating Landings

Location of suitable landing sites is a key component of the initial layout. Figure 8 illustrates an ideal designed landing, and Figure 9 is a photo of a suitable landing. Some things to consider when choosing suitable landing sites can be summarized in a checklist:
$\checkmark$ Where will the yarder be positioned?
$\checkmark$ What is the direction of haul?
$\nabla$ Where is the truck turnaround?
$\checkmark$ Will the guylines interfere with log processing, decking, or loading? (This is a greater concern with a fan-shaped yarding corridor layout.)
$\checkmark$ Is the size adequate for the yarder and loader, tree processing equipment, and log decking and loading?
$\checkmark$ What are the $\log$ chute possibilities?

## Koller 501 yarder with standing skyline and mechanical slackpulling carriage


$\checkmark$ What are the road conditions into the landing?
$\checkmark$ Are there safety concerns with soft edges, snags, high cutbanks?
$\checkmark$ Where can the decks be built safely?
$\square$ Where will the flow of yarding begin?
$\checkmark$ What is the required sorting for grade and species mix?
$\checkmark$ Are other activities going on nearby, such as ground-based skidding or falling?
$\checkmark$ Is there room for the crew transport vehicles and fire truck?
$\checkmark$ Are through traffic and recreational use on the roads of concern?

Figure 9. A suitable landing, with yarder and loader.


Figure 10. Landing operations diagram for a Koller 300 yarder and rubbertired skidder swinging logs from the chute to a decking location. Consult the manufacturer, the appropriate Safety Code, or both for exact specifications.

The abundance and location of suitable guyline anchors are other concerns. Figure 10 illustrates a Koller K300 yarder and the recommended guyline zones. The landing location and design should include the guyline anchor locations and the potential for their interfering with landing turns in the $\log$ chute, log decking, loading logs on trucks, log hauling, and other vehicular traffic.

## Locating Corridors

The overall layout should maximize the number of corridors perpendicular to the slope. A unit layout with sidehill corridors (Figure 11) and downhill yarding should be avoided. Occasionally landing locations, topography, or other operational limitations may force placement of part or all of a corridor on a sidehill. Sidehill corridors increase the potential for stand damage, especially along the downhill side of the corridor. Gravity pulls the turn of logs downhill during the inhaul cycle, increasing the chances for contact with residual trees along the lower edge of the corridor. Even where the skyline is offset towards the uphill side of the corridor, there is potential for increased tree damage. In addition, opportunity for yarding hang-ups on the downhill standing trees is increased. Downhill skyline thinning also presents a higher risk for stand damage and yarding hangups.


Corridors should be straight and <1200-1500 ft slope distance in length, depending on the yarder (Figure 12). This keeps lateral excursion of the skyline to an acceptable level, minimizing damage to the corridor trees and making it easier to keep the corridors straight. The corridors should be between $100-200 \mathrm{ft}$ apart, depending on the specific yarder and carriage, to minimize residual stand damage and optimize yarding efficiency.

Parallel skyline corridors (Figure 13) and continuous roadside landings are commonly used in topography having continuous slopes that are more or less perpendicular to the corridors. Parallel skyline roads may be used on topography that is sloping gently in one continuous direction, even though it is not entirely perpendicular to the road. The road must be wide enough to provide for safe landing and decking of the logs. This type of layout includes several advantages: the landing size is relatively small, yarder guyline locations usually do not interfere

Figure 11. Sidehill corridor.


Figure 12. A long straight corridor.

with loader operations, it is relatively simple to lay out on the ground, and the yarding area per skyline corridor is optimized. The yarder must be moved with every road change, however, and the landing size and decking area are usually limited by the road width.

