

# Management Of Timber Under A Habitat Conservation Plan (HCP) In The Pacific Northwest

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**ABSTRACT.** *West Fork Timber Company (WFTC) is a private timber company that manages approximately 54,000 acres on the western slopes of the Cascade Mountains. West Fork's goal was to develop a long-term harvest plan that would improve asset value over time, while simultaneously ensuring that habitat requirements set forth in their Habitat Conservation Plan (HCP) would be realized. The primary constraint set forth in the HCP is the maintenance of a unique Dispersal Landscape Index (DLI) within a narrow (+/- 5%) range of pre-determined levels for the life of the HCP. The DLI is derived by assigning different values to areas within specific distances of existing dispersal habitat (DH) in a complex formula; the dispersal habitat (DH) values are then summed and divided by the total number of acres in the forest to arrive at a DLI value for the ownership. This paper discusses DLI calculation and the challenges involved in modeling this problem, including the types of constraints needed in the strategic model, the spatial allocation of activities associated with existing and future stands in a Model II framework, and the development of a rapid DLI calculator to facilitate the evaluation of alternatives. Overall, West Fork was able to meet objective of higher returns from the forest while simultaneously demonstrating improvement in dispersal habitat over the next four decades.*

**Key Words:** habitat conservation plan, northern spotted owl, spatial planning, spatial restrictions, harvest scheduling.

## INTRODUCTION

West Fork Timber Company, LLC (WFTC) is a private timber company that manages approximately 54,000 acres on the western slopes of the Cascade Mountains in Washington, known as the Mineral Tree Farm. In 1993, the US Fish and Wildlife Service (USFWS) believed that continued harvest of mature forest habitat on WFTC lands presented the risk for an incidental take of resident northern spotted owls (*Strix occidentalis caurina*). To minimize and mitigate the effects of any incidental take, Murray Pacific Corporation, WFTC's parent company and owners of the Mineral Tree Farm, agreed to manage the tree farm under the terms and conditions of a habitat conservation plan (HCP) for 100 years (Murray 1993). The permit provided assurance that WFTC could continue to operate the tree farm without risk of prosecution for the take of owls. Continued operation of the tree farm provided the means for WFTC to undertake conservation and management requirements of the HCP. And finally, the HCP provided the USFWS assurance of long-term management consistent with recovery of the northern spotted owl.

### *The Mineral Tree Farm*

The Mineral Tree Farm encompasses 53,818 acres on the west slope of the Cascade Mountains, and is characterized by steep terrain, abundant precipitation and dense coniferous forest predominated by younger age classes (< 60 yr).

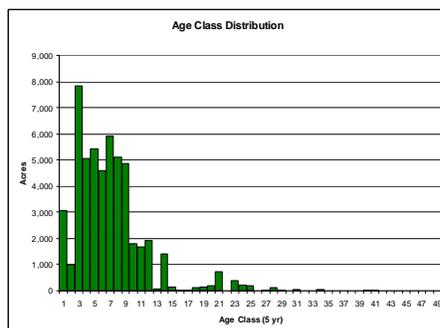


Figure 1. Age-class distribution of Mineral Tree Farm (2005).

Virtually all of the tree farm has been managed for commercial timber production, and most of it has been clearcut or partially harvested at least once since 1913. Extensive logging also occurred in the mid to late 1980s with a significant curtailment in the mid to late 1990s.

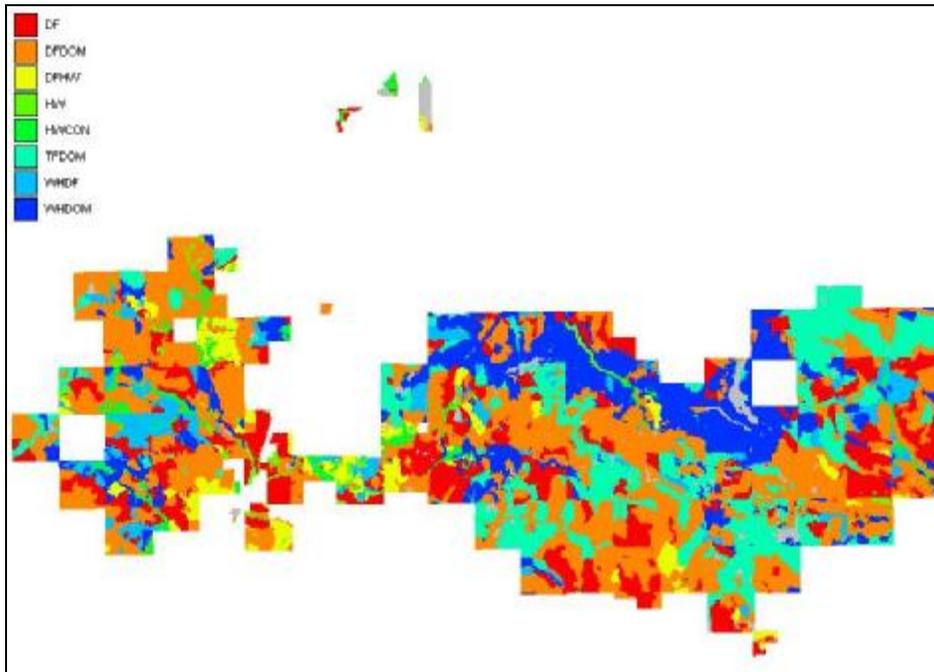


Figure 2. Forest cover and extent of the Mineral Tree Farm (2005).