Fan-shaped or wagon-wheel-patterned skyline roads and a common landing (Figure 13) are typically used at the end of an access road, where adequate landings are limited, or in alignment with a topographic feature, such as a ridgeline, where parallel corridors would greatly increase sidehill yarding. Advantages of the common landing include a relatively large work area for landing turns, limbing and bucking trees, and decking and loading logs. The need to move the yarder and guylines with skyline road changes also is minimized; however, guyline anchor locations may require changing when the yarder position is changed on the same landing. The fan-shaped yarding pattern presents several possible disadvantages: a sizeable area immediately in front of the landing, where all of the skyline corridors converge, may be opened up; the larger landing occupies more of the productive land base; yarder guyline locations may interfere with loader operations; and the yarding area per skyline road is less than that with parallel corridors.

A feasibility analysis of a skyline corridor may be accomplished by running a ground profile along the centerline of a proposed corridor, taking notes on the location, size, and species of suitable intermediate support and lift trees and a tailhold. This profile can then be entered into a skyline payload analysis program such as LOGGERPC V. 4.0 (2002). This program analyzes the profile for operational feasibility and provides useful information for the unit layout process. The output includes information such as maximum allowable payload, line tensions given certain rigging configurations for the skyline corridor, an intermediate support jack passage angle, and forces on the intermediate support jack(s). The program can also help determine if the skyline corridor is feasible and confirm the location of support trees and rigging heights for support jack(s) and the lift tree block. Heavy brush and broken terrain can increase the difficulty of a skyline profile survey.

## Flagging Corridors

Once the suitable landings are located, skyline corridor centerlines are flagged on the ground. Corridor azimuths are determined from a combi-

Figure 13. Parallel and fan-shaped patterns of corridors in a completed skyline thinning unit.
nation of factors, including skyline corridor planning on maps (Figure 14), designed spacing between corridors, and ground/stand conditions. The key for flagging in a workable corridor is to make sure it is straight (personal communications, May 2001: P Bailey, Skyline Thinning Co., Springfield, Oregon; H Christensen, Northwest Timberland Consulting, Eugene, Oregon; B Cornell, Miller Timber Logging, Inc., Philomath, Oregon). The problems of flagging straight corridors and some layout practices are presented in the Tools, Techniques, and Procedures section, pp. 21-24). Skyline corridors typically vary in width from 12 to 16 ft . The centerline flagging needs to be visible and consistent in pattern, and what the markings represent must be communicated to the operator and falling crew.

Tail trees and lift trees are located at the end of the skyline corridor and provide lift for the skyline and adequate carriage clearance. The OR-OSHA recommendations for minimum tail tree size, based on skyline size and rigging height, are provided in Table 2.

Intermediate support trees are usually located just below the landing; mid-span on long, even slopes; or at a significant topographic break along the corridor. Generally, no more than two supports are used on any one corridor because of the operational feasibility and cost of rigging. It is usually easier to locate one suitable tree along the corridor than to find and flag a pair. It is often helpful to mark several possible support trees at various positions along the corridor to provide options for the hooktender to rig.


Ft
Figure 14. Unit layout map with flagged skyline corridors and field notes.


Figure 16. Single-tree intermediate support: (a) sideblock, (b) centerblock. Two guylines are typically used with the side-block rigging configuration. In the centerblock configuration, additional guylines may be needed on either the right or the left side of the support tree, depending on the resulting force on the tree (see Figure 19). Consult the appropriate Safety Code for exact specifications.

The supports may have a double-tree (Figure 15) or a single-tree (Figure 16) configuration (Anderson and Pyles 1992). Single-tree configurations are either side-block (Figure 16a; the upper block pulls to the side of the tree in the direction of the intermediate support line) or center-block (Figure 16b; the intermediate support line 2 goes through the upper block, which is usually aligned with the center of the tree). Support trees can be rigged quickly ( $\sim 0.5$ to 1 hr ) once the rigging is carried to the location. Rigging guidelines recommended by OR-OSHA for a double-tree intermediate support are given in Table 3. All trees used for rigging should be straight, sound, live conifers and meet or exceed the guidelines specified in the Safety Code.

In general, to begin a new setting, the flagging is started at the landing and continued downslope to the lift tree or tailhold. Flagging can start at the lift tree or intermediate support trees if these features are more limiting than the landing location. In sparsely stocked or mixed stands, suitable lift trees and tailholds often are lacking at the back end of the corridor. In these situations, it is best to begin at the back end of the corridor at a suitable lift tree or tailhold and run the skyline corridor back to the landing.

Occasionally, a situation warrants the use of tree-marking paint in addition to flagging to delineate the edges of the corridor, lift trees, tailholds, and guyline anchors. Tree fell-

Table 3. Recommended rigging guidelines for a double-tree intermediate support system ${ }^{1}$.

| Dragging Ioad size (lb) | Intermediate support DBH (in.) when rigging height in tree is ${ }^{3}$ |  |  |
| :---: | :---: | :---: | :---: |
|  | line, minimum size ${ }^{2}$ (in.) | $<30 \mathrm{ft}$ | 30-40 ft |
| 0-5,000 | 7/16 | 11.0 | 13.0 |
| 5,000-6,000 | 1/2 | 12.0 | 14.0 |
| 6,000-8,000 | 9/16 | 12.5 | 14.5 |
| 8,000-10,000 | 5/8 | 13.0 | 15.0 |
| 10,000-14,000 | 3/4 | 14.0 | 16.0 |
| 14,000-19,000 | 7/8 | 14.5 | 17.0 |
| 19,000-25,000 | 1 | 15.5 | 18.5 |
| 25,000-32,000 | $11 / 8$ | 16.0 | 19.5 |
| 32,000-40,000 | $11 / 4$ | 17.0 | 20.5 |
| 40,000-48,000 | $13 / 8$ | 17.5 | 21.5 |

${ }^{1}$ OR-OSHA Chapter 437, Division 7.
${ }^{2}$ Line sizes are based on IWRC extra-improved plow steel (Studier and Binkley 1974, p. 25). Smaller rope of equivalent breaking strength is acceptable. Tree diameters are for firmly rooted, sound, straight Douglas-fir trees. Other coniferous trees may be used, provided the loads are reduced $25 \%$. For example, a $13-\mathrm{in}$. western hemlock support tree rigged at 30 ft can carry a maximum 7500-lb load.
${ }^{3} \mathrm{Dbh} 4.5 \mathrm{ft}$ above ground
ing often knocks flagging down. In other situations, where there is wide spacing between residual trees, it can be difficult for the rig-up crew to locate the corridor for laying out the haywire and rigging trees. When laying out the corridor in these situations, it can be helpful to go off the corridor and paint the corridor number and an arrow pointing to the corridor.

The options for proceeding with the layout of subsequent corridors depend on the topography and other features of the unit and thinning operation. All intermediate support trees and the lift trees need to be marked to reserve them from being felled during the thinning. The tailhold is marked to be felled, and it is best to mark all in-unit trees that will be felled for anchors so that the fallers can adjust tree selection to meet the thinning prescription and leave higher stumps for rigging to anchors.

In flagging the centerline of the skyline corridor, the flag line generally should be within $3-5 \mathrm{ft}$ of the bole of the lift tree. Also, according to OR-OSHA ${ }^{1}$ rules, the tailhold should be within $\pm 8^{\circ}$ of the bearing of the


Figure 17. Guidelines for placement of support trees, lift trees and anchors. Consult the appropriate Safety Code for exact specifications.

[^0]

Figure 18. Single-tree intermediate support (side-block rigging) with (a) one guyline and (b) two guylines. Consult the appropriate Safety Code for exact specifications.


Figure 19. General guyline configuration for a single-tree intermediate support (center-block rigging). Consult the appropriate Safety Code for exact specifications.
corridor when projected behind a lift tree. Double support trees should not be $>20-25 \mathrm{ft}$ apart or $<10 \mathrm{ft}$ apart and not $>10 \mathrm{ft}$ in difference on the perpendicular from the corridor. Single-tree support trees should be 3-10 ft from the center of the skyline corridor. Factors that affect these distances include the steepness and amount of sideslope of the ground and the lean of the trees from vertical. Figure 17 illustrates the general guidelines. Guidelines for minimum slope distances for desired guyline angles on various slopes are shown in Figure 4.