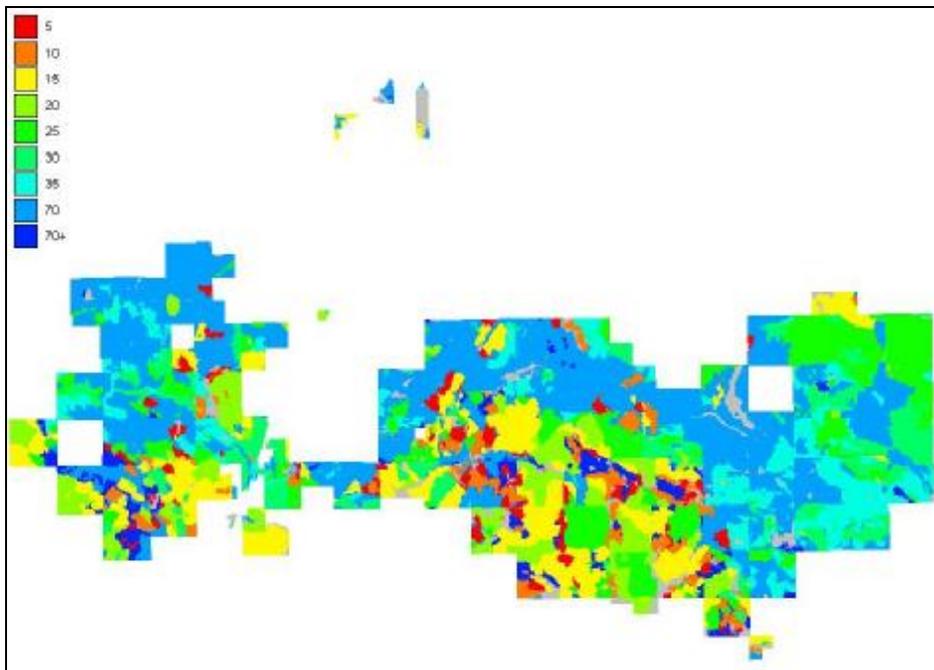


Figure 3. Spatial distribution of age classes across the Mineral Tree Farm (2005).

The tree farm is surrounded by private, state and federal timberlands. The private and state timberlands are managed for commercial timber production much like the tree farm, but the federal lands of the Gifford Pinchot National Forest that border the Mineral Tree Farm to the east and west are largely managed as late-successional reserves with the objective of maintaining mature and old-growth forest.

## *Dispersal Habitat*

Dispersal has been defined as the movement an animal makes from its point of origin to the place where it reproduces or would have reproduced if it had survived and found a mate (Howard 1960). It is distinguished from movements made by individual animals within home ranges or seasonal migrations made between summer and winter habitats. Juvenile dispersal best fits the definition of *innate dispersal* (Howard 1960), which is a spontaneous, random movement related more to genetics than proximal environmental conditions.

Juvenile spotted owls initiate dispersal in September and October of their first year (Allen and Brewer 1985, Herter 1992). Dispersal is rapid at first, but is interrupted by a period of “settling” in the winter. Both Gutierrez et al (1985) and Miller (1989) reported active and settled phases to dispersal. Juveniles that died during the settled phase had considerably smaller ranges than those that survived and re-initiated dispersal (Miller 1989). The total straight-line distance between the nest and the final point of detection (which represented the location of death for many juvenile owls) has been reported to be more than 30 miles in some cases in Washington (Allen and Brewer 1985). Miller (1989) noted that owls that survived until their second year had a mean straight-line dispersal distance of only 9.4 miles, which may indicate that first-year survival depends on how quickly an owl locates suitable, vacant habitat in which to settle.

While dispersal appears to move randomly across a landscape, the spotted owl tends to show preference for roosting in older stands. Although owls were observed roosting in a variety of habitats, Miller (1989) noted that mature and old-growth forest were used disproportionately to their availability, closed sapling pole/sawtimber habitat<sup>1</sup> was used roughly in proportion to availability, and younger forest types were avoided. From a management perspective, the goal of an HCP should be to provide suitable roosting and foraging habitat in such a manner that an owl moving randomly across a landscape is more likely to encounter suitable habitat than unsuitable habitat. Thus, it is imperative that suitable habitat not be confined to a few concentrated areas and corridors but scattered over the landscape.

## *HCP Rationale*

Based on the scientific literature and recommendations of the Interagency Scientific Committee Report (Thomas et al. 1990), it was decided that the Mineral Tree Farm would be managed to provide dispersal habitat and contribute to the maintenance of a general landscape amenable to the dispersal of juvenile spotted owls. The shape of the tree farm and its proximity to other habitat conservation areas (HCAs) nearby would allow dispersal habitat on the ownership to function as a link connecting them. Habitat management on the tree farm was to focus on three main areas: protection of water quality and fish habitat, growth and maintenance of mature forest habitat in designated reserve areas (primarily along streams), and enhancement of wildlife habitats in managed commercial stands across the tree farm. WFTC’s contributions to habitat management complement the efforts on adjacent public lands, by interconnecting late-successional habitat on adjacent federal lands through the habitat reserves across the tree farm, and by providing habitat for early and mid-successional species elsewhere. Protection of streamside areas along fish-bearing streams and reduction in sediment delivery to streams also figured prominently in the HCP. The most important element of the HCP, however, was management of the commercial timberlands.

Historically, WFTC harvested timber at an economic rotation age of 40 to 60 years. Under the HCP, this management prescription is still permitted in areas where it does not conflict with the maintenance of dispersal habitat. The management of stands between harvests and the size and timing of harvests were modified from previous standard practices when necessary to create a landscape conducive to dispersal including,

1. avoidance of large areas of very young forest (gaps in dispersal landscape),
2. reducing the time stands exist in early successional conditions,
3. thinning stands to hasten development of suitable habitat conditions and,
4. retaining logs and snags after harvest to increase habitat diversity for owl prey.

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<sup>1</sup> Defined as coniferous forest with average stand dbh between 1 and 21 inches and canopy closure exceeding 60% (Hall et al. 1985). In all likelihood, owls select for stands of larger trees and against those of smaller trees.

Like any natural landscape, the Mineral Tree Farm is a complex mosaic of physical and biological conditions. Management of such a mosaic over time is a dynamic and iterative process that cannot be done according to a rigid set of rules established at a single point in time. Instead, progress toward and achievement of a dispersal landscape would be monitored over time, allowing for deviations from guidelines on individual harvest units, so long as those deviations fit within the overall landscape objectives.

### *Dispersal Landscape Index*

The spatial arrangement of stands is just as important as the total area of forest in determining habitat for dispersing spotted owls. To evaluate and monitor dispersal habitat (DH) at the landscape level, a numerical index was developed called the dispersal landscape index (DLI). To calculate DLI, all areas within the Mineral Tree Farm were assigned a dispersal habitat value (DHV) value based on their proximity to stands of suitable DH. As originally developed, the process for calculating DH values involved the creation of a series of concentric buffers around stands of suitable habitat and assigning progressively lower values to buffers more distant.

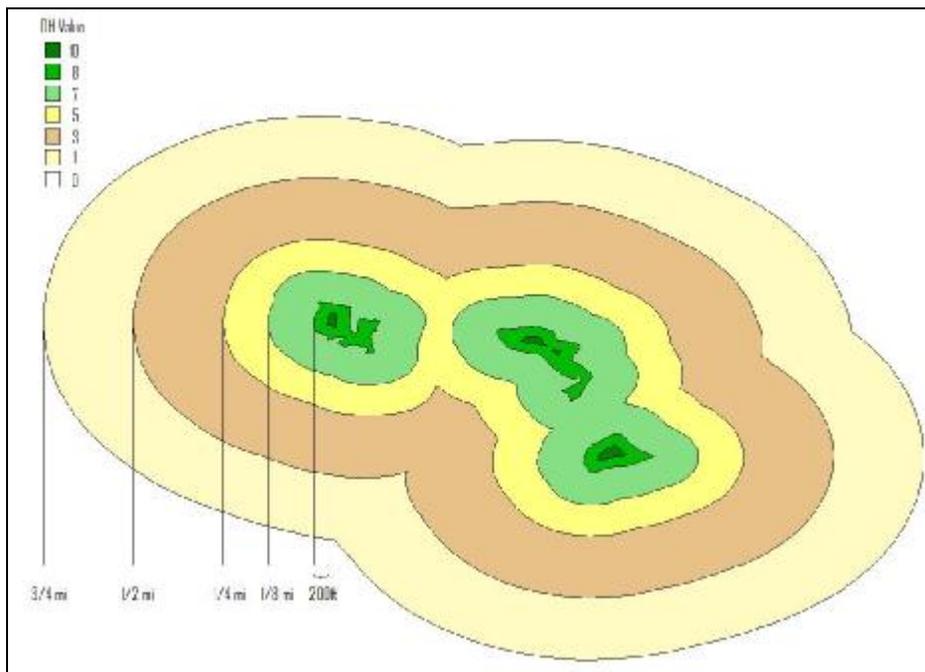


Figure 4. Defining dispersal habitat values for 3 suitable stands.

In Figure 4, there are 3 stands that are deemed suitable dispersal habitat for spotted owls. Interior portions of stands meeting the definition of roosting and foraging habitat (beyond 200 ft from a clearcut edge) are assigned the highest DHV of 10, and edge areas within the stand are assigned a DHV of 8. Beyond the stand boundary, forest areas that are within  $\frac{1}{8}$  mi of the stand boundary are assigned a DHV of 7; within buffers of  $\frac{1}{4}$  mi,  $\frac{1}{2}$  mi,  $\frac{3}{4}$  mi, DHVs of 5, 3 and 1 are assigned, respectively. Forest areas greater than  $\frac{3}{4}$  mi from suitable dispersal habitat are deemed to have no dispersal habitat value. Once DHVs have been calculated for every acre of the forest, the DLI is calculated simply by summing DHVs for each acre in the forest, and dividing the total by the total number of acres. For example, if the total DHV for the Mineral Tree Farm was calculated to be 240,000, the DLI score would be 4.59.

The net effect of the scoring is to give higher DLI values to landscapes with greater dispersal habitat and more uniform distribution of that habitat. Forests with comparable acres of dispersal habitat can have very different DLI scores: clumping of the habitat does not increase scores of the stands since interior portions are already at the maximum DHV, and if the habitat is clumped there are necessarily greater amounts of gap in the landscape. A DLI value of 10 would place the entire tree farm in dispersal habitat, but no harvesting could take place without increasing gap areas. Therefore, to make the tree farm economically sustainable, it was determined that the optimum configuration of stands within a landscape managed for timber production and owl dispersal be composed of stands 5 to 120 acres in size (with an optimum size of 40 acres) spaced no more than  $\frac{1}{4}$  mile apart, which yields a DLI of

7.50. At the time the HCP was signed, the Mineral Tree Farm DLI was 5.34, and the projected DLI after the first 50 years implementation of the HCP was 7.47, after which it was to remain at or above this value.

WFTC developed a geographic information system database for tracking stand conditions and a model for predicting dispersal habitat (DH). Future dispersal habitat was initially estimated by modeling the growth of existing stands using the Stand Projection System (SPS) growth and yield model (Arney 1986) for the first 50 years of the HCP. All stands then considered suitable were considered to remain suitable unless harvested. Stands that were not considered suitable initially would become suitable when they attained an average dbh of 9.2 inches and a minimum age of 27 to 53 years, depending on site class. This was considered a conservative estimate because many stands would meet the DH criteria before they reached an average dbh of 9.2 inches, but it was used as a limit to avoid the risk of assuming a stand being deemed DH before it actually qualified as such. By projecting stands forward through time, and estimating harvests based on guidelines established in the HCP, WFTC was able to predict how the forest would develop, and calculate DLI for the Mineral Tree Farm for the next 50 years.