Recommended guyline configurations for intermediate support trees are illustrated in Figures 18 and 19. Figure 20 illustrates the guyline configuration for a lift tree. Most safety codes require two guylines on liff trees; additional guylines may be needed, depending on the terrain, tree species, and logging conditions. When two guylines are used, the two guylines should be located either in front of or behind the lift tree, depending on the yarding direction (uphill or downhill) and the resultant force angle exerted by the skyline on the lift tree.

## Mapping the Layout

As the layout progresses, the landing locations and skyline corridor locations are mapped (Figure 14). The skyline corridors may be numbered to indicate the preferred sequence for felling and yarding. In addition, potential problem areas (e.g., rock bluffs, understocked nonthinning


Figure 20. Skyline positioning limits for a taillift tree. Consult the appropriate Safety Code for exact specifications.

Final layout as of 12-20-00 NOTE．Corridors $\# 5$ and $\# 9-$ Stay within 50 feet of
lift tree IIIIArea to Exclude（Unyardable）
（3）Flagged corvidars．
$s$ Intermediate support
$L$ Lift tree
$x$ Tailhold anchor
コスデン Directional falling／linepull
－．－Skid trail
Roads with surfacing
Contours 40 ft interval
Planned sales


Figure 21．Completed corridor layout map with field notes and instructions．
areas）and the felling pattern for long corners or special areas that do not follow a regular layout and yarding pattern should be identified on the map．

A map with a completed setting layout is shown in Figure 21．Some maps will also include the location and description（e．g．，species and tree size）of the intermediate support trees，lift trees，tailholds，and anchors．The map shows skyline corridors with a common landing．There are advantages and disadvantages to different patterns of layouts and associated reasons for using them，as mentioned previously．

When the skyline corridor layout for each unit is complete，copies of the layout map are provided to the contract administrator（if applicable），the operator，the hooktender，and the falling crew，at a minimum．It is critical that the falling crew understand the overall unit layout and the falling and yarding sequence so they can fall the timber as needed for the safest and most efficient yarding．

## Follow－up

The final step is to follow up after falling and yarding have begun．This gives the layout person invaluable feedback on how well the layout matches the unit and the harvest system require－ ments and allows adjustments as needed to current and future projects．

## Tools, Techniques, and Procedures Tools

The basic tool in laying out skyline corridors is a good map showing accurate unit boundaries. A topographic map is best, but a good planimetric map is suitable. A corrected orthophoto of the unit is ideal. Another key piece of equipment is highly visible flagging, used to mark the centerline of the corridor, support trees, lift tree, tailhold, and anchors. Usually flags at least 12 in. long are hung along the centerline of the corridor at eye height and not more than 50-60 ft apart, such that they are intervisible. Typically, one piece of flagging is tied around support

To tailhold


Figure 22. Procedure for prolongation of a straight line for corridor location.


Figure 23. Hand compass method to offset around obstacles in corridor.

from the current position to the previous ribbons and prolonging a straight line. Although this is usually done by eye without the aid of surveying equipment, a staff compass can improve the accuracy of the backsight. Occasionally, as work progresses along the corridor, the bearing of the line is checked with the compass to ensure that it is not diverging because of local attraction or other errors. This is important when an obstacle is encountered along the skyline corridor. To offset around the obstacle, visual rectification ("eyeballing") and use of the hand compass (Figure 23) ensures prolonging the line of sight in a straight line through the object. If a staff compass or more sophisticated piece of equipment is used, a perpendicular or angular offset may be used to get around the obstacle and keep the corridor centerline straight (Figure 24).

One key component of successful prolongation of a backsight is prolonging only a distance that is very similar to the distance of the backsight. Prolongation of a short backsight for a long distance can introduce unacceptable error.