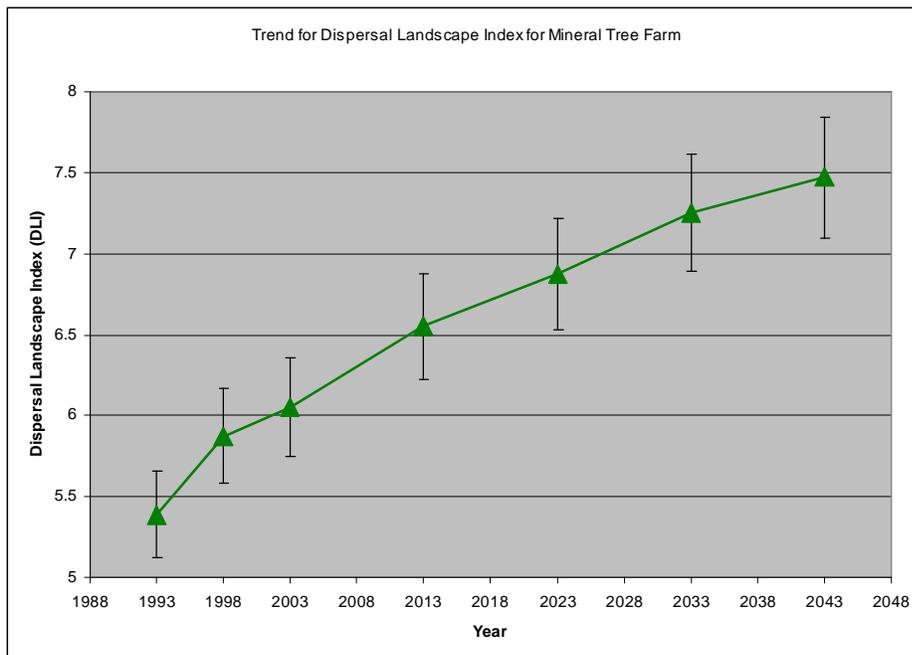


Figure 5. DLI trend for the Mineral Tree Farm for implementation of HCP for 50 years.

WFTC operated the tree farm for over 10 years under the HCP, using periodic re-projections of the existing inventory (as described) to demonstrate continued improvement in dispersal habitat and dispersal landscape index scores, while continuing to harvest timber. However, the timber markets in the Pacific Northwest had changed significantly in the ten years that had passed since the HCP was signed. WFTC management was interested in exploring optimization and spatial planning tools to see if the economic returns from the Mineral Tree Farm could be simultaneously improved along with dispersal habitat. FORSight Resources, LLC (FORSight) was contracted in 2005 to develop a strategic forest management model and spatial harvest schedule for the Mineral Tree Farm.

## Strategic Model

FORSight chose the Remsoft Spatial Planning Suite as the modeling environment for this project, with Spatial Woodstock as the strategic modeling environment and Stanley as the tactical planning tool. WFTC management had numerous objectives that required the development of a fairly sophisticated strategic planning model. The mountainous conditions on the tree farm make stand elevation and logging season important considerations in running a profitable logging operation and cost-effective silviculture program. The mix of steep terrain and valley floors require controls on logging method to balance operations assigned to shovel, hi-lead and helicopter logging. The goal of maintaining and improving dispersal habitat across the forest necessitated the inclusion of existing

suitable-habitat stands, watersheds, reserve areas, and management emphasis in the overall stratification. A tree-based growth and yield model (Organon-SMC variant) was used to develop yield tables, based on cover type, basal area, site and stocking/planting density. Overall, WFTC's strategic planning model required 13 landscape themes to fully describe the forest land base. A planning horizon of 150 years, composed of 5-year planning periods was chosen to match the resolution of the growth and yield model, and to provide sufficient time to avoid model artifacts within the first 10 planning periods that are attributable to the effects of the end of the planning horizon.

The silvicultural program implemented in the model included planting (2 species – Douglas-fir and noble fir, 2 planting densities each), precommercial thinning to 4 different spacings, fertilization and herbaceous competition control, commercial thinning, pruning and clearcut harvesting. Pruning and precommercial thinning to four spacings are not typical for commercial timberlands and many would question their economic value to timber production. In direct terms, these treatments generally do not improve volume or value growth sufficiently to warrant the expenditure, but WFTC was interested to know if these treatments would pay indirectly by developing suitable foraging and roosting habitat sooner in younger stands.

### Objective function

The objective function used for the strategic planning model maximized discounted revenue from timber harvesting, net of silviculture, logging and hauling costs. Instead of a pure-stumpage model, WFTC opted for a coarse-level delivered price model using mill-delivered prices, average hauling costs, and sophisticated logging cost functions for each logging method that varied by stand volume.

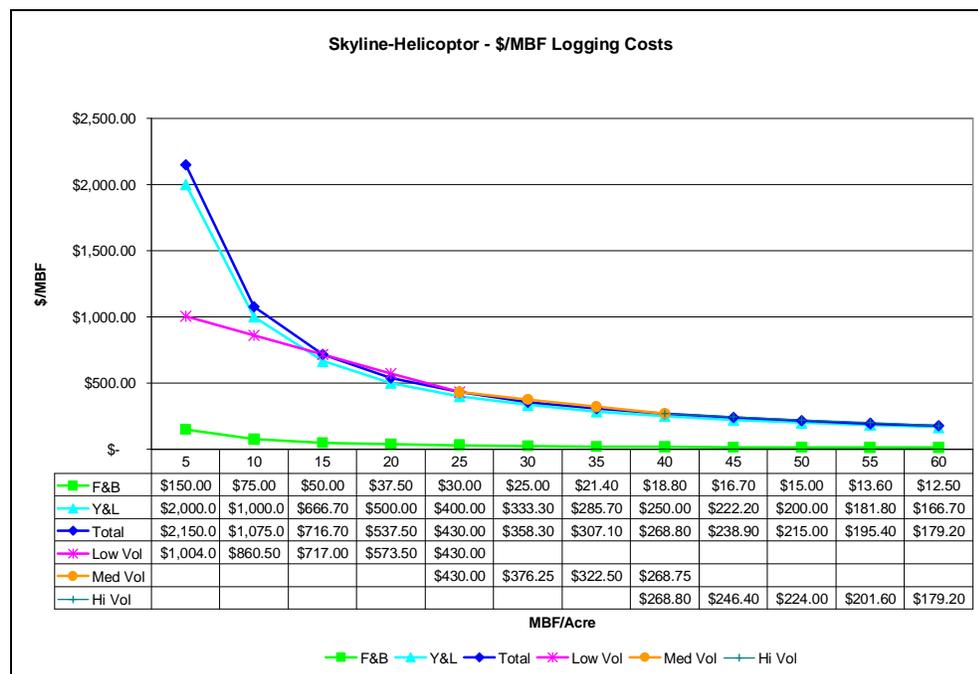


Figure 6. Skyline and helicopter logging cost function for Mineral Tree Farm (2005).

### Constraints

WFTC management had specific objectives for improving economic efficiency. Based on their previous projections (described earlier), they believed that they had reasonable estimates of annual harvest volumes that could be achievable under the HCP. What they were lacking were controls on harvest volume flows, not only from year-to-year, but on a quarterly basis. Given the mix of logging equipment available in the area, it was important for WFTC to schedule a mix of flat and steep-terrain, as well as summer versus winter harvest blocks. Constraints were included that required the number of acres assigned to shovel logging be greater than or equal to the acres assigned to the more expensive helicopter logging operations. Total saw log harvests were allowed to vary by as much as 10% period-to-period, provided that harvest volumes never fell below harvest goals established with WFTC's previous projection methods.

Because the calculation of DLI is complex and inherently non-linear, it was impossible to directly constrain it in the strategic model. WFTC used stand age and a projected time to reach a DBH of 9.2 as a proxy for estimating time to reach DH status. FORSight decided to try to model DH directly by tracking several stand parameters in the growth and yield projections. Considerations in the determination of DH status are:

- Species. A stand must be dominated by conifer species.
- Density. A stand must have fewer than 300 trees/ac and basal area of at least 70 ft<sup>2</sup>/ac in trees greater than 10" DBH.
- At least 20' of clear flying space must be available.

The last requirement is difficult to model directly but we decided to include as a yield component in the model a proxy: average height to crown base (AVHCB) - the space between the ground and lowest branches of the live crown. The calculation of AVHCB depends not only on height growth but crown recession as well. Clear flying space would also depend on how quickly trees shed dead limbs. Using WFTC's experience with monitoring dispersal habitat, an empirical relationship was developed by calculating the AVHCB for stands that already qualify as DH. Within the strategic planning model, acres are counted as DH if they meet the species and density requirements and exceed a threshold value for AVHCB. The higher the threshold, the longer it takes to achieve DH status. The threshold values of AVHCB that best matched the empirical data were 35 ft for unthinned stands, 30 ft for thinned stands and 25' for pruned stands. Once DH acres could be calculated in the model, it was easy to formulate floor constraints on acres of dispersal habitat that corresponded to the acres specified in the HCP.

## **Tactical Model**

FORSight used Spatial Woodstock and Stanley in concert to block out the first 40 years of the planning horizon (8 five-year periods) that corresponded to the time remaining in the HCP to reach a maximum DLI. The process was complicated by the need to control both activity-generated outputs (harvest volumes) and inventory outputs (DH), and the need to spatially allocate activities on future stands. At that time, Stanley was not able to control for inventory-based outputs, or spatially allocate activities beyond the final harvest. To get around this limitation, FORSight developed an iterative rollover process of spatial allocation, until all 8 periods of the tactical planning horizon were completed.

A spatial simulation (Remsoft's term for allocating activities without spatial restrictions) mapped out most treatments well. Blocking final harvests worked so long as only stands that currently existed were harvested, because the thematic attributes matched what was in the shapefile. Once a stand was thinned or pruned or fertilized, its thematic attributes in Woodstock no longer matched the theme fields in the shapefile. The rollover process involved the following steps:

1. Run Stanley to allocate initial harvest blocks (Schedule file attributes match shapefile). Post activities to Treatments field.
2. Use the Assign Schedule to Polygons feature to spatially allocate the mid-rotation treatments (Append to Treatments field).
3. Use the time selector to advance one period.
4. Copy virtual thematic attributes to temporary fields
5. Use time selector to revert to the previous period and copy thematic attributes from temporary fields to theme fields.
6. Repeat process iteratively until all periods are adequately allocated.

Once the activities were spatially allocated, thematic maps indicating the location of suitable DH stands had to be produced for each of the tactical planning periods for DLI calculation. A sequence file was also generated so that reports of the tactical harvest schedule could be produced by running the tactical harvest schedule back through Woodstock.

## Updated DLI calculation

The original process of calculating DLI using a GIS to generate iterative buffers was too slow and cumbersome for this process. Instead, a raster-based method using ESRI software was developed by FORSight to process vectorized versions of the maps produced after spatial allocation. A pixel size of 220 feet was chosen because all of the DLI buffer distances were integer multiples except one: the interior space of a suitable stand would be slightly underestimated because the required edge buffer needed to only be 200 feet. Since this would yield a conservative estimate of DLI, it was deemed acceptable. In minutes, the new DLI calculator was able to process 9 DH maps and produce DLI scores corresponding to the end of each planning period plus initial conditions.