Using a plumb bob to line up the backsight on the preceding ribbons works well to keep the line straight on steep ground with slope changes, such as when crossing a drainage or sidehill area.

## Procedures

Gathering information on a skyline corridor for feasibility and payload analysis is straightforward. A survey of the targeted skyline corridor is completed between the landing and tailhold. The profile may be run from top to bottom, or in reverse. Information collected along the centerline of the corridor includes, but is not limited to, the slope distance and percent slope between each terrain point; location, size, and species of potential intermediate support trees, lift trees or tail trees, tailholds, and other anchors; and any special operations problems (e.g., full suspension over a stream, rock bluffs, etc.). There are similarities and differences in laying out parallel or fan-shaped skyline corridors.

The procedure for laying out parallel skyline corridors is quite simple (Figure 25). Begin the first corridor from the road at a designated bearing. At the end of the corridor, pace off the set lateral yarding distance at $90^{\circ}$ from the current corridor to the end of the next corridor. From a suitable tailhold and lift tree, run this corridor back to the roadside landing at the reverse bearing of the first corridor. Once on the road, pace off the set lateral yarding distance to the beginning of the next corridor and continue, repeating the process


Figure 25. Layout of parallel skyline corridors.

Option 1: Return to landing


Option 2: Run line back up hill

used to run the first corridor. If landings are a concern on the road, another option is to pace the distance to the next landing on the road before running the first corridor to check the landing location, and then match that distance at the back end of the first corridor. Continue with either one of these procedures until the topography, road width and conditions, or both justify another type of layout (e.g., fan-shaped corridor pattern).

Laying out fan-shaped corridors can get more complicated and may involve more effort. On the unit map, tentatively lay out the skyline corridors to scale for an entire setting from a common landing. Begin on one side of the setting at a predesignated bearing calculated from the harvest unit map. Run in the centerline for this corridor on the ground from the landing to the tailhold. If the layout is good on the ground, there are two alternatives for running in the next skyline road (Figure 26).

The first option is to return to the landing to begin the second skyline road from the exact location of the first. The length and bearing for the second skyline road are calculated from the map harvest unit by using the scaled horizontal distance and trigonometry of a right triangle to figure the angle difference in the bearings. The remaining setting roads are laid out in the same manner. Although each corridor begins at the exact desired location on the landing, this involves some unproductive time walking back to the landing after each corridor. Table 4 summarizes the angle to turn to locate the next skyline road in this manner with various tailhold (or lift tree) spacings.

A second option, on completion of the first corridor, is to pace off the horizontal offset distance to the tailhold of the next corridor. Measure the length of the corridor on the map. Using the same mathematical technique mentioned above, calculate the bearing of the second corridor. From the tailhold, run the second skyline corridor back to the landing. When successful, this procedure reduces the amount of unproductive time spent walking back to the landing after each corridor. In addition, beginning at the tailhold ensures that a suitable anchor and lift tree are located for the corridor. This

Figure 26. Layout of a fan-shaped corridor pattern.

Table 4. Angle $\left({ }^{\circ}\right)$ to turn from current road to locate next road (starting at landing).

| Horizontal distance <br> to tailhold (ft) | Tailhold spacing (ft) |  |  |
| :---: | :---: | :---: | :---: |
|  | 50 | 100 | 150 |
| 100 | 29.0 | 60.0 | 97.2 |
| 200 | 14.4 | 29.0 | 44.0 |
| 300 | 9.6 | 19.2 | 29.0 |
| 400 | 7.2 | 14.4 | 21.6 |
| 500 | 5.7 | 11.5 | 17.3 |
| 600 | 4.8 | 9.6 | 14.4 |
| 700 | 4.1 | 8.2 | 12.3 |
| 800 | 3.6 | 7.2 | 10.8 |
| 900 | 3.2 | 6.4 | 9.6 |
| 1000 | 2.9 | 5.7 | 8.6 |
| 1100 | 2.6 | 5.2 | 7.8 |
| 1200 | 2.4 | 4.8 | 7.2 |
| 1300 | 2.2 | 4.4 | 6.6 |
| 1400 | 2.0 | 4.1 | 6.1 |
| 1500 | 1.9 | 3.8 | 5.7 |