The process of generating DH maps required Spatial Woodstock's time selector to project future conditions. A thematic map was created based on the inventory output DH. After the treatments from the Stanley allocation were posted to the Treatments field, it was easy to use the time selector to generate maps of DH condition for current and future planning periods. A shapefile was exported for each time period of interest, and these in turn were converted to a raster format using ESRI's ArcGIS software. Once rasterized, the DLI calculation was performed for each mapped time step.

## Results

In total, 12 runs of the strategic model were completed before a preferred alternative was selected. Because this was the first time WFTC had used an optimization approach, it was important to see the effects of the various constraints on the objective function (present net value). The first model run was completely unconstrained to serve as a benchmark for later runs and additional constraints. Over the course of the analysis, some constraints were eliminated; for example, the constraints on harvest season made a difference of only a few thousand dollars over the entire planning horizon, and WFTC management considered the benefit to be minimal. The constraints on minimal dispersal habitat were tightened in the strategic model by 2.5% in each period to facilitate tactical planning: since there is usually some fall-down in output levels from the strategic plan in a Stanley solution, requiring more DH than the minimum in the strategic solution would allow a fall-down in the tactical solution that still met requirements of the HCP. Under the HCP, WFTC is restricted to clearcut no more than 10,000 acres per decade and no more than 2,500 acres in any given year. Since the planning model uses 5 year periods, it was decided to constrain using the more restrictive limit (1,000 ac per year), requiring no more than 5,000 acres of clear cut harvesting in any planning period.

### *Strategic results*

One of the motivations for WFTC to explore optimization in their planning was to determine if it was possible to increase harvest levels while continuing to comply with the requirements of the HCP. The strategic model demonstrated that increased harvest levels were indeed possible in the final preferred alternative. In the first three planning periods, total saw log harvests exceeded WFTC's previous volume goals by at least 47% and as much as 62%. The source of this additional harvest volume was attributed to the harvest of existing DH stands, which could be harvested sooner through a form of allowable cut effect.

Allowable cut effects are usually attributable to non-declining flow constraints and improved growth of future stands, such that an immediate increase in harvest can be attained. In the case of the Mineral Tree Farm model, it was not a change in volume growth that allowed the increased harvest, but a shortening of the time to DH through silviculture (thinning and pruning). WFTC management was surprised by the extent of pruning selected in the optimal solution but quickly realized how the model was trading off the additional expense of silviculture against the holding cost of retaining existing DH stands longer in the future. By producing suitable DH stands at a younger age through silviculture, the model demonstrated how it was possible to shorten overall timber rotations and thus improve economic returns from the tree farm.

### *Tactical results*

While the results of the strategic modeling exercise were exciting, there was no guarantee that similar benefits would accrue once the solution was allocated spatially. WFTC was interested in a spatial solution for the first 40 years of the planning horizon, but to give Stanley some extra flexibility in choosing candidate stands FORSight

decided to schedule the first 10 planning periods with Stanley. And though the objective function in the Woodstock model maximized discounted net revenue, it seemed more prudent to set harvest volume and acre outputs as the objectives for the Stanley runs. Six Woodstock outputs were chosen as the weighted scoring criteria: total saw log harvest volume (weight = 2.0), Douglas-fir saw log volume (weight = 1.5), white wood saw log volume (weight = 1.5), clearcut acres (weight = 1.25), hi-lead logging acres (weight = 1.0) and shovel logging acres (weight = 1.0).

The results were remarkably good for a heavily constrained harvest schedule. Relative to the minimum volume goals specified as constraints for the first 10 periods, the Stanley tactical solution generated 14% more volume over the first 10 periods, using a Woodstock solution that was 21% higher than the minimum targets. The tactical solution attained 93% of the present net value predicted in the strategic planning model.

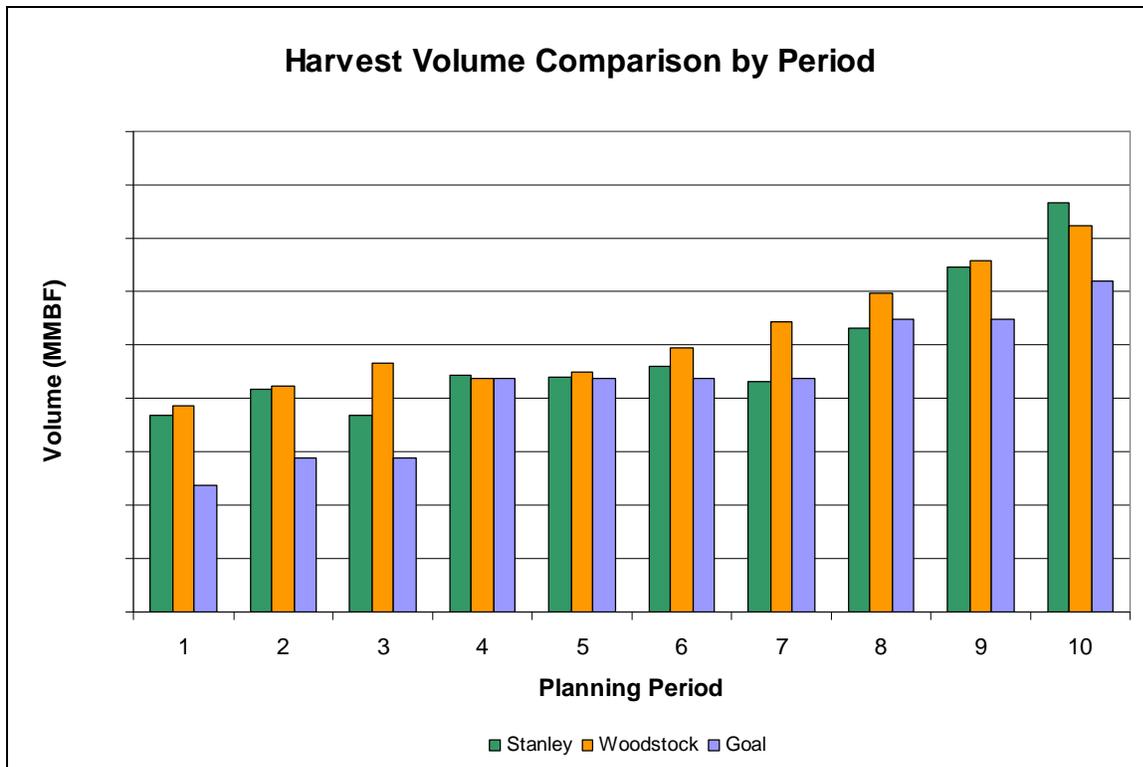


Figure 7. Projected harvest levels in Stanley and Woodstock solutions relative to WFTC goals.

Figure 7 indicates illustrates that planning periods 3, 7 and 8 are more adversely affected by spatial constraints, exhibiting significant reductions from the predicted volumes in the corresponding Woodstock solution. Only in the latter periods does the Stanley result fall below the goal values established by WFTC in earlier analyses, and the shortfalls are minor.

There is also remarkably close correspondence between the Woodstock and Stanley solutions in terms of acres allocated to mid-rotation silviculture and final harvests. No timing choice deviations on the mid-rotation silvicultural treatments and only minimal deviations on the timing of harvests (clearcuts, commercial thins) were allowed, to facilitate the roll-over process described earlier. In early periods, it is trivial to allocate mid-rotation silvicultural treatments because the treated stands already exist. In later periods, where a mid-rotation treatment is applied to a stand that does not yet exist (it was final harvested earlier), it becomes more problematic since the final harvest in the Stanley solution that led to its creation may have deviated from the Woodstock solution. This issue could probably be overcome by iteratively going back and forth to the Woodstock model, each time including more pre-allocated treatment decisions from the previous Stanley solution. However, the time and effort required would be substantial but would not yield significantly improved results.

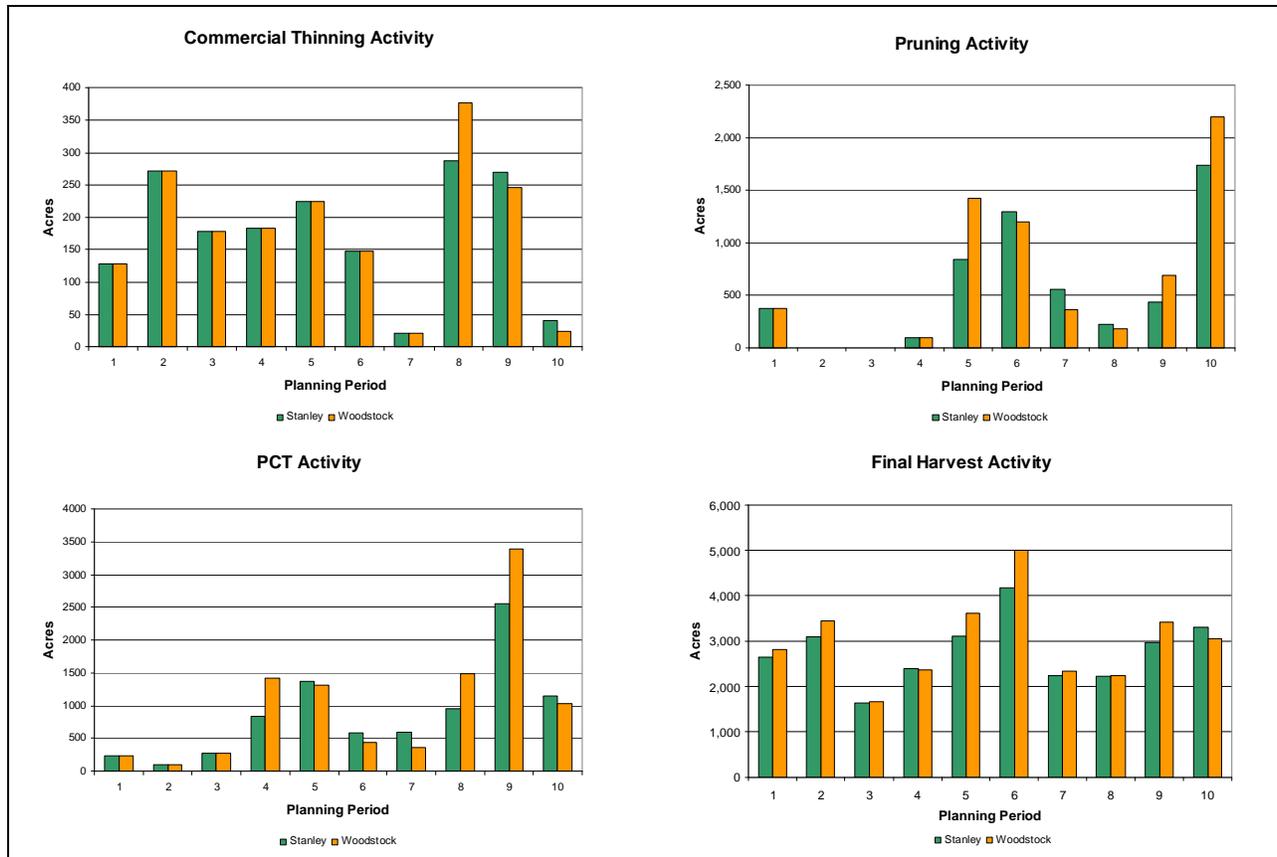


Figure 8. Acres allocated in the tactical solution relative to the strategic planning model solution.

The final hurdles to declaring success in this planning effort were to demonstrate that dispersal habitat acres and DLI scores for the Mineral Tree Farm conformed to the requirements of the HCP. For DH acres, the tactical solution could not allow DH acres to fall below the minimum acres specified in the HCP. For DLI scores, a margin of error of  $\pm 5\%$  around the values specified in the HCP are permitted.