Table 5. Angle ( ${ }^{\circ}$ ) to adjust original azimuth in order to calculate new azimuth from landing to tailtree.

| Horizontal distance | Offset to tailhold (ft) |  |  |  |  |
| :---: | ---: | ---: | ---: | ---: | ---: |
| to tailhold (ft) | 10 | 20 | 30 | 40 | 50 |
| 100 | 5.7 | 11.5 | 17.3 | 23.1 | 29.0 |
| 200 | 2.9 | 5.7 | 8.6 | 11.5 | 14.4 |
| 300 | 1.9 | 3.8 | 5.7 | 7.6 | 9.6 |
| 400 | 1.4 | 2.9 | 4.3 | 5.7 | 7.2 |
| 500 | 1.1 | 2.3 | 3.4 | 4.6 | 5.7 |
| 600 | 1.0 | 1.9 | 2.9 | 3.8 | 4.8 |
| 700 | 0.8 | 1.6 | 2.5 | 3.3 | 4.1 |
| 800 | 0.7 | 1.4 | 2.1 | 2.9 | 3.6 |
| 900 | 0.6 | 1.3 | 1.9 | 2.5 | 3.2 |
| 1000 | 0.6 | 1.1 | 1.7 | 2.3 | 2.9 |
| 1100 | 0.5 | 1.0 | 1.6 | 2.1 | 2.6 |
| 1200 | 0.5 | 1.0 | 1.4 | 1.9 | 2.4 |
| 1300 | 0.4 | 0.9 | 1.3 | 1.8 | 2.2 |
| 1400 | 0.4 | 0.8 | 1.2 | 1.6 | 2.0 |
| 1500 | 0.4 | 0.8 | 1.1 | 1.5 | 1.9 |

- Add the angle to your original azimuth if you offset to the right from your original line to locate a tailtree.
- Subtract the angle from your original azimuth if you offset to the left from your original line to locate a tailtree.
- Right and left offsets are defined off the original line, with your back to the landing.
- To flag the new corridor from the tail tree to the landing, either add $180^{\circ}$ to the new azimuth to get the back azimuth, or backsight with the south needle aligned with the north declination arrow.

Landing


Calculate new bearing:
$\mathrm{S} 10^{\circ} \mathrm{W}-2.9^{\circ}=\mathrm{S} 7.1^{\circ} \mathrm{W}$ from the landing or $\mathrm{N} 7.1^{\circ} \mathrm{E}$ from the lift tree

Missed lift tree
by 50 ft

Figure 27. Application of a corrected bearing.
technique works well when used by an exceptionally skilled layout expert in areas with relatively short yarding distances ( $<1000 \mathrm{ft}$ ), brush that is not too heavy, uniform topography, and well-stocked stands.

When one is working with a distinctive ridgeline system, another option is to center the first corridor of the setting down the ridgeline. The remainder of the corridors for the setting can be laid in on either side of this corridor by using the above techniques.

On occasion, when a skyline corridor is run on the ground, it may not line up with intermediate support trees, a lift tree, the landing, or a tailhold anchor. If the distance along the skyline corridor is known or can be determined from a map and the offset distance to the desired tree or set of trees is known, simple trigonometry may be used to calculate the angle offset to be applied to the bearing of the current corridor to get a corrected bearing. Beginning at a known point, the corridor may be rerun at the corrected bearing (Figure 27). Table 5 is a table of offset distances and angle adjustments to correct the corridor alignment from the landing to line up with the lift tree and/or tailhold.

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[^0]:    ${ }^{1}$ Refer to Safety Codes for specific regions for exact specifications.