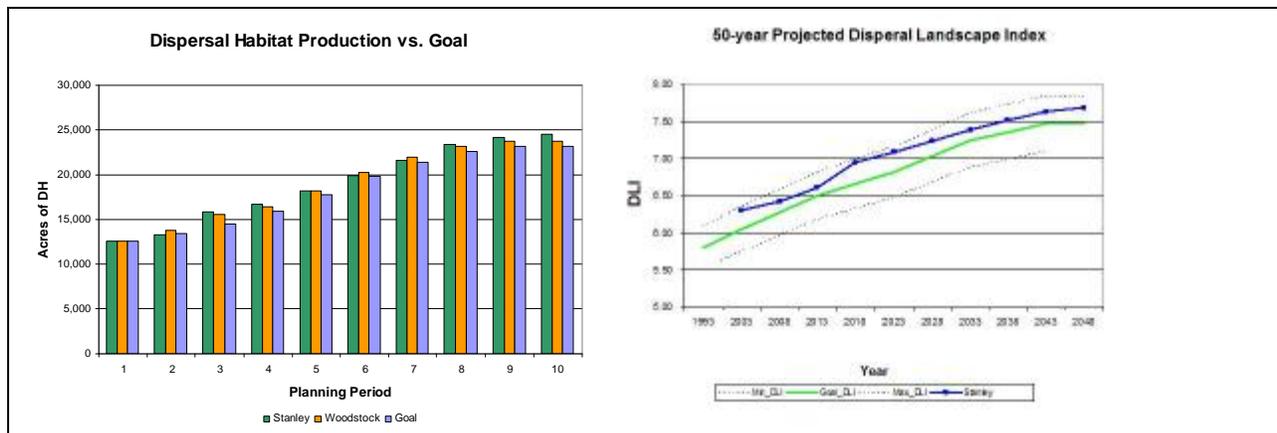


Figure 9. Projected dispersal habitat and DLI scores.

Because dispersal habitat was an inventory measure in the strategic model and could not be directly controlled in Stanley, there was concern that DH acres may have varied too greatly in the tactical solution. Luckily, this was not the case but the model was constructed to allow constraints on activities at the watershed level. If necessary, harvests could have been concentrated in watersheds or dispersed across watersheds to bring the DLI scores closer to desired levels. In both cases, the tactical solution met or exceeded the requirements of the HCP. Moreover, the

projected DLI scores exceeded the baseline requirements in every planning period by a substantial amount, although still within the 5% margin of error.

## Discussion

WFTC undertook this planning effort to determine if optimization and hierarchical planning tools could improve financial returns on the Mineral Tree Farm. Based on the results, the answer was a resounding yes. Some of the important outcomes included,

- An economically efficient strategic plan was devised using an optimization model with discounted net revenue as its objective; previous planning efforts at WFTC focused on volume production as the objective.
- Relative to goals established in previous WFTC planning efforts, harvest levels over the first 50 years were 21% higher in this strategic planning solution and 14% higher in the tactical planning solution. Harvest levels were constrained to fluctuate within acceptable tolerances, and harvest acres were kept within allowable limits.
- The results indicated that investments in thinning and pruning, while not necessarily economically advantageous from a timber production standpoint, had the potential to reduce timber rotations by producing foraging and roosting habitat in less time, requiring less holding time for existing DH stands.
- Dispersal habitat creation met or exceeded targets established in the HCP and the spatial arrangement of harvests in the tactical solution yielded DLI scores that were well within tolerances specified in the HCP.
- A new DLI calculator was developed using a raster-based approach instead of the vector-based buffer approach used previously. The new calculator was significantly faster.

The Mineral Tree Farm HCP is unique in the State of Washington in the use of the dispersal landscape index as a basis for evaluating management progress; the authors are aware of no other habitat conservation plans that use this approach. Nevertheless, it could be used to supplement planning efforts on other habitat conservation areas where the northern spotted owl is an important consideration.

## Literature Cited

- ALLEN, H.L. AND L.W. BREWER. 1985. A review of current northern spotted owl (*Strix occidentalis caurina*) research in Washington State. IN R.J. Gutierrez and A.B. Carey, eds. Ecology and management of the spotted owl in the Pacific Northwest, USDA For. Serv. Gen. Tech. Rept. PNW-185, Portland, OR.
- GUTIERREZ, R.J., A.B. FRANKLIN, W. LAHAYE, V.J. MERETSKY AND J.P. WARD. 1985. Juvenile spotted owl dispersal in northwestern California: Preliminary results. IN R.J. Gutierrez and A.B. Carey, eds. Ecology and management of the spotted owl in the Pacific Northwest, USDA For. Serv. Gen. Tech. Rept. PNW-185, Portland, OR.
- HERTER, D.R. 1992. Spotted owl monitoring reports: 15 September 1991 to 15 December 1991 and 15 December 1991 to 15 January 1992. Reports to Plum Creek Corporation, Raedeke Assoc. Scientific Consulting, Seattle, WA.
- HOWARD, W.E. 1960. Innate and environmental dispersal of individual vertebrates. *Am. Midl. Nat.* 63(1):152-161.
- MILLER, G.S. 1989. Dispersal of juvenile northern spotted owls in Western Oregon. M.S. Thesis, Oregon State Univ., Corvallis. 139pp.

MURRAY PACIFIC CORPORATION. 1993. Habitat Conservation Plan for the Northern Spotted Owl (*Strix occidentalis caurina*) on Timberlands owned by The Murray Pacific Corporation, Lewis County, Washington. 100pp + appendices.

THOMAS, J.W., E.D. FORSMAN, J.B. LINT, E.C. MESLOW, B.R. NOON AND J. VERNER, 1990. A conservation strategy for the northern spotted owl. Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl, Portland, OR.